The comparison of visual skills, lifestyle evaluation, body composition, blood pressure and cardio stress index, before and after sports vision exercises

Dissertation in compliance with the degree MSc: Human Physiology

Faheema Mahomed Ali
Department of Physiology
Faculty of Health Sciences
University of Pretoria

Supervisor: Prof PJ du Toit
Department of Physiology
Faculty of Health Sciences
University of Pretoria

Co- Supervisor: Prof PE Kruger
Institute for Sport Research
University of Pretoria

November, 2013

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and not necessarily to be attributed to the NRF.

Forward

I sincerely thank and acknowledge the following people for their role played in the completion of this research and dissertation:

Prof du Toit for the idea of the research topic and invaluable guidance, support and motivation during the planning and testing phases of this research and for making work on this research project inspiring and stimulating. I am also grateful to Prof du Toit and co- supervisor Prof. Kruger for the valuable advice and guidance afforded during the writing of this mini- dissertation.

All my colleagues who have assisted in the testing and data collection, your help and passion is greatly appreciated and went a long way in making the testing phase of this research project well-organized, efficient and fun.

Dr Fletcher and other members of the statistics department of the University of Pretoria, for the assistance with an accurate and insightful statistical analysis of the data.

To all 600 subjects of this study for taking time to participate in this research project with cooperation and contagious enthusiasm.

To all those who have supported and assisted with guidance and advise in the writing of this mini-dissertation.

And finally, all thanks to the Creator, the Almighty, without whom nothing is possible and has made this task easy and possible for me to complete.
"..nothing is easy except what You make it and You make the difficult easy"

Thank You

Dedicated to:

My parents, who have always been there to inspire and motivate me in all endeavours of my life.

My family and friends for their encouragement and support.

The scientific community, may this be of value to the sports vision field and a stepping stone for further research.

Published articles and congresses

Article

Du Toit, P.J., **Mahomed, A.F.,** Govender, C., Kleynhans, M., Jay-du Preez, T., Mercier, J., Kruger, P.E. (2011). The effect of sports vision exercises on the visual skills of university students. AJPHERD, 17(3):September.

Congresses

Neuroscience day (UP- May 2012)

The effect of sports vision exercises on the visual skills of university students

J Armstrong, **AF Mahomed,** E Henning, M Kleynhans, HC Terblanche, N Coetzee, PS Wood, CC Grant, PJ du Toit.

Suid Afrikaans Akademie vir Wetenskap en Kuns (Potchefstroom October 2012)

Die effek van sport visie oefeninge op die visuele vaardighede van universiteit studente.

J. Armstrong, **A.F. Mahomed,** E. Henning, M. Kleynhans, H.C. Terblanche, D. Crafford, N. Coetzee, P.S. Wood, C.C. Grant, P.J. du Toit

Faculty Day 2012 (University of Pretoria- Faculty Health Sciences)

The effect of sports vision exercises on the visual skills of university students

J Armstrong, **AF Mahomed,** E Henning, M Kleynhans, HC Terblanche, D Crafford, N Coetzee, PS Wood, CC Grant, PJ du Toit.

Neuroscience day (UP- May 2011)

The influence of an intense training programme on the visual skills of males and females, aged between 18 and 22.

T Broodryk, E Henning, MJ Kleynhans, HC Terblanche, L Naicker, **F Mahomed,** D Crafford, P Wood, PJ du Toit.

The influence of an intense training program on Cardio Stress Index.

T Claassen, E Henning, MJ Kleynhans, HC Terblanche, L Naicker, **F Mahomed,** R Grant, P Wood, PJ du Toit.

Comparing visual skills in sedentary and active work environments.

L Naicker, E Henning, MJ Kleynhans, HC Terblanche, D Crafford, **F Mahomed,** C Govender, R Grant, P Wood, PJ du Toit.

The correlation between cardio stress and visual skills.

HC Terblanche, **F Mahomed,** L Naicker, E Henning, MJ Kleynhans, N Mthembu, R Grant, P Wood, PJ du Toit.

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Abstract

Title: The comparison of visual skills, lifestyle evaluation, body composition, blood pressure and cardio stress index, before and after sports vision exercises.

Candidate: Ms F Mahomed Ali

Supervisor: Dr PJ du Toit

Department: Physiology

Degree: MSc: Human Physiology

Sports vision gained attention in the late 90's and has since been the focus of many research studies. Thus far sports vision research has effectively succeeded in determining the importance of visual skills and also discovering the ability to improve visual skills through training. It is this ability to enhance visual skill performance that has led to the development of vision training programmes. However, the effectiveness of these training programmes is far from unanimous with many studies yielding inconclusive results. Possible reasons for this are the lack of scientific measures implored, testing and training of skills that are not specific to the subjects and training programmes that are unrealistic. Another major area that is missing from sports vision research is the accountability of external variables like; lifestyle, anthropometric and cardiac measurements. Aspects such as; stress, nutrition and hypo/hypertension are proposed to either have an enhancing or declining effect on visual skills. These relationships have not been scientifically tested and remain undefined. It is also important to note that research has thus far been limited to athletes.

This study therefore aimed to determine the effect of two different training programmes on the visual skill performance of university students. Furthermore, external variables are determined to certify that visual skill training alone would improve visual skills and to determine and define if any relationships exist between visual skills and external variables.

In order to meet the aims of this study, volunteer university students underwent pre testing of specific visual skills together with lifestyle evaluations, body composition

and cardiac health testing. Thereafter the total participants (n=600) were divided into three groups. Group 1 (n=169) acted as a control group with no visual training taking place in a six week period, group 2 (n=225) underwent lab-based training with a simple repetition of testing methods used as training methods and group 3 (n=205) underwent training via an internet- based training method. Thereafter all variables were tested again and statistical analysis of the data was performed.

Results showed the lab-based training group having the most improvement in visual skills with all skills improving besides vergence. The Eyedrills training group also showed significant improvements in focusing, tracking and eye- hand coordination. The control group showed the least improvement in visual skills thereby ruling out the notion of improvements occurring only due to test familiarity.
Significant changes occurred in a variety of the external variables across the three groups. Due to the varied results with regards to external variables, correlations between these variables and visual skill performance is still unclear and remains undefined.

There is enough evidence from this study to conclude that visual skills are improved due to visual skill training. The change from the typical subject type (i.e. athletes) is important in the expansion of visual skill testing and training to other fields besides the sports one. The effect of external variables on visual skills still remains unanswered and therefore more precise research in this regard is warranted.

Key terms: sports vision, visual skills, visual skill training, students, lifestyle evaluation, anthropometric measurements, cardiac health measurements.

Abstrak

Titel:	'n Vergelyking van visuele vaardighede, lewensstyl evaluering, liggaamshouding, bloeddruk, en kardio-stresindeks - voor en na sport visie oefeninge.
Kandidaat:	Me. F Mahomed Ali
Studieleier:	Dr PJ du Toit
Departement:	Fisiologie
Graad:	MSc: Menslike Fisiologie

Sport visie het gedurende die laat 90's aandag verkry en is sedertdien die fokus van verskeie navorsing studies. Hierdie navorsing het tot dusver effektief daarin geslaag om die belangrikheid van visuele vaardighede te beklemtoon en ook die vermoë om visuele vaardighede deur sport visie oefening te verbeter, aan die lig gebring. Hierdie vermoë om visuele vaardighede te bevorder,het aanleiding gegee tot die ontwikkeling van visuele vaardighede oefenprogramme. Die effektiwiteit van hierdie programme was egter nie versoenbaar nie, met verskeie studies wat onbesliste resultate gelewer het. Moontlike redes hiervoor is die gebrek aan die toepassing van wetenskaplike metodes, die toets en / of opleidingsvaardighede wat nie van toepassing was op die respondent nie, en oefenprogramme wat onrealisties is. 'n Ander belangrike aspek wat ontbreek in sport visie navorsing is die aanspreeklikheid eksterne faktore soos ; lewenstyl,antropometriese en kardiologiese waarnemings . Aspekte soos stres, voeding en hipertensie is voorgestel om of visuele vaardighede te bevorder of te benadeel. Hierdie samehangende faktore is nie wetenskaplik verklaar nie en is steeds onbeantwoord. Dit is belangrik om daar op te let dat navorsing tot dusver beperk was tot atlete.

Hierdie studie was daarop gemik om die effek van twee verskillende sport visie oefenprogramme op die visuele vaardighede van universiteit student te evalueer.
Verdel was eksterne veranderlikes bepaal om te bevestig dat sport visie oefeninge alleen visuele vaardighede vermoë sal verbeter en ook om vas te stel of daar enige verband bestaan tussen visuele vaardighede en eksterne veranderlikes.

Om die doelwitte van hierdie studiete bereik, het vrywillige universiteit student vooraf toetsing van spesifieke visuele vaardighede saam met leefstyl evaluering, liggaams komposisie en kardiologiese gesondheidstoetsing ondergaan. Daarna is die totale aantal deelnemers (n=600) verdeel in drie groepe. Groep een (n=169) is gebruik as die kontrolegroep met geen sport visie oefening gedurende 'n periode van ses weke nie. Groep twee (n=225) het laboratorium gebaseerde oefening ondergaan. Groep drie (n=205) het oefening deur middel van internet gebaseerde oefeningsmetodes ondergaan. Hierna is alle veranderlikes weer getoets en 'n statistiese analise van die data is uitgevoer.

Resultate het getoon dat die laboratorium gebaseerde oefengroep die beste verbetering in visuele vaardighede gehad het met uitsondering van enkele grensgevalle. Die internet oefengroep het ook merkwaardige verbetering van fokus, navolging en hand-oogkoördinasie getoon. Die kontrole groep het die minste verbetering van visuele vaardighede getoon.

Merkwaardige veranderinge is waargeneem in verskeie eksterne veranderlikes in al drie die groepe. As gevolg van die afwisselende resultate van eksterne veranderlikes is korrelasie tussen die veranderlikes en visuele vaardighede steeds onduidelik en bly onverklaarbaar.

Volgens die studie is daar genoegsame bewyse om tot die slotsom te kom dat visuele vaardighede verbeter word deur sport visie oefeninge. Die verandering van die tipiese proef persoon-tipe (i.e. atlete) is belangrik in die uitbreiding van visuele vaardigheid toetsing en oefening na ander gebiede anders as sport. Die effek van eksterne veranderlikes op visuele vaardighede bly steeds onbeantwoord en dus is meer akkurate navorsing in hierdie verband nodig.

Kernwoorde:
Sport visie, visuele vaardighede, sport visie oefening, student, lewenstylevaluering, antropometriese metings, kardiogesondheidmetings

CHAPTER 1: INTRODUCTION

1.1 AN INTRODUCTION TO VISION

The visual system is arguably the most important sensory system in the human body. Considering that the majority of our bodies' sensory receptors are found in the eye, vision is probably the major contributor to the extraction of information from our environment (1). However, vision is often undervalued and imprecisely defined as merely the ability to "see" objects clearly. This is a very vague definition that limits the role of vision.

Vision is an interconnected process that involves not only the visual system but also the Central Nervous System (CNS) and the skeletal- muscular system (2). A more precise definition of vision would therefore be not only the ability to view objects clearly, but also the ability to use the CNS to select relevant information from the environment and plan an appropriate response to the stimuli, which will then be executed by the skeletal- muscular system (3). It is through this definition that the role and importance of vision can be more clearly understood.

Our environment is a dynamic and ever- changing source of visual information. It is the efficient and well-organised visual processing system that helps us to select the most relevant information, and therefore act upon it in the most appropriate and effective manner to meet these complex demands (4,5). It is due mainly to this perceptual- motor link that vision is of utmost importance to our everyday lives (5).

Vision is important in every aspect in our daily lives that involve perceptual processing and motor execution. Efficient and effective visual processing plays a major and specific role in areas like music, military training, medical work and the sporting environment (6,7). More importantly, adequate vision is essential for the most basic everyday activities that involve the planning and execution of specific coordinated movements, from the simple tasks like reaching, grasping and manipulating objects to more complex tasks like driving, writing and participating in various sports (5,6,8,9). Vision is also found to play a significant role in general movement like walking and balance (10). Vision therefore has a variety of effects on spatial, motor and temporal aspects of everyday living (11,12).

The role of vision can be further emphasised when taking into account the detrimental effects to motor execution of those with visual deficits or deficiencies. This has especially been brought to attention by the numerous studies of visual skills in the elderly, who are shown to have an age-related decline of visual performance, and in children with visual deficiencies. It has been found that elderly, who especially suffer from deficits in visual attention, are susceptible to an increase risk of motor- vehicle accidents and falling incidents due to an inability to avoid obstacles (13,14). Children with amblyopia, a visual deficit common in children and which largely affects visual binocularity, are found to have slower movement and a poor control thereof (8). It is therefore clear that not only is vision essential to many tasks of our daily lives, but also the quality and efficiency of the visual processing system is important to accurate and speedy motor execution (9,15).

It is clear that vision plays a significant part in the lives of everyone. This simple term involves many interconnecting processes that includes receiving visual information, analysing and interpreting it and finally responding to it in the most appropriate manner, which is collectively named the ‘visual processing system’. Vision, although simple in nature, has many underlying implications. The best way to understand vision and its implications is to get a deeper knowledge of the visual processing system.

1.2 THE VISUAL PROCESSING SYSTEM

In order to better understand vision, it is important to comprehensively understand the fundamental mechanisms of visual processing. Visual processing is a simple process and follows the basic method of any sensory processing system in the human body i.e. the afferent/ efferent method. Firstly, stimuli from the environment is picked up and received by receptors (via the afferent system), the information is then analysed and eventually a response is carried out (via the efferent system) (3,16). Visual processing can also be explained further according to the different physiological systems it uses i.e. the visual system, CNS and skeletal-muscular system. With the use of this method of classification, visual processing can be explained in three steps: **Perception, integration and response** (Figure 1.1).

Perception involves the reception of visual information from the environment and the processing thereof with the use of the visual system (17). The information is then further processed during the **integration** phase in the CNS. During this phase a response is decided, often based on past experiences (17). During the **response** phase a precise and accurate response to the initial stimuli is carried out via the skeletal- muscular system (17).

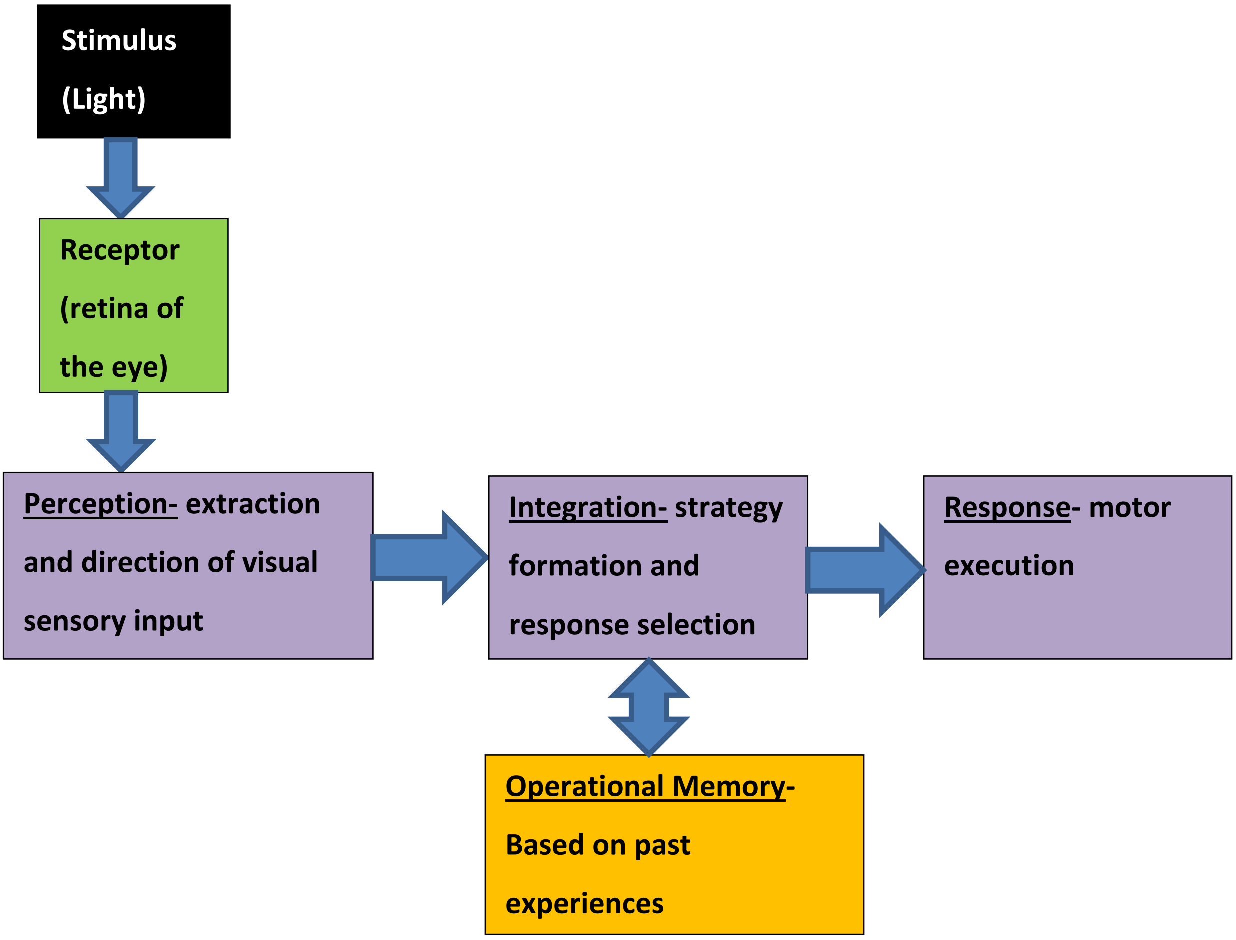

Figure 1.1: Steps involved in visual processing (redrawn and modified) (17)

Although explained as three different steps, all three phases are dependent on each other for the efficient and effective processing of visual information. A detailed view of each phase is important in order to further understand vision and its importance and therefore a precise summary of each phase is explained in the sections that follow.

1.2.1 Perception

Perception is the first phase in response to a stimulus. Perception can be analysed further into three basic steps:

1) The activation of a receptor (retina) by a stimulus (light) and the processing of this light energy;
2) The conversion of this light energy into a nerve impulse (electrical energy) via a chemical reaction; and
3) The travelling of this nerve impulse to the integrative centres in the CNS

Firstly, stimuli from the environment activate the receptor of the eye (Figure 1.2). Light (stimulus) enters the eye and is focused on the retina (receptor) (2). The focusing on the retina takes place with the help of other structures of the eye such as the cornea, aqueous humour, vitreous humour and most importantly, the lens (2,18).

The light that is focused on the retina thereafter activates the photoreceptors that are widely found in the retina (Figure 1.2). These photoreceptors are the site of phototransduction: the conversion of light energy into a nerve impulse via a chemical reaction, the next step in the perception of visual information. The photoreceptors consist of two types of cells: rods, which are involved in non- colour vision, and cones, which are involved in colour vision. Through a series of chemical reactions an action potential is initiated and a nerve impulse is finally formed (2).

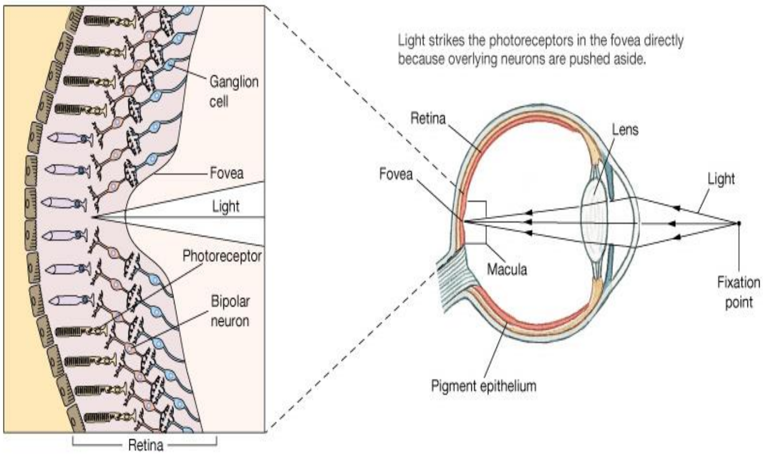

Figure1.2: Basic anatomical view of the eye (2)

Finally, once a nerve impulse is formed it must travel via neurons to the integrating centres in the CNS. Eventually, these neurons form the optic nerve (cranial nerve II) and exit the eye (18). The optic nerve enters the brain at the optic chiasm where the nerve fibres from each eye then cross to the opposite side, allowing the visual areas to receive information from both eyes (Figure 1.3) (2,18). Most of these fibres then synapse in the lateral geniculate body of the thalamus and thereafter travel to the integrative centre for vision: the visual cortex in the occipital lobe of the brain (Figure 1.3) (2).

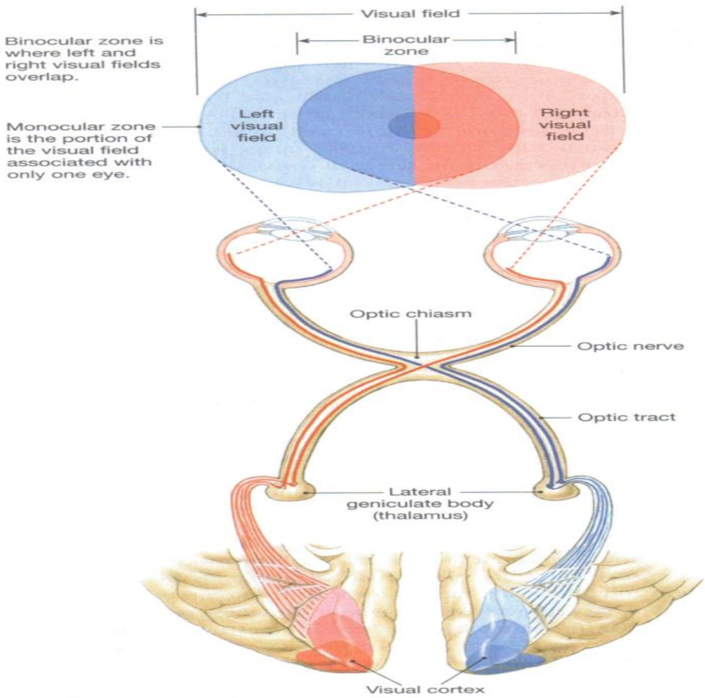

Figure1.3: The pathway of optic nerve fibres to the brain(2)

Perception is a very important phase of visual processing. Although it is unlikely that aspects of perception of visual information can be enhanced in any manner, it stands to reason that any defects or deficiencies in this early stage of visual processing will surely have a detrimental effect to the phases that are to follow.

1.2.2 Integration

The next phase of visual system is the integration phase. Integration involves the interpretation and analysis of the visual information. The goal of the integration phase is to determine whether a response is required and then decide as to what would be the most appropriate response (17).

Once the optic nerve fibres crossover at the optic chiasm they first travel to a part of the brain named the thalamus. The thalamus is the brain structure responsible for the relay of information between the different structures of the CNS (2). Most often, any visual information (now in the form of nerve impulses) will travel via the thalamus to the visual cortex which is located in the occipital lobe in the cerebral cortex (Figure 1.4, point 2). The visual cortex is the integrating centre for visual information, is part of the decision making areas of the brain and plays the major role in the interpretation of visual information (2).

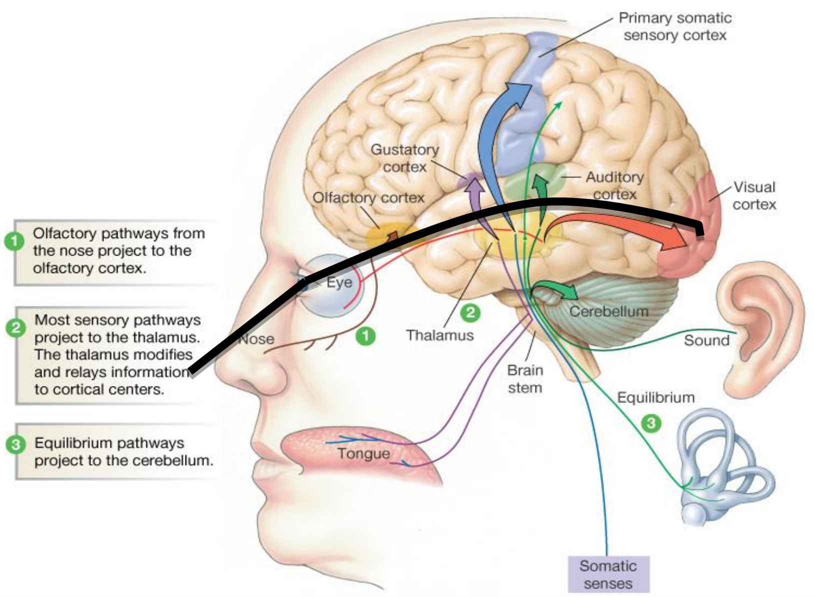

Figure1.4: Visual pathway to the brain (2)

Visual information, like almost any other information the human body has to deal with, is not interpreted only using the visual cortex. Many other structures of the CNS are involved when dealing with visual information.

