MINOR "DINGS" - MAJOR EFFECTS?
A STUDY INTO THE COGNITIVE EFFECTS OF MILD HEAD INJURIES IN HIGH SCHOOL RUGBY

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ABSTRACT

The present study is part of a larger and ongoing research initiative investigating the cumulative cognitive effects of mild head injury in rugby union and focused specifically on high school rugby players. A comprehensive battery of neuropsychological tests was administered to top team high school rugby players (n = 47), and a non-contact sport control group of top team high school hockey players (n = 34). Direct comparisons of group mean scores and standard deviations across each neuropsychological test were carried out for the Total Rugby group versus the Total Hockey group as well as for the subgroups Rugby Forwards versus Rugby Backs. A correlational analysis was conducted to ascertain whether a relationship exists between the number of mild head injuries reported by the players and their cognitive test performance. Results of the group comparisons of means and variability on WMS Paired Associate Learning Hard Pairs - Delayed Recall provides tentative indications of the initial stages of diffuse damage associated with mild head injury in the rugby group and provides some evidence for impairment of verbal learning and memory in the Rugby Forwards group. The correlational analysis revealed no significant relationship between number of reported mild head injuries and cognitive performance. The findings and possible latent effects of the multiple mild head injuries reported by the rugby players are discussed in terms of brain reserve capacity theory and suggestions for future research are provided.

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CHAPTER 1: RESEARCH CONTEXT

The aim of this research is to investigate the effects of cumulative mild head injuries in high school rugby. The research is considered necessary in view of the frequent occurrence of concussion amongst schoolboys in the top rugby teams (Nathan, Goedeke, & Noakes, 1983) and the growing concerns about the permanent and lasting effects following such repeated mild head injuries. Recent research on professional rugby players has provided evidence for the presence of deleterious effects following repeated mild head injuries and raises concerns about the short and long term effects of such injuries on the intellectual abilities of high school rugby players (Ancer, 1999; Bold, 2000; Border, 2000; Dickinson, 1998; Finkelstein, 2000; Reid, 1998).

Research into the effects of concussion in rugby is situated within the broader context of mild head injury. Variations exist in exact definitions of the upper and lower limits of what constitutes mild head injury. Typically, however, it is understood as brain trauma which results in *brief* loss of consciousness (LOC) of around 30 minutes or less (but usually not more than an hour), or being dazed *without* LOC, an initial Glascow Coma Scale (GCS) score of 13 to 15 without subsequent deterioration, and the absence of focal neurological deficits or neurosurgical pathology (for example, Evans, 1992). Although some mild head injuries are seen as "minor" in that they merely produce a subjective feeling of being "dinged" or dazed, they may result in reduced mental efficiency, which some authors believe can be long-lasting (for example Alexander, 1995).

The permanent and lasting effects of this type of injury to the brain have been more difficult to assess. Whilst the immediate sequelae of a mild head injury are widely accepted and include deficits in speed of information processing, attention and complex memory capacity (Alexander, 1995; Barth et al., 1983), there is no consistent evidence of prolonged cognitive impairment following such an injury (Binder, 1986). Controversy surrounds the long-term outcome following mild head injury. A meta-analytic review of research in this area has, in fact, suggested a weak causal association between mild head injury and persisting neuropsychological deficits (Binder, Rohling & Larrabee, 1997). This review has been criticised by Shuttleworth-Jordan (1999) who provides a more rigorous theoretical framework for research in this area and who suggests that long term effects following mild head injury may not be apparent at the time of injury but may act as risk factors increasing the brain's vulnerability for future functional impairment.

Furthermore, as early as 1975, researchers Gronwall and Wrightson asserted that persistent objective deficits are evident when *multiple* or *cumulative* mild head injuries have been sustained. Players of contact sports are at great risk of sustaining such multiple mild head injuries and the concept of *cumulative* damage has gained currency amongst researchers investigating the effects of repeated sub-concussive blows to the head sustained in contact sports such as boxing (for example Casson et al., 1984). Researchers have also attempted to investigate the effects of mild head injury in other contact sports such as soccer (for example Matser, Kessels, Jordan, Lezak & Troost, 1998), American football (for example Barth, et al., 1989), Australian Rules football and rugby league (for example Hinton-Bayre, Geffen, & McFarland, 1997). A South African study by Shuttleworth-Jordan, Balarin and Puchert (1993) was the first to investigate the cumulative effects of mild head injury in rugby union[1] players. These authors drew attention to the fact that rugby/football related sports are similar in that mild head injury occurs as a result of impacts to the head and neck during scrumming (blocking), tackling and when players collide with each other. Since then, there has been growing interest in the investigation of cumulative mild head injury in the professional South African rugby playing population and a large research initiative was launched by Rhodes University in 1996, in collaboration with the South African Rugby Football Union (SARFU) and the South African Sports Science Institute, to pursue research on this topic.

This present study forms the *third phase* of this broader and ongoing research initiative into the effects of cumulative mild head injury in South African rugby union players and focuses specifically on rugby players at high school level. *The first phase* (Phase I) of the research investigated a professional rugby playing population and used professional cricket players as a control group. A range of neuropsychological tests was administered to both groups of players and the emergent data were analysed in three ways and formed the basis for three separate dissertations (Ancer, 1999; Dickinson, 1998; Reid, 1998). The analyses revealed that rugby forwards performed more poorly in the tests sensitive to the effects of diffuse brain damage when compared to rugby backs and to the control group. The study was limited in that a relatively small sample was used and the cricket players were not considered an ideal control group as a number of them had a history of playing rugby as a winter sport. *The second phase* (Phase II) of the research was initiated to address the methodological concerns of the previous phase and a larger sample and a new control group were used by incorporating into the original sample the cognitive performances of Under 21 national rugby players and a matched non-contact sport control group consisting of national Under 21 hockey players. A replication of the three separate data analyses was carried out (Bold, 2000; Border, 2000; Finkelstein, 2000). The rugby group demonstrated poorer test performances than the control group and, again, the rugby forward players showed poorer performance on tests sensitive to the effects of diffuse brain damage.

Whereas these studies focused on the effects of mild head injury in professional rugby players, there has as yet not been any research examining the effects of mild head injury at the level of school rugby. As previously mentioned, this is a matter for concern as a study of the incidence of rugby injuries at school level found concussion to be the single most common injury (Nathan et

[1] Rugby union rules are played in South Africa. The game differs from rugby league in that it presents more opportunity for head injury as there are a greater number of players in the scrum. Furthermore, rucks and mauls are allowed to develop.

al., 1983). This present study, *the third phase* (Phase III) of the ongoing Rhodes/SARFU/Sports Science Institute research initiative, attempts to address the lack of research in this area. This phase of the research poses the question: Does cumulative mild head injury sustained in high school rugby cause brain injury as evidenced by impaired performance on neuropsychological tests sensitive to the effects of diffuse brain damage? This particular thesis attempts to address this question by making a direct comparison of the cognitive performance of top team school rugby players versus a hockey control group across a battery of neuropsychological tests. The comparison of the performance of rugby forward players and rugby backline players is an additional focus. The central hypothesis of this study is that rugby players and especially forward players will show impairment on tests sensitive to diffuse brain damage when compared to the hockey group and backline rugby players. A new focus, not included in Phases I and II of the research, will be to investigate the relationship between the number of reported mild head injuries in the rugby group, particularly amongst the rugby forwards, with their performance on neuropsychological tests. In this regard, it is hypothesised that a relationship will be found between the number of reported mild head injuries sustained by rugby players with poorer performance on neuropsychological tests when compared with the hockey control group.

In conclusion and by way of summary, the findings will be integrated within the theoretical context of Satz's (1993) brain reserve capacity theory and Shuttleworth-Jordan's (1999) hypothetical indications, and the implications of the research findings and directions for future research will be discussed.

CHAPTER 2 : LITERATURE REVIEW

This chapter provides a context for mild head injuries in general and focuses specifically on mild head injuries sustained in contact sports. First, the definitions of mild head injury and concussion are addressed and the neuropathological mechanisms, neuropsychological sequelae and the course of recovery following mild head injury are discussed. Thereafter, a review focusing on neuropsychological research pertaining to boxing, soccer, American football, Australian Rules football, rugby league and rugby union is presented. Finally, the study is situated within the theoretical context of Satz's (1993) brain reserve capacity theory and hypothetical indications for the study are proposed.

2.1. MILD HEAD INJURIES - GENERAL

2.1.1. DEFINITION AND CLASSIFICATION OF MILD HEAD INJURY

The present study is concerned primarily with "mild" or "minor" closed head injuries. *Closed* head injuries refer to head injuries resulting from a blunt impact to the head as opposed to penetrating head injuries, which are head wounds resulting from sharp objects e.g. knives (Levin, Benton & Grossman, 1982). Head injuries are categorised on a continuum of severity ranging from mild to moderate to severe. The severity of the injury is traditionally defined by its acute injury characteristics using objective clinical measures such as alteration of consciousness level (Glascow Coma Scale or GCS), duration of consciousness (loss of consciousness or LOC), and changes in orientation and memory (post traumatic amnesia or PTA). The severity of head injury is regarded as a defining factor and predictor of the outcome when examining head trauma (Anderson, 1996).

The terms *mild* or *minor* are typically used to define head injuries where the period of unconsciousness or post traumatic amnesia is short and where there is no easily demonstrable structural damage to the brain. Evaluation of moderate to severe head injury is easier as the duration of coma is defined specifically in terms of different levels of responsiveness and as the upper and lower limits for the classification of moderate to severe head injuries are relatively clear (see Teasdale & Jennett, 1974). The use of these aforementioned parameters is less applicable in the milder range of head injury and becomes more difficult as patients with mild head injury often experience transient symptoms and no LOC. In this regard, research in the area of mild head injury has been characterised by inconsistent and ambiguous definitions as the upper and lower limits of *mild* have not been clearly defined resulting in a wide variety of definitions (Kibby & Long, 1996).

In an attempt to clarify the confusion, the Mild Traumatic Brian Injury Committee of the Head Injury Interdisciplinary Special Interest Group of American Congress of Rehabilitation Medicine developed criteria for defining mild head injury. These criteria include a *period of LOC* of 30 minutes or less, an initial GCS of 13-15, loss of memory (PTA or other) of 24 hours or less, an alteration of mental state (feeling dazed or confused) and focal neurological deficits which may or may not be transient (1993, in Kibby & Long, 1996). The above definition requires a period of LOC. However, arguably, the terms "minor" and "mild" can be seen to subsume a broader range of severity than this to include instances involving no LOC or focal neurological deficits. Hence certain authors have proposed that the term "mild head injury" encompasses incidences where persons are momentarily *stunned* or *dazed* and experience a short period of confusion or disorientation involving *no loss of consciousness* and, where no focal neurological deficit is present (for example Alexander, 1995; Evans, 1992).

Thus, for the purposes of this study, Evans's (1992) more clearly delineated criteria have been used to define mild head injury. His definition includes instances of injury involving *no LOC* (i.e.dazing) as well as instances of *brief loss of consciousness* of around thirty minutes or less, an initial Glascow Coma Scale (GCS) score of 13 to 15 without subsequent deterioration, and the absence of focal neurological deficits or neurosurgical pathology.

2.1.2. DEFINITION AND CLASSIFICATION OF CONCUSSION

Lezak (1995) defines concussion as immediate disturbances in neurological functioning created by mechanical forces of rapid acceleration / deceleration of the brain inside the skull as a result of a shock, jarring, or blow to the head. In defining the parameters of concussion, the Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons proposed in 1966 that even transient impairment of neural function following head injury, such as the alteration of consciousness and disturbances of vision and equilibrium, constitutes concussion (in McCrory, 1997). Attempts have been made to grade the severity of cerebral concussion and in 1974, Ommaya and Gennarelli proposed a classification scheme incorporating six grades of cerebral concussion. Three of these six grades of concussion involved no loss of consciousness. Since then, numerous attempts have been made to grade concussion, resulting in a variety of definitions (for example Nelson, Jane & Giek, 1984).

Cantu (1986) has raised concerns about the wide variety of often differing categories of concussion which make the comparison of research data difficult. He subsequently develops a classification system for grading the severity of concussion which is primarily aimed to assist sports medicine clinicians in their assessment of concussion. The classification system is presented in Table 2-1, p.6.

Table 2-1. Classification System for Grades of Concussion (Cantu, 1986)

Grade	Severity	Description of Severity
I	Mild	No LOC PTA less than 30 minutes
II	Moderate	LOC less than 5 minutes PTA greater than 30 minutes and less than 24 hours
III	Severe	LOC greater than 5 minutes PTA greater than 24 hours

For the purposes of this study, the term mild head injury is used to denote the types of head injuries under investigation and to conceptually link this study to research in the area of mild brain injury at large. However, the term concussion will be used descriptively to refer to a type of *mild closed head injury* resulting from a *blunt impact* or *whiplash injury* such as are frequently sustained in a contact sport such as rugby and a term which is frequently used in research pertaining to mild head injury. The term concussion enables the use of an additional description within the spectrum of mild head injuries, namely sub-concussive head injuries which are explained in the literature as involving subtle changes in consciousness difficult to detect and usually lasting seconds to minutes (De Villiers, 1987). In this study, sub-concussive head injuries refer to blows to the head which go unnoticed and which may frequently occur in a contact sport such as rugby.

Thus by way of summary, the title of this thesis refers to the investigation of mild head injuries with the implication that the effects of closed head injury will be examined from the most conceivably mild end of the continuum through to its upper limits as per Evan's definition of mild head injury of up to 30 minutes LOC.

2.1.3. MECHANISMS OF MILD HEAD INJURY

The result of a mild head injury is generally a diffuse type of cerebral damage for which a direct impact to the head is not necessary (Binder, 1986; Lezak, 1995). The primary neuropathology of traumatic brain injury is thought to be diffuse axonal injury caused by shearing forces generated in the brain by *sudden* acceleration-deceleration or rotation of the head such as takes place in whiplash injuries (Alexander, 1995; Barth et al, 1983, Boll, 1983; Lezak, 1995). Such injuries may be sustained by a rugby player who is tackled or a football player who collides with an opponent. The strains of the shearing forces are mainly responsible for the neural damage sustained in a mild head injury - the greater the force, the greater the injury. In 1961 Strich, based on post mortem examinations, hypothesised that tissues deep inside the brain are torn or stretched by shear strains and stresses set up during rotational acceleration of the head at the time of an accident.

Experimental models have shown that acceleration-deceleration can cause axonal degeneration in the brainstem. This is expected to have a disruptive effect on cortical arousal and hence impair cognitive performance which in turn, leads to attentional and executive deficits (Alexander, 1995; Gentilini et al., 1985; Ommaya & Gennarelli, 1974). Post mortem examinations of patients who have died of complications following a mild head injury show that the smallest injuries may result in tiny lesions of the cerebral white matter (Oppenheimer, 1968). This has led researchers to assert that even clinically trivial injuries during which only the slightest period of unconsciousness occurs, may result in structural brain damage (Gronwall & Wrightson, 1975), a notion that is central to this thesis.

2.1.4. MILD HEAD INJURY: A QUIET DISORDER

The exact incidence of mild head injuries in unknown. Epidemiological data concerning mild head injury in South Africa is not available and it is, therefore, necessary to refer to literature generated abroad. The annual incidence of all brain injuries in the USA is thought to be approximately 150 per 100,000 population with mild head injury accounting for 90% of these injuries (Evans, 1992). The accuracy of these figures is questionable as it is widely accepted that the incidence of mild head injury is underreported and is, in fact, higher, as people incurring such an injury do not often seek medical attention (Alexander, 1995). An estimated 20 - 40 % of all mild head injured patients in the USA do not seek medical care (Evans, 1992). Furthermore, it appears that mild head injury incidents in high school are more prevalent than documented in hospital surveys. In this regard, Segalowitz and Lawson (1995) found the head injury prevalence in a high school sample to be 35%. Mild head injury can thus be seen as a quiet disorder as it has no dramatic manifestations, as the incidence is widely underreported and it is symptomatically deceptive (Boll, 1983).

In the 1980's researchers became increasingly concerned about the possibility of brain damage occurring as the direct result of a seemingly *mild* head injury in the absence of gross neurological complications (Binder, 1986; Boll, 1985). These authors issued warnings about the not so minor and previously overlooked effects of mild head injury. In an earlier article, Boll (1983) warns that disruption in coping capacity caused by a seemingly "minor" head injury can lead to psycho-social and academic hardship, particularly as the presence of subtle deficits following a mild head injury may go undetected, especially in a school context. In this regard, a child who may appear attentive, may in fact be struggling to concentrate and may subsequently fail to perform and thus risk the disapproval of peers and teachers. Furthermore, children with mild head injuries experience personality changes, headaches, irritability, school learning difficulties and memory and attention problems. Younger children who suffer from a mild head injury manifest more serious intellectual difficulties than do adolescents with head injuries (Klonoff & Paris, 1984 in Boll, 1985). Impairments in memory and attentional and information processing ability can, even when appearing to be mild and transient, produce altered patterns of achievement and self-confidence with long lasting repercussions. Boll (1985) reports that the most common types of head injuries and those now understood to be the most productive of psychological-behavioural disruption, are those which result from acceleration/deceleration or rotation of the head *without the necessity of a blow being struck to the head.*

2.1.5. SUB-ACUTE NEUROPSYCHOLOGICAL SEQUELAE OF MILD HEAD INJURY

Although the present study focused on mild head injury in a late adolescent population, reference is also made to relevant research pertaining to adults and at times to children, as research specific to the adolescent population appears to be sparse. The more immediate, sub-acute effects of mild head injury will be discussed first, followed by a review of the literature pertaining to neuropsychological recovery following such an injury. For the purposes of this study, neuropsychological sequelae refer to the objective, measurable cognitive deficits following mild head injury.

The *sub-acute* neurological sequelae, common for the first few days following a mild head injury, include disturbances in attention and concentration, complex information processing skills and visuospatial deficits as well as reduced memory capacity (see for example Alexander, 1995; Barth et al, 1983; Gronwall and Wrightson, 1974; Levin et al., 1987; McLean, Temkin, Dikmen & Wyler, 1983; Rimel, Giordani, Barth, Boll, & Jane, 1981).

Studies evaluating the more immediate cognitive sequelae of mild head injuries suggest that such an injury reduces the capacity to process information rapidly. As early as 1974, neuropsychologists Gronwall and Wrightson asserted that the principal dysfunction in minor head injuries is that of a *reduced efficiency of* or a *slowing of central information processing*, with a diminution of channelling capacity. The latter term refers to the amount of information that can be processed at one time. The same authors evaluated 10 patients (aged 17-25) immediately following a minor head injury and again 35 days post injury. They used the Paced Auditory Serial Addition Task (PASAT), which is a test sensitive to speed of information processing, and found that shortly after sustaining the injury, the patients showed poorer performance than controls on this task. MacFlynn, Montgomery, Fenton & Rutherford (1984) examined 45 patients with minor closed head injury (aged 16-65) 24 hours after injury using a Four Choice Reaction Time test and report *slowed reaction time* in these patients.

Other research strongly supports the thesis that *attention and concentration ability* and *memory functions* are also compromised in the sub-acute phase following a mild head injury. It appears from a meta-analytic review of neuropsychological research in the area of mild head injury, that measures of attention and concentration may be the most sensitive indicators of cognitive dysfunction associated with mild head injury (Binder et al., 1997). McLean et al. (1983) found patients with mild head injuries (aged 15-60) to have depressed scores on the Stroop Colour Word Interference task (a measure of *speed, attention and distractibility*) and on the Selective Reminding Test which measures *recent memory*. In a corroborating study, Levin et al. (1987) report impairment of attention, memory, and information processing functions in mild head injury patients (aged 16-32).

In examining mild head injury patients aged 15-56 years, Barth et al. (1983) suggest that impairment in *visuospatial deficits* may follow mild head injury. Furthermore, adolescents evaluated immediately after sustaining a mild head injury exhibited dysfunction in the areas of *learning, abstraction and reasoning* whilst attention, motor speed and visual memory remained unimpaired (Spear Bassett & Slater, 1990).

2.1.6. NEUROPSYCHOLOGICAL RECOVERY FOLLOWING MILD HEAD INJURY

Whilst the more immediate or sub-acute sequelae of a mild head injury are widely accepted, researchers report conflicting results with regard to the course of recovery post injury. Certain studies suggest that resolution of neuropsychological deficits occurs *four or five weeks post injury* although a disruption of psychosocial functioning may remain (Gentilini et al., 1985; Gronwall & Wrightson, 1974; McLean et al., 1983). The study by Gentilini and colleagues used a closely matched control group and the researchers conclude that possible cognitive deficits one month post injury are limited to a subgroup of patients complaining of subjective symptoms like headaches, memory problems and fatigue. Rimel et al. (1981) found deficits in attention, concentration, memory and judgement in patients who had suffered mild head injuries at *three months post injury*. Barth et al., (1983) on examining the same subject pool as Rimel et al. (1981) found impairments in memory and visuo-spatial deficits to be present in subjects three months post injury. In contrast to this, Levin et al (1987) report that deficits in memory, attention, information processing speed are resolved three months after injury, a finding supported by other researchers reporting neuropsychological recovery within three months (for example, Alves, Rimel & Nelson, 1986; Binder, 1986; Evans, 1992). A study by MacFlynn et al. (1984) showed slowing in reaction time in concussed patients six weeks post injury with a resolution of symptoms *six months post injury*. In contrast to this, Gulbrandsen (1984), in a study using a closely matched control group found neuropsychological deficits in school children between the ages of 9 and 13, tested six months post concussion, even in the absence of subjective deficits. Research by Bohnen, Jolles & Twijnstra (1992), conducted on an adult population, suggests that neuropsychological deficits in the areas of attention and information processing persist at six months post injury.

Other studies of adult mild head injury patients have found persisting neuropsychological deficits at *twenty-one months post injury* (Raskin, Mateer & Tweenen, 1998). In a prospective study, Klonoff, Low and Clark (1977) found that a high percentage of pre-school and school age children had not recovered *four to five years post injury* with 27% of these children needing special education for a period of one year.

A review of the research literature reveals differing and often contradictory findings with regard to the course of neuropsychological recovery following mild head injury. It is clear that a significant number of patients continue to complain of persisting deficits months to years after sustaining a mild head injury whilst others do not. In this regard, Binder refers to "selective vulnerability" or "individual difference" (1986, p. 328). Authors assert that the recovery process is mediated by factors such as occupation, age, education, prior head trauma, premorbid functioning, neuropsychiatric history, alcohol use, personality structure, and psychological reaction to injury (Barth et al., 1983; Binder, 1986; Dicker, 1989; Kibby & Long, 1996; Satz et al., 1997). There appears to be a complex interrelationship between head injury, individual differences and interpersonal adjustment (Boll, 1985). These variables serve to complicate the debate surrounding neuropsychological recovery following mild head injury. Furthermore, methodological concerns have contributed to conflicting research findings such as poorly controlled studies and a failure to account for pre-morbid factors (for example, Barth et al., 1983; Rimel et al., 1983)

Whilst prominent researchers embarked on a vehement consciousness raising exercise in the 1980's, warning about possible deleterious cognitive effects following seemingly "minor" head injuries (for example, Binder, 1986; Boll, 1983; 1985), certain of these authours have recently recommend a more conservative approach to evaluating outcomes following mild head injury. Recent reviews appear to deviate widely from these earlier expressions of concern and point to predominantly nul outcomes (for example, Binder et al, 1997). In their meta-analytic review of research in the area of mild head injury, Binder and colleagues in fact suggest a weak causal association between mild head injury and persisting neuropsychological deficits (Binder et al., 1997). These authors, along with Satz et al. (1997), suggest that the false positive diagnoses of brain dysfunction are too common and caution against the undiscriminating acceptance of significant results with regard to neuropsychological outcome following mild head injury.

In response to these reviews, Shuttleworth-Jordan (1999) criticises the authors for taking a purely empiricist view of outcome in that they interpret nul outcomes as meaning recovery has occurred. She asserts that these authors lose sight of the fact that even in the absence of clinically visible symptoms there may be injury to the brain in the form of "silent" (or sub-clinical) head injuries.

These "silent" brain injuries may in turn act as risk factors for future functional impairment. She argues further that meta-analytic reviews use group mean scores in their analyses, whilst significant variability of results *within* samples is overlooked. She proposes that significant variability within a sample on certain tests may show that some individuals *do* show significant deficits. In this regard, researchers investigating potential *future risk* factors as a result of a mild head injury have found that patients who have apparently shown full recovery following a mild head injury, exhibit increased vulnerability to a second stressor such as hypoxia, fatigue or a further head injury (Ewing, McCarthy, Gronwall and Wrightson, 1980). In the latter study, patients examined one to three years post concussion proved to be inferior to controls on auditory vigilance and memory tasks during hypoxic states. Parasuraman, Muller & Molloy (1991) found that during the first month following mild head injury, patients exhibited no impairment of vigilance performance under normal task conditions, but did show impairment under conditions requiring sustained effortful processing which can be considered to involve a higher task challenge. Furthermore, Mortimer et al. (1991) report an association between prior head trauma and Alzheimer's disease, although not specifically with respect to mild head injury. In this regard, Rasmusson, Brandt, Marin and Folstein (1995) report that head trauma may be a predisposing factor for the development of Alzheimer's Disease particularly in the absence of clear genetic contributions.

2.1.7. POSTCONCUSSIVE SYNDROME: A MULTI-DIMENSIONAL DISORDER

The previous section elaborated on the *objective* changes in intellectual function following a mild head injury, i.e. those changes which are able to be measured by a variety of neuropsychological tests. A cluster of self-reported or *subjective* symptoms may persist long after the injury, even after neuropsychological testing indicates resolution. They are referred to in the literature as postconcussive symptoms (Alexander, 1995; Barth et al., 1983; Busch & Alpern, 1998).These symptoms include subjective somatic, cognitive and affective complaints such as headaches, dizziness, irritability, emotional lability, anxiety, depression, blurred vision, insomnia, persistent fatigue, poor concentration and memory difficulties. Controversy surrounds the aetiology of postconcussive symptoms, with possible causes ranging from organic shear-strain injury to pre-existing emotional problems (Klonoff & Lamb, 1998). It is generally postulated that these persisting symptoms are not caused by brain injury in a simple cause and effect way but result rather from a complex interplay of both physiological and psychological issues (Alexander, 1995). Mild head injury is a *multi-dimensional* and *multifactorial* disorder and the sequelae following damage caused by such an injury will vary from person to person depending on age, education level, premorbid neuropsychological integrity, injury characteristics and psychological reaction to the injury (Barth et al., 1983). Such symptomatic reactions to mild head injury are mediated by variety of issues from concerns about compensation claims to emotional reactions (King, 1997). In sum, many persistent postconcussive symptoms are an interaction between organic and psychological factors and may start on an organic basis and persist and be experienced on a psychological level (Levin et al., 1982). The DSM-IV has proposed certain research criteria for postconcussional disorder which, whilst including self-reported postconcussional symptoms require objective evidence of neuropsychological deficits such as is gleaned from neuropsychological testing and quantifiable cognitive assessment (American Psychological Association, 1994). Postconcussive syndrome is not the main focus of this present study, which is exclusively concerned with sequelae observable on cognitive test data and not self reported symptoms, and has thus been reviewed here only in a cursory manner.

