THE EFFECT OF A PERCEPTUAL-MOTOR TRAINING PROGRAMME ON THE COINCIDENT ANTICIPATION TIMING AND BATTING PERFORMANCE OF CLUB CRICKET PLAYERS

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signature: Grant David van Velden

Date

Abstract

The purpose of this study was to determine the effects of a perceptual-motor training programme on the coincident anticipation timing and batting performance of university club cricket players. The intervention programme focused on developing players' visual attention and concentration. Vickers' (2007) Three-Step Decision Training Model was used to structure the training sessions.

The study followed a repeated measures experimental design with three groups (experimental, placebo, and control) formed by volunteers from a university club cricket team. The independent variable was a four-week training programme. The dependent variables were coincident anticipation timing and performance on a cricket batting test. Subjects were pre- and post-tested with retention tests occurring after a set period of "no training" following the post-tests.

Differences between groups were compared using Kruskal-Wallis ANOVA by Ranks Tests. Differences within each group were compared using multiple Mann-Whitney U-Tests. No significant improvements were observed in the experimental group's coincident anticipation timing and batting performance. Although neither coincident anticipation timing nor batting performance significantly improved, further research into the use of Vickers' (2007) Model to enhance sport performance is recommended.

Keywords: cricket batting; perceptual-motor training; coincident anticipation timing; batting performance; gaze control.

Opsomming

Die doel van hierdie studie was om die uitwerking van ŉ perseptueel-motoriese opleidingsprogram op die samevallende vooruittydsberekening ("coincident anticipation timing") en kolfprestasie van universiteitsklubkrieketspelers te bepaal. Die klem van die intervensieprogram het op die ontwikkeling van spelers se visuele aandag en konsentrasie geval. Die opleidingsessies is volgens Vickers (2007) se drieledige model vir besluitnemingsopleiding saamgestel.

Die studie het ŉ eksperimentele ontwerp van herhaalde metings op drie groepe (eksperimenteel, plasebo en kontrole) van ŉ universiteitsklubkrieketspan toegepas. Die onafhanklike veranderlike was ŉ vier weke lange opleidingsprogram. Die afhanklike veranderlikes was samevallende vooruittydsberekening, en prestasie in ŉ krieketkolftoets. Proefpersone het voor en net ná die opleiding toetse ondergaan, sowel as behoudtoetse drie weke ná die na-opleidingstoetse.

Verskille tussen groepe is met behulp van rangtoetse uit Kruskal-Wallis se variansie-analisemodel (ANOVA) bepaal, terwyl verskille binne groepe met veelvuldige Mann-Whitney-U-toetse vergelyk is. Geen beduidende verbetering is in die eksperimentele groep se samevallende vooruittydsberekening of kolfprestasie waargeneem nie. Hoewel nóg samevallende vooruittydsberekening nóg kolfprestasie aansienlik verbeter het, word verdere navorsing oor die gebruik van Vickers (2007) se model vir die verbetering van sportprestasie aanbeveel.

Trefwoorde: krieketkolfwerk; perseptueel-motoriese opleiding; samevallende vooruittydsberekening; kolfprestasie; visiebeheer

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Opinions expressed and conclusions arrived at, are those of the author and do not necessarily reflect those of the above institutions.

Table of Contents

List of Figures

List of Tables

Chapter One

Setting the Context of the Study

In today's sporting world, players, coaches, and conditioning staff place an enormous amount of emphasis on winning. Sportsmen and women work to be fitter and mentally stronger than their opponents. Coaches strive to develop better game-play and training strategies than their counterparts. Conditioning staff try to link results from scientific research to the practical implementation of physical conditioning programmes. Within these efforts to get "one step ahead" of their opponents, there has been sustained interest in exploring the role of variables associated with perception, especially vision, as critical performance indicators in a variety of different sport performance contexts (Wilson & Falkel, 2004).

The central role of visual perception and motor skill performance is well established both in terms of players' understanding what is happening in the environment as well as for controlling their execution of motor skills (Magill, 2003). The potential of different kinds of visual/perceptual-motor control training programmes to improve understanding the environment and sport skill performance has grown as a topic of scientific and applied research (Ferreira, 2003). The reports of the success of these programmes has been mixed, perhaps as a reflection of the wide variety of different kinds of programmes, different perceptual-motor variables, different sports and different research methods that have been involved.

One line of research dealing with the perceptual-motor link between visual perception and sport performance has been developed by Vickers (2007). In order to be successful in a sport situation, she noted that players must learn to look for the most important locations and objects in the environment to provide the information needed for decision making. In her research, learning to control where to look and at what to look and when to look was labelled "gaze control". She proposed a Gaze Control Framework that differentiated among the demands in different categories of perceptual-motor tasks in sport situations. She then proceeded to develop a Three-Step Decision-Training Model based on her study of gaze control. This training model has yet to be applied to the sport of cricket, and in particular, the skill of cricket batting. The application of this decision-training model to the performance of cricket batsmen is the focus of this study.

The Gaze Control Framework

Vickers (2007) defined gaze control as the control of eye movements to achieve successful visual search patterns. She indicated that these patterns were achieved through fixations and pursuit tracking, including saccadic eye movements. She proposed a framework of gaze control that categorised the challenges to visual search into three major types of tasks:

1. Targeting tasks
2. Interceptive timing tasks
3. Tactical tasks

It is not unusual for tasks from all three categories of gaze control to be found within a single sport. However, because this study deals with batting in cricket, only gaze control as used for the performance of interceptive timing tasks will be discussed.

Interceptive timing tasks involve an object travelling toward a player and the player attempts to meet the object in some way to either control it or re-direct it toward a target (Vickers, 2007). The challenge to the player is to control both their attention and gaze control in order to recognise the characteristics of the object as it is delivered, track it as it approaches and then control the object as it is received. Stretch, Bartlett and Davids (2000) stated that when performing dynamic interceptive actions, *“athletes need precise information to locate the ball in space (‘where’ information) at a specific time (‘when’ information)”.* There are two variations of this challenge within the category of interceptive timing tasks that provide another level of detail in the Gaze Control Framework: The path taken by the object may be predictable or unpredictable (Figure 1). Put into a cricket batting context, the batsman reads the cricket ball as it is delivered by the bowler, tracks it as it makes its way down the pitch and then plays the appropriate shot to control the ball with the bat in order to score runs.

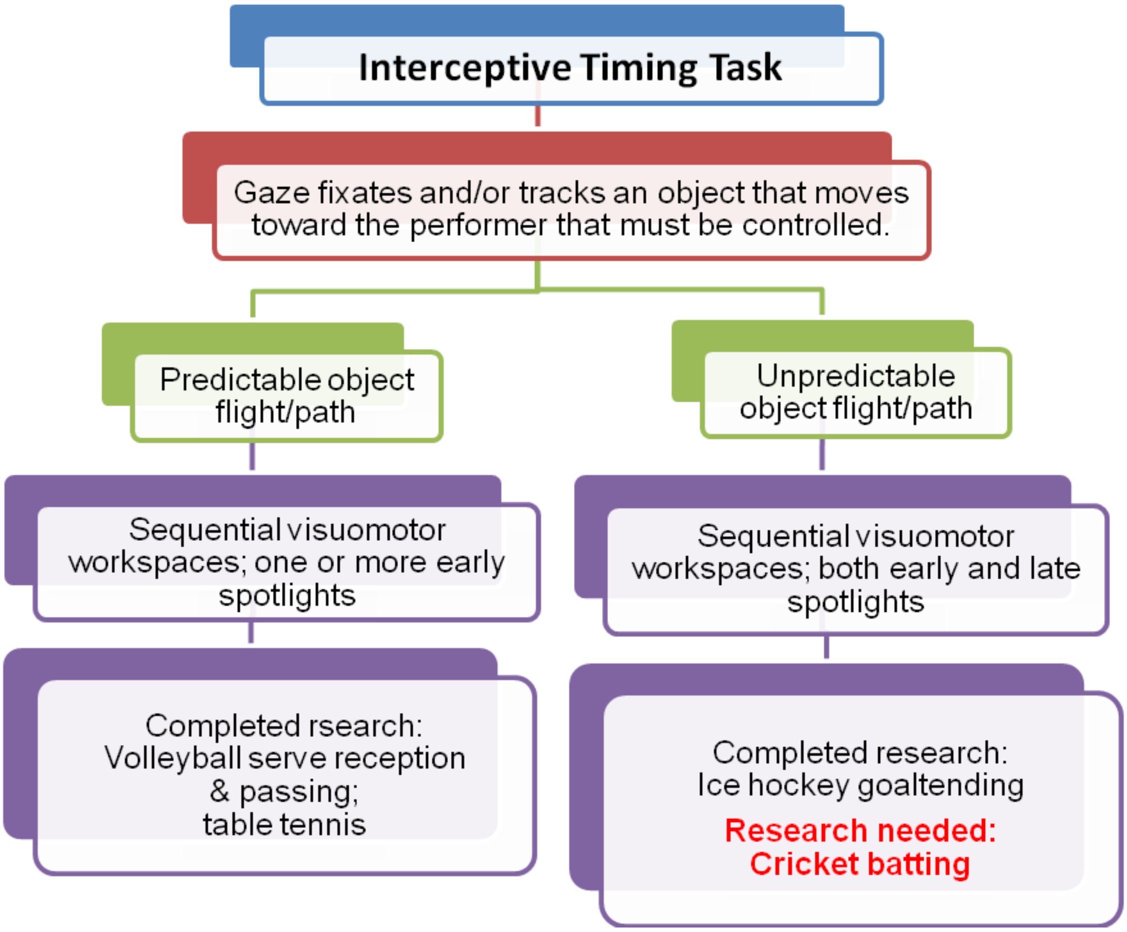

Figure 1. *Vickers' (2007) Gaze Control Framework for interceptive timing tasks highlighting the lack of gaze control research on cricket batting.*

The pathway of the ball is unpredictable because it often strikes the pitch prior to reaching the batsman, which makes its direction and speed extraordinarily challenging to predict.

According to Vickers (2007), studies focused on cricket batting are an important direction for new research on gaze control. She also proposed that gaze control for interceptive timing tasks be divided into three sequential phases: Object recognition, object tracking and object control. The challenges posed in all three phases must be met in order to achieve a successful performance. In the case of batting in cricket, a batsman tries to contact the ball with the cricket bat so that the ball travels in the intended direction onto the field of play.

Object Recognition Phase

During the first phase of gaze control (object recognition), the player uses the visual skills of fixations with pursuit tracking and/or saccades to read both the characteristics of the object and the individual delivering the object (Vickers, 2007). In cricket batting, this would entail the batsman watching the movements of the cricket ball as well as the bowler's movements during the run-up and release parts of the bowling delivery action.

Object Tracking Phase

During the second phase (object tracking), the player attempts to use the visual skill of pursuit tracking to keep the image of the object on the fovea in order to determine what the object is doing (e.g. spinning, accelerating or decelerating, moving laterally through the air). Croft, Button and Dicks (2009) defined pursuit tracking as *"eye movements that allow humans to extract detailed, continuous information about a moving object... and involves slow rotations of the eyeballs to fixate the tracked object within foveal vision, thereby enhancing perceptual acuity of the object."* In cricket batting, this would entail trying to detect swing through the air, spin off the pitch, or whether the delivery is a slower or a quicker ball. An important variable during this phase is the speed at which the object is moving (Croft *et al.*, 2009). The human eye cannot use pursuit tracking to keep the image of the object focused on the retina if it is moving faster than 150°/sec (Vickers, 2007). In order to keep track of objects that move at faster speeds, saccadic eye movements are used. Vickers (2007) stated that saccadic eye movements are used to try to keep track of the flight/path of quickly moving objects, especially when they change directions unpredictably. Land and McLeod (2000) described saccades in cricket batting as coordinated quick eye movements used to "jump to fixate ahead" of the path of the ball as it moves so that the batter can keep track of its flight by interpreting the series of focused images of the ball.

Object Control Phase

During the third phase (object control), the player attempts to control the object using either a part of the body or an implement. Vickers (2007) concluded that the player stabilises his/her head in order to facilitate a stable platform for gaze control as the object is caught, kicked, hit, etc. In cricket batting, this would entail the batsman hitting the ball with a cricket bat onto the field of play.

The Decision Training Model

Vickers (2007) proposed that if gaze control were “trained” within sport-specific practice sessions, players would improve in their ability to read the environment and take actions to achieve their goals. She presented her Decision Training Model as a method of coaching that is specifically aimed at improving players’ ability to make decisions about their actions. The model called for the design and implementation of practice activities focused on the development of the perceptual-cognitive-motor linkages that support successful sport skill performance. She contrasted her Decision Training Model with more traditional models for designing practice sessions which she classified as “behavioural training.”

Behavioural Training

From Vickers’ (2007) perspective, behavioural training was focused on learning motor skill techniques. Although practice sessions were often accompanied by high levels of physical effort, she noted that the activities seldom emphasised the development of either perceptual or cognitive processes. Complex skills and learning to apply tactics were only introduced into practice sessions after the basic skills have been mastered. Coaches who followed a behavioural training approach provided players with frequent feedback on the mechanics of their skills and seldom encouraged players to think about their own performance. Vickers concluded that automation of performance was the goal of the behavioural training approach and as a consequence, players did not develop the higher-order cognitive skills needed to play with flair, innovation and responsiveness to unexpected actions by their opponents. There was some research to support Vickers’ (2007) conclusions that behavioural training lead to gains in skill proficiency in the short-term, but these improvements faded over time and when the environment called for responses to new variations or unanticipated changes (Swinnen, Schmidt, Nicholson & Shapiro, 1990; Winstein & Schmidt, 1990).

Decision Training

The decision training approach includes technical skill and fitness development, but within a different kind of practice session. Vickers (2007) claimed that sessions should be structured around learning the perceptual and cognitive skills needed to support successful decision making in a variety of performance environments. She cited research that supported her position that subjects who are trained using the decision training approach seem to retain their level of skill proficiency over a longer period of time when compared to subjects trained using a behavioural approach. She described this as the *paradox in motor learning* i.e. the behavioural approach often produced positive gains in motor proficiency more quickly than the decision training approach, but over longer periods of time, the players who follow the decision training approach surpass them and ultimately achieve higher levels of expertise.

The Decision Training Model was proposed by Vickers (2007) to provide a systematic approach to the design of practice sessions that would promote perceptual and cognitive skills development as an integral part of motor skill learning (Figure 2). She specifically identified seven cognitive skills, seven cognitive triggers and seven decision making tools that could serve as the focus points for designing innovative drills and games that simulate the tactical challenges presented by a particular sport. Coaches will often stop play and ask players to analyse their own performance and provide potential solutions to any problems that they might identify. The coach tries to increase players' cognitive involvement during training by asking good questions that test their understanding of the tactics and skills of their sport. Players must not only move well, they must make good decisions in appropriate situations.

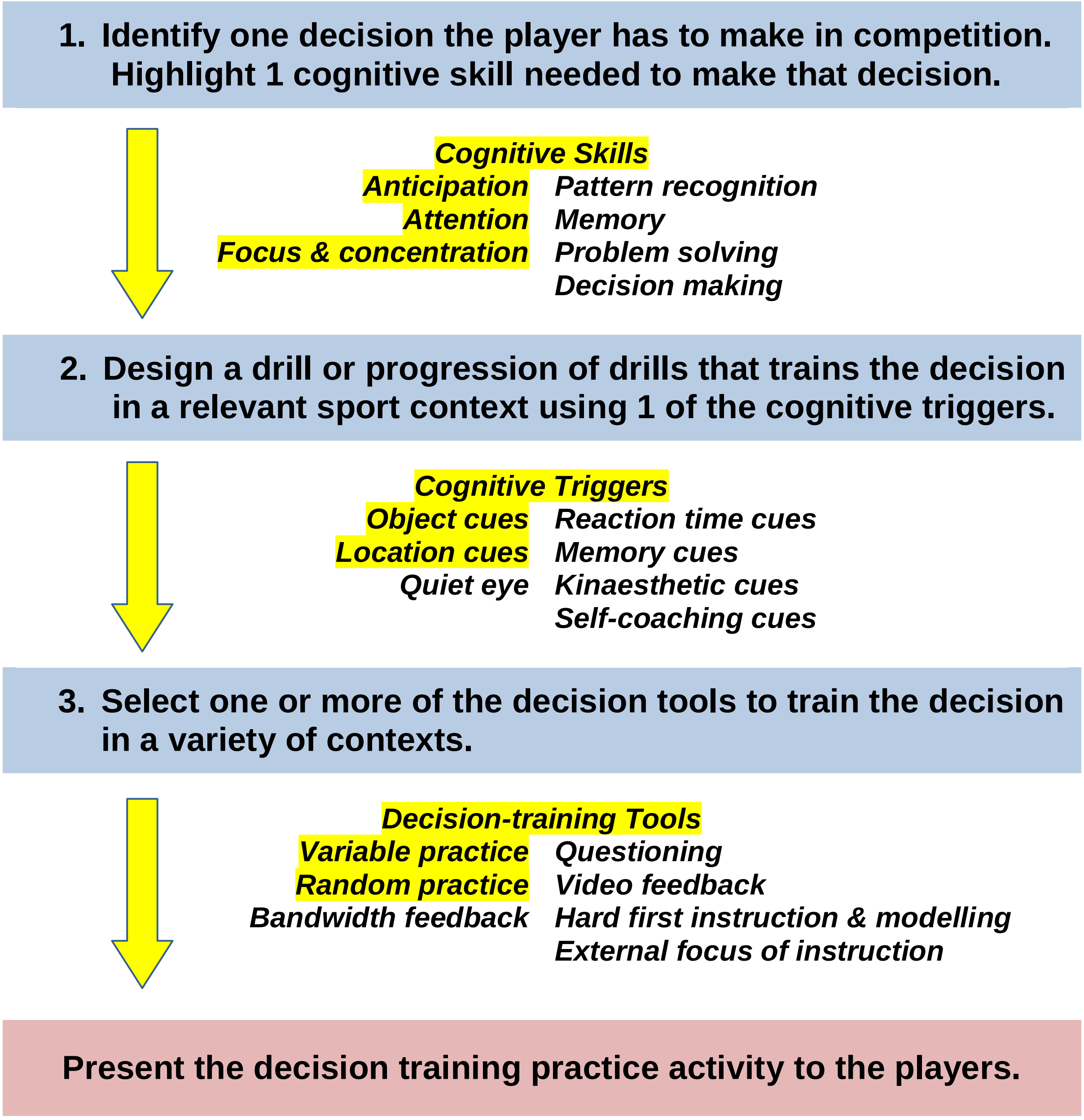

Figure 2. *Vickers' (2007) Three-Step Decision Training Model highlighting the skills, triggers and tools used in this study.*

The application of the Decision Training Model in this study is characterised by the three-step structure (Vickers, 2007). Each step involves the specification of at least one aspect of the perceptual-cognitive-motor process as the focus for a drill or game. The aspects emphasised in this study are highlighted in Figure 2.

The following sections provide a brief description of Vickers' (2007) Decision Training Model as it was applied in this study. Only those aspects included in the intervention programme in this study are described.

Step 1: Identify a Decision then Highlight a Cognitive Skill

Before the practice activities in an intervention programme can be designed, there must be a clear identification of the decision that will be the focus for each of the practice activities. In the case of this study, the decision by a batsman of when and how to move his bat to make a "good hit" with the ball was the decision identified. Vickers (2007) recommended that each practice activity focus on one of what she termed "the seven cognitive skills." Each decision should include one of the seven cognitive skills: Anticipation, attention, focus and concentration, pattern recognition, memory, problem solving and decision making. For the purpose of this study, the three cognitive skills of anticipation, attention, and focus and concentration were highlighted in practice activities.

1. Anticipation is "the ability to predict what will occur when preparing to perform a skill or tactic" (p. 166) (Vickers, 2007). Anticipation includes the identification of the relevant cues in the environment as well as the perception of their meaning. The coach must determine what information must be seen, felt, heard, or otherwise perceived in order for a player to have the information needed to predict what should be done and when it should be done.

2. Attention is the ability to direct one or more sensory systems to pick-up stimulation from a particular source (Magill, 2003). The coach needs to identify what sources provide critical information during the execution of a specific skill or tactic. Players will have to direct their sensory systems to that source to gather that information. For example, when batting in cricket, the visual system must be directed to provide critical information about the flight of the ball.

3. Focus and concentration refers to the ability to direct attention to a particular cue, object, etc. (focus) and then to maintain that focus and continue to gather information from that source despite distractions from

irrelevant sources (concentration) (Magill, 2003). For example, a batsman may have to disregard the irrelevant body actions of a bowler during the follow through phase of a delivery in order to keep gathering information about the flight of the ball.

Step 2: Design an Activity with a Cognitive Trigger

In this step the coach designs a drill, a progression of drills or games that call on the player to make decisions similar or identical to the decision identified as the focus for practice. For this study, that meant that drills and games were designed to develop anticipation, attention and focus and concentration in drills or games that simulated the environmental demands of making a good hit while batting in cricket. The added feature in Step 2, however, is that each drill or game must have a "cognitive trigger." Vickers (2007) identified seven cognitive triggers: Object cues, location cues, quiet-eye cues, memory cues, reaction-time cues, kinaesthetic cues, and self-coaching cues. Within her model, these triggers encourage players to become cognitively involved in their own performance by challenging them to control their attention on relevant information or to use their knowledge to help them. For the purpose of this study, only two triggers were incorporated into the practice activities: object cues (e.g. looking at the ball) and location cues (e.g. looking at the point of release of the ball).

1. Object cues: The player tries to gather information from an object that will provide him/her with an idea about what is happening or is going to happen to the object. An example of this is the painting of numbers on a volleyball, then asking players who are receiving the serve to call out the number on the ball as they track it (Adolphe, Vickers & LaPlante, 1997).

2. Location cues: The player tries to focus attention on a space or place that provides information about what is happening in the environment. Soccer goalkeepers provide an example of using location cues. They focus on the body of the shooter to get information to predict the direction of the shot (Savelsbergh, Williams, van der Kamp & Ward, 2002).

Step 3: Use Decision Training Tools to Promote Cognitive Involvement

In this step, coaches use one or more of the seven tools for decision training to shape the way they present the practice activities. The seven decision training tools identified by Vickers (2007) are variable practice, random practice, bandwidth feedback, questioning, video feedback, hard-first instruction and modelling, and external focus of instruction. For the purpose of this study, only the tools of variable and random practice were used to shape practice activities. Both of these tools create a contextual interference effect in the sequencing of practice activities which raises the cognitive effort that players must invest in participation (Magill, 2003):

1. Variable practice: Vickers (2007) associated variable practice with players learning how to perform a particular skill under all the different conditions that might occur during actual game play. This tool is in contrast to the behavioural approach where players first try to achieve a sound technique in a predictable situation before attempting to deal with variety. For example, variable practice for a cricket batsman would involve practicing the hook shot along the ground, in the air, in front of square on the leg-side, and behind square on the leg side all during the same practice activity. Different variations of the hook shot need to be played in different situations in the game such as when the fielders are standing in front of square or behind square on the leg-side, within the inner ring or on the boundary.