One of these structures is the spinal cord. The spinal cord deals with information that does not require higher brain structures. In the spinal cord information is received, integrated and a response is made immediately. This is the mechanism used when dealing with visual skills that are automated.

Another important structure to the integration of visual information is the somatosensory cortex situated in the parietal lobe (Figure 1.4). The parietal lobe is known to play a role in spatial aspects of vision (2).

An aspect that aids the quick and efficient integration of visual information is memory. Decisions are based on past experiences stored in memory and therefore brain structures such as the hippocampus will also play a role in the integration phase (2).

1.2.3 Response

The final phase of visual processing is the response phase. During this phase impulses are sent out to the appropriate effector and a response to the initial stimulus is made.

Once the visual information is analysed and decisions are made as to what an adequate response should be in the visual cortex, impulses are sent to the premotor and motor areas, situated in the frontal lobe of the brain (2). The motor area is responsible for the direction of skeletal movement and the premotor area integrates information from both the sensory and motor areas thereby acting as a link between sensory and motor information (2). The motor and premotor areas are both essential for the execution of voluntary movement.

After being processed in these two brain structures impulses are sent via the corticospinal tract to an effector (a muscle group) (2,17). Thereafter a series of reactions occur ultimately resulting in a response being executed (e.g. muscle contraction). This response is highly specific to the stimuli and accurate in timing and intensity (2,17). As is with all actions carried out in the human body, a feedback mechanism is in place to ensure accuracy of the response (17).

Unlike the perception phase of visual processing, the integration and response phases are not limited by specific physiological characteristics and have the capabilities to be enhanced.

1.2.4 Practical implications of the knowledge of visual processing

As mentioned before, the knowledge of visual processing is important, but what makes this knowledge of such importance?

The previous sections showcase the importance of the CNS in the integration and, to an extent the response phase of the visual processing system. A significant characteristic of the brain areas (i.e. cerebral cortex: visual cortex in occipital lobe and motor and premotor cortex in the frontal lobe) is the possibility of neuroplasticity in these areas (18). Neuroplasticity refers to structural changes and an increase of neural efficiency of the brain that can occur in response to an increased exposure to a certain stimulus. The result of neuroplasticity is often a more precise and efficient integration and response to stimuli (19).

In neurological studies, neuroplasticity and its effects have been best understood by studying the brain structure and activity of athletes. Athletes are the ideal subjects because they are characterised by a greater efficiency in the integration (i.e. quicker and more precise decision making) and response (i.e. quicker and more precise motor responses) phases of visual processing (20).

Due to the demands of the sporting environment it is important that visual processing is precise and accurate. Although perception leaves little room for improvement as it is limited by the physiological characteristics of the visual system, integration and response have been found to be more efficient in athletes as compared to non-athletes. In EEG and fMRI studies comparing the athletes and non-athletes, athletes were found to have significant changes in the structure and activation of the visual and motor cortex (19,20,21). But what is it that causes these changes?

From studies comparing athletes and non-athletes and furthermore studies that compare elite athletes and non- elite athletes, it can be seen that the most significant factor that distinguishes the two classes is the amount of time and the quality of training undertaken. Training is shown to have led to a great degree of motor skill learning where motor ability is enhanced through continuous practise (21). Neurological studies have shown that training has led to neuroplasticity and a greater efficiency in the activation of the motor cortex (9,19-21).

It is this possibility of the enhancement of visual processing that has given birth to the ever progressing field of sports vision. Sports vision is a dynamic and ever growing field and will be discussed in the sections to follow.

1.3 SPORTS VISION

1.3.1 A brief introduction to sports vision

Sport is an important part of not only the extra-curricular activities of many countries as a whole, but it is now also an essential block of the economy of many developed countries. Millions of dollars are essentially involved in sport and therefore different and innovative ways are sought to improve sporting performance and techniques before any competitors (22). Traditionally, key aspects like nutrition, physical strength and endurance, and sport psychology were considered and training was put into place to improve and enhance these traits if needed (1,23). In the past, vision was not considered as important as the other aspects involved in sport and little consideration was taken to evaluate visual aspects of athletes (24). However, as the importance of vision became more evident, the evaluations of vision and visual skills have become a necessity in many of the different sports (24).

Vision has two facets when it comes to sport. Firstly, vision in sport can be viewed in a way that merely looks at correcting visual deficiencies. As vision is important in extracting most information from our environment, correcting any visual inaccuracies could help to improve sporting performance, allowing athletes to perform at their ideal levels (1,16,23,25). As understanding of vision evolved, another facet to vision has come to the fore, the ability to improve vision through the introduction of vision training. Vision training involves the introduction of specific vision exercises that are said to enhance the visual processing system thereby leading to more efficient and precise sporting performance (1,11). This ability to improve sporting performance through vision has led to the field of sports vision and sports vision training that is becoming popular in many of the countries that have a great sporting culture like the United States of America, the United Kingdom, Australia and South Africa. From an academic point of view, these aspects of vision has led to an increasing amount of research conducted and literature published in the field of sports vision.

1.3.2 Previous research

As the importance of sports vision was established, coaches and sports scientists started incorporated aspects of sports vision in the preparation of athletes for athletic events. Academic research and clinical trials regarding the effectiveness and the training of visual skills also increased (1,17). Over the years there has been a steady increase in the publication of sports vision articles not only from a sport physiology/ sport science view but also from an optometric and sport psychological point of view (11). Initially, most studies aimed at the identification of visual skills that are important to sporting performance and the differences between the skills required in different sporting codes (26). Steadily, as the visual skills required were understood better, researchers looked at determining whether differences in visual skills existed between athletes and non- athletes, which throughout the years, many studies have showed athletes generally having superior visual skills as compared to non- athletes (1,20).

In the addition to this, there has been an increase over the years in the creation of sports vision training programs, especially in the sporting domain (1,7). With the development of numerous training programs promising significant improvement in visual skills, clinical trials are being conducted testing the effectiveness of such training programs. Although many studies show positive effects of sports vision training, inadequacies in many of the study designs leaves a lot to be questioned regarding the validity of certain results (27).

The study of new and innovative vision training programs that promises improvements in motor performance is constantly being tested. However, few studies have taken into account external variables that could have a profound effect on visual skills and the training of visual skills (28). The human body, although studied traditionally as '*systems*', functions in an interconnected manner. Therefore, it is assumed that there are possibly other physiological, emotional, psychological and even environmental variables that could affect vision and visual skills that have not been accounted for in almost all sports vision studies (1,28,29). One such factor that could influence visual skills is stress. Stress, often accompanied by anxiety, triggers many physiological processes in the human body that could severely hamper visual skill performance (27). This is emphasised especially in the sporting domain where the inability to deal effectively with stress has led to severe underperformance by athletes in a competition (7). Participants that undergo a lot of stress are found to be less focused and organised in their visual search behaviour and are less effective in making appropriate responses to visual stimuli (29).

General cardiac health is an important variable that should also be considered. Not only can cardiac health be used as a general indication of physiological stress, but due to the cardiovascular system having an effect on almost every other physiological system in the body, it could also have an effect on visual processing. It has been determined that chronic hypo/hypertension could have an adverse effect on the brain thereby possibly affecting the integration of visual information (30).

Another aspect that could affect visual skills is body composition. Although the prevalence of obesity is on a steady increase worldwide, not much is known about the effect obesity could have on visual skills.

Generally it is assumed that all lifestyle factors such as; nutrition, physical fitness and emotional and psychological factors could have some kind of impact on visual skills however, due to the lack of research, it is difficult to know exactly what is the effect of these factors and if it has a significant impact.

Besides the external factors that are not accounted for in sports vision research, there are also other areas that have not been taken into account or addressed unsatisfactorily.

Many studies make use of very small sample sizes and conduct testing in environments that are unsuitable for the subjects and type of visual skills that are being tested. With regards to the training programs introduced, the training methods have often been found to be too closely related to the tests and it is unclear whether results are actually due to test familiarity or actual improvement in skills (1). Another limitation to sports vision research is that researchers take into account only short periods of training and therefore the time spent on training is too little to yield significant results as visual and motor skills require a few training sessions atleast to actually be affected (9,27).

Research has also been limited to specific subject types and environments. Traditionally, research has been conducted in athletes who already have superior skill, the elderly who are undergoing natural age- related visual and motor decline or patients who already have visual defects (1,13,27). Most of the current research is limited to the sporting domain and although some studies have tried to expand research into other domains and other subject matters like students, the research conducted thus far is very minimal (6,27).

Another important aspect is the lack of understanding of the visual skills tested. Many of the earlier studies conducted, tested visual skills that were not important to the subjects of the study and much of the training programs aimed to train visual skills that are not easily conducive to improvement. The different visual skills will be further explained.

1.3.3 Visual skills

In order to fully comprehend sports vision and sports vision training it is important to have a good understanding of the different visual skills (1,26). Visual skills can be loosely divided into two types.

The first type of visual skills, which have been commonly labelled in literature as "*Hardware*" visual skills, are those visual skills involving the physical properties and capabilities of the visual system (17). These visual skills are termed "*Hardware*" visual skills because they are not task specific and are most often merely, or an extension thereof, of the same visual skills that are tested during standard optometric visual screening (16). They are also not very favourable to change and are unlikely to improve beyond a specific threshold. Some of the visual skills that have these characteristics are; visual acuity, accommodation, vergence, depth perception, colour discrimination, contrast sensitivity and peripheral vision (16,17,26).

The second type of visual skills, which have been commonly labelled in literature as "*Software*" visual skills, are those skills that make use more of the cognitive aspects of visual processing (17). These are skills that are more conducive to improvement, probably due to the neuroplasticity nature of the brain. These include visual skills like; visual concentration, visualisation, sequencing and eye-hand coordination (16). It is these skills that are most important in a variety of different settings and to a variety of different subjects but have often been neglected in previous research, perhaps because it is more difficult to evaluate than that of the "Hardware" visual skills.

Both these visual skills are important and should be considered in the testing and training of visual skills. It has been found that there are often no significant differences in the "*hardware*" visual skills between athletes and non- athletes (17). Although the "*hardware"* visual skills may not have the ability to be improved in any significant manner, it is still very important. It has been found that inadequate levels of "*hardware"* visual skills could limit other visual skills in a severely detrimental manner (17). For example, visual acuity, often the starting point in visual screening, if weak can severely affect the performance of other visual skills and also motor performance resulting in slower and less accurate responses to stimuli (15,26). "*Software*" skills however have been shown to be very conducive to improvement but are neglected in testing and training.

In order to accurately test and train visual skills it is important to understand which visual skills are important. Thereafter, training programs should be created correcting deficiencies in the "*Hardware"* skills and specifically improving the "Software" visual skills needed.

1.4 BRIEF OVERVIEW OF CURRENT RESEARCH

The purpose of the current research is to further develop the field of scientific research into sports vision by addressing the limitations of sports vision research discussed in previous sections. This study also moves away from the traditional subject types i.e. athletes and focuses on visual skills and visual skill training in university students thereby possibly extending the role of sports vision and sports vision training.

The role of vision in a classroom is vast but little interest is taken into assessing visual skills in students. Traditionally in education if a student is found to have a learning problem a variety of psychological factors are considered to determine the cause of the problem (31). Although, visual skills are important to various activities in a classroom setting and research has indicated that vision problems are closely associated with poor reading and learning, visual skills, besides simple visual acuity, are rarely tested in most schools (32-34). Visual acuity is an especially important test for younger students in primary schools, who may not be able to understand the effects of poor visual acuity and therefore may not express any problems they are facing with regards to simple visual acuity. However, at a tertiary level of education (i.e. a university setting), students probably would have addressed any visual acuity problems they may be facing. Other visual skills have not been addressed and just as training is introduced to improve the visual skills of athletes, the introduction of visual skill training in students could also improve certain visual skills. This study takes into account the specific visual skills needed by university students and ascertains whether these skills can be significantly improved by visual skill training. The visual skills important to students include both the "hardware" and "software" visual skills and are as follows:

1) **Static Visual acuity:** visual acuity is the ability to clearly see a stationary object at a given distance (1). This can be understood simply as a general eye test. Visual acuity is the most common visual skill tested. Although tested very often it is important to make sure that there has been no decline in visual acuity and that visual acuity is within acceptable values. Visual acuity needs to be sufficient especially for university students to see the presentations of lecturers in large lecture rooms. If visual acuity is insufficient and uncorrected academic performance may be affected. Strain to the eyes caused by uncorrected visual acuity can lead to extreme discomfort and frequent headaches (35). Another aspect that is commonly tested with visual acuity is ocular dominance which is the ability of one eye to dominate in the creation of a binocular image during sight (1).
2) **Eye movements:** there are a variety of activities that involve eye movements. Movements of the eye help in the extraction of visual information (1).There are also variety of eye movements that are important. These include:
    - **Focusing-** is the ability of the eyes to focus and clearly see objects at various distances alternatively (1). This occurs due to the physical properties of the eye. When viewing far objects, the ciliary muscle relaxes and the lens is in an elongated state. Conversely, when looking at near objects, the ciliary muscle contracts, and the lens bulges (3). This is an important visual skill for students as they constantly must look from far to near objects when taking notes in a lecture etc. If there is a problem with the focusing system of the eyes this could lead to eyestrain and discomfort for the student which could affect academic performance (32).
    - **Tracking**-is another form of eye movement. This entails the ability of the eye to make small saccades/ "jumps" (2). This is a visual skill that

is needed during reading and is critical for students who must often read large volumes of text in short periods.

- **Vergence-** this entails the ability to maintain binocular vision when crossing and uncrossing the eyes therefore maintaining clear vision from far to near/ near to far distances (1). This is a natural ability of the eye which is important in the maintenance of the formation of a single image at all time. This is another skill important to students especially during taking notes and studying between different books.

3) **Visualization:** refers to the ability to form a mental image (1). This skill can significantly help to decrease reaction time and involves a great degree of visual concentration (36,37). This skill can be used as a study technique for students who often have large volumes of work to study and very little time.

4) **Sequencing-** this entails the ability to organise visual information. This too is a skill that could be used to make learning and studying more effective.

5) **Eye- hand coordination-** this is a skill that is used by everyone in their daily lives. Eye-hand coordination refers to the ability of the brain to receive visual information from the eyes and effectively send out motor signals to the hand to respond in a coordinated manner (1). Not only is it important in many aspect of life like driving, writing etc. but it is especially important to students who have practical classes that require skilled hand and eye movements.

This study will specifically test these visual skills that are important to the students and thereafter determine whether the visual skills will be improved through the introduction of visual skill training.

The study also addresses common limitations and inadequacies of previous research that has been conducted in the sports vision field. Large sample sizes are in place and the study is controlled by having an adequate control group. Training will specifically address the skills tested and because in most previous research it was unclear what effect familiarity to the testing had on the results, two training methods will be employed. The first training method would entail a simple repeating of the tests in training sessions and the other training method will make use of a developed online training program Eyedrills. With research indicating that training and acquiring certain skills require a few training sessions at least, training will also be for a longer period than had been traditionally used in previous research (9).

A major gap in sports vision research, which has not been addressed in any significant manner in the academic articles to date, is the influence of external factors on vision and visual training. External variables that could have an effect on visual skills include; lifestyle, anthropometric measurements (body mass index, body fat percentage) and cardiac health (cardiac stress and blood pressure) variables (29). Lifestyle factors that could have an effect on visual skills include; nutrition, fitness, alcohol and tobacco use, emotional and psychological health. It is difficult to test lifestyle factors and in order to get an overall view of a subject's lifestyle different types of questionnaires are used.

Anthropometric measurements such as body mass index (BMI) and body fat percentage together give an accurate view of body composition. BMI is simply calculated by determining height and weight and body fat percentages are calculated by a simple skinfold test (2). Overall body composition may have an influence on visual skills.

Stress is one of the external variables that are often taken into account in relation to visual skills. Although it is almost an established fact that stress could have a detrimental effect on the extraction of visual information, the testing of stress have not been done in a scientific manner in most past studies. An inexpensive and at the same time scientific method of determining general physiological stress is to test cardio stress index and resting blood pressure. Cardio stress index (CSI) determines, in the form of a percentage, the amount of physical stress the heart is under and resting blood pressure is also one of the key indicators of stress in an otherwise healthy cardiovascular system (2). Emotional and psychological stress can also be determined in the form of questionnaires in addition to physiological stress determined by cardiovascular measurements.

Each of these variables will be addressed and compared to the visual skills to determine if any possible correlations exist. In addition to determining possible correlations between visual skills and these variables it is also important to be certain that the any improvements in visual skills after training was not significantly affected by any significant changes in the external variables between pre and post testing.

Therefore, the aim of this study is to determine whether the introduction of a 6 week, well controlled, sports vision training program (Eyedrills training program) will significantly improve the visual skills of students. This study also aims to determine if external variables like; lifestyle variables, body composition, blood pressure and cardio stress index will have a significant impact on the visual skills tested.

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CHAPTER 2: LITERATURE STUDY

2.1 SPORTS VISION TESTING: BACKGROUND

Although visual skills are an important aspect in all areas of life, the study of visual skills as a science found its fame in the sports arena. In order to be the best in an industry that is highly competitive, sports scientist, coaches and athletes themselves sought other means to improve sporting performance other than the traditional aspects like strength, physical fitness, nutrition etc.(1,2). Previously, the only aspect of the eyes that were of concern was protection from injury, however as the study of sports became more scientifically enriched, it became quickly evident that the entire visual processing system (which includes; the visual system, central nervous system (CNS) and skeletal- muscular system) is an important aspect in performance of sport skills which allows information to be gathered quickly, processed quickly and accurately, and is responsible for quick and accurate responses to this information (3).

Vision and visual screening was traditionally used in the sports field to identify deficits in the visual system of athletes (4). The reasoning behind this type of screening was that if deficits existed in athletes this could adversely affect performance. However, in the later years researchers questioned the possibility of athletes having better visual skills and furthermore the possibility of a better athlete having more superior visual skills. This possibility was tested on Babe Ruth, one of the greatest baseball players, who was found to have 12% faster and 90% more efficient use of the eyes and brain (4,5). Although, this study conducted in 1924 was a small one and not the most scientifically accurate, it is arguably the study that opened the doors of sports vision testing as we know it today. The field of sports vision is one that involves many subfields such as sports science, optometry, physiology and neurology. Due to the amount of different areas involved in sports vision testing, a variety of tests have been conducted taking into account different aspects of vision testing.

Initial research was primarily conducted by optometrists and sport scientists and they mainly focussed on the visual skills themselves. In one of the most popular review articles dealing with sports vision by Abernethy (6), the author proposed important aspects that need to be considered in sports vision research (6). Two of which have been vastly researched and is widely found in sports vision literature, these are 1) determination of important visual skills and 2) how and to what degree can visual skills be trained and improved (6). Therefore, to address these aspects of sports vision, scientists actively started research in these areas.

Most of the initial research conducted, much like the study on Babe Ruth, dealt with the visual skills of athletes and difference of visual skills of athletes and non-athletes. Research conducted then, and conclusions still hold to date, proved that athletes do have superior visual skills than non-athletes as supported by superior performance by athletes (7). However, the testing of these skills helped to uncover an important feature of visual skills, i.e. not all visual skills are the same. This fact is more articulately explained by Abernethy in his review article published in 1986, who divided visual skills into two types; "*hardware*" visual skills that include all those skills that are more dependent on the physical properties of the eyes and "*software*" visual skills that include those visual skills that are dependent more on the cognitive capabilities of the visual processing system (6). Furthermore, research conducted also showed that athletes have superior performance in the "software" visual skills like anticipation and choice reaction time etc.(6,8). These types of studies therefore also helped to better understand visual skills and also the different type of visual skills that are important in the different sporting areas, for example, the visual skills important to a cricket player are different to the visual skills needed by an Olympic swimmer.

Another area that elucidates on the above point is the difference in visual skills between professional and non- professional athletes. Throughout the literature available it is generally accepted that professional/elite/expert athletes have superior visual skills to non- professional/ amateur athletes (5- 7). However, again the visual skills involved are not the same. Studies conducted by Abernethy and Neal in 1999 (9) and Ludeke in 2003 (10), looking at the difference in visual skills between professionals and non-professionals in different sporting codes, both show professionals having superiority but in only specific visual skills. The skills that are superior in professionals are those of the “software” type. Other researchers, although not scientifically tested, have proposed that “*software*” visual skills are more efficient in professional athletes and therefore give them an advantage in recognising visual information, recalling visual information and decision- making that thereafter ultimately leads to better sports performance (10-12). The importance of “*software*” visual skills in professional athletes are further highlighted by studies that have shown that even if professional athletes had deficiencies in their “hardware” visual skills, for example, below normal visual acuity, this did not detrimentally affect the *“software*” visual skills or general performance in any significant manner (6,13). However, it is important not to neglect “*hardware*” visual skills as there is a strong possibility that deficiencies in “*hardware*” visual skills can affect the performance of “*software*” visual skills which could have a detrimental effect on sporting performance.

From a neurological point of view, researchers have made use of scans and other methods of testing brain activity to further prove the difference between the brains of professional athletes compared to that of a non- professional athletes. In review articles by Nakata, Yoshie and Miura *et .al.* (14) and before them Yarrow, Brown and Krakauer (15), the authors studied research on the handling of visual stimuli of athletes that was conducted using various neurophysiological and neuroimaging methods. Through their vast review of the literature it was found and widely accepted that professional athletes had a more efficient manner of dealing with visual information than non- professional athletes (14,15) (Figure 2.1). There is also vast evidence proving that professional athletes have structural and physiological differences of the brain as compared to non- professional athletes (14,15).

This has been physically tested by Wei and Luo (16), who used fMRI scans to determine the brain activation of professional divers as compared to non-professional athletes when exposed to motor imagery (16). The motor imagery the subjects were exposed to included diving imagery (DI) i.e. imagery that was specific and known to the subject and gymnastic imagery (GI) i.e. imagery that was unknown and non- specific to the subject. Overall the results indicated that the professional athlete had a greater activation in the frontal lobe of the brain indicating better cognitive processing of the visual information and also a greater activation of the parahippocampus (fig 2.1) (16). This greater brain efficiency of professionals are however only limited to diving imagery highlighting another important aspect of visual skills in professional athletes, i.e. superiority in the visual skills are most often only found in those visual skills that are specific to the sporting code of the athlete (16).

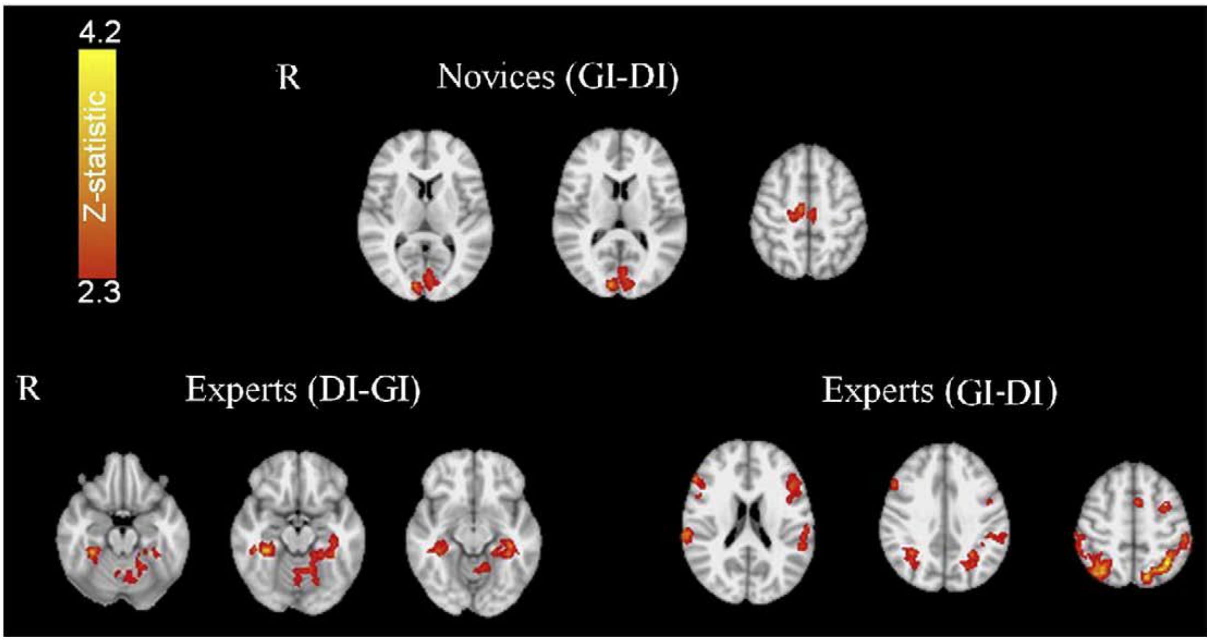

Figure 2.5: Neuroimaging of professional vs non-professional athletes when exposed to specific and non- specific imagery. Overall professional athletes (experts) showed a greater activation and more efficient use of the brain. This greater efficiency is highlighted when exposed to imagery that is specific and known to the subject (Experts (DI-GI)) (16)

Although neuroimaging studies like the above, gives a more visual indication of the efficiency of an athletes' brain, the fact that imagery has to be used instead of the subject actually performing the task is a major limitation. However, studies have indicated that the areas activated when exposed to visual stimuli and performing the actual task are the same (16). Another limitation is that due to neurophysiological and neuroimaging equipment being expensive, sample sizes of these types of studies are often quite small and therefore results can be questioned. However, together with the other types of studies carried out, it is generally accepted that athletes do have superior visual skills than non-athletes; professional athletes do have superior visual skills than non- professional athletes and the type of visual skills that differentiate the two are the "*software*" visual skills.