2.1.8. CUMULATIVE MILD HEAD INJURY

The previous sections attempted to highlight the complex and yet unresolved issue of the long-term effects following mild head injuries. Authors suggest it is safe to conclude that a *single* mild head injury to persons with no prior compromising condition, probably produces mild, clinically insignificant difficulties one month after injury and has as yet no clearly demonstrable permanent effects (for example, Dikmen, McLean & Temkin, 1986; Levin, 1997). However, the reversibility of sub-acute cognitive deficit after a mild head injury in no way excludes the presence of microscopic lesions (Oppenheimer, 1968) which may reduce patients' cerebral reserve in response to later insults. In a seminal study, Gronwall and Wrightson (1975) report that patients who are concussed a second time, show a decreased rate in information processing and slower reaction time than patients with a first concussion. The same authors conclude that objective cognitive deficits are more persistent in patients with a history of *multiple* head injuries. A later study by Gronwall (1989) examining patients with mild head injury, corroborates these earlier findings in that older patients and patients with previous head injuries showed impairment in speed of information processing as measured by the PASAT and took longer to recover than the group with a single episode of mild head injury. These findings provide support for the hypothesis that the effects of mild head injury may be cumulative and indicate that the course of recovery is increasingly prolonged after successive injuries which are thought to inflict progressive diffuse axonal injury.

It appears from the above-mentioned studies that the sequelae following a mild head injury may be *cumulative* even after a person has recovered clinically and, in fact, that the course of recovery is prolonged after each successive injury. It is, therefore, safe to conclude that there is a risk of increasingly negative consequences from subsequent head injuries (Levin et al., 1987). The most dangerous of these consequences is referred to in the literature as *second impact syndrome*, when even a minor second impact sustained before full resolution of symptoms of the first concussion, may result in fatal brain swelling (Saunders & Harbaugh, 1984). The concept of *cumulative damage* is central to this thesis as players of contact-sports such as rugby are at risk of sustaining repeated mild head injuries.

However, a study of Australian Rules footballers by Maddocks, Saling & Dicker (1995) does not support the notion of cumulative effects from repeated mild head injury. The authors argue that the Gronwall and Wrightson (1975) included patients who had been injured in motor vehicle accidents involving acceleration/deceleration forces of greater significance than the acceleration/deceleration forces involved in a sporting head injury, thus leading to positive outcomes. However, the Maddocks et al. (1995) study has certain methodological limitations in that a retrospective concussive head injury history was obtained from the players and in that the control group consisted of a so-called non-head injured football group. This may have confounded results as it is typically difficult accurately to assess head injury history in sports players who are known to underreport mild head injuries and in view of the prevalence of sub-concussive head injuries or frequent knocks to the head which are barely noticeable (Gerberich et al., 1983; MacLeod, 1993; Roux, Goedeke, Visser, Van Zyl & Noakes, 1987). With regard to repeated concussions in football, Binder (1997) asserts that football is

> probably a special case because participants experience an extremely large number of blows. Professional football probably results in thousands of player-to-player collisions with many of the blows either directly to the head or causing the head to shake.
>
> (Binder, 1997, p. 442)

2.2. MILD HEAD INJURIES IN SPORT

The high incidence of sports-related head injuries is alarming, representing approximately 20% of 1.54 million head injuries which occur annually in the USA (Erlanger, Kutner, Barth & Barnes, 1998). The prevalence of sports-related head injuries in South Africa is unknown and difficult to assess as the seemingly trivial injuries frequently remain unreported (Roux et al., 1987). This is especially applicable in sports where a milder form of head injury is common. This is cause for concern as cumulative head injuries traditionally regarded as trivial or "minor", may result in players running a risk of increasingly negative consequences following subsequent head injuries. In fact there may be no such thing as "mild" head injury or "mild" concussion if one considers the rare but catastrophic outcome of second impact syndrome as previously discussed. Kelly et al. (1991) report on a high school football player who died of diffuse brain swelling after repeated concussions without loss of consciousness. Players of contact sports are at great risk of sustaining repetitive mild head injuries. The negative outcome following repetitive minor head injuries has been demonstrated by numerous studies on boxers and other athletes exposed to repeated concussive and sub-concussive blows (for example McLatchie et al., 1987). Players of contact-sports such as American football, "amateur" wrestling, ice hockey, soccer, martial arts and rugby, are at a high risk of sustaining mild head injuries (Lehman & Ravich, 1990).

Cerebral injuries in sports can be caused by a moving head hitting the ground or some other relatively stationary object, or by tackling or being tackled, or during a collision. The head comes to an abrupt halt and the relative movement of the brain continues with translational and rotational acceleration, usually of a low velocity, taking place (Kelly et al., 1991). The rotational and shear strains are less severe than for example those sustained in a motor vehicle accident and most sports related injuries fall in the mild range of severity evidenced by confusion and disorientation and infrequently require hospitalisation. These episodes are referred to informally as "dings" or having one's "bell rung". However, if the blow is not anticipated, as would happen when a player is tackled from behind, the acceleration forces to the head are increased substantially (Cantu, 1996). Mild head injuries in contact sports may also be attributed to a lack of skill and training and, at times, to foul play.

The occurrence of head injuries in contact sports is inevitable. However, provision can be made for adequate assessment of players who have sustained any degree of head injury and to advise both players and coaches alike to avoid the development of serious neurological complications following such the injury. The accurate evaluation of concussion is at times difficult, particularly in the cases where concussions are mild (Grade 1) and where no loss of consciousness occurs but where there may be impairment in intellectual function, especially in recalling recent events and assimilating and interpreting new information (Anderson, 1986; Cantu, 1986). Furthermore, assessment and subsequent treatment in these cases is difficult as concussive (and sub-concussive) injuries are frequently minimised by athletes who do not want to be seen as "weak", "a failure" or as "letting the team down". Medical personnel and coaches have often not been able to assess concussion adequately owing to the differing definitions of concussion which abound and the inadequate assessment measures available. Guidelines for removal from play have emerged from the literature and Cantu (1986) proposes that a single mild concussion (Grade 1) should warrant an athlete's removal from play for one week, that a second mild concussion warrants removal for two weeks and that after a third mild concussion, the athlete should terminate play for the rest of the season. Cantu's guidelines for return to play following concussion are tabulated below (see Table 2-2, p. 15).

The use of neuropsychological testing has been recognised as being a sensitive and effective method of determining subtle deficits associated with mild head injuries (for example Barth et al., 1989). Tests which are sensitive to the effects of subtle but diffuse brain damage may be extremely useful in determining baseline levels of functioning, post injury levels of functioning and may also be used as an objective measure in determining whether a player is ready to return to play. The role of neuropsychological testing has gained particular credibility with the inclusion of neuropsychological testing in research criteria of postconcussional disorder in the DSM-IV (American Psychological Association, 1994).

Table 2-2. Guidelines for Return to Play after Concussion (after Cantu, 1986)

	First Concussion	Second Concussion	Third Concussion
Grade 1 (Mild) No LOC PTA < 30 min	Return to play after asymptomatic for 1week	Return to play in 2 weeks if asymptomatic at that time for 1 week	Terminate season; may return to play next season if asymptomatic
Grade 2 (Moderate) LOC < 5 min PTA > 30 min PTA < 24 hours	Return to play after asymptomatic for 1 week	Minimum of 1 month; may return to play then if asymptomatic for 1 week; consider terminating the season	Terminate season; may return to play next season if asymptomatic
Grade 3 (Severe) LOC > 5 min PTA > 24 hours	Return to play after a minimum of 1 month; may then return to play after being asymptomatic for 1 week	Terminate season; may return to play next season if asymptomatic	

Asymptomatic means no headache, dizziness, or impaired orientation, concentration, or memory during rest or exertion.

Recently the importance of neuropsychological testing for the assessment and management of concussions in the sports arena has come to light and the following sections discuss neuropsychological research conducted in specific contact sports, namely: boxing, soccer, American football, Australian Rules football, rugby league and rugby union. Although boxing and soccer may appear to be unrelated to rugby, neuropsychological research in boxing and soccer have provided evidence for the deleterious effects of repeated mild head injuries sustained in contact sports, a theme central to this thesis. The rugby/football related sports are more obviously similar, thereby warranting specific scrutiny. Where possible, the differing mechanisms of mild head injuries sustained in the various sports, are highlighted.

2.2.1. BOXING

Boxing is unique as a sport in that the main aim of the boxer is to render the opponent unconscious. Historically, boxers who have suffered numerous "knock-outs" and display certain symptoms including poor co-ordination, speech difficulties, resting tremor and even memory difficulties, have been known to suffer from "punch drunk syndrome" or "dementia pugilista" (Lezak, 1995; Martland, 1928; Ruchinskas, Francis & Barth, 1997). This syndrome degenerates into a Parkinsonian type of movement disorder. The mechanisms involved in brain injury sustained in boxing are clear. A punch causes rotational acceleration of the head and the veins and long axon fibres may be stretched and torn resulting in subdural heamotomas or axonal damage. Furthermore, falling against the ropes may cause impact deceleration and blows to the neck may injure the carotoid artery (Haglund & Eriksson, 1997).

Boxers appear to be at risk for the progressive consequences of tissue damage resulting from repeated head trauma. Researchers have become aware that the most important factor contributing to the severity and long term consequences of head trauma in boxing is not necessarily the number of knock outs, but rather the subtle and chronic *cumulative* effect of multiple blows sustained over a long time. Ross, Casson, Siegal & Cole (1987) find neuropsychological test impairment to be correlated with the number of professional fights. Studies using neuropsychological testing and other neurological examinations (e.g. CT and MRI), show the deleterious cognitive effects following punishment to the head in boxing. In this regard, Casson et al, (1984) studied a mixed group of 18 active and former boxers, using a combination of neurological, EEG, CT and neuropsychological examinations. A large number of these boxers (87%) exhibited abnormal findings on at least two of four measures. Each boxer showed impairment on more than one neuropsychological measure which included the Trailmaking Test, the Digit Symbol Test and the Weschler Memory Scale. Furthermore, abnormal scores correlated highly with abnormal CT scans, age and number of fights. The researchers conclude that there is a direct relationship between length of career and presence of brain damage.

Whilst a number of studies suggest the presence of deleterious cognitive effects following participation in *amateur* boxing, research concerning the risk of chronic brain damage in amateur boxing has shown inconsistent results. Kaste et al. (1982) studied amateur and professional boxers and found the amateur boxers to show mild deficits on certain neuropsychological tests. Whilst the amateur boxers suffered less brain damage than did the professionals, the researchers conclude that modern medical control of boxing cannot prevent chronic brain damage in amateur boxers. McLatchie et al. (1987) found amateur boxers to show more deficits as measured on neuropsychological tests of attention, verbal and visual memory, than did a control group and the authors conclude that neuropsychological tests are the most sensitive measures in ascertaining these deficits. A study investigating 23 *amateur* boxers before and after an amateur boxing event found verbal and incidental memory to be diminished after a bout (Heilbronner, Henry & Carson-Brewer, 1991). However, no matched control group was used in this study.

In contrast to the studies supporting the presence of cognitive difficulties, other researchers have reported nul outcomes when examining the neurocognitive effects of amateur boxing. A study of amateur boxers which used tests of information processing, reaction time and learning and memory, found the boxers to exhibit no significant differences when compared with controls (Brooks, Kupshik, Wilson, Galbraith & Ward 1987). The authors further conclude that amateur boxing appears to be well-controlled and thus neurologically safe. They do, however highlight certain methodological limitations of their study in that their subjects and their controls were inadequately matched. A retrospective study of fifty former amateur boxers in Sweden found only a minimal neuropsychological deficit in fine-motor speed when amateur boxers were compared with control groups (Haglund & Eriksson, 1993). The slightly inferior performance of the boxers on the Fingertapping Test is attributed to damage of peripheral nervous and/or motor function rather than central diffuse damage.

In view of contradictory results emerging from research in this area, the effects of mild head injury in the acute and long term functioning in *amateur* boxers remain unclear. In contrast, however, the presence of chronic, *cumulative* effects of multiple blows sustained over a long time in professional boxers, remains relatively undisputed.

2.2.2. SOCCER

Soccer is a sport which is played widely all over the world and which commands a huge following both in South Africa and abroad. The deliberate use of the head to propel the ball is relatively unique to soccer; thus the risk of sustaining mild head injuries whilst playing in competitive soccer is thought by some to be high. In recent times, the "heading" of a hard and fast moving ball has been a cause for concern as head injuries have been found to number between 4% and 22% of all soccer injuries (Ruchinskas et al., 1997). Abreau, Templer, Schuyler and Hutchison (1990) cite an incidence study conducted in New Zealand by McKenna and colleagues in 1986 which finds that soccer accounts for the second highest number of head injuries in winter sports with 33% of these injuries attributed to heading. A further study by Barnes et al. (1998) reports that 52% of elite soccer players sustain concussions during their career, with male soccer players showing a higher incidence (in Boden, Kirkendall & Garret 1998). In view of the growing concern about the risks of "heading", Boden and colleagues (1998) have researched the injury mechanisms involved in soccer head injuries. They report that the most frequent injury mechanism involved in soccer concussions appears to be a collision with another player's head; the second most frequent concussion results from "unintentional" contact with the soccer ball (Boden, et al., 1998). The same researchers found, in contrast to the New Zealand study, that no concussion was caused by the routine heading of the ball. Other mechanisms of injury include a loss of balance resulting in the head being hit against the ground and, less commonly, collisions with elbows, knees, feet and goalposts.

Research into the neuropsychological effects of repeated mild head injuries in soccer has shown certain ambiguous results. A study by Abreau et al. (1990) found no significant differences between the neuropsychological test performance of soccer players and tennis players on tests of attention and concentration. However, there appeared to be a significant negative correlation between the number of games played and performance on the PASAT amongst the soccer players. Furthermore, soccer players more frequently complained of subjective symptoms e.g. headaches, dizziness and blurred vision. The authors themselves highlight certain limitations of their study, namely that it is regarded as a pilot study, that the use of volunteers may have confounded results in that the players may have been eager to recall subjective symptoms associated with concussion in order to please the researchers and that the study was retrospective in nature. These methodological limitations lead to the results providing only tentative support for the existence of neuropsychological deficits following repetitive mild head trauma. A further study revealing nul outcomes, was carried out on active elite soccer players to determine the effects of repetitive heading of the ball by using a questionnaire and MRI examination (Jordan, Green, Galanty, Mandelbaum & Jabour, 1996). Analysis of the questionnaire and MRI revealed no statistical difference between soccer players and a control group consisting of track and field athletes. However, reported head injury symptoms in the soccer group correlated highly with a history of prior head injuries. The authors conclude that evidence of encephalopathy in soccer players relates more to acute head injuries than to repetitive heading.

Other studies provide more definitive support for the existence of neurological and neuropsychological impairment following repeated mild head injury in soccer. A study by Tysvaer and Storli (1989) reveals a significantly increased incidence of EEG disturbances in soccer players when compared to matched controls, especially among the younger players and these EEG disturbances are attributed to neural damage caused by repeated minor head traumas. In 1991, Tysvaer and Lochen evaluated the neuropsychological functioning of 37 former professional soccer players. The soccer players show more variability on Verbal IQ scales and poorer performance than controls on the Trailmaking Test. A high percentage (81%) of soccer players were characterised as having some neuropsychological deficit in attention, concentration, memory and judgement versus 49% of controls. The study concludes that blows to the head by headers show convincing evidence that brain damage can be expected from repeated mild traumas to the head. A further study by Tysvaer (1992), which included the use of CT scans and Weschsler Adult Intelligence Scale (WAIS) Tests, again revealed definitive neurocognitive results. This study reports that 30 % of retired soccer players complained of chronic postconcussive symptoms and 81% showed mild to moderate deficits on neuropsychological tests of memory, attention, concentration and judgement, as opposed to a 40% impairment among age-appropriate controls. Furthermore one-third of the players were found to have central cerebral atrophy. Paradoxically, fewer abnormal EEG's were apparent in players who describe themselves as "typical headers" when compared with non-headers. Baroff (1998) explains this paradox by arguing that headers are in fact more skilled and practised with regard to heading techniques. However, these studies have methodological limitations in that they failed to control for pre-morbid factors such as pre-existing neurological disturbances, alcohol abuse, and previous non sports related head injuries. A corroborating and well-controlled study by Matser, Kessels, Jordan, Lezak and Troost (1999) compares the neuropsychological test performances of amateur soccer players with a control group consisting of swimming and track and field athletes The soccer players show poorer performance than the controls on tests of attention, memory and planning abilities. These results are similar to the same researcher's study on professional soccer players who showed impaired performance on tests of memory, planning and visuoperceptual processing when compared with controls (Matser et al., 1998). The poor performance of soccer players on neuropsychological tests was highly correlated with the number of previous concussions and number of "headings". Furthermore, the forward and defensive players whose positions are associated with the most heading of the ball, showed more neurocognitive impairment than players of other soccer positions.

The question of whether heading actually causes deficits remains unresolved. Although evidence is equivocal, Kernick (1999) suggests that intuitively one would anticipate a degree of minor brain trauma in headers and he suggests that heading only be allowed in the penalty area, thereby eliminating trauma from long directly returned balls which could cause the most damage. This author cites a study by Auitti and colleagues (1997) which found that amateur soccer players show a higher incidence of white matter foci (changes correlated with subtle cognitive dysfunction) than American football playing controls. The researchers conclude that these changes are a result of brain trauma sustained during the game. Whilst the pathological effects and long term risks of minor head injuries in soccer are not well researched, soccer players are more likely to have EEG abnormalities and cortical atrophy when compared with the general population. It is, however, not known whether they are at risk for developing dementia, although Spear (1995) poses participation in soccer as a potential risk factor.

2.2.3. RUGBY/FOOTBALL

Whilst the focus of the present study is on the cumulative effects of mild head injury in rugby union players, research pertaining to American football, Australian Rules football and rugby league will also be discussed as these sports strongly resemble rugby union which is played in South Africa. These sports all involve a measure of tackling, scrumming and collisions which often occur at high speed. Head injuries are not primarily due to direct blows to the head such as may be sustained in boxing and, arguably in soccer, but are rather the result of stresses and impacts on the neck and head sustained during the above mentioned manoeuvres (Shuttleworth-Jordan et al., 1993). The mechanisms of head injury are similar in that they are caused by rapid acceleration/deceleration and rotational forces. These sports differ in terms of their rules and number of players on the field but the methods of play are similar.

2.2.3.1. American Football

Despite the fact that American football players are required to wear protective clothing, the likelihood of sustaining minor brain trauma during play is high. A recent epidemiological study found football injuries to account for 63.4% of all reported sport-related minor traumatic brain injuries in the USA, with either tackling or being tackled accounting for the greatest frequency of these injuries (Powell & Barber-Foss, 1999). Research involving college football players reported that 45% of the injuries involved direct impact to the head (mostly helmet-to-helmet collisions) whilst 34,6% involved no impact to the cranium but resulted mostly from collisions with other players involving some kind of rotational injury. Rule changes have eliminated the use of "spearing" (the use of the head in a defensive manoeuvre) thus removing the head from primary contact and reducing head injuries. It appears, however, that the risk of injury, particularly mild head injuries, is still a cause for concern. In a prospective study of head and neck injuries in university football players over an eight year period, Albright and colleagues (1985), report an incidence of 175 head and neck injuries per 100 players. They also report that after sustaining a single head injury, the probability of subsequent head injuries escalates sharply and that players appear to be more affected by the second injury. The prevalence of mild head injury in high school football is high. A study by Gerberich and colleagues (1983) reports that 19% of high school football players in their study suffered from concussion as defined by loss of consciousness or loss of awareness, or, as diagnosed by a physician. However, it appears that concussion often remains unrecognised and undiagnosed. In this regard, the same researchers report that 69% of the athletes who experienced a loss of consciousness returned to play the same day. The authors hypothesise that players fear ridicule and are highly ignorant of the risk they undertake when returning to play. Furthermore, the "mild concussions" involving no loss of consciousness receive infrequent medical attention in this population. The authors note that unless the player is told he has concussion, he does not associate the symptoms of loss of awareness and transient amnesia or loss of consciousness with the word concussion. Furthermore persistent concussive symptoms are reported for as long as six to nine months following the end of the season.

The first major study to use neuropsychological testing in this sport embarked on a four year prospective research project on a large sample of college football players to assess the recovery curve of football players with mild head injury (Barth et al. 1989). Pre-season data was gathered on measures of attention and concentration (Trailmaking Test), psychomotor problem-solving and visuo-perceptual abilities (Symbol Digit Modalities Test), complex sustained attention and immediate recall and rapid mental processing (PASAT). Concussed players were re-tested twenty-four hours, five days and ten days post injury and again post season. The results suggest that a single mild head injury in football causes cognitive deficits as seen on neuropsychological assessment within twenty-four hours, with recovery taking between five to ten days. Previous studies by Barth et al. (1983) and Rimel et al. (1981) suggest that symptoms persist beyond three months but these studies show methodological limitations. A more recent prospective, controlled study by Macciocchi, Barth, Alves, Rimel and Jane (1996) achieved similar results to the Barth et al. (1989) study, in that impairment in their subject group as measured on the Trailmaking Test, Digit Symbol Test and PASAT, appeared to resolve within five days. The authors conclude that a *single* uncomplicated mild head injury shows rapid resolution of symptoms.

A study by Wilberger, Haag and Maroon (1991 in Wilberger, 1993) investigates the long term neuropsychological functioning of high school football players who sustained *two* concussions in one season. The players showed abnormalities on the PASAT, Symbol Digit Modalities Test and the STROOP at three months post injury. More recently, Collins et al. (1999) attempted to assess the relationship between a history of concussion and learning disorder and between these two variables and neuropsychological test performance. The researchers used college football players as their sample who were given baseline neuropsychological evaluation. Thereafter, players who sustained concussion were tested along with a control group of non-concussed players. The neuropsychological test battery included the Trailmaking Test, Digit Span, Symbol Digit Modalities Test and controlled oral word association. The researchers report a significant interaction between learning disability and a history of multiple concussions and learning disability on two neuropsychological tests (Trailmaking B and Symbol Digit Modalities) indicating a poorer performance in players with learning disabilities and multiple concussions than other groups. The authors conclude that both a history of *multiple concussions* and *learning disability* are associated with reduced cognitive performance and that neuropsychological assessment is a useful indicator of cognitive functioning in athletes.

There have, however, been few controlled prospective neuropsychological studies examining the effects of cumulative mild head injuries in American football, despite the high incidence of mild head injuries in this contact sport.

2.2.3.2. <u>Australian Rules Football</u>

Australian Rules football is a variant of rugby league (see section 2.2.3.3) and is played with eighteen rather than thirteen players on a bigger field. More kicking, running and jumping is involved and the game is thought to involve less body contact than rugby league (Gibbs, 1993). However, as with other rugby/football related sports, players of Australian Rules football run a high risk of sustaining mild head injury. A study of professional Australian Rules football players found that 25% of all injuries were to the head and neck and 5% of all injuries were concussions (Dicker, McColl & Sali, 1986 in Maddocks, Saling & Dicker, 1995). Researchers investigating the neuropsychological effects of mild head injury in this sport, find that deficits are indeed detectable in the early stages following mild head injury, even once neurobehavioural symptoms (e.g. headaches, nausea) have resolved (Maddocks & Saling, 1991). The latter researchers administered the PASAT, Digit Symbol Substitution Test and a number of reaction time tests to Australian Rules football players to establish baseline data for the players. Thereafter, concussed players and a matched control group of non-injured players were re-tested five days post injury. The injured players exhibited poorer performance on the Digit Symbol Test and decision time tests.

A later study by Maddocks et al. (1995), aimed at collecting normative data for Australian Rules football players on the Digit Symbol Test, as well as at ascertaining whether the existence of previous concussive injuries leads to a poorer performance on the Digit Symbol Test six months post injury. Pre-season baseline data was collected for professional players and the Digit Symbol Test was subsequently administered. Of the 198 players, 119 had been previously concussed, but not within six months of the time of the assessment. No significant difference was found between the groups of players who had no history of concussion, a history of single concussion, or two or more concussions. The results lead the researchers to assert that players with a history of concussion show no residual effects six months or longer post injury as measured by the Digit Symbol Test. The authors further conclude that their results do not support the concept of cumulative damage as set out by Gronwall and Wrightson (1975). They argue that these authors selected a sample of patients with motor vehicle accident (MVA) related head injuries and that sport-related head injuries result from smaller deceleration forces and are, therefore, more minor. Maddocks and colleagues (1995) describe the limitations of their own study being retrospective in nature and emphasise that the concussive histories were gained from self-report with no medical confirmation. Furthermore, an appropriate control group was not used in this study in that they were comparing rugby players with each other, many of whom may have suffered multiple knocks to the head which they did not count as concussion for the purposes of the research histories.

Certain studies suggest the presence of persisting deficits following mild head injury in this sport. Cremona-Meteyard & Geffen (1994) compared the performance of Australian Rules football players who had sustained a mild head injury on cued reaction time tasks, with a non-injured control group. The results led them to suggest that persistent deficits one year post injury may include the inability to act rapidly in response to spatial events. However, studies into the long term effects of mild head injuries in this particular sport remain limited.

2.2.3.3. Rugby League

Rugby league is an extremely physical game which requires a great deal of speed, stamina and strength from the players. The ball cannot be thrown forward but must be kicked down the field or carried forward over the goal line to score a "touch-down" or "try". The ball is passed between the teams after a certain amount of tackles (which are a prominent part of the game) and the same players are thus offensive and defensive players. The game carries the inherent risks of being knocked over backwards and sustaining whiplash by the clashing of heads. The forward players are involved in sustained body contact throughout the game because they are involved in rucks and reportedly incur more injuries than the backline players do (Gibbs, 1993; Gissane, Jennings, Cumine, Stephenson & White, 1997; Seward, Orchard, Hazard & Collinson, 1993; Stephenson, Gissane & Jennings, 1996). The body part most freqently injured in this game is the head and neck region which according to a recent epidemiological study by Stephenson et al., 1996, accounts for 33% of all injuries. Incidence studies show that concussion accounts for between 5% and

8.5% of all injuries sustained amongst rugby league players (Alexander, Kennedy & Kennedy, 1979; Seward et al., 1993). The study by Alexander and colleagues (1979) reports that ten out of thirteen concussions occur in front-row players. Seward et al, (1993) conclude from their study that with respect to frequency of injuries, rugby union (see section 2.3.1) is a safer game to play than rugby league at elite club competition level.

Despite the potential hazards of playing this sport and the high frequency of head injuries revealed by epidemiological research, there have been few studies investigating the neurocognitive effects of mild head injury in rugby league. In this regard, Hinton-Bayre and colleagues (1997) examined the hypothesis that an impairment of speed of information processing underlies the poor neuropsychological performance following mild head injury in rugby league football. The researchers initially measured the sensitivity of certain neuropsychological tests namely, the Symbol Digit Modalities Test, the Digit Symbol Substitution test and the Speed of Comprehension Test. The second phase of the study showed measures of speed of information processing to be sensitive in the post-acute phase following mild head injury. Speed of Comprehension was more sensitive to impairment than the other two tests. It seems clear that this research needs to be augmented by further investigations into the neuropsychological sequelae of mild head injury in rugby league.

