Investigating the emotional and behavioural sequelae of concussive injury among young adult rugby players

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"By Your grace, for Your glory."

Abstract

Given its rising incidence rates and potentially debilitating neurodegenerative outcomes, sports-related concussion has received dramatically increased attention over recent years. Rugby is among the highest-risk contact sports for diagnoses of concussion or mild traumatic brain injury. The occurrence of rugby-related concussion mirrors the repetitive, high impact nature of the game. This research forms part of a larger research project that aims to investigate the long term neuropsychological outcomes of repeated concussions and sub-concussive injuries in rugby players. The current project explores the relationship between concussion and emotional and behavioural disturbance in rugby players and non-contact sportsmen. Questionnaires measuring depression, anxiety, general health, anger, impulsivity and alcohol usage were administered to a sample of 114 participants including rugby players (n = 88) and non-contact sport participants (n = 26), matched on age and intelligence. 45 rugby participants (51%) reported 1 to 5 previous formally diagnosed concussions and 30 (34%) reported potential undiagnosed concussions ranging from 1 to multiple incidents. In total, 68% of the rugby players in the sample reported previous concussive injury. I conducted discriminant function analysis with three groups (rugby players with concussion, rugby players without concussion and non-contact sport control participants) using measures of emotional and behavioural disturbance as predictors. Results indicated that the groups did not differ on emotional and behavioural disturbance and that discriminant functions could not be used to significantly predict group membership. The findings of this study suggest that emotional and behavioural disturbance after concussion might dissipate altogether in the acute phase of concussive injury or may only surface later in life. In addition, it appears that outcomes of emotional and behavioural disturbance after mTBI cannot be predicted solely by injury-related variables. Further considerations including the possible implications of self-report measures on the reliability of emotional and behavioural disturbance in the sample are discussed.

Keywords: concussion; sports concussion; rugby; emotional disturbance; mild traumatic brain injury.

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Traumatic brain injury (TBI) is a significant public health problem faced globally; population based studies suggest that prevalence is particularly high in low- and middle-income countries (LAMICs) such as South Africa (Bruns & Hauser, 2003; Corrigan, Selassie, & Orman, 2010). TBI refers to a change in brain function which may result in variations in level of consciousness, confusion, seizures and alteration in neurological function (Bruns & Hauser, 2003). As well as being a leading cause of death, TBI is associated with substantial morbidity including impairments in cognitive, behavioural, emotional and psychological domains which contribute significantly to national burden of disease (Naidoo, 2013; Webster, Taylor, & Balchin, 2015). The vast majority of traumatic brain injuries globally are minor or mild in nature; most do not involve intracranial complications, do not require surgery and have a substantially low fatality rate (0.1%) but despite this, these injuries can produce significant adverse outcomes (Vos, et al., 2012).

Prevalence of Traumatic Brain Injury

The actual prevalence of TBI globally is not known: researchers previously estimated that the number of cases that result in death or are severe enough to require medical attention exceeds 9.5 million a year (Corrigan, et al., 2010). The global incidence rate is probably higher as this figure often does not consider mild TBI or subconcussive injuries, which are often not reported in hospital settings. While it is recognised that TBI represents a significant public health burden across the world, it is especially prominent in LAMICs due to a greater prevalence of risk factors for the causes of TBI coupled with less developed health systems often not adequately prepared to provide care for the outcomes of TBI in these countries (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusigye, 2007).

One review of incidence rates of TBIs indicates that the incidence of TBI in Latin America and Sub-Saharan Africa, ranging from 150-170 per 100 000, is higher than the global rate of 106 per 100 000 (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusigye, 2007; Murray & Lopez, 1996). South Africa lacks data on country-wide TBI incidence rates (Naidoo, 2013). An internal audit at Groote Schuur Hospital in Cape Town, Western Cape showed that 24% of the total trauma patients admitted in the year 2009 (10 046) presented with TBI. Of these cases, 9 392, 93% of TBI patients, presented with mild TBI (Webster, et al., 2015). These statistics are in line with the trend in TBI diagnosis identified in etiological studies: typically 80% of diagnosed TBIs are mild, 10% are moderate and 10% are severe (Bruns & Hauser, 2003). Despite these statistics, because moderate and severe TBIs are

associated with more fatalities, severe disability and long-term outcomes, mTBIs are often not being met with as much concern.

Mild TBI and Concussion

Mild TBI (mTBI) and concussion have historically been used as interchangeable terms describing the milder end of the TBI spectrum. Concussion/mTBI refers to low velocity impacts to the head or body which cause biomechanical forces to be transmitted to the brain causing it to shake. Subconcussive injuries are physiological or microstructural injuries in the brain due to the same biomechanical forces present in a concussion without the manifestation of symptoms (Giza & Kutcher, 2014; McCrory, et al., 2013).

Sports-related injuries. Over recent years diagnoses of mTBI have increased and have become particularly prevalent in the sporting arena; it is estimated that between 1.6 and 3.8 million sports related mTBI cases or concussions occur in the United States each year with contact sports such as football, rugby, and wrestling being particularly high risk (Giza & Kutcher, 2014; Langlois, Rutland-Brown, & Wald, 2006).

It can be argued that sports related mTBI should be investigated as a distinct entity separate from generally occurring mTBI due to the fact that sports related mTBI is repetitive by nature (Carrol, et al., 2004; Shuttleworth-Edwards, Smith, & Radloff, 2008). The distinguishing feature of sports concussion is that return to the risk environment is expected, therefore there is a substantial susceptibility to repeated injury. This is a significant impetus for increased research to ensure better diagnosis and an increased knowledge base to inform treatment, particularly since there is a growing body of evidence for the cumulative effect of repeated concussive injuries in the development of chronic neuropsychological dysfunction (Giza & Kutcher, 2014; Shuttleworth-Edwards., Smith, & Radloff, 2008; Shuttleworth-Edwards, Noakes et al., 2008). Such dysfunction relates to the pathophysiology of concussive injuries.

Pathophysiology. Forces applied to the brain during concussive injury result in a pathophysiological process which typically presents in an acute phase of rapid onset neuropsychological functional impairment and spontaneous recovery, usually without macrostructural brain damage. Advanced neuroimaging has shown that microstructural changes can be detected including changes in the direction of water diffusion in white matter and decrease in cerebral blood flow (Giza & Kutcher, 2014; McCrory, et al., 2013). Subconcussive injuries are physiological or microstructural injuries in the brain due to the same biomechanical forces present in a concussion without the manifestation of symptoms (Giza & Kutcher, 2014).

Symptoms and diagnoses. Apart from a Glasgow Coma Scale (GCS) score of 13 to 15, concussions are diagnosed based on a range of somatic symptoms, cognitive impairment, neurobehavioural dysfunction, emotional symptoms, physical consequences, and sleep disturbances. These generally include headaches, dizziness, mental fuzziness, amnesia, emotional lability, irritability, insomnia and cognitive reaction time slowing (Giza & Kutcher, 2014; McCrory, et al., 2013).

There is no perfect test for the presence of concussion: identification of these symptoms happen on a case-by-case basis largely reliant on clinical judgement and in some cases, neuropsychological tests. Since loss of consciousness is not always present and neuropsychological signs may not always develop, it is clear to see that this is a difficult injury to accurately diagnose. In addition, concussion is a rapidly evolving injury by nature so assessments at different time points will likely have different diagnostic outcomes (McCrory, et al., 2013). In most cases, mTBI results in acute symptoms which typically resolve within a few days to a month after injury but studies show that some patients do in fact experience ongoing symptoms. When concussive symptoms last for longer than 3 months, often in addition to depression and anxiety, it is referred to as post-concussion syndrome (PCS); a condition generally considered significantly disabling and distressing to patients (Carrol, et al., 2004; Giza & Kutcher, 2014).

Although a large body of research exists on mTBI in general, not enough studies have been done on its potentially significant residual and persistent effects (Corrigan, et al., 2010). Of the longitudinal studies on mTBI that do exist in the literature, the substantial variation in designs and measurement tools makes it difficult to synthesise information into an accurate, reliable profile of mTBI and its associated long-term outcomes (Frencham, Fox, & Maybery, 2005).

Long term effects of concussion. Frencham, Fox, and Maybery (2005) performed a meta-analytic study to follow up on a meta-analysis done by Binder et al. in 1997 to provide a picture of the current body of research on the long term outcomes of mTBI. The results of that analysis showed that very few studies exist that examine the post-acute phase of concussion or if they are being done, that they are not being published due to insignificant results. This lack of data makes it difficult to establish a coherent picture of significant long term effects of mTBI. Nevertheless, studies showed small positive effects in terms of neuropsychological performance from the acute to post-acute phases of concussion recovery particularly in the domains of working memory, attention, processing speed and executive function. The researchers report that the effects of mTBI attenuate over time, becoming an

insignificant factor in impairment severity into the post-acute phase. The small study sample is a severe limitation in meta-analytic studies such as Frencham, Fox and Maybery's study as pooling effects may mask significant long-term impairments in a smaller number of participants. Due to this effect, reliable conclusions about the long-term outcomes of concussion cannot be made in absence of more studies using measurement tasks more sensitive to impairments (Frencham, et al., 2005; Karr, Areshenkoff, & Garcia-Barrera, 2014).

Cumulative effects of repetitive concussive injury. Some long terms effects of concussive injury have been found to result specifically from the repeated nature of such injuries, even when such injuries are subconcussive. These are of particular concern in a sport such as rugby in which multiple knocks to the head are sustained in quick succession without adequate recovery time. Research has shown that these kinds of injuries, by increasing the biological vulnerability of the brain, increase the risk of long term impairment and even neurodegradation (Giza & Kutcher, 2014). Chronic traumatic encephalopathy (CTE) presents an example of such outcome which has recently received a great deal of attention in the literature. CTE refers to a neurodegenerative process that ensues after repetitive concussive and subconcussive head injuries resulting in similar symptomatology and neuropathology to dementia, amyotrophic lateral sclerosis (ALS), Parkinson's disease and Major Depression (Gavett, et al., 2011; Randolph, Karantzoulis, & Guskiewicz, 2013; Yi, Padalino, Chin, Montenegro, & Cantu, 2013). This includes widespread impairment in memory, executive functioning, mood (depression, apathy and suicidality are common), personality, impulse control and inhibition (Gavett, et al., 2011).

While CTE research investigates mood and behavioural disturbance, the majority of existing studies on the long-term outcomes of concussion investigate neurocognitive and somatic impairments; research on the behavioural and emotional outcomes of mTBI in general and particularly in sport is markedly sparse.