The probable reason for the efficiency of visual skills and neuroplasticity in professional athletes can be attributed to the hours of training undertaken by professional athletes (14). Therefore, at the same time researchers tried to understand visual skills further, the second point highlighted by Abernethy i.e. can visual skills be improved, how and to what extend can visual skills be trained was also addressed in sports vision studies.

At the very early stage of sports vision research, sports scientists and optometrists started designing and implementing sports vision training programs (1). It was proposed by sport optometrists that the training of visual skills is as important to sports performance as the correcting of visual deficiencies (17). The training of visual skills is an aspect that really found fame in sports science because the possibilities that visual information can be identified faster and responded to faster through training, could ultimately give an athlete an added advantage in performance, especially in fast ball sports and others where there are time pressures (18,19). This led to the development of commercially available training programs, whose use is currently on an increase, and therefore studies of the effectiveness of these training programs too increased. In the following section sports vision training programmes, the effectiveness of these training programmes (tested via research on the programmes) and limitations in these studies will be further discussed.

2.2 PREVIOUS RESEARCH AND LIMITATIONS

The development of training programmes began from the very beginnings of sports vision research. One of the foremost concerns with the early training programmes that were developed is that designers of the programmes had very little knowledge of visual skills, which were still in the process of being understood. These programmes became readily available to athletes and the general public without being tested and having very little scientific basis to begin with (6,20). In order to determine whether these programmes actually did improve visual skills as promised, researchers conducted a variety of different studies. The results from these studies showed a significant improvement, no significant improvement or an improvement in very specific visual skills of the subjects tested. This generally shows that it is not certain whether the training of visual skills has a role in the race to improve performance however, a deeper look at the studies conducted showed important limitations in the study design of the research conducted and design of the training programmes themselves that could have led to these inconclusive results.

One of the early studies by Wood and Abernethy conducted in 1997 (21), tested the efficacy of vision training programmes that were easily accessible and accepted to improve visual skills at that time. The researchers tested the ability to improve the visual skills of subjects after exposure to four weeks of visual training using sports vision exercises found in three different sports vision manuals. The results showed an improvement in the visual skills of the subjects that have undergone visual training but this improvement was not significant and the authors attributed this improvement to no more than simple familiarity to the tests (21). Although the study was well-designed and well- controlled with a control group (no visual exercises undertaken in the four weeks) and a group acting as a placebo (simple reading undertaken in the four weeks), the sample was a total of only thirty subjects. This small sample size leaves open a possibility of errors during statistical analysis.

An extension of the study conducted in 1997 was done in 2001 again by Abernethy and Wood (13). This time the authors looked at the ability to improve visual skills through other training programmes that were commercially available at that time. The researchers implemented four weeks of visual training, much like the study in 1997, but with two different training programmes that were commercially available on the internet and also widely accepted to improve visual skills. Similarly, the test was well-controlled with a control group and a placebo group in place (reading group) (13). Overall results indicated a general improvement in visual skills but this improvement was not group dependent. This study, together with the one in 1997, gives credence to the idea that mere familiarity to visual skills testing would improve results which makes testing of visual training programmes very difficult. However, the limitations of the training programmes themselves should not be disregarded.

A further look into the training programmes that were tested highlights some concerns. Firstly, much of early visual skills studies conducted were done on those that had visual defects or deficiencies. Due to the positive results obtained from the training undertaken by subjects with visual deficiencies, the training programmes designed for athletes and the general public were based on the same principles (21). Therefore, the training programmes tested in the above two studies focussed mainly on simple "*hardware"* visual skills that apart from correcting deficiencies are not easily trainable (6). In the above two studies not only is the training programmes more focussed on " *hardware*" visual skills but the vision tests too mainly focus on these *"hardware*" visual skills. It has been previously discussed that the main type of skill that is found to be better in athletes as compared to non- athletes and professional athletes as compared to the non- professional athletes are the "*software*" visual skills. Therefore, it can be implied that "*software*" visual skills should be more readily able to change and be improved (22). Therefore, merely taking into consideration one type of visual skill is a limitation to the studies performed. Another aspect of the studies that should be considered is the sample sizes. The study conducted by Abernethy and Wood in 2001 too has the same problem with a fairly small sample size used (40 subjects equally divided into 4 groups). Similarly, the time spend on training may be too short. A change in the time spent and the duration of training if considered, would have indicated better if the time spent on training would have made a difference to the results. Similar studies to these testing training programmes in the early 2000's have also shown no significant improvement in the visual skills tested (20).

Overall, although the study designs were a good ones, the limitations to these studies and the training programmes themselves cannot be overlooked, which could have been the reason for no significant improvements in visual skills. This can be further emphasised by studies that have shown significant improvements in visual skills through training.

There are a considerable amount of studies that have indicated a significant improvement in the visual skills of subjects after undertaking visual training. Why have these studies show an improvement in visual skills and not the others mentioned previously? There exist many possible reasons but one that is consistent throughout the literature is the difference in the type of visual skills tested and trained. In a study conducted in 2002 by Farrow and Abernethy (23), the ability to improve anticipation in junior tennis players through two different types of visual skills training programmes; a video-based training programme and a verbal training programme was tested. The results indicated that anticipation skills can be significantly improved through the video based training programme. It is also important to note that significant improvement in anticipation occurred only through the video based training programme and not in the other groups (i.e. verbal training, control and placebo groups) eliminating the possibility of mere familiarity to the test. The duration of training was also four weeks (the same duration of time spent in previous studies that have not yielded favourable results) therefore it is more likely that improvement was due to the training method and the skill trained itself.

In similar studies to the above, researchers have concentrated on the ability to improve certain visual skills through specific exercises and training programmes. This is can be further explained by studying research by du Toit, Kruger and Neves (24), who sought to determine whether specific sports vision exercises could improve the visual skills of thirty school boy rugby players. The vision testing consisted of four different eye-hand coordination tests and the exercises were specifically designed to improve eye-hand coordination. This specificity of training is a fact that had been neglected in many previous studies. Therefore, it is possibly one of the main reasons results of significant improvement in eye-hand coordination was found in the end of the study as compared to the control group that was in place. In studies by du Toit, Kruger, and Joubert *et al*. (25) and du Toit, Kruger, and Fowler *et al*. (26), which tested similar visual skills using the same training exercises also on rugby players but different type of subjects (adult female rugby players and adult male rugby players respectively), similar significant improvements in eye-hand coordination, visual concentration, visual memory and reaction time were found (25) (26). This shows the consistency of the training programme designed. As mentioned previously, a feature of this training programme that makes it effective is the specificity of the exercises i.e. each exercise is in place to improve the very skill that is tested and the exercises are very realistic and suitable to the environment of the subjects (exercises stimulate skills needed in a rugby game) (24-26). Similarly, the visual skills tested are specific to the needs of the subjects. This is important because as exemplified by a study of the visual skills needed by Olympic-level athletes by Laby, Kirschen and Pantall (5), the visual skills requirements are different for different subjects even to an extent that different visual skills are important in a specific sport and not so important in other sports (5). Therefore, taking into account the visual skill requirement of a subject is important to obtain positive results. Another important feature is that the visual skills that improved significantly are all "*software*" visual skills which are more trainable than "hardware" visual skills (22).

Although these studies showing that sports vision training does lead to improvements in visual skills are well- controlled (all have control groups in place) and scientifically designed studies, they are not without limitations. The sample sizes used in these studies have also been small and statistical errors could be possible. Another factor is the time spent on training. In the studies conducted by du Toit, Kruger and Neves (24), du Toit, Kruger, and Joubert *et al*. (25) and du Toit, Kruger, and Fowler *et al.* (26), there was only one training session between pre-testing and post-testing. It is therefore difficult to determine whether learning of the skills has actually taken place and whether these training exercises could lead to long- term improvement in visual skills. It is also of concern that most of the studies that have shown results with no significant improvements were those whose subjects were non-athletes [Wood & Abernethy (21) and Abernethy & Wood (13)] and all those that have shown significant improvements were studies conducted on athletes [Farrow & Abernethy (23), du Toit, Kruger & Neves (24), du Toit, Kruger, Joubert *et al*. (25) and du Toit, Kruger, Fowler *et.al* (26)]. This trend makes one question whether visual skills can be improved through training in everyone or only athletes who are accustomed to improving their skills through sports training.

This question was partly answered by a recent study by du Toit, Kruger, and Mahomed *et al.* (27), who looked at improving specific visual skills needed by university students through sports vision exercises. Although the results indicated a significant improvement in eye-hand coordination and sequencing skills, other visual skills did not see any significant improvements. A part of the reason for this result is that the sports vision exercises did not address the needs of all the skills tested. The sports vision exercises were more sports based and therefore favoured skills like eye-hand coordination and sequencing and did not efficiently address skills like those involving eye movements which are especially important to students who read a lot. The study also addressed the limitations of sample sizes by making use of a fairly large sample size of 169 students divided into a control group (no visual training) and an experimental group (visual training). A limitation that wasn't addressed by this study is the short-term method of training with just a mere twenty minutes between pre and post testing. Therefore, it is still unclear whether the training exercises would translate into long-term improvements in visual skills. Although further limitations exist, this study is a good stepping stone to determine whether visual skills can be significantly improved through visual training programmes in subjects other than athletes and children with visual deficiencies. Therefore, this current study expands on some of the research done by du Toit, Kruger, and Mahomed *et al*. (27) by determining whether the visual skills of university students can be significantly improved through different training methods and at a more long-term basis (reasons for the use of research methods will be discussed in the next section).

To summarise, although in early studies scientific design was severely lacking in sports vision research, steps have been effectively taken to ensure a more well-controlled research in the sports vision field (7) (28). However, limitations still do exist which leads to questioning the reliability of results and the occurrences of the inconclusive results that are so evident amongst sports vision literature today. The type of visual skills tested and trained have been neglected or not understood properly with many of the visual skills tested not being specific to the needs of the subject and many of the training programmes taking into account the wrong set of visual skills and not matching the skills that needs to be trained (6,18,19,22). Training programmes are mostly designed based of simple optometric training programmes in place for subjects with visual difficulties and therefore lack specificity, are far removed from the environments of the subjects and are therefore not realistic (19,23,29). Other limitations include small sample sizes with a possibility of statistical errors being made when interpreting the data, possibility that mere familiarity leads to improvements in visual skills, training not done for the correct period of time and studies limited to only certain type of subjects (7). In order to further expand on sports vision research these limitations need to be addressed.

2.3 EXPLANATION FOR RESEARCH METHODOLOGY USED

The study design and research methodology used in this current research study is in place to firstly, address the limitations and shortcomings of previous research and secondly, to make use of other visual skill testing methods and training methods that are not very common in sports vision literature today. These methods are used to ultimately meet the goal in determining whether these specific visual skills training programmes would lead to significant improvements in the visual skills of university students.

When studying sports vision literature a common talking point is the type of visual skills tested and trained. Most previous research have only accounted for either "*hardware*" visual skills or either "*software"* visual skills. Although almost all literature available are in agreement that "*hardware*" visual skills are not easily conducive to be significantly improved through training and merely need to be in a normal range to translate into efficient enough visual skills, many research studies have still only concentrated on "*hardware"* visual skill testing and training (6,10). Similarly, other studies have concentrated on the testing and training of only "*software*" visual skills, but visual skills are often dependent on each other and single testing of one visual skill or one type of visual skill is ineffective (6,30). Therefore, improvement in *"hardware*" visual skills only may not translate into improvement in "software" visual skills and overall visual skill performance as a whole, and improvement in *"software*" visual skills may firstly be quite difficult if uncorrected *"hardware*" visual skills deficiencies exist and also may not translate into improvement in visual skills performance as an entirety due to the interdependence of these types of visual skills (12). In the same vain, just testing one or two visual skills is not enough to conclude that the visual skill performance as an entirety has been improved through visual skills training and the visual skills themselves are often dependent on each other too.

To address these issues, in this study both "*hardware*" and *"software"* visual skill types are tested and trained. Accounting for both type of visual skills will correct any "*hardware*" visual skill deficiencies that exist and trains both "*hardware"* and *"software*" visual skills that will more likely lead to enhancement of overall visual performance. Testing and training both "*hardware"* and "*software*" visual skills have been found to show the best results (22). The skills themselves that are tested are a variety and cover many aspects of visual skills like; eye movements, visual concentration, eye-hand coordination, visual memory and visual sequencing. These are a combination of simple and complex skills and are very specific to the needs of the students who mainly use visual skills that are important for reading quickly and accurately, studying via many visual techniques and skills required for everyday activities like driving, cooking etc. It is important that the skills tested and trained match the needs of the subjects as subjects are more likely to do better and learn better the skills that are specific to their needs (13,21,31). Another important feature of this study is that all skills trained match the skills that are tested, an aspect that has been neglected previously.

Another limitation that is addressed is the unrealistic testing and training environments of previous studies. Many studies that have failed to take into account the environment of the subjects have yielded unfavourable results (29). For example, visual skill testing done on sportsman have often taken place in a lab setting that is unnatural and far removed from the environment athletes are accustomed to (29). It is important that testing and training matches the environment of the subjects as closely as possible (32). In order to achieve this in the current study testing and training methods are used that are somewhat different than the traditional sports vision methods.

Firstly, the testing method of visual skills moves away from the traditional methods used to test athletes. Although the testing methods used for athletes are well established and accepted throughout the world, the equipment is expensive and the tests are more suited to address the visual skills needs of athletes and not really the needs of other subjects. This study makes use of a battery of visual skills that are described in a sports vision manual by Wilson and Falkel (33). The tests described by Wilson and Falkel are preferred in this study over the more well-known sports vision testing methods commonly used on athletes because the methods are inexpensive, easy and quick to carry out (especially important when dealing with large sample sizes) and contains different tests to address different visual skills. Another important feature of this testing method is that tests are suited for the environment of the subjects and testing can be done in this same environment and does not have to be carried out in a high performance centre or the like, which may be daunting for some subjects.

Similarly, two different training techniques are in place that has previously not been tested. The first technique uses the testing method as a training programme where subjects go through the same battery of tests but in specific training sessions. This method makes use of that fact that testing and training can occur interchangeably (33). It has been found that repetitive training such as this has previously led to improvements in eye movement skills which, according to the literature available, are a skill that is not easily improved (13). This training method tests the statement "*practice makes perfect*" in a scientific manner. Furthermore, this training method has a second purpose which is to test the notion that familiarity to the test could translate into significant improvements in visual skills. Many researchers have previously attributed any improvement in visual skills after training that closely matches the method of testing to mere familiarity(13,21). The actual repetition of the testing methods in a training programme such as this one can give a clearer view if improvements in visual skills are a simply a matter of familiarity or if actual performance enhancement has occurred.

The second method of training is a more modern approach to sports vision training. This method makes use of a commercially available internet- based training programme Eyedrills. Previous research on commercially available sports vision training programmes did not show favourable results mainly because the training was an adaptation of training designed for children with visual difficulties. Eyedrills is a programme that is more suited to the needs of those that do not have visual deficiencies and was designed and developed by sports vision specialist. This programme is also different from other internet-based training programmes in that training has some control by having an online coach that can advise subjects. The coach is made of aware of the amount of time each participant spends on training and if the amount of time spent on training is inefficient the participant is notified to increase the time spent on training. This is important to ensure that training effects do not wear off. This computer- based method of training is favoured from other non-computer based methods available because the computer is something that a diverse number of subjects spend a large amount of time using either for work or leisure (34). The Eyedrills programme consists of six different drills and each drill consists of 100 levels. This ensures that training is challenging and keeps the interest of the subjects who might have found other methods boring and tiresome (32). The two training methods are both important in that they are carried out in the environment that the subjects are accustomed to and another important characteristic of these training methods is that they are somewhat different from traditional methods available. There is always a need for alternative testing and training methods to be used and tested. The two environments that the training programmes take place, although related, are somewhat different (a sports vision lab for the repetitive method of training and the computer for the Eyedrills method of training) and gives an idea of the difference of results in using different training methods and environments.

Other aspects that needed to be considered were the study-design itself. Although previous studies had a good study design there were aspects that were not effectively addressed or neglected. Many of the previous studies only took into account training of visual skills in one type of subjects i.e. athletes. It is fairly acceptable to say that visual skills in the sports domain can be related to visual skills in any other domain (12). However, the lack of testing in other domains leaves the question of the possibility of sports vision training improving visual skills in other domains unanswered. The testing of visual skills training in students is a good way to introduce sports vision concepts into other domains because students need and make use of a variety of visual skills. The research in students has already been started to a degree by du Toit, Kruger, and Mahomed *et al*. (27), and therefore extensions to this study needs to be carried out by correcting shortcomings and using different methods. A favourable view of sports vision in an academic setting could quickly lead to the introduction of sports vision in corporate and other such domains in a larger scale.

In this study there are also large enough sample sizes that are used and a control group in place to keep the validity of the study- design that have often been ignored in previous studies. An additional reason that university students are used in this study is not only because they are under a greater visual skills demand but also because they fall into an age category that would be more suitable to improving and developing visual skills. It is expected that the age category of 18-25 years of age would yield the best results of learning of visual skills because they are neither too old (who experience a natural decline in visual and motor skills) or too young (2,22,35).

Another feature that is considered in the study-design is the time spent on training. Previous results have showed an improvement in visual skills through training programmes that were once-off and very short and no significant improvements in studies that were fairly long. The accepted time to improve a skill has been found to be through about 3-6 weeks of training (32). It is also found that skills acquisition occurs first at a very quick rate and then slows down or even declines (36). The reason for significant results in previous studies that used short bursts of training could be due to this initial quick rate of visual skill learning. The problem with these studies however, is that no indication is given if visual skill performance will decrease with time in the long run. In this study the training programme ensues for 6 weeks. Although that is the furthest limit of time set out for training (32), this amount of time better indicates the long- running effects of training that have not been sufficiently testing previously (37). The six weeks also allow for consolidation of the skill to take place which is very important to skill acquisition (36,38). Even though other studies that have tested training programmes for similar amount of time have indicated subjects become bored, because training methods used in this study are interesting and challenging this should not be a problem.

There is an additional matter that had not been discussed thus far i.e. the influence external variables could have on the visual skills tested and trained. There are very few studies to date that have considered the possible effects external variables could have on visual skills and whether improvements in visual skills are due to the actual training alone and not due to the effects of other variables (7,27). It is surprising that external variables have not been accounted for in many of the previous studies due to many scientists indicating that stress, anxiety, confidence and fatigue are likely factors that could have a profound effect of visual skills (13,39). Accounting for external variables would make a research study more realistic and give it further credibility (24). The effect of external variables on visual skills is an extensive one and will be further explained in the sections to follow.

2.4 EXTERNAL INFLUENCES ON VISUAL SKILLS

External variables that could have an impact on visual skills can be divided into two broad categories; organismic variables and environmental variables (40). Environmental variables deals with the physical environment that testing and training takes place. Although not everything in the physical environment can be controlled, the testing and training environments are the same for all participants and it is therefore safe to conclude that slight day-day variables in the environment will not significantly affect results and comparisons between the different groups.

It is more likely to find greater differences in the organismic variables of subjects. Organismic variables are the physical, physiological, cognitive and emotional makeup of a subject that often differs significantly from person to person (40). The human body is an interconnected group of systems that often have direct or indirect effects on each other. The most famous example of this is the heart that has an effect on every aspect of human functioning i.e. blood flow controlled by the pumping of the heart (among other features) affects the respiratory, neurological, muscular-skeletal and other systems. This ability of organismic variables to have an effect on different aspects of human body functioning could be profound but the scant literature available makes it very difficult to quantify if significant interactions could occur. This fact therefore makes it possible that other external variables could have had an impact on visual skills and the training thereof. The effect of external variables have often been neglected leaving a gap in sports vision research and often making one question if these external variables had a greater effect on the visual skills than the training itself. Previous studies that have accounted for external variables have not found any significant effect on visual skills but they have only taken into account one or two factors or have not expanded on the relationship these external variables may have on visual skills (27, 41).

In order to fill this gap in sports vision research and to provide more accuracy to this current study, organismic external variables are accounted for. The external variables tested in the current study include; lifestyle variables, anthropometric variables and cardiac health variables that covers all physical, physiological, cognitive and emotional differences that exist between the subjects. Accounting for these variables will clarify if possible relationships exist between visual skills and any of these variables and if improvements in visual skills are indeed due to the training methods and not due to external variables.

2.4.1 Lifestyle variables

Lifestyle variables take into account the differences in the daily activities, habits and wellness of a participant and therefore cover aspects of cognitive, emotional psychological and physical well- being that are self- reported by the participants (42). There are various aspects that need to be considered when aiming to obtain a view of the lifestyle of participants and factors like diversity in ethnicity and religion are some of the things that need to be considered. The aspects that are important to the lifestyle of students and to this study are; personal and family medical history, emotional/psychological/stress-related temperament, fitness, nutrition, tobacco/alcohol/drug use and safety and disease prevention. These aspects considered together give an overall view of the type of lifestyle led by the participant i.e. healthy/ unhealthy lifestyle and therefore the well-being of the participants. Each aspect will be discussed further.

2.4.1.1 Personal and Family medical history

Personal and family medical history gives a general view of any medical conditions a participant or any of their immediate family members has/had. Conditions that are considered when obtaining a personal/family medical history include all common physiological conditions, neurological conditions and any history of substance abuse.

This information is important to determine if the subject is suitable for participation in the research study for example, any condition that has a profound and detrimental effect on the eyes and cognitive processing, or any condition that will significantly affect any of the other external variable tests that are to follow, will need to be taken into account or in some cases a participant will need to be excluded. Family medical history is also considered for the same reason as family medical history of immediate family members gives a generalized view of possible conditions, mental and emotional states participants are predisposed to.

2.4.1.2 Emotional/psychological and stress-related aspects

Emotions, stress, anxiety and the psychological makeup of a person are important because it can affect lifestyle in a profound way. The above terms are not something that can be considered in isolation as they have vast influences on each other and are therefore almost always considered together. Stress occurs in a situation where there is an imbalance of demand and the ability to deal with this demand (43). Often this imbalance is a psychological one and in this case it can be termed as "*perceived*" stress. A more severe form of stress is anxiety which is when a person has overwhelming feelings of distress in stressful situations. The way one expresses him/herself in situations can be termed as emotions and an emotional state of a person is often dependent on the psychological makeup/ personality traits of that person. Therefore in order for a person to lead healthy lifestyle they must have the personality traits to manage and control their emotions and to cope with stress and anxiety. In all aspects of life ones emotional state is important to carry out certain tasks. In sport, the emotional state and capabilities of dealing with emotions are often heightened (44). An important feature that sport psychologists have uncovered from very early is that the ability to deal with stress and anxiety, and other emotions like anger and depression is dependent on the personality traits more than the skill level of that athlete (45, 46). Therefore in order to determine if stress will have an effect on performance the state (current emotional state that is context specific) and trait (emotional disposition) both need to be considered.

The possible effects stress and anxiety could have on visual skill performance is one that is fairly well accepted by sports scientists but no specific testing has been done.

It is proposed that stress could have two possible effects on visual performance i.e. either an improvement or a detrimental effect on visual skill performance. An improvement in visual skill performance can be explained by participants having greater attention and motivation to perform under stressful conditions (46, 47). A realistic view of better performance under pressure is athletes who perform at their best during tough situations in a game or big competitions.

