A LABORATORY SIMULATION INVESTIGATING THE IMPACT OF SUNGLASS TINT ON THE CATCHING PERFORMANCE OF CRICKET FIELDERS

BY

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THESIS

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ABSTRACT

Background: Sunglasses are popularly worn by outdoor athletes such as cricketers. They are primarily worn to preserve ocular health due to the length of time exposed to the sun's glare on the field. More recently, sunglasses are now worn for their purported performance-enhancing benefits supposedly allowing athletes to "see clearly, react faster and perform with confidence". Fielders typically wear sunglasses, but it is rare to see the bowler or the batter wearing sunglasses although they are exposed to the same conditions. If sunglasses provide visual clarity for better reaction time, it is assumed this would also be beneficial for both batsmen and bowlers alike. It is interesting that although fielding plays a key role in the winning of a match, it has received very little research in comparison to the areas of batting and bowling. Research concerning sunglasses in the past has been concerned with its effect on ocular parameters such as colour vision and contrast sensitivity, with minimal research on their effect on performance, specifically on how different colour tints may affect performance such as catching in fielding. Objective: The purpose of this study was to compare the catching performance of fielders when wearing three different colour tints of sunglasses. Methods: Thirty male cricketers currently playing for Rhodes University or country districts sides in Makhanda, South Africa, who were non-habitual sunglass wearers were recruited for this study. An optician administered a pre-screening test to ensure participants did not have any visual defects that would affect the results, determining who was eligible to continue with the research project. Twenty-five participants qualified with a further four withdrawing during the experimentation phase due to personal reasons. Eligible participants were required to complete four testing sessions on separate days thereafter in which they wore a different colour tint at each session (clear, blue, G30 and red). These tints were randomised among participants. Participants were required to catch 18 balls projected from a bowling machine in each session. The number of balls caught as well as the quality of catch was recorded. At the end of the fourth session, participants were presented with a questionnaire investigating their subjective experience of the protocol and preference for any particular colour of lens. Results: Statistically significant results were found between the different colour lenses for the ocular parameters of contrast sensitivity and stereopsis tested by the optician. The red lens was found to be the best for contrast sensitivity with the blue lens performing the worst on this test. With regard to stereopsis, the G30 lens was the worst, with the red lens performing the best. The performance measures resulted in no significant difference between the different colour lenses both concerning the total number of catches taken as well as the quality of catch taken. The same result was found irrespective of the colour of lens used in each session. Data gathered from the questionnaire regarding visual comfort and target visibility resulted in the red lens being rated statistically worse than the other three conditions. In terms of personal preference, the G30 lens was rated statistically as the best coloured lens. Conclusion: It can be concluded that objectively there is no difference in performance between the three coloured lenses. Although from an ocular perspective, the red lens was expected to perform the best in terms of catching performance, there was no difference. Subjectively there was a strong preference among the players for the G30 lens with players strongly disliking the red lens.

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CHAPTER I:
INTRODUCTION

BACKGROUND TO THE STUDY

Vision is one of many factors that impact successful competitive sports performance. The visual information gathered from the surrounding environment is attended to without conscious effort. Through a complex set of processes, muscles of the body are directed to respond rapidly to various stimuli (Erickson, 2007; Venter, 2003). This visual feedback ensures the execution of appropriate sports-related actions (Schenk, Mair, & Zihl, 2004). Spatial and temporal information acquired from the eyes is processed by the brain allowing for the successful execution of actions, i.e. catching (Kirschen & Laby, 2011). Visual perception is a highly-skilled, albeit involuntary ability that regulates movement through the ability to detect structures and events in the surrounding environment and is key to the effectiveness of information processing (Bruce, Green, & Georgeson, 1996; Kirschen & Laby, 2011; Knudson & Kluka, 1997). The quality of the visual information received, contributes to the effectiveness of decision making as it affects a player's ability to selectively attend to, interpret, analyse and utilise this information in the execution of the appropriate motor response (Abernethy & Wood, 1992; Kirschen & Laby, 2011).

The sport of cricket is mostly played outdoors, and thus players have to contend with a variety of environmental conditions, particularly the aspect of natural light. Long term exposure to ultraviolet B (UV-B) sunrays has adverse effects on certain aspects of health, particularly as cricket is played between 10 am and 4 pm, when these rays are at their most intense (Woolmer & Noakes, 2008). These damaging rays, in particular UV-B rays, result in the increased risk of ocular health degeneration through the development of cataracts or macular degeneration which affects the quality of vision (Erickson, 2007; Thomas, 2008; Woolmer & Noakes, 2008). Along with this, natural variation in ambient light occurs throughout the day from illuminance values of 400lx at sunrise or sunset on a clear day to 1000lx on an overcast day to 100000lx when one is in direct sunlight. Such high values of light intensity often result in the experience of glare due to the combination of strong sunlight and the reflective ground surface. The diminished visual ability caused by glare is often experienced by players in sports like cricket when attempting to execute overhead catches into the sun emphasising the significance of quality visual information in the planning and execution of motor skills (Krüger, Campher, & Smit, 2009; Loran & MacEwen, 1995). The combination of high light intensity and damaging

UV rays that players are exposed to throughout the day has resulted in optometrists strongly encouraging the use of sunglasses, to maintain and protect the ocular health of players as well as to enhance performance through glare reduction (Erickson, 2007; Thomas, 2008).

The traditional use of sunglasses has evolved from the need to provide only ocular protection from trauma and solar radiation, to incorporating performance-enhancing features, particularly for outdoor sporting demands (Davis & Buszard, 2011; Erickson, 2007). These performance enhancing claims are purported to be due to a combination of the manipulation of visible light transmitted to the eye, based on the colour of the tint used, as well as the type of material used in the lens (Erickson, 2007). These performance features supposedly improve visual factors such as visual acuity, depth perception and contrast sensitivity, which enhances one's ability to discern crucial details, such as tracking the trajectory of the ball and judging depth (Erickson, 2007; Erickson, Horn, Barney, Pexton, & Baird, 2009; Porisch, 2007). However, support for these purported benefits is lacking and thus requires further investigation. Within the context of cricket, such improvements potentially aid a fielder in determining the appropriate position for successful interception of a lofted ball for example. Fielding is a key area in the game of cricket as it is influential on the outcome of the match in two primary forms. The first is ground fielding, whereby the player has to restrict the number of runs conceded by a batter through preventing the ball from getting to the boundary (Woolmer & Noakes, 2008). The second is by taking a wicket through catching a ball that has not hit the ground first (Woolmer & Noakes, 2008). Although fielding is key to the game and the skills required for players in different positions varies, very little research has been done in this area (Bartlett, 2003). The use of sunglasses while fielding may be one such factor and may impact catching performance due to its effect on perception. For this reason, it requires some investigation.

Scientific information substantiating that tint selection impacts visual parameters such as contrast sensitivity, depth perception, and visual acuity is scarce (Moore, 1997). Such visual factors affect catching performance, and therefore any improvements should guide tint selection (Knudson & Kluka, 1997). Both colour and density of tint are purported to be advantageous to sports performance, which is generally accepted information, disseminated by manufacturers with little scientific support. The colour of the tint affects vision as the colours perceived in the environment are altered due to the transmission and absorption properties of the lens thus affecting perception (Knudson & Kluka, 1997; Moore, 1997). The density of the colour of the tint affects the amount of visible light transmitted to the eye (Erickson, 2007). Together, the colour and density of the tint therefore affect how objects are perceived

(Erickson, 2007). This alteration in perception may contribute to improved reaction time by increasing image clarity, which could improve decision making speed (Lacharez, Saeri, Wood, Atchison, & Horswill, 2013). In the context of cricket, this may translate to a fielder being capable of moving into an appropriate position quicker to intercept a catch.

Through personal communication with sales representatives of leading brands, it has been reported that athletes tend to select sunglasses based on personal preference rather than performance benefits (G. Barnett, personal communication, February 24, 2015, S. Jones, personal communication, May 12, 2015). Selection on this basis ultimately results in an array of tints being worn by athletes in the same match situation. There is a paucity of research that has investigated how the change in perception, through the use of different tints of sunglasses, affects the catching performance of cricketers. Research of this nature would be useful. This study therefore aimed to determine if a particular tint of sunglass aided catching performance for out-fielders in cricket better than others.

AIMS AND OBJECTIVES

The current investigation aims to determine the impact of different tints of sunglasses on the catching performance of out-fielders in cricket. Furthermore to determine players subjective experience of catching while using the different colour tints.

To address the above aim, the objectives of the investigation are:

(i) To quantify any differences in ocular parameters when wearing the different colour tints

(ii) To quantify the difference in number of catches while wearing the different colour tints of sunglasses

(iii) To quantify the difference in the quality of the catches executed when wearing the different colour tints

(iv) To use questionnaires to assess players preference for any particular tint used in the experiment

STATEMENT OF THE PROBLEM

The use of sunglasses for protection against UV radiation in outdoor sport is imperative for the maintenance of ocular health. Their use has further evolved to include performance benefits that improve perception. Despite the established benefits for ocular health, no research has established the efficacy of the supposed performance advantages of sunglasses associated with different colour tints. Research surrounding the purported performance enhancement of the colour of sunglass tint and how it affects catching performance while fielding during the game of cricket is limited.

Sales representatives indicate that cricket players commonly tend to use the G30 lens when playing and therefore this tint warrants investigation. There have been no studies that have investigated tint of sunglasses and catching performance. For this reason, there is no baseline information regarding which colour of tints that affect catching performance therefore warranting initial investigation into colours of tint on either end of the colour spectrum. As this study will be the first of its kind, it will be interesting to establish whether a blue or a red tint is beneficial or not to catching performance and compare these results to the commonly used G30 tint within cricket.

This research therefore investigated the catching performance of fielders while wearing three different colour tints, red, G30 and blue, under a single light intensity.

RESEARCH QUESTION AND HYPOTHESIS

The experimentation will seek to answer the following question: Is catching performance influenced by different colour tints of sunglasses (red versus G30 versus blue) in comparison to a clear tint? A secondary question is: What is the preference of tint amongst players and how does this influence players perceptions when wearing the different tints?

Based on the small amount of literature surrounding the research, it was expected that vision and catching performance, would be influenced differently by the selected tint of sunglass. Furthermore it was expected that the tint of sunglass would affect the wearers perception of the environment differently.

THESIS OUTLINE

This thesis will be constructed in the following manner. The literature review will give an overview of what vision is and its importance in sport, covering the topics of sight, human information processing and how these components combine to allow for perception and affordances of behaviour in the athlete’s environment. The third chapter will detail the protocols and procedures employed to answer the research question. The results chapter will highlight the outcomes of the experimentation with regard to how each tint affected each of the visual parameters fundamental to vision, followed by number and quality of catches taken. Subjective measures such as visual comfort, target visibility, personal preference and pain data are also reported on. The subsequent chapter will interpret the findings of the experimentation in relation to the literature from chapter two. The final chapter will provide a summary of procedures and main outcomes from the investigation and conclusions will be drawn.

CHAPTER II:
REVIEW OF LITERATURE

INTRODUCTION AND ROADMAP

When playing cricket, the old adage of ‘catches win matches’ strongly implies the importance of catching the ball on the outcome of the game. Catching as a skill is affected by several factors, for example, crowd pressure, angle of the sun overhead, cloud cover or confidence to mention a few. However, although these all may impact the outcome of the catch, catching as a skill is underpinned by the fundamentals of vision. It is important to distinguish between sight and vision, as neither can function without the other. Vision or visual perception is a result of the integration of selected information from the eyes through sight, and cognitive processing that gives us an awareness of the environment we exist in. Vision as an integration of these two processes relies on effective extraction of information and decision making for the resultant action of possible successful execution of the catch (Mark Williams, Davids, & Williams, 1999). Many processes occur in a short amount of time from scanning and extracting data from the environment to processing and effecting the appropriate action successfully to improve the odds of winning in a match. The addition of a filtered lens may affect what information is detected, ultimately affecting interpretation and thus may alter chances of a successful catch dependent on what colour tint of sunglasses worn. For this reason, this project has decided to investigate the effect sunglasses may have at the level of sight on the success of catches.

This chapter describes why vision is important and focuses on explaining the two concepts of sight and human information processing that allow for visual perception to occur. The concepts of perception-action coupling and affordance of behaviour will be explored to understand how sight is translated into action. Fielding in cricket as an under-researched area will be discussed and will explain how vision impacts the skill of fielding. The chapter will end off discussing how sunglasses affect visual perception in addition to how they are marketed as performance-enhancing tools.

WHY VISION IS IMPORTANT IN A SPORTING CONTEXT

Vision is a complex multi-sensory, integrative process that involves the eyes, brain and body and is the result of gaining meaning through the interpretation of what the eye has detected (Mark Williams et al., 1999). The eyes provide input (sight), in the form of spatial and temporal information, the brain integrates and interprets this information gathered from the eyes with other sensory information (Gardner & Sherman, 1995; Kirschen & Laby, 2011). The processed information then stimulates the action systems of the body (neuromuscular) for output (selected action) (Gardner & Sherman, 1995; Kirschen & Laby, 2011). Feedback occurs within this process of vision and therefore is not limited to the eyes alone (Gardner & Sherman, 1995). In fast ball sports such as cricket, it is important that the information received is optimal so the athlete can process and act on this information quickly and effectively (Kirschen & Laby, 2011). Athletes in these sports demonstrate feats of eye limb co-ordination by hitting or catching a ball with incredible precision by moving the bat or hand into the right place at the right time with positional errors of less than 5cm and temporal errors of less than 2-3ms (Regan, 1997). Reflex catches that occur with minimum input of visual cues challenge the models of visuo-motor co-ordination, emphasising the role of other factors that may contribute to the execution of such tasks as is the case with slip fielders in cricket (Regan, 1997).

Top-level sporting performance is not only affected by the ability to receive visual information, but also by the ability to selectively attend to, interpret, analyse and utilise this information (Abernethy & Wood, 1992). The limited time available to extract and process the given information is demonstrated in fast ball sports such as cricket. In this context, players in both a batting and fielding circumstance have minimal time to react to either the delivery of a ball or in the instance of the inner or outer circle fielder, to set themselves up to catch a lofted ball to dismiss the batter (Abernethy, 1987b). It highlights the complex process of visual perception in sporting performance through the integration and co-ordination of sensory, motor, perceptual and cognitive skills (Loran & MacEwen, 1995). These complex and integrated processes will be explained in greater detail.

SIGHT

Sight is our dominant sense, that aids in day to day activities as well as in sports (Erickson, 2007; Kirschen & Laby, 2011). It is seen as dominant as more than half of the sensory receptors present in the human body are found within the eye along with a large area of the cerebral cortex being devoted to the processing of visual information gained from the eye (Tortora & Derrickson, 2009).

Sight is the ability of the sensory organ of the eye to resolve images and detail clearly on the retina (Gardner & Sherman, 1995). It is possible due to energy emitted from the sun at different wavelengths in the form of electromagnetic waves forming part of the electromagnetic spectrum. The electromagnetic spectrum is a variety of electromagnetic waves that travel at the speed of light with vastly differing wavelengths, frequencies and energies (Shapely, 2012). As can be seen from Figure 1, the spectrum ranges from gamma radiation (the shortest wavelength, highest frequency and greatest energy) to radio waves (longest wavelength, lowest frequency and energy) (Shapely, 2012). A small portion of these electromagnetic waves along the electromagnetic spectrum are present as visible light and are capable of being detected by the eye.

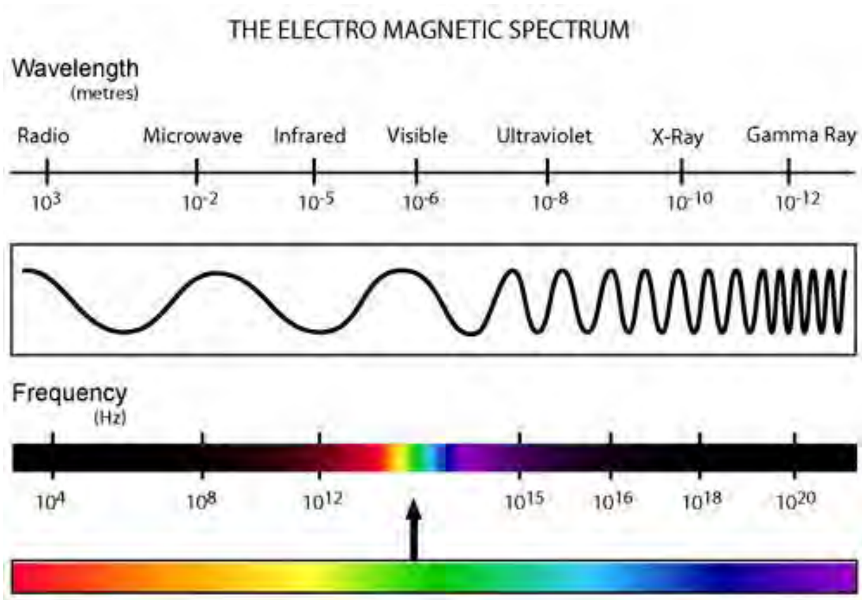


Figure 1: Electromagnetic Spectrum (Online image taken from ("Theoretical Background on the Camera Spectrophotometer," 2019))

Figure 1 illustrates the very small range within which the eye detects visible light, this range being between 380nm and 760nm. Sight is possible, due to the presence of sensory cells in the eye, known as rods and cones. These cells detect the frequency and intensity of the visible light entering the eye. This detection of visible light, causes photochemical changes to occur that further result in the conversion of electromagnetic waves into nerve impulses that are conducted to the brain allowing vision to occur as a result of visual information processing (Khurana, 2007).

To see an image/object clearly three initial processes need to occur before processing of this information ensues. These processes are namely refraction of incoming light rays through the cornea and lens, accommodation through alteration of the shape of the lens and dilation or constriction of the pupil (Tortora & Derrickson, 2009). As a result of the different wavelengths of light, different colours refract through the ocular media such as the lens and cornea with different focal points (Erickson, 2007). Due to the different focal power of each wavelength, there is resultant chromatic aberration (Erickson, 2007). Chromatic aberration occurs when light enters an optical medium, causing differential refraction of different wavelengths and can result in image blur, which typically affects what information is detected (Voke, 2010). Chromatic aberration is an important consideration in the quest for optimal image quality which impacts what key information is detected, which ultimately affects visual information processing (For a detailed account of how vision occurs, please see APPENDIX C: OVERVIEW OF HOW VISION OCCURS).

HARDWARE AND SOFTWARE OF THE VISUAL SYSTEM

Two general overarching components underpin visual perception. The first component is known as the hardware of the visual system and is comprised of the physical, mechanical and optometric components (quality of the player's visual system). Hardware factors mainly refer to the reception of visual information detected through sight, as a result of many different eye movements involved in tracking and detecting the different contours in the environment. The second component is known as the software of the visual system, which is a combination of knowledge and cognitive structures, playing a dominant role in perception. Software factors refer to the analysis, selection, coding, retrieval and overall understanding of visual information received by sight (Abernethy, 1987b).

Ten key factors contribute to the extraction of information that is necessary to effect desired goal-directed behaviour. These ten factors are: *visual acuity* (static, dynamic and contrast sensitivity), *colour vision*, *eye movements* (saccades, pursuit eye movements, vestibulo-ocular motor movements and vergence), *focus flexibility* (accommodation), *fusion flexibility* (binocular vision), *depth perception* (stereopsis), *visual reaction time* (response speed), *central peripheral awareness*, *eye-hand-body co-ordination* (perception-action coupling and visual adjustability) and *visualisation* (Gardner & Sherman, 1995; Loran & MacEwen, 1995; Mark Williams et al., 1999). These factors are divided into two specific groups, known either as a visual skill or visual ability. A factor that is considered a visual ability is known as the 'hardware' of the visual system and has to do with the reception of visual information

(Abernethy, 1987a; Paterson, 2010; Mark Williams et al., 1999). The visual abilities that form part of the hardware system are static and dynamic visual acuity, depth perception, accommodation, focus and fusion flexibility, colour and contrast sensitivity (Abernethy, 1987a). A factor considered a visual skill is considered to be the 'software' of the system and includes cognitive elements which influence the ability to interpret visual information through the perception of visual information (Abernethy, 1987a; Mark Williams et al., 1999; Paterson, 2010). Visual skills that form part of the software system are aspects such as eye-hand-body co-ordination, visual adjustability, central-peripheral awareness, visual reaction time and visualisation (Abernethy, 1987a).

Visual skills and abilities are integrated and co-ordinated in such a way that purposeful tasks such as catching are executed effectively. In this way, visual skills are supported by visual abilities, and they come together to result in visual motor control (Paterson, 2010). Overall, information received from the eyes feeds into multiple complex central processes that aid in the execution of a decided action (such as a catch). To demonstrate the number of processes that occur simultaneously to result in integrated motor control while catching a ball: the eyes scan the environment for pertinent information, fixate on the moving ball, tracks its trajectory to co-ordinate the convergence of its approach while concurrently co-ordinating the head movement to help stabilise the image of the ball (Moss & Moore, 1987).

Due to the eyes as a sensory organ detecting and providing the initial information that is fed into the cognitive decision-making process, there are a few key visual functions that must be optimal to result in successful task execution (Kirschen & Laby, 2011). Figure 2 depicts the sports vision pyramid developed by Kirschen & Laby (2011). It illustrates the importance of visual functions such as visual acuity, contrast sensitivity, stereovision and depth perception in their contribution to task execution such as catching (Erickson et al., 2009; Kohmura, Murakami, & Aoki, 2013). Visual acuity and contrast sensitivity are situated at the base of the pyramid and moving further up, depth perception and stereovision form the second base indicating that these visual characteristics are the fundamental cornerstones to achieving the goal of optimal visual performance.

These visual attributes form the base of the pyramid and contribute the most to the achievement of the ultimate goal of on-field performance enhancement (Zimmerman, Lust, & Bullimore, 2011). Best on-field performance will occur provided the solid base of visual function supports it (Kirschen & Laby, 2011). As these four visual functions provide this base, they were selected as objective ocular measures for this study.

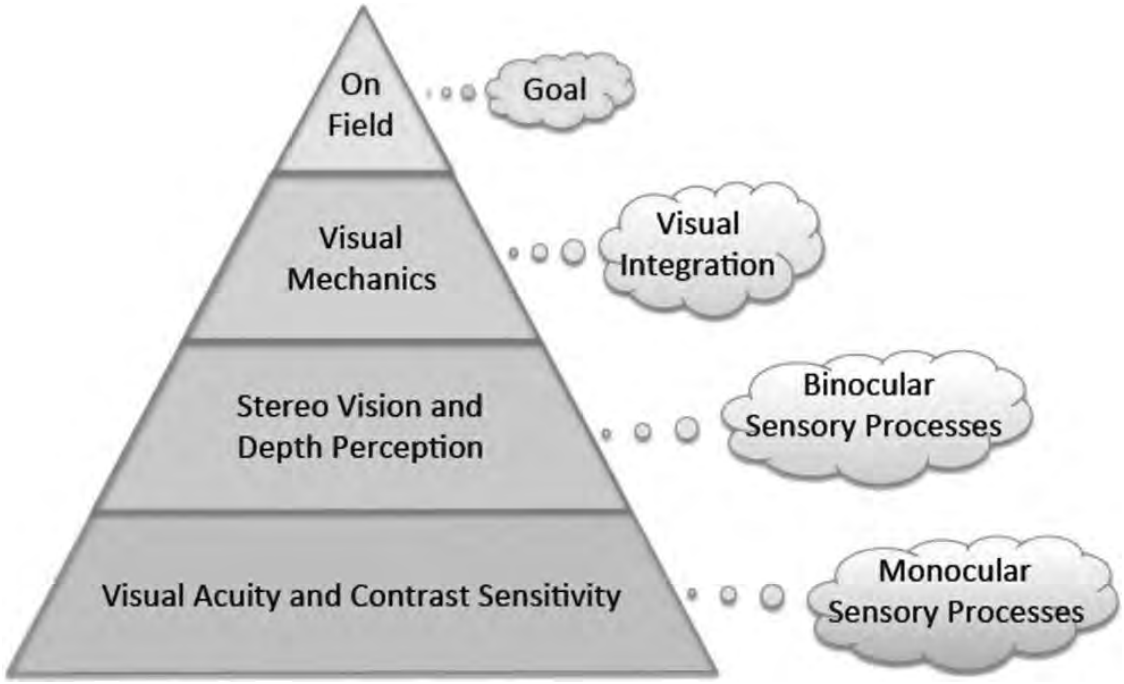


Figure 2: The Sports Vision Pyramid (taken from (Kirschen & Laby, 2011))

Each visual function and how it is to be measured will be described below:

VISUAL ACUITY

Visual acuity refers to the resolving ability of the eye to discern detail of objects in the surrounding environment (Mark Williams et al., 1999; Zimmerman et al., 2011). This ocular measure needs to be at a particular standard to ensure they resolve pertinent images in the environment in as much detail as possible. The more detail that is resolved, the more information can be contributed to the information processing chain to aid in the appropriate choice selection for successful task execution.

Visual acuity is typically measured using a Snellen Chart, like the chart pictured in Figure 3. Alongside each line of letters that appear on this chart, there is a number that describes the smallest size of letter the participant can identify correctly. This number is known as the Snellen fraction and is composed of a numerator and denominator. The fraction compares the patient's result (denominator) to the result expected from the 'normal' vision system (numerator). 6/6 vision is the standard result for a person with normal vision. This means that the patient can read the same line of letters at six feet that a normal person can read at six feet. Considering that sport occurs in a dynamic environment where moving objects such as balls need to be localised and tracked, it would be preferable that dynamic visual acuity could be tested. There is however no widely accepted test that has been developed or standardised that can be used to test this critical factor (Zimmerman et al., 2011).

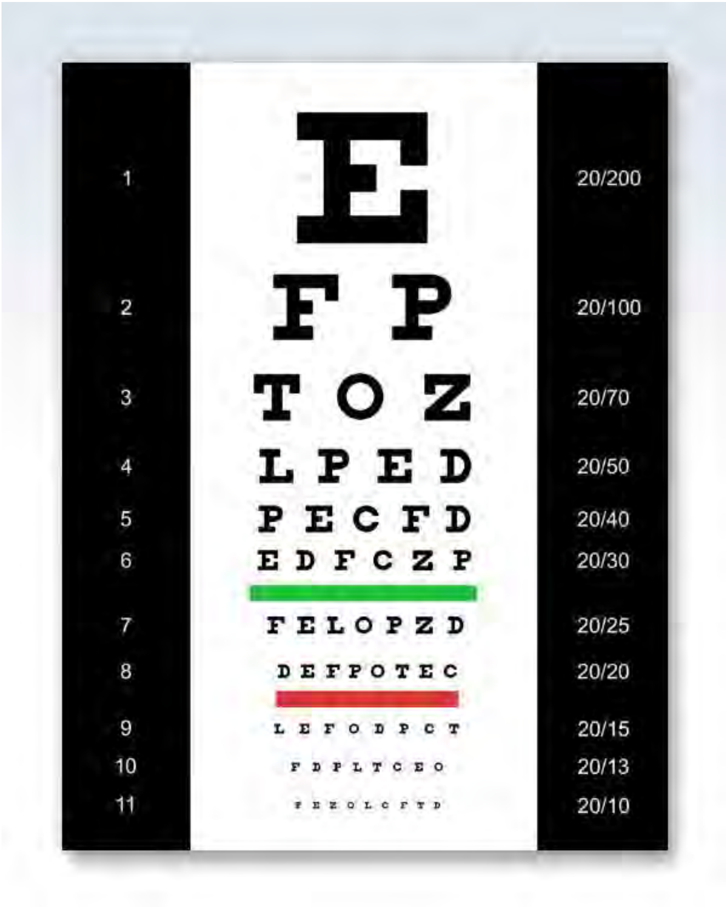


Figure 3: Snellen Visual Acuity Chart (Online image taken from ("Clin. Posters," 2019))

CONTRAST SENSITIVITY

Contrast sensitivity refers to the athlete's ability to discriminate objects from background information under varying conditions of illumination (Erickson, 2007; Mark Williams et al., 1999). It is a key ocular parameter that, in combination with visual acuity, contributes significantly to visual perception. It is especially important in situations of low light, fog or glare when the contrast between objects and their background is often reduced. It is important in a sporting environment as players need to be capable of discerning the moving ball against the background of the crowd to know which direction to move. This ocular measure can be measured using the Pelli-Robson test seen in Figure 4. This test consists of capital letters that decrease in contrast as you read horizontally across the line but the contrast of the letters decreases with each successive line (Heiting, 2018).

Figure 4: Pelli-Robson contrast sensitivity chart (Taken from (Pelli, 1997))

STEREOPSIS

Depth perception and stereopsis are known to be different but related concepts. As there is no other measure that is capable of reliably measuring depth perception, stereopsis is used to infer depth perception. The Stereo-Fly test seen in Figure 5 is considered the most reliable and valid test to investigate this ocular measure (Moore, 1997).

Figure 5: Stereo-fly Test with 3-D viewer glasses (Online image taken from (“Bondeye Optical,” 2015))

These visual parameters are just a few abilities that contribute overall to task execution such as catching. The other skills that contribute to task execution are a combination of mechanical and cognitive functions such as visual sensitivity (which encompasses visual acuity and dynamic visual acuity), accommodation and vergence facility, vergence stability and control, binocular vision, visual-spatial perception, visual processing speed, visual reaction and response speed, eye-hand co-ordination and peripheral vision (Loran & MacEwen, 1995; Mark Williams et al., 1999). Other contributing factors are attention, as well as templates of previous experience which players rely on (Hayhoe, Mennie, Sullivan, & Gorgos, 2005; Mark Williams et al., 1999). The above-mentioned visual skills all contribute to visual perception of the surrounding environment while attending to the necessary detail to successfully execute actions like catching (Mark Williams et al., 1999).

HUMAN INFORMATION PROCESSING

Sport in general is performed in an environment that is ever-changing and with dynamic conditions that continuously challenge the limits of human behaviour (Mark Williams & Ericsson, 2005). It is accepted that skilful action execution in sport is preceded and determined by perceptual skill (Krüger et al., 2009; Mark Williams et al., 1999). Vision is perhaps the most variable and selective of all the senses, in that information received is integrated and interpreted in a very small space of time (Knudson & Kluka, 1997; Mann, Williams, Ward, & Janelle, 2007). It is a strong contributing factor to the execution of motor skill performance as it helps the player to understand what is occurring in the surrounding environment to make adjustments to execute the necessary movement with precision (Erickson, 2007; Gardner & Sherman, 1995; Griffiths, 2007; Paterson, 2010). The ability to alter and fine-tune motor skills is known as perceptual-cognitive skill and is crucial in the player's ability to selectively direct their attention appropriately to information-rich areas and extract meaning from the situation efficiently and effectively (Mann et al., 2007).

To understand and explain how these adjustments may occur, a model was proposed by Welford (1960). This model proposed skilled motor action is a result of three central processing mechanisms as seen in Figure 6. The three mechanisms are the perceptual, decision and effector mechanism, which all occur sequentially.

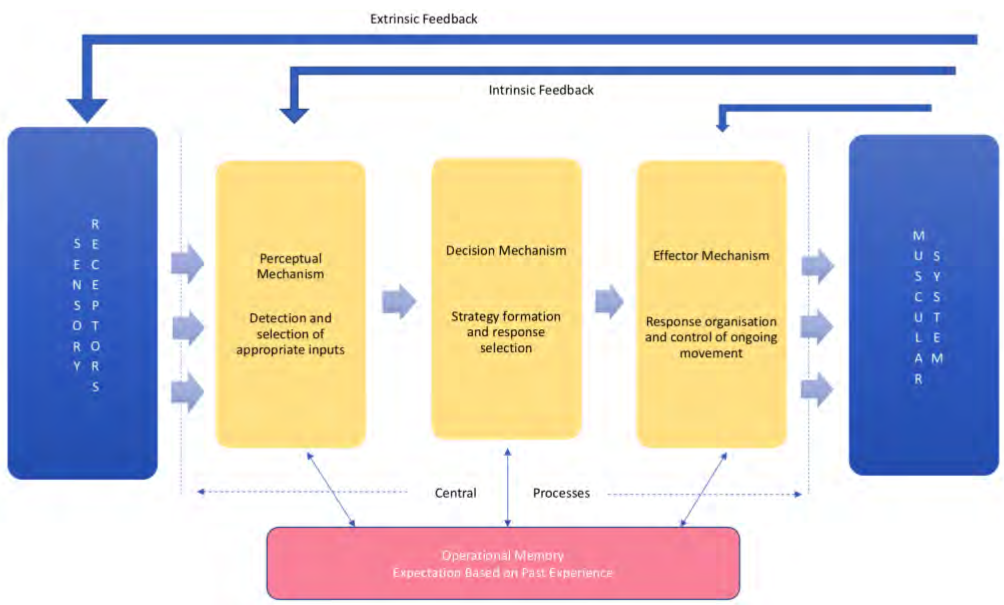


Figure 6: Information Processing Model of Skilled Performance (taken from (Erickson, 2007))

All sensory receptors, not only those of the eyes, provide an overwhelming amount of initial information to the brain. It is necessary for this information to be filtered such that the most pertinent information is selected to be utilised effectively in this process ensuring appropriate action is executed.

PERCEPTUAL MECHANISM

The selected information received at this stage of processing is provided from a variety of sources such as vision, vestibular, tactile and auditory receptors (Erickson, 2007). The amount of visual information received is a combination of visual resolution, depth judgement, eye movements and peripheral vision (Erickson, 2007). The information selected to be passed on to the perceptual mechanism needs to be of immediate relevance to the task needing to be executed (catching). The athlete's experience and ability to control attention are suggested to guide this selection and filtering process. All of this information provided by the eyes and other senses continually contribute to the intrinsic and extrinsic feedback systems that allow for adjustments to be made as the ball comes toward the fielder. The perceptual mechanism is responsible for organising and interpreting the selected information in an approach that facilitates optimal performance (Erickson, 2007).

DECISION MECHANISM

After information is processed in the perceptual mechanism, the information is then conveyed to the decision mechanism. Here the appropriate motor response is determined. At this stage of the information processing process, the athlete's knowledge and experience of the situation again have an important influence on the selection of appropriate action that needs to be taken resulting in a higher chance of success (Erickson, 2007). Experts have an increased chance of success due to the athlete having experienced a similar situation more often than a novice and therefore is capable of making quicker, more accurate decisions in the same time period (Erickson, 2007). The ability to do this is also supplemented through the use of advanced cue utilisation employed in the perceptual mechanism, therefore enabling the athlete to make predictions based on partial or advanced sources of visual information (Mark Williams et al., 1999; Poulton, 1957). The anticipation of the forth-coming action or trajectory of the on-coming ball based on these advanced cues allows the athlete to use prior experience and knowledge to select the most likely scenario, therefore reducing the amount of time needed to select the appropriate action (Erickson, 2007).

EFFECTOR MECHANISM

The final stage of the information processing model results in the selected motor response from the decision mechanism being transmitted to the effector mechanism. The effector mechanism both initiates and executes the appropriately chosen action. For successful execution of the catch, the motor response must be able to be fine-tuned and adjusted based on intrinsic and extrinsic feedback from the previous two mechanisms, provided there is sufficient time to effect these adjustments (Erickson, 2007; Savelsbergh et al., 1993). In order to have the most successful outcome and therefore an advantage in fast-action sports, one must have excellent perceptual skills in combination with exceptionally fast decision making processes to execute the most appropriate motor response (Erickson, 2007; Farrow & Southgate, 2000).

As the amount of information from all these sources can be overwhelming, the athlete must be capable of processing and filtering the most important aspects of this information. The selective attention to pertinent cues will contribute to action execution for successful performance (Erickson, 2007; Savelsbergh, Van der Kamp, Williams, & Ward, 2007). The filtering process that contributes to skilled perception is influenced by the athlete's capability of rapidly incorporating previous experience and expert knowledge into low-level visual processing. Another aspect that aids in skilled perception is the ability to utilise predictive information ('advanced cues') to guide their anticipatory response in a game situation (Erickson, 2007; Savelsbergh et al., 2007). The ability to correctly apply selective attention to the correct cues within the time constraints of a moving ball for interception is what separates novices from experts (Abernethy & Russell, 1987). Given the short amount of time athletes have to respond to on-field events, the role that attention and anticipation play in improving the efficiency of information processing will be described below.

