Demographic Predictors of ImPACT (Concussion Test Battery) Performance among South
African Sportsmen

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Glossary

Term	
TBI	Traumatic brain injury
mTBI	Mild traumatic brain injury
SRC	Sports-related concussion
USA	United States of America
ImPACT	Immediate Post-Concussion Assessment and Cognitive Testing
LOC	Loss of consciousness
ADHD	Attention-deficit hyperactivity disorder
CNS	Central nervous system
HIT	Head Impact Telemetry
UCT	University of Cape Town
SRPP	Student Research Participation Programme

Abstract

Mild traumatic brain injuries (mTBIs), namely concussion, are a major public health concern. One of the most widely used neuropsychological test batteries in concussion management is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. Concussion management involves baseline evaluation, return-to-play assessments and treatment. Studies have found variables other than the presence/absence of concussion predict baseline scores on ImPACT. This is problematic, as it may have implications for the interpretation of outcome scores and consequently, concussion management. Therefore, this study aimed to determine whether demographic, injury-related, and/or behavioural and academic factors affect baseline ImPACT scores, using a South African sample, given the lack of research in this particular setting. The study investigated the following hypotheses: that age, a history of concussion (including number of times one is concussed), and behavioural and academic factors (attention-deficit hyperactivity disorder and/or a learning disability), are predictors of baseline ImPACT scores. This study employed an exploratory within-subjects design with an element of a between-subjects design using baseline ImPACT data obtained from a larger study (Stephen, 2016). The participants ($N = 105$), aged 18-27 years, were male sportsmen, recruited from various rugby clubs and students from the University of Cape Town. Using forward stepwise multiple regression, we found that only age and learning disability significantly predicted baseline scores on one module of ImPACT, Impulse Control. Out of interest, an independent sample t-test and a one-way ANOVA were run to determine any between-group differences. The results of the analyses revealed no between-group difference on any module of ImPACT for history of concussion or number of times concussed. Given the widespread use of ImPACT for baseline testing, it is important for an athlete's baseline ImPACT score to be as accurate as possible because the difference between baseline and subsequent ImPACT scores are being used to make important return-to- play decisions as well as aid in future management of concussions. This study highlights the need to consider possible confounds to outcomes of ImPACT testing.

Traumatic brain injuries (TBIs) are a major cause of mortality and morbidity worldwide (Roozenbeek, Maas, & Menon, 2013). TBIs can range from mild to moderate to severe. The conversation around mild TBIs, such as concussion, and sport-related concussions (SRCs) in particular, is of relevance today as such injuries have long been and still are considered a public health concern, both locally and globally (Lovell et al., 2003; Rao, Syeda, Roy, Peters, & Vaishnavi, 2017; Schatz, Pardini, Lovell, Collins, & Podell, 2006). This is evident when considering the significant number of people who sustain one or more concussions while participating in a sport. For example, in the United States of America (USA), between 1.6 and 3.8 million people report experiencing a SRC per year (Weinberger & Briskin, 2013). Added to this, the number of high school athletes in the USA that sustain SRCs has reportedly grown by 16.5% in the years 1997 to 2008 (Weinberger & Briskin, 2013). The sensationalism on the topic of SRCs has been reinforced in the media and awareness around the importance of diagnosis and management has increased. Despite this, most cases of SRCs go undiagnosed (Littleton & Guskiewicz, 2013). This is possibly due to the lack of any obvious physical symptoms, athletes failing to report symptoms due to a fear of missing game time, and/or a belief that the injury was not severe enough to seek medical attention (Littleton & Guskiewicz, 2013; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Therefore, it is important to consider the diagnosis of SRCs and the neurocognitive tools that are available to aid in diagnosis and management of the injury. One such tool is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) neuropsychological battery, which has been widely-used. One might expect that having sustained a concussion or not should be the main predictor of performance on this measure, however emerging research suggest that other factors, other than presence of concussion, might affect performance on ImPACT.

Concussion

Concussion is caused by impacts that are directly or indirectly applied to the head, neck or shoulder area (Barlow, Schlabach, Peiffer, & Cook, 2011; Patricios, Kohler, & Collins, 2010). These impacts result in biomechanical forces being relayed to the brain, which may or may not result in a loss of consciousness (LOC; McCory et al., 2013; Rao et al., 2017; Weinberger & Briskin, 2013). The injury is generally described as a neuropathological disturbance that is functional rather than structural in nature (McCory et al., 2013; Rao et al., 2017; Weinberger & Briskin, 2013). Although concussion is classified as mild, this does not imply that the injury has no associated concerning symptoms. The symptoms of concussion are generally broken down into three groups: physical (e.g., nausea, headache), emotional (e.g.,

depressed, irritable) and cognitive (e.g., decreased attention, processing speed and executive dysfunction). These typically resolve within 7-10 days (Rao et al., 2017).