Stress that leads to a decrease in performance have been found to affect actual visual search behaviour. Visual search has often been found to be unfocussed and unorganised in stressful situations (40,45,47). A study determining the effect of anxiety on an archery task by Behan and Wilson (44), have found subjects to be easily distracted, found to have erratic eye movements and significant decreases in reaction time(44,46). This would explain why suddenly athletes have problems even hitting a ball in tough games or students sometimes miss entire questions in exams when situations get stressful.

The most probable reason for the variation of effects on visual skills is the capability of the subjects handling and managing stress. Another possibility is that stress has a curvilinear effect on visual skills. Excessive stress becomes too much for the visual processing system to handle and hampers visual skills performance whereas just enough stress allows for greater attention and improves visual skills performance (46). It is difficult to ascertain what the actual effect of stress is on visual skills because much of the previous studies have poorly defined stress, have not accounted for ability to manage stress and have mainly focussed on perceived or physical stress in isolation. Through a series of questionnaires that are part of a lifestyle evaluation on the students, perceived stress together with emotional states, personality traits and other psychological factors are collectively used to determine if any effects on visual skills exist. Perceived stress and physical stress (tested via cardiovascular methods explained later in the cardiac health subsection) together gives a more holistic view of the effect stress has on visual skills.

2.4.1.3 Fitness

Fitness/ level of physical activity are a key feature of lifestyle evaluations. Physical fitness/ activity have numerous cardiovascular, neurochemical and cerebrovascular benefits and are an essential factor to promoting a healthy lifestyle, prevention of diseases and general physical and mental well-being (48,49). Physical activity is also an important feature in improving cognitive performance. Many studies in children have shown that introducing physical activities is schools will improve the cognitive performance and learning of students (50). This fact has been widely accepted in many fields and many schools have adopted it by making some form of physical activity compulsory for their students. Similar studies in older adults have likewise showed physical activity improving cognitive performance. With cognitive processes playing an important role in the visual processing system and execution of visual skills, it is likely that physical fitness/ activity could play an essential role in the performance of visual skills. This is further supported by studies that have indicated an improvement in visual skills of those with visual difficulties after participating in a physical fitness programme (51). However, many studies that have indicated an ability of physical activity to improve visual skills have not clearly defined the type, time spent, intensity or frequency of the physical activity. This is a key factor because as shown in a study by Thomson, Watt and Liukonnen (52), submaximal physical activity is more likely to see greater improvements in visual skills like reaction time. Likewise, a study by du Toit, Kruger, and Naicker *et al*. (53), that evaluated the visual skills in training recruits who undergo organised physical activity as compared to students who undergo very light physical activity, have shown a greater performance in visual skills like eye-hand coordination and visualization (53). Although it would be easy to say that it is the physical activity differences that has led to these results, results which also show a better performance in eye movement skills by the students leans more to the view that the participants did better and improved more in skills that they use more often and are accustomed to.

In order to have a clearer view of the effect physical fitness has on visual skills, or if physical fitness could influence the results of visual skill testing and training it is essential to account for the differences in type, time spent, intensity and frequency of physical activity performed. Through the use of different questionnaires that take into account all these factors the physical activities of the students as related to visual skills are addressed.

2. 4.1.4 Nutrition

Nutritional status is an important feature in overall lifestyle and is a key predictor of many health outcomes. Poor nutrition is a major problem around the world, be it either from overeating, under eating or eating nutritiously poor food. The field of nutrition is one that is constantly researched and one of the active areas of research for many years now is the effect of nutrition on cognitive performance (54). Together with other aspects of cognitive performance, an area that is often considered is the relationship of nutrition and performance of visual skills. It is proposed that nutrition could affect information processing of visual stimuli, perception and visual memory with poor nutrition severely hampering the processes mentioned (54). In the sports science field, research specifically looks at the blood glucose levels and how varying levels of blood glucose could have an effect on visual skills. du Toit, Kruger, and de Wet *et al*. (55), found in their study on professional cricket players that even though visual skills improved significantly after visual skill training, they improved even more in subjects who were given a high carbohydrate drink in conjunction with the training (55). This is probably due to the sudden increase in blood glucose and cerebral blood flow. There is reason to believe that both hypo and hyperglycemia, whether acute or chronic, both could have some type of an effect on visual skills. In fact, studies on a group of older adults showed that those who are more towards the hypoglycemic spectrum have been found to have poor visual memory and visual organisation (56). These studies are not without limitations though which makes it difficult to ascertain whether visual skills are really affected by nutrition. Besides the fact that results could be highly influenced by the type of subject that is used (older adults visual skills undergo a natural decline and control and a hyperglycemic group was not used to compare results), most studies only account for one nutritional aspect and not nutrition as a whole (54). By considering only certain parts of nutrition and not accounting for others, results only indicate isolated aspects of nutrition.

Through the use of questionnaires determining usual meal patterns and eating habits, a more holistic view of general nutrition is obtained. This makes it easier to compare nutrition as a whole to the performance of visual skills.

2. 4.1.5 Tobacco, alcohol and drug use

An accurate lifestyle evaluation also accounts for the abuse of substances that is deemed unhealthy and detrimental to general well-being. The use of tobacco, alcohol and drugs and its effects on various systems of the human body is well-known and greatly warned against. These substances are not only found to have behavioural and physiological effects but also serious and detrimental cognitive effects. Although tobacco has been found to have mixed effects on cognitive abilities, alcohol and drugs (even if moderate use only) have been found to affect attention, information processing, planning and strategy, reasoning and the ability to learn visuospatial skills (57,58). Furthermore, excessive alcohol was found to cause lasting damage to the brain irrespective if use is classified as chronic drinking or binge drinking (59). One study that specifically looked at the effect of moderate drinking of alcohol on visual response, made use of BOLD fMRI scans after ingestion of moderate alcohol levels when exposed to visual stimuli (60). The results indicate a decrease in somatosensory and visual evoked potential amplitudes and a decrease in BOLD density (60). This shows a general decrease in visual skill performance which agree with other studies that have found a decline in visuospatial skills, visual memory, unfocussed eye movements and eye tracking and a decline in reaction time (57,59). An important feature of the mentioned studies is that skills were tested immediately after ingestion and therefore in is unclear if alcohol consumption other than when testing would have an effect on visual skills.

To obtain a broader sense of how general tobacco, alcohol and drug use could affect visual skills, a questionnaire is a better method to implement. Through questionnaire other aspects of use such as frequency and quantity can also be accounted for.

2.4.1.6 Safety and Disease Prevention

The final facets that are considered in a lifestyle evaluation are safety and disease prevention. This establishes if a participant accounts for safety of practises in all aspects of life and is well-versed and careful to prevent diseases which are preventable. This information is useful to further determine if the participant is conscious of decisions, actions and habits that may compromise overall wellness and well-being. All the aspects discussed are essential to give a general view of the lifestyle of the participants. Although discussed separately, these aspects as a whole are used to compare lifestyle and possible effects it may have on the performance and training of visual skills.

2.4.1.7 Explanation and reasoning of methodology used

To obtain a generalised view of lifestyle and all the above factors that contribute to a good lifestyle evaluation, various questionnaires are used. The practice of using questionnaires to carry out a lifestyle evaluation is one of the most commonly used methods and also a very accurate method. The usage of questionnaires has many benefits but also do have some limitations which are explained in Table 2.1.

The usage of questionnaires in assessing lifestyle, although not without its limitations, is the most suitable method to give an overall generalised view of all the aspects previously discussed. Through this method, a more accurate and comprehensive assessment can be made on the influence of lifestyle issues on the performance of visual skills.

2.4.2 Anthropometric Variables

Anthropometry deals with the size and measurements of the human body. There are various anthropometric variables that can be used to obtain a general view of the body composition of a person. Body composition measurements are loosely used to classify a person as underweight, normal weight, overweight, obese and severely obese. The body composition of a person can have various effects on other physiological processes in the human body and accounting for body composition is important in physiological studies.

There is very little research that has sought to determine the effect of body composition on visual skills across all age groups and therefore the relationship of body composition and visual skills is a fairly unknown one (61). Some studies have shown that body size could have an effect on motor skill development in children (22). In a study by Skurvydas, Gutnik, and Zuaza *et al*. (62), the authors looked at the influence body mass index (BMI) on reaction time by categorising participants into three different BMI categories and exposing them to a simple reaction time joy stick test. The authors found that the greater the BMI the slower the reaction time. This gives one the impression that being overweight/ obese may hamper visual skills. But, even though factors like anticipation and fatigue were accounted for, there are other medical issues that are often an underlying factor in weight problems that was not accounted for and could have affected the results (63).

Table 2.1: Benefits and limitations of research methodology implemented in evaluating lifestyle

Benefits of questionnaires in assessing lifestyle	Limitations of questionnaires in assessing lifestyle
➢ Questions can be designed specifically for students taking into account different ethical backgrounds.	➢ Some participants do not answer questionnaires truthfully.
➢ Questionnaires make psychological variables and emotions (eg. Perceived stress and personality) easy to measure. These aspects cannot be measured physically	➢ Results are often merely what is perceived by the student and may not be actual.
➢ It gives an overall view of aspects like fitness and nutrition. Physical tests performed in previous tests could only give a view of very specific aspects (within fitness and nutrition) at that specific time. Therefore, questionnaires can give a view of long-term and short-term effects.	➢ The assessment of nutrition through a questionnaire has often found to be a poor reflection of actual nutrition in children. This may not be the case in students who often have to prepare their food themselves and will therefore better know their nutritional habits.
➢ Completing questionnaires are easy and less time consuming.	➢ Questionnaires can be confusing and frustrating especially if they are seemingly repetitive.
➢ Questionnaires are fairly standardised and easy to compare between studies.	➢ Questionnaires are often long and could be found to be boring.
➢ It is easy to account for variables that have an influence on each other, as in a lifestyle evaluation, through the use of one questionnaire that accounts for all aspects.	➢ Participants may be unwilling to divulge personal information even though questionnaires are confidential.
➢ It is possible to use different questionnaires in conjunction (as is the case in this study) to increase the reliability and sensitivity of results.	➢ Some form of social bias may exist when answering questionnaires.
➢ Due to confidentiality that is imperative when using questionnaires, this might be the only way of accurately determining alcohol and drug abuse.	

Reaction time was the only factor considered and therefore it is difficult to ascertain if a high BMI affects only reaction time or other visual skills too. Similarly, other studies have too looked at certain aspects of body composition in relation to certain visual skills with the results being inconclusive and sometimes contradictory (61). There is a need for more research to be conducted taking into account different and a variety of visual skills and various methods of determining body composition.

Three of the most common measurements that are used when determining body composition are; body mass index (BMI), body circumferences and skeletal breadth and body fat percentages. BMI is a simple calculation of weight (kg)/height (m^2) (61,62). BMI is a standard measurement that can classify a subject into different weight categories based on age and gender. Although a standard measurement and an accepted manner of weight classification throughout the world, it is limited somewhat by the fact that it does not account for the muscle or fat composition of a subject (62). This could make results in some cases misleading. The standard classification of BMI in adults according to the WHO guidelines is depicted in Table 2.2 (63).

Table 2.2: Standard classification of BMI in adults

Weight category	BMI Range (kg/m^2)
Severely underweight	15.0 - 15.9
Underweight	16.0 - 18.49
Normal weight	18.5 - 24.9
Overweight	25.0 - 29.9
Obese I	30.0 - 34.9
Obese II	35.0 - 40.0
Obese III	Over 40.0

Body circumferences and skeletal breadth is another method of determining body composition. This method takes circumference measurements of different parts of the body such as; the neck, shoulder, chest, waist, abdomen, arm, forearm, wrist, hips, proximal thigh, mid- thigh, distal thigh, knee, calf and the ankle. Measurements are only taken from the right side of the body to maintain uniformity. These measurements together with skeletal breadth measurements of the knee and elbow give an accurate picture of bone structure of the participant that is probably missing from simple BMI calculations. Another measurement derived from these measurements is a simple calculation of waist to hip ratio (WHR). WHR is said to be one of the most accurate indicators of obesity (64). WHR also gives a general view of health risk based on gender (Table 2.3).

Table 2.3: Health risk in males and females based ion WHR values

Male	Female	Health Risk Based Solely on WHR
0.95 or below	0.80 or below	Low Risk
0.96 to 1.0	0.81 to 0.85	Moderate Risk
1.0+	0.85+	High Risk

Body fat percentage is the measure of subcutaneous fat commonly in eight areas of the body namely; biceps, triceps, subs- scapular, abdomen, suprailliac, thigh, calve and mid- axcillary. These measurements are used in different equations based on gender to determine body fat percentage. The body fat percentage obtained can then be analysed to determine body composition based on age and gender (Table 2.4 and Table 2.5)(62).

Table 2.4: Body fat percentage categories in young male adults

Category	20-39 years
Essential	3- 5
Low/athletic	6- 7
Recommended	8- 19
Overweight	20- 24
Obese	≥ 25

Table 2.5: Body fat percentage categories in young female adults

Category	20-39 years
Essential	8 -12
Low/ athletic	13- 20
Recommended	21- 32
Overweight	33- 38
Obese	≥ 39

In order to determine whether any relationship could exist between visual skills and body composition, all three methods of determining body composition is implemented. The methodology used here is a good one because the measurements used and calculations done are easy to carry out. Measurements are standard across the world and subjects can be accurately categorised into weight classes. Each measurement by itself has been used in many studies and results are acceptable but the use of all three together gives a more accurate view of body composition that accounts for body structure, muscle mass and body fat percentages. The only limitation is that obtaining some measurements could be time consuming and need may arise in a large study for more than one person to take measurements which could lead to inaccuracies due to measuring differences. However, its inexpensive nature and accepted accuracy makes it the best method in helping to determine possible relationships between visual skills and body composition in its entirety or specific body measurements.

2.4.3 Cardiac health variables

The cardiovascular system affects various physiological processes of the body and is therefore an important variable to consider. The cardiovascular variables have an extra significance because not only can it showcase general cardiac health but it is also found to give an actual scientific measurement of the prevalence of a subject being under some form of psychological strain. There are many important measurements within the cardiac health field that can give an indication of general physiological and also psychological health. Some of these important measurements are; blood pressure, heart rate and cardio stress index.

2.4.3.1 Blood Pressure

Blood pressure (BP) commonly refers to the pressure of the blood against the inner walls of the blood vessels. Blood pressure is reported as systolic pressure/ diastolic pressure. Systolic pressure reflects the highest pressure created in the aorta during the process of ventricular systole (64). Diastolic pressure reflects the process of ventricular diastole and therefore the lowest pressure that is found in the arteries (64). Blood pressure is easily measured and is a good indication of the general health of the cardiovascular system. Blood pressure can be easily classified into different categories. A standard method of classifying blood pressure according to hypotension and hypertension at a variety of degrees are depicted in Table 2.6. Classification can however vary slightly in values according to age and gender.

Table 2.6: Standard classification of systolic and diastolic pressure values

Category	Systolic (mmHg)	Diastolic (mmHg)
Hypotension	< 100	<60
Normal	100- 130	60-85
High Normal	130- 139	85- 89
Mild Hypertension	140- 159	90- 99
Moderate Hypertension	160- 179	100- 109
Severe Hypertension	180- 209	110- 119

The nature of the cardiovascular system is such that it has effects on a variety of other physiological systems and processes. It is therefore very likely that the measures of cardiovascular health have effects on aspects of visual processing. There are a few studies that have specifically considered the effect blood pressure may have on various visual skills. A long-term study of over 25 years that sought to track the effect of systolic blood pressure on the cognitive performance of older adults by Swan, Carmelli and Larue showed that those subjects with high systolic blood pressures were found to have very poor visual memory and a poor overall cognitive performance (67). On the other side of the scenario, studies that have considered low systolic blood pressure in older adults have also found a decrease in cognitive performance (68). Although in older adults it is very possible that they experience a natural decline in visual skills similar results have been obtained in the few studies that have considered blood pressure (systolic and diastolic pressure as a whole) as related to visual skills in young adults (69). Therefore, it is very likely that visual skills and blood pressure share a curvilinear relationship with a normal range of blood pressure resulting in the optimum performance of visual skills. However, there is a need of more studies as previous studies are few and have not considered a variety of visual skills.

2.4.3.2 Heart Rate

Another measurement in cardiovascular health that needs to be considered in heart rate (HR). HR gives a view of the rate that the heart contracts (64). HR is controlled by the sinoarterial (SA) node which is commonly known as the pacemaker of the heart (64). HR therefore has the ability to increase/ decrease quickly and accurately based on the physiological changes or demands of the body. Therefore, a HR that is not within the normal range (60-80 bpm for young adults) can affect other physiological systems of the body. A change in HR could possibly affect the visual processing system in a similar manner as BP as a change in HR likely affects the way blood flows through the body i.e. increasing or decreasing blood flow. However, it is difficult to establish a relationship between HR and visual skills as no studies have specifically looked at this relationship. Therefore, further studies are needed to determine if HR could affect the performance of visual skills in any significant manner.

2.4.3.3 Heart rate variability, cardio stress index and the link between cardiovascular measures and psychological variables.

The relationship between the cardiovascular system and psychological variables like stress, anger, depression etc. is one that has been studied for years and has been well- researched (70-72). It is commonly accepted that strong emotions like stress for example, will lead to significant increases in blood pressure and heart rate. Another important cardiovascular measurement that has not been mentioned as yet is heart rate variability (HRV). HRV is not only used to give an indication of cardiovascular wellness but is also more sensitive manner of indicating if a subject is under stress (or any other psychological disturbances) through an actual scientific measurement. HRV is closely linked to psychological features because it determines the efficiency of the autonomic nervous system (ANS) (70). HRV is derived from a standard ECG by determining the standard deviation of intervals between successive R waves (SDRR) of the ECG (73). Through the SDRR a histogram can be created and the frequency domains are used to give more information on the parasympathetic and sympathetic influence on the ANS (73). The low frequency (LF) and high frequency (HF) ranges on their own offers important information about the ANS but the most important value is the LF to HF ratio (LF/HF) which indicates autonomic balance. Therefore, an LF/HF ratio of greater than 2 indicates sympathetic dominance (see Figure 2.2) (73).

This indication of ANS balance is an important one because from HRV, cardio stress index (CSI) can be derived. An increase in HRV= a decrease in CSI and a decrease in HRV = an increase in CSI. CSI is a measurement of stress as derived from HRV in a percentage form. This indicates the psychophysiological state of a subject. Although the reason for a high percentage of CSI could be due to physical stress on the heart and other external and internal stressors in addition with psychological stress, it is still an accurate means of determining psychological if other factors are accounted for.

The effect that variations of these cardiovascular measurements may have on visual skill performance could be much on the line as perceived stress is said to have on visual skills. Hypothetically, perceived stressed and physical stress should correlate very well and therefore high measures of CSI could translate into inconsistent and erratic visual search behaviour (40). Although speculation as to the effects of a high CSI can be made no research study has been carried out and therefore there is a great need to scientifically determine what relationship exists between visual skills and CSI if one does exist. Due to CSI providing a physical measure of stress and perceived stress determined too (as mentioned in section 2.4.1.2), these measures together can be used to determine whether a relationship exists between stress and visual skill performance too.

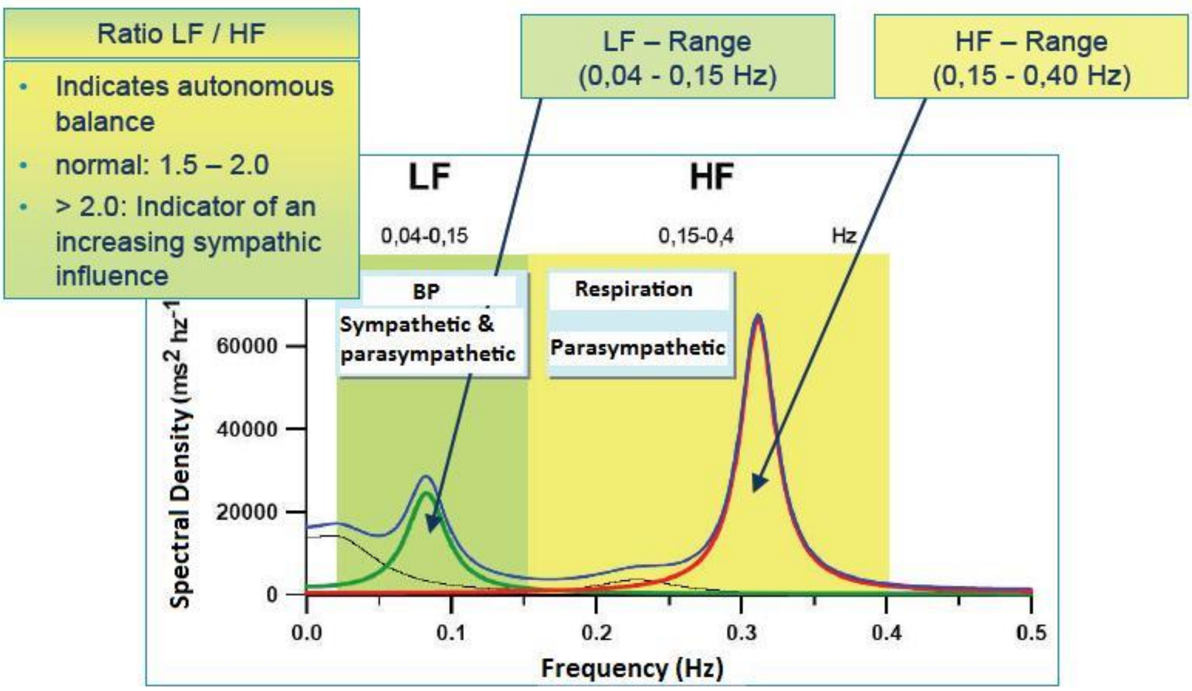

Figure2. 6: Heart rate variability analysis in frequency domain

2.4.3.4 Explanation and reasoning of methodology used

In order to determine if, what and how the cardiovascular system could affect visual skill performance different measures like BP, HR and CSI are determined and compared to visual skill performance. BP, HR and CSI on their own are good indicators of cardiovascular health but together they give more accuracy and a wider range of cardiovascular processes can be referred to. CSI has another role in the entire scope of this research study. In addition to indicated whether cardiovascular measures can affects visual skills, it is also a physical measure of stress (referred to as physical stress). The use of CSI adds more credibility in determining whether stress affects visual skills. CSI being a physical measure is not dependent on the participants elucidating their emotions (71). This brings another dimension to the research study. Therefore, together with perceived stress determined through questionnaires, CSI gives a more accurate view of the effect of stress on visual skills. Stress is one of the most common problems everyone in all forms of life have to deal with therefore to obtain the most accurate measure of stress is of importance.

The methods used to determine BP are standard and used in research throughout many different fields. In this study the method of determining CSI and heart rate is different from what is traditionally used. The norm for determining HRV would be to perform an ECG and then to perform certain calculations to determine CSI. In many cases, subjects often find an ECG uncomfortable. It is also expensive and very time consuming which normally limits sample sizes. In this study a Viport^{TM} is used (73). This is an innovative way is determining CSI and has many advantages over a standard ECG. Through the use of the Viport^{TM} , which is a portable hand-held device, the subjects experience no discomfort, testing is quick and easy (2 mins) and the device calculates CSI immediately therefore no further calculations are needed (73). The device is also inexpensive and therefore is suitable for use in large sample sizes. Although not used in many studies, therefore it is difficult to compare between studies and therefore difficult to ascertain its validity in measuring CSI, its use in general and sport medicine to date have shown positive results. Another advantage is that it also measures and displays HR, QRS duration and SDRR further making it possible to use just one device to determine a variety of cardiovascular measurements.

Therefore the determination of cardiovascular variables mentioned is used to determine if and how visual skills can be affected by the cardiovascular system. The determination of other lifestyle and anthropometric variables is a good feature of this study because all external variables that can interact with each other are accounted for. Therefore, through accounting for all these variables not only are possible relationships determined but it is also possible to determine that visual training itself and not any other external variables are the reasons for any possible improvements in visual skills.

2.5 IMPACT ON STUDENTS

The current study is aimed at determining the effectiveness of two visual training methods to improve the visual skills of university students after 6 weeks of visual skill training. This is important and extremely beneficial to university students because they require the effective use of a variety of visual skills throughout their tertiary academic career. Training of visual skills improves the way visual stimuli is processed and therefore visual skill performance (74).

Another important aspect is the influence of other external variables on visual skill performance. To date, very little consideration has been taken on the effect external variables may have on visual skills. By understanding if and how visual skills are affected by external variables, students can learn to gain control of these aspects which therefore may help in better visual skill execution (42). Through the performance of a complete lifestyle evaluation, an understanding of what aspects of life and wellness students are struggling with which, may affect academic performance, is achieved and therefore measures can be put in place by the student to rectify these problem areas. This information could also be beneficial to the university at large. This could help to improve general student life and academic performance (42).

