

**VISIO-SPATIAL INTELLIGENCE (VSI) BETWEEN PREMIER LEAGUE, FIRST DIVISION  
RUGBY PLAYERS AND NON-ATHLETES IN THE DEVELOPMENT OF A SPORT-  
SPECIFIC VISIO-SPATIAL INTELLIGENCE TEST BATTERY**

by

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## ABSTRACT

Competitive rugby is a popular sport in South Africa, that not only serves as a major commercial platform viewed by millions of spectators weekly, but also hosts a large number of players that participate in the sport. Athletes in any sport can spend hours training in order to improve their strength, speed and the endurance of their muscles. However, if their visual processing capabilities are inadequate, their physical training may not be optimised and thus their performance will suffer. Despite this, sport vision has only received attention in relation to research in recent years. The reliance and importance of the visual system necessitates the need to determine the factors that affect an athlete's ability to obtain and respond to appropriate visual stimuli. To date, research has focused on individual factors that affect vision and visio-spatial intelligence (VSI). However, a combination of factors could warrant a more holistic approach. This study summarised and compiled an overview of the factors affecting vision and VSI in athletes, covering those factors previously connected with sport, as well as those hitherto not yet associated with athletic activities, but that could also play a part in sporting performance. In this study, fourteen factors affecting vision and VSI in athletes were identified, and this compilation provides a starting point for further study. This study reveals that many factors can affect vision and VSI, and could add significantly to the processes relating to visual testing of athletes and assessments of their decision-making skills. This study further indicates that while current research still tends to focus on single factors affecting vision and VSI, a large number of these factors have been identified and empirically researched. This offers new opportunities for researchers to investigate the effects of a combination of factors, and for coaches to explore further possibilities for competitive advantage.

Research suggests that athletes have enhanced visio-spatial expertise in comparison to non-athletes. However, conflicting research suggests that this is not always the case as non-athletes possess similar visio-spatial expertise in certain visual skills. In this regard, the present study has compared the visual expertise of first-division rugby players to non-athletes. Participants underwent an optometric assessment after which the following six VSI components were measured, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination using the following tests: hart near far rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests. Results indicated that first-division rugby players performed significantly ( $p \leq 0.05$ ) better in five of the six tests, with the exception of visual memory ( $p = 0.893$ ). While this study substantiates the notion that athletes, in this case first-division rugby players, perform significantly better in most VSI components, this is not the case for all aspects of vision.

Further, this study attempted to discern whether Premier League rugby players have superior VSI in comparison to non-athletes when comparing six visual skills namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination. As with first-division rugby players, a statistically significant ( $p \leq 0.05$ ) difference existed between Premier League rugby players and non-athletes for five out of the six tests. Conversely, no real evidence is shown that visual memory differs between Premier League rugby players and non-athletes ( $p = 0.599$ ).

While novices in sport possess similar visual skills to that of experts playing at a higher level, there may be major differences in performance in these VSI skills. In addition, expert athletes may only demonstrate superiority in specific vision skills and not all aspects of vision. Thus, the present study compared the performance of Premier League rugby players ( $n = 40$ ) and first-division rugby players ( $n = 40$ ) on six specific components of vision, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination. Premier League rugby players performed significantly ( $p \leq 0.05$ ) better than the first-division rugby players in five of the six tests, but were found to be similar in visual memory performance ( $p = 0.810$ ).

The findings of the present study indicate that first-division and Premier League rugby players have superior VSI when compared to non-athletes. What is particularly noteworthy is that non-athletes are not worse than either first-division or Premier League rugby players with regards to visual memory. Further, while this study substantiates the proposal that expert athletes, and specifically rugby players, have superior visual expertise to novice athletes, it also found that this is not the case with all vision skills. Again, no difference was found in visual memory between novice (first-division) and expert (Premier League) rugby players. These findings suggest that sport-specific vision testing batteries may be required to distinguish high performers from low performers in the same vein as physical tests are utilised in the selection and recruitment of athletes. In this regard, the present study proposes a rugby-specific test battery in an attempt to distinguish high VSI performers from low VSI performers.

## DECLARATION

This thesis is a presentation of my original research work. Wherever the contribution of others is involved, every effort is made to indicate this clearly, with due reference to the literature and acknowledgement of collaborative research and discussions. The co-authors of the articles in the thesis, Prof. Brandon S. Shaw (Supervisor), Prof. Ina Shaw (Co-supervisor), Dr. Gerrit Jan Breukelman (Advisor) hereby give permission to the candidate, Mr. Lourens Millard, to include the articles as part of his Ph.D. thesis. The contribution (advisory and supportive) of these co-authors was kept within reasonable limits, thereby enabling the candidate to submit the thesis for examination purposes. This thesis serves as the fulfilment of the requirements for the Ph.D. degree in Human Movement Science within the Department of Human Movement Science in the Faculty of Science and Agriculture at the University of Zululand.

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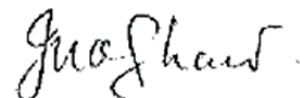
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## CHAPTER ONE: PROBLEM STATEMENT AND OBJECTIVES

### INTRODUCTION

Competitive rugby is a popular sport in South Africa. Not only does it serve as a major commercial platform that is viewed by millions of spectators weekly, but there are also a large number of players that participate in the sport. Rugby is of significant importance to South African fans, and while it can be a source of pride and joy, it can also be a source of shattering disappointment (Morgan, 2013). In a study by the International Rugby Board (2013), there were 651 146 players registered in South-Africa in 2013, of which 633 229 are male and 17 917 are female. A total of 325 364 of these players are pre-teens, 204 119 are teens and 234 837 are senior players (Hoskins, 2013).

Sport vision has only received attention in relation to research in recent years (Millard *et al.*, 2020; Wimhurst, 2012). However, there are still debates as to the role vision plays in sport performance. It is clear that in the majority of sports, the visual system provides the athlete with information regarding where, when and what to focus on in a specific sporting situation, which has a significant impact and positively influences the athletes' response to visual information. It is therefore important to realise that the eyes, via neurological pathways to the brain, are responsible for directing the body's muscles to respond appropriately (Wimhurst, 2012). Athletes in any sport they participate in, can spend hours training to improve the strength, speed and endurance of their muscles, but if their visual processing capabilities are inadequate, their physical training may not be optimised and thus their performance will suffer (Millard *et al.*, 2020; Wimhurst, 2012).

There are large debates between athletes, journalists and conditioning specialists surrounding the possible reasons for superior performance by successful athletes, particularly when it comes to ball sports, such as rugby, cricket and tennis (Davids, 1999; Grobler, Shaw & Coopoo, 2016). Unsurprisingly, the view of experts in these sports state that, in order to perform optimally, a player needs to have a "great eye", superb vision or excellent peripheral vision (Davids, 1999). A large amount of research has been conducted on rugby, specifically with regards to the anthropometrical, physiological and physical characteristics of the sport, and how those specific aspects enhance performance (Gabbett, 2000; Lynch *et al.*, 2013). It is perceived that in order for a rugby player to be successful, the player needs a decreased amount of body fat, which is tested through several means, including skinfolds, they need to be aerobically fit, which is tested through several means, including the incremental shuttle run, and anaerobically fit, which can be tested through the use of shuttle sprinting tests (Duthie, Pyne & Hooper, 2003). It is also stated that rugby players need to have excellent visual skills, but there is currently no sport-specific test battery developed for this application in rugby. Thus, it seems visual performance is an aspect of rugby that has been neglected (Gabbett, 2000).

## **PROBLEM STATEMENT**

Coaches and conditioning specialists spend a large amount of time improving their rugby players physiologically and anthropometrically. This is in spite of the critical importance of and competitive advantage that can be obtained through optimising a player's visio-spatial intelligence (VSI).

## **OBJECTIVES**

The objectives of the proposed study are to:

- Investigate if a significant difference in VSI exists between non-athletes and first division rugby players.
- Investigate if a significant difference in VSI exists between non-athletes and premier league rugby players.
- Investigate if a significant difference in VSI exists between first division rugby players and premier league rugby players.
- Develop a rugby-specific VSI test battery.

## **HYPOTHESIS**

The alternative hypotheses of the proposed study are as follows:

- A significant difference in VSI will be found between non-athletes and first division rugby players.
- A significant difference in VSI will be found between non-athletes and premier league rugby players.
- A significant difference in VSI will be found between first division rugby players and premier league rugby players.

## **THESIS STRUCTURE**

This thesis is presented in article format as approved by the University of Zululand consisting of six major parts, namely, an introduction (Chapter One) and a literature review (Chapter Two) which is presented as a published review article. The findings of the study are presented in the Chapters Three, Four and Five. The final Chapter (Six) contains a summary with conclusions, limitations and recommendations.

Chapter One presents the problem, and states the aim and the hypotheses of this study, as well as the structure of the thesis. Chapter Two contains a published literature review entitled: "Factors affecting vision and visio-spatial intelligence (VSI) in sport: a review of the literature". This article is published in the *Asian Journal of Sport Medicine*. Chapters Three, Four and Five present the experimental findings of the study and are also presented as three manuscripts. Chapter Three presents a manuscript entitled: "Differences in visio-spatial expertise

between first-division rugby players and non-athletes”. This manuscript is formatted for and has been submitted to *Vision Research Journal*. Chapter Four presents an article entitled: “Visio-spatial skills in athletes: Comparison of rugby players and non-athletes”. This article is published in the *Sport Sciences for Health* journal. Chapter Five presents a published manuscript entitled: “Visual abilities distinguish level of play in rugby”. This manuscript was published in the *Annals of Applied Sport Science* journal. Chapter Six offers the development of a rugby-specific visio-spatial intelligence test battery, limitations, further research and conclusions. Each chapter is followed by its specific references. References for Chapters One and Six are according to the American Psychological Association (APA) style as prescribed by the University of Zululand. The references at the end of Chapters Two, Three and Four are according to the guidelines set out for authors by the specific journals.

## REFERENCES

- Davids, K. 1999. *Visual perception and action in sport*. London: Routledge
- Duthie, G., Pyne, D., Hooper, S. 2003. Applied Physiology and Game; Analysis of Rugby Union. *Sports medicine*, 33(13): 973-991.
- Gabbett, T. J. 2000. Physiological and anthropometric characteristics of amateur rugby league players. *British Journal of Sports Medicine*, 34: 303-307.
- Grobler, T.D.T., Shaw, B.S., Coopoo, Y. 2016. Relative Age Effect (RAE) in male school-aged rugby union players from Gauteng, South Africa. *African Journal for Physical Activity and Health Sciences*, 22(2:2): 626-634.
- Hoskins, O. 2013. International Rugby Board. [Online]. Available: <http://www.irb.com/unions/union=11000034/> [Accessed on 24 September 2018].
- Lynch, E., Lombard, A.J.J., Coopoo, Y., Shaw, I., Shaw, B.S. 2013. Shoulder injury incidence, risk factors and prevention in rugby union players. *Pakistan Journal of Medical Sciences*, 29(6): 1400-1405.
- Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S. (2020). Factors affecting vision and visio-spatial intelligence (VSI) in sport: a review of the literature. *Asian Journal of Sport Medicine*. In press.
- Morgan, D. 2013. Rugby in South-Africa. [Online]. Available: <http://www.southafrica.info/about/sport/rugby.htm#.UX0NSGZwZhE> [Accessed on 24 September 2018].
- Wimhurst, Z. 2012. Visual skills of elite athletes. Unpublished doctoral dissertation, University of Surrey.

## **CHAPTER TWO: ARTICLE ONE - FACTORS AFFECTING VISION AND VISIO-SPATIAL INTELLIGENCE (VSI) IN SPORT: A REVIEW OF THE LITERATURE**

Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S. (2020). Factors affecting vision and visio-spatial intelligence (VSI) in sport: a review of the literature. *Asian Journal of Sport Medicine*. In press.  
(Appendix A)

### **ABSTRACT**

**Background:** Sport has become increasingly competitive, prompting the need to determine, as far as possible, any likely performance advantage. While the focus of athletic research, testing and training has been on the physiological and physical characteristics of the sport, visual abilities not only affect sports performance directly but also affects the acquisition of motor skills. Vision, and Visio-spatial intelligence (VSI), is a relatively new and underexplored area of athletic performance. As with physiological and physical parameters, a range of factors affect vision and VSI in sporting activities.

**Objectives:** This review of the literature is a first attempt to summarize and compile an overview of the factors affecting vision and VSI in athletes, covering those previously connected with sport, as well as those hitherto not associated with athletic activities, but that could also play a part in sports performance.

**Discussion:** The evidence from this review suggests that while current research still tends to focus on single factors affecting vision and VSI, a large number of such factors have been identified that could affect vision and VSI. This offers new opportunities for researchers to investigate the effects of a combination of factors, and for conditioning and/or sports vision specialists to explore further possibilities for competitive advantage.

*Keywords:* Athletic performance; Decision making; Optometric intervention; Sport performance; Sports vision; Visual abilities.

### **BACKGROUND**

Significant debate still surrounds the possible reasons for superior athletic or sports performance by successful athletes, particularly in ball sports such as rugby, cricket and tennis (1). Unsurprisingly, experts in these sports believe that, to perform optimally, a player needs a “great eye”, superb vision or excellent peripheral vision (1). Athletes can spend thousands of hours in physical training to improve their physical attributes. However, if their vision or visual processing capabilities are inadequate, their physical training may not be optimized and their athletic performance will suffer (2). The eye is the most important receptor in the human body (3) and as such, the human visual information processing system has been recognized

as playing a critical role in athletic performance (4, 5, 6) and has generated concomitant interest in the area of sport vision (2).

This reliance and importance of the visual system necessitates the need to determine the factors that affects an athlete's ability to obtain and respond to appropriate visual stimuli. Conversely, challenges in the ability to obtain and process specific and appropriate visual stimuli can lead to incorrect or ineffective movement outcomes (5, 6). To date, research has focused on individual factors that affect vision and VSI. However, a combination of factors may play a part and could warrant a more holistic approach. This review of the literature attempts to summarize and compile an overview of the factors affecting vision and VSI in athletes, covering those previously connected with sport, as well as those hitherto not yet associated with athletic activities, but that could also play a part in sports performance.

## **OBJECTIVES**

The aim of this review is to identify and summarize a body of relevant, previously researched factors that have or have not yet been associated with athletic activities, and that could affect vision and VSI, and thus athletic performance.

## **METHODS**

A review of the scholarly literature related to the factors affecting vision and VSI was performed using standardized procedures (7). To identify potentially relevant articles for focused searching and to reduce the potential for random errors and bias, data abstraction was performed independently by two of the authors. This was to ensure consistent application of the inclusion and exclusion criteria, and to eliminate efficiently all obviously ineligible publications. These two authors reviewed each citation and, whenever an abstract was available, the abstract. These authors compared decisions for inclusion and discrepancies in inclusion were resolved by discussion and re-review, and by consulting a third author when consensus could not be reached. Following this, a careful review of the full-text publications was conducted.

To review the scholarly literature of factors affecting vision and VSI an electronic search was performed on the following databases that were available to the researchers: PubMed (1966–June 2019), Sport Discuss (1975–June 2019), Science Direct, Current Contents, CISTI Source (1993–June 2019), Google Scholar, Cochrane Database of Systematic Reviews, EBM Reviews, and international e-catalogues. A keyword search yielded MeSH headings: “factors affecting vision”, “sport vision”, “ophthalmology”, “visual disturbances”, “visual factors”, “visual pain”, “visual temperature”, “humidity and vision”, “vision and diet”, “visual psychology”, “sleep and vision”, “hydration and vision”, “visual infections”, “hormones

and vision”, “retinal disorders”, “light sensitivity”, “age and vision”, and “fatigue and vision” which were combined and exploded. Searches were restricted to peer-reviewed articles in the English language. Articles included in this review were required to describe factors that had a direct impact on vision, or the visual capabilities of individuals.

## RESULTS

The electronic searches yielded 1,577 citations of which only 46 full-text English-language articles were deemed relevant for use in this study. Following the removal of duplicates and review of full-text versions, a total of 37 articles remained for physiological factors that affect vision, five for environmental factors that affect vision, and four for psychological factors that affect vision (Table 1).

**Table 1.** Factors affecting vision and Visio-spatial intelligence (VSI) in sport.

| <b>Physiological factors</b> |   |
|------------------------------|---|
| Eye conditions               | <ul style="list-style-type: none"> <li>• Amblyopia causes deficit in perception of global motion, processing of global contours, and shape detection (8, 9, 10).</li> <li>• Glaucoma causes gradual loss of vision (11).</li> <li>• Color blindness causes performance decrease without special provisions (12).</li> <li>• Refractive error causes blurred vision (13).</li> <li>• Dry eye affects tear fluid osmolarity (14).</li> <li>• Eye-structure variance affects the corneal stroma (15).</li> </ul> |
| Pain                         | <ul style="list-style-type: none"> <li>• Headaches affect vision (16, 17, 18, 19).</li> </ul>   |
| Sleep deprivation            | <ul style="list-style-type: none"> <li>• Leads to modifications in specific areas of the brain (20, 21, 22, 23).</li> </ul>   |
| Infection and diseases       | <ul style="list-style-type: none"> <li>• Infection affects color vision and contra sensitivity (24).</li> <li>• HIV alters the retinal nerve fiber (25).</li> <li>• Fungal infections lead to blurred vision and a decrease in the visual field (26).</li> <li>• Conjunctivitis leads to vision loss (27, 28).</li> </ul>   |
| Endocrine system             | <ul style="list-style-type: none"> <li>• Hyperthyroidism or hypothyroidism causes multiple visual impairments including peripheral vision loss (29).</li> <li>• Thyroid hormone levels affect the cones of the eyes (30).</li> </ul>  |
| Retinal detachment           | <ul style="list-style-type: none"> <li>• Causes complete vision loss (31).</li> </ul>   |
| Aging                        | <ul style="list-style-type: none"> <li>• Causes muscle deterioration, blurred vision, and “wear and tear” of the eye (32, 33).</li> </ul>   |
| Diet                         | <ul style="list-style-type: none"> <li>• Certain foods can influence vision (34).</li> <li>• Docosahexaenoic acid (DHA) causes improvements in the retina (35, 36).</li> <li>• DHA deficiency causes problems with vision (37).</li> <li>• Caffeine can enhance visual capabilities and reduce visual fatigue (38).</li> </ul>  |
| Exercise                     | <ul style="list-style-type: none"> <li>• Prolonged exercise leads to brain fatigue (38).</li> </ul>   |

|                              |  |
|------------------------------|--|
| Medication                   | <ul style="list-style-type: none"> <li>• Can lead to loss of central vision (39).</li> <li>• May cause brain fog and lead to a decrease of visual ability (40, 41, 42, 43).</li> </ul>   |
| <b>Environmental factors</b> |  |
| Temperature                  | <ul style="list-style-type: none"> <li>• The lens of the eye is affected by changes in temperature (44).</li> <li>• Increase in temperature causes light scattering from lens proteins (45).</li> </ul>  |
| Lighting                     | <ul style="list-style-type: none"> <li>• Light-emitting diode (LED) bulbs improves visual acuity (46).</li> <li>• Visual stimuli are influenced by the chromaticity of light (47, 48).</li> <li>• Increasing the quality of artificial light positively affected vision (49).</li> </ul> |
| <b>Psychological factors</b> |  |
| Anxiety                      | <ul style="list-style-type: none"> <li>• Leads to “tunnel vision” (50).</li> </ul>   |
| Stress                       | <ul style="list-style-type: none"> <li>• Causes a decrease in visual acuity and progressive vision loss (51).</li> <li>• Leads to temporary vision loss (52).</li> </ul>   |

## DISCUSSION

To date, studies relating to vision and VSI have tended to focus on single factors only in isolation. This review has identified and summarized information about previously researched factors related to sports, as well as others that were previously not associated with having an effect on vision and VSI in relation to athletic performance.

Athletes competing in ball sports, such as basketball, rugby, volleyball, and netball require a variety of visual skills such as catching, passing and kicking, to enable them to advance the ball beyond the opposing team’s defensive line (53). Furthermore, athletes that compete in a racquet sport, such as tennis, badminton, and table tennis are exposed to multisensory visual constraints, where they are required to perform in spite of visual uncertainty thereby tasking their ability to predict the event (54). These events can be seen as an interaction between two systems namely, a ‘software’ system of acquired skill prediction and a ‘hardware’ system of intrinsic visual ability (54). Both systems need to work in harmony in order to perform visual tasks to enable optimal performance. Thus, whether athletes compete in team sports (rugby) or individual sports (tennis), experts suggest that they require a “great eye”, superb vision or excellent peripheral vision (1). To measure the VSI in athletes accurately, it is important to consider the factors that affect vision.

