Neuropsychological assessment of elite level rugby players and the relationship with on-field performance

A Kruger

11755350

Dissertation submitted in fulfilment of the requirements for the degree *Magister Scientiae* in Counselling Psychology at the Potchefstroom Campus of the North-West Universit y

Supervisor: Dr K du Plooy

Co-Supervisor: Prof P Kruger

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TABLE OF CONTENTS

APPENDICES

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SUMMARY

Rugby is regarded as one of the most popular professional team sports in the world and characterized by various high-intensity activities such as sprints, accelerations from a static position, rucking, mauling, tackling and breaking through tackles. In addition to the physical demands players have to deal with, there are also psychological, emotional, social and behavioural demands which need to be addressed. Athletes have to excel in four domains in order to perform at elite levels of sport, namely the physiological, technical, emotional and cognitive levels.

The aim of this study was to determine the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance [as determined by the Key Performance Indicators (KPIs)] of university-level rugby players. A quantitative research method, namely a cross-sectional research design with a convenience sample, was used. A group of 25 male university-level rugby players were recruited from a South African University's Rugby Institute squad who participated in the Varsity Cup Tournament. The group consisted of eight tight five players (numbers 1-5), five loose forwards (numbers 6-8) and twelve backline players (numbers 9-15) with an average age of 22.63, 22.80 and 21.50 years respectively. The participants' cognitive functioning was measured using the WebNeuro Sport, a web-based assessment instrument developed by the Brain Resource Company. In order to quantify the players' on-field performance, the Key Performance Indicators (KPIs) of each player were determined for each game by the full-time, qualified coders of the technical support department of The South African Rugby Union (SARU) by using the technical analysis software, Stratus. The following KPIs were included in the analysis: Attacking variables, including the total number of contributions a player provided during attacking play, carries (number of carries), passes (number of passes a player made), kicks (number of kicks during the game), ball recycler (number of times a player recycled the ball from a maul), breakdown arrivals (number of times a player is part of breakdowns) and attacking mauls (number of times a player was part of an attacking maul. Defensive variables included total number of contributions a player provided during defensive play, tackle attempts (number of attempts), missed tackles (number of tackles missed), breakdown arrivals on defence (number of times a player is part of breakdowns) and defensive mauls (number of times a player was part of a defensive maul).

According to our knowledge this is the first study of its kind, which makes a comparison of our findings with existing literature virtually impossible. The analyses of the tight five forwards revealed that players' sensory-motor ability might contribute to the number of carries the players perform during attacking play. In terms of the loose forwards the positive correlation between total contribution and emotion identification might be indicative of the important role of good pattern recognition and associated quick decision-making. In line with the results of the loose forwards, the analyses of the backs revealed medium to strong positive correlations between emotion identification and total attacking contribution, passes as well as kicks. It therefore appears that good pattern recognition ability and associated quick decision-making might be important cognitive functions for backline players as well as loose forwards to enhance their performance.

Although this is the first study of its kind and the fact that most of the explanations are based on hypotheses, it might lay the foundation for further research regarding rugby players' cognitive functioning and related on-field performance.

An important implication of the present findings is that knowledge of the positive as well as the negative relationships and certain measures of cognitive functioning may be of value for improving on-field performance by means of the application of cognitive interventions programs.

KEYWORDS: cognitive functioning, neuropsychology, rugby performance, performance indicators, rugby union, sports psychology

OPSOMMING

Rugby word geag as een van die populêrste professionele spansporte in die wêreld en word gekenmerk deur verskeie hoë-intensiteit aktiwiteite soos naellope, versnelling vanaf ‘n statiese posisie, losskrums, losgemaal, duikslae en deurbrake deur duikslae. Bykomend tot die fisieke vereistes wat spelers moet hanteer is daar ook psigologiese, emosionele, sosiale en gedrags vereistes wat aangespreek moet word. Atlete moet presteer in vier areas ten einde in ‘n elite-vlak sport te presteer, naamlik fisiologies, tegnies, emosioneel en kognitief.

Die doel van hierdie studie was om die verband tussen metings van kognisie (geheuekapasiteit, aandag- en gedragstake, sensoriese-motoriese funksionering, verbale take, uitvoerende funksionering en identifisering van emosie) en op-die-veld prestasie [soos bepaal deur die Sleutel Prestasie Indikatore (SPI)] van universiteitsvlak rugbyspelers, te bepaal. ‘n Kwantitatiewe navorsingsmetode genaamd ’n dwarsdeursnit navorsingsontwerp met ’n gerieflikheidssteekproef is gebruik. ’n Groep van 25 manlike universiteitsvlakrugbyspelers van ‘n Suid-Afrikaanse Universiteit se Rugby-Instituut se span wat deelgeneem het aan die “Varsity Cup”-toernooi is gewerf. Die groep het bestaan uit agt vaste vyf spelers (nommers 1-5), vyf losvoorspelers (nommers 6-8) en twaalf agterlynspelers (nommers 9-15) met ’n gemiddelde ouderdom van 22.63, 22.80 en 21.50 jaar respektiewelik. Ten einde die spelers se prestasie op die veld te kwantifiseer, is die SPI’s van elke speler bepaal vir elke wedstryd deur voltydse, gekwalifiseerde kodeerders van die tegniese ondersteunings departement van die Suid Afrikaanse Rugby Unie (SARU) deur gebruik te maak van die analisesagteware genaamd Stratus. Die volgende SPI’s is ingesluit in die analise: Aanvallende veranderlikes het die totale aantal bydraes wat ’n speler tydens die aanval gemaak het, dra van die bal (aantal kere ’n speler die bal gedra het), aangeë (aantal aangeë wat ’n speler gemaak het), skoppe (aantal skoppe tydens ’n wedstryd), balherwinnaar (aantal kere wat ’n spelers die bal herwin het uit ’n losgemaal), arrivering by die afbreekpunte (aantal kere wat ’n speler deel was by ’n afbreekpunt) en aanvallende losgemaal (aantal kere wat ’n speler deel was van ’n aanvallende losgemaal), ingesluit. Verdedigende veranderlikes het die totale aantal bydraes wat ’n speler gemaak het tydens verdedigende spel, duikslagpogings (aantal pogings), duikslae gemis (aantal duikslae gemis), arrivering by die afbreekpunte op verdediging (aantal kere wat ’n spelers deel van ’n afbreekpunt) en verdedigende losgemale (aantal kere wat ’n speler deel was van ’n verdedigende losgemaal).

Volgens ons kennis is hierdie die eerste studie van sy soort, wat die vergelyking van ons bevindinge met bestaande literatuur bykans onmoontlik maak. Die analise van die vaste vyf voorspelers dui daarop dat spelers se sensories-motoriese vermoë moontlik kan bydra tot die aantal kere wat spelers die bal dra tydens aanvallende spel. In terme van die losvoorspelers kan die positiewe korrelasie tussen totale bydrae en die identifisering van emosies ŉ aanduiding wees van die belangrike rol van goeie patroonherkenning en gepaardgaande vinnige besluitneming. In lyn met die resultate van die losvoorspelers dui die analise van die agterspelers op medium tot sterk positiewe korrelasies tussen die identifisering van emosies en die totale bydrae tydens die aanval, aangeë sowel as skoppe. Dit blyk dus asof goeie patroonherkenningsvermoë en geassosieerde vinnige besluitneming belangrike kognitiewe funksies kan wees vir beide agterspelers en losvoorspelers ten einde hulle prestasie te verbeter.

Alhoewel hierdie studie die eerste van sy soort is en die feit dat die meeste verduidelikings gebaseer is op hipoteses kan dit die fondasie lê vir verdere navorsing met betrekking tot rugbyspelers se kognitiewe funksionering en verbandhoudende op-die-veld prestasie.

‘n Belangrike implikasie van die huidige bevindinge is dat kennis van die positiewe sowel as die negatiewe verhoudings en sekere metings van kognitiewe funksionering van waarde kan wees ten einde op-die-veld prestasie te verbeter deur middel van die toepassing van kognitiewe intervensieprogramme.

SLEUTELWOORDE: kognitiewe funksionering, neuropsigologie, rugby prestasie, prestasie-indikatore, rugby-unie, sportpsigologie

DECLARATION AND PERMISSION FROM SUPERVISORS

This dissertation serves as fulfilment for the degree Magister Scientiae in Counselling Psychology at the Potchefstroom Campus of the North-West University. We, the supervisors of this study, hereby declare that the article entitled "**Thinking differently about rugby performance: The relationship between cognitive functioning and on-field performance of university-level rugby players"**, written by Ankebé Kruger, does reflect the research regarding the subject matter. The co-authors of the article that forms part of this dissertation, namely Dr Kobus Du Plooy (supervisor and co-author) and Prof Pieter Kruger (co-supervisor and co-author), hereby give permission to the candidate, Ankebé Kruger, to include the article as part of a master's dissertation and that the candidate may submit the article for publication in *Journal of Applied Sport Psychology*. The contribution (advisory and supportive) of these two co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes.

_____ _____

Dr Kobus Du Plooy
Supervisor and co-author

Prof Pieter Kruger
Co-supervisor and co-author

DECLARATION FROM LANGUAGE EDITOR

Declaration

This is to declare that I, Annette L Combrink, accredited language editor and translator of the South African Translators' Institute, have language-edited the mini-dissertation by

A Kruger (11755350)

with the title

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Prof Annette L Combrink
Accredited translator and language editor
South African Translators' Institute
Membership No. 1000356
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FOREWORD

Magister Scientiae in Counselling Psychology in article format

This dissertation will be submitted in article format according to rule A.5.4.2.7 of the North-West University, Potchefstroom campus yearbook. The article will be submitted for publication in *Journal of Applied Sport Psychology*. Please take note that the article is presented according to the authors' guidelines of the abovementioned journal. The in-text citations as well as the references of Section 1 and 3 are prepared according to the APA (American Psychological Association) method as provided by the reference guide (2012) of the North-West University.

SECTION 1

INTRODUCTION TO THE STUDY

1. INTRODUCTION

Rugby union (hereafter referred to as rugby) is regarded as one of the most popular, professional team sports in the world. Rugby is a high-intensity, full contact team sport played by millions of people across the world (Heyns, 2012). A rugby match consists of two halves of 40 minutes each with a ten-minute break and is characterized by various high-intensity activities such as sprints, accelerations from a static position, rucking, mauling, tackling and breaking through tackles (Gill, Beaven, & Cook, 2006; Suzuki, Umeda, Nakaji, Shimoyama, Mashiko, & Sugawara, 2004). The above-mentioned activities are alternated by short bouts of low-intensity activities such as walking and jogging (Gill et al., 2006; Suzuki et al., 2004).

In addition to the physical demands players have to deal with, there are also psychological, social and behavioural demands which need to be addressed (Suzuki et al., 2004; Venter, Potgieter, & Barnard, 2010). According to Janelle and Hillman (2003) athletes have to excel in four domains in order to perform at elite levels of sport, namely the physiological, technical, emotional and cognitive.

A review of the literature found ample research which addressed the physical and physiological demands (Austin, Gabbett, & Jenkins, 2011; Deutsch, Kearney, & Rehrer, 2007; Duthie, Pyne, & Hooper, 2003; Gill et al., 2006; Jougla, Micaleff, & Mottet, 2010; King, Hume, Milburn, & Guttenbeil, 2010; Smit, 2011; Sparks & Coetzee, 2013) as well as the psychological demands of the game (Jeffreys, 2005; Knobel, 2010; McKay, Lavallee, Niven, & White, 2008; Suzuki et al., 2004; Wieser & Thiel, 2014). Studies pertaining to rugby players' cognitive functioning mostly investigated the effect of traumatic or mild brain injuries (concussion) on the players' cognitive functioning (Alexander, Shuttleworth-Edwards, Kidd, & Malcolm, 2015; Bleiberg et al., 2004; Gardner et al. 2015; Hinton-bayre, Geffen, & McFarland, 1997; King, Brughelli, Hume, & Gissane, 2013; King, Gissane, Hume, & Flaws, 2015; Kirkwood, Parekh, Ofori-Asenso, & Pollock, 2015). According to the authors' knowledge, no studies exist that investigated the relationship between players' cognitive functioning and on-field performance.