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CHAPTER 3: RESEARCH PROCEDURE AND METHODOLGY

3.1 RESEARCH PROCEDURE

3.1.1 Research Participants

The participants of this study consisted of undergraduate physiology students registered at the University of Pretoria. An information session was held and students were informed of the nature, duration, logistics and basic procedure of the study. The students were not informed of possible expected results to prevent study bias. The students were asked to voluntarily participate in the study and all those that signed the informed consent form were eligible to be included in the study (Appendix A). The students were furthermore asked to inform the principal investigator of any medical or mental illnesses they may suffer from or if they were at that time on any medication. Participants were included in the study if they met the following inclusion/ exclusion criteria (Table 3.1).

Table 3.1: Inclusion/ Exclusion criteria

Inclusion Criteria	Exclusion Criteria
• Male and female undergraduate physiology students	• Medical illnesses - Cardiovascular diseases - Parkinsons disease - Untreated hyper/hypotension
• Age 18-25 years old	• Visual deficiencies - Colour blindness
• Voluntary participation and signed informed consent	• Medication that could affect the Central Nervous System
• Normal/ Corrected to normal vision.	• Diagnosed with any learning disability or mental illness

The sample size consisted of 600 undergraduate physiology students between the ages of 18-25 years old. The sample consisted of students of various ethnicities and each group had a random mixture of both males and females. There were no significant differences between groups in gender and age.

The study also presented no harm or danger to participants as all the methodology applied was non- invasive. Participants therefore experienced no discomfort. Participants were also assigned subject numbers before any testing took place to be used throughout the study. This ensured the confidentiality and privacy of the students at all times. The safety and comfort of the participants were maintained throughout the study and this study has been approved by the student research ethics committees of the Faculties of Health Science and Humanities.

3.1.2 Study design and procedure

This study consisted of a pre-test/ post-test study design. The participants after signing the informed consent form and completing a basic biographical information form (Appendix B) were assigned a subject number and thereafter all participants were randomly divided into three groups which differed in the visual training that they were exposed to. No specific group had a significant advantage in the natural visual skills at their disposal and no group as a whole were previously exposed to visual skill training or were part of a professional sports team which would give a significant edge over other groups where visual skills and visual skills training is concerned. Group 1 (n=169) acted as the control group, group 2 (n=225) and group 3 (n=206) underwent two different forms of visual skills training. Before analysis of the results students were also excluded from the study for incomplete participation or poor training attendance.

The entire study was carried out in 8 weeks. In week one all groups underwent initial testing which consisted of a lifestyle evaluation through the completion of a variety of standard and validated questionnaires that was used to obtain a general view of the type of lifestyle, habits and psychological makeup of the participants. Thereafter several physical and physiological measures of the participants were obtained such as; anthropometric measures (BMI, body circumferences and breadth, body fat percentages) and cardiac health measures (CSI, BP, HR). Finally a battery of visual skills (Visual acuity, Focusing, Tracking, Vergence, Sequencing, Eye-hand coordination, Visualisation) were tested according to methods outlined by Wilson and Falkel (1). The visual skills tested consisted of both *"hardware"* and *"software"* visual skills which gave a more holistic view of the effect of training on visual skills in its entirety (2,3). Following the initial week of testing the participants were exposed to different forms of training depending on the group they were allocated to. Group 1 (n=169) underwent no visual skills training for 6 weeks and therefore acted as the control group. Group 2 (n=225) underwent lab-based visual skills training and group 3 underwent an internet-based visual skills training programme. Both training programmes were carried out for a period of 6 weeks which is the most suitable time period for learning of new skills and consolidation of these skills (4). After this training period all groups underwent post-testing on all the variables tested during pre- testing. All testing took place at the University of Pretoria, Hatfield Campus. The testing conditions were identical for all groups (2). The study design and procedure is summarised in Table 3.2.

3.1.3 Statistical Analysis

Statistical analysis was done with the support of Dr L Fletcher, Department of Statistics,University of Pretoria. Data analysis consisted of univariate frequency tables, T-tests and repeated measures ANOVA's. All data that was collected was captured after weeks 1 and 8 and statistical analysis was done by means of the statistical package IBM SPSS Statistics 19.

The results from week 1 was compared to week 8 to determine if visual skills was affected by the two different approaches to visual skill training. A repeated measures MANOVA (Multivariate Analysis of Variance) was used to statistically analyse the results to protect against an inflated type I error. Post-hoc analyses consisted of paired t-tests for pairwise comparisons of the data. The comparisons of this study therefore consisted of between group comparisons of visual skills to determine if visual skill training significantly impacted all the visual skills tested and within group comparisons of visual skills and the other variables mentioned to determine if visual skills is significantly affected by external variables.

Table 3.2: A summary of research procedure

<table>
<tr><th>Pre- test</th><th>Group Allocations</th><th>Training</th><th>Post-test</th></tr>
<tr><td rowspan="3">Pre- testing was done on all groups. All groups completed the following tests:
• Lifestyle evaluation question naires
• Anthropo metric measures
• Cardiac health evaluation
• Visual skill battery of tests</td><td>Group 1- Control</td><td>No visual skills training for 6 weeks</td><td rowspan="3">Post- testing after 6 weeks on all groups. All variables were testes which include:
• Lifestyle evaluation question naires
• Anthropo metric
• Cardiac health evaluation
• Visual skill battery of tests</td></tr>
<tr><td>Group 2- Lab-based visual skills training</td><td>Lab- based visual skills training for 6 weeks. Visual skills training consisted of two sessions per week of 15 minutes each session. The training was a simple repetition of the tests in the visual skills battery designed by Wilson & Falkel (1). Training was supervised by trained assistants.</td></tr>
<tr><td>Group 2- internet-based visual skills training.</td><td>Internet based visual skills training for 6 weeks using a programme named Eyedrills. The participants trained using the Eyedrills VTS Drill skill which consists of 6 different drills. The amount of training done within this period was controlled by an online coach.</td></tr>
</table>

3.1.4 Special Requirements

1) Questionnaires were completed under supervision of the investigator to ensure that participants understood the questions and also to ensure that participants were not influenced by peers/friends.

2) Participants were asked not eat, drink or participate in any strenuous exercise or sport one hour prior to testing to ensure that immediate physiological responses to food and exercise do not influence the results.

3) Mood state questionnaires were completed at the same time of the day at both pre-testing and post-testing as mood could be significantly affected by time of day.

3.2 RESEARCH METHODOLOGY

All methods applied in this study were the standard methods used to test and measure the variables applicable to this study. These methods have well-known validity in the scientific community, are reproducible and can be used with ease in future studies and extensions to this study. The methodology applied is also not very technically challenging, fast to apply and inexpensive which is important to this study as the sample size is large. The methodology applied to test each variable will be explained in detail in the sections to follow.

3.2.1 Lifestyle evaluation questionnaires

A lifestyle evaluation is important to determine the general wellbeing of the participants which incorporates both physiological and psychological aspects of life (5). A lifestyle evaluation is important in this study to ensure that the participants do not significantly differ in lifestyle aspects that could affect the performance and training of visual skills. A good lifestyle evaluation accounts for aspects like nutrition, fitness and emotional and psychological health. The measurement of lifestyle aspects mentioned above are extremely difficult to measure physically and are therefore obtained from the answering of standard, validated questionnaires. This study made use of a variety of questionnaires to obtain a more accurate view of lifestyle of the participants.

An information session was held to explain the questionnaires to the participants. To ensure a comfortable and accurate completion of the questionnaires, the confidentiality of the participants were maintained by allocating subject numbers to all participants which appeared on the questionnaire forms instead of names. During this information session all questionnaires were thoroughly explained to the participants and any uncertainties regarding terminology and phrasing of questions were explained if required during the completion of questionnaires. All questionnaires were answered at the beginning of both the pre-testing and post-testing phases of this study.

All psychological-related questionnaires were evaluated and interpreted with the help of the psychology department, Faculty of Humanities, University of Pretoria. The questionnaires completed were as follows:

3.2.1.1 Family and personal medical history (Appendix C1)

The family and personal medical history form ascertains if the participants or any of their immediate family members suffer or died from any medical or psychological conditions. This is important information that was used to exclude any subjects that have conditions that will affect results. The family medical history is important information personally for the participants as it gave an idea of conditions that they may be predisposed to. The participants can use this information to implement prevention techniques.

3.2.1.2 State/ Trait personality inventory (STPI) (Appendix C2)

Spielberger's state/trait personality inventory (STPI) is used in psychology research to determine the emotional state and disposition of subjects. The STPI's reliability and validity has been well established and its use has been the standard method of psychological evaluation for many years (6). The questionnaire measures both state and dispositional anger, anxiety, curiosity and depression. The first 40 questions determined the current emotional state and participants answered about how they currently feel according to intensity with "not at all"= 1, "somewhat"=2, "moderately so"=3 and "very much"=4. The next 40 questions determined the disposition to have a personality trait of anger, anxiety, curiosity or depression and participants answered about how they generally feel according to frequency with "almost never"=1, "sometimes"=2, "often"=3 and "almost always"=4.

This questionnaire was used to determine if and how visual skills could be affected by emotions and personality traits.

3.2.1.3 Nutritional assessment (Appendix C3)

The nutritional assessment is 15 questions that were adapted and modified from the book "Fitness and Wellness for Life" (7). The questionnaire determines dietary behaviour and participants were asked to indicate the frequency of their food consumption or behaviour with either "always", "often", "sometimes", "rarely" or "never". The dietary behaviour of the participants was quantified and was used to determine if and how visual skill performance is affected by dietary behaviour.

3.2.1.4 Stress Index (Appendix C4)

The stress index is simply 16 questions regarding the prevalence of stressful situations in the participants' life and how stress is dealt with. This questionnaire was adopted and modified from the book "Total fitness and wellness" by Powers, Dodd and Noland (8). Participants simply answered "yes" or "no" to the questions. A questionnaire about stress is very much based on a personal perspective of the stress one is experiencing therefore this questionnaire gave a view of the "perceived" stress participants were under and not physical stress that is usually measured through physiological methods. Therefore this questionnaire was important to determine if and how perceived stress affects visual skill performance.

3.2.1.5 Lifestyle evaluation (Appendix C5)

This lifestyle evaluation questionnaire adapted and modified from the book "A wellness way of life" by Robbins, Powers & Burgess looks at the various lifestyle aspects like exercise/fitness, nutrition, tobacco use, alcohol and drug use, emotional health and safety and disease prevention which is important indicators of behaviour of the participants (9). Participants were asked to answer that which best describes their behaviour in each category with "always", "sometimes" or "never". This questionnaire together with the others was used to determine if and how each lifestyle variables affected the performance of visual skills.

3.2.1.6 Health/fitness and activity index (Appendix C6)

The Paffenbarger Physical Activity questionnaire was used to further determine the lifestyle behaviour of the participants (10). In this questionnaire participants were further questioned on dietary history and asked to rate their nutritional knowledge. In the health/lifestyle index section of the questionnaire participants answered lifestyle frequency of behaviour regarding nutrition, exercise and other health aspects with “very often”, “often”, “sometimes”, “rarely” or “never”. In the work/activity index and leisure activity index frequency of working activities and how leisure time is generally spent was rated using the same criteria. This questionnaire was used to further determine if and how visual skill performance is affected by lifestyle aspects.

3.2.1.7 FIT index of Kasari (Appendix C7)

The final questionnaire completed by the participants was the FIT index of Kasari which determines the frequency, intensity and time spent on physical activity (11). Therefore this questionnaire was used to determine if and how fitness levels affect visual skill performance. These questionnaires were collectively used to obtain a lifestyle evaluation of the participants.

3.2.2 Anthropometric Measurements

After questionnaires were answered anthropometric measurements of the participants were taken. The anthropometric measurements were used to determine BMI, body circumferences and skeletal breadth, and body fat percentages. All these measurements are easy to perform and can be done at a very low cost. These measurements together give a more realistic view of body composition as they account for body fat and muscle mass and can therefore be used to determine if and how visual skill performance is affected by body composition. All measurements were taken by trained lab assistants in a separate room or behind a screen to ensure the privacy of participants.

3.2.2.1 Body mass index (BMI)

BMI is a value calculated by obtaining height and weight of an individual. To determine height participants were asked to remove their shoes and stand against a height measuring ruler with feet together flat on the ground, head straightened and in a neutral position. Height was measured in metres (m). Weight was obtained by participants removing shoes and any heavy clothing and standing on a digital, calibrated scale. Weight was measured in kilograms (kg). BMI was then calculated using the following equation:

$$\text{BMI} = \frac{\text{Weight/ Height}^2}{\text{Kg/m}^2}$$

3.2.2.2 Body circumferences and skeletal breadth

Participants were asked to stand with feet slightly apart and circumferences of various parts of the body were taken using a standard measuring tape. All measurements were taken on the right side of the body to maintain uniformity. The body parts measured included the upper part of the body such as; the neck, shoulder, chest, waist, abdominal, arm, forearm, wrist and the lower part of the body such as; hips, proximal thigh, mid- thigh, distal thigh, knee, calf and ankle. All circumference measurements were taken in centimetres (cm). The waist to hip ratio (WHR) was also calculated using the following equation:

$$\text{WHR} = \frac{\text{waist (cm)}}{\text{hip (cm)}}$$

Skeletal breadth of the elbow and knee was also determined in millimetres (mm).

3.2.2.3 Body fat percentages

Body fat percentages were obtained by determining the amount of subcutaneous fat at 8 different parts of the body. The subcutaneous fat was determined by performing a skinfold test using a standard calliper. All measurements were taking on the right side of the body. Measurements were taken at the biceps, triceps, sub- scapular, abdomen, suprailliac, thigh, calve and midaxcilliary in mm. These measurements were then applied in equations (different equations according to gender) to determine body fat percentage.

3.2.3 Cardiac health measurements

Cardiac health assessments were then performed by determining resting blood pressure (BP), heart rate (HR) and cardio stress index (CSI). These measurements not only indicate cardiovascular health but are also strongly associated with stress (12). Therefore these measurements give an idea of if and how cardiovascular health and physical stress (as opposed to perceived stress obtained from questionnaires) can affect the performance of visual skills. Resting BP, CSI and HR were obtained via the following methods:

3.2.3.1 Resting Blood pressure (BP)

Resting blood pressure was taken using a certified and standard electronic blood pressure device. Blood pressure was taken with participants in a seated position. The cuff was wrapped around the left arm above the elbow of participants. The cuff was automatically inflated and deflated by the machine and both systolic and diastolic BP measurements were displayed in mmHg.

3.2.3.2 Cardio stress index (CSI) and heart rate (HR)

In order to obtain a CSI percentage values, methods in the past involved many time consuming calculations and the use of expensive ECG equipment. This has been remedied by the design of handheld devices that provide a fast, easy and inexpensive way to calculate CSI % (13). The device used in this study was the Viport™ (Energy- Lab Technologies GmBH) (Figure 3.1) (14). The Viport uses the same technology as an ECG and displays and calculates the CSI% without the investigators having to perform calculations themselves. Participants were asked to be seated in a separate room or behind a screen to ensure privacy. The Viport was placed on the left side of the participants' chest with conducting gel on all three electrodes of the Viport. Participants were asked not to talk during the 2 minutes of measuring as this could interfere with the Viport measuring process. After the 2 minutes the following measurements are displayed on the Viport screen:

CSI= %
QRS duration (stimulus conduction through ventricles) = ms
Heart rhythm = yes/ no
HR= beats per minute (bpm)
RRSD (standard deviation as absolute degree of heart rate variability)

Therefore from this device both CSI % and HR was obtained and used to be compared with visual skills.

Figure 3.1: A Viport device (14)

3.2.4 Visual skills testing

The visual skills testing method in this study is a battery of visual skills tests designed by Wilson & Falkel (1). This battery of visual skills tests are suited for students and therefore move away from the traditional sports vision testing methods and apparatus used when testing athletes. The battery of tests designed by Wilson & Falkel has been used before in sports vision research and is a validated and effective way of testing visual skill performance. This method is simple, easily reproducible and inexpensive as it does not require the expensive equipment used for sports vision research on athletes.

Those participants who had corrected vision via prescriptions were asked to wear their prescription lenses/ contact lenses throughout the visual skills testing process. The battery consisted of testing of visual skills that were all important to university students. The visual skills tested were:

3.2.4.1 Visual acuity

Visual acuity is the ability to clearly see detail of a stationary object consisting of different sizes at a specific distance. The universal standard of testing visual acuity is by using a Snellen chart. The Snellen chart consists of rows of alphabet which each row consisting of different sizes of alphabets. The chart was placed on a wall and participants were asked to stand 6m from the chart. They were then required to read each row of letters from the top monocularly and then binocularly. The visual acuity was recorded for each case in the form of a fraction indicating where on the Snellen chart the participant could read accurately. All participants that did not have normal/ corrected to normal visual acuity was excluded from this study as performance of other visual skills would be hampered.

3.2.4.2 Focusing

Eye movements are an important visual skill for university students who read and take notes while studying and in lectures. This research study tests three different forms of eye movements; focusing, tracking and vergence.

Focusing tests the accommodative abilities of the eyes and therefore its ability to see and focus clearly at different distances. In order to test this focusing ability a large letter chart was placed on a wall and participants were asked to stand at the furthest distance they were able to see all letters clearly of the large letter chart. A small letter chart was held by the participants about 10cm from the face at nose level. Starting with the small letter chart participants were required to read one letter from the small letter chart and one letter from the large letter chart and continue alternating between charts for 1 min or until a mistake was made (Figures 3.2 & 3.3). The number of letters correctly read was recorded for that 1 min period or until the mistake was made. This therefore tested the speed and accuracy of the focusing abilities of the eyes.

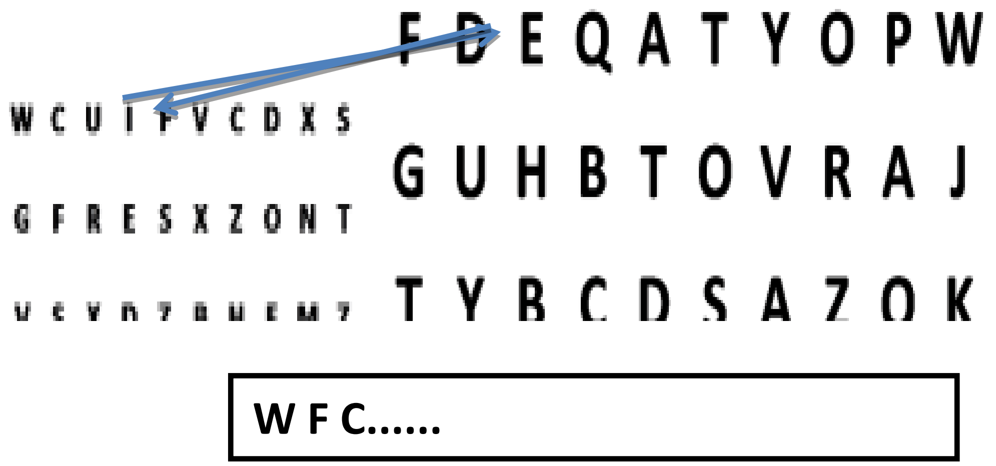

Figure 3.2: The large and small letter charts used when testing focusing.

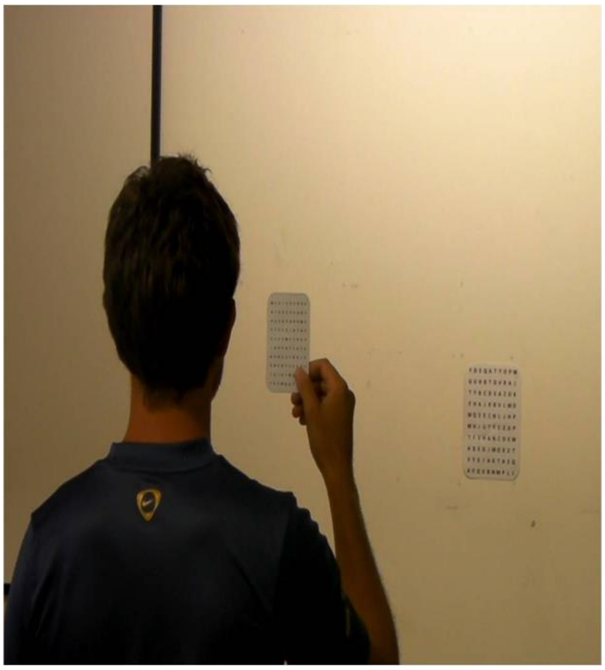

Figure 3.3: A participant performing the focusing test.

3.2.4.3 Tracking

The next eye movement tested is the tracking abilities of the eyes. This tests the ability of the eyes to make quick saccadic jumps from one point to another. Two strips of letters were placed on a wall with 1m between each other. The participants were required to stand 1m from the wall and without moving the head read one letter from each strip alternatively started from the left strip (Figure 3.4). The number of letters read correctly in 1min or until a mistake was made was recorded.

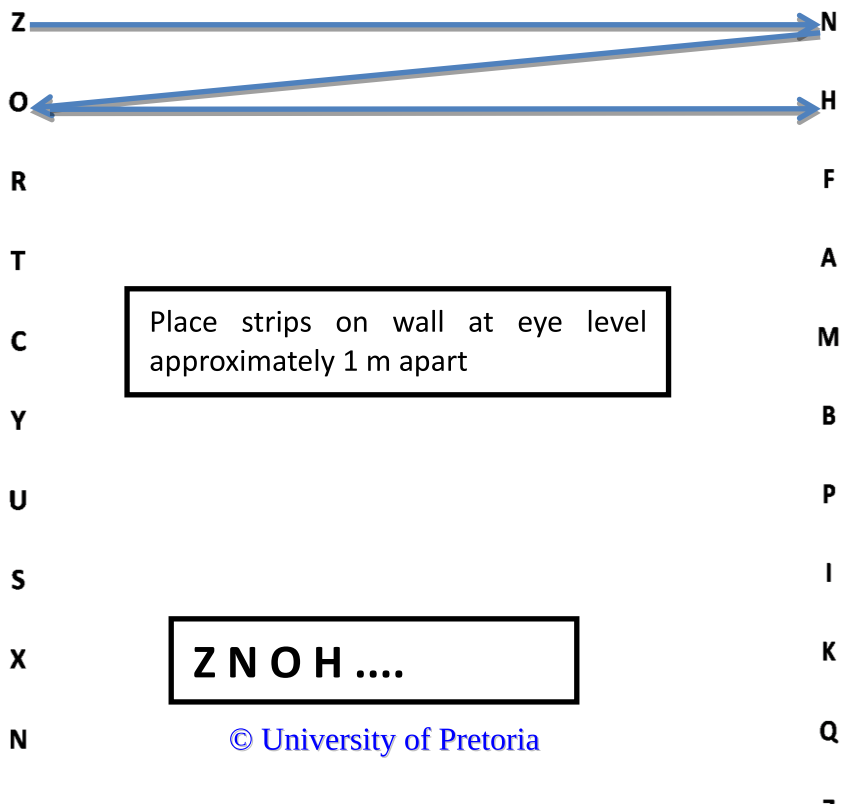

Figure 3.4: Two strips of letters used when testing tracking.

3.2.4.4 Vergence

The final type of eye movement test is vergence. Vergence is the ability to cross and uncross the eyes and maintain single vision (1). At the point that the eyes are no longer able to converge a double image is seen. A pencil- push up test was done in order to test vergence. Participants were asked to hold a pencil at arm's length. Focusing on the tip of the pencil and in line with the nose participants were required to slowly move the pencil closer. They stopped as soon as a double image was seen and the distance from the tip of the participants' nose and the tip of the pencil was recorded in centimetres (cm). If no double image was seen at all, the distance was recorded as 0 cm (Figure 3.5).

Figure 3.5: Pencil push- up test.

3.2.4.5 Sequencing

Sequencing skills entails the ability to organise and structure visual information (1). Adequate sequencing techniques are important to university students and can be a good studying skill. In order to test this ability to organise visual information participants were shown a sequence of hand movements by a trained assistant that consisted of either P= palm face down, S= side of hand and F= fist. The first sequence started with three movements and increased each time (Figure 3.6 and Figure 3.7). Participants were required to repeat each sequence to the assistant after being shown the sequence. The number of sequences correctly repeated was recorded.