Vision is created by the brain and through the visual pathways that consist of the optic nerve, optic chiasm, optic tract, optic radiation and the visual cortex in the occipital lobes (55). Thus, any condition that affects the brain or the visual pathway are the most obvious factors affecting vision and VSI in athletes.

The most common factors affecting vision and VSI relates to the eye itself and conditions associated with the eye. However, the multitude of such conditions that may affect vision is beyond the scope of the

present study and this review focuses on maladies that most often affect athletic populations. The conditions that will be discussed in this study include amblyopia, glaucoma, colorblindness, refractive error, recent eye surgery, dry eye and eye-structure variance. Amblyopia (“lazy eye”) is a neurodevelopmental disorder traditionally characterized by low-level deficits including reduced visual acuity, stereoacuity, and contrast sensitivity (56). It is caused by an abnormal visual experience during early childhood when the input to the central nervous system from one eye is suppressed. Individuals with amblyopia have shown to have deficits in the perception of global motion (8), processing of global contours (9), and shape detection (10). A combination of all of these deficits will have a major influence on visual performance in athletes. Glaucoma is a neurodegenerative disorder of the optic nerve, which is caused by retinal ganglion cell deaths, which leads to characteristic patterns of visual field loss (11). Glaucoma can be caused by multiple factors, including a chemical or blunt injury (as is common in sports) to the eye, severe eye infection (as is common during sporting events during extreme environmental conditions), blocked eye blood vessels, and inflammatory conditions (11). Colorblindness is caused if one, two or three of these types of cones in the retina is either missing or dysfunctional (57). Problematically, athletes with colorblindness need special provisions to be made during training such as to adjust uniforms or equipment (i.e. balls) to compensate for possible confusion (12). Refractive error occurs when the optical system of the non-accommodating eye fails to bring parallel rays of light to focus on the fovea (13). This leads to myopia and hyperopia, which are states of refractive error in which the optical system of the eye brings parallel rays of light into focus anterior and posterior to the fovea, respectively, resulting in blurred vision (13) and effectively resulting in an increased chance of mistakes being made during athletic training and competition. Dry eye is common among athletes. It affects tear fluid osmolarity and arises out of even modest changes in whole-body hydration (14). These changes have various causes including: exercise modality, type of play, level of competition, metrological conditions (i.e. humidity and environmental temperature) and type of sport (58). Since individuals with dry eye, which indicates suboptimal hydration, have higher plasma osmolality than those without dry eye, it can be safely stated that if an athlete hydrates properly, this condition could be prevented (59). A further hydration-related feature is eye-structure variance, which can affect vision when the corneal stroma is highly dependent on an individual’s hydration status (15) and any change in corneal hydration status can result in variations in central corneal thickness (60). Even when over-hydration exists, the optically transparent corneal stroma swells, meaning a lowering of hydration is needed to return it to its normal thickness (61).

In addition to high temperatures causing fluid loss and affecting whole-body hydration, temperature itself, in the form of ambient and body temperature, is an important factor that can profoundly affect vision and

VSI. Athletes generally train or compete outdoors or in venues without temperature control for extended periods of time. Problematically, if the ambient temperature rises beyond a certain threshold, proteins denature and may not function properly (44), which means that proteins of the lens of the eye are also susceptible to changes in temperature. Lowering the temperature of the lens too much, as during training or when competing in cold conditions, causes the formation of a temporary or “cold” cataract that disappears when the temperature is normalized (44). Even a slight increase in body temperature above the physiological level of 37° C increases light scattering from lens proteins because of protein aggregation and denaturation (45). Thus, it is logical to suggest that relationships exist between vision and VSI on the one hand and environmental temperature and eye temperature on the other (62).

With regards to the brain and vision in athletes, any factor that creates clouding of consciousness may affect vision and VSI in athletes. Clouding of consciousness or brain fog is not a medical condition itself, but rather a symptom of other medical conditions (63). Clouding of consciousness is a type of cognitive dysfunction involving: memory problems, lack of mental clarity, poor concentration, and inability to focus. There are numerous explanations for why brain fog occurs and includes *inter alia*: stress, lack of sleep, hormonal changes, diet, medication, and medical conditions (63).

Anxiety is common when athletes doubt their ability to cope with external or internal demands (64) and can affect performance in drawing attention away from relevant task-related information to task-irrelevant cues instead (50). In essence, increasing anxiety can lead to “tunnel vision” in which an athlete focuses on internal or external distracting stimuli instead of concentrating on task-relevant information (50). Bittner et al. (51) have also found that visual acuity can be influenced by stress and individuals with high levels of stress display progressive losses in vision. Moschos (52) has further demonstrated that when stress leads to profound suffering, vision disorders can arise and even to the extent of temporary loss of vision. Problematically, this stress is an inherent aspect of sports performance (65).

A large body of research has been published on the effect of sleep deprivation on both physical and mental performance (66). However, it also appears that sleep deprivation may affect vision and VSI since functional imaging studies during cognitive tasks have shown that total sleep deprivation leads to modifications in specific areas of the brain. Among the main areas affected are the frontal and parietal cortices (20). An individual deprived of sleep for just 24 hours suffers a significant decrease in glucose metabolism in the prefrontal and parietal cortices during the performance of difficult arithmetic working memory activity (21). It seems likely, therefore, that other cognitive tasks involving the frontal-parietal network, such as Visio-spatial attention (necessary for visually searching for information during athletic

competition) could also be affected (22, 23).

The endocrine system can have several detrimental effects on vision. Specifically, hyperthyroidism and hypothyroidism can not only lead to poor quality of life but can also affect an athlete's vision (67). This is because these conditions can result in bulging eyes, decreased vision, distorted vision, double vision, loss of peripheral vision, a dark curtain or veil that blocks vision, excess watering of the eye, pain in the eye, and unusual red eyes (29). Individuals with higher levels of thyroxine are at an increased risk of age-related macular degeneration (AMD) and other retinal changes. Thyroid hormone levels also appear to affect the ongoing development and regulation of the eye's cones (that is, the cells responsible for color vision) (30).

Diet is a factor not always associated with vision. However, several studies have demonstrated that eating certain foods can influence vision (34). Specifically, diets high in mercury have been found to be detrimental to visual acuity, whereas the consumption of omega-3 fatty acids have been associated with laying the foundation for the development and maintenance of the visual and ocular system (34). Docosahexaenoic acid (DHA) too should be considered an essential part of an athlete's diet as it contains polyunsaturated fatty acids, which enrich not only the brain, but also the retina and specifically the photoreceptor cells (35, 36, 37). Caffeine is a common ergogenic aid utilized by athletes, since even a moderate dose prevents fatigue in the skeletal muscle system and improves athletic performance (68). The effect of caffeine is no different in the eye and it has been demonstrated to result in fatigue-induced reductions in the velocity of saccades ("voluntary, high-velocity eye movements that allow rapid changes in fixation") and the quick ("resetting eye movements") phase of optokinetic nystagmus (OKN) (38). However, it has been noted that the effect of both fatigue and caffeine on oculomotor control appear to be independent of the processes supporting visual attention and visual perception (38).

Medication such as benzodiazepines (40), anticholinergics (41), antipsychotics and mood-stabilizers (42), and opiate pain medications (43) may cause brain fog and can lead to a decrease of visual ability. There are multiple other medications affecting vision, including, but not limited to, antihyperglycemic agents such as corticosteroids (chloroquine and hydroxychloroquine), antirheumatic medication, medication implicated in optic neuritis and atrophy, medication with an anticholinergic action, oral contraceptives, and topical medication and systemic effects (39). Athletes with hyperglycemia may use medications such as chloroquine and hydroxychloroquine which can cause irreversible maculopathy with resultant loss of central vision.

Brain fog can be caused by multiple conditions including, anemia (69), diabetes (70), lupus (71), multiple sclerosis (72), arthritis (73), Alzheimer's disease (74), hypothyroidism (75), and migraines (76). Athletes are commonly influenced by anemia, diabetes, migraines and hypothyroidism. If red blood cells do not deliver enough oxygen to the brain, due to iron deficiency anemia, an athlete may experience shortness of breath and brain fog. Recent clinical evidence shows that individuals with diabetes have increased incidences of vascular dementia, ventricular hypertrophy, lacunar infarcts, hemorrhage, all of which leads to a decrease in brain function (77). Athletes with diabetes need to be aware that the condition can lead to brain dysfunction, and needs to be monitored and treated accordingly. Brain structure and function are altered in hypothyroid patients, with decreased hippocampal volume, cerebral blood flow, and function globally and in regions that mediate attention, visuospatial processing, working memory, and motor speed (75). Thus, athletes with hypothyroidism may experience brain fog, which in turn influences vision, and can lead to a decrease in performance. Pain, in the form of headaches or migraines due to concussion that can occur on the field of play, has been shown to have associated visual features, which include light sensitivity (16). According to a study by Queiroz et al. (17), more than half of all patients with headaches or migraines have blurred vision. This is caused by the imbalance in sympathetic and parasympathetic systems, and may be due to tear film changes (18). Headache or migraine pain and ocular symptoms can be connected by two facts: first, trigeminal activation, which causes eye pain and second, autonomic dysfunction in either the sympathetic or parasympathetic pathway that generates autonomic symptoms such as pupillary changes, lacrimation, redness of the eye, and even blurred vision (19). Some individuals have transient neurological disturbances called auras migraines (76). Auras can cause visual, language, motor and sensory disturbances as well as brainstem symptoms as dysarthria, vertigo, tinnitus, ataxia, and double vision (76). Thus, those individuals responsible for the care and training of athletes should be aware, when athletes receive a blow to the head, that headache or migraines are likely to occur and that vision can be affected.

A multitude of further medical conditions affects vision. Ocular opportunistic infections are especially common in individuals with human immunodeficiency virus (HIV) (24). This may prove problematic for South African sport and athletes, since South Africa already has a 37% prevalence rate of HIV for adults aged 15 to 49 and such prevalence rates may be even higher in athletes due to their risk of infection based on behaviors associated with participation in their sport and away from competition (78). HIV-associated "neuroretinal disorder" results in changes in vision because the retinal nerve fiber layer is altered by the virus, causing a decrease in the visual field (25). Fungal infections too can affect vision in that dermatophytes can infect sections of the eyelid, eventually infecting the eye, leading to blurred vision and a decrease in the field of vision (26). Conjunctivitis, more commonly known as "pink eye", results from

inflammation of the conjunctiva that can be caused by bacteria, viruses, fungi, or parasites (79). With conjunctivitis, the entire conjunctiva is involved and there is often discharge (27) which leads to vision loss, moderate to severe pain, hypopyon, hyphema, pupil asymmetry, decreased pupil response, and trouble opening the eye or keeping the eye open (28). Infections, bacteria and viruses too can influence visual performance by altering color vision, causing a decrease in one's visual field, and reducing contrast sensitivity (24). Infections can thus significantly impact an individual's vision and need to be taken into consideration when testing athletes.

Retinal detachment (RD) can occur as a result from aging or trauma, as is commonly experienced during sports (31). The detachment of the retina is serious and can cause complete blindness. If the retina is detached from the choroid, the photoreceptors will fail (31). While RD causes sudden and painless loss of vision, in cases where there is not a full detachment, the athlete can experience blurred vision (31). With gradual RD, floaters and flashes may occur in the eye in the weeks leading up to the detachment (31). In addition, RD can be accompanied by mild discomfort and redness due to associated uveitis and hypotony (31). Thus, RD can have a significant impact on an athlete's vision, especially in contact sports where trauma-related RD, sudden or gradual, can most easily occur.

Normal aging in athletes can affect vision as it causes all the muscles of the body to deteriorate over time, influencing both activities of daily living (ADLs) and athletic performance (32). The same is true in relation to the eye muscles and their function. Other changes associated with aging include changes in the shape and tone of the ciliary bodies, as well as reduced elasticity of the lens capsule and compactness of the lens fibers. This leads to a decrease in the amplitude of accommodation resulting in presbyopia, hardening (nuclear sclerosis) of the lens resulting in blurred vision (33). Aging also affects an athlete's vision through "wear and tear" and suggests that the body and its cells, including eye cells, are damaged by overuse and abuse, from such influences as, among others, ultraviolet (UV) rays from the sun, and excessive consumption of fat, sugar, caffeine, alcohol and nicotine (33). This may be true of a younger athlete who experiences "accelerated aging", especially if they have been exposed to prolonged and extreme environmental conditions and diets throughout their careers (33).

A great problem for athletes is the finding that the act of engaging in exercise itself, either during training or competition, affects vision. Recent studies have demonstrated that prolonged exercise can cause brain-based fatigue in the corticospinal motor system, which impairs the oculomotor system. Specifically, three hours of strenuous cycling has been shown to reduce the velocity of rapid eye movements (moving your eye in a rapid manner from one object to another) independently of other visual processes (such as dorsal

cortical processing stream function) (38). This may be a result of the neurotransmitter systems' experiencing significant perturbation during prolonged exercise (80). However, it is not known if enhanced physical conditioning may provide some fatigue-resistance to brain-based fatigue, and future studies could determine whether or not there is a relationship between physical conditioning and VSI in athletic populations.

For an athlete's visual system to perform optimally, the lighting of the area where testing, training or performance take place is crucial. Light-emitting diode (LED) bulbs seem to produce the same amount of light as incandescent bulbs while saving power and being both energy- and cost-efficient, but there is little consideration in the literature of their impact on visual comfort or ocular health (81). There is evidence that scotopic rich fluorescent source illumination (a type of LED lighting) improves visual acuity and decreases pupil size (46). The effect, however, is measurable only with low-contrast briefly-presented stimuli. Visual stimuli are influenced by the chromaticity of light (47) and Yamagishi et al. (48) found that visual performance, mood, and an individuals' perception of comfortable reading and visual task performance improved under artificial LED lighting. In a study performed by Mott et al. (49), it was found that, compared to natural lighting conditions, increasing the quality of artificial light positively affected the visual performance of participants. Since most visual testing studies have been conducted indoors, their findings could have been affected by the artificial lighting used and it is this comparative factor that may offer opportunities for future research.

## **LIMITATIONS**

While an in-depth search was performed to find a large number of previously known and unknown factors that could affect the vision of athletes, there is the possibility that other factors have not be identified. This may be related to articles not published in the English-language, the use of only published citations, and the use of the defined/selected databases due to time, budget, and resource constraints. In addition, the inclusion criteria may be considered either too narrow resulting in eligible evidence not being found or even too loosely defined increasing the possibility of poor reproducibility due to many subjective decisions regarding what to include.

## **CONCLUSIONS**

Factor by factor, this review has highlighted areas for future research, pointing to opportunities to broaden the scope of the knowledge base. Fourteen factors affecting vision and VSI in athletes have been identified and this compilation provides a starting point for further factors to be added. This study reveals that many factors can affect vision and VSI and could add significantly to processes relating to visual testing of

athletes and assessments of their decision-making skills. This review further indicates that while current research still tends to focus on single factors affecting vision and VSI, a large number of such factors have been identified and empirically researched. This offers new opportunities for researchers to investigate the effects of a combination of factors, and for coaches to explore further possibilities for competitive advantage.

## Footnotes

**Authors' contribution:** Lourens Millard, Ina Shaw and Brandon S. Shaw made substantial contributions in design of the study, acquisition, analysis, writing and critically reviewing the article and its intellectual content; final approval of the manuscript; and agreeing to take responsibility for all aspects of the study. Gerrit J Breukelman made substantial contributions in writing and critically reviewing the article and its intellectual content; final approval of the manuscript; and agreeing to take responsibility for all aspects of the study.

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## REFERENCES

1. Davids K. Visual perception and action in sport. London: Routledge. 1999.
2. Wimhurst Z. Visual skills of elite athletes. Unpublished doctoral dissertation, University of Surrey. 2012.
3. Schmidt RA, Lee TD. Motor control and learning: a behavioural emphasis. Champaign: Human Kinetics.1999.
4. Baker J, Farrow D. Routledge handbook of sport expertise. London: Routledge. 2015.
5. Abernethy B. Enhancing sports performance through clinical and experimental optometry. *Clin Exp Optom.* 1986;69(5):186-96. doi:10.1111/j.1444-0938.1986.tb04589.x.
6. Nieuwenhuys A, Pijpers JR, Oudejans RRD, Bakker FC. The Influence of anxiety on visual attention in climbing. *J Sport Exerc Psychol.* 2008;30(2):171-85. doi:10.1123/jsep.30.2.171. [PubMed: 18490789].
7. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA,

- PRISMA-P Group. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement. *Syst Rev.* 2015;4(1):1. doi: 10.1186/2046-4053-4-1. [PubMed: 25554246].
8. Aaen-Stockdale C, Hess RF. The amblyopic deficit for global motion is spatial scale invariant. *Vision Res.* 2008;48(19):1965-71. doi:10.1016/j.visres.2008.06.012. [PubMed: 18625265].
  9. Levi DM, Yu C, Kuai SG, Rislove E. Global contour processing in amblyopia. *Vision Res.* 2007;47(4):512-24. doi: 10.1016/j.visres.2006.10.014. [PubMed: 17223155].
  10. Hess RF, Wang YZ, Demanins R, Wilkinson F, Wilson HR. A deficit in strabismic amblyopia for global shape detection. *Vision Res.* 1999;39(5):901-14. doi: 10.1016/s0042-6989(98)00157-6. [PubMed: 10341944].
  11. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *Br J Ophthalmol.* 2006;90(3):262-7. doi: 10.1136/bjo.2005.081224. [PubMed: 16488940].
  12. Knudson D, Kluka DA. The impact of vision and vision training on sport performance. *JOPERD.* 1997;68(4):17-24. doi: 10.1080/07303084.1997.10604922.
  13. Sperduto RD, Seigel D, Roberts J, Rowland M. Prevalence of myopia in the United States. *Arch Ophthalmol.* 1983;101(3):405-7. doi: 10.1001/archoph.1983.01040010405011. [PubMed: 6830491].
  14. Walsh NP, Fortes MB, Esmaeelpour M. Influence of modest changes in whole-body hydration on tear fluid osmolarity: important considerations for dry eye disease detection. *Cornea.* 2011;30(12):1517. doi:10.1097/ICO.0b013e31821ddd3a. [PubMed: 21849890].
  15. Kostyuk O, Nalovina O, Mubard TM, Regini JW, Meek KM, Quantock AJ, Elliot GF, Hodson SA. Transparency of the bovine corneal stroma at physiological hydration and its dependence on concentration of the ambient anion. *J Physiol.* 2002;543:633-42. doi: 10.1113/jphysiol.2002.021527. [PubMed: 12205195].
  16. Digre KB. More than meets the eye: The eye and migraine – what you need to know. *J Neuroophthalmol.* 2018;38(2):237-43. doi: 10.1097/WNO.0000000000000660. [PubMed: 29738351].
  17. Queiroz LP, Friedman, DI, Rapoport AM, Purdy RA. Characteristics of migraine visual aura in Southern Brazil and Northern USA. *Cephalalgia.* 2011;31(16):1652-8. doi: 10.1177/0333102411430263. [PubMed: 22116942].
  18. Friedman DI, Evans RW. Are blurred vision and short-duration visual phenomena migraine aura symptoms? *Headache.* 2017;57(4):643-7. doi: 10.1111/head.13042. [PubMed: 28181231].
  19. Jacobson DM. Benign episodic unilateral mydriasis. Clinical characteristics. *Ophthalmology.*

- 1995;102(11):1623-7. doi: 10.1016/s0161-6420(95)30818-4. [PubMed: 9098253].
20. Drummond SP, Brown GG. The effects of total sleep deprivation on cerebral responses to cognitive performance. *Neuropsychopharmacology*. 2001;25(5):S68-73. doi: 10.1016/S0893-133X(01)00325-6. [PubMed: 11682277].
  21. Thomas H, Sing H, Belenky G, Holcomb H, Mayberg H, Dannals R, Wagner H, Thorne D, Popp K, Rowland L, Welsh A, Balwinski S, Redmond D. Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24 hours of sleep deprivation on waking human regional brain activity. *J Sleep Res*. 2000;9(4):335-52. doi: 10.1046/j.1365-2869.2000.00225.x. [PubMed: 11123521].
  22. Posner MI, Walker JA, Friedrich FJ, Rafal RD. Effects of parietal injury on covert orienting of attention. *J Neurosci*. 1984;4(7):1863-74. [PubMed: 6737043].
  23. Bocca ML, Denise P. Total sleep deprivation effect on disengagement of spatial attention as assessed by saccadic eye movements. *Clin Neurophysiol*. 2006;117(4):894-9. doi: 10.1016/j.clinph.2006.01.003. [PubMed: 16497551].
  24. Shah KH, Holland GN, Yu F, Van Natta M, Nusinowitz S; Studies of Ocular Complications of AIDS (SOCA) Research Group. Contrast sensitivity and colour vision in HIV-infected individuals without infectious retinopathy. *Am J Ophthalmol*. 2006;142(2): 284-92. doi: 10.1016/j.ajo.2006.03.046. [PubMed: 16876510].
  25. Kozak I, Bartsch DU, Cheng L, Kosobucki BR, Freeman WR. Objective analysis of retinal damage in HIV-positive patients in the HAART era using OCT. *Am J Ophthalmol*. 2005;139(2):295-301. doi: 10.1016/j.ajo.2004.09.039. [PubMed: 15733991].
  26. Agarwal M, Gupta C, Gujral GS, Mittal M. Tinea corporis infection manifesting as retinochoroiditis—an unusual presentation. *J Ophthalmic Inflamm Infect*. 2019;9(1):8. doi: 10.1186/s12348-019-0173-z. [PubMed: 31131426].
  27. Ramirez DA, Porco TC, Lietman TM, Keenan JD. Epidemiology of conjunctivitis in US emergency departments. *JAMA Ophthalmol*. 2017;135(10):1119-21. doi: 10.1001/jamaophthalmol.2017.3319. [PubMed: 28910427].
  28. Ryder EC, Benson S. Conjunctivitis. USA. StatPearls Publishing LLC. 2019.
  29. Burch HB, Cooper DS. Management of graves disease: a review. *JAMA*. 2015;314(23):2544-54. doi: 10.1001/jama.2015.16535. [PubMed: 26670972].
  30. Riguetto CM, Neto AM, Tambascia MA, Zantut-Wittmann DE. The relationship between quality of life, cognition, and thyroid status in Graves' disease. *Endocrine*. 2019;63(1):87-93. doi: 10.1007/s12020-018-1733-y. [PubMed: 30173328].
  31. Jalali S. Retinal detachment. *Community Eye Health*. 2003;16(46):25-6. [PubMed: 17491854].