Emotional and behavioural effects of concussion. Among the few studies that have been done in the sporting context, Hutchison, Mainwaring, Comper, Richards and Bisschop (2009; 2010) have conducted two prospective studies investigating how emotional responses differ between athletes from various sports with concussion and those with musculoskeletal injuries. They found that concussed athletes display significantly more symptoms of fatigue and a higher total mood disturbance with a significantly larger standard deviation. This statistic indicates high variability in the emotional response to concussion within the group. Concussed athletes remained emotionally distressed after return-to-play, which provides

evidence against the theory that emotional reaction is due to removal from play and not the concussion itself. These findings are new and are not discussed elsewhere in the existing literature base on sports concussion (Hutchison, et al., 2009).

There exists a substantial lack of studies which investigate the behavioural and emotional consequences of sports related concussions among young adults; most literature on this domain centres on paediatric populations and neurocognitive symptoms (e.g. Belanger & Vanderploeg, 2005, Meehan & Bachur, 2009; Thornton, Cox, Whitfield, & Fouladi, 2008). A meta-analysis on the psychological and psychosocial outcomes of concussion confirms the need for methodologically sound studies with proper controls to fill the gap of knowledge on the long-term behavioural and emotional sequelae of concussion (Panayiotou, Jackson, & Crowe, 2010).

Aims and Hypotheses

This study forms part of a larger study that aims to investigate the long term neurocognitive outcomes of repeated concussions and/or subconcussive head injuries among rugby players. This study investigated the possible enduring behavioural and emotional outcomes of concussions and recurrent head impacts. Specifically, the purpose of this study was to identify whether rugby players that have experienced previous concussions have significantly greater levels of emotional and behavioural disturbance than rugby players without previous concussions and non-contact sportsmen.

While exploratory research usually does not test predetermined hypotheses, research on TBI in general indicates a well-established dose-response relationship between TBI and adverse outcomes which gave rise to specific predictions in the current study. I therefore tested the following tentative hypotheses:

1. Rugby players with a history of previous concussions will have higher scores of emotional and behavioural disturbance in comparison to rugby players without concussions and non-contact sport control participants. These differences could be used to successfully predict group membership from scores of emotional and behavioural disturbance.
2. Rugby players with a higher the number of previous concussions (both diagnosed and undiagnosed) and longer duration of loss of consciousness with incidents of concussion will have higher the scores of emotional and behavioural disturbance than those with less serious concussive injury (lower number of previous injuries and shorter duration of loss of consciousness).

Methods

Design and Setting

This is an exploratory, quantitative study. I utilised a descriptive design to investigate the relationship between previous concussions and measures of emotional and behavioural outcomes among rugby players and non-contact sport participants. I investigated differences on six different measures of emotional and behavioural outcomes between three groups: rugby players with previous reported concussions (Rugby Concussed group), rugby players without previous reported concussions (Rugby Not Concussed group) and non-contact sportsmen (control group). This design is suitable to facilitate comparison between participants with varying levels of exposure to head impacts. Data collection for this study took place at the University of Cape Town (UCT).

Participants

The study consisted of a rugby group, divided into two groups based reported history of concussions (previous concussive injury or not), and a control group. Participants constituting the rugby group (n = 88) were recruited using purposive sampling techniques. Players from the UCT Rugby Football Club, Hamilton's Rugby Football Club, The Western Province Rugby Academy and Villager Rugby Club completed the testing. These participants were proficient in English, male and aged from 18 to 31 years. The control group (n = 26) was recruited using convenience sampling. I made use of the Student Research Participation Programme (SRPP) run by the UCT Department of Psychology and personal communication with the non-contact sport clubs at UCT. Participants were matched to the rugby participants on sex, age and IQ and participated in a non-contact sport or exercise activity instead of rugby.

Exclusion criteria. Exclusion criteria for participation in the study included prior or current diagnosed learning disability and psychiatric or neurological illness. In addition, control group participants were not previously formally diagnosed with concussion.

Power analysis. An a priori power analysis for a MANOVA (for discriminant function analysis) indicated that 99 participants were needed to have 80% power for detecting a medium effect (f^2 (V) = .18) at α = .05.

Materials

Screening measures. These measures were completed by the participants to acquire information for exclusion and matching purposes as well as relevant demographic and medical history details.

Demographic and medical history questionnaire. This questionnaire (see Appendices C and D) is based on the Immediate Post-Concussion Assessment and Cognitive Testing demographic form (Lovell, Collins, Podell, Powell, & Maroon, 2000). It provided information regarding participants' age, height, weight, language proficiency, learning disabilities, psychiatric disorders, current and/or previous concussions, and current and/or previous exposure to contact sport.

Shipley-2. The Shipley-2 (Shipley, Gruber, Martin, & Klein, 2009) is a measure of general cognitive functioning that uses two scales: the Vocabulary Test scale and either the Abstract Thinking Test scale or the Block Patterns scale. The test is self-administered and suitable for respondents aged 7 to 89 years (Shipley et al., 2009). Shipley-2 composite scores (the combined results of two Shipley-2 scales) is highly internally consistent for adults aged between 17 and 89 years (r = .92; Shipley et al., 2009) and has high concurrent validity with other tests of its kind (Shipley et al., 2009). This measure has been used in a recent concussion study (Hill, Womble, & Rohling, 2015). For the current study the Vocabulary (Shipley-V) and Abstraction (Shipley-A) scales were used.

Testing measures. These measures were administered to assess the participants' level of emotional and behavioural disturbance.

Alcohol Use Disorders Identification Test (AUDIT). The AUDIT (Saunders, Aasland, Babor, De La Fuente, & Grant, 1993) is a 10-item self-report questionnaire used to screen for current and lifetime problematic alcohol consumption. Participants respond to each item on a five-point Likert scale; higher scores indicate more damaging alcohol consumption. The AUDIT has high validity and it has been identified as both sensitive and specific across cultures (Saunders et al.,1993). It has been used in the South African context (Adams, Savahl, Isaacs, & Zeta Carels, 2013; Myer, et al., 2008) and in research on concussion (Straume-Naesheim, Andersen, Dvorak, & Bahr, 2005).

Barratt Impulsiveness Scale (BIS). The BIS-11 (Patton, Stanford, & Barratt, 1995) is a measure of impulsive behaviour. It is a 30 item self-report questionnaire which tests three domains of impulsivity (attentional, motor and non-planning impulsiveness) on a four-point Likert response scale. The scale has high internal consistency (r = .83) and has satisfactory retest reliability (r = .83; Reid, Cyders, Moghaddam & Fong, 2013; Travis Seidl, Pastorek, Troyonskaya & Scheibel, 2015). The BIS-11 has been used extensively in research on TBI (Berlin, Rolls, & Kischka, 2004; Travis Seidl, et al. 2015).

Beck Depression Inventory – Second Edition (BDI-II). The BDI-II (Beck, Steer, & Brown, 1996) is a 21-item self-report measure of depression symptoms. The questionnaire

consists of groups of statements; respondents indicate which statement in each group most reflects how they have been feeling over the two weeks up to and including the day of assessment. A score of 21 or higher indicates dysphoria or moderate depression (Beck et al., 1996; Dozois, Dobson, & Ahnberg, 1998). The BDI-II has good test-retest reliability (r = .93; Beck et al., 1996) and has been used in sports concussion studies in South Africa (Shuttleworth-Edwards, Whitefield-Alexander, Radloff, Taylor, & Lovell, 2009).

General Health Questionnaire (GHQ-28). The General Health Questionnaire-28 (Goldberg & Williams, 1988) is a screening measure for general psychological distress in adolescents and adults. The GHQ-28 is the most widely used version of the GHQ and contains four subscales: somatic symptoms, anxiety/insomnia, social dysfunction and severe depression. Participants are asked to indicate how their current health state differs from their general health state on a four point Likert scale. The GHQ-28 has high internal consistency and reliability varies between .82 and .92 (Nagyova, et al., 2000). It has been used extensively in studies on TBI and has been used in a South African context (Moch, Panz, Joffe, Havlik, & Moch, 2003; Ward, Lombard, & Gwebushe, 2006).

State Trait Anger Expression Inventory – 2 (STAXI-2). The STAXI (Spielberger, 1988) is a 44-item self-report questionnaire which measures state anger, trait anger and anger expression on a four point Likert scale. Reported reliability, validity and consistency of the STAXI is high (Etzler, Rohrmann & Brandt, 2014; Medd & Tate, 2000; Spielberger, 1988). The STAXI has been used extensively in studies on TBI (Anson & Ponsford, 2006; Medd & Tate, 2000).

State Trait Anxiety Inventory (STAI). The STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) measures state anxiety and trait anxiety. It is a 20 item self-report questionnaire on which participants indicate the extent to which each statement is suitable to them on a four point Likert scale. The STAI has high internal consistency (r = .88; Spielberger & Vagg, 1984) and has been used in a South African context (Seedat, Fritelli, Oosthuizen, Emsley, & Stein, 2007) as well as in studies on TBI (Curran, Ponsford, & Crowe, 2000).

Procedure

Participants were contacted via e-mail to set up times for testing sessions to fit into their schedules. All participants (N = 114) completed one testing session lasting approximately 1.5 to 2 hours in a computer lab at UCT administered in group format. Upon arrival, I explained to the participants the details of the study and what would be required of them should they consent to participate; this was also an opportunity for the participants to

ask any questions they might have had. Once the participants provided informed consent the testing session commenced and consisted of multiple pencil-and-paper type screening measures and emotion and behaviour questionnaires as well as a computerised test which related to the larger study. Responses were collected and analysed.

Data analysis. Data analysis was done using IMB SPSS version 22 with a significance level set at $\alpha = .05$.

Correlational analyses. I utilised correlational analysis to investigate within-group differences in the rugby group between emotional and behavioural outcomes and 1) number of previous concussions, 2) presence of loss of consciousness, and 3) duration of loss of consciousness. For duration of loss of consciousness, I created a continuous variable (loss of consciousness composite) for each participant. This score was computed by allocating points corresponding to duration of loss of consciousness (illustrated in Table 1) and summing these points together for each participant. In this way, the larger the total duration of loss of consciousness across number of concussions was, the larger the score would be.

Table 1: *Calculation of the Duration of Loss of Consciousness Composite Score*

Duration of loss of consciousness	Points allocated towards composite score
No loss of consciousness	0
> 1 minute	1
Unspecified duration	1
2 minutes – 5 minutes	2
6 minutes – 20 minutes	3

In addition, a concussion composite score was created for each participant in an attempt to merge number of previous concussions with duration of loss of consciousness to create a score representative of seriousness of previous concussive injury. This was done by summing the total number of previous concussions (diagnosed and suspected undiagnosed) and the total duration of loss of consciousness (computed in the loss of consciousness composite score described above) for each participant. A higher score indicating more serious concussive injury.