Therefore the aim of this study was to explore the relationship between cognition and on-field performance of university-level rugby players.

2. RATIONALE FOR THE STUDY AND LITERATURE REVIEW

This research study formed part of a larger service delivery project which aimed to provide sports psychological support to rugby players. This study made use of the existing infrastructure used for the sports psychological service delivery provided by the Institute of Psychology and Wellbeing of the North-West University. This study was approached from the biopsychosocial perspective (Butcher, Mineka, & Hooley, 2013), with the main focus on the biological and psychological factors.

The participants were required to visit a website in order to complete the WebNeuro Sport online assessment (BRC, 2010). The assessment was thoroughly explained to the participants, both orally by the investigator and by way of instructions on the computer screen. Each participant received a client code in order to ensure confidentiality of their results. Upon completion of the assessment the data was automatically sent to the international database for processing. The investigator received a comprehensive, computer-generated report for each participant. The investigator had access to the raw data of each participant for the purposes of statistical analysis.

Cognitive functioning consists of four major domains, namely receptive functioning, memory and learning, thinking and expressive functions (Lezak, Howieson, Bigler, & Tranel, 2012). In the sports context, cognitive functioning refers to the ability to remain optimistic, keep a confident perspective, and avoid pessimistic self-talk and intrusive thoughts (Leunes, 2008). In sport, various cognitive functions are involved such as anticipation, expertise, judgment and decision-making, mental imagery, and perceptions (Moran, 2009). Kremer, Moran, Walker, and Craig (2012) added mental practice, concentration, optimistic self-talk, thought control and mental toughness as important cognitive processes involved in sport. According to Carlstedt (2007) cognitive functioning of an athlete includes memory, attention and behavioural tasks, sensory-motor/spatial functioning, verbal functioning, executive functioning and emotion recognition. From the above-mentioned it is clear that cognitive functioning refers to various aspects, but for the purposes of this study, Carlstedt's (2007) understanding of cognitive functioning will be used for further discussion.

2.1 Working memory

Team sport athletes, such as rugby players, often need to select situation appropriate actions in a quick and efficient manner and under extreme pressure in high interference situations (Furley & Memmert, 2013). Recent research (Furley & Memmert, 2010; Furley, Memmert, & Heller, 2010; Furley & Memmert, 2012) suggests that a player's attention and working memory (WM) (Baddeley, 2007) are important cognitive factors in understanding performance in situation as described above. Working memory capacity (WMC) has been defined as the ability to attend to, learn, store, retrieve and manipulate new information, which includes long and short-term memory (Brain Resource Company, 2010). Since rugby became a professional sport in 1995 (Mellalieu, 2008), the game has evolved into a more structured sport with teams displaying more complex match strategies and tactics (Hendricks, Roode, Matthews, & Lambert, 2013). One can assume that in order to successfully execute these strategies and tactics, a player needs to be able to retrieve the correct responses for the specific situation. According to the researchers' knowledge no studies have thus far investigated the relationship between WMC and sports performance. However, Mayers, Redick, Chiffriller, Simone, and Terraforte (2011) speculate that only athletes with a higher WMC will excel in football and volleyball given the need for continuous updating and preventing the multiple play calls in these sports. Since the abovementioned is only speculative, further research is deemed necessary to confirm whether higher WMC relates to better sports performance, especially in rugby.

2.2 Attention and behavioural tasks

The necessity for athletes to maintain task-relevant information despite interference of distractions on the playing field is clear, both for performance and for the prevention of physical injuries (Mayers et al., 2011; Furley, Bertrams, Englert, & Delphia, 2013). The Brain Resource Company (2010) defines attention and behavioural tasks in a sports context as the ability to selectively concentrate during cognitive tasks, detect and respond to changes in the environment; sustain attention over time and control impulses. Most team sports, such as rugby, provide a source of unpredictability and uncertainty for all players (Passos, Araújo, Davids, & Shuttleworth, 2008). Therefore, one can assume that a player's ability to effectively detect and respond to the constantly changing environment will have a significant effect on performance. Furthermore, attentional lapses in sport are inevitable and occur when an athlete's concentration momentarily becomes disengaged from the task at hand (Moran, 2009). In this regard, Chuang,

Haung and Hung (2013) found that sustained attention led to optimal performance of basketball players during free throws. Regarding rugby, Holland, Woodcock, Cumming, and Duda (2010) identified an appropriate attentional focus as one of nine qualities crucial for participation in elite youth rugby. However, no published research could be traced which determines the relationship between a rugby players' attention and behavioural tasks and their on-field performances.

2.3 Sensory-motor/spatial tasks

Sensory-motor functioning refers to the ability to perform motor skills, respond to information in a timely fashion and includes reaction time as well as hand-eye coordination (Brain Resource Company, 2010). According to Ludeke (2003) hand-eye coordination, reaction time and peripheral awareness are visual skills that any rugby player needs to master in order to perform at an elite level. Hand-eye coordination has been defined as a synchronized perceptual-motor response to visual sensory stimuli, with the hands (Ludeke & Ferreira, 2003). Reaction time refers to the time it takes to perceive and respond to visual stimulation (Ludeke, 2003), while peripheral awareness "is the ability of the athlete to maintain central fixation on a target, yet be aware of what is happening to the sides or in the peripheral visual field" (Ludeke, 2003, p. 15).

With specific reference to rugby, a jumper in the lineout who jumps to catch the ball needs good hand-eye coordination to successfully catch the ball (Van Velden, 2013). Furthermore, for taking a high ball successfully a player needs to catch the ball at the highest point of his jump, therefore exact timing is of the utmost importance. Simultaneously with the jump, the player has to position his body in a way that he protects himself from approaching defenders and does not knock the ball on when he makes a mistake during the catch. Good hand-eye coordination is important in executing this skill (Van Velden, 2013). In addition, Greenwood (1993) indicated that the flyhalf and the scrumhalf are both particularly important in decision-making. The flyhalf is responsible for the coordination of the backline players while he selects the speed and attacking mode. Therefore, the flyhalf needs the ability to summarize the situation effectively. Thus, peripheral awareness, reaction time and visual concentration are extremely important in order to successfully execute these tasks. On the other hand, the scrumhalf controls the attack of the team from the side of the forwards (Greenwood, 1993). The scrumhalf needs to pass the ball to the flyhalf, kick the ball or play on the blind side. He also needs the ability to scan and make the correct decisions in a limited time period (Ludeke, 2003). In this regard, Ludeke (2003) found that senior professional rugby players performed statistically significantly better ($p<0.05$)

compared to club players in eye-body coordination and reaction time. Although not statistically significant, the professional players outperformed their club level counterparts in hand-eye coordination and peripheral awareness. From the abovementioned discussion it is evident that sensory-motor functioning plays an important role in rugby performance.

2.4 Verbal functioning/Language tasks

It is important to note that verbal functioning and language tasks will be used interchangeably throughout the dissertation. Language tasks refer to the ability to recognize and access words as well as remember what has been heard (Brain Resource Company, 2010). Language plays an important role, in everyday life as well as sport, because of its ability to transfer information (Lyons, Mattarello-Micke, Cieslak, Nusbaum, Small, & Beilock, 2010). With specific reference to rugby, Westgate (2007) identified communication as one of ten key factors for successful defence in a game. According to Westgate (2007), communication is vital in organizing the teams' defenders and to identify the attacking threats. Furthermore, the defending players inside and outside the ball carrier have to communicate clearly and loudly while they are pushing forward. Despite the benefit of organizing the team defence, it is also used to exert pressure on the opposition by means of "big talk" (intimidation) and "small talk" (organization). In addition, Laycock and Midcalf (2008) stated that effective communication might result in the difference between players being able to prevent a situation before its happening and players having to react to a situation. Effective communication can also be the difference between making an informed decision about a specific situation and an educated guess about what to do (Laycock & Midcalf, 2008). It is clear that effective communication plays an important role in rugby, but to the authors' knowledge, no study has thus far investigated the relationship between a players' language or verbal ability and his on-field performance.

2.5 Executive functioning

Executive functioning refers to the ability to plan, strategize, execute complex tasks, abstract thinking, rule acquisition, inhibiting inappropriate actions and ignoring irrelevant sensory information (Brain Resource Company, 2010). In addition, executive functioning can also include problem-solving, inhibition and decision-making (Jacobson & Matthaeus, 2014). Several researchers agree that efficient decision-making is of decisive importance in a team sport (Tavares, 1997; Furley et al., 2013). Decision-making in a team sport implies a player's ability to

make quick and accurate tactical decisions. Rugby is played in a dynamic environment where players need to make continuous decisions (Tavares, 1997). The quality and speed of a player's decision-making depends on various factors such as speed and accuracy of which information is received, tactical knowledge, skill and the player's experience (Tavares, 1997).

A player does not only make decisions when in possession of the ball, but also when his teammates or opponents are in possession of the ball. When a player has possession of the ball, he must decide whether to run with it, kick it, retain possession or pass to a teammate. If the player decides to pass the ball, he must determine to whom it should be passed in the most effective way as well as the appropriate time to make the pass (Allen, 2007). To further underline the importance of decision-making in sport, Ibáñez, Sampaio, Lorenzo, Gómez, and Ortega (2008) found that poor decision-making is one of the most important predictors of losses in basketball leading to turnovers – particularly in closely contested games (Lorenzo, Gómez, Ortega, Ibáñez, & Sampaio, 2010). In addition, a study done by Raab, Masters and Maxwell (2005) on table tennis players indicated that players who focus on decision-making during training show improvements in performance. The important role of executive functioning in sport, and especially rugby, is clear from the abovementioned discussion. Despite the importance thereof in rugby, no published research could be found which specifically focuses on the relationship between a player's level of executive functioning and his or her on-field performance.

2.6 Emotion recognition

Emotion recognition refers to the ability to recognize interpersonal emotions through facial expression (Brain Resource Company, 2010). Literature reveals six universal emotions that are disclosed by different facial expressions which include anger, surprise, fear, sadness, happiness and disgust (Ekman & Friesen, 1971; Batty & Taylor, 2003; Boloorizadeh & Tojari, 2013). The expression of people's emotions is not only as a result of the emotions they experience, but also to transmit a communicative message to people around them (Parkinson, 1996). One can therefore assume that if an observer can't recognize emotions effectively through facial expression, he or she might miss the communicative message the other person had intended to send. This communicative message contains a vast amount of information for the observer. The observer might be able to make inferences about a person's feelings, attitudes, relational orientation and behavioural intentions by just watching other people's emotional expression

(Keltner & Haidt, 1999). In the context of sport it is vital to understand and recognize the emotions that are subjectively experienced and being exhibited by others during different situations in a game, especially for coaches to make appropriate changes to guarantee improved performance (Bolaarizadeh & Tojari, 2013). Furthermore, the expression of emotions might reveal an important cue about an opponent's intentions. Although literature indicated the importance of emotional expression and emphasized the importance of emotional recognition for coaches (Bolaarizadeh & Tojari, 2013), no studies could be traced which investigated the relationship between emotional recognition and performance in sport, especially rugby.