32. Loewenfeld IE. Pupillary changes related to age, *Topics in Neuro-Ophthalmology*. Baltimore: Williams & Wilkins. 1979.
33. Salvi SM, Akhtar S, Currie Z. Aging changes in the eye. *Postgrad Med J*. 2006;82(971):581-7. doi: 10.1136/pgmj.2005.040857. [PubMed: 16954455].
34. Fillion M, Lemire M, Philbert A, Frenette B, Weiler HA, Deguire JR, Guimaraes JR, Larribe F, Barbosa F Jr, Mergler D. Toxic risks and nutritional benefits of traditional diet on near visual contrast sensitivity and color vision in the Brazilian Amazon. *Neurotoxicology*. 2013;37:173-81. doi: 10.1016/j.neuro.2013.04.010. [PubMed: 23680050].
35. Lauritzen L, Hansen HS, Jorgensen MH, Michaelsen KF. The essentiality of long chain *n*-3 fatty acids in relation to development and function of the brain and retina. *Prog Lipid Res*. 2001;40(1-2):1-94. doi: 10.1016/s0163-7827(00)00017-5. [PubMed: 11137568].
36. SanGiovanni JP, Chew EY. The role of omega-3 long-chain polyunsaturated fatty acids in health and disease of the retina. *Prog Retin Eye Res*. 2005;24(1):87-138. doi: 10.1016/j.preteyeres.2004.06.002. [PubMed: 15555528].
37. Benolken RM, Anderson RE, Wheeler TG. Membrane fatty acids associated with the electrical response in visual excitation. *Science*. 1973;182(4118):1253-4. doi: 10.1126/science.182.4118.1253. [PubMed: 4752217].
38. Connell CJ, Thompson B, Turuwheua J, Szrich A, Gant N. Fatigue-related impairments in oculomotor control are prevented by norepinephrine-dopamine reuptake inhibition. *Sci Rep*. 2017;7:42726. doi: 10.1038/srep42726. [PubMed: 28198465].
39. Taylor F. Drugs affecting the eye. *Aust Fam Physician*. 1985;14(8):744-5.
40. Stewart SA. The effects of benzodiazepines on cognition. *J Clin Psychiatry*. 2005;66(2):9-13. [PubMed: 15762814].
41. Lieberman JA. Managing anticholinergic side effects. *Prim Care Companion J Clin Psychiatry*. 2004;6(2):20-3. [PubMed: 16001097].
42. Correll CU, Detraux J, Lepeleire JD, De Hert M. Effects of antipsychotics, antidepressants and mood stabilizers on risk for physical diseases in people with schizophrenia, depression and bipolar disorder. *World Psychiatry*. 2015;14(2):119-36. doi: 10.1002/wps.20204. [PubMed: 26043321].
43. Younger JW, Chu LF, D'Arcy NT, Trott KE, Jastrzab LE, Mackey SC. Prescription opioid analgesics rapidly change the human brain. *Pain*. 2011;152(8):1803-10. doi: 10.1016/j.pain.2011.03.028. [PubMed: 21531077].
44. Kiss AJ, Mirarefi AY, Ramakrishnan S, Zukoski CF, Devries AL, Cheng CH. Cold-stable eye lens crystallins of the antarctic nototheniid toothfish *dissostichus mawsoni* norman. *J Exp Biol*. 2004;207:4633-49. doi: 10.1242/jeb.01312. [PubMed: 15579559].

45. Regini JW, Grossmann JG, Timmins P, Harding JJ, Quantock AJ, Hudson SA, Elliot GF. X-ray- and neutrons scattering studies of alpha-crystallin and evidence that the target protein sits in the fenestrations of the alpha-crystallin shell. *Invest Ophthalmol Vis Sci.* 2007;48(6):2695-700. doi: 10.1167/iovs.06-0559. [PubMed: 17525201].
46. McColl SL, Veitch JA. Full-spectrum fluorescent lighting: a review of its effects on physiology and health. *Psychol Med.* 2001;31(6):949-64. doi: 10.1017/s0033291701004251. [PubMed: 11513381].
47. Wurtz RH, McAlonan K, Cavanaugh J, Berman RA. Thalamic pathways for active vision. *Trends Cogn Sci.* 2011;15(4):177-84. doi: 10.1016/j.tics.2011.02.004 [PubMed: 21414835].
48. Yamagishi M, Yamaba K, Kubo C, Nokura K, Nagata M. Effects of LED lighting characteristics on visual performance of elderly people. *Gerontechnology.* 2008;7:243.
49. Mott MS, Robinson DH, Walden A, Burnette J, Rutherford AS. Illuminating the effects of dynamic lighting on student learning. *SAGE Open.* 2012;2:85. doi: 10.1177/2158244012445585.
50. Eysenck MW, Calvo MG. Anxiety and performance: The processing efficiency theory. *Cogn Emot.* 1992;6:409-34. doi: 10.1080/02699939208409696.
51. Bittner AK, Edwards LMPH, George M. Coping strategies to manage stress related to vision loss and fluctuations in retinitis pigmentosa. *Optometry.* 2010;81(9):461-8. doi: 10.1016/j.optm.2010.03.006. [PubMed: 20591747].
52. Moschos MM. Physiology and psychology of vision and its disorders: a review. *Med Hypothesis Discov Innov Ophthalmol.* 2014;3(3):83-90. [PubMed: 25741524].
53. Meir RA. Conditioning the visual system: a practical perspective on visual conditioning in rugby football. *Strength Cond J.* 2005;27(4):86-92. doi: 10.1519/1533-4295(2005)27[86:CTVSAP]2.0.CO;2.
54. Williams AM, Davids K, Williams JG. Visual perception and action in sport (1st Edition). New York: Routledge. 1999.
55. Moodley A. Understanding vision and the brain. *Community Eye Health.* 2016;29(96):61-3. [PubMed: 28381903].
56. McKee SP, Levi DM, Movshon JA. The pattern of visual deficits in amblyopia. *J Vis.* 2003;3(5):380-405. doi: 10.1167/3.5.5. [PubMed: 12875634].
57. Curcio CA, Sloan KR, Kalina RE, Hendrickson AE. Human photoreceptor topography. *J Comp Neurol.* 1990;292(4):497-523. doi: 10.1002/cne.902920402. [PubMed: 2324310].
58. Thein LA. Environmental Conditions Affecting the Athlete. *J Orthop Sports Phys Ther.* 1995;21(3):158-71. doi: 10.2519/jospt.1995.21.3.158. [PubMed: 7742842].
59. Walsh NP, Fortes MB, Ramond-Barker P, Bishop C, Owen J, Tye E, Esmaeelpour M, Purslow C, Elghenzai S. Is whole-body hydration an important consideration in dry eye? *Invest Ophthalmol Vis*

- Sci.* 2012;53(10):6622-7. doi: 10.1167/iovs.12-10175. [PubMed: 22952120].
60. Sabetti L, Renzetti A, D' Alessandri L, Balestrazzi E. Eventual error caused by dehydration with pachometry. *Ophthalmologica.* 2001;215:97-101. doi: 10.1159/000050837. [PubMed: 11244338].
  61. Matsuura T, Ikeda H, Idota N, Motokawa R, Hara Y, Annaka M. Anisotropic swelling behavior of the cornea. *J Phys Chem B.* 2009;113:16314-22. doi: 10.1021/jp907232h. [PubMed: 19954152].
  62. Scott JA. A finite-element model of heat transport in the human eye. *Phys Med Biol.* 1988;33(2):227-41. doi: 10.1088/0031-9155/33/2/003. [PubMed: 3362966].
  63. Ocon AJ. Caught in the thickness of brain fog: exploring the cognitive symptoms of Chronic Fatigue Syndrome. *Front Physiol.* 2013;4:63. doi: 10.3389/fphys.2013.00063. [PubMed: 23576989].
  64. Woodman T, Hardy L. Stress and anxiety, handbook of sport psychology. New York: John Wiley & Sons. 2001.
  65. Filaire E, Sagnol M, Ferrand C, Maso F, Lac G. Psychophysiological stress in judo athletes during competitions. *J Sports Med Phys Fitness.* 2001;41(2):263-8. [PubMed: 11447372].
  66. Dinges DF, Kribbs NB. Performing while sleepy: effects of experimentally induced sleepiness. Chichester. Wiley. 1991.
  67. Smith TJ, Hegedus L. Graves' disease. *N Engl J Med.* 2016;375(16):1552-65. doi: 10.1056/NEJMra1510030. [PubMed: 27797318].
  68. Nienhueser J, Brown GA, Shaw BS, Shaw I. Effects of energy drinks on testing and submaximal metabolism in college age males. *Int J Exerc Sci.* 2011;4(1):65-76. <http://digitalcommons.wku.edu/ijes/vol4/iss1/8>.
  69. Soppi ET. Iron deficiency without anemia – a clinical challenge. *Clin Case Rep.* 2018;6(6):1082-6. doi: 10.1002/ccr3.1529. [PubMed: 29881569].
  70. Stoykovich S, Gibas K. APOE ε4, the door to insulin-resistant dyslipidemia and brain fog? A case study. *Alzheimers Dement.* 2019;11:264-9. doi: 10.1016/j.dadm.2019.01.009. [PubMed: 30923733].
  71. Lynall M. Neuropsychiatric symptoms in lupus. *Lupus.* 2018;27(1):18-20. doi: 10.1177/0961203318801672. [PubMed: 30452327].
  72. Kalb R. Multiple sclerosis: The questions you have, the answers you need (5th Edition). USA: Demos. 2000.
  73. Shin SY, Katz P, Wallhagen M, Julian L. Cognitive impairment in persons with rheumatoid arthritis. *Arthritis Care Res.* 2012;64(8):1144-50. doi: 10.1002/acr.21683. [PubMed: 22505279].
  74. Theoharides TC, Stewart JM, Hatziagelaki E, Kolaitis G. Brain “fog,” inflammation and obesity: key aspects of neuropsychiatric disorders improved by luteolin. *Front Neurosci.* 2015;9:225. doi:

- 10.3389/fnins.2015.00225. [PubMed: 26190965].
75. Samuels MH. Psychiatric and cognitive manifestations of hypothyroidism. *Curr Opin Endocrinol Diabetes Obes.* 2014;21(5):377-83. doi: 10.1097/MED.0000000000000089. [PubMed: 25122491].
  76. Farooqi AM, Padilla JM, Monteith TS. Acute confusional migraine: Distinct clinical entity or spectrum of migraine biology? *Brain Sci.* 2018;8(2):29. doi: 10.3390/brainsci8020029. [PubMed: 29414874].
  77. Huber JD. Diabetes, cognitive function, and the blood-brain barrier. *Curr Pharm Des.* 2008;14(16):1594-600. doi: 10.2174/138161208784705441. [PubMed: 18673200].
  78. Clem KL, Borchers JR. HIV and the Athlete. *Clin Sports Med.* 2007;26(3):413-24. doi: 10.1016/j.csm.2007.04.012. [PubMed: 17826192].
  79. Alfonso SA, Fawley JD, Alexa Lu X. Conjunctivitis. *Prim Care.* 2015;42(3):325-45. doi: 10.1016/j.pop.2015.05.001. [PubMed: 26319341].
  80. Hasegawa H, Piacentini MF, Sarre S, Michotte Y, Ishiwata T, Meeusen R. Influence of brain catecholamines on the development of fatigue in exercising rats in the heat. *J Physiol.* 2008;586(1):141-9. doi: 10.1113/jphysiol.2007.142190. [PubMed: 17947314].
  81. Ram MS, Bhardwaj R. Effect of different illumination sources on reading and visual performance. *J Ophthalmic Vis Res.* 2018;13(1):44-49. doi: 10.4103/jovr.jovr\_50\_17. [PubMed: 29403589].

## **CHAPTER THREE: ARTICLE TWO - DIFFERENCES IN VISIO-SPATIAL EXPERTISE BETWEEN FIRST-DIVISION RUGBY PLAYERS AND NON-ATHLETES**

Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S. Differences in Visio-spatial expertise between first-division rugby players and non-athletes. *Vision Research Journal*. Submitted. (Appendix B)

### **ABSTRACT**

The present study aimed to compare the visual expertise of first-division rugby players to non-athletes. Research suggests that athletes have enhanced Visio-spatial expertise when compared to non-athletes. However, conflicting research suggests that this is not always the case, as non-athletes possess similar Visio-spatial expertise in certain visual skills. Participants underwent an optometric assessment after which the following six Visio-spatial intelligence (VSI) components were measured, namely accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination using the following tests: Hart Near Far Rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests. Results indicated that first-division rugby players performed significantly ( $p \leq 0.05$ ) better in five of the six tests performed, with the exception for visual memory ( $p = 0.893$ ). While this study substantiates the notion that athletes, in this case, first-division rugby players, perform significantly better in most VSI components, this is not the case for all aspects of vision. To more accurately distinguish between athletes and non-athletes, research should move away from tests that focus on basic visual function and develop sport-specific testing methods.

Keywords: Perceptual performance, Sport vision, Visual classification, Visual function

### **INTRODUCTION**

It is estimated that 85–90% of sensory information regarding the external environment is obtained visually (Loran & MacEwen, 1995). Vision is crucial in performing motor tasks that are ubiquitous features of human action and interaction in our world, for example shaking hands or crossing the street (Barret et al., 2017). It provides information regarding the “where”, “when” and “what” action to complete (Wimhurst et al., 2012), and is of vital importance to perform more complex motor tasks such as catching, passing and kicking, which is needed to perform at an optimal level in sport (Meir, 2005).

Historically, researchers have relied on physical condition testing and training techniques to classify and compare athletes to non-athletes (Du Toit et al., 2010; Millard et al., 2020a). However, recent interest has

developed around how the testing and training of vision can affect sports performance and assist in classifying and comparing athletes from non-athletes (Du Toit et al., 2009; Millard et al., 2020a). It has been suggested that irrespective of enhanced physical strength, speed, and technical skill, the ability to quickly and correctly process visual information presented may be what differentiates athletes from non-athletes (Kuan et al., 2018).

It has also been suggested that vision is superior in athletes compared to the general population (Gao et al., 2015). However, there are multiple visual skills and each sport utilizes different aspects of vision, which in turn, allows athletes to improve their visual skills through training and testing (Barrett et al., 2017). Classé et al. (1997) found the visual reaction time of baseball players is enhanced in comparison to non-athletes. Similarly, Laby et al. (1996) found the visual acuity, and distance stereo-acuity of baseball players exceeds that of non-athletes. Conversely, Ciućmański and Wątroba (2005) found that no differences exist in the accommodation facility of football players and non-athletes. Likewise, Babu (2004) found that there is no difference in the saccadic eye movements between badminton players and non-athletes.

Athletes train vigorously to ensure optimal performance on the field of play. Research suggests that visual performance can be improved through physical training and provides an explanation as to why athletes outperform non-athletes in certain visual skills, and due to the demanding nature of the sport, rugby players are no different (Du Toit et al., 2012; Elsayy, 2011). A major cause of the inconsistent findings when comparing the visual skills of athletes and non-athletes is due to the generalization of visual training programs and testing batteries used by the researchers. Abernethy and Wood (2001) stated that most visual testing and training programs tend to focus on the basic visual functions only and do not take into consideration that for testing and training to be effective and result in an improvement to on-pitch performance, those methods need to be sport-specific. The contradictory nature of the research findings necessitates the need for a study that incorporates a sport-specific visual test battery to clarify the visual skills of rugby players that are enhanced in comparison to non-athletes.

## **MATERIAL AND METHODS**

### **Subjects**

Eighty young adult males (range: 19-35 years; mean age:  $23.73 \pm 4.33$  years) comprising of 40 first-division rugby players (mean age:  $23.88 \pm 4.36$  years), and 40 non-athletes ( $n = 40$ ; mean age:  $22.13 \pm 2.37$  years) participated in the study. All subjects were recruited from the Zululand region in the KwaZulu-

Natal province of South-Africa, and the first-division rugby players were sampled using a non-probability technique. To partake in the study, non-athletes were required not to have taken part in any form of organized sport or physical activity (Millard et al., 2020b; Stern & Kysilka, 2008). The first-division rugby players were required to have participated in a minimum of 30 hours of training per week, and having played at least one competitive game in the first division. If the conditions were not met, subjects were excluded from the study. The study followed the tenets of the declaration of Helsinki and approval was obtained from the ethical board committee of the University of Zululand. Informed consent was obtained from all subjects before participating in the study after indications and potential consequences of the study were explained in detail.

### **Optometric Assessment**

To participate in the study, subjects were required to undergo an optometric assessment to ensure normal (20/20) vision. Spectrum Eyecare software (Version 6.0.0, Digital Optometry, Republic of South Africa) was used to measure the subject's visual acuity and depth perception to ensure that all subjects met the minimum requirements, which in turn allowed participation in the study.

### **Visio-spatial test battery**

A VSI test battery was designed to measure the following six components of vision for both the first division rugby players and non-athletes: 1) accommodation facility; 2) saccadic eye movements; 3) speed of recognition; 4) hand-eye coordination; 5) peripheral awareness and 6) visual memory. To decrease the effect of various factors affecting vision such as diet and physical and mental influences, testing was conducted between 07:00 and 12:30 in the morning. Testing was performed while the athletes were in a post-absorptive state following a 9- to 12-hour fast, and at least 48 hours after any other physical exercise was performed. For each of the tests two trials were performed with a five-minute rest in between trials, with the top score being recorded and used in the final data analysis (Millard et al., 2020b).

### **Accommodation facility**

The function whereby the refractive power of the optical system of an eye can change, which enables images of both distant and near objects to be viewed clearly (Mcbrien & Millodor, 1987). Research suggests that this function can be measured through the use of the Hart Near Far Rock Test (Adler, 2007). This test makes use of the Hart Chart, which was placed three meters away from the subjects on a board, at head height (Du Randt et al., 2016; Millard et al., 2020b). Researchers instructed subjects to hold another smaller chart at arm's length away, after which they were tasked to read the first letter of the first line of the chart on the board three meters away and then proceed to read the first letter of the chart at

arm's length away (Du Randt et al., 2016; Millard et al., 2020b). This process continued for 30 seconds, after which errors were subtracted from each subject's score to determine their final score (Millard et al., 2020b).

### **Saccadic eye movement**

Saccades are rapid, ballistic movements of the eyes that abruptly change the point of fixation, and can be measured through the use of a saccadic eye movement chart (Purves, 2001). To ensure subjects cannot memorise the letters on a chart, a standardized, yet adjustable saccadic eye movement chart was used, whereon letters running down vertically on both sides of the page. The primary researcher placed two charts on a board, 1 meter apart, at a distance of 3 meters away from the subjects (Du Randt et al., 2016; Millard et al., 2020b). Subjects were instructed to read the first letter on the lateral side of the left chart, and then rapidly move their eyes and read (without moving their heads) the first letter on the lateral side of the right chart (Du Randt et al., 2016; Millard et al., 2020b). This process continued for 30 seconds, after which any errors were subtracted from each subject's score to determine their final score (Millard et al., 2020b).