Discriminant function analysis. I employed discriminant function analysis to investigate between-group differences in emotional and behavioural disturbance based on history of concussions. In addition, the discriminant function analysis was used to identify functions comprised of linear combinations of individual emotional and behavioural predictor

variables, which would discriminate best between groups. The ability of these functions to discriminate between groups was tested.

Ethical Considerations

The study was approved by the UCT Health Sciences Human Research Ethics Committee (HREC REF 010/2015) and the Department of Psychology Research Ethics Committee. This research was conducted in a manner that abides by the ethical guidelines and principles of the International Declaration of Helsinki.

Informed consent. Both the rugby and control group received a brief presentation of the nature of the study at the testing session after which each participant had the opportunity to sign the consent form to participate (see Appendices A and B). By signing this form, the participants consented to complete all questionnaires and to other components which only relate to the larger study. Participation in the study was voluntary and participants were free to withdraw from the study without penalty at any time.

Confidentiality. Participants' identities were kept confidential at all times during the study and will be kept confidential in the event that it is published; participants were made aware of this. Participants were assigned numbers which were used to label their data instead of their names. A separate, private record was kept to identify a participant by his number in the event that he needed to be contacted during the study or needs to be contacted in the future. All data was be stored in a secure venue, the ACSENT laboratory at UCT, and all electronic information was password protected. Only the researchers of this study are able to review these research records.

Referrals. In the event that participants' scores on the emotional and behavioural measures indicated clinically significant concerns, they were referred to the UCT Student Wellness Service or to a qualified sports psychologist at the Sports Science Institute of South Africa (based in Cape Town) for counselling to be received if desired.

Debriefing. Participants will be given a debriefing form (see Appendix E) at the conclusion of the larger study. The debriefing form contains contact information for various parties involved in the study to address any potential questions or concerns from the participant.

Risks and benefits. The study had minimal risks; participants may have experienced some slight discomfort. The testing process was reasonably lengthy and consisted of multiple questionnaires which may have resulted in fatigue and boredom effects. Participants received no direct benefits from their participation in the study. Those who were also undergraduatepsychology students were however awarded 3 SRPP points.

Results

Descriptive Statistics

Participant characteristics. Table 2 shows the age and IQ of the three groups in the sample; these are the variables on which the groups were matched.

Among all of the rugby players in the sample (Rugby Not Concussed and Rugby Concussed; *n*=88), 45 participants (51%) reported previous formally diagnosed concussions (*Range* = 1-5) with 17 of these also reporting potential undiagnosed concussions. In addition, 15 other rugby players reported potential undiagnosed concussions (*Range* = 1 – multiple). Together, these participants formed the Rugby Concussed Group (*n* = 60). Amongst those with formally diagnosed concussions (45/60), 30 participants (67%) reported having lost consciousness during at least one of their concussions. Duration of loss of consciousness ranged from a few seconds to 20 minutes with the majority (47%) reporting having lost consciousness for less than a minute and 30% for between 1 and 5 minutes. Only 1 participant (2%) lost consciousness for longer than 5 minutes, reporting loss of consciousness for 20 minutes. For the remaining 21% of participants who reported concussions, duration of loss of consciousness was not specified.

The remainder of rugby players in the sample (*n* = 28) who had not reported either formally diagnosed or suspected undiagnosed previous concussions constituted the Rugby Not Concussed group. Finally, the control group (*n* = 26) consisted of non-contact sports participants not exposed to head impacts. While this group reported no formally diagnosed concussions, 4 participants reported instances in which they felt they may have been concussed due to symptoms of memory loss, disorientation or loss of consciousness. Concussion figures used to divide the sample into these three groups are illustrated in Table 3.

Table 2. *Participant Characteristics: Age and IQ per Group*

	Control				Rugby Not Concussed				Rugby Concussed			
	N	Min	Max	M (SD)	N	Min	Max	M (SD)	N	Min	Max	M (SD)
Age	26	18	25	21.4 (2.08)	28	18	31	22.1 (3.93)	60	18	32	22.13 (4.07)
Shipley-V	10	10	36	26.1 (7.37)	26	10	35	23.42 (7.1)	55	9	37	28 (5.6)
Shipley-A	10	11	20	15.1 (3)	26	7	22	13.39 (3.66)	55	5	22	15.5 (3.47)

Table 3. *Participant Characteristics: Concussion Figures per Group*

	Control (*n* = 26)			Rugby Not Concussed (*n* = 28)			Rugby Concussed (*n* = 60)		
	Min	Max	M (SD)	Min	Max	M (SD)	Min	Max	M (SD)
No. of previous diagnosed concussions	0	0	0 (0)	0	0	0	0	5	1.33 (1.31)
No. of previous undiagnosed concussions	0	2	.38 (.57)	0	0	0	0	3	.67 (.752)
Total concussions	0	2	.38 (.57)	0	0	0	1	7	2 (1.38)

Measures of emotional and behavioural outcomes. Table 4 illustrates descriptive statistics for scores on the measures of emotional and behavioural outcomes between groups. The only variable that significantly differed between rugby players (Rugby Concussed and Rugby Not Concussed) and non-contact sportsmen was alcohol usage (F (1, 112) = 6.79, p = 0.01). Both the Rugby Concussed and Rugby Not Concussed groups have statistically significant higher levels of alcohol usage than the control group (F (2, 112) = 3.412, p = 0.04). This suggests that the significant difference in alcohol usage is not due to concussive injury but might be explained by drinking behaviour specific to the rugby population. In addition, although not statistically significantly, the Rugby Concussed group has marginally higher average scores on measures of impulsivity and trait anger than the Rugby Not Concussed and control groups. On the measure of anger-expression, the Rugby Not Concussed group has a higher average score than the other groups but this also does not approach significance. These results are illustrated in Table 4 and suggest that there is no significant long term emotional and behavioural impairment following concussive injury.

The Rugby Concussed, Rugby Not Concussed and control groups do not differ in the domains of depression, general health and anxiety but the results suggest that concussions and multiple head impacts may result in slightly increased impulsivity, anger and alcohol usage in the long term. Notably, these differences are extremely slight as is evident by the diminutive effect sizes (see Table 4); serious caution must therefore be taken in drawing conclusions from these results. These analyses do however suggest that the first hypothesis is not supported: rugby players with previous concussions do not exhibit enduring symptoms of emotional and behavioural disturbance in comparison to non-concussed rugby players and non-contact sport control participants.

Within-group Correlational Analyses

These analyses were done within the rugby participants (Rugby Concussed and Rugby Not Concussed) to determine whether specific characteristics of concussive injury, namely the number of concussions and presence and duration of loss of consciousness, were related to emotional and behavioural outcomes. The correlation matrices are provided in Appendix F.

Number of previous concussions. This analysis pertains to the second hypothesis which predicted that as the number of concussions increase, scores of emotional and behavioural disturbance would also increase.

Table 4. *Emotional and Behavioural Outcomes Scores per Group*

	Control		Rugby Not Concussed		Rugby Concussed			
	N	M (SD)	N	M (SD)	N	M (SD)	F (df)	p	η^2
AUDIT	26	5.77 (5.14)	28	9.14 (6.18)	59	8.78 (5.09)	3.412 (2, 112)	.037	.058
BIS-11	26	61.58 (8.08)	28	61.32 (7.99)	58	62.86 (9.67)	.358 (2, 111)	.700	.007
BDI-II	26	5.54 (4.13)	28	4.68 (4.03)	60	5.58 (4.88)	.411 (2, 113)	.664	.012
GHQ-28	25	3 (3.37)	28	2 (2.74)	60	2.53 (3.36)	.643 (2, 112)	.528	.019
AXIndex	26	31.77 (10.85)	27	35.33 (10.46)	60	32.03 (11.80)	.927 (2, 112)	.399	.007
T-ANG	26	16.77 (4.58)	27	16.48 (4.5)	60	17.25 (4.23)	.318 (2, 112)	.729	.006
STAI-T	26	36.39 (8.15)	28	35.60 (9.23)	60	33.76 (7.86)	1.093 (2, 113)	.339	.017

Note: BIS-11: impulsivity, T-ANG: trait-anger, AXIndex: anger expression, AUDIT: alcohol usage, BDI-II: depression, GHQ-28: general health and STAI-T: anxiety. η^2 is the measure of effect size.

The results of this analysis indicated that there were no significant relationships between the measures of emotional and behavioural disturbance and number of previous concussions (p = >0.05 for all measures; see Table 9 in Appendix F).

These results suggest that emotional and behavioural disturbance is not exacerbated by repeated concussive injury. This is in line with the findings of the descriptive analyses above which showed no large differences in mean scores between the Rugby Concussed and the Rugby Not Concussed groups.

Loss of consciousness.

Presence of loss of consciousness. **S**cores of emotional and behavioural disturbance on each measure were correlated with the presence of loss of consciousness in any of concussive incidents reported by the participants (see Table 10 in Appendix F). Depression scores (r = .178, p = .048) and impulsivity scores (r = .183, p = .046) were weakly related to presence of loss of consciousness; the direction of these correlations suggests that depression and impulsivity scores increase if consciousness was lost during the concussive incident. Effect sizes for these correlations are very small however, η^2 = 0.03 for each, indicating that only 3% of the variance in depression and impulsivity scores can be explained by presence of loss of consciousness.

Duration of loss of consciousness (composite score). Correlational analysis (see Table 11 in Appendix F) using this variable indicated one significant positive relationship between duration of loss of consciousness and depression (r = .233, p = .014), which indicates that level of depression increases as duration of loss of consciousness increases. The effect size for this correlation is also very small, η^2 = .1, which indicates that duration of loss of consciousness explains 10% of the variance in depression scores.

Overall, these results suggest that loss of consciousness has no relationship with emotional and behavioural outcomes of anger, general health, anxiety and alcohol usage and weak significant relationships with impulsivity and depression.

Concussion composite score. The calculated concussion composite scores ranged from 0 to 11. Correlational analyses (see Table 12 in Appendix F) were done to investigate the relationship between this variable and emotional and behavioural disturbance measures and found that there was no significant relationship between seriousness of concussive injury and emotional and behavioural disturbance.

Discriminant Function Analysis

Based on the descriptive statistics, I chose to run a simultaneous discriminant function analysis to include each of the measures of emotional and behavioural outcomes in

the analysis. Each of these measures were entered into the analysis as predictors and Rugby Concussed, Rugby Not Concussed, and control, were entered as the groups. Both descriptive and predictive discriminant function analyses were run to determine whether the groups differed significantly on emotional and behavioural disturbance and whether groups could accurately be discriminated based on these differences.