ATTENTION AND ANTICIPATION IN HUMAN INFORMATION PROCESSING

Although complex, the flexible behaviour of players in response to events on field is possible due to the critical role that attention plays in sculpting the visual processing that occurs, resulting in a decision and therefore resultant action that is executed (Miller & Clapp, 2011). Attention is a key concept in all stages of information processing. It selects the most important information detected by the eye to be passed on to the perception and decision-making mechanisms. These mechanisms draw on previous experience to result in the eventual action that is selected to be performed (Hijazi, 2013; Mark Williams & Davids, 1998; Mark Williams et al., 1999). Visual attention is the core of the perception-action construct, which will be explained further on in the review, and is synonymous with aiding the effectiveness of visual information processing. The visual system is responsible for providing and detecting cues that inform the constantly changing environment around the player (Abernethy, 1987b; Blundell, 1985). In a catching situation where both the player and ball are moving, there is a great amount of temporal demand placed on the athlete as well as sensory information supplied to the brain (Le Runigo, Benguigui, & Bardy, 2005, 2010; Miller & Clapp, 2011; Mark Williams et al., 1999). The brain is required to come up with strategies to increase the efficiency and speed of perception and attend to only the most pertinent information (Abernethy, 1987b; Miller & Clapp, 2011; Sanderson & Whiting, 1974).

It is understood that there are limits to the capacity of humans in processing incoming information (Abernethy, 1987b). Players are capable of overcoming these limitations through selective attention. Selective attention is important as it relies heavily on the allocation of attention based on available sensory information as well as contextual information that is gained from past experiences (Abernethy, 1987a). Inherently the brain receives a lot of information, and due to limited time constraints and neural resources, it must attend to only the most critical inputs to guide decision making to efficiently execute an action (Miller & Clapp, 2011). The most efficient way to execute actions effectively is to make use of predictive models that integrate both past experience with the current goal-directed behaviour (Miller & Clapp, 2011; Regan, 1997).

Anticipation is another key factor at play that contributes to the effectiveness of decision making in information processing (Mark Williams et al., 1999). This factor contributes to separating the experts from the novices as it is believed that anticipation is mediated by knowledge structures stored in memory and that this knowledge base is more extensive for experts than for that of novices (Mark Williams et al., 1999). Anticipation aids in quicker decision making due to the ability to detect, identify and retrieve sport-specific information quickly, therefore decreasing response time through reliance on this comprehensive knowledge base (Mark Williams et al., 1999). Anticipation is therefore a by-product of selective attention through efficient scanning and the direction of attentional resources to relevant stimuli, resulting in a refined perceptual strategy (Mark Williams et al., 1999).

The extreme temporal pressure players are under when executing tasks such as catching is affected by several factors such as the velocity of the ball, the distance the ball travels as well as the inherent latencies of the catcher's reaction and movement time (Abernethy, 1987b). To execute such actions successfully, it has been proposed that the player's response selection is based on information available prior to ball flight or early ball flight information (Abernethy, 1987b). The use of advanced cues emphasises how important perception is and how it is influenced by attention and previous experience (Regan, 1997). Depending on when the object for interception has deviated from previous predictions is detected, appropriate action can be taken to compensate for these changes, but if detected too late, neural conduction limits the possibility for modification of motor action (Regan, 1997). These adjustments are possible due to the complex series of processes that occur in the brain, bridging the gap between perception from the eyes and action that occurs through motor co-ordination and control (Miller & Clapp, 2011).

PERCEPTION ACTION COUPLING

The concept of perception-action coupling explains the ability of the player being able to modify their actions right up to the threshold of neural activity through rapidly incorporating previous experience and expert knowledge (Miller & Clapp, 2011; Mark Williams et al., 1999). Visual input from the eyes contribute to complex brain mechanisms that ultimately results in action, based on rapid decision processes (Miller & Clapp, 2011). The brain integrates a multi-sensory experience through the theoretical construct of the perception-action cycle, which enables the guidance of behaviours that execute specific actions (Miller & Clapp, 2011). It is a most important construct that underpins sporting performance where visuo-motor integration functions under intense temporal (time) demands (Erickson, 2007; Le Runigo, Benguigui, & Bardy, 2005, 2010; Miller & Clapp, 2011; Mark Williams et al., 1999). The intense temporal demand is particularly apparent in sports that are classified as open skill, whereby the athlete must act on a moving target at a specific externally paced point in time (Mann, 2010). The spatio-temporal demands imposed are extremely high requiring millisecond-level decision making to convert vision to action in a constantly changing environment (Williams & Ericsson, 2005; Erickson, 2007; Mann, 2010; Miller & Clapp, 2011). The rapid and complex interaction that takes place in information processing is particularly important in reactive roles such as fielding in cricket. Balls nicked off the bat to slip catchers or hit hard and flat to fielders in the inner ring, move at velocities above the tracking threshold of the human eye and require quick and accurate information processing for interception. In the case of the outfielder, the ball's flight is sufficiently long that visual information can be updated to ensure the appropriate motor action is effected to execute the catch (Regan, 1997).

The processes of perception and action are linked, and one cannot occur without the other (Mark Williams et al., 1999, Miller & Clapp, 2011). The construct is based on the ecological (Gibsonian) theory of perception which implies that perception enables action to occur, but similarly, action is necessary for perception to occur as activity creates information (Oudejans & Nieuwenhuys, 2009). Visual perception of the environment enables perception-action coupling to occur as the athlete detects and interprets spatiotemporal changes that enable adjustments to be made for successful task execution (Mark Williams et al., 1999).

Visual information needs to be updated right up to the point just before interception, where neural relay prevents any further modification of motor action (Regan, 1997). Attention plays a critical role in the sculpting of the visual process, contributing to a final decision and action as a result of visuo-motor integration which provides real-time sensory updates, allowing action planning and action execution (Miller & Clapp, 2011).

When catching a ball visual perception helps to gain and interpret precise information as to the location of the ball in space (the 'where' information) in combination with the prediction of the specific point in time of contact (the 'when' information) which is then acted upon (Bootsma & Peper, 1992; Kirschen & Laby, 2011; Mark Williams et al., 1999). The visual information received is attended to without conscious effort and directs the muscles of the body to respond to various stimuli appropriately, indicating a link between the visual system and motor skill execution (Erickson, 2007; Venter, 2003). The visual system is crucial in guiding and extracting essential information from the environment to determine skilful behaviour (Krüger et al., 2009). Visual perception results in the effective and rapid task execution such as catching a ball and is affected by numerous factors such as eye movements, visual search strategies, as well as anticipation (Erickson, 2007; Knudson & Kluka, 1997; Mark Williams et al., 1999).

Perception-action coupling used in the context of a successful catch depends on the ability of the catcher to effectively combine information extracted from the environment such as where the ball is located in space, with the knowledge of where the limb is in relation to the rest of the body (Fischman & Schneider, 1985; Smyth & Marriott, 1982). Perception-action coupling has been demonstrated to exist through experimentation of participants having to catch a ball that is deflating (Savelsbergh & Bootsma, 1994). When catching these types of balls, participants have to adjust the aperture of the hand used to catch the ball through the alteration of finger flexion (Savelsbergh & Bootsma, 1994). This observation has led to the understanding that there are two main components concerning catching a ball. These are orientation and flexion, relating to predictions made about when and where the ball will arrive resulting in the appropriate orientation of the limb to intercept the ball's trajectory (Alderson, Sully, & Sully, 1974). The adjustments that occur based on the deflating ball indicate that the information received is constantly updated and based strongly on a prediction of the time to contact of the ball into the hand (Savelsbergh & Bootsma, 1994). Players need to be able to detect the spatio-temporal information related to the approaching ball early for the appropriate muscle co-ordination to occur to effectively execute the catch for a dismissal of the batter (Mark Williams et al., 1999). Closing of the hand too early or too late may result in a dropped catch. In this case, the ball either hits the fingers as a result of too much finger flexion or it hits the palm and bounces out as there is too little finger flexion to secure the ball respectively (Savelsbergh & Bootsma, 1994). This requires perceptual-cognitive skill which refers to athletes being able to identify the most crucial environmental information and integrate this with previous knowledge of the situation to effect appropriate responses (Mann, Williams, Ward, & Janelle, 2007). This is referred to as experiential memory which is also utilised for successful task execution through practice. It contributes to catching by using proprioception for accurate limb positioning becoming part of central pre-programming so that monitoring of limb movement is less reliant on vision for control (Smyth & Marriott, 1982). Central pre-programming, as a result of experiential memory, frees the role of vision for planning future actions or detecting important environmental changes to adapt for this (Smyth & Marriott, 1982). Acquiring and identifying the most important and relevant information from an environment that is saturated with information both relevant and irrelevant to the task, requires athletes to be able to direct their attention appropriately and extract meaning from this to execute the catch successfully (Mark Williams et al., 1999). The eyes are a key component in providing this perceptual information necessary to execute the above-mentioned tasks when fielding.

PERCEPTION AND AFFORDANCE OF BEHAVIOUR

The complex concept of perception as part of human information processing is not solely reliant on optical and ocular motor information but is also influenced by many non-visual factors such as social, emotional, past experience and cognitive workload (Proffitt, 2006). Athletes flexibly attune and adapt their selected action in the ever-changing playing environment due to the history of recurrent interactions of the body, environment and social context which results in multiple similar past situations to draw upon and make appropriate decisions (Cappuccio, 2015; Fajen, 2007). This tacit or procedural knowledge relies on concrete familiarity which is built on the continuous development of direct responsiveness to the given surroundings, readiness to anticipate and take advantage of opportunities for action (Cappuccio, 2015). Perception evaluates the behavioural possibilities of the environment, otherwise known as affordances (Fajen, Riley, & Turvey, 2008; Oudejans, Michaels, Bakker, & Dolné, 1996). These affordances are the possibilities on offer for potential actions offered by the environment and the events that occur in it (Fajen et al., 2008; Oudejans et al., 1996). Taking this into account, it is clear perception is not solely a visual process but is said to be embodied in that it relates the body to its desired goals (Proffitt, 2006). Embodied perception informs and evaluates the potential opportunities for action as well as the associated costs of the chosen action and is therefore influenced by one's purposes, physiological state and emotions (Proffitt, 2006). One’s goals, physiological state and emotions are theorised to affect motor performance from an attention perspective (Nieuwenhuys & Oudejans, 2012).

Emotions alter how environments are perceived through altering scanning patterns which ultimately impacts what stimuli receive attention furthermore impacting the outcome of perceptual-motor performance (Nieuwenhuys & Oudejans, 2012). The emotion that has received the most research on its influence on cognitive performance and thus in turn motor performance, has been anxiety, through its effect on attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007). Under the influence of an emotion such as anxiety, the altered scanning pattern becomes less efficient as people tend to execute more fixations for shorter durations and increase the amount of attention to task-irrelevant stimuli (Nieuwenhuys & Oudejans, 2012; Oudejans & Nieuwenhuys, 2009). Fixation on a particular target allows for accurate calibration through the adjustment and fine-tuning of movements relative to the target (Nieuwenhuys & Oudejans, 2012). Adjustment of movement in relation to a target ultimately impacts the perception of action possibilities as well as the selection of appropriate action possibilities (Nieuwenhuys & Oudejans, 2012; Oudejans & Nieuwenhuys, 2009). Anxiety increases the amount of attention dedicated to threat-related sources of information and therefore reduces the amount of attention available for perception, selection and realisation of possibility for action (Nieuwenhuys & Oudejans, 2012; Proffitt, 2006). Emotional states such as anxiety tend to decrease efficiency of movement resulting in a breakdown of automatic control of motor performance due to its influence on various operational levels (attentional, interpretational and behavioural) (Nieuwenhuys & Oudejans, 2012; Proffitt, 2006). It is believed in tasks such as catching that require a lot of online (visual) control, emotion particularly exerts its effect at the attentional level, as more of the limited resource of attention is directed towards threat-related stimuli, thus rendering less attentional resources available for calibration of movement (motor performance) thus resulting in a decrease in performance (Nieuwenhuys & Oudejans, 2012).

PERCEPTION AND AFFORDANCE OF BEHAVIOUR IN CRICKET

Cricket is a summer team sport played outdoors. It involves two opposing teams of 11 players with one team batting and one team fielding. The batting team has two players in the field, whereas the fielding side has 11 players in the field. The sport has three formats (Test, One

Day and Twenty 20) that are differentiated based on the number of overs permitted on the day of play. Cricket requires players to assume a number of roles in the game, namely batter, bowler, fielder or wicket-keeper. Players typically take on either two or three roles during the course of the game. This is due to all players being required to be a batter and a fielder but not every player having to be a bowler or a wicket-keeper (MacDonald, Cronin, McGuigan, & Stretch, 2013). The batting and fielding components of the game are therefore the most important as all players contribute in these formats. Perception action coupling and affordance of behaviour underpin all actions performed when playing in any of the aforementioned roles of the game, including fielding. Vision from a catching perspective is crucial. It is of particular importance in fielding for players to place themselves in the best position to execute a catch, cut off a ball in the field or to prevent a ball crossing the boundary.

FIELDING IN CRICKET: A VALUABLE YET UNDER-RESEARCHED SKILL

Players fulfilling the role of fielding need to support the bowler by either restricting the number of runs conceded, catching airborne balls to dismiss batters or help to effect run-outs (MacDonald, Cronin, McGuigan, et al., 2013; MacDonald Wells, Cronin, & Macadam, 2018; Saikia, Bhattacharjee, & Lemmer, 2012). Despite the importance of the role of fielding in the game of cricket, it is the least studied skill with minimal literature investigating this component either from a physiological demand perspective (Barlett, 2003; MacDonald, Cronin, McGuigan, & Stretch, 2013) or from a performance or task execution perspective. The few physiological demand studies that have been conducted on fielding have been done using time-motion analyses with GPS tracking to inform strength and conditioning practices (Petersen, Pyne, Portus, & Dawson, 2011; Petersen, Pyne, Dawson, Portus, & Kellett, 2010; Petersen, Pyne, Portus, & Dawson, 2009; Rudkin & O'Donoghue, 2008). To the author's knowledge, there have been no studies that have investigated fielding in cricket from a task execution perspective for example concerning what factors may impact the skill of catching. Given the importance of fielding as a way to win matches in the game of cricket, it is perplexing that there is so little research on this skill (MacDonald, Cronin, McGuigan, et al., 2013; MacDonald Wells et al., 2018).

The different skills the various fielding positions require gives some insight as to the role vision plays (MacDonald, Cronin, Mills, McGuigan, & Stretch, 2013). The role of the slip fielder is seen to be more difficult than that of the outfielder due to their proximity to the batter. The slip fielder is given little time to predict the trajectory of the ball and catches are therefore typically as a result of reflex reaction and anticipation to the ball's deflection off the bat (Regan, 2012).

The slip fielder receives no cues from the batter's body position to aid with prediction, leaving very few visual cues to aid in catching the ball (Regan, 2012). When catching a high lofted ball, outfielders utilise continuous coupling between perception and action, while running up to 30m exploiting the visual information of the where and when of the ball as well as the required movement to position oneself appropriately (Regan, 2012; Smyth & Marriott, 1982). Another aspect that proficient players rely on for ball interception is previous fly ball experiences that informs the likelihood of success based on the results of being in similar situations multiple times (Chapman, 1968).

FIELDING POSITIONS AND CATEGORIES

Figure 7 illustrates the main fielding positions players are typically assigned to. The 25 main fielding positions can be further categorised into the more general sections of the field of play resulting in players being classified as either a close, inner ring or outer ring fielder as seen in Figure 8 (MacDonald, Cronin, McGuigan, et al., 2013; MacDonald, Cronin, Mills, et al., 2013).

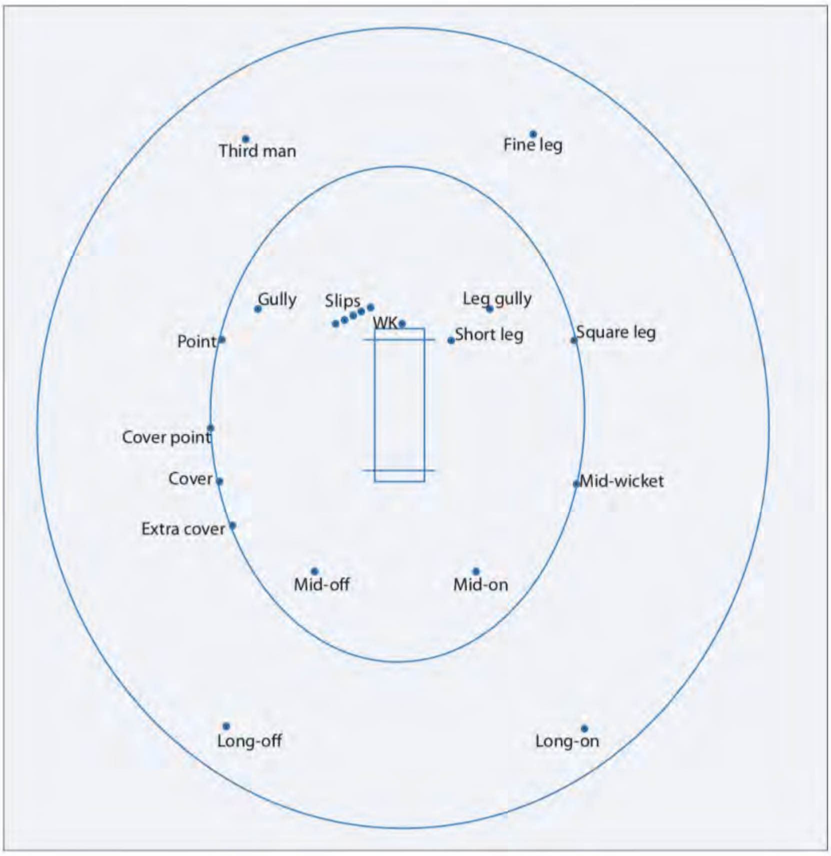


Figure 7: Pitch map illustrating main fielding positions (taken from MacDonald et al. 2013)

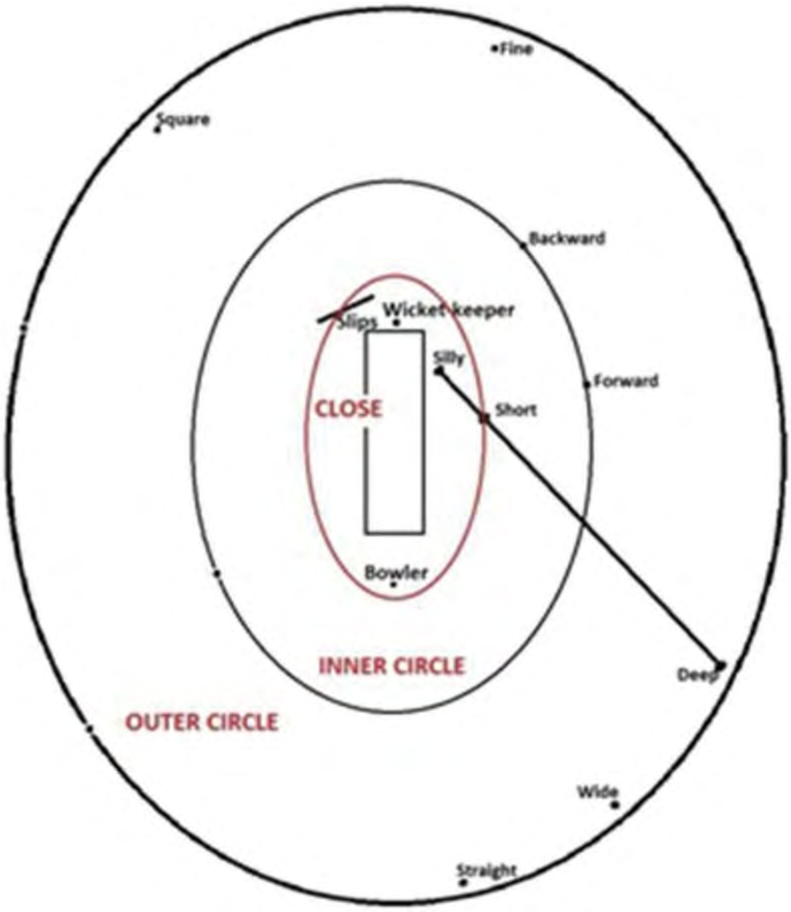


Figure 8: Fielding categories (taken from MacDonald Wells et al. (2018))

MacDonald Wells et al. (2018) performed a time-motion analysis of 8 games during the Cricket World Cup 2011 in India to quantify the movement demands of fielders in the close, inner and outer ring. It was deduced that the close fielders had successful catches as well as dropped catches that were a result of having minimal time to anticipate and react to potential catches due to their close proximity to the batter (MacDonald Wells et al., 2018). Fielders in this position category moved very small distances and were required to stop and catch the ball (MacDonald Wells et al., 2018). Fielders in the inner ring participated in over half of all fielding in the game and fielders in these positions collectively had the most number of catches in the games analysed (MacDonald Wells et al., 2018). It was found that inner circle fielders tend to have more time for decision making and initiation of movement than close fielders but have a greater amount of distance to cover (MacDonald Wells et al., 2018). Outer circle fielders caught almost as many catches as the inner circle and were also required to move from their original position to field the ball (MacDonald Wells et al., 2018). Fielders in these positions tended to have more time to position themselves for the catch as the batter tended to mistime the ball but often covered the most distance to get into the correct position (MacDonald Wells et al., 2018).

Dropped catches in these positions tend to be as a result of fielders being subjected to a variety of catching conditions and pressures causing them to misjudge the distance to position themselves appropriately (MacDonald Wells et al., 2018).

Fielders are selected for particular positions on the field based on where their strength lies within their skillset. To achieve a run-out, restrict runs or dismiss batters, there are four key fielding skills that comprise the fielding skillset, namely ground fielding, retrieving, throwing and catching(Woolmer & Noakes, 2008). All these aspects influence the success with which totals are defended and therefore need to be executed well by all players. Each of these aspects will be further addressed in more detail.

GROUND FIELDING AND RETRIEVING

The focus of ground fielding is to reduce the number of runs conceded. Depending on the status of the game, fielding can be done either in a defensive or attacking manner. Defensive fielding forms the basis of attacking fielding (Woolmer & Noakes, 2008). Defensive fielding involves the use of the 'long barrier' technique to safely ensure the ball does not pass the fielder(Woolmer & Noakes, 2008). One may notice that fielders tend to go back to defensive fielding if there have been mistakes in the field such as a fumble in the field while trying to retrieve the ball, and therefore try to prevent a ball reaching the boundary. In comparison, attacking fielding requires more 'trigger movement' where the fielder rather pounces on the ball than using the body as a barrier as in 'long barrier'(Woolmer & Noakes, 2008). This type of fielding is more pertinent as the fielding side will want to apply some pressure on the batter to reduce the number of runs the batter can concede before the ball reaches the fielder.

Retrieving fielding occurs when the ball passes the fielder, and the player has to turn and chase the ball to prevent the ball from crossing the boundary to automatically award the batting side four runs. The turn and chase often involves sliding to retrieve the ball, which is effective in reducing runs and setting up run-outs as the ball is in the air sooner and therefore reaches the wicket-keeper or stumps quicker (Stretch, Bartlett, & Davids, 2000).

THROWING AND CATCHING TECHNIQUES IN FIELDING

Throwing and catching are the other two aspects that comprise fielding skill.

Throwing contributes to the outcome of the game in two main ways, the first is by reducing the number of runs conceded by the batters running between the wickets and the second is by taking a batter's wicket by means of a run-out. Once the batter has hit the ball into the field, depending on how the captain has set his field and placed his fielders, the ball may be fielded close to the batter in the inner ring or in the outfield. The fielded ball needs to get back to either the bowler, another fielder or wicket-keeper behind the stumps. There are three main throwing movements that are utilised to achieve this depending on where the ball is fielded. These are known as underarm, sidearm or overarm throws (Bartlett, 2002). Under arm throws are typically executed over shorter distances as it is a quick release. Over arm throws require more strength and accuracy than the sidearm throw and are generally executed in the midfield or outfield due to the distance the ball has to travel (Woolmer & Noakes, 2008).

Catching is perhaps the most important skill in cricket due to the dismissal of the batter and can mean the difference between victory and defeat in a game (Woolmer & Noakes, 2008). The research that has focused on catching has focused on the interceptive skill of catching (Bartlett, 2003). The skill of catching varies across the different fielding positions that players fulfil, with wicket-keepers and slip fielders needing to catch balls with minimal visual cues to aid their response, and outfielders who need to catch balls that come overhead (Bartlett, 2003; MacDonald Wells et al., 2018). Catches are therefore categorised into either, slip, close or high catching. Close and slip catching occurs in the inner ring and is based more on reflex action and anticipation of fast-moving balls typically edged off the bat or hit hard at close fielders in the inner ring (Bartlett, 2003; Woolmer & Noakes, 2008). Players need to anticipate the catch by taking cues from the batter's position, the pace of the delivery of the ball and the nature of the wicket (Woolmer & Noakes, 2008). For cricket balls that tend to remain low due to the ball 'dying' off the bat, players employ the 'cupping' technique, to secure their hands under the ball preventing it making ground contact. Balls caught in the inner ring that are nicked off the bat to the slip cordon or are cracked off the bat to attempt penetrating the inner ring fielders, typically remain hard and fast coming towards the chest or face. In this instance, the 'reverse cup' technique of catching the ball is employed (Woolmer & Noakes, 2008).

High catching mainly occurs but is not limited to, the outer ring. This type of catch requires good judgement, concentration and swift movement to place oneself in a stable position underneath the ball falling from overhead (Bartlett, 2003; Woolmer & Noakes, 2008). Again two variations of catching technique are utilised, the English or Australian technique (Woolmer & Noakes, 2008). In the English method, the hands are held high, with the palms facing the fielder's face and cupped in the direction of the ball to guide the ball into the hands (Woolmer & Noakes, 2008). In comparison with the Australian method, the hands are also held high, but the palms now face away from the fielders face to allow a better view of the ball against the bright sun (Woolmer & Noakes, 2008). Players tend to use both methods of catching throughout the game depending on the height of the ball. For example, if the ball comes overhead, the Australian method is typically used, but for balls that arrive at the level of the collarbone or neck, the method of choice is less obvious (Woolmer & Noakes, 2008).

INFLUENCE OF VISION ON CATCHING

The processes that underpin catching from a technical perspective have typically been understood from a mathematical perspective and is beyond the scope of this thesis (for an understanding from this perspective, please see the following papers, Chapman, 1968; Diaz, Cooper, Rothkopf, & Hayhoe, 2013; Dienes & McLeod, 1993; Fink, Foo, & Warren, 2009; Hayhoe, Mennie, Sullivan, & Gorgos, 2005; Kistemaker, Faber, & Beek, 2009; Mazyn, Savelsbergh, Montagne, & Lenoir, 2007; McBeath, Shaffer, & Kaiser, 1995; McLeod & Dienes, 1996; McLeod, Reed, & Dienes, 2006; Peper, Bootsma, Mestre, & Bakker, 1994; Regan & Gray, 2000; Savelsbergh et al., 1993; Shaffer & McBeath, 2002; van der Kamp, Savelsbergh, & Smeets, 1997; Whiting, Gill, & Stephenson, 1970). However, it is known that successful catching from a visual perception and visuo-motor integration perspective requires continuous spatiotemporal information gained from the eyes (Mazyn et al., 2007). This aids in the ability to co-ordinate the athlete into the appropriate position, swiftly and efficiently for successful execution of the action (Williams et al., 1999). Along with the high temporal demands in fast ball sports, multiple factors may affect catching. Some of these factors are, environmental changes that affect ball trajectory, match or scoreboard pressure, crowd pressure, situational awareness from peripheral vision as to where another teammate may be, colour of the ball, speed of the ball, height of the catch (if it is low or high), wind, cloud cover, mechanical factors such as spin due to the seam of the ball, as well as whether sunglasses are worn or not, are just a few. All of these factors contribute to how information is extracted and processed. The information received from the eye must be optimal, especially with regards to fastball sports where information must be gathered, processed and acted upon quickly for accurate task execution (Kirschen & Laby, 2011). The execution of a catch as a fielder or shot as a batsman is more likely to occur if the information received is clear and of high quality. This clarity aids in the ability of the athlete to accurately and efficiently perceive what is occurring in the environment, ensuring the best course of action is taken (Farrow & Southgate, 2000). For this reason, when catching, if the quality of sight can be improved in any way to assist in the decision-making process, players may be able to position themselves quicker to ensure successful interception (Farrow & Southgate, 2000). Sunglasses have been marketed as one such method to effect an improvement in visual information received to translate into an improvement in sport performance (Erickson et al., 2009) with their frequent use by players now becoming commonplace while fielding in the context of cricket.

SUNGLASSES AND SPORT

SUNGLASSES AS A PROTECTIVE MEDIUM IN SPORT

Outdoor sports such as cricket expose players to conditions of high solar illumination for prolonged periods, typically between the hours of 09H00 and 18H00 in summer (Moore & Ferreira, 2005). The visual system is capable of dealing with gradual changes in illumination such as the slow diurnal changes that occur throughout the day. In the outdoor sporting context difficulties may arise particularly in fast ball games when abrupt changes occur with fast-moving overhead cloud or when natural illuminance levels fall to a low level (Gardner & Sherman, 1995). The illumination levels that players are exposed to are often between 1000 and 10 000 lx during play. Problems may occur throughout this range as light saturates the retina and causes reduction in finer levels of contrast sensitivity (Erickson, 2007).

Sunglasses are worn for various reasons; the most important and widely accepted is for the prevention of ocular diseases through exposure to UV radiation (Dain, 2003). There are three types of UV radiation known as UV- A, UV- B and UV- C. UV- C radiation is absorbed by the ozone layer and therefore presents no threat to ocular degeneration. UV- A and B both have adverse effects on the eyes and vision (Monireh, Hamed, & Marziyeh, 2014). These two types of radiation can cause cataracts, macular degeneration and cancer of the eyelids and skin around the eyes (Monireh et al., 2014; Thomas, 2008). For this reason, sunglasses typically have a filter or tint applied to the lens that absorbs short-wavelength visible light measuring between 380 and 500nm. The most harmful wavelength measuring at 440nm, that causes damage to the retina is removed (Erickson, 2007). Athletes who participate in outdoor sports such as cricket choose to make use of sunglasses for this protection (Erickson, 2007; Thomas, 2008).

Further reasons for the use of sunglasses are for protection from ocular trauma, reduction in visual fatigue and discomfort experienced with glare, and chromatic aberration for anecdotal performance enhancement. (Erickson, 2007; Porisch, 2007; Thomas, 2008). Glare is a common environmental factor that interferes with comfortable vision and contributes to eye fatigue due to squinting (Erickson, 2007; Farrow & Southgate, 2000; Hammond, Renzi, Sachak, & Brint, 2010). It occurs as a result of the eyes being exposed to a light source, either direct or indirect, that is in excess of their adaptive state causing a reduction in visual performance (Erickson, 2007; Farrow & Southgate, 2000; Hammond et al., 2010).

SUNGLASSES EFFECT ON VISUAL PERCEPTION

The concept of tinted glasses affecting the visual system was first investigated in the late 1930s where researchers started recommending certain tints of sunglass lenses for military and aviation use to optimise visual performance at high altitudes and bright environments such as snowfields (Clark, 1969a). There has been very little research into the subjective and objective effect of coloured and tinted lenses on vision and visual parameters such as visual acuity, depth perception, contrast sensitivity and colour discrimination (Cates, Davis, & Guzman, 1994; Clark, 1969a; De Fez, Luque, & Viqueira, 2002; Moore, 1997; Teikari & Lindström, 1995). Sunglass use should not negatively affect these key visual parameters in addition to increasing distortions or prismatic effect which would affect depth perception (Dain, 2003; De Fez et al., 2002; Shaik et al., 2013; Teikari & Lindström, 1995). Although there are many studies on the effect of sunglasses being used to reduce UV radiation, there are very few studies that investigate the effect of sunglass tint on optical parameters such as visual acuity and contrast sensitivity (Teikari & Lindström, 1995). Visual acuity is dependent on illumination levels and as such sunglasses should not retain lighting levels between 300 - 3 000 candelas.m^{-2} (Miller, 1974). This range represents a variety of lighting conditions from common indoor lighting to moderate daylight conditions (Cates et al., 1994). Illumination levels above or below this range begin to affect vision and performance by decreasing visual acuity and retinal image (Cates et al., 1994).

Sunglasses affect the visual process through the presence of a tint or filter that adjusts/reduces the natural light passing through it (Clark, 1969b; D. Miller, 1974; Shaik et al., 2013). The tint eliminates harmful wavelengths and is purported to potentially improve retinal image clarity (Miller, 1974). It affects light transmitted to the eye in three particular ways namely intensity, spectral distribution and environmental factors that affect light, such as haze and fog or reflecting surfaces (Clark, 1969b; Miller, 1974). The tint affects the amount of visible light that is transmitted to the eye, meaning that the darker the tint, the less amount of visible light is transmitted (Dain, 2003; Shaik et al., 2013).

The percentage of light that passes through the lens is known as transmittance (Griffiths, 2003; Shaik et al., 2013). The colour of the tint gives an indication of its absorption characteristics, but the exact transmission spectrum can only be determined by a spectrophotometer (Griffiths, 2003). Different colour tints affect the portion of the visible light spectrum that is filtered out and transmitted to the eye, therefore affecting how objects in the environment will be perceived (Shaik et al., 2013). The density of these colours of tint is often varied, producing differing grades of tint, which in turn affects the transmittance of light (Shaik et al., 2013). For example, a strong yellow tint reduces the transmittance of blue light (its opponent colour) (Shaik et al., 2013). Sunglasses should reduce glare by reducing the amount of light transmitted to the eye, but not to the extent that colour discrimination is affected (Tuchinda, Srivannaboon, & Lim, 2006).

Tinted lenses that reduce the effect of chromatic aberration typically caused by short-wavelength light (blue) often result in better image clarity for the wearer (De Fez et al., 2002; Erickson, 2007; Erickson et al., 2009). The reduction in short-wavelength light is found to reduce stimulus luminance but increases brightness, contributing to the subjective feeling of improved vision (De Fez et al., 2002; Erickson et al., 2009). In addition it results in decreased chromatic aberration which tends to cause visual discomfort or decreased contrast sensitivity (Erickson, 2007; Erickson et al., 2009; Monireh et al., 2014). Tinted lenses reduce the transmittance of the visible spectrum and change colour perception, either enhancing or distorting them to a greater or lesser degree (De Fez et al., 2002). Therefore, it is important to select a tint that will enhance visual perception to aid in successful sporting performance.

SUNGLASSES EFFECT ON PERFORMANCE

Tinted sunglasses worn by athletes, aid in reducing glare as well as improve contrast to enhance optimal visual performance in sport (Erickson, 2007; Porisch, 2007). Typically, information collected by the naked eye is done quickly and effectively. However, the addition of sunglasses may act as a barrier that hinders the effectiveness of visual processing, particularly if the right tint is not chosen (Miller, 1974). The quality of visual parameters of sight, such as contrast sensitivity, can be negatively affected by outdoor factors without the use of sunglasses (Monireh et al., 2014). The possible decrement in quality of visual information transmitted for central processing may impact/affect the execution of tasks (Miller, 1974; Monireh et al., 2014) such as catching in cricket.