2.3. NEUROPSYCHOLOGICAL SEQUALAE OF MILD HEAD INJURY IN RUGBY

2.3.1. RUGBY UNION

As previously mentioned, this study focuses on rugby union players. Rugby union (hereafter referred to as rugby) commands a huge following and is likened by some to a 'religion' in South Africa. Similar to rugby league, rugby union is a high intensity game, often involving manoeuvres executed at considerable speed. Although researchers have asserted that rugby union is a safer game to play than rugby league with respect to frequency of injuries (Seward et al., 1993), the extent of the injuries in rugby union may be more severe. South African studies report that up to 21 % of all rugby related injuries are to the head and neck, with 10 - 13% of these injuries involving concussion (Roy, 1974; Van Heerden; 1976). Phases of play such as tackling or being tackled, scrummaging, rucks or mauls, line-outs and inadvertent collisions provide ample opportunity for injury. Concussive and (sub-concussive) mild head injuries in rugby are highly prevalent. The game of rugby offers a variety of forward (8) and backline (9) positions and players are allocated to these positions depending on their particular levels of physical skill and psychological characteristics. Players accept that they are at high risk for injury and the more experienced players may protect various parts of their body that are vulnerable to injury by using supportive strapping and, more frequently by using individually fitted mouthguards. The rules of the game permit the use of a lightweight "scrumcap" to protect players' scalp and ears (MacLeod, 1993).

2.3.2. MANAGEMENT OF MILD HEAD INJURY IN RUGBY

The resolutions of the International Rugby Football Board (IRFB), identify concussion to be an injury warranting special attention from players, referees and coaches alike (MacLeod, 1993). The IRFB recommends that after a single concussion a player is removed from any form of play for three weeks. Furthermore, it is accepted by the rugby community that a second concussion in one season warrants the removal from contact with the sport for three months and a third concussion in one season warrants removal for six months. Shuttleworth-Jordan et al. (1993) recommend a more conservative approach in the management of a single concussion and discourage participation in the sport for at least three months following such an injury. The incidence of mild concussion (Grade 1) is widely underreported and MacLeod (1993) suggests that this may be so because of a degree of collusion between players, coaches and medical attendants who are reluctant to make a diagnosis without adequate objective evidence of concussion and who, in all likelihood, would like to avoid the three weeks recommended rest following a single concussion.

2.3.3. SCHOOLBOY RUGBY

Rugby appears to be the winter sport most encouraged in South African English and Afrikaans medium schools. Whilst it is not necessarily compulsory, it appears to be the "default sport" according to Shuttleworth-Jordan et al. (1993) and there is a great deal of peer pressure to play the rugby. These latter authors report that exemptions from playing rugby are not often granted unless there are serious medical reasons for not playing. Certain trends emerge from research into the pattern of injuries in schoolboy rugby. Injury rates appear to be higher at the beginning of the season or after the winter break due to a "lack of match fitness", with hookers and eighth men sustaining the highest number of injuries (Lee & Garraway, 1996; Nathan et al., 1983; Roux et al., 1987). These studies suggest that the increased prevalence of injuries with age may be due to "psyching up" factors prevalent in the top teams. The greater incidence of injury amongst fast, mobile players is attributed to "speed of play", especially when players are involved in tackling or being tackled, these manoeuvres accounting for up to two thirds of schoolboy match injuries (Lee & Garraway, 1996). An epidemiological study of all serious rugby injuries sustained in one playing season in a schoolboy population, reports *concussion* to be the single most common injury accounting for 21.5% of all injuries (Nathan et al., 1983). According to Roux et al. (1987), the incidence of concussion at schoolboy level remains widely underreported and the gathering of epidemiological data via correspondence, which has been a convenient method of research, appears to be problematic as players and coaches may minimise injuries. These latter researchers suggest in their report that the most accurate method of data collection is direct contact between the researcher and the injured player.

2.3.4. RESEARCHING THE EFFECTS OF MILD HEAD INJURY IN RUGBY

Whilst there have been numerous studies focusing on boxing, soccer, and other rugby/football related sports, research into the cumulative effects of mild head injury in rugby union players (as well as in rugby league players) remains sparse. Shuttleworth-Jordan et al. (1993) were the first to investigate the cumulative effects of mild head injury in rugby union players. A sample of South African university rugby players was assessed pre- and postseason on a battery of neuropsychological tests which included the Purdue Pegboard, the Digit Span and Supraspan tests and the Trailmaking Test. Players who were formally declared concussed during the season were excluded from post-season testing in order selectively to investigate long-term and sub-concussive effects. Rugby players exhibited deficits on hand motor dexterity tasks, working memory tasks and tasks of new verbal learning when compared with a matched non-contact sport control group. Furthermore, the control group exhibited significant practice effects when tested post season in comparison with the rugby playing group who showed less capacity to benefit from practice than the control group (i.e. they manifested new learning abilities). Impairment in these modalities is typical of the type associated with diffuse brain damage effects and lends support to the presence of deleterious effects following cumulative mild head injury in rugby. In addition the Shuttleworth-Jordan et al., (1993) study found that forwards showed more impairment than did backs and the authors argue that this is as a result of the forwards being involved in more scrumming and thus being exposed to repeated head to head and head to torso pressure. In this study, rugby players who reported more than one mild head injury in the three years prior to the research, were excluded in an attempt to target permanent effects, and the results of the study are thus deemed by the researchers to be conservative estimates of deficits in the rugby playing group. In the concussed rugby group, compared with matched non-contact sport controls, recovery as measured by the neuropsychological tests was not complete at a three month follow-up, even though self-reported symptoms were not present. In view of the latter finding, the authors raise concerns about "silent" head injuries, which has particular relevance for schoolboys who are at a high risk of effects following mild head injury.

> The risks are particularly severe for candidates who are aiming for competitive scholarships, or for borderline achievers who were already in danger of failing pre-injury. In such individuals, a permanently reduced level of functioning, however slight, might be a factor which tips the balance with significantly disruptive and possibly even disastrous effects. Generally, if attempts are made to undertake tasks in the face of unrecognised head injury effects, this can result in unexpected failure, and set up a cycle of negative psychological consequences such as depression and self-doubt.
>
> (Shuttleworth-Jordan et al., 1993, p.17).

The Shuttleworth-Jordan et al. (1993) study inspired an ongoing research initiative which was launched in 1996 by Rhodes University in conjunction with SARFU and the Sports Science

Institute in Cape Town. The research purported to investigate the effects of cumulative mild head injury on the cognitive functioning of *professional* South African rugby players as evidenced on neuropsychological tests deemed to be sensitive to the effects of diffuse brain damage. The research thus far has comprised three phases.

The first stage (Phase I) of the research involved the neuropsychological testing of *professional* rugby players and professional cricket players (control group). The protocol comprised a selection of neuropsychological tests and a detailed clinical interview comprising demographic and postconcussive questionnaires. The neuropsychological tests battery was designed to include tests particularly sensitive to the effects of diffuse damage associated with mild head injury as well as to test current functioning across a comprehensive spectrum of key cognitive modalities including: attention and concentration, memory/new learning ability, verbal fluency, visuoperceptual tracking and fine motor dexterity. The test battery included tests to estimate players' pre-morbid intellectual ability (calculated from the SAWAIS Comprehension and Picture Completion subtest scores). All players with mild head injury were included in the sample, and those players with a prior moderate to severe head injury were excluded from the study. Testing for rugby players was conducted strictly pre-season in an attempt to isolate permanent rather than acute effects. Data were analysed in three ways, namely: (1) A direct comparison of neuropsychological test scores of rugby players versus cricket players (Ancer, 1999); (2) a comparison of rugby and cricket players scores versus normative data (Reid, 1988); (3) a comparison of the percentages of individual rugby versus cricket players who exhibited deficits compared with the norms and, a comparison of the frequency of reported postconcussive symptomology in rugby players and controls (Dickinson, 1998).

Taken together, the results of these three studies from Phase I of the research initiative support the presence of cognitive deficits suggestive of brain injury following cumulative concussive mild head injuries. Of particular relevance are the findings of Ancer (1999) whose method is replicated for the purposes of the present study. Patterns of increased variability of performance were evident within the rugby playing group when compared with the cricket group on tests of visuoperceptual tracking sensitive to the effects of diffuse brain injury, namely the SA WAIS Digit Symbol Substitution Subtest and Trailmaking B. Mean score comparisons within the rugby group indicated that the rugby forwards showed poorer performance relative to the backs on tests of attention and concentration, working memory, visuoperceptual tracking, verbal memory and visual memory, a pattern of deficits commensurate with cumulative mild head injury. These latter tests included the Digit Symbol Substitution Incidental Recall - Delayed task, Digits Backward and the Trailmaking Test. The study used a relatively small sample size and, retrospectively, the cricket players (cricket traditionally being a summer sport) were not considered an ideal control group as certain cricket players had a history of playing rugby as a winter sport and thus a high incidence of mild head injury. Furthermore, they were tested post-season when they were considerably fatigued.

The second stage (Phase II) of research attempted to replicate the first phase but used a larger sample of *professional* rugby players and more appropriate non-contact sport control group consisting of elite hockey players. The neuropsychological test performances of the National Under 21 Rugby squad and a non-contact sport control group of national hockey players on the same neuropsychological test battery used in Phase I, were included in the comparison. The use of a hockey control was considered to be an improvement over the first stage of research as hockey is traditionally considered a winter sport and as there is little overlap with playing rugby. Furthermore, both the rugby players and the hockey controls were tested pre-season. For the purposes of Phase II of the research, the three separate data analyses carried out in Phase I were replicated for the rugby versus the hockey control groups, as well as for rugby forwards versus rugby backs (Bold, 2000; Border, 2000; Finkelstein, 2000).

Taken together, the results of the three studies from Phase II again support the presence of cognitive deficits suggestive of brain injury following cumulative concussive mild head injuries. In particular, Finkelstein's (2000) group mean comparisons revealed a consistent pattern of poorer performance across the rugby groups (Total Rugby, Springbok Rugby and U/21 Rugby) relative to the controls on tests sensitive to the effects of brain damage including the Digit Symbol Substitution subtest, Trailmaking B and Words-in-one minute. The main functions impaired were working memory, visuoperceptual tracking and verbal fluency. Furthermore, Springbok Rugby players demonstrated a strong tendency towards poorer performance relative to hockey controls on WMS Paired Associate Learning Hard Pairs - Immediate and Delayed Recall. This task is a measure of new verbal learning and verbal memory. Comparisons *within* the rugby groups demonstrated poorer test performances for the forwards versus backs on tests of attention and concentration, working memory, verbal memory, visual memory and visuoperceptual tracking. These tests included the Digit Symbol Substitution subtest, Trailmaking B and Digit Symbol Substitution Incidental Recall - Delayed and Digits Backward. Furthermore, amongst the U/21 rugby players, a significant difference was found on WMS Paired Associate Learning Hard Pairs - Delayed Recall in the direction of poorer performance of the Forwards when compared with the Backs.

The findings relating to poorer test performance of rugby forwards versus the backline players in Phase I and Phase II could conceivably be accounted for by "pre-selection" into these groups. However, in neither of the first two stages of research was there a significant difference in pre-morbid IQ level between forwards and backs. Furthermore the forwards were not impaired across *all* tasks relative to backs, and their *pattern* of impairment was consistent with that typically associated with diffuse brain injury. In this regard, the forwards and backs were well matched on tests less sensitive to the effects of diffuse brain damage and which are considered to be good "hold" tests, for example the Digits Forward component of the SAWAIS Digits Span Subtest and the Trailmaking Test Part A, whereas the forwards tended to perform poorer on tests which are more sensitive to diffuse brain damage effects, for example, Digits Backward, Trailmaking B and Digit Symbol Substitution subtest of the SAWAIS as well as delayed memory tasks such as Digit Symbol Incidental - Delayed Recall and Paired Associate Learning Hard Pairs - Delayed Recall. Thus the results of the first two stages of the research imply that professional rugby players, and particularly forward players, are at risk of adverse cognitive effects resulting from cumulative concussions.

In sum, research findings support the presence of cognitive deficits following cumulative mild head injury in sports such as boxing, soccer, American Football, Australian Rules Football and rugby league. Despite the high incidence of rugby-related head injury in rugby union players there has been no neuropsychological research directed at rugby union players apart from the Shuttleworth-Jordan et al. (1993) study on University rugby players and the current Rhodes/ SARFU/ Sports Science Institute research initiative. As previously mentioned, results from the studies on University and professional level players consistently showed patterns of deficits commensurate with cumulative mild head injury in the functional areas of speed of information processing, attention and concentration, verbal and visual memory, working memory, speech and language and hand motor dexterity in the rugby group. However, there has been no neuropsychological research on school rugby players despite evidence from epidemiological studies of the high number of head injuries sustained by this population (Nathan et al., 1983; Roux et al. 1987).

2.4 THEORETICAL CONTEXT AND HYPOTHETICAL INDICATIONS FOR THE PRESENT STUDY

2.4.1. THEORETICAL CONTEXT FOR PRESENT STUDY

In a recent paper, Shuttleworth-Jordan (1999) criticizes research on mild head injury as being conspicuously lacking in theoretical elaboration. She proposes a theoretical backdrop for research into the cumulative effects of mild head injury sustained in rugby. The hypothetical indications of her proposal place a strong emphasis on the variability of functional outcome and are based on Satz's (1993) Brain Reserve Capacity Theory (BRC) and her own model of inter-individual variability (Jordan, 1997).

BRC theory refers to a threshold factor in each individual which represents a critical point at which normal functioning is sustained prior to the manifestation of symptoms caused by damage to the brain. Inherent in this model is the notion that individual differences exist with regard to BRC which account for variable instances of vulnerability and symptom onset. Satz (1993) proposes that a greater BRC may serve as a protective factor in the face of disease, thus decreasing the risk of functional impairment, whilst a lower BRC may serve as a vulnerability factor, thereby increasing the risk of functional impairment. Certain risk factors such as previous head injuries, age, and lower education level, may lower the threshold and are likely to increase an individual's vulnerability to functional impairment. Shuttleworth-Jordan (1999) proposes that even in the absence of functional outcome, mild brain injury may result in a reduction in brain reserve capacity.

Shuttleworth-Jordan (1999) asserts that Jordan's (1997) model of inter-individual variability, which was developed within the context of BRC theory to delineate cognitive aging, can be extrapolated to describe outcomes following mild head injuries sustained in rugby. She conceptualizes normal aging as a form of progressive mild brain injury and identifies a pattern of variability, much the same as can be expected from mild head injury. The model proposes that inter-individual variability in cognitive reserves (brain reserve capacity) in association with the onset of neural attrition, result in the differences of symptom presentation and the variability of cognitive test scores between individuals. In other words, due to protective factors, certain individuals may not present with cognitive dysfunction whilst others, due to threshold lowering factors, may show a conspicuous fall-off in functioning. This may lead to a wide distribution of scores *within* a group, a fact which is not represented by average group effects.

The concepts of brain reserve capacity and inter-individual variability are central to this thesis and provide a more grounded theoretical framework for the examination of the effects of cumulative mild head injuries in rugby. The notion of inter-individual variability allows for a richer and less fallacious interpretation of cognitive outcomes than is found in the use of group mean comparisons alone. Furthermore, Shuttleworth-Jordan's (1999) proposition serves as a reminder that a null outcome at a particular point in time following mild head injury does not equate to null brain injury, raising concerns regarding latent effects.

2.4.2. RATIONALE FOR PRESENT STUDY

Whereas the previous studies focused on the effects of mild head injury in rugby played on a *professional* level, there does not as yet appear to have been any research examining the effects of mild head injury in schoolboy rugby as yet. This is a matter for concern as Roux et al. (1987) assert that on average during the course of one season, concussion will be sustained by 10% of schoolboy rugby players, a figure which is deemed to be conservative as it is likely that these figures do not take into account the underreported "minor" head injuries. As previously mentioned, the risk of "silent head" injuries cannot be ignored. It appears that schoolboys playing in top teams may be running similar risks to professional players and, with the high number of underreported concussions, the implications of these "silent" head injuries on scholastic performance are highly speculative. This is particularly relevant for the top team players, many of whom prepare for matriculation examinations and who may have difficulties with memory ability and speed of information processing.

This study formed *the third stage* of the Rhodes/SARFU/Sports Science Institute research initiative. This phase of the research posed the question whether cumulative mild head injury sustained in *high school rugby* causes brain injury as evidenced by impaired performance on neuropsychological tests sensitive to the effects of diffuse brain damage. This particular thesis addressed this question by making a direct comparison of the cognitive performance of school level rugby players versus a hockey control group across a battery of neuropsychological tests. In addition, the cognitive test performances of rugby forward players and rugby backline players were compared. Attempts were made to gauge variability of performance *within* groups, thereby pre-empting the hasty acceptance of null outcomes. It was further decided to investigate whether a relationship exists between the number of reported mild concussive head injuries recalled by currently active rugby players and their cognitive test performance.

The neuropsychological test battery was modelled on the two previous phases of research with professional players which were successful in detecting deficits associated with brain damage but was amended to include a more comprehensive and updated measure of pre-morbid IQ, including a reading test component, The National Adult Reading Test (Nelson, 1991), as well as two subtests from the WAIS-III, namely Vocabulary and Picture Completion (Wechsler, 1997). In addition the WAIS-III Letter-number Sequencing subtest, considered to be highly sensitive to the effects of diffuse brain damage, and the Stroop Neuropsychological Screening Test (Trenerry, Crosson, BeBoe & Leber, 1989), a measure of selective attention, were included in the test battery. A larger sample size was used for this study as well as an improved method of estimating premorbid IQ levels for the purposes of establishing whether the sample group and control groups are equivalent in terms of pre-morbid levels of functioning.

On the basis of indications arising from prior research and the implications of brain reserve capacity theory, the following hypotheses were posed for the purposes of this study. Top team high school rugby players (who are hypothesised to be intensively exposed to repetitive mild head injuries) will show neuropsychological impairment evidenced by a significant difference of mean scores in the direction of poorer performance of rugby players and/or increased variability of test performance on tests sensitive to diffuse damage when compared with non-contact sport controls. Top team high school rugby forward players (who are hypothesised to have a higher risk of sustaining mild head injuries than backline players), will show neuropsychological impairment evidenced by a significant difference of mean scores in the direction of poorer performance of rugby players and/or increased variability of test performance on tests sensitive to diffuse damage when compared with non-contact sport controls and backline players. Furthermore, it is hypothesised that a significant correlation will be revealed between the number of reported mild head injuries sustained by top team high school rugby players and poorer performance on neuropsychological tests sensitive to the effects of diffuse brain damage.

CHAPTER 3 : METHODOLOGY

As previously mentioned, this study forms the *third phase* (Phase III) of an ongoing research initiative into the effects of cumulative mild head injuries in rugby. The previous research was conducted in two phases, the first phase involved a comparison of professional Springbok rugby players with professional Proteas cricket players (Ancer, 1999; Dickinson, 1998; Reid, 1998). The second phase used a larger sample and a new control group by incorporating into their comparison the cognitive performances of Under 21 national rugby players and a matched non-contact sport control-group consisting of national Under 21 hockey players (Bold, 2000; Border, 2000; Finkelstein, 2000). Although the aim of this present study is to provide a direct comparison of group mean scores between the school rugby and hockey players as was done with the professional teams in phases I and II of the research (Ancer, 1999; Finkelstein, 2000), this study did not entirely replicate the previous studies on professional rugby players in that participants were tested well into the rugby season as opposed to being tested strictly pre-season. The rationale for this was to allow for the detection of old effects *and* the overlay of any acute effects sustained during the present season which would help ascertain more fully the present extent of intellectual difficulties in so-called active, healthy players.

3.1 PARTICIPANTS

3.1.1. SELECTION CRITERIA

The participants for this study were drawn from top team school rugby players (chosen in view of lengthy rugby careers and a more intensive and competitive level of play) and top team school hockey players. The players were drawn from three Cape Town English medium high schools known for their long-standing tradition of excellence in rugby. Participants included only currently active members of the top teams between the ages of 16 and 19 years. The hockey players were considered a good non-contact sport control group, equivalent in terms of level of play (i.e. top teams), age, equivalent quality schools and educational standard (hence probably IQ level). Although the research targeted the top 30 rugby players and top 30 hockey players from each of the schools (i.e. 180 participants), consent to participate in the research was refused by a large number of the pupils because of work pressures at school and the concomitant time constraints. As a result, only 96 participants were initially assessed between April and May 2000. The assessments were conducted after school hours at the respective schools so as not to interfere further with the participants' pressured school schedules.

3.1.2. EXCLUSION CRITERIA

Although 96 players were assessed, the following exclusion criteria were applied with respect to inclusion in the final sample used for data analysis: a history of substance abuse; neurological or psychiatric/psychological disorder; previous diagnosis of a learning disorder; recent neuropsychological assessment (to control for practice effects); or previous moderate to severe head injury sustained for any reason (moderate to severe head injuries were considered any injuries greater than mild head injury as previously defined). In addition, players in Grade 10 were excluded and hockey players who had sustained a recent mild head injury were excluded to control for the presence of acute effects in this group. Hockey players who had reported once-off incidents of mild head injury in the past were not excluded as the study purports to investigate the effects of *cumulative* mild head injury with respect to rugby players sustained during their rugby playing careers.

As a result of the above-mentioned exclusion criteria, the following participants were excluded: rugby players (n=6) - neurological disorder (n=1), previous diagnosis of learning disorder (n=2), learning disorder with accompanying neurological disorder (n=1), recent neuropsychological assessment (n=1), previous moderate head injury (n=1); and, hockey players (n=9) - psychological disorder (n=1); previous diagnosis of learning disorder (n=3); players in Grade 10 (n=2); and, previous moderate head injury (n=3). The final sample used for the data analysis thus consisted of 81 top school team rugby and hockey players including a Total Rugby group (n = 47) and a Total Hockey group (n = 34). In addition rugby sub-groups were established consisting of Rugby Forwards (n = 28) and Rugby Backs (n = 19).

With regard to establishing whether the Total Rugby and Total Hockey groups, and the Rugby Forwards and Rugby Backs were equivalent in terms of level of IQ, an *estimated premorbid IQ score* was established for each of the participants. In this study, the estimated premorbid level of intellectual functioning was calculated using a combination of (i) two Wechsler Adult Intelligence Scale - Third Edition subtests namely, Vocabulary and Picture Completion (Wechsler, 1997), and (ii) the National Adult Reading Test or NART (Nelson, 1991). First, a pro-rated estimated IQ was calculated using Vocabulary and Picture Completion as these tests have been considered to be relatively unaffected in the presence of diffuse damage and, therefore are good indicators of premorbid ability (Lezak, 1995). Thereafter, the Wechsler pro-rated estimated IQ score was combined with the estimated IQ established from the NART scores. The average of these two IQ scores was considered the best possible indicator of pre-morbid levels of intellectual functioning. This method of calculating pre-morbid intellectual functioning was thought to be an improvement on the method used by the first two phases of the research as a result of the incorporation of a reading test component. The rationale for the use of the above-mentioned tests is discussed in more detail in Section 3.2.3.1. No players were excluded from the analysis due to outlying defective or inflated premorbid IQ estimates which might be considered to skew the comparisons.

In Phase II, two Under 21 rugby players and two national hockey players whose IQ fell in the defective range (IQ < 85) or in the exceptionally superior range (IQ > 140) were excluded to ensure that groups were equivalent in terms of premorbid IQ level. It was not necessary to exclude participants on this basis for Phase I of the research, or for the purposes of the present study (Phase III), in that the IQ scores for the present sample fell within the range 89 - 133.

3.1.3. DEMOGRAPHIC DATA

As certain demographic data such as age, education level and estimated premorbid IQ are known to affect performance on cognitive tests, group mean comparisons between the Total Rugby group and the Total Hockey group, and within the Rugby group (Forwards versus Backs) were calculated for these variables using a pooled independent two sample t-test. In addition, the average school grade achieved by participants in 1999 was used for informal comparison when calculating premorbid IQ. With regard to the demographic data of the participants, no significant difference of means (significance level of $p < 0.05$) was apparent between any of the groups or sub-groups for any of the variables including age, educational level, overall grade achieved in 1999 and estimated premorbid IQ level. The group mean comparisons for these variables are discussed and listed below (see Tables 3-1 to 3-4, pp. 34-36).

With respect to age and education level (see Tables 3-1 and 3-2, pp. 34 and 35), for *age* the means of all groups were equivalent (approximately 17 years). The age for Total Rugby ranged from 16-18 years, whilst the Total Hockey group showed a slightly wider range with a maximum age of 19 years. The Rugby Forwards and Rugby Backs showed the same age range of 16 - 18 years. For *educational level* the means were virtually equivalent across the groups and sub-groups. The Total Rugby group and Total Hockey group both showed the same range of 10 - 12 years of education whereas the Rugby Backs showing a slightly smaller range of 10 - 11 years in comparison with the Rugby Forwards (10-12 years).

Table 3-1. Demographic Data of Hockey and Rugby Players with Between Group Mean Comparisons for Age and Education

		Age				Education Level [1]			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Total Rugby	47	17.3	0.7	16 - 18		10.8	0.6	10 - 12	
Total Hockey	34	17.0	0.7	16 - 19	0.07	10.7	0.6	10 - 12	0.46

[1] Numbers of years of education completed.

Table 3-2. Demographic Data of Rugby Forwards and Backs with Within Group Mean Comparisons for Age and Education

		Age				Education Level [1]			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Rugby Forwards	28	17.3	0.7	16 - 18		10.9	0.7	10 - 12	
Rugby Backs	19	17.2	0.6	16 - 18	0.42	10.7	0.5	10 - 11	0.26

[1] Numbers of years of education completed.

With respect to grade and estimated IQ (see Tables 3-3 and 3-4, pp. 35 and 36), for *average grade achieved in 1999* the group mean comparisons did not show a significant difference between or within groups. Of note is whilst the mean estimated IQ's show no significant differences across groups, the Rugby Forwards showed a higher upper limit (Range = 55-93) when compared with the Rugby Backs (Range = 50-86) with the Total Hockey group showing a high upper limit of 97.

With regard to *estimatedpremorbid IQ*, again no significant differences were found between the means of Total Rugby and Total Hockey groups and between the means of Rugby Forwards and Rugby Backs. However, the Rugby Forwards showed a higher upper limit of IQ level (Range = 89.5-133) when compared with the Rugby Backs (Range = 89-119) and Total Hockey group (Range = 90.5-129.5). Of note is that the mean estimated IQ level for all the groups and sub-groups falls within the high average range bordering on the above average range. This is reflected in the high average 1999 grade across the groups.