Descriptive discriminant function analysis. The discriminant function analysis revealed two discriminant functions and these are illustrated in Table 5. These factors represent linear combinations of emotional and behavioural predictors which discriminate best between groups. The ability of each function to discriminate between groups is relatively similar: the first function has a slightly larger Eigenvalue and explains 56.1% (canonical $R^2 = .11$) of the variance in discriminating ability whereas the second function explains 43.9% of the variance (canonical $R^2 = 0.09$). Wilks's Lambda test indicated that neither function significantly discriminates between groups: for function 1 and 2 in combination: $\Lambda = .80$, $\chi2(14) = 22.6$, $p = .067$ and for function 2: $\Lambda = .91$, $\chi2(6) = 10$, $p = .125$. Based on these results the null hypothesis (that the functions have no discriminating ability) would be retained.

Table 5. *Eigenvalues of Discriminant Functions*

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.130	56.1	56.1	.339
2	.102	43.9	100.0	.304

The results indicate that combinations of varying domains of emotional and behavioural disturbance cannot explain differences between groups based on varying levels of exposure to head impacts and concussive injury. In other words, the groups do not differ significantly on emotional and behavioural disturbance; this confirms the interpretation of the descriptive statistics. Given these outcomes, I would reject the first hypothesis of the study. Given that the current study is exploratory, analysis of the constituents of the discriminant functions will be explored even in the absence of significance.

Table 6 illustrates the relative importance of each predictor in discriminating between groups, where a higher value indicates that the groups differ more on that predictor. From this output it is evident that alcohol usage will have the greatest impact on discriminant ability of factor one as the standardised coefficient (.897) is substantially higher than that of the other predictors. Anger will have the greatest impact on the discriminant ability of the second function, with an anger expression standardised coefficient of -.948.

Table 6. *Discriminant function analysis: Standardized Canonical Discriminant Function Coefficients*

	Function	
	1	2
AUDIT	.897	-.363
BDI-II	.256	.324
GHQ-28	-.275	.335
STAI-T	-.578	-.549
BIS-11	.037	.573
T-ANG	.336	.773
AXIndex	-.112	-.948

Note: BIS-11: impulsivity, T-ANG: trait-anger, AXIndex: anger expression, AUDIT: alcohol usage, BDI-II: depression, GHQ-28: general health and STAI-T: anxiety.

Table 7 illustrates the canonical loadings onto the discriminant functions, these are correlations between the predictor variables and the discriminant functions. Interpretation of this output gives insight into the relative contribution of each predictor to group discrimination and therefore which constructs may underlie the discriminant functions. From this output it is evident that alcohol usage loads very strongly on the first function (r = .8) compared to the second (r = -.24) in addition to trait anger and anxiety. Anger expression loads higher on the second function (r = .39) than the first (r = .09) in addition to general health, depression and impulsivity. This suggests that the first function represents something that differentiates between groups by a factor related strongly to levels of alcohol usage and the second function differentiates between groups by a factor related weakly to levels of anger expression.

Table 7. *Discriminant function analysis: Structure Matrix*

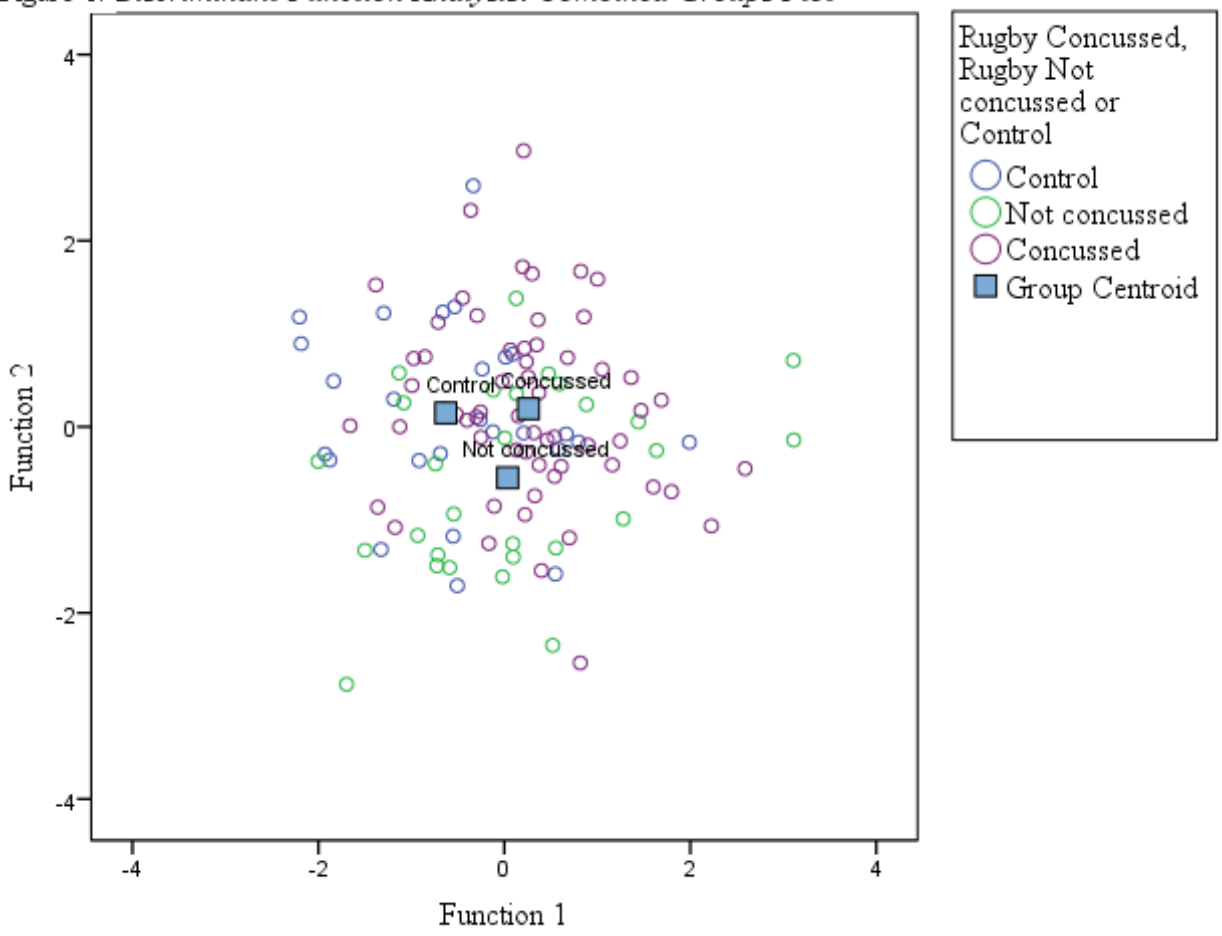
	Function	
	1	2
AUDIT	.804*	-.241
STAI-T	-.252*	-.158
T-ANG	.246*	.235
AXIndex	.085	-.387*
GHQ-28	-.170	.246*
BDI-II	.028	.245*
BIS-11	.161	.201*

*Note:**: Largest absolute correlation between each predictor variable and discriminant function. BIS-11: impulsivity, T-ANG: trait-anger, AXIndex: anger expression, AUDIT: alcohol usage, BDI-II: depression, GHQ-28: general health and STAI-T: anxiety.

Predictive discriminant function analysis. The discriminate functions identified in the preceding section can be used to predict group membership. Figure 1 is a graphical representation of which function discriminates between which groups in the analysis. It plots the discriminant scores for each participant coded by the group to which the participant belonged as well as group centroids (mean discriminant scores for each group) which are plotted in larger squares.

This graph indicates that function 1 discriminates between the control group and the Rugby Concussed and Rugby Not Concussed groups and that function 2 discriminates between the control and Rugby Concussed groups and the Rugby Not Concussed group. Relating this back to the canonical loadings, this output suggests that the control group can be differentiated from both rugby groups on scores of alcohol usage, this is in line with the analysis of the descriptive statistics. In addition, it seems that the Rugby Concussed group can be differentiated from the Rugby Not Concussed group on the basis of anger expression. It has to be remembered however, that these discriminates are not significant, this is further evident in the distribution of points on the plot.

Figure 1. *Discriminant Function Analysis: Combined Groups Plot*



To conclude the predictive discriminant function analysis, participants are classified into groups the original groups using the discriminant functions. Table 8 illustrates these results. These results illustrate that using the discriminant functions, 26.9% of control participants were correctly predicted, 35.7% of Rugby Not Concussed participants and 86.7% of Rugby Concussed participants. Overall, 60.5% of original grouped cases were identified. After cross validation, 55.3% of cases are correctly identified.

Table 8. *Discriminant Function Analysis: Classification Results*

			Predicted Group Membership			
		Group	Control	Not concussed	Concussed	Total
Original	Count	Control	7	4	15	26
		Rugby Not Concussed	2	10	16	28
		Rugby Concussed	4	4	52	60
	%	Control	26.9	15.4	57.7	100
		Rugby Not Concussed	7.1	35.7	57.1	100
		Rugby Concussed	6.7	6.7	86.7	100

Assumptions of discriminant function analysis. Sample size was sufficient: the sample size of the smallest group is at least 20 (control = 26) and is larger than the overall number of predictor variables (7). The assumption of multivariate normality was sufficiently upheld. There was no threat of multi-collinearity in the sample. The assumption of independent observations is upheld. The assumption of equality of covariance matrices is upheld: *Box's M* = 32.8, $p = .407$. Some outliers were identified but did not contribute to any significant results in the analyses so they were not removed. The assumptions are upheld for this dataset and the results of the analysis can be deemed reliable.

Discussion

The aim of the current research was to investigate the potential long term emotional and behavioural outcomes of repeated concussions and head impacts in young adult rugby players. Using multiple measures of emotional and behavioural outcomes I investigated the differences in emotional and behavioural outcomes between participants who reported previous concussions and those who did not. I also explored the relationship between these outcomes and number of previous concussions and the presence and duration of loss of consciousness as indicators of seriousness of the concussive injury. The results of the current study indicated that levels of emotional and behavioural disturbance did not differ significantly between groups based on history or nature of previous concussions. Injury-

related factors (repetitive incidence of concussion and duration of loss of consciousness) were not significantly related to emotional and behavioural disturbance. Although my hypotheses were rejected, these results are in line with research suggesting that long term emotional and behavioural outcomes of TBI are dependent on many interacting factors rather than injury-related factors alone.

Summary of Results for Hypotheses 1 and 2

The first hypothesis I tested was that rugby players who had reported previous concussions would have significantly greater levels of emotional and behavioural disturbance than rugby players without previous concussions and the non-contact sport control participants. I predicted that differences in emotional and behavioural disturbance between these groups could be used to predict group membership. The results of the discriminant function analysis indicated that groups could not be successfully differentiated based on emotional and behavioural outcomes; there were no clear differences between groups on the measures of emotional and behavioural outcomes. Furthermore, both rugby and control groups showed no clinically significant scores of emotional and behavioural disturbance which suggests an absence of long term impairment in these domains in relation to concussive injury. The exception however, is the finding that rugby players generally (both Rugby Concussed and Rugby Not Concussed) had significantly higher levels of alcohol usage than the control group.