Due to the high incidence of, and sequelae associated with, the injury, concussion management is important. Concussion management involves baseline evaluation, return-to-play assessments and treatment (Cottle, Hall, Patel, Barnes, & Ketcham, 2017). Cognitive testing is widely used in the assessment and management of concussion injuries (McCory et al., 2013). These commonly take the form of computerized tests that tend to involve the use of symptom scales and cognitive tasks (McCory et al., 2013). One of the most widely used computerized tests in concussion management is ImPACT (Shuttleworth-Edwards et al., 2008a; Shuttleworth-Edwards, Smith, & Radloff, 2008b).

ImPACT

ImPACT was developed and first used by Lovell, Collins, Podell, Powell, and Maroon in 2000, and consists of three components: a demographic scale, a post-concussion symptom scale, and a neuropsychological test battery (Cottle et al., 2017). The demographic scale is used to document factors about each participant, including their age, race, sex, and previous history of concussion, diagnoses of learning disabilities and/or attention-deficit disorders (Cottle et al., 2017; Lovell, Collins, Podell, Powell, & Maroon, 2000). The post-concussion symptom scale measures the severity of symptoms (e.g., headache, dizziness, difficulty concentrating and visual problems) related to concussion (Lovell et al., 2000). The scale also involves investigating the number of hours the participant slept the previous day, medication usage and the date on which the participant sustained their most recent concussion (Lovell et al., 2000). The neuropsychological test battery investigates cognitive functioning. This component involves the computerized administration of seven modules that can take up to 30 minutes to complete, and results in a total of 5 computer-generated scores: memory (visual and verbal), visual motor processing speed, reaction time and impulse control (Lovell et al., 2000; Lovell et al., 2003; Shuttleworth-Edwards et al., 2008a).

ImPACT globally and locally. ImPACT is used widely in South Africa in clinical settings, but studies on the effectiveness of ImPACT with South African samples are limited. However, ImPACT has been widely studied in a global context, especially in the USA. One such study by Lovell et al. (2003) used the memory measure of ImPACT to investigate high school students' recovery from SRCs. Participants were split into two groups, those with a history of concussion and those without. ImPACT baseline scores for the high school sample revealed that within the group with a history of concussion, those with a more severe

concussion history performed poorer than those with a milder concussion history, in terms of the number and severity of concussions (Lovell et al., 2003).

In line with this, in local research conducted by Shuttleworth-Edwards et al. (2008a; the most recent South African study on the topic to date), neurocognitive vulnerability of South African university rugby players, as a function of multiple concussions over time, was compared to non-contact sports controls on 3 of the 5 ImPACT composite scores assessing memory and attentional modalities. Baseline ImPACT scores showed that South African rugby players performed poorer on measures of memory and attention than controls (Shuttleworth-Edwards et al., 2008a). These findings suggest that variables other than immediate concussions can affect performance on ImPACT. In both of these studies, a history of concussion, and not just the immediate concussion, could predict performance on the baseline ImPACT scores.

Predictors of performance on ImPACT. ImPACT is the most widely used neurocognitive test in studies of predictors of baseline scores (Covassin, Elbin, Larson, & Kontos, 2012; Solomon & Kuhn, 2014; Solomon & Haase, 2008). A number of international studies have suggested that various factors can affect an individual's performance on this test battery. Demographic variables (such as age), injury-related variables (i.e. previous history of concussion and number of times concussed), and behavioural and academic factors (i.e. attention-deficit disorders and learning disabilities), have been found to affect cognitive baseline performance on ImPACT (Covassin et al., 2012; Solomon & Kuhn, 2014; Solomon & Haase, 2008).

Demographic predictors. Researchers report age as one of the demographic factors influencing baseline performance on ImPACT. Studies on the influence of age on baseline ImPACT scores often involve comparing high school and college (university) athletes and seem to report consistent results that high school athletes perform significantly poorer than college athletes on baseline ImPACT scores (Covassin et al., 2012; Littleton & Guskiewicz, 2013). The results of one such study showed that high school athletes have significantly lower scores on verbal memory, visual memory and reaction time compared to their college counterparts (Littleton & Guskiewicz, 2013). These scores were still lower than college athletes' 7 days after concussion (Littleton & Guskiewicz, 2013). Although sex and race are other demographic predictors reported in the literature, these are not relevant to the current study. This is because data used in the current study were collected in a previous, larger study (Stephen, 2016). Participants in the Stephen (2016) study were all male, and race was not collected as part of those data.

Injury-related predictors. Researchers have shown that a previous diagnosis of concussion/s affects and subsequently predicts performance on baseline ImPACT scores. Participants with a history of concussion (apart from the immediate concussion) perform significantly worse on ImPACT than participants with no history of concussion (Lovell et al., 2003). Specifically, Lovell et al. (2003) found that the group with a history of concussion performed significantly poorer on the memory (verbal and visual) modules than controls. Furthermore, those with concussions classified as 'more severe' (i.e. sustaining mental changes lasting longer than 5 minutes after sustaining the injury) performed significantly poorer on the memory module than those with concussions that were classified as 'less severe' (i.e. sustaining no mental changes that lasted less than 5 minutes after sustaining the injury) (Lovell et al., 2003).