From the abovementioned discussion it is clear that the different measures of cognition, namely memory, attention and behavioural tasks, sensory-motor/spatial functioning, verbal functioning, executive functioning and emotion recognition all play an important role in sports performance. However, the importance of specific cognitive characteristics of a player is reduced if the cognitive attributes do not transfer to on-field playing performance. From the abovementioned discussion one could assume that a higher level of cognitive functioning will lead to better performance in sport; however, no studies could be found that have quantified the direct relationship between cognitive functioning and specific KPIs in rugby.

2.7 Key Performance Indicators

Key Performance Indicators (KPIs) refer to a combination of specific action variables that aim to define the identified aspects of performance (Hughes & Bartlett, 2002). The development of KPIs leads to the creation of performance profiles which can provide information regarding the pattern of performance by a team or an individual (James, Mellalieu, & Jones, 2005). In this regard a study conducted by James and co-workers (2005) identified the common performance indicators as successful and unsuccessful tackles, successful and unsuccessful carries, successful and unsuccessful passes, tries scored, penalties conceded as well as handling errors. Furthermore, the position-specific performance indicators identified were the lineout throw (hooker), successful/unsuccessful lineout takes and successful/unsuccessful restart takes (lock), turnovers won (back line players), successful/unsuccessful kicks (scrum-half, outside-half, centre, wing and full-back) and successful/unsuccessful high balls (wing and full-back). In order to ensure acceptable reliability, both intra- and inter-observer tests were calculated with the percentage errors for each variable (Huges, Cooper, & Nevill, 2002). The intra-observer procedure resulted in a low percentage of errors for all the variables when the differences were

re-examined to identify reasons for the discrepancy (mean +/- s: 1.97 +/- 3.14%). With regards to the inter-observer procedure, the test suggested that a good knowledge of rugby alone is not sufficient for adequate reliability, seeing that a substantial amount of training regarding the specific behavioural analysis system is required (James, Mellalieu, & Holley, 2002).

The selection of KPIs plays an important part in the development of a real-time performance analysis system (O'Donoghue, 2008). Furthermore O'Donoghue (2008) stated that it is necessary to have an optimal set of performance indicators to ensure that coaches and players receive sufficient information regarding their performance in order to support the coaching process.

The important role of effective cognitive functioning in sport performance is clear. However, despite proof of this notion no published research could be identified that investigated the direct relationship between cognitive functioning and on-field performance among rugby players. It is in the light of this paucity of information with regard to existing research that the following research question was posed: What is the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance (as determined by the KPIs) of university-level rugby players? Answers to this research question would provide coaches and sport psychologists with information regarding the relationship of various psychological constructs and the performance of players. These answers could further contribute to the development of psychological intervention programmes to improve on-field player performance and will lead to a better understanding of a player's individual needs to excel in performance. Furthermore the result of this study can assist in the compilation of individual player profiles which could assist coaches with team selections. Lastly, an expansion of the existing knowledge in the field of Applied Sport Psychology can be transferred to the wider sporting community.

3. AIM OF THE STUDY

The aim of this study was to:

- Determine the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance (as determined by the KPIs) of university-level rugby players.

4. HYPOTHESIS

- We expect that a significant positive relationship will exist between memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification and on-field performance (as determined by the KPI's) of university-level rugby players.

5. STRUCTURE OF THE DISSERTATION

The dissertation will be submitted in article format, consistent with the General Regulation A.13.7 of the North-West University and is structured as follows:

Section 1: Introduction, the rationale for the study and literature review, the aim of the study as well as the structure of the study.

Section 2: Research article: Thinking differently about rugby performance: The relationship between cognitive functioning and on-field performance of university-level rugby players. This article will be submitted for publication in the *Journal of Applied Sport Psychology*. This section and the reference list at the end of the section were compiled in accordance with the guidelines of the last-mentioned journal (see Appendix for the author guidelines). Although not in accordance with the guidelines of the journal, the figure and tables were included in the text to make the article easier to read and understand. For the sake of optimal use of space, the line spacing within the tables were changed to 1.15 instead of double-spacing as suggested by the journal's guidelines. Lastly, the page numbers have been inserted at the bottom of the page and not in the upper right corner as suggested by the journal's guidelines.

Section 3: Critical reflection.

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SECTION 2

ARTICLE

Thinking Differently about Rugby Performance: The Relationship between Cognitive Functioning and On-field Performance of University-level Rugby Players

Running title: Cognitive functioning and performance in rugby

Ankebé Kruger[1&2*], Kobus du Plooy[1&3] and Pieter Kruger[1&3]

[1]*Community Psychosocial Research (COMPRESS), North-West University, Potchefstroom, South Africa.*

[2]*Physical Activity, Sport & Recreation (PhASRec), North-West University, Potchefstroom, South Africa.*

[3]*Institute for Psychology & Wellbeing, North-West University, Potchefstroom, South Africa.*

* Correspondence:

Ankebé Kruger

11755350@nwu.ac.za

Abstract

Expert performance in sport depends on physiological, technical, emotional and cognitive domains. The Spearman Partial Correlation, controlled for playing times of the tight five forwards revealed that players' sensory-motor ability might contribute to the number of carries the players perform during attacking play. In terms of the loose forwards the positive correlation between total contribution and emotion identification might be indicative of the important role of good pattern recognition and associated quick decision-making. In line with the results of the loose forwards, the analyses of the backs revealed medium to strong positive correlations between emotion identification and total attacking contribution, passes as well as kicks. It therefore seems as if effective pattern recognition ability and associated quick decision-making might be important cognitive functions for backline players as well as loose forwards.

Keywords: cognitive functioning, neuropsychology, performance, performance indicators, rugby union, sport psychology

INTRODUCTION

Rugby Union (hereafter referred to as rugby) forms part of a cluster of rugby/football games which include Rugby League, American Football, Australian Rules football as well as soccer (Shuttleworth-Rdwards & Radloff, 2008). Rugby is regarded as one of the most popular, professional team sports in the world with nearly 200 countries affiliated at the International Rugby Board (Brooks, Fuller, Kemp, & Reddin, 2005; Kemp, Hudson, Brooks, & Fuller, 2008). Furthermore, in 2014, South Africa had a total of 418 509 players of which 342 316 were registered players (Worldrugby, 2016). A rugby match consists of two halves of 40 minutes each which is divided by a 10-15 minute break. Rugby is characterized by various high-intensity activities (Gill, Beaven, & Cook, 2006; Suzuki, Umeda, Nakaji, Shimoyama, Mashiko, & Sugawara, 2004), short bouts of low-intensity activities (Gill et al., 2006; Suzuki et al., 2004) as well as psychological, social and behavioural demands which need to be addressed (Suzuki et al., 2004; Venter, Potgieter, & Barnard, 2010). According to Cox and Yoo (1995), expert performance in sport does not only depend on a player's physical and tactical skills, but also on the player's psychological skills.

Contributors to expert performance

Expert performance in sport (including rugby) can be defined as "the consistent superior athletic performance over an extended period" (Starkes as cited in Janelle & Hillman, 2003, p. 21), and such expert performance in sport depends on no less than four domains, namely the physiological, technical, psychological and cognitive domains (tactical/strategic, perceptual/decision-making) (Janelle & Hillman, 2003). As this study focusses on the relationship between cognition and on-field performance, the physiological and technical demands fall outside the scope of the study and therefore only the cognitive domains are discussed next.

Cognitive domains

Cognitive functioning of an athlete includes working memory, attention and behavioural tasks, sensory-motor/spatial functioning, verbal functioning, executive functioning and emotion recognition (Carlstedt, 2007). Rugby players often need to quickly and efficiently select situation-appropriate actions under extreme pressure and in high interference situations where all the aforementioned cognitive abilities are required (Furley & Memmert, 2013).

Working memory

A player's attention and working memory (WM) (Baddeley, 2007) are important cognitive factors in understanding performance in such situations (Furley & Memmert, 2010; Furley, Memmert, & Heller, 2010; Furley & Memmert, 2012). According to Goldman-Rakic (as cited in Lezak, Howieson, Bigler, & Tranel, 2012) WM functions to keep information in mind, to internalize the information, and to use that information in order to guide behaviour without the support of or in the absence of trustworthy external cues. Rugby has developed into a more structured sport with teams displaying more complex match strategies and tactics (Hendricks, Roode, Matthews, & Lambert, 2013). One can assume that in order to successfully execute these strategies and tactics, a player must be able to retrieve the correct responses for the specific situation and therefore needs optimal working memory.

Attention and behaviour

Expert athletes have the ability to attend to and extract the most relevant cues in the sporting environment and avoid paying attention to irrelevant or distracting information (Starkes, 1993). Rugby is an unpredictable and uncertain game, therefore it can be assumed that a player's ability to effectively detect and respond to the constantly changing environment will have a significant effect on performance (Passos, Araújo, Davids, & Shuttleworth, 2008).

Sensory-motor/spatial functioning

Sensory-motor functioning refers to another cognitive function which plays an important role in rugby performance that includes the ability to perform motor skills, respond to information in a timely fashion, reaction time as well as hand-eye coordination (Brain Resource Company (BRC), 2010; Lezak et al., 2012). With specific application to rugby for example, a jumper in the lineout who jumps to catch the ball not only needs good eye-hand coordination to successfully catch the ball, but he needs to catch it at the highest point of his jump, therefore exact timing is of utmost importance (Van Velden, 2013). Simultaneously with the jump, the player has to position his body in a way that he protects himself from approaching defenders without knocking the ball on during the catch and therefore needs effective hand-eye coordination and sensory motor spatial awareness (Van Velden, 2013).

Verbal functioning

A team's ability to verbally communicate effectively to each other during the course of a game has a direct relationship with its success. Or stated differently, teams that do not communicate effectively will have a harder time winning, because communication is one of ten key factors for a successful defence in a game. Communication is vital in organizing the teams' defenders and to identify the attacking threats, trigger timely reactions and assuring that the team is functioning as a unit, and not as individuals (iSport, 2016; Westgate, 2007).

Executive functioning

Another factor to consider is executive functioning, which is also referred to as higher-order cognitive functioning (Verburgh, Scherder, van Lange, & Oosterlaan, 2014). This can be conceptualized as having four main components, namely volition, planning and decision-making, purposive action and effective performance (Lezak et al., 2012). In addition, executive functioning can also include inhibition of behaviour, attention and working memory (Pennington & Ozonoff, 1996). Over the last decade, with the advances in

sports science, sports medicine and technology, rugby players have become fitter, faster, stronger, bigger and more skilful, analysing the opposition much more effectively, with most teams also adopting fairly similar in-game defensive patterns. As a result of these changes over time, the outcome of a game is increasingly decided by complex systems and game strategies. Executive functions might play an important role in the successful performance in rugby, since these functions enable adaptation to new and constantly changing situations, attention as well as recall of game strategies (Williams & Ericsson, 2005).

Emotional domain

One final factor to consider is a concept called 'emotion recognition'. This refers to the ability to recognize interpersonal emotions through facial expression (BRC, 2010; Lezak et al., 2012). Body language, which includes facial expressions, amongst others, is thought to play an important role in sport (The British Psychological Society, 2000-2016). Team sport players have to be able to rapidly interpret and send nonverbal signals to their teammates and opponents. Rugby players, for example, have to communicate with their teammates on the field without saying anything when they have to know when to receive a pass or when someone will move to the left or the right into space. Some non-verbal cues rugby players might use include the eyebrow flash when they want to initiate a pass, torso tilting when they want another player to engage with them and the chin salute, a more subtle way players use to point towards an opening or another player. It is thus clear why rugby players need to be able to effectively identify and accurately interpret different nonverbal signs (Van Edwards, 2013). In order to determine the relationship between a player's cognitive functioning and his on-field performance, as set of Key Performance Indicators (KPIs) were used.