Table 3-3. Demographic Data of Hockey and Rugby Players with Between Group Mean Comparisons for Average Grade 1999 and Estimated IQ

		Average Grade 1999 (%)				Estimated IQ			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Total Rugby	47	69.0	10.3	50 - 93		109.0	9.7	89.0 - 133.0	
Total Hockey	34	72.2	11.6	50 - 97	0.20	109.1	8.6	90.5 - 129.5	0.96

Table 3-4. Demographic Data of Rugby Forwards and Backs with Within Group Mean Comparisons for Average Grade 1999 and Estimated IQ

		Average Grade 1999 (%)				Estimated IQ			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Rugby Forwards	28	70.5	10.1	55 - 93		110.0	10.3	89.5 - 133.0	
Rugby Backs	19	66.8	10.5	50 - 86	0.23	107.6	9.0	89.0 - 119.0	0.42

In sum, it appears that both the Total Rugby and Total Hockey groups, and the Rugby Forwards and Rugby Backs are equivalent in terms of age, level of education, school achievement and estimated premorbid level of intellectual functioning, making it unlikely that these demographic data could act as confounding variables in this study.

3.1.4. HEAD INJURY HISTORY

With regard to the participants' *head injury history*, group mean comparisons of the reported incidences of both sport and non-sport related mild head injury were run between the Total Rugby group and the Total Hockey group, and, within the Rugby group (Forwards versus Backs) using pooled independent two-sample t-tests. The group mean comparisons of the reported mild head injuries are presented and discussed below (see Tables 3-5 and 3-6, p.37).

When comparing the Total Rugby group versus the Total Hockey group, a significant difference ($p = 0.00$) was apparent in reported incidences of *sport related mild head injury* in the direction of rugby players sustaining more mild head injury whilst playing rugby. Rugby players reported an average incidences of 2.3 mild head injury sustained during their rugby playing careers compared with hockey players who reported a mean incidence of 1 mild head injury sustained whilst playing hockey. In addition the Total Rugby group showed a wider range of incidence with a maximum reported incidence of 7 mild rugby head injuries (range 0 - 7) in comparison with the Total Hockey group where the incidence ranged from 0 - 1. With regard to the reported *incidences of non-sport related mild head injury*, the comparative analysis revealed no significant differences between the Total Rugby group and Total Hockey group, both groups having a mean incidence of 0.3.

When comparing the Rugby Forwards versus Rugby Backs, the analysis revealed no significant differences between the group means of either *sport or non-sport related head injuries.* However, the Rugby Backs showed a wider range of incidence of rugby mild head injuries (0 - 7) in comparison with the Rugby Forwards (0 - 5).

Table 3-5. Between Group Mean Comparisons of the Incidence of Reported Mild Head Injuries (MHI) (including both Sport and Non-Sport Injuries) in Rugby and Hockey Players.

		MHI Sport [1]				MHI Non-Sport				Total MHI			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Rugby	47	2.3	0.5	0 to 7		0.3	0.6	0 to 2		2.6	1.6	0 to 7	
Hockey	34	0.1	0.3	0 to 1	0.00 *	0.3	0.5	0 to 1	0.83	0.4	0.5	0 to 1	0.00 *

Significant Difference ($p<0.05$)

[1] Where MHI Sport is reported, this refers to those injuries sustained by Rugby and Hockey Players in their respective sports.

Table 3-6. Within Group Mean Comparisons of the Incidence of Reported Mild head Injuries (MHI) (including Sport and Non-Sport Injuries) in Rugby Forwards and Backs.

		MHI Sport [1]				MHI Non-Sport				Total MHI			
	n	Mean	SD	Range	p-value	Mean	SD	Range	p-value	Mean	SD	Range	p-value
Forwards	28	2.2	1.4	0 to 5		0.3	0.6	0 to 2		2.5	1.6	0 to 7	
Backs	19	2.4	1.7	0 to 7	0.74	0.3	0.6	0 to 2	0.74	2.6	1.7	0 to 7	0.85

[1] Where MHI Sport is reported, this refers to those injuries sustained by Rugby Players whilst playing rugby.

3.2. MATERIALS

The materials for the study consisted of a demographic questionnaire, a postconcussive symptom checklist and a neuropsychological test battery. Materials were modelled on the two previous phases of research with professional players which were successful in detecting deficits associated with brain damage.

3.2.1. DEMOGRAPHIC QUESTIONNAIRE

The pre-assessment questionnaire (see Appendix I) aimed to provide the researchers with information on (a) biographical data such as age, educational level, average grade past academic year; (b) sporting history including years of participation in a particular sport, position played, reason for choosing particular sport, use of headgear; (c) head injury history (both sport-related and non-sport related) including all dimensions of mild head injury and concussion as previously defined and (d) exclusion criteria (neurological, psychiatric or psychological/psychiatric disorders including learning disorders, substance abuse).

3.2.2. POSTCONCUSSIVE QUESTIONNAIRE

The postconcussive questionnaire consisting of 31 items was compiled as part of Phase I of the research (Dickinson, 1998) to elicit information on a wide range of postconcussive symptoms and was used again in Phase II of the research (Border, 2000). The questions were drawn from a questionnaire which was originally designed to elicit the neuropsychological sequelae of anuerysmal sub-arachnoid haemorrhages in patients without neurological deficits 6 to 8 months post operatively (Burbach, 1987). The questionnaire encompassed 14 content areas which included, physical/neurological symptoms, perceptual disturbances, sexual problems, speech and language difficulties, memory difficulties, attention and concentration difficulties, emotional lability, frustration tolerance, depression, social withdrawal, restlessness, vegetative symptoms, anxiety, and aggression. The postconcussive questionnaire was not part of the database for this study and has therefore been excluded from the appendices.

3.2.3. NEUROPSYCHOLOGICAL TEST BATTERY

The neuropsychological test battery incorporated tests used routinely for neuropsychological assessment measuring cognitive functioning across the following range of modalities: general intellectual functioning; attention and concentration; visuoperceptual tracking; verbal memory; visual memory; verbal fluency and hand-motor dexterity. Certain of the test included are known to be sensitive to the effects of diffuse brain damage of the kind associated with closed head injury whilst others were used to provide estimates for pre-morbid IQ level. Subtests from the WMS (Wecshler, 1945) and where appropriate the SAWAIS (SAWAIS Manual, 1969), were used instead of subtests from the WMS-III and WAIS-III respectively as age specific South African norms were available for these which were required for other aspects of the study utilising norm-based comparisons (see Shuttleworth-Jordan, 1996). Although the neuropsychological test battery was modelled on the previous phases of research with the professional players, the test battery was amended to include the following: NART; Stroop Neuropsychological Screening Test (SNST) and three subtests from the WAIS-III (Vocabulary, Letter-number Sequencing, Picture Completion). The neuropsychological test battery was administered in the following sequence (see Appendix II): Sequential Finger Tapping Test, South African Wechsler Adult Intelligence Scale (SAWAIS) Digit Symbol Substitution Subtest including Immediate Recall, Trailmaking Test (TMT) part A and B, Words-in-One-Minute Unstructured Verbal Fluency Test, "S" Words Structured Verbal Fluency Test, National Adult Reading Test (NART), WAIS-III Vocabulary subtest, SAWAIS Digit Symbol Substitution Delayed Recall, SAWAIS Digit Span subtest, Wechsler Memory Scale (WMS) Visual Reproduction Immediate Recall, WMS Paired Associate Learning, SNST, WAIS-III Letter-number Sequencing subtest, WMS Visual Reproduction Delayed Recall, WMS Paired Associate Learning Delayed Recall, WAIS-III Picture Completion subtest. The test battery will be discussed in terms of the range of cognitive modalities mentioned above.

3.2.3.1. Tests of General Intellectual Functioning

For the purposes of this study, estimates of premorbid levels of intellectual functioning were calculated in order to ensure that the groups and sub-groups were equivalent in terms of IQ level. This was achieved by calculating an estimated IQ for each player using a combination of two WAIS-III subtests (Wechsler, 1997) and an IQ estimate from the NART. The method of calculating premorbid IQ was discussed in section 3.1.2. The WAIS-III Vocabulary subtest (measuring verbal abilities) and Picture Completion subtest (which measures mainly visual reasoning and remote memory but also involves visuoperceptual and limited verbal abilities) were considered good indicators of premorbid ability based on the assumption that these cognitive skills hold in the face of diffuse brain damage. McFie (1975, in Lezak, 1995) considered Wechsler's Vocabulary and Picture Completion to be the two sturdiest tests. However, it has been contended that vocabulary tests which require oral definitions may be more vulnerable to brain damage than previously asserted (Russel 1972, in Lezak, 1995). For this reason the NART, which does not require oral definitions but only with word reading ability, was introduced into this study to augment the previous method of calculating estimated premorbid levels of IQ. The NART was designed to estimate pre-morbid ability in dementia patients after Nelson and McKenna (1975, in Nelson 1991) found word-reading ability to be generally well-maintained in the face of more widespread dementing processes and that it provided a more accurate indicator of premorbid intelligence that the traditionally used hold tests from the Wechsler scale. The NART is also considered to have potential in the matching of subjects on the basis of premorbid IQ in studies comparing groups (Nelson, 1991). The tests used to calculate pre-morbid IQ levels and thus ensure equivalent sample groups were considered more than adequate for this purpose.

3.2.3.2. Tests of Attention and Concentration

Impairment in attention and concentration are amongst the most common cognitive difficulties associated with diffuse brain damage (Lezak, 1995). The following tests of attention and concentration were included in this study: the SAWAIS Digits Forward and Digits Backward subtests (SAWAIS Manual, 1969); the WAIS-III Letter-number Sequencing (LNS) subtest; and, the Stroop Neuropsychological Screening Test (SNST) (Trenerry et al., 1989). Although the Digits Forward and Digits Backward subtests measure immediate verbal recall (Digits Forward) and working memory function (Digits Backward), they primarily assess an individual's ability to attend without distraction or "freedom from distractibility" (Lezak, 1995 p. 359). Furthermore, an individual's performance on Digits Forward tends to hold relative to Digits Backward in the presence of diffuse damage as the working memory component renders Digits Backward more sensitive to the effects of diffuse brain damage (Lezak, 1995). Hold tests provide additional support for pre-morbid matching across groups. The WAIS-III Letter-number Sequencing was designed to assess attention and working memory as the task requires the individual to simultaneously track letters and numbers whilst sequencing them without forgetting any part of the series. The SNST was incorporated into the test battery to assess the participant's ability to concentrate on a particular task, the Colour-Word component being particularly taxing. Although some neuropsychologists have asserted that the SNST measures response conflict or a failure of response inhibition and selective attention, Lezak (1995) maintains that individuals who struggle with the test have difficulties concentrating and warding off distractions.

In view of the above, the tests selected were considered to be good measures of attention and concentration. In particular, the Digits Backward subtest was sensitive in detecting signs of diffuse brain damage in Phase I and Phase II of the research in that Rugby Forwards showed poorer performance relative to Rugby Backs on this task (Ancer, 1999; Finkelstein, 2000).

3.2.3.3 Tests of Visuoperceptual Tracking

The tests of visuoperceptual tracking included the SAWAIS Digit Symbol Substitution subtest (SAWAIS Manual, 1969) and the Trailmaking Test (TMT) part A and B (Reitan, 1956). The Digit Symbol Substitution subtest is a test of complex visuoperceptual tracking, perceptual organisation and selective attention and is a test sensitive to the effects of even minimal brain damage (Lezak, 1995). Similarly, TMT is a test of complex visuoperceptual scanning and sustained attention with a motor component. Part B is generally considered to be more sensitive to the effects of brain damage as it involves working memory and in the presence of brain damage, scores on Part B are likely to be discernibly depressed relative to those on Part A. The Digit Symbol Substitution subtest and TMT part B were particularly successful in detecting cognitive deficit during both Phase I and Phase II of the research (Ancer, 1999; Finkelstein, 2000). During Phase I, the Rugby group showed higher variability on these tasks when compared with the control group and whilst the group mean comparisons of these tasks showed poorer performance of Rugby Forwards when compared with the Backs. In Phase II, Rugby players showed poorer performance than controls on these tests whilst Forwards performed worse when compared with the backs on these tasks.

3.2.3.4. Test of Verbal Memory

The WMS Paired Associate Learning subtest from Form I of the WMS manual (Wechsler, 1945), including the delayed recall task, was used to assess verbal memory function. The test measures old associate learning ability (easy pairs) and new associate learning ability (hard pairs). The ability to remember the hard pairs relies more on new learning ability and thus the hard pairs are considered to be more susceptible to the effects of brain damage. Research in the area of focal epilepsy indicates that the ability to learn unfamiliar pairs of words is probably the most sensitive indicator of minor neurological dysfunction (Saling, 1999). A study examining neuropsychological difficulties following mostly mild head injury in an adolescent school population showed verbal learning and memory to be the only discriminator between subject group and control group (Leathem & Body, 1997). The delayed memory component of this subtest was included as according to Lezak (1995), delayed recall ability is more sensitive to the effects of diffuse brain damage than immediate memory. Furthermore, delayed verbal recall is seen to be the best discriminator of early dementia (Ferris & Kluger, 1996). In this regard, the WMS Paired Associate Learning Hard pairs delayed recall task was shown to be a good indicator of cognitive deficit in Phase II of the research, where Springbok Rugby players tended towards poorer performance on this task when compared with controls and more specifically, where a significant difference was found in the U/21 Rugby group in the direction of Rugby Forwards performing worse than Rugby Backs.

3.2.3.5. Tests of Visual Memory

The tests of visual memory include the WMS Visual Reproduction subtest taken from Form I of the WMS manual (Wechsler, 1945), and the Digit-Symbol Incidental and Delayed Recall task.

The WMS Visual Reproduction task taps visual memory function (Lezak, 1995) and has been sensitive in distinguishing patients with mild head trauma from controls (Stuss et al., 1985 in Lezak, 1995). Although this test was originally designed as an immediate recall task, examiners have added a delayed recall component which was also included in the test battery for the purposes of this study. As with tests of verbal memory, the delayed memory component is considered more sensitive to the effects of diffuse brain injury than immediate memory (Lezak, 1995).

Digit Symbol Incidental Recall measures recent memory functioning which is sensitive to the effects of diffuse cerebral pathology. Hart, Kwentus, Wade & Hammer (1987, in Shuttleworth-Jordan & Bode, 1995) have demonstrated that this task may be useful in the differential diagnosis of Alzheimer's Dementia and Depressive Pseudo-dementia. The administration of the WAIS Digit Symbol subtest has been extended to include a measure of incidental recall. This method was originally described by Kaplan et al. (1991, as cited in Lezak, 1995) and Shuttleworth-Jordan and Body (1995) developed a shorter form which was used for this study. The Digit Symbol Incidental Recall - delayed task was sensitive in detecting deficits associated with diffuse brain damage during Phase I of the research in that the Rugby Forwards showed poorer performance when compared with the Rugby Backs (Finkelstein, 2000).

3.2.3.6. Tests of Verbal fluency

The tests used to assess verbal fluency included the Words-in-One-Minute Unstructured Verbal Fluency test and the "S" Words Verbal Fluency test (Terman & Merril, 1973). Impaired verbal fluency (i.e. the speed and ease of verbal production) is associated with brain damage and especially with frontal lobe damage (Janowsky, Shimamura, Kritchevsky, Squire, 1989 in Lezak, 1995). These above-mentioned tests measure verbal productivity and are thus considered to be good indicators of brain dysfunction, and the unstructured verbal fluency task picked up deficits during Phase II when Rugby players were compared with Hockey controls (Finkelstein, 2000).

3.2.3.7. Fine hand motor dexterity

Denckla's Sequential Finger Tapping Test (1973) was administered to assess hand motor dexterity. Brain damage tends to have a slowing effect on finger tapping rate and therefore bilateral slowing would indicate diffuse brain damage in the absence of physical impairment (Lezak, 1995). This specific finger tapping test was used as it is simple, easy to administer and requires no instrumentation. Furthermore, age appropriate South African norms are available for other aspects of the study utilising norm-based comparisons (see Shuttleworth-Jordan, 1996).

3.3. DATA COLLECTION

As mentioned in section 3.1, the rugby and hockey players were tested between April and May 2000. The core research team consisted of two Intern Clinical Psychologists who were assisted in the administration of the assessments by three qualified Clinical Psychologists who were involved in phase II of the research. To ensure uniformity, the assessors were briefed as to the standardised administration procedure of both the questionnaires and the neuropsychological test battery, and had all received their training from Rhodes University. An attempt was made to ensure consistency between this phase of the research and the previous two phases by furnishing each test protocol with written test instructions as per the first two phases. Where new tests were used, a written test instruction was compiled from the relevant manual.

Each participant was individually assessed for approximately 90 to 120 minutes. Before each assessment, the nature and purpose of the research was explained and a signed consent form was obtained from each pupil (see section 3.4). The researchers explained to the participants that individual results obtained from the assessments would remain confidential and that the data would be used for group analysis only.

3.4. CONSENT

Prior to the research, written consent was obtained from the Department of Education to conduct this study. The two core researchers approached the headmasters of the three targeted schools and obtained permission to conduct the study. The rugby and hockey coaches from the respective schools assisted the researchers to obtain the sample by approaching the relevant pupils on the researchers' behalf. Consent forms were handed out to the top team rugby and hockey players along with a covering letter addressed to their parents/guardians explaining the nature and purpose of the research. The consent form was drawn up (see Appendix III) in such a way that written consent could be obtained from parents or guardians for the pupils involvement in the study. The consent form provided an option of feedback to parents in the unlikely event that the researchers discovered a pattern of results which might give cause for medical or scholastic concern.

3.5. DATA PROCESSING

Each test protocol was scored twice (once by each of the two core researchers) to ensure inter-rater reliability. The standardised scoring procedure was used as per the previous two phases of research to ensure continuity of scoring standards between all phases of the research. The new tests included in the present phase of the research were scored as per the relevant manuals. The two researchers involved consulted with each other when discrepancies emerged on tests where the scoring had a subjective component.

Data analysis for this particular thesis involved a direct comparison of group mean scores and standard deviations across each neuropsychological test for a) the Rugby group versus the Hockey control group; b) the Rugby Forwards versus the Rugby Backs; c) the Rugby Forwards versus the Hockey control group; and, d) the Rugby Backs versus the Hockey control group. In addition, a correlational analysis was run to ascertain whether a relationship existed between the number of reported mild concussive head injuries recalled by currently active players (including "hits", "dings" or "dazes") with their cognitive test performance. For the purposes of the correlational analysis, the number of reported mild head injuries included the *total* number of both sport and non-sport related mild head injuries as the study purports to investigate the effects of cumulative mild head injury, and therefore non-sport related head injuries have and additive infulence which is taken into account for this research.

3.6. STATISTICAL ANALYSIS

Means and standard deviations were calculated for each of the groups and subgroups (Total Rugby, Total Hockey, Rugby Forwards and Rugby Backs) on all the neuropsychological tests. The neuropsychological data were analysed using independent t-tests (which assume normality of distribution) to test for differences between the group mean scores of the various tests. The t-test analysis used pooled sample variances if homogeneity of the variances was appropriate, and separate sample variances if heterogeneity of variances was appropriate. Levene's F statistic was also used in the analysis to test the equality of the variances of the test scores between groups (Mardia, Kent & Biddy, 1979). Bonferroni adjustments were made to the significance levels as pairwise comparisons were performed between Rugby Forwards versus Rugby Backs, Forwards versus Hockey, and Backs versus Hockey. Thus, an adjusted probability level of 0.025 was set in these instances in order to ensure that the overall level of significance did not exceed 0.05 (Miller, 1981). The analysis yielded the following comparisons: Rugby versus Hockey; Forwards versus Backs; Forwards versus Hockey; and, Backs versus Hockey.

CHAPTER 4 : RESULTS

In this chapter, the results of (i) the group mean comparisons across each neuropsychological test and, (ii) the correlational analysis between the number of mild head injuries (MHI) and cognitive test results will be presented. The results of the group mean comparisons will be presented as follows. Significant results for each analysis will be discussed first, and where relevant, certain results approaching significance will be highlighted. Thereafter, significant variability in results between groups and sub-groups will be discussed and a graph illustrating the distributions will be presented and discussed. Trends for each analysis will be highlighted at the end of each subsection.

The results of the statistical analysis are tabulated together at the end of this chapter (see Tables 4-1 to 4-5, pp. 53-57).

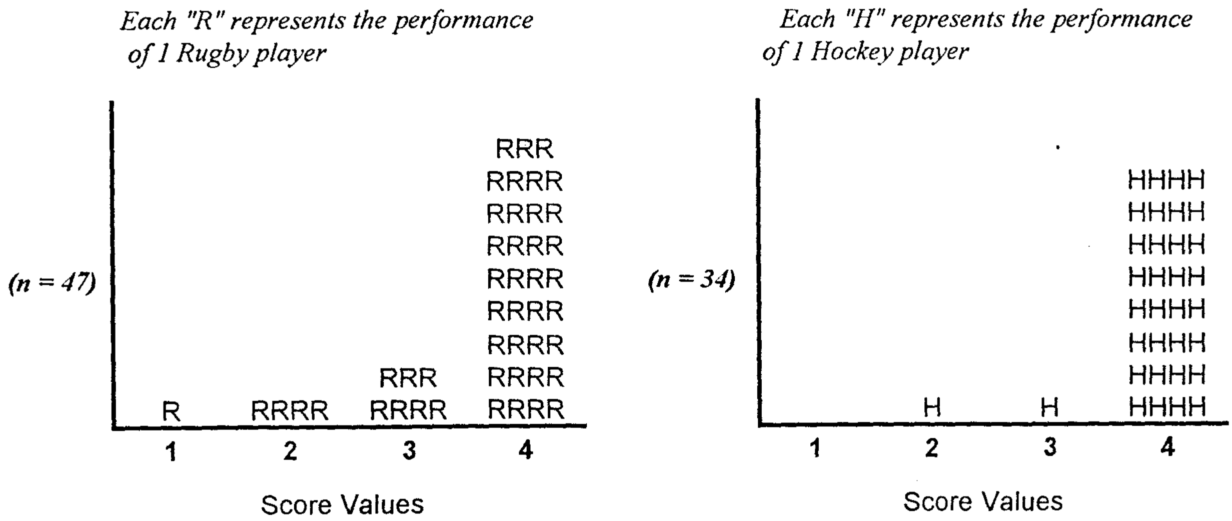
4.1. COMPARISON OF GROUP MEANS ACROSS ALL NEUROPSYCHOLOGICAL TESTS.

The cognitive test data across all groups were analysed using pooled independent two sample t-tests and Levene's F-test for variability resulting in a t-statistic and a F-statistic respectively. The comparative analyses of neuropsychological test performances between all groups and sub-groups will be presented in the following order: Total Rugby versus Total Hockey, Rugby Forwards versus Rugby Backs, Rugby Forwards versus Total Hockey, Rugby Backs versus Total Hockey. Where appropriate, graphical representations of the frequency distributions appear within the text.

4.1.1. TOTAL RUGBY VERSUS TOTAL HOCKEY (see Table 4-1, p.53)

For the group mean comparison of Total Rugby versus Total Hockey, a significant difference was found on the WMS Paired Associate Learning Hard Pairs - Delayed Recall subtest in the direction of a poorer performance of the Total Rugby group ($p = 0.0219$). Furthermore, this subtest revealed significant variability of results ($p = 0.000$) in the direction of Total Rugby showing more variability with a higher standard deviation (SD = 0.74) and a wider range of scores (Range = 1 - 4) when compared to the Total Hockey group (SD = 0.38; Range = 2 - 4). The frequency distribution for both groups on this subtest is shown in Figure 1 (p. 45). It is apparent from the distribution that the Total Rugby group shows a wider range of performance whereas the scores in the Total Hockey group are clustered around the top score with only two hockey players scoring below this.

Figure 1. Frequency Distribution of scores for Total Rugby versus Total Hockey on WMS Paired Associate Learning Hard Pairs - Delayed Recall



On all other tests no results showed significance or even approached significance in group mean comparisons or in variability. Marginal but consistent trends emerge within the functional modalities. When comparing means, the Total Hockey group tended to perform worse on the Attention and Concentration and Visual Memory tests and the Total Rugby group tended to perform worse on the Visuoperceptual Tracking and Hand Motor Dexterity functions.

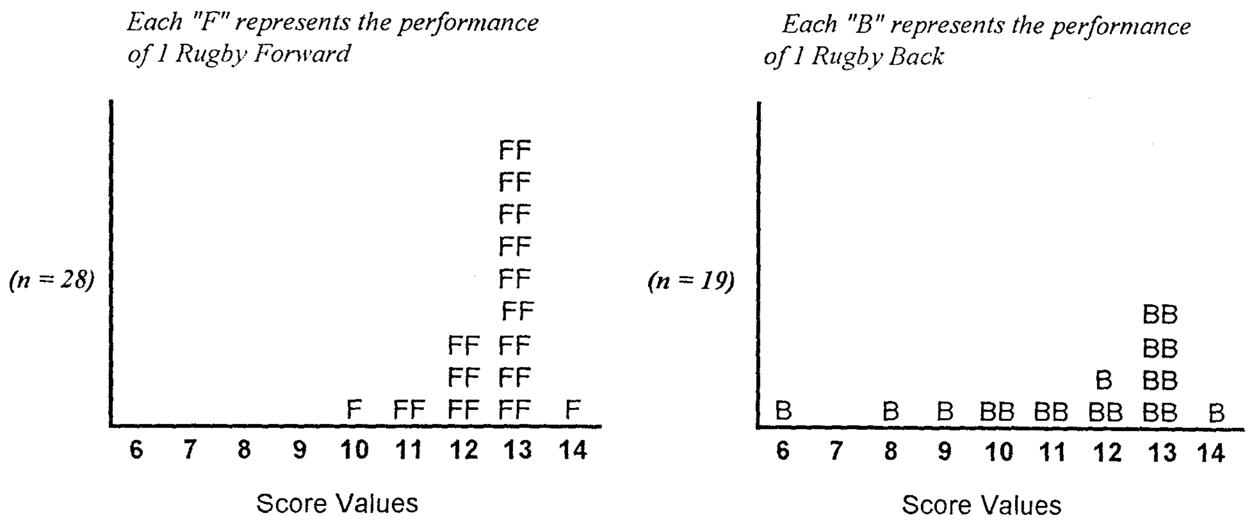
4.1.2 RUGBY FORWARDS VERSUS RUGBY BACKS (see Table 4-2, p.54)

For the group mean comparison of Rugby Forwards versus Rugby Backs, no significant difference was found across any of the cognitive tests. However, Digits Backward, WMS Visual Reproduction - Immediate Recall, Digit Symbol Incidental Recall - Immediate and Structured Verbal Fluency were found to be approaching significance ($p = 0.03$, $p = 0.05$, $p = 0.03$, $p = 0.05$ respectively) in the direction of Rugby Backs performing worse than Rugby Forwards.