Mannix et al. (2014) conducted a similar study investigating the association between a history of concussion and baseline performance on ImPACT. Results showed a negative relationship between number of concussions and scores on baseline testing (Mannix et al., 2014). Specifically, the higher the number of previous concussions, the lower the performance on the verbal memory and impulse control modules of the ImPACT battery (Mannix et al., 2014). Similar to Mannix et al. (2014), Plancher, Brooks-James, Nissen, Diduch, and Petterson (2014) found that individuals with a history of concussion had a lower baseline performance ImPACT score than individuals with no history of concussion. However, there are other variables, including behavioural and academic factors that have also been shown to predict performance on baseline ImPACT scores.

Behavioural and academic predictors. Research has shown a diagnosis of Attention-Deficit Hyperactivity Disorder (ADHD) and/or a learning disability to be associated with poorer baseline performance on ImPACT (Cottle et al., 2017; Elbin et al., 2013; Zuckerman, Lee, Odom, Solomon, & Sills, 2013). These behavioural factors appear to be associated with impaired performance, especially on baseline visual motor processing speed (Cottle et al., 2017; Zuckerman et al., 2013) as well as baseline verbal and visual memory scores (Zuckerman et al., 2013). Studies using computerised batteries similar to ImPACT, such as the Central Nervous System (CNS) Vital Signs, have found that the baseline scores of participants with ADHD were significantly worse on psychomotor speed than controls (Littleton et al., 2015). The CNS Vital Signs tests included similar components to those included in ImPACT - such as measures of verbal memory, visual memory, attention, processing speed, and reaction time (Littleton et al., 2015).

Aim, Rationale and Hypotheses

There are many factors that can influence baseline cognitive performance in concussion testing. To use the data collected from these tests in the best possible way, there is a need to consider the factors that influence such performance. As discussed above there are demographic, injury-related, and behavioural and academic factors that reportedly predict performance on ImPACT.

ImPACT is one of the most widely used computerized tests for baseline testing. It is therefore important for an athlete's baseline ImPACT score to be as accurate as possible as this score is compared with the athlete's subsequent ImPACT scores, for example, post-concussion. It is also important because the difference between baseline and subsequent ImPACT scores are being used to make important return-to-play decisions as well as aid in future management of concussions (Barlow et al., 2011). However, this becomes problematic because individuals may perform poorly on this concussion test for reasons other than having sustained a concussion.

The aim of this research was therefore to investigate what, if any, demographic, injury-related and/or behavioural and academic factors affect baseline ImPACT scores using a South African sample.

This study tested the following hypotheses:

1. Age is a predictor of baseline ImPACT scores
2. A history of concussion is a predictor of baseline ImPACT scores.
3. Behavioural and academic factors (ADHD and/or learning disability) are predictors of baseline ImPACT scores.

Methods

Study design and setting

The study was located in the quantitative paradigm and employed an exploratory, within-subjects design, with an element of a between-subjects design. The data for this study was collected as part of a larger study by Stephen (2016) in the Department of Psychology at the University of Cape Town (UCT) titled: *Concussion, Head Impact Telemetry (HIT) Data and Neuropsychological Outcomes in Rugby.* We used the baseline ImPACT and demographic, injury-related, and behavioural and academic data that was collected for that study. All participants completed testing in a private computer room at UCT's Upper Campus. In the current study, baseline ImPACT scores were analysed in order to determine whether there was

a relationship between certain variables on the demographic scale (which includes demographic, injury-related, and behavioural and academic data) and baseline ImPACT performance.

Participants

The participants ($N = 105$) were recruited using purposive and convenience sampling techniques. Participants included male rugby players who were purposively recruited from the UCT Rugby Football Club, Western Province Rugby Academy, Villager Football Club, and a rugby team that participated in the UCT Internal League. Convenience sampling was used to recruit participants who were male Psychology non-contact sports students at UCT who were awarded 3 Student Research Participation Points (SRPP) that were necessary to meet course requirements. All participants in the larger study were English-speaking males, aged 18-27 years.

Power analysis. Based on literature on the topic (Cottle et al., 2017; Covassin et al., 2012; Zuckerman et al., 2013), 95% power for detecting a medium sized effect (0.5), $p = .05$, was selected. According to G-Power, a significance level of .05 requires a sample size of at least 30 participants. In order to improve the ability to generalise to the larger population, more than 30 participants were included in the analyses.

Exclusion criteria. The exclusion criteria for the larger study were the following: (a) the female sex, (b) individuals who were not fluent in English (because the tests being employed in the larger study were only available in English) and, (c) individuals who are younger than 18 years of age.

Materials

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). This neuropsychological test battery is comprised of three components: the demographic scale, post-concussion scale, as well as a neuropsychological test battery (Lovell et al., 2000). For the purpose of this study, we only used the demographic scale and the neuropsychological test battery.

ImPACT demographic scale. This scale involved a series of questions requiring participants to report their age, weight, height, language proficiency, learning disabilities, current or previous history of concussion, current or previous history of psychiatric disorder/s, and the use of chronic medication.

ImPACT neuropsychological test battery. This neuropsychological test battery included measures of memory, processing speed, attention and reaction time (See Appendix A; Lovell et al., 2003). The scores from these tests were converted into five separate composite

scores: Verbal Memory (assesses verbal attentional processes, learning and memory), Visual Memory (assesses visual attention and scanning, learning, and memory), Visual Motor Processing Speed (assesses visual processing, learning and memory, and visual motor response speed), Reaction Time (assesses average response speed), and Impulse Control (assesses sum of errors committed).