2. Random Practice: In a random practice schedule, different skills are practiced in an unpredictable succession in order to tax the players' ability to reorganise actions depending on the circumstances (Vickers, 2007). Using the same example from cricket as above, the batsman may first have the opportunity to hit his hook shot, only to find on the next series of balls he must hit a cover drive, and then the situation may shift again quickly and a hook shot is more appropriate again. It is up to the coach to create the circumstances that call for different skills so that the batsman can learn how to determine which skill to use and when to use it.

Purpose of the Study

The purpose of this study was to determine the effects of a perceptual-motor training programme, based on Vickers' (2007) Three-Step Decision Training Model, on the coincident anticipation timing and batting performance of cricket players. The specific focus of the intervention programme was the development of players' anticipation, attention and focus and concentration skills through variable and random practice activities in order to help players make decisions about their batting performance based on object and location cues.

Research Questions

The following research questions guided this study:

1. What is the effect of participation in a four-week perceptual-motor decision training programme on the coincident anticipation timing of cricketers?

2. What is the effect of participation in a four-week perceptual-motor decision training programme on the batting performance of cricketers?

3. What is the effect of a period of "no training" on the coincident anticipation timing retention test of cricketers who have participated in a four-week perceptual-motor decision training programme?

4. What is the effect of a period of "no training" on the batting performance retention test of cricketers who participate in a four-week perceptual-motor decision training programme?

Significance of the Study

Vision is used continuously as a critical source of information during interceptive timing tasks (Williams, Singer & Frehlich, 2002) such as batting in cricket. Not only must batsmen accurately perceive what is happening in their environment so that they can predict when the ball will arrive at a particular place (coincident anticipation timing), but they also must develop their motor coordination in order to get the bat to the ball at the right time to make good contact (Ripoll & Latiri, 1997). A training programme designed to optimalise batsmen's coincident anticipation timing would only address the first part of the batting challenge in cricket. In effect it would be a perceptual training programme rather than a perceptual-motor training programme.

Vickers (2007) was convinced that training must include improving the decisions batsmen make about how to intercept the ball and send/hit it out on to the field of play. This was her point of departure for proposing the Decision Training Model. Decision training is more than just developing the relationship between perception and motor performance, which in the past has been viewed by many coaches and sport scientists from a behavioural perspective i.e. training to establish automatic connections between stimuli and response. It incorporates the cognitive thought processes of the players during practice sessions. By testing one application of this model, the results of this study may help sport scientists determine if the Three-Step Decision Training Model is a promising approach to implementing perceptual-motor training programmes. Coaches are always seeking the most efficient and effective training methods, and if the decision training approach can produce improvements in perception (*e.g*. coincident anticipation timing) and in motor performance in dynamic situations (*e.g.* batting performance), they may want to consider learning more about how to add it to their options for training.

There has been some previous research on the Decision Training Model. Vickers, Livingston, Umeris-Bohnert and Holden (1999) manipulated some of the decision training tools in their comparison of the decision training approach to the behavioural approach (*e.g.* variable vs. blocked practice, bandwidth feedback vs. high frequency feedback). Their results were consistent with other motor learning literature that found novices may benefit more from a behavioural approach, but as skill level increases, the decision training approach is increasingly more effective (Magill, 2006).

There have been other studies that have compared decision training to behavioural training, but very few studies have focused on the effectiveness of the cognitive triggers as a way to improve some of the cognitive skills. Adolphe *et al.* (1997) studied the use of object cues to improve anticipation in a study of elite level volleyball when receiving the serve then passing. They reported a trend toward greater accuracy among the players who had received their training. Because this study will incorporate object and location cues into the training sessions, it could be considered a kind of field-based visual skills training programme. There has been sustained interest among coaches about the potential of sports vision training (Ferreira, 2003) and this study may be able to contribute to an understanding of these kinds of interventions. The results of this study may also be helpful for researchers interested in methods for improving visual perception in sport. The particular aspects of the model tested in this study involved using object and location cues to challenge gaze control as a way to develop anticipation, attention and focus and concentration. This emphasis on the vision training dimension to the programme may encourage sports vision specialists and optometrists to look at the Decision Training Model as a possible direction for their future investigations.

Methodology

This experimental study followed a repeated measures design with three groups. All of the subjects (*N*=21) involved in the study were volunteers who played cricket at the top level of university competition. There were three groups involved in the study; two of which were randomly formed and a third group which for practical reasons had to remain intact.

The independent variable was the perceptual-motor training programme, and the dependent variables were the players' coincident anticipation timing and their performance on a cricket batting test. The experimental group (*n*=7) partook in a four week perceptual-motor training programme designed using the principles of Vickers' (2007) Three- Step Decision-Training Model, the placebo group (*n*=7) partook in four weeks of whole-body coordination training and the control group (*n*=7) received no intervention. An Inter-class Correlation Coefficient was completed on the "good contact" scores of the batting performance pre-test in order to determine whether the experts understood how to correctly score the contact type. The data from the three groups pre-, post-, and retention tests were compared using a Kruskal-Wallis ANOVA by Ranks Test, while the differences within each group were compared using multiple Mann-Whitney U tests where appropriate.

Limitations

The following limitations must be taken into consideration when reading the results of this study:

- The number of subjects in each group (n=7) was small. Justification for group size was based on the need for participation to be truly voluntary since a four-week intervention programme was involved for both the experimental and placebo groups.

- Injuries are a common occurrence in sport and two subjects were unable to complete the post- and retention tests of batting performance.

- The use of an intact group was problematic. These players indicated that they could not be in either of the intervention groups (experimental or placebo) since they felt they would be selected for the provincial squad. If that happened, they said they would not be able to complete an intervention programme. This meant that the players in the so-called control group also might have been slightly better cricket players than the others, which could have an effect on the pre- and post-test scores.

Summary

The search for an effective perceptual-motor control training programme to enhance sporting performance is ongoing. Perceptual-motor training has long been investigated with many different kinds and variations of visual/perceptual-motor training programmes being developed claiming to improve the athletes understanding of the sporting environment, as well as the sporting skill of the athlete. This has lead to the growth of scientific and applied research into perceptual-motor training programmes in order to establish if these programmes do in fact affect sporting performance and therefore warrant being included into an athlete's training regime. Some have been found to improve sporting performance, whereas others have been found to have no influence on sporting performance.

Research into the gaze control of athletes has yielded some positive results which could be practically applied to the development of perceptual-motor training programmes. However, there is a distinct lack of research involving gaze control in the game of cricket, and in particular the skill of cricket batting. A particular model of interest that aims to improve gaze control through improved decision making is Vickers (2007) Three-Step Decision Training Model. This model has been applied to many different sports with success but has yet to be applied to cricket batting. By testing one application of this model, the results of this study may help sport scientists determine if the Three-Step Decision Training Model is a promising approach to implementing perceptual-motor training programmes. If the decision training approach can produce improvements in perception (*e.g.* coincident anticipation timing) and in motor performance in dynamic situations (*e.g.* batting performance), coaches and athlete's may want to consider learning more about how to add it to their options for training to improve their sporting performance.

The purpose of this study was, therefore, to determine the effects of a perceptual-motor training programme based on Vickers' (2007) Three-Step Decision Training Model on the coincident anticipation timing and batting performance of cricket players. The specific focus of the programme was to development the players' anticipation, attention, and focus and concentration skills though variable and random practice activities that, in the end, would help players make decisions about their batting performance based on object and location cues.

Chapter Two

Review of Literature

Cricket has been through many changes over the last decade as the game has been promoted to a larger audience in order to increase participation at grass roots level, expand media coverage and attract more sponsorship (Scott, Kingsbury, Bennett, Davids & Langley, 2000). At present, a cricket match may take one of three forms. Test match cricket is played over five days. A good batting innings lasts at least several hours and can extend to several days (Stretch *et al.*, 2000). In the accelerated forms of the game, teams are limited to the number of overs they are allowed to bat (50 overs or 20 overs). The team at bat tries to score as many runs as possible in their allotted overs without losing 10 wickets, which would result in their team being out before they took their full quota of overs.

Each form of the game emphasizes different aspects of the game in order to be successful. For example, a common batting strategy in a Twenty20 limited overs game is to score as many runs as possible in the short, 20-over period by trying to hit as many boundaries (fours or sixes) as possible and while limiting the number of balls where no runs are scored. In a five-day test match, the strategy may be for batsmen to occupy the crease for as long as possible and to accumulate runs over an extended period of time. Cricket players who want to play all forms of the game must be able to adjust their cricket skills to the technical and tactical requirements of a wide variety of possible game situations. In all forms of the game, however, every player must be prepared to be a fielder and to be a batsman.

Bartlett (2003) remarked that the critical confrontations in cricket are often more individual vs. individual than they are team vs. team. The game itself is played on a field that is oval-shaped and encircled by a boundary rope or marker. Woolmer, Noakes and Moffett (2008) described the field as having an east-west measurement of at least 128m and a north-south measurement of at least 109.72m, with a pitch 20.2m long with wickets at either end approximately in its centre. The pitch is where the batsmen attempt to score runs by hitting balls delivered by the bowler into the playing field, and where bowlers try to limit the number of runs scored by getting the batsmen out (*i.e.* taking wickets).

The contest between the bowler and the batsman is the classic example of the individual vs. individual competition. One way that bowlers try to limit the number of runs scored by batsmen is by testing the precision with which they can react to changes in speed (Regan, 1997). Bowlers use their hand and arm to direct a cricket ball towards batsmen at speeds of up to 160 km/h (Regan, 1997; Dash, 2010). Batsmen have to attempt to defend themselves and their wicket with only a 10.8 cm wide wooden bat to either hit the ball or to block it (Müller, Abernethy & Farrow, 2006). Müller *et al.* (2006) estimated that batsmen may have as little as 500 ms from the time the bowler releases the ball until they have to strike it with their bat. This places a tremendous amount of stress on the response timing of batsmen (Müller, Abernethy, Reece, Rose, Eid, McBean, Hart & Abreu, 2009).

The speed of the ball is not the only challenge to batsmen's timing. The ball is usually bowled so that it hits the pitch before it reaches a batsman. If a fast bowler couples ball velocity with any lateral movement of the ball during its flight, batsmen may be deceived and incorrectly predict the landing place of the ball (Stretch *et al.* 2000). Batsmen who make this mistake often select the wrong shot to try to play, which makes it very difficult to make good ball contact (Müller *et al.*, 2009). When the ball strikes the pitch, its flight path can suddenly deviate either laterally or vertically depending on whether the ball hits the leading or trailing edges of a crack on the pitch (Müller & Abernethy, 2006). This puts still more pressure on batsmen's response timing.

Spin bowlers deliver the ball at a lower velocity than fast bowlers. Müller *et al.* (2009) estimated that the average delivery ranges between 70 and 80 km/h. Spin bowlers vary the trajectory and velocity of early ball flight in order to confuse the batsmen and make it very difficult to predict where the ball will hit the pitch (Sparrow, Shemmell, Shinkfield, 2001). The spin bowler can also place different actions on the ball so that the flight path of the ball after it hits the pitch is erratic.

This can makes it very difficult for batsmen to make good contact with the ball (Müller *et al.*, 2009).

The lateral deviation of the ball as it bounces off the pitch is a unique problem for cricket batsman that is not encountered in other batting sports, such as baseball and softball, where the ball does not bounce before it is hit (Wilson & Falkel, 2004). This may be why Land and McLeod (2000) described cricket batting as a contest between the visual-motor skills of the batsman and the skills of the bowler. They concluded that the limits of the human visual-motor system may be tested by the most skilful bowlers. Thomas, Harden and Rogers (2005) agreed and stated that the development of the visual-motor system is the key to skilful batting. Dash (2010) explained that cricket specifically requires batsmen to learn to adapt their gaze control to changes in the flight path of the ball both before and after it hits the pitch. This means that batting in cricket is one of the most demanding skills in sport in terms of visual-motor coupling (Tourky, Bartlett, Hill & Jeh, 2005).

The following chapter reviews literature that describes the role of vision in sport performance and shares the results of research into expert-novice differences found in visual skills with special reference to cricket batting. Visual-motor control is then discussed in the context of an interceptive timing task such as batting, and the role of coincident timing is introduced. The chapter concludes with a sample of some of the studies that have tried to measure the impact of visual skills training programmes on sport performance. The equivocal results of this body of research are given as support for further investigations looking at the effectiveness of alternative methods of training vision for sport.

Vision and Sport Performance

The visual system is a highly complex and integrated system. In an effort to provide clarity for professional purposes, Gardner and Sherman (1995) suggested that sight be distinguished from vision, defining sight as “the ability of the eye to resolve detail and to see clearly” and vision as “the interpretation of that which is seen (*i.e.* the ability to gain meaning from what the eyes see)” (p. 22). This division of the functions of the visual system into two types of variables was compatible with earlier work by Abernethy (1986), who suggested that the visual system can be thought of in terms of “hardware” and “software” components. The limiting factors on the functional capacity of the hardware components included the physical characteristics of the ocular system. He associated the software components with “vision as perception” and suggested that the limiting factors on the software components were the strategies for visual search and the cognitive knowledge for interpreting visual information

The proposal that there were functional components within the visual system that could be characterised as “hardware” and “software” was intended to be helpful for understanding which visual components might benefit from sport-specific training (Abernethy, 1991). Ferreira (2003) cautioned that the term “hardware” implied that the visual components in this category were structurally fixed and cannot be improved. He preferred the term “information gathering visual abilities.” He noted that these visual abilities were properties of the physical structure of the visual system and that their optimal functioning was a matter of ocular health – a health that could be affected by many factors, some of which can be controlled and/or corrected. He felt it was critical to optimalise the functional capacity of the visual “hardware” abilities because they set limits on the development of software skills.

Ludeke and Ferreira (2003) defined the hardware components of vision as non-task specific abilities that are resistant to change. They identified ocular health, visual acuity, accommodation, fusion and depth perception as examples of visual hardware. These structurally-fixed components or the hardware of the visual system may set the potential limit to visual performance in sport. Once any deficiencies have been addressed, it is the visual-perceptual or software skills that may separate the expert athlete from the non-expert athlete (Ferreira, 2003). Ludeke and Ferreira (2003) identified visual perception, visual concentration, visual-motor response time, central peripheral awareness and visualisation as examples of visual software.

According to Williams, Davids and Williams (1999), visual software skills have a cognitive component that supports the processing of information, *e.g.* “the analysis, selection, coding, retrieval, and general handling of the available visual information" (p. 61). Although the functional effectiveness of visual-perceptual skills may be limited by visual hardware and cognitive development, they are regarded as visual skills that can be improved through experience/learning (Magill, 2003). Because visual coincident anticipation timing involves the perception of visual information, it is also regarded as visual software that may respond to training.

Expert-Novice Differences

Ludeke and Ferreira (2003) tested the proposition that if software skills benefit from learning and practice, then there should be expert-novice differences in visual skills proficiency. In their study of 95 rugby players, central-peripheral awareness, eye-hand coordination, eye-body coordination, visual reaction time and visual concentration (all software skills of the visual system) were tested. The professional players performed better than the novice players on most of their tests, supporting an expert-novice difference in software skills.

Venter (2003) completed research in rugby that compared older to younger players on a variety of so-called hardware and software skills (Table 1). The visual software skills of eye-hand coordination, eye-body coordination and visual reaction times of the older players were significantly better than the younger players, which she expected since software skills rely on learning and practice. However, in some cases the older players were not as proficient as the younger players in their visual hardware skills. This led her to conclude that some players may not have reached the full physical potential of their visual hardware skills and as a result might benefit from some kind of intervention.

Other studies investigating the expert-novice difference have been conducted on a wide variety of open and closed skill sports:

- Badminton (Abernethy & Russell, 1987)
- Field hockey (Starkes, 1987)
- Table tennis (Hughes, Blundell & Walters, 1993; Ripoll & Latiri, 1997)
- Soccer and softball (Christenson & Winkelstein, 1988)
- Snooker (Abernethy, Neal & Koning, 1994)

Table 1

Examples of the visual hardware abilities and visual software skills studied by Venter (2003)

Visual Hardware Abilities (information gathering)	**Visual Software Skills (information processing)**
Static Visual Acuity	Eye-hand Coordination
Dynamic Visual Acuity	Eye-body Coordination
Contrast Sensitivity	Visual Reaction Time
Colour Discrimination	Central Peripheral Awareness
Stereopsis	Visual Adjustability
Focus Flexibility	Visualisation
Fusion Flexibility	

These studies found no expert-novice differences with regards to the hardware component of the visual system. However their results did confirm that there were differences in experts' who did display an advantage over novices in terms of their cognitive processing of visual information (software component).

Cricket-specific Research

Research on batting and cricket has generally supported findings from other sports. Expert-novice differences have been found for visual software skills but not for visual hardware. For example, Mcleod and Jenkins (1991) completed a study in which expert cricket batsmen and non-cricketers were compared on a cricket-specific simple reaction task. Subjects were expected to react to a ball bowled to them onto an uneven surface. Results of the study showed that even the expert cricket batsmen's simple reaction times were no faster than that of normal subjects.

Land and McLeod (2000) studied the eye and head movements of cricket batsmen (*N*=3) at different levels of play: professional (expert), successful amateur (intermediate) and low-level club (novice). The eye movements of the batsmen were measured with a head mounted eye camera which recorded the view from their left eye, as well as the direction of the fovea's gaze. Each batsman faced either 36 or 48 balls which were projected at 25 m/s from a bowling machine 18.5 m away from the batsman. The batsmen were encouraged to play naturally, playing each ball in either a defensive or offensive way as they saw fit. The results showed that the batsmen's overall visual strategies were similar. However, there were important differences:

- The expert batsman used significantly more pursuit tracking than either the intermediate or novice cricketers, both of whom relied more on a combination of and pursuit tracking.

- The novice batsman was also slower to respond to the initial appearance of the ball than either the expert or intermediate batsman, taking at least 0.2 s to initiate a saccade.

Land and McLeod (2000) concluded that the speed of the initial saccade to the ball was a critical factor in successful batting performance that distinguished intermediate and expert batsmen from novices. They also identified the expert's proficiency in combining the two tracking skills (*i.e.* pursuits and saccades) as he locates the bounce point of the delivery as one of the characteristics that separates him from the intermediate level batsman.

Müller and Abernethy (2006) studied the ability of cricket batsmen to pick-up visual information from the pre-release movement patterns of the bowler, the pre-bounce ball flight, and the post-bounce ball flight. In their study, six highly skilled batsmen (expert) and six low skilled (novice) batsmen batted against three different leg-spin bowlers while wearing liquid crystal spectacles. These liquid spectacles permitted the information available on each ball delivery to be manipulated, so that their vision was either:

1. Occluded at a point before the point of release of the ball.

2. Occluded at a point prior to the point of ball bounce.

3. Not occluded.

Each batsman faced at least 45 deliveries in rotating blocks of six by each bowler. The three leg-spin bowlers were instructed to bowl three different types of delivery: A full length leg-spinner, a full length "wrong-un" and a short length leg-spinner. Each batsman's trials were recorded. After video analysis of the full length deliveries:

- No differences were found between experts and novices in the percentage of bat-ball contacts when vision was occluded pre-release of the ball.
- There was a performance advantage for expert batsmen under the pre-bounce condition. Their contact percentage increased significantly from their pre-release occlusion trials to the pre-bounce occlusion trials.
- Novice batsmen did not achieve significant improvements in their contact percentage under either the pre-bounce occlusion trials or the no-bounce occlusion trials.

Initial ball flight apparently provided visual information that the experts were able to use more effectively than the novices, which in turn allowed them to achieve more bat-ball contacts on full length deliveries. These results were the same when the researchers screened the data to count only the "good" bat-ball contacts.

Müller and Abernethy's (2006) video analysis of the short length deliveries revealed a different pattern. They found that the experts had significantly more bat-ball contacts compared to the novices in only the no occlusion condition. The experts did significantly improve their number of contacts between the trials in the pre-release and the pre-bounce conditions, but the novice batsmen did not. Therefore, like in the case of the full length deliveries, pre- and post-bounce ball flight seemed to contain information that experts were able to use better than novices in order to make bat-ball contacts.

When only "good" contacts were considered on the short length deliveries, expert players achieved significantly more good contacts than the novice players only under the no occlusion condition (Müller & Abernethy, 2006). The experts achieved a significant improvement in good contacts between the pre-release and pre-bounce conditions, as well as between the pre-bounce and no occlusion conditions. The novice players showed significant improvement in good hits only between the pre-bounce and no occlusion conditions. While both the experts and the novices showed an ability to use information from post-bounce ball flight to improve good bat-ball contacts, the experts also gained valuable information from pre-bounce ball. Müller and Abernethy (2006) concluded that expert cricket batsmen have superior visual perception that allows them to make use of earlier ball flight (pre-bounce) information to make more successful bat-ball contacts (interception), when compared to novice cricket batsmen.

Eye Dominance as a Consideration

Questions around the role of eye dominance in relation to vision in sport have been of recurring interest to coaches and scientists (Pointer, 2008). Knudson and Kluka (1997) defined the dominant eye as the eye that processes and transmits information to the brain a few milliseconds faster than the other eye. Kluka (1991) proposed that the dominant eye helps to guide the movement and fixations of the other eye. It is sometimes referred to as the preferred eye and they reported that most people have one. Just as most people are either right-handed or left-handed, most people are also either right-eye or left-eye dominant. Shneor and Hochstein (2006) agreed with this and found in their study that the dominant eye seems to have priority in the visual system when it comes to processing information.

Previous research exploring the relationship among eye dominance, hand dominance and sport performance in a number of different sports has been conducted:

- Brown, Tolsma, and Kamen (1983) conducted a study to determine the relationship between eye dominance and handedness and preferred direction of rotational movements in gymnasts and non-athletes. They found no consistent correlations between twist direction, and either eye dominance or handedness in either experienced gymnasts or non-athletes.

- Abernethy *et al.* (1994) investigated whether there were significant differences on a range of general visual tests and sport-specific perceptual and cognitive tests in snooker players, with eye dominance forming one of these tests. No significant expert-novice difference was found for the eye dominance of the snooker players.

- Classe, Daum, Semes, Wisniewski, Rutstein, Alexander, Beisel, Mann, Nowakowski, Smith and Bartolucci (1996) investigated the effect of eye dominance on the batting skill of baseball players and concluded that eye dominance did not affect batting skill.

- Laby, Kirschen, Rosenbaum and Mellman's (1998) study involved determining whether a performance difference existed between baseball players with "same" (right-right) and "crossed" (right-left) hand-ocular dominance. They concluded that hand-ocular dominance did not have an effect on the batting average or earned run average (ERA) of baseball players.

- Griffiths (2003) investigated the eye dominance of tennis players (interceptive timing task) and clay shooters (targeting task) and found that tennis players performance was not affected when their dominant eye was occluded; however the clay shooters performance deteriorated when their dominant eye was occluded.