Key Performance Indicators (KPIs)

For teams to track their performance during the course of a week, month or season, they need some independent measures to be able to know how well they are performing. This

is something referred to as Key Performance Indicators (KPIs) (Hughes & Bartlett, 2002). These KPIs are a combination of specific action variables that aims to define the identified aspects of performance (Hughes & Bartlett, 2002). O'Donoghue (2008) stated that it is necessary to have an optimal set of performance indicators to ensure that coaches and players receive sufficient information regarding their performance in order to support the coaching process. For the purpose of this study the Stratus game analysis programme was used. Stratus is technical analysis software developed by the South African Rugby Union (SARU) to monitor the on-field performance of rugby players. Stratus is used to code an individual player's on-field performance for thousands of matches every season with each "action" being coded in the database by the full-time qualified coders of the technical support department of SARU. The system was therefore not developed by SARU for research purposes but rather for practical purposes to track the on-field performance of players. As a result no scientific literature could be identified which utilised the Stratus system as a measuring tool for research purposes to date.

In sum, the literature revealed that the different measures of cognition, namely memory, attention and behavioural tasks, sensory-motor/spatial functioning, verbal functioning, executive functioning and emotion recognition play an important role in sport performance. Therefore, the aim of this study was to determine the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance (as determined by the KPIs) of university-level rugby players. According to the researchers' knowledge, it is assumed that the present study is among the first that investigated such a relationship.

METHOD

Participants

A group of 25 male university-level rugby players were recruited from the North-West University's (NWU) Rugby Institute squad who participated in the Varsity Cup Tournament. The group consisted of eight tight five players (numbers 1-5), five loose forwards (numbers 6-8) and twelve backline players (numbers 9-15) with an average age of 22.63 (SD=0.74), 22.80 (SD=1.30) and 21.50 (SD=0.38) respectively. In the interest of clarity, Figure 1 provides a depiction of the different positions of a 15-a side rugby team.

The Varsity Cup Tournament originated in 2008 and begins with a round robin stage in which all teams play against one another which results in a total of nine games played during the tournament. At the end of the round robin stage, the top four teams go through to the knockout stage with the two top teams being awarded a home semi-final. The inclusion criteria employed in the recruitment of the participants included that they had to be part of the University's squad for the Varsity Cup Tournament, they had to be literate in English and computer use, they had to provide voluntary consent for their data to be used for research purposes, they had to be injury free on their dominant hand at the time of the assessment and they had to be totally free of any serious injuries and known illnesses, including mental illnesses. The exclusion criteria included players who were unable to read or write English, participants who did not give voluntary consent to participate in the study, participants who sustained an injury to their dominant hand and participants who sustained any other injury and/or known illness that would cause the player to be unable to play for the duration of the entire season, including a mental illness.

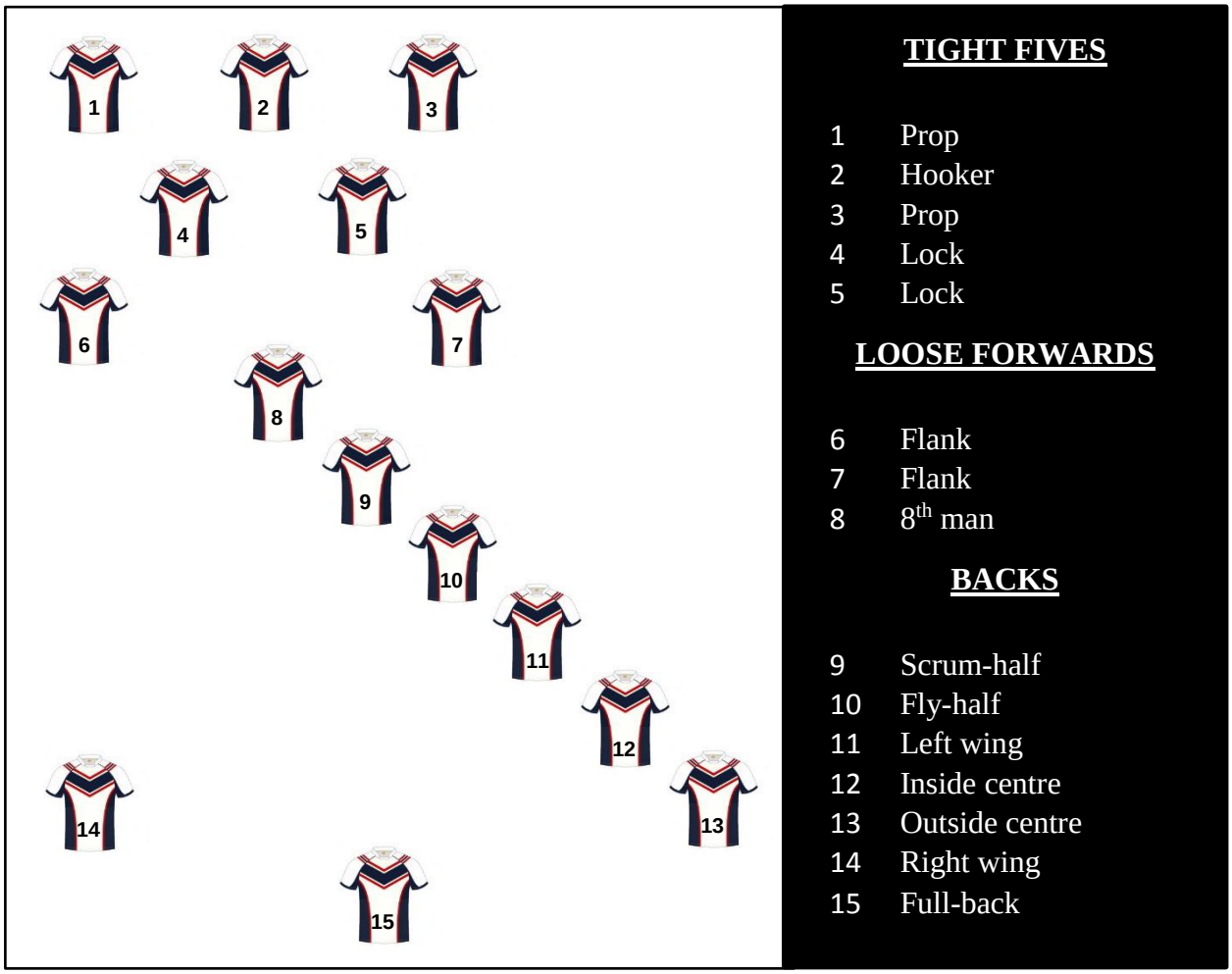

Figure 1. Visual representation of the positions in rugby

Measures

Cognitive functioning. The WebNeuro Sport (BRC, 2010) is one of various assessments developed by the BRC. The BRC is a service company which provides standardised test batteries in order to measure brain function and cognition across different applications. The cognitive functioning of the participants in this study was measured using the WebNeuro Sport which consists of a demographic questionnaire (name, surname, age and gender) and seven measuring scales namely the Carlstedt Subliminal Attention, Reactivity and Coping Scale-Athlete Version (CSARCS-A), a cognitive functioning domain, the Brain Resource Inventory for Screening Cases (BRISC) which is a screening tool for markers of self-regulation, a Depression Anxiety Stress scale (DASS), sleep, Brain Resource Inventory

for Emotional Intelligence Factors (BRIEF) and Personality (BRC, 2010). However, for the purposes of this study, only the cognition scale was used for further analysis.

Memory domain. The memory domain was measured by the *memory recall*, *digit span* and *emotion bias* tasks. The *memory recall* task consists of 2 parts. The first part assessed immediate memory recall and learning. Each trial involved a list of 20 words which was visually presented one at a time on the computer screen. Twenty sets of 3 response words were then presented to the participants. One of each response word in each set was a word that was previously presented and the participants had to select the word in each set that they remembered. The word response combinations was altered for each trial. The second part of the memory recall task assessed delayed memory recall and was completed 10 minutes after the first part. In this trial the participants were presented with 20 sets of 3 3 response words again, from which they had to select 1 word from each set (without a repeated presentation of the initial list). The total duration of this task was approximately 4 minutes. *Digit span* entailed a series of digits which were sequentially presented on the screen. After this initial presentation of the digits, a 9-digit button pad appeared on the screen and the participants had to reproduce the sequence order that the numbers were presented in by clicking on each number with the mouse in the correct order. The first sequence consisted of 3 digits where after each trial progressively increased in length, with 2 trials for each length level. The task was terminated after 2 incorrect trials at the same length level or when the maximum length of 9 digits was completed (a maximum total of 14 trials). The maximum duration of the task was approximately 3 minutes. The *emotion bias* task involved sets of 2 faces which were presented on the computer screen. One of the faces was repeated from the Emotion Identification task which was done before this particular task, and the other face was new. The participants used the mouse to click on the face they remembered from the previous task.

In total, there were 24 face pairs presented. The duration of the task was approximately 2 minutes.

Attention/Behavioural domains. This domain included the *continuous performance test, switching of attention, verbal interference* and the *Go/No-Go test*. The *continuous performance test* involved a series of letters (B, C, D or G) which were presented one at a time on the screen (display time is 200ms, ISI 2600ms). The participant had to respond as quickly as possible by pressing the spacebar on the keyboard as soon as the same letter appeared twice in a row. There were a total of 63 stimuli, with 12 "response" trials where the same letter was repeated twice in a row. The task lasted about 3 minutes. The *switching of attention task* involved a pattern of 13 numbers (1-13) and 12 letters (A-L) which was displayed on the screen. The participant had to alternatively selected numbers and letters in an ascending sequence (1, A, 2, B etc.) as quickly as possible. When the participant made a correct response, a line appeared on the screen between the last choice and the current choice. The duration of this task was approximately 2 minutes. The *verbal interference* test refers to 1 of 4 colour words (red, blue, yellow, green) which was displayed on the screen in 1 of 4 font colours (red, blue, yellow, green) with 4 response buttons (1 for each word, all displayed in black) displayed underneath the colour words. The participants had to click on the response button that described the font colour of the word which was displayed above. The participants had to respond as quickly as possible after each stimulus appeared. The task lasted about 30 seconds. The *Go/No-Go test* involved the word "PRESS" which was presented on the screen repeatedly (display time 500ms, ISI 500ms). The word was displayed frequently in green font colour and infrequently in red. The participants had to respond to each stimulus by pressing the spacebar on the keyboard as soon as the green "PRESS" stimuli appeared, but not when the red "PRESS" stimuli appeared. In total, there were 168 stimuli (126 green, 42 red) and the task duration was approximately 4 minutes.

Sensory-motor domains. The sensory-motor domain included the *motor tapping* test and the *choice reaction time* test. With the *simple motor tapping test*, the participants were required to tap the space bar on the computer's keyboard as fast as possible with their dominant hands' index finger for the duration of 30 seconds. The *choice reaction time test* consists of 20 trials which was presented in a pseudo-random sequence with random time delays of 2-4 seconds between trials. The total duration of this task was approximately 2 minutes. On each trial, one of two black circles changed to green and was positioned on the left and right hand side of the screen. The participant had to respond as quickly as possible by pressing the left arrow key if the left circle was green, and the right arrow key if the circle on the right was green. For each trial, the green circle continued to display until the participant made the correct response. This task assessed the participant's speed of sensory-motor function and information processing speed.

Verbal. The language domain was assessed by the *Spot the real word t*est. The participants were asked to select the real word which was presented next to a nonsense word.

Executive function domains. During the *maze test*, the participant was presented with a grid of circles on the computer screen. The aim of this task was to identify the hidden path through the grid, from the beginning at the bottom to the end at the top. The purpose of the task was to assess how quickly the participant learned the route through the maze as well as their ability to remember that route. The participant was able to navigate around the grid by pressing the arrow keys on the computer's keyboard. To complete the maze, a total of 24 successive moves were required. Across the trials, only one maze was presented and the test ended when the participant completed the maze twice without making an error or when the maximum task duration of 5 minutes was reached.