Research has shown that ImPACT is both reliable and stable – it has a test-retest reliability ranging from 0.65 to 0.86 (Iverson, Lovell, & Collins, 2003). ImPACT also reportedly has good validity and is sensitive, at about 90%, in its ability to detect dysfunction in cognitive processes and concussion diagnoses (Van Kampen, Lovell, Pardini, Collins, & Fu, 2006).

A study was conducted by Shuttleworth-Edwards, Whitefield-Alexander, Radloff, Taylor, and Lovell (2015) to determine whether ImPACT can be appropriately used in a South African context. This was achieved by comparing the baseline ImPACT neuropsychological test battery scores and post-concussion symptom scales for South African rugby players to age-matched USA football players (Shuttleworth-Edwards et al., 2015). Results of the study found that ImPACT can be appropriately used in a South African context on athletes whose first language is English.

Procedure

Prior to data collection, for participants who were rugby players, information sessions were held at each rugby club. During these sessions, rugby players and support staff were informed of the nature of the study, including the aims, objectives, procedure, and the exclusion criteria. Male, Psychology, non-contact sports students at UCT were informed about the study through a SRPP announcement. Consent forms (see Appendix B) were distributed which participants returned to the researcher of the larger study. The contact details of the researcher in charge were given to the participants so that testing sessions could be arranged at a time suitable for each participant. Each testing session lasted approximately one hour and thirty minutes. To be time effective, group testing sessions were offered. There were no more than ten participants in a testing session.

Baseline assessments. Participants completed ImPACT testing in a private computer room at UCT's Upper Campus. At the start of each session, participants were given the opportunity to leave after they had read the consent forms and if they did not want to continue with their participation in the study. Each participant had access to a computer on which ImPACT was run. ImPACT required the participants to complete the demographic scale first. This was then followed by ImPACTs 5-component neuropsychological test battery. Each

cognitive task started with a practice round in order to familiarise participants on how to approach each task.

Statistical Analysis

We used the statistical software SPSS, version 24.0, in the current study to analyse the data collected in the Stephen (2016) study, with the significance level set at $\alpha = .05$. First we generated descriptive statistics, including central tendency data. From this analysis, the presence of any outliers or missing data was detected. The main analysis for the current study was a forward stepwise multiple regression. The predictor variables for this study included age (demographic variable), history of concussion and number of times concussed (injury-related variables), and ADHD and learning disability (behavioural and academic factors). The outcome variables included the following modules of ImPACT: Memory (Visual), Memory (Verbal), Visual Motor Processing Speed, Reaction Time and Impulse Control. The assumptions that are relevant to multiple regression were considered, and if it was upheld the analysis continued. An independent samples t-test was also run to determine whether there were any between-group differences on baseline scores of ImPACTs modules for history of concussion. Lastly, a one-way ANOVA was run to determine whether there were any between-group differences on the baseline scores of ImPACTs modules for number of times concussed.

Ethical considerations

The larger study had ethical approval from both the UCT Faculty of Health Sciences Human Research Ethics Committee (REF: HREC010\2015; see Appendix C). The current study received ethical approval from UCT Department of Psychology.

Informed consent process. In the Stephen (2016) study consent forms were distributed to participants as described before. The consent forms informed the participants that participation was voluntary, that they were free to withdraw participation from the study at any point without being penalized.

Privacy and confidentiality. Each participant was assigned a number. The identities of the participants were kept private from the public. All information obtained from the testing session was kept strictly confidential. In the event that the research is published, participant numbers will be used instead of names of participants and/or rugby clubs. In no way are the names of the participants connected to their assigned number in the case that the findings are published.

Potential risks and discomforts. There was minimal risk associated with participation in the Stephen (2016) study. Fatigue and/or irritability as a result of the lengthy testing sessions

and/or the concentration required to complete the cognitive tests, may have been a cause for discomfort. However, participants were allowed to take breaks whenever necessary.

Minimising risk. To further minimize the risk involved in participation, the participants were informed of the nature of the study during the information sessions at each rugby club.

The participants received debriefing after participation. The debriefing form included contact numbers and email addresses of the researchers if participants had any unanswered questions at any time after the testing session.

Potential benefits of the current study.

The findings may be beneficial in creating awareness of confounding variables that predict baseline ImPACT performance and that factors other than concussion may affect performance on ImPACT.

Results

Descriptive Statistics. Table 1 presents the descriptive data for participants in the study. Participants were on average, 20 years old. Results show that participants performed better, on average, for the *Verbal* as compared to the *Visual* component of *Memory,* although, according to normative data, both scores were relatively average when considering that the upper range of these scores is 100 (Iverson et al., 2003; see Appendix D for Approximate Classifications Ranges for Index Scores). Participants performed well within the average for *Visual Motor Processing Speed, M* = 38.16, considering that the average index score for university men is between 32.5 to 42.0 (Iverson et al., 2003). Participants performed average for *Reaction Time* as average index scores range between .60 to .52 (Iverson et al., 2003). Considering that the lower the score for *Impulse Control* the better the performance, a score of 0 indicates that some participants (*n* = 6) made no errors on this component, while a score of 28 indicates confusion and/or carelessness as more than 20 errors were made.