- Sugiyama and Lee (2005) investigated the relation of eye dominance with performance and subjective ratings in golf putting. Their findings suggest that eye dominance could have some influence on putting performance of Japanese novice golfers.

- Pointer (2008) investigated the sensory-motor lateral preferences of amateur motorsport drivers and found that the eye-hand dominance of motorsport drivers was no different to a non-motorsport population.

Steinberg (1999) was convinced that the dominant eye controls many important visual motor functions, one of these being the ability to aim accurately. The author concluded that the dominant eye should play a significant role in the development of sport skills in aiming tasks (*e.g.* archery and putting in golf) to skills in faster-paced sports such as in cricket. The premise for the central role of the dominant eye in a sport like cricket was the assumption that the dominant eye leads the focus of attention toward any external stimuli such as an oncoming ball. However, if one accepts Vickers (2007) position that the visual system is challenged differently in different kinds of visual-motor tasks (*i.e.* target tasks, interceptive timing tasks and tactical tasks), the effect of eye dominance on visual-motor control would require sport skill and sport situation specific research before drawing conclusions. No evidence was found that eye dominance has an impact on batting proficiency in cricket.

Visual-Motor Control

The way in which visual information is used to guide action is known as visual-motor control (Vickers, 2007). Visual-motor control is based on a linking of perception (the acquisition and processing of visual information from the environment) to action (the activation of coordinative structures to effect motor performance). If visual hardware provides the structural constraints when receiving visual information and visual software provides functional constraints during the perception of this visual information, then visual-motor control is the effectiveness of the coupling of this perception to the action. Because vision provides a constant stream of information for initiating, as well as fine-tuning the stroke of the bat in cricket, cricket batting is considered a classic example of a visually-guided action in sport. According to McLeod and Jenkins (1991), batting in cricket is an example of the visual-motor system operating at its limits.

Batting and Visual-Motor Control

From a motor control perspective, batting in cricket is categorised as an interception or dynamic interceptive timing task (Stretch *et al.,* 2000). Mann, Ho, De Souza, Watson and Taylor (2007) defined an interceptive task as one that involves an actor perceiving relative motion with, and formulating a response to, a targeted object. Stretch *et al.* (2000) explained that in order to be successful at any interception tasks, players need precise information in order to estimate where the ball will be and when it will be there. Marinovic, Plooy and Tresilian (2009) provided a cricket-specific definition, describing the interceptive action of hitting a ball in cricket as initiating movement at an appropriate moment in time so that the bat reaches a specific location on the path of the ball. The arrival of the bat must be coincident with the arrival of the ball.

In fast ball sports in particular, players depend on their visual systems to provide them with the information they need to make decisions and take actions in an environment characterised by rapidly changing circumstances (West, Calder & Bressan, 1995). Successful performance in ball sports relies heavily on the visual system to help produce extremely accurate visual coincident anticipation timing behaviour (Ripoll & Latiri, 1997). For example, top class cricket batsmen are able to accurately intercept balls that travel at a variety of different speeds on a variety of different and unpredictable pathways (Atchison, Mon-Williams, Tresilian, Stark & Strang, 1997).

The Role of Coincident Anticipation Timing

Intercepting objects is made more difficult when players need to move their bodies in response to other demands of the sport situation (Knudson & Kluka, 1997). Cricket batsmen need to coordinate their body movements in order to swing a bat with a high degree of precision to intercept a fast moving ball (Müller & Abernethy, 2008) yet at the same time remain balanced as they shift their weight during the shot. The actions of a batsman are initiated at a precise time in order to coincide with the arrival of the ball at a place where it can be directed successfully out into the field of play (Abernethy, Wann & Parks, 1998). In other words, the batsmen's coincident anticipation timing needs to be precise in order to successfully make contact with the ball, making visual coincident anticipation timing one of the most important visual abilities in cricket (Morwood & Griffiths, 1998).

Despite the acknowledged importance of coincident anticipation timing in interceptive tasks, Mann *et al.* (2007) explained that the nature of motor control during interceptive timing tasks has not been finally determined. Traditional information-processing models have used the predictive model of control. In these models, a prediction of where and when the ball will arrive at a particular location is based on past experiences and then associated with a motor response stored in the memory (Regan, 1997; Mann *et al.*, 2007). Once the motor response is decided upon, it is initiated as motor commands and performance is executed.

A more dynamic type of process characterises the ecological models of motor control. A coupling of perception and motor actions is proposed up to and past the point of interception. Stretch *et al.* (2000) suggested that the perception-action coupling was more descriptive of the control of cricket batting than the information processing approach. Research by Williams, Singer and Frehlich (2002) found that vision was used continuously during interceptive tasks. Renshaw and Davids (2004) supported this finding and stated that as an object approaches there is a continuous interaction of the visual system, the skeleton-muscular system, and the environment to provide a constant flow of perceptions about position of the ball. Mann *et al.* (2007) noted that even after performance was initiated, performers were able to make adjustments according to a continuous flow of perceptions about the environment.

Visual Skills and Visual-Motor Control

The role of effective visual skills in gathering and processing visual information was logical even if not fully understood. If athletes could not “move their eyes quickly and effectively” deduced Wilson and Falkel (2004), they could not perform sport-specific tasks to the best of their ability. The need to keep track of the fast movements of a cricket ball meant that cricket players needed to have quick eye movements to Griffiths (2002), and Witt and Proffitt (2005) were certain that “seeing the ball well” would improve batting performance.

Different authors have presented different time frames for the phases of batting in cricket. For example, Muller *et al.* (2006) estimated that it takes approximately 500 ms from the time the bowler releases the ball until it reaches the batsman, and Woolmer *et al.* (2008) estimated that it takes approximately 300 ms to make the visual-based decision whether or not to play at the ball. They concluded that for certain shots to be successful there were only a few milliseconds available for timing errors by the batsman.

Visual Skills

Ferreira (2003) identified visual software skills, including the perceptual skills linked to visual-motor control, as the one component of the visual system that may most directly benefit from training. He noted that visual hardware abilities (information gathering hardware) do need a stimulating environment in which to develop normally, but they appear to be structural constraints that fall under the scope of practice of an ophthalmologist or an optometrist. From the sport science perspective, the emphasis should be on the design and implementation of practice activities to help sportsmen and women improve their capacity to use visual information in order to control motor skill performance (Erickson, 2007).

Vickers (2007) decided to focus her sport-specific programmes on the development of gaze control, which she equated with a combination of fixations and pursuit tracking (a software skill involving the ability of the eyes to smoothly follow an object through space) as well as saccadic eye movements (a software skill involving the quick jump of the eyes from one point to another). Her intervention activities were designed to challenge players to control where they were looking to gather visual information. This is similar to training visual search. Magill (2003) defined visual search as “directing visual attention to locate the information in the environment that will enable a person to determine how to prepare and perform a skill in a specific situation” (p.153). Visual search is a visual skill and is influenced by practice and past experience in similar situations.

Training Visual Skills

Considerable literature has been published about vision and sport, although consensus has not been reached about the potential to improve their visual skills through specialised training. Even those studies that have shown improvements in visual skills through training have not been able to state categorically that these improvements have a positive effect on sport performance (Kunicki, 1997). Despite this gap in the research, authors such as Knudson and Kluka (1997), Wilson and Falkel (2004) and Zupan, Arata, Wile and Parker (2006) have contended that visual skills performance can be trained and improved through specific exercises just as athletes use sport-specific drills to improve overall sporting performance. Wilson and Falkel (2004) explained that overloading the visual system during sport-specific training helped players deal with the visual and physical challenges of performance so that they could perform at an advanced level more efficiently in competitive situations. Meir (2005) felt that the same should hold true for the cricketer's visual system and that it should be trained just like every other aspect of performance.

Zupan *et al.* (2006) acknowledged that improvements in the performance of visual skills do not necessarily produce better performances on the playing field. There are those that say that improvements in the laboratory are transferrable to on-field performance and there are those who say that they are not transferable.

Support for Transferability to Sport Performance

Quevedo and Solé (1995) implemented a visual training programme to improve visual skills of precision shooters and then determined if improvements in laboratory performance were transferrable to on-field performance. The visual skills programme was specifically designed to enhance the visual skills needed for precision shooting. The shooters attended 22 clinical and 27 individual vision training sessions. Each clinical session lasted between 30-40 minutes and the individual sessions lasted between 10-15 min. With regards to the precision shooting, the results of the study showed significant improvements in precision shooting:

- 73% of the subjects obtained their personal record while following the visual skills training programme.
- Every subject had significantly improved their performance and these improvements were greatest for those subjects who initially had lower pre-test shooting results.

When Quevedo and Solé (1995) then looked at the shooting scores obtained three months after finishing the programme, they found the mean groups scores not only decreased by 0.92 points from the post-test mean but also was less that the pre-test mean. In fact, 54.54% of the subjects obtained scores below the average pre-test scores, 22.27% been able to maintain their score, and only 18.18% had been able to remain above the pre-test average. They concluded that although their visual training programme had been highly effective in its immediate impact on performance in competition, it should have been sustained for a longer period.

West and Bressan (1996) studied the effects of a general visual skills training programme versus a specific visual skills training programme on the accuracy of judging the length of deliveries by cricket batsmen. The subjects (*N*=18) were divided into two experimental groups and one Control Group. Experimental Group 1 received the general visual skills training programme and Experimental Group 2 received a cricket-specific visual skills training programme. The Control Group received no visual skills training. Pre- and post-tests were administered that measured visual skills as well as a field test where subjects had to judge the "length of balls" bowled by cricket bowlers after it passed under an occlusion screen. Both the general and the specific visual skills training programmes were conducted five times per week for three weeks. The results of the study revealed that:

- Only the subjects who took part in the general visual skills training programme improved in all four of the visual skills that were tested. The subjects who took part in the specific visual skills training programmes showed an improvement in only two of the four skills. The control group also achieved a slight improvement in two visual skills.

- With regards to the "length of ball" test, the general visual skills training group showed the greatest improvement in their accuracy in judging the length of deliveries, and improved their pre-test to post-test scores by 14%. The specific visual skills training group also improved, but only by 8% and the control group improved by only 2%.

West and Bressan (1996) explained that the superior improvements by the general visual skills training group highlighted a number of issues surrounding visual skills training. First, the visual skills selected for training must be critical for processing information during the sport situation targeted for improvement and the training activities must be highly relevant. Second, the tests selected to measure visual skills must be valid and reliable. Third, participants in a programme might be at different levels of visual skills development. Less proficient players might benefit more from general (fundamentals) training while more proficient players might benefit from more specific programmes. Finally, the assessment of on-field transfer must be ecologically valid (*i.e.* a true reflection of the demands of the sport).

Williams, Ward and Chapman (2003) conducted research on the transferability of perceptual training in the laboratory to on field performance of goalkeeping in field hockey. The subjects (*N*=24) were female field hockey players who played at the university level, but none of them had ever played goalkeeper (*i.e.* they were novice goalkeepers). The subjects were divided into three groups (experimental, placebo and control). Footage of four experienced players taking penalty flicks was captured from the perspective of the goalkeeper's view of the action. The video clips from two of the players were used to create the pre- and post-tests, and the video clips from the other two players were used for the training programme for the experimental group.

The laboratory pre- and post-tests involved using the clips of the penalty flick and projecting them in a sequence onto a large screen (Williams *et al*., 2003). The subjects were positioned 5 m from the screen so that the image of the penalty taker was on a visual angle of approximately 80°, which provided a nearly life-size image. The subjects were required to wear all the correct protective goalkeeper equipment. Each subject had five practice trials and 20 test trials. The subjects were instructed to respond quickly and accurately to the video projection of each penalty flick by moving as if to intercept the ball before it crossed the goal line. They were instructed to not move before the ball had been struck, as per official regulations. The subject's response was filmed using a digital video camera placed slightly to the subject's side. This image was recorded in sync with the projected test clip.

The field test required goalkeepers to move in response to "live" penalty flicks (Williams *et al*., 2003). The subjects received five practice trials and 20 test trials, with each penalty taker having 10 penalty attempts at the regulation distance of 6.4 m away from the goal line. The subject's actions were recorded using a digital video camera positioned behind and slightly to the right of the penalty taker. The camera was positioned so that both the goalkeeper's and the penalty taker's actions were clearly visible within its field of view. This was done so that the movements could be analyzed by the researchers, with respect to each other, at a later stage.

After pre-testing, Williams *et al*. (2003) provided a 45-minute individual video-based perceptual training session to each member of the experimental group. Each subject viewed a training tape containing 20 randomly placed penalty flicks. Instruction was provided pointing out the important information cues to help the subjects anticipate the speed and direction of the ball. Once the subjects had received feedback, a further 10 penalty flicks were shown to the subjects using a progressive temporal occlusion paradigm. These clips were initially occluded six video frames after ball contact, and the subject's were then required to verbally indicate where the ball was likely to end up. The subjects received further feedback regarding correct performance. Finally, the subjects were required to respond to a series of 10 clips that were occluded at impact, and once again feedback about their performance was provided.

The placebo group in the Williams *et al*. (2003) study watched a 45-minute instructional video focusing on field hockey goalkeeping skills. They were informed that the training tape was expected to have a positive effect on their goalkeeping performance. This was done in order to provide an expectancy set for training benefits that were comparable to that of the perceptual training group. No additional training information was provided. The control group received no training or feedback. The post-tests were followed by an analysis of differences in the decision time (time period from stick-to-ball contact by the penalty taker and the initiation of movement by the goalkeeper) and response accuracy (the accuracy of the response relative to the ball's intended destination). The results indicated that:

- The subjects who underwent perceptual training significantly reduced their decision time. The researchers concluded that this difference could be attributed to an improvement in anticipation because the subjects had been taught what object and location cues gave advanced insight into the speed and direction the flick.

- Although there were no changes in response accuracy as a result of perceptual training, subjects did maintain levels of accuracy similar to their pre-test scores (they got faster without losing accuracy.

- In contrast, no significant pre- to post-test differences in performance were found for the subjects in either the control or the placebo group.

According to Williams *et al*. (2003), the improvements in performance in the perceptual training were matched by their post-test performances on the field test. They concluded that this demonstrated that laboratory-based perceptual training could have a positive effect and was transferable to on-field performance of sport skills.

Bowen and Horth (2005) investigated the use of an electronic vision training device (EYEPORT™) on the visual performance of Little League baseball players. The EYEPORT™ is a 36 inch light-tracking machine that has 12 light emitting diodes (LED's) in a row that alternate in colour between red and blue. The product was designed to improve the speed and accuracy of visual tracking. Pre- and post-testing involved the subjects facing 40 balls in an outdoor batting cage. The balls were pitched towards the subjects at 50 mph from a pitching machine that was set to deliver an overhand throw. The researchers recorded the total number of hits, fouls, and misses for each subject. After pre-testing, the subjects were each given an EYEPORT™ to take home and were instructed on how to train. The subjects completed a daily 10-minute session on the system for three weeks, six days per week. The post-test established that:

- There was a 34% average improvement in players' making contact with the ball.

- There was a 90% average improvement between pre- and post-test scores for making solid contact with the ball.

Although this study had limitations which were acknowledged by Bowen and Horth (2005) (*e.g.* no control group and a small sample size), they stated that the size of the improvement in ball contact in such a short time was compelling evidence for future studies of visual skills training.

Gabbett, Rubinoff, Thorburn and Farrow (2007) investigated the use of video-based perceptual training to improve anticipatory skill in softball fielders. The subjects (*N*=25) were randomly allocated to one of three groups: A video-based perceptual training group (*n*=9), a placebo training group (*n*=8), and a control group (*n*=8). The perceptual training group took part in a four-week video-based intervention programme of 12 sessions (each 10 minutes long). The placebo group watched a video presentation of series of arrows that directed them to move either to the left or to the right and were told it was a kind of reaction intervention.

Decision accuracy and speed were pre- and post-tested in the laboratory by Gabbett *et al.* (2007) by having the fielders respond to a video presentation of a batter. A practical test of fielding was also administered to determine if anticipation skills could be transferred to on-field performance. Finally, a retention test was conducted four weeks later. After analysis of the data, it was found that:

- The video-based perceptual training group had superior decision accuracy and faster decision times than both the placebo and the control group in the laboratory based test.

- They attributed these improvements to improved anticipation and noted that the subjects in the experimental group also performed better on the field test than subjects in the other groups, suggesting that positive transfer had occurred to on-field performance. They also noted that these improvements were retained after a four week, non-training period.

Gabbett *et al.* (2007) concluded that video-based perceptual training could improve decision accuracy and decision time in a game-specific task, and that these improvements were associated with improved anticipation that could be transferred to the on-field environment.

A more recent and cricket-specific study by Balasaheb *et al*. (2008) investigated the impact of visual skills training on the batting performance of cricketers. The subjects (*N*=30) were club level male cricket batsmen who had played at least one year of competitive cricket. They were randomly divided into an experimental, placebo and control group. Pre- and post-testing were conducted on the visual variables of depth perception, horizontal and vertical saccades, accommodation, and simple reaction time and movement time. Batting performance was assessed by recording the subjects batting average from five matches played before and five matches after the intervention programme. The subjects in the experimental group received six weeks of visual training exercises, three times per week, with each session been 30 minutes in duration. The subjects in the placebo group were given reading material and watched televised Twenty20 cricket matches for six weeks. The control group followed the same daily cricket training with the other two groups (batting practice, catching practice, and fielding drills) but received no supplementary training. After analysing the data, the following was reported:

- The experimental group significantly improved their horizontal and vertical saccades.
- Movement time significantly improved for all three groups however the experimental group improved more than either the placebo or the control group.
- Reaction time significantly improved in the experimental group, and no improvement was seen in the placebo and the control group.
- There was also a significant improvement in the accommodation facility for the experimental group when compared to both the placebo and the control group.
- In terms of batting performance, all groups achieved significant improvements in their performance. However, the improvements achieved by the experimental group were significantly greater than those of either the placebo or the control group.

Balasaheb *et al*. (2008) attributed the improvement in batting performance by all groups to the “practice effect” because they all had the same regular cricket practice during the study period. However, the significantly greater improvements by the experimental group led them to conclude that the visual skills training had indeed made a contribution and cited their improvements in reaction time, movement time, saccadic eye movements and accommodation facility as evidence that visual skills training had transferred to batting performance.

Doubts about Transferability to Sport Performance

There is other research that has not been able to find results that support the transfer of visual skills training to on-field performance. Wood and Abernethy (1997) assessed the effectiveness of sports vision training programmes in a study of 30 subjects with no previous experience in racket sports. The subjects were divided into three groups. The experimental group received vision training, the placebo group read about tennis and watched recorded tennis games on television, and the control group received no special training. The intervention programme for both the experimental and placebo groups involved four weeks of training consisting of four 20-minute training sessions per week, as well as one 20 minute session of motor practice per week. The control group only received one 20-minute motor practice session per week. Pre- and post-testing were conducted on the following visual skills: static visual acuity, dynamic visual acuity, heterophorias, accommodation, vergence, stereopsis, depth perception, colour vision, reaction time, visual field size, eye movement skills, rapid ball detection, anticipation, and coincident anticipation timing. Pre- and post-testing was also conducted on the tennis forehand drive for accuracy, to see whether visual training could transfer to improvement in sports performance.

The results of the Wood and Abernethy (1997) study led the researchers to conclude that visual training does not necessarily transfer to sports performance and that research citing improvements in either sport performance or visual skills performance might only be providing evidence of test familiarity.

In a similar study, Abernethy and Wood (2001) again investigated whether visual training programmes for sport really work. They conducted a study involving 40 subjects who had no previous competitive experience in racquet sports. The subjects were divided into four groups. Experimental Group 1 was trained using exercises from a commercially available sports vision training programme. Experimental Group 2 was trained using a commercially available sports vision videotape-based programme. Group 3 was the placebo group and they watched televised tennis matches and read about tennis. Group 4 was the control group and they received no specialised training. All groups participated in one 20-minute tennis training session per week.

All the groups in the Abernethy and Wood (2001) study were pre- and post-tested on their visual function (static visual acuity, dynamic visual acuity, phoria, accommodation, vergence, stereopsis, depth perception, reaction time, field of view, peripheral response time, eye movement skills, and coincident anticipation timing) and their tennis forehand drive for accuracy. The results of this study agreed with their previous work, which led them to conclude that generalised visual training programmes did not appear to produce improvements either in basic visual function or in motor performance.

Vision Training and Decision Training

The uncertainty about the effectiveness of laboratory-based visual skills has a long history, and there has been little research that has taken visual skills training out on to the sports field.

Vision Training vs. Visual Skills Training

The logical application of visual skills training in practical sport settings was investigated by West *et al*. (1995). They were interested in comparing the effects of visual skills training and a kind of sport-specific vision coaching. They thought that vision coaching should include biomechanical elements such as positioning of the visual system during the performance of sport skills, as well as highlighting for players where they should look for what cues while performing specific skills. The subjects (*N*=29) in their study were all elite level field hockey players. Group 1 received visual skills training and a sport-specific vision coaching programme on the field, Group 2 received only visual skills training and Group 3 formed the control group. All of the subjects attended their normal hockey practice sessions while involved with the study. Four visual skills (horizontal saccades, vertical saccades, rotational skill, and accommodative flexibility) and 22 hockey skills (*e.g.* flick into goal, passing the ball on the run, etc.) were pre- and post-tested.

The intervention programmes for Groups 1 and 2 were conducted over a four week period, with the subjects receiving laboratory-based visual skills training five days per week (each session lasting between 8-10 minutes). Group 1's sport-specific vision training was conducted three times per week and was one hour in duration. These sessions emphasised visual search, head position and posture during skill performance and the location of cues to develop anticipation. After analysis of the data, it was evident that Group 1 showed a significant improvement in their performance of all four of the visual skills. West *et al*. (1995) attributed this difference to the added experience of vision coaching which Group 1 had received. Group 3 (control) significantly improved their vertical saccades even though they received no visual skills training. The researchers remarked that sport participation, particularly in fast moving ball sports may provide substantial indirect practice of some visual skills.

When looking at the data from the subject's hockey skills tests, West *et al*. (1995) found that the subjects in Group 1 significantly improved on 13 of 22 skills. Group 2 achieved significant improvements in 5 out of the 22 hockey skills and Group 3 achieved a significant improvement in only one skill. West *et al*. (1995) concluded that visual skills' training combined with on-field vision coaching can have a positive effect on sport skill performance.

Decision Training

Vickers *et al.* (1999) pushed the thinking about training models to improve perceptual-motor functions to emphasise the decision-making aspects of sport performance. Although decision-making can be either at the conscious or non-conscious level, they believed that a new idea for training could come from taking a "top-down" perspective. From this perspective, training activities should not focus on the parts of skills or parts of games, but rather try to keep the practice as close to the whole performance context as possible. They labelled their approach "decision training" because it was based on the recognition that improvements in sport performance were dependent on improvements in the ability to make decisions under the environmental, physical and time constraints of the sport situations. The training activities presented in such an approach aims to help players develop the cognitive skills of anticipation, directing attention to critical cues, maintaining focus and concentration, retrieving solutions from memory and solving problems (Vickers, 2007).