### **Speed of recognition**

For this study, the Batak Pro was used to measure the speed at which individuals can process and act on visual information in an environment (Lobier et al., 2013; Quotronics Limited, 2011). The Batak Pro consists of 12 visually bright light-emitting diodes (LED) and contains a microcomputer that allows for multiple different programs to be employed. To measure the speed of recognition, this study used the Evasion program, which causes the LED lights to randomly light up for 1 second, with a maximum of 100 targets being illuminated. If a subject struck an incorrect target or did not reach the target in time, the program would speed up and increase its level of difficulty (Quotronics Limited, 2011). For the duration of the test, if a target lit and flickered, subjects were instructed to not strike the target, but rather to only strike the solid lights. If the subject struck a flickering target, the Batak Pro would subtract 5 points from the subject's score (Quotronics Limited, 2011). Lastly, when all of the lights in the middle of the Batak Pro began to flicker, the subject was required to get out of the way of a small infrared beam. If caught, a further 5 points were deducted (Quotronics Limited, 2011). The final score was automatically calculated by the microcomputer.

### **Hand-eye coordination**

Optimal coordination between eye and hand was tested by making use of the ball wall toss test (Laplante, 2001; Rizzo et al., 2019). A subject was instructed to position themselves at a mark measured two meters

from a wall, and to throw a standard tennis ball at the wall, and catch it, while alternating hands for 30 seconds (Du Randt et al., 2016; Millard et al., 2020b). The number of successful catches were recorded (Millard et al., 2020b).

### **Peripheral awareness**

The ability of individuals to respond rapidly and successively to peripherally present stimuli was measured by the accumulator program on the Batak Pro (Kruger et al., 2009; Quotronics Limited, 2011). The microcomputer caused random targets to illuminate, and to remain illuminated until they are struck by a subject. As soon as a subject struck a target, another would illuminate, and this process would continue for 60 seconds (Quotronics Limited, 2011). The final score was calculated, automatically stored and displayed by the microcomputer.

### **Visual memory**

The ability to store and retrieve visual information that has been previously experienced was measured, for this study, using the flash memory program of the Batak Pro (Quotronics Limited, 2011; Shurgin, 2018). This program caused the microcomputer to illuminate six targets for half a second, after which the targets disappeared. The subjects were required to remember the six illuminated targets as well as the order in which they appeared (Quotronics Limited, 2011). The microcomputer calculated the maximum score at the end of the session for each subject.

### **Statistics**

This study was conducted using quantitative research methods and employed already established visual skills assessments. Descriptive statistics such as the mean, standard deviation, ranges and percentage differences were calculated through the use of the Statistical Package for Social Sciences (SPSS) version 22 for Windows (SPSS Inc., Chicago, IL, USA). To measure the differences that existed between the two groups, the Mann-Whitney U test was employed. This method was used because the dependent variable was continuous, and not normally distributed. Concurrently, a rank-ordered analysis was performed, to better discriminate as to which visual skills were superior. The Kaiser-Meyer-Olkin measure of sampling adequacy was employed to indicate whether the data was suitable for factor analysis and to create an overall combined measure of visual expertise. Lastly, in order to check if the data was suitable for a reduction of exploratory factor analysis, Bartlett's test of sphericity was utilized. Statistical significance was set at  $p \leq 0,05$ .

## RESULTS

In evaluating the results, it was found that a significant difference existed between first division rugby players and non-athletes for five out of the six Visio-spatial skills tested (Table 1). Upon viewing the results in more detail, first division rugby players outperformed non-athletes significantly in accommodation facility ( $p = 0.000$ ), saccadic eye movement ( $p = 0.000$ ), speed of recognition ( $p = 0.000$ ), hand-eye coordination ( $p = 0.000$ ) and peripheral awareness ( $p = 0.000$ ). Interestingly, however there was no significant difference found in visual memory between the two groups ( $p = 0.893$ ).

A rank-ordered analysis revealed that even though there were significant differences in five of the six visual skills tested, the magnitude of the difference varied. Firstly, the analysis indicated that first division rugby players were 93% more proficient at speed of recognition in comparison to non-athletes. Secondly, the first division rugby players performed 23% better in hand-eye coordination skills in comparison to non-athletes, followed by saccadic eye movements (19%), peripheral awareness (15%), and accommodation facility (9.59%) (Table 1).

Upon further investigation, an exploratory analysis found that first division rugby players significantly outperformed non-athletes ( $U = 167.500$ ,  $p$ -value = 0.000), with first division rugby players performing better on average than non-athletes.

**Table 1** Differences in visio-spatial expertise between 1<sup>st</sup> division rugby players and non-athletes

| Visio-spatial skill    | Non-athletes<br>( $n = 40$ ) | Rugby players<br>( $n = 40$ ) | Difference<br>(%) | Significance<br>( $p$ -value) |
|------------------------|------------------------------|-------------------------------|-------------------|-------------------------------|
| Accommodation Facility | 28.78±2.93                   | 31.68±4.29                    | 9.59              | 0.000*                        |
| Saccadic Eye Movement  | 32.98±4.70                   | 40.03±7.26                    | 19.31             | 0.000*                        |
| Speed of Recognition   | 11.23±6.05                   | 30.88±15.35                   | 93.33             | 0.000*                        |
| Peripheral Awareness   | 56.20±3.39                   | 65.40±6.13                    | 15.13             | 0.000*                        |
| Hand-Eye Coordination  | 19.55±4.48                   | 24.75±3.68                    | 23.48             | 0.000*                        |
| Visual Memory          | 45.10±5.46                   | 45.28±7.01                    | 0.40              | 0.893                         |

Mean±SD; \*: Statistically significant ( $p \leq 0.05$ )

## **DISCUSSION**

This study was to compare the visual expertise of first division rugby players to non-athletes. A VSI test battery was utilized to differentiate between both groups based on the following VSI components: accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination. It was found that first division rugby players outperformed non-athletes on all VSI components, except visual memory.

While there is evidence to suggest that athletes were found to have lower accommodation facility abilities when compared to non-athletes (Christenson & Winkelstein, 1988), the finding of superior accommodation in first-division rugby players were similar to that of studies by Jafarzadehpur et al. (2007) and Omar et al. (2017), which found that accommodation facility was significantly different when comparing volleyball players and non-athletes. Accommodation is crucial to enable athletes to perform optimally, and as such, athletes spend a large amount of their training time on attaining and focusing on targets to achieve higher accuracy on the field of play. This allows athletes to adjust their focus rapidly for stable and clear vision, especially when attempting to fixate from distance to near or vice versa (Omar et al., 2017). This causes athletes to have enhanced accommodation in comparison to non-athletes.

Findings by Yilmaz and Polat (2018) suggests that there are no differences when comparing the saccadic eye movements of basketball players, volleyball players and swimmers to non-athletes. However, it was reported that no sport-like dual-task was included, which influenced the results, as the specificity of the task is crucial to ensure accurate findings. Studies conducted by Fujiwara et al. (2009), and Nakamoto and Mori (2008a) supported the notion that saccadic eye movements are significantly enhanced in basketball players and baseball players when compared to non-athletes. Athletes have the unique ability to learn dynamic complex scenes rapidly due to their superior perceptual skills (Faubert, 2013), which increases the capacity to resolve spatial dynamic objects during head fixation or movement, as well as allocating their attention more efficiently than non-athletes (Mann, 2007). This allows athletes an enhanced ability to move their eyes rapidly from one target to the next and provide more information regarding the targets. The present study found that there was a significant difference in the speed of recognition between first division rugby players when compared to non-athletes. This is supported by the findings of Thomson et al. (2005), and Nakamoto and Mori (2008b) who found that there was a significant difference in the speed of recognition when comparing basketball, volleyball, and baseball players to non-athletes. To perform optimally, rugby players train vigorously to improve skills such as catching, passing and kicking in pressure situations (Meir, 2005). Research suggests that chronic training produces modifications in the number of synapses, synaptic strength, and topography of stimulus-evoked movement representation and

induces persistent-encoded behaviours within the nervous system (Monfils et al., 2005; Nielsen & Cohen, 2008). This causes athletes to improve exponentially in relation to decision making tasks that occur within their sporting environment, which in turn causes enhanced performance when compared to non-athletes. However, this also explains the findings of Mori et al. (2002), who stated that there was no significant difference for in the speed of recognition between karate athletes and non-athletes. If the decision-making skills of athletes are tested using tasks that are not specific to their sporting environment, no difference would be found between athletes and non-athletes (Abernethy & Wood, 2001). Testing needs to be conducted using sport-specific testing methods because if generalized methods are used, the results found would be inaccurate. Significantly, this study found that speed of recognition was the VSI component that exhibited the largest difference between first division rugby players and non-athletes with a difference of 93%. Thus, to be a successful rugby player, speed of recognition may be the most important VSI component to focus on.

Based on the results of peripheral awareness, previous research by Ando et al. (2001), and Williams and Thirer (1975) found similar differences in peripheral awareness when comparing soccer, American football, and fencing athletes to non-athletes. Contradictory, Zwierko (2007) found that there was no significant difference in peripheral awareness when comparing handball players to non-athletes. Interestingly, athletes may have enhanced peripheral awareness due to their higher level of visual perception, which is related to recognition speed and responsiveness to stimuli, and the functioning of the visual system in the peripheral field (Blundel, 1982). Furthermore, research suggests that sport disciplines which require multiple stimuli involvement of visual perception improves peripheral awareness (Blundel, 1982). It is thus safe to state that peripheral awareness in rugby players may be enhanced when compared to non-athletes, due to the multiple stimuli involvement needed to perform the skills needed to succeed. Hand-eye coordination was found to be superior in this study's first-division rugby players and is supported by the findings of Chen et al. (2017), and Halder and Saha (2013). This is expected in an open skill sport such as rugby, due to players being required to process information in a rapidly changing, unpredictable environment, which may lead to a superior performance of hand-eye coordination skill and also result in developing more flexible visual attention, decision making and action execution when compared to non-athletes (Lees, 2003; Taddei et al., 2012).

Lastly, the only VSI component tested where no significant difference was found between first-division rugby players and non-athletes, was visual memory, which concurs with the findings of Chase and Simon (1973). While there were differences found initially when structured scenes were used to distinguish between basketball players and non-athletes, there were no differences found when using unstructured

scenes, which suggests that athletes only have enhanced results regarding visual memory when faced with familiar situations (Chase & Simon, 1973). There are multiple possible reasons as to why no significant differences were found in this study, including visual memory not being a crucial VSI component when differentiating between first division rugby players and non-athletes, or that the Batak Pro Flash Program is not able to differentiate between first-division rugby players and non-athletes specifically concerning visual memory, which provides an opportunity for further research.

## CONCLUSIONS

While this study substantiates the notion that athletes, in this case, first division rugby players, perform significantly better in most VSI components, this is not the case for all, as with visual memory in this study. To more accurately distinguish between athletes and non-athletes, research should move away from tests that focus on basic visual function and develop sport-specific testing methods that can be used by a variety of sports, as with the findings of this study in relation to the speed of recognition where there was a 93% difference. Future studies should use sport-specific testing methods to measure the transferability of visual training programs to on-pitch performance.

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## REFERENCES

- Abernethy, B., Wood, J. M. (2001). Do generalized visual programs for sport really work? An experimental investigation. *Journal of Sport Science*, 19, 203–222. <https://doi:10.1080/026404101750095376>.
- Adler, P. (2007). Be the best you can be: performance, vision and sport. Middle East. [Course notes].
- Ando, S., Kida, N., Oda, S. (2001). Central and peripheral visual reaction time of soccer players and nonathletes. *Perceptual Motor Skills*, 92(3), 786–794. <https://doi:10.2466/pms.2001.92.3.786>.
- Babu, R. J., Meyers, J. P., Irving, E. L. (2004). Athletes' vs. non-athletes: an investigation comparing the latency, accuracy, peak velocity and adaptation of saccades. *Investigative Ophthalmology & Visual Science*, 45, 2511.

- Barret, B. T., Flavell, J. C., Bennett, S. J., Cruickshank, A. G., Mankwoska, A., Harris, J. M., Buckley, J. G. (2017). Vision and visual history in elite/near-elite-level cricketers and rugby-league players. *Sports Medicine-Open*, 3, 39. <https://doi:10.1186/s40798-017-0106-z>.
- Blundell, N. L. (1982). A multivariate analysis of the visual-perceptual attributes of male and female tennis players of varying ability levels. Psychology of motor behaviour and sport: North American society for the psychology of sport and physical activity. *Published Master dissertation*, University of Maryland.
- Chase, W. G., Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, 4(1), 55–81. [https://doi:10.1016/0010-0285\(73\)90004-2](https://doi:10.1016/0010-0285(73)90004-2).
- Chen, W. Y., Wu, S. K., Song, T. F. (2017). Perceptual and motor performance of combat-sport athletes differs according to specific demands of the discipline. *Perceptual and Motor Skills*, 124(1), 293–313. <https://doi:10.1177/0031512516681342>.
- Christenson, G. N., Winkelstein, A. M. (1988). Visual skills of athletes versus non-athletes: development of a sports vision testing battery. *Journal of the American Optometric Association*, 59(9), 666–675.
- Ciućmański, B., Wątroba, J. (2005). Training selected visual perception abilities and the efficiency footballers. (in Polish) In: Gry zespołowe w wychowaniu fizycznym i sporcie, [red Żak S., Spieszny M., Klocek T.], Studia i Monografie nr 33 AWF Kraków 298–303.
- Classé, J. G., Semes, L. P., Daum, K. M., Nowakowski, R., Alexander, L. J., Wisniewski, J., Beisel, J. A., Mann, K., Rutstein, R. M., Smith, M., Bartolucci, A. A. (1997). Association between visual reaction time and batting, fielding, and earned run averages among players of the Southern Baseball League. *Journal of the American Optometric Association*, 68, 43–49.
- Du Randt, R., Raffan, R., Millard, L., Venter, D. (2016). Impact of a visual skills training program on the visual ability of elite rugby players. *Published Masters dissertation*, Nelson Mandela University.
- Du Toit, P. J., Kruger, P. E., Naicker, L. A., Govender, C., Jay-Du Preez, T., Grobbelaar, C., Grant, R., Wood, P. S., Kleynhans, M., Mercier, J. (2012). Evaluation of visual skills in sedentary and active work environments. *African Journal for Physical, Health Education, Recreation and Dance*, 18(1), 178–191.
- Du Toit, P. J., Kruger, P. E., Chamane, N. Z., Campher, J., Crafford, D. (2009). Sport vision assessment in soccer players. *African Journal for Physical, Health Education, Recreation and Dance*, 15(4), 594–604.
- Du Toit, P. J., Kruger, P. E., Fowler, K. F., Govender, C., Clark, J. (2010). Influence of sport vision techniques on adult male rugby players. *African Journal of Physical, Health Education, Recreation and Dance*, 16(3), 510–517.
- Elsawy, G. Y. (2011). Eye movements among female taekwondo players with high and low levels. *World Journal of Sport Sciences*, 4(4), 347–350.

- Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports*, 3, 1154. <https://doi:10.1038/srep01154>.
- Fujiwara, K., Kiyota, N., Maekawa, M., Kunita, K., Kiyota, T., Maeda, K. (2009). Saccades and prefrontal hemodynamics in basketball players. *International Journal of Sports Medicine*, 30(9), 647–651. <https://doi:10.1055/s-0029-1220732>.
- Gao, Y., Chen, L., Yang, S. N., Wang, H., Yao, J., Dai, Q., Chang, S. (2015). Contributions of visuo-oculomotor abilities to interceptive skills in sports. *Optometry and Vision Science*, 92, 679–689. <https://doi:10.1097/OPX.0000000000000599>.
- Halder, S., Saha, G. C. (2013). A comparative study of hand eye coordination between sportsmen and non sportsmen. *International Journal of Health, Physical Education and Computer Science in Sports*, 9(1):76-9. <https://doi:10.18869/acadpub.aassjournal.4.4.69>.
- Jafarzadehpur, E., Aazami, N., Bolouri, B. (2007). Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. *Scandinavian Journal of Medicine and Science in Sport*, 17, 186–190. <https://doi:10.1111/j.1600-0838.2005.00535>.
- Kruger, P. E., Campher J., Smit, C. E. (2009). The role of visual skills and its impact on skill performance of cricket players. *African Journal for Physical, Health Education, Recreation and Dance*, 15(4), 605–623.
- Kuan, Y. M., Zuhairi, N. A., Manan, F. A., Knight, V. F., Omar, R. (2018). Visual reaction time and visual anticipation time between athletes and non-athletes. *Malaysian Journal of Public Health Medicine*, 1, 135–141.
- Laby, D. M., Rosenbaum, A. L., Kirschen, D. G., Davidson, J. L., Rosenbaum, J. L., Strasser, C., Mellman, M. F. (1996). The visual function of professional baseball players. *American Journal of Ophthalmology*, 22, 476–485. [https://doi:10.1016/S0002-9394\(14\)72106-3](https://doi:10.1016/S0002-9394(14)72106-3).
- Laplante, P. A. (2001). *Dictionary of computer science engineering and technology*. USA: CRC Press.
- Lees, A. (2003). Science and the major racket sports: A review. *Journal of Sports Sciences*, 21, 707–732. <https://doi:10.1080/0264041031000140275>.
- Lobier, M., Dubois, M., Valdois, S. (2013). The role of visual processing speed in reading speed development. *Plos One*, 8(4), 58097. <https://doi:10.1371/journal.pone.0058097>.
- Loran, D. F. C., MacEwen, C. J. (1995). *Sports Vision*. Oxford: Butterworth-Heinemann.
- Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: a meta-analysis. *Journal of Sport & Exercise Psychology*, 29(4), 457–478. <https://doi:10.1123/jsep.29.4.457>.
- Mcbrien, N. A., Millodot, M. (1987). The relationship between tonic accommodation and refractive error. *Investigative Ophthalmology & Visual Science*, 28, 997–1004.

- Meir, R. (2005). Conditioning the visual system: a practical perspective on visual conditioning in rugby football. *Strength and Conditioning Journal*, 27(4), 86–92. <https://doi:10.1519/1533-4295>.
- Millard, L., Shaw, I., Breukelman, G.J. & Shaw, B.S. (2020a). Factors affecting vision and visio-spatial intelligence (VSI) in sport: a review of the literature. *Asian Journal of Sport Medicine*, In press.
- Millard, L., Shaw, I., Breukelman, G.J. & Shaw, B.S. (2020b). Visio-spatial skills in athletes: Comparison of rugby players and non-athletes. *Sport Science in Health*, <https://doi.org/10.1007/s11332-020-00663-1>.
- Monfils, M. H., Plautz, E. J., Kleim, J. A. (2005). In search of the motor engram: motor map plasticity as a mechanism for encoding motor experience. *Neuroscientist*, 11, 471–483. <https://doi:10.1177/1073858405278015>.
- Mori, S., Ohtani, Y., Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science*, 21, 213–230. [https://doi:10.1016/s0167-9457\(02\)00103-3](https://doi:10.1016/s0167-9457(02)00103-3).
- Nakamoto, H., Mori, S. (2008a). Effects of stimulus-response compatibility in mediating expert performance in baseball players. *Brain Research*, 1189, 179–188. <https://doi:10.1016/j.brainres.2007.10.096>.
- Nakamoto, H., Mori, S. (2008b). Sport-specific decision-making in a go/nogo reaction task: difference among nonathletes and baseball and basketball players. *Perceptual and Motor Skills*, 106, 163–170. <https://doi:10.2466/pms.106.1.163-170>.
- Nielsen, J. B., Cohen, L. G. (2008). The Olympic brain. Does corticospinal plasticity play a role in acquisition of skills required for high-performance sports? *Journal of Physiology*, 586, 65–70. <https://doi:10.1113/jphysiol.2007.142661>.
- Omar, R., Kuan, Y. M., Zuhairi, N. A., Manan, F. A., Knight, V. F. (2017). Visual efficiency among teenaged athletes and nonathletes. *International Journal of Ophthalmology*, 10(9), 1460–1464. <https://doi:10.18240/ijo.2017.09.20>.
- Purves, D., Augustine, J. G., Fitzpatrick, D., Katz, L. C., LaMantia, A. S., McNamara, J. O., Williams, S. M. (2001). *Neuroscience: 2nd edition*. Sunderland: Sinauer Associates.
- Quotronics Limited. (2011). Batak Pro Manual. Surrey. United Kingdom.
- Rizzo, J. R., Beheshti, M., Shafieesabet, A., Fung, J., Hosseini, M., Rucker, J. C., Snyder, L. H., Hudson, T. E. (2019). Eye-hand re-coordination: A pilot investigation of gaze and reach biofeedback in chronic stroke. *Progress in Brain Research*, 243, 361–374. <https://doi:10.1016/bs.pbr.2019.04.013>.
- Shurgin, M. W. (2018). Visual memory, the long and the short of it: A review of visual working memory and long-term memory. *Attention, Perception, and Psychophysics*, 80, 1035–1056. <https://doi:10.3758/s13414-018-1522-y>.
- Stern, B. S., Kysilka, M. L. (2008). *Contemporary readings in curriculum*. USA: Sage publications.