Table 1

Descriptive Statistics of Sample (N = 105)

	M	*SD*	*Min*	*Max*
Age	20.52	2.03	18.00	27.00
Memory (Verbal)	86.40	9.69	45.00	100.00
Memory (Visual)	78.99	13.58	41.00	100.00
Visual Motor Processing Speed	38.16	7.37	9.25	52.00
Reaction Time	.59	.10	.45	1.17
Impulse Control	5.36	4.53	.00	28.00

Note. Memory (Verbal) and *Memory (Visual)* scores ranged from 0-100 with scores closer to 100 indicating better performance. For *Visual Motor Processing Speed* the higher the score the better the performance, with scores between 42 and ≤ 50 indicating better performance. The lower the score for *Reaction Time* the better the performance with scores ranging between $\leq .44$ and .51 seconds indicating better performance. *Impulse Control* was measured by the number of error made in the tasks, with a low score indicating better performance.

Additional analyses, show that 48.60% (*n* = 51) of the sample have a *history of concussion*, with 98% (*n* = 50) of those participants being rugby players. From Table 2, we can see that of those who have a history of concussion, most sustained only a single concussion. Results also show that 7.60% (*n* = 8) of the sample were diagnosed with *ADHD*, while 4.80% (*n* = 5) of the sample were diagnosed with a *learning disability*. Only 4 participants (3.81%) had been diagnosed with both *ADHD* and a l*earning disability*.

Table 2

Frequency (%) of Number of Times Concussed

Number of Times Concussed	Percentage (%)
None	51.40
One	24.80
Two	7.60
Three	7.60
Four	2.90
Five or more	5.70
Total	**100**

Correlations. From Table 3, we can see that *age, number of times concussed (r = .21)* and *learning disability* (*r* =.33) are all moderately correlated with *Impulse Control*, with *age* having a negative association with *Impulse Control*. Regarding *age*, this suggests that older individuals are more likely to score lower on *Impulse Control*, which means that they made fewer impulsive errors than younger individuals. Regarding *number of times concussed* and *learning disability*, results suggests that individuals with a presence of a *learning disability* or the greater the *number of times concussed* are likely to score higher on *Impulse Control*, indicating more errors and poorer performance.

None of the independent variables are highly correlated with each other, so we do not have a problem with multicollinearity (there are no correlations higher than .8). However, what is a cause for concern is the number of very low correlations between the predictor variables and the outcome variables. For example, the relationship between *ADHD* and *Visual Motor Speed* is *r* = .00. It is evident that the strongest correlations are between specific outcome variables, including *Reaction Time* and *Visual Motor Speed*, *Reaction Time* and *Memory* (*Visual*; *r* = -.50), and *Visual Motor Speed* and *Memory (Visual).*

Table 3

Correlation between Predictor Variables and Components of ImPACT

Variable	Age	History of concussion	Number of concussions	Learning disability	ADHD	Memory (verbal)	Memory (visual)	Visual motor speed	Reaction time	Impulse control
Age	1									
History of concussion	-.05	1								
Number of concussions	-.08	.74**	1							
Learning disability	.03	.14	.09	1						
ADHD	.07	.08	.14	.61**	1					
Memory (verbal)	.13	.06	-.02	-.09	-.001	1				
Memory (visual)	.05	-.03	-.17	-.09	-.02	.47**	1			
Visual motor speed	.01	.05	.03	-.18	.00	.41**	.54**	1		
Reaction time	-.02	-.05	-.03	.03	-.01	-.36**	-.50**	-.69**	1	
Impulse control	-.23*	.12	.21*	.33**	.17	-.19	-.29**	-.16	-.02	1

Note. *. Correlation is significant at the 0.05 level (1-tailed). **. Correlation is significant at the 0.01 level (1-tailed).

Regression analysis. Simultaneous multiple regressions were conducted for each outcome variable. The results show that only one model (see Table 4) significantly predicted the outcome variable, *Impulse Control*, $R = .45$, $R^2 = .21$, $F (5,99) = 5.10$, $p < .001$. See Table 6-9 for results of simultaneous multiple regressions that were not significant.

On further analysis, a forward stepwise regression was run for *Impulse Control* to determine which variables had the greatest impact in predicting performance on this outcome variable. From Table 5, we can see that l*earning disability* and *age* are the predictors with the greatest influence on *Impulse Control*, $R = .41$, $R^2 = .16$, $F (1,102) = 6.81$, $p = .01$.