Martell and Vickers (2004) specifically identified fast ball sports like cricket that involved open skills as classic examples of sports that could benefit from decision training. They cited the complex challenges to gaze control as the players search for information within a dynamic environment. In cricket batting in particular, batsmen must adjust their gaze in order to deal with the uncertainty of the information obtained from late ball flight. In other words, expert batsmen adapt their gaze in order to deal with the late changes in the objects flight as the ball travels towards them after bouncing on the pitch. Martell and Vickers (2004) believe that expert batsmen are therefore better at adapting their gaze in order to visually process the rapidly changing conditions in time to effectively change the action if needs be. This was demonstrated in Land and McLeod's (2000) study where they identified that expert batsmen differed in their gaze control to intermediate and novice batsmen due to the experts using a combination of two eye movements (pursuits and saccades) to gather information about the bounce point of the ball.

One implication identified by Martell and Vickers (2004) with regards to the designing of decision training drills is that athletes who are constantly exposed to varying attention-demanding situations develop an ability to decrease attention durations more so than athletes who are exposed to standard, non-varying attention demanding tasks. This supports the notion of variable and random practice in Vickers' (2007) Three-Step Decision Training Model.

Conclusion

From the previous research it is apparent there is still much research to be done to define how and what kind of vision-oriented intervention programmes might contribute to improvements in sport skills performance. There is consensus, however, that improvements in laboratory performance are not sufficient and only programmes in which there is transfer to skill performance on the field are worthy of inclusion in sport training programmes. Stretch *et al.* (2000) supported the position that different methods of improving sports performance deserve investigation and identified sports vision training is one of those methods.

In terms of the interception timing challenge of batting in cricket, Stretch *et al.* (2000) identified the development of perceptual anticipation strategies as particularly important. If the intervention programme in this study contributes to improving anticipation strategies in cricket players, then it may contribute to improved batting performance. By using Vickers' (2007) Three-Step Decision-Training Model as a basis for the development of a perceptual-motor training programme (a kind of sports vision training programme), this study investigated an alternative method of training the coincident anticipation timing of cricketers with a clear link to improving batting performance.

Chapter Three

Methodology

The following chapter presents the research design followed in this study and describes the procedures followed in gathering and analysing the data.

Research Design

The study followed a repeated measures experimental design with three groups (experimental, placebo, and control). The independent variable was a type of perceptual-motor training programme that was classified as a sports vision training programme because it worked continuously on fixation and tracking of object and location cues. The dependent variables were coincident anticipation timing and performance on a cricket batting test. According to Thomas, Nelson and Silverman (2005), the major purpose of this type of design is to determine the amount of change produced by the participation in the intervention programme. In other words, did the coincident anticipation timing or the batting performance of the players in the experimental group change more than either the players in the control group or the placebo group?

To implement this design, the experimental group participated in a four-week sports vision training programme and the control group received no intervention. The purpose of the placebo group was to evaluate whether changes in performance could be brought about by the psychological impact of receiving special training. The placebo group participated in four weeks of whole-body coordination training which was not expected to have any effect on either their coincident anticipation timing or their batting performance. The participants in the placebo group were not aware that the whole-body coordination programme was a placebo, so in their minds it was a legitimate intervention programme. Thomas *et al.* (2005) labelled this strategy a blind set-up.

An additional feature of this design that is recommended in perceptual-motor learning studies in the literature is that of a retention test following a period of no intervention for any of the participants. Magill (2003) recommends that retention tests be administered to determine if intervention programmes have had any lasting effects.

Procedures

The procedures followed in this study include the selection of subjects, the administration of the assessment protocols as the pre-tests, the implementation of the intervention programmes, and the administration of the post-and retention tests.

Selection of Subjects

After receiving ethical clearance from the university's Ethics Committee, a university cricket club was approached to see if they would be interested to take part in the study. The head coach confirmed the interest of the first, second and third team club members. The study was explained to members of the club before one of their afternoon practice sessions. It was described as a study to determine whether either of the training programmes (sports vision training or whole-body coordination training) would have an effect on their coincident anticipation timing and their batting performance. A sign-up sheet was posted in the clubhouse where players indicated if they wanted to take part in the research project. Thirty prospective subjects volunteered, however nine of them were subsequently excluded from the study based on the application of the following inclusion and exclusion criteria:

Inclusion Criteria

- The subjects were registered to play cricket for the university cricket club at the start of the year in which the intervention programme was conducted.
- The subjects were between 18 - 28 years old at the start of the year in which the intervention programme was conducted.
- The subjects read and voluntarily signed the informed consent form before the start of this study.

Exclusion Criteria

- If a subject missed more than one session of the training programme.
- If a subject had an eye injury or eye infection/illness during any part of the research project.
- If a subject took any performance enhancement substance within three months of the beginning of the research or took any medication that might have an effect on vision or batting.

The prospective subjects who complied with the inclusion criteria were then contacted telephonically as well as via email to confirm their interest in the study. Of these, 21 prospective subjects (mean age ± SD; 21.048 years ± 1.83) playing in different positions (Figure 3) confirmed their interest in the study and subsequently formed the subjects in the study (*N*=21).

It was necessary to accept that the control group (*n*=7) needed to be an intact group of players who would be unavailable to commit to participation in an intervention programme because of their potential involvement on their provincial team. In order to create an experimental group (*n*=7) and a placebo group (*n*=7) of similar skill levels, these two groups were formed based on the principle of matched pairs (Vincent, 1999). The matching process involved first ranking all subjects based on their performance on the pre-test of coincident anticipation timing test. The top ranked subject was assigned to Group 1 (experimental), the next ranked to Group 2 (placebo) and the third and fourth ranked to Group 1. Then the fifth and sixth ranked was assigned to Group 2 and the seventh and eight ranked to Group 1, and so on until all subjects were assigned to a group.

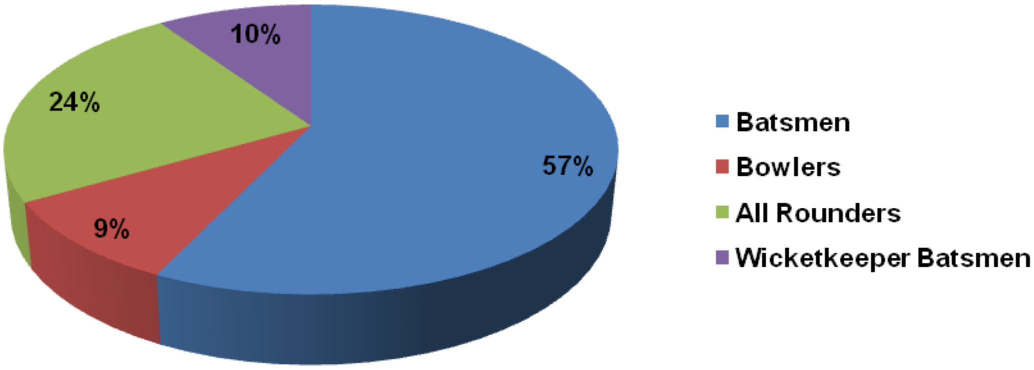

Figure 3. *The playing positions of the subjects in the study (N=21).*

Pre-Test Assessment Protocols

This research project did not require any invasive procedures. Coincident anticipation timing was assessed with a Bassin Anticipation Timer (Lafayette Instruments, Lafayette, IN). Batting performance was assessed on an indoor cricket pitch at a local cricket facility following an adaptation of a protocol used by Müller and Abernethy (2008). It was also decided to determine the eye dominance of the participants after the review of literature revealed that it might have some impact on the results of this study.

Before any testing commenced, the subjects (*N*=21) were required to read and voluntarily sign an informed consent form (Appendix A) before participating in the study. The subjects were ensured that they would be free to stop testing and withdraw from the intervention programme at any time without any negative consequences, and that all results and information would be kept confidential.

Testing on all three occasions was conducted over a two-day period, with all of the subjects taking their coincident anticipation timing test on Day 1 and their batting performance test on Day 2.

Coincident Anticipation Timing Test

The Bassin Anticipation Timer is the standard instrument for assessing coincident anticipation timing (Gardner & Sherman, 1995; Erikson, 2007) and is also the most common test of coincident anticipation timing (Abernethy *et al*., 1998; Erikson, 2007). Morwood and Griffiths (1998) identified the results of performance on the Bassin Anticipation Timer (Figure 4) as an important test for cricket. This piece of equipment is still being used in research today (Reichow, Citek, Blume, Corbett, Erickson & Yoo, 2010) even though the instrument is relatively old and has been in use for many years. With this apparatus, the subject is presented with the apparent motion of a light moving down a runway, imitating the path of a ball travelling towards him in a batting situation. The test of coincident anticipation timing takes approximately 20 minutes and the subjects were not allowed to view each other's trials.

Figure 4. *The Bassin Anticipation Timer (Lafayette Instruments, Lafayette, IN).*

The test protocol followed in this study consisted of the following:

1. The subject stands upright in his batting position at the designated end of the Bassin Anticipation Timer (Figure 5).

2. The subject uses the hand closest to the Bassin Anticipation Timer to perform the test (*i.e.* a right-handed batsman would use his left hand to perform the test).

3. The subject is instructed that the yellow warning light on the Bassin Anticipation Timer will be illuminated for 3 seconds before the onset on each trial in order to simulate the bowler running in to bowl a delivery towards them; thereafter the lights will illuminate in sequence along the runway imitating the path of the ball travelling towards him.

4. The subject is asked to make a simple finger-press response of a button to accurately coincide with the arrival of the light at the end of the runway.

Figure 5. *A right-handed subject standing in his batting position, ready to perform the coincident anticipation timing test on the Bassin Anticipation Timer.*

5. The subject is given five practice trials for familiarisation - one trial at each one of the speeds (5, 10, 15, and 24 mph) used during the trials, and one trial at a random speed of either 5, 10, 15, or 24 mph. Subjects will be informed prior to the five familiarisation trials as to what speed each trial will be conducted at, but for the test trials the subjects will not know at what speed the lights will be coming towards them.

6. The subject then performs 20 test trials at random speeds of 5, 10, 15, and 24 mph. The number of test trials performed at the four different speeds will be the same for each subject i.e. each subject will perform four 5 mph test trials, four 10 mph test trials, etc. In order to make sure that there is no learning of the sequence at which the different speeds travel down the runway, five tables are to be constructed and allocated a letter from A to E. Each table shall contain a different random order at which the speeds will travel down the runway. Before the commencement of the test trials, the subjects choose a letter (A - E), which is recorded on the score sheet. The test trials then progress according to the sequence that the speeds appear on the table for that particular letter.

7. The results of each trial on each testing occasion were recorded on a score sheet by the researcher and then transferred into a Microsoft Excel spreadsheet. A total absolute error time is calculated after completion of all the test trials.

Batting Performance Test

The batting performance test used in this study was adapted from that used in Müller and Abernethy (2008) who found it to be both a valid and reliable measure for the assessment of the quality of bat-ball interception in cricket batting. According to Müller and Abernethy (2008), this test is both a simple and viable means of assessing the efficacy of perceptual-motor training programmes that specifically focus on improving the subject’s bat-ball interception.

In the original Müller and Abernethy (2008) test, the batsman faced 45 deliveries from a right arm leg-spin bowler that were full in length and of two variations (either a “leg-spinner” or a “wrong-un”). The batsmen tried to play the appropriate shots to each delivery. The test was conducted in an indoor practice facility on a synthetic rubber pitch. The entire test was filmed using a video recorder for analysis at a later stage by a cricket expert. A trained observer also viewed the test during real-time performance and rated each bat-ball interception as either a "good contact," a "bad contact" or "no contact." The same rating form was done at a later stage when the cricket expert viewed the video footage captured during the test.

- Good Contact was defined by Müller and Abernethy (2008) as:

  "when the ball was contacted with the blade of the bat (not the handle or gloves) and travelled in a direction post-contact that was consistent with the pre-contact plane of bat motion" (p. 550).

- Bad Contact was defined by Müller and Abernethy (2008) as:

  "when the ball contacted the blade of the bat but deflected in a different direction to the plane in which the batsman swung the bat to execute a stroke" (p. 550).

- No Contact was defined by Müller and Abernethy (2008) as:

  "when the ball did not make contact with the blade of the bat" (p. 550).

These same definitions were used in a previous study by Müller and Abernethy (2006) and subsequent studies by Croft *et al.* (2009), Müller *et al.* (2009), and Müller, Abernethy and Tor (2010). All four of these studies focussed on cricket and bat-ball interception of cricket batsmen to varying degrees. The original test used by Müller and Abernethy (2008) was adjusted slightly for this study due to time constraints limiting the availability of the subjects and the indoor cricket facility.

Before commencement of the pre-testing, four cricketing experts were approached and asked if they would assist by viewing the video footage of the subjects as they took the test, and then rate the quality of the subjects' bat-ball contact. Two of the cricketing experts were ex-international cricket batsmen who represented South Africa. The third expert contacted played first-class cricket in

South Africa and was subsequently contracted as the overseas professional at a cricket club in Scotland, and the fourth expert was a cricketing journalist for an internationally recognised online cricket website. Two positive responses were received: one from the cricketing journalist and one from the overseas cricketing professional.

The testing took place in an indoor practice net on a synthetic carpet surface at a local cricketing facility. The subjects regularly trained at the facility on a year round basis so they were familiar with the testing environment. The batting performance test took approximately 20 minutes per person. The test required the subjects to wear their full cricket attire and bat as if they were going in to bat in a game situation. The subjects were asked to play a shot at each ball that was delivered towards them, while at the same time playing each ball on merit as if he would in a match situation.

The balls were delivered toward the batsmen via the Kanon bowling machine (Howard Manufacturing, Port Elizabeth, South Africa) with the speed gauge set to project balls at between 70-100 km/h. The balls that were used were specifically designed for use with the Kanon bowling machine and are called "*Kanon Dimple Balls*" (Figure 6). According to the manufacturer, these hard Kanon dimple balls provide a realistic bounce, feel on the bat, and a true sound on impact.

Figure 6. *Kanon Dimple Ball used in conjunction with the Kanon Bowling Machine.*

The Kanon bowling machine was set-up for cricket bowling according to the assembly instructions in the operating manual (p.2) provided with the Kanon bowling machine (Figure 7).

Figure 7. *Kanon Bowling Machine set-up for cricket bowling.*

The angle of the Kanon bowling machines projection arm was set so that the length or area where the ball pitches is approximately 4m in front of the batsman's crease, which Woolmer *et al.* (2008) identified as a *"good length"*. The Kanon bowling machine was situated at the non-strikers end of the pitch and was placed directly in line with the middle stump at the striker's end of the pitch. The point at which the ball emerges from the barrel was perpendicular to the bowling crease and did not extend beyond it. For subjects who bat right-handed, the projection arm of the Kanon bowling machine was swivelled slightly so that the ball pitched in the "corridor of uncertainty", which is a narrow line on and just outside of a right handed batsman's off stump. The same setup protocol was used for subjects who bat left-handed.

The subject's testing session was digitally recorded for analysis by two previously mentioned cricketing experts using a Panasonic NV-GS400GC digital video camera (Matsushita Electrical Industrial Co., Osaka, Japan). The digital video camera was set to "*Sports Mode*" which the manufacturers operating manual clearly states should be used for "*recording scenes involving quick movements, such as sports scenes*" (p.87). The digital video camera was plugged directly into a power source to avoid running the digital video camera off of its own battery power supply. A USB cable was connected to the digital video camera and linked to an AMILO Li 2727 notebook (Fujitsu Siemens Computers, Munich, Germany), where the footage was captured live using the software provided on the notebook and immediately stored on a WD2500JB external hard drive (Western Digital Corporation, California, United States of America) for future editing and safe keeping.

The digital video camera was placed on top of a tripod and positioned in front of the Kanon bowling machine so that it too was in line with the middle stump at the striker's end of the pitch. The camera was set at a perpendicular height of 1.2 m to the pitch and was checked to be perfectly horizontal to the pitch with the use of a spirit level. It was decided to place the digital video camera at this location because this perspective is similar to that of an umpire in a match and is a necessary perspective in order to assess the quality of bat-ball interception made by the subjects (Müller & Abernethy, 2006; Müller & Abernethy, 2008; Müller *et al.*, 2009; Croft *et al.*, 2009).

Each subject then faced 12 balls (the equivalent of two, 6-ball overs), which were not digitally recorded using the digital video camera, in order for them to get familiarised with the testing setup (Müller & Abernethy, 2006; Müller & Abernethy, 2008; Croft *et al.,* 2009; Müller *et al.*, 2009). Thereafter each subject faced 35 deliveries which were digitally recorded and subsequently edited to form a ball-by-ball video package. The records for each subject were stored and later compiled along with the post-test and retention test performance to be sent to the cricket experts for evaluation of their contacts.

This protocol differs from the original test setup of Müller and Abernethy (2008) in which 45 balls were filmed for analysis. As previously mentioned, this was done because of time constraints limiting the availability of the subjects and the indoor cricket facility.

Eye Dominance Test

A test for eye dominance was administered after the review of literature revealed it might be a factor in the performance of the subjects either during the tests or the intervention programme. Eye dominance was determined using the same procedure as those found in Knudson and Kluka (2007) and Thomas *et al.* (2005). The subjects were asked to make a small hole with their two hands, then straighten their arms and raise them to look through a hole at the researcher who stood 3m away. The eye that the researcher could see through the small hole was identified as the subjects' dominant eye.

Administration of the Post- and Retention Tests

The identical procedures for the coincident anticipation timing test were followed for the post- and retention tests, except the previously selected letters are eliminated as potential choices. The identical procedure was followed for the batting post- and retention tests. It was not necessary to re-test eye dominance. Retention testing took place three weeks after the post-tests during which time the subjects partook in no intervention training programmes.

After all subjects had completed the retention tests, a custom-labelled DVD was then burned from the video records of their performances and delivered with a letter (Appendix B) to the two cricket experts. The DVD contained the following:

1. A video package for each one of the subjects (21 videos in total).
2. An electronic score sheet in the form of a Microsoft Excel spreadsheet.
3. A letter describing in detail what was required of them with regards to what to look for when scoring the bat-ball interception of each subject for each delivery. This included scoring each delivery for each subject, based on the definitions of "*Good Contact*", "*Bad Contact*", and "*No Contact*" as used by Müller and Abernethy (2008). The letter also explained how to complete the score sheet and return it to the researcher. The experts were also asked to destroy the DVD once they had finished with their analysis.

The scores on the batting performance test for the pre-, post- and retention tests for each subject was then calculated by the researcher as the average of the total score assigned by the first and the second expert for each test. This process entailed the following steps:

- The scores obtained from the two experts for each subject were converted to a percentage for each type of contact made (*i.e.* percentage of good, poor and no contacts) for each subject.
- Each subject had two average percentage scores (one from each expert) per type of contact made during the test.
- These scores were then converted to a mean average percentage score for each subject per type of contact made.

The mean average percentage scores per type of contact were used in the statistical analysis.

Intervention Programme

The weekly training schedules for the intervention programme for each of the subjects in the experimental group and the placebo group were determined after completion of the pre-testing period. The exact time/date for training was determined individually, depending on the subject's timetable. Due to the subjects being students, the majority of the training sessions were conducted in the afternoon/evening after they had completed classes for the day. The intervention programme consisted of four training sessions per week for four consecutive weeks (16 training sessions in total), with each session being approximately 30 minutes long.

The subjects in the experimental group attended sessions of the sports vision training programme (Appendix C) designed on the basis of Vickers (2007) Three-Step Decision-Training Model. The sessions involved a combination of drills specifically designed to focus on practicing their anticipation, attention and focus and concentration skills in activities that emphasised object cues and/or location cues. These activities challenged visual fixations and eye motility *i.e.*

saccadic eye movements and pursuit tracking which were identified by Land and McLeod (2000) as being the eye movements used by expert cricket batsmen.

The drills in each session made use of both variable and random practice schedules by using various pieces of equipment such as different coloured, sized, shaped and weighted balls. Targets were introduced of varying size, shape and colour. Hitting implements that varied in size, shape and weight were also used. Creativity and variety in each training session has been identified as the optimal approach to achieving the best results (Wilson & Falkel, 2004).

The subjects in the placebo group attended sessions of the whole-body coordination training programme that involved a combination of drills that featured rhythmic training activities that challenged different combinations of movements of the hands, arms, feet and legs, as well as imitating different cricket shots. No visual challenges were presented during these sessions.

Data Analysis

Statistica 8.0 (Statsoft, Inc.) was used to analyse the data under the guidance of the Centre for Statistical Consultation at Stellenbosch University. The data was analysed between groups as well as within each group. Changes in coincident anticipation timing and batting performance were considered statistically significant at $p \leq 0.05$. The effect of eye dominance on the subject's coincident anticipation timing and batting performance was compared using a Mann-Whitney U-Test. The data from the three groups pre-, post- , and retention tests were compared using a Kruskal-Wallis ANOVA by Ranks Test, while the differences within each group were compared using multiple Mann-Whitney U-Tests where appropriate.

All 21 subjects were able to complete the coincident anticipation timing test on all three testing occasions; however, two subjects could not complete all of the batting performance tests. One subject (who fell into the placebo group) had to withdraw himself from the batting performance retention test due to a leg injury, and the other subject (who fell into the control group) had to withdraw himself from the batting performance post- and retention testing sessions due to nerve damage in his arm.

Summary

The study followed a repeated measure experimental design with three groups (experimental, placebo, and control). Each group consisted of seven subjects (*n*=7) aged between 18 and 28 years of age who played cricket for a university club cricket team.

Three tests were conducted:

- Eye Dominance Test.
- Coincident Anticipation Timing Test.
- Batting Performance Test.

Testing took place three times over the duration of the study. The first round of tests was conducted to gather baseline data and establish the groups that the subjects fell into. The second round of tests were conducted after a four week period where the experimental group took part in a perceptual-motor training programme, the placebo group took part in a whole-body coordination training programme, and the control group received no training. The third round of tests was conducted after a three-week period of no training.

The perceptual-motor training intervention took the form of a sports vision training programme based on Vickers (2007) Three-Step Decision Training Model and consisted of 16 sessions, which took place over four weeks, four times per week. These sessions were approximately 30 minutes long. The sessions involved a combination of drills specifically designed to focus on practicing their anticipation, attention and focus and concentration skills in activities that emphasised object cues and/or location cues.

Data were analysed between groups as well as within each group. The effect of eye dominance on the subject’s coincident anticipation timing and batting performance was compared using a Mann-Whitney U-Test. The data from the three groups pre-, post- , and retention tests were compared using a Kruskal-Wallis ANOVA by Ranks Test, while the differences within each group were compared using multiple Mann-Whitney U-Tests where appropriate.