- Taddei, F., Bultrini, A., Spinelli D., Di Russo, F. (2012). Neural correlates of attentional and executive processing in middle-aged fencers. *Medicine & Science in Sports & Exercise*, 44, 1057–1066. <https://doi:10.1249/MSS.0b013e31824529c2>.
- Thomson, K., Watt, A., Liukkonen, J. (2008). Skill-Related Differences between Athletes and Nonathletes in Speed Discrimination, *Perceptual and Motor Skills*, 107(3), 893–900. <https://doi:10.2466/pms.107.3.893-900>.
- Williams, J. M., Thirer, J. (1975). Vertical and horizontal peripheral vision in male female athletes and non-athletes. *Research Quarterly*, 46, 200–205.
- Wimhurst, Z. L., Sowden, P. T., Cardinale, M. (2012). Visual skills of elite athletes. *Published Doctoral dissertation*, University of Surrey.
- Yilmaz, A., Polat, M. (2018). Prosaccadic and antisaccadic performance of the athletes in different types of sports. *Journal of Biomedical Research*, 29, 1–5. <https://doi:10.4066/biomedicalresearch.29-17-3224>.
- Zwierko, T. (2007). Differences in peripheral perception between athletes and nonathletes. *Journal of Human Kinetics*, 19, 53–62. <https://doi:10.2478/v10078-008-0004-z>.

## CHAPTER FOUR: ARTICLE THREE - VISIO-SPATIAL SKILLS IN ATHLETES: COMPARISON OF RUGBY PLAYERS AND NON-ATHLETES

Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S. (2020). Visio-spatial skills in athletes: Comparison of rugby players and non-athletes. *Sport Sciences for Health*. <https://doi.org/10.1007/s11332-020-00663-1>. (Appendix C)

### ABSTRACT

**Background:** Research regarding the superiority of athletes' Visio-spatial expertise when compared to non-athletes is conflicting. This discrepancy may arise due to superiority in athletes in only specific Visio-spatial skills (VSS) and not all aspects of vision.

**Aims:** This study aimed to discern whether rugby players have superior VSS/expertise in comparison to non-athletes when comparing six visual skills (accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination).

**Methods:** The participants underwent an optometric assessment, after which the VSS components of non-athletes and premier league rugby players were assessed using six existing tests namely; the Hart Near Far Rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests.

**Results:** A statistically significant ( $p \leq .05$ ) difference existed between rugby players and non-athletes for five of the six tests. Conversely, no real evidence is shown that visual memory differs between rugby players and non-athletes ( $p = .599$ ).

**Conclusion:** This study found that rugby players have an enhanced accommodation facility, saccadic eye movements, speed of recognition, peripheral awareness and hand-eye coordination, but not visual memory when compared to non-athletes. These findings of the superiority of rugby players in specific VSS skills have broad implications for theories of sports vision, how best to select tests and in the development of sport-specific VSS testing batteries.

Keywords: Sports Vision, Visual expertise, Visual skill, Visio-spatial Intelligence (VSI)

### INTRODUCTION

To perform fundamental movement activities, such as walking, running, catching and jumping, individuals, and especially athletes, need to be able to use motor skills [1]. These motor skills are stable, long-lasting and are essential for athletic performance. Thankfully, these motor skills can be developed through motor activity or practice. This is the reason coaches and conditioning specialists spend a large amount of time improving their athletes anthropometrically and physiologically.

Sports vision has only received attention concerning athletic performance in recent years [2]. Athletes spend numerous hours training, to improve their conditioning to increase *inter alia*: body composition, cardiorespiratory endurance and muscular fitness, while inadequate visual processing capabilities could affect their physical training and thus their performance [2]. For example, a crucial component of coordination is Visio-spatial skill (VSS), which can be defined as a wide variety of individual skills that vary from recognizing brightness or darkness, identifying complex intersecting angles and curves to recognizing faces by the shape of eyes, noses, mouths and hair [3, 4]. This is because improvements in the physical skill of coordination can be achieved through a complex interplay of proprioception, sensory input from vision, and the vestibular system [5]. It is clear that in the majority of sports, the visual system provides the athlete with information regarding where, when and what to focus on in a specific sporting situation, which has a significant impact and positively influences athletes' response to visual information. It is therefore important to realize that the eyes, via neurological pathways to the brain, are responsible for directing an athlete's muscles to respond appropriately [2].

While VSS are increasingly being considered as important as physical skills in athletes, VSS is still not thoroughly researched. Further confounding the importance of VSS in athletes are conflicting findings. Some research has indicated improved VSS in athletes when compared to non-athletes [6, 7], while other research has indicated that there may be no difference in VSS between athletes and non-athletes [8-10].

Research is unequivocal regarding the efficacy of physical training at improving cognitive functioning and altering the structural and functional aspects of the human brain. So too has research proposed that physical activity can influence the visual performance skills. This is because exercise facilitates multiple cognitive processes under different conditions, and can enhance response accuracy and response speed, as well as facilitate the cognitive processes which are central to goal-orientated actions and problem-solving [11-13]. In this regard, not only are rugby players physically active, training for up to five days per week, they also need to possess a variety of skills such as catching, passing and kicking, to enable them to advance the ball beyond the opposing team's defensive line [14]. To limit mistakes during the performance of these skills, a significant amount of time may need to be spent during training to improve rugby players' VSS including accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination, while factoring in variables such as fatigue and conditions that occur during a match [14]. While non-athletes use their VSS daily to perform activities, non-athletes are in many cases not physically active. This may, in turn, lead to a decrease in a variety of VSS [6]. Due to the conflicting research that exists with regards to VSS in athletes versus non-

athletes, it is imperative to determine which specific VSS are enhanced in athletes.

## **AIMS AND HYPOTHESIS**

The study aimed to discern whether rugby players have enhanced VSS in comparison to non-athletes. This study specifically compared rugby players and non-athletes on six VSS components, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination. Based on previous research, it was hypothesized that rugby players would prove significantly superior to non-athletes on all six measured VSS components, however not to the same magnitude.

## **METHODS**

### **Participants**

Following institutional ethics approval and informed consent, the study sampled 19- to 35-year old male non-athletes ( $n = 40$ ; mean age:  $22.13 \pm 2.37$  years) and male premier league rugby club players ( $n = 40$ ; mean age:  $25.20 \pm 5.23$  years). The non-athletes were recruited from the Zululand region in the KwaZulu-Natal province of the Republic of South Africa and were required to not be participating in any structured sporting/physical activity program [15]. Rugby players were sampled using a non-probability sampling technique from all the premier league rugby teams within the same region as the non-athletes. Rugby players were required to have participated in 30 hours of rugby training and played at least one competitive game per week in the premier league within the past three months. To ensure group equalization, participants in each group were age-matched.

### **Optometric assessment**

All participants underwent general optometric screening using the Spectrum Eyecare software (Version 6.0.0, Digital Optometry, Republic of South Africa) to determine if any limitations existed in any of the participants' vision and thus suitability for the study. All participants reported normal or corrected-to-normal vision (20/20 or better). None of the subjects had previous experience with VSS testing.

### **Visio-spatial skill test battery**

Testing was performed on weekday mornings between 07:00 and 12:00 in the post-absorptive state following a 9- to 12-hour fast to minimize the influence of any dietary or supplemental factors. In an attempt to avoid any physical and mental influences, participants were tested only after at least 48 hours following any physical exercise. Both groups performed the same VSS test battery and tests were

performed in the following sequence to ensure prior tests did not influence later tests: 1) accommodation facility; 2) saccadic eye movements; 3) speed of recognition; 4) hand/eye coordination; 5) peripheral awareness and 6) visual memory. A five-minute rest period was observed between each trial to ensure adequate recovery.

### **Accommodation facility**

As suggested by Adler [16], the Hart Near Far Rock Test was utilized to assess visual accommodation via speed of the response of the eye movements and their ability to maintain this response over time [17]. The Hart Chart was placed at the head height of each participant on a wall three meters away. Participants were instructed to hold another chart at arm's length away from themselves. Participants were then asked to read the first letter of the first line of the chart on the wall three meters away, after which they read the first letter on the chart at arm's length away [18]. The participants were instructed to continue in this manner for 30 seconds after which the errors were recorded as well as their end score (i.e. how many letters were read correctly). The final score was calculated by subtracting the number of errors the participant made from their end score. Different charts were used to ensure that letters cannot be memorized [18]. Two trials were performed with a five-minute rest period between trials, after which the highest score was recorded and utilized in the final analysis.

### **Saccadic eye movements**

To assess how rapidly the participant's eye movements are in repositioning the fovea to a new location in the visual environment, a saccadic eye movement chart was utilized [19]. This chart contained adjustable letters running vertically downward on both sides of the page. Different charts were used to ensure that letters could not be memorized [18]. In this test, two saccadic eye movement charts were placed 1m apart on a wall, with the participant standing 3m from the charts. The participant then had to look at the first letter on the lateral side of the left chart and say it out loud, after which he then needed to quickly look over at the chart on the right and read the first letter on the lateral side out loud. The participants were instructed to keep their heads still and to only move their eyes. This test was performed for 30 seconds and the number of errors made was measured as well as the end score (i.e. how many letters were read). The final score was determined by deducting the number of errors from the number of letters read. Two trials were performed, with the highest score recorded and utilized in the final analysis [18].

### **Speed of recognition**

To assess the speed at which a participant recognizes a specific target, the present study made use of the Batak Pro [20]. This equipment involves 12 visually bright light-emitting diode (LED) cluster targets that

are numbered and arranged in a maximum stretch type configuration and put under the control of a dedicated microcomputer. The targets were lit up using the Evasion Program [20]. This program allowed 100 timed targets to illuminate at random with the “time” LED screen on the Batak counting the targets down from 100 to zero and the “score” LED screen showing each successful strike. The targets remained lit for a 1-second strike opportunity. If the wrong target was struck “out of time”, the routine would speed up. During the course of this routine, if the participant saw a flashing target, they were required not to strike it. Hitting this target caused the equipment to give the participant a verbal “foul” and the loss of five points on the score. If all the center targets illuminated at the same time, the participant was then immediately required to avoid an infrared beam emitted or be penalized five points. The number of errors made was recorded by the equipment, and the end score was determined after deducting the errors [20]. Two trials were performed with a five-minute rest period between trials, after which the highest score was recorded and utilized in the final analysis.

### **Hand-eye coordination**

To assess hand-eye coordination, this study made use of a tennis ball and the ball wall toss test [21]. A spot was marked 2m away from the wall, and each participant was required to throw the ball at the wall and catch the ball using alternating hands. Participants continued to do this for 30 seconds [18]. Each time the participant caught the ball is counted as a score. The participants were required to complete as many catches as possible within the available 30 seconds. Two trials were performed with a five-minute rest period between trials, after which the highest score was recorded and utilized in the final analysis.

### **Peripheral awareness**

To assess the ability of the participants to see objects and movement outside of their direct line of vision, the Batak Pro [20] was utilized using the Accumulator Program. The Accumulator Program consisted of random targets remaining lit on the Batak Pro for 60 seconds until the participant touched them [20]. The number of targets correctly touched in 60 seconds was recorded by the machine and two trials were performed with a five-minute rest period in between trials, after which the highest score was recorded and utilized in the final analysis.

### **Visual memory**

To assess the memory where the stored information was acquired by the visual system, the Batak Pro Flash Program was utilized and entailed the illumination of six random targets for a display time of half a second [18]. Participants were required to correctly remember the specific targets and the order in which they were activated, and strike the illuminated targets (that illuminated in a specific order) after the

“double beep” prompt sounds. The maximum score was displayed on the “score b” LED screen and the points scored for each correct strike were shown on the “score a” LED screen [20]. The maximum score obtained from the two trials were recorded and used in the final data analysis. A five-minute rest period was given between trials.

### **Data Analysis**

The study made use of quantitative research methods, involving already established VSS assessments. This study made use of the Statistical Package for Social Sciences (SPSS) version 22 for Windows (SPSS Inc., Chicago, IL, USA), which calculated the descriptive statistics including the means, standard deviations, ranges and percentage difference of the data collected. The Mann-Whitney U test was used to compare differences between the two independent groups since the dependent variable was continuous, and not normally distributed. To more accurately empirically evaluate on which visuospatial skills rugby players were more superior, a rank-ordered analysis was conducted to support the findings of the Mann-Whitney U test. In addition, to create an overall combined measure of visual expertise, exploratory factor analysis was utilized following application of the Kaiser-Meyer-Olkin measure of sampling adequacy to indicate whether the data was suitable for factor analysis. Bartlett’s test of sphericity was also utilized to indicate if the data was suitable for reduction for exploratory factor analysis. Statistical significance was set at  $p \leq .05$ .

### **RESULTS**

The results indicated that a significant difference ( $p \leq .05$ ) existed for five out of the six tests between the rugby players and non-athletes (Table 1). The rugby players were significantly superior for accommodation facility ( $p = .000$ ), saccadic eye movement ( $p = .000$ ), speed of recognition ( $p = .000$ ), hand/eye coordination ( $p = .000$ ) and peripheral awareness ( $p = .000$ ), but not visual memory ( $p = .599$ ).

**Table 1** Visio-motor expertise comparison in rugby players and non-athletes

| <b>Visio-spatial skill</b> | <b>Non-athletes<br/>(<i>n</i> = 40)</b> | <b>Rugby players<br/>(<i>n</i> = 40)</b> | <b>Difference<br/>(%)</b> | <b>Significance<br/>(<i>p</i>-value)</b> |
|----------------------------|---|--|---------------------------|--|
| Accommodation Facility     | 28.78±2.93                              | 38.33±4.39                               | 28.46                     | .000*                                    |
| Saccadic Eye Movement      | 32.98±4.70                              | 47.70±6.61                               | 36.49                     | .000*                                    |
| Speed of Recognition       | 11.23±6.05                              | 49.53±14.31                              | 126.07                    | .000*                                    |
| Peripheral Awareness       | 56.20±3.39                              | 76.02±4.28                               | 29.98                     | .000*                                    |
| Hand-Eye Coordination      | 19.55±4.48                              | 29.70±3.50                               | 41.22                     | .000*                                    |
| Visual Memory              | 45.10±5.46                              | 45.70±5.96                               | 1.32                      | .599                                     |

Mean±SD; \*: Statistically significant ( $p \leq .05$ )

Rank-ordered analysis indicated that the rugby players were 126% more proficient than non-athletes at speed of recognition, followed by 41% for hand-eye coordination, 36% for saccadic eye movement, 30% for peripheral awareness and 28% for accommodation facility (Table 1).

Further exploratory analysis indicated a significant difference existed for the overall performance between rugby players and non-athletes ( $U = 0.000$ ,  $p = .000$ ), with rugby players performing better on average than non-athletes.

## DISCUSSION

The primary aim of the present study was to discern whether rugby players possess enhanced VSS in comparison to non-athletes. This study specifically compared rugby players and non-athletes on six components of VSS, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination.

The present study found a significant difference in accommodation facility between the rugby players and non-athletes. This is similar to the studies of Jafarzadehpur et al. [22], and Vera et al. [23] and found there was a difference in accommodation facility when comparing university athletes and non-athletes. However, Ciuémański and Wątroba [8] and Ward et al. [24] found no significant difference in accommodation facility when both studies compared soccer players and non-athletes. Athletes may have an increased accommodation facility due to a better tracking (from far to near) ability in comparison to non-athletes. Athletes may be successful at (a particular) sport because they possess superior accommodation and vergence functions, as well as ocular motility [25, 26]. Possible reasons

as to why there was no difference was found in accommodation facility in the studies of Ciućmański and Wątroba [8] and Ward et al. [24] may be due to certain athletes being found to have a lower amplitude of accommodation than non-athletes, indicating that they are only superior to non-athletes when they focus on multiple targets and not single targets [23].

The finding of superior saccadic eye movements in rugby players and non-athletes in this study is similar to that of Sokhn et al. [27] and Mann et al. [28] who found a significant difference in saccadic eye movements when comparing cricket players and non-athletes. However, Babu, [9, 10] found no difference in saccadic eye movements when comparing badminton and squash players, and non-athletes. Athletes may have superior saccadic eye movements to non-athletes because they incorporate the use of priority selection of information, the elimination of irrelevant cues, and spend a greater amount of time to ensure that the correct response is selected in comparison to non-athletes [29]. Rugby players, in particular, spend a significant amount of time during training attempting to improve their ability to select the correct response during competition situations [14]. Interestingly, rugby players may be at a particular risk to have reduced saccadic eye movements because contact sports, such as rugby, have high incidences of concussion and sub-concussive impacts, leading to a decreased ability to move one's eyes as quickly as possible from one target to the next [30].

With regards to the speed of recognition, the present study demonstrated that rugby players were superior to non-athletes. This is similar to the studies of Wang et al. [31] and Zwierko [32] who found a difference in speed of recognition when comparing basketball players and fencers to non-athletes. Of particular interest, the present study found that the largest difference between the rugby players and non-athletes was found in the speed of recognition, where the rugby players scored 126% higher than the non-athletes. Kaya [33] proposes that decision making takes on three characteristics in the field of sport. Firstly, it is naturalistic, meaning that athletes naturally always encounter the decision in a sports environment with some degree of task familiarity [33]. In other words, athletes have enhanced decision-making skills when faced with a Visio-spatial decision that occurs regularly in their sport, which in turn, means that if the test battery is sport-specific, athletes will outperform non-athletes. Secondly, since the majority of sports decisions are dynamic, decisions in sports reveal over time. The dynamic aspect of decision-making has a double impact, meaning that information is not immediately gathered and processed, but rather, a decision-maker must accrue information over time, and subsequent processing of this information takes additional time. However, sports situations and decisions possess external dynamics, meaning that the situation itself changes over time [33]. Lastly, most decisions made by athletes are made in motion, which increases the difficulty level of the

decision to be made. Due to decision-making in sport being naturalistic, dynamic in nature, and performed in motion (which increases the difficulty level), the speed of recognition may be the most critical VSS linked to success in rugby

The present study's finding of a superior peripheral awareness in rugby players when compared to non-athletes is similar to that of Khanal [6] and Ciućmański and Wątroba [8], who found differences in peripheral awareness when comparing soccer players and non-athletes. Athletes have a larger extent of horizontal and vertical visual fields in comparison to non-athletes, and they have better form recognition at more peripheral locations [34]. Participating regularly in sport allows athletes to restrict their peripheral awareness to only crucial stimuli in the environment to perform a sport specific task, which in turn increases the latency and accuracy of head movements during eye movement localization tasks [34]. Therefore, the peripheral sensitivity of athletes seems to be enhanced, which causes a rapid reaction to stimuli in their peripheral field of vision.

Similar to the studies of Chraif [35] and Akarsu et al. [36], the present study found significant differences in hand-eye coordination between rugby players and non-athletes. This is to be expected in that individuals with intrinsic neurological advantages, such as enhanced eye-hand reaction time and VSS, can readily participate in sports [36]. Hand-eye coordination is critical for success in rugby since it involves passing and handling of the ball, receiving the ball and tackling moving targets, mostly while running [37].

Visual memory was the only VSS, of the six measured, to be found to be similar in the sampled rugby players and non-athletes. This finding is similar to a study by Tomczyk et al. [38] that too found no difference in visual memory when comparing athletes and non-athletes. The lack of difference in visual memory in athletic and non-athletic populations may be due to visual memory not being different from verbal memory in its strategic nature, and thus there is no special motor program for visual memory [38]. Contradictory, Chueh et al. [39] found that athletes that participate in both open (rugby and cricket) and closed-skill sports (jogging and swimming) have enhanced visual memory in comparison to non-athletes. A possible reason for this finding is that regardless of whether visual skills are practicable or not, research suggests that exercise and training can develop brain-related visual areas such as visual memory [40].

This study highlighted the finding that rugby players have enhanced VSS performance to non-athletes. While this, and previous studies, propose that physical activity and/or training may be the

reason for this superior VSS, the importance of a fortuitous genetic predisposition towards an enhanced VSS in athletes cannot be downplayed [41]. This is because of the complex interaction between psychological, physiological and socio-cultural factors which interact over the long term to have a resultant effect on the phenotype of the athlete. This may be the same for the VSS of athletes and leads to the conclusion that athletes may have superior VSS due to a combination of regular exercise training and a genetic predisposition.