P S F

F P S F

S F P S P

F S F P F S

P P S F S F P

S F P F P S F P

F F P S P S F P F

S P F P S P F P S P

P = Palm S; = Side of Hand; F = Fist

Figure 3.6: Sequences required to be repeated by participants

Figure 3.7: Participant performing the sequencing test

3.2.4.6 Visualization

Visualization involves the ability to form a mental image (1). Visualization is another important studying technique especially in subjects that require a lot of visual information to be processed and understood. The ace to seven test is an effective way to test visualization. In this test seven cards from ace to seven was placed on a table in random order. Participants were asked to look at the cards and try to remember the order of each card. All the cards were then flipped over (i.e. face down) and participants were then required to turn over the cards in order from ace to seven in the quickest time possible (Figure 3.8). If a card was turned over out of order all the cards had to be put face down again and participants would start again beginning from ace. The recording of time started as soon as the participants looked at the ordered cards and stopped when the last card was turned over. The amount of time it took to complete this test was recorded in seconds (sec).

Figure 3.8: Participant completing the ace to seven visualization test

3.2.4.7 Eye- hand coordination

Eye- hand coordination involves the ability to respond to visual stimuli in a coordinated manner via the CNS and response system. It is a skill that is required by everyone in all walks of life. An easy and inexpensive way of testing eye- hand coordination is through the ice-cube tray catch test. An ice-cube tray was marked from 1 to 12 sequentially with 1 being in the upper left corner, 2 in the lower left corner, 3 in the 2nd upper cube and so on (Figure 3.9). A coin was placed in the cube numbered 1 and participants were required to flip the coin in order from 1 to 12. If the coin fell out or a number was skipped the participant started from the last correct number. The time taken to flip the coin from 1 to 12 in order was recorded in seconds (sec).

Figure 3.9: Participant performing the ice-cube tray coordination test

3.2.5 Visual skill training

Two training methods were tested in this study. During both training methods participants were required to wear any prescription/contact lenses if they had corrected visual acuity. This ensured that any improvements in visual skills were due to the enhancement of the skill and not a mere correction of visual deficiencies (15).

The first training method as applied to group 2 was lab- based training of visual skills that consisted of attending two training sessions per week at the University of Pretoria, Hatfield campus. The training involved the repetition of the visual skills tests mentioned previously which was designed by Wilson & Falkel (1). As is common with sports vision exercises, visual skills tests can interchangeably be used as visual skill training. Participants were required to attend two sessions of training per week that consisted of 15 minutes per session for a six week duration. During each session participants went through all the visual skills tests once per session. Training was at all times performed under the supervision of trained assistants.

The second training method that was applied to group 3 was an internet based training programme *Eyedrills*. Eyedrills is a visual skill training programme that was scientifically developed by a group of sports vision specialist. Participants were asked to train visual skills by using the *Eyedrills VTS drill skin* that consists of six sports vision exercise drills. Each drill trains different visual skill elements that are very specific to the needs of the participants and consists of 100 levels each with each level being more challenging than the previous one. This makes visual skill training not only more interesting but also challenging and competitive as participants aimed to complete as many levels as possible. Each drill and the rules pertaining to training are adequately explained on the website. The drills completed consisted of:

- **Avoiding**- this drill consisted of a blue balls and red balls moving randomly on screen. Participants were required to control the movement of the blue ball with a computer mouse such that contact with the red balls is avoided. If contact with a red ball is made a deduction to the score is made. To complete a level a target score for that level had to be reached.
- **Bouncing ball**-A bouncing soccer ball was displayed on screen and participants were required to continuously click on the ball to keep the ball in air. A level is completed once a target score is reached.
- **Moving arrows**- displayed on the screen was three arrows (black, red and green) that moved in either a left to right, right to left, top to bottom or bottom to top manner. Participants were required to press the keyboard arrows in correspondence with the black arrow only. If the wrong direction was pressed a score was deducted. A level was completed once a target score was reached.
- **Peripheral awareness**- 5 pictures were displayed, a picture in the middle, and pictures to the left, right, top and bottom of the middle picture. Participants were required to focus on the middle picture and using peripheral vision select from the other pictures the one that matches the middle picture. A selection was made by using the keyboard arrows. A level was completed when a target score was reached.
- **Rotating arrows**- three arrows (black, red and green) are rotating forming circles at a certain speed. The participants were required to indicate the direction of the black arrow while focusing on the inner circle in a certain time

limit with an indication of the wrong direction resulting in a deduction in the score. a level was completed once a target score was reached.

- **3D stereograms**- a set of 3D images with possible answers are displayed at the bottom of the image. Participants were required to click on the correct answer. A level was completed once a target score was reached.

These drills together aim to improve a mixture of visual skills like eye movements, visual concentration, eye- hand coordination etc. Participants were required to access the training on the Eyedrills website and complete each drill. Training took place at any time suitable to the participant during a six week period and at any place that had a computer with internet access. The amount of training done by each participant was controlled by the unique coaches corner that is available on the programme and if training was insufficient participants were informed to increase their time spent on training.

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CHAPTER 4: RESULTS AND DISCUSSION

4.1 RESULTS

Statistical analysis consisted of univariable frequency tables, t- tests and repeated measure ANOVA's. Repeated measure MANOVA's were also carried out to protect against type I errors that are common when dealing with large sample sizes like these. Statistical analysis was done with the help of the University of Pretoria's Statistics Department and was performed using the statistical package IBM SPSS Statistics19. The results obtained for each group are displayed in the tables that follow.

4.1.1 Group 1(Control group) results

Table 4.1 depicts the mean values and standard deviations of the performance of visual skills in the control group at pre and post testing. Although performance of all visual skills improved only performance in visualization ($p<0.001$) and vergence ($p<0.008$) improved significantly. The improvement in the performance of the visualization test also moved the group from an average performance to an excellent performance in visualization according to the standards set out by Wilson and Falkel (see Appendix D1 for standards on performance of visual tests) (1). Although results are not significant statistically, the improvement in the tracking and eye-hand coordination test also moved the group from a low performance to an average performance. Visual skill performance as a whole improved from a low performance level to an average performance level between pre and post testing.

Table 4.1: Mean values (SD) of visual skill performance at pre and post testing in the control group

	Pre- test		Post- test	
	Mean (SD)	Sample size(n)	Mean (SD)	Sample size(n)
Focusing(letters/min)	48.95(±22.12)	112	53.95 (±21.25)	112
Tracking(letters/min)	34.34(±21.80)	112	40.40 (±21.45)	112
Vergence(cm)*	3.58 (± 3.27)	112	2.66 (± 2.44)	112
Sequencing(#correct sequence)	2.01 (± 1.03)	112	2.33 (± 1.05)	112
Visualization(sec)**	47.03(±21.79)	112	37.23 (±18.65)	112
Eye-hand coordination(sec)	43.57(±27.11)	112	38.32 (±21.92)	112

*p<0.008 **p<0.001

Table 4.2 depicts the mean values and standard deviations of anthropometric measurements of the control group at pre and post testing. Only body fat percentage (p<0.001) increased significantly. All body composition measures were in the low/ low- moderate risk category (risk levels were designed to accommodate for a mean value that would include both genders (See Appendix D2).

Table 4.2: Mean values (SD) of anthropometric measurements at pre and post testing in the control group

	Pre- test		Post- test	
	Mean (SD)	Sample size(n)	Mean (SD)	Sample size(n)
Waist to Hip ratio (WHR)	0.82(±0.07)	160	0.80(±0.09)	138
Body Mass Index (BMI)	23.16(±4.09)	159	23.45(±4.11)	139
Body Fat percentage(%)*	19.99(±8.16)	159	21.78(±7.74)	139

*p<0.001

Table 4.3 depicts the mean values and standard deviations of cardiac health variables within the control group at pre and post testing. Cardio stress index (p<0.001) increased significantly but stayed within in the moderate risk level (see Appendix D3). Heart rate (p<0.001) also increased significantly and moved from a low risk value to a moderate risk value.

Table 4.3: Mean values (SD) of cardiac health variables at pre and post testing in the control group

	Pre- test		Post- test	
	Mean (SD)	Sample Size (n)	Mean (SD)	Sample Size (n)
Systolic BP (mmHg)	124.24(±15.11)	121	128.59(±13.40)	121
Diastolic BP (mmHg)	80.69(±7.83)	121	78.45(±9.30)	121
Cardio Stress Index (CSI) (%)*	28.91(±21.26)	121	31.51(±20.90)	121
Heart Rate (HR) (bpm)*	78.26(±13.27)	121	81.64(±12.77)	121

*p<0.001

4.1.2 Group 2 (Lab- based training) results

Table 4.4 depicts the mean values and standard deviations of the performance of visual skills in the lab-based visual skill training group at pre and post testing. After the training of visual skills for six weeks by using the testing methods as training methods, all visual skills improved at a significance level of p<0.001 with the exception of vergence. The tracking visual skill improved such that the group moved from an average performance to an excellent performance. Overall the visual skill level remained at an average performance level after training.

Table 4.4: Mean values (SD) at pre and post testing of visual skill performance in lab-based training group.

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
Focusing(letters/min)*	42.52(±18.81)	162	52.97(±18.74)	162
Tracking(letters/min)*	55.97(±17.58)	162	62.48(±18.23)	162
Vergence(cm)	4.41(±3.60)	162	4.41(±4.02)	162
Sequencing(#correct sequence)*	2.03(±0.96)	162	2.38(±1.14)	162
Visualization(sec)*	52.44(±25.79)	162	41.96(±19.89)	162
Eye-hand coordination(sec)*	47.81(±31.95)	162	30.36(±18.37)	162

*p<0.001

Table 4.5 depicts the mean values and standard deviation values of anthropometric measurements at pre and post testing in the lab- based visual skill training group.

BMI (p<0.001) increased significantly but this increase did not translate in a shift in risk level and the group still remained at a low risk level. Body fat percentage (p<0.001) also improved significantly with a decrease in mean values at post-testing. This improvement too did not translate into a shift in risk level.

Table4.5: Mean values (SD) of anthropometric measurements at pre and post testing in lab-based training group

	Pre-test		Post-test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
WHR	0.76(±0.07)	155	0.77(±0.06)	155
BMI*	22.99(±4.13)	155	23.50(±4.15)	155
Body fat %*	24.31(±8.16)	155	22.86(±7.76)	155

*p<0.001

Table 4.6 depicts the mean values and standard deviations of cardiac health variables at pre and post testing in the lab- based visual skill training group. Systolic blood pressure increased significantly but at a significance level of p<0.039 and CSI too increased significantly at p<0.017. Systolic blood pressure remained at a low risk level and CSI also remained within the moderate risk level.

Table4.6: Mean values (SD) of cardiac health variables at pre and post testing in the lab-based training group

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
Systolic blood pressure(mmHg)*	117.41(±12.35)	161	119.45(±12.43)	161
Diastolic blood pressure(mmHg)	72.69(±9.63)	161	72.90(±9.91)	161
CSI(%)**	31.15(±20.55)	162	36.02(±24.06)	162
HR(bpm)	81.4(±12.95)	162	83.21(±14.77)	162

*p<0.039 **p<0.017

4.1.3 Group 3 (Eyedrills training) results

Table 4.7 depicts the mean values and standard deviation of the performance of visual skills at pre and post testing of the Eyedrills training group. After six weeks of training via the internet training programme Eyedrills, focusing ($p<0.001$), tracking ($p<0.004$) and eye- hand coordination ($p<0.001$) significantly improved but still remained within the average performance level. The overall visual skill performance was at an excellent level and remained at an excellent performance level after visual skill training.

Table4.7: Mean values (SD) of visual skill performance at pre and post testing in Eyedrills training group

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
Focusing(letters/min)*	46.22(±21.89)	186	53.60(±19.84)	186
Tracking(letters/min)**	46.35(±22.90)	186	51.79(±22.15)	186
Vergence(cm)	1.86(±2.22)	186	2.22(±2.22)	186
Sequencing(#correct sequence)	1.96(±1.01)	186	2.03(±0.94)	186
Visualization(sec)	38.66(±18.13)	186	39.36(±18.16)	186
Eye- hand coordination(sec)*	37.41(±20.10)	186	32.14(±19.38)	186

Table 4.8 depicts the mean values and standard deviation of anthropometric measurements at pre and post testing in the Eyedrills training group. There were no significant changes in all anthropometric measurements. The group was in the low risk level for all anthropometric measurements at both pre and post testing.

Table4.8: Mean values (SD) of anthropometric measurements at pre and post testing in the Eyedrills training group

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
WHR	0.82(±4.11)	119	0.82(±7.41)	119
BMI	23.46(±4.20)	202	23.47(±4.11)	187
Body fat %	24.47(±7.75)	119	23.55(±7.41)	119

*p<0.001 **p<0.004

Table 4.9 depicts the mean values and standard deviation of cardiac heart variables at pre and post testing in the Eyedrills training group. After the six weeks significant increases were found in diastolic blood pressure and heart rate both at a significance level of p<0.034. Although significant increases were found, diastolic blood pressure remained within a low risk level and heart rate remained within the moderate risk level at post- testing.

Table4.9: Mean values (SD) of cardiac health variables at pre and post testing in Eyedrills training group

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
Systolic blood pressure(mmHg)	127.62(±13.87)	191	128.72(±14.20)	191
Diastolic blood pressure(mmHg)*	84.52(±11.61)	191	86.06(±9.93)	191
CSI(%)	36.43(±24.94)	191	38.15(±26.31)	191
HR(bpm)*	83.79(±14.98)	191	85.71(±15.85)	191

*p<0.034

Lifestyle was also another external variable that was considered in the Eyedrills training group only. Table 4.10 depicts the mean values and standard evaluations of lifestyle factors that were scored using questionnaires. There was a significant decrease on the tobacco use score at p<0.012 indicating a slight increase in tobacco use. The tobacco use however still remained in the low risk category. Disease prevention knowledge also increased significantly at p<0.048. All other lifestyle variables remained within a low-moderate risk level.

The results can be further analysed by looking at comparisons between all three groups considering visual skill performance, anthropometric measurements and cardiac health variables. Lifestyle variables were only considered in the Eyedrills group and therefore no comparisons to other groups can be made.

Table 4.10: Mean values (SD) of lifestyle variables at pre and post testing in the Eyedrills training group

	Pre- test		Post- test	
	Mean(SD)	Sample size(n)	Mean(SD)	Sample size(n)
Exercise	4.92(±2.73)	193	4.87(±2.64)	193
Nutrition	4.80(±2.38)	193	4.64(±2.32)	193
Tobacco use*	8.68(±2.53)	193	8.15(±2.68)	193
Alcohol and drugs	8.14(±2.19)	193	7.88(±2.35)	193
Emotional health	5.96(±1.99)	193	5.90(±2.24)	193
Safety	8.64(±1.24)	193	8.64(±1.43)	193
Disease Prevention**	6.07(±1.81)	193	6.38(±2.24)	193
Lifestyle Total	47.20(±7.56)	193	46.46(±8.96)	193

*p<0.012 **p<0.048

4.1.4 Visual skills

In order to obtain a graphical presentation of the improvements or decrease in performance of each visual skill within each group, the mean difference within each group between pre and post testing was calculated. These mean differences are graphically displayed in Figure 4.1. Visual skill performance greatly improved in the lab- based training group with significant improvements in all visual skills with the exception of vergence. Although the other groups did have improvements in sequencing, the lab- based training group was the only group that had significant improvements in this skill. When comparing the two training methods with the skills that both groups experienced significant improvements, the lab- based training group had greater improvements in focusing and much greater improvement in eye- hand coordination. The lab-based training group also had significant improvements in visualization whereas the Eyedrills training group actually suffered a slight decline in visualization performance.

The control group was the only group that had significant improvements to vergence and the significant improvement in visualization in the group was quite similar to that of the lab- based training group.

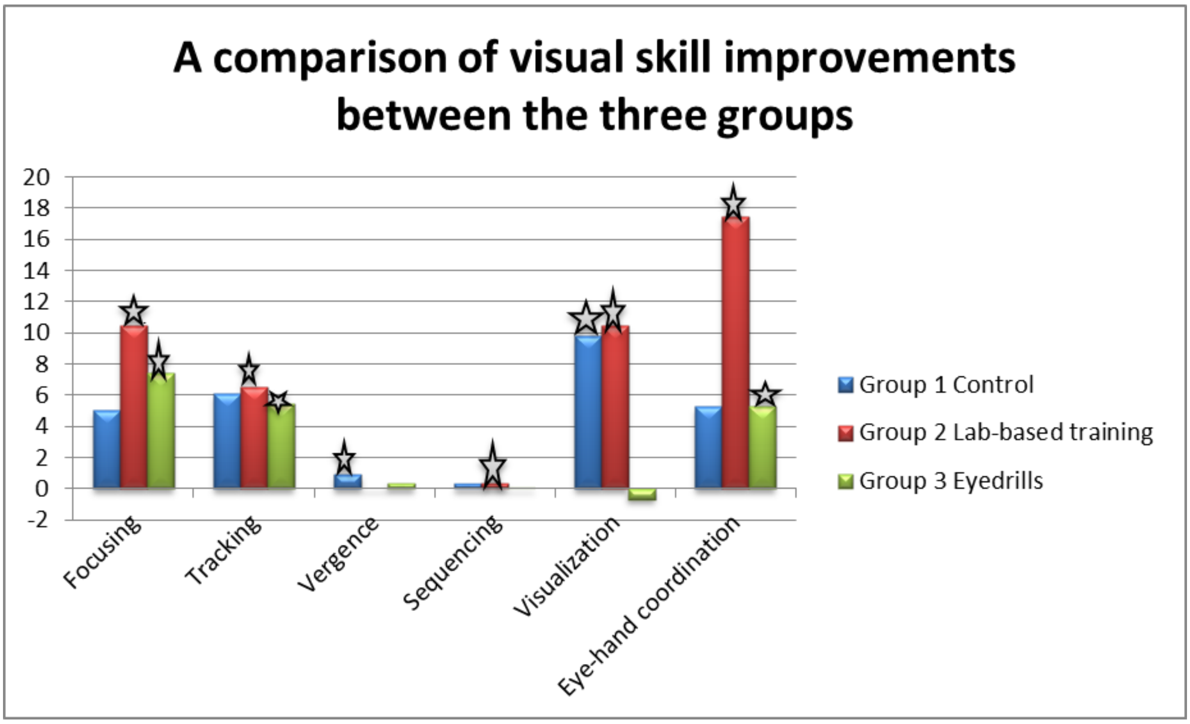

Figure 4.1: Comparison of visual skill improvements between the three groups

4.1.5 Anthropometric measurements

The mean difference within each group between pre and post testing was calculated and differences between each group for each body composition measurement was compared and graphically displayed in Figure 4.2. The Eyedrills training group experienced no significant changes in anthropometric measurements. Although body fat percentage did decrease and therefore improve, this change was not significant. The control group did experience a significant increase in body fat percentage. The lab-based training group experienced the most change to body composition measurements as compared to the other groups with a significant decrease and therefore an improvement to body fat percentage and increase of BMI. The WHR was one of the most consistent measurements that experienced very little change in all three groups.

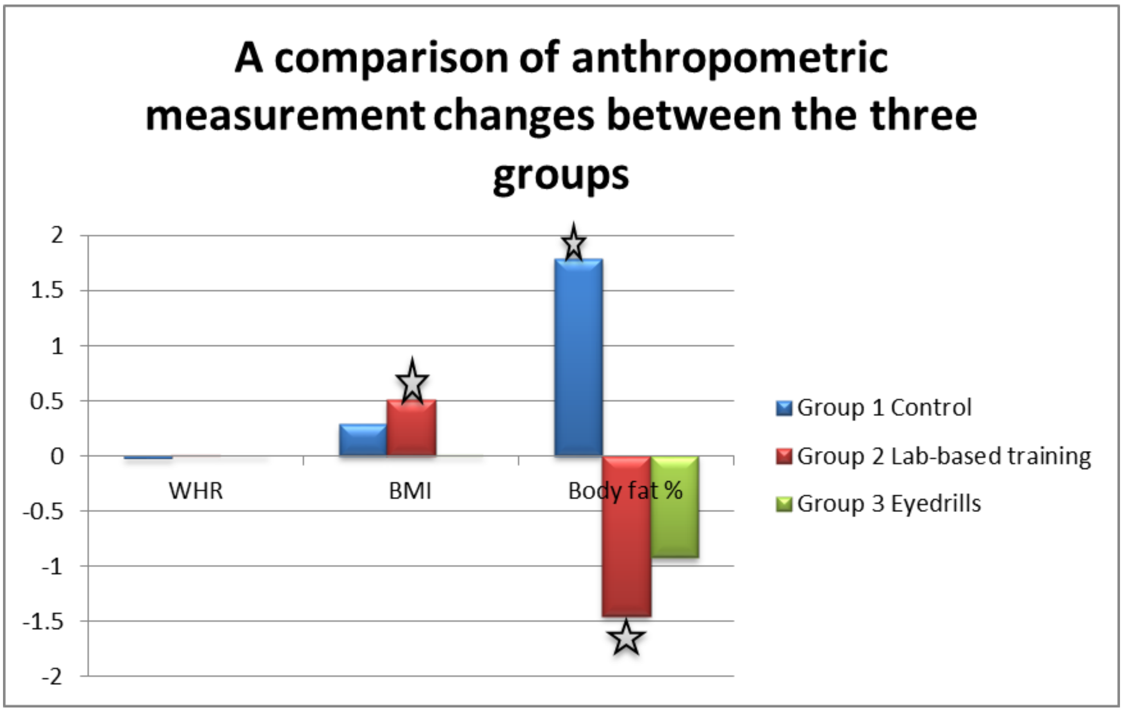

Figure 4.2: Comparison of anthropometric changes between the three groups

4.1.6 Cardiac health variables

The mean differences within each group between pre and post testing were determined for each cardiac health variable. The differences were compared between each group and displayed graphically to demonstrate the changes in each cardiac variable that took place within each group. This data is depicted in Figure 4.3. All variables increased at post testing with the exception of diastolic pressure in the control group that experienced a decrease. Systolic blood pressure increased in all three groups but only the increase in the lab- based training group was significant. The only significant change to diastolic pressure was an increase in the Eyedrills training group. Cardio stress index increased in all three groups but only the increase in the control group and lab- based training group was significant. Heart rate too increased in all three groups with significant increases in only the control and Eyedrills training group. The changes to cardiac health variables across the three groups were quite several and varied.

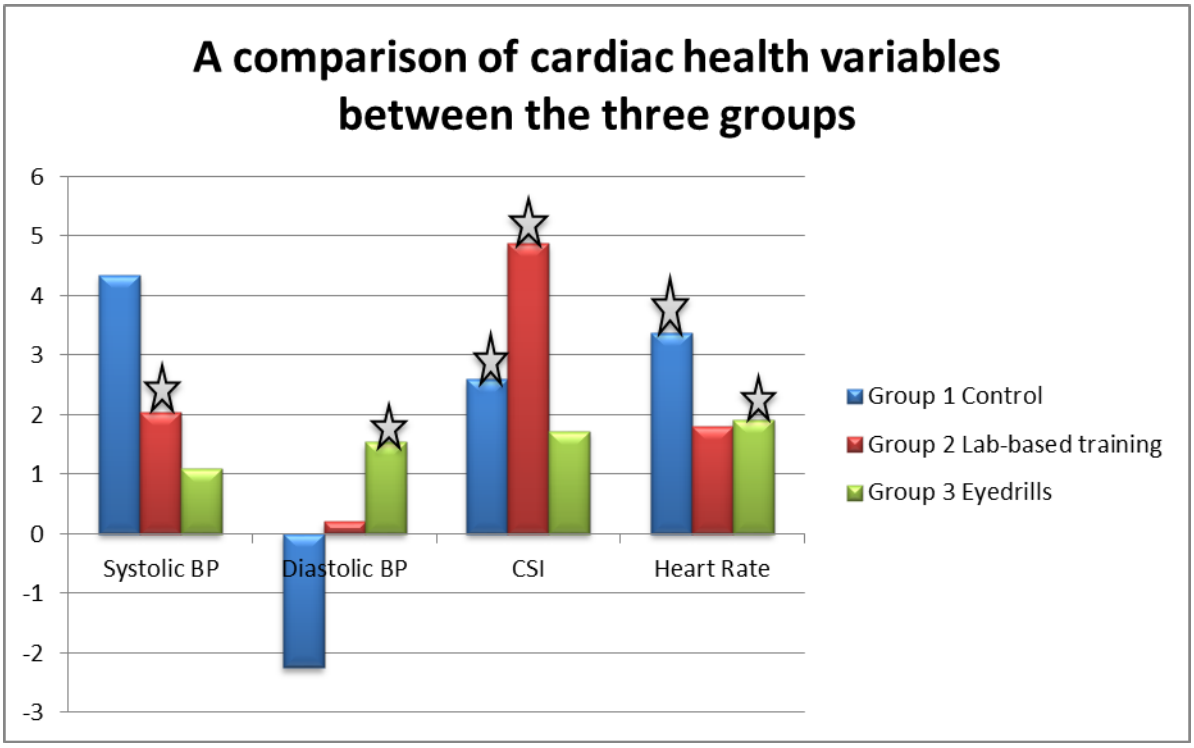

Figure 4.3: Comparison of cardiac health variables between the three groups

4.2 Interpretation of results and discussion

This research study looked at two main aspects; the ability to improve visual skills through training and the interaction of visual skills and other external variables. The results of these two aspects will be discussed in the sections that follow.