All 21 subjects were able to complete the coincident anticipation timing test on all three testing occasions; however, two subjects could not complete all of the batting performance tests.

Chapter Four

Results and Discussion

The results are presented in relation to the four research questions that guided this study. The primary purpose of this study was to explore the effectiveness of a perceptual-motor training intervention (sports vision training programme) on the coincident anticipation timing and the batting performance of cricketers.

The results for subjects from the experimental, placebo, and control groups were analysed by using their scores on pre-tests, post-tests and retention tests in order to determine both changes in performance and differences among groups. In addition to looking at within and between group differences, the data was analysed to determine if eye-dominance had any effect on the results. To accomplish this analysis, three assessments were implemented.

1. Eye Dominance was assessed with a generally accepted field test described by Knudson and Kluka (2007) and Thomas *et al.* (2005). The subjects were instructed to look through a hole formed by their hands, at the researcher, who stood 3m away. The researcher could then identify the dominant eye as the eye he could see through the hole formed by the subject's hands. This is the same method that was employed by Griffiths (2003) in his study on eye dominance in tennis players and in clay pigeon shooters.
2. Coincident Anticipation Timing was assessed using a Bassin Timer on a test consisting of 20 trials.
3. Batting Performance was assessed using a qualitative rating scale on a test consisting of 35 trials.

Descriptive Data

The ages of the subjects in the study ranged between 18 – 26 years of age with the mean age (mean age ± SD) of 21.1 years ± 1.8.

Table 2

Descriptive statistics of the ages of the subjects in each group (N=21) age

Age	**Group 1 (n=7) Experimental**	**Group 2 (n=7) Placebo**	**Group 3 (n = 7) Control**
Mean	20.6 yrs	21 yrs	21.6 yrs
Median	21	21	21
Mode	22	21	20
SD	1.3	1.8	2.4
Minimum	19	18	19
Maximum	22	24	26

The youngest subject was 18 years of age at the beginning of the year that the study commenced, and the oldest subject was 26 years of age. Table 2 presents the descriptive statistics for the ages of the subjects from each group.

Preliminary Data Analysis

Preliminary data analysis was considered important in order to put the results of this study in a scientific context. First, data was processed to determine whether eye dominance influenced coincident anticipation timing and batting performance. Second, the similarity of the three groups prior to the introduction of the intervention programme was assessed. Third, data was processed to determine the inter-rater reliability between the experts who assessed the number of “good contacts” made by the subjects during the batting performance test.

Eye Dominance and Coincident Anticipation Timing

According to Shneor and Hochstein (2006), eye dominance is the tendency to prefer visual input from one eye to input from the other. If eye dominance did have an effect on either coincident anticipation timing or batting performance as measured in this study, then it would have an effect on the interpretation of the results of this study.

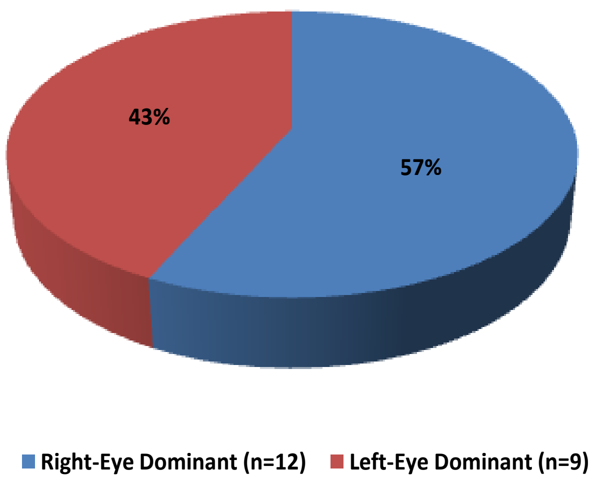

Figure 8*. Eye dominance of subjects in the study (N=21).*

Twelve (*n*=12) of the subjects in this study (*N*=21) were right eye dominant (57%) and nine (*n*=9) were left eye dominant (43%) (Figure 8). These percentages were very similar to that found by Griffiths (2003), who identified that 53.3% of the players in the Scottish National Cricket team (*N*=15) were right eye dominant and 46.6% of the players were left eye dominant.

A Mann-Whitney U Test was conducted on the subject's pre-test coincident anticipation timing scores in order to determine if there was a significant difference between the right eye dominant subjects and the left eye dominant subjects with regards to the absolute error they obtained on the coincident anticipation timing test. Absolute error (AE) is defined by Magill (2003) as "the absolute difference between the actual performance on each trial and the goal" (p. 24). In other words, it is the sum of all the trials irrespective of the direction of the deviation (early or late). According to Magill (2003), "error measures allow us to evaluate performance for skills for which accuracy is the goal" (p. 23). This would apply to the skill of cricket batting because the goal is to accurately direct the cricket ball out into the field of play in order to score runs. AE provides the researcher with useful information about the "magnitude of error" a subject has made on a single

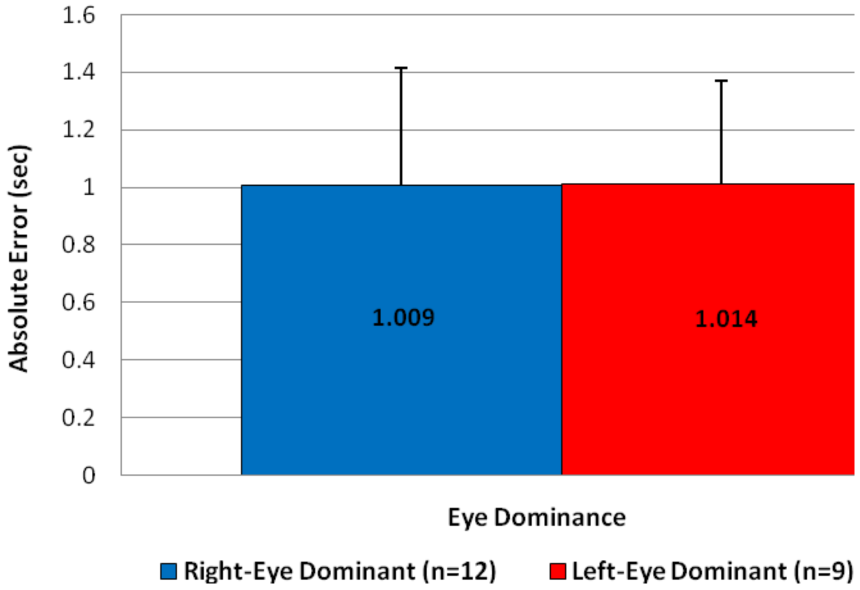

Figure 9. *Mean absolute error ± SD of right-eye vs. left-eye dominant subjects.*

trial or over numerous trials. The AE score provides the researcher with a general index of accuracy for the subject.

No significant difference ($p>0.05$) was found between the right (mean absolute error ± SD, 1.009 sec ± 0.404) and left eye (mean absolute error ± SD, 1.014 sec ± 0.358) dominant subjects with regards to their coincident anticipation timing ability ($p=0.92$).

The coincident anticipation timing test that was used in this study was performed binocularly by the subjects (*i.e.* both eyes were used at the same time during the performance of the test) (Magill, 2003; Naidoo, Mashige & Ferreira, 2003; Vickers, 2007). The answer to the first part of the preliminary data analysis was that there was no significant difference between right and left eye dominant subjects with regards to their coincident anticipation timing ability.

Eye Dominance and Batting Performance

A Mann-Whitney U Test was conducted to determine if there was a significant difference between the right eye dominant subjects and the left eye dominant subjects with regards to the mean average percentage of good, poor, and no contacts they made during the batting performance pre-test. The scores obtained from the two experts for each subject were converted to a percentage for each type of contact made (*i.e.* percentage of good, poor and no contacts) for each subject. Each subject had two average percentage scores (one from each expert) per type of contact made during the test. These scores were then converted to a mean average percentage score for each subject per type of contact made. The mean average percentage scores per type of contact were used in the statistical analysis.

No significant differences ($p>0.05$) were found between the right- and left-eye dominant subjects in terms of good contacts ($p=0.19$), poor contacts ($p=0.16$), and no contacts ($p=0.69$). A summary of the data can be found in Table 3.

Similar findings were found in a study by Laby *et al.* (1998) with professional baseball players, who found no significant differences between professional baseball player's eye dominance and either their batting averages or earned run averages (ERA's). Baseball is similar to cricket. In both sports the batter/batsman attempts to strike a ball, which is thrown/delivered by the pitcher/bowler, with a bat in order to score runs for his team. This makes both baseball and cricket interceptive timing tasks which really heavily on coincident anticipation timing. However, the fundamental difference between the two sports is that in baseball, the pitcher gets penalised if the ball bounces on the ground before it reaches the batter, whereas in cricket there is no such penalty. In cricket, bouncing the ball on the ground before it reaches the batsmen is encouraged and bowlers attempt to exploit this by varying the distances that they bounce the ball in front of the batsmen. This fundamental difference changes the visual constraints of batting since there are changes in the flight of the ball after it hits the ground in cricket, which makes it a different type of interceptive action compared to baseball. However, both sports require the batter/batsmen to strike the ball with a bat under severe time constraints. It is for this reason that it is interesting to note that the results of this study are the same as those found by Laby *et al.* (1998). In both baseball and cricket, eye dominance does not appear to have an effect on the batting performance of the subjects.

Table 3

The mean average percentage (%) contact type in right eye vs. left eye dominant subjects

Mean Average % Contact Type ± SD	Right-Eye Dominant	Left-Eye Dominant	p-value
Good Contacts	82.1% ± 8.1	87.1% ± 2.9	0.19
Poor Contacts	10.7% ± 4.4	7.8% ± 2.8	0.16
No Contact	7.0% ± 4.8	5.1% ± 2.7	0.69

Similarity between Groups

Before processing any data, it was crucial to establish the degree of similarity between groups. If the groups were not similar at the onset of the study, then the results of any comparisons of changes in either coincident timing or batting performance would be compromised. As explained in Chapter Three, practical considerations led to the use of an intact group as the control group (*n*=7). After analysis of the individual scores on the coincident anticipation timing pre-test, the remaining subjects were randomly assigned to either the experimental group (*n*=7) or placebo group (*n*=7). A Kruskal-Wallis ANOVA by Ranks Test was used to determine whether the groups' mean absolute error scores were similar. P-values were examined for significance at the 5% level. This was done to determine whether one group had a significantly higher or lower absolute error at the onset of the study, when compared to the other two groups. No significant difference ($p>0.05$) was found between the experimental (1.046 sec. ± 0.402), placebo (1.036 sec ± 0.490) and control (0.952 sec. ± 0.250) groups at the onset of the study ($p=0.974$) in terms of their coincident anticipation timing (Figure 10).

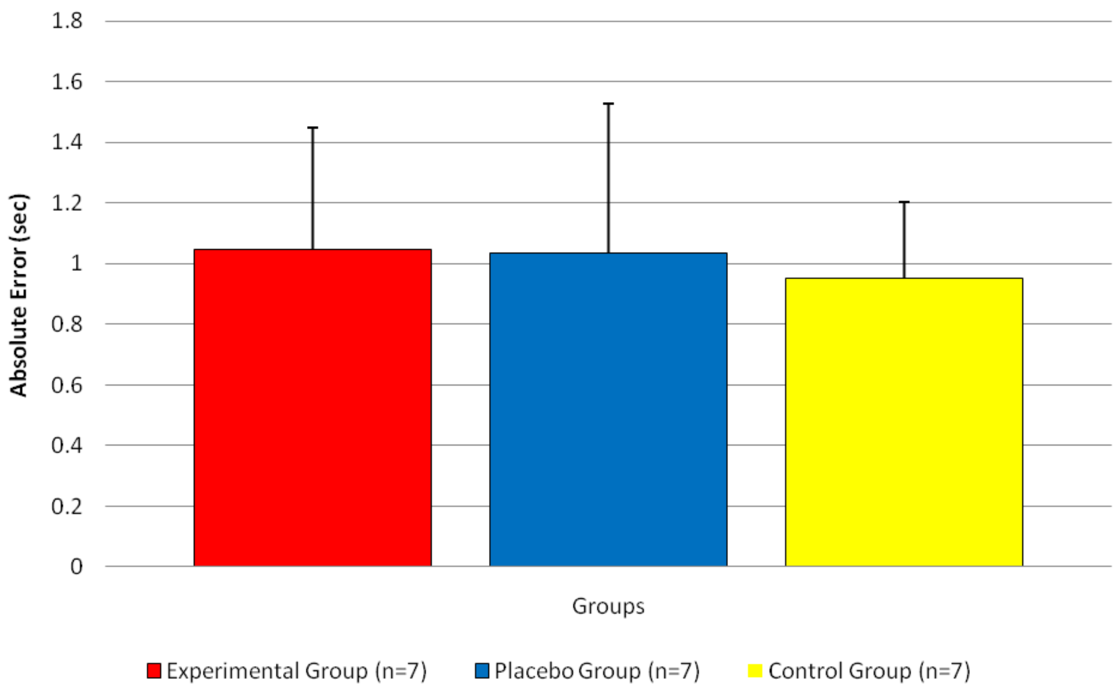

Figure 10. *Mean coincident anticipation timing pre-test scores (mean absolute error ± SD) for each group.*

A Kruskal-Wallis ANOVA by Ranks Test was also conducted on the pre-test mean percentage of good contacts, averaged over the two raters/experts, to determine whether there was a difference in the batting performance of the different groups. The results of the test show that there was a significant difference ($p \leq 0.05$) between the groups with regards to their mean average percentage of good contacts ($p=0.016$) at the onset of the study. Multiple Mann-Whitney U tests were conducted (experimental vs. placebo; experimental vs. control; placebo vs. control) in order to establish between which two groups a significant difference ($p \leq 0.05$) occurred. The results of the multiple Mann-Whitney U tests were as follows (Figure 11):

- There was no significant difference between the experimental group (88.98% ± 2.94) and the placebo group (84.898% ± 6.142) group ($p=0.160$).

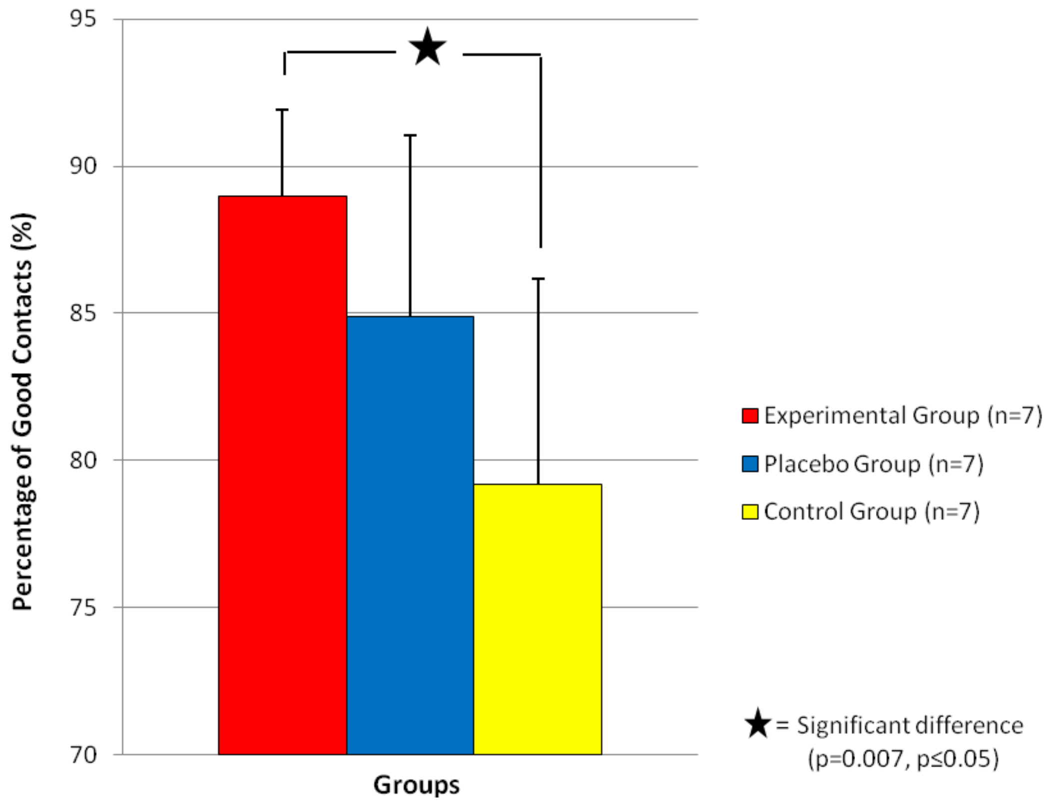

Figure 11. *Mean Average Percentage of Good Contacts (Pre-test) for each group ($p \leq 0.05$).*

- There was a significant difference between the experimental group (88.98% ± 2.94) and the control group (79.184% ± 6.992) group (p=0.007). The rating of "good contacts" for the control group was significantly lower than the ratings for "good contacts" of the experimental group.

- There was no significant difference between the placebo group (84.898% ± 6.142) and the control group (79.184% ± 6.992) group (p=0.142).

Inter-rater Reliability

It was also of interest to determine whether the two experts were in agreement with each other with regards to the type of contact made by the subjects in the batting performance pre-test. This was done in order to see whether the experts had a common understanding about how to evaluate the good contacts based on the criteria provided to them by the researcher. The Batting

Performance Test used in this study was previously established to be valid and reliable by Müller and Abernethy (2008). It was however, still important to verify the reliability of the specific experts who rated the subjects on the Batting Performance Test in this study.

In order to establish this, the pre-test "good contact" percentages that were assigned to each subject by the two experts were compared using a Two Way Inter-class Correlation (*r*). This comparison yielded an r-value of 0.80 (*r*=0.80). Müller and Abernethy (2008) found a similarly high inter-rater correlation (*r*=0.83) in their study. This is seen as a strong, positive correlation and indicates that there was a relationship between the two experts evaluation of the good contacts in the pre-test (Figure 12). From this the researcher concluded that the experts had a common understanding of how to score the contacts made by the subjects in the Batting Performance Test.

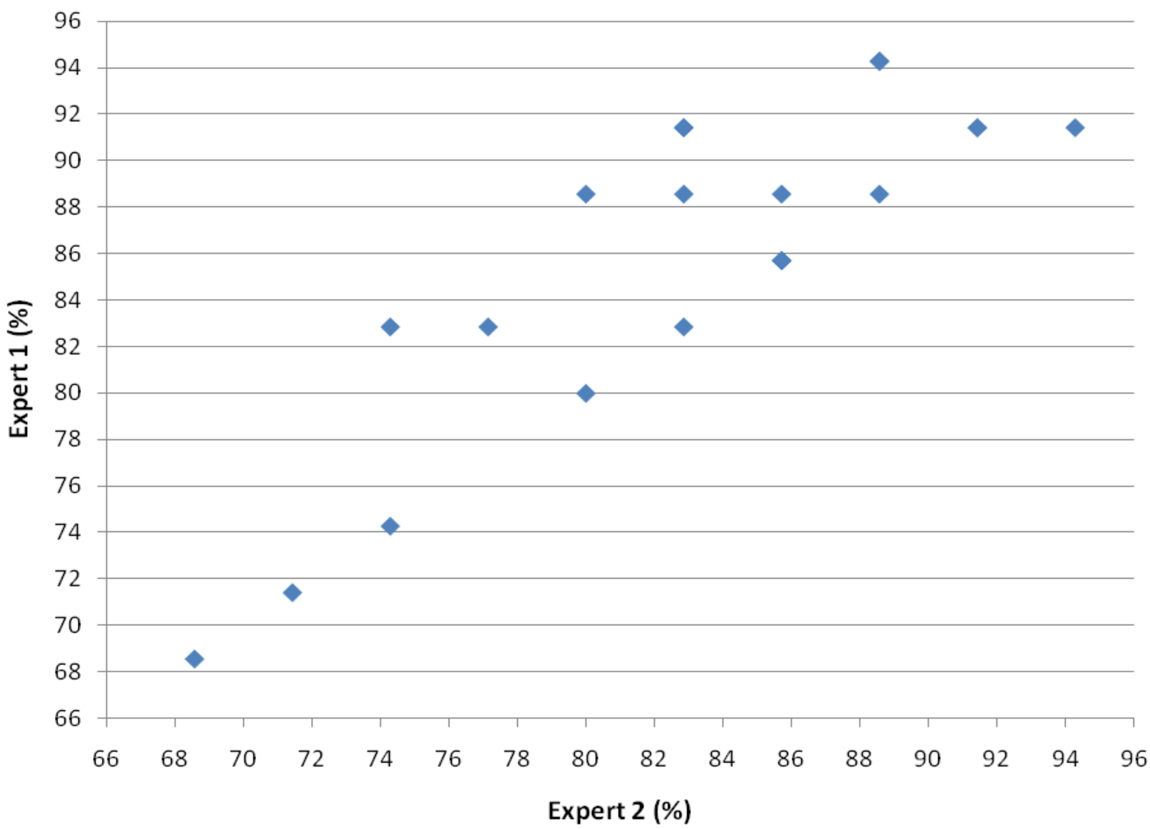

Figure 12. *Comparison between the pre-test "good contact" percentage scores of Expert 1 and Expert 2 (r=0.80).*

Research Question One

5. What is the effect of participation in a four-week perceptual-motor decision training programme on the coincident anticipation timing of cricketers?

The pre- and post-test scores of the subjects in the three different groups on the coincident anticipation timing test were compared to determine if there were any changes between the groups and then within each group. This was done in order to determine whether the perceptual-motor training programme had any effect on the subjects' batting performance.

The pre- and post-test scores that the subjects' earned on the coincident anticipation timing test were compared to see whether the perceptual-motor training programme had any impact on the performance of subjects' in the experimental group. A Kruskal-Wallis ANOVA by Ranks Test was conducted to process the pre- to post-test changes in the each groups' coincident anticipation timing. The Kruskal-Wallis Test yielded a p-value of 0.260 ($p=0.260$), indicating that there were no significant differences ($p>0.05$) between the three groups following participation of the experimental group in the intervention programme (Figure 13).

Although there were no statistically significant differences between the groups, there does appear to be a trend indicating that the experimental group achieved some improvement in their coincident anticipation timing. The experimental groups pre-test mean absolute error ± SD (1.046 sec ± 0.402) was higher than the post-test mean absolute error ± SD (0.881 sec ± 0.207) which indicates that they were more accurate in their coincident anticipation timing on the post-test. It is important however to view these results in conjunction with the experimental groups results on the batting performance test.