Based on previous research, the present study hypothesized that rugby players would have superior VSS when compared to non-athletes, however not to the same magnitude. This was confirmed in the present study which indicated that rugby players were 126% more proficient than non-athletes at speed of recognition, followed by 41% for hand-eye coordination, 36% for saccadic eye movement, 30% for peripheral awareness and 28% for accommodation facility. As such, these findings suggest that these VSS may be needed in varying levels of importance for success in rugby. In addition, the degree of expertise of the rugby players (i.e. number of years of practice) should be recorded and correlated to VSS to determine if the level of play or some other variable may be related to VSS in athletes and/or for a particular sport.

## **CONCLUSION AND PRACTICAL IMPLICATIONS**

The finding of the superiority of only specific VSS in the context of this study has broad implications for theories of vision, how best to select tests and in the development of sport-specific VSS testing batteries. While this study substantiates the proposal that athletes, and specifically rugby players, have superior VSS/expertise to non-athletes, this study also found that this is not the case with all VSS, as with visual memory in this study. Research should, therefore, establish which VSS tests are better able to distinguish athletes from non-athletes, and further establish which VSS test is more appropriate for specific sports to not only distinguish non-athletes from athletes, but also for distinguishing level of play in the same vein as anthropometric and physiological tests are utilized in the selection and recruitment of athletes. Future research should also explore the mechanisms or reasons why specific athletes have improved specific visual skills when compared to non-athletes and even other sporting codes.

## **Footnotes**

**Authors' contribution:** Lourens Millard, Ina Shaw and Brandon S. Shaw made a substantial contribution in the design of the study, acquisition, analysis, writing and critically reviewing the article and its intellectual content; final approval of the manuscript; and agreeing to take

responsibility for all aspects of the study. Gerrit J. Breukelman made substantial contributions writing and critically reviewing the article and its intellectual content; final approval of the manuscript; and agreeing to take responsibility for all aspects of the study.

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## REFERENCES

1. Schmidt RA, Wrisberg CA (2008) Motor learning and performance. Human Kinetics, Champaign.
2. Wimhurst ZL (2012) Visual skills of elite athletes. Dissertation, University of Surrey.
3. Wolbers T, Hegarty M (2010) What determines our navigational abilities? *Trends Cogn Sci* 14(3):138–146. <https://doi.org/10.1016/j.tics.2010.01.001>
4. Sasikumar N, Roja MP, Fathima MP (2014) Visuospatial skills and teaching learning process. *ISRJ* 4(3):1–4.
5. Vona G, Massidda M, Cireddu MI, Calò CM (2005) Genetics and sport performance. *Ital J Sport Sci* 12:105–115.
6. Khanal S (2015) Impact of visual skills training on sports performance: current and future perspectives. *Adv Ophthalmol Vis Syst* 2(1):26–28. <https://doi.org/10.15406/aovs.2015.02.00032>
7. Uchida Y, Kudoh D, Murakami A, Honda M, Kitazawa S (2012) Origins of superior dynamic visual acuity in baseball players: superior eye movements or superior image processing. *PLoS One* 7(2): e31530. <https://doi.org/10.1371/journal.pone.0031530>
8. Ciućmański B, Wątroba J (2005) Training selected visual perception abilities and the efficiency of footballers. (in Polish) In: *Gry zespołowe w wychowaniu fizycznym i sporcie*, [red Żak S., Spieszny M., Klocek T.], *Studia i Monografie nr 33 AWF Kraków* 298–303.
9. Babu RJ, Meyers JP, Irving EL (2004) Athletes' vs. non-athletes: an investigation comparing the latency, accuracy, peak velocity and adaptation of saccades. *Invest Ophthalmol Vis Sci* 45(13):2511–2511.
10. Babu RJ, Lillakas L, Irving EL (2005) Dynamics of saccadic adaptation: differences between

athletes and nonathletes. *Optom Vis Sci* 82(12):1060–1065.  
<https://doi.org/10.1097/01.opx.0000192346.84549.6a>

11. Du Toit PJ, Kruger PE, Naicker LA, Govender C, Jay-Du Preez T, Grobbelaar C, Grant R, Wood PS, Kleynhans M, Mercier J (2012) Evaluation of visual skills in sedentary and active work environments. *AJPHRD* 18(1):178–191.
12. Elsayy GY (2011) Eye movements among female taekwondo players with high and low levels. *World J Sport Sci* 4(4):347–350.
13. Du Toit PJ, Janse van Vuuren P, le Roux S, Henning E, Kleynhans E, Terblanche HC, Crafford D, Grobbelaar C, Wood PS, Grant CC, Fletcher L (2012) The effect of sport specific exercises on the visual skills of rugby players. *WASET* 71:2029–2032.
14. Meir R (2005) Conditioning the visual system: a practical perspective on visual conditioning in rugby football. *Strength Cond J* 27(4):86–92. [https://doi.org/10.1519/1533-4295\(2005\)27\[86:CTVSAP\]2.0.CO;2](https://doi.org/10.1519/1533-4295(2005)27[86:CTVSAP]2.0.CO;2)
15. Stern BS, Kysilka ML (2008) *Contemporary readings in curriculum*. Sage publications, California.
16. Adler P (2007) *Be the best you can be: performance, vision and sport*. Middle east. [Course notes].
17. Maxwell J, Tong J, Schor CM (2012) Short-term adaptation of accommodation, accommodative vergence and disparity vergence facility. *Vision Res* 62:93–101. <https://doi.org/10.1016/j.visres.2012.03.013>
18. Millard L (2016) *Impact of a visual skills training program on the visual ability of elite rugby players*. Dissertation, Nelson Mandela University.
19. Wilson TA, Falkel JE (2004) *Sports vision: training for better performance*. Human Kinetics, Champaign.
20. BATAK Pro Hardware Operation (2011) *Users manual*. Quotronics Limited, Horley.
21. Faber IR, Oosterveld FGJ, Nijhuis-Van der Sanden MWG (2014) Does an eye-hand coordination test have added value as part of talent identification in table tennis? A validity and reproducibility study. *PLoS One* 9(1):e85657. <https://doi.org/10.1371/journal.pone.0085657>
22. Jafarzadehpur E, Aazami N, Bolouri B (2007) Comparison of saccadic eye movements and facility of ocular accommodation in female volleyball players and non-players. *Scand J Med Sci Sports* 17(2):186–190. <https://doi.org/10.1111/j.1600-0838.2005.00535.x>
23. Vera J, Jiménez R, Cárdenas D, Redondo B, García JA (2017) Visual function, performance, and processing of basketball players versus sedentary individuals. *J Sport Health Sci* 1–8. <https://doi.org/10.1016/j.jshs.2017.05.001>

24. Ward P, Williams AM, Loran DFC (2000) The development of visual function in expert and novice soccer players. *IJSV* 6:1–11.
25. Jafarzadehpur E, Yarigholi MR (2004) Comparison of visual acuity in reduced lumination and facility of ocular accommodation in table tennis champions and non-players. *J Sports Sci Med* 3(1):44–48.
26. Scheiman M, Wick B (2008) Clinical management of binocular vision: heterophoric, accommodative, and eye movement disorders. Lippincott Williams & Wilkins, Philadelphia.
27. Sokhn N, Wuilleret A, Caldara R (2019) Go/no-go saccadic reaction times towards visual field targets differ between athletes and nonathletes. 11th International Conference on Knowledge and Smart Technology (KST) :222–225. Phuket, Thailand. <https://doi.org/10.1109/KST.2019.8687809>
28. Mann DL, Ho NY, De Souza NJ, Watson DR, Taylor SJ (2007) Is optimal vision required for the successful execution of an interceptive task? *Hum Mov Sci* 26(3):343–356. <https://doi.org/10.1016/j.humov.2006.12.003>
29. Yilmaz A, Polat M (2018) Prosaccadic and antisaccadic performance of the athletes in different types of sports. *Biomed Res* 29(3):539–543. <https://doi.org/10.4066/biomedicalresearch.29-17-3224>
30. Kelly KM, Kiderman A, Akhavan S, Quigley MR, Snell ED, Happ E et al (2019) Oculomotor, vestibular, and reaction time effects of sports-related concussion: video-oculography in assessing sports-related concussion. *J Head Trauma Rehabil* 34(3):176–188. <https://doi.org/10.1097/HTR.0000000000000437>
31. Wang YT, Chen S, Limroongreungrat W, Change LS (2005) Contributions of selected fundamental factors to wheelchair basketball performance. *Med Sci Sports Exerc* 37(1):130–137. <https://doi.org/10.1249/01.mss.0000150076.36706.b2>
32. Zwierko T (2008) Differences in peripheral perception between athletes and nonathletes. *J Hum Kinet* 19:53–62. <https://doi.org/10.2478/v10078-008-0004-z>
33. Kaya A (2014) Decision making by coaches and athletes in sport. *Soc Behav Sci* 152:333–338. <https://doi.org/10.1016/j.sbspro.2014.09.205>
34. Erickson G (2007) Sports vision: vision care for the enhancement of sports performance. Butterworth Heinemann, St. Louis.
35. Chraif M (2013) Gender influences in peripheral and central visual perception for the young. *Procedia Soc Behav Sci* 84:1100–1104. <https://doi.org/10.1016/j.sbspro.2013.06.707>
36. Akarsu S, Caliskan E, Dane S (2009) Athletes have faster eye-hand visual reaction times and higher scores on visuospatial intelligence than nonathletes. *Turk J Med Sci* 39(6):871–874.

<https://doi.org/10.3906/sag-0809-44>

37. Pool G (2006) Rugby, verstaan die spel: “n visuele uiteensetting” (understanding the game of rugby, a visual exposition). Rapid access publishers, Stellenbosch.
38. Tomczyk CP, Mormile M, Wittenberg MS, Langdon JL, Hunt TN (2018) An examination of adolescent athletes and nonathletes on baseline neuropsychological test scores. *J Athl Train* 53(4):404–409. <https://doi.org/10.4085/1062-6050-84-17>
39. Chueh TY, Huang CJ, Hsieh SS, Chen KF, Chang YK, Hung TM (2017) Sports training enhances visuo-spatial cognition regardless of open-closed typology. *PeerJ* 5:e3336. <https://doi.org/10.7717/peerj.3336>
40. Afshar A (2019) The effect of visual-sport specific exercise on shooting skill performance in football players. *BJSTR* 15(3):11420–11426. <https://doi.org/10.26717/BJSTR.2019.15.002714>
41. Brutsaert TD, Parra EJ (2006) What makes a champion? Explaining variation in human athletic performance. *Resp Physiol Neurobi* 151(2-3):109–123. <https://doi.org/10.1016/j.resp.2005.12.013>

## CHAPTER FIVE: ARTICLE FOUR - VISUAL ABILITIES DISTINGUISH LEVEL OF PLAY IN RUGBY

Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S. (2020). Visual abilities distinguish level of play in r Rugby. *Annals of Applied Sport Science*. In press. (Appendix D)

### ABSTRACT

While novices in sport possess similar visual skills to that of experts playing at a higher level, there may be major differences in the magnitude of performance in these skills. In addition, expert athletes may only demonstrate superiority in specific vision skills and not all aspects of vision. Thus, this study compared the performance of Premier League rugby players ( $n = 40$ ) and First Division rugby players ( $n = 40$ ) on six specific components of vision, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination. Premier League rugby players performed significantly ( $p \leq 0.05$ ) better than the First Division rugby players in five of the six tests, but were found to be similar in visual memory performance ( $p = 0.810$ ). While this study substantiates the proposal that expert athletes, and specifically rugby players, have superior visual expertise to novice athletes, this study also found that this is not the case with all vision skills. The present study's findings suggest that sport-specific vision testing batteries may be required to distinguish high performers from low performers in the same vein as physical tests are utilized in the selection and recruitment of athletes.

**Keywords:** sport, visio-spatial intelligence, vision, visual performance, visual testing,

### INTRODUCTION

Rugby union is one of the most popular professional team sports in the world and has become increasingly professionalized in modern times (Garraway et al., 2000; Lynch et al., 2013). This professionalism has resulted in a need for rugby players, whether full-time or amateur, to achieve an ever-increasing level of conditioning (Garraway et al., 2000). To meet these ever-increasing demands, rugby players spend thousands of hours improving *inter alia* their body composition, cardiorespiratory fitness, muscular fitness, and flexibility amongst others (Lynch et al., 2013, Wimhurst, 2012).

However, increasing professionalism combined with increasing technologies has made the sport much more complex (Du Toit et al., 2010). It is this ability to better interrogate an athlete that has led to the increasing importance of sports vision testing in athletes. This is especially true in rugby in that to perform

optimally in a ball sport such as rugby, experts suggest that player's require a "great eye", superb vision or excellent peripheral vision (Davids, 1999). Visual skills are particularly important in rugby as players need to perform skills catching, passing and kicking to allow for the ball to be advanced up the field beyond the opposing team's defensive line (Meir, 2005).

While research into vision expertise in rugby players has indicated that rugby players have enhanced skills when compared to non-athletes (Christenson & Winkelstein, 1988; Ishigaki & Miyao, 1993), no research exists to determine if rugby players at different levels of play exhibit different levels of visual expertise. At present, it has been suggested that novices in sport may possess similar visual skills to that of experts playing at a higher level (Ludeke, 2008). However, there is evidence to suggest that experts only excel in certain visual skills, such as the cognitive aspects of vision, which include visual perception, visual concentration, visual reaction time, central peripheral awareness, and visualization (Ferreira, 2002). Research further suggests that visual skills such as visual acuity, accommodation and fusion remain relatively consistent for both novice and expert rugby players (Ferreira, 2003). A further explanation as to why some research demonstrates that there is no difference between experts and novices is due to the generalized tests utilised that only measure the visual reception of information rather than the sport-specific, perceptual interpretation of information (Abernethy & Woods, 2001). While novices in sport possess similar visual skills to that of experts playing at a higher level, there may be major differences in the magnitude of performance in these skills. This may necessitate the determination of which vision tests can discriminate high performers from low performers in the same vein as physical tests would. This would allow for the eventual development of sport-specific vision testing batteries.

## **METHODS**

### **Participants**

The study sampled 19- to 35-year old male First Division rugby players ( $n = 40$ ; mean age:  $23.88 \pm 4.36$  years) and male Premier League rugby club players ( $n = 40$ ; mean age:  $25.20 \pm 5.23$  years). Rugby players from both groups were sampled from Kwazulu-Natal province using a non-probability sampling technique. Inclusion criteria were (a) players with normal (20/20) vision, (b) participation in a minimum of 30 hours of rugby training and (c) played at least one competitive game per week in the Premier League and/or First Division. Exclusion criteria were (a) players with visual impairments that caused a loss of vision, (b) players that did not participate in a minimum of 30 hours of training and one competitive game per week, (c) players that were injured or had recent surgery (eye surgery or otherwise). All participants provided informed written consent, and our study protocol was approved by the Institutional Review

Board of the University of Zululand.

## **Procedures**

All participants undertook a general optometric assessment using the Spectrum Eyecare software (Version 6.0.0, Digital Optometry, Republic of South Africa) to conclude whether any limitations existed in any of the participants' vision and thus suitability for the study. All participants included in the study presented with normal vision.

The Hart Near Far Rock Test was utilized to assess visual accommodation (Adler, 2007; Radomski & Latham, 2002) The Hart Near Far Rock chart was placed at head height and 3 meters (m) away from each participant. Another smaller chart was held at arm's length away from each participant. At the instruction of the primary researcher, the first letter of the first line of the chart on the wall 3m away was read, after which the first letter on the closer chart was read (Du Randt et al., 2016). The test lasted 30 seconds and the final score was calculated by subtracting errors from the end score. The best score of the two trials was utilized in the data analysis (Du Randt et al., 2016).

A standardized saccadic eye movement chart with adjustable letters was utilized to ensure letters could not be memorized (Du Randt et al., 2016; Wilson & Falkel, 2004). Two such charts were spaced 1m apart and placed on a wall 3m away from each participant. At the instruction of the primary researcher, participants were required to read out loud the first letter on the lateral side of the left chart and then immediately move their eyes to the chart on the right and to read out loud the corresponding first letter on the lateral side. This test lasted 30 seconds and the final score calculated by number of correct matched letters read out loud (Du Randt et al., 2016).

To measure the speed of recognition, the present study made use of the Batak Pro (Quotronics Limited, 2011) The Batak Pro's Evasion Program, which was controlled by a microcomputer, randomly illuminated any of the 12 visually bright light-emitting diode (LED) targets for a period of 1 second for a maximum of 100 times (Quotronics Limited, 2011). However, if the participant pressed the wrong target or failed to touch the target, the entire routine would speed up. Further, participants were required to not touch flashing targets. If such a target was touched, the microcomputer subtracted five points for each incorrect flashing target touched. In the Evasion Program, the center targets infrequently illuminated at the same time, requiring participants to immediately avoid an infrared beam emitted or be penalized five points. The Batak Pro automatically recorded the end score and the best of the two trials were utilized in the data analysis (Quotronics Limited, 2011).

To assess hand-eye coordination, the current study used the ball wall toss using a standard tennis ball (Laplante, 2001). Each participant was required to throw the ball at a mark on a wall 2m away. When the ball returned, each participant attempted to catch the ball using alternating hands for a duration of 30 seconds. The highest number of successful catches attained from one of the two trials was used in the data analysis (Du Randt et al., 2016).

The Batak Pro (Quotronics Limited, 2011) was utilized to assess peripheral awareness using the Accumulator Program. This program caused random targets to light up, and remain lit on the Batak Pro for 60 seconds until the participant touched them (Quotronics Limited, 2011). A microprocessor recorded the number of targets correctly touched in the 60 seconds with the best score of the two trials utilized in the data analysis.

The Batak Pro (Quotronics Limited, 2011) Flash Program was utilized to assess visual memory. The Flash Program illuminated six random targets for a display time of half a second and participants were required to remember not only the specific light lit but also the order in which they were activated (Du Randt et al., 2016; Quotronics Limited, 2011). The maximum score was recorded, and the best score attained during the two trials was utilized in the data analysis.

## **Data Analysis**

This study utilized quantitative research methods, making use of already established visual skill assessments. Descriptive statistics including the means, standard deviations, ranges and percentage difference were calculated while the Mann-Whitney U test was applied to compare the differences between the two independent groups employed post hoc rank-ordered analysis was conducted to more accurately and empirically evaluate which group had more superior visual skills. An exploratory factor analysis was also applied post hoc to create an overall combined measure of visual expertise. This was applied following the application of the Kaiser-Meyer-Olkin Measure of Sampling Adequacy to indicate whether the data was suitable for factor analysis and following Bartlett's Test of Sphericity to determine if the data was suitable for reduction for exploratory factor analysis. The Statistical Package for Social Sciences (SPSS) version 22 for Windows (SPSS Inc., Chicago, IL, USA) was used for this study and statistical confidence set at  $p \leq .05$ .

## RESULTS

The results indicated that a significant difference ( $p \leq 0.05$ ) existed between the Premier League rugby players and First Division rugby players for five out of the six tests (Table 1). Specifically, it was found that the Premier League rugby players significantly bested the First Division rugby players with regards to accommodation facility ( $p = 0.000$ ), saccadic eye movement ( $p = 0.000$ ), speed of recognition ( $p = 0.000$ ), hand/eye coordination ( $p = 0.000$ ) and peripheral awareness ( $p = 0.000$ ), but not visual memory ( $p = 0.810$ ).

Post hoc analysis using rank-ordered analysis indicated that the Premier League rugby players were 46% more proficient than First Division rugby players at speed of recognition, followed by accommodation facility at 19%, hand-eye coordination and saccadic eye movement at 18%, and lastly peripheral awareness at 15% (Table 1).

Following further exploratory analysis, a statistically significant difference existed for the overall performance between Premier League and First Division rugby players ( $U = 173.000$ ,  $p$ -value = 0.000), with Premier League athletes performing better on average than First Division athletes.

**Table 1** Visual abilities distinguished between premier league rugby players and first division rugby players

| <b>Visual skill</b>    | <b>First Division<br/>Rugby<br/>players<br/>(<math>n = 40</math>)</b> | <b>Premier<br/>Rugby<br/>players<br/>(<math>n = 40</math>)</b> | <b>Difference<br/>(%)</b> | <b>Significance<br/>(<math>p</math>-value)</b> |
|------------------------|---|--|---------------------------|--|
| Accommodation Facility | 31.68±4.29  | 38.33±4.39   | 18.99                     | 0.000*   |
| Saccadic Eye Movement  | 40.03±7.26  | 47.70±6.61   | 17.49                     | 0.000*   |
| Speed of Recognition   | 30.88±15.35   | 49.53±14.31  | 46.39                     | 0.000*   |
| Peripheral Awareness   | 65.40±6.13  | 76.02±4.28   | 15.02                     | 0.000*   |
| Hand-Eye Coordination  | 24.75±3.68  | 29.70±3.50   | 18.18                     | 0.000*   |
| Visual Memory          | 45.28±7.01  | 45.70±5.96   | 0.92                      | 0.810  |

Mean±SD; \*: Statistically significant ( $p \leq .05$ )

## **DISCUSSION**

The present study investigated and compared the performance of Premier League rugby players and First Division rugby players on six specific components of vision. Results indicated that Premier League rugby players performed better than the First Division rugby players in five of the six tests, but not in visual memory performance.