In addition, there were significant differences in variability between Rugby Backs versus Rugby Forwards on certain tests. WMS Visual Reproduction Immediate Recall showed significant variability ($p = 0.0003$) of results in the direction of Rugby Backs showing more variability with a higher standard deviation (SD = 2.09) and a wider range of scores (Range = 6 - 14) when compared with the Rugby Forwards (SD = 0.84; Range = 10 - 14). Similarly, WMS Visual Reproduction Delayed Recall showed significant variability ($p = 0.0043$) of results with Rugby Backs showing a higher standard deviation (SD = 2.43) and a wider range of scores (Range = 5 - 14) than the Rugby Forwards (SD = 1.12; Range = 8 - 13). Rugby Backs showed more variability on Digit Symbol Incidental Recall - Immediate with a higher standard deviation (SD = 2.01) and a wider range of scores (Range = 2 - 9) when compared with the Rugby Forwards (SD = 1.23;

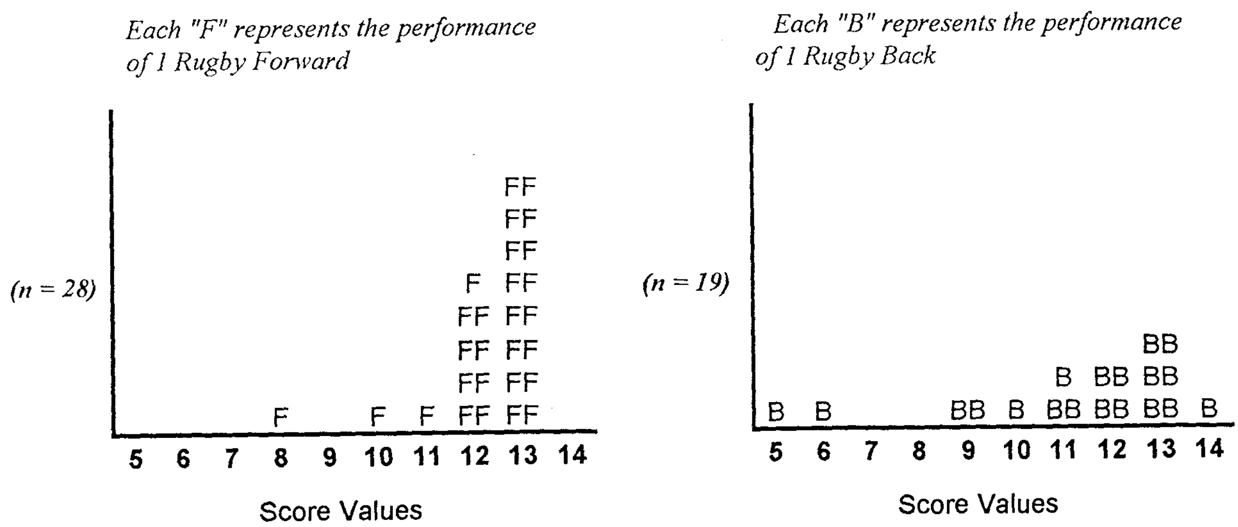
Range = 5 - 9). Figures 2-4 (pp. 46-47) show the frequency distributions for both the Rugby Forwards and Rugby Backs on those tests where results indicated significant variability.

Figure 2. Frequency Distribution of scores for Rugby Forwards versus Rugby Backs on WMS Visual Reproduction - Immediate Recall



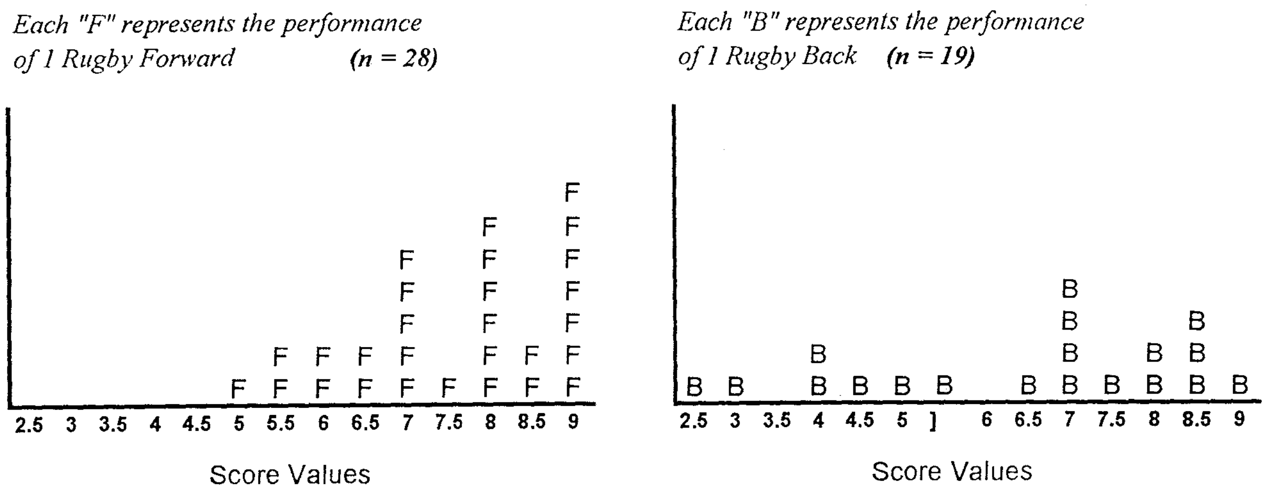
It is apparent from the distribution that on WMS Visual Reproduction - Immediate Recall, the scores for the Rugby Forwards are clustered in the main around the higher part of the range, whereas the Backs show more variability with a few low scorers.

Figure 3. Frequency Distribution of scores for Rugby Forwards versus Rugby Backs on WMS Visual Reproduction - Delayed Recall



On the WMS Visual Reproduction Delayed task, (as with the immediate recall task), the scores for the Forwards are clustered in the main around the higher part of the range, the lowest score being 8, whereas the performances vary widely for the Rugby Backs with a few outlier scores as low as 5 and 6.

Figure 4. Frequency Distribution of scores for Rugby Forwards versus Rugby Backs on Digit Symbol Incidental Recall - Immediate.



On the Digit Symbol Substitution Incidental Recall - Immediate task, the Rugby Forwards show a more even distribution with scores clustered mainly in the higher part of the range when compared with the Backs who show a wide range of results with a few backs tending to be low scorers.

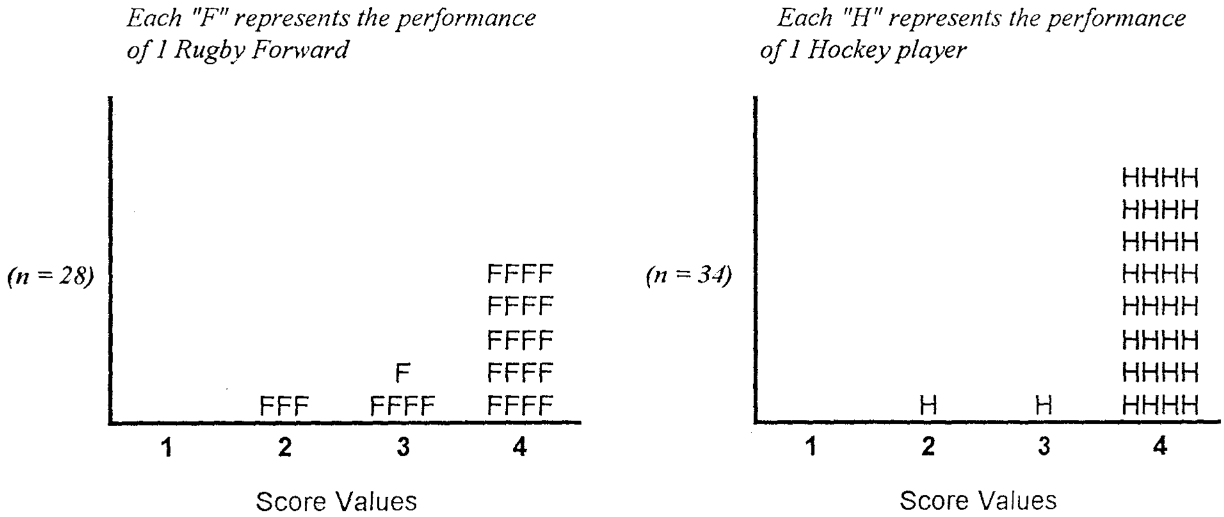
On all other tests for Rugby Forwards versus Rugby Backs, no results showed significance or even approached significance in group mean comparisons or in variability. However, when comparing group means, trends appear within the functional modalities, namely for Forwards to perform worse on Verbal Memory tasks and for Backs to perform worse on the Visual Memory and Verbal Fluency tasks.

4.1.3 RUGBY FORWARDS VERSUS TOTAL HOCKEY (see Table 4-3, p.55)

The only significant difference between the means of Rugby Forwards versus Total Hockey, was found on the WMS Visual Reproduction - Delayed Recall ($p = 0.0137$) in the direction of Total Hockey showing poorer performance. WMS Paired Associate Learning Hard Pairs - Delayed Recall was found to be approaching significance ($p = 0.04$) in the direction of Forwards showing poorer performance.

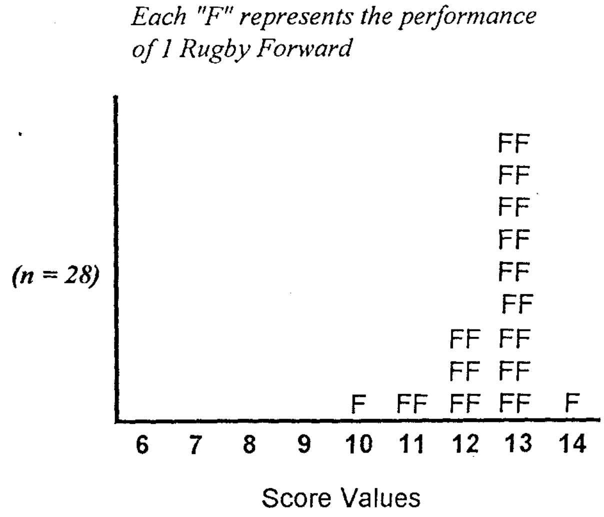
The WMS Paired Associate Learning Hard Pairs - Delayed Recall showed significant variability (p = 0.0001) of results in the direction of Rugby Forwards showing a higher standard deviation (SD = 0.69) when compared with the Total Hockey group (SD = 0.38). Three subtests revealed significant variability of results in the direction of Total Hockey showing more variability when compared with the Rugby Forward group. The WMS Visual Reproduction Immediate Recall showed significant variability (p = 0.0192) with the Total Hockey group showing higher variability of results (SD = 1.40; Range: 9 - 14) than the Rugby Forwards (SD = 0.84; Range = 10 - 14). Similarly, significant variability in results on WMS Visual Reproduction Delayed Recall was found (p = 0.0030) with Total Hockey showing a higher standard deviation (SD = 1.84) and a wider range of scores (Range = 6 - 14) in comparison with Rugby Forwards (SD = 1.12; Range = 8 - 13). Digit Symbol Incidental Recall - Immediate showed significant variability (p = 0.0085) of results with Total Hockey showing more variability (SD = 2.01; Range: 1.5 - 9) than the Rugby Forwards (SD = 1.23; Range = 5 - 9). Where results showed significant variability, the frequency distribution for both groups are presented in Figures 5-8 (pp.48-50) and discussed below.

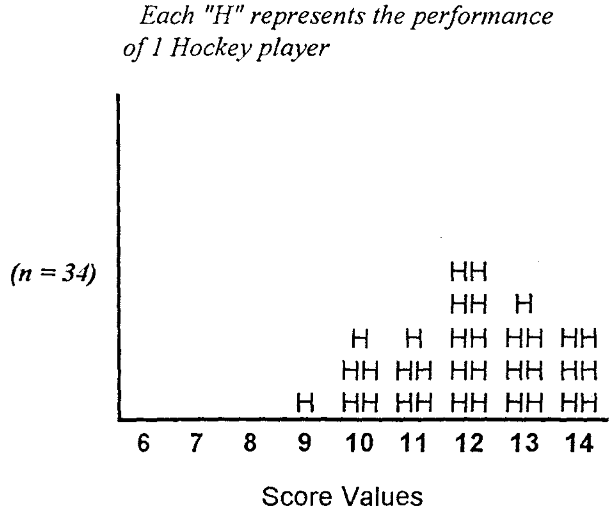
Figure 5. Frequency Distribution of scores for Rugby Forwards versus Total Hockey on WMS Paired Associate Learning Hard Pairs - Delayed Recall.



It is apparent from the distribution that Rugby Forwards showed more variability on the WMS Paired Associate Learning Hard Pairs - Delayed Recall, with a few scorers in the mid-range, whereas the scores for the Total Hockey group are clustered in the main around the higher part of the range.

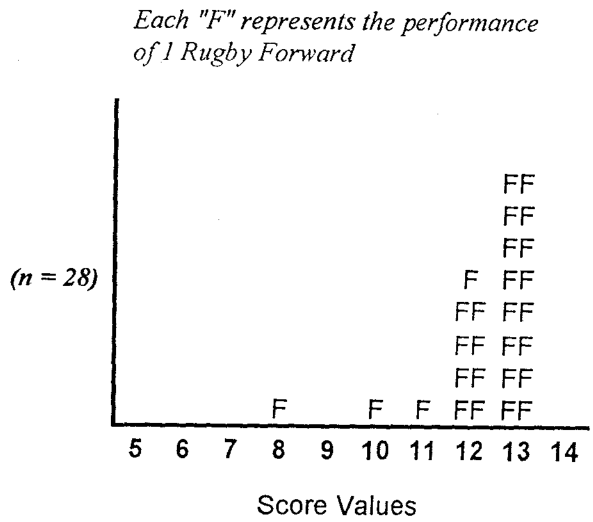
Figure 6. Frequency Distribution of scores for Rugby Forwards versus Total Hockey on WMS Visual Reproduction - Immediate Recall

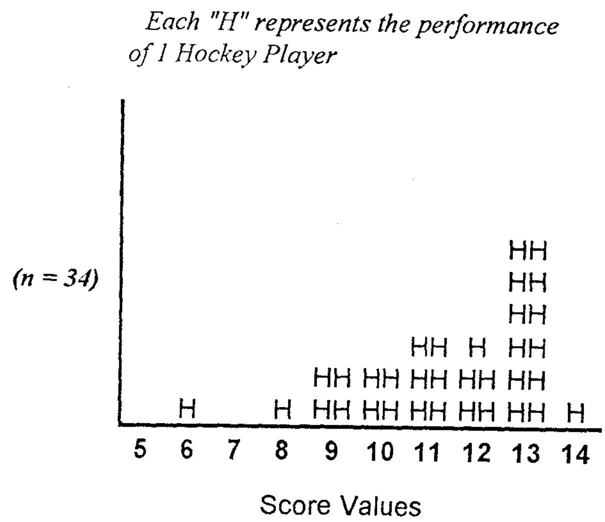




On the WMS Visual Reproduction - Immediate Recall, the distribution shows Rugby Forwards exhibiting in the main a cluster of high scores whereas the Hockey group show greater variability of results.

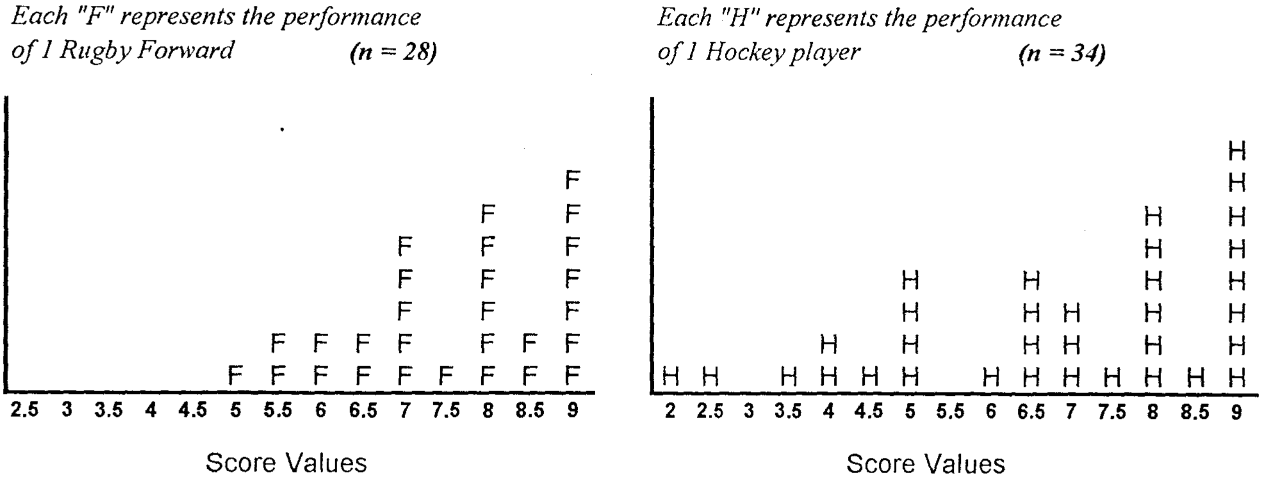
Figure 7. Frequency Distribution of scores for Rugby Forwards versus Total Hockey on WMS Visual Reproduction - Delayed Recall





On the WMS Visual Reproduction Delayed Task, the scores for the Forwards are clustered in the main around the high scores, the lowest score being 8, whereas the distribution varies widely for the Total Hockey group with one score as low as 6.

Figure 8. Frequency Distribution of scores for Rugby Forwards versus Total Hockey on Digit Symbol Incidental Recall - Immediate.



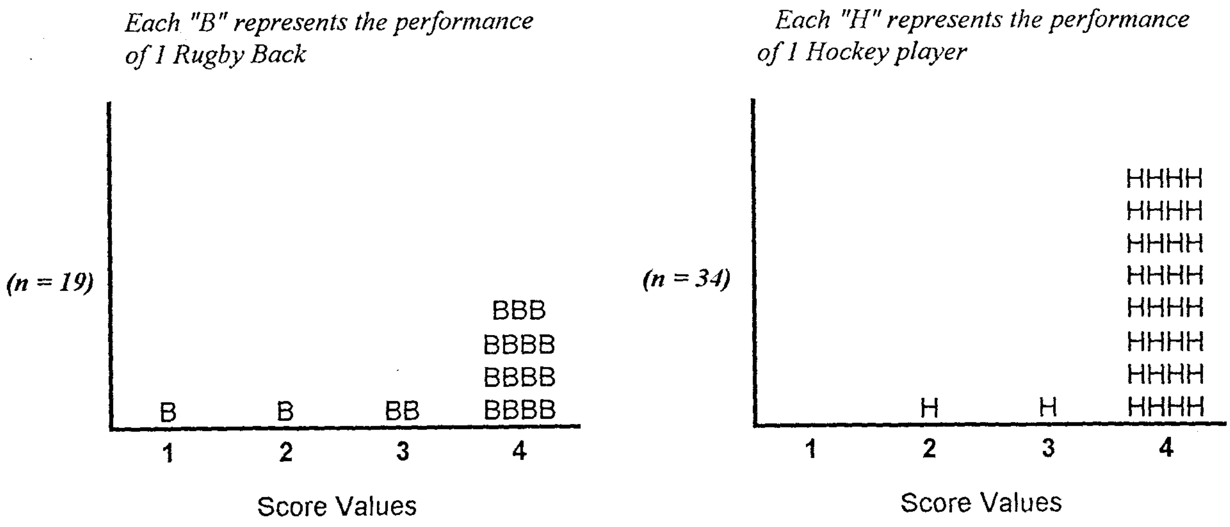
On the Digit Symbol Substitution Incidental Recall - Immediate task, the Forwards showed no outlier scores in the lower part of the range. Whereas the Hockey group showed a wide range of results with a few hockey players tending to be low scorers.

On all other tests, no results showed significance or even approached significance in group mean comparisons or in variability. However, the comparison revealed marginal trends within the functional modalities, namely for Forwards to perform worse on Visuoperceptual Tracking and Hand Motor Dexterity tasks and for Hockey players to perform worse on the Visual Memory tasks.

4.1.4. **RUGBY BACKS VERSUS TOTAL HOCKEY** (see Table 4-4, p.56)

No significant difference was found between the means of Rugby Backs versus Total Hockey. However, the WMS Paired Associate Learning Hard Pairs - Delayed Recall showed significant variability ($p = 0.0017$) of results in the direction of Rugby Backs showing more variability with a higher standard deviation (SD = 0.83; Range = 1 - 4) when compared with the Total Hockey group (SD = 0.38; Range = 2 - 4). For WMS Paired Associate Learning Easy Pairs - Immediate Recall variability was found to be approaching significance ($p = 0.0446$) with the Total Hockey group showing marginally higher variability (SD = 0.39; Range: 7 - 9) than the Rugby Backs (SD = 0.28; Range = 8 - 9). The frequency distribution for both groups on the WMS Paired Associate Learning Hard Pairs - Delayed Recall appears in Figure 9 (p. 51). The distribution shows one very low outlier score in the Rugby Back group, whereas the scores for the Total Hockey group are clustered in the main around the higher part of the range.

Figure 9. Frequency Distribution of scores for Rugby Backs versus Total Hockey on WMS Paired Associate Learning Hard Pairs - Delayed Recall.



On all other tests no results showed significance or even approached significance in group mean comparisons or in variability. However, the mean comparison revealed marginal trends for Rugby Backs to perform worse than the Total Hockey group on Visuoperceptual Tracking, Visual Memory, Verbal Fluency and Hand Motor Dexterity Tasks.

4.2. CORRELATIONAL ANALYSIS REFLECTING THE RELATIONSHIP BETWEEN THE NUMBER OF REPORTED MHI AND COGNITIVE TEST RESULTS

For the purposes of the correlational analysis, the number of reported MHI included the *total* number of both sport and non-sport related MHI. The data were analysed using Pearson's Product-Moment correlation resulting in a correlation coefficient and a p-value respectively (see Table 4-5, p.57). The statistical analysis points to one significant result in the Rugby Forwards group on Fingertapping Preferred Hand which resulted in a correlation coefficient of -0.3857 ($p = 0.04$). Digit Symbol Substitution Copy was found to be approaching significance in the Rugby Forward group ($p = 0.06$) with a correlation coefficient of 0.2729. Both these results indicate a relationship between better performance on the tasks and higher number of reported MHI. Across all other tests, there were no significant correlations. An overall trend for these results was a low range of correlations, with the highest correlation coefficient being -0.3857 ($p = 0.04$) and the second highest being 0.3644 ($p = 0.06$).

4.3. <u>SUMMARY OF SIGNIFICANT RESULTS</u>

The comparisons of *group means* revealed significant differences on a) WMS Paired Associate Learning - Delayed Recall in the direction of Total Rugby performing worse than Total Hockey; and, b) WMS Visual Reproduction - Delayed Recall in the direction of Total Hockey showing poorer performance than Ruby Forwards.

No consistent *group mean trends* were apparent across modalities when comparing means between the groups and sub-groups.

Significant *variability of results* was shown on a) WMS Paired Associate Learning Hard Pairs - Delayed Recall in the direction of Total Rugby, Rugby Forwards and Rugby Backs showing significant variability of results when compared with the Total Hockey group; b) WMS Visual Reproduction - Immediate <u>and</u> Delayed Recall, in the direction of Rugby Backs and Total Hockey showing significant variability when compared with the Rugby Forwards; c) Digit Symbol Substitution Incidental Recall - Immediate in the direction of Rugby Backs and Total Hockey showing significant variability when compared with Rugby Forwards.

The *correlational analysis* revealed a significant result in the Rugby Forward group, indicating a relationship between a higher number of reported MHI and better performance on the Fingertapping Preferred Hand task.

Table 4-1. Comparison of Total Rugby and Total Hockey across Cognitive Modalities

Test	Total Rugby				Total Hockey				t-statistic	p-value	Levene's	p-value
	n	Mean	SD	Range	n	Mean	SD	Range			F-statistic	
Attention and Concentration (Mental Tracking):												
Digits Forward	47	6.96	1.27	5 - 10	34	6.91	1.26	5 - 9	0.16	0.87	0.21	0.65
Digits Backward	47	5.34	1.36	3 - 8	34	5.26	1.50	3 - 8	0.24	0.81	0.13	0.72
Letter-Number Sequencing	47	11.79	2.86	6 - 18	34	11.74	3.04	7 - 18	0.08	0.94	0	0.95
SNST-CW	46[1]	106.72	6.95	83 - 112	34	106.59	7.86	80 - 112	0.08	0.94	0.47	0.50
Visuoperceptual Tracking												
Digit Symbol Substitution - Copy	47	49.03	8.59	31 - 67	34	51.34	12.25	30 - 67	-1.00	0.32	1.55	0.22
Trail Making Test A	47	26.32	6.72	15 - 46	34	24.39	6.65	13 - 40	1.28	0.20	0.03	0.87
Trail Making Test B	47	56.63	14.53	31 - 88	34	53.95	14.96	34 - 87	0.81	0.42	0.13	0.72
Verbal Memory												
WMS ALE (Easy) - Imm.	47	8.82	0.32	7.5 - 9	34	8.74	0.39	7.5 - 9	1.06	0.29	2.63	0.11
WMS ALE (Hard) - Imm.	47	9.55	2.29	3 - 12	34	10.09	1.78	5 - 12	-1.13	0.26	1.99	0.16
WMS ALE (Easy) - Del.	47	6.00	0.00		34	6.00	0.00		*No Statistic*[2]	0.00	*No Statistic*[2]	0.00
WMS ALE (Hard) - Del.	47	3.62	0.74	1 - 4	34	3.91	0.38	2 - 4	-2.34	0.0219 *	18.72	0.0000 *
Visual Memory												
WMS VR - Imm.	47	12.15	1.55	6 - 14	34	12.03	1.40	9 - 14	0.36	0.72	0	0.99
WMS VR - Del.	47	11.85	1.84	5 - 14	34	11.35	1.84	6 - 14	1.20	0.23	0.9	0.35
Digit Symbol IR - Imm.	47	7.07	1.68	2.5 - 9	34	6.75	2.05	2 - 9	0.78	0.44	2.52	0.12
Digit Symbol IR - Del.	47	6.76	1.90	2 - 9	34	6.47	2.01	1.5 - 9	0.65	0.52	0.19	0.66
Verbal Fluency												
Verbal Fluency - Uns.	47	38.02	8.71	21 - 60	38.74	38.74	7.18	24 - 52	-0.39	0.70	1.99	0.16
Verbal Fluency - Str.	47	16.19	4.49	6 - 27	39	15.68	4.45	7 - 24	0.51	0.61	0.09	0.76
Hand Motor Dexterity												
Fingertapping - PH	47	5.77	1.01	3.87 - 7.5	39	5.55	1.01	2.59 - 7.86	0.98	0.33	0.89	0.35
Fingertapping - NPH	47	6.11	1.06	4.02 - 8.37	39	5.94	1.04	2.74 - 7.75	0.72	0.48	0.29	0.59

Significant Difference (*p<0.05)

[1]On the SNST, n = 46 for Total Rugby as one colour-blind rugby forward's result was not included in the analysis.

[2]Where *No Statistic* is reported, all subjects have perfect scores thus rendering a statistical comparision null and void.