Table 4
Simultaneous Multiple Regression and Significant Outcome Variable

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.45ª	.21	.17	4.14	.21	5.10	5	99	.000	1.95

Note. a. Predictors: (Constant), ADHD, Age, History of Concussion, Learning Disability, Number of Times Concussed

b. Outcome Variable: Impulse Control

Table 5
Forward Stepwise Multiple Regression for Impulse Control

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.33ª	.11	.10	4.29	.11	12.55	1	103	.001	
2	.41ᵇ	.16	.15	4.18	.06	6.81	1	102	.010	2.01

Note. a. Predictors: (Constant), Learning Disability

b. Predictors: (Constant), Learning Disability, Age

c. Outcome Variable: Impulse Control

Table 6

Simultaneous Multiple Regression for Memory (Verbal) ImPACT Module

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					F Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.22[a]	.05	-.001	9.69	.05	.97	5	99	.439	2.10

a. Predictors: (Constant), ADHD, Age, History of Concussion, Learning Disability, Number of Times Concussed

b. Outcome Variable: Memory (Verbal)

Table 7

Simultaneous Multiple Regression for Memory (Visual) ImPACT Module

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					F Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.25[a]	.06	.02	13.47	.06	1.32	5	99	.260	1.92

a. Predictors: (Constant), ADHD, Age, History of Concussion, Learning Disability, Number of Times Concussed

b. Outcome Variable: Memory (Visual)

Table 8

Simultaneous Multiple Regression for Visual Motor Speed ImPACT Module

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					F Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.24[a]	.06	.01	7.33	.06	1.24	5	99	.295	1.88

a. Predictors: (Constant), ADHD, Age, History of Concussion, Learning Disability, Number of Times Concussed

b. Outcome Variable: Visual Motor Speed

Table 9

Simultaneous Multiple Regression for Reaction Time ImPACT Module

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics						F Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change		
1	.08[a]	.01	-.04	.10	.01	.13	5	99	.985		1.87

a. Predictors: (Constant), ADHD, Age, History of Concussion, Learning Disability, Number of Times Concussed

b. Outcome Variable: Reaction Time

Independent samples t-test. We ran an independent samples *t*-test to determine whether there were between-group differences on ImPACT modules for participants with a history of concussion and those with no history of concussion. Results showed that there were no significant between-group differences on any module of ImPACT for *history of concussion* (see Table 10).

Table 10

Independent Samples T-Test for History of Concussion

	t	*df*	*Sig. (1-tailed)*
Memory (Verbal)	-.64	103	.264
Memory (Visual)	.29	103	.385
Visual Motor Speed	-.55	103	.293
Reaction Time	.54	103	.296
Impulse Control	-1.19	103	.119

Note. Equal variances assumed for all modules

ANOVA. A one-way ANOVA was conducted to determine if there were any between-group differences on baseline scores on all modules of ImPACT for *number of times concussed*. From Table 11, we can see that there were no significant between-group differences on any of the modules of ImPACT for this predictor variable, with small effect sizes, except for *Impulse Control* and *Memory (Visual)*, which had medium effect sizes.

Table 11

One-Way ANOVA Comparing Number of Times Concussed

	F	df	Sig(1-tailed)	Partial η^2
Memory (Verbal)	.358	5	.876	.02
Memory (Visual)	1.17	5	.327	.06
Visual Motor Processing Speed	.40	5	.845	.02
Reaction Time	.21	5	.956	.01
Impulse Control	1.26	5	.143	.06

Note. Number of times concussed ranged from 0, 1, 2, 3, 4 and 5 or more

Discussion

The aim of this study was to determine whether demographic, injury-related, and behavioural and academic factors of South African sportsmen predict baseline scores on a neuropsychological concussion test battery, ImPACT. This was achieved by analysing data collected in Stephen's (2016) study, the aim of which was to assess concussion, HIT, and neuropsychological outcomes data in South African male rugby players aged 18 to 27 years. Three hypotheses for the current study were tested: that 1) *age*, 2) a *history of concussion* and 3) behavioural and academic factors (*ADHD* and *learning disability*), are predictors of baseline ImPACT scores.

Summary of Results

The regression results of the current study showed that only baseline scores on *Impulse Control* were significantly influenced by the predictors. Simultaneous multiple regression revealed that *age, history of concussion, number of times concussed, ADHD* and *learning disability* significantly predicted baseline scores on the *Impulse Control* module of ImPACT only. In order to determine which of these predictors were strongest in predicting *Impulse Control*, a forward stepwise multiple regression analysis was run. Results from this analysis revealed that *age* and *learning disability* significantly predicted baseline scores on *Impulse Control*. These results are inconsistent with previous studies of this nature, which have consistently found that not only *Impulse Control*, but all components of ImPACT, are significantly influenced by the predictors investigated in the current study (Cottle et al., 2017; Covassin et al., 2012; Mannix et al., 2014).

Looking at the descriptive statistics for the current study, it is clear that relative to all of the other ImPACT modules, *Impulse Control* had the greatest variation in scores with a mean of approximately 5 and a standard deviation of approximately 4. Other factors that separate *Impulse Control* from the other ImPACT modules is 1) that it is an executive function task, whereas the others are related to other cognitive domains, 2) the score for *Impulse Control* is the only score that consists of an average of errors made on tasks; whereas the scores for the other modules are timing or measures of correct responses, and perhaps most importantly, 3) this module is the only module of ImPACT still under experimental review. As such, *Impulse Control* has not yet been normed (Iverson, 2003). Perhaps once it has been normed it can be interpreted more clearly and an account for performance on it and its significance with predictors can be provided with more confidence. In sum, the listed factors may impact on the sensitivity of the *Impulse Control* module to within group variation on the significant predictors, *age* and *learning disability*, more so than the other modules. We discuss each of the hypotheses below.