Factors such as glare are one of the key elements that encourage sunglass use by players in the field. The inability to distinguish fine detail when affected by glare impacts performance negatively as a result of delayed reaction time (Erickson, 2007; Farrow & Southgate, 2000). The appropriate selection of tint of sunglasses is again of pertinence concerning retinal image clarity. The benefit of improved retinal image quality, particularly of moving targets, is of great advantage to athletes in dynamic sports as it contributes to the effectiveness of decisions made. In addition, the selection of coloured or tinted lenses is important as it may change colours in the visual field as a result of a decrease in retinal illuminance. This causes non-specific colour loss (Wolffsohn, Cochrane, Khoo, Yoshimitsu, & Wu, 2000). These changes may cause undesirable effects, particularly in a sporting situation. A ball could be picked up late, due to the change in the perception of the environment and therefore the embodied perception of reaching the goal of catching the ball as well as the costs associated with taking action in this environment, such as if the ball is not caught well, the player may injure his/herself (Nieuwenhuys & Oudejans, 2012; Proffitt, 2006; Van Der Kamp, Savelsbergh, & Rosengren, 2001). This may result in the player hesitating due to the fear of injury along with the altered perception of the environment reducing the choice reaction time that may be available to respond appropriately (Le Runigo et al., 2010; Proffitt, 2006). Erickson (2007) suggests athletes playing in variable lighting conditions should be prescribed more than one pair of sunglasses to allow for different illumination conditions throughout the game. (pink balls)

SUNGLASSES AS A PERFORMANCE ENHANCEMENT TOOL IN SPORT

Athletes that compete in fastball sports such as cricket and tennis have anecdotally reported an improvement that the ball appears clearer while wearing sunglasses (Farrow & Southgate, 2000). Clarity of image is a key aspect in visual performance as it contributes to the athlete's ability to understand, interpret and react to this visual information (Farrow & Southgate, 2000). It is important for players to choose the correct sunglasses to ensure that their vision is not compromised in match situations while still providing the necessary protection. It is recommended that sports players should consider sunglasses that are polarised to effectively combat glare. They should be fitted with poly-carbonated lenses as this offers good impact protection (Thomas, 2008).

An important fact to consider is the role of brand sponsorship in the use of sunglasses by athletes, and the impact this has on choosing suitable protective and performance-enhancing eyewear. Brand sponsorship has become a lucrative source of income and marketing for both professional athletes and the brand itself (Erdogan, 2008; Frederick & Patil, 2009; Lamont, Hing, & Gainsbury, 2011; Nucci, 2015; Stevens, Lathrop, & Bradish, 2003). Sponsorship typically involves a sense of reciprocity between two parties, whereby both mutually benefit from the relationship (Lamont et al., 2011). This reciprocity generally involves the exchange of resources whereby brands remunerate athletes to endorse and promote a particular product

(Bauer, Stokburger-Sauer, & Exler, 2016; Lamont et al., 2011). This endorsement carries an expectation of return on investment through an increase in sales of that product (Bauer et al., 2016; Lamont et al., 2011). To maximise return on investment, marketers have taken advantage of the increased screen time sports receive in addition to a spectator's desire to be branded similarly to top players (Bauer et al., 2016; Lamont et al., 2011; Nucci, 2015). Sunglasses are marketed to consumers in multiple outdoor sporting disciplines such as golf, cricket and cycling with the message that their product will improve performance.

Sunglasses have successfully been marketed to athletes and consumers alike based on the purported benefits of glare reduction, which increases visual comfort and clarity. Although this has been anecdotally confirmed, athletes have also reported that some sunglasses can hinder performance, making it difficult to distinguish the ball from its background (referring to reduced contrast sensitivity) (Farrow & Southgate, 2000). Such reports have resulted in sunglass manufacturers developing sport-specific sunglasses that are supposedly advantageous performance. Sunglasses are advertised to improve performance through the enhancement of visual information that would not normally be capable with the naked eye. With this visual information now available, the assumption is that the consumer will perform better due to superior action selection. This assumption is then further cemented when brands endorse top athletes to promote their brands, which subtly suggests that the athlete's use of this brand improves the way they perform in their sport (Erdogan, 2008). These sunglasses are then promoted for benefits that have received very little empirical research investigating the evidence for these claims (Farrow & Southgate, 2000). For example, Oakley Prizm lenses claim to offer enhanced colour and contrast so one can see in more detail, with minimal objective evidence available for how this occurs.

Cricket players have become accustomed to wearing sunglasses for ocular health and protection but also through brand sponsorship (Moore & Ferreira, 2005). A study conducted on students at the University of Johannesburg by Moore & Ferreira (2005) identified that 57% of players did not wear sunglasses at all, and a further 14% admitted to wearing sunglasses because a specific brand had sponsored them. Those that chose to wear sunglasses either allowed the brand to dictate the colour of tint they wore or based their choice on personal preference aligned with fashion (Moore & Ferreira, 2005). Similarly, De Fez et al. (2002) support this finding as they too believe lenses tend to be selected based on fashion. This highlights that very little professional ophthalmic advice was sought when selecting the sunglasses used, which may have resulted in poor visual performance (Moore & Ferreira, 2005).

SUNGLASS USE IN FIELDING: WHAT IS THE IMPACT ON CATCHING PERFORMANCE?

It is known that vision is a complex phenomenon involving perception-action coupling, playing a critical role in the control of skilled movement (Fajen, 2007; Gardner & Sherman, 1995; Kirschen & Laby, 2011; Mark Williams et al., 1999; Miller & Clapp, 2011). Information extracted from the surrounding environment through visual hardware abilities is integrated with perceptual-cognitive software skills which ultimately results in the appropriate action to be selected and executed (Abernethy, 1987b; Abernethy, 1986; Mann et al., 2007). Through the addition of a lens, optometrists can effect a change at the level of visual information received at the eye before it is processed centrally at the level of the brain (Abernethy, 1986). The addition of a lens is a further structure that light has to pass through before information is received, processed and acted upon. The lens alters the transmission of light entering the eye and potentially affects key ocular parameters such as contrast sensitivity, colour vision or visual acuity. The potential alteration of these parameters could affect the perception of the surroundings, affecting familiarity of the environment, thus impacting the athlete's perception of affordances for action (Dain, 2003; De Fez et al., 2002; Fajen, 2007; Fajen et al., 2008; Oudejans et al., 1996; Shaik et al., 2013; Teikari & Lindström, 1995). These two levels of visual information processing (reception and perception) are inextricably linked and one cannot occur without the other (Abernethy, 1986). A study conducted by Adie & Arnold (2017), demonstrated that the use of sunglasses with a rose tinted filter alleviated deficits of response times when performing interceptive timing tasks in a laboratory setting. This study alludes to the use of sunglasses to aid in the ability to artificially brighten the ball relative to certain backgrounds (Adie & Arnold, 2017b). The use of these tinted glasses helps to discern the ball more distinctly from its background particularly with the changes in composition of light which often creates a challenging visual environment (Adie & Arnold, 2017a).

Sunglasses are produced in a variety of colours but there is very little literature to support the use of one colour over the next in the prescription of sunglasses to athletes. As there are no studies that have investigated if different colour of tint impacts performance measures such as catching in fielding, this study attempted to investigate this.

CHAPTER III:
METHODOLOGY

RESEARCH DESIGN

A within subjects-repeated measures design was implemented to assess the effect of four different sunglass tints on catching performance. Ocular measures, catching performance as well as qualitative measures were used to determine these effects. Participants were exposed to a pre-screening ocular examination to establish the players quality of vision and therefore, eligibility to continue with the research project. Those that qualified then continued on to four experimental sessions that looked at their catching performance while wearing each of the different tinted sunglasses.

The four experimental conditions tested four different colour tints which included a control condition with a clear tint (see design matrix in

Table I). The conditions were then randomised among participants to ensure no learning effect occurred dependent on the order of presentation of the coloured lenses (Please see APPENDIX

	Clear tint (C)	Blue tint (B)	G30 tint (G)	Red tint (R)
500-1500lx				

B: DATA COLLECTION for reference to how randomisation occurred). Each experimental condition was tested on a separate day to avoid fatigue and transfer effects.

Table I: Design matrix of the study

	Clear tint (C)	Blue tint (B)	G30 tint (G)	Red tint (R)
500-1500lx				

The experimental conditions were conducted between 9 a.m. and 4 p.m. These hours were chosen as they were representative of when a cricket match is played.

Participants were habituated to a catching protocol (described later) that was used to evaluate catching performance while wearing a different tint of sunglasses during each condition. A bowling machine was used to project red bowling machine balls at the participants. A habituation session was therefore required, as participants may not be accustomed to catching balls projected from a bowling machine as it is typically used for batting, not fielding practice.

ETHICAL CONSIDERATIONS

Ethical approval was obtained (HKE-2015-6) from the Human Kinetics and Ergonomics Ethical Committee before the research process began.

RECRUITMENT

Following ethical approval, recruitment of potential participants was undertaken. Participants were selected from the Rhodes University student population who were part of the Rhodes University cricket teams or the Rhodes University Internal League teams as well as first-team players from local cricket clubs within the Makhanda area. Advertisements for participation in the study were placed in the university gymnasium and library, and supermarket noticeboards as part of the recruitment strategy. Other strategies that were used were social networks such as Facebook, the Makhanda Parent's Network (a local newsletter) as well as sending the advertisement in an e-mail to people who subscribe to the student-news mailing list as well as the Human Kinetics and Ergonomics department mailing list. Personal e-mails were sent to members of the Rhodes Cricket Club to appeal for participation in the study.

INFORMED CONSENT

Each participant also received a letter of information (APPENDIX A: GENERAL INFORMATION which was taken home to refer to should they have forgotten anything mentioned in the presentation. This letter allowed them to familiarise themselves with the project and it detailed the purpose of the study, the procedures that would be followed to investigate the research question, the potential risks and benefits associated with the study as well as the requirements prior to and during the experimentation phase. The informed consent form (APPENDIX A: GENERAL INFORMATION was signed at the introductory session.

PRIVACY AND ANONYMITY OF RESULTS

All data collected, whether personal or experimental, were kept confidential through the assignment of a code to each player. Assigned codes were kept separate from participants' names to protect the anonymity of results. This information was conveyed to players to inform them of the strategies undertaken to ensure anonymity was maintained during the study.

EXPERIMENTAL PROCEDURES

After the recruitment process, participants that responded were contacted and informed of a date that an introductory session would take place at the Human Kinetics & Ergonomics Department. Participants were required to attend this session. The introductory session was utilised as a platform for the researcher to explain what to expect from the experimentation process through a PowerPoint presentation, allowing them to ask any questions regarding the experimentation process. Following this, on a separate day, participants were then required to attend one ocular pre-screening session and those eligible to continue to the data collection phase were then required to attend a further four experimental conditions. All ocular proceedings were conducted at Dr Davies Optometrists Inc.® in a registered optician's examination room and all other experimental procedures were held at the High-Performance Centre, Kingswood College in Makhanda.

SESSION ONE: INTRODUCTION

Players were verbally informed of the aims and purpose of the study and presented with a letter of information. They were also given the opportunity to ask any questions pertaining to the study to clarify anything that may have been unclear. Players satisfied with the given information and willing to participate further were required to sign an informed consent form. This form indicated their agreement to partake in the research provided they were deemed eligible to participate in the study after the pre-screening ocular examination was conducted. After signing the consent form, participants then had their stature, mass and age recorded. They were also required to answer a few questions regarding their playing history, such as number of years they have played cricket and the position they typically fulfil on the field during play.

Participants were then given a range of days of which they had to select one that they would attend an appointment with the optician to determine their eligibility to continue with the study. A registered optician conducted the ocular examination according to their standards of practice. Ocular measures tested during the ocular screening included measurements of contrast sensitivity, stereopsis and visual acuity. Eligible participants hereafter were required to return on four separate days to participate in four further experimental sessions. During these experimental sessions, players were required to catch bowling machine balls and wore a different colour of tinted lens at each session. Eligible participants, who satisfied the above-mentioned criteria thus partook in five sessions in total. In comparison, ineligible participants only attended the ocular pre-screening.

SESSION TWO: OCULAR PRE-SCREENING

On a pre-arranged date and time, players were required to attend the ocular pre-screening test at Dr Davies Optometrists Inc.® in Makhanda, South Africa. A registered optician conducted ocular tests to assess the participant's ocular health before partaking in the experimental conditions.

Participants were welcomed to the practice where the screening took place. The participant was asked to sit in an examination chair, and a case history was taken to establish if there was any history of ocular injury or disease that may have affected ocular health. Hereafter the participant was taken through preliminary ocular tests to "warm-up" the eyes before the ocular assessment tests were administered. After these preliminary tests were administered, a registered optician conducted the following tests and assessments according to optician standards:

- Objective refractive error (Phoropter)
- Colour vision deficiency test (Ishihara)
- Visual acuity (Snellen Chart)
- Contrast sensitivity (Spectrum)
- Stereopsis (Stereofly test)
- Ocular health assessment (Slit Lamp Examination)

The optician completed the ocular assessment according to his standards of practice. Each measure was conducted initially without any lenses and then tested with each of the four different tinted lenses. Players were then informed as to whether they were eligible to continue or not. Ineligible participants were respectfully informed as to why they would be unable to continue with the study and were not required to attend any further sessions. Eligible participants were then required to return and participate in a further four experimental sessions at the High-Performance Centre on four separate days that were convenient for them.

SESSIONS THREE, FOUR, FIVE & SIX: EXPERIMENTAL SESSIONS

At the beginning of each experimental session, eligible participants were exposed to a habituation session while wearing the specific tint being tested. Each session was approximately an hour-long, based on the inter delivery time.

Habituation

Participants needed an habituation session as an adjustment period is necessary and important in the interception of a ball with different dynamic properties is encountered (Hayhoe et al., 2005). This adjustment period is rapid and was particularly important in this context as the players were catching bowling machine balls which are different to the cricket balls typically used in fielding practice, thus affecting players ability to pursue the ball in flight (Hayhoe et al., 2005). The habituation session also exposed participants to the catching protocol used as catching performance was used to assess the performance of the different tints in each condition. During habituation, the researcher delivered six balls to the participant with a bowling machine, using the same catching protocol utilised in the experimental condition.

Catching Protocol

A Jugs Cricket Bowling Machine (Jugs, Australia) delivered 18 balls to the participant. It was decided that 18 balls were appropriate as after pilot testing the protocol, catching more than 18 balls was very uncomfortable as players were catching bowling machine balls and not cricket balls. The use of a bowling machine to deliver balls to participants, was necessary as this provided considerable experimental control in terms of ball direction and velocity, therefore reducing the amount of noise in the data collected (Mann, Abernethy, & Farrow, 2010). The bowling machine was set at a height of 0.8m from the ground as this is equivalent to the average waist height of a batsman playing a front foot shot (Scott, Kingsbury, Bennett, Davids, & Langley, 2000). The ball was projected from the bowling machine that stood at approximately 1.46m (this measurement was taken from the point where the ball exits the chute to the ground). The height of where the ball exited the machine was adjusted marginally to accommodate for stature differences between participants to ensure the ball was received within the correct height range. The use of the bowling machine resulted in participants receiving only straight catches, which would be delivered between waist and chest height. Straight catches were selected as this removed the element of head movement that would affect catching performance, therefore ensuring only the investigation of the effect of the tinted lenses on catching performance. Players were required to stand between 2 cones. The two cones were placed a meter apart, set at 23.5m and 24.5m away from the front leg of the bowling machine. Players therefore stood approximately 24m away from the bowling machine when receiving the catch. The inter delivery time between each ball was 32.67s based on time-motion analysis conducted by Sheppard (2012). Due to the variable nature of the bowling machine, balls were delivered between the speeds of $20.5 m.s^{-1}$ and $21.7 m.s^{-1}$.

Experimentation Venue

Testing was completed in the High-Performance Centre at Kingswood College, Makhanda, South Africa. To replicate the effect of a crowd of spectators, a printed cloth spray painted with blotches was draped across a board (see Figure 9 below) behind the bowling machine so that the participant had to be capable of discriminating the ball from the crowd of spectators as would be the case in a match situation.

Figure 9: Background & Bowling Machine Setup

Lighting

As this is the first study to ask the question being posed within the cricketing context, control over extraneous factors is important. This is to ensure the question being asked can be answered most effectively. For these reasons, lighting and environmental factors were controlled, as far as possible, within a laboratory setting, acknowledging that this will not fully replicate outside, real match play conditions. Lighting conditions were controlled within a certain range to ensure this did not affect the results due to poor visibility. The acceptable light range that testing occurred in was between 500-1500lx (Cruse et al., 2008; “Guide to sports lighting levels,” 2014). This range was deemed suitable as it is the recommendation for indoor cricket (Cruse et al., 2008). A range was selected as light intensity is subject to variance throughout testing due to the influence of natural light from outside the testing venue. It is important to note that as this was a laboratory-based experiment, thus it was impossible to replicate the light intensity experienced outdoors, as this value can typically range between 10 000 and 120 000lx (Erickson, 2007).

The reasons for not selecting a field-based project are several-fold. Firstly, the control over extraneous factors is considered most important. However, to ensure that a lot of natural light is available, a laboratory with a significant amount of natural light exposure was selected to compensate for the fluorescent lighting. Secondly, the weather conditions in Makhanda are temperamental and previous cricket studies from our department have demonstrated how projects can be delayed by this alone. As this project had a time deadline, it was deemed necessary to conduct the study within a laboratory environment without delays due to inclement weather.

Players were required to arrive at the High-Performance Centre at Kingswood wearing comfortable clothing that would not restrict movement and comfortable shoes with non-slip soles. The player was then required to perform a 5-minute warm-up that included dynamic stretching (please see APPENDIX A: GENERAL INFORMATION for detailed warm-up procedure). One of the four different coloured tinted lenses was selected by the researcher and given to the player to wear. At the beginning of each experimental session, eligible participants were exposed to a habituation session while wearing the specific tint being tested. The player was habituated to the catching protocol before data collection was begun. This was also considered the warm-up. Following this, data collection for the experimental condition began. During the experimental condition, the participant was required to catch 18 balls in total that were delivered by the researcher inserting balls into the bowling machine. A video camera was utilised to film all the catches during the testing session to retrospectively analyse the quantity and quality of the catches using Wickstrom's Catching Performance Scale (see page 53). The fourth, fifth and sixth sessions required the participant to repeat the above-mentioned procedure, with either the red, grey, blue or clear tint on separate occasions depending on which tint was selected first. In the final experimental session, the player was issued with a questionnaire (please see APPENDIX B: DATA COLLECTION). Players were required to complete this questionnaire to give their subjective opinion of how they felt the different tints affected their performance. Each session was approximately an hour-long, based on the inter delivery time.

PARTICIPANT CHARACTERISTICS

Inclusion and Exclusion Criteria for Participation

The age of the players was controlled as it is known that vision is susceptible to age-related degradation (Morrison & McGrath, 1985). The deterioration of vision with age occurs due to the reduction in the amount of elasticity in the lens, affecting the focusing power of the eye (Morrison & McGrath, 1985). Players therefore had to be within the range of 18-30 years of age to qualify for the study. Participants below the age of 18 years were excluded due to the continued maturation and development of the frontal and the visual cortex that occurs until this age (Blakemore & Frith, 2006). As vision was the main interest of the project, the ocular pre-screening test ruled out ocular deficiencies that would affect data collection. To qualify for the study, there were several pre-requisites participants were required to fulfil.

Participants were required to have the following visual characteristics to be eligible to continue with the study:

- No colour vision deficiencies
- Emmetropic (no refractive error) therefore have 20/20 (6/6) vision or better and were therefore not permitted to wear spectacles or contact lenses to correct their vision.
- Good ocular health and therefore not have the following conditions conjunctivitis, cataracts, macular degeneration, diabetic retinopathy or retinal detachment
- No prior history of or existing trauma to the eye
- No significant binocular issues due to suppression of either eye or strabismus (squint)
- Players were required to have five years of experience playing cricket and have played cricket competitively at club level or above in the last year, to ensure participants were well versed in executing the task requirements of catching a ball. This is necessary to take into consideration as it affects the player’s experience with the ball’s aerodynamic properties, which impacts the likelihood of ball interception (Hayhoe et al., 2005).
- Players were required to have experience of playing with a red ball as the investigation involved the use of the red ball.
- Non-habitual sunglass wearer during play to gain the true effect of wearing sunglasses while playing and the effect it has on catching performance.

ANTHROPOMETRIC MEASUREMENTS

The introduction and informed consent session served as a basis for the collection of demographic and anthropometric data. This included gender, age, stature and mass. The following equipment was utilised to record this data.

Stature

Each participant was asked to remove excess clothing, (including shoes, necklaces and jewellery) before taking position on the stadiometer. The stature of participants was recorded while standing in the anatomical position with their feet together and heels pressed against the base of a Harpenden stadiometer (London, United Kingdom). Stature was measured with the head in a neutral position at the highest point of the vertex of the head.

Mass

Following stature, body mass was measured on a calibrated LifeMax electronic scale (Johannesburg, South Africa). The participant was asked to stand in the middle of the scale, standing upright and looking straight ahead and the result was recorded in kilograms.

INDEPENDENT AND DEPENDENT VARIABLES

INDEPENDENT VARIABLES

Tint Colour Selection

Four different tints were selected for this research protocol: clear, red, blue and a G30 tint. The clear tint was selected as a reference or control tint with which the other tints could be compared. Red and blue tints were selected from a research perspective as they are on opposite ends of the visible light spectrum. Red tint lenses enhance the red colour of the ball due to longer wavelengths within the visible light spectrum being transmitted to the eye (Erickson, 2007). This colour of tint is reportedly most useful in “flat” light. It results in enhancement of contrast judgement and depth perception, which is useful within the cricketing context particularly concerning perception of the ball and catching it. “Flat” light refers to conditions where light produces little contrast and shadows, which makes it difficult to judge depth. Blue tinted lenses reportedly do not offer a substantive benefit for most sports (Erickson, 2007). These lenses selectively transmit short-wavelength light, which may increase chromatic aberration resulting in reduced visual acuity, therefore degrading visual performance (Erickson, 2007). Chromatic aberration occurs as a result of differences in refraction of each wavelength through the ocular media (cornea, lens, aqueous and vitreous humour). The difference in refraction results in different focal points that culminates in a blurry image (Erickson, 2007). The fourth tint that was selected was a rose-based tint known as the G30. This tint was selected following personal communication with sales representatives of leading brands (Barrett, personal communication, 2014 & Jones, personal communication, 2014) who state that this is the preferential tint among cricket players at the time of investigation.

Frames and Tint Density

The same frame (model) of sunglass was used for the clear, red and blue lenses. Unfortunately, the G30 lenses were unable to be modified to fit the same frame as the other three as can be seen from Figure 10 below.

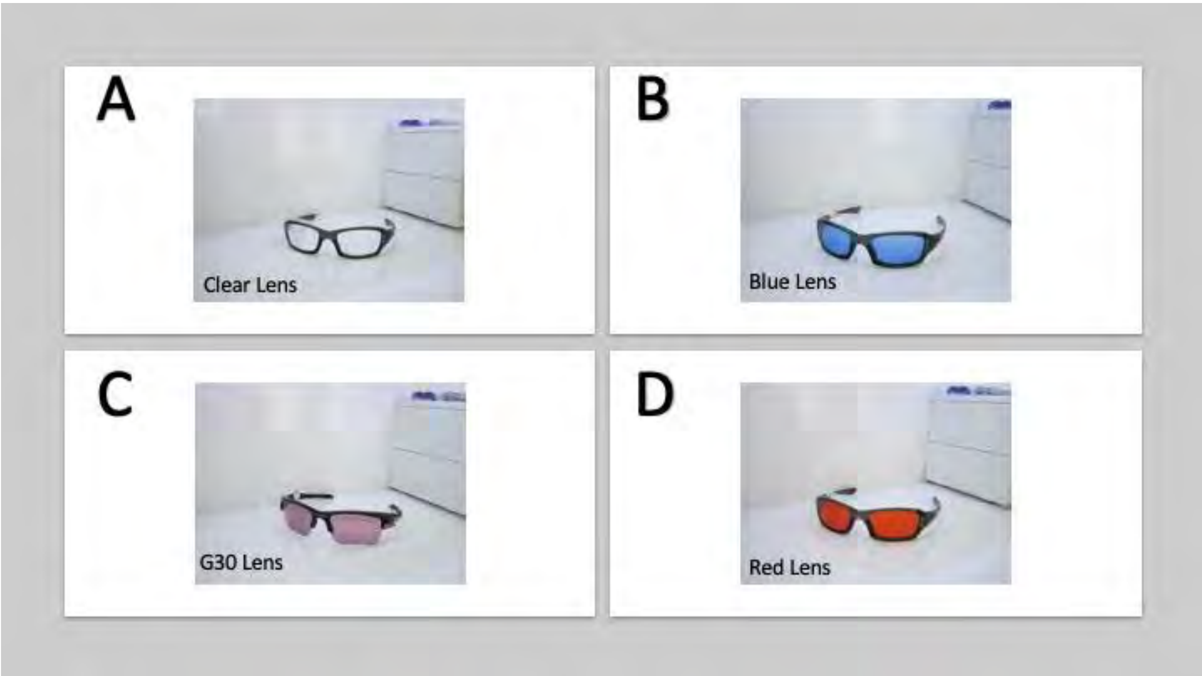


Figure 10: The different colour lenses used for testing

As different colours of tint were tested, the density of the tint was also kept constant. Density of tint refers to the transmittance characteristics of the lens and indicates the amount of light transmitted to the eye through the lens (Erickson, 2007). In the case of this study, the light transmittance value used was a value of 30% based on the rose-tinted lens that was used as it was a commercially produced lens. A registered optician produced the red and blue-tinted lenses to have the same light transmittance value, as these colours were not available commercially. The commercially produced G30 lens was made of material that is classified as high-velocity impact lenses by ANSI (American National Standards Institute) standards under the Z87.1-2003 standard. The clear, blue and red tints that were produced by the optician were manufactured using the lens material CR-39 that is classified as a basic impact lens under the same standard mentioned above.

Spectral transmission curves of all the tinted lenses were obtained to investigate which wavelengths are transmitted through each specific lens (Figure 11). The spectral transmission was conducted using a spectrophotometer in the Physics Department at Nelson Mandela Metropolitan University. This was done at the Nelson Mandela Metropolitan University as the spectrophotometer at the Rhodes University Physics Department was not working at the time of the project and we therefore had to outsource.

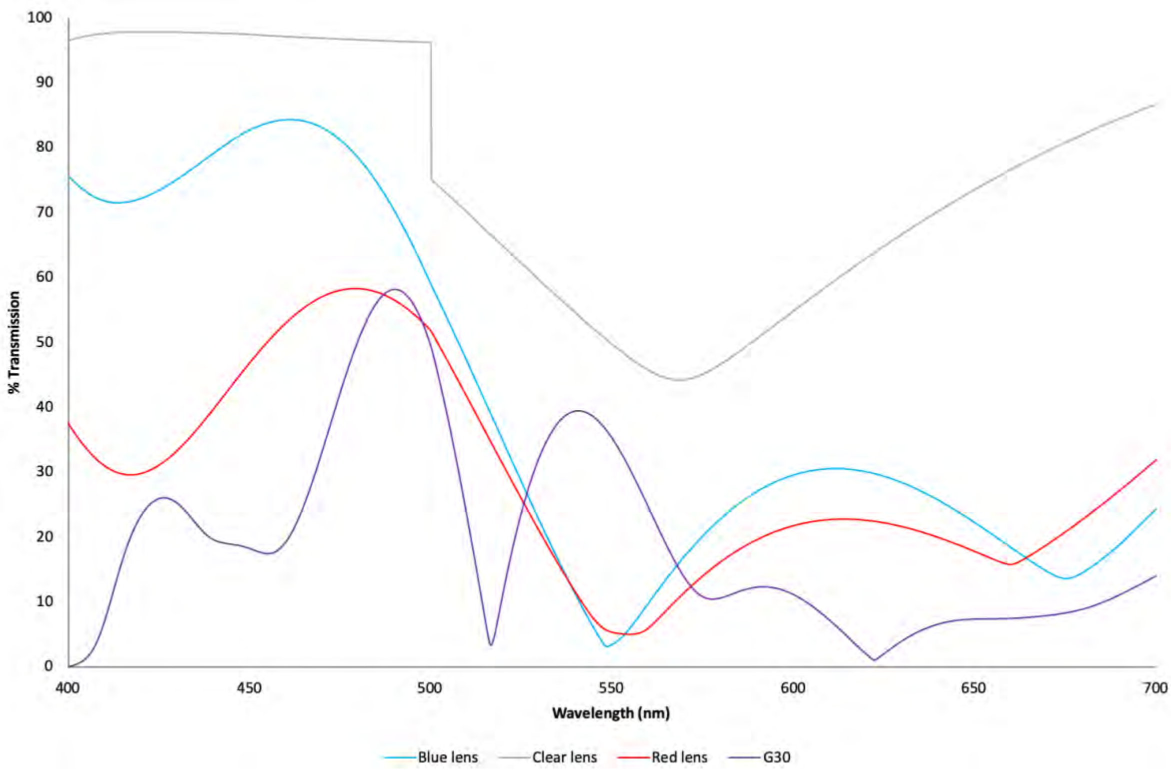


Figure 11: Transmission curve for all lenses

OBJECTIVE DEPENDENT VARIABLES

To investigate how vision is affected by the colour of tint during catching, several objective and qualitative measures were selected. Ocular parameters such as visual acuity, contrast sensitivity and stereopsis were measured to determine eligibility and differences between the colour tints and each will be described below. Catching performance was also included as a dependent measure to classify the quality of the catch (Scott et al., 2000).

Objective Refractive Error

Participants' refractive error was assessed using with a phoropter (Magnon RT-600) (See Figure 12 below). This assessment was used to rule out hyperopia (far-sightedness), myopia (near-sightedness) or astigmatism and takes into account the participant's subjective perception of what is viewed.

With the participant seated in the examination chair, the phoropter was placed in front of the participant. The lights in the examination room were turned off and the participant was required to look through this piece of equipment and focus on an LED screen ahead that displayed several images. The optician then instructed the participant to keep both eyes open while he used a technique known as retinoscopy to objectively determine the participant's refractive error. The optician used a retinoscope to shine light into the participant's eye and then based on the reflection of this light off the retina, he objectively determines the refractive error. Hereafter the light is turned on again and the participant's subjective perception is taken into account. Each eye was tested separately with the eye not being tested being put out of focus. The test however, required the participant to keep both eyes open while the test was being conducted. The optician selected a single row of the Snellen chart and the participant was then requested to read the selected row. The optician presented a series of lens choices, typically two lens choices were presented at a time and the participant stated which lens gave the best perception of these letters. The optician determined the participant's refractive error by switching between the lens options and asking the participant "is your vision better or worse, with this lens or this lens?" If the refractive error was determined to be larger than the stipulated range of between 0 and 0.5 diopters, no further tests were administered as the participant was excluded. If there was no refractive error determined, the participant progressed to the next test, which was the Ishihara colour deficiency test.

Figure 12: Phoropter (Online image taken from (“Manual Phoropter Nidek RT-600 Refractor,” 2015))

Colour Vision Deficiency Test

To rule out red-green colour vision deficiency, the Ishihara test for colour deficiency (concise edition, 2012, Tehara Trading, INC. Tokyo, Japan) was administered. The test is carried out at 66cm or at arm’s length and participants are given a maximum of 4 seconds to identify the figure (Formankiewicz, 2009). The Ishihara test is the most frequently used test to screen for red-green colour deficiencies (Formankiewicz, 2009). In this test, participants were shown several different ‘plates’ and asked to read out the number that is on that plate. As can be seen from Figure 13, the number and the background are made up of discrete discs that vary in size and luminance (Formankiewicz, 2009). These differences ensure that the figure can only be identified by its chromatic difference from the background (Formankiewicz, 2009). This test was not carried out with the different colour tints as this was not used as a performance measure but rather as a purely diagnostic tool.

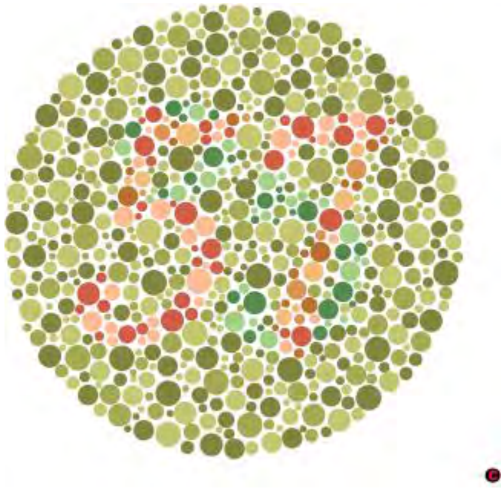


Figure 13: Example of a test plate from Ishihara Test (Online image taken from (Heffernan, 2017))

The measures of visual acuity and contrast sensitivity were measured using The Spectrum Eye Care Software package (Nevada Cloud, Port Elizabeth, South Africa) as this is what the optician utilised at his practice.

Visual Acuity

Once the participant had passed both of the above tests and was cleared of any visual deficits to prevent this being an influencing factor on the results, visual acuity was then determined. Participants were required to read the 6/6 line of the visual acuity chart to qualify to participate. Visual acuity was measured with the chart depicted in Figure 14 which is like the typically used Snellen chart. This test was first determined with the naked eye. The participant was then given the different colour tints of sunglasses to determine if the colour affected this ocular parameter.

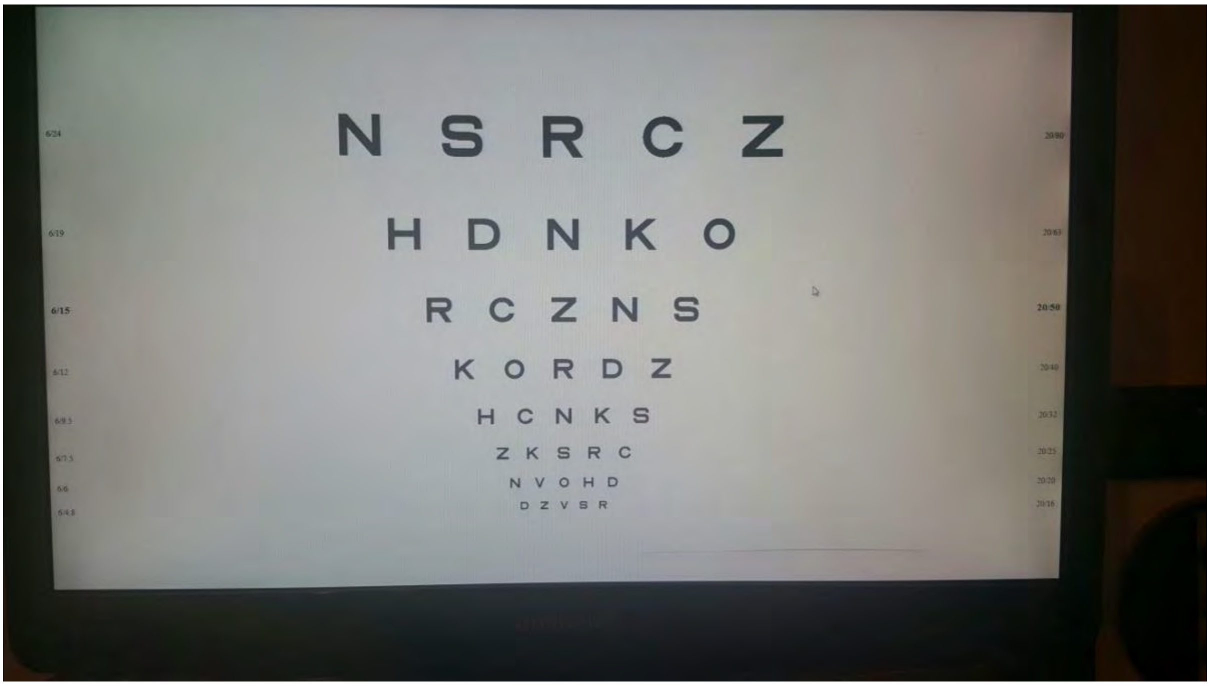


Figure 14: Visual acuity chart from Spectrum program

Dynamic visual acuity has been tested with the Wayne Robot Rotator test, however the optometrist on the project did not have access to this test and therefore static visual acuity was tested. That static visual acuity was tested rather than dynamic visual acuity, must be considered a limitation in this project. Testing was conducted in an office setting with no natural light due to the non-portable nature of the equipment. These conditions are also acknowledged as a limitation.

Contrast Sensitivity

The test involves the use of a chart with a combination of five numbers per line read. The contrast of these numbers decreases with each successive line as seen in Figure 15 below. The contrast of each line is adjusted to become increasingly similar in brightness to the background until it can no longer be seen. Participants are required to read from the top of the chart down. They are required to correctly identify as many numbers as possible per line. The last line with all numbers correctly identified is an indication of the participant's level of contrast sensitivity. This is measured and recorded as a percentage. This test was also done initially with the naked eye followed by the different lenses to see if contrast sensitivity improved or deteriorated based on the different colour of tint.