For the second hypothesis I predicted that more severe concussive injury, indicated by the number of previous concussions and the duration of loss of consciousness with concussive injury, would be positively related to emotional and behavioural disturbance. I found somewhat disparate results. Correlational analysis indicated no significant differences in emotional and behavioural outcomes based on number of previous concussions which suggests that emotional and behavioural disturbance is not exacerbated by repeated concussive injury. The relationship between emotional and behavioural disturbance and loss of consciousness appears slightly more complex. Results indicated the depression and impulsivity scores increase if consciousness was lost and that the longer the loss of consciousness, the higher the depression score. Although significant, these relationships have very small effect sizes which discourages reading into these results for meaningful conclusions. A concussion composite score encompassing these two variables also showed no relationship with emotional and behavioural outcomes; overall, the severity of previous concussive injury appeared to have no significant relationship to emotional and behavioural disturbance and the second hypothesis is also rejected.

These findings are discussed below. I begin with the alcohol usage findings and then proceed to discuss the non-significant results regarding behavioural and emotional outcomes in relation to history of concussion.

Alcohol usage. The developers of the Alcohol Use Disorders Identification Test (AUDIT) suggest that scores between 8 and 15 indicate hazardous drinking, scores between 16 and 19 indicate high level alcohol problems and scores of 20 or above indicate clinically significant alcohol dependence (Babor, Higgins-Biddle, Saunders, & Monteiro, 2001). 53% of participants in the Rugby Concussed group and 57% of the Rugby Not Concussed group had scores higher than 8 compared to 35% of the control group. In addition, one participant in the control group had a score of 20 whereas 2 participants in the Rugby Concussed group and 3 participants in the Rugby Not Concussed group had a score of between 20 and 24. Given that there is no significant difference in alcohol usage between the Rugby Concussed and Rugby Not Concussed groups, these results suggest that the high alcohol consumption is related to participation in rugby rather than exposure to concussion.

This finding confirms previous research which has found atypically higher alcohol consumption and binge drinking associated with rugby (Lawson & Evans, 1992; Quarrie, et al., 1996; Potgieter, et al., 2014; Sekulic, Bjelanovic, Pehar, Pelivan, & Zenic, 2014). These studies have samples of similar age and matched sex to the current sample. One such study found that 60% of rugby players binged at least once a month with 30% binging at least once a week (Sekulic, Bjelanovic, Pehar, Pelivan, & Zenic, 2014). Another study found that 78% of rugby players scored at or above 8 on the AUDIT with 64% of the sample reporting consuming alcohol at least two or three times a week and drinking on average 10 drinks per session (Quarrie, et al., 1996). A South African study done on the dietary intake of Varsity Cup rugby players at Stellenbosch University found that players consumed on average 5.4 drinks (SD = 6), which are most often beer, after each rugby game (Potgieter, et al., 2014). The authors of this study comment that "consuming alcohol on Monday nights after a Varsity Cup game has become culture among university students in SA" (Potgieter, et al., 2014, p. 42). Given that the current study consisted primarily of students this observation is as relevant to this sample, however, research suggests the presence of a hazardous drinking culture among rugby players in general, not simply within the student population. While the rates of alcohol consumption among rugby players has received a fair amount of attention, the significant risk of serious harm and alcohol dependence is impetus for further research and indicates a great need for education of this population regarding the adverse effects of alcohol on recovery and performance (Quarrie, et al., 1996; Potgieter, et al., 2014).

While the culture of harmful alcohol consumption among rugby players is the most likely explanation for these findings, one study on long term alcohol usage following a TBI found that 6% of their sample reported increased alcohol consumption after their injury. This proportion of the sample were more likely to be younger, single, have been diagnosed with depression since their TBI, have lower life satisfaction and mental health scores than those who reported no change or a decrease in their drinking habits compared to before their injury (Horner, et al., 2005). While the current study found no relationship between alcohol consumption and age, the results did indicate a significant positive relationship between alcohol consumption and scores of depression which corresponds somewhat to this research suggesting a possible association between exposure to head impacts and depressive symptoms. However, the previous study examined this relationship using formally diagnosed depression whereas the current study relied on a self-report measure. The results from the current study indicate no difference in alcohol usage between the Rugby Concussed and Rugby Not Concussed groups which suggests that problematic alcohol usage in this sample is not related to previous concussions, but more focussed research in this domain is necessary to draw this conclusion.

Emotional and behavioural outcomes. The discriminant function analysis confirmed the preliminary descriptive statistics indicating no significant difference on emotional and behavioural outcomes between groups based on history of concussions. This analysis identified two discriminant functions but neither of these were able to significantly differentiate between the three groups nor predict group membership. The results are in contrast to the only two studies on emotional and behavioural outcomes utilising an athlete sample. These studies by Hutchison, Mainwaring, Comper, Richards, and Bisschop, (2009; 2010) found that athletes who suffered concussions displayed significantly higher scores of total mood disturbance as measured by the Profile of Mood States (Heuchert & McNair, 2012) and fatigue than athletes who suffered musculoskeletal injuries. Furthermore, high levels of total mood disturbance remained in the athletes with concussions even after they had returned to the sporting environment, which implies some degree of long term impairment. The results of the current study however suggest the absence of mood impairment after concussion. It is of importance to note that this evidential variability in emotional and behavioural outcomes after concussion is in keeping with the literature on the topic which indicates disparate findings across studies.

Based on the results of the discriminant function analysis in combination with the descriptive statistics the null hypothesis, that the identified functions comprised of linear

combinations of emotional and behavioural measures have no discriminant ability, is retained. The first hypothesis is rejected: the rugby concussed, rugby not concussed and control groups cannot be differentiated based on levels of emotional and behavioural disturbance; in other words, emotional and behavioural disturbance cannot explain differences between groups based on exposure to head impacts and concussive injury, at least on its own.

There are a number of explanations which could account for these findings. First, these findings might suggest that emotional and behavioural disturbance dissipates entirely in the acute phase of concussive injury. This phase of concussion is generally defined as 7 to 10 days post-injury (McCrea, et al., 2003; McCrory, et al., 2013). In the current study the average duration since concussive injury was 2.82 years (*SD*= 3.3) and duration since last formally diagnosed concussion was 3.57 years (*SD*= 3.7). Several previous studies on the long term outcomes of mTBI have found enduring impairments in cognitive aspects in the post-acute phase of mTBI (*Range* = 7 months – 13 years, *M* = 4.7 years since injury) and an absence of enduring psychological deficits (Ettenhoffer & Abeles, 2009; Segalowitz, Bernstein, & Lawson, 2001). In contrast, one study has investigated the long term emotional disturbances related to mTBI and has found an increased rate of depression in head injury patients on average 6 years after injury (Konrad, et al., 2010). Furthermore, research on post-concussion syndrome has reported frequent incidence of depression, anxiety, irritability, agitation, loss of motivation, social withdrawal and difficulties with interpersonal relationships that persist for years after the injury (Frencham, Fox, & Maybery, 2005; Konrad, et al., 2010; Carrol, et al., 2004; Giza & Kutcher, 2014). Overall, research on the emotional and behavioural outcomes following mTBI is sparse and those studies that have been done present contradictory results and utilise significantly different methods of investigation (Konrad, et al., 2010).

Second, the development of emotional and behavioural outcomes might be due to a more complex interconnection of various factors, rather than simply a feature of the concussive injury. Previous findings show that, unlike cognitive impairments, emotional outcomes such as anxiety and depression do not increase with an increase in injury severity (Hibbard, Uysal, Kepler, Bogdany, & Silver, 1998; Jamora, Young, & Ruff, 2012; Levin, et al., 1987; Washington, et al., 2012). While studies in humans have been predominantly retrospective and correlational, the use of experimental studies on emotional and behavioural outcomes after induced mTBI in animals has only recently been done. One such study using mice found that depressive and anxious behaviour did not differ as a product of injury

severity whereas significant cognitive deficits were found which increased with an increase in injury severity in the same animals (Washington, et al., 2012). Human studies in paediatric populations have confirmed these findings indicating that injury-related variables are not directly related to emotional and behavioural dysfunction after TBI and that a combination of factors both injury-related and environmental predict emotional and behavioural outcomes (Johnson, et al., 2011; Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Schrieff-Elson, Thomas, Rohlwink, & Figaji, 2015; Schwartz, et al., 2003).

Researchers have conceptualised the emotional and behavioural outcomes of TBI as multifaceted and complex, associated with a wide range of interacting factors which include non-injury related variables such as social support, psychosocial disadvantage, psychiatric history and access to resources. Given that these studies are done with paediatric samples, there is also large emphasis on family functioning which may not translate to this level of significance in young adult and older adult populations (Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Kinsella, Ong, Murtagh, & Sawyer, 1999; Schrieff-Elson, Thomas, Rohlwink, & Figaji, 2015; Schwartz, et al., 2003). Studies on post-concussion syndrome, which often involve affective symptoms and behavioural disruption (Anson & Ponsford, 2006; Carrol, et al., 2004; Konrad, et al., 2010), may offer a model for the explanation of the development of enduring emotional and behavioural outcomes in older populations such as the current sample.

Wood (2004) utilises a diathesis-stress model to provide a related explanation of post-concussion syndrome in terms of individual vulnerability and protective factors. The author emphasises that the development of post-concussion syndrome can be best understood as an interaction between biology and experience. This relates to the theory that the development of enduring symptoms after concussion is due to individual variability in cognitive, behavioural, affective, social and biological factors such as reaction to the injury, pre-accident functioning, post-accident demands and pressures, coping styles and injury characteristics (Kay, 1992). Much the same as the predictors of behavioural disturbance in paediatric populations after TBI, this model proposes that the development of enduring emotional and behavioural dysfunction after concussion is related to a combination of individualised factors which creates vulnerabilities and protective factors. While long term emotional and behavioural dysfunction may not be present in the current sample due to a high degree of individual protective factors in addition to their injury being on the milder end of the spectrum, the current study did not investigate these individual psychosocial factors. In sum, it is possible that a wide range of non-injury related variables in addition to history of

mTBI/concussion, are better able to predict emotional and behavioural outcomes between groups rather than history of concussion alone.

Limitations and Recommendations for Future Research

The most significant limitation to the current research is highly prevalent in all research studies of this kind. This limitation relates to confounding effects introduced by relying on self-report measures for an indication of emotional and behavioural disturbance in contrast to more objective measures of cognition. Self-report measures are vulnerable to being influenced by self-awareness, social desirability and subjective interpretation (Konrad, et al., 2010; Washington, et al., 2012). This limitation might be improved in future research in this domain by measuring emotional and behavioural reactions in rugby players with concussions to stimuli in experimental conditions.