Emotion identification. This domain was determined by the *emotion identification test*. The participant was presented with a series of faces with different

emotional expression for example fear, anger, disgust, sadness, happiness or neutral. By using the mouse, the participant had to identify the correct emotional expression presented by the face on the computer screen. In total there were 48 trials and the task lasted about 4 minutes.

The table below (Table 1) summarizes the correlation between the IntegNeuro and the WebNeuro for each of the cognitive functioning tests (Silverstein, Berten, Olson, Paul, Williams, Cooper, & Gordon, 2007).

Table 1

Correlations between IntegNeuro and WebNeuro critical scores for each test

Test score	Validity coefficient	Interpretation
Sensorimotor tapping (average numbers)	0.56	Moderately high
Switching of attention duration	0.73	High
Visual interference accuracy	0.65	High
Verbal interference accuracy	0.45	Moderate
Sport the word accuracy	0.70	High
Digit span forward accuracy	0.74	High
Working memory (Reaction time)	0.43	Moderate
Working memory accuracy	0.87	Extremely high
Executive maze duration	0.79	High

Table 2 summarizes the test-retest reliability (Cronbach's alpha) of the Thinking and Emotion (Cognition) markers. Data are shown for subjects across all ages (BRC, 2010).

Table 2

Test-Retest Reliability (Cronbach's alpha) of the Thinking and Emotion (Cognition) markers across all ages.

Thinking and Emotion markers	Task measure	Test-Retest Reliability
Response speed	Motor tapping task	0.89
Impulsivity	Go-no-go test	0.79
Attention and concentration	Sustained attention	0.75
Information processing efficiency	Choice reaction time	0.66
	Verbal interference	0.77
	Switching of attention	0.85
Memory	Memory recognition	0.62
	Digit span	0.78
Executive function	Maze	0.73
Emotion identification	Emotion identification	0.79
Emotion bias	Implicit emotion recognition test of bias	0.72

On-field performance. In order to quantify the players' on-field performance, the Key Performance Indicators (KPIs) of each player were determined for each game by the full-time, qualified coders of the technical support department of The South African Rugby Union (SARU) by using the technical analysis software, Stratus. Stratus went live in January 2014 and was designed from scratch and is therefore still in its infancy stage. After the coding of each game, the coaches of the team had access to the statistics for use according to their needs. The Rugby Institute of the University where the research was conducted bought and used the Stratus game analysis software which motivated its use in the present study. Furthermore it was selected in order to contribute to the reliability and validity of the

program for future use in similar research studies. For the purposes of this study one of the co-researchers chose the following variables for the different positions as indicated in the table below. The variables were chosen based on the principal investigators' extensive experience of 15 years within the domain of rugby and according to the roles each of the different positions had to fulfil during a game.

Table 3

Key Performance Indicators for the different positions

Tight five	Loose forwards	Backs
Attacking variables		
Total attack contribution	Total attack contribution	Total attack contribution
Carries	Carries	Carries
Ball recycler	Ball recycler	Passes
Passes	Passes	Kicks
Attacking mauls	Attacking mauls	Breakdown arrivals
Breakdown arrivals	Breakdown arrivals	
Defence variables		
Total defence contribution	Total defence contribution	Total defence contribution
Tackle attempts	Tackle attempts	Tackle attempts
Missed tackles	Missed tackles	Missed tackles
Defensive mauls	Defensive mauls	Breakdown arrivals
Breakdown arrivals	Breakdown arrivals	

As seen in Table 3, attacking variables include total number of contributions a player made during attacking play, carries (number of carries), passes (number of passes a player gave), kicks (number of kicks during the game), ball recycler (number of times a player recycled the ball from a maul), breakdown arrivals (number of times a player is part of breakdowns) and attacking mauls (number of times a player was part of an attacking maul. Defensive variables include total number of contributions a player provided during defensive play, tackle attempts (number of attempts), missed tackles (number of tackles missed),

breakdown arrivals on defence (number of times a player is part of breakdowns) and defensive mauls (number of times a player was part of a defensive maul).

Procedure

The participants were tested in groups of eight per session in the computer laboratory at the Department of Psychology of the University where the research was conducted. After providing written consent to participate in the study, they completed the WebNeuro Sport web-based assessment. On the day of the assessments, the procedures were explained to all the participants after which they were given time to ask questions. The co-researcher, a registered clinical psychologist, was present for the duration of the assessment to answer any questions or to explain any unfamiliar terms to the players and provide support to participants, if required. The venue was set up to ensure that participants had the necessary privacy and limited distractions. The online assessment was done before commencement of the tournament and the data for the KPI's for each of the 9 games were collected during the Varsity Cup tournament. Ethical approval for the study was granted by the Health Research Ethics Committee of the Faculty of Health Sciences of the university where the research was conducted (XXX-00093-15-S1).

RESULTS AND DISCUSSION

Data analysis

The Statistical Package for the Social Sciences (SPSS) (2013) version 23 was used to process the data. All the analyses were applied on the average values of the nine games which were played during the Varsity Cup Tournament. Firstly, descriptive statistics (minimum, maximum, means, standard deviations and 90% confidence intervals) were reported for all the testing variables and biographical information for each group (tight five, loose forwards, backs). Secondly, a Spearman Partial Correlation, controlled for playing time, was conducted for all the variables for each of the three groups. Because all the players did not play an equal

amount of time in each game throughout the season, the researchers corrected for the playing time of each player. The correlations were interpreted according to Cohen's (1992) effect size guidelines for correlation coefficients, with values of .10, .30, and .50 representing small, medium and large effect sizes, respectively.

The means, standard deviations and 90% confidence intervals for the cognition variables and the attacking and defensive KPI's for the tight five, loose forwards and backs can be seen in Tables 2, 3 and 4 respectively. It is important to take note of the difference in the KPIs between the forwards (tight five and loose forwards) and the backs. With the attacking KPIs, kicking was added for the backs and breakdown recycler and mauls removed. The defensive KPIs for all the groups remained unchanged. The researchers assigned different KPIs for the forwards (tight five and loose forwards) and the backs based on the different roles that players in these different positions (forwards vs. backs) have to fulfil in the team.

Table 4

Descriptive statistics for the cognition variables and the on-field performance variables of the university-level rugby players: ***Tight fives***

Variable	**n**	***M***	***SD***	**90% CI**	
				LL	**UL**
Age	8	22.63	0.74	22.13	23.12
Years of education	8	14.88	1.73	13.72	16.03
Cognition variables					
Memory	8	0.27	0.47	-0.04	0.59
Attention	8	-0.31	0.65	-0.74	0.13
Sensory (motor/spatial)	8	0.58	0.86	0.01	1.15
Verbal	8	-0.65	1.05	-1.35	0.05
Executive function	8	-0.44	0.98	-1.10	0.22
Emotion identification	8	0.39	0.72	-0.10	0.88
KPIs - Attack					
Total contributions	8	606.75	264.77	429.40	784.10
Carries	8	35.63	18.66	23.12	48.13
Passes	8	11.50	10.28	4.61	18.39
Breakdown recycler	8	33.38	16.69	22.20	44.55
Breakdown arrivals	8	106.00	37.68	80.76	131.24
Mauls	8	37.63	19.43	24.61	50.64
KPIs- Defence					
Total contribution	8	240.88	121.20	159.69	322.06
Tackle attempts	8	57.63	29.22	38.05	77.20
Missed tackles	8	6.00	4.47	3.00	9.00
Breakdown arrivals	8	29.63	19.14	16.80	42.45
Mauls	8	32.25	24.26	16.00	48.50

Note. CI = confidence intervals; LL = lower limit; UL = upper limit; KPI = key performance indicator

Table 5

Descriptive statistics for the cognition variables and the on-field performance variables of the university-level rugby players: ***Loose forwards***

Variable	**n**	***M***	***SD***	**90% CI**	
				LL	**UL**
Age	5	22.80	1.30	21.56	24.04
Years of education	5	6.40	6.11	0.58	12.22
Cognition variables					
Memory	5	0.47	0.38	0.11	0.83
Attention	5	0.34	0.46	-0.10	0.77
Sensory (motor/spatial)	5	0.95	0.62	0.36	1.54
Verbal	5	-0.41	0.63	-1.01	0.19
Executive function	5	-0.21	0.40	-0.59	0.17
Emotion identification	5	0.70	1.09	-0.34	1.75
KPIs - Attack					
Total contributions	5	539.60	275.81	276.65	802.55
Carries	5	34.40	20.88	14.50	54.30
Passes	5	16.80	11.19	6.13	27.47
Breakdown recycler	5	38.20	22.44	16.80	59.60
Breakdown arrivals	5	100.60	44.76	57.92	143.28
Mauls	5	31.60	18.22	14.23	48.97
KPIs- Defence					
Total contribution	5	200.60	112.39	93.45	307.75
Tackle attempts	5	76.40	41.07	37.24	115.56
Missed tackles	5	7.20	6.30	1.19	13.21
Breakdown arrivals	5	33.40	18.50	15.76	51.04
Mauls	5	17.20	13.27	4.54	29.86

Note. CI = confidence intervals; LL = lower limit; UL = upper limit; KPI = key performance indicator

Table 6

Descriptive statistics for the cognition variables and the on-field performance variables of the back university-level rugby players: ***Backs***

Variable	n	*M*	*SD*	90% CI	
				LL	UL
Age	12	21.50	1.38	20.78	22.22
Years of education	12	14.50	1.88	13.52	15.48
Cognition variables					
Memory	12	0.18	0.74	-0.20	0.57
Attention	12	-0.20	0.96	-0.69	0.30
Sensory (motor/spatial)	12	0.94	0.72	0.56	1.31
Verbal	12	-1.44	1.40	-2.17	-0.72
Executive function	12	-0.19	1.78	-1.12	0.73
Emotion identification	12	-0.01	1.01	-0.53	0.51
KPIs - Attack					
Total contributions	12	305.00	195.81	203.49	406.51
Carries	12	44.08	25.80	30.71	57.46
Passes	12	93.42	147.03	17.19	169.64
Kicks	12	19.92	25.77	6.56	33.28
Breakdown arrivals	12	34.92	25.11	21.90	47.93
KPIs- Defence					
Total contribution	12	74.25	40.01	53.51	94.99
Tackle attempts	12	56.67	31.01	40.59	72.74
Missed tackles	12	10.83	6.48	7.47	14.19
Breakdown arrivals	12	14.50	9.48	9.58	19.42
Mauls	12	1.58	1.93	0.58	2.58

Note. CI = confidence intervals; LL = lower limit; UL = upper limit; KPI = key performance indicator

Relationship between cognitive variables and attacking and defensive KPIs

Spearman partial correlation, controlling for playing time, were computed between the cognitive variables and the KPI's (attacking and defensive) to address the key aim of this study. An inspection of the zero order correlation suggested that controlling for playing time had a significant effect on the strength of the relationship between the cognition variables and KPIs and therefore we controlled for playing time in the Spearman partial correlation.