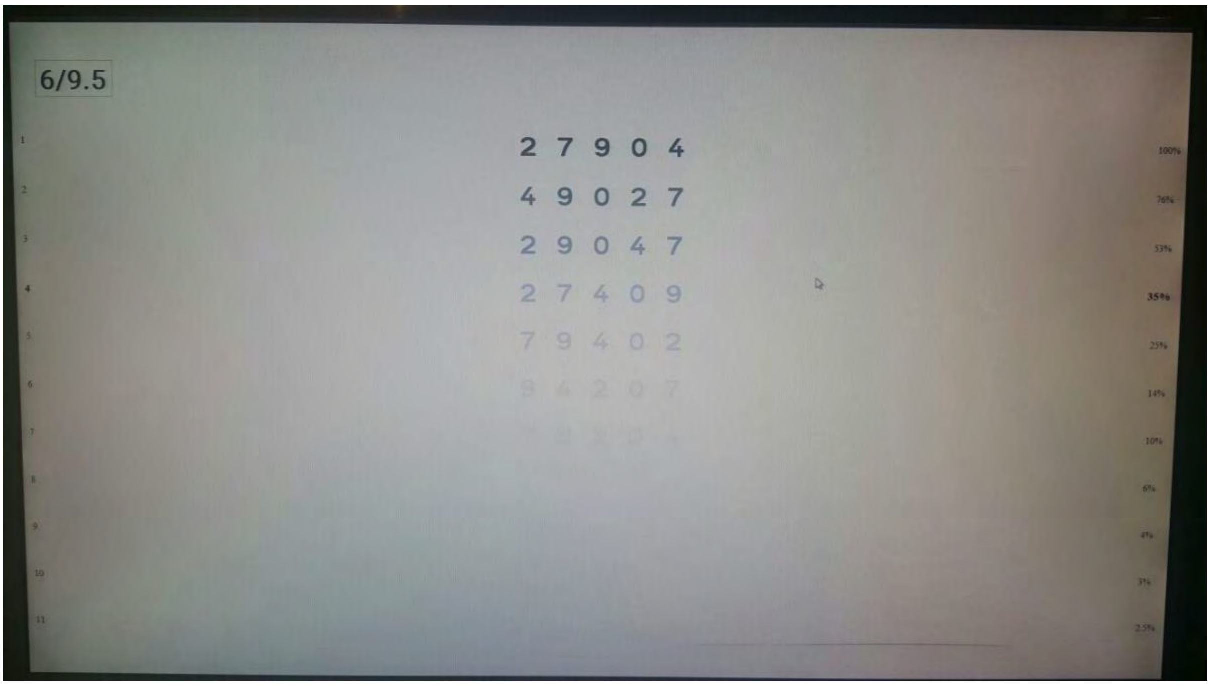


Figure 15:The Spectrum Contrast Sensitivity Test

Stereopsis

The stereopsis test administered was the Stereofly test (SO-001, Stereo Optical Company, Inc.) to evaluate both gross stereopsis and fine depth perception. The test was administered at a distance of 40cm. Participants were required to look at nine sets of four circles and identify which circle in each set stood out. Participants would state either the left, right, top or bottom circle stood out for each set. In this test participants wore a pair of standard polarised 3-D Viewers and looked at a graded circle test (pictured on the left in Figure 16) while wearing the different colour lenses at the same time. The polarised lenses were placed over the tinted lens as was done in the study conducted by Moore (1997) to see if more or less of the nine sets of circles were identified correctly.

After all the lenses had been measured, the test was conducted with the polarised lenses alone. Using the polarised lenses alone allowed the optician to see the results of the original test, effectively to serve as a baseline. It was decided that the baseline test would be administered last as if it was administered at the beginning of the procedure, participants may have learned which of the circles should be raised. This knowledge may have influenced their responses when the tinted lenses were tested, and they may have been dishonest about which circles were seen to be raised based on previous experience.

Figure 16: Stereo-fly Test with 3D viewer glasses (Online image taken from ("Bondeye Optical," 2015))

Ocular Health Assessment

The participant was then subjected to bio-microscopy. This was a non-invasive ocular health assessment that provided a magnified, three-dimensional view of different parts of the eye and was assessed using a slit lamp microscope (Huvitz HS-5000, Korea). The optometrist used this apparatus to focus an intense narrow line of light on the eye, allowing a thorough evaluation of eye health. This procedure aided in the detection of any signs of infection or disease, including conjunctivitis, cataracts, macular degeneration, diabetic retinopathy or retinal detachment. The microscope (see Figure 17 below) was placed in front of the participant and they were required to place their chin in the chin rest and rest their head against the forehead strap to ensure the head was steady during the examination. The optician then used different lenses to investigate the eye closely by looking for any abnormalities or problems with the conjunctiva, iris, lens, sclera and cornea as well as the retina and optic nerve.

Figure 17: Huvitz slit lamp (Online image taken from ("Huvitz HS 5000 Digital Imaging 3 Step Galilean Converging Binocular Slit Lamp," n.d.))

Absolute Number of Catches

This performance measure involved the researcher recording the total number of catches completed by players out of the total of 18 balls that were delivered in the experimental session. The balls were delivered to the player by the researcher inserting balls into the bowling machine.

Quality of Catching Performance

The quality of catch performed, was assessed according to the Wickstrom Catching Performance Scale (1983) (See Table II) as used in the study performed by Scott et al. (2000). Each ball that was delivered and caught by the player was recorded using a video camera (Canon Powershot SX1 IS, USA) and then retrospectively classified and scored according to the description in Table II. The way in which each ball was caught was given a score from zero to five. Each score is given a description that aids the individual who judges the catch in assigning the correct score. The higher the score assigned to the catch, the better the quality of the catch. Scores were collected for the 18 balls that were delivered to the participant. Hereafter the scores were then totalled and averaged for each participant.

Table II: Wickstrom Catching Performance Scale

Outcome score	Description
5 (Clean catch)	The ball is contacted and retained by the hands
4 (Assisted catch)	The ball is juggled and retained by the hands
3 (Hand contact)	The ball contacts the hand but is dropped
2 (Upper body contact)	Upper body (but no hand) contact
1 (Lower body contact)	Lower body (but no hand) contact
0 (No ball contact)	No cricket ball contact

SUBJECTIVE DEPENDENT VARIABLES

A post-test questionnaire to investigate personal subjective experiences of the tints worn during experimentation was administered (Please see APPENDIX B: DATA COLLECTION). Upon consultation with experts in the field, it was established that there are no standardised questionnaires that investigate the user's subjective experience of different colour tinted lenses. The questionnaire that was used in this study was adapted from a study performed by Erickson et al. (2009), that investigated different colour tints of contact lenses in natural sunlight. The questionnaire gathered data on four different experiences as well as allowing participants to freely comment on experiences during the experimentation.

Visual Comfort

Participants were asked to rate how they felt the various tints aided visual comfort when they partook in the experimental phase of the research. Visual comfort was rated on a Likert scale from 1 to 6 (where 1 = strongly agree and 6 = strongly disagree).

Target Visibility

Similarly, participants were asked to rank how well they felt they were able to view the target (ball) when wearing the different tints using the same Likert scale as described for the visual comfort.

Personal Preference

Participants were then required to rank the four lenses in terms of which tint they preferred the most based on which tint they felt helped performance the best (1 = first preference and 4 = last preference).

Pain Data

Pain data were also collected as while players were undertaking the protocol, the researcher became acutely aware that after some time into the session, the players were more prone to drop the ball or shy away from the ball due to their pain experiences. It was therefore necessary to collect data on this as it may have been an area that impacted catching performance other than the colour of tint. Participants were asked to identify two areas on both the right and left hands where pain was felt when executing the catches. This was achieved using the image derived from the Cornell Musculoskeletal Discomfort Questionnaire for both the right and left hand (Please see APPENDIX B: DATA COLLECTION. Participants were asked to rate the intensity of the pain felt for the two areas identified using the 0-10 numeric pain intensity scale.

Free Writing Comments

The post-test questionnaire had a section entitled "additional comments" allowing for free writing comments. Here participants were allowed to freely comment on their feelings on any of the lenses or the protocol.

STATISTICAL HYPOTHESES

OBJECTIVE PERFORMANCE HYPOTHESES:

Number of Catches

1. H_0: $\mu NCT_0 = \mu NCT_1 = \mu NCT_2 = \mu NCT_3$

   H_a: $\mu NCT_0 \neq \mu NCT_1 \neq \mu NCT_2 \neq \mu NCT_3$

Where NC = number of catches

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

Quality of Catch

2. H_0: $\mu QCT_0 = \mu QCT_1 = \mu QCT_2 = \mu QCT_3$

   H_a: $\mu QCT_0 \neq \mu QCT_1 \neq \mu QCT_2 \neq \mu QCT_3$

Where QC = quality of catch

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

Number of Catches Over Time

3. H_0: $\mu NCOTT_0 = \mu NCOTT_1 = \mu NCOTT_2 = \mu NCOTT_3$

   H_a: $\mu NCOTT_0 \neq \mu NCOTT_1 \neq \mu NCOTT_2 \neq \mu NCOTT_3$

Where NCOT = number of catches over time

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

Quality of Catch Over Time

4. H_0: $\mu QCOTT_0 = \mu QCOTT_1 = \mu QCOTT_2 = \mu QCOTT_3$

   H_a: $\mu QCOTT_0 \neq \mu QCOTT_1 \neq \mu QCOTT_2 \neq \mu QCOTT_3$

Where QCOT = quality of catch over time

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

SUBJECTIVE PERFORMANCE HYPOTHESES:

Visual Comfort

1. H_0: $\mu VCT_0 = \mu VCT_1 = \mu VCT_2 = \mu VCT_3$

H_a: $\mu VCT_0 \neq \mu VCT_1 \neq \mu VCT_2 \neq \mu VCT_3$

Where VC = Visual Comfort

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

Target Visibility

2. H_0: $\mu TVT_0 = \mu TVT_1 = \mu TVT_2 = \mu TVT_3$

   H_a: $\mu TVT_0 \neq \mu TVT_1 \neq \mu TVT_2 \neq \mu TVT_3$

Where TV = Target Visibility

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

Personal Preference

3. H_0: $\mu PPT_0 = \mu PPT_1 = \mu PPT_2 = \mu PPT_3$

   H_a: $\mu PPT_0 \neq \mu PPT_1 \neq \mu PPT_2 \neq \mu PPT_3$

Where PP = Personal Preference

T_0 = no tint

T_1 = G30 tint

T_2 = red tint

T_3 = blue tint

STATISTICAL ANALYSES

Statistical analyses were performed using statistical software STATISTICA © (Statsoft. Inc.) Version 13. The Shapiro-Wilk test for normality was performed on the data. It was determined that the data was not normally distributed as would be expected, given that participants caught the ball majority of the time and most of the catches were of high-quality rating. Typically non-parametric statistics would be utilised to analyse the data, however the General Linear Model was utilised as it has greater power to identify model effects as statistically significant when data is not normally distributed (Hoang Diem Ngo & La Puente, 2016). One way Analysis of Variance (ANOVA) with repeated measures was used to compare the effect of the different tints on catching performance. In the instance that statistical significance was determined; a confidence interval of $p \leq 0.05$, associated with a confidence interval of 95% was used in an attempt to falsify the null hypothesis. If a statistical difference was found, Tukey's Post-Hoc analyses was performed to determine where the differences lay between conditions. Following this, descriptive statistics were performed to determine the means, standard deviations and coefficient of variation for all outcomes.

CHAPTER IV:
RESULTS

The measures reported on are from the twenty-one university level cricket players that fulfilled the necessary criteria for ocular health and completed the research protocol. The flow diagram illustrates the recruitment and selection process that resulted in the final number of participants that ultimately partook in the research project (Figure 18).

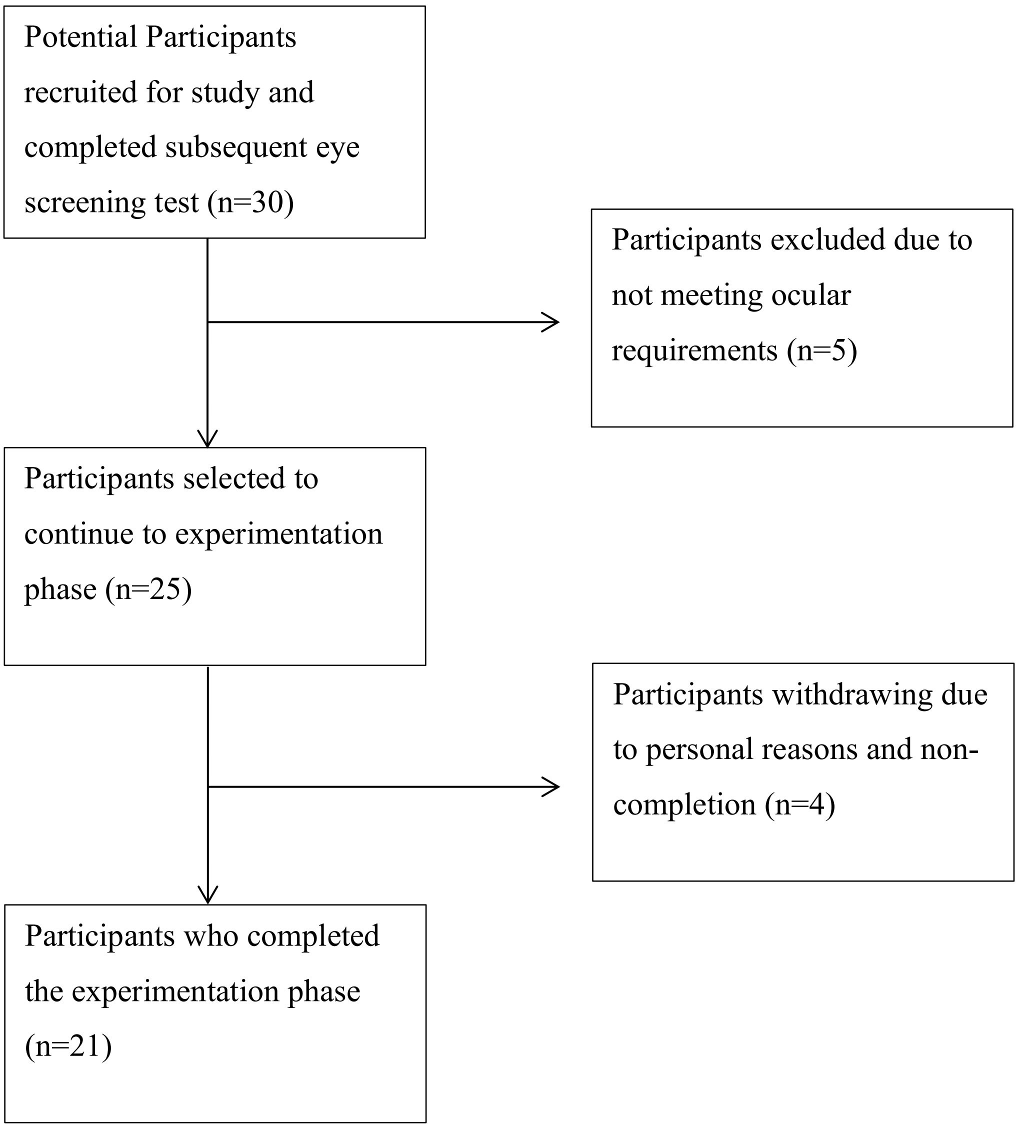


Figure 18: Flow diagram of recruitment and final sample size

PARTICIPANT CHARACTERISTICS

Twenty-one university level cricket players participated in this study. Table III illustrates their characteristics.

Table III: Basic demographic and anthropometric data of participants

	Mean	Standard Deviation	Coefficient of Variation (CV) %
Age (yrs)	22.19	3.01	13.57
Stature (mm)	1771.33	57.08	3.22
Mass (kg)	81.73	18.86	23.08
BMI ($kg.m^{-2}$)	26.00	5.32	20.47

There was some variation in the data in terms of age, stature and body mass. The most variation was seen with body mass and the least with stature (Table III). Players all reported playing in at least two of the following positions regularly: slip, cover, point, mid-on, mid-off or wicket-keeper which are all positions within the 30 yard circle.

Most of the participants had blue eyes followed by brown, green, and blue green (Table IV). Of the sample of 21 participants, 20 were right-handed and one was left-handed.

Table IV: Distribution of eye colour

Colour	Number of Participants
Blue	11
Green	3
Blue-green	2
Brown	5

PRE-SCREENING OCULAR MEASURES

VISUAL ACUITY

All participants qualified with the required 6/6* vision (see APPENDIX B: DATA COLLECTION) or better to participate in the research study. They also received 6/6 scores for visual acuity when wearing each of the different tints of sunglasses.

*please refer to page 10 in the review of literature for clarification as to what 6/6 vision indicates

PLEASE NOTE:

All numbers presented ABOVE the bars in the subsequent figures denote coefficient of variation (%) unless otherwise stated.

All vertical bars in the subsequent figures denote standard deviation unless otherwise stated.

CONTRAST SENSITIVITY

There was a statistically significant difference between the different colour tints concerning contrast sensitivity ($p < 0.01$) (Figure 19). It is important to note when interpreting the results recorded for this test, the *lower* the value recorded, the *better* the performance on the test.

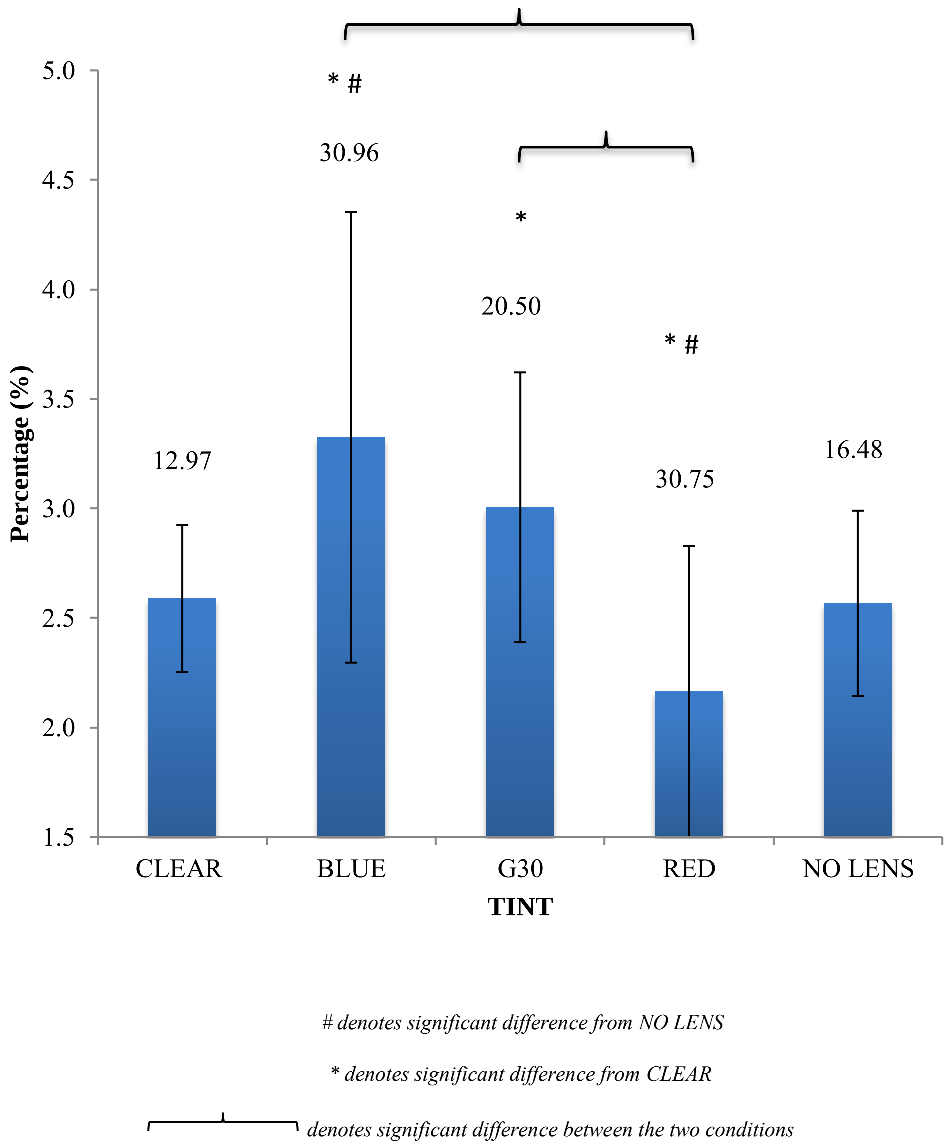


Figure 19: Mean contrast sensitivity for different tints

Although the blue tint resulted in the worst contrast sensitivity, this tint had the largest variation of all the tints tested, reflected in the standard deviation as well as coefficient of variation values.

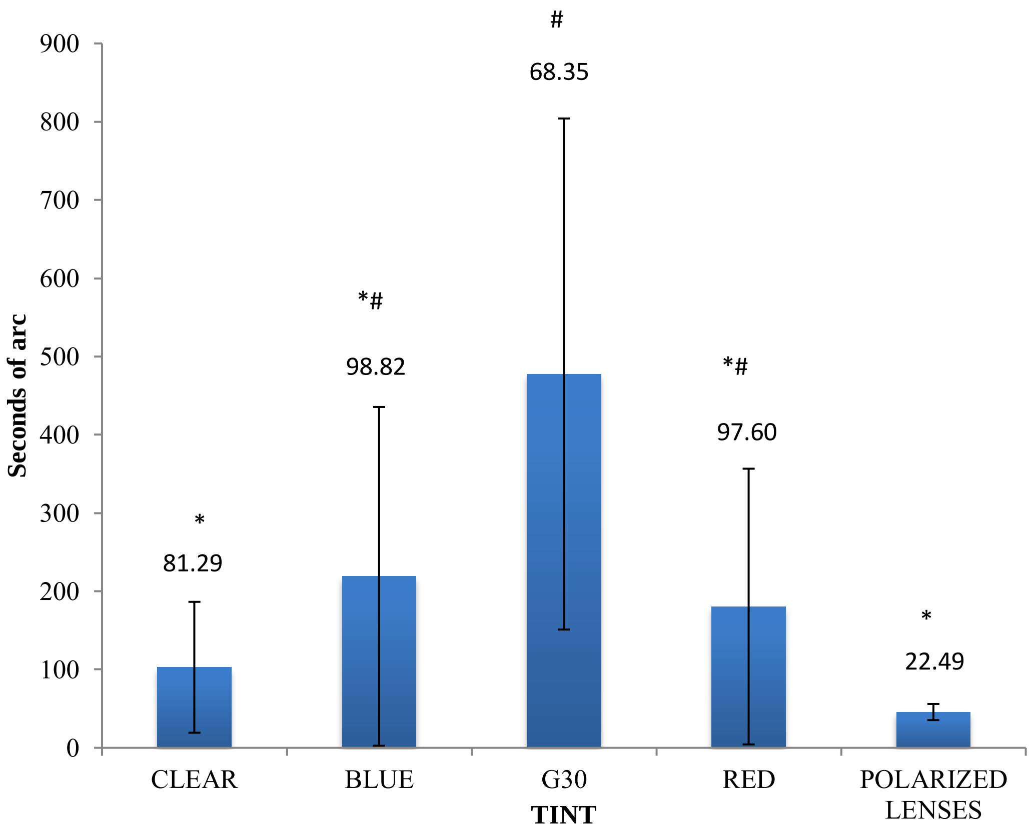
On average the red tint aided contrast sensitivity the best with the blue tint impacting it worst (Figure 19). However, both these tints had large variability. The clear lens was not significantly different from the condition where the naked eye was tested (indicated as NO LENS in Figure 19 above). The blue and G30 lenses statistically ($p < 0.0001$ and $p < 0.01$ respectively) impacted contrast sensitivity negatively in comparison to the clear lens. However, the red tint statistically ($p < 0.01$) positively impacted contrast sensitivity in comparison to the clear lens.

The red tint was significantly ($p < 0.002$) better in comparison to the naked eye whereas the blue tint was significantly ($p < 0.0002$) worse. Both the blue and the G30 tints had significantly ($p < 0.0001$ and $p < 0.0001$ respectively) diminished performance in comparison to the red tint (Figure 19).

STEREOPSIS

A statistically significant difference between the different tints was found ($p < 0.01$) (Figure 20). In this test the larger the value recorded the worse the performance. (It is important to remember that NONE in Figure 20 refers to the baseline condition where the polarised lenses were used alone without any tint)

On average the G30 tint negatively affected stereopsis the most. In comparison as can be seen in Figure 20, the clear tint resulted in the lowest score suggesting it affected stereopsis the least. Overall, the condition where the participants wore the polarised lenses alone resulted in the best score. The clear, blue and red tints all resulted in better values for stereopsis and were significantly better than the G30 lens. The red, G30 and blue tints also differed significantly from the condition where the polarised lens was worn alone (NONE); these tints were worse.



** denotes significant difference from G30 tint*

 # denotes significant difference from POLARIZED LENSES

Figure 20: Mean stereopsis for all tints

There was large variation in the data for stereopsis. The largest standard deviation was seen for the G30 lens, however the coefficient of variation for this lens was the second lowest. The largest coefficient of variation (98.82%) was seen for the blue lens. On average, in terms of the tinted lenses used for this research, the red lens resulted in the best stereopsis value after the clear lens, followed by the blue lens and then the G30 (Figure 20).

PERFORMANCE MEASURES

ABSOLUTE NUMBER OF CATCHES

Figure 21 displays the average total number of catches per tint. The maximum total number of catches players could execute per tint was 18 catches.

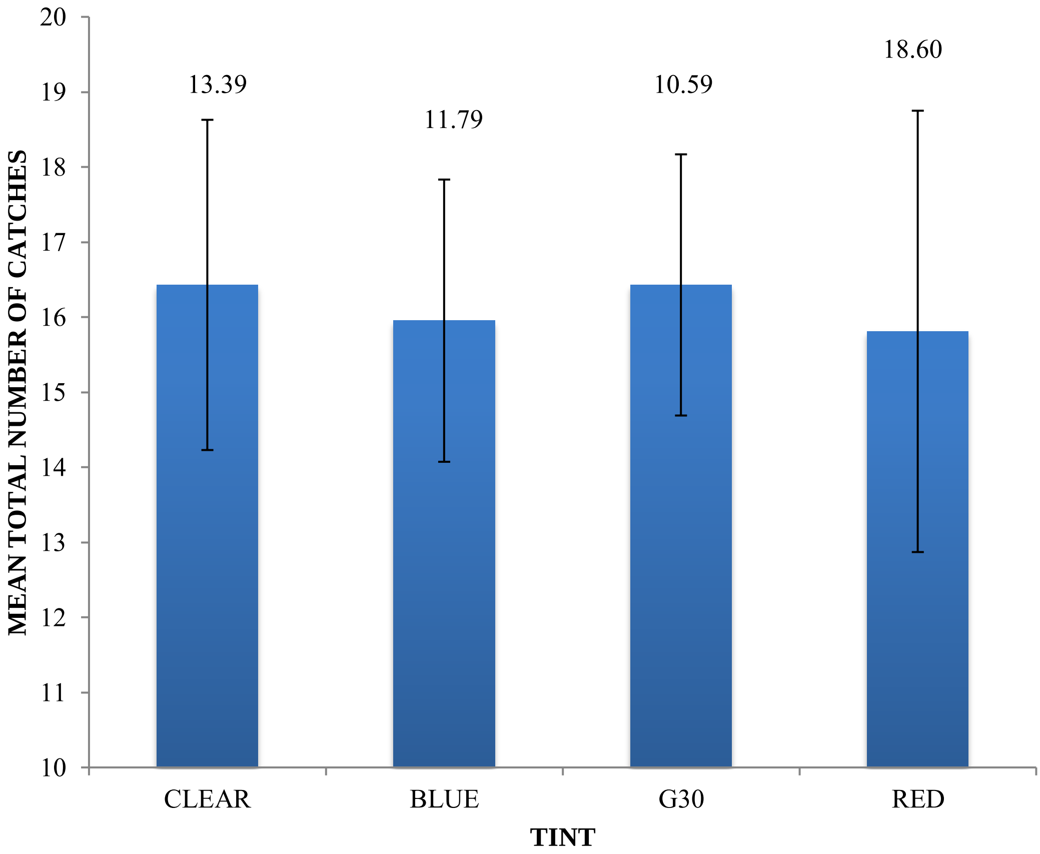


Figure 21: Mean total number of catches across conditions

The average absolute number of catches did not differ significantly between the four conditions ($p = 0.424$). The clear and G30 lenses resulted in a marginally better result than the other lenses (Figure 21). Both lenses, on average, yielded the same number of catches successfully being completed (16.45 catches). The G30 lens yielded the lower coefficient of variation value (10.59%), indicating that participants consistently caught more balls more often in comparison to the clear lens.

There was low variance seen for the data collected across the different tints, however the red tint yielded the largest variation. Along with the large variation associated with this tint, on average, it also yielded the worst average number of catches completed (15.91 catches), indicating it was the worst lens in terms of absolute number of catches, although this was not significant.

QUALITY OF CATCH

There were no significant differences between the different colour tints with respect to the quality of catch ($p = 0.623$) (Figure 22).

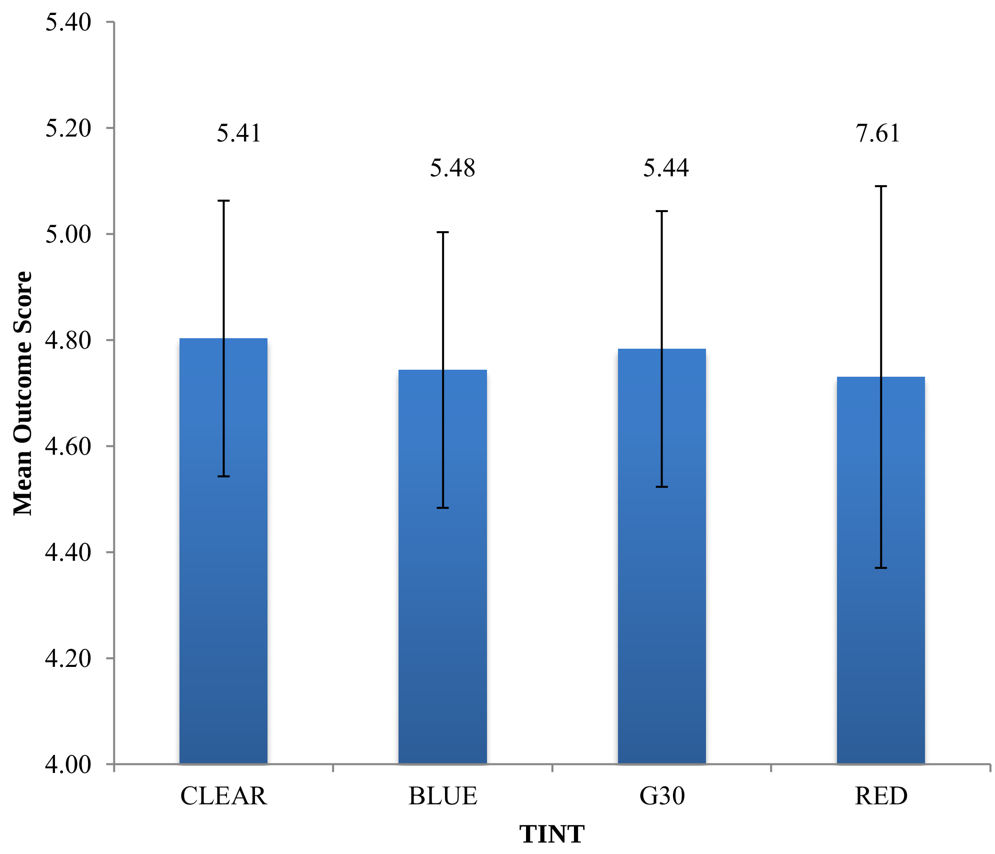


Figure 22: Mean outcome score across conditions

Across all conditions, the average outcome score was between 4 (assisted catch) and 5 (clean catch) which infers that the majority of the balls were caught regardless of the quality of catch (Figure 22).

The red and blue tinted lenses resulted in the lowest average quality score (4.73 and 4.74 respectively). Although there was no significant difference between them, the clear and the G30 lenses had an average outcome score closer to 5, indicating that these two lenses were marginally better in terms of the quality of catch executed. Variation across all the lenses was quite similar, except for the variation of the red tint which was marginally larger in comparison to the other lenses.

BETWEEN SESSION DIFFERENCES IRRESPECTIVE OF TINT

The next figures illustrate the average number of catches and average quality of catch over each session participants took part in irrespective of what tint was worn by any of the participants. To clarify, in session one an equal number of participants wore the clear, blue and G30 lenses but six participants wore the red tint. The question is whether this will affect the outcome of the number of catches taken and quality of catch executed across the sessions. Table V shows the number of participants wearing each colour lens in each of the sessions. The table shows some sessions may have had more of one colour lens in one session over the other colour lenses due to the randomisation of the lenses among participants.

Table V: Distribution of tints used in each session

	Session 1	Session 2	Session 3	Session 4
Clear	5	4	6	6
Blue	5	6	6	4
G30	5	5	6	5
Red	6	6	3	6

Total Number of Catches Over Time

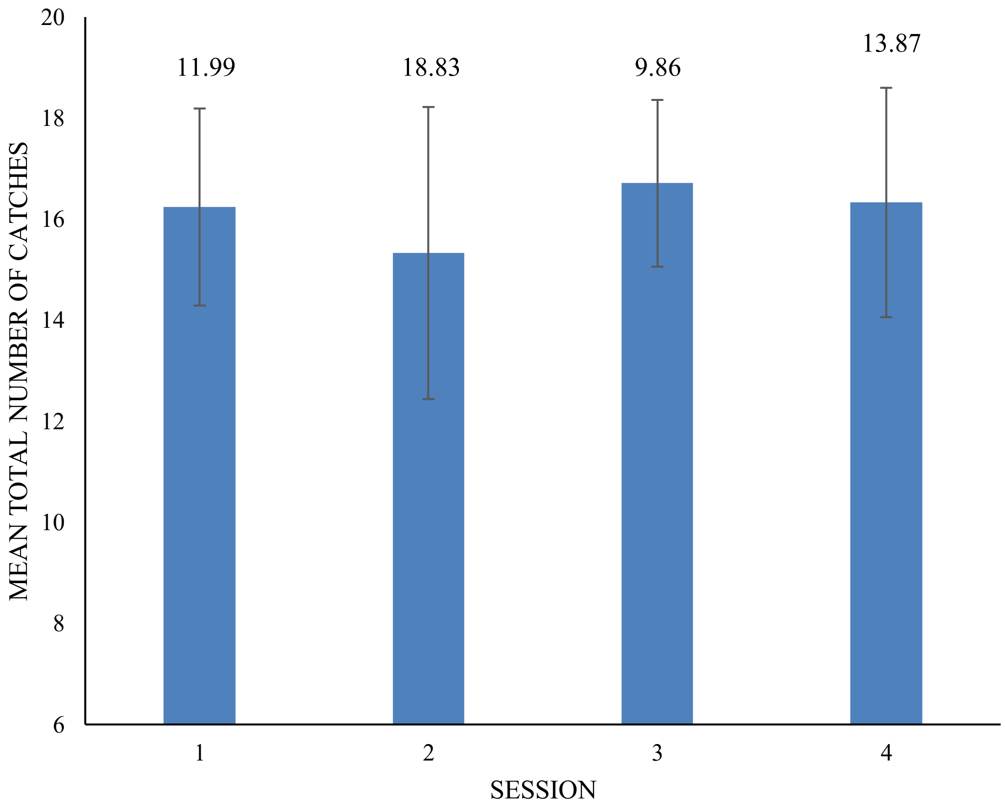


Figure 23: Mean total number of catches by session

All sessions yielded a similar average number of catches, with between 15 and 17 catches taken per session. The highest average number of catches taken was in session three (16.71 catches) and the lowest during session two (15.33 catches) (Figure 23). Session three also had the lowest variability and session two the highest variability.