Age

With regards to Hypothesis 1, several studies have found that *age* is a predictor of baseline ImPACT scores. In most of these studies, performance on *Memory* (*Visual* and *Verbal*) and *Reaction Time* has been found to be greater in older college (university) participants compared to younger high school participants (Covassin et al., 2012: Littleton & Guskiewicz, 2013). This study did not include high school students, and participants' ages ranged between 18 and 27 years. The findings from previous studies are consistent with the results from both the simultaneous multiple regression and forward stepwise multiple regression run in this study as *age* was shown to be a predictor of baseline scores on ImPACTs *Impulse Control*. Therefore, Hypothesis 1 was supported, at least in terms of *Impulse Control*.

History of concussion

With regards to Hypothesis 2, several studies have found that history of concussion predicts baseline ImPACT scores. Performance on *Memory* (*Verbal* and *Visual*) has been found to be greater for those who do not have a history of concussion compared to those who do have a history of concussion (Lovell et al., 2003). In addition, performance on *Memory (Verbal)* and *Impulse Control* has shown to be greater for those with fewer number of concussions compared to those with a higher number of previous concussions (Mannix et al., 2014). From the simultaneous multiple regression run in this study, *history of concussion* was found to be a significant predictor of baseline scores on ImPACTs *Impulse Control* module. However, on closer inspection, this was not supported by the forward stepwise multiple regression which

revealed that *history of concussion* is not a significant predictor of baseline scores on *Impulse Control*. Therefore, Hypothesis 2 was not upheld.

Out of interest, an independent samples t-test was conducted to determine whether there were any significant between-group differences in baseline scores on ImPACT for *history of concussion* (i.e. those who had and did not have a history of 1 or more concussions). The analysis revealed that there were no significant between-group differences on any of the baseline scores of ImPACTs modules based on this predictor variable. In addition, a one-way ANOVA was conducted to determine if there were any between-group differences on baseline scores on ImPACT for *number of times concussed* (i.e. number of reported concussions of those with a history). Again, the analysis revealed that there were no significant between-group differences on any of the baseline scores of ImPACTs modules based on this predictor variable.

These findings could be due to the sample consisting of both rugby players and non-contact sport players. Due to the sample in this study consisting of both contact and non-contact sports players – and considering that one is more likely to sustain a concussion in contact sport versus in non-contact sport - this could have impacted the results. As previously mentioned, out of the 51 participants who had a history of concussion in this study, only one participant was a non-contact sports player. Further, most participants who reported that they had previously sustained a concussion, had only sustained one concussion. Perhaps results would differ with samples where more participants sustained multiple concussions. Finally, of those who sustained multiple concussions, some of those concussions were sustained two or more years before. ImPACT is sensitive in picking up cognitive dysfunction after a concussion, but may not necessarily be sensitive to those effects after such extended periods of time.

Behavioural and academic factors

With regards to Hypothesis 3, several studies have found that behavioural and academic factors (*ADHD* and *learning disability*) predict baseline ImPACT scores. In these studies, performance across all components of ImPACT was shown to be poorer for participants with a diagnosis of *ADHD* and/or *learning disability* (Cottle et al., 2017; Elbin et al., 2013). More specifically, performance on *Visual Motor Processing Speed* has been found to be particularly poor for those with a diagnosis of *ADHD* and/or *learning disability* (Zuckerman et al., 2013).

From the simultaneous multiple regression run in this study, both *ADHD* and *learning disability* were found to be significant predictors of baseline scores on *Impulse Control*. However, the forward stepwise multiple regression revealed that only *learning disability* and *age* were significant predictors of baseline scores on ImPACTs *Impulse Control* component. Therefore, Hypothesis 3 was only partly supported.

Learning disability as a significant predictor of baseline scores on *Impulse Control* of ImPACT may be explained by the nature of the task (i.e., measured by number of errors) and the possibility that accuracy and speed may be compromised among individuals with learning disabilities. The result that *ADHD* was not a significant predictor of baseline scores on ImPACT may be explained by the fact that the sample only included 8 participants with a diagnosis of *ADHD*. Therefore, it is likely that there were not enough participants with a diagnosis of *ADHD* for it to impact significantly on baseline ImPACT scores.

Limitations and Directions for Future Research

There are several limitations to this study. First, the nature of data collection took the form of self-report measures. Relying on self-report measures of injury-related variables, (including reporting a history of concussion and number of times concussed), and behavioural and academic factors (including reporting a diagnosis of ADHD and/or learning disability) especially retrospectively, can be unreliable. Future research could include an independent confirmation of injury-related, and behavioural and academic diagnoses, perhaps by professional bodies (a doctor or a mental health professional) or proof in the form of documentation.