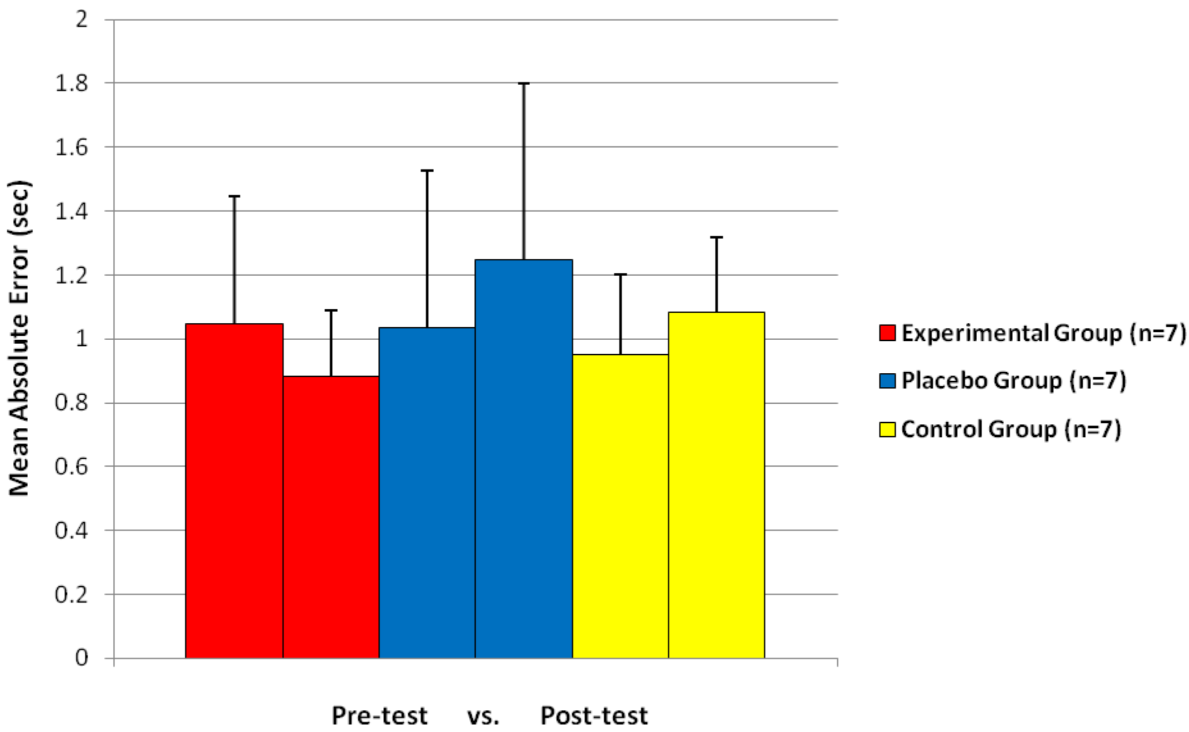

Figure 13. *Pre- to post-test comparison of coincident anticipation timing test scores for each group.*

Both the placebo group and the control group showed a trend toward less accuracy in their coincident anticipation timing on the post-test. The placebo group's pre-test mean absolute error (1.036 sec ± 0.460) was lower than the post-test mean absolute error (1.248 sec ± 0.553). The same was found with the control group, whose pre-test mean absolute error (0.952 sec ± 0.250) was lower than the post-test mean absolute error (1.084 sec ± 0.234). The trend for both the placebo group and the control group was a deterioration in the accuracy of their coincident anticipation timing. It is important that the placebo group and the control group's results are discussed in conjunction with the results of the batting performance test in order to get a better understanding of them.

Research Question Two

6. What is the effect of participation in a four-week perceptual-motor decision training programme on the batting performance of cricketers?

The pre- and post-test scores of the subjects on the batting performance test were compared to see whether there were any changes in the subjects' batting performance ability as a group (experimental, placebo, and control) and then as individuals within each group (experimental, placebo, and control). This was done in order to determine whether the perceptual-motor training programme had any effect on the subjects' batting performance.

Changes in a subject's batting performance were measured by comparing the mean average percentage of good contacts made on the pre-test vs. the post-test. The reason why only the good contacts were focussed on was because they are the most important type of contacts in order to be successful at batting in cricket – if a player cannot make good contact with the ball consistently, then the chances of them being successful at batting in cricket are questionable. For example:

- Poor contacts could result in the ball travelling in a direction that the batsmen was not intending it to travel in and could lead to them being dismissed.

- No contacts could lead to the batsmen being dismissed by either being bowled or by the ball striking his pads leading to him being dismissed "leg-before-wicket" (LBW).

A Kruskal-Wallis ANOVA by Ranks Test was conducted on the mean average percentage of good contacts between the three groups (Table 4). One subject from the control group was injured during the post-testing period and therefore could not complete the batting performance test. The results showed no significant difference ($p>0.05$) between the groups after the intervention period ($p=0.197$).

In terms of within group changes, only the control group showed a significant difference ($p \leq 0.05$) when the pre- to post-test comparisons were made ($p=0.04$). Unfortunately for this research, three of the members in the control group had been receiving additional batting practice at their provincial franchise on top of their usual practice regime, because of their selection for an upcoming tournament in Dubai and Abu Dhabi, United Arab Emirates (UAE). This additional batting practice could not be controlled for by the researcher and could have had a positive impact on post-test batting test performances. This could also perhaps explain why the subjects in the control group got slower on their coincident anticipation timing test; the subjects receiving additional batting practice may have been mentally and physically preparing for the tour and may have seen the coincident anticipation timing test as not being beneficial enough to their game to give it their best attempt, whereas the batting performance test was seen as being more beneficial to their game due to them being able to have additional batting time in the nets. This may have led to these subjects not performing at their best during the coincident anticipation timing test, whereas they attempted to perform at their best in the batting performance test.

The experimental group and placebo group also showed a trend toward improvement in their batting performances, but these improvements were not statistically significant ($p>0.05$). The experimental group's improvement could suggest that the intervention programme had an effect on their batting performance due to the paralleled improvement in their coincident anticipation timing ability. In other words, their improved coincident anticipation timing ability enabled them to improve their batting performance (mean average percentage of good contacts). On the other hand, the placebo group only improved on the batting performance test and not on the coincident anticipation timing test. This result was also not unexpected due to the nature of the placebo being used by the placebo group.

The placebo (whole-body coordination training) had been described by its manufacturers as having the ability to improve one's balance and motor coordination, amongst other things (www.interactivemetronome.com). Balance is

Table 4

Groups pre-test vs. post-test mean average percentage of good contacts (mean average % of good contacts ± SD)

Group	**Pre-test Mean Average % of Good Contacts ±SD**	**Post-test Mean Average % of Good Contacts ±SD**
Experimental (n=7)	88.98% ± 2.94	91.24% ± 4.69
Placebo (n=7)	84.89% ± 6.16	89.38% ± 5.65
Control (n=6)	79.18% ± 6.99	85.23% ± 6.80*

* ($p \leq 0.05$)

a critical component of almost every movement (Burton & Davis, 1992; Williams & Woollacott, 1997; Goddard Blythe, 2000). Stretch *et al.* (2000) stated that:

> Successful interceptive actions require good coordination not only between relevant parts of the movement system, but also between relevant motor system components and the projectile to be intercepted. (p. 934)

Having good balance and motor coordination would therefore be crucial in cricket batting. Woolmer *et al.* (2008) stress that good footwork aids good balance and that the hands, body and feet need to be in the correct position for a successful shot to be played. In order for this to occur, a player needs to have good balance and a strong base which will ensure that the intended shot is executed correctly. An improvement in batting performance by the placebo group, while the group decreased in their coincident anticipation timing ability could therefore be due to the placebo itself *i.e.* whole-body coordination training. The whole-body coordination training may have improved the subjects balance and not their coincident anticipation timing ability, which led to an improvement in the batting performance test. This warrants further investigation as to the effects of a whole-body coordination training intervention on the balance and batting performance of cricketers.

Research Question Three

3. What is the effect of a period of “no training” on the coincident anticipation timing retention test of cricketers who have participated in a four-week perceptual-motor decision training programme?

The post- and retention test scores of the subjects on the coincident anticipation timing test were compared to see whether any changes occurred after a period when none of the subjects were involved in any intervention programme.

A Kruskal-Wallis ANOVA by Ranks Test was conducted on the groups’ post- and retention test mean absolute error scores (mean absolute error ± SD). Figure 14 was produced in order to get a complete picture of the pre- to post- to retention test performances. It can be noted in this figure that no significant differences ($p>0.05$) were found between the groups after the retention period ($p=0.732$).

The experimental group’s mean absolute error ± SD on the retention test (0.983 sec ± 0.317) was greater than their post-test mean absolute error ± SD (0.881 sec ± 0.207), meaning they were less accurate in their coincident anticipation timing on the retention test. However, their retention test scores were still more accurate than their pre-test scores (1.046 sec ± 0.402). This indicates that after the retention period, the experimental group appeared to deteriorate somewhat in their coincident anticipation timing, but not to the level of errors achieved on the pre-tests. This indicates that in order for the perceptual-motor training programme to have a continued effect on a cricketer’s coincident anticipation timing ability, it needs to form part of their weekly training regime. If the perceptual-motor training programme is neglected for a period of time, then the benefits that have been made will progressively be lost. Further research could shed some light onto how often perceptual-motor training sessions need to be completed after an intervention period for the benefits to be maintained. For example, a study investigating whether one or two perceptual-motor training sessions per week following a four week intervention programme would be enough to maintain any improvements in coincident anticipation timing.

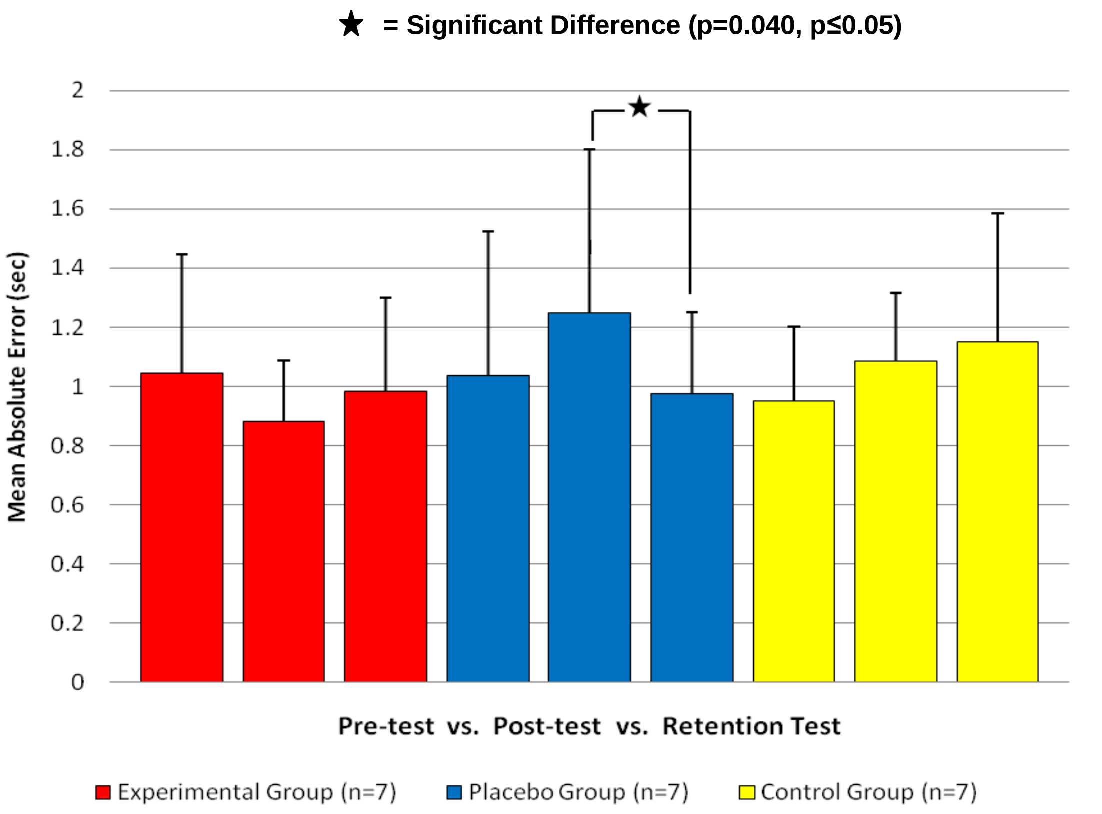

Figure 14. *Group comparison of mean absolute errors (sec) over the duration of the study (p≤0.05).*

The only within group change that achieved statistical significance (p≤0.05) between the post- and retention tests was found within the placebo group. They were significantly more accurate (p=0.040) on the retention test than they had been on the post-test. This group's mean absolute error on the pre-test had been 1.036 sec ± 0.250, on the post-test had been 1.248 sec ± 0.553, and on the retention test was 0.975 sec ± 0.277. In other words the placebo group achieved their best score out of the three tests on the retention test; however the retention test score was not significantly different (p>0.05) from the pre-test score which is an important point to remember when discussing the results. These results may have occurred due to the whole-body coordination training disrupting the placebo groups coincident anticipation timing ability at the post-testing stage, however once the whole-body coordination training programme was stopped during the period of "no training", the subjects were able to recover their coincident anticipation timing ability at the retention test stage to levels that were similar to their pre-test scores.

The coincident anticipation timing of the control group appeared to get progressively less accurate throughout the study period ranging from their pre-test (0.952 sec ± 0.250) to their post-test (1.084 sec ± 0.234) to their most inaccurate performance occurring during the retention test (1.150 sec ± 0.435). These results could be attributed to the control group’s motivation. Potgieter (2006) said that “motivation is concerned with why people behave in a certain way and why a particular course of action is preferred to other options” (p. 7). Some of the subjects within this group had just returned from an overseas cricket tour the evening prior to the retention testing session and may have lacked the motivation to perform at their best due to them being slightly mentally and physically fatigued. This could have led to the subjects in question not performing to the best of their abilities due to their motivation, focus, and attention being impaired.

Research Question Four

4. What is the effect of a period of “no training” on the batting performance retention test of cricketers who participate in a four-week perceptual-motor decision training programme?

The post- and retention test scores of the subjects on the batting performance test were compared. In both cases, between group comparisons were made and then the comparison of individuals within groups were made.

A Kruskal-Wallis ANOVA by Ranks Test was conducted on the groups’ post- and retention test mean average percentage of good contacts (mean average percentage of good contacts ± SD). Figure 15 was produced to trace changes in percentage of good contacts made on the pre- to the post- to the retention test. After statistical analysis of the data, no significant differences ($p>0.05$) were found between the groups after the retention period ($p=0.593$).

The experimental group has managed to maintain and very slightly improve their batting performance from post-test (91.224% ± 4.697) to retention test (91.429% ± 5.216). This shows that the improvements that they made in their batting performance after the intervention period have been maintained after the “no training” period. These results are interesting seeing as the experimental group’s coincident anticipation timing ability decreased from post- to retention test.

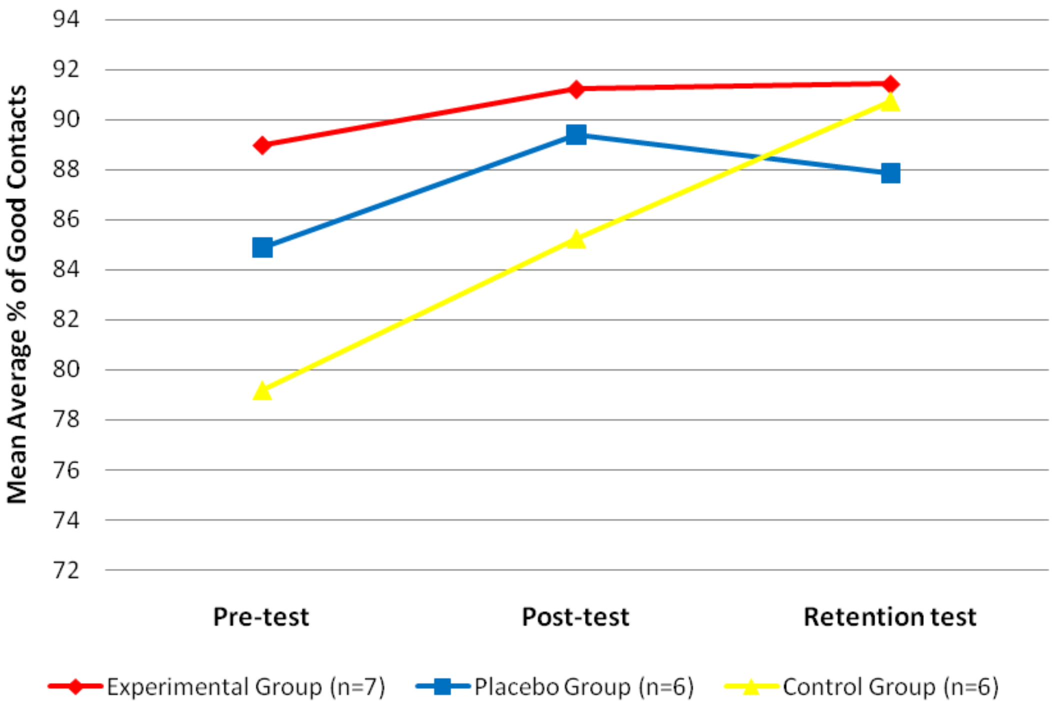

Figure 15. *Group comparison of the mean average percentage of good contacts (%) over the duration of the study.*

The placebo group decreased in their batting performance from post-test (89.388% ± 5.646) to retention test (87.857% ± 5.01), but this decrease in batting performance was small enough to return their performance to a level similar to the pre-test (84.898% ± 6.164). In other words the placebo group's batting performance was almost the same at the end of the study as it was at the beginning.

This decrease in batting performance for the placebo group is interesting considering that the only significant difference in any of the three groups coincident anticipation timing came between the placebo groups post- and retention test. In discussing the placebo group's results in Research Question Two, it was speculated that a decrease in their coincident anticipation timing and an improvement in their batting performance might have been due to a possible improvement in balance. On the retention test, they significantly improved their coincident anticipation timing, suggesting that they may have recovered their sense of internal timing after they stopped their whole-body coordination training programme. The period of “no training” may have been sufficiently long enough for the subjects to recover their coincident anticipation timing ability in time for the retention testing.

The control group’s consistent improvement in their batting performance over the duration of the study (pre-test: 79.184% ± 6.992; post-test: 85.238% ± 6.801; retention test: 90.714% ± 4.585) could be an artefact increase in time spent at batting practice by the three subjects who had made their provincial side. In retrospect, the subject’s in the control group were in their off-season break from cricket, having played for the club, their province, and in some cases their franchise teams. They may have scored lower on the pre-test of their batting performance as a result, especially when compared to the experimental and placebo group who may have been physically fresher and less mentally fatigued than the subjects in the control group at the onset of the study.

On the post-test there was an increase in batting performance for the control group. Three subjects in the control group were receiving additional batting practice in the nets in preparation for an upcoming tour, which gave them more practice time than any of the other subjects in this study. Their performance on the coincident anticipation timing test, however, produced the groups’ worst performance. Due to the structure of the study and for consistency purposes across the groups, the coincident anticipation timing test was always conducted first (Day 1), followed on the next day by the batting performance test (Day 2). As previously mentioned, the three subjects in the control group who had gone on an overseas cricket tour had only returned to South Africa the evening before the coincident anticipation timing test. They may have lacked the motivation to perform or may have been mentally and physically fatigued from the tour and the long flight. With the batting performance test occurring two days after the subjects arrived back in the country, this may have enabled them to sufficiently recover to produce their best performance on the batting performance test. The three strong batsmen may also have still been mentally “in the zone” (Potgieter, 2006) with regards to their approach to batting and so were able to produce a batting performance that almost equalled that of the experimental group. This brings a completely different aspect of cricket batting into question that deserves investigation, namely the sports psychology of cricket, and future research may like to look at the mental state of players and its influence on their batting performance.

Another factor influencing the control groups batting performance may be how expert batsmen rely a lot on pre-delivery anticipatory cues that they pick-up from the bowler in order to judge the line and length of a delivery (Muller *et al.,* 2006). Experienced intermediate and novice cricket batsmen rely almost solely on picking up information about the line and length of a delivery from the balls flight through the air. Seeing that the control group was formed using an intact group of sub-elite cricketers and a bowling machine was used in the batting performance test instead of a "live" bowler, this may have impacted on the batting performance of the sub-elite control group due to the removal of the pre-delivery anticipatory cues that they are used to using to help determine the line and length of a delivery. The experimental and placebo groups, however, were formed by players that could not be classified as sub-elite players, but more as experienced intermediate players. These experienced intermediate players may have relied less on pre-delivery anticipatory cues and more on ball flight in order to pick up the information they needed to perform successfully. In doing so, they were able to perform better on the batting performance test because the bowling machine did not provide any anticipatory cues but rather just delivered the balls, which they were able to pick up on better using their gaze control strategy. Muller *et al.* (2006) stated that:

> Skilled batsmen not only use effectively the same perceptual information as do less skilled batsmen but additionally show a unique capability to pick up useful information from early occurring cues – cues to which less skilled batsmen are not attuned. (p. 2163)

Over the course of the three testing sessions, the control group may have adjusted their gaze control strategy in order to succeed at making good contacts with the balls being delivered form the bowling machine, and this can be seen in figure 15 where the control group progressively improves in each testing session as their gaze control strategy becomes more focussed on the ball flight and not on pre-delivery anticipatory cues. This brings into question the use of bowling machines at cricket practices because according to Gibson and Adams (1989), batting against a bowling machine is greatly different from batting against a "live" bowler, at least up to the point where the bowler releases the ball. If players want to develop their game and strive to play at an elite level, they may have to limit the amount of practice time they dedicate to facing balls delivered from a bowling machine and focus more on facing deliveries from “live” bowlers. Future research could investigate the quality of bat-ball interception when batsmen of differing skill levels face “live” bowlers compared to a bowling machine.

Chapter Five

Summary and Conclusions

The findings in this study are varied; however they shed some light on a few issues surrounding the use of the Three-Step Decision Training Model (Vickers, 2007) to guide perceptual-motor training with particular reference to cricket batting. Although not the main focus of this study, eye dominance was found to have no influence on the coincident anticipation timing ability in cricket players. Eye dominance was also found to have no influence on their batting performance. This is in line with previous studies involving eye dominance and batting performance in baseball (Laby *et al.,* 1995; Classe *et al.*, 1996).

Effects of the Training Programme

The Three-Step Decision Training Programme (Vickers, 2007) implemented in this study centred on the manipulation of object and location cues to challenge players' anticipation, attentional control, and focus and concentration. The data revealed a trend toward improvement in coincident anticipation timing of the players participating in the intervention programme and they also displayed a trend toward improvement in their batting performance. However, these improvements were not statistically significant. The study did have a very small sample and it is possible that a larger group would have achieved significant results. But that would be speculation. The players were at the high intermediate to sub-elite level which means it is more difficult to achieve significant improvements than at the novice level.

Looking at the pattern of changes from pre- to post- to retention tests of coincident anticipation timing for all three groups it is interesting that there is a different pattern for each group.

1. The decision training group showed an improvement from pre- to post-test, but went back to their original level on the retention test. This pattern is typically associated with an intervention programme that is not long enough for subjects to consolidate the improvements they have made. Their batting

performance showed a steady improvement, even through to the retention test.