Session two had the lowest number of participants that caught balls using the clear lens as seen (Table V). Overall, the mean total number of catches across the sessions is very similar with low coefficients of variation.

Quality of Catch Over Time

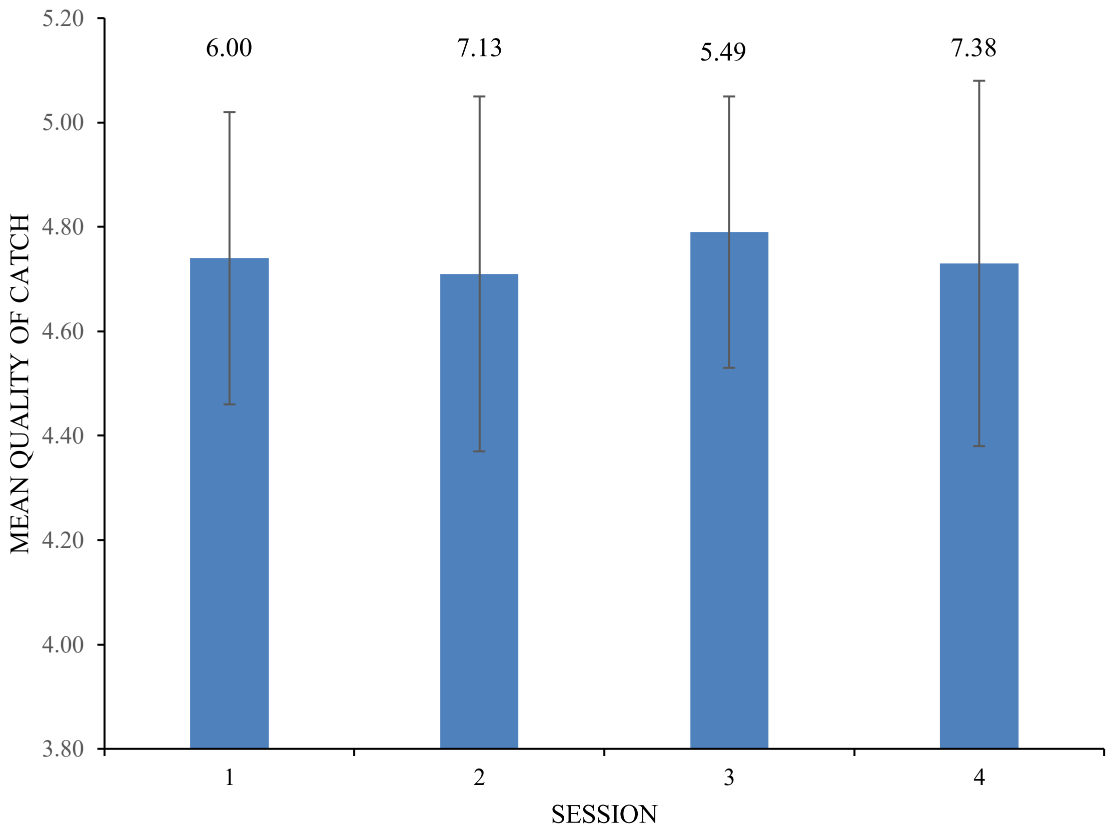


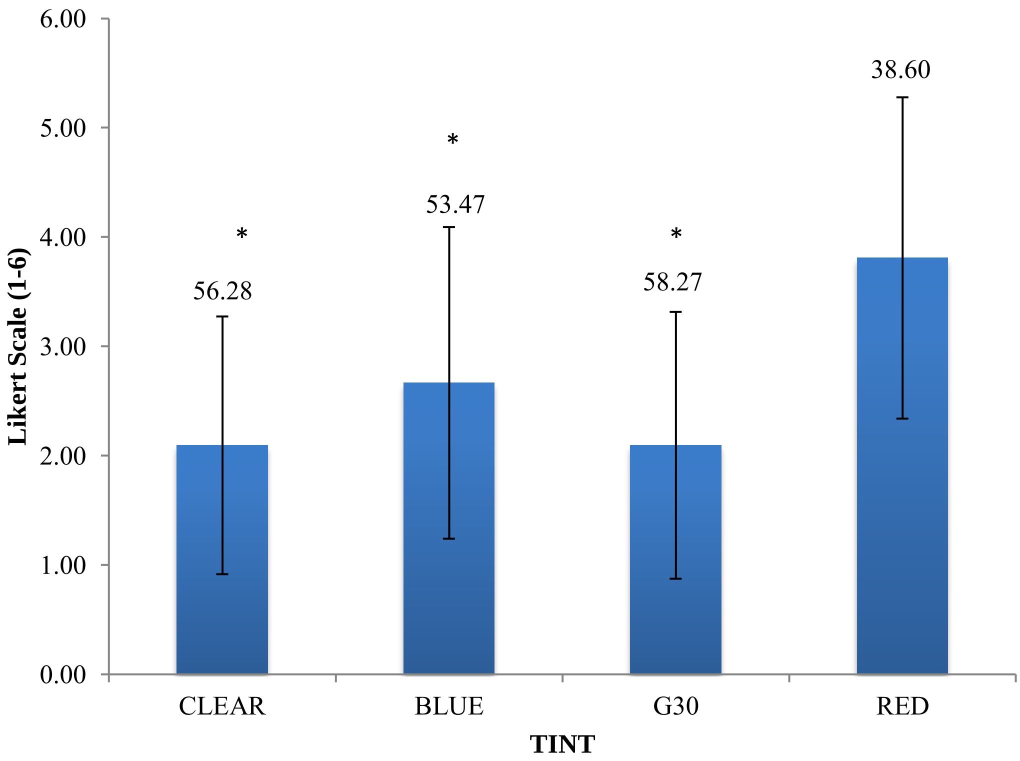
Figure 24: Mean quality of catch by session

Similarly, all sessions yielded a similar average quality of catch, with no significant difference between the sessions. Session three resulted in the best quality of catch, with the least variation of the sessions. Session two resulted in the worst quality of catch. Session four had the largest variation of the sessions with the second worst quality of catch.

SUBJECTIVE MEASURES

VISUAL COMFORT

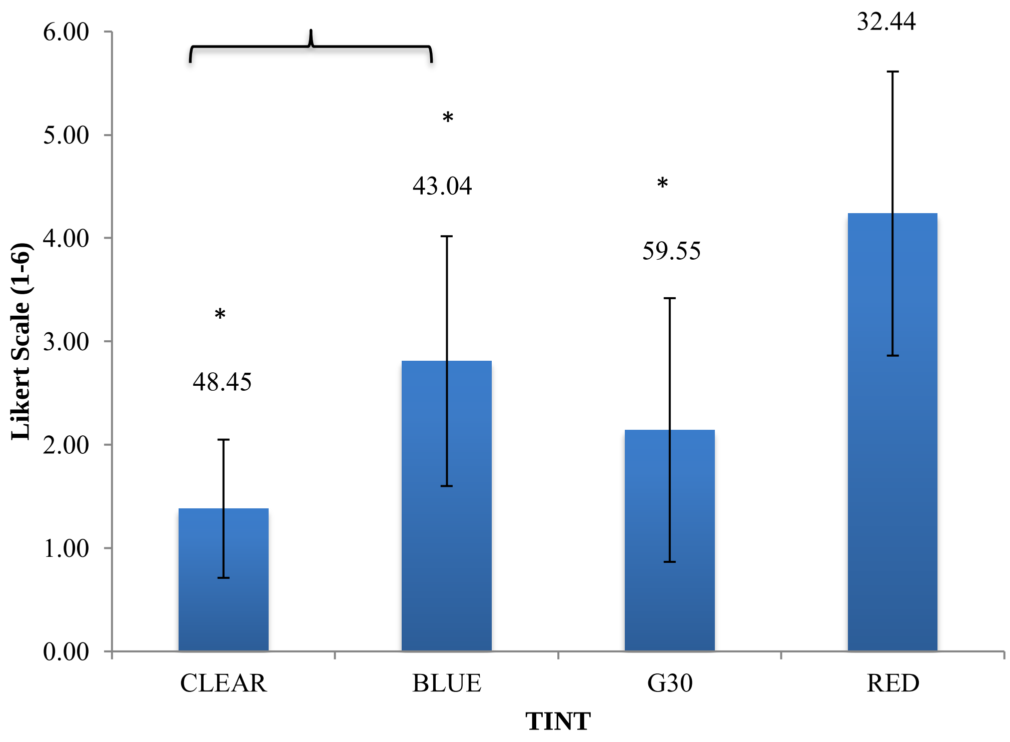
The clear (2.10), blue (2.67) and G30 (2.10) were all rated significantly better ($p < 0.01$) in providing visual comfort than the red lens (3.81). The clear and G30 lenses were, on average ranked the best, followed by the blue lens and the red being ranked as the worst.



* denotes significant difference from RED tint

Figure 25: Mean visual comfort rating

TARGET VISIBILITY



* denotes significant difference from RED tint

denotes significant difference between the two conditions

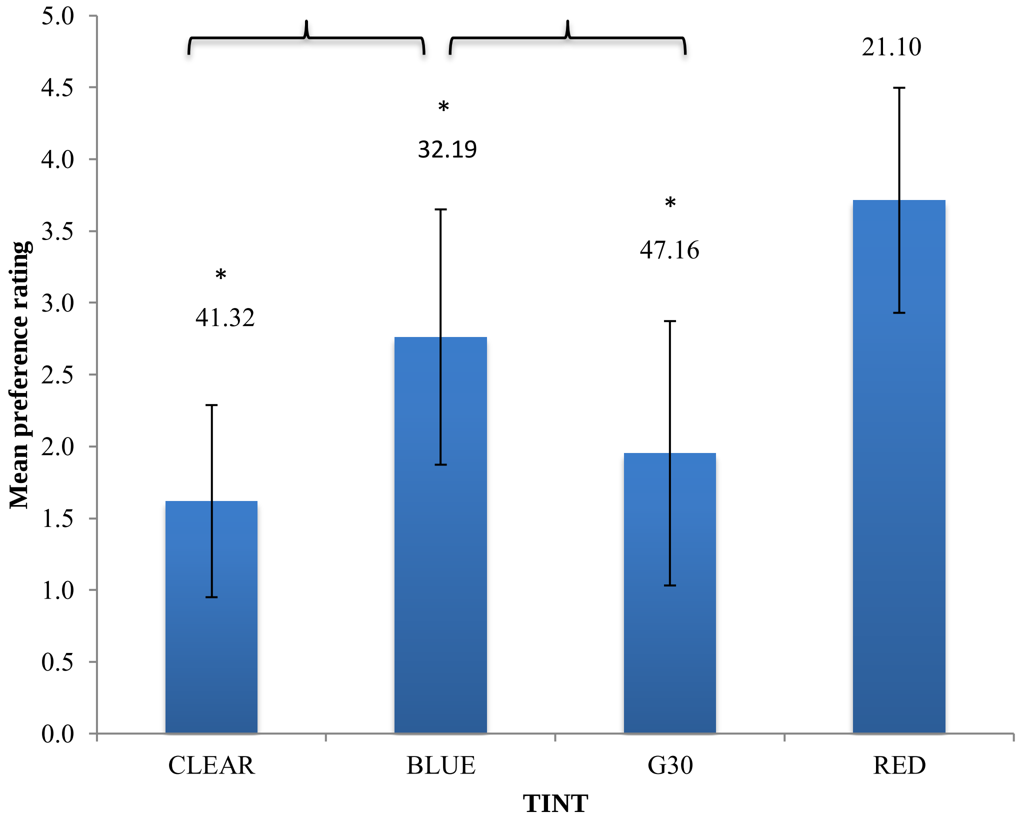
Figure 26: Mean target visibility rating

Target visibility was rated significantly ($p < 0.01$) higher for the clear (1.38), blue (2.81) and G30 (2.14) lenses in comparison to ratings for the red (4.24) lens (Figure 26). Furthermore, the blue tint was rated significantly ($p < 0.01$) worse than the clear lens.

The red lens had the lowest amount of variation (32.44%) across the tints. Overall, the clear tint was rated as the best lens for target visibility, followed by the G30 lens, the blue lens, and the red lens rated as the worst.

PERSONAL PREFERENCE

The clear lens was rated as the most preferred lens (1.62) (Figure 27). The clear (1.62), G30 (1.95) and blue (2.67) lens were rated significantly ($p < 0.0001$) more preferable than the red lens. The clear and G30 lenses were ranked significantly ($p < 0.001$ and $p < 0.04$ respectively) better than the blue lens.



** denotes significant difference from RED tint*

denotes significant difference between the two conditions

Figure 27: Average preference of different tints

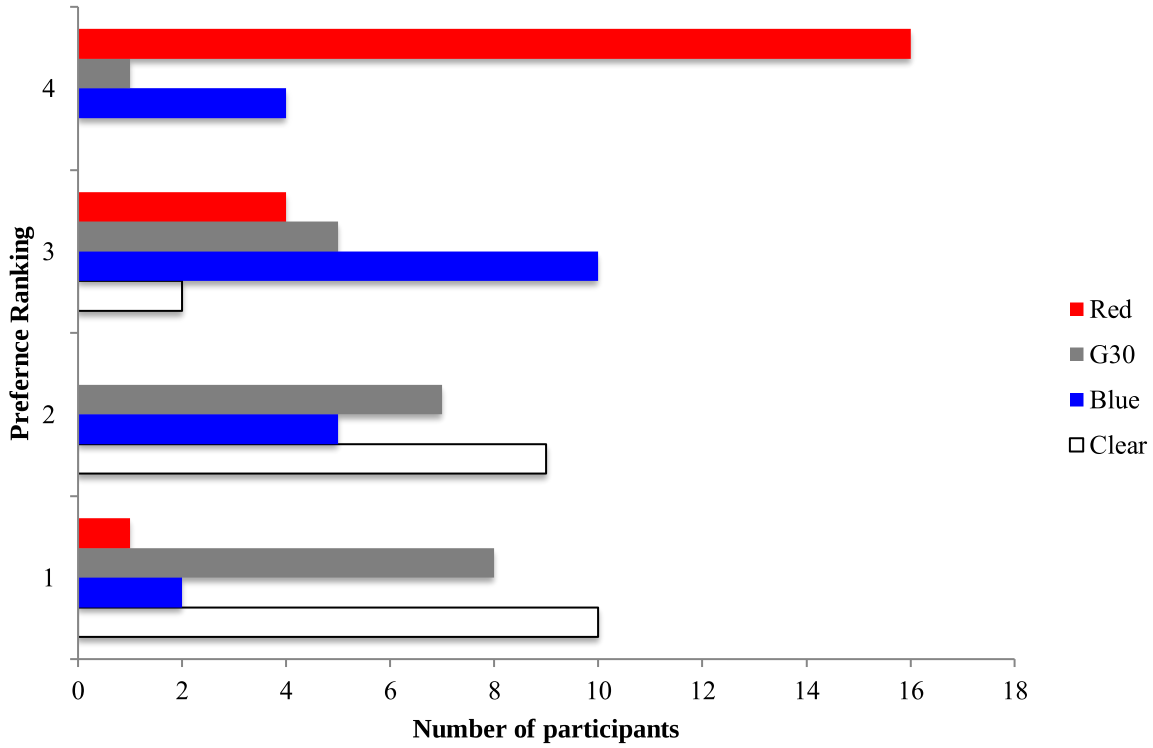
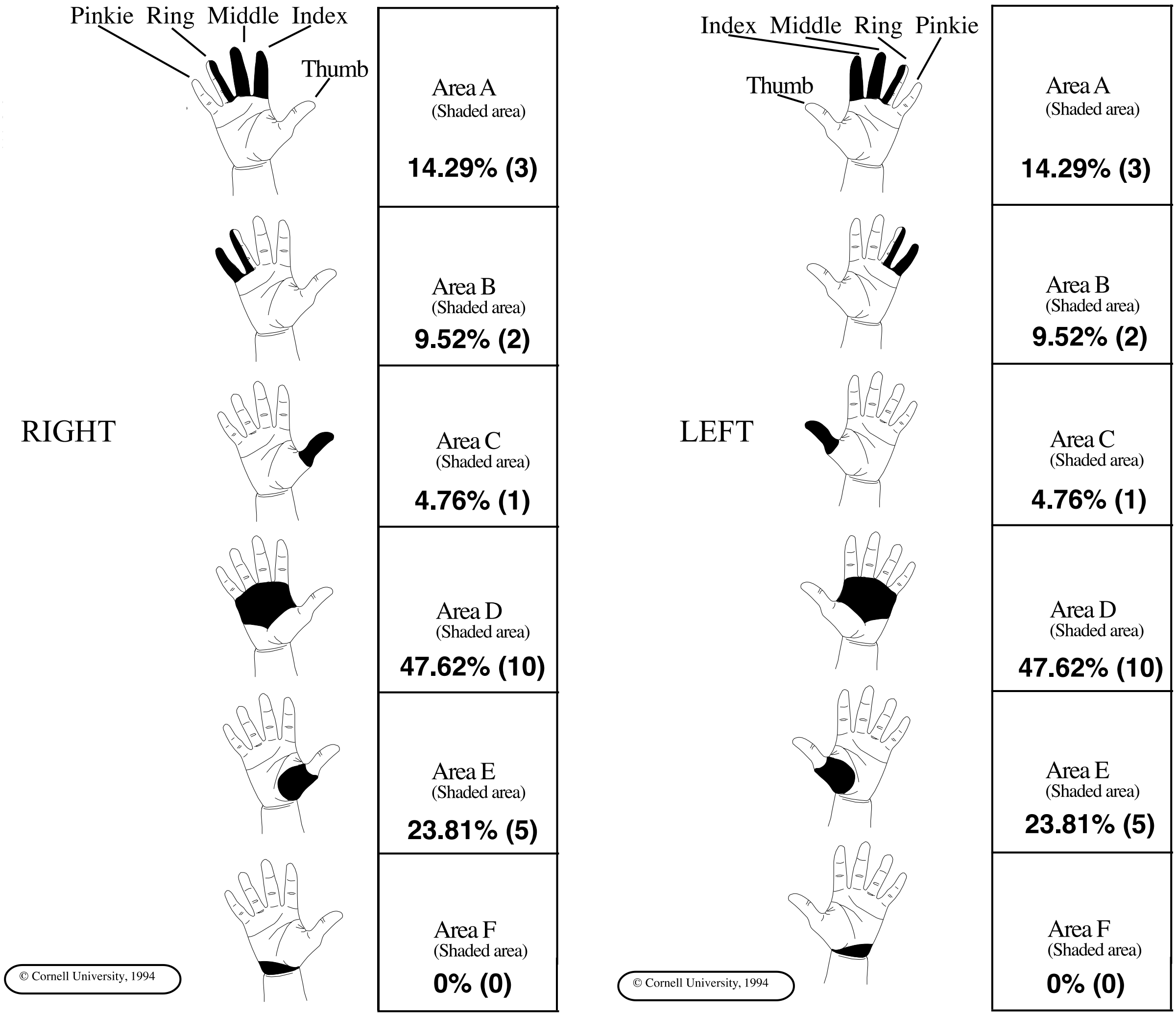


Figure 28: Distribution of participants rating for each lens

Figure 28 illustrates the distribution of the total number of participants ranking each colour tint in each ranking category. The figure represents how many participants ranked each tint for the specific preference ranking (1 = best 4 = worst). All four tints are represented within each preference ranking showing the distribution of the 21 participants for that specific ranking. The red tint was ranked by 16 participants as the least preferable tint, supporting the average finding in Figure 27 above. It is also evident that the majority of the participants ranked the clear tint as either their most preferred or second preferred tint. Not one participant rated the clear lens as the worst (category 4), with only one participant rating the red tint as the best (category 1). Overall, there was a clear indication that the red tint was the least preferable with a close contest for the most preferred tint between the clear and G30 tint.

PAIN DATA



(x) denotes the number of participants rating

Figure 29: Areas of the right and left hand rated as the most painful

Equal numbers of participants rated each area on both hands as painful (Figure 29). Almost half of the participants rated Area D (palm) as one of the most painful areas with Area E (thenar eminence) coming in as the second most commonly rated painful area.

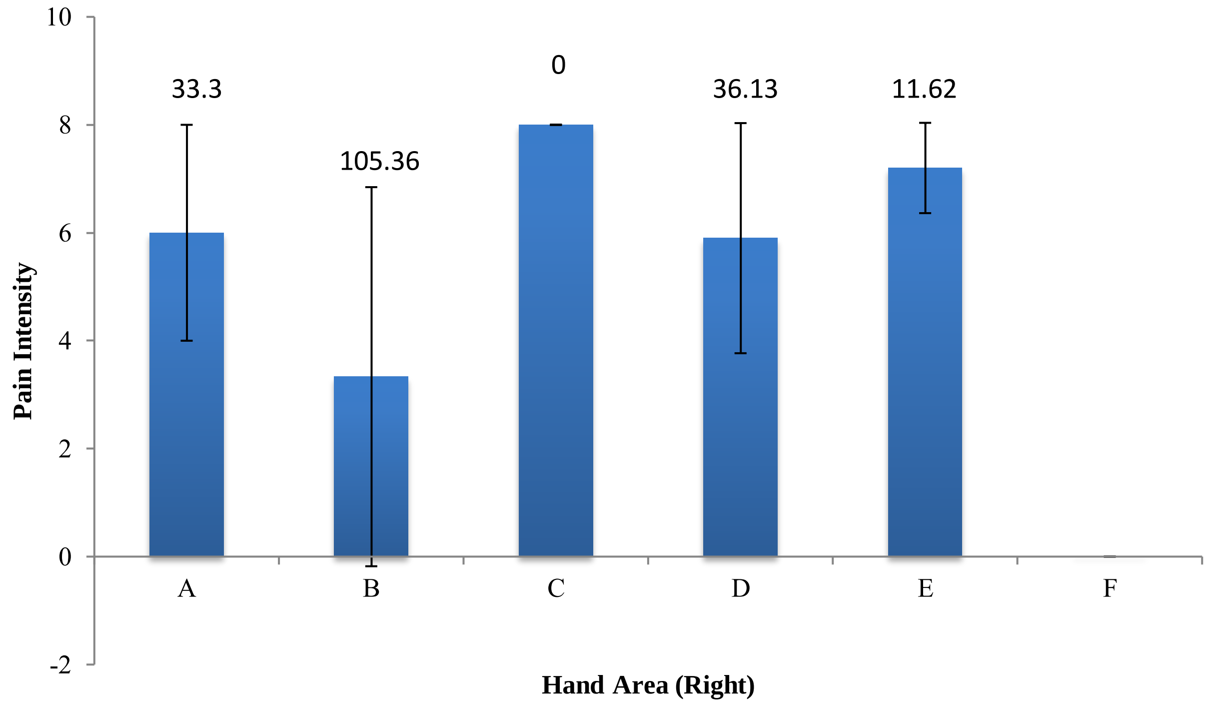


Figure 30: Mean pain intensity ratings of areas of the right hand that experienced the most pain

Figure 30 and Figure 31 illustrate the mean pain intensity ratings for each of the areas of the right and left hand respectively. 10 participants rated Area D as a painful area, Area C was rated as the most painful area with a mean pain intensity rating of 8 (Figure 30). However it must be noted that only one participant rated that area. In comparison the pain intensity rating for Area E was averaged across five participants rating this area as painful resulting in an average score of 7.2. The average score of this same area (Area E) on the left hand was 5.72 (Figure 31). As pain is a subjective measure there was a range of pain ratings in each of the areas shown in Table VI, which accounts for the large standard deviations and coefficient of variations.

Table VI: Number of participants rating each area and range of pain ratings

Area	Number of participants (R)	Number of participants (L)	Range of ratings (R)	Range of ratings (L)
A	3	3	4-8	4-6
B	2	2	3-7	2-7
C	1	1	8	3
D	10	10	3-9	2-8
E	5	5	6-8	4-9

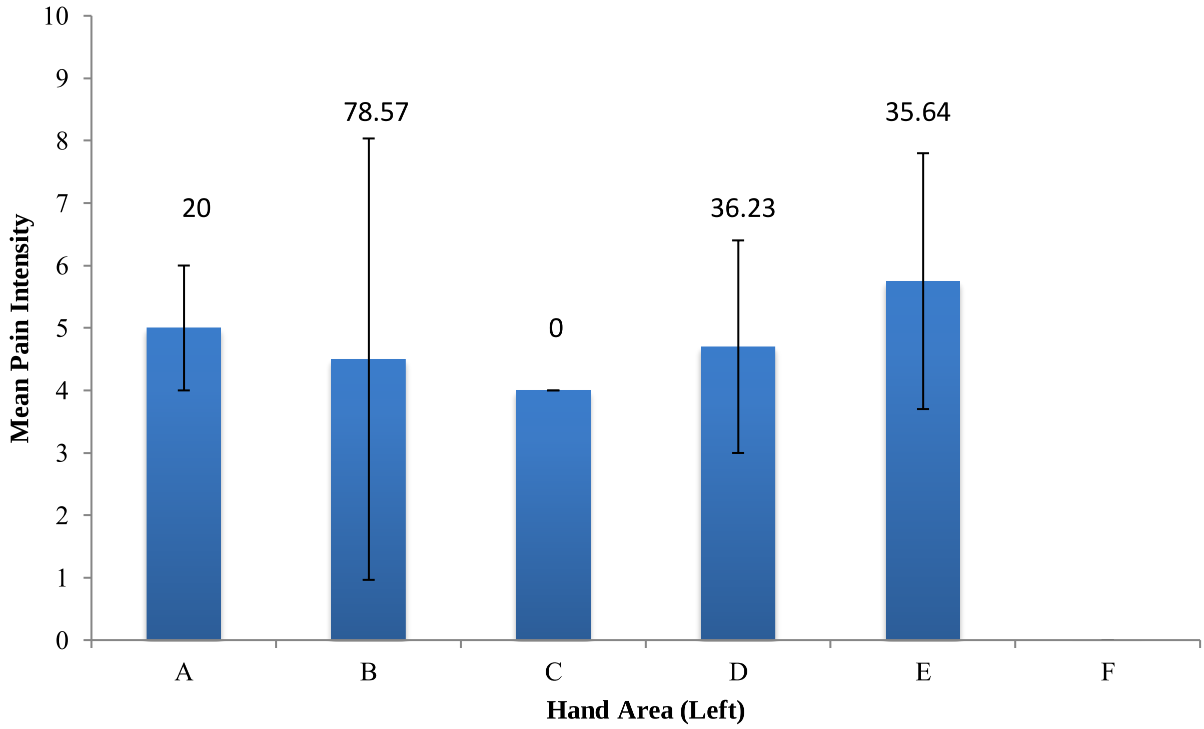


Figure 31: Mean pain intensity ratings of areas of the left hand that experienced the most pain

The mean pain intensity ratings of the areas of the left hand were relatively similar across the different areas. The main differences between the different areas are the standard deviation and coefficient of variation. As can be seen, the largest standard deviation and coefficient of variation is for Area B due to the range of ratings and only two participants rating that area as painful. The highest pain intensity rating on average was for Area E with a rating of 5.75 which is lower than the rating for this area on the right hand. This area had a much broader range of ratings than the right hand Table VI above also confirmed by the larger standard deviation. The second most painful area was Area A with an average rating of 5 and a much smaller coefficient of variation, standard deviation and range of ratings. Area D was rated as the third most painful area on average with a rating of 4.7. This area had a similar standard deviation and range of ratings to the same area on the right.

FREE WRITING COMMENTS

Participants were given the opportunity to comment upon the experience of the protocol and the lenses. Comments that were returned were about the pain experienced, lens preference or difficulty and how catching technique affected pain. Note that these comments are not edited.

Five of the 21 participants commented that the red lens made catching difficult, below are sections of the comments participants wrote:

P8:

> "Red tint glasses made it very hard to pick up the red ball, while with the clear tint it is very easy"

P12:

> "The red lens brightened everything up but it was difficult to see the ball all the time"

P13:

> "Red and blue had immediate hindrance on catching ability… strongly disliked red as it turned everything into different shades of red i.e. struggled to pick it up"

P22:

> "Picked the ball up a lot later with the red and G30 lenses, compared to the blue and clear"

P27:

> "The red tint was by some distance the hardest to catch with. It was hard to pick the ball up from the background"

Two participants commented on catching technique affecting pain ratings:

P5:

"Pain in each hand depends on where the ball was positioned. If it came to my right hand side, I would use my right hand as the back stop. The same applies for the left"

P20:

"Catching with the fingers facing down affected the ring and pinky finger knuckles. Catching with the fingers facing up affected pain more towards the thumb area."

Six participants commented on their preference and experience with the lenses:

P10:

"G30 lens was by far the most enjoyable/clear choice for me. I would consider using glasses like that in the future."

P12:

"The G30 lens sharpened everything up and made it easier to see and identify the ball."

P13:

"Clear provides no hinderance to visual ability, whereas red and blue and immediate hinderance on catching ability as you had to get used to seeing the balls movement against the backdrop. No opinion about G30."

P21:

"There wasn't much difference between the lenses. Maybe my eyes were able to adjust quick enough to make sure it didn't affect the catching."

P24:

"I struggled with the blue lens. I felt like I was constantly having to squint/blink to get my eyes to focus"

P27:

"the clear tint was the easiest to catch with"

CHAPTER V:
DISCUSSION

INTRODUCTION

The main finding of this study was that there was no difference in terms of objective performance measures between the different colour tints. There was however, a distinct difference concerning the subjective measures such as visual comfort and target visibility with close competition for preference among the players between the rose-based tint (G30) and the clear tint.

This chapter will first discuss the pre-screening measures and then discuss the results of the performance and subjective measures. The chapter ends with the limitations of the project and suggestions for future research, ending with an integrated discussion.

PRE-SCREENING OCULAR MEASURES

VISUAL ACUITY

With visual acuity forming the base of the sports vision pyramid, it is evident from the non-significant result of this measure, that the ability to see and detect the ball, which contributes to perception, was not affected by the colour of tint in this sample of cricketers. Therefore, visual acuity as part of the visual hardware that provides visual information (Abernethy, 1987a; Mark Williams et al., 1999), was not an influencing factor on the quality of information players received when executing the protocol. To the author's knowledge, only two other studies conducted by Moore (1997) and Teikari & Lindström, (1995) investigated the effects of different tints of sunglasses on visual acuity. Moore (1997) found that certain colour tints (clear, yellow, red and pink lenses) had similar visual acuity to when no lens was worn, which was also observed in this study. In contrast, these same authors found that black, grey, green and blue colour tinted lenses reduced visual acuity (Moore, 1997) which was in contrast to our finding with the blue lens tint where visual acuity was not reduced. However, it is important to note, that the results of the study conducted by Teikari & Lindström (1995) are difficult to compare to this study as their study investigated differences in visual acuity of different commercially available sunglasses. They found that brown lenses followed by grey lenses affected visual acuity the least, and the mirror lenses affected visual acuity the most.

In this study visual acuity was measured to ensure all players had 6/6 vision when wearing each of the different tints, it may have been useful to investigate how far down the visual acuity test participants could read down with each lens rather than only ensuring they had 6/6 vision with the lenses on. According to the author's understanding, measurements for each colour lens in the Moore (1997) was taken to the line that the participant could correctly identify the letters completely. This may explain the contrasting findings of Moore (1997) where this study found blue lenses decreased visual acuity with this study finding no difference. The differences observed in the Teikari & Lindström (1995) study may be explained by the fact that the colour of the lenses tested were very different to the ones used in this study, thus making comparison difficult.

As visual acuity was not affected by the different tint of sunglasses in this study, this implies that the players ability to get into position to catch the ball should not be affected as the clarity of the image perceived is the same. Visual acuity as one of the most important bases contributing to visual perception in fast ball sports is important and thus if it can be improved, the premise is that better perception will result in better chance for interception due to the ventral system of vision resulting in recognition of the ball therefore allowing the dorsal system responsible for the visual control or body response to the given information (Mann, 2010). The inextricable link between these two visual systems of perception and cognitive processes in the visuomotor system affecting motor control dictate that if perception is improved, this allows for cognitive processes to occur quicker thus resulting in better chance for interceptive actions to occur (Milner & Goodale, 2006b).

CONTRAST SENSITIVITY

The red tint, on average, scored the best on the contrast sensitivity test (even when compared to the naked eye and clear lens) meaning it was the best lens for discriminating detail. This observation may be explained by the fact that the filter of the red lens, which affects light transmission, may reduce the luminance of the background relative to the object (Hammond et al., 2010). Other suggestions for this improvement were that the tint in the lens could either decrease the amount of chromatic aberration, increase the brightness or decrease the intraocular straylight (De Fez et al., 2002). These suggestions require more specialised optometric research to determine if this is true. This finding suggests that performance with the red lens should be enhanced as players should be able to discern the ball quicker; however this was not the case.

The blue tint scored the lowest on the contrast sensitivity test. The large variability in the findings of both the red and blue lenses is important to take into consideration when interpreting these results, as this suggests that individual responses are key. There was a high amount of variability for all the coloured lenses (red, blue and G30) with the G30 resulting in the least amount of variation. The lower amount of variation may imply that although on average, the red tint had the best score, the G30 may be optimal for more players. As contrast sensitivity is another key parameter in the foundation of the sports vision pyramid (Kirschen & Laby, 2011), this parameter should be considered carefully when players make their choice of lens. This parameter is particularly important in the game of cricket as it aids in helping discriminate the ball from the crowd or against the sky when the ball is more lofted. Why this did not translate to better catching performance needs to be interrogated further.

STEREOPSIS

The findings from the stereopsis measure need to be interpreted with caution as suggested by the consulting optometrist. This caution is due to the limitation of the test, which may have compromised the validity of the test due to participants being required to look through two pairs of lenses. However, there was no other method available that would have been capable of testing this ocular measure.

Stereopsis was negatively affected by all the colour lenses except the clear lens. This lens also had the smallest variance and was most similar to when the test was conducted with the polarised lenses alone. The low standard deviation and coefficient of variation demonstrate the similar results of the participants for the condition where only the polarised lenses were used. The large variability in the findings with the coloured lenses suggests that, like contrast sensitivity, individual responses are key. Again, however, habitual sunglass use is an area that requires careful investigation as the results for this study may be due to participants being accustomed to not wearing sunglasses and needs to be investigated further. It is interesting to note that the G30 lens had the worst result when being tested for stereopsis. With this result, it was expected that this lens would negatively impact performance, which was not found in this study.

PERFORMANCE MEASURES

ABSOLUTE NUMBER OF CATCHES

Overall the different colour of tinted lenses had very little effect on the average number of catches taken. Further, the coefficients of variance for all lenses were low with the least variance for the G30 lens. The red lens had the most variance and the lowest average number of catches which suggests that this colour tint is not preferable for fielders.

Based on the results of the ocular pre-screening measures, it was expected that the red tint would yield the best results in terms of performance. However, based on these preliminary findings, no tint was superior with the performance data tentatively suggesting that the G30 lens may be the best tinted lens, although more research is needed to substantiate this claim.

To make a more substantiated claim that one tint may be better than another, it may be useful to get more objective data such as eye movement data while wearing the different colour tints. This type of data may give more in-depth understanding of how the light transmission affects the eye with regard to the size of the pupil or the eye tracking capabilities which all affect how quickly information is transmitted to the brain for processing thus affecting outcomes such as interceptive actions (Erickson, 2007).

QUALITY OF CATCH

As with the total number of catches, there was no significant difference in the quality of catch when comparing the different colour lenses. Most catches were classified as high-quality catches, irrespective of tint. The G30 and clear lenses had a mean outcome score closer to five. These lenses had the least number of balls caught that were classified as a category three or below. This resulted in a better average score than the other lenses. The red lens had the lowest average quality score, with the largest variation. These results could tentatively indicate that the red lens affects catching quality the most out of all the lenses tested, which needs to be explored further optometrically.