In addition, various premorbid psychological factors may contribute to post-injury levels of emotional and behavioural dysfunction which makes it difficult to draw direct conclusions between the concussive injury and its emotional and behavioural outcomes (Washington, et al., 2012). While the current sample did not report any previously diagnosed psychiatric illnesses, premorbid individual tendencies towards specific psychological dysfunction are not known. Prospective study designs may provide better means of gauging differences in emotional and behavioural states before concussive injury compared to post-concussion. Future research should also explore broader psychosocial factors such as social support, psychosocial disadvantage and access to resources which may be better predictors of emotional and behavioural outcomes after TBI. Another recommendation for future research is the clarification of the definition of mTBI towards consistent inclusion criteria across studies to facilitate cross-study comparisons necessary to build and refine the literature base on the long term emotional and behavioural outcomes of concussion in general and in rugby players.

Conclusions

Diagnosis of concussion remains based on clinical judgement, symptom checklists and standardised assessment tools with questionable validity, reliability, specificity and sensitivity (Harmon, et al., 2013). Many concussive and subconcussive injuries go unrecognised and therefore do not receive treatment or follow return to play protocols (Giza & Kutcher, 2014; McCrory, et al., 2013). Even in the case of successful diagnosis, treatment and adherence to return to play protocols, rugby players remain at risk for repeated concussive injuries due to the highly physical nature of the game. Given the increase in evidence that repeated concussive injury leads to long term neurological impairment, there

exists a need for research on the possible long term effects of these injuries to inform diagnostic and management procedures (Giza & Kutcher, 2014; Harmon, et al., 2013). The results of the current study pertains specifically to enduring emotional and behavioural outcomes of concussions in rugby players and suggests that these outcomes may be dependent on a variety of interacting factors including injury-related factors and environmental and personal factors. Future research utilising more objective measures of emotional and behavioural outcomes and investigating broader psychosocial factors is necessary to understand the mechanisms predicting emotional and behavioural outcomes after concussions.

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Appendix A: Informed Consent Document (Rugby)

University of Cape Town
Psychology Department
Telephone: +27 21 650-3430
Fax: +27 21 650-4104

Investigating the neuropsychological effect and long term outcomes of multiple concussions and/or head injuries among university rugby players

Informed Consent to Participate in Research and Authorisation for Collection, Use, and Disclosure of Protected Health Information

This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your protected health information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. By participating in this study you will not be penalized or lose any benefits to which you would otherwise be entitled.

This study will be conducted in a manner that adheres to the ethical guidelines and principles of the International Declaration of Helsinki (Fortaleza, Brazil, 2013).

1. **Name of Participant**

_____

2. **Title of Research Study**

Investigating the neuropsychological effect and long term outcomes of multiple concussions and/or head injuries among university rugby players.

3. **What is the purpose of this research study?**

The purpose of this research study is to better understand whether or not, and how repeated instances of concussions and/or other head injuries contribute to altered brain functioning. More specifically the research intends to find out how these injuries manifest how the individual thinks, feels and behaves, and in any microstructural brain abnormalities. Also, the purpose is to observe how individuals with head injuries and concussions compare to people who have had no such injuries.

4. Principle Investigator(s) and Telephone Number(s)

Leigh Schrieff, Ph.D. (PI and supervisor)

Psychology Department

University of Cape Town

0216503708

Dale Stephen (Masters student)

Psychology Department

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Lydia Wepener (Honours student)

Psychology Department

University of Cape Town

0716771182

5. What will be done if you take part in this research study?

During this study, you will be required to complete a number of questionnaires and scales to obtain individual demographic information, personal characteristics, and an approximation of your ability to think. Following initial testing, if you have sustained a concussion over the course of the 2015 rugby season and while participating in rugby, you will be required to undergo a brief concussion screen immediately following the injury as well as 7 days post-concussion. Additionally, you will be contacted by one of the researchers to complete a brain scan and post-concussion assessment within 48 hours of the concussion. All rugby players may also be contacted for repeated testing in September, 2015. These testing procedures will involve a computer based concussion assessment as well as a brain scan, and will be conducted in a private room at the Cape Universities Brain Imaging Centre (CUBIC), Groote Schuur Hospital. By signing the consent form, you are consenting to participation in these possible follow-up assessments as well.

For the purposes of this study and for gathering important quantitative data, you may be required to wear a plaster (XPatch) behind either your left or right ear – this contains an accelerometer. This is a head collision monitoring device and will enable us to track head movements and forces involved in all head collisions during rugby games. The XPatch will not cause any danger to you or others while playing a rugby match, and should not cause any discomfort. You will have the opportunity to view this device before signing consent.

6. What are the possible discomforts and risks?

There is minimal risk associated with this study. You may be required to wear a plaster (XPatch) which you will be able to view before signing consent to participation. You may also be required to return for repeated testing in September at the Cape Universities Brain Imaging Centre. You will be contacted by the Principle Investigator if this is the case. Each assessment will last approximately 1 ½ hours per person to complete. Due to it being a more lengthy process, participants may feel fatigued or irritable during testing as the tasks require

concentration. However, each participant will be given breaks where necessary as well as refreshments.

7. **What are the possible benefits of this study?**

Rugby coaches and players will have access to the overall results upon completion of the study. Each rugby player will have the option of contacting the Principle Investigator for their individual brain scan and test results, if these are administered, and upon completion of the study. Significantly, this research aims to contribute to practical information regarding return-to-play decisions, thresholds of concussion injuries, and diagnostic indicators of concussion that are important for player safety. It thus provides all those involved with contact sport, including the health services, evidence for the neuropsychological effects of repeated head trauma.

8. **Can you withdraw from this research study and if you withdraw, can information about you still be used and/or collected?**

You may withdraw your consent and stop participation in this study at any time. Information already collected may still be used.

If you have a complaint or complaints about your rights and welfare as research participants, please contact the Human Research Ethics Committee.

Tel: 021 406 6492

E-mail: sumaya.ariefdien@uct.ac.za

9. **Once personal information is collected, how will it be kept confidential in order to protect your privacy and what protected health information about you may be collected, used and shared with others?**

If you agree to be in this research study, it is possible that some of the information collected might be copied into a "limited data set" to be used for other research purposes. If so, the limited data set will only include information that does not directly identify you. So, your identity will remain anonymous. Data will be labelled using participant numbers rather than names, so that they cannot be used to directly identify any particular individual. A separate and private log will be used simply to relate participant names to numbers in the event that a participant needs to be contacted or contacts the Principle Investigator. This contact will only be with the Principle Investigator or Dale Stephen.

All information collected will be stored in locked filing cabinets and on computers with security passwords, in a secure computer lab at the University of Cape Town. Only certain people - the researchers for this study and certain University of Cape Town officials - have the legal right to review these research records. Your research records will not be released without your permission unless required by law or a court order. This data may be used to compliment further research in the field of concussion and head injuries, and provides researchers at UCT with a very specific and unique data set. However, the researchers involved in this study will only keep the data for a maximum of 5 years following the final hand-in of the Masters thesis

pertaining to Dale Stephen for which this project was intended. Once this time has elapsed, all data pertaining to individual participants stored on the computers will be permanently deleted, and all hard copies of this data will be shredded.

Do you agree to have your data stored for future use? Please circle.

AGREE / DISAGREE

10. Potential Risks

Some participants in the research study may feel anxious or claustrophobic with regards to the brain scan. Before the scan, an assistant will explain the scanning procedure to you. The research assistant will also allow you to have a "mock scan" where you will experience what it is like to have a scan, before undergoing the actual scan. The scan will not hurt you and it will not be dangerous in any way.

During the MRI neuroimaging assessment, certain metal objects, such as watches, credit cards, hairpins, and writing pens, may be damaged by the MRI scanner or pulled away from the body by the magnet. For these reasons, the participant will be asked to remove these objects before entering the scanner. When the scanner takes the images, the bed may vibrate, and the participant will hear loud banging noises. The participant will be given earplugs or earphones to protect the ears. Also, some people feel nervous in a small enclosed space such as that of the scanner. The participant will be able to see out of the scanner at all times, and the radiographer will not start the procedure until he/she tell us that you are comfortable. The participant will be able to stop the procedure at any time by squeezing a ball and can talk to the radiographers using an intercom that is built into the scanner. There are no known harmful long-term effects of the magnetic fields used in this study. Scans will be no longer than 1 hour.

In the event that this research-related activity results in an injury, treatment will be available including first aid, emergency treatment and follow-up care, as needed. If you have suffered a research related injury, let the investigator know right away.

If you wish to discuss the information above or any discomforts you may experience, you may ask questions now or call the Principal Investigators listed on this form.

Please note that the University of Cape Town carries a No Fault Clinical Liability policy for participants who suffer a research-related injury in researcher-initiated clinical research:

http://www.health.uct.ac.za/usr/health/research/hrec/forms/No_Fault_Insurance_2013.pdf

11. What if something goes wrong?

The University of Cape Town (UCT) has insurance cover for the event that research-related injury or harm results from your participation in the trial. The insurer will pay all reasonable medical expenses in accordance with the South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI) in the event of an injury or side effect resulting directly from your

participation in the trial. You will not be required to prove fault on the part of the University.

The University will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by

- ***The use of unauthorised medicine or substances during the study***
- ***Any injury that results from you not following the protocol requirements or the instructions that the study doctor may give you***
- ***Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the study medication***
- ***An injury that results from negligence on your part***

"By agreeing to participate in this study, you do not give up your right to claim compensation for injury where you can prove negligence, in separate litigation. In particular, your right to pursue such a claim in a South African court in terms of South African law must be ensured. Note, however, that you will usually be requested to accept that payment made by the University under the SA GCP guideline 4.11 is in full settlement of the claim relating to the medical expenses".

An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

12. Management of incidental findings on MRI scans

A radiologist on CUBIC staff and linked to this study, is going to review all the structural MRI scans for incidental findings. In an unfortunate case of an incidental finding a participant will be referred for further evaluation. Professor Figaji is a neurosurgeon who is regularly referred incidental lesions on MRI scan. He will undertake to consult, examine and counsel the participant where necessary as well as determine any further course of management that may be needed.

13. Signatures

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; the alternatives to being in the study; and how the participant's protected health information will be collected, used, and shared with others:

_____ _____

Signature of Person Obtaining Consent and Authorization Date

You have been informed about this study's purpose, procedures, and risks; how your protected health information will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your protected health information. By signing this form, you are not waiving any of your legal rights.

_____ _____

Signature of Person Consenting and Authorizing Date

Appendix B: Informed Consent Document (Control)

University of Cape Town
Psychology Department
Telephone: +27 21 650-3430
Fax: +27 21 650-4104

Investigating the neuropsychological effect and long term outcomes of multiple concussions and/or head injuries among university rugby players

Informed Consent to Participate in Research and Authorisation for Collection, Use, and Disclosure of Protected Health Information

This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your protected health information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. By participating in this study you will not be penalized or lose any benefits to which you would otherwise be entitled.