Table 7

Spearman partial correlations between measures of on-field performance and cognition variables, controlling for playing time, of the university-level rugby players: ***Tight five (n=8)***

Scale	**Memory**	**Attention**	**Sensory (motor/spatial)**	**Verbal**	**Executive function**	**Emotion Identification**
Attack						
Total contributions	.10	-.91**	-.58	-.79*	-.67	-.13
Carries	.18	.36	.81*	.24	.51	-.11
Passes	-.38	.28	069	.71	.75	-.35
Breakdown recycler	.66	-.06	.26	-.36	-.05	.23
Breakdown arrivals	.26	-.26	-.54	-.56	-.38	.20
Mauls	-.52	-.37	-.45	.00	-.26	-.33
Defence						
Total contribution	-.14	-.68	-.52	-.53	-.71	-.11
Tackle attempts	.08	-.60	-.60	-.92**	-.72	.26
Missed tackles	-.22	-.17	-.50	.31	-.07	-.04
Breakdown arrivals	-.03	-.40	.24	-.68	-.44	-.33
Mauls	-.11	-.47	-.68	-.18	-.48	.03

Note. * $p < 0.05$; ** $p < 0.01$

Regarding the attacking KPIs, in the tight five, the results revealed strong, negative partial correlations between total contribution and attention, ($r = -.91$, $p < .01$), total contribution and the verbal aspect of cognition ($r = -.79$, $p < .05$) and a strong positive partial correlation between carries and the sensory aspect of cognition ($r = .81$, $p < .05$). In the defensive KPI's, the results revealed a strong, negative partial correlation between the tackle attempts and the verbal component of cognition ($r = -.92$, $p < .01$).

Table 8

Spearman partial correlations between measures of on-field performance and cognition variables, controlling for playing time, of the university-level rugby players: ***Loose forwards (n=5)***

Scale	**Memory**	**Attention**	**Sensory (motor/spatial)**	**Verbal**	**Executive function**	**Emotion Identification**
Attack						
Total contributions	.78	.18	-.99*	-.49	.12	.85
Carries	.22	.05	-.34	-.25	-.81	-.06
Passes	.78	.94	-.25	.69	.29	.35
Breakdown recycler	-.31	-.19	.21	-.12	-.97*	-.57
Breakdown arrivals	-.60	-.88	.04	-.79	-.38	-.21
Mauls	.52	.14	-.68	-.37	-.52	.34
Defence						
Total contribution	.75	.21	-.86	-.31	.71	.99*
Tackle attempts	.42	-.19	-.82	-.73	-.20	.57
Missed tackles	.40	.21	-.46	-.19	-.72	.09
Breakdown arrivals	.20	-.26	-.47	-.45	.94	.75
Mauls	.73	.47	-.58	.11	.82	.81

Note. * $p < 0.05$; ** $p < 0.01$

Among the loose forwards, a strong, negative partial correlation emerged for attacking total contributions and the sensory aspect of cognition ($r = -.99$, $p < .05$) as well as for attacking breakdown recycler and executive functioning ($r = -.97$, $p < .05$). For the defensive KPIs, a strong, positive partial correlation existed between total contribution and emotion identification ($r = .99$, $p < .05$).

Table 9

Spearman correlations between measures of on-field performance and cognition variables, controlling for playing time, of the university-level rugby players: ***Backs (n=12)***

Scale	**Memory**	**Attention**	**Sensory (motor/spatial)**	**Verbal**	**Executive function**	**Emotion Identification**
Attack						
Total contributions	.47	.44	.12	.47	.17	.64*
Carries	-.03	.25	.09	.07	.01	.28
Passes	.44	.32	.15	.48	.11	.67*
Kicks	.57	.37	.52	.57	.33	.65*
Breakdown arrivals	-.20	-.09	-.31	-.42	.02	-.58
Defence						
Total contribution	-.06	.32	-.22	-.04	.09	-.29
Tackle attempts	-.12	.29	-.33	-.01	.09	-.34
Missed tackles	.20	.49	-.03	.21	.37	-.12
Breakdown arrivals	-.18	.25	-.04	-.24	.04	-.43
Mauls	.50	.39	.21	.21	.18	.41

Note. * $p < 0.05$; ** $p < 0.01$

From the table above it is clear that the backs showed strong, positive partial correlations for attacking total contributions and emotion identification ($r = .64$, $p < .05$) passes and emotional identification ($r = .67$, $p < .05$) as well as kicks and emotion identification ($r = .65$, $p < .05$).

The aim of the present study was to determine the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance (as determined by the KPIs) of university-level rugby players. The results of the study revealed several interesting findings on the relationship between rugby players' cognitive functioning and their on-field performance.

Tight fives

More specifically, amongst the tight five forward players, the findings indicated a strong negative partial correlation between players' total attacking contributions and attention, total attacking contribution and verbal tasks and a strong positive partial correlation between the amount of carries and sensory-motor functioning. Since this is according to our knowledge the first study of its kind, it makes the comparison of our findings with existing literature virtually impossible. Attention and behavioural tasks in a sport context have been defined as the ability to selectively concentrate during cognitive tasks, detect and respond to changes in the environment, sustain attention over time and to control impulses (BRC, 2010). According to this definition, a potential hypothesis for the strong negative partial correlation between the players' total attacking contributions and attention is that players with a stronger ability in terms of focused attention will adjust their behavior in a way that they might first evaluate the changes in the environment and then decide whether it is appropriate to contribute or not. In addition, players with better attention and behavioural ability might control their impulses more optimally and therefore not make random or impulsive contributions before evaluating the situation on the field. Further research regarding this matter is necessary in order to obtain further clarity on this phenomenon.

'Verbal tasks' refer to the ability of an individual to recognize words, access words and remember what has been heard (BRC, 2010). These verbal functions are only a few of the many functions that take place in the prefrontal cortex of the brain (Lezak et al., 2012). However, successful rugby players need to be able to make repeated, accurate decisions during play. Since this dynamic game is played in a confined space with limited time for decision-making, the players need well-developed pattern recognition and spatial awareness skills and abilities (conditioned responses). Effective spatial awareness skills are important in order to know where teammates and opponents are at all times in relation to them, while

keeping track of the ball in play (Baker, Côte, & Abernethy, 2003). A study done by Forsythe, Lias, Trumbo, and Cardona-Rivera (2015) showed that the pre-cuneus region of the parietal lobe as well as the caudate nucleus of the basal ganglia plays a functional role in perceptual pattern recognition and spatial awareness. Therefore, the strong negative partial correlation between total attacking contribution and high verbal processing abilities raises the question as to whether players who scored high in the verbal processing abilities experience increased activation in the frontal lobe, which in turn might cause lower activity in the parietal lobe and basal ganglia with a consequent detrimental effect on pattern recognition and subsequent decision-making. Therefore, players might find it difficult to make effective and timeous decisions which will have an effect on their total contribution to the game if they tend to have more activity in the prefrontal cortex.

The results furthermore indicated a strong positive correlation between the number of carries and the sensory-motor task of the tight fives. The sensory-motor task measured a player's hand-eye coordination as well as the accuracy of selecting an appropriate response based on visual input and also includes reaction time (BRC, 2010). This strong positive correlation between the number of carries and the sensory-motor functioning of the tight five could potentially be as a result of the players' ability to be able to effectively see space in the opposition's defence, position themselves accordingly and judge the most effective running lines which might make it more likely for them to receive the ball in play. Hand-eye coordination, which refers to the ability of the eyes and hands to work as a dynamic whole (Haggard, 1997), would furthermore allow players to collect the ball at a high speed while running into the opposition's defence and still maintaining control of the ball. The results of our study are thus in line with literature confirming the fact that in order to be able to carry the ball effectively, a player requires effective sensory-motor abilities (Haggard, 1997). Furthermore, optimal sensory-motor abilities might make it easier for a player to be in the

right place at the right time and execute the expected behaviour while running at a defensive line.

Regarding the tight five's defensive KPIs, the results revealed a strong negative correlation between the number of tackles a player attempted and his verbal processing abilities. Verbal processing is defined by the BRC (2010) as the ability to recognize words, access words and to remember what has been heard. On-field communication forms an integral part of any effective rugby defence. Players continuously communicate with each other in order to organize the defensive structures and identify the attacking threats and thus execute the defence effectively. In addition the defending players on the inside and outside of the ball-carrier need to communicate clearly and loudly while they are pushing forward (Westgate, 2007). Applied to the game of rugby, verbal processing might refer more to players recalling defensive patterns and calls instead of them recognizing words and accessing words. It is clear that the players have to attend to a large volume of on-field communication and external cues during a game.

Due to the fact that verbal processing takes place in the prefrontal cortex, a possible explanation for the negative correlation between the number of tackles a player attempted and his verbal processing abilities might be that players experience an overload in the frontal cortex, which gets in the way of automatic execution of the tackle. In addition, when the player's thinking takes over, it might cause a disruption of motor and or technical skills (Carlstedt, 2013) due to the fact that the increased activation of the prefrontal cortex could lead to lower activity in the parietal lobe and basal ganglia with a consequent detrimental effect on pattern recognition and subsequent decision-making. Therefore, players might be indecisive regarding tackling of an opponent but their speed of decision-making might also be affected based on their impaired ability to recognize certain patterns and the automatic execution of the tackle.

Loose forwards

The analyses of the loose forwards' attacking KPIs revealed strong negative partial correlations between the players' total attacking contribution and their sensory-motor ability as well as successful breakdown recycling and executive functioning. Sensory-motor abilities include aspects such as hand-eye coordination and the accuracy of selecting an appropriate response during play, based on visual input (BRC, 2010). According to this definition, players with good sensory-motor ability might be more selective in their actions and therefore not aimlessly migrate from one situation to the next, which might explain the negative correlation between the players' total attacking contribution and their sensory-motor ability. According to the current KPIs that we measured in this study, we only have statistics about the player's attacking contribution, but we don't know if the contribution was successful or not. Therefore, for future research we would recommend determining the accuracy of the players' attacking contribution and its correlation with cognitive abilities.

Furthermore we found a strong negative relationship between the number of times a player successfully recycled the ball from a maul (breakdown recycler) and executive functioning among the loose forwards. According to the BRC (2010), executive functioning refers to a player's ability to plan, strategize and execute complex tasks, to apply abstract thinking, to learn rules, to refrain from inappropriate actions and to ignore irrelevant sensory information. Executive functioning takes place in the frontal cortex of the brain (Lezak et al., 2012). The results suggest that the more a player thinks (instead of relying on pattern recognition) the less accurate he is in the quick and successful execution of ball retention on attack. The strong negative relationship between successful ball recycling and executive functioning could therefore possibly be ascribed to the fact that overthinking during the game might interfere with automated execution of actions during play, which could slow down

reaction and decision-making under pressure. Again, further research is deemed necessary to obtain further clarity on these results.

Regarding the defending KPIs, a strong positive partial correlation was found between total contribution and emotion identification. It is important to take note of the fact that the sub-test which was used to determine the players' ability to identify emotions consists of two parts. During the second part of the test (Emotion bias) the individual is presented with two sets of faces on the screen of which one face is repeated from the previous part of the emotion identification task. The player selects the face they remembered from the previous task as quickly as possible. Thus, it is clear that the participants need good judgement and be able to make very quick decisions to perform optimally on this test. On the field, players are continually faced with situations in which they need good judgment and take decisions very quickly. Therefore, it seems logical to hypothesize that players with good judgement and a good ability to make quick decisions (as determined by the emotion bias task) would also tend to make more contributions on the field. It is important to take note of the fact that a player's ability to identify an emotion is dependent on multiple factors such as his psychological status (level of anxiety, depression etc.) and his dispositional temperament which could have mediated the abovementioned associations.

Backs

In terms of the backline players, the results of this study revealed a medium to strong positive partial correlation between the attacking total contribution and emotion identification, passes and emotion identification as well as kicks and emotion identification. Passes, as well as kicks (which form a big part of the total contribution of backline players) involve quick decision-making by the players, in a dynamic situation, with time pressure. Therefore, the same line of reasoning could be used to explain these results as had been used to explain the strong positive partial correlation between total contribution and emotion

identification among the loose forwards. As stated previously, it is important to take note of the fact that a player's ability to identify an emotion is dependent on multiple factors such as his psychological status (level of anxiety, depression etc.) and his dispositional temperament which could have mediated the abovementioned associations.