4.2.1 Visual skill training

This research study looked at the ability to train and improve visual skill performance through two different training programs. The six weeks of visual skill training generally resulted in visual skill improvement in both the lab- based training group and Eyedrills training group. The fact that both training groups improved in visual skill performance highlights the effectiveness of visual skill training and therefore the need for visual skill training programs. This somewhat clears the doubts created by previous research that has shown inconclusive results of whether visual skill training is of benefit. When compared to the most highly referenced research studies in the sports vision field, this study disagrees with conclusions reached in works by Abernethy & Wood (2) and Wood & Abernethy (3), who due to insignificant improvements in visual skills tested after training, concluded that visual skills are not trainable and that any improvements in visual skills after training is due mainly to test familiarity. However, the results of this study do agree with more recent research by Farrow & Abernethy (4), du Toit, Kruger & Neves (5), du Toit, Kruger, Joubert et al (6) and du Toit, Kruger, Fowler et al (7), all of which have found significant improvements in visual skills tested after visual skill training. The significant improvements in visual skills further show that not only are visual skills trainable in athletes but are also trainable in students. Although this is contradictory to previous research with most of the studies conducted on athletes like that by Farrow & Abernethy (4), du Toit, Kruger & Neves (5), du Toit, Kruger, Joubert et al (6) and du Toit, Kruger, Fowler et al (7) as mentioned above, resulting in significant improvements and those conducted on non-athletes like that by Wood & Abernethy (3) and Abernethy & Wood (2) have resulting in non-significant results, this study agrees with a study also on university level students by du Toit, Kruger, Mahomed et al (8), that has also found significant improvements in visual skills after visual skill training. This notion that visual skills are trainable in students and not only athletes is important in the extension of sports vision to other fields besides the sports science field.

Another important aspect is the training methods that were implemented in this study. Comparisons between different studies that use different training methods are difficult to carry out because of other variables that are not constant between the studies such as; time spent on training, intensity of training and the type of skills trained. Therefore implementing two different training methods while keeping the other variables mentioned above constant within this study is an ideal way to compare different training methods. On further analysis of the two training methods it is clear that the lab- based training group experienced a wider improvement in visual skills, with more visual skills improving and also in some cases a greater improvement than the Eyedrills training group. This gives credence to the notion that "*practice makes perfect*" as the training consisted of a simple repetition of the testing methods as a training program. The improvement of all types of visual skills and not only those that involve eye movements strongly contradict Abernethy and Wood (2), who suggested that only skills which largely involve a great deal of eye movements are likely to be affected by a repetitive manner of training (2). However, with the use of the testing method as training for six weeks and thereafter using the same testing methods at post- testing a glaring question emerges; are visual skills actually learnt or does mere learning of the test occur? With the use of the same testing and training method it is difficult to ascertain if visual skill learning can be transferred to other settings. A simple way to test this would have been to change the testing method at post testing. If just a simple change of the focusing and tracking alphabet charts or the actual sequences in the sequencing test took place for example, this would have provided a clearer perspective if visual skill improvement actually did occur in the lab based training group. Furthermore, the improvements in the Eyedrills training group contradicts previous research that have formerly tested internet- based visual training programs and have not found significant improvements in visual skill performance like that tested by Abernethy & Wood (2).

Conversely, results of the control group who underwent no visual skill training are also able to shed some light on the test itself being easy to learn. In the control group there were significant improvements of vergence and visualization. When compared to the other two training groups that saw a much wider improvement this trend clearly moves a long way to show that mere familiarity and learning of the test cannot be the main reason for visual skill improvement. Another fact to be considered is the results of the study by du Toit, Kruger, Mahomed *et al*. (8), who used the same visual skill testing methods but different training methods (8). The results of that study showed a significant improvement in sequencing and eye- hand coordination only. The fact that different groups that used different training methods and used the same testing methods yielded a variety of results indicates that the training did lead to improvements in visual skill performance and not the simplicity of the test. However, if it is only training that improves visual skills then how can the significant improvement of visualization and vergence in the control group be explained? One way of explaining this is simply by chance. Another possible reason, which is a limitation of the study design, is that each test was only performed once at pre testing and once at post testing. This is a problem because if the participant did not understand the test during pre-testing and understood it better the second time around which happened to be post testing, this could translate to significant changes. This is a highly unlikely scenario as all tests were explained thoroughly and with the big sample sizes it is unlikely that such a scenario would significantly affect group results.

The Eyedrills group too experienced significant improvements in visual skills but not as much an improvement as compared to the lab- based training group. Eventhough the improvement was not as great as the lab- based group, the improvements in the Eyedrills group gives a clearer view of the transferability of visual skills learnt during training as training methods and testing methods were completely different. However, two very important visual skills which are essential to students i.e. sequencing and visualization did not improve in the Eyedrills group. A possible reason for no improvement in sequencing is that no specific drill in the Eyedrills VTS skin specifically trains sequencing skills. This further highlights the need for training to be highly specific to the skills it aims to train. This specificity of skills tested and trained is an important one as previous research has clearly indicated that the neglect of specific training has led to insignificant results (9). A reason for an actual slight decline in the visualization performance could be that performance on the visualization test began at an excellent level. Even with the slight decline, performance in visualization remained at an excellent level.

On further investigation in the Eyedrills group it is evident that visual skills that were at an excellent level performance to begin with, did not experience significant improvements whereas those that began at an average level were more likely to significantly improve. This trend could be one of the reasons the lab-based training group experienced a greater overall improvement in visual skills. The lab-based training group started with an overall visual skill level that was average whereas the Eyedrills training group started with an overall skill level that was excellent. Although these skill levels are very loosely defined by Wilson & Falkel, this difference in starting skill level could possibly have an impact on the ability to train these visual skills and ultimately the final results (1). The starting skill level could indeed be a significant factor in visual skill testing and training as visual skills are said to be trainable to a certain extend and then level off (10,11). Another limitation of previous research is that no mention of the initial visual skill performance level is reported and therefore it is unknown whether skills have not improved significantly due to a levelling off of performance or ineffectiveness of the training programmes. This aspect should be considered in all future research.

Overall the results of this study both contradicted and agreed with previous studies. It is important to note that visual skill performance did not only improve in the *"software"* type of visual skills that have generally been the norm in former studies showing a significant improvement post training, but also the "*hardware*" visual skills which have previously proved untrainable. This contradicts Abernethy's statement that "*hardware*" visual skills are only able to improve if they are deficient to begin with (12). In both the lab- based training group and Eyedrills group where "*hardware*" visual skills like eye movements involved in tracking and focusing significantly improved, these skills were either at an average or excellent skill level to begin with, (with the exception of tracking in the lab-based training group which was at a low level) and therefore were clearly not deficient yet still improved significantly. There was also no visual acuity deficits in the groups as all participants with deficient visual acuity that was uncorrected were excluded from the study. There exist many possible reasons for the improvement of the "*hardware*" visual skills in this study and not in previous studies like that of Wood and Abernethy in 1997 (3) and Abernethy and Wood in 2001 (2). This includes; ineffective training programmes, training that is not suitable and duration of training that is simply not enough. These "*hardware*" visual skills are extremely important to students during note- taking at lectures and when reading and studying large volumes of text. Therefore, the importance of these skills to the participants could have led to the greater improvements as participants would pay more attention to skills that are important to them personally. This is similar to studies in athletes which have found that athletes would improve in skills that were important to the sport they participated in and not in skills that were no importance to their respective sport domain (9). It is also key to note that vergence did not improve significantly in any of the training groups. Therefore, it may be possible to say that vergence is a visual skill that is unlikely to change through training.

Another important trend that would be imperative to highlight is the ability to improve eye- hand coordination through training. Numerous studies have reported the improvement of eye-hand coordination after introducing a visual skill training program. This does not only include studies involving athletes who require excellent eye- hand coordination especially in ball sports, but also previous studies on students like that by du Toit, Kruger, Mahomed et al (8), have reported the ability of eye- hand coordination to improve significantly after training (8). This shows that eye- hand coordination is probably one of the most receptive skills to improvement and change.

Although these results alone show the efficacy of the training programmes tested, the interaction of other external variables and their effect on visual skills is another important aspect that should be discussed before final conclusions on the training programmes can be reached. The effect of external variables such as; anthropometric variables, cardiac health variables and lifestyle variables on visual skills and the training thereof will be discussed in the section that follows.

4.2.2 Visual skills and external variables

The determination of various external variables were important in this study for two main reasons; to insure that it was the training alone that led to visual skill improvement in the training groups and not any significant changes in external variables and to try and ascertain if any relationships exist between visual skills and the external variables tested.

On closer inspection of the external variables of all three groups various trends arise. Ideally to be absolutely certain that no external variable had an effect on visual skills and the training thereof, there should have been no significant changes to these variables at post- testing. However, this is not the case with all three groups experiencing some significant change in certain variables.

Firstly looking at the training groups, the lab- based group that experienced the most improvement in visual skills after training also experienced a significant increase in BMI and a significant decrease in body fat percentage. This is also accompanied with significant increases in systolic blood pressure and CSI. Due to the significant changes in a good number of the external variables it definitely casts doubt to whether visual skills actually improved through training or if any of the external variables had a profound effect of visual skill performance.

The Eyedrills training group which also experienced a good improvement in some of the visual skills after training experienced no significant changes to any of the anthropometric measurements but did experience a significant increase in diastolic pressure and heart rate. Similar to the lab-based training group, with the significant changes to these external variables it cannot be concluded with certainty that these external variables did not significantly affect visual skill training and its performance.

However, a deeper look into the control group could clarify what effect the external variables could have on visual skill performance as this group did not undergo any training. The control group experienced a significant increase in body fat percentage, CSI and heart rate. If we look at the results across the three groups it is possible to determine if certain trends exist and therefore if visual skill performance was indeed affected by these external variables.

When looking at anthropometric measurements only the control group and lab-based training group found significant changes. They had two very different results with an increase in body fat percentage in the control group but a decrease in body fat percentage in the lab- based training group. The lab- based training group also had an increase in BMI, possibly indicating an increase in muscle mass. Before any trends can be drawn it's important to determine whether the values fall within the standard norms and at what risk level it is categorised (13). With the body fat percentage of both groups remaining at a low risk level and the BMI in the lab- based group also remaining at a low risk level at post- testing it would be difficult to guess how these changes to the anthropometric values affected visual skill performance. Eventhough, there were significant changes in these anthropometric measurements, all groups as a whole had a normal body composition. Furthermore, there are no previous studies to compare results to except one by Skurvydas, Gutnik, Zuaza *et al*. (14), who found an increase in BMI led to a decrease in reaction time (14). Although in the current study reaction time was not tested directly, the increase of BMI in the lab- based training group did not seem to hamper the performance of other visual skills. Although it is still possible that the changes in anthropometric measures could have affected visual skill performance, from the results obtained and lack of previous research in this regard it is difficult to draw any trends.

A further look at the cardiac health variables saw a variety of changes across the three groups with a significant increase in CSI in the control and lab- based training group, a significant increase in heart rate in the control and Eyedrills group, a significant increase in systolic blood pressure in the lab- based training group and a significant increase in diastolic pressure in the Eyedrills groups.

According to previous research blood pressure is found to have a curvilinear relationship with visual skill performance. Participants who are hypotensive or hypertensive were found to have poor visual memory and cognitive performance which therefore would hamper the performance of visual skills across the board (15-17). This relates to both systolic and diastolic pressure. Although both training groups have experienced significant changes to blood pressure measures, they were still within the normal limits and therefore are not expected to have any effect on visual skill performance and training. This is further emphasised by the fact that eventhough blood pressure values increased, there was an improvement in visual skill performance and not a decline as would have been expected.

More worrying however are the changes to CSI and heart rate. CSI is not only a value that provides information of the physical state of a participant but also the psychological state. This is due to its relationship with heart rate variability and therefore the autonomic nervous system. A high CSI often indicates a high stressed state. Stress is one of the most accepted variables found to affect visual skill performance. Stress is found to either enhance visual skill performance through greater attention or hamper it through erratic visual search behaviours (18,19). An increase in CSI can be translated to an increase in stress. CSI was found to be at a moderate risk level in all three groups (although CSI did not significantly change in the Eyedrills group it was also at a moderate level). This moderate level did not seem to hamper the performance of visual skills especially in the training groups that experienced vast improvements. This contradicts results obtained by Behan & Wilson (20), who found stress to significantly decrease visual skill performance in the form of a decreased reaction time in archery (20). Eventhough a high CSI could possibly enhance visual skills too, but because all three groups had different results with regards to visual skill performance (training groups experienced significant improvements and the control groups only experienced significant improvements in two visual skills), a relationship to visual skill performance cannot be drawn. Therefore it is more likely that visual skills improved due to training and not any change to CSI and stress. However, because CSI levels were only at a moderate risk level, the level of stress could have been not enough to elicit any significant effect on visual skills.

Heart rate was also found to significantly increase in the control group and Eyedrills group at post testing. Although both groups remained at the same risk level at post-testing, it's interesting to note that all three groups had a moderate risk level for heart rate both at pre and post- testing. Heart rate could be said to have a similar effect as blood pressure on visual skills with a high heart rate hampering the performance of visual skills although this relationship has not been adequately tested. Heart rate as with CSI is another indicator of psychological state or more specifically stress (18). Due to the diversity of results between visual skill performance in the control group and the Eyedrills group after the six weeks (Eyedrills group experiencing more visual skills resulting in a significant improvement), it is difficult to extrapolate any relationships. Although heart rate is at the moderate risk level in all three groups, it is at the lower end values and could be expected as the novelty of any new situation which often has a physiological response of an increase in heart rate (21). Although cardiac heath variables experienced many changes, the changes were across the three groups. The different groups had very different visual skill performance changes and therefore no clear correlation can be made between visual skill performance and the cardiac health variables tested. The cardiac health measures were also all within the low- moderate risk level and therefore it is very likely improvements to visual skills in the training groups are due to the training alone and not the changes in cardiac health measures.

Lifestyle was another aspect that was considered. Due to lifestyle only determined in the Eyedrills group alone, it is very difficult to try and infer any sort of relationship between visual skill performance and lifestyle variables. Most factors did not see any significant change with the exception of tobacco use and knowledge of disease prevention. Tobacco use could be the only factor that may have influenced visual skill performance. Tobacco use has been found to have mixed effects on cognitive abilities but with use still being at a low risk level it is unlikely to have affected results. Previous research has indicated that fitness and nutrition could have an effect on visual skills but because a lifestyle evaluation was only completed by the Eyedrills group and no significant change occurred within this group with regards to those two factors no deductions can be made. However, because no significant changes occurred in the overall lifestyle of the Eyedrills group it is known for certain that training alone and not lifestyle changes are responsible for the improvement of visual skills in this group.

Overall, it would be safe to say that external variables did not affect visual skill performance in any significant manner. The results of this study therefore agree with previous studies by du Toit, Kruger, Mahomed et al (8) and Jafarzadehpur, Aazami, Balouri (22), which have also showed no significant changes to visual skill performance due to certain external variables like those stated in this study. However, this study by no means expelled the doubts surrounding visual skill performance and its relationship with external variables. With the results obtained no definite conclusions can be reached on the effect of the external variables tested on visual skills and therefore further research is warranted.

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CHAPTER 5: CONCLUSION

The purpose of this study was to determine if two different visual training programmes resulted in the improvement of visual skill performance in university students. In addition to this, possible existence of relationships between visual skills and external variables such as anthropometric measurements, cardiac health variables and lifestyle were tested. Visual skill performance was significantly improved for many of the visual skills in both the lab- based training group and the Eyedrills training group. The control group only improved significantly in two of the visual skills tested and this improvement can possibly be explained due to chance. This clearly shows that the two training programmes were effective in improving visual skill performance in university students. Due to the training groups experiencing a much greater significant improvement to visual skill performance than the control group that did not undergo any training, improvements cannot be explained as mere familiarity to the test (1).

The results in this study which clearly show the favourability of training visual skills to improve visual skill performance contradicts many studies on non –athletes like that by Wood & Abernethy (2) and Abernethy & Wood (3) that have indicated that training visual skills is a waste of time if skills are within a normal level of performance. The favourability of the results can be explained by an improvement in study design and the actual training programmes themselves.

This study addressed many of the limitations and deficiencies that were evident in previous studies. Firstly, the visual skills tested and trained were specific to the needs of the participants (4). This meant that the testing of these skills was of importance to the participants and therefore greater attention was paid to their performance of these skills. Even of more importance is that the training specifically addressed the skills that were tested. This is a point that was overlooked in many of the previous research as training was often a mere adaptation of the training applied to those with visual deficiencies (3). The training was also more controlled, challenging and interesting so that boredom and lack of interest can be avoided. Another important aspect is that testing environments were more realistic and suitable for the type of participant and identical for all three groups making comparisons between them easy. All the above factors went a long way to addressing the problems of previous research and therefore it can be safely concluded from the results in this study that visual skill performance can be trained and improved. The easy, inexpensive and efficient manner of testing and training makes this a study one that can be easily repeated and verified.

Another aspect that should also be highlighted is the debate of whether *"software"* and *"hardware"* visual skills have the ability to be improved. As with previous research the *"software"* visual skills, especially eye- hand coordination was found to be a skill that is conducive to improvement.

The other major objective of this study was the relationship of visual skill performance and external variables. However, external variables were not only considered to ascertain any relationships that may exist but also to determine if training alone led to the improvement of visual skills or if these variables could significantly impact visual skill performance. Although, some variables did significantly change at post- testing, the changes were few and so diverse across the three groups, therefore it cannot be certain if visual skills were impacted in any way although it is fairly unlikely that they were. It is for this same reason that trying to extrapolate any existing relationships between visual skill performance and these external variables are extremely difficult. Therefore, in order to understand the relationship between visual skills and external variables that may affect it, further and more specific research in this area should be carried out.

Although, the paragraphs above highlight the positives and general conclusions deduced from the results, limitations to this study do exist and will be discussed in the section that follows.

5.1 LIMITATIONS

Limitations in the study design and testing procedure exist that concern both the testing and training of visual skills and also the testing of the external variables.

The limitations that involve visual skill testing and training are as follows:

1) Due to the training being the same as the testing of visual skills in the lab-based training group, it is difficult to ascertain whether visual skills did actually improve. Although significant improvements in the visual skills were evident it is unknown if a transfer of skills would be possible. In other words, if the post-test were different would there still be an improvement in visual skills in its essence? Although we can say that training through practise did improve mean score in many of the tests would this relate to better visual skills or just getting better at the test?
2) The initial level of visual skill performance was not at a same level in all three groups. With this difference in initial performance there is a possibility that visual skill performance could reach a threshold and not be able to improve much in the groups that had a better performance level, or conversely have a better potential to improve than any of the other two groups (3,5). This makes comparisons between groups difficult.
3) Gender differences were not accounted for. Previous studies have shown a significant difference in cognitive and spatial skills between the two genders (6). However, because there were no significant differences in gender between the groups, the differences in gender is unlikely to affected results and comparisons between groups.
4) A limitation with computer training as a whole, as is with the Eyedrills program, is that participants with low computer proficiency may have difficulty training. Although this is not a problem in university students as all students must undergo a computer class during their first year of study, this

may be a problem to people in other fields. Another limitation of the Eyedrills training is that because it can be done at any time and not under supervision, the participant cannot receive advice. Eventhough there is a coacher's corner and questions can be asked at any time, this does not have the same advantages as having an instructor that can see what you are doing and advise you.

5) It is unknown what the long-term effects of training would be on visual skill performance. Will there be a wear- off effect and is continuous training required?

6) Although anthropometric measurements, cardiac variables and lifestyle were considered other factors that also could affect performance of visual skills such as; personality, confidence, motivation and fatigue were not considered. Environmental factors that are also considered to have an effect of visual skill performance such as; light, humidity and noise were not accounted for.

The limitations that involve the testing of external variables are as follows:

1) The manner of testing lifestyle variables through a questionnaire although acceptable is not ideal. Many questionnaires are answered with social desirability in mind and self- reported indications of physical activity and nutrition were found to be largely inaccurate (7,8).

2) Cardiac levels differ significantly at different times of the day with heart rate, heart rate variability and systolic blood pressure being at its highest in the morning (9).

3) Heart rate variability, and therefore CSI, is sensitive to sleep quality, physical activity, smoke and caffeine (9). Although participants were advised to avoid these things before testing, it is difficult to control all aspects. It is therefore possible that CSI could have been influenced by other aspects and not a true reflection of stress. This could also be the reason for the high values of CSI in the groups.

5.2 BENEFITS OF THE STUDY

Firstly, this study benefits the sports vision research community because it addresses many past issues and can also be a stepping stone to much more research in the sports vision field to follow. The improvement of visual skills can be highly beneficial to students and could aid in improving the extraction of visual information (10). This would help students to respond to visual information much quicker which is essential to university students who often deal with tight time constraints. Good visual skills have also been found to correlate with higher levels of cognitive control, being more focused and less easily distracted and having a good working memory (1). This would be a great advantage to university students and could possibly help to improve academic performance.

One of the pivotal points of sports vision training that still requires some addressing is whether improving visual skills in its essence would translate into better performance as a whole. For an athlete, in order for visual skill training to be of benefit there needs to be an improvement in sports performance on the field. For students, an improvement in visual skills should ideally translate in an improvement in academics or in general the ability to cope with visual demands in a university setting. Although this point is beyond the scope of the present study it should be addressed in future studies. Through the study of past research though, we can get an idea of how visual skill training could impact on academic performance.

A study by Clark, Ellis, et al. (9), that specifically looks at visual skill improvements relating to sports performance in university baseball players showed that after introducing visual skill training in the offseason, batting averages increased significantly as compared to the previous season (9). Although many external variables, which were not accounted for, could have been the cause of the batting average improvements, this study does indicate somewhat that visual skill improvements translate into improvements in performance. Furthermore, studies done on high school students have found a strong positive association between visual skills, reading skills, comprehension and fluency (11,12). Studies in children have also shown that poor reading skills are often the result of poor visual skills and that poor mathematical skills are often found in children with visual processing deficiencies (13,14). This together with the fact that visual skills and academic skills share many underlying processes makes it highly probable that significant improvements in visual skills could translate in improvements in academics. If this is proven in further research visual screening and training would be of great benefit in universities, workplaces and almost every other field.

Furthermore, the testing of external variables is not only of benefit to questions asked in this study but is also of benefit to the students themselves. It gives a general idea of well- being of the groups of students. This is information that the students can use to improve their general well- being and lifestyle. Well-being also affects academic performance so the information obtained here could be a start in remedying aspects in their lives that might be affecting academic performance.

5.4 RECOMMENDATIONS FOR FUTURE STUDIES.

The current study provides a good indication of the effectiveness of visual skill training however further research is needed to enhance the field of sports vision.

An important issue that needs to be addressed in future research is the transferability of visual skills. It is important to ascertain if visual skill improvements translate into performance improvements. Although early studies and reviews like those by Abernethy (15), Wood & Abernethy (3), and Abernethy & Wood (5) have proposed that visual skill improvements would not affect performance in any significant manner, recent research have provided encouragement and therefore further research into this is advised (16). A simple way to do this with regards to tests on students would be to add some form of academic performance test at both pre- testing and post- testing and thereafter determine if improvements in visual skill performance correlates with improvements in the academic performance test.

Another issue that needs to be addressed in future studies is skill retention. It is important to know whether training effects wear-off after sometime or if visual skills learnt are retained for long periods. This can be done by testing visual skill performance at different intervals after training and with no further training introduced. This information would be instrumental in implementing visual skill training programmes.

Furthermore, most sports vision research look at very simplified visual skills. Future research could look at visual skills in more complex situations and possibly also introduce dual tasks.

Although external variables were addressed in this study, the inconclusive nature of results leaves this area of sports vision in need of further research. In order to truly determine if any relationships exist between visual skill performance and external variables, each variable needs to be considered in isolation with an effort to account for other factors. For example, if a relationship between stress and visual skill performance is to be determined, researchers could possibly have a pre- test and then introduce a certain stress and then see how this affected visual skill performance at post- testing. Similarly, to determine a relationship between physical fitness and visual skill performance, physical measures of physical fitness should be obtained and then compared to visual skill performance. This could be implemented for other external variables and therefore would make results more tangible. In addition, no training should be implemented when determining relationships between visual skills and external variables. In future research social and psychological factors should also be considered as emotional handling of situations play a big role in performance.