Table 4-2. Comparison of Rugby Forwards and Rugby Backs across Cognitive Modalities

Test	Rugby Forwards				Rugby Backs				t-statistic	p-value	Levene's	p-value
	n	Mean	SD	Range	n	Mean	SD	Range			F-statistic	
Attention and Concentration (Mental Tracking):												
Digits Forward	28	7.07	1.22	5 - 9	19	6.79	1.36	5 - 10	0.74	0.46	0.12	0.73
Digits Backward	28	5.68	1.42	3 - 8	19	4.84	1.12	3 - 7	2.16	0.03 ~	3.03	0.09
Letter-Number Sequencing	28	11.82	2.97	6 - 18	19	11.74	2.77	7 - 18	0.10	0.92	0.78	0.38
SNST-CW	27[1]	106.22	8.12	83 - 112	19	107.42	4.97	96 - 112	-0.57	0.57	3.15	0.08
Visuoperceptual Tracking												
Digit Symbol Substitution - Copy	28	48.41	9.27	31 - 67	19	49.95	7.62	38 - 65	-0.60	0.55	1.15	0.29
Trail Making Test A	28	25.24	6.44	15 - 38	19	27.91	6.97	18 - 46	-1.35	0.18	0.01	0.92
Trail Making Test B	28	54.85	15.26	31 - 84	19	59.25	13.35	44 - 88	-1.02	0.31	0.81	0.37
Verbal Memory												
WMS ALE (Easy) - Imm.	28	8.79	0.35	7.5 - 9	19	8.87	0.28	8 - 9	-0.87	0.39	1.38	0.25
WMS ALE (Hard) - Imm.	28	9.50	2.30	3 - 12	19	9.63	2.34	5 - 12	-0.19	0.85	0.04	0.83
WMS ALE (Easy) - Del.	28	6.00	0.00		19	6.00	0.00		*No Statistic*[2]		*No Statistic*[2]	
WMS ALE (Hard) - Del.	28	3.61	0.69	2 - 4	19	3.63	0.83	1 - 4	-0.11	0.91	0.02	0.88
Visual Memory												
WMS VR - Imm.	28	12.57	0.84	10 - 14	19	11.53	2.09	6 - 14	2.07	0.05 ~	14.98	0.0003 *
WMS VR - Del.	28	12.32	1.12	8 - 13	19	11.16	2.43	5 - 14	1.95	0.06	9.05	0.0043 *
Digit Symbol IR - Imm.	28	7.55	1.23	5 - 9	19	6.37	2.01	2.5 - 9	2.30	0.03 ~	7.43	0.0091 *
Digit Symbol IR - Del.	28	7.18	1.62	3 - 9	19	6.13	2.15	2 - 9	1.90	0.06	2.6	0.11
Verbal Fluency												
Verbal Fluency - Uns.	28	38.36	8.20	25 - 60	19	37.53	9.63	21 - 58	0.32	0.75	0.95	0.34
Verbal Fluency - Str.	28	17.25	3.96	11 - 27	19	14.63	4.87	6 - 25	2.03	0.05 ~	0.92	0.34
Hand Motor Dexterity												
Fingertapping - PH	28	5.78	0.97	3.98 - 7.47	19	5.77	1.09	3.87 - 7.5	0.02	0.99	0.55	0.46
Fingertapping - NPH	28	6.01	0.10	4.02 - 7.68	19	6.26	1.19	4.41 - 8.37	-0.79	0.43	1.62	0.21

Significant Difference (* $p<0.025$), Approaching Significance ($\sim 0.025<p<0.05$) following Bonferroni's adjustments.

[1]On the SNST, n = 27 for Rugby Forwards as one colour-blind rugby forward's result was not included in the analysis.

[2]Where *No Statistic* is reported, all subjects have perfect scores thus rendering a statistical comparision null and void.

Table 4-3. Comparison of Rugby Forwards and Total Hockey across Cognitive Modalities

Test	Rugby Forwards				Total Hockey				t-statistic	p-value	Levene's	p-value
	n	Mean	SD	Range	n	Mean	SD	Range			F-statistic	
Attention and Concentration (Mental Tracking):												
Digits Forward	28	7.07	1.22	5 - 9	34	6.91	1.26	5 - 9	0.50	0.62	0.28	**0.60**
Digits Backward	28	5.68	1.42	3 - 8	34	5.26	1.50	3 - 9	1.11	0.27	0	**0.97**
Letter-Number Sequencing	28	11.82	2.97	6 - 18	34	11.74	3.04	7 - 18	0.11	0.91	0.11	**0.74**
SNST-CW	27[1]	106.22	8.12	83 - 112	34	106.59	7.86	80 - 112	-0.18	0.86	0.03	**0.87**
Visuoperceptual Tracking												
Digit Symbol Substitution - Copy	28	48.41	9.27	31 - 67	34	51.34	12.25	30 - 67	-1.04	0.30	0.44	**0.51**
Trail Making Test A	28	25.24	6.44	15 - 38.8	34	24.39	6.65	13.4 - 40.3	0.50	0.62	0.01	**0.91**
Trail Making Test B	28	54.85	15.26	31 - 84.6	34	53.95	14.96	34.2 - 87	0.23	0.82	0.03	**0.87**
Verbal Memory												
WMS ALE (Easy) - Imm.	28	8.79	0.35	7.5 - 9	34	8.74	0.39	7.5 - 9	0.53	0.60	0.95	**0.33**
WMS ALE (Hard) - Imm.	28	9.50	2.30	3 - 12	34	10.09	1.78	5 - 12	-1.13	0.26	1.31	**0.26**
WMS ALE (Easy) - Del.	28	6.00	0.00		34	6.00	0.00		*No Statistic* [2]		*No Statistic* [2]	
WMS ALE (Hard) - Del.	28	3.61	0.69	2 - 4	34	3.91	0.38	2 - 4	-2.10	0.04 ~	18.79	**0.0001 ***
Visual Memory												
WMS VR - Imm.	28	12.57	0.84	10 - 14	34	12.03	1.40	9 - 14	1.88	0.07	5.79	**0.0192 ***
WMS VR - Del.	28	12.32	1.12	8 - 13	34	11.35	1.84	6 - 14	2.55	0.0137 *	9.59	**0.0030 ***
Digit Symbol IR - Imm.	28	7.55	1.23	5 - 9	34	6.75	2.05	2 - 9	1.91	0.06	7.40	**0.0085 ***
Digit Symbol IR - Del.	28	7.18	1.62	3.5 - 9	34	6.47	2.01	1.5 - 9	1.51	0.14	1.65	**0.20**
Verbal Fluency												
Verbal Fluency - Uns.	28	38.36	8.20	25 - 60	34	38.74	7.18	24 - 52	-0.19	0.85	0.65	**0.42**
Verbal Fluency - Str.	28	17.25	3.96	11 - 27	34	15.68	4.45	7 - 24	1.46	0.15	1.25	**0.27**
Hand Motor Dexterity												
Fingertapping - PH	28	5.78	0.97	3.98 - 7.47	34	5.55	1.01	2.59 - 7.86	0.89	0.38	0.26	**0.61**
Fingertapping - NPH	28	6.01	0.98	4.02 - 7.68	34	5.94	1.04	2.74 - 7.75	0.27	0.79	0.05	**0.82**

Significant Difference (* p<0.025), Approaching Significance (~0.025<p<0.05) following Bonferroni's adjustments.

[1]On the SNST, n = 27 for Rugby Forwards as one colour-blind rugby forward's result was not included in the analysis.

[2]Where *No Statistic* is reported, all subjects have perfect scores thus rendering a statistical comparision null and void.

Table 4-4. Comparison of Rugby Backs and Total Hockey across Cognitive Modalities

Test	Rugby Backs n	Rugby Backs Mean	Rugby Backs SD	Range	Total Hockey n	Total Hockey Mean	Total Hockey SD	Range	t-statistic	p-value	Levene's F-statistic	p-value
Attention and Concentration (Mental Tracking):												
Digits Forward	19	6.79	1.36	5 - 10	34	6.91	1.26	5 - 9	-0.33	0.74	0	0.95
Digits Backward	19	4.84	1.12	3 - 7	34	5.26	1.50	3 - 9	-1.07	0.29	2.3	0.14
Letter-Number Sequencing	19	11.74	2.77	7 - 18	34	11.74	3.04	7 - 18	0.00	1.00	0.28	0.60
SNST CW	19	107.42	4.97	96 - 112	34	106.59	7.86	80 - 112	0.42	0.68	2.82	0.10
Visuoperceptual Tracking												
Digit Symbol Substitution - Copy	19	49.95	7.62	38 - 65	34	51.34	12.25	30 - 67	-0.45	0.66	1.77	0.19
Trail Making Test A	19	27.91	6.97	18 - 46	34	24.39	6.65	13.4 - 40.3	1.82	0.08	0.04	0.85
Trail Making Test B	19	59.25	13.36	44 - 88	34	53.95	14.96	34.2 - 87	1.28	0.21	0.6	0.44
Verbal Memory												
WMS ALE (Easy) - Imm.	19	8.87	0.28	8 - 9	34	8.74	0.39	7.5 - 9	1.30	0.20	4.24	0.0446 ~
WMS ALE (Hard) - Imm.	19	9.63	2.34	5 - 12	34	10.09	1.78	5 - 12	-0.80	0.43	1.81	0.18
WMS ALE (Easy) - Del.	19	6.00	0.00		34	6.00	0.00		*No Statistic*[1]		*No Statistic*[1]	
WMS ALE (Hard) - Del.	19	3.63	0.83	1 - 4	34	3.91	0.38	2 - 4	-1.39	0.18	10.97	0.0017 *
Visual Memory												
WMS VR - Imm.	19	11.53	2.09	6 - 14	34	12.03	1.40	9 - 14	-1.05	0.30	3.76	0.06
WMS VR - Del.	19	11.16	2.43	5 - 14	34	11.35	1.84	6 - 14	-0.33	0.74	0.76	0.39
Digit Symbol IR - Imm.	19	6.37	2.01	2 - 9	34	6.75	2.05	2 - 9	-0.66	0.52	0	1.00
Digit Symbol IR - Del.	19	6.13	2.15	2 - 9	34	6.47	2.01	1.5 - 9	-0.57	0.57	0.2	0.66
Verbal Fluency												
Verbal Fluency - Uns.	19	37.53	9.63	21 - 58	34	38.74	7.18	24 - 52	-0.52	0.61	3.15	0.08
Verbal Fluency - Str.	19	14.63	4.87	6 - 25	34	15.68	4.45	7 - 24	-0.79	0.43	0.01	0.93
Hand Motor Dexterity												
Fingertapping - PH	19	5.77	1.09	3.87 - 7.5	34	5.55	1.01	2.59 - 7.86	0.74	0.46	1.12	0.30
Fingertapping - NPH	19	6.26	1.19	4.41 - 8.37	34	5.94	1.04	2.74 - 7.75	1.02	0.31	1.09	0.30

Significant Difference (* p<0.025), Approaching Significance (~0.025<p<0.05) following Bonferroni's adjustments.

[1] Where *No Statistic* is reported, all subjects have perfect scores thus rendering a statistical comparision null and void.

Table 4-5. Correlation Coefficient reflecting the Relationship between the number of reported Mild Head Injuries (Total Non-Sport and Sport) with Cognitive Test Results

Test	Total Hockey			Total Rugby			Rugby Forwards			Rugby Backs		
	n	Correlation	p-value	n	Correlation	p-value	n	Correlation	p-value	n	Correlation	p-value
Attention and Concentration (Mental Tracking):												
Digits Forward	34	0.0113	0.95	47	0.1272	0.39	28	-0.0395	0.84	19	0.3420	0.15
Digits Backward	34	0.1329	0.45	47	0.1058	0.48	28	0.1935	0.32	19	-0.0030	0.99
Letter-Number Sequencing	34	0.0940	0.60	47	0.0452	0.76	28	0.0131	0.95	19	0.0942	0.70
SNST-CW	34	0.0831	0.64	46[1]	0.0669	0.66	27[1]	0.2031	0.31	19	-0.2318	0.34
Visuoperceptual Tracking												
Digit Symbol Substitution - Copy	34	0.0481	0.79	47	0.2729	0.06 ~	28	0.3644	0.06 ~	19	0.1222	0.62
Trail Making Test A	34	-0.0764	0.67	47	-0.0811	0.59	28	-0.2745	0.16	19	0.1478	0.55
Trail Making Test B	34	0.1873	0.29	47	-0.1652	0.27	28	-0.2934	0.13	19	0.0178	0.94
Verbal Memory												
WMS ALE (Easy) - Imm.	34	-0.0453	0.80	47	0.0988	0.51	28	0.1151	0.56	19	0.0658	0.79
WMS ALE (Hard) - Imm.	34	-0.2464	0.16	47	0.2146	0.15	28	0.1863	0.34	19	0.2517	0.30
WMS ALE (Easy) - Del.		*No Statistic*[2]										
WMS ALE (Hard) - Del.	34	0.0377	0.83	47	0.2216	0.13	28	0.1655	0.40	19	0.2854	0.24
Visual Memory												
WMS VR - Imm.	34	-0.0610	0.73	47	0.0170	0.91	28	0.0119	0.95	19	0.0410	0.87
WMS VR - Del.	34	0.1667	0.35	47	0.0362	0.81	28	-0.0169	0.93	19	0.0933	0.70
Digit Symbol IR - Imm.	34	0.0445	0.80	47	0.1225	0.41	28	0.2289	0.24	19	0.0729	0.77
Digit Symbol IR - Del.	34	-0.0933	0.60	47	0.0984	0.51	28	0.0906	0.65	19	0.1324	0.59
Verbal Fluency												
Verbal Fluency - Uns.	34	0.1664	0.35	47	0.1590	0.29	28	-0.0095	0.96	19	0.3607	0.13
Verbal Fluency - Str.	34	-0.1973	0.26	47	0.0586	0.70	28	0.0015	0.99	19	0.1472	0.55
Hand Motor Dexterity												
Fingertapping - PH	34	0.0064	0.97	47	-0.1888	0.20	28	-0.3857	0.043 *	19	0.0517	0.83
Fingertapping - NPH	34	0.0569	0.75	47	-0.1085	0.47	28	-0.1556	0.43	19	-0.0645	0.79

Significant Difference (* $p<0.05$); Approaching Significance (~ $0.05<p<0.10$)

[1]On the SNST, n = 46 for Total Rugby and n = 27 for Rugby Forwards, as one colour-blind rugby forward's result was not included in the analysis.

[2]Where *No Statistic* is reported, all subjects have perfect scores thus rendering a statistical comparison null and void.

CHAPTER 5 : DISCUSSION

This chapter focuses on a discussion of the results yielded by the statistical analysis. The findings are examined in terms of the hypotheses for this study as formulated in section 2.4.2. and are synthesised within the theoretical context of Satz's (1993) brain reserve capacity (BRC) theory and Shuttleworth-Jordan's (1999) hypothetical indications. Furthermore, the implications of this research are discussed and the methodological strengths and limitations of the study are highlighted. In conclusion, directions for future study are presented.

5.1. REVISITING THE AIMS, METHODS AND HYPOTHESES OF THE STUDY

As previously mentioned, this study purports to investigate the effects of cumulative mild head injuries in top team South African high school rugby players. The main aim of the study was to ascertain whether this population runs similar risks to the professional rugby players who were previously investigated for the deleterious effects of repeated mild head injuries. In order to achieve these aims, a comprehensive battery of neuropsychological tests was administered to a group of top team high school rugby players and a control group consisting of top team high school hockey players. Exclusion criteria with respect to participant selection included a reported history of neurological or psychiatric/psychological disorder, learning disorder and previous moderate to severe head injury, making it unlikely that differences between groups could be accounted for by these factors.

In addition, with regard to demographic data, no significant difference of means was noted for Total Rugby versus Total Hockey or Rugby Forwards versus Rugby Backs for any of the variables including age, educational level, overall grade achieved 1999 and estimated premorbid IQ level. It appears that both the Total Rugby and Total Hockey groups, and the Rugby Forwards and Rugby Backs were equivalent in terms of age, level of education, school achievement and estimated premorbid level of intellectual functioning, making it unlikely that these demographic data could act as confounding variables in this study. Of note is that the Rugby Forwards showed a higher range of educational level (Range: 10-12) when compared with the Rugby Backs (Range 10-11), a higher premorbid IQ range (Range: 89.5-133) when compared with the Rugby Backs (89-119) and a higher upper limit for school grade (Range = 55-93) when compared with the Rugby Backs (Range = 50-86). This may indicate that although differences between the group means were statistically insignificant, for these demographic variables, the Rugby Forwards group appeared to have included a number of high functioning individuals, providing some evidence to suggest the Forwards to be a group skewed in the direction of being a slightly higher functioning group than the Backs.

Data analysis for this particular thesis involved a direct comparison of group mean scores and standard deviations across each neuropsychological test for a) the Rugby group versus the Hockey control group; b) the Rugby Forwards versus the Rugby Backs; c) the Rugby Forwards versus the Hockey control group; and, d) the Rugby Backs versus the Hockey control group. In addition, a correlational analysis was run to ascertain whether a relationship existed between the number of reported mild head injuries recalled by currently active players with their cognitive test performance.

It was hypothesised that top team high school rugby players would show neuropsychological impairment evidenced by a significant difference of mean scores in the direction of poorer performance of rugby players and/or increased variability of test performance on tests sensitive to diffuse damage when compared with non-contact sport controls. Furthermore, it was hypothesised that top team high school rugby forward players would show neuropsychological impairment evidenced by a significant difference of mean scores in the direction of poorer performance of forwards and/or increased variability of test performance on tests sensitive to diffuse damage when compared with backline players and non-contact sport controls. Increased variability amongst the rugby group would imply that a significant proportion of players were showing problems relative to others in the group that were not. Finally, it was hypothesised that a strong correlational relationship would be revealed between the number of reported mild head injuries sustained by top team high school rugby players and poorer performance on neuropsychological tests sensitive to the effects of diffuse brain damage.

5.2. DISCUSSION OF RESULTS

Each analysis will be discussed by focusing on significant results of the comparisons of means and variability. Thereafter, results approaching significance and trends for each analysis will also be discussed. Following this, the results of the correlational analysis will be reviewed.

5.2.1. GROUP MEAN COMPARISONS FOR TOTAL RUGBY VERSUS TOTAL HOCKEY

The analysis revealed a significant finding on WMS Paired Associate Learning Hard Pairs - Delayed Recall in the direction of significantly poorer group mean score performance and significantly higher variability of performance of the Total Rugby group relative to the Hockey controls. With regard to within group variability, the frequency distributions for this task (see Figure1, p. 45) indicates significant variability of performance amongst the Total Rugby group with only 74% of the rugby players able to recall all Hard Pairs when compared with the Hockey group of whom 94% showed perfect scores.

As previously mentioned, the ability to remember Hard Pairs is related to new learning ability and is thus more susceptible to the effects of brain damage than the easy pairs. This test has been singled out by Saling (1999) as being a highly sensitive indicator of mild neurocognitive impairment and was successful in detecting deficits amongst the Springbok Rugby players versus Hockey controls and the U/21 Rugby Forwards when compared with the Backs in Phase II of the research (Finkelstein, 2000). Furthermore, research has shown verbal memory ability to be the only discriminator of mild cognitive impairment in a mostly mild head injured adolescent group when compared with controls (Leathem & Body, 1997). The delayed memory component is especially sensitive to the effects of diffuse damage and delayed verbal recall seems to be the best discriminator of early dementia (Ferris & Kluger, 1996; Lezak, 1995). It is noted that the Rugby group showed significantly poorer performance on the delayed recall task as opposed to the immediate recall task when compared with the Hockey group, suggesting that poorer performance on the delayed task may well be as a result of diffuse brain damage effects. Whilst the poorer performance of the Total Rugby group on WMS Paired Associate Learning Hard Pairs - Delayed Recall is an isolated finding, the Rugby group's impaired performance on this task may tentatively indicate the initial signs of diffuse damage associated with cumulative mild head injury, especially in view of the fact that the Total Rugby group reported a significantly higher incidence of mild head injury than the Total Hockey group. The significance of this finding is much enhanced by the fact that this was a replication of an effect detected for the U/21 Rugby Forwards group of professional rugby players when compared with Rugby Backs.

With respect to the Total Rugby group, a marginal trend emerged of poorer performance relative to the Hockey controls on tests of Visuoperceptual Tracking and Hand Motor dexterity. Digit

Symbol Substitution Subtest and the Trailmaking Test are tests known to be highly sensitive to the effects of diffuse damage and were successful in detecting deficits amongst the Rugby players in Phase I and Phase II of the research. This trend is in a direction which is commensurate with the presence of deleterious effects following cumulative mild head injuries sustained in rugby. With regard to trends in the Total Hockey group, the control group tended to perform worse on tests of Attention and Concentration, and Visual Memory when compared with the Rugby players. Since there is no reason to propose the presence of brain injury in this group, this trend is likely to be accounted for by normal variability effects rather than deficits in these functions.

5.2.2. GROUP MEAN COMPARISONS FOR RUGBY FORWARDS VERSUS RUGBY BACKS

The Rugby sub-group analysis revealed no significance difference of means when the Rugby Forwards were compared with the Rugby Backs. However, Digits Backward, WMS Visual Reproduction - Immediate Recall, Digit Symbol Substitution Incidental Recall - Immediate and Structured Verbal Fluency were found to be approaching significance in the direction of Rugby Backs showing poorer performance when compared with Rugby Forwards. The analysis revealed significant variability of results amongst the Rugby Backs on tests of visual memory namely, the WMS Visual Reproduction - Immediate and Delayed Recall and Digit Symbol Substitution - Incidental Recall tasks when compared with the Rugby Forwards group. The frequency distributions for these tests (see Figures 2, 3 and 4, pp. 46-47) indicate a few Rugby Backs to be very low scorers, whilst the scores for the Forwards are more evenly distributed and are clustered in the main around the higher part of the range. When comparing individual scores to available normative data (see Bold, 2000) for Visual Reproduction - Immediate Recall, 26% of Backs showed impairment (i.e. scores of more than 1 standard deviation below the mean) compared with only 4% of the Forwards. Similarly, on the Delayed Recall task 21% of Backs scored in the impaired range compared with only 4% of the Forwards. Furthermore, on the Digit Symbol Incidental Recall - Immediate task, 37% of the Backs showed impairment compared with only 11% of the Forwards.

This significant variability of results amongst the Rugby Backs may be accounted for by the presence of diffuse brain damage effects on tasks of visual memory in this subgroup which may have been obscured in the main group analysis (Total Rugby versus Total Hockey) because of a relatively high functioning Forwards group. On the other hand, this may be accounted for by normal variability of performance which gains statistical significance when compared with the unusually high functioning Rugby Forwards group. With respect to marginal trends of performance emerging within functional modalities, the Rugby Backs tended towards poorer performance on the Visual Memory and Verbal Fluency tasks whilst the forwards tended towards poorer performance on Verbal Memory tasks.

These findings from the direct comparisons of Rugby Forwards versus Backs do not corroborate the results from the previous two phases of research in which the Rugby Forwards showed poorer performance and higher variability of performance on neuropsychological tests when compared with the Rugby Backs (Ancer, 1999; Finkelstein, 2000). For the purposes of this thesis, it was hypothesised that Forwards are exposed to more repetitive physical collisions and hence exposed to more cumulative mild head injuries than the Backs. This would be expected to lower the critical threshold at which functional symptomotology manifests in terms of BRC theory, thus increasing the players' vulnerability to neuropsychological deficit as evidenced by test performance and predisposing them to functional impairment. The fact that we are not seeing a similar pattern of results in the Rugby Forwards versus Rugby Backs comparison as was evidenced in the first two phases of research, may be accounted for by various factors. Firstly, there is some evidence to suggest that the Rugby Forwards are an inherently higher functioning group when compared with the backs and show less variability of performance. Furthermore, an uninitiated comment from one of the school headmasters suggests that it is oftentimes the backline players who sustain the more severe concussions at school level. Lastly, players at school level are more likely to have shifted between Forward and Backline positions before settling into a their present position, making it likely that the distinction between Forward and Backline positions less useful for the purposes of this study.

5.2.3. GROUP MEAN COMPARISONS FOR RUGBY FORWARDS VERSUS TOTAL HOCKEY

With respect to the group mean comparison, the analysis revealed one significant result, in that the Total Hockey group showed significantly poorer performance on the WMS Visual Reproduction - Delayed Recall when compared with the Rugby Forwards. WMS Associate Learning Hard Pairs - Delayed Recall was found to be approaching significance in the direction of Rugby Forwards showing poorer performance when compared with Total Hockey. Furthermore, significant variability of performance was found amongst the Forward players on this task. An analysis of the frequency distribution for this test (see Figure 5, p.48) indicates that only 71% of the Rugby Forwards were able to recall all Hard Pairs when compared with the Hockey controls of whom 94% showed perfect scores.

Overall, the Hockey players showed significant variability of performance on tests of visual memory (WMS Visual Reproduction - Immediate Recall and Delayed Recall, and Digit Symbol Substitution Incidental Recall - Immediate) when compared with the Rugby Forwards along with a marginal but consistent trend towards poorer mean scores on the visual memory tasks. Overall, the Forwards tended towards marginally poorer performance on tests of Visuoperceptual Tracking and Hand Motor Dexterity, although results on these subtests were not shown to be statistically significant or to be approaching significance.

Both the Total Hockey group and the Rugby Backs (see section 5.2.2.) showed significant variability of results on visual memory tasks when compared with the Rugby Forwards group. It is apparent from the frequency distributions that both the Rugby Backs (see Figures 2, 3 and 4, pp.46-47) and the Hockey group (see Figures 6, 7, and 8, pp.49-50) show a number of low scores whilst the Rugby Forwards show scores clustered in the main around the upper part of the range. This lends additional support for the fact that the Forwards may be a generally higher functioning group and it would appear that the significant result on WMS Visual Reproduction - Delayed Recall reflects a more normal pattern of variability amongst the Hockey group. The fact that the results on visual memory support the notion of a particularly high functioning set of individuals in the forwards group would lead one to expect an equally high level of functioning across all functions in the forward group which is not the case for verbal learning. By implication the deficit noted on verbal learning for the generally high functioning forwards players takes on greater significance with respect to forward players succumbing to repetitive brain insults since they presumably started with a higher level of protective effects in the first place.

Thus, in spite of the absence of evidence for enhanced deficit amongst the forwards from the direct comparisons as discussed above (Section 5.2.2), a fine analysis of the individual level for the only significant effect does lend support to some extent for greater fall-off in the learning of unfamiliar pairs amongst the forwards, strengthened by evidence of the forwards being otherwise a particularly high functioning group.

5.2.4. GROUP MEAN COMPARISONS FOR RUGBY BACKS VERSUS TOTAL HOCKEY

The group mean comparisons revealed no significant results. However, WMS Paired Associate Learning Easy Pairs - Immediate Recall was found to be approaching significance in the direction of Hockey showing poorer performance than the Rugby Backs. Significant variability of results amongst the Rugby Backs was shown on WMS Paired Associate Learning Hard Pairs - Delayed Recall. The frequency distributions showed one very low outlier score for the Rugby Backs whilst scores for the Total Hockey group were clustered in the main around the highest score (see Figure 9, p.51). Only 79% of the Rugby Backs were able to recall all hard pairs when compared with the Hockey controls of whom 94% achieved perfect scores. Thus again, fine analysis of individuals shows up greater individual impairment in the direction of rugby players being at greater risk than hockey players for clinically significant impairment. Marginal trends indicate that the Rugby Backs show poorer mean scores on tests of Visuoperceptual Tracking, Visual Memory, Verbal Fluency and Hand Motor Dexterity.