In summary, players with good judgement and a good ability to take quick decisions (as determined by the emotion bias task) might contribute to effective decision making, whether to kick or to pass. Although this study mostly investigated the total contribution of players and the correlation with cognitive measures, future research can look into the individual accuracy of these contributions in order to establish the predictive value of cognitive measures when it comes to on-field execution in rugby.

Moreover, overall associations appear to be more significant with the attacking KPI's in comparison to the defensive KPI's. This could give rise to the question whether specific cognitive domains measured are associated more with certain types of play (e.g. attack vs. defence) rather than others and other cognitive abilities such as working memory have no associations with any position and type of action relevant to rugby? In order to shed more light on these phenomena further similar research is deemed necessary.

This study was the first to the authors' knowledge to explore the relationship between cognitive functioning, as determined by die WebNeuro Sport web-based assessment battery, and on-field performance among university-level rugby players. The results of this study revealed a positional difference in the relationship between cognition and on-field performance amongst the tight five forwards, loose forwards and backline players. Interesting results came to the fore. The analyses of the tight five forwards revealed that players' sensory-motor ability might contribute to the number of carries the players perform during attacking play. In terms of the loose forwards the positive correlation between total contribution and emotion identification might be indicative of the important role of effective

pattern recognition and associated quick decision-making. In line with the results of the loose forwards, the analyses of the backs revealed medium to strong positive correlations between emotion identification and total attacking contribution, passes as well as kicks. It therefore seems as if effective pattern recognition ability and associated quick decision-making might be important cognitive functions for backline players as well as loose forwards. Although this is the first study of its kind and the fact that most of the explanations were based on hypotheses, it might lay the foundation for further research regarding rugby players' cognitive functioning and related on-field performance.

CONCLUSION

At present, there appears to be insufficient literature regarding the relationship between rugby players' cognitive functioning and their performance on the field and therefore our results could not be compared to similar studies. Due to the small sample size of university-level rugby players used in this study, the results should be interpreted with caution. Therefore, there are several recommendations for future research. The results of this study should be verified in future studies on rugby players at different participation levels. The KPIs that were used in this study could be influenced by the style of play of a particular team, and therefore it would be informative to investigate the link between measures of cognitive functioning and measures of more objective on-field performance in rugby such passing accuracy, kicking accuracy, individual negative turnovers, successful tackles and possession kept or conceded. In addition, it might also be valuable to investigate the association between cognitive functioning and successful and unsuccessful KPIs, meaning that the actions either succeeded in achieving their intended goals or not.

Since the outcomes of neuropsychological assessments are sensitive to amongst others, the range of head injuries, cumulative head injuries and the time since a player sustained a head injury, it is deemed important that future studies included such information.

Furthermore, cognitive aspects such as emotional recognition is dependent on multiple factors such as a player's psychological status (e.g. levels of anxiety, depression etc.) as well as his dispositional temperament. Therefore, a recommendation for future research would be to incorporate a player's psychological status and his dispositional temperament as these factors could have mediated the associations between found between emotional recognition and certain KPIs.

An important implication of the present finding is that knowledge of the positive as well as the negative relationships and certain measures of cognitive functioning may be of value for improving on-field performance by means of the application of cognitive interventions programmes. Further research on the relationship between cognitive functions and on-field performance among rugby players will enhance our understanding of the relationship between cognition and performance.

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SECTION 3

CRITICAL REFLECTION

1. INTRODUCTION

After the Rugby World Cup in 1995, the International Rugby Board repealed the rules with regards to amateurism and consequently rugby became a professional sport (Treasure, Carpenter, & Power, 2000). Following rugby's transformation from amateurism to professionalism, interest in factors that might contribute to rugby performance increased significantly in academic journals, but not to the levels of others sports that have been played professionally for longer periods (Mellalieu, 2008). Research with regards to rugby can be grouped into four areas of interest namely performance analysis (Hughes & Bartlett, 2002), physiology of rugby players (Duthie, Pyne, & Hooper, 2003), biomechanics (Quarrie & Wilson, 2000) and the psychology of rugby players (Beauchamp, Bray, Eys, & Carron, 2002, Evans, Jones, & Mullen, 2004, Nicholls, Holt, Polman, & Bloomfield, 2006). In line with the abovementioned research, Janelle and Hillman (2003) stated that athletes must excel in four domains to be able to perform at elite levels of their respective sport namely the physiological, technical, cognitive and emotional domains. As early as in 1995, Cox and Yoo (1995) also stated that success in professional sport does not only depend on the participant's physical and tactical aspects, but that psychological skill should also be addressed. The only studies pertaining rugby players' cognitive functioning included studies which investigated the effect of concussion on the players' cognitive functioning (Hinton-bayre, Geffen, & McFarland, 1997; Hume, & Gissane, 2013; King, Brughelli, Alexander, Shuttleworth-Edwards, Kidd, & Malcolm, 2015; King, Gissane, Hume, & Flaws, 2015; Kirkwood, Parekh, Ofori-Asenso, & Pollock, 2015). According to the researchers' knowledge, no studies exist that investigated the relationship between players' cognitive functioning and their on-field performance.

2. CRITICAL REFLECTION OF THE PRESENT STUDY

In order to assess the relationship between cognitive functioning and on-field performance, a set of key performance indicators (KPI's) were used. Key performance indicators (KPI's) refer to a combination of specific action variables that aims to define the identified aspects of performance

(Hughes & Bartlett, 2002). Furthermore O'Donoghue (2008) stated that it is necessary to have an optimal set of performance indicators to ensure that coaches and players receive sufficient information regarding their performance in order to support the coaching process.

The aim of this study was to determine the relationship between measures of cognition (memory capacity, attention and behavioural tasks, sensory-motor functioning, verbal tasks, executive functioning and emotion identification) and on-field performance (as determined by the KPI's) of university-level rugby players. For the purpose of this study, the group of players were divided in the tight fives, loose forwards and backline players. In addition, the relationship between the players' cognitive functioning and on-field performance were determined for both attacking and defensive play. Findings regarding the tight five players' attacking play revealed a strong, negative partial correlation between total contributions and attention, total contribution and the verbal aspect of cognition and a strong positive partial correlation between carries and the sensory aspect of cognition. In the defensive play, the results showed a strong, negative partial correlation between the tackle attempts and the verbal component of cognition.

Among the loose forwards, a strong, negative partial correlation emerged for attacking total contributions and the sensory aspect of cognition and for attacking breakdown recycler and executive functioning. For the defensive KPI's, a strong, positive partial correlation existed between total contribution and emotion identification. Regarding the backs the results revealed a strong, positive partial correlations for attacking total contributions and emotion identification passes and emotional identification as well as kicks and emotion identification. With regards to defensive play, no significant partial correlations were found.

From the aforementioned summary of the results of this study it is clear that the aim of this was attained in that various KPI's showed either positive or negative relationships with some of the domains of cognitive functioning amongst the tight forwards, loose forwards and the backline players. These results may be of value for improving on-field performance by means of the application of cognitive intervention programs. The results might furthermore be used in the combination with other variables to assist the management team in selecting a team.

3. RECOMMENDATIONS FOR FURTHER RESEARCH

Since our study was done on a relatively small sample size of university-level rugby players, we recommend that the results of this study should be verified in future studies which involve rugby players of different participations levels. Furthermore it is recommended that the relationship between measures of cognitive functioning and measures of more objective key performance indicators such as number of successful passes and kicks, amount of knock-ons of the ball, successful tackles and possession kept or concede be included in future studies.

In addition, it might also be valuable to investigate the association between cognitive functioning and successful and unsuccessful KPIs, meaning that the actions either succeeded in achieving their intended goals or not.

Since the outcomes of neuropsychological assessments are sensitive to amongst others, the range of head injuries, cumulative head injuries and the time since a player sustained a head injury, it is deemed important that future studies included such information. Furthermore, cognitive aspects such as emotional recognition is dependent on multiple factors such as a player's psychological status (e.g. levels of anxiety, depression etc.) as well as his dispositional temperament. Therefore, a recommendation for future research would be to incorporate a player's psychological status and his dispositional temperament as these factors could have mediated the associations between found between emotional recognition and certain KPIs.

4. CONCLUSION

Although no literature could be found specifically pertaining the relationship between cognitive functioning and on-field performance of rugby players, what did clearly emerge from the literature review was that the different measures of cognition namely memory, attention and behavioural tasks, sensory-motor/spatial functioning, verbal functioning, executive functioning and emotion recognition all play an important role in sport performance. Since one of the researchers is working as a Performance Psychologists of the team which participated in this study, it was decided to explore the relationship between the players' cognitive functioning and their on-field performance in order to shed more light on the topic. From the results of this study it became clear that significant correlations (positive and or negative) exist between the players' cognitive functioning and on-field performance.

The results of this study might inform the Performance Psychologist in the planning of future intervention programs and might also assist in team selection. Furthermore it is hoped that this study might lay the foundation for further research regarding the relationship between a player's cognitive functioning and his performance on the field. It is foreseen that the value of such research will increase in the professional area of rugby as the margins between good and the best teams become smaller and the importance of performing under pressure to ensure victories, increases.

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APPENDIX A

INFORMED CONSENT FOR THE RESEARCH PARTICIPANTS

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

HREC Stamp

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR THE RUGBY PROJECT

TITLE OF THE RESEARCH PROJECT:

Neuropsychological assessment of elite university-level rugby players and the relationship with on-field performance

REFERENCE NUMBERS:

Ethical approval in process

PRINCIPAL INVESTIGATOR:

Dr Kobus Du Plooy

ADDRESS:

Institute for Psychology and Wellness

North-West University, Potchefstroom Campus

Private Bag X6001

Potchefstroom

2520.

CONTACT NUMBER: (018) 2991737

You are being invited to take part in a research project that forms part of larger service delivery project by the Institute for Psychology and Wellbeing as well as post graduate Master's and PhD-studies. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you choose not to participate, this will not have any detrimental implications for you in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study will be submitted for approval by the Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (Ethical approval in process) **and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.**

1.1 What is this research study all about?

- *This study will be conducted at the Institute for Psychology and Wellbeing at the North-West University, and will involve the completion of an online Neuropsychological*

assessment (WebNeuro Sport) and game analysis by means of the Stratus game analysis program. Experienced Clinical Psychologists with extensive experience in sport will conduct the assessments. The aim is to recruit between 35 and 42 male university-level rugby players to participate in this project.

- *The objectives of this research are to determine:*
  - *The neuropsychological profile of each player to determine strong- and weak points.*
  - *The relationships between the different neuropsychological variables and the on-field key performance indicators over the course of a tournament for each player.*
  - *The difference in the neuropsychological profile between forwards and the backline players.*

Why have you been invited to participate? Based on the knowledge available to us:

- *You have been invited to participate because you are an elite male university-level rugby player who has been chosen for the squad for the Varsity Cup Tournament who receive sport psychological assistance from a Clinical Sports Psychologist.*
- *You have also complied with the following inclusion criteria: You provided voluntary consent, while the coaches and management team gave permission for you to participate in the project. You also do not have an injury to your dominant hand that can prevent you from completing the neuropsychological assessment.*
- *Furthermore, you are actively involved and competing as a member of the squad of the Varsity Cup team and you are totally free of any serious injuries and known illnesses. You are also free from any mental illnesses.*
- *Please note that you will be excluded if you become injured or ill at any time during the tournament which will prevent you to play. You will also be excluded if you have an injury to your dominant hand at the time of the neuropsychological assessment. You will furthermore be excluded if you do not complete the online neuropsychological assessment and/or if you do not give written consent to participate in the project.*

1.2 What will your responsibilities be?

- *You will be expected to complete an online neuropsychological assessment in the computer room of the Institute for Psychology and Wellbeing at the North-West University. The assessment will take approximately 60-90 minutes to complete and will*

be arranged for a time that suits you. You will be expected to complete the assessment only once.