Finally, effort needs to be exerted within the sports vision field to make sports vision testing and training more accessible to everyone. This is extremely challenging because even in sport where sports vision training has seen great results, the implementation of visual skill training programmes are often neglected, slow or merely considered as a form of injury prevention (11). Studies like this one, which used inexpensive methods of visual screening and training opens up the possibility of sports vision extending to other fields besides sport. Through the development of specific visual skill testing and training programmes, sports vision can be implemented in various fields.

This research study clearly proved that visual skills can be improved and that the two training methods implemented were effective means of training visual skills. The relationship between visual skills and the external variables tested was difficult to ascertain and therefore more concise and specific research is warranted.

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Appendix A- Informed Consent form

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

Investigator:	Supervisor:
Faheema Mahomed Ali	Dr PJ du Toit
Department of Physiology	Department of Physiology
Faculty of Health Sciences	Faculty of Health Sciences
Tel: 0720552263	Tel: (012) 420-2536
Email: faheema.m.ali@gmail.com	Email: peet.dutoit@up.ac.za

TITLE: The comparison of visual skills, lifestyle evaluation, body composition, blood pressure, and cardio stress index, before and after sports vision exercises.

INTRODUCTION

You are invited to volunteer for a research study. This information leaflet will help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions, which are not fully explained in this leaflet, do not hesitate to ask the investigator. You should not agree to take part unless you are completely happy about all the procedures involved.

WHAT IS THE PURPOSE OF THIS STUDY

The aim of the study is to determine the effect of a 6-week sports vision training program on the visual skills of students taking into account external factors such as, lifestyle, body composition and cardiac health.

WHAT IS THE DURATION OF THIS STUDY?

The study consists of the completion of various questionnaires and tests performed. The study will be completed over a time frame of 6-8 weeks. Various tests will be conducted including; visual skills tests, cardio stress index, resting blood pressure, body composition tests and lifestyle factors will be determined using a questionnaire. The answering of the questionnaires will take a maximum of 10mins and testing will take 30mins per testing. session (i.e. pre -test session and post- test session). Visual skill training will take place over a period of 6 weeks. The visual skills training program is either an online program and can be done on any computer with internet access or training sessions that will take place at the University of Pretoria, Hatfield campus under the supervision of a trained assistant. No compensation will be given to participants

EXPLANATION OF PROCEDURES TO BE FOLLOWED

This study involves completing several tests and a questionnaire. The questionnaires have to be completed at the beginning of each testing session. Participants are required to complete the questionnaires at pre testing as well as after a 6 week period. Questionnaires include the following:

- **Personal & family medical history questionnaires**

  This questionnaire requests that information regarding any diseases/conditions that the participant may have or has a history of to determine compliance of criteria and risks that may be involved. The estimated completion of this section is 5 minutes.
- **Lifestyle evaluation questionnaire.**

  This questionnaire provides insight into the participants' lifestyle and level of physical activity. Based on this information, a sense of wellness can be obtained and to an extent, perceived wellness. The estimated completion time for the questionnaire is 5 minutes

The tests include:

- **Anthropometric measurements**: this includes measuring weight and height to determine body mass index, measuring body circumferences, skeletal breadth and determining body fat percentage to obtain an overall view of body composition.
- **Cardiac health tests**: this includes testing cardio stress index using a non-invasive Viport™ machine and measuring blood pressure.
- **Sports vision testing**- this includes a variety of different visual skills tests which include; visual acuity, focusing, visualization, eye-hand coordination etc.

NOTE:

It is important that you let the investigator know of any medicines (either prescriptions or over-the-counter medicines), herbal or traditional medication, alcohol or other substances that you are currently taking.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This research study protocol was submitted to the faculty of Health Science Research Ethics Committee and Research Ethics Committee, Faculty of Humanities, University of Pretoria and written approval has been granted by both the committees.

Contact Details: Research Ethics Committee, Faculty of Health Sciences, HW Snyman South Building, Rooms 2.33; 2.34 & 2.35. Tel: 012 354 1330 or 012 354 1677
Fax: 012 354 1367.
E -mail: deepeka.behari@up.ac.za

Research Ethics Committee, Faculty of Humanities, Tel: 420-4850;
E-mail: tracey.andrew@up.ac.za

WHAT ARE YOUR RIGHTS AS A PARTICIPANT IN THIS STUDY?

Your participation in this trial is entirely voluntary and you can refuse to participate or stop at any time without stating a reason. Your withdrawal will not affect your access to other medical care or your studies at the University of Pretoria. The investigator retains the right to withdraw you from the study if it is considered to be in your best interest. If it is detected that you did not give an accurate history you may be withdrawn from the study at any time.

MAY ANY OF THESE STUDY PROCEDURES RESULT IN DISCOMFORT OR INVOLVE ANY SORT OF RISKS?

The only possible discomfort could be emotional discomfort owing to the personal nature of certain questions. No blood will be drawn and no invasive procedures will be used.

CONFIDENTIALITY

All information obtained during the course of this study is strictly confidential. Data that may be reported will not include any information which identifies you as a participant. In connection with this research, it might be important to the Faculty of Health Science Research Ethics Committee, University of Pretoria, as well as your doctor, to be able to review your medical records.

You will be informed of any finding of importance to your health or continued participation in this study but this information will not be disclosed to any third party in addition to the ones mentioned above without your written permission

INFORMED CONSENT AND INDEMNITY

I hereby confirm that I have been informed by the investigator, F Mahomed Ali, about the nature, conduct, benefits and risks of the research study. I have also received, read and understood the above written information (Patient Information Leaflet and Informed Consent) regarding the research study.

I am aware that the results of this study, including personal details regarding my sex, age, date of birth, initials, health and performance will be anonymously processed into a study report.

I may, at any stage, without prejudice, withdraw my consent and participation in the study. I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in this study.

I hereby declare that I fully understand the procedure of the evaluation and I had the opportunity to discuss all relevant matters. I participate in the evaluation exercises at my own risk and won't hold the University of Pretoria responsible for any injury obtained.

Participant's name

…………………………………………………………………….
(Please print)

Participant's signature……………………………………………...

Date………………………………………………………………

I, F. Mahomed Ali herewith confirm that the above participation has been informed fully about the nature, conduct and risks of the above study.

Investigators name: Faheema Mahomed Ali

Investigator's signature……………………………………..

Date……………………………………………………………

Witness's name*……………………………………………..

Witness's signature…………………..Date………………...
(Please print)

*Consent procedure should be witnessed whenever possible.

Appendix B: Biographical information form

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

Subject Number: Number

Date: DD | MM | YEAR

PERSONAL AND BIOGRAPHICAL INFORMATION

Gender: M Male F Female

Age: YRS

Dominant hand: RIGHT/LEFT

Appendix C1- Family and Medical History form

Subject Number: ______________

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YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

Do any of your immediate family members (grandparents, parents, brother(s) or sister(s) suffer from, or take medication for the following health factors?

☐ Heat attack	☐ Heart disease	☐ Lung disease
☐ Any cancer	☐ Overweight	☐ High blood pressure
☐ High cholesterol levels	☐ Any substance dependency	☐ Renal disease
☐ Connective tissue disease	☐ Autoimmune disease	☐ Liver disease
☐ Neurological disease	☐ Psychiatric disease	☐ None

Have any of your immediate family members (grandparents, parents, brother(s) or sister(s) died from the following health factors?

☐ Heat attack	☐ Heart disease	☐ Lung disease
☐ Any cancer	☐ Overweight	☐ High blood pressure
☐ High cholesterol levels	☐ Any Substance dependency	☐ Renal disease
☐ Connective tissue disease	☐ Autoimmune disease	☐ Liver disease

☐ Neurological disease	☐ Psychiatric disease	☐ None

Do you suffer or take medication for the following chronic conditions?

☐ Heat attack	☐ Heart disease	☐ Lung disease
☐ Any cancer	☐ Overweight	☐ High blood pressure
☐ High cholesterol levels	☐ Any substance dependency	☐ Renal disease
☐ Connective tissue disease	☐ Autoimmune disease	☐ Liver disease
☐ Neurological disease	☐ Psychiatric disease	☐ None

Appendix C2- State/Trait personality inventory

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel:

Self-analysis questionnaire
STPI Form

Part 1 Directions: A number of statements that people have used to describe themselves are given below. Read each statement and then darken the appropriate value to the right of the statement to indicate how you feel **right now**, that is, **at this moment**. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to **best** describe your **present feelings**.

State – Answer on how you feel at this moment	Not at all	Somewhat	Moderately so	Very much
1. I feel calm	1	2	3	4
2. I am in a questioning mood	1	2	3	4
3. I am furious	1	2	3	4
4. I feel strong	1	2	3	4
5. I am tense	1	2	3	4
6. I feel curious	1	2	3	4
7. I feel like banging on the table	1	2	3	4
8. I feel blue	1	2	3	4
9. I feel at ease	1	2	3	4
10. I feel interested	1	2	3	4
11. I feel angry	1	2	3	4
12. I feel miserable	1	2	3	4
13. I am presently worrying over possible	1	2	3	4

misfortunes				
14. I feel inquisitive	1	2	3	4
15. I feel like kicking somebody	1	2	3	4
16. I feel downhearted	1	2	3	4
17. I feel nervous	1	2	3	4
18. I feel like exploring my environment	1	2	3	4
State – Answer on how you feel <u>at this moment</u>	**Not at all**	**Somewhat**	**Moderately so**	**Very much**
19. I feel like breaking things	1	2	3	4
20. I feel alive	1	2	3	4
21. I feel jittery	1	2	3	4
22. I feel stimulated	1	2	3	4
23. I am mad	1	2	3	4
24. I feel sad	1	2	3	4
25. I am relaxed	1	2	3	4
26. I feel mentally active	1	2	3	4
27. I feel irritated	1	2	3	4
28. I feel safe	1	2	3	4
29. I am worried	1	2	3	4
30. I feel bored	1	2	3	4
31. I feel like hitting someone	1	2	3	4
32. I feel gloomy	1	2	3	4
33. I feel steady	1	2	3	4
34. I feel eager	1	2	3	4
35. I feel annoyed	1	2	3	4
36. I feel healthy	1	2	3	4
37. I feel frightened	1	2	3	4
38. I feel disinterested	1	2	3	4
39. I feel like swearing	1	2	3	4

40. I feel hopeful about the future	1	2	3	4

Self-analysis questionnaire
STPI Form

Part 2 Directions: A number of statements that people have used to describe themselves are given below. Read each statement and then darken the appropriate value to the right of the statement to indicate how you **generally** feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to **best** describe how you **generally feel**.

Trait – Answer on how you generally feel	**Almost never**	**Sometimes**	**Often**	**Almost always**
41. I am a steady person	1	2	3	4
42. I feel like exploring my environment	1	2	3	4
43. I am quick tempered	1	2	3	4
44. I feel gloomy	1	2	3	4
45. I feel satisfied with myself	1	2	3	4
46. I am curious	1	2	3	4
47. I have a fiery temper	1	2	3	4
48. I feel happy	1	2	3	4
49. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4
50. I feel interested	1	2	3	4
51. I am a hot-headed person	1	2	3	4
52. I feel depressed	1	2	3	4
53. I wish I could be as happy as others seem to be	1	2	3	4

54. I feel inquisitive	1	2	3	4
55. I get angry when I'm slowed down by other's mistakes	1	2	3	4
56. I feel sad	1	2	3	4
57. I feel like a failure	1	2	3	4
58. I feel eager	1	2	3	4

Trait – Answer on how you <u>generally feel</u>	**Almost never**	**Sometimes**	**Often**	**Almost always**
59. I feel annoyed when I am not given recognition for doing good work	1	2	3	4
60. I feel hopeless	1	2	3	4
61. I feel nervous and restless	1	2	3	4
62. I am in a questioning mood	1	2	3	4
63. I fly off the handle	1	2	3	4
64. I feel low	1	2	3	4
65. I feel secure	1	2	3	4
66. I feel stimulated	1	2	3	4
67. When I get mad, I say nasty things	1	2	3	4
68. I feel whole	1	2	3	4
69. I lack self-confidence	1	2	3	4
70. I feel disinterested	1	2	3	4

71. It makes me furious when I am criticized in front of others	1	2	3	4
72. I feel safe	1	2	3	4
73. I feel inadequate	1	2	3	4
74. I feel mentally active	1	2	3	4
75. When I get frustrated, I feel like hitting someone	1	2	3	4
76. I feel peaceful	1	2	3	4
77. I worry too much over something that really does not matter	1	2	3	4
78. I feel bored	1	2	3	4
79. I feel infuriated when I do a good job and get a poor evaluation	1	2	3	4
80. I enjoy life	1	2	3	4

Appendix C3- Nutritional Assessment

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel:

Indicate the statement that best describes the frequency of your food-related behaviour, always (A), often (O), sometimes (S), rarely (R) or never (N)

	A	***O***	***S***	***R***	***N***
1. Everyday I eat a nutritious breakfast.	A	O	S	R	N
2. I try to include recommended servings from each of the food groups in my daily diet.	A	O	S	R	N
3. I eat unsalted food.	A	O	S	R	N
4. When I snack, I choose fruits, vegetables, low-fat yogurt, or cheese.	A	O	S	R	N
5. I try to include mostly fresh and less-processed foods in my daily diet.	A	O	S	R	N
6. I avoid fatty foods and trim off the visible fats from meats.	A	O	S	R	N
7. I include foods containing fibre, such as fruits, vegetables, whole grain products, and beans in my diet.	A	O	S	R	N
8. I drink skim milk instead of whole or 2% milk.	A	O	S	R	N
9. I consume fish at least once a week.	A	O	S	R	N
10. I consume caffeine-free beverages.	A	O	S	R	N

11. I avoid foods that contain large amounts of honey and sugar.	A	O	S	R	N
12. For reliable nutrition information, I ask a qualified nutritionist instead of relying on the popular press.	A	O	S	R	N
13. I do not drink alcoholic beverages.	A	O	S	R	N
14. I keep my weight within acceptable limits.	A	O	S	R	N
15. I obtain my nutrients through foods rather than relying on nutritional supplements	A	O	S	R	N

Appendix C4- Stress index

Department of Physiology, Faculty of Health Sciences PO Box 2034,
Pretoria 0001, Republic of South Africa Tel: (012) 420-4482

Choose YES (Y) of NO (N) for each question

	Y	N
1. I have frequent arguments.	Y	N
2. I often get upset at work/school/university.	Y	N
3. I often have neck and/or shoulder pains due to anxiety/stress.	Y	N
4. I often get upset when I stand in long lines.	Y	N
5. I often get angry when I listen to the local, national or world news or read the newspaper.	Y	N
6. I do not have a sufficient amount of money for my needs.	Y	N
7. I often get upset when driving.	Y	N
8. At the end of a day I often feel stress-related fatigue.	Y	N
9. I have at least one constant source of stress/anxiety in my life (e.g., conflict with boss, neighbour, mother-in-law etc.).	Y	N
10. I often have stress-related headaches.	Y	N
11. I do not practice stress management techniques.	Y	N

12. I rarely take time for myself. Y N

13. I have difficulty in keeping my feeling of anger and hostility under control. Y N

14. I have difficulty in managing time wisely. Y N

15. I often have difficulty sleeping. Y N
16. I am generally in a hurry. Y N

Appendix C5: Lifestyle evaluation questionnaires

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

For each question, choose the answer that best describes your behaviour, always (A), sometimes (S) or never (N). Answer always if you agree with a statement.

Exercise/Fitness

	A	*S*	*N*
1. I engage in moderate exercise such as brisk walking or swimming for 20 to 60 minutes, three times a week.	A	S	N
2. I do exercise to develop muscular strength and endurance at least twice a week.	A	S	N
3. I spend some of my leisure time participation in individual, family, or even team activities such as gardening, bowling, or softball.	A	S	N
4. I maintain a healthy body weight and am not overweight or underweight.	A	S	N

Nutrition

	A	*S*	*N*
1. I eat a variety of foods each day, including seven or more servings of fruit and/or vegetables.	A	S	N
2. I limit the amount of total fat and saturated trans fats in my diet.	A	S	N
3. I avoid skipping meals.	A	S	N
4. I limit the amount of salt and sugar I eat.	A	S	N

Tobacco use

If you never or no longer use tobacco, indicate always for both questions.

	A	*S*	*N*
1. I avoid using tobacco.	A	S	N
2. I smoke only low-tar-and-nicotine cigarettes, or smoke a pipe or cigars, or I use smokeless tobacco.	A	S	N

Alcohol and drugs

	A	*S*	*N*
1. I avoid alcohol, or I drink no more than one (woman) or two (men) drinks a day.	A	S	N
2. I avoid using alcohol and/or other drugs.	A	S	N
3. I am careful not to drink alcohol when taking medications (such as cold or allergy medications) or when pregnant.	A	S	N
4. I read and follow the label directions when using prescribed and over-the-counter drugs.	A	S	N

Emotional health

	A	*S*	*N*
1. I enjoy being a student and/or I have a job or do other work that I enjoy.	A	S	N
2. I find it easy to relax and express my feelings freely.	A	S	N
3. I manage stress well.	A	S	N
4. I have close friends, relatives, or others whom I can talk to about personal matters and call on for help when needed.	A	S	N

Safety	*A*	*S*	*N*
1. I wear a safety belt when riding in a car.	A	S	N
2. I avoid driving while under the influence of alcohol or other drugs.	A	S	N
3. I obey traffic rules and the speed limit when driving.	A	S	N
4. I read and follow instructions on the labels of potentially harmful products or substances, such as household cleaners.	A	S	N
5. I avoid smoking in bed.	A	S	N

Disease prevention	*A*	*S*	*N*
1. I know the warning signs of cancer, heart attack, and stroke.	A	S	N
2. I avoid overexposure to the sun and use sunscreen.	A	S	N
3. I get recommended medical screening tests (such as blood pressure and cholesterol checks and Pap tests), immunizations and booster shots.	A	S	N
4. I practice monthly skin and breast/testicle self-exams.	A	S	N
5. I am not sexually active, or have sex with only one mutually faithful, uninfected partner, or I always engage in safe sex (using condoms), and I do not share needles to inject drugs	A	S	N

Appendix C6: Health/fitness and activity index

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

Please fill in all the required information as accurately as possible

Present health status: *Has your doctor ever told you that any of the following conditions? (Answer YES or NO)*

	Y	*N*
1. Coronary heart disease	Y	N
2. High blood pressure	Y	N
3. High cholesterol levels	Y	N
4. Cancer	Y	N
5. Diabetes mellitus	Y	N
6. Lung disease	Y	N
7. Other major illness/es	Y	N

Please list: ____________________

Family History: *Do/did your father or mother suffer from any of the following conditions? Check Mother (M) if your mother does/did, check Father (F) if your father does/did, and both (B) for both of them, and leave blank if neither of them does/did.*

	M	*F*	*B*
1. Coronary heart disease	M	F	B
2. High blood pressure	M	F	B
3. High cholesterol levels	M	F	B
4. Cancer	M	F	B
5. Diabetes mellitus	M	F	B
6. Lung disease	M	F	B
7. Other major illness/es	M	F	B

Please list: ____________________

Dieting History: *Answer YES (Y) or NO (N) for each question*

	Y	*N*
1. Have you ever been on a weight-reducing diet?	Y	N

2. If yes, name the diets you have used. List

List

3. Coronary heart disease Y N

4. If yes, name the diet you are using. List

List

Choose well-informed (W), averagely informed (A) or poorly informed (P) *W* *A* *P*

5. Do you consider yourself to be well-informed with regard to nutrition W A P

6. Would you like to be better informed with regard to what you eat? Yes (Y) or No (N) Y N

Health/Lifestyle Index:

Choose >30/day (1), 20-30/day (2), 10-20/day (3), <10/day (4) or never (5)

	1	*2*	*3*	*4*	*5*
1. Do you smoke.	1	2	3	4	5

Choose very often (V), often (O), sometimes (S), rarely (R) or never (N)

	V	*O*	*S*	*R*	*N*
2. Do you eat a balanced diet?	V	O	S	R	N
3. Do you try to cut down on fats and oils in your diet?	V	O	S	R	N
4. Do you have sufficient relaxation time and sleep?	V	O	S	R	N
5. Would you describe your typical day as highly stressful?	V	O	S	R	N
6. Do you exercise?	V	O	S	R	N

Work/Activity Index:

Choose very often (V), often (O), sometimes (S), rarely (R) or never (N)

	V	O	S	R	N
1. At work I sit:	V	O	S	R	N
2. At work I stand:	V	O	S	R	N
3. At work I walk:	V	O	S	R	N
4. At I lift heavy objects:	V	O	S	R	N
5. At work I sweat from physical exertion:	V	O	S	R	N
6. At work I am physically tired:	V	O	S	R	N

Leisure Activity Index:

Choose very often (V), often (O), sometimes (S), rarely (R) or never (N)

	V	O	S	R	N
1. During leisure time, I watch TV, read or nap:	V	O	S	R	N
2. During leisure time, I sweat from physical activity:	V	O	S	R	N

Choose more than 4 hours (>4), 3-4 hours (3-4), 2-3 hours (2-3), 1-2 hours (1-2) or less than 1 hour (<1)

	>4	3-4	2-3	1-2	<1
1. During my leisure time, I exercise (hours/week):	>4	3-4	2-3	1-2	<1

Appendix C7- FIT index of Kasari

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Department of Physiology, Faculty of Health Sciences PO Box 2034, Pretoria 0001, Republic of South Africa Tel: (012) 420-4482 Fax: (012)420-4483

Choose the most appropriate statement in frequency, intensity and time that most accurately reflect your level of physical activity.

Frequency	More than 6 times per week	F
	3 to 5 times per week	F
	1 to 2 times per week	F
	A few times per month	F
	Less than one time per month	F
Intensity	Sustained heavy breathing and perspiration	I
	Moderate high aerobic activities and intermittent sport activities that result in sustained heavy breathing and perspiration (step aerobic, stair-stepping, speed walking, tennis, racquetball, squash)	I
	Moderate aerobic activities (normal bike riding, jogging, low impact aerobics	I
	Low to moderate aerobic and sports activities (recreational volleyball, moderate speed walking)	I
	Light aerobic exercise (normal walking, golfing)	I
Time	More than 30 minutes	T
	20 to 30 minutes	T
	10 to 20 minutes	T
	Less than 10 minutes	T

Appendix D1: Data interpretation guidelines: visual skills

Component	• Focusing (letters/min)	• **≥60** (Excellent performance) • **40-59** (Average performance) • **≤39** (Low performance)
	• Tracking (letters/min)	• **≥60** (Excellent performance) • **40-59** (Average performance) • **≤39** (Low performance)
	• Vergence (cm)	• **≤2.54** (Excellent performance) • **2.55-4.21** (Average performance • **≥4.22** (High risk)
	• Sequencing (# correct sequences)	• **≥5** (Excellent performance) • **3-4** (Average performance) • **≤2** (Low performance)
	• Eye- hand coordination (seconds)	• **≤20** (Excellent performance) • **21-40** (Average performance) • **≥41** (Low performance)
	• Visualization (seconds)	• **≤39** (Excellent performance) • **40-69** (Average performance) • **≥70** (Low performance)

Focusing + **Tracking** + **Vergence** + **Sequencing** + **Eye- hand coordination** + **Visualization**	Excellent performance=3 Average performance=2 Low performance=1	**≥14** (Excellent performance) **9-13** (Average performance) **≤8** (Low performance)

Appendix D2: Data interpretation guidelines: Body composition

Component	• Body Mass Index	• **≤24.9** (Low risk) • **25-29.9** (Moderate risk) • **≥30** (High risk)
	• Waist- to-Hip ratio	• **≤0.8** (Low risk) • **0.81-1.0** (Moderate risk) • **≥1.0** (High risk)
	• Body fat percentage (based on female standards)	• **≤20** (Low risk) • **21-32** (Moderate risk) • **≥33** (High risk)

Appendix D3: Data interpretation guidelines: Cardiac health variables

Component	• Cardio Stress Index (%)	• **≤25** (Low risk) • **26-49** (Moderate risk) • **≥50** (High risk)
	• Heart rate (beats/minute)	• **≤80** (Low risk) • **80-99** (Moderate risk) • **≥100** (High risk)
	• Systolic BP (mmHg)	• **≤139** (Low risk) • **140-159** (Moderate risk) • **≥160** (High risk)
	• Diastolic BP (mmHg)	• **≤89** (Low risk) • **90-99** (Moderate risk) • **≥100** (High risk)