Based on the results of accommodation facility, previous research by Ghasemi et al. (2009), and Jafarzadehpur and Yarigholi (2004) has found similar differences in accommodation facility when comparing experts and novices, albeit in soccer referees and table tennis champions, respectively. However, the findings of Ferreira (2003), and Land and Furneaux (1997) found no difference in accommodation facility when comparing novice and expert players competing in bat-/racket-ball sports. Interestingly, expert athletes, when compared to novices, may have an increased accommodation facility due to having a better developed visual system that allows a quicker and more efficient adjustment of their eyes from a far to a near target (Paul et al., 2011). This more efficient adjustment may allow experts to better track objects like a ball in rugby (Paul et al., 2011).

While Bahill and LaRitz (1984), and Kukla et al. (1993) found that that there was no difference in saccadic eye movements when comparing expert and novice athletes in soccer and baseball, respectively, the finding of superior saccadic eye movements in Premier League rugby players concurs with studies conducted by Christensen and Ruhling (1983), and Ripoll and Latiri (1997) who found a significant difference in saccadic eye movements when comparing expert and novice women marathon runners, and table tennis players, respectively. Experts may have superior saccadic eye movements to novices due to these movements having different underlying neural visual mechanisms, as well as different neural motor mechanisms that allow for improvement through large amounts of training (Griffin, 1988; Hitzeman & Beckerman, 1993). However, previous research has also found that experts do not have shorter latencies for the initiation of pursuit or saccadic eye movements as it is a visual hardware skill and cannot be improved through training (Bahill & LaRitz, 1984; Deshaies & Pargman, 1976; Kukla et al., 1993). This supposition would imply that no difference exists in saccadic eye movements between experts and novices in any sports and is proved incorrect by the present study.

The speed of recognition of Premier League rugby players was found to be superior to that of First Division rugby players in this study. This is similar to the studies of Kioumourtzoglou et al. (1998), and Kukla et al. (1993) who found a difference in speed of recognition when comparing expert and novice basketball, volleyball and water-polo players. However, Allard and Burnett (1985), and Garland and Barry

(1990) found no difference in the speed of recognition when comparing experts and novices in soccer and basketball players, respectively. The lack of changes in those studies may have been due to expert athletes in those sports not using a sport-specific test since expert athletes may only have superior recall when it comes to task-specific experience (Christenson & Winkelstein, 1988). The lack of superiority in those studies does also not imply that the speed of recognition is not important in those sports since the need for efficiency of decision-making in response execution and inhibition is clear in those sports (Di Russo et al., 2006). Interestingly, this study found that the speed of recognition may be the most critical visual skill of the six measured, due to the 46% difference and rank ordering, when assessing whether a rugby player can be viewed as an expert or a novice.

Peripheral awareness was found to be superior in the present study's Premier League rugby players and is supported by the previous findings of Schumacher et al. (2019). However, Abernethy and Wood (2001), and Helsen and Starkes (1999) found no differences in peripheral awareness when comparing expert and novices in racquet sports and soccer players, respectively. A possible reason as to why no significant differences were found in the studies of Abernethy and Wood (2001), and Helsen and Starkes (1999) may be that to find a significant difference in peripheral awareness, the tests need to be more sport-specific and not have generalized measures (Helsen & Starkes 1999; Williams & Ericsson, 2005). In this regard, Abernethy and Wood (2001) stated that generalized (non-specific) tests only measure the visual reception of information rather than the sport-specific, perceptual interpretation of information. The latter is critical in distinguishing the visual-perceptual skill of expert and novice performers, which in turn, means that if a peripheral awareness test lacks specificity, it will lead to non-significant results.

The present study further demonstrated that a difference existed in hand-eye coordination between the Premier League and First Division rugby players. The findings of Paul et al. (2011), and Przednowek et al. (2019) concur with the current study and also found differences in hand-eye coordination between expert and novice table tennis players and handball players, respectively. Experts athletes generally have better skill, accuracy and Spatio-temporal constraints on visual information acquisition, which leads to enhanced hand-eye coordination and thus improved athletic performance (Loran & Griffiths, 2001).

The only visual skill of the six measured to be found to be similar in the present study's expert and novice rugby players was visual memory. While no studies could be found to support or disprove this finding, it may be due to the expert rugby players not exhibiting superior recall when presented with unstructured movements, suggesting that the superior recall of experts only occurs when faced with task-specific experiences (Allesandro, 2010). Thus, this finding may suggest several possibilities, including that visual

memory is not important to rugby prowess, that visual memory cannot distinguish the level of play in rugby players, that an upper-limit of visual memory exists in that sport, or that The Batak Pro Flash Program is not able to distinguish prowess in rugby players. However, these suppositions require more research.

While this study substantiates the proposal that expert rugby players have superior visual expertise to lower level rugby players, it also found that this is not the case with all visual skills. Further, the findings suggest that sport-specific vision testing batteries may be required to distinguish high performers from low performers in the same vein as physical tests are utilized in the selection and recruitment of athletes and to measure the transferability of visual training to on-pitch performance.

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### **REFERENCES**

- Abernethy, B., & Wood, J. M. (2001). Do generalized visual programs for sport really work? An experimental investigation. *Journal of Sport Science*, 19, 203–222.
- Adler, P. (2007). Be the best you can be: performance, vision and sport. Middle East. [Course Notes].
- Allard, F., & Burnett, N. (1985). Skill in sport. *Canadian Journal of Psychology*, 39(2), 294–312.
- Allesandro, P. (2010). Visual scanning in sports actions: comparison between soccer goalkeepers and judo fighters. *Published Masters Dissertation*, University of Bologna.
- Bahill, A. T., & LaRitz, T. (1984). Why can't batters keep their eyes on the ball? *American Scientist*, 72(3), 249–253.
- Christensen, C. L., & Ruhling, R. O. (1983). Physical characteristics of novice and experienced women marathon runners. *British Journal of Sport Medicine*, 17, 166–171.
- Christenson, G. N., & Winkelstein, A. M. (1988). Visual skills of athletes versus non-athletes: development of a sports vision testing battery. *Journal of the American Optometric Association*, 59(9), 666–675.
- Davids, K. (1999). *Visual Perception and Action in Sport*. Routledge.
- Deshaies, P., & Pargman, D. (1976). Selected visual abilities of college football players. *Perceptual motor*

*skills*, 43, 904–906.

Di Russo, F., Taddei, F., Apnile, T., & Spinelli, D. (2006). Neural correlates of fast stimulus discrimination and response selection in top-level fencers. *Neuroscience Letters*, 408(2), 113–118.

Du Randt, R., Raffan, R., Millard, L., & Venter, D. (2016). Impact of a visual skills training program on the visual ability of elite rugby players. *Published Masters dissertation*. Nelson Mandela University.

Du Toit, P. J., Kruger, P. E., Fowler, K. F., Govender, C., & Clark, J. (2010). Influence of sports vision techniques on adult male rugby players. *African Journal for Physical Health Education, Recreation and Dance*, 16(3), 510–517.

Ferreira, J. T. (2002). *Sport vision as a hardware and software system*. Eyesight.

Ferreira, J. T. (2003). *The application of sport vision on cricket*. Eyesight.

Garland, D. J., Barry, J. R. (1990). Sports expertise: the cognitive advantage. *Perceptual motor skills*, 70, 1299–1314.

Garraway, W. M., Lee, A. J., Hutton, S. J., Russel, E. B. A. W., & Macleod, D. A. D. (2000). Impact of professionalism on injuries in rugby union. *British Journal of Sport Medicine*, 34, 348–351.

Ghasemi, A., Momeni, M., Rezaee, M., & Gholami, A. (2009). The difference in visual skills between expert versus novice soccer referees. *Journal of Human Kinetics*, 22, 15–20.

Griffin, J. (1988). *Binocular anomalies procedures for vision therapy*. Professional Press Books.

Helsen, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, 13(1), 1–27.

Hitzeman, S. A. & Beckerman, S. A. (1993). What the literature says about sports vision. *Optometry Clinical*, 3(1), 145–169.

Ishigaki, H., & Miyao, M. (1993). Differences in dynamic visual acuity between athletes and non-athletes. *Perceptual and Motor Skills*, 77, 835–839.

Jafarzadehpur, E., & Yarigholi, M. R. (2004). Comparison of visual acuity in reduced lumination and facility of ocular accommodation in table tennis champions and non-players. *Journal of Sport Sciences and Medicine*, 3(1), 44–48.

Kioumourtzoglou, E., Kourtessis, T., Michalopoulou, M., & Derri, V. (1998). Differences in several perceptual abilities between experts and novices in basketball, volleyball and water-polo. *Perceptual motor skills*, 86, 899–912.

Kukla, D. A., Love, P. A., & Sanet, R. (1993). Contrast sensitivity function profiling: by sport and sport ability level. *International Journal of Sports Vision*, 1, 25.

Land, M. F., & Furneaux, S. (1997). The knowledge base of the oculomotor system. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 352, 1231–1239.

Laplante, P. A. (2001). *Dictionary of computer science engineering and technology*. CRC Press.

- Loran, D., & Griffiths, G. (2001). Visual performance and soccer skills in young players. *Optometry Today*, 41, 32–34.
- Ludeke, A. A. (2008). The visual skills of professional and amateur rugby players. *Masters dissertation*, University of Johannesburg.
- Lynch, E., Lombard, A. J. J., Coopoo, Y., Shaw, I., & Shaw, B. S. (2013). Shoulder injury incidence and severity through identification of risk factors in rugby union players. *Pakistan Journal of Medical Sciences*, 29(6), 1400–1405.
- Meir, R. A. (2005). Conditioning the visual system: a practical perspective on visual conditioning in rugby football. *Strength and Conditioning Journal*, 27(4), 86–92.
- Paul, M., Biswas, S. K., & Sandhu, J. S. (2011). Role of sports vision and eye hand coordination training in performance of table tennis players. *Brazilian Journal of Biomotricity*, 5(2), 106–116.
- Przednowek, K., Sliz, M., Lenik, J., Dziadek, B., Cieszkowski, S., Lenik, P., Kopeć, D., Wardak, K., & Przednowek, K. H. (2019). Psychomotor Abilities of Professional Handball Players. *International Journal of Environmental Research and Public Health*, 16(11), 1909.
- Quotronics Limited. (2011). Batak Pro Manual. Surrey. United Kingdom.
- Radomski, M. V., & Latham, C. A. (2002). *Occupational therapy for physical dysfunction*. 6th Edition. Williams & Wilkins.
- Ripoll, H., & Latiri, I. (1997). Effect of expertise on coincident-timing accuracy in a fast ball game. *Journal of Sport Science*, 15(6), 573–580.
- Schumacher, N., Schmidt, M., Reer, R., & Braumann, K. M. (2019). Peripheral vision tests in sports: training effects and reliability of peripheral perception test. *International Journal of Environmental Research and Public Health*, 16(24), 5001.
- Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport; Some considerations when applying the expert performance approach. *Human Movement Science*, 24(3), 283–307.
- Wilson, T. A., & Falkel, J. (2004). *Sports vision: training for better performance*. Champaign, IL: Human Kinetics.
- Wimhurst, Z. (2012). Visual skills of elite athletes. *Doctoral Thesis*, University of Surrey.

## **CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS**

Sports vision is a relatively modern discipline that has only recently received attention (Wimhurst, 2012). When athletes are competing, there is a large amount of information that needs to be processed effectively for the correct decision to be made. For example in team sports such as rugby and cricket, players need to know where their team mates are and where the ball is going next (Davids, 1999). While the athletes are in these situations, they do not think about how the information is processed, but instead only focus on the variables in play.

Many coaches still believe that it is sufficient for athletes to have 20/20 vision to perform optimally (Wilson & Falkel, 2004). This, of course, is a misapprehension, that does not only occur at youth level but at the professional level as well. Wilson and Falkel (2004) believe that the visual system is just like any other motor system in the body and needs to be trained to gain optimal performance. To train visual skills at the highest level, it is crucial to use a reliable and sport-specific visual testing battery to ensure that the training improves performance (Wilson & Falkel, 2004).

### **VISIO-SPATIAL INTELLIGENCE (VSI) DIFFERENCES BETWEEN PREMIER LEAGUE AND FIRST-DIVISION RUGBY PLAYERS AND NON-ATHLETES**

After a careful review of the literature, it was found that athletes have superior Visio-spatial expertise when compared to non-athletes. Conversely, this was not always the case, as non-athletes did prove to have at least similar Visio-spatial expertise when comparing certain Visio-spatial skills. A study performed by Ciućmański and Wątroba (2005) found that no differences exist in the accommodation facility of football players and non-athletes. Likewise, Babu (2004) found that there is no difference in the saccadic eye movements between badminton players and non-athletes. Due to the conflicting research, the current study aimed to compare the Visio-spatial skills of first-division rugby players to non-athletes. Firstly, participants had to perform an optometric assessment, which was followed by the measurement of six VSI components namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination using the following tests; Hart near far rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests. In evaluating the results, it was found that a significant difference existed between first division rugby players and non-athletes for five out of the six Visio-spatial skills tested. Upon viewing the results in more detail, first division rugby players outperformed non-athletes significantly in accommodation facility, saccadic eye movement, speed of recognition, hand-eye coordination and peripheral awareness. Interestingly, however, there was no significant difference found in visual memory between the two groups. While this study substantiates the notion that athletes, in this case first-division rugby players, perform significantly better in most VSI components, this is not the case for all

aspects of vision. This study found that to more accurately distinguish between athletes and non-athletes, research should move away from tests that focus on basic visual function and develop sport specific testing methods that can be used by a variety of sports.

Additionally, this study aimed to investigate if Premier League rugby players have superior Visio-spatial expertise in comparison to non-athletes. This was done by comparing the following six Visio-spatial skills; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination through the use of the following tests; hart near far rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests. As with the first-division rugby players, there was a significant difference when comparing Premier League rugby players and non-athletes for five out of the six tests. Visual memory was again the only Visio-spatial skill that showed no difference when comparing Premier League rugby players and non-athletes.

Even though research indicates that novice players possess similar visual skills to that of experts playing at a higher level (Ludeke, 2008), major differences might exist in the magnitude of the performance of these Visio-spatial skills. Furthermore, the superiority of expert athletes may only be demonstrated when performing specific visual skills, and not all aspects of vision. This was enhanced by the contradictory evidence that was found in this regard. Ferreira (2003) found that visual skills such as visual acuity, accommodation and fusion remain relatively consistent for both novice and expert athletes, whereas Jafarzadehpur and Yarigholi (2004) found that there is a significant difference when comparing the accommodation facility of expert and novice athletes. Based on the contradictory nature of the evidence, this study aimed to compare the Visio-spatial skill performance of Premier League rugby players to first-division rugby players using six components of vision, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination by utilizing the following tests; hart near far rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests. It was found that Premier League rugby players outperformed first-division rugby players in five of the six tests, with only visual memory being similar.

The present study found that both first division-rugby players and Premier League rugby players outperformed, and have superior VSI, when compared to non-athletes. Interestingly, non-athletes were not outperformed by Premier League rugby players and first-division rugby players with regards to visual memory. Additionally, even though this study substantiates the proposal that expert athletes, and specifically rugby players, have superior visual expertise to novice athletes, it also found that this is not the case with all vision skills. Visual memory was again found to be similar between novice (first-division) and expert

(Premier League) rugby players, and thus there was no significant difference found. Based on the findings of the current study, sport-specific vision testing batteries should be employed to distinguish between high performers and low performers in the same vein as physical tests are utilized in the selection and recruitment of athletes. Thus, the present study proposes a rugby-specific test battery in an attempt to distinguish high VSI performers from low VSI performers.

**Table 6.1. Summarised findings of the present study regarding Visio-spatial intelligence (VSI) differences between Premier League and first-division rugby players, and non-athletes**

| <b>Visual skill</b>    | <b>Non-Athletes<br/>(n = 40)</b> | <b>First Division<br/>Rugby players<br/>(n = 40)</b> | <b>Premier<br/>Rugby players<br/>(n = 40)</b> |
|------------------------|----------------------------------|--|---|
| Accommodation Facility | 28.78±2.93                       | 31.68±4.29   | 38.33±4.39                                    |
| Saccadic Eye Movement  | 32.98±4.70                       | 40.03±7.26   | 47.70±6.61                                    |
| Speed of Recognition   | 11.23±6.05                       | 30.88±15.35  | 49.53±14.31                                   |
| Peripheral Awareness   | 56.20±3.39                       | 65.40±6.13   | 76.02±4.28                                    |
| Hand-Eye Coordination  | 19.55±4.48                       | 24.75±3.68   | 29.70±3.50                                    |
| Visual Memory          | 45.10±5.46                       | 45.28±7.01   | 45.70±5.96                                    |

Mean±SD; \*: Statistically significant ( $p \leq 0.05$ )

### **DEVELOPMENT OF A RUGBY-SPECIFIC VISIO-SPATIAL INTELLIGENCE TEST BATTERY**

One of the objectives of the present study was to develop a rugby-specific VSI test battery that would allow for the differentiation between rugby players and non-athletes and to distinguish between different levels of play. In this regard, this study investigated and described the differences in specific VSI skills between first-division rugby players and non-athletes, Premier League rugby players and non-athletes, and first-division and Premier League rugby players. While differences were found in five of the six measured VSI skills in all three comparisons, it is essential to determine the magnitude of difference in VSI skills in the comparative pairs. In this regard, *post hoc* analysis revealed that first-division rugby players were 93% more proficient at speed of recognition in comparison to non-athletes. Secondly, the first division rugby players performed 23% better in hand-eye coordination skills in comparison to non-athletes, followed by saccadic eye movements (19%), peripheral awareness (15%), and accommodation facility (9.59%).

This study found similar results when comparing Premier League rugby players to non-athletes. Premier League rugby players outperformed non-athletes significantly in five of the six Visio-spatial skills tested.

Rank-ordered analysis indicated that the Premier League rugby players were 126% more proficient than non-athletes at speed of recognition, followed by 41% for hand-eye coordination, 36% for saccadic eye movement, 30% for peripheral awareness and 28% for accommodation facility.

Lastly, this study investigated whether the test battery could differentiate between levels of play by comparing first-division rugby players to Premier League rugby players. The results indicated that Premier League rugby players outperformed first-division rugby players significantly in five of the six Visio-spatial skills tested. *Post hoc* analysis using rank-ordered analysis indicated that the Premier League rugby players were 46% more proficient than first-division rugby players at speed of recognition, followed by accommodation facility at 19%, hand-eye coordination and saccadic eye movement at 18%, and lastly peripheral awareness at 15%.

A possible reason for rugby players out performing non-athletes is that research is unequivocal regarding the efficacy of physical training at improving cognitive functioning and altering the structural and functional aspects of the human brain (Du Toit et al., 2012). So too has research proposed that physical activity can influence visual performance skills (Elsawy, 2011). This is due to the fact that exercise facilitates multiple cognitive processes under different conditions, and can enhance response accuracy and response speed, as well as facilitate the cognitive processes which are central to goal-orientated actions and problem-solving (Du Toit et al., 2012). Effectively, this study's proposed Visio-spatial test battery was able to distinguish between different levels of play in rugby. Research indicated that to find significant differences between different levels of play, the tests need to be sport-specific and not have generalized measures (Helsen & Starkses 1999; Williams & Ericsson, 2005). Generalized (non-specific) tests only measure the visual reception of information rather than the sport-specific, perceptual interpretation of information. The latter is critical in distinguishing the visual-perceptual skill of expert and novice performers (Abernethy & Wood, 2001).