2. The placebo group became less accurate in their coincident anticipation timing on the post-test but also recovered to their pre-test level on the retention test. This type of pattern suggests that the placebo training programme may have actually created some kind of disruption to their coincident anticipation timing. However, they showed an improvement in their batting performance on the post-test at the very time their coincident anticipation timing deteriorated. On the retention test of batting, their scores went down toward pre-test levels. This result suggests that a closer look at the whole-body training programme is warranted.

3. The control group got progressively less accurate in their coincident anticipation timing which suggests some kind of sustained negative influence which affected their performance. However, they also got progressively better on the batting performance test which is opposite to the pattern for coincident anticipation timing. So what would make their scores on one test deteriorate while their scores on the other test improved? This inverse relation requires exploration.

Whole-Body Coordination Training

The whole-body coordination training was intend to be the placebo treatment, yet it also yielded positive results for the cricketer's batting performance, but not for their coincident anticipation timing. The programme did involve gross motor performance usually to steady rhythmic cadence and some of the motions were similar to cricket batting. However, no activities requiring interceptive timing were included in this programme. There were no balls to hit or catch or even to track. Two possibilities come to mind that might help explain how this type of programme might facilitate batting performance but negatively impact on a strict measure of coincident anticipation timing.

In terms of batting performance, the whole-body coordination training may have had a positive influence on balance control and coordination of the limbs. Unfortunately, these variables were not tested in this study, but both balance and limb coordination are central to success in cricket batting. This finding opens another pathway for cricket research that deserves to be investigated in the future as a potential training method for performance enhancement. As far as the researcher knows, there has been no study on the influence of whole-body coordination training on the batting performance of cricket players. Whole-body coordination training is a cost-effective programme that if found to have a positive influence on the batting performance of cricketers could be easily accessible to most players. Of interest to the researcher is how whole-body coordination training could influence the performance of players who may be out of form.

In terms of coincident anticipation timing, the activities in the whole-body coordination programme were presented with a cadence delivered by an external timing source. Players were asked to perform the various activities to this external beat. This external control of their performance may have temporarily disrupted their internal sense of timing. Although the test of coincident anticipation timing does have the performer respond to his/her perception of the arrival of an external signal, the performer organises his/her own motor response. Was the external cadence disruptive to internal timing? When the players had a break from this kind of training, did their internal sense of timing return to its initial levels? This also bears future investigation.

Disruptions for the Control Group

The practical limitation of using an intact group of players for the control group was identified in Chapter One. These players were more likely than the players in the other two groups to be selected for their provincial side, and in fact this did happen during the study. This means that several of them got more cricket batting practice than the players in the other groups. This explains their steady improvements in their performances on the batting skills test. But why would their coincident anticipation timing not improve as well?

It could be that the test for coincident anticipation timing was not very attractive for these players. They knew that they would receive no intervention programme, so they may have lost interest in whether or not they improved their scores on this laboratory-based test. If their motivation to perform on the test diminished with each test administration, that would explain why they got progressively slower.

Additional Concerns

There are many possible factors that could influence the performance of players during a study. Two specific areas of concern relevant to this study deserve comment: The assessment of batting performance and the psychological aspects of cricket batting.

Assessment of Batting Performance

The assessment of batting performance in this study used a criterion-based judgement of “good contacts” by cricket experts who could play and re-play the video records of each player’s performance on the test. This protocol was quite similar to the protocol used by Müller and Abernethy (2008). However, the test did use a bowling machine to deliver the balls to the bowlers, which denies batters information normally available from a bowler’s run-up to ball release. This information is used to help anticipate the speed and direction of a delivery, which detracts from the ecological validity of the test. Müller and Abernethy (2008) did state that this method of assessment is valid for determining the effects of perceptual-motor training programs targeting improvements in bat-ball interception. It might be more accurate to refer to the quality of bat-ball interception as the outcome measure of this test, rather than batting proficiency.

The research by Balasaheb *et al.* (2008) measured batting proficiency by calculating the batting averages of the cricket players in their study based on five matches played before and five matches played after the intervention training period. However there are obvious weaknesses to using this method, including the different opposition in each game, the inconsistent pitch conditions from game to game, different game situations requiring differing styles of batting (aggressive or defensive), different skill levels of the opposition and in particular the bowlers. This approach also does not appear to provide an objective measure of batting proficiency.

The development of a test of batting proficiency that would be useful for research purposes is seen as a challenge. Video-based performance analysis is one productive direction. Stretch, Buys, Du Toit and Viljoen (1998) used cinematographic analysis to document the stroke patterns of provincial cricket batsmen in terms of kinematic factors, grip forces and bat-ball contact. In subsequent research on cricket batting, Stretch, Nurick, Balden and McKellar (2004) were able to determine variations in bat-ball impact among cricketers of different batting skill levels. They developed an instrumented bat to assess both the consistency and accuracy of different strokes. The application of this kind of technology could support a more sophisticated approach to determining the effectiveness of intervention programmes on batting proficiency.

Psychological Aspects of Batting

A factor that may need to be considered in the future when looking at cricket batting and the effects of a perceptual-motor training programme is the psychology of the game itself, as well as the individuals playing within the game. Although no psychological tests were administered on the subjects in this study, it was quite evident to the researcher how life outside of cricket can have an effect on player's performance, including their performance on the coincident anticipation timing and batting performance tests in this study. Outside factors such as family issues, studying, peer pressure, etc. could all have an impact on performance. These factors are known to influence attention and focus and concentration. This was observed by the researcher and later confirmed by the head coach of the players as an issue that he constantly has to deal with within the cricket clubs environment. Future research could look at the psychological state of the players before they go into bat or perform any test to see how different mood and anxiety states can influence their test results. This could have important implications for developing the coping and mental skills of an athlete in order to deal with all of these outside factors.

Thoughts on Training Programmes

Over the many years that perceptual-motor training programmes have been investigated, no "golden standard" method has been established. Researchers in this field of study have used many different methods to try and bring about a change in sport performance with some studies being successful and others not. The programme implemented in this study was based on Vickers (2007) Three-Step Decision Training model. It was concerned with the development of players' anticipation, attention, and focus and concentration skills through variable and random practice activities in order to help players make decisions about their batting performance based on object and location cues. This approach tested only one possible combination of skills, triggers and tools in the model and so can only claim to make a small contribution to understanding its potential. Much more research is needed. There are other approaches to perceptual-motor training that also require further research, including visual skills training programmes and video-based perception training programmes.

Video-based perceptual training programmes have become very popular in recent years as researchers try to improve the ecological validity of their studies; however the benefits of such programmes are still questionable especially with regards to the transfer of improvements onto the field of play. Research involving video-based perceptual training has been conducted on fast ball sports such as tennis (Farrow & Abernethy, 2002), field hockey (Williams *et al.,* 2002), baseball (Fadde, 2006) and softball (Gabbett *et al*., 2007). All of these studies produced positive if not significant results for anticipation and decision-making skills. More research needs to be conducted on this field of perceptual training.

Visual search and gaze control research using eye movement tracking systems, such as the Mobile Eye (Applied Science Laboratories, Bedford, MA), can further enhance the practical design of perceptual-motor training programmes. The Mobile Eye has been designed to "collect eye movements and point of gaze information during the performance of natural tasks allowing the use of unconstrained eye, head and hand movements under variable lighting conditions" (www.asleyetracking.com). This device allows researchers to study vision in actual sport environments and to gather accurate data in terms of where athletes look and when they look at certain objects and locations. Research on cricket batting using an eye tracking system has already been conducted (Land & McLeod, 2000) and has provided insight into how expert, intermediate, and novice batsman control their gaze. This kind of information can have implications for the design and delivery of perceptual training programmes for cricket batting.

Thoughts on Vision and Cricket

Just as developing a cricketers fielding, bowling, and batting skills are important, so too is the development of their gaze control and in turn their decision making. A fundamental step forward in the development of cricketer's gaze control and decision making abilities would be to make visiting an optometrist every six months or before the start of every season compulsory. Abernethy (1986) acknowledge many years ago that a clinical optometrist should be involved in training programmes to ensure that athletes have at least adequate levels of visual 'hardware' and ocular health. As previously mentioned in Chapter Two, once the visual hardware has been dealt with, then programmes can be implemented to deal with the visual software side of the sport. Some cricket playing countries, such as England, have realised the potential that an optometrist and sports vision specialist can contribute to their team and have subsequently added them to their medical support staff (Dash, 2010). This needs to become the norm for all teams playing cricket all around the world.

Recommendations for Future Programmes

One of the main points that can be taken out of this study is that perceptual-motor training programmes may have the potential to improve cricketer's coincident anticipation timing and batting performance and the Three-Step Decision Training Model is worth further exploration as a method for structuring those programmes. However, it is recommended that if these programmes are implemented, they need to be conducted continuously in order to have a long lasting effect. Coaches and cricketers should look at including a perceptual-motor training programme into their daily training schedules in order for the benefits of such a programme to take effect.

It is also recommended that no innovative training programmes be implemented until the players involved have had a chance to understand the programmes purpose. The importance of perceptual-motor training programmes need to be stressed and a belief created within the team environment (*i.e.* from the coach, selectors, and management of the team all the way down to the individual players within the team). It is also recommended that the activities in the programmes are engaging and challenging to ensure that the players find the programme attractive. This will reduce player boredom which can lead to a situation where the players lose interest in the programme and subsequently do not try their best. Player boredom can be accounted for by ensuring that there is creativity and variety in each training session that the players are involved in (Wilson & Falkel, 2004).

Future Research

The game of cricket is forever changing and with the advent of Twenty20 cricket, the game is being watched by more and more people from all around the world. This makes the potential for new research in the sport immense.

- In future research involving perceptual-motor training programmes, larger sample sizes are needed in order to establish significant results. One of the limitations to this study was the sample size, although this could not be controlled by the researcher. Perceptual-motor training studies need to look carefully at appropriate group sizes.

- There is also a need to further investigate the effects of a perceptual-motor training programme on expert vs. novice cricket players. Changes in performance are more likely to occur between levels of skill proficiency than within the same levels of proficiency. In Chapter Two, previous literature establishing that there is an expert-novice difference with regards to the visual software skills in a number of different sports was discussed. However there is a distinct lack of literature on the expert-novice difference in cricket batting, more specifically whether a perceptual-motor training programme can influence an expert cricketer's visual software skills and subsequently improve performance.

- The potential influence of the whole-body coordination training programme on players' timing is particularly interesting and certainly warrants further investigation since timing is critical to coordination in all sports. An interesting study may look at a longer intervention period in which a comparison is made between a sample group receiving only sports vision training, a sample group receiving only whole-body coordination training, and a sample group receiving a combination of the whole-body coordination programme and the sports vision training programme, investigating to what degree the different training programmes influence batting performance.

- Further research using the Mobile Eye and its application to cricket batting also holds promise for learning about the visual search patterns of experts, specifically the object and location cues they use to anticipate what will happen in sport situations. This type of investigation could shed some light onto the visual search and gaze control strategies used by cricket players.

Conclusion

In conclusion, it appears that coincident anticipation timing and batting performance were not improved significantly through the use of Vickers (2007) Three-Step Decision Training Model to structure a perceptual-motor intervention programme. The lack of research in cricket batting using Vickers' (2007) approach warranted the conduction of this study. The results of the study expose yet another potential source to coaches and athletes who are looking to improve athletic performance.

References

Abernethy, B. (1986). Enhancing sports performance through clinical and experimental optometry. *Clinical & Experimental Optometry*, **69**(5):189-196.

Abernethy, B. (1991). Visual search strategies and decision-making in sport. *International Journal of Sport Psychology,* **22**:189–210.

Abernethy, B. & Russell, D.G. (1987). The relationship between expertise and visual search strategy in a racquet sport. Human Movement Science, **6**:283-319.

Abernethy, B. & Wood, J.M. (2001). Do generalized visual training programmes for sport really work? An experimental investigation. *Journal of Sports Sciences,* **19**:203-222.

Abernethy, B., Neal, R.J. & Koning, P. (1994). Visual-perceptual and cognitive differences between expert, intermediate, and novice snooker players. *Applied Cognitive Psychology*, **8**:185-211.

Abernethy, B., Wann, J. & Parks, S. (1998). Training Perceptual-Motor Skills for Sport. In B. Elliot (Ed.), *Training in Sport – Applying Sport Science* (pp. 6, 12). New York: John Wiley & Sons.

Adolphe, R.M., Vickers, J.N. & LaPlante, G. (1997). The effects of training visual attention on gaze behaviour and accuracy: A pilot study. *International Journal of Sports Vision,* **4**(1):28-33.

Atchison, D., Mon-Williams, M., Tresilian, J., Stark, L.R. & Strang, N.C. (1997). The value of training accommodative facility for ball sports. *Clinical and Experimental Optometry*, **80**(4):127-132.

Balasaheb, T., Maman, P. & Sandhu, J.S. (2008). The impact of visual skills training program on batting performance in cricketers. *Serbian Journal of Sports Sciences*, **2**(1):17-23.

Bartlett, R. (2003). The science and medicine of cricket: an overview and update. *Journal of Sports Sciences*, **21**:733-752.

Bowen, T. & Horth, L. (2005). Use of the EYEPORT™ vision training system to enhance the visual performance of little league baseball players. *Journal of Behavioural Optometry*, **16**(6):143-148.

Brown, J., Tolsma, B. & Kamen, G. (1983). Relationships between hand and eye dominance and direction of experienced gymnasts and non-athletes. *Perceptual and Motor Skills,* **57**(2):470.

Burton, A.W. & Davis, W.E. (1992). Assessing balance in adapted physical education: Fundamental concepts and applications. *Adapted Physical Activity Quarterly*, **9**:14-46.

Christenson, G.N. & Winkelstein, A.M. (1988). Visual skills of athletes versus nonathletes: development of a sports vision testing battery. *Journal of the American Optometric Association*, **59**(9):666-675.

Classe, J.G., Daum, K., Semes, L., Wisniewski, J., Rutstein, R., Alexander, L. Beisel, J., Mann, K., Nowakowski, R., Smith, M. & Bartolucci, A. (1996). Association between eye and hand dominance and hitting, fielding and pitching skill among players of the Southern Baseball League. *Journal of the American Optometric Association,* **67**(2):81-86.

Croft, J.L., Button, C. & Dicks, M. (2009). Visual search strategies of sub-elite cricket batsmen in response to different ball velocities. *Human Movement Sciences*, doi:10.1016/j.humov.2009.10.004

Dash, N. (2010). An alternative look at sports vision: Part 4 – Cricket. *OPTICIAN,* **239**(6249):20-21.

Erikson, G. (2007). *Sports Vision: Vision Care for the Enhancement of Sports Performance,* Boston: Butterworth-Heinemann-Elsevier.

Fadde, P.J. (2006). Interactive video training of perceptual decision-making in the sport of baseball. *Technology, Instruction, Cognition and Learning*, **4**:265-285.

Farrow, D. & Abernethy, B. (2002). Can anticipatory skills be learned through implicit video based perceptual training?.*Journal of Sport Sciences,* **20**(6):471-485.

Ferreira, J.T. (2003). An overview of research in sports vision: its history and optometric perspective. *The South African Optometrist,* **62**(4):142-159.

Gabbett, T., Rubinoff, M., Thorburn, L. & Farrow, D. (2007). Testing and training anticipation skills in softball fielders. *International Journal of Sports Science & Coaching*, **2**(1):15-24.

Gardner, J.J. & Sherman, A. (1995). Vision requirements in sport. In D.F.C. Loran & C.J. MacEwen (Ed.), *Sports Vision* (p.22). Oxford: Butterworth-Heinemann.

Gibson, A.P. & Adams, R.D. (1989). Batting stroke timing with a bowler and a bowling machine: A case study. *The Australian Journal of Science and Medicine in Sport,* **21**(2):3-6.

Goddard Blythe, S. (2000). Early learning in the balance: Priming the first ABC. *Support for Learning*, **15**(4):154-158.

Griffiths, G.W. (2002). Eye speed, motility and athletic potential. *Optometry Today*, **42**(12):34-37.

Griffiths, G.W. (2003). Eye dominance in sport: A comparative study. *Optometry Today,* **43**(16):34-40.

Hughes, P.K., Blundell, N.L. & Walters, J.M. (1993). Visual and psychomotor performance of elite, intermediate and novice table tennis competitors. *Clinical & Experimental Optometry*, **76**(2):51-60.

Interactive Metronome - http://www.interactivemetronome.com

Kanon Dimple Ball (Yellow) - http://www.kanonball.co.za/balls.php

Kluka, D.A. (1991). Visual skills: Considerations in learning motor skills for sport. *ASAHPERD Journal*, **14**(1):41-43.

Knudson, D. & Kluka, D.A. (1997). The impact of vision and vision training on sports performance. *Journal of Physical Education, Recreation & Dance,* **68**(4):17-24.

Kunicki, M. (1997). Can eye hand coordination be trained on the AcuVision 1000?. Unpublished Hons. (Applied Vision Sciences) thesis. Sydney: University of Sydney.

Laby, D.M., Kirschen, D.G., Rosenbaum, A.L. & Mellman, M.F. (1998). The effect of ocular dominance on the performance of professional baseball players. *Ophthalmology*. **105**(5):864-866.

Land, M.F. & McLeod, P. (2000). From eye movements to actions: how batsmen hit the ball. *Nature Neuroscience,* **3**(12):1340-1345.

Ludeke, A. & Ferreira, J.T. (2003). The difference in visual skills between professional versus non-professional rugby players. *The South African Optometrist,* **62**(4):150-158.

Magill, R.A. (2003*).* *Motor learning and control – concepts and applications* (7th Ed). Boston, MA: McGraw-Hill.

Mann, D.L., Ho, N.Y., De Souza, N.J., Watson, D.R. & Taylor, S.J. (2007). Is optimal vision required for the successful execution of an interceptive task?. *Human Movement Science*, **26**:343-356.

Marinovic, W., Plooy, A.M. & Tresilian, J.R. (2009). Preparation and inhibition of interceptive actions. *Experimental Brain Research*, **197**:311-319.

Martell, S.G. & Vickers, J.N. (2004). Gaze characteristics of elite and near-elite athletes in ice hockey defensive tactics. *Human Movement Science,* **22**(6):689-712.

McLeod, P. & Jenkins, S. (1991). Timing accuracy and decision time in high-speed ball games. *International Journal of Sport Psychology*, **22**:279-295.

Meir, R. (2005). Conditioning the visual system: A practical perspective on visual conditioning in rugby football. *Strength and Conditioning Journal*, **27**(4):86-92.

Mobile Eye - http://www.asleyetracking.com

Morwood, R. & Griffiths, G. (1998). Visual performance in cricket. *OPTICIAN*, **215**(5639):21-26.

Muller, S., Abernethy, B. & Tor, E. (2010). Training anticipatory skill in a natural setting of cricket batting through selective visual occlusion: A preliminary investigation. *Journal of Science and Medicine in Sport*, **12**(2):e14-e15

Müller, S. & Abernethy, B. (2006). Batting with occluded vision: An in situ examination of the information pick-up and interceptive skills of high- and low-skilled cricket batsmen. *Journal of Science and Medicine in Sport*, **9**:446-458.

Müller, S. & Abernethy, B. (2008) Validity and reliability of a simple categorical tool for the assessment of interceptive skill. *Journal of Science and Medicine in Sport*, **11:**549-552.

Müller, S., Abernethy, B. & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *The Quarterly Journal of Experimental Psychology*, **59**(12):2162-2186.

Müller, S., Abernethy, B., Reece, J., Rose, M., Eid, M., McBean, R., Hart, T. & Abreu, C. (2009). An in-situ examination of the timing of information pick-up for interception by cricket batsmen of different skill levels. *Psychology of Sport and Exercise*, **10**:644-652.

Naidoo, K.S., Mashige, P. & Ferreira, J.T. (2003). Visual Skills and Ocular Health: Relevance and Application to the Code of Cricket. In M.Y. Hassan, S Vallabhjee, Y. Coopoo & M. Patel (Ed.), *Cricket IQ* (pp.140-150). Lansdowne: Nazbin Computers CC.

Panasonic NV-GS400GC Digital Video Camera Operating Manual (p.87)

Pointer, J.S. (2008). Sensory motor lateral preferences of amateur motor sport drivers. *Research Journal of Medical Science,* **2**(3):121-127.

Potgieter, J.R. (2006). *Sport Psychology: Theory and Practice.* Stellenbosch: Institute for Sport Science.

Quevedo, L. & Solé, J. (1995). Visual training programme applied to precision shooting. *Ophthalmic & Physiological Optics*, **15**(5):519-523.

Regan, D. (1997). Visual factors in hitting and catching. *Journal of Sports Sciences*, **15**:533-558.

Reichow, A., Citek, K., Blume, M., Corbett, C., Erickson, G. & Yoo, H. (2010). The Effectivity of Stroboscopic Training on Anticipation Timing. *Journal of Vision,* doi:10.1167/10.7.1031

Renshaw, I. & Davids, K. (2004). Nested task constraints shape continuous perception-action coupling control during human locomotor pointing. *Neuroscience Letters*, **369**(2):93-98.

Ripoll, H. & Latiri, I. (1997). Effect of expertise on coincident-timing accuracy in a fast ball game. *Journal of Sports Sciences*, **15**:573-580.

Savelsbergh, G., Williams, A.M., van der Kamp, J. & Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences*, **20:**279-287.

Scott, K., Kingsbury, D., Bennett, S., Davids, K. & Langley, M. (2000). Effects of cricket ball colour illuminance levels on catching behaviour in professional cricket. *Ergonomics*, **43**(10):1681-1688.

Shneor, E. & Hochstein, S. (2006). Eye dominance effects in feature search. *Vision Research,* **46:**4258-4269.

Sparrow, W.A., Shemmell, J. & Shinkfield, A.J. (2001). Visual perception of action categories and the “bowl-throw” decision in cricket. *Journal of Science and Medicine in Sport*, **4**(2):233-244.

Starkes, J.L. (1987). Skill in field hockey: The nature of the cognitive advantage. *Journal of Sport Psychology*, **9**(2):146-160.

Steinberg, G.M. (1999). The benefits of assessing eye dominance in motor skill instruction. *The Journal of Physical Education, Recreation & Dance*, **70**(3):20-21.

Stretch, R.A, Bartlett, R. & Davids, K. (2000). A review of batting in men's cricket. *Journal of Sports Sciences,* **18:**931-941.

Stretch, R., Buys, F., Du Toit, E., & Viljoen, G. (1998). Kinematic and kinetics of the drive off the front foot in cricket batting. *Journal of Sport Science*, **16**(8):711-720.

Stretch, R.A., Nurick, G.N., Balden, V. & McKellar, D.K. (2004). The position of impact of a ball striking a cricket bat: assisting coaches with performance analysis of cricket technique and skill levels. *International Journal of Performance Analysis in Sport,* **4**(2):74-81(8).