A second limitation relates to the sampling methods used to obtain data in the Stephen (2016) study. There are limitations to both convenience and purposive sampling. The credibility of convenience and purposive sampling comes in to question due to, for example, the possibility of selection bias. Perhaps this current study did not find that the predictors in question influenced baseline ImPACT scores due to the fact that the sample of participants were not representative of the larger population. Investigating this topic requires a large, representative sample and this can be achieved through random sampling. Therefore, studies in the future should randomly sample participants in the pursuit of being able to generalise something meaningful.

A third limitation might be that ImPACT is not sensitive to time and severity of concussion/s. With regard to participants with a history of concussion, ImPACT does not take into account the time since concussion and time between multiple concussions, and severity of concussion. ImPACT could include individual investigation into the history of participants' concussion/s, and take this into account when interpreting their performance on baseline ImPACT scores.

Conclusion

Although all of the study hypotheses were not confirmed, the significant findings reported in the current study still suggest that there are variables other than the presence of a

concussion that predict baseline ImPACT scores. This knowledge has implications for how one interprets ImPACT scores and highlights the need to carefully consider such baseline performances. This is important in terms of avoiding attributing poor performance solely to concussion history, when there are other possible underlying variables that may predict baseline performance on this neuropsychological test battery. Thus, the utility of this study, together with the body of literature emerging on this topic, may be to highlight the need to consider possible confounds to ImPACT test battery performance and the need to control for these variables or remind users to be aware of these factors, when creating concussion-management protocols.

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Appendices

Appendix A: The ImPACT Neuropsychological Test Battery (Stephen, 2016)

The ImPACT neuropsychological test battery computerised tasks and composite scores.

Test name	Cognitive domain measured
Word Memory	Verbal recognition memory (learning and retention
Design Memory	Spatial recognition memory (learning and retention)
X's and O's	Visual working memory and cognitive speed
Symbol Match	Memory and visual-motor speed
Colour Match	Impulse inhibition and visual-motor speed
Three Letter Memory	Verbal working memory and cognitive speed
Symptom Scale	Rating of individual self-reported symptoms

Composite Scores	Contributing tasks
Verbal Memory	Word Memory (learning and delayed), Symbol Match memory score, Three Letters Memory Score
Visual Memory	Design Memory (learning and delayed), X's and O's percent correct
Reaction Time	X's and O's (average correct distracters), Symbol Match (average weighted reaction time for correct responses), Colour Match (average reaction time for correct response)
Visual Motor Processing Speed	X's and O's (average correct distracters), Symbol Match (average correct responses), Three letters (number of correct numbers correctly counted)
Impulse Control	X's and O's (number of incorrect distracters), Colour Match (number of errors)

Appendix B: Informed Consent Document

University of Cape Town
Psychology Department
Telephone: +27 21 650-3430
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Investigating history of concussion and data from head impact telemetry (xPatch) in relation to neuropsychological outcomes in a sample of adult rugby players in Cape Town

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 history of concussion and data from head impact telemetry (xPatch) in relation to neuropsychological outcomes in a sample of adult rugby players in Cape Town.

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-Elson, Ph.D. (PI and supervisor)   Dale Stephen (Masters student)

Psychology Department   Psychology Department

University of Cape Town   University of Cape Town

0216503708   0722352009

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, 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 later in the year; this comprises part of a larger research study that is attached to this one. 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 later in the year. You will be contacted by the Principle Investigator if this is the case. The testing procedures take approximately 1 ½ 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 3 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 - 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**

As discussed, some participant may be recalled for a brain scan, and this forms part of a larger research study that is attached to this one. While undergoing the brain scan some participants may feel anxious or claustrophobic. 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:

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 Obtaining Consent and Authorization   Date

_____   _____

Signature of Person Consenting and Authorizing   Date

Appendix C: Ethical Approval from the UCT Faculty of Health Sciences Human Research Ethics Committee

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

08 April 2015

HREC REF: 010/2015

Dr L Schrieff-Elson
Psychology
Humanities Graduate School Building
Upper Campus

Dear Dr Schrieff-Elson

PROJECT TITLE: INVESTIGATING THE NEUROPSYCHOLOGICAL EFFECT AND LONG TERM OUTCOMES OF MULTIPLE CONCUSSIONS AND /OR HEAD INJURIES AMONG UNIVERSITY RUGBY PLAYERS (Masters-candidate- D Stephen)

Thank you for your response to the Faculty of Health Sciences Human Research Ethics Committee dated 20 March 2015.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30th April 2016.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

We acknowledge that the student, Dale Stephen will also be involved in this study.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical

HREC 010/2015

Appendix D: Approximate Classification Ranges for Index Scores – University Men

	Verbal Memory	Visual Memory	Processing Speed	Reaction Time
Impaired	≤ 71	≤ 51	≤ 23.8	$\leq .75$
Borderline	72-77	52-60	23.9-28.3	.74-.67
Low Average	78-82	61-68	28.4-32.4	.66-.61
Average	83-94	69-94	32.5-42	.60-.52
High Average	95-97	95-97	42.1-46	.51-.48
Superior	98-99	98-99	46.1-50	.47-.45
Very Superior	100	100	≥ 50.1	$\leq .44$