SUBJECTIVE MEASURES

VISUAL COMFORT

Glare is known to decrease visual function and performance due to the impaired ability to see detail and is typically an uncomfortable experience on the eyes. The red tint was visually uncomfortable for the players, with players disagreeing that this tint reduced glare or squinting;

a significant finding in comparison to the other tints. The low variability in this measure supports the notion that most players perceived this tint to be the most visually uncomfortable. It is interesting to note that the G30 and clear lenses received similar mean ratings in terms of visual comfort. The control condition using the clear lenses had the lower variability and therefore is the best condition for visual comfort for this sample of cricketers. This is an important finding, particularly as the players were non-habitual sunglass wearers which may have impacted the findings. The clear and G30 lenses received the best ratings for visual comfort, which aligns well with the result of these two lenses resulting in the best quality of catch and absolute number of catches above. These results could suggest that the players found the G30 lens to provide a similar visual experience to one that is unhindered by a coloured tint. Visual comfort is a key area that determines which sunglasses players select as it reduces the effects of glare disability which affects eye fatigue due to squinting (Erickson, 2007; Farrow & Southgate, 2000; Hammond et al., 2010). Although players were habituated to all the tints, experience wearing tints is important and is something that warrants further investigation. There may have been some level of anxiety when players wore different colour tints which would impact players variability in performance concerning the absolute number of catches and quality of catch. Anxiety alters perception as it typically increases the amount of attention allocated to threat-related sources of information, decreasing the amount of information allocated to the perception of relevant information, selection of appropriate behaviour and realisation of possibility for action (Nieuwenhuys & Oudejans, 2012). This will ultimately affect the way the environment is scanned for relevant information and therefore impact the effective execution of a catch (Nieuwenhuys & Oudejans, 2012). However, as we did not measure levels of anxiety, this is speculative. Further, catching performance was generally good irrespective of the condition.

TARGET VISIBILITY

Similar to the visual comfort findings, players found that the red tint was significantly worse for detecting the ball in comparison to the other tints. The low variability seen for the red tint is an indication of the consistency of players assigning this lens a lower rating. Although there was a difference in the overall average rating of the clear and G30 lens, it was a non-significant difference which infers the two lenses were rated similarly for their ability to aid in efficient target visibility. The clear lens, on average, had the lowest result with a rating of either one or, two, meaning they strongly agreed with the statement that this lens provided superior visual performance and target visibility. This result was to be expected as players recruited for the study were non-habitual sunglass wearers, so they prefer to field without sunglasses in normal catching circumstances. The lack of tint in the clear lens would not hinder perception of the ball and possibly may have decreased anxiety for the players anyway meaning they would have scanned the environment differently (Nieuwenhuys & Oudejans, 2012). The lack of significant difference between the average ratings of the clear and G30 lens suggests that players perceived the G30 impacted the visibility of the ball the same as the clear lens which supports the findings for visual comfort. Lighter tints may, therefore, be more preferable as it interferes least with the perception of the ball a finding observed previously as lighter tints deviate least from the naked eye (Shaik et al., 2013). Further, darker tints cause greater pupil dilation, which increases the amount of aberration experienced in the eye, thus degrading retinal image (De Fez et al., 2002; Marmor, 2001; Shaik et al., 2013).

PERSONAL PREFERENCE

The ranking of the various colour tints resulted in the clear and G30 lenses being the preferred lens. The least favoured lens was the red. This result is most likely due to a combination of both the above-mentioned factors of visual comfort and target visibility, which would ultimately affect visual performance. Players would therefore tend to avoid this colour of tint. These results may be explained from a psychological perspective within the context of familiarity and experience. Players selected actions are built on the recurrent history of interactions between the body, environment and context of the given situation (Cappuccio, 2015). These actions are constructed based on the continuous development of direct responsiveness to the surroundings, readiness to anticipate and take advantage of opportunities for action other less skilled players may not see, which is characterised as implicit or procedural knowledge (Cappuccio, 2015). The addition of a lens alters the way information from the environment is processed as the familiarity of the context has changed thus affecting procedural knowledge, affecting the opportunities for action as the player is unfamiliar with the environment and conditions thus affecting how the player now interprets the given information (Cappuccio, 2015; Fajen, 2007; Fajen et al., 2008; Oudejans et al., 1996; Proffitt, 2006). This psychological principle is known as the ‘mere-exposure effect’ or the ‘familiarity principle’ which implies that people prefer and rate things that they are more familiar with more positively (Zajonc, 1968).

TOTAL NUMBER OF CATCHES IN EACH SESSION

This data looked at the average the number of catches executed, irrespective of colour tint worn for each of the four testing sessions. As can be seen in APPENDIX B: DATA COLLECTION testing of the coloured lenses was randomised to reduce the chance of a learning effect. The non-significant difference in the results of each session suggests there was no learning effect that occurred across the testing. The lowest average number of catches was seen in session two where most players wore the least favoured coloured tints (red and blue; 12 out of 21 participants) which may account for this. Session three had the highest number of catches with the least variance. In this session, the red tint was worn by very few players (3 out of 21). Again, suggesting that the red tint is limiting catching performance.

QUALITY OF CATCH IN EACH SESSION

Similarly to the number of catches over time, this data investigated the average quality of catch irrespective of the colour of tint worn for the session. Again the non-significant difference found across the sessions indicates a lack of learning effect. These results mirrored the findings above, with the lowest quality of catch being recorded for the second session and the highest quality of catch in the third session. The third session also had the smallest variance. Session four was the second-worst average quality of catch over time. One would have expected this would have improved as it was the last session. The variation of results over the sessions infers that the tint of glasses may have affected catching, although not significantly.

PAIN DATA

On average the pain intensity ratings were higher on the right than they were on the left, as 19 of the 21 players were right-handed. This result is to be expected as the right hand would typically be used as the backstop when right-handers catch the ball.

As pain is a very subjective concept, and the average pain intensity ratings that were selected for each area are therefore dependent on the number of participants rating that area as painful. The lower the number of individuals rating pain for that area, the less accurate the rating is due to less variance for the ratings of that area. This is particularly important to remember when investigating the pain intensity ratings for areas of each hand. For this reason, it is useful to eliminate Area C (the thumb) for both hands as only one participant rated the pain for this area on both hands. The order of rank for the most painful area in terms of pain intensity was the same for the right and left hands, with a lower rating for the left hand. With Area C excluded, Area E (the thenar eminence) was given the highest pain intensity rating followed by Area A (the index, middle and ring fingers) which was closely followed by Area D (the palm). Area E on the left hand may have a lower rating due to the range of ratings being larger than that of the right hand (refer to Table VI). However, the palm (area D) was the most commonly rated area of pain.

FREE WRITING COMMENTS

The participants were given an opportunity to write about the experience of the different tints and the protocol employed. Not all participants commented on their experience. A little less than a quarter of the participants (five out of 21 participants) believed that the red lens made it difficult to see, 'pick up' the ball or that they 'picked it up later'. There has not been much research on how different tints of sunglasses affect the detection of objects but rather more on how the tints affect colour perception. Data has shown that there is a relationship between luminance and acuity, indicating that as luminance increases, so does acuity, up to a certain point (Marsh, Cushman, & Temme, 1953). It is possible that the red lens may have increased the luminance in the room to a point where acuity of the ball was affected, which may have affected the timing of the catch. The lenses affecting the timing of the catch may be due to an increase in visuo-motor delay (VMD). Increases in VMD results in the player having less time to interpret information before interception of the ball, giving the player less time to adjust and improve online regulation of movement resulting in interception of the ball being less likely (Benguigui, Baures, & Le Runigo, 2008). Only two participants commented on the catching technique and its effect on the pain experienced in the hands. Where pain is experienced would have been influenced by the participant's dominant hand and choice of catching technique based on how the ball would be projected from the bowling machine. One participant said, *"pain in each hand depends on where the ball was positioned. If it came to my right-hand side, I would use my right hand as the backstop. The same applies for the left"*. Two participants expressed their preference for the G30 lens with comments such as *"G30 lens was by far the most enjoyable/clear choice for me. I would consider using glasses like that in the future"* and *"the G30 lens sharpened everything up and made it easier to identify the ball"*. Although these comments are only from two participants, it does give some insight. These experiences support the ratings for target visibility and visual comfort for both the G30 lens and then the clear tint. Two participants expressed their preference for the clear tint for two reasons; it *"provides no hinderance to visual ability"* and *"was the easiest to catch with"*. To the author's knowledge, there are no studies that investigate individual's preference for specific coloured lenses. Thus it is difficult to accurately speculate as to why specific tints could have been preferred over others. The preference for clear lenses could be due to this set of participants being used to not wearing sunglasses. Players may therefore feel more comfortable and familiar in an environment that does not alter colour perception, contrast sensitivity or visual acuity with the addition of a coloured lens.

INTEGRATED DISCUSSION

It is widely accepted that sportsmen and women wear sunglasses. Still, it is interesting to investigate athletes' reasons for opting to use sunglasses as well as why they select a particular kind of sunglass. The primary reason would be for ocular health and safety reasons with strong scientific evidence for why this is necessary (Davis, 1990; Erickson, 2007; Thomas, 2008). Along with the development of professional sport over the decades, other factors are considered when selecting sunglasses. One of the other factors that contribute to the selection of sunglasses worn by athletes is brand sponsorship. Brand sponsorship has added another dimension as to which sunglasses athletes choose. In addition to brand sponsors dictating what sunglasses athletes should wear, there is also the fashion or aesthetic dimension that is considered by players and the brand (Moore & Ferreira, 2005). Brand sponsors typically purport that particular models in their range provide performance enhancements, with no scientific data to substantiate these claims. The current study has demonstrated that, albeit in a very controlled environment, there are objectively no differences between tinted lenses that are on opposite ends of the colour spectrum as well as one that is closer to the red end of the spectrum. This study has however highlighted, that subjective measures such as visual comfort and target visibility may play a part in sunglass selection based on the user's experience while executing the task. The data collected on the subjective measures provided useful and interesting information as it contradicted the objective findings. The subjective data gave us insight into which lenses players preferred to use despite there being a non-significant difference in the number of balls caught, i.e. performance.

Based on the results of the ocular measure of contrast sensitivity, the red lens performed better than all the tints, including the clear and naked eye. In terms of the coloured tints (red, blue and G30), the red tint was objectively the best after the clear lens for the measure of stereopsis. These results positioned the red tint as one that could potentially improve performance on the field; however, given the limitations of both tests, it is clear why this was not the case. Based on the results from this measure, the G30 lens should have diminished the execution of the catch the most. This result however was not corroborated in the final scores for either the absolute number or quality of catches or the subjective perceptions of the different tints, where the G30 was on average the most preferred tint after the control tint of clear. Although the ocular parameter of stereopsis tested by the Stereofly test in the current study is not depth perception per se, it is difficult to draw conclusions as to whether or not different colour tints affect depth perception. Depth perception can only be measured using the Howard-Dolman device, and it only measures this optical parameter statically. Thus, any claims that brands make implying sunglasses improve depth perception, must be questioned as to how this was measured.

Although objectively all lenses were similar, the subjective responses to the red lens suggests it was not optimal. Therefore, indicating player perceptions/preference have a bearing on the selection of sunglass tint but not necessarily performance. The results also suggest that perhaps lighter density tints such as the G30 are more preferable as a choice for athletes. Player perceptions cannot be ignored as although the tint may not affect performance objectively, players need to be comfortable with the tint selected and this should be more of an influencing factor in choice. This is particularly important from a psychological perspective as if players are prescribed a particular tint of sunglass as objectively it has been determined there is no difference from a performance standpoint; yet they feel uncomfortable wearing this tint for example, due to due to the tint brightening the room, potentially affecting the player's confidence in what is perceived. This uncertainty increases the amount of anxiety experienced, causing the player to hesitate as a result of not detecting the ball well enough, ultimately affecting perceptual-motor performance and the likelihood of a catch being successfully executed (Nieuwenhuys & Oudejans, 2012).

CONCLUSION

The findings from this study suggest that there is no superior tint for catching performance. However, it is interesting to note that although the clear lens was the most favourable across most measures, of the tinted lenses, the G30 lens had the best result with the least variance over most measures (quality of catch, visual comfort, target visibility, preferred lens). Further, the red tint was the least favourable across most measures and had the greatest variance (number of catches, quality of catch, visual comfort, target visibility and preferred lens). As the clear lens has no tint and was the control condition, the tinted lens that was most preferred was the G30 lens.

CHAPTER VI:
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

Cricket is a sport typically played outdoors during the day with exposure to high luminance values that affect vision. For this reason, sunglasses are often worn by players out in the field, firstly for ocular health but more recently, for their marketed, purported performance-enhancing benefits with respect to vision. These benefits surround the ability to improve visual parameters such as contrast sensitivity, depth perception and visual acuity. Although there is literature that investigates the impact certain tints have on such parameters, there is comparatively little literature that investigates if these translate to performance-enhancing benefits such as improved number of catches. This study aimed to investigate if the catching performance of cricketers is affected by three different tints of sunglasses. A secondary purpose of the study was to investigate the players' subjective experience of catching when wearing the three different tints of sunglasses.

SUMMARY OF PROCEDURES

The current investigation assessed visual performance, catching performance as well as subjective measures to obtain insight into factors that improve or degrade task performance. Participants were required to attend five different sessions. The first being a pre-screening vision test investigating visual acuity, contrast sensitivity, stereopsis, colour vision and overall ocular health. If the participant passed this initial test, they would be required to wear the four different lenses to investigate if the visual parameters were affected by these tints. The other four sessions were the experimental conditions where catching performance was tested with the participant wearing a different tint of sunglass at each session. Each experimental session required participants to catch 18 balls that were projected to them from a bowling machine at a speed of between 74-78km/hr due to the variable nature of the bowling machine. The number of catches, as well as the quality of the catch taken, was recorded. Players were then required to complete a questionnaire at the last session to gain insight into their subjective experience of the protocol.

SUMMARY OF RESULTS

To determine the impact of different colour tints on catching performance the investigation first examined if there were any differences experienced at the ocular hardware that influences the reception of the visual information detected by the eye. Statistical differences were found for some of the visual parameters that were tested with others resulting in non-significant outcomes. Contrast sensitivity was found to be improved with the use of the red lens, with the G30 and blue lens negatively impacting this ocular measure. Stereopsis was found to be degraded with all the tints, with the G30 lens resulting in the worst depth perception. There was a non-significant difference in performance on the stereopsis test between the clear and the polarised lenses. This demonstrates that the clear tint would hinder performance the least in comparison to the polarised lenses alone. Of the three coloured lenses (red, blue & G30), the red tint performed the best on stereopsis after the clear and polarised lenses alone. Although the result was the best of the coloured lenses it still negatively affected stereopsis in a statistically significant manner.

The research then investigated whether the different tints impacted the number and quality of catches taken in the protocol. These performance measures resulted in no significant differences between all lenses for both the total number of catches as well as the quality of catch. There was also no statistical difference found for the number of catches as well as the quality of catch over time irrespective of the tint used for the four experimental sessions.

Questionnaires were administered to investigate participants subjective response to the different tints used in the protocol. There were some interesting findings for these subjective measures, with statistical differences found for visual comfort, target visibility and personal preference. The clear lens was rated as the best for visual comfort, target visibility as well as personal preference but with regard to the tinted lenses, the G30 was the lens that was rated as the best with the red lens being rated the worst in all three categories. The pain data collected determined that majority of participants felt pain in the palm (Area D) however the thenar eminence (Area E) was given the highest pain rating, particularly on the right hand.

PRACTICAL IMPLICATIONS

The colour of tint has been shown in this study to impact certain ocular parameters such as contrast sensitivity (a hardware ability) which may affect skills such as hand-eye coordination (a software skill) which impacts successful execution of a catch. This study therefore highlights the complex interaction that the addition of a lens may have on performance from both a motor performance standpoint as well as a central processing standpoint. Although the clear tint was the control condition, and participants for this study were required to be non-habitual sunglass wearers, the clear tint was consistently ranked similarly to the G30 lens. This similarity indicates that perhaps lighter density tints should be considered for prescription as this would be similar to having no tint at all and therefore have less impact on performance.

The psychological impact of the use of different colour tints cannot be ignored in the interpretation of these results and the results obtained from the personal preference section of the results warrants further investigation. Future research may investigate the players scanning strategies of the environment and see if this differs between different colours of tint. Scanning behaviour is linked to the model of anxiety and perceptual-motor performance which implies that search strategies are altered in unfamiliar environments which alters attentional control, which in turn, may affect goal-directed action (Nieuwenhuys & Oudejans, 2012, 2017; Oudejans & Nieuwenhuys, 2009). Affordances of action as well as embodied perception and cognition are all important considerations in perceptual-motor performance and cannot be disregarded in the interpretation of results of this kind (Cappuccio, 2015; Nieuwenhuys & Oudejans, 2012; Proffitt, 2006; Van Der Kamp, Savelsbergh, & Rosengren, 2001). Perception and the action thus determined appropriate is not solely reliant on optical information but is also influenced by non-visual factors (Proffitt, 2006).

LIMITATIONS AND FUTURE RESEARCH

The area of fielding in cricket and in particular the use of sunglasses is under-researched. This study has primarily set the foundation for further research in this area. This study was performed in very controlled conditions that were not representative of a normal cricket fielding environment in order to isolate any possible effects of tinted lenses on the performance of cricketers catching a ball. In retrospect, there were a number of areas in which the data that was collected could be improved upon for future studies. Some were necessary to isolate and eliminate further causes for dropping a catch, for example, the ball was delivered by a bowling machine which takes out the element of looking for cues from the batsman as to the direction a ball may be coming. The use of the bowling machine also removed the need for players to be vigilant and take cues from both batsman and bowler to predict where the ball might come as they knew when the ball would be delivered. There was still some element of the players having to perceive or predict how the ball should be caught due to its varying trajectory as it was delivered from the bowling machine. With the ball being delivered by the bowling machine it minimised head movement that would have occurred in a representative fielding environment, again isolating, as much as possible, the effect of tint on the catching performance.

Testing was administered in an indoor facility, which also eliminates the effect of crowd or scoreboard pressure as well as in dimmer lighting to outdoors, which is not representative of an outdoor match situation. The light did fluctuate in the facility due to the presence of windows, but the changes would have been minimal in comparison to outdoors with clouds passing over the sun. As this study was setting the baseline for future studies, it was necessary to be in such a controlled environment, to isolate the effect of the tint, but these limitations may be improved upon, and results may be more applicable when further research is performed under normal game conditions with variable light.

As this study decided to investigate the colour of tint, non-polarised lenses were used to take this out as a possible confounding factor in the results. The polarisation of sunglasses may be the one feature that perhaps distinguishes the effectiveness of lenses and results in alleged enhancement of contrast and visual acuity. The polarisation of lenses may result in these changes due to the reduction of glare off surfaces as a result of a reduction in the amount of light scatter, thus making objects appear clearer. When further research is conducted in more applicable surroundings, this may be something to consider.

In terms of measuring ocular parameters such as contrast sensitivity and visual acuity, it is key that there be more research into developing tests that measure these aspects in a more relevant, dynamic and sports-specific way. The main limitation of testing contrast sensitivity in the way that it was tested was that the test is only designed to be performed indoors with a white background against black/grey lettering which is not reflective of a sporting environment. In real match situations, players wear different coloured uniform with the use of coloured equipment such as a red or white ball in cricket as well as illumination levels fluctuating throughout the match. The test used in the protocol therefore was more applicable to investigate the effect of the lenses in white-ball cricket rather than red-ball cricket which was utilised in this protocol. To the author's knowledge as well as the optometrists assisting, there are no tests that fulfilled the criteria of testing ocular parameters such as contrast sensitivity on different coloured backgrounds. The use of a red ball was considered more applicable for our protocol as red-ball cricket is the format that is typically played by players recruited for the study. Utilising the white ball would have introduced a variable that players would have been unaccustomed to. The limitation of this test may explain why objectively the red lens should have resulted in players being able to detect the ball earlier but rather translated to a result where players found it more difficult to detect due to the use of the red ball rather than the white. It would be interesting in further research to investigate if this result translates to a better ability to detect the white ball. It may also be interesting to investigate if the pupil size correlates with an improvement in said contrast sensitivity as it may result in brightness increment which may be correlated with improved or impaired catching performance (De Fez et al., 2002).

There were also limitations concerning the measurement of the ocular parameter of stereopsis. Players had to look through two sets of lenses to get a result on this test. According to the author's knowledge and in consultation with the optometrists that were assisting with the pre-screening process, the only test that would measure depth perception is the Howard-Dolman device, which was not available. Thus, the Stereofly Test was the only and best option available to test this parameter. It would also be preferable to test depth perception dynamically, however there currently is no commercially available test to do this and there is a call to develop a test that investigates this parameter better (Erickson, 2007).

When it comes to quantifying the quality of catch, the use of the Wickstrom catching scale is a very subjective method of assessing the catch during the protocol. If there were more resources available for this project, reaction time would have been the more preferential method to investigate differences between the lenses. Data on players' reaction time would give a more objective measure of how quickly participants detect the ball with different colour tints. This would have been an important measure to have particularly as players reported 'picking up the ball later', this measure would have objectively answered if this was the case. Other suggestions to objectively investigate differences between different colour tints, would be to measure pupil dilation (Shaik et al., 2013). It is hypothesised that darker tints such as the blue tint cause greater pupil dilation, increasing the amount of aberration in the eye which degrades image clarity (Shaik et al., 2013). The results of this study clearly show that individuals respond differently to the same tints and lighting conditions. One explanation for this response may be due to participants pupils reacting differently to the light as although exposed to the same amount of light, different amounts of light will reach the retina depending on the size of the individual's pupil (Marsh et al., 1953).

The questionnaire used to measure areas of pain and intensity in the hands as well as preferences was developed by the author. To the author's knowledge, there is no validated questionnaire that investigates this. Future research is needed to develop and validate such a questionnaire. Future studies should consider collecting this information after each condition rather than in the last condition participants attended.

The free writing comments section could be structured better in the future, to gather more specific and detailed information regarding why players believed certain areas of the hand hurt and their reasons for selecting particular colour tints as preferential. In line with this, there is a call for studies to develop questionnaires that investigate players' motives as to which colour tints are more desirable as well as if there has been a shift among players to select their sunglass choice based on professional optometric advice (Moore & Ferreira, 2005).

CONCLUSION

Objectively this study found that there was no difference between the different colours of tint in either total number of catches or quality of the catches. A similar result was found when the number of catches was tallied, irrespective of colour of tint worn by all participants in each session. Although this experiment set out to investigate objective differences, the more interesting and telling data emerged from the qualitative questionnaire investigating the players' experience of the protocol and preferences for different colours. From the results, it was clear that the G30 lens was the preferred tint in comparison to the two colours at either end of the spectrum. Subjectively participants consistently ranked the G30 lens as the preferred colour of tinted lens from both a target visibility and visual comfort stance.

This study therefore demonstrated that although objectively colour of tint does not seem to impede or reduce the number of catches taken in an indoor and controlled setting, there is a preference among the players as to which lens they preferred to wear. This preference should be taken into account when prescribing lenses for athletes as from a psychological perspective; this may have an impact on players confidence. Viewing the environment through coloured lenses alters the luminous contrast polarity of the ball and the background affecting the familiarity of a given sporting context which ultimately affects implicit and procedural knowledge (Adie & Arnold, 2017a, 2017b; Cappuccio, 2015; Fajen, 2007; Fajen et al., 2008; Proffitt, 2006)

Sunglasses are marketed by brands as tools that may enhance performance in sport through the improvement of reception of visual information. This purported improvement is marketed to the consumer as enabling the wearer to see more detail which would not have been seen with the naked eye alone. The consumer is then left with the assumption that this will impact and improve decision making and performance due to this information now being available to the athlete. This assumption is then further impacted when brands endorse top athletes to promote their brands, which subtly suggests that using this brand improves the way they perform in their sport (Erdogan, 2008). The lack of literature that objectively supports these claims for improvement in concrete visual parameters such as contrast sensitivity or visual acuity required some investigation. Ultimately as this is the first study to investigate this, there is still room for improvement to yield concrete data that helps in the prescription and validity of particular colours of sunglasses to impact performance in sport.

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APPENDIX A: GENERAL INFORMATION

ETHICAL APPROVAL

INFORMATION TO PLAYERS

PLAYER CONSENT FORM

EQUIPMENT CHECKLIST

WARM UP

ETHICAL APPROVAL

HUMAN KINETICS AND ERGONOMICS

RHODES UNIVERSITY
Where leaders learn

APPLICATION FOR ETHICAL APPROVAL

Student Name: Stacy Nelleman

Type of Research: MSc

Project Title: A laboratory simulated investigation into the impact of sunglass tint on the catching performance of fielders during cricket.

Supervisor: Dr CJ Christie and Mr JP Davy

Application received: 18 May 2015

Code: HKE-2015-6

Dear Stacy

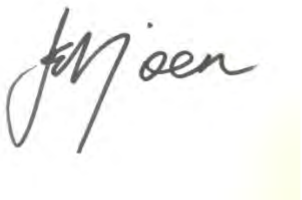
The reviewers have considered the corrections you re-submitted and have indicated that you may commence with your study.

Best wishes for the continuation of your project.

Please note that any unintended changes to the documents to submitted should be indicated as such to the Chair of the committee in writing via email for inclusion to your documentation.

Approved ✓	Approved, on condition that suggestions have been effected	Request for rework and resubmission	Rejected

Signed



Dr JE Viljoen

Chair: Human Kinetics and Ergonomics Ethics Committee

INFORMATION TO PLAYERS

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

HUMAN KINETICS & ERGONOMICS

Tel: (046) 603 8471 • Fax: (046) 603 8934 • e-mail:
c.christie@ru.ac.za/j.mcdougall@ru.ac.za

Dear ____,

Thank you for your interest in participating in my Master's degree research project entitled:

A laboratory simulated investigation into the impact of sunglass tint on the catching performance of fielders during cricket

This letter will explain the aims of this project, detailing the potential risks as well as the benefits that will be associated with partaking in this research. The information contained in this letter will enable you to make an informed decision as to you wanting to continue with the involvement in this research project. It is of utmost importance that you read the contents of this document carefully before signing the accompanying consent form. If you have any concerns or queries regarding the study, please feel free to raise these and I will attempt to address these to the best of my ability.

AIM OF THE STUDY

The aim of the research is to examine what areas of visual performance are affected when the player wears different colour tints and more specifically how these affect catching performance. The areas of visual performance that will be investigated in this research will be how clearly one can identify objects (visual acuity), the ability to judge depth (depth perception) as well as the ability to discriminate an object such as the cricket ball from the surrounding environment (contrast sensitivity).

PROCEDURES

You will be required to attend five sessions (one introductory and ocular pre-screening session at an optometrist and four experimental sessions at the High Performance Centre at Kingswood College, Makhanda, South Africa).

The first session serves as a briefing session where an explanation of the procedures, the aims and purpose of the study will be detailed in the Human Kinetics and Ergonomics Department. If you are comfortable with the procedures that will be followed and are happy to participate in the study, you will be asked to sign a consent form, granting your permission to participate in the study. You will also be assigned a code that will ensure that any data collected during the study will remain anonymous. Hereafter I will drive you to Dr Davies Optometrists where a general eye examination will be performed (for free) in order to establish the state of your vision. Here a registered optician will perform the eye examination according to their code of practice. During the eye examination, you will be exposed to a number of ocular tests, such as the Ishihara colour vision deficiency test to test for forms of colour blindness and the Stereofly test to investigate your ability to judge depth. You will then have your eyes examined by a non-invasive machine, known as a slit lamp to investigate your ocular heath. The optician will then investigate if there are any problems with focusing images on your retina with a machine known as a phoropter. This session should take no longer than an hour. This routine eye assessment is necessary in order to ensure that there are no underlying or undetected eye problems that could affect the results of the study. This assessment will either allow you to continue with the study or not. If you fulfil all the necessary criteria, you will be required to complete a further set of ocular tests with four different coloured tints that will be tested in the experimental sessions. If you do not fulfil all the criteria you will be informed as to why you will be unable to continue with the study and will not be required to attend any further sessions.

If you do qualify to continue with the study, you will then be required to attend a further four experimental sessions that will be held at the Kingswood High Performance Centre. Each of these four sessions will be testing a different colour tinted lens on a separate day. You will be required to attend these sessions dressed in comfortable, loose fitting clothing that will not restrict movement as well as comfortable shoes with no slip soles. During these four sessions you will be required to complete a catching protocol with a different tinted lens worn at each session. The different colours of tint that will be tested will be a clear, red, grey and blue colour. Prior to data collection, you will be exposed to a habituation session, where by you will be familiarized with the catching protocol used during the experimentation phase. Before habituation begins you will be required to perform a five minute warm up consisting of dynamic stretches such as lunges, side skips, open and close the gate, as well as arm circles, scissor stretch and triceps stretch in order to prevent injury. During habituation you will be required to wear the particular tint of sunglass that is being tested as well as wear a pair of fielding hand protectors (catching gloves) both during habituation and when undertaking the experimental procedure. You will be required to stand approximately 17m from the bowling machine and receive 12 catches in order to allow you to become accustomed with the dynamic properties of bowling machine balls. The balls will be projected towards you using a bowling machine and will be projected at a speed of $95km.h^{-1}$. Hereafter data collection will begin. During data collection, performance measures will be recorded on a video camera as 30 balls are delivered to you. The information that is recorded on the video camera will be used solely for analysis purposes. The performance measures that will be recorded will be the absolute number of catches completed as well as the quality of catching performance. You will be required to catch each of the 30 deliveries to the best of your ability while wearing the particular tinted lens. This session should take no more than an hour. This procedure is followed for all four experimental conditions and in the last of the four conditions you will be required to answer a short questionnaire investigating your subjective experience of catching with the different tinted lenses. Before answering the questionnaire, you will be required to catch 6 balls with each of the previously tested lenses in order to refresh your memory as to the experience had with these lenses for reference. This will allow you to make an accurate comparison of the lenses, rather than relying on memory.

POTENTIAL RISKS AND BENEFITS

It is unlikely that you will experience any injuries during this study as the procedures are not considered harmful in any way. The procedures have been designed to expose you to minimal risk as you will be executing a task that is carried out in the field often and thus is a skill that due to experience is expected to be well honed. The angle of projection of the bowling machine will ensure that balls will be delivered within the range of waist to mid chest height in order to prevent harm to the face if the ball is not caught. If the ball is not caught properly however, there is potential for bruising to occur to the body in this area. There is also still potential for the face to be injured if the ball is not caught properly and the ball deflects off the hand towards the face. There is also the potential risk of the fingers being broken or the webbing of the fingers being split if the ball is not caught correctly. Although unlikely to occur, there is also the possibility of permanent eye damage occurring if the lens of the sunglass shatters into the eye due to the speed that the ball is being projected towards you. If any of the abovementioned risks occur, doctors will be contacted immediately to ensure that the least amount of permanent damage will occur.

Potential benefits derived from this study include obtaining knowledge of the state of your vision. Through participation in the study one is able to compare different tints of sunglasses and judge for oneself, personal preference of tint. This information may increase your understanding of the effect that different tints incur on catching performance and therefore how selecting the correct tint can benefit performance. Participation in this study may also improve your catching performance, as it will serve as pre-season training.

ETHICAL CONSIDERATIONS

Prior to any data collection being undertaken, the Human Kinetics & Ergonomics Department Ethics Committee will have granted ethical clearance for the performance of this research. Photographs may be taken while experimentation occurs but you have the right to refuse photographs being taken or to be used at any stage. If these photographs are included in the final thesis with your permission, your anonymity will be protected through the blocking of the eyes or the face in the photograph, in an attempt to minimize identifying features. It is important to know that participation in this study is voluntary and you may withdraw from the study at any point without any adverse consequences to you.

PLEASE TAKE NOTE OF THE FOLLOWING REQUIREMENTS BEFORE YOUR TESTING SESSION:

- At least 7-8 hours sleep the night before testing
- No alcohol 24 hours prior to testing
- No coffee/caffeinated drinks at least an hour prior to testing

If you are concerned about anything regarding the testing procedure that will be followed, are unsure about the abovementioned pre-requisites or regarding the feedback of results from this project, please do not hesitate to ask or contact myself as the principle researcher. My contact details are thus provided at the end of this letter. If you were unable to comply with or adhere to these requirements before testing commences, please inform me as the principal researcher. We will either attempt to reschedule the experimentation time or you will be excluded from the study due to non-compliance. If you have any queries or concerns that you feel you would be unable to speak to me about, you may also contact my supervisor, whose details are displayed below.

Thank you for your time and co-operation

Yours Sincerely,

Researcher:	Supervisor:
Stacy Nellemann	Candice Christie
Human Kinetics & Ergonomics	Head of Department
072 108 5643	083 561 6936
g10n0941@campus.ru.ac.za	c.christie@ru.ac.za

PLAYER CONSENT FORM

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PARTICIPANT CONSENT FORM

I, ________________________________, give my consent to participate in the study entitled:

A laboratory simulated investigation into the impact of sunglass tint on the catching performance of fielders during cricket

I agree that I have been fully informed, both verbally and in writing, of the procedures involved in this research project. I have read the associated information sheet and fully understand the testing procedures that will take place during this study. I understand that the aim of the study is to investigate the effect of different tints of sunglasses on catching performance and that each of the conditions will be different. I have also been alerted to the potential risks that are associated with the protocol.

I realise that whilst my anonymity will be protected at all times, my results may be published or used for scientific and statistical purposes. I understand the conditions with which I am expected to comply for the duration of the protocol, and any queries I may have with regard to the procedures of the research project have been answered to my satisfaction.

In the unlikely event of an injury occurring during the course of the study as a result of either the experimental protocol or equipment used, the Human Kinetics and Ergonomics Department will be liable for any costs incurred and will reimburse the participant to the full amount i.e. doctors consultation, etc. The department will, however, waive any legal recourse against the researcher or Rhodes University in the event that the injury is proved to be self-inflicted or due to your own negligence and not adhering to the issued instructions. This waiver shall be binding upon my heirs and representatives. I am aware that it is necessary and important to promptly report any experiences of discomfort, distress, or abnormality that may occur during the course of the testing proceedings. I am cognisant of the participation in this research being voluntary and of my right to withdraw my participation from the study at any point during the research process without any negative consequences.

I have read and understood the above information, as well as the information provided in the letter of information to the participant that accompanies this form. Any concerns or queries that have occurred to me have been answered to my satisfaction.

Signed at the Department of Human Kinetics and Ergonomics, Rhodes University on the _______________________ 2015

Participant name: __________________ Signature:_______________________

Witness name: __________________ Signature:_______________________

Witness name: __________________ Signature:_______________________

Researcher name: _______________ Signature:_______________________

EQUIPMENT CHECKLIST

- Bowling machine
- Stadiometer
- Toledo Electronic scale
- Tennis ball
- Light meter
- Video camera
- Bowling machine balls
- Data collection sheets
- Anthropometer
- Tripod
- Radar gun
- 50m tape measure

WARM UP

5 MINUTE DYNAMIC STRETCHES

- 2x 10m sprint
- 2x 10m side to side skips
- 10m open the gate dynamic stretching
- 10m close the gate dynamic stretching
- 20 seconds arm circles
- 20 reps scissor stretch

  Stand with feet shoulder width apart

  Hold arms straight out to the sides and parallel to the ground

  Swing arms in front of and behind the body in a wide crisscross or scissoring motion

  With every motion alternate the top arm
- Pec Stretch
- 20 seconds triceps stretch (10 seconds each arm)
- Squeeze tennis ball for 10 seconds
- 20 seconds praying position stretch

  While standing, place palms together in a praying position. Have your elbows touch each other. Your hands should be in front of your face. Your arms should be touching each other from the tips of your fingers to your elbows.

  With your palms pressed together, slowly spread your elbows apart. Do this while lowering your hands to waist height. Stop when your hands are in front of your belly button or you feel the stretch.
- Extended arm stretch

  Extend one arm in front of you at shoulder height.

  Keep your palm down, facing the floor.

  Release your wrist so that your fingers point downward.

  With your free hand, gently grasp your fingers and pull them back toward your body.

  Hold for 10 to 30 seconds.

To stretch in the opposite direction:

Extend your arm with your palm facing toward the ceiling. With your free hand, gently press your fingers down toward the floor. Gently pull your fingers back toward your body. Hold for 10 to 30 seconds.