5.2.5. DISCUSSION OF GROUP MEAN COMPARISONS

The results of the group mean comparisons can be considered to lend tentative support for presence of cognitive deficits in the high school rugby playing population as evidenced by impaired performance on neuropsychological tests sensitive to the effects of diffuse brain damage, with additional tentative support for the hypothesis that schoolboy rugby forwards run higher risks than rugby backs for the deleterious cognitive effects consequent on repetitive concussive injuries. Clearly, the analysis of the frequency distributions allows for a more detailed investigation of the variability of scores *within* groups. It is apparent that this method of analysis provides a richer and more meaningful breakdown of the inter-individual variability of cognitive performance (Shuttleworth-Jordan, 1999) within the rugby group and sub-groups and within the hockey group.

5.2.6. CORRELATIONAL ANALYSIS REFLECTING THE RELATIONSHIP BETWEEN THE NUMBER OF REPORTED MHI AND COGNITIVE TEST RESULTS

The correlation analysis revealed only *one* significant result, indicating a relationship between the number of mild head injuries reported by the Rugby Forwards and their performance on Fingertapping Preferred Hand. However, the correlation related to this finding is not very strong and is in the reverse direction of what is expected, indicating better performance on the task associated with a higher number of reported mild head injuries. This can be accounted for by the relatively high functioning Forwards sample or by the unreliable nature of a retrospective self-report measure used to glean information about head injury history in this study. Furthermore, the Fingertapping task is not measured by mechanical device, but by a hand held stopwatch which lacks precision for the purposes of this test. The results may not have been accurate but a mere statistical artefact, as raised by Shuttleworth-Jordan et al. (1993). Overall, the correlation coefficients yielded from the analysis are not very high making it likely that this significant result is a highly isolated event across all the tests, as well as within the Fingertapping test itself as the Preferred Hand and not the more vulnerable Non-preferred proved to be the single and not very significant finding.

5.3. THEORETICAL IMPLICATIONS OF THE RESEARCH FINDINGS

Overall, the results are able to provide only very tentative support for the hypothesis that schoolboy rugby players are susceptible to the cognitive effects of cumulative concussive and sub-concussive injuries and are only tentatively able to corroborate the findings of previous studies on professional rugby players. However, the findings are all in the correct direction and provide a measure of corroboration for prior research and the deficits show up on a test which is earmarked as a highly sensitive indicator of mild neuropsychological impairment. It is cause for concern that a highly sensitive test of verbal learning and delayed recall (WMS Paired Associate Hard Pairs - Delayed Recall) is showing up significantly poorer performance amongst a relatively high functioning group of rugby players who have not had as lengthy rugby exposure as the professional players. Although this appears to be an isolated test finding, and along with the usual precautions against extrapolating significance from one test finding, this result may still be a subtle indicator of diffuse brain damage effects in this relatively high functioning group. The ability to learn unfamiliar material and to sustain the learning in the face of interference, is vital for anyone hoping to write matric exams and for university student who are required to learn and retain large amounts of unfamiliar material.

The question whether *minor "dings"* lead to *major effects* in schoolboy rugby remains largely unanswered. However, the absence of a more definitive pattern of positive clinical findings in this study does not preclude the existence of "silent" or sub-clinical damage. There may be a host of *protective factors* accounting for this such as the high average IQ level of the sample and the high quality of schooling received by the players. Satz (1992) equates level of brain reserve capacity with IQ and proposes that if one starts with a low level of BRC, the threshold is lower and is reached easier. Therefore, in terms of BRC theory, were this sample to have been a less high functioning group with a lower IQ level, significant clinical deficits may well have been found.

Despite the absence of a pattern of clinically noticeable cognitive deficits within the rugby group, the rugby players are reporting a significantly higher incidence of mild head injuries than the hockey players. Both the rugby forwards and backs report an average incidence of approximately 2-3 mild head injuries whilst hockey players report an average at most 0.4 mild head injuries. In terms of BRC theory, each player has a critical threshold or critical point at which normal functioning is sustained prior to the clinical manifestation of symptoms caused by brain damage. This leads one to postulate that the top team school rugby players are perhaps sustaining "silent" brain injury which lowers the cerebral reserve threshold and thus increases their vulnerability to functional impairment. Should they continue playing and subjecting themselves to further insults to the brain, the critical threshold could be reached (such as was demonstrated with the professional rugby players). In other words, these mild head injuries reported by the rugby players, although appearing to be largely clinically insignificant, may act as *risk factors,* increasing the brain's vulnerability for future functional impairment and disease. The lowered threshold capacity and latent effect of these injuries may become evident when more sensitive test are used, particularly under stress related conditions (see for example Ewing et al. 1980). Furthermore, the latent effects may emerge under stressful conditions such as matriculation examinations, especially amongst those players whose verbal memory ability is already compromised.

A recent study by Collins and colleagues (1999) describes a clear link between learning disability and increased vulnerability to cognitive decline amongst College Football players. Whereas the sample of rugby players chosen for this study showed only extremely subtle cognitive deficits as evidenced on neuropsychological testing, those rugby players who are less protected, and whose cerebral reserve has already been compromised as a result of prior moderate to severe head injury and/or learning difficulties, or low IQ, may well have shown deficits concomitant on cumulative mild head injury. Specifically those players who were excluded from the present study for these reasons warrant follow-up in their own right.

5.4. EVALUATION OF THE STUDY AND FUTURE DIRECTIONS

5.4.1. EVALUATION OF THE STUDY

The study showed the following methodological strengths:

The use of an adequate sample size provided a robust data base for the analysis of sub-groups.

1. The groups and sub-groups used in the study were equivalent in terms of demographic data and the study was considered to be well controlled for potentially confounding variables such as age, educational level, school performance, and estimated pre-morbid IQ.
2. A sound method of calculating pre-morbid intellectual functioning, comprising the WAIS-III Vocabulary and Picture Completion subtests and the NART, was used to control for pre-selected differences within and between groups. This method was considered an improvement on the method used in the first two phases of the research as a reading test component in the form of the NART was incorporated into the test battery.
3. An extensive neuropsychological test battery was used which incorporated tests measuring abilities across a variety of modalities and included tests sensitive to the effects of diffuse brain damage associated with mild head injury. The test battery was a refined and more updated version of the test battery used in the first two phases of research on professional rugby players in that it included the Stroop Neuropsychological Screening test and three additional subtests of the WAIS-III (Vocabulary, Letter-number Sequencing, and Picture Completion).
4. The present study examined the variability of data within groups and was able to elicit evidence of inter-individual variability which enriched the interpretation of results by allowing for individual analysis. The analysis of variability augmented the frequently used method of comparing group means alone providing indications of clinical significance which were lost in the overall statistical analysis.
5. The findings were located within a strong theoretical framework, namely Satz's (1993) brain reserve capacity (BRC) theory and Shuttleworth-Jordan's (1997) model of inter-individual variability, thus pre-empting the premature acceptance of null outcomes.

This study showed certain methodological limitations which included the following:

1. This study was restricted in its cross-sectional nature in that it is not possible entirely to control for pre-existing differences. However, the research was considered to be well-controlled study with respect to age, education level, premorbid IQ and school achievements

and significant results and trends were conceptually consistent with expected patterns of test deficit following mild closed head injury.

2. It is not possible to generalise the findings to pertain to the South African high school rugby playing population as a whole. The three schools investigated in the study are elite, advantaged schools were pupils exhibited above average intellectual abilities.

5.4.2. FUTURE DIRECTIONS

The implications of the present research findings and directions for future research include the following:

1. A qualitative analysis is needed of the extent to which the sequelae of concussive and sub-concussive head injuries may impact on the individual's scholastic functioning.
2. A longer term study is needed to examine the more persistent and long-term effects of mild head injuries in school rugby players which should include neuropsychological screening and follow-up of high school rugby players throughout their rugby playing careers in order to ascertain whether clinically noticeable deficits appear over time. In this way, those rugby players at risk of increasing cognitive fall-off due to their continued participation in rugby can be identified.
3. Computerised neuropsychological testing for the evaluation of concussions, which includes reaction time tests, has proved to be highly sensitive in evaluating improvements of cognitive function in adolescents (for example, Daniel et al., 1999). These tests are able to notice the more subtle, persisting deficits. The use of more sensitive tests and the testing of participants under stressful conditions such as hypoxic states or using tests requiring higher task challenge, may also allow for the detection of the more latent, sub-clinical effects.
4. A study of rugby mild head injuries in previously disadvantaged school populations is needed to ascertain the extent of neuropsychological deficits resulting from repeated concussions in this group.
5. Similarly, it would be necessary to investigate those currently active rugby playing pupils who have a history of learning disability or previous moderate to severe head injuries or both and are thus at higher risk for the deleterious effects following such injuries.
6. A second study using a similar population needs to be conducted to ascertain whether the results will be replicated. An investigation of this nature could, for instance, target three elite schools in Grahamstown with a long-standing tradition of playing rugby.
7. The efficacy of protective headgear needs to be researched.

5.5. CONCLUDING COMMENTS

This study purported to investigate the cognitive effects of cumulative mild head injuries in a high school rugby playing population. The results tentatively indicate the presence of deleterious effects following cumulative mild head injuries in the Rugby group. Although the significant result on the verbal memory task is an isolated test finding, it gains significant weight when examined in the light of prior research which has found WMS Paired Associate Learning Hard Pairs to be a highly sensitive indicator of diffuse brain damage which was successful in detecting deficits in Phase II of the research. However, in spite of the fact that there is also much in the way of theory and empirical research to lend support for the present hypothesis, this finding must be interpreted cautiously. Isolated test results need replication and in view of the fact that this study was cross-sectional in nature, the differences between groups can always be accounted for by preselection. Although the findings are only tentatively able to corroborate previous research findings, the presence of sub-clinical damage which may lower brain reserve capacity threshold cannot be discounted. The lack of robust empirical data to support the presence of cognitive deficits in school level rugby players should not impede continuing efforts to educate players and coaches alike about the potential deleterious cognitive effects of cumulative mild head injury. What is especially worrying is the high number of head injuries being reported by the rugby players in this sample who may be at risk for brain damage. Furthermore, it is especially important to identify those players who run serious risks for the deleterious effects of multiple "dings", like for example, players with learning disorders and prior moderate to severe head injuries. Parents, coaches and teachers need to be reminded that "silent" head injuries lead to brain damage and should be provided with quick and reliable measures of assessing concussion. Minor "dings" may lead to major effects.

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APPENDIX - I

DEMOGRAPHIC QUESTIONNAIRE

RHODES UNIVERSITY PSYCHOLOGY CLINIC
Pre-assessment Questionnaire

NAME:_______________ FIRST LANGUAGE:_______________

AGE: _______________ D.O.B: _______________

SCHOOL STANDARD: _______________ SPORT: RUGBY / HOCKEY

TEAM: _______________ POSITION CURRENT: _______________

MOST FREQUENTLY PLAYED PAST POSITION: _______________

GENERAL HISTORY

QUESTION 1

Have you ever failed a standard at school? ☐ Yes ☐ No

If Yes, when?_______________ For what reason?_______________

What was your overall grade in 1999? _______________

How many of your subjects did you take on Standard Grade _______________ / Higher Grade?_______________

QUESTION 2

Have you ever experienced learning difficulties or required remedial classes? ☐ Yes ☐ No

If Yes, what was the problem?_______________

QUESTION 3

Have you ever experienced neurological problems (e.g. seizures, tremors, stroke)?

☐ Yes ☐ No

If Yes, what was the problem?_______________

QUESTION 4

Have you ever suffered from a psychological/psychiatric disorder (e.g. depression, anxiety, attention deficit or hyperactivity) which needed the help of a psychologist/psychiatrist? ☐ Yes ☐ No

If Yes, what was the problem?_______________

QUESTION 5

Are you currently taking any form of medication? ☐ Yes ☐ No

If Yes, please specify?_______________

QUESTION 6

Do you smoke? ❑ Yes ❑ No

If **Yes**, how much?____

QUESTION 7

Do you drink alcohol? ❑ Yes ❑ No

If **Yes**, how much?____

Have you ever felt that you should cut down on your drinking? ❑ Yes ❑ No

QUESTION 8

Do you use any other substances? ❑ Yes ❑ No

If **Yes**, specify type and frequency of use?____

QUESTION 9

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 10

Rugby Players

- At what age did you first start playing rugby? ____________________
- For how many consecutive years have you been playing rugby? ____________________
- Have you ever used protective headgear while playing rugby? ☐ Yes ☐ No

  If **Yes**, specify type and duration ____________________

Hockey Players

- At what age did you first start playing hockey? ____________________
- For how many consecutive years have you been playing hockey? ____________________

Rugby and Hockey Players

- What made you choose the sport you are currently playing? ____________________
- Have you ever played any other sport for a lengthy period of time?

  (For **rugby players**, check whether they have participated in BOXING and SOCCER)

  (For **hockey players**, check whether they have participated in RUGBY, BOXING and SOCCER)

  ☐ Yes ☐ No

  If **Yes**, specify sport and time period played ? ____________________

QUESTION 11 **(Rugby players only)**

How many times can you remember sustaining a head injury or concussion during a game of rugby, including occasions when you were knocked or "dinged" so hard that you felt dazed, confused and/or disoriented, even though you continued to play in the game? ***(Note to examiners: Try to ascertain the specific incidences of injury, beginning with the most recent, followed by other incidences in as consecutive an order as the subject can recall.)***

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

Injury 3 ____________________ **Injury 4** ____________________ **Injury 5** ____________________

Injury 1

- What caused the injury/concussion? ______________________________

____

____

- Where you dazed, confused and/or disoriented? ☐ 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 taken off the field? ☐ Yes ☐ No

  If **Yes**, for how long ? ______________________________
- Were you hospitalised? ☐ Yes ☐ No

  If **Yes**, for how long ? ______________________________
- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ☐ Yes ☐ No

  If **Yes**, please specify? ______________________________

Injury 2

- What caused the injury/concussion? ______________________________

____

____

- Where you dazed, confused and/or disoriented? ☐ 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 taken off the field? ☐ Yes ☐ No

  If **Yes**, for how long ? ______________________________
- Were you hospitalised? ☐ Yes ☐ No

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

- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ☐ Yes ☐ No

  If **Yes**, please specify? ______________________________

Injury 3

- What caused the injury/concussion? ______________________________

  ____

  ____

- Where you dazed, confused and/or disoriented? ☐ 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 taken off the field? ☐ Yes ☐ No

  If **Yes**, for how long ? ______________________________
- Were you hospitalised? ☐ Yes ☐ No

  If **Yes**, for how long ? ______________________________
- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ☐ Yes ☐ No

  If **Yes**, please specify? ______________________________

Injury 4

- What caused the injury/concussion? ______________________________

  ____

  ____

- Where you dazed, confused and/or disoriented? ☐ 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 taken off the field? ❑ Yes ❑ No

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

- Were you hospitalised? ❑ Yes ❑ No

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

- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ❑ Yes ❑ No

  If **Yes**, please specify? ______________________________

<u>Injurv 5</u>

- What caused the injury/concussion? ______________________________

  ____

  ____

- Where you dazed, confused and/or disoriented? ❑ 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 taken off the field? ❑ Yes ❑ No

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

- Were you hospitalised? ❑ Yes ❑ No

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

- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ❑ Yes ❑ No

  If **Yes**, please specify? ______________________________

<u>QUESTION 12</u>

What other injuries have you sustained while playing rugby (e.g. hand injuries, sprains, fractures)?

Please specify. ______________________________

____

QUESTION 13

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

☐ Yes ☐ No

If **Yes**, specify which sport/s and date/s?

Injury 1 ____________ **Injury 2** ____________ **Injury 3** ____________

Sport ____________ **Sport** ____________ **Sport** ____________

Injury 1

- What caused the injury/concussion? ____________

____

____

- Where you dazed, confused and/or disoriented? ☐ 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 removed from the game ? ☐ Yes ☐ No

  If **Yes**, for how long ? ____________
- Were you hospitalised? ☐ Yes ☐ No

  If **Yes**, for how long ? ____________
- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ☐ Yes ☐ No

  If **Yes**, please specify? ____________

Injury 2

- What caused the injury/concussion? ____________

____

____

- Where you dazed, confused and/or disoriented? ☐ 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 removed from the game ? ❑ Yes ❑ No

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

- Were you hospitalised? ❑ Yes ❑ No

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

- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ❑ Yes ❑ No

  If **Yes**, please specify? ____________________

<u>Injury 3</u>

- What caused the injury/concussion ? ____________________

  ____

  ____

- Where you dazed, confused and/or disoriented? ❑ 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 removed from the game ? ❑ Yes ❑ No

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

- Were you hospitalised? ❑ Yes ❑ No

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

- Did you have any other neurological symptoms (e.g. seizures, weakness of limbs, tremors)?

  ❑ Yes ❑ No

  If **Yes**, please specify? ____________________

APPENDIX - II

NEUROPSYCHOLOGICAL TEST BATTERY

NEUROPSYCHOLOGICAL TESTING

ASSESSMENT SCHEDULE

Testee: ________________________ **Date:** _________________

Time **Test**

1. Consent form
2. Pre-assessment questionnaire
3. Symptom checklist
4. Finger Tapping Test
5. Digit Symbol *including* INCIDENTAL RECALL
6. Trail Making A and B
7. Words-in-a-Minute
8. "S" Words-in-a-Minute
9. National Adult Reading Test (NART)
10. Vocabulary
11. Digit Symbol DELAYED RECALL

BREAK

12. Digit Span
13. WMS - Designs - IMMEDIATE RECALL
14. WMS - Paired Associate Learning - IMMEDIATE RECALL
15. Stroop Neuropsychological Screening Test
16. Letter-number Sequencing
17. WMS - Designs - DELAYED RECALL
18. WMS - Paired Associate Learning - DELAYED RECALL
19. Picture Completion

FINGER TAPPING TEST

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

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.

AAM
AME ....

Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9
—	И	⊐	L	U	O	Λ	X	=

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

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

DIGIT SYMBOL SUBSTITUTION - INCIDENTAL RECALL

Testee's Name: ______________________________

Requirements: Test sheet
Pencil

NOT TIMED

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

SCORE:

Number remembered correctly: ____________

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

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

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9

TRAIL MAKING

Requirements: test sheets (4 pages)
pencil
Stop watch

TIMED

Instructions:

TRAIL A:

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

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

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

Record time

TRAIL B:

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

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

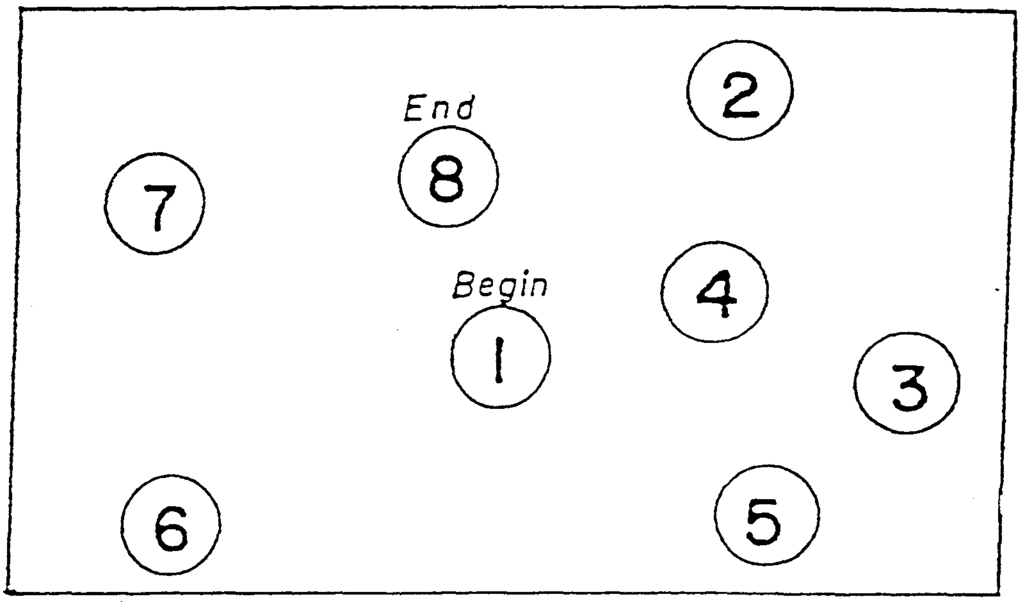
Draw a line to join the circles consecutively by alternating between 1 and A, as fast as you can.

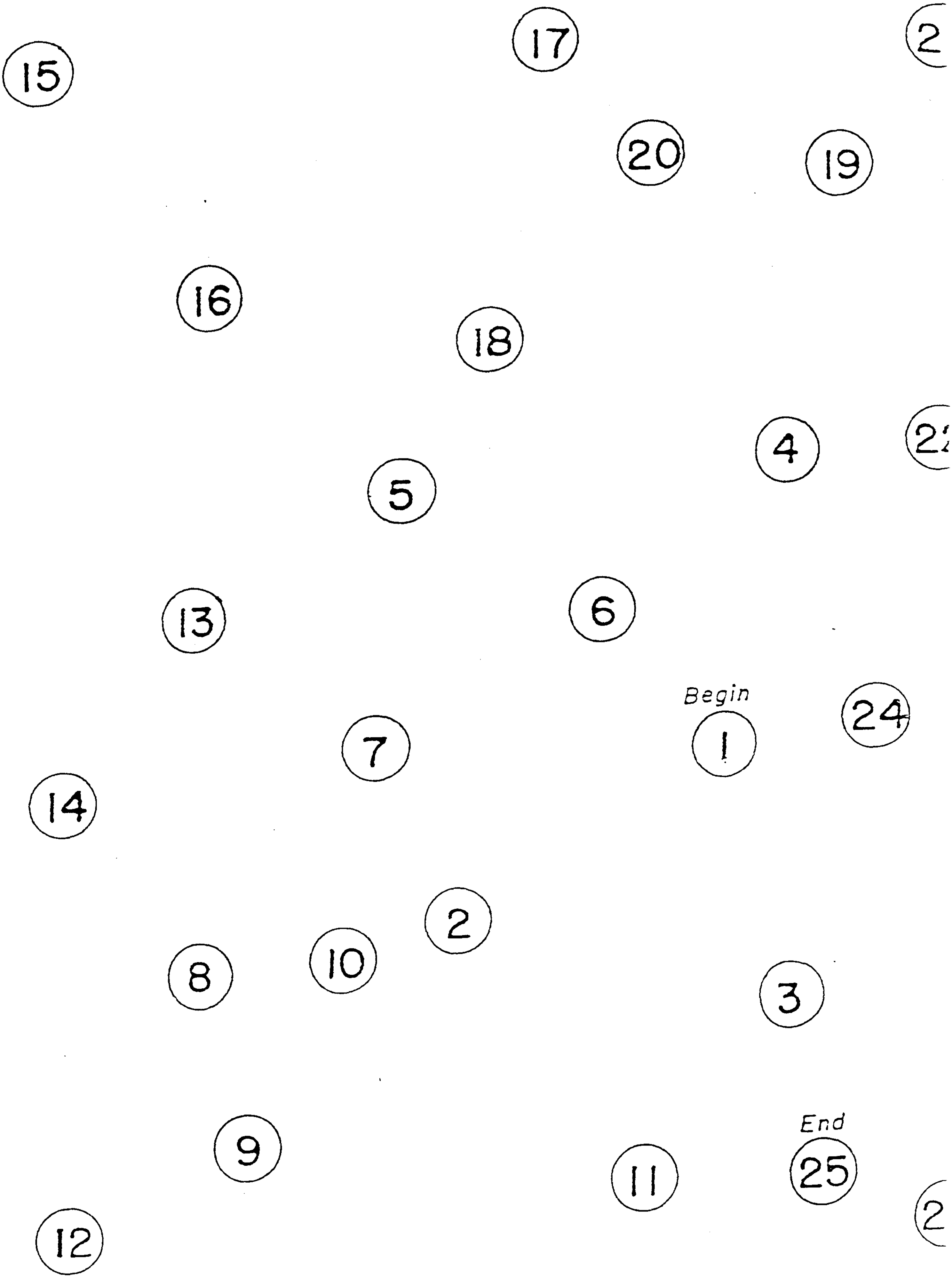
(Note: If subject makes mistake, don't stop timing; point out mistake and subject carries on).