1.3 Will you benefit from taking part in this research?

- The direct benefits for you as a participant will be that you will be able to gain access to your results as well as a personalized report explaining your results. Your data will also be used by the Clinical Sport Psychologist to tailor your individualized session if necessary in order to prepare you for the demands of the game. Players and the coaches will have the opportunity to talk to the researchers about any advice regarding psychological preparation for a game. Furthermore, the neuropsychological data will allow the researchers to evaluate players' neuropsychological profile and to address any weak points which might be detrimental to their on-field rugby performance.
- The indirect benefit will be an expansion of the existing knowledge in the field of Applied Sport Psychology which can be transferred to the wider sporting community.

1.4 Are there risks involved in your taking part in this research?

- The project should pose no foreseeable risk to you, since the questions in the test batteries are not of a sensitive nature. However, minor negative risks which might occur include amongst others psychological fatigue, boredom, headache, frustration, anxiety and fear; however, precautions are put in place to manage these possible negative consequences should any of them occur. Players will also be given sufficient time to recuperate after completion of each assessment.

1.5 What will happen in the unlikely event of some form of discomfort occurring as a direct result of your taking part in this research study?

- *Should you have the need for further discussions after completion of the neuropsychological assessment an opportunity will be arranged for you to talk to an independent psychologist which will be available on demand. Pending the outcome of such a discussion the most effective approach to manage the need of the player will be provided such as a referral to a professional.*

1.6 Who will have access to the data?

- *Anonymity will be ensured by coding of the data to make sure that no link can be made to a specific player. Confidentiality will be ensured by making sure only the researchers have access to the data. All the researchers involved will have access to the data. Reporting of findings will be anonymous by only authorizing the head researcher to have control over the distribution of the results. Data will be kept safe and secure by locking hard copies in locked cupboards in the researcher's office and for electronic data it will be password protected. Data will be stored for seven years.*

Will you be paid to take part in this study and are there any costs involved?

No, you will not be paid to take part in the study. There will also be no costs involved for you to take part should you agree to do so.

Is there anything else that you should know or do?

- **You can contact Dr Kobus Du Plooy at** (018) 299 1737 / kobus.duplooy@nwu.ac.za **if you have any further queries or encounter any problems.**
- **You can contact the Health Research Ethics Committee via** Mrs Carolien van Zyl **at** 018 299 2094 / carolien.vanzyl@nwu.ac.za **if you have any concerns or complaints that have not been adequately addressed by the researcher.**
- **You will receive a copy of this information and consent form for your own records.**

How will you know about the findings?

- The findings of the research will be shared with you by if you are interested. You are welcome to contact us regarding the findings of the research. We will be sharing the findings with you as soon as it is available.

Declaration by participant

By signing below, I ……..…… agree to take part in a research study entitled: **Neuropsychological assessment of elite university-level rugby players and the relationship with on-field performance**

I declare that:

- I have read this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions to both the person obtaining consent, as well as the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) .....….....…….. on (*date*) ……...…….. 2015

..... **.....**

Signature of participant **Signature of witness**

Declaration by person obtaining consent

I *(name)* ……..…… declare that:

- I explained the information in this document to …….I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above

- I did/did not use an interpreter.

Signed at (*place*) .....…..……. on (*date*) ……...…….. 2015

..... **.....**

Signature of person obtaining consent **Signature of witness**

Declaration by researcher

I *(name)* ……..…… declare that:

- I explained the information in this document to ……I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) .....…..……. on (*date*) ……...…….. 2015

..... **.....**

Signature of researcher **Signature of witness**

APPENDIX B

PROOF OF ETHICAL APPROVAL FOR THE STUDY

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Institutional Research Ethics Regulatory Committee
Tel +27 18 299 4849
Email Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by **Health Research Ethics Committee (HREC)**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: The relationship between cognition and on field performance of university level rugby players.

Project Leader: Dr JC du Plooy

Ethics number: N W U - 0 0 0 9 3 - 1 5 - A 1
(Institution / Project Number / Year / Status)

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Approval date: 2015-12-11 **Expiry date:** 2016-12-10 **Risk** Minimal

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC:*
  - *annually (or as otherwise requested) on the progress of the project,*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-RERC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-IRERC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC for any further enquiries or requests for assistance.

Yours sincerely

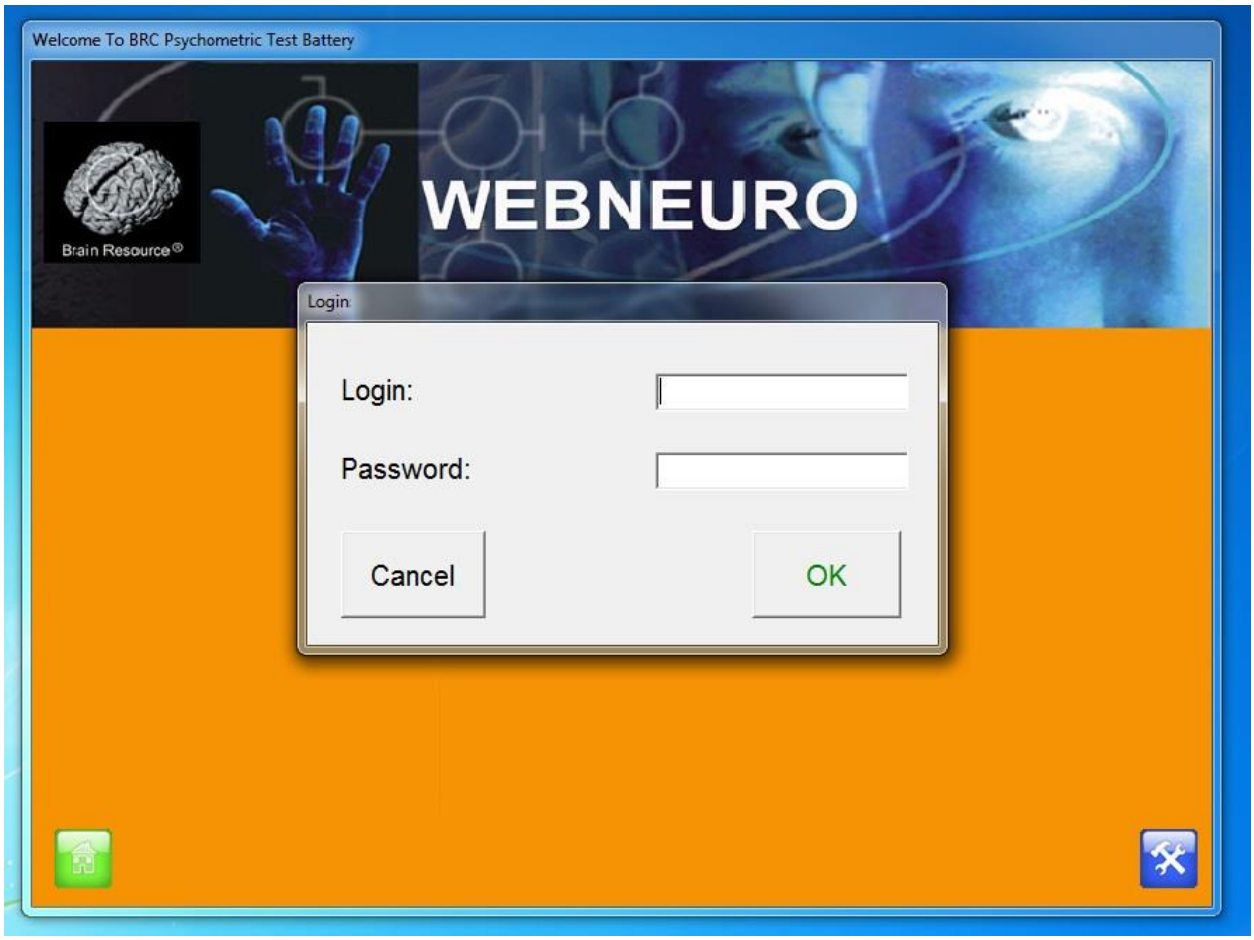
Prof LA Du Plessis

Digitally signed by Prof LA Du Plessis
DN: cn=Prof LA Du Plessis, o=North-West University, ou=Campus Rector, email=Linda.DuPlessis@nwu.ac.za, c=ZA
Date: 2016.01.28 07:49:47 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

APPENDIX C

A SCREEN PRINT EXAMPLE OF THE WEBNEURO SPORT WEB BASED ASSESSMENT



Accessible at http://dl.brainresource.com/download/webneuro.html

APPENDIX D

AN EXAMPLE OF THE OUTPUT FILE OF THE GAME ANALYSIS PROGRAM (STRATUS)

Team X – KPIs

Player	Position	Match time	Match time (Minutes)	Playing time	Playing time (Minutes)	Total contributions
#	Prop	04:23:53	264	01:45:05	105	320
#	Prop	01:51:06	111	00:42:52	43	129
#	Prop	13:11:31	792	05:17:46	318	871
#	Hooker	02:13:19	133	00:53:01	53	144
#	Hooker	00:21:36	22	00:11:02	11	30
#	Hooker	00:22:23	22	00:09:11	9	33

#	Hooker	11:03:51	664	04:26:04	266	748
#	Hooker	05:44:37	345	02:10:01	130	307
#	Lock	14:17:31	858	05:44:26	344	979
#	Lock	07:01:18	421	02:44:32	165	481
#	Lock	07:03:00	423	02:44:14	164	533
#	Lock	05:49:52	350	02:15:50	136	398
#	Lock	02:49:19	169	01:14:22	74	225
#	Loose forward	08:07:56	488	03:15:09	195	548
#	Loose forward	15:29:05	929	06:12:32	373	1089
#	Loose forward	08:09:54	490	03:16:51	197	596
#	Loose forward	08:41:35	522	03:23:42	204	588
#	Scrumhalf	14:27:22	867	05:35:14	335	899

#	Scrumhalf	04:52:26	292	02:05:47	126	353
#	Flyhalf	03:57:04	237	01:31:42	92	152
#	Flyhalf	18:37:06	1117	07:20:23	440	645
#	Centre	05:07:54	308	02:12:57	133	166
#	Centre	08:39:31	520	03:24:42	205	216
#	Centre	09:07:54	548	03:38:00	218	269

The names of the players have been deleted for the sake of confidentiality

APPENDIX E

AUTHOR GUIDELINES FOR THE JOURNAL OF APPLIED SPORT PSYCHOLOGY

Instructions for authors

Thank you for choosing to submit your paper to us. These instructions will ensure we have everything required so your paper can move through peer review, production and publication smoothly. Please take the time to read them and follow the instructions as closely as possible.

Should you have any queries, please visit our Author Services website or contact us at authorqueries@tandf.co.uk.

This journal uses ScholarOne Manuscripts (previously Manuscript Central) to peer review manuscript submissions. Please read the guide for ScholarOne authors before making a submission. Complete guidelines for preparing and submitting your manuscript to this journal are provided below.

Please note that the *Journal of Applied Sport Psychology* uses CrossCheck™ software to screen papers for unoriginal material. By submitting your paper to the *Journal of Applied Sport Psychology* you are agreeing to any necessary originality checks your paper may have to undergo during the peer review and production processes.

Editorial Statement: The *Journal of Applied Sport Psychology* is a non-proprietary journal that is operated by the Association for Applied Sport Psychology for the promotion of quality research in the field of applied sport psychology. The publisher of the *JASP* is Taylor and Francis, Inc. of Philadelphia, PA. The *JASP* is published four times a year, and is a refereed publication with all submissions reviewed by three peers via blind review process. The editor of the journal is selected by the Executive Board of AASP by a formal vote. He/she is appointed to a three-year term with one consecutive renewal possible if so voted by the Executive Board. The

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