Sugiyama, Y. & Lee, M.S. (2005). Relation of eye dominance with performance and subjective ratings in golf putting. *Perceptual and Motor Skills,* **100**(3):761-766.

Swinnen, S., Schmidt, R.A., Nicholson, D.E. & Shapiro, D.C. (1990). Information feedback for skill acquisition: Instantaneous knowledge of results degrades learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **16**(4):706-716.

The Kanon Premier Ball Machine Operating Manual (p.2)

Thomas, J.R., Nelson, J.K. & Silverman, S.J. (2005). *Research Methods in Physical Activity (5th Ed)*. Champaign, IL: Human Kinetics.

Thomas, N.G., Harden, L.M. & Rogers, G.G. (2005). Visual evoked potentials, reaction times and eye dominance in cricketers. *Journal of Sports Medicine and Physical Fitness*, **45:**428-433.

Tourky, A., Bartlett, B., Hill, V. & Jeh, M. (2005). Colour vision and distant visual acuity of elite and junior cricketers: Educational and sporting implications for students. In B. BARTLETT, F. BRYER & D. ROEBUCK (Ed.), *Stimulating the “action” as participants in participatory research: Vol 3* (pp. 131-141). Queensland: Griffith University, School of Cognition, Language and Special Education.

Venter, S.C. (2003). A comparison of the visual skills of two different age group high school rugby players. Unpublished (Optometry) Masters thesis. Johannesburg: University of Johannesburg.

Vickers, J.N. (2007). *Perception, cognition, and decision training: The quiet eye in action*. Champaign, IL: Human Kinetics.

Vickers, J.N., Livingston, L., Umeris-Bohnert, S. & Holden, D. (1999). Decision training: The effects of complex instruction, available practice and reduced delayed feedback on the acquisition and transfer of a complex motor skill. *Journal of Sport Sciences,* **17**:357-367.

Vincent, W.J. (1999). *Statistics in kinesiology (2nd Ed*). Champaign, IL: Human Kinetics.

West, K., Calder, S., & Bressan, E.S. (1995). The effects of visual skills training and sport specific vision coaching on the skill performance of elite level field hockey players. Unpublished manuscript, Department of Sport Science, Stellenbosch University.

West, K.L. & Bressan, E.S. (1996). The effect of a general versus specific visual skills training program on accuracy in judging length-of-ball in cricket. *International Journal of Sports Vision*, **3**(1):41-45.

Williams, A.M., Davids, K. & Williams, J.G. (1999). *Visual perception and action in sport*. New York: Taylor & Francis.

Williams, A., Ward, P. & Chapman, C. (2003). Training perceptual skill in field hockey: is there transfer from the laboratory to the field?. *Research Quarterly for Exercise and Sport*, **74**(1):98-103.

Williams, A.M., Singer, R.N. & Frehlich, S.G. (2002). Quiet eye duration, expertise, and task complexity in near and far aiming tasks. *Journal of Motor Behavior*, **34**(2):197-207.

Williams, H.G. & Woollacott, M. (1997). Characteristics of neuromuscular responses underlying posture control in clumsy children. In J.E. Clark & J.H. Humphrey (Ed.)*. Motor development: Research and Reviews Volume 1* (pp. 8-23). Reston, VA: NASPE Publications.

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

Winstein, C.J. & Schmidt, R.A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16**(4):677-691.

Witt, J.K. & Proffitt, D.R. (2005). See the ball, hit the ball: Apparent ball size is correlated with batting average. *Psychological Science*, **16**(12):937-938.

Wood, J.M. & Abernethy, B. (1997). An assessment of the efficacy of sports vision training programs. *American Journal of Optometry,* **74**(8):646-659.

Woolmer, B., Noakes, T., & Moffett, H. (2008). *Bob Woolmer's Art and Science of Cricket.* Cape Town: Struik Publishers.

Zupan, M.F., Arata, A.W., Wile, A., Parker, R. (2006). Visual adaptations to sports vision enhancement training. In D. Challinor (Ed.), *Optometry Today*, (pp.43-48*)*, London: Ten Alps Publishing.

Appendix A

Informed Consent Form

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

THE EFFECT OF A PERCEPTUAL-MOTOR TRAINING PROGRAMME ON THE COINCIDENT ANTICIPATION TIMING AND BATTING PERFORMANCE OF CLUB CRICKET PLAYERS.

You are asked to participate in a research study conducted by Grant van Velden (BSportScience Hons.), from the Department of Sport Science at Stellenbosch University. The results of the study will contribute to a Masters Research paper. You were selected as a possible participant in this study because you fall into the inclusion criteria of the study, that being you are a male between the ages of 18 – 28 years, and you play cricket for Maties Cricket Club.

1. PURPOSE OF THE STUDY

The purpose of this study is to determine the effects of a perceptual-motor training programme on the coincident anticipation timing and batting performance of university club cricket players.

2. PROCEDURES

If you volunteer to participate in this study, I would ask you to take note of following things:

Participants will be assigned into one of three groups after pre-testing and each group will receive a different four week intervention program. The effect of the different interventions on the coincident anticipation timing and batting performance of the participants will be analysed. All three groups will be advised not to participate in any additional training or activities above what they are currently doing.

- **<u>Place of Study</u>**

The coincident anticipation timing test will be administered in the Perceptual and Motor Learning Laboratory of the Department of Sport Science, Stellenbosch University. The batting performance test will be conducted in the indoor cricket facility at the Maties Cricket Club. The intervention training programs will be administered at the Department of Sport Science, Stellenbosch University.

- **<u>Methods of collecting data for the study:</u>**

Coincident anticipation timing pre-testing will be conducted individually. Participants will be instructed as to how the test will be administered and how they should perform the test. There will also be an opportunity for the participants to ask questions if they are unsure about anything.

Batting performance pre-testing will involve the use of a batting performance test which will require the batsmen to hit balls that are bowled from a bowling machine. The data will be recorded on Microsoft Excel and all calculations will be done using Microsoft Excel.

- **<u>Intervention</u>**

Two of the groups will take part in either a four week sports vision training programme or a four week whole-body coordination training programme. Within each of the four weeks, the participant will take part in four 30 minute training sessions per week. These sessions will take place in the specifically designated areas as mentioned previously. These sessions will involve a combination of drills specifically designed to focus on coincident anticipation timing and cricket batting.

The drills will make use of various pieces of equipment such as different coloured, sized, shaped and weighted balls; targets of varying size, shape and colour; hitting instruments that vary in size, shape and weight; the various physical walls of the Vision Court, and the cricket fields themselves. Some drills will also include the use of pieces of electronic equipment, such as the ReactionCoach™, where the participant is given a visual cue to which they have to respond as quickly as possible.

The third group will receive no training program and participants who fall into this group will form the control group for the study.

- **<u>Post- and Retention Test</u>**

After the four week intervention programme, the groups will be tested using the same protocols and methods as in the pre-tests. This data will then be compared to the data collected in the pre-tests using statistical procedures. After a three week period where no participants take part in any intervention programmes, a retention test will be conducted on all the participants to see whether there has been a change, if any, in their scores when compared to their post-test scores. This will give an indication as to whether the intervention programmes continued to have an effect after they ceased or not.

Overall, the participants will be involved in the study for approximately two months – within these two months there will be three testing occasions as well as four weeks of visual skills training (four 30 minute sessions per week) for one group, and four weeks of whole-body coordination training (four 30 minute sessions per week) for another group.

Once the study is complete, the participants who were involved with the sports vision training programme will be offered the opportunity to do the whole-body coordination training, and vice versa with the participants who were involved with the whole-body coordination training. The participants who fall into the control group will also be offered the opportunity to take part in both training programmes so that they too can benefit from any advantages that the interventions may have.

3. **POTENTIAL RISKS AND DISCOMFORTS**

Due to the nature of the intervention programme, there is a risk that some minor injuries may occur. Some common injuries associated with physical activity that may occur include twisted ankles, grazes, and contusions.

The risk of injury is minimised in the intervention programme because it is presented by the investigator to a small group of players (n=1 or 2) at a time. The activities can therefore be adjusted to fit the level of skill shown by the players.

The players will not be at any greater risk of general sports injuries that they may experience when playing their sport i.e. cricket. The testing and training procedures constitute no more risk than those normally experienced by cricketers during their training sessions. The investigator will provide a first aid kit that will be easily accessible at all times in case of any minor injuries.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The potential benefits that the subject may experience include an improvement in their coincident anticipation timing, which may potentially lead to an improvement in their cricket batting.

This project will also benefit the scientific field of sports vision and help to broaden the current body of literature surrounding sports vision training, specifically for cricket players. By providing guidelines as to what worked in the study or what did not work, this study will benefit coaches who are trying to get their athletes to improve their performance and are looking at sports vision training as a potential source of improvement.

5. PAYMENT FOR PARTICIPATION

The subjects will not receive any payment for taking part in the study.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of prescribing each participant with a unique 2-digit code that will correspond to their name. All participants' data will be recorded and processed according to their code. This code will be used on all documents or referencing to specific results that will be included in the final research project. The investigator will keep a master list of names and coded numbers in case the identity of a particular subject is necessary for later interpretation of the data. All data will be kept as a soft copy on the researchers personal computer, which is password protected, and as a hard copy in a locked drawer in the Perceptual and Motor Learning Laboratory at the Department of Sport Science, Stellenbosch University. The researcher and his study leader are the only people who will have access to the raw data.

Some of the intervention sessions may be videotaped for future use in presentations of the study. Participants will be able to view the footage and give consent for it to be used before it is saved and kept on the researcher's computer. The researcher and study leader will be the only people who have access to the videotapes. The footage will be kept for referencing for 3 years after the study and thereafter erased.

7. **PARTICIPATION AND WITHDRAWAL**

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Participants may be removed from the study if they miss more than one training sessions or any of the pre-, post-, and retention tests. This will be left up to the researchers' discretion.

8. **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact the following research personnel: Grant van Velden (cell: 0724601728 email:14721155@sun.ac.za), Prof E Bressan (phone: 021 8084722/4915 email: esb@sun.ac.za).

9. **RIGHTS OF RESEARCH SUBJECTS**

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Prof E Terblanche at the Unit for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me, ……………………………………………………………………………., by ……………………………………………………………………………. in [*Afrikaans/English/Xhosa/other]* and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study and I have been given a copy of this form.

____

Name of Subject/Participant

____

Name of Legal Representative (if applicable)

____ _______________

Signature of Subject/Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ___________________ [*name of the subject/participant]* and/or [his/her] representative _____________________ [*name of the representative]. [H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into* ___________ by ________________________*.*

____ _______________

Signature of Investigator **Date**

Appendix B

Expert Information Sheet

What do I require of you?

I need you to please view each clip and give your expert opinion on the type of contact made by the bat with the ball, based on the type of shot the subject played and the direction that the ball ended up travelling.

These contacts have been grouped into three categories: 1) *Good Contact*, 2) *Bad Contact*, and 3) *No Contact*.

1) *Good Contact*: This is defined as when the ball strikes the blade of the bat (not the handle or gloves) and travels in a direction post-contact that is consistent with the type of shot played and the direction that the shot intended to direct the ball.

2) Bad Contact: This is defined as any contact that the ball makes with the handle of the bat or the gloves of the batsmen. It also includes contact that is made with the blade of the bat where the ball ends up travelling in a direction post-contact that is not consistent with the type of shot played and the direction that the shot intended to direct the ball. An example of bad contact would be a player playing a front foot off-drive and, instead of the ball travelling in the intended direction through the cover region post-contact, he gets an inside edge so that the ball travels towards fine-leg post-contact.

3) *No Contact*: This is defined as when the batsmen either leaves a ball or plays at a ball and misses it completely.

Scoring

I have included a score sheet for each subject that can be opened using Microsoft Excel. Please copy the file to a convenient location on your computer. The first sheet that you will see when you open up the workbook will be an example score sheet of how I would like you to fill in your analysis answers. Each player has their own sheet and these sheets can be accessed by clicking on the blue tabs on the bottom of the workbook. After each player's analysis, please save the changes you made to the Excel sheet. Once all 21 of the player's analysis are complete, the updated Excel file can be emailed back to me.

Finally...

You are more than welcome to keep the CD with the footage and use it for anything that you see fit. If you decide to dispose of the CD, please make sure that it is broken in half before throwing it in the trash. Confidentiality issues surrounding the subjects and their footage require that the footage be destroyed before been disposed of in the trash.

Please feel free to contact me if you have any questions or you are unsure of anything.

Appendix C

Sports Vision Intervention Programme	Cognitive Skill	Cognitive Trigger	Decision-Training Tool
Session 1: Swinging Ball • Marsden Ball in the horizontal, vertical, and both diagonal planes, just looking at the ball. • Marsden Ball in the horizontal, vertical, and diagonal plane, looking for and calling out a nominated letter. • Cricket Ball on a string – subject lies on their back on the ground, swing ball in horizontal and vertical plane approximately 20cm from eyes.	**Attention** **Focus and Concentration**	**Object Cues**	**Variable Practice**
Session 2: Swinging Ball with Bat • Cricket Ball on string suspended from a metal frame – player makes contact with the ball using their bat so the ball swings through the guide poles on the side without making contact with the poles. Then progresses to a thin bat, approximately 5cm in width, and continues hitting through the frame. • Rubber ball on string suspended from the roof – player makes contact with the ball using his bat. Then progresses onto thin bat.	**Anticipation** **Attention**	**Location Cues**	**Variable Practice**
Session 3: Find the Number • Four coloured number charts (blue, red, green, purple; ranging from 1-20) are placed at eye-level approximately 40cm apart from one another in a horizontal line. Subjects stand 6m away facing the chart. Instructor calls out a number, then a colour and the subject must first locate the colour then the specific number within that colour. Subjects must indicate that they see the number by tapping their thigh with their right hand. • Progress onto bouncing slightly up and down on a Bosu ball. • Then progress onto bouncing on a trampoline.	**Attention** **Focus and Concentration**	**Object Cues**	**Variable Practice**

Session 4: Table tennis Rally's • Start with the subjects rallying on a small table tennis table. • Progress onto covering the left eye with their free hand, then onto covering their right eye with their free hand, and then continue rallying. • Move onto quick backhand rally's against a wall, then forehand rally's, then hit ball into the table-wall-table on backhand then forehand. • Progress onto standing on a wobble-board and following the directions of a chart placed above the hitting area on the wall. • End off with a long rally on the small table tennis table.	**Anticipation** **Attention**	**Location Cues**	**Random Practice**
Session 5: Eye Jumps • Subjects stand in a batting position 9m away from a wall with their leading arm extended towards the wall. A large letter alphabet is placed vertically down the wall, with another small letter alphabet placed onto the floor 5m away from the wall (in the same direction of the pitch). Subjects start their gaze at the large letter A, then shift their gaze quickly and accurately to the small letter A, then shift their gaze to their thumb finger nail. The cycle is then repeated with the letter B, C, etc. Subjects look for the first 6 letters then relax, then the next 6 letters then relax, and repeat this until they have completed the alphabet. They then run through the entire alphabet without taking a break. • The entire process is then repeated but this time an audio clip is played to try and distract the subjects. This audio clip is one of commentators commentating on a cricket match.	**Attention** **Focus and Concentration**	**Object Cues**	**Variable Practice**

Session 6: Bead String & Saccade Jumps • Subjects stand in a batting position, holding the bead string in between their eyes. They start by focussing on the far bead, being conscious of a V-formation, then they focus on the next bead, being more conscious of an X-formation, etc. They progress till they reach the bead closest to their face. • They then go from focussing on the far to the near bead as quickly as possible. • They then move over to the saccade chart and try to complete the chart in as quick a time as possible. • This cycle is repeated three times. The second time they stand on a Bosu Ball while doing the bead string and the saccade chart. The third time they stand on a wobble board.	**Focus and Concentration**	**Object Cues**	**Random Practice**
Session 7: Hoola-hoop shot direction • Subjects stand in a "batting cage" facing the Kanon bowling machine wearing boxing sparring gloves on each hand. Four different colour hoola-hoops are attached to the four walls of the batting cage. Each colour corresponds to a tennis balls colour. Balls are then fired at the subject with the speed gauge completely open (slowest speed) and they have to attempt to hit the tennis balls through the specific coloured hoola-hoop that it corresponds to. They can use either hand to do this. • 56 balls are initially fired at the subject, who then takes a break. The second set involves the subject now standing on a Bosu Ball while trying to hit the balls into the corresponding hoola-hoops.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Variable Practice**

Session 8: Thin bat hits • Subjects stand in a "batting cage" in their batting positions. They are given the same thin bat to bat with that was used in session 2. The Kanon bowling machine is set so that the ball bounces approximately 3m in front of the subject. The speed gauge is closed to approximately ¾ (3/4 of full speed), so it is much quicker than in session 7. The subjects are instructed to play normal cricket shots, but to concentrate on trying to hit the ball with the centre of the bat each time. • Each subject faces 56 balls per set and they each complete two sets.	**Anticipation** **Attention** **Focus and Concentration**	**Location Cues**	**Variable Practice**
Session 9: Table Tennis ball hits/catches • Subject stands in the batting cage holding a QuikStick in each hand. The ReAction Coach is positioned below the table tennis ball projector and set to "Preset 3". The "coaches remote" is plugged into the ReAction Coach so that the researcher has full control over which arrows are illuminated or not. Table tennis balls are then shot at the subject with the ball frequency set at 1, the ball speed set at 10, and the oscillator speed turned off. The researcher randomly pushes a button on the remote (either left, right, or center) just before the table tennis ball is shot at the subject. This indicates the direction that the subject has to hit the ball with either one of the QuikSticks. Each subject hits 25 balls. • The drill then progresses to them standing on a Bosu Ball with support, then on a Bosu Ball without support, then a wobble board. The same sequence of drills are then repeated but this time the ReAction Coach is not used and the subject has to try and catch the table tennis balls with their right hand, then their left hand, then their right hand, etc. • A total of 8 sets are completed.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**

Session 10: Wall Rally's & Find The Light • Subject stands facing a wall and continually tries to rally a tennis ball back and forth between their cricket bat and the wall. The subject must try and hit the ball so that it bounces in an A4 piece of paper that is attached to the wall, and then rebounds towards the bat. This is continued for three minutes. The subject then moves over to the Smart Speed Cells circuit where they attempt to break the laser light that corresponds to one of the flashing cells. The four flashing cells will flash at random and continue to flash until the beam is broken. The subject must break the beam with their bat. The subjects are instructed to try and break as many beams as possible in 3min. • After the 3min cycle, they rest for 1minute and then proceed to the wall rally's again. They then wall rally for 2min, do the cells circuit for 2min, rest for 1min, then rally for 1min and do the circuit for 1min.	**Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**
Session 11: Coloured Ball Hits/Dodges & ReAction Coach • The subject stands in the batting cage wearing the boxing sparring pads. The subjects are instructed to hit all the red tennis balls with their right hand, and to hit all the green tennis balls with their left hand. All the other colour tennis balls (yellow, orange and pink) must be ignored and the subject must sway out the way of them like they would a bouncer directed at their head/body in a match situation. Each subject faces 50 balls. • After that they move to a table where the ReAction Coach is positioned. It is set to "Preset 3" and the researcher uses the remote to indicate which target the subject must hit with the QuikSticks (either the left, right or centre target). Each subject hits 25 targets. • Overall the subject completes three sets in the batting cage and two sets on the ReAction Coach.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**

Session 12: Hoola Hoop Ball Toss & Cup Pong • The four hoola-hoops are attached to the two side walls of the batting cage; one is attached at the square-leg position, another at the wid-wicket position, another at the cover position, and the last one is attached at the point position. The cricketer takes up a batting position in the centre of the batting cage so that he is halfway between each of the side walls. The bowling machine is placed approximately 6m away from the batsmen and set at the slowest speed. It is also set to deliver the ball to the batsmen without a bounce at approximately waist height. The cricketer, while still maintaining his batting position, must catch the ball and then direct it towards the hoola-hoop that corresponds to the tennis balls colour. This must be done by playing a conventional cricket shot that one would play in order to get the ball in the designated target areas i.e. a cut shot must be played if the ball colour corresponds to the hoola-hoop in the point position. • Next they move over to the cup pong table and attempt to throw table tennis balls into one of four plastic cups. Each subject gets 25 attempts to try and get as many table tennis balls into the cups as possible. Each subject does three sets of the hoola hoop ball toss and the two sets of the cup pong.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**

Session 13: Slap Jack & Coloured Pitch • Subjects shuffle a deck of cards and place them face down on the table. The subjects then turn each card over one by one and place them face down on the table. As soon as a Jack is spotted, the subject slaps the turned over cards with their hand that is not turning over the cards. Two sets. • The bowling machine is set to ½ pace so that the tennis balls bounce 3m in front of the subject. The subject stands in the batting cage with his bat. A multicoloured sheet of non-slip plastic (2mx1m) is attached to the floor approximately 2-4m away from the subject. The multicoloured tennis balls are then shot from the bowling machine so that the ball gets "lost" in the multicoloured pitch in front of the subject. They then have to rely on pre-bounce ball flight information in order to judge the line and length of the delivery so that when they play a shot, good contact is made.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**
Session 14: Zone Hits • Three coloured target zones (green, orange, and white) are placed against a wall at eye-level, approximately 40cm away from one another. The table tennis balls are then shot out from the RoboPong at full speed and the subjects have to direct the balls towards the appropriately coloured target zones. The balls bounce on a table in front of the subjects so that it reaches them at chest height. Subjects stand approximately 4m away from the wall. They then move over to the saccade chart and try to complete the chart in a clockwise direction in as quick a time as possible. • This cycle is repeated three times. The second time the subjects stand on a Bosu Ball while doing the saccade chart and read the chart anti-clockwise. The third time they stand on a wobble board and read it clockwise.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Variable Practice**

Session 15: Crazy Catch Rebounds • Right hand throw, left hand catch. Left Hand throw, Right hand catch. Right hand throw, double hand catch. Left hand throw, double hand catch. Right hand throw, bouncing on trampoline, double hand catch. Right hand throw, spin left, double hand catch. Right hand throw, spin right, double hand catch. Near-far shift and throw (forwards). Near-far shift and throw (backwards). Circuit Near-far (forward). Circuit Near-far (backwards). Pattern recognition and repetition with throw (three times).	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**
Session 16: Spot The Dot • A single black dot is drawn on half of the various coloured table tennis balls with permanent marker. All of the balls are then mixed together and placed in the loading bucket of the RoboPong. The RoboPong is placed on the floor approximately 5m in front of the cricketer who is standing in a batting position, holding the table tennis bat as he would a cricket bat. The ball launching device on the RoboPong is angled upwards so that the balls reach the cricketer at approximately waist height. The cricketer is then instructed to play the appropriate shot to each ball; however, the balls with the black dot have to be played to the offside and the balls without the black dot have to be played towards the leg side.	**Anticipation** **Attention** **Focus and Concentration**	**Object Cues** **Location Cues**	**Random Practice**