TRAIL MAKING

Part A

SAMPLE



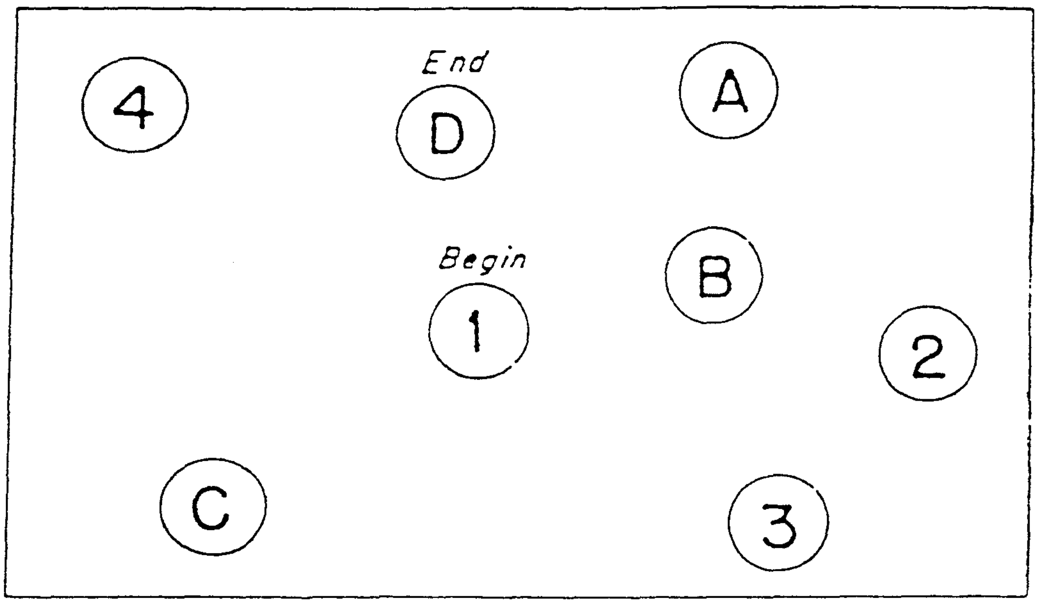


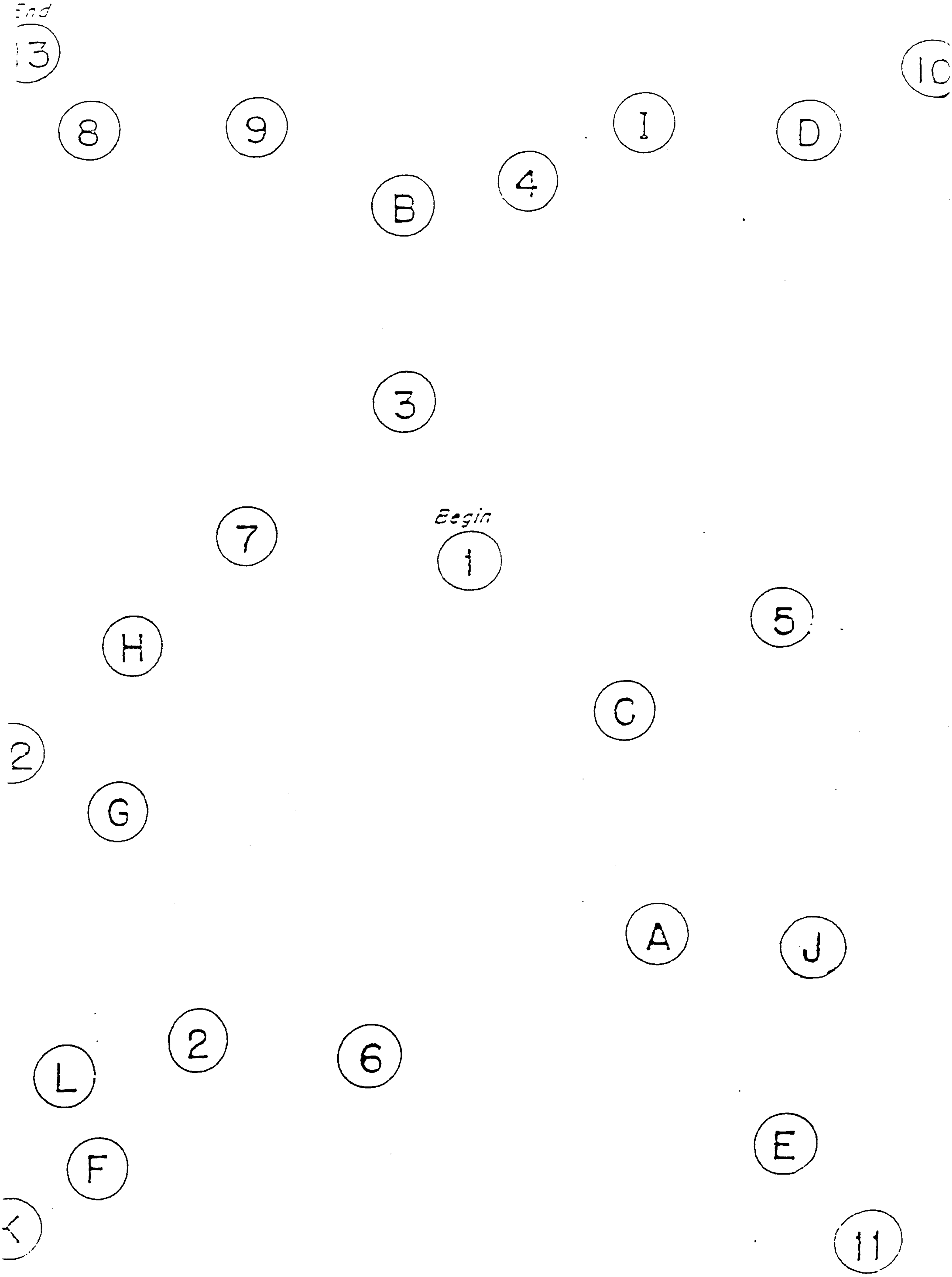
15
17
20
19
16
18
4
5
13
6
Begin
1
24
7
14
2
10
8
3
End
25
9
11
12

TRAIL MAKING

Part B

SAMPLE




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

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:

"S" 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.*

"Now I would like you to say as many words as you can think of that begin with the letter "S". You must say the words as fast as you can and I will count them. Remember that you can say any words except proper nouns like a person's name or the name of a city. For example, you cannot say Susan or Sarah or Scotburgh. 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 all starting with the letter "S". 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:

NART Testee's Name: ____________________

Requirements: Word Card / Pencil

Instructions: "I want you to read slowly down this list of words starting here." *Indicate* ACHE. "After each word please wait until I say **'next'** before reading the next word. I must warn you that there are many words that you probably won't recognise, in fact most people don't know them, so just have a quess at these, O.K.? Go ahead."

If the participant fails to wait, repeat this instruction. The participant should be encouraged to attempt every word and instructed to guess where necessary. Reinforce all responses, for example "That's fine, good". *The participant may change a response but if more than one version is given, they must decide which is their final choice. Record errors on answer sheet.*

	Pronounciation	Error
CHORD	körd	_____
ACHE	āk	_____
DEPOT	dep'o	_____
AISLE	īl	_____
BOUQUET	bo͞ok'a, bo͞okā', bōkā'	_____
PSALM	säm	_____
CAPON	kā'pn	_____
DENY	di-nī	_____
NAUSEA	nö'si-e, nö'zhe	_____
DEBT	det	_____
COURTEOUS	kûrt'yes	_____
RAREFY	rār'-I-fī	_____
EQUIVOCAL	I-kwiv'e-kl	_____
NAÏVE	nä-ēv	_____
CATACOMB	kat'e-ko͞om	_____
GOALED	jāld	_____
THYME	tīm	_____
HEIR	ār	_____
RADIX	ra'diks	_____
ASSIGNATE	as'-ig-nāt	_____
HIATUS	hī-ā'tes	_____
SUBTLE	sut'l	_____
PROCREATE	prō'kri-āt	_____
GIST	jist	_____
GOUGE	gowj	_____

	Pronounciation	Error
SUPERFLUOUS	so͞o-pûr'flo͝os-es sū-pûr'flo͝o-es	_____
SIMILE	sim'ili	_____
BANAL	ben-al'	_____
QUADRUPED	kwod'ro͝o-ped	_____
CELLIST	chel'ist	_____
FACADE	fa-säd'	_____
ZEALOT	zel'et	_____
DRACHM	dram	_____
AEON	ē'on	_____
PLACEBO	ple-sē'bō	_____
ABSTEMIOUS	ab-stē'mi'es	_____
DÉTENTE	dā-tât (Fr.)	_____
IDYLL	id'il, id'el	_____
PUERPERAL	pū-ûr'per-el	_____
AVER	e-vûr'	_____
GAUCHE	gō sh	_____
TOPIARY	tō'pi-e-ri	_____
LEVIATHAN	le-vī'e-then	_____
BEATIFY	bi-at'i-fi	_____
PRELATE	prel'it	_____
SIDEREAL	sī-dē'ri-el	_____
DEMESNE	di-mān', di-men'	_____
SYNCOPE	sing'ke-pē	_____
LABILE	lā'bīl	_____
CAMPANILE	kam-pan-ē'lā, kam-pan-ē'lē	_____

TOTAL ERROR SCORE ________

VOCABULARY

Testee's Name: ______________________________

Requirements: Vocabulary Cards
Sample responses
Record Form
Pencil

Instructions: "In this section, I want you to tell me the meaning of some words. Now listen carefully and tell me what each word I say means. Are you ready?"

Start: Start on Item 4. If subject obtains perfect scores (2 points) on Items 4 and 5, give full credit for Items 1-3. If subject scores 0 or 1 on either Items 4 and 5, administer Items 1 - 3 in ***reverse*** sequence until the subject obtains perfect scores (2 points) on *two* consecutive items.

Locate Vocabulary card with Item 4 on it and place it in front of the subject. Simultaneously point to and say: "Tell me what __________ means."

Record the response verbatim on the Record Form. Use the Sample Responses as scoring guidelines. If the subject's response is unclear or too vague you may say: "Tell me more about it" or "Explain what you mean".

Discontinue: Discontinue after ***six*** consecutive scores of 0.

Item	Response	Score (0, 1,or 2)
1. Bed		
2. Ship		
3. Penny		
ART 4. Winter		
5. Breakfast		
6. Repair		
7. Assemble		

Item	Response	Score (0, 1, or 2)
8. Yesterday		
9. Terminate		
10. Consume		
11. Sentence		
12. Confide		
13. Remorse		
14. Ponder		
15. Compassion		
16. Tranquil		
17. Sanctuary		
18. Designate		
19. Reluctant		
20. Colony		
21. Generate		
22. Ballad		
23. Pout		
24. Plagiarize		
25. Diverse		
26. Evolve		
27. Tangible		
28. Fortitude		
29. Epic		
30. Audacious		
31. Ominous		
32. Encumber		
33. Tirade		

Total Raw Score
(Maximum = 66)
(Include credit for items on previous page.)

DIGIT SYMBOL SUBSTITUTION - DELAYED RECALL

Testee's Name:______________________________

Requirements: Test sheet
Pencil

NOT TIMED

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

SCORE:

Number remembered correctly: ____________

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

NAAM
NAME ....

Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9

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 <u>both</u> 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

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: _______________

Digits Backwards: _______________

Digits Difference: _______________ (Forwards minus Backwards)

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:

WMS : ASSOCIATE LEARNING - *IMMEDIATE RECALL*

Testee's Name:______________________________

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

NOT TIMED

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

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

SCORE:

First Recall	Second Recall	Third Recall
TOTAL ____ ____	TOTAL ____ ____	TOTAL ____ ____

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

Score: A/2 + B = ____

Read 1 pair every 2 seconds.

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

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

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

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

Score: A/2 ÷ B = ____

STROOP NEUROPSYCHOLOGICAL SCREENING TEST

Testee's Name: ______________________________

Requirements:

Card with Pictures	
Form C Stimulus Sheet	Form C Stimulus Record Form
Form C-W Stimulus Sheet	Form C-W Stimulus Record Form
Stopwatch	Pencil

Time Limit: 120'' (2 mins) per task

Instructions: **Screening for Colour Naming:** Show subject card with pictures. Then say: "Can you tell me what each of these colours are?" If the subject says BROWN where TAN is indicated, explain to subject that for the purposes of this test, the colour they have identified as BROWN will be called TAN.

Colour Task: "On this page are some words. I would like you to read these words aloud as quickly as you can, starting at the top of this first column. When you finish this column, go to the top of the next column and so on *(point to the top of the columns and indicate that the subject should read all the columns in the same manner).* Read the words aloud as quickly and as accurately as you can. If you make a mistake, just correct yourself and keep on going. Ready? Begin."

Colour-Word Task: "Here is a page with more words on it. This time, I would like you to name aloud the colour of the ink - RED, BLUE, GREEN, or TAN *(point to words printed in these colours)* - in which the word is printed. Go as quickly as you can, going down the columns just as you did before. For this first one you would say "RED". Understand? If you make a mistake, just correct yourself and keep on going. Name the colour of the ink as quickly and as accurately as you can. Ready? Begin."

Remember: Subjects may not cover up a part of any of the words in an attempt to reduce the interference effect, neither can they pick up the stimulus sheet in an attempt to facilitate responding but must leave it on the flat surface.

SCORING (for both tasks):

Record correct responses by making a check mark next to the item as shown on the Record Form. Record incorrect responses by entering an X next to the item. If the subject gives an incorrect response and corrects it spontaneously, mark a C next to that item.

Remember: If subjects give BROWN as a response instead of TAN, this will still be considered a correct answer.

SCORE:

	Colour Task	Colour-Word Task
Number of responses	________	________
Incorrect Responses	________	________
Score	________	________
Percentile		________

Form C Responses – Color Task

1 BLUE ______	29 RED ______	57 TAN ______	85 RED ______
2 GREEN ______	30 GREEN ______	58 RED ______	86 TAN ______
3 TAN ______	31 TAN ______	59 TAN ______	87 RED ______
4 RED ______	32 BLUE ______	60 BLUE ______	88 TAN ______
5 GREEN ______	33 GREEN ______	61 TAN ______	89 BLUE ______
6 BLUE ______	34 BLUE ______	62 RED ______	90 GREEN ______
7 GREEN ______	35 TAN ______	63 GREEN ______	91 RED ______
8 BLUE ______	36 GREEN ______	64 RED ______	92 BLUE ______
9 RED ______	37 TAN ______	65 BLUE ______	93 RED ______
10 BLUE ______	38 BLUE ______	66 TAN ______	94 TAN ______
11 TAN ______	39 GREEN ______	67 RED ______	95 GREEN ______
12 RED ______	40 BLUE ______	68 GREEN ______	96 TAN ______
13 TAN ______	41 GREEN ______	69 RED ______	97 BLUE ______
14 GREEN ______	42 RED ______	70 TAN ______	98 RED ______
15 BLUE ______	43 BLUE ______	71 BLUE ______	99 BLUE ______
16 TAN ______	44 GREEN ______	72 TAN ______	100 RED ______
17 GREEN ______	45 TAN ______	73 GREEN ______	101 GREEN ______
18 RED ______	46 RED ______	74 TAN ______	102 RED ______
19 TAN ______	47 TAN ______	75 BLUE ______	103 BLUE ______
20 RED ______	48 GREEN ______	76 TAN ______	104 TAN ______
21 TAN ______	49 TAN ______	77 BLUE ______	105 BLUE ______
22 RED ______	50 RED ______	78 GREEN ______	106 GREEN ______
23 GREEN ______	51 BLUE ______	79 RED ______	107 BLUE ______
24 RED ______	52 RED ______	80 GREEN ______	108 RED ______
25 TAN ______	53 GREEN ______	81 TAN ______	109 BLUE ______
26 BLUE ______	54 RED ______	82 RED ______	110 TAN ______
27 GREEN ______	55 TAN ______	83 GREEN ______	111 BLUE ______
28 TAN ______	56 BLUE ______	84 BLUE ______	112 GREEN ______

Form C-W Responses – Color-Word Task

1 RED ______	29 BLUE ______	57 BLUE ______	85 TAN ______
2 BLUE ______	30 TAN ______	58 TAN ______	86 RED ______
3 GREEN ______	31 GREEN ______	59 RED ______	87 GREEN ______
4 BLUE ______	32 RED ______	60 GREEN ______	88 BLUE ______
5 RED ______	33 BLUE ______	61 TAN ______	89 TAN ______
6 TAN ______	34 GREEN ______	62 RED ______	90 GREEN ______
7 BLUE ______	35 BLUE ______	63 GREEN ______	91 RED ______
8 RED ______	36 GREEN ______	64 BLUE ______	92 TAN ______
9 TAN ______	37 RED ______	65 GREEN ______	93 BLUE ______
10 GREEN ______	38 TAN ______	66 TAN ______	94 GREEN ______
11 BLUE ______	39 BLUE ______	67 BLUE ______	95 RED ______
12 RED ______	40 RED ______	68 GREEN ______	96 TAN ______
13 TAN ______	41 BLUE ______	69 RED ______	97 RED ______
14 BLUE ______	42 TAN ______	70 BLUE ______	98 GREEN ______
15 GREEN ______	43 RED ______	71 RED ______	99 RED ______
16 RED ______	44 TAN ______	72 GREEN ______	100 BLUE ______
17 TAN ______	45 BLUE ______	73 BLUE ______	101 RED ______
18 GREEN ______	46 RED ______	74 TAN ______	102 BLUE ______
19 BLUE ______	47 GREEN ______	75 GREEN ______	103 TAN ______
20 RED ______	48 BLUE ______	76 BLUE ______	104 GREEN ______
21 TAN ______	49 TAN ______	77 RED ______	105 RED ______
22 GREEN ______	50 GREEN ______	78 TAN ______	106 TAN ______
23 BLUE ______	51 RED ______	79 GREEN ______	107 BLUE ______
24 GREEN ______	52 TAN ______	80 RED ______	108 TAN ______
25 TAN ______	53 GREEN ______	81 TAN ______	109 RED ______
26 BLUE ______	54 TAN ______	82 BLUE ______	110 BLUE ______
27 TAN ______	55 BLUE ______	83 GREEN ______	111 GREEN ______
28 RED ______	56 RED ______	84 BLUE ______	112 TAN ______

LETTER-NUMBER SEQUENCING

Testee's Name: ______________________________

Requirements: Record Form
pencil

Not timed

Instructions: **Practice Items:** "I am going to say a group of numbers and letters. After I say them, I want you to tell me the numbers first, in order, starting with the lowest number. Then tell me the letters in alphabetical order. For example, if I say B - 7, your answer should be 7 - B. The number goes first, then the letter. If I say 9 - C - 3, then your answer should be 3 - 9 - C, the numbers in order first, then the letter in alphabetical order. Let's practice."

Administer all practice trials. For each Practice Item and item trial, say each combination at a rate of one number or letter per second.

6 - F	**(6 - F)**
G - 4	**(4 - G)**
3 - W - 5	**(3 - 5 - W)**
T - 7 - L	**(7 - L - T)**
1 - J - A	**(1 - A - J)**

If the subject makes an error on any Practice Item, correct them and repeat instructions as necessary. Even if the subject fails all Practice Items, continue with the test.

P.T.O for Item Trials.

	Trial	Item/Response	Trial Score (0 or 1)	Item Score (0, 1, 2, or 3)
1.	1	L - 2 (2 - L)		
	2	6 - P (6 - P)		
	3	B - 5 (5 - B)		
2.	1	F - 7 - L (7 - F - L)		
	2	R - 4 - D (4 - D - R)		
	3	H - 1 - 8 (1 - 8 - H)		
3.	1	T - 9 - A - 3 (3 - 9 - A - T)		
	2	V - 1 - J - 5 (1 - 5 - J - V)		
	3	7 - N - 4 - L (4 - 7 - L - N)		
4.	1	8 - D - 6 - G - 1 (1 - 6 - 8 - D - G)		
	2	K - 2 - C - 7 - S (2 - 7 - C - K - S)		
	3	5 - P - 3 - Y - 9 (3 - 5 - 9 - P - Y)		
5.	1	M - 4 - E - 7 - Q - 2 (2 - 4 - 7 - E - M - Q)		
	2	W - 8 - H - 5 - F - 3 (3 - 5 - 8 - F - H - W)		
	3	6 - G - 9 - A - 2 - S (2 - 6 - 9 - A - G - S)		
6.	1	R - 3 - B - 4 - Z - 1 - C (1 - 3 - 4 - B - C - R - Z)		
	2	5 - T - 9 - J - 2 - X - 7 (2 - 5 - 7 - 9 - J - T - X)		
	3	E - 1 - H - 8 - R - 4 - D (1 - 4 - 8 - D - E - H - R)		
7.	1	5 - H - 9 - S - 2 - N - 6 - A (2 - 5 - 6 - 9 - A - H - N - S)		
	2	D - 1 - R - 9 - B - 4 - K - 3 (1 - 3 - 4 - 9 - B - D - K - R)		
	3	7 - M - 2 - T - 6 - F - 1 - Z (1 - 2 - 6 - 7 - F - M - T - Z)		

START

Total Raw Score
(Maximum = 21)

Scoring: Record subjects response to each trial **verbatim,** the trial score, the item score, and the total test raw score. For each trial of an item, score 1 point for each correct response, 0 point for each incorrect response. A response is incorrect if a number or letter is omitted or if the numbers or letters are not said in the specified sequence. **As long as the numbers and letters are recalled in sequence, give credit if the subject gives the letters in sequence before the number.**

Discontinue: Discontinue after scores of 0 on all **three trials** of an item.

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 *DELAYED RECALL*

Testee's Name:______________________________

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

NOT TIMED

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

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

SCORE:

Delayed recall = ___

PICTURE COMPLETION

Testee's Name: ______________________________

Requirements: Picture Completion Items
Pencil
Stopwatch

Time limit: 20'' per card to respond

Instructions: "I am going to show you some pictures in which there is some important part missing. Look at each picture and tell me what is missing?"

Start: Start on Item 6. If subject obtains perfect scores (1 point) on Items 6 and 7, give full credit for Items 1-5. If subject scores 0 on either Items 6 or 7, administer Items 1 - 5 in ***reverse*** sequence until the subject obtains perfect scores (1 point) on ***two*** consecutive items.

Place Picture Completion Items in front of subject, starting at Item 6 and say:
"Now, look at this picture. What important part is missing?"
Continue with succeeding items saying:
"Now, what is missing in this one?"
If the participant fails Items 6 or 7, point and say:
"You see the doorknob/the bridge or nose piece is missing." *No other "teaching" may be offered on any other item.*

Each of the following prompts may only be used once:
If the subject merely names the object pictured rather than the missing part, say:
"Yes, but what's missing?

If the subject mentions a part that is off the page (e.g., the hand that holds the pitcher in Item 8), note the response on the Record From and say:
"Something is missing in the picture. What is it that is missing?"

If the subject mentions an unessential missing part (e.g., the life jacket in Item 18), note the response on the Record Form and say:
"Yes, but what is the most important part that is missing?

Record the response verbatim on the response form below.

Discontinue: Discontinue after five consecutive scores of 0.

Item Response	Score (0 or 1)
1. Comb	
2. Table	
3. Face	
4. Briefcase	
5. Train	
6. Door	
7. Glasses	
8. Pitcher	
9. Pliers	

Item Response	Score (0 or 1)
10. Leaf	
11. Pie	
12. Jogging	
13. Fireplace	
14. Mirror	
15. Chair	
16. Roses	
17. Knife	
18. Boat	

Item Response	Score (0 or 1)
19. Basket	
20. Clothing	
21. Lockers	
22. Cow	
23. Tennis Shoes	
24. Woman	
25. Barn	
Total Raw Score (Maximum = 25)	

APPENDIX - III

CONSENT FORMS

Navrae
Enquiries Mahoney Mavuka [illegible]
Imibuzo [illegible]

Telefoon
Telephone [illegible]
Ifoni

Faks
Fax 403-6570
Ifeksi

Verwysing
Reference [illegible] 2000
Isalathiso

PROVINSIALE ADMINISTRASIE WES-KAAP
Onderwysdepartement

PROVINCIAL ADMINISTRATION WESTERN CAPE
Education Department

ULAWULO LWEPHONDO LENTSHONA KOLONI
ISebe leMfundo

Professor Ann B. Edwards
Fax : 0466361296

RESEARCH PROPOSAL: Participation in research on concussion in school rugby

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

- Principals, teachers and learners are under no obligation to assist you in your investigation.
- Principals, teachers, learners and schools should not be identifiable in any way from the results of the investigation.
- You make all arrangements concerning your investigation.
- Your work should not disrupt the functioning of the school during school hours.
- The investigation is not conducted during the fourth school term.
- There are no financial implications for the Western Cape Education Department.
- A photocopy of this letter is submitted to the principal of each school where the intended research is to be conducted.
- A brief summary of the content, findings and recommendations is provided to the Director: Curriculum Management (Research Section).
- The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Curriculum Management
    (Research Section)
    Western Cape Education Department
    Private Bag 9114
    CAPE TOWN 8000

We wish you success in your research.

Kind regards

HEAD: EDUCATION
DATE: 11 February 2000

RHODES UNIVERSITY
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PSYCHOLOGY CLINIC • Tel: (046) 636 1296/7 • Fax: (046) 636 1296

23 February 2000

Dear School Principal

PARTICIPATION IN RESEARCH ON CONCUSSION IN SCHOOL RUGBY

It has become apparent from preliminary consultation with some of the schools we have approached about the above research study, that the rugby season starts much earlier than we had anticipated. Consequently it is not possible for us to complete all the required research planning, acquisition of parental consent, and assessment pre-season as hoped. This has caused us to reconsider our research objectives as follows.

Testing pre-season would have provided us with outcome that would have eliminated any acute effects of play during the current season, and hence shown up permanent effects, which was our original objective. This was a replication of our earlier research study conducted on professional rugby players. However, it has occurred to us that in the school situation, there is significant merit in testing much later into the season when we will detect not only old effects, but the overlay of any acute effects sustained during the present season. Clearly, it is important to ascertain the full extent of intellectual difficulties that may have relevance for scholastic performance in the immediate situation. This is important for scholars at any level, but has particular pertinence for top team players many of whom will be preparing for their Matriculation examinations.

Thus we would now like to plan our testing of the top team rugby and hockey players for later on in the year at a time that will suit both your school schedule and the objectives of the research project. My research assistants will discuss this with you, as well as the issue of parental consent as per the attached documents.

Thank you for your interest and assistance with our rugby head injury project.

Yours sincerely

Ann B Edwards.

PROFESSOR ANN EDWARDS
CLINIC DIRECTOR

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Grahamstown, 6140
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22 February 2000

Dear Parent / Guardian

PARENTAL CONSENT FOR SCHOLAR'S PARTICIPATION IN RESEARCH ON CONCUSSION IN SCHOOL RUGBY

We wish to request permission for your son's participation in an important research project which is being conducted on the effects of concussion in school rugby (see consent form attached).

The project, which has been condoned by the Education Department of the Western Cape, is being undertaken by Rhodes University in collaboration with Professor Tim Noakes of the South African Sports Science Institute and the South African Rugby Football Union (SARFU). It forms part of a larger investigation in which the effects of concussion on the intellectual functioning of professional rugby players have recently been studied. The second phase of the project is to determine the effects of concussion in rugby at school level.

In order to do this we wish to gain access to the top rugby and hockey teams at a selection of boys high schools in Cape Town. (The hockey players serve as a non-rugby playing comparison group). The research involves the administration of a questionnaire and tests, lasting about 1½- 2 hours, to individual rugby and hockey playing team members. The tests employed are those used routinely in the assessment of intellectual ability, and are usually quite enjoyable to the testee. Individual results will remain strictly confidential and anonymous, and will be used for the group analyses of the project only. Testing will be done at pre-arranged times that are convenient for the school and which do not interfere with the school programme.

We would appreciate it if you would sign the attached consent form, and thank you in anticipation for considering your son's involvement in this important research on the effects of concussion in school rugby.

If you have any concerns that you would like addressed before signing this form, please feel free to contact one of the following two members of the research team who are resident in Cape Town: Ms Tessa Ackerman (Tel. 021-6891044); Ms Taryn Beilonsohn (Tel. 0835244863).

Yours sincerely

Ann B. Edwards

PROFESSOR ANN EDWARDS
DIRECTOR: RHODES PSYCHOLOGY CLINIC

Rhodes University - Department of Psychology

NEUROPSYCHOLOGICAL ASSESSMENT RESEARCH CONSENT FORM

As legal guardian of ______________________________, I hereby give permission for him to undergo a neuropsychological assessment for research purposes.

I understand the following:

1. The assessment will be conducted by a Clinical Psychologist (or training Clinical Psychologist) especially schooled in the practical administration of the research questionnaire and tests;

2. The assessment takes 1 ½ to 2 hours, and takes the form of a series of questions and a variety of verbal and written intellectual tests which are not harmful, and which are usually quite enjoyable for the testee;

3. The testing will not interfere with the scholars' academic programme;

4. Individual results will be totally confidential and remain anonymous - they will not be made available to parents, the school or the scholar himself (except under the conditions referred to in paragraph 7 below);

5. The results will be in the form of group data which will allow the researchers to make a comparison between the scores of scholars who are intensively involved in the contact sport of rugby and those who are not;

6. As is regularly done in the dissemination of scientific knowledge, results of the group comparisons may be used for publication purposes at scientific conferences, in journals, books, and in the media;

7. In the unlikely event that the researchers discover a pattern of results which might give cause for medical or scholastic concern, they are willing to discuss this with the parent(s)/ guardian(s) of the scholar concerned - please indicate whether, in this event, you would like them to contact you by placing a ✔ in one of the boxes below:

Yes: I would like them to contact me			No: I would not like them to contact me	

NAME: ______________________________

SIGNED: ______________________________ DATE: ____________________