Upon analysing the results, it was found that when differentiating between rugby players (Premier League and first-division) and non-athletes, speed of recognition seems to be the Visio-spatial skill that has the largest difference (126% and 93% respectively). Thus, the speed of recognition may be the most important Visio-spatial skill when differentiating between rugby players and non-athletes. Furthermore, speed of recognition was also the Visio-spatial skill with the largest difference (46%) when differentiating between Premier League and first-division rugby players. This study found that the speed of recognition may also be the most important Visio-spatial skill when differentiating between different levels of play. The following is therefore the proposed visual test battery in the order it should be implemented:

## **Millard-Shaw Rugby VSI Test Battery (MSRV Test Battery)**

**Purpose:** A test battery used to measure the six Visio-spatial intelligence (VSI) skills crucial to rugby players.

**Equipment required:** Batak pro, hart charts, saccadic eye movement charts, and tennis balls.

**Pre-test:** To ensure reliability, participants need to be in a post-absorptive state following a 9- to 12-hour fast to minimize the influence of any dietary or supplemental factors. In an attempt to avoid any physical and mental influences, participants should only be tested at least 48 hours following any physical exercise. Before testing, the test procedure needs to be explained to the participants; after which they should fill in the informed consent form. Lastly, participants need to perform an optometric assessment in order to measure their visual acuity, to ensure all participants have a minimum of 20/20 vision before the test battery is applied.

**Procedure:** The Hart Near Far Rock Test is utilized to assess visual accommodation (Adler, 2007; Radomski & Latham, 2002). The Hart Near Far Rock chart is placed at head height and 3m away from each participant. Another smaller chart is held at arm's length away from each participant. At the instruction of the primary researcher, the first letter of the first line of the chart on the wall 3m away is read, after which the first letter on the closer chart is read (Du Randt et al., 2016). The test should last 30 seconds, and two trials should be administered with a five-minute rest period in between each trial.

**Scoring:** The final score is calculated by subtracting errors from the end score. The best score of the two trials is used (Du Randt et al., 2016).

**Procedure:** A standardized saccadic eye movement chart with adjustable letters is utilized to ensure letters could not be memorized for the saccadic eye movement test (Du Randt et al., 2016; Wilson & Falkel, 2004). Two such charts spaced 1m apart are placed on a wall 3m away from each participant. At the instruction of the primary researcher, participants are required to read out loud the first letter on the lateral side of the left chart and then immediately move their eyes to the chart on the right and to read out loud the corresponding first letter on the lateral side. The test lasts 30 seconds and two trials should be administered with a five-minute rest period in between each trial (Du Randt et al., 2016).

**Scoring:** The final score is calculated by subtracting errors from the end score. The best score of the two trials is used (Du Randt et al., 2016).

**Procedure:** To measure the speed of recognition, this test battery uses the Batak Pro (Quotronics Limited, 2011) The Batak Pro's Evasion Program, which is controlled by a microcomputer, randomly illuminates any of the 12 visually bright light-emitting diode (LED) targets for a period of 1 second for a maximum of 100 times (Quotronics Limited, 2011). Each target remains illuminated for 1 second. However, if the participant presses the wrong target or fails to touch the target, the entire routine speeds up. Further, participants are required to not touch flashing targets and if such a target is touched, the microcomputer subtracts five points for each incorrect flashing target touched. In the Evasion Program, the center targets infrequently illuminate at the same time, requiring participants to immediately avoid an infrared beam emitted or be penalized five points. Two trials are given, with a five-minute rest period in between each trial.

**Scoring:** The Batak Pro automatically records the best of the two trials as the end score (Quotronics Limited, 2011).

**Procedure:** In order for hand-eye coordination to be assessed, the ball wall toss test is utilized through the use of a standard tennis ball (Laplante, 2001). Each participant is required to throw the ball at a mark on a wall 2m away. When the ball returns, each participant attempts to catch the ball using alternating hands for a duration of 30 seconds. Two trials are performed with a five-minute rest period in between each trial.

**Scoring:** The highest number of successful catches attained from one of the two trials is recorded (Du Randt et al., 2016).

**Procedure:** The Batak Pro (Quotronics Limited, 2011) is utilized to assess peripheral awareness using the Accumulator Program. This program causes random targets to light up, and remain lit on the Batak Pro for 60 seconds until the participant touches them (Quotronics Limited, 2011). Two trials are performed with a five-minute rest period in between each trial.

**Scoring:** A microprocessor records the number of targets correctly touched in the 60 seconds with the best score of the two trials recorded.

**Procedure:** The Batak Pro (Quotronics Limited, 2011) Flash Program is utilized to assess visual memory. The Flash Program illuminates six random targets for a display for half a second and participants are required to remember not only the specific light lit, but also the order in which they are activated (Du Randt et al., 2016; Quotronics Limited, 2011). Two trials are performed with a five-minute rest period in between each trial.

**Scoring:** The maximum score is recorded, and the best score attained during the two trials is used.

## LIMITATIONS

The test battery designed for this study is novel and as such has never before been applied to rugby players. It follows that no norms have been created to compare the results to. The six Visio-spatial skills selected for this study were identified through reviewing other research and there is still the possibility that other Visio-spatial skills applicable to rugby still need to be addressed. In addition, the sample size used in this study only allowed for a limited number of players to be tested. Even though this study included an in-depth review of factors affecting vision, there might still be other factors not taken into consideration during testing, due to the sheer magnitude of factors affecting vision. This study only utilized South-African club rugby players and should be generalized with caution to other rugby populations. Finally, the proposed test battery is laboratory-based and cannot be implemented in an on-field setting, effectively not only increasing the cost of implementation to resource-poor clubs and/or federations but also limiting real-world simulation.

## **FURTHER RESEARCH**

Future research should focus on investigating how a combination of factors can affect vision in a sporting environment to assist coaches to explore further possibilities for a competitive advantage. In addition, future research should focus on establishing which Visio-spatial tests are better able to distinguish athletes from non-athletes, and further establish which Visio-spatial skill tests are more appropriate for specific sports to distinguish between levels of play in the same vein as anthropometric and physiological tests are utilized in the selection and recruitment of athletes. Future research should also explore the mechanisms or reasons why specific athletes have improved specific visual skills when compared to non-athletes and even other sporting codes. Lastly, the end goal for future studies should be to use sport-specific testing methods to measure the transferability of visual training programmes to on-pitch performance.

## **CONCLUSIONS**

The finding of the superiority of only specific Visio-spatial skills in the context of this study has broad implications for theories of vision, how best to select tests and in the development of sport-specific Visio-spatial testing batteries. While this study substantiates the proposal that athletes, and specifically rugby players, have superior Visio-spatial skills /expertise to non-athletes, it also found that this is not the case with all Visio-spatial skills, as with visual memory. Furthermore, this study corroborates the notion that expert rugby players have superior visual expertise to lower level rugby players, although this was not the case with all visual skills. The study's findings suggest that sport-specific vision testing batteries may be required to distinguish high performers from low performers in the same vein as physical tests are utilized in the selection and recruitment of players. As such, research should move away from tests that focus on basic visual function and develop sport-specific testing methods that can be used by a variety of sports. In this vein, this study proposes a rugby-specific Visio-spatial intelligence (VSI) test battery.

## REFERENCES

- Abernethy, B., & Wood, J. M. (2001). Do generalized visual programs for sport really work? An experimental investigation. *Journal of Sport Science*, 19, 203–222.
- Adler, P. (2007). Be the best you can be: performance, vision and sport. Middle East. [Course Notes].
- Babu, R. J., Meyers, J. P., Irving, E. L. (2004). Athletes' vs. non-athletes: an investigation comparing the latency, accuracy, peak velocity and adaptation of saccades. *Investigative Ophthalmology & Visual Science*, 45, 2511.
- Ciućmański, B., Wątroba, J. (2005). Training selected visual perception abilities and the efficiency footballers. (in Polish) In: Gry zespołowe w wychowaniu fizycznym i sporcie, [red Żak S., Spieszny M., Klocek T.], Studia i Monografie nr 33 AWF Kraków 298–303.
- Dauids, K. 1999. *Visual perception and action in sport*. London: Routledge
- Du Randt, R., Raffan, R., Millard, L., & Venter, D. (2016). Impact of a visual skills training program on the visual ability of elite rugby players. *Published Masters dissertation*. Nelson Mandela University.
- Du Toit, P.J., Kruger P.E., Naicker, L.A., Govender, C., Jay-Du Preez, T., Grobbelaar, C., Grant, R., Wood, P.S., Kleynhans, M., Mercier, J. (2012). Evaluation of visual skills in sedentary and active work environments. *African Journal for Physical Health Education*, 18(1):178–191.
- Du Toit, P.J., Janse van Vuuren, P., le Roux, S., Henning, E., Kleynhans, E., Terblanche, H.C., Crafford, D., Grobbelaar, C., Wood, P.S., Grant, C.C., Fletcher, L. (2012). The effect of sport specific exercises on the visual skills of rugby players. *World Academy of Science, Engineering and Technology*, 71:2029–2032.
- Elsawy, G.Y. (2011). Eye movements among female taekwondo players with high and low levels. *World Journal of Sport Sciences*, 4(4):347–350.
- Ferreira, J. T. (2003). The application of sport vision on cricket. Eyesight.
- Helsen, W. F., & Starkes, J. L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, 13(1), 1–27.
- Jafarzadehpur, E., & Yarigholi, M. R. (2004). Comparison of visual acuity in reduced lumination and facility of ocular accommodation in table tennis champions and non-players. *Journal of Sport Sciences and Medicine*, 3(1), 44–48.
- Laplante, P. A. (2001). *Dictionary of computer science engineering and technology*. CRC Press.
- Ludeke, A. A. (2008). The visual skills of professional and amateur rugby players. *Masters dissertation*, University of Johannesburg.
- Quotronics Limited. (2011). Batak Pro Manual. Surrey. United Kingdom.
- Radomski, M. V., & Latham, C. A. (2002). *Occupational therapy for physical dysfunction*. 6<sup>th</sup> Edition.

Williams & Wilkins.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport; Some considerations when applying the expert performance approach. *Human Movement Science*, 4(3), 283–307.

Wilson, T. A., & Falkel, J. (2004). *Sports vision: training for better performance*. Champaign, IL: Human Kinetics.

Wimhurst, Z. 2012. Visual skills of elite athletes. Unpublished doctoral dissertation, University of Surrey.



## Factors Affecting Vision and Visio-Spatial Intelligence (VSI) in Sport: A Review of the Literature

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### Abstract

Sport has become increasingly competitive, prompting the need to determine, as far as possible, any likely performance advantage. While the focus of athletic research, testing, and training is on the physiological and physical characteristics of the sport, visual abilities not only affect sport performance directly, but also affect the acquisition of motor skills. Vision, and visual-spatial intelligence (VSI), are a relatively new and underexplored area of athletic performance. As with physiological and physical parameters, a range of factors affect vision and VSI in sporting activities. This review of the literature is a first attempt to summarize and compile an overview of the factors affecting vision and VSI in athletes, covering those previously connected with sport, as well as those hitherto not associated with athletic activities, but that could also play a part in sports performance. The evidence from this review suggests that while current research still tends to focus on single factors affecting vision and VSI, a large number of such factors have been identified that could affect vision and VSI. This offers new opportunities for researchers to investigate the effects of a combination of factors, and for conditioning and/or sports vision specialists to explore further possibilities for competitive advantage.

**Keywords:** Athletic Performance, Decision Making, Optometric Intervention, Sport Performance, Sports Vision, Visual Abilities

### 1. Context

Significant debate still surrounds the possible reasons for superior athletic or sports performance by successful athletes, particularly in ball sports, such as rugby, cricket, and tennis (1). Unsurprisingly, experts in these sports believe that in order to perform optimally, a player needs a "great eye", superb vision or excellent peripheral vision (1). Athletes can spend thousands of hours in physical training to improve their physical attributes; however, if their vision or visual processing capabilities are inadequate, their physical training may not be optimized, and their athletic performance will suffer (2). The eye is the most important receptor in the human body (3) and as such, the human visual information processing system has been recognized as playing a critical role in athletic performance (4-6) and has generated concomitant interest in the area of sports vision (2).

This reliance and importance of the visual system necessitates the need to determine the factors that affect an athlete's ability to obtain and respond to appropriate visual stimuli. Conversely, challenges in the ability to obtain and process specific and appropriate visual stimuli lead to incorrect or ineffective movement outcomes (5, 6).

To date, research has focused on individual factors that affect vision and VSI. However, a combination of factors may play their part and could warrant a more holistic approach. This review of the literature novelly attempts to summarize and compile an overview of the factors affecting vision and VSI in athletes, covering those previously connected with sport, as well as those hitherto not yet associated with athletic activities, but that could also play a part in sports performance.

### 2. Objectives

The aim of this review is to identify and summarize a body of relevant, previously researched factors that have or have not yet been associated with athletic activities, and that could affect vision and VSI, and thus athletic performance.

### 3. Methods

A review of the scholarly literature related to the factors affecting vision and VSI was performed using standardized procedures (7). To identify potentially relevant articles for focused searching and to reduce the potential for


**APPENDIX B: SUBMITTED ARTICLE** - Millard, L., Shaw, I., Breukelman, G.J., Shaw, B.S.  
Differences in visio-spatial expertise between first-division rugby players and non-athletes. *Vision Research Journal*. Submitted.



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## Visio-spatial skills in athletes: comparison of rugby players and non-athletes

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### Abstract

**Background** Research pertaining to the superiority of athletes' visio-spatial expertise when compared to non-athletes is conflicting. This discrepancy may arise due to a superiority in athletes in only specific visio-spatial skills (VSS) and not all aspects of vision.

**Aims** The aim of this study was to discern whether rugby players have superior VSS/expertise in comparison to non-athletes, when comparing six visual skills (accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory and hand-eye coordination).

**Methods** The participants underwent an optometric assessment, after which the VSS components of non-athletes and premier league rugby players were assessed by using six different existing tests namely, the Hart Near Far Rock, saccadic eye movement, evasion, accumulator, flash memory and ball wall toss tests.

**Results** A statistically significant ( $p \leq .05$ ) difference existed between rugby players and non-athletes for five out of the six tests. Conversely, no real evidence is shown that visual memory differs between rugby players and non-athletes ( $p = .599$ ).

**Conclusion** This study found that rugby players have an enhanced accommodation facility, saccadic eye movements, speed of recognition, peripheral awareness and hand-eye coordination, but not visual memory, when compared to non-athletes. These findings of a superiority of rugby players in specific VSS have broad implications for theories of sport vision, how best to select tests and in the development of sport-specific VSS testing batteries.

**Keywords** Sport vision · Visual expertise · Visual skill · Visio-spatial intelligence (VSI)

### Introduction

In order to perform fundamental movement activities, such as walking, running, catching and jumping, individuals, and especially athletes, need to be able to use motor skills [1]. These motor skills are stable, long-lasting and are essential for athletic performance. Thankfully, these motor skills can be developed through motor activity or practice. This is the reason coaches and conditioning specialists spend a large amount of time improving their athletes anthropometrically and physiologically.

Sport vision has only received attention in relation to athletic performance in recent years. Athletes spend

numerous hours training, in order to improve their conditioning to increase inter alia: body composition, cardio-respiratory endurance and muscular fitness, while inadequate visual processing capabilities could affect their physical training and thus their performance. For example, a crucial component of coordination is visio-spatial skill (VSS), which can be defined as a wide variety of individual skills that vary from recognizing brightness/darkness, identifying complex intersecting angles and curves to recognizing faces from the shape of eyes, noses, mouths and hair [2, 3]. This is because improvements in the physical skill of coordination can be achieved through a complex interplay of proprioception, sensory input from vision, and the vestibular system [4]. It is clear that in the majority of sports, the visual system provides the athlete with information about where, when and what to focus on in a specific sporting situation, which has a significant impact and positively influences athletes' response to visual information. It is therefore important to realize

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ORIGINAL ARTICLE



## Visual Abilities Distinguish Level of Play in Rugby

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### ABSTRACT

**Background.** Novices in sport possesses similar visual skills to that of experts, however there may be major differences in magnitude of performance in these skills, with expert athletes only demonstrating superiority in specific vision skills and not all aspects of vision. **Objectives.** In this vain, the aim of this study was to discern whether Premier League rugby players has enhanced visio-spatial skills in comparison to First Division rugby players. **Methods.** Thus, the present study compared the performance of Premier League rugby players (n = 40) and First Division rugby players (n = 40) on six specific components of vision, namely; accommodation facility, saccadic eye movement, speed of recognition, peripheral awareness, visual memory, and hand-eye coordination. **Results.** Premier League rugby players performed significantly (p = 0.001) better than the First Division rugby players in five of the six tests. but were found to be similar in visual memory performance (p = 0.810). **Conclusion.** While this study substantiates the proposal that expert athletes, and specifically rugby players, have superior visual expertise to novice athletes, this study also found that this is not the case with all vision skills. The present study's findings suggest that sport-specific vision testing batteries may be required to distinguish high performers from low performers in the same vein as physical tests are utilised in the selection and recruitment of athletes.

**KEYWORDS:** Sport, Visio-Spatial Intelligence, Vision, Visual Performance, Visual Testing

### INTRODUCTION

Rugby union is one of the most popular professional team sports in the world, and has become increasingly professionalized in modern times (1, 2). This professionalism has resulted in a need for rugby players, whether full-time or amateur, to achieve an ever-increasing level of conditioning (1). To meet these ever-increasing demands, rugby players spend thousands of hours improving inter alia their body composition, cardiorespiratory fitness, muscular fitness, and flexibility amongst others (2).

However, increasing professionalism combined with increasing technologies has made sport much more complex (3). It is this ability to better interrogate an athlete that has led to the increasing importance of sports vision testing in athletes. This is especially true in rugby in that to

perform optimally in a ball sport such as rugby, experts suggest that player's in these sports require a "great eye", superb vision or excellent peripheral vision (4). Visual skills are particularly important in rugby as players need to perform skills catching, passing and kicking to allow for the ball to be advanced up the field beyond the opposing team's defensive line (5).

While research pertaining to vision expertise in rugby players has indicated that rugby players have enhanced skills when compared to non-athletes (6, 7), no research exists to determine if rugby players at different levels of play exhibit different levels of visual expertise, which necessitates a study in this vain. At present, it has been suggested that novices in sport may possesses similar visual skills to that of experts playing at a higher level (8). However,

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## APPENDIX E: ETHICAL CLEARANCE CERTIFICATE

**UNIVERSITY OF ZULULAND**  
**RESEARCH ETHICS COMMITTEE**  
 (Reg No: UZREC 171110-030)



**RESEARCH & INNOVATION**

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### ETHICAL CLEARANCE CERTIFICATE

|   |   |              |   |
|---|---|--------------|---|
| <b>Certificate Number</b>                 | UZREC 171110-030 PGD 2019/24  |              |   |
| <b>Project Title</b>                      | VISIO-SPATIAL INTELLIGENCE (VSI) BETWEEN PREMIER LEAGUE, FIRST DIVISION RUGBY PLAYERS AND NON-ATHLETES IN THE DEVELOPMENT OF A SPORT-SPECIFIC VISIO-SPATIAL INTELLIGENCE TEST BATTERY |              |   |
| <b>Principal Researcher/ Investigator</b> | Lourens Millard   |              |   |
| <b>Supervisor and Co-supervisor</b>       | Prof B.S Shaw   | Prof I. Shaw |   |
| <b>Department</b>                         | Human Movement Science  |              |   |
| <b>Faculty</b>                            | Science and Agriculture   |              |   |
| <b>Type of Risk</b>                       | Med Risk – Data collection from people, laboratory research   |              |   |
| <b>Nature of Project</b>                  | Honours/4 <sup>th</sup> Year  | Master's     | Doctoral <input checked="" type="checkbox"/> Departmental |

The University of Zululand's Research Ethics Committee (UZREC) hereby gives ethical approval in respect of the undertakings contained in the above-mentioned project. The Researcher may therefore commence with data collection as from the date of this Certificate, using the certificate number indicated above.

- Special conditions:**
- (1) This certificate is valid for 1 year from the date of issue.
  - (2) Principal researcher must provide an annual report to the UZREC in the prescribed format [due date-01 October 2020]
  - (3) Principal researcher must submit a report at the end of project in respect of ethical compliance.
  - (4) The UZREC must be informed immediately of any material change in the conditions or undertakings mentioned in the documents that were presented to the meeting.

The UZREC wishes the researcher well in conducting research.

  
 Professor Gideon De Wet  
 Chairperson: University Research Ethics Committee  
 Deputy Vice-Chancellor: Research & Innovation



02 October 2019

## APPENDIX F: LANGUAGE EDITOR LETTER

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24 September 2020

To whom it may concern,

RE: EDITING OF PHD SUBMISSION ON BEHALF OF MR. L. MILLARD

This letter serves to confirm that Mr L. Millard of the Department of Human Movement Science, Faculty of Science and Agriculture at the University of Zululand, did submit a full proposed PHD submission to myself for editing and proofreading.

The editing process has been completed and the full document was returned to Mr Millard, with suggested changes to be confirmed by Mr Millard himself.

For any further queries, please feel free to contact me directly on the details above.

Kind regards,

A handwritten signature in black ink, appearing to read "MEGANS", is written over a horizontal line.

Megan Erasmus Gauld