APPENDIX B: DATA COLLECTION

DATA COLLECTION SHEET

RANDOMISATION OF TINTED LENSES

POST-TEST QUESTIONNAIRE

VISUAL ACUITY RESULTS

STATISTICAL TABLES

DATA COLLECTION SHEET

Experimental Session: Eye Examination

Participant Code: _________________________

Stature: __________ Mass: _______________ Age: _________

Position: _______________________________

Eye Colour: ___________________________

Experimental Session: Clear glasses

Catch	Classification	Caught/Not (✓/✗)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		

Experimental Session: Blue sunglasses

Catch	Classification	Caught/Not (✓/✗)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		

Experimental Session: G30 Sunglasses

Catch	Classification	Caught/Not (✓/✗)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		

Experimental Session: Red Sunglasses

Catch	Classification	Caught/Not (✓/✗)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		

RANDOMISATION OF TINTED LENSES

C	B	G	R
C	B	R	G
C	G	B	R
C	G	R	B
C	R	B	G
C	R	G	B
B	C	G	R
B	C	R	G
B	G	C	R
B	G	R	C
B	R	C	G
B	R	G	C
G	C	B	R
G	C	R	B
G	B	C	R
G	B	R	C
G	R	C	B
G	R	B	C
R	C	B	G
R	C	G	B
R	B	C	G
R	B	G	C
R	G	C	B
R	G	B	C

*Where C = clear tint, B = blue tint, G = G30 tint & R = red tint

POST-TEST QUESTIONNAIRE

POST-TEST QUESTIONNAIRE

Participant code: ________ *Date:*___/___/___

Please rate the following when comparing the Clear, Blue, G30 and Red tinted lenses:

Overall visual comfort is superior (Superior = relaxed, no glare or squinting)	Strongly Agree				Strongly Disagree	
Clear	1	2	3	4	5	6
Blue	1	2	3	4	5	6
G30	1	2	3	4	5	6
Red	1	2	3	4	5	6

Overall visual performance is superior

(Superior = clear, efficient target visibility)

Clear	1	2	3	4	5	6
Blue	1	2	3	4	5	6
G30	1	2	3	4	5	6
Red	1	2	3	4	5	6

Please rank your preference of tint of lens from 1 to 4

*base your choices in terms of which tint you felt helped performance the best

(1 = first preference, 4 = last preference)

Tint	Clear	Red	G30	Blue
Ranking				

Additional Comments

Please tick the appropriate box for hand dominance and rate your pain perception for each hand on the scale to the right (1 =very slight discomfort, 10= Very uncomfortable).

Hand dominance: Right ☐

1	2	3	4	5	6	7	8	9	10

Left ☐

1	2	3	4	5	6	7	8	9	10

Have you had any injury or surgery to your hands? Yes/No

If yes please elaborate as to what the nature of the injury was, when it was sustained and what areas of your had it has affected.

____

____

____

____

____

____

____

____

____

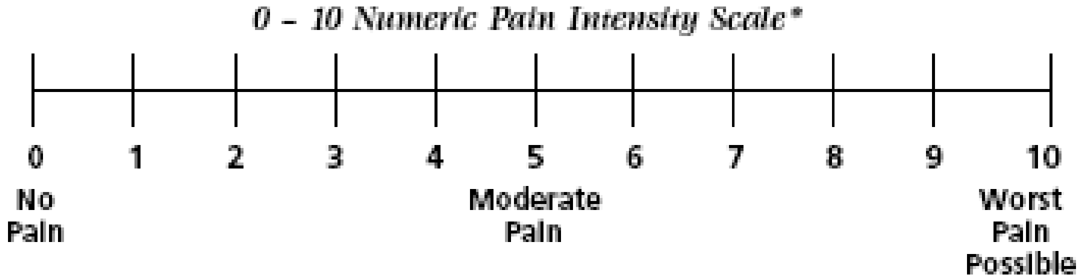
____

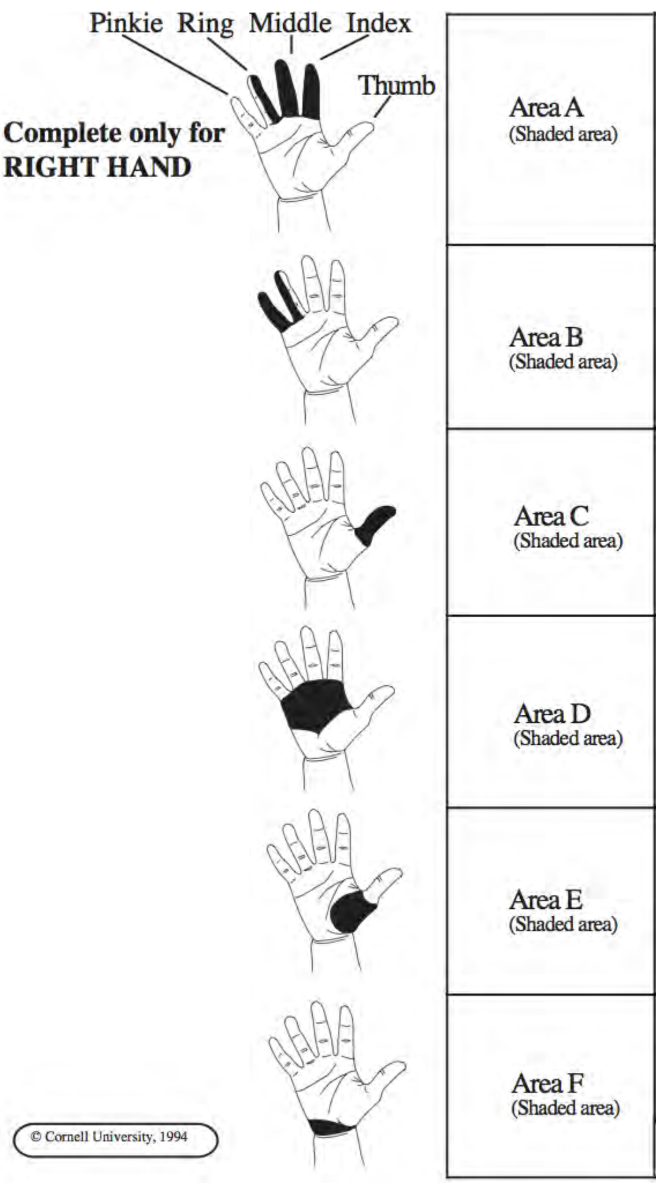
____

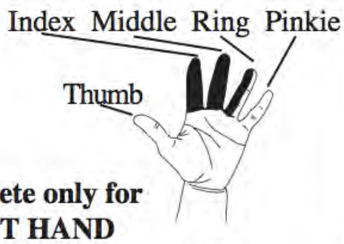
____

The shaded areas in the diagrams below show the position of the body parts referred to in the questionnaire.

Please indicate 2 areas on each hand where pain was felt the most when engaging in the catching sessions. Please rate the intensity of pain felt for each of the 2 areas with reference to the scale below







Complete only for LEFT HAND

	Area A (Shaded area)	
	Area B (Shaded area)	
	Area C (Shaded area)	
	Area D (Shaded area)	
	Area E (Shaded area)	
	Area F (Shaded area)	

VISUAL ACUITY RESULTS

Participant code	Clear	Blue	Grey	Red
P4	6/6	6/6	6/6	6/6
P5	6/6	6/6	6/6	6/6
P7	6/6	6/6	6/6	6/6
P8	6/6	6/6	6/6	6/6
P10	6/6	6/6	6/6	6/6
P12	6/6	6/6	6/6	6/6
P13	6/6	6/6	6/6	6/6
P14	6/6	6/6	6/6	6/6
P15	6/6	6/6	6/6	6/6
P16	6/6	6/6	6/6	6/6
P18	6/6	6/6	6/6	6/6
P20	6/6	6/6	6/6	6/6
P21	6/6	6/6	6/6	6/6
P22	6/6	6/6	6/6	6/6
P23	6/6	6/6	6/6	6/6
P24	6/6	6/6	6/6	6/6
P25	6/6	6/6	6/6	6/6
P26	6/6	6/6	6/6	6/6
P27	6/6	6/6	6/6	6/6
P28	6/6	6/6	6/6	6/6
P30	6/6	6/6	6/6	6/6

STATISTICAL TABLES

Ocular Measures:

CONTRAST SENSITIVITY

Stats Table

Effect	Repeated Measures Analysis of Variance (Spreadsheet22) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1.235993				
	SS	Degr. of Freedom	MS	F	p
Intercept	671.3281	1	671.3281	439.4432	0.000000
Error	29.0259	19	1.5277		
COND	13.7344	4	3.4336	21.2475	0.000000
Error	12.2816	76	0.1616		

Post Hoc

Cell No.	Tukey HSD test; variable DV_1 (Contrast Sensitivity in Contrast Sensitivity & Steropsis) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .16160, df = 76.000					
	TINT	{1} 2.4450	{2} 3.1050	{3} 2.8650	{4} 2.0250	{5} 2.5150
1	CLEAR		0.000135	0.012410	0.012410	0.981594
2	BLUE	0.000135		0.332717	0.000123	0.000245
3	GREY	0.012410	0.332717		0.000123	0.055547
4	RED	0.012410	0.000123	0.000123		0.002303
5	NONE	0.981594	0.000245	0.055547	0.002303	

STEREOPSIS

Stats Table

Effect	Repeated Measures Analysis of Variance (Stereopsis in Contrast Sensitivity & Steropsis) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 307.6315				
	SS	Degr. of Freedom	MS	F	p
Intercept	4418777	1	4418777	46.69179	0.000001
Error	1892743	20	94637		
TINT	2329423	4	582356	24.03378	0.000000
Error	1938457	80	24231		

Post Hoc

Cell No.	Tukey HSD test; variable DV_1 (Stereopsis in Contrast Sensitivity & Steropsis) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 24231., df = 80.000					
	TINT	{1} 102.86	{2} 219.05	{3} 477.62	{4} 180.48	{5} 45.714
1	CLEAR		0.120964	0.000121	0.491952	0.757384
2	BLUE	0.120964		0.000126	0.929043	0.004843
3	GREY	0.000121	0.000126		0.000121	0.000121
4	RED	0.491952	0.929043	0.000121		0.048305
5	NONE	0.757384	0.004843	0.000121	0.048305	

Performance Measures:

QUALITY OF CATCH

Stats Table

Effect	Repeated Measures Analysis of Variance (Spreadsheet7) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: .5059850				
	SS	Degr. of Freedom	MS	F	p
Intercept	1999.776	1	1999.776	7810.987	0.000000
Error	5.376	21	0.256		
COND	0.039	3	0.013	0.591	0.623336
Error	1.380	63	0.022		

ABSOLUTE NUMBER OF CATCHES

Stats Table

Effect	Repeated Measures Analysis of Variance (Spreadsheet9) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 3.719799				
	SS	Degr. of Freedom	MS	F	p
Intercept	21922.01	1	21922.01	1584.315	0.000000
Error	276.74	20	13.84		
TINT	6.51	3	2.17	0.946	0.424409
Error	137.74	60	2.30		

Subjective Measures:

VISUAL COMFORT

Stats Table

Effect	Repeated Measures Analysis of Variance (Visual Comfort in Quality of Catch) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1.460593				
	SS	Degr. of Freedom	MS	F	p
Intercept	597.3333	1	597.3333	280.0000	0.000000
Error	42.6667	20	2.1333		
TINT	41.1429	3	13.7143	8.3237	0.000103
Error	98.8571	60	1.6476		

Post Hoc

Cell No.	Tukey HSD test; variable DV_1 (Visual Comfort in Quality of Catch) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 1.6476, df = 60.000				
	TINT	{1} 2.0952	{2} 2.6667	{3} 2.0952	{4} 3.8095
1	CLEAR		0.478385	1.000000	0.000463
2	BLUE	0.478385		0.478385	0.027193
3	GREY	1.000000	0.478385		0.000463
4	RED	0.000463	0.027193	0.000463	

TARGET VISIBILITY

Stats Table

Effect	Repeated Measures Analysis of Variance (Target Visibility in Quality of Catch) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1.157275				
	SS	Degr. of Freedom	MS	F	p
Intercept	586.7143	1	586.7143	438.0800	0.000000
Error	26.7857	20	1.3393		
TINT	92.7143	3	30.9048	22.6725	0.000000
Error	81.7857	60	1.3631		

Post Hoc

Cell No.	Tukey HSD test; variable DV_1 (Target Visibility in Quality of Catch) Approximate Probabilities for Post Hoc Tests Error: Within MSE = 1.3631, df = 60.000 TINT	{1} 1.3810	{2} 2.8095	{3} 2.1429	{4} 4.2381
1	CLEAR		0.001225	0.160293	0.000156
2	BLUE	0.001225		0.260557	0.001225
3	GREY	0.160293	0.260557		0.000157
4	RED	0.000156	0.001225	0.000157	

PERSONAL PREFERENCE

Stats Table

Effect	Repeated Measures Analysis of Variance (Spreadsheet4) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: .1091089 SS	Degr. of Freedom	MS	F	p
Intercept	530.0119	1	530.0119	44521.00	0.000000
Error	0.2381	20	0.0119		
TINT	54.9881	3	18.3294	20.46	0.000000
Error	53.7619	60	0.8960		

Post Hoc

Cell No.	Tukey HSD test; variable DV_1 (AVERAGE RATING in Average rating) Approximate Probabilities for Post Hoc Tests Error: Within MSE = .89603, df = 60.000 TINT	{1} 1.6190	{2} 2.7619	{3} 1.9524	{4} 3.7143
1	CLEAR		0.001429	0.665877	0.000156
2	BLUE	0.001429		0.036449	0.009771
3	GREY	0.665877	0.036449		0.000156
4	RED	0.000156	0.009771	0.000156	

APPENDIX C: OVERVIEW OF HOW VISION OCCURS

The Visual Pathway

Vision is a complex phenomenon particularly important in the aid of human performance through feedback mechanisms that guide the execution of tasks by ensuring the perception of the environment is continually updated. The physiology of the process of vision is still poorly understood and requires further research but in order to understand how we perceive and interact with the environment, the visual pathway will be described in detail below. This shall be divided into the following sections:

- Retinal image formation and detection
- Photo-transduction and perception
- Information Processing

The different structures of the eye and their associated function designed to facilitate the process of vision will be described in detail below.

Retinal image formation and detection

Clear image formation is dependent upon 3 processes:

- Refraction of incoming light rays through the lens and the cornea
- Accommodation through the alteration of the shape of the lens
- Dilation or constriction of the pupil.

Firstly, light entering the eye undergoes refraction. It is known that 75% of light refraction occurs at the cornea and 25% occurs at the lens. Depending on the distance of the viewed object the refraction of the light rays must be adjusted to ensure the image is focused on the retina and this is typically achieved through the process of accommodation. All these terms mentioned above will be described in detail along with the associated anatomical structures that make retinal image formation possible.

More than half of the sensory receptors present in the human body are found within the eye with a large area of the cerebral cortex being devoted to the processing of visual information (Tortora & Derrickson, 2009). Vision is possible due to energy emitted from the sun at different wavelengths in the form of electromagnetic waves forming part of the electromagnetic spectrum. The electromagnetic spectrum is a variety of electromagnetic waves that travel at the speed of light with vastly differing wavelengths, frequencies and energies (Shapely, 2012). As can be seen from Figure 1 below, the spectrum ranges from gamma radiation (the shortest wavelength, highest frequency and greatest energy) to radio waves (longest wavelength, lowest frequency and energy) (Shapely, 2012). A small portion of these electromagnetic waves along the electromagnetic spectrum present as visible light and are capable of being detected by the eye.

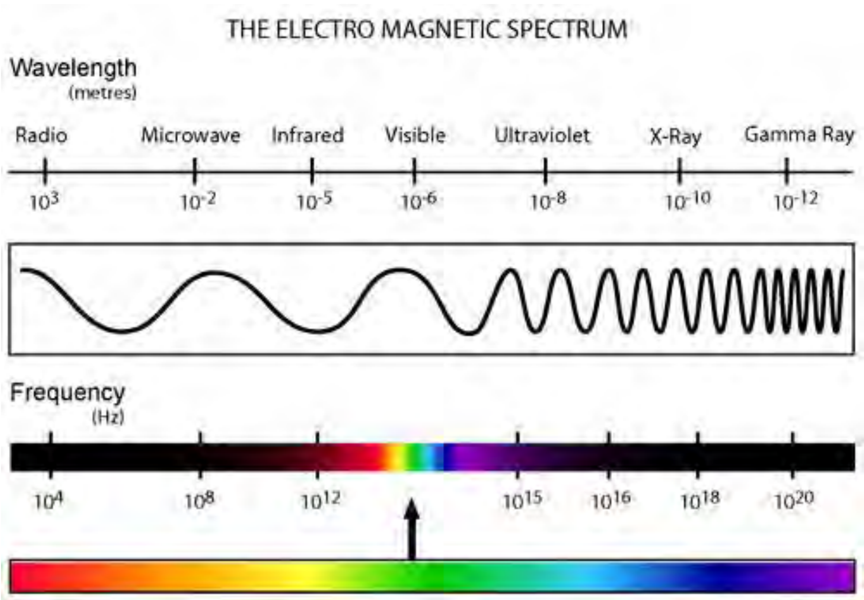


Figure 32: Electromagnetic Spectrum

As can be seen from Figure 1 above the eye detects visible light within a very small range between the wavelengths of 400nm and 700nm.

The eye is designed in such a way that it transforms this detectable visible light to give us the perception of the environment that we exist in. In order to understand the process that facilitates vision, the many layers and internal structures of the eye responsible for detecting visible light, converting these electromagnetic waves into nerve impulses to the brain as well as visual information processing will be explored below.

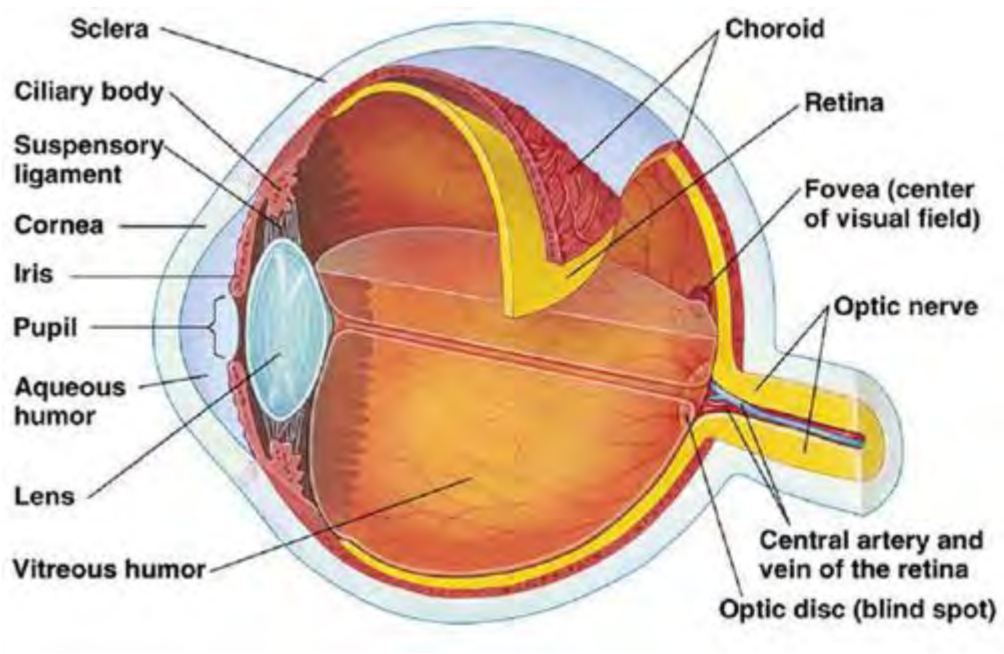


Figure 33: Anatomy of the Eye

The eye is constructed of three layers (moving from outermost layer to the inner most layer):

- The fibrous tunic
- The vascular tunic
- The nervous tunic (retina)

These layers will detail the various structures that contribute towards the process of vision.

The outer most layer of the eye (fibrous tunic) is divided anteriorly and posteriorly into the cornea and the sclera respectively and can be seen in Figure 33 above. The sclera is seen as the "white" of the eye, composed of tough, white, dense connective tissue. It provides structural support and maintains the shape of the eye (Tortora & Derrickson, 2009). The sclera covers the entire eyeball except for the most anterior part of the eye, known as the cornea (Tortora & Derrickson, 2009). Refraction is the process where by incoming light is focused The cornea is an important structure in the process of vision as this structure aids in focusing light, through refraction, onto the retina (Tortora & Derrickson, 2009). Refraction is what occurs when incoming light rays travelling through the air pass into a substance with a different density, such as the cornea. Refraction is the bending of these light rays at the junction of these 2. The convex shape of the cornea is what helps to begin the focusing of the rays of light as they enter the eye (Tortora & Derrickson, 2009).

The middle layer of the eye (vascular tunic) can be divided into three parts, namely, the choroid, ciliary body, lens and iris (Tortora & Derrickson, 2009). The choroid absorbs any stray light in order to prevent reflection and scattering of light within the eyeball to improve visual clarity. The ciliary body has a number of structures that attach to the lens and is active in the process of accommodation. During the process of accommodation the ciliary body either contracts or relaxes depending on the distance of the object being viewed in order to focus the image onto the retina clearly. The lens is a structure that aids in further refraction of the incoming light rays onto the retina to facilitate clear vision. The contraction or relaxation of the ciliary body muscle affects clarity of the image through the alteration of the curvature of the lens. The iris is the coloured part of the eye that serves the purpose of controlling the amount of light that is let into the eye to ensure image clarity. The iris is composed of circular and radial muscles that alter the size of the pupil. Contraction of the circular muscles cause constriction of the pupil thus allowing less light to enter the eye and contraction of the radial muscles cause dilation of the pupil allowing as much light in as possible. The size of the pupil is involuntarily controlled by the autonomic nervous system and is dependent on the amount of light that is necessary in a particular situation. The constriction and dilation of the pupil occurs simultaneously with accommodation and aids in clear image formation by allowing the appropriate amount of light into the eye. Too much or too little light will affect the clarity of the image and therefore must be controlled.

The third and innermost layer (nervous tunic) of the eye is the retina, which is responsible for the next level in the visual pathway (Tortora & Derrickson, 2009). This layer contains photo-receptors known as rods and cones that serve the purpose of detecting the intensity and frequency of the light entering the eye. Rods and cones occur in different quantities and each have a specific function in the interpretation of visible light. There are three different types of cones that when stimulated provide colour vision. The three types of cones responsible for colour vision are known as L (or red) cones, M (or green) cones and S (or blue) cones representing the different wavelengths that each are more sensitive to. The colours the brain perceives are a result of the ratio of excitation of each of the different cone photoreceptors. There are approximately 6 million cones present in each eye. The highest number of cones in the retina is found in an area known as the central fovea. The fovea is a small depression in the centre of the macula lutea that contains only cones (Tortora & Derrickson, 2009). The macula lutea is a small flat spot found in the centre of the posterior part of the retina and due to the number of cones present provides the clearest and most distinct vision. In stark contrast, there are approximately 120 million rods within each eye. Rods are activated at low light levels and are responsible for the detection of the intensity of light. The distribution profile of the different photorecpetors is found to vary across the retina where as can be seen in Figure 34 below, the foveal area contains up to 160 000 cones/mm^2 and moving away from this area the number of cones drops drastically with rods predominating. Together these photoreceptors convert light into electrical impulses to the brain for interpretation.

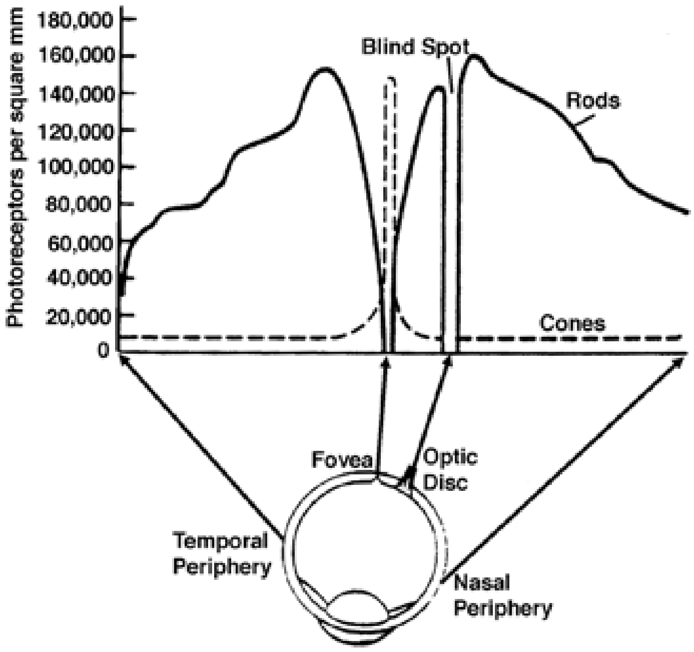


Figure 34: Distribution of Photoreceptors

The retina is also comprised of a pigmented and neural layer (Tortora & Derrickson, 2009). The pigmented layer is also responsible for absorption of stray light and the neural layer is a multi-layered structure that processes visual information thoroughly before impulses are conducted to the optic nerve for transmission to the primary visual cortex in the brain for further interpretation (Tortora & Derrickson, 2009).

<u>Photo-transduction and Perception</u>

Initiation of vision:

Vision is initiated within the biochemical reactions of the visual cycle. These chains of biochemical reactions establish equilibrium between decomposition and regeneration of photo-pigments following light exposure and will be explained below (Ala-Laurila et al., 2006; Khurana, 2007).

The photochemical changes that occur to the photoreceptors in photo-transduction happen as a result of photo-pigments contained within the outer segment of the photoreceptors (Tortora & Derrickson, 2009). Photo-pigments are unstable pigments that alter their chemical processes and result in structural changes when exposed to light (Tortora & Derrickson, 2009). All photo-pigments consist of two parts: a glycoprotein called opsin and a chromophore, the light absorbing part of the pigment, called retinal (Tortora & Derrickson, 2009). Within the eye, humans have four different opsins as a result of having rods and three types of cones.

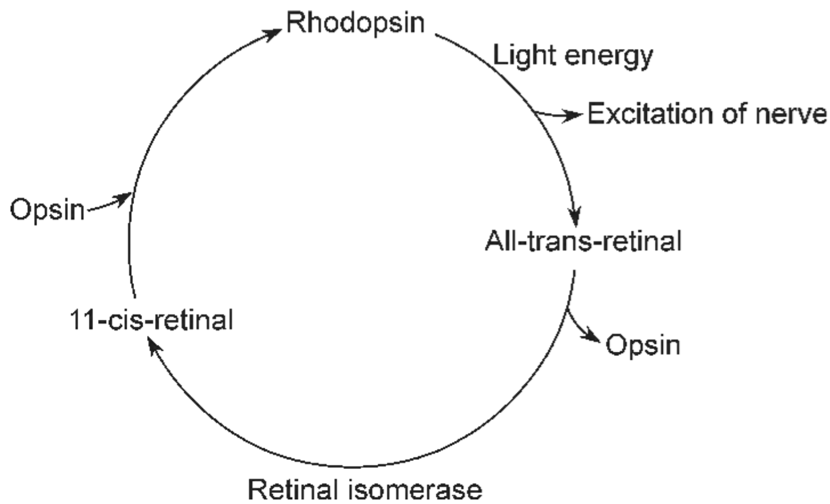


Figure 35: Visual Cycle

Photo-transduction is a result of the conversion of light energy into electrochemical energy that produces action potentials (nerve impulse) within the optic nerve. It is the first step in the visual cycle for the initiation of vision. The process occurs when light entering the eye falls onto the retina and activates the photoreceptors. The first step in photo-transduction occurs when retinal absorbs photons of light and is activated at specific wavelengths, triggering molecular changes to occur as a result of isomerisation (Khurana, 2007). The isomerisation that occurs due to the activation of the photo-pigment causes retinal that exists in the 'cis' form to change shape to become 'trans'-retinal. Due to the altered molecular structure of retinal from the 'cis' to the 'trans' state, retinal dissociates from its binding site on opsin in a process known as bleaching (Khurana, 2007; Tortora & Derrickson, 2009). These chemical changes lead to the production of receptor potentials. This is the only step in vision that is light dependent. In order for vision to occur continuously and for the visual cycle to be complete, the photo-pigments must return to their original state for new receptor potentials to be generated (Tortora & Derrickson, 2009). The regeneration of the bleached photo-pigment is light independent and occurs due to the presence of an enzyme known as retinal isomerase (Tortora & Derrickson, 2009). This enzyme converts retinal back from the 'trans' state to the 'cis' state allowing it to bind to opsin again to become a functional photo-pigment (Khurana, 2007; Tortora & Derrickson, 2009). The cyclical bleaching and regeneration of the photo-pigments induce the production of receptor potentials. These receptor potentials or electrical impulses that are generated are ultimately transmitted to the brain for further processing via the optic nerve and visual pathway.

Processing and Transmission of Visual Impulse

In order to understand how the nerve impulses generated by the photoreceptors are transmitted to the optic nerve it is important to understand the different layers that comprise the neural layer of the retina. As can be seen from Figure 37 below, there are a number of different layers that the nerve impulse must pass through to reach the optic nerve. Each of these layers and their functions in the transmission of the nerve impulse will be detailed below.

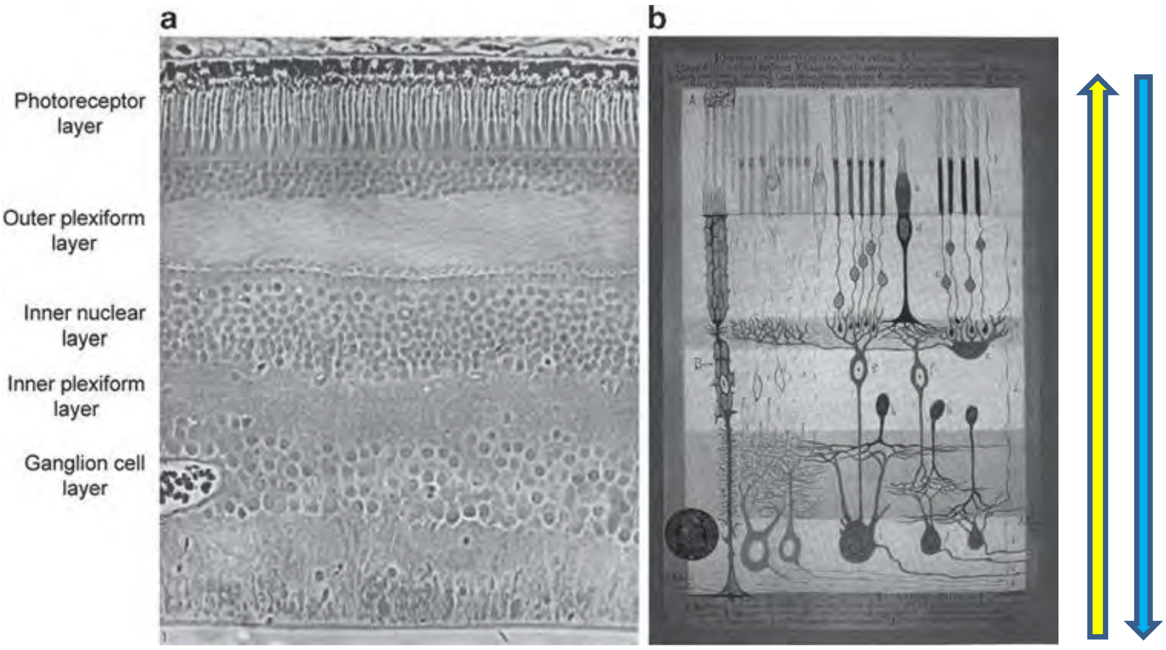


Figure 36: Retinal Layers (a) Light micrograph of a vertical section of the human retina (b) Cross-sectional microscopic drawing. Taken from (Troncoso, Macknik, & Martinez-Conde, 2011)

 Path of light through the retina

 Direction of nerve impulses through the retina

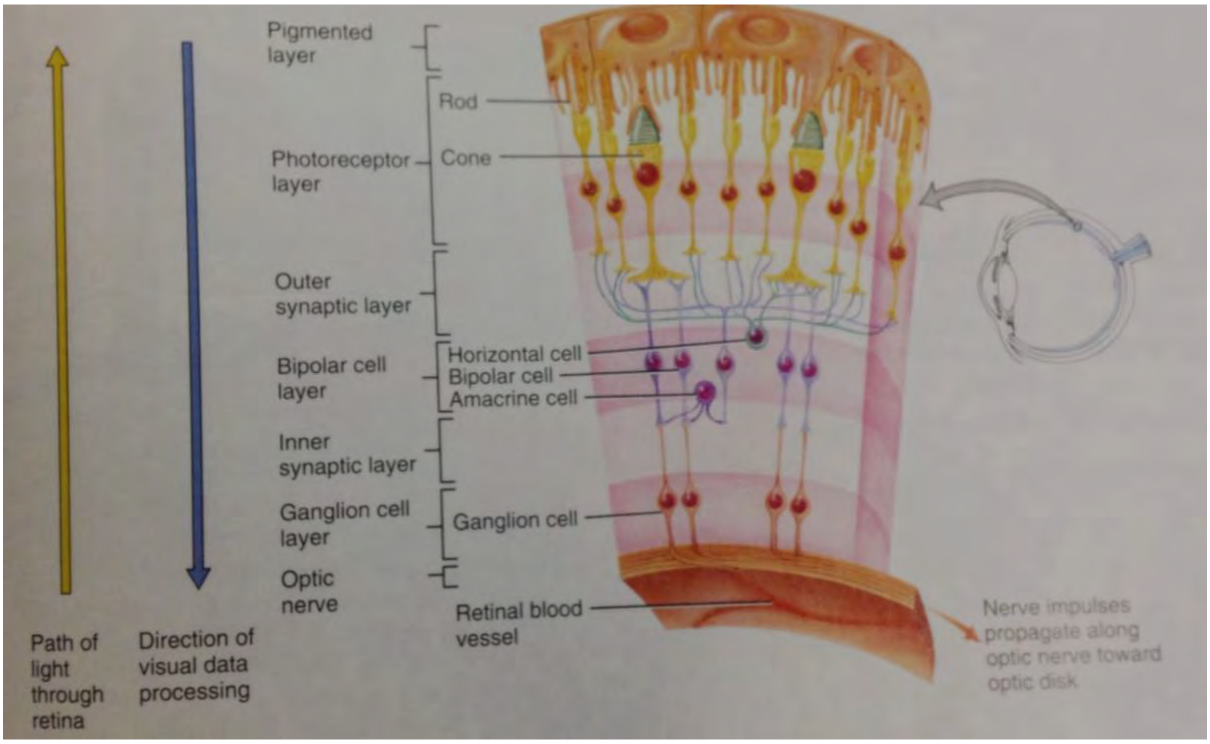


Figure 37: Microscopic structure of the retina

The nuclear layer is comprised of three main layers of neuronal bodies. These three distinct layers are comprised of retinal neurons and are know as the photoreceptor layer, the inner nuclear (bipolar cell) layer and the ganglion cell layer (Tortora & Derrickson, 2009). These main layers are further separated by the outer and inner plexiform (synaptic) layers where synaptic contact is made (Tortora & Derrickson, 2009). The described layers can be seen in the Figure 37 and Figure 36 below. It is important to note that light is transmitted through the ganglion and bipolar cell layers before it reaches the innermost photoreceptor layer and once the receptor potential has been generated it is then transmitted through all the neural layers before reaching the optic nerve (Tortora & Derrickson, 2009).