This study will be conducted in a manner that adheres to the ethical guidelines and principles of the International Declaration of Helsinki (Fortaleza, Brazil, 2013).

1. **Name of Participant**

_____

2. **Title of Research Study**

Investigating the neuropsychological effect and long term outcomes of multiple concussions and/or head injuries among university rugby players.

3. **What is the purpose of this research study?**

The purpose of this research study is to better understand whether or not, and how repeated instances of concussions and/or other head injuries contribute to altered brain functioning. More specifically the research intends to find out how these injuries manifest how the individual thinks, feels and behaves, and in any microstructural brain abnormalities. Also, the purpose is to observe how individuals with head injuries and concussions compare to people who have had no such injuries.

4. Principle Investigator(s) and Telephone Number(s)

Leigh Schrieff, Ph.D. (PI and supervisor)

Psychology Department

University of Cape Town

0216503708

Dale Stephen (Masters student)

Psychology Department

University of Cape Town

Lydia Wepener (Honours student)

Psychology Department

University of Cape Town

5. What will be done if you take part in this research study?

During this study, you will be required to complete a number of questionnaires and scales to obtain individual demographic information, personal characteristics, an approximation of your ability to think as well as the different ways in which you act and how you feel. Following initial testing, you may be contacted for repeated testing in September/October, 2015), where you may be asked to complete a brain scan. These testing procedures will be conducted in a private room at the Cape Universities Brain Imaging Centre (CUBIC), Groote Schuur Hospital. By signing the consent form, you are consenting to participation in the possible follow-up assessments as well.

6. What are the possible discomforts and risks?

There is minimal risk associated with this study. You may be required to return for a repeated assessment in September at CUBIC. You will be contacted by the Principle Investigator if this is the case. The testing procedures take approximately 1 ½ - 2 hours per person. Due to it being a more lengthy process, participants may feel fatigued or irritable during testing as the tasks require concentration. However, each participant will be given breaks where necessary as well as refreshments. The follow-up session is however not as time consuming.

7. What are the possible benefits of this study?

Significantly, this research aims to contribute to practical information regarding return-to-play decisions, thresholds of concussion injuries, and diagnostic indicators of concussion that are important for player safety. However, in order to do so it is necessary to compare the results of our rugby sample to those of individuals who have not sustained a concussion.

Also, as an undergraduate Psychology student you will be awarded 3 SRPP points for your participation in the initial testing session. If you are contacted for the repeated testing session you will be awarded a further 4 SRPP points.

8. Can you withdraw from this research study and if you withdraw, can information about you still be used and/or collected?

You may withdraw your consent and stop participation in this study at any time. Information already collected may still be used.

If you have a complaint or complaints about your rights and welfare as research participants, please contact the Human Research Ethics Committee.

Tel: 021 406 6492

E-mail: sumaya.ariefdien@uct.ac.za

9. Once personal information is collected, how will it be kept confidential in order to protect your privacy and what protected health information about you may be collected, used and shared with others?

If you agree to be in this research study, it is possible that some of the information collected might be copied into a "limited data set" to be used for other research purposes. If so, the limited data set will only include information that does not directly identify you. So, your identity will remain anonymous. Data will be labelled using participant numbers rather than names, so that they cannot be used to directly identify any particular individual. A separate and private log will be used simply to relate participant names to numbers in the event that a participant needs to be contacted or contacts the Principle Investigator. This contact will only be with the Principle Investigator or Dale Stephen.

All information collected will be stored in locked filing cabinets and on computers with security passwords, in a secure computer lab at the University of Cape Town. Only certain people - the researchers for this study and certain University of Cape Town officials - have the legal right to review these research records. Your research records will not be released without your permission unless required by law or a court order. This data may be used to compliment further research in the field of concussion and head injuries, and provides researchers at UCT with a very specific and unique data set. However, the researchers involved in this study will only keep the data for a maximum of 5 years following the final hand-in of the Masters thesis pertaining to Dale Stephen for which this project was intended. Once this time has elapsed, all data pertaining to individual participants stored on the computers will be permanently deleted, and all hard copies of this data will be shredded.

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AGREE / DISAGREE

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During the MRI neuroimaging assessment, certain metal objects, such as watches, credit cards, hairpins, and writing pens, may be damaged by the MRI scanner or pulled away from the body by the magnet. For these reasons, the participant will be asked to remove these objects before entering the scanner. When the scanner takes the images, the bed may vibrate, and the participant will hear loud banging noises. The participant will be given earplugs or earphones to protect the ears. Also, some people feel nervous in a small enclosed space such as that of the scanner. The participant will be able to see out of the scanner at all times, and the radiographer will not start the procedure until he/she tell us that you are comfortable. The participant will be able to stop the procedure at any time by squeezing a ball and can talk to the radiographers using an intercom that is built into the scanner. There are no known harmful long-term effects of the magnetic fields used in this study. Scans will be no longer than 1 hour.

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The University will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by

- ***The use of unauthorised medicine or substances during the study***
- ***Any injury that results from you not following the protocol requirements or the instructions that the study doctor may give you***
- ***Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the study medication***
- ***An injury that results from negligence on your part***

"By agreeing to participate in this study, you do not give up your right to claim compensation for injury where you can prove negligence, in separate litigation. In particular, your right to pursue such a claim in a South African court in terms of South African law must be ensured. Note, however, that you will usually be requested to accept that payment made by the University under the SA GCP guideline 4.11 is in full settlement of the claim relating to the medical expenses".

An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

12. Management of incidental findings on MRI scans

A radiologist on CUBIC staff and linked to this study, is going to review all the structural MRI scans for incidental findings. In an unfortunate case of an incidental finding a participant will be referred for further evaluation. Professor Figaji is a neurosurgeon who is regularly referred incidental lesions on MRI scan. He will undertake to consult, examine and counsel the participant where necessary as well as determine any further course of management that may be needed.

13. Signatures

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; the alternatives to being in the study;

and how the participant's protected health information will be collected, used, and shared with others:

_____ _____

Signature of Person Obtaining Consent and Authorization Date

You have been informed about this study's purpose, procedures, and risks; how your protected health information will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your protected health information. By signing this form, you are not waiving any of your legal rights.

_____ _____

Signature of Person Consenting and Authorizing Date

Appendix C: Demographic and Medical History Questionnaire (Rugby Group)

Name: Age: Race:

Occupation:

Rugby team currently playing for:

Student Number (if applicable):

Rugby Playing Position(s):

Cell Number: Email address:

Height (cm): Weight (kg):

Are you fluent in English? YES NO

Please specify any current/past learning disabilities:

Have you been previously diagnosed with a psychiatric illness? YES NO
If yes, please specify what you were diagnosed with, when you were diagnosed and list your medication under the relevant headings below.

Diagnosis	Age at diagnosis/ Year diagnosed	Medication	Still on Medication?

Have you been previously formally diagnosed with a concussion by a medical health practioner? *(please specify dates, and details regarding whether or not there was a loss of conciousness and for how long. Please also state how long you were subsequently booked off playing sport.*

Date of diagnosis	Loss of consciousness	Duration of loss of consciousness	Duration booked off sport participation
	YES NO		
	YES NO		

If you answered yes to the question above, indicate in a few words what it was like being concussed. What was your experience in terms of symptoms you experienced, ability to return to exercise, ability top do school or office work, your relationships with your peers ect.?

Is there any instance(s) where you feel you may have been concussed despite no formal diagnosis? *(headache, nausea, dizziness, ringing in the ears ect.) Please provide details of this regarding when it occurred, what symptoms you felt, and for how long you were booked off sport after this injury.*
YES NO
WHEN?

SYMPTOMS

DURATION BOOKED OFF SPORT FOR
How many years have you been playing contact rugby for? _____

Please list what types of sporting/exercise activities you have been or are currently involved in e.g., soccer, American football, running, swimming, squash, hiking, gym etc.
Please also state how often you are involved in each one and at what level you play(ed) (social, school team, university team ect.)

Sport	Duration of participation	Level of play

Appendix D: Demographic and Medical History Questionnaire (Control Group)

Demographic and medical questionnaire

Name: Age: Race:

Occupation:

Telephone Number: Email address:

Student Number (if applicable):

Height (cm): Weight (kg):

Are you fluent in English? YES NO

Please specify any current learning disabilities:

Have you been previously diagnosed with a psychiatric illness? YES NO
If yes, please specify what you were diagnosed with:

Have you been previously formally diagnosed with a concussion by a medical health practioner? *(please specify dates, and details regarding whether or not there was a loss of conciousness and for how long. Please also state how long you were booked off playing sport for.*

Date of diagnosis	Loss of consciousness	Duration of loss of consciousness	Duration booked off sport participation
	YES NO		
	YES NO		
	YES NO		

If you answered yes to the question above, indicate in a few words what it was like being concussed. What was your experience in terms of symptoms you experienced, ability to return to exercise, ability top do school or office work, your relationships with your peers ect.?

Is there any instance(s) where you feel you may have been concussed despite no formal diagnosis? *(headache, nausea, dizziness, ringing in the ears ect.) Please provide details of this regarding when it occurred, what symptoms you felt, and for how long you were booked off sport after this injury.*
YES NO
WHEN?

SYMPTOMS

DURATION BOOKED OFF SPORT FOR

Please list what types of sporting/exercise activities you have been or are currently involved in e.g., running, swimming, squash, hiking, gym.
Please also state how often you are involved in each one and at what level you play (social, school team, university team ect.)

Sport	Duration of participation	Level of play

Have you ever been or are currently involved in contact sport that may result in head collisions? e.g., rugby, American football, soccer.
If yes, please specify which sport, the duration of your participation and at what level you play(ed) (social, school team, university team ect.)

Sport	Duration of participation	Level of play

Appendix E: Debriefing Form

Debriefing Form

University of Cape Town
Psychology Department
Telephone: +27 21 650-3430
Fax: +27 21 650-4104

Formal Study Debriefing Form

Thank you for participating in the research study.

This form provides you with information about the study in which you have just participated, and explains in full the methods of collection of data for this research study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also explain this study to you in full and answer all of your questions.

1. **Name of Participant ("Study Subject")**

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2. **Title of Research Study**

Investigating the neuropsychological effect and long term outcomes of multiple concussions and/or head injuries among university rugby players.

3. **What is the purpose of this research study?**

The purpose of this research study was to better understand the nature of repeated concussive and/or sub-concussive head injuries in rugby and how they affect brain functioning compared with those not involved in a contact sport and no such injuries. Furthermore, the study was designed to collect data on the forces involved with head injuries sustained by rugby players during the season and, and whether these impacted on brain functioning. The long-term design of the study ensured that as the researched I could track individuals' recovery over the course of the season.