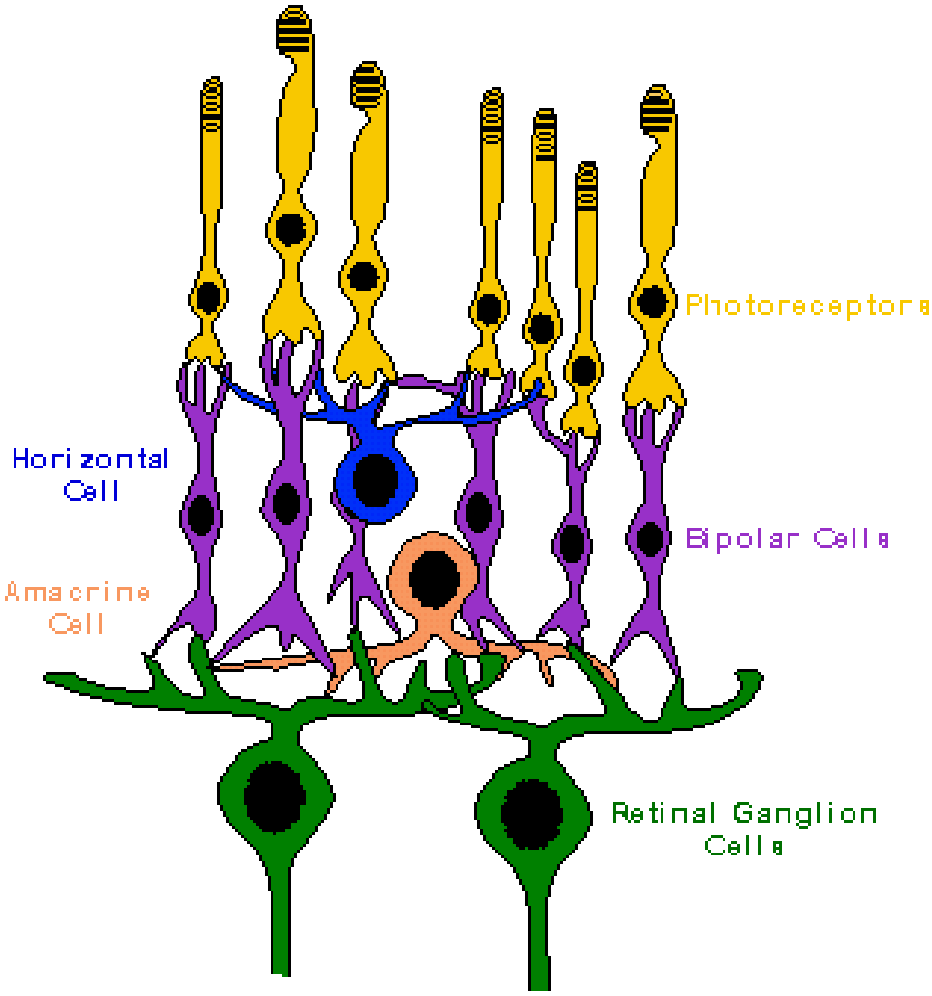


Figure 38: Structure of the inner nuclear layer

The inner nuclear layer is comprised of three classes of neurons: namely horizontal, bipolar and amacrine cells; pictured above in Figure 38 in blue, purple and orange respectively. Photoreceptors generate a receptor potential and then release neurotransmitters via chemical synapses causing graded potentials in horizontal and bipolar cells (Tortora & Derrickson, 2009). The impulse is thus transmitted to horizontal cells (blue cells in Figure 38 above) via the outer plexiform layer to the inner nuclear layer as this is where their cell bodies are located (Troncoso et al., 2011). Horizontal cells enhances contrast seen in the visual scene between areas of the retina that are strongly stimulated and others that are more weakly stimulated and are also useful in assisting in the differentiation of various colours (Tortora & Derrickson, 2009). In terms of bipolar cells (purple cells in Figure 38 above) there are over 13 different types present and all have some dendritic processes in the outer plexiform (synaptic) layer, the soma in the inner nuclear layer and some axon terminals in the inner plexiform (synaptic) layer (Troncoso et al., 2011). It is important to note that the dendritic processes of the bipolar cells only receive input from one kind of photoreceptor, either a cone or a rod, but never from both (Troncoso et al., 2011). Bipolar cells then communicate their response from the photoreceptor to the inner plexiform (synaptic) layer where they interact with the amacrine and ganglion cells (Troncoso et al., 2011). Amacrine cells (orange cell in Figure 38 above) are located and are synaptically active in the inner plexiform layer (Kolb, 2013). These cells serve as a temporal domain where visual information is presented to the ganglion cell and are responsible for the complex processing of the retinal image, specifically adjusting image brightness as well as the detection of motion through the sequential activation of neurons (Cuenca, 2008 & Kolb, 2013). Ganglion cells or retinal ganglion cells (green cells in Figure 38 above) are located in the inner most layer of the retina known as the ganglion layer and serve the role of integrating visual information from bipolar and amacrine cells (Nelson, 2007). These cells are the final output neurons and are the most complex information processing systems found in the retina (Nelson, 2007). Amacrine cells that are activated by bipolar cells, synapse with ganglion cells and serve the function of transmitting information about changes in illumination levels (Tortora & Derrickson, 2009). Bipolar and amacrine cells are responsible for the depolarisation of ganglion cells causing the initiation of nerve impulses (Tortora & Derrickson, 2009; Troncoso et al., 2011). The axons of retinal ganglion cells provided output from the retina to the brain through the activation of the optic (II) nerve (Troncoso et al., 2011).

Visual Perception

Once the action potential has been initiated and is transmitted to the brain via the optic nerve, these impulses then follow a specific pathway within the brain to areas for interpretation of these resultant action potentials. This is known as the visual pathway as seen in Figure 39 below. Visual perception occurs as the result of the processes that occur within the visual cortex of the brain. The brain is a very important component in the understanding and interpretation of the resultant action potentials that occur. One of the most important regions in this process is the lateral geniculate nucleus (LGN) of the thalamus located in the brain.

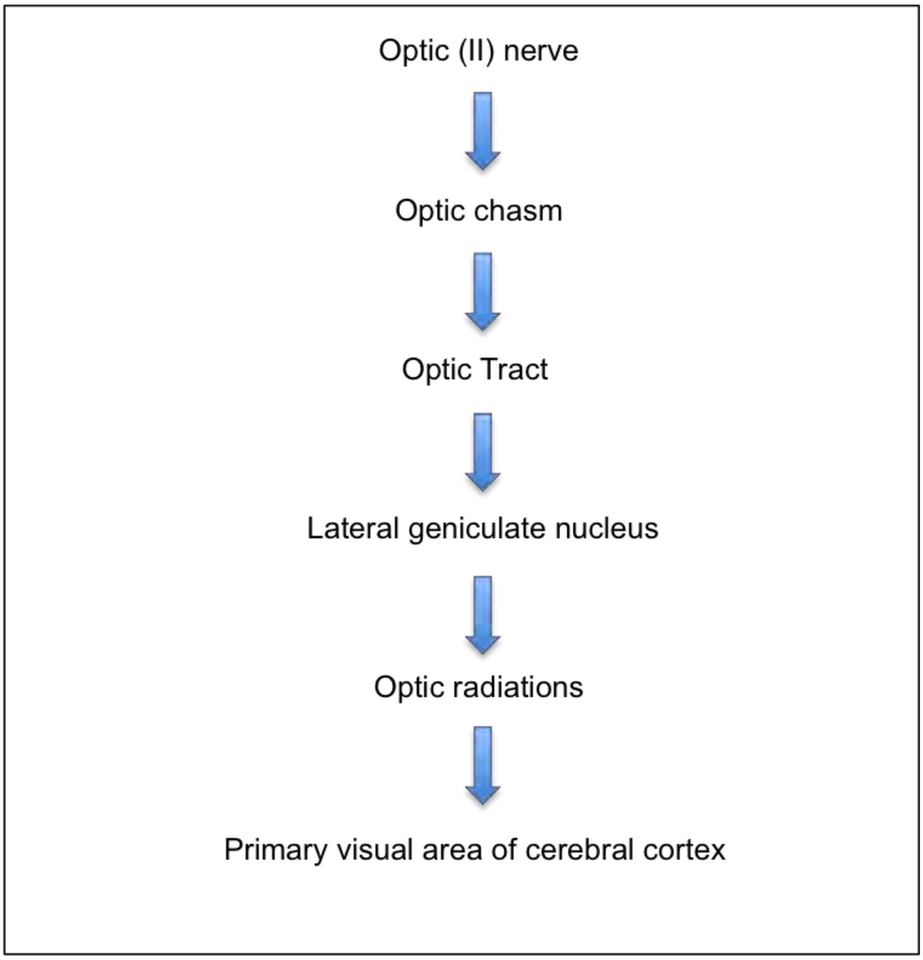


Figure 39: Schematic diagram of the visual pathway

The axons of the retinal ganglion cells that send action potentials along the optic nerve then pass through the optic chasm, a crossing point of the optic nerves from both eyes as seen in Figure 40 below (Tortora & Derrickson, 2009).

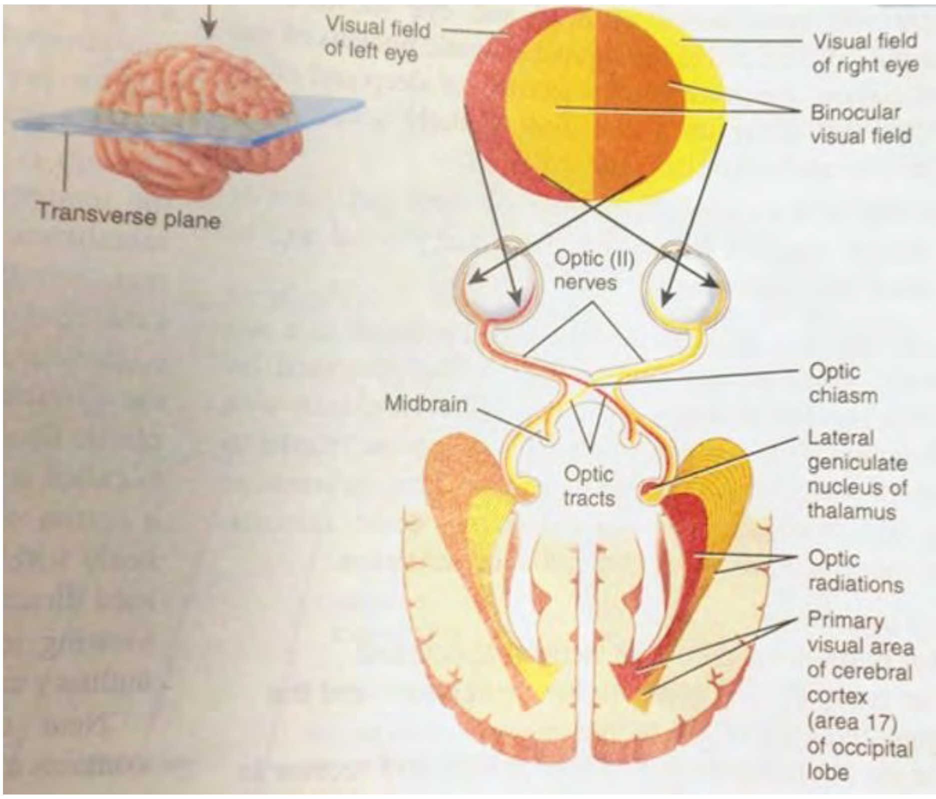


Figure 40: Superior view of transverse section through eyeballs and brain

Within the optic tract, axons of the nasal region of the retina cross to the opposite side of the brain, whereas axons of the temporal region of the retina remain uncrossed (Tortora & Derrickson, 2009). The action potentials then continue on from the optic tract and terminate in the lateral geniculate nucleus (LGN) of the thalamus, as seen above (Tortora & Derrickson, 2009). Within the LGN there are six layers of cell bodies that can be classified based on their histological characteristics (Livingstone & Hubel, 1988; Milner & Goodale, 2006b; Troncoso et al., 2011). The two bottom layers have large cell bodies and known as the magnocellular layers and the four upper layers are smaller and known as the parvocellular layers (Livingstone & Hubel, 1988; Troncoso et al., 2011). It is important to note at this stage that there is contention as to the division of labour between these two seemingly distinct pathways (Milner & Goodale, 2006b). It has been suggested, with evidence, that although the two streams may have been seen to function with a degree of independence, this segregation may be far less clear cut than originally thought (Milner & Goodale, 2006b). The LGN is the principle structure that sends visual information to the visual cortex as it receives 90% of its input from the retinal ganglion cells (Troncoso et al., 2011). Although there are over 20 different types of ganglion cells, the midget and parasol ganglion cells constitute almost 80% of the ganglion population

(Milner & Goodale, 2006b; Troncoso et al., 2011). These two cells lead to two different pathways that remain segregated through the early visual system (Troncoso et al., 2011). These retinal ganglion cells terminate selectively within the LGN; The midget ganglion cells project into the four parvocellular layers and the parasol ganglion cells project into the two magnocellular pathways (Livingstone & Hubel, 1988; D. L. Mann, 2010; Milner & Goodale, 2006b). These layers contribute to visual processing along two parallel but interacting pathways as a result of this selective termination of retinal ganglion cells within the LGN (D. L. Mann, 2010).

Ungerleider & Mishkin (1982) were among the first to suggest these two separate cortical pathways in the processing of this information which still influences the understanding of higher visual organisation and processing today (Milner & Goodale, 2006a). This division into the magno and parvocellular layers seems to be the first major split in the visual information in the pathway after the crossing of the visual information from the nasal region of the retina (Livingstone & Hubel, 1988). These two pathways differ physiologically from each other in four major ways, namely colour, acuity, speed and contrast sensitivity (Livingstone & Hubel, 1988). In terms of colour, the cells of the parvocellular pathway are seen to be colour sensitive whereas the cells of the magnocellular pathway are in effect colour blind (Livingstone & Hubel, 1988). In terms of acuity, magnocellular cells are found to have a larger receptive field centre than parvo cells but in terms of processing speed, magnocellular cells are found to respond faster than parvocellular cells (Livingstone & Hubel, 1988). Magnocellular cells are also found to be more sensitive to contrast than the parvocellular cells (Livingstone & Hubel, 1988). This suggests that the information these pathways contribute to vision is different (Livingstone & Hubel, 1988). The neurons within these pathways then synapse with neurons that form the optic radiations thus transferring the visual information to the primary visual cortex (also known as the striate cortex or V1) of the occipital lobe (Tortora & Derrickson, 2009). Once information reaches the striate cortex (V1), information is processed through the extrastriate areas (V2, V3, V4 and V5) (Dragoi & Tsuchitani, 1997). The extrastriate areas all contribute differently to the processing of different parts of the incoming visual information dependent on the information received from either the magno or parvocellular pathways. The information processed within the extrastriate areas will contribute to the object identification as well as provide information on how to act on the object based on its location (Ludeke, 2010). The magno and parvocellular pathways continue to project into the striate cortex which is also found to be separated into several layers (Livingstone & Hubel, 1988). Within the striate cortex, the magnocellular pathways project into the layer 4Cα as seen in Figure 41 below (Livingstone & Hubel, 1988). The parvocellular pathways however project into layer 4Cβ and then further on into layers two and three of the striate cortex (Livingstone & Hubel, 1988).

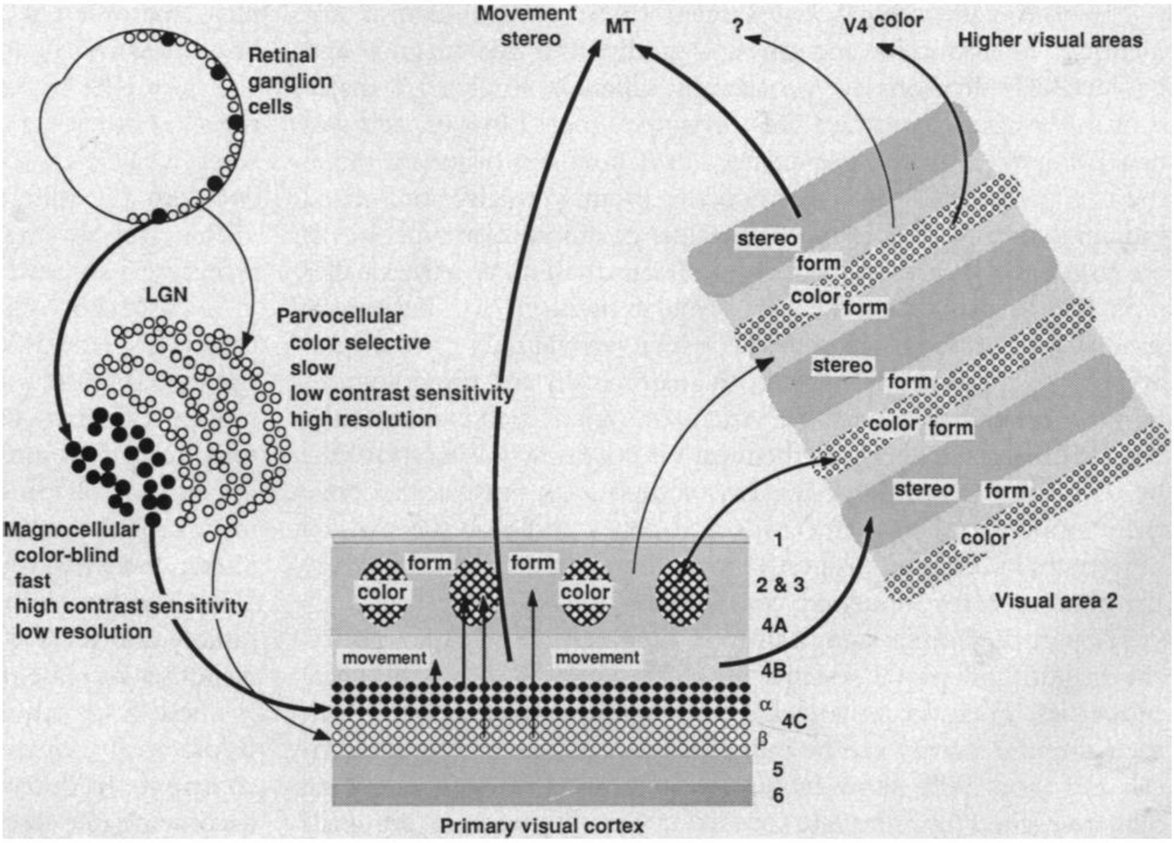


Figure 41: Divisions of striate cortex from Livingstone & Hubel (1988)

Based on the region that the pathways project into, neurons within the striate cortex maintain the differences seen between the magno and parvocellular pathways and send information relating to colour, shape or form, location and motion, to the different areas of the extrastriate cortex as can be seen in Figure 42 below (Dragoi & Tsuchitani, 1997).

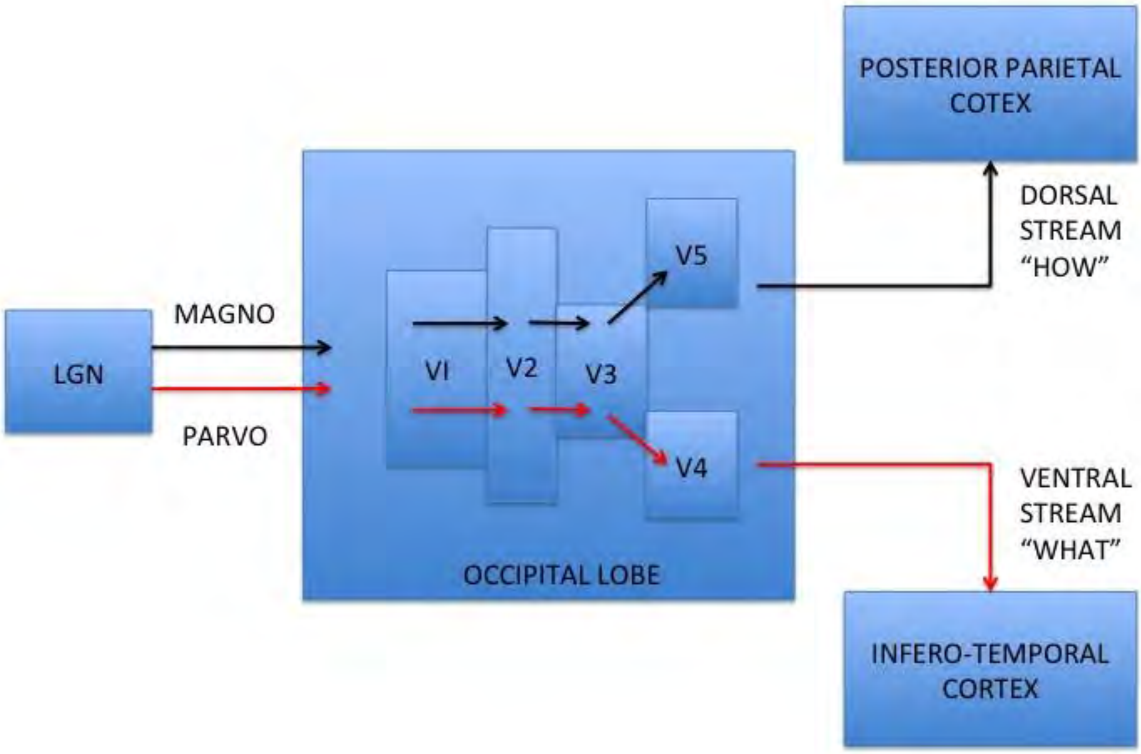


Figure 42: Schematic flow diagram of visual information within the brain. Black arrows indicate input from magnocellular pathway and red arrows indicate input from the parvocellular pathway. Figure adapted from Ludeke, (2010); Skillen, (2009).

In terms of vision, the most important information to be gathered from the visual scene is to know what objects are (object recognition and identification) and where they are located (spatial location). Following the first separation of visual information into the magno and parvocellular pathways in the LGN, information leaving the striate cortex (V1) then enters the dorsal and ventral streams respectively as shown in Figure 42 above. These two pathways are functionally and neurally distinct, one pathway is specialised for object perception and the other for spatial relations between those objects (Milner & Goodale, 2006a). Although early suggestions of the magnocellular pathway continuing into the dorsal stream and the parvocellular pathway into the ventral stream originally was thought to be clear cut, more recent research has shown this not to be the case (Milner & Goodale, 2006b). Evidence has now shown that projections from the striate cortex into the dorsal stream largely has its contributions from the magnocellular pathways but contains a significant albeit small input from the parvocellular pathway (Milner & Goodale, 2006b). Projections into the ventral stream have been shown to be even more mixed with an almost even contribution of both pathways (Milner & Goodale, 2006b). Although this is now known, there is still much contention as to the contributions of each of these pathways and how they interact within the two streams projecting from the visual cortex, that is beyond the scope of this review (project/thesis?).

Although there is contention and room for more understanding of this process of vision, there are some general agreements with respect to the pathways of the ventral and dorsal streams within brain and their contributions to vision. In terms of the dorsal stream, projections from the striate cortex transmit visual information to the posterior parietal lobe as seen in Figure 43 below (Goodale & Milner, 1992; Milner & Goodale, 2006b). This visual information relates to object spatial location (spatial awareness) and thus influences action taken on the object through visuo-motor control of online actions such as reaching, grasping (Goodale & Milner, 1992; Ludeke, 2010; D. L. Mann, 2010; B. T. Miller & Clapp, 2011; Milner & Goodale, 2006a, 2008; Ungerleider & Mishkin, 1982).

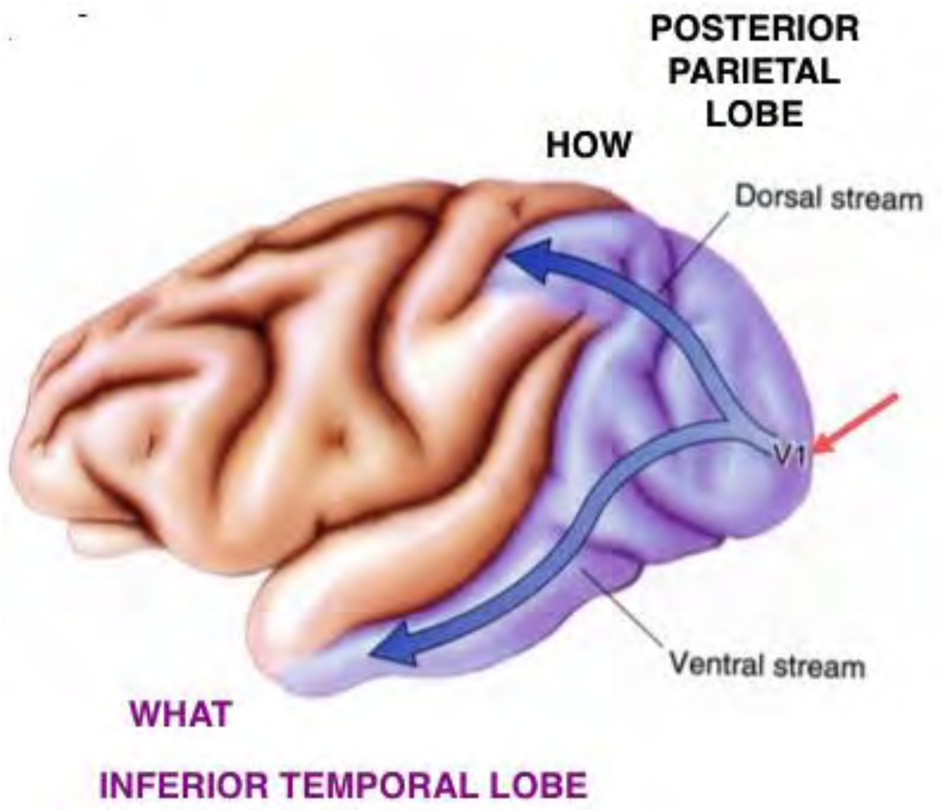


Figure 43: Ventral and Dorsal Pathways

The dorsal stream is the more primitive and slower of the two pathways and further relays information to the frontal eye fields (FEF) which is the region of the brain that controls the shift of eye movements with spatial attention (B. T. Miller & Clapp, 2011). The ventral stream however, transmits information that aids in the analysis of visual detail, such as colour, shape, size and orientation and is specialised for the conscious visual perception and recognition of objects in the surrounding environment (Ludeke, 2010; D. L. Mann, 2010; B. T. Miller & Clapp, 2011; Milner & Goodale, 2006b, 2008). The visual information within the ventral stream is processed from the visual cortex to the infero-temporal cortex as seen in Figure 43 above (Goodale & Milner, 1992; Milner & Goodale, 2006b). The ventral pathway terminates in the pre-frontal cortex that integrates object and spatial information in order to guide appropriate decisions on the action undertaken (B. T. Miller & Clapp, 2011).

Information Processing

There has always been an interest in developing models that illustrate how the brain perceives the environment in which we exist and its capacity to link perceptions and to interpret them accordingly resulting in appropriate action. Within a sporting environment, and even for any activities performed in daily living, visual information is required to be processed in order to make appropriate decisions about the actions to be performed, whether it be to pick up a glass or to intercept a ball. Based on The execution of these actions is the result of three central processing mechanisms

Information processing on perception and action in sport:

. Welford's and Whiting's models of information processing among others have emerged to help explain how this may occur. These models were developed in order to explain the interplay of the different mechanisms that enable one to execute skilled movement for example how interceptive actions are accomplished.

In order for interceptive actions to occur Poulton (1975) spoke of the need for two types of predictive information for successful execution of such actions; these were receptor anticipation information and when to initiate movement. During the stage of receptor anticipation information the player gathers information that enables one to estimate the time to contact of the approaching object. The information gained during this stage is utilised in the second stage (when to initiate action) where the information is compared to the memory component of the information processing system. This information is then used to make appropriate decisions in relation to the interceptive task at hand. The timing of the interceptive task becomes more successful based on knowledge of the specific task from previous experience. Interestingly, the basis for many of the occlusion studies that have been done has been based on the premise of the player having access to an extensive knowledge base for interception. This has given rise to the question of how much information the brain actually needs to make appropriate decisions as well as the exact point in time that information needed to be accessed by the performer's perceptual system. Occlusion studies have thus been devised in order to investigate how much of the ball flight information is necessary for the successful execution of action, particularly during batting. Interceptive skills require the constant interaction and continuous coupling of the perceptual and motor system to result in successful performance. Successful interceptive actions may occur more frequently in experts due to shorter visuo-motor delays in the regulation of action (Le Runigo et al., 2005). Visuo-motor delay is defined as the time period between visually registering some information to be used to produce an adjustment and the resulting observable movement (Le Runigo et al., 2005). Experts execute interceptive actions better due to the ability to register and use visual information to alter motor behaviour. The alteration in motor behaviour ultimately aids in the accurate execution of intercepting the object.

Some researchers have argued for skilled movements of expert players being included in a repertoire of programmed actions that is developed based on skilled perception of ball flight characteristics. Other researchers have subsequently stated that this explanation is less likely for players that participate in fast ball sports. These researchers argue that the time constraints associated with fast ball sports are too limited to allow for the modification of skilled movements that constitute the repertoire of programmed actions. It is believed that the necessary modification would increase the processing demand required of the player thus rendering the idea of programmed actions. It has now been suggested that athletes 'buy' time to execute skilled movements by exploiting advanced cue utilisation of opponents for decision making and preparation of response (Mark Williams et al., 1999).

In the instance of a cricket fielder attempting to intercept the ball, it is believed that the skilled player forms situational probabilities of events to plan actions in advance. This requires players to be capable of detecting and interpreting early cues in order to execute the interceptive task of catching the ball. Through the use of early rather than late visual cues, players are able to programme basic postural and orientational movements to allow the fielder to be in the correct position and thus 'freeing' up attentional resources to inform what should be done with the ball after interception. Expert fielders are capable of using peripheral vision to inform the decision to throw the ball to either the wicket-keeper or bowler's end.

Anticipation

It is believed that anticipation and decision making are mediated by knowledge structures stored in memory and that this knowledge base is more extensive for experts than for that of novices (Mark Williams et al., 1999). It has been suggested that experts have better anticipation than their novice counterparts due their greater ability to encode and retrieve sport specific information which in turn enables them to recognise and recall patterns of play more effectively (Mark Williams et al., 1999). This has been demonstrated in studies performed on experts versus non-players or novices. These studies have investigated how players of different expertise level respond to structured and unstructured representations of patterns of play. It has been found that experts respond much better when asked to recall the structured patterns of play and respond in a similar manner to the non-players when asked to respond to the unstructured pattern of play. These results suggest that experts possess an advantage over novices due to a more advanced task specific knowledge base pertaining to that sport (Mark Williams et al., 1999). Anticipation is also hypothesised to be better in experts due to their ability to encode information presented to them in larger 'chunks' than novices. This enables experts to take in more information in a shorter space of time thus allowing patterns of play to emerge and be recognised quicker, enhancing anticipation.

The above mentioned studies and results have been scrutinized based on the method by which data was collected. The experiments employed the use of static slides of match play that were typically taken from overhead rather than a player's point of view. It has since been suggested that these methods remove the dynamic situation players operate within during a game due to the use of the static, slide representations of the game. The dynamic nature of sport is an integral component in the pattern recognition process and allows players to utilise player kinematics that aid in anticipation. Another criticism is that the static nature of those studies only investigates recognition and recall, which is only one component of how play is executed, and neglects the need for players to perform the necessary action under time pressure accurately for success on field (Mark Williams et al., 1999).

Research has also been performed to investigate the link between advanced cue utilisation and anticipation in sport. This link is an important consideration as the use of advance cues aids the player in making predictions about an opponent's subsequent movements or placement of the ball. These predictions aid successful performance through the facilitation of anticipation. Advance cue utilisation is defined as an athlete's ability to make accurate predictions based on contextual information available early in an action sequence (Abernethy, 1987a in Mark Williams et al., 1999). It can also be referred to as perceptual anticipation and is an essential element in sporting contexts as there are limitations in the player's visual system with regards to reaction time. This is important due to the limited time available to correct movements in order to execute a particular action.

Two methods have been utilised to investigate the advanced cue utilisation. These have been the temporal and the event occlusion approaches. The temporal occlusion method investigates subjects' predictive ability based on the occlusion of different parts of an action sequence at different times, for example at certain time periods, sections of the ball flight information, before, at or after impact are occluded. This method has been criticised as being limited as it does not give any information pertaining to the nature of the anticipatory cues used by the player in the anticipation process. This resulted in the development of the event occlusion technique. This method entails the subject being presented with different action sequences, as in the temporal method, but specific cue *sources* are occluded for the duration of the trial. Subjects are required to indicate, for example the intended direction of the ball, based on the omission of different cue sources such as the racket and the arm or the racket alone. This method is underpinned by the argument that the accessibility of the cue and the time at which it becomes available affects the player's perceptual strategy. This time period is crucial for the extraction of pertinent anticipatory cues. Studies conducted by Abernethy & Russell (1984) confirmed the premise underpinning the event occlusion technique and indicated that cue sources such as the arm and racket were important contributors to anticipation.

The criticism that has resulted from these studies is that the film that is presented to the participants allows for storage of the event within the short term memory and therefore the visual information may be stored for delayed processing. It has therefore been suggested that in future research, more realistic time constraints should be imposed upon subjects in order to imitate similar authentic situations that would occur within the actual sporting context. This would more realistically reflect anticipation in sport. Another great criticism that will always undermine (downplay?) this type of research is the disregard of situational information whereby there is other information the player can utilise to aid anticipation such as the type of shots that have been played before, the pressure felt within a match situation or player profile that has been investigated before, whereby players will know what type of shot opponents prefer. These factors all contribute to how players respond to anticipation within the real sporting context and should not be undervalued within the real match context. Knowledge of such information reduces reaction time due to reduced decision making time.

Contributions of the Ventral and Dorsal Stream in successful performance

The key to success in sports such as cricket is the ability of players to intercept the ball at the right place and time, while receiving and returning the fast moving ball in the same action. The visual system of humans have intrinsic limitations such as visuo-motor delay, which is defined as the time period between the detection of information and its use in producing an adjustment in movement, and is particularly important in interceptive actions such as catching (Benguigui et al., 2008). As mentioned previously, it has been postulated that there are two visual pathways that work together and contribute to action, but in different ways, ultimately enabling one to make appropriate decisions (Milner & Goodale, 2008). Previously it was believed that these two pathways were separate. A new framework to understand visual anticipation has been suggested that emphasizes the interacting contributions of the ventral stream in perceiving what action the situation affords and the dorsal system in the visual guidance of that action (van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). This has been an important development in the understanding of visual anticipation and has questioned much of the previous research that has been conducted, in particular the use of the occlusion technique as it only investigates the role of the ventral stream and excludes the role of the dorsal stream (van der Kamp et al., 2008). The ventral stream plays a key role in perception of the given situation and is involved in the detection of visual information in order to gather knowledge of the environment and supports vision for perception process (Milner & Goodale, 2008; van der Kamp et al., 2008). Perception represents the individual's visual experience and is the conscious experience of seeing (Milner & Goodale, 2008). The ventral stream enables cognitive control and utilises detailed, central vision from the fovea in visual processing as well as using peripheral vision as support to provide a coarse contextual framework to aid perception (Milner & Goodale, 2008). The dorsal stream uses current visual information in order to program and control skilled movement in order to carry out actions and is involved with detailed programming and implementation of these actions (Milner & Goodale, 2008). This stream provides automatic control and mediates visual control of skilled actions such as reaching and grasping (Milner & Goodale, 2008). In order to achieve this visual information that is received must be regulated on a moment to moment basis to guide the effector (such as the hand) to the appropriate co-ordinates for actions such as interception (Milner & Goodale, 2008). In most normal situations actions that are executed are co-determined by complementary processing in both dorsal and ventral streams (Milner & Goodale, 2008).

The old adage of ‘keep your eye on the ball” becomes increasingly difficult as the velocity of the ball increases as the speed far greater than the actual capabilities of the human visual tracking system. Due to this in ability to track the object there is a ‘zone of fog’ that affects all sports requiring the eye-body co-ordination. The size and density of this zone is dependent on a number of factors such as dynamic visual acuity, illumination, contrast and fatigue. It is also important to note that even if this zone of fog did not exist, there is a neural time lag of 1/5 of a second that is necessary for the processing of visual information and the initiation of the necessary corrective eye/hand movement.

The ability to maintain a clear retinal image of a moving target is of great advantage to the sportsman involved in dynamic sport as one is capable of gaining better visual information. This can often involve up to 4 different types of eye movements to achieve this: pursuit, saccadic, vestibulo-ocular and vergence eye movements. These eye movements are typically tested individually which is however not representative of the real dynamic situation in which these take place. There are also 2 separate visual mechanisms with their own pathways that control these eye movements; these are the focal and the ambient systems. The focal system is concerned with central, detailed vision and conscious object identification and the ambient system is reflex, peripheral and controls fine movement. These 2 mechanisms work together as the peripheral retina responds to movement and initiates corrective eye movement to re-direct vision to enable objects of interest to be viewed by the central retina where visual acuity is best.

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