4. **What was done during this research study?**

During this study, you were required to complete a number of questionnaires and scales to obtain individual demographic information, personal characteristics, and an approximation of cognitive functioning. You may also have been involved in follow-up testing if you had sustained a concussion and/or multiple high impact head injuries. If you were a rugby player in the study you were required to wear a small patch that could monitor head collisions in real time to determine the amount and intensity of head collisions.

5. **Was any deception used in this research study?**

No.

6. **Is anything further required of you?**

There is nothing further required of you. If you do however have any questions or concerns regarding my research you may contact the Principle Investigator involved: either Dale Stephen (dalste12@gmail.com) or Dr. Leigh Schrieff-Elson (leigh.e.elson@gmail.com).

7. **Confidentiality**

All data collected for the study will be kept confidential – this is not to be confused with the results of the study which will be made available. Data will be labelled using participant numbers rather than names, so that they cannot be used to directly identify any particular individual. Furthermore, all data will be stored in a locked filing cabinets in the department. Data will also be stored on a password-protected computer. Only certain people – the researchers for this study and certain University of Cape Town officials – are afforded the legal right to review these research records.

8. **Signatures**

As a representative of this study, I have explained to the participant, in detail, the purpose, the procedures, and any deception used in this research study.

_____ _____

Signature of Person Obtaining Consent and Authorization Date

I have been informed, in detail, about this study's purpose, procedures, and deceptions. I have been given the opportunity to ask questions before I sign. By signing this form, I am not waiving any of my legal rights.

_____ _____

Signature of Person Consenting and Authorizing Date

Appendix F: Within-group Correlation Matrices

Table 9. *Within-group correlations between number of previous concussions (total concussions) and emotional and behavioural outcomes.*

		Total concussions	AUDIT	BDI-II	GHQ-28	STAI-T	BIS-11	T-ANG	AXIndex
Total concussions (undiagnosed + diagnosed)	Pearson Correlation	1	-.035	.097	.100	-.169	-.048	.107	-.045
	Sig. (1-tailed)		.374	.184	.178	.058	.332	.161	.338
	N	88	87	88	88	88	86	87	87
AUDIT	Pearson Correlation	-.035	1	.229*	.245*	.266**	.354**	.219*	.238*
	Sig. (1-tailed)	.374		.016	.011	.006	.000	.022	.014
	N	87	87	87	87	87	85	86	86
BDI-II	Pearson Correlation	.097	.229*	1	.500**	.563**	.366**	.253**	.236*
	Sig. (1-tailed)	.184	.016		.000	.000	.000	.009	.014
	N	88	87	88	88	88	86	87	87
GHQ-28	Pearson Correlation	.100	.245*	.500**	1	.386**	.190*	.138	.114
	Sig. (1-tailed)	.178	.011	.000		.000	.040	.101	.147
	N	88	87	88	88	88	86	87	87
STAI-T	Pearson Correlation	-.169	.266**	.563**	.386**	1	.431**	.361**	.438**
	Sig. (1-tailed)	.058	.006	.000	.000		.000	.000	.000
	N	88	87	88	88	88	86	87	87
BIS-11	Pearson Correlation	-.048	.354**	.366**	.190*	.431**	1	.271**	.442**
	Sig. (1-tailed)	.332	.000	.000	.040	.000		.006	.000
	N	86	85	86	86	86	86	85	85
T-ANG	Pearson Correlation	.107	.219*	.253**	.138	.361**	.271**	1	.581**
	Sig. (1-tailed)	.161	.022	.009	.101	.000	.006		.000
	N	87	86	87	87	87	85	87	87
AXIndex	Pearson Correlation	-.045	.238*	.236*	.114	.438**	.442**	.581**	1
	Sig. (1-tailed)	.338	.014	.014	.147	.000	.000	.000	
	N	87	86	87	87	87	85	87	87

Table 10. *Within-group correlations between presence of loss of consciousness and emotional and behavioural outcomes*

		LOC_y_n	AUDIT	BDI-II	GHQ-28	STAI-T	BIS-11	T-ANG	AXIndex
LOC_y_n	Pearson Correlation	1	.068	.178*	.123	-.047	.183*	.032	-.063
	Sig. (1-tailed)		.267	.048	.128	.331	.046	.385	.281
	N	88	87	88	88	88	86	87	87
AUDIT	Pearson Correlation	.068	1	.229*	.245*	.266**	.354**	.219*	.238*
	Sig. (1-tailed)	.267		.016	.011	.006	.000	.022	.014
	N	87	87	87	87	87	85	86	86
BDI-II	Pearson Correlation	.178*	.229*	1	.500**	.563**	.366**	.253**	.236*
	Sig. (1-tailed)	.048	.016		.000	.000	.000	.009	.014
	N	88	87	88	88	88	86	87	87
GHQ-28	Pearson Correlation	.123	.245*	.500**	1	.386**	.190*	.138	.114
	Sig. (1-tailed)	.128	.011	.000		.000	.040	.101	.147
	N	88	87	88	88	88	86	87	87
STAI-T	Pearson Correlation	-.047	.266**	.563**	.386**	1	.431**	.361**	.438**
	Sig. (1-tailed)	.331	.006	.000	.000		.000	.000	.000
	N	88	87	88	88	88	86	87	87
BIS-11	Pearson Correlation	.183*	.354**	.366**	.190*	.431**	1	.271**	.442**
	Sig. (1-tailed)	.046	.000	.000	.040	.000		.006	.000
	N	86	85	86	86	86	86	85	85
T-ANG	Pearson Correlation	.032	.219*	.253**	.138	.361**	.271**	1	.581**
	Sig. (1-tailed)	.385	.022	.009	.101	.000	.006		.000
	N	87	86	87	87	87	85	87	87
AXIndex	Pearson Correlation	-.063	.238*	.236*	.114	.438**	.442**	.581**	1
	Sig. (1-tailed)	.281	.014	.014	.147	.000	.000	.000	
	N	87	86	87	87	87	85	87	87

Table 11. W*ithin-group correlations between duration of loss of consciousness (composite score) and emotional and behavioural outcomes*

		Duration of LOC composite	AUDIT	BDI-II	GHQ-28	STAI-T	BIS-11	T-ANG	T-ANG%	AXIndex
Duration of LOC composite	Pearson Correlation	1	.103	.233*	.115	-.102	.087	.013	.003	-.033
	Sig. (1-tailed)		.171	.014	.143	.172	.214	.452	.487	.382
	N	88	87	88	88	88	86	87	87	87
AUDIT	Pearson Correlation	.103	1	.229*	.245*	.266**	.354**	.219*	.195*	.238*
	Sig. (1-tailed)	.171		.016	.011	.006	.000	.022	.036	.014
	N	87	87	87	87	87	85	86	86	86
BDI-II	Pearson Correlation	.233*	.229*	1	.500**	.563**	.366**	.253**	.246*	.236*
	Sig. (1-tailed)	.014	.016		.000	.000	.000	.009	.011	.014
	N	88	87	88	88	88	86	87	87	87
GHQ-28	Pearson Correlation	.115	.245*	.500**	1	.386**	.190*	.138	.136	.114
	Sig. (1-tailed)	.143	.011	.000		.000	.040	.101	.105	.147
	N	88	87	88	88	88	86	87	87	87
STAI-T	Pearson Correlation	-.102	.266**	.563**	.386**	1	.431**	.361**	.340**	.438**
	Sig. (1-tailed)	.172	.006	.000	.000		.000	.000	.001	.000
	N	88	87	88	88	88	86	87	87	87
BIS-11	Pearson Correlation	.087	.354**	.366**	.190*	.431**	1	.271**	.250*	.442**
	Sig. (1-tailed)	.214	.000	.000	.040	.000		.006	.010	.000
	N	86	85	86	86	86	86	85	85	85
T-ANG	Pearson Correlation	.013	.219*	.253**	.138	.361**	.271**	1	.970**	.581**
	Sig. (1-tailed)	.452	.022	.009	.101	.000	.006		.000	.000
	N	87	86	87	87	87	85	87	87	87
T-ANG%	Pearson Correlation	.003	.195*	.246*	.136	.340**	.250*	.970**	1	.582**
	Sig. (1-tailed)	.487	.036	.011	.105	.001	.010	.000		.000
	N	87	86	87	87	87	85	87	87	87
AXIndex	Pearson Correlation	-.033	.238*	.236*	.114	.438**	.442**	.581**	.582**	1
	Sig. (1-tailed)	.382	.014	.014	.147	.000	.000	.000	.000	
	N	87	86	87	87	87	85	87	87	87

Table 12. W*ithin-group correlations between concussion composite score and emotional and behavioural outcomes*

		Concussion_Composite	AUDIT	BDI-II	GHQ-28	STAI-T	BIS-11	T-ANG	AXIndex
Concussion_Composite	Pearson Correlation	1	.021	.162	.103	-.142	.005	.108	-.036
	Sig. (1-tailed)		.424	.066	.170	.093	.480	.161	.371
	N	88	87	88	88	88	86	87	87
AUDIT	Pearson Correlation	.021	1	.229*	.245*	.266**	.354**	.219*	.238*
	Sig. (1-tailed)	.424		.016	.011	.006	.000	.022	.014
	N	87	87	87	87	87	85	86	86
BDI-II	Pearson Correlation	.162	.229*	1	.500**	.563**	.366**	.253**	.236*
	Sig. (1-tailed)	.066	.016		.000	.000	.000	.009	.014
	N	88	87	88	88	88	86	87	87
GHQ-28	Pearson Correlation	.103	.245*	.500**	1	.386**	.190*	.138	.114
	Sig. (1-tailed)	.170	.011	.000		.000	.040	.101	.147
	N	88	87	88	88	88	86	87	87
STAI-T	Pearson Correlation	-.142	.266**	.563**	.386**	1	.431**	.361**	.438**
	Sig. (1-tailed)	.093	.006	.000	.000		.000	.000	.000
	N	88	87	88	88	88	86	87	87
BIS-11	Pearson Correlation	.005	.354**	.366**	.190*	.431**	1	.271**	.442**
	Sig. (1-tailed)	.480	.000	.000	.040	.000		.006	.000
	N	86	85	86	86	86	86	85	85
T-ANG	Pearson Correlation	.108	.219*	.253**	.138	.361**	.271**	1	.581**
	Sig. (1-tailed)	.161	.022	.009	.101	.000	.006		.000
	N	87	86	87	87	87	85	87	87
AXIndex	Pearson Correlation	-.036	.238*	.236*	.114	.438**	.442**	.581**	1
	Sig. (1-tailed)	.371	.014	.014	.147	.000	.000	.000	
	N	87	86	87	87	87	85	87	87