GAZE BEHAVIOUR OF VOLLEYBALL PLAYERS DURING SUCCESSFUL SERVE RECEPTION

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Gaze behaviour of volleyball players during successful serve reception

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In accordance with Rule G4.6.3, I hereby declare that the above-mentioned dissertation is my own work and that it has not previously been submitted for assessment to any other University or for another qualification. As far as is known, all material used has been acknowledged and recognised.

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This dissertation is dedicated to my family and a contribution to my sport, Volleyball.

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ABSTRACT

The aim of this study was to identify and compare the gaze behaviour of both advancement levels (Advanced and Not Advanced) and genders (female and male) during successful serve reception. A quantitative, exploratory and quasi-experimental research design was used in which 50 ToppVolley Norway student athletes aged 16 to 19 years were sampled.

The gaze behaviour of junior volleyball athletes was assesed as they received two types of serves (1 float and 1 top spin jump serve) and performed a forearm and/or overhead pass to a setter's target while wearing an ASL mobile eye tracker. Gaze characteristics such as fixation number, fixation duration and areas of interest were used to achieve the aim of the study.

The study found that Advanced participants differed from the Not Advanced athletes in employing fewer (9.70 ± 1.14 versus 10.77 ± 3.63 , $p<.05$, $d>.20$) fixations but for longer durations per fixations (1.64 ± 0.20 versus 1.60 ± 0.34, $p<.05$, $d>.20$) in receiving the float serve. Contrary, for the reception of the top spin jump serve, the Advanced athletes employed more fixations (12.11 ± 2.40 versus 11.83 ± 2.17, $p<.05$, $d>.20$) but for shorter durations per fixations (1.57 ± 0.26 versus 1.65 ± 0.34 sec, $p<.05$, $d>.20$) than the Not Advanced athletes. Male athletes in this study were more experienced than their female counterparts (5.97 ± 1.62 years versus 4.75 ± 1.59 years, $p<.05$, $d>.20$) with males employing more fixations than the females (11.02 ± 3.63 versus 9.19 ± 1.55 and 12.26 ± 2.46 versus 11.36 ± 1.69, $p<.05$, $d>.20$) for the float and top spin serves respectively but for shorter durations per fixation (1.62 ± 0.27 versus 1.76 ± 0.29 sec (float) and 1.56 ± 0.32 versus 1.73 ± 0.28 sec (top spin) $p<.05$, $d>.20$) than the female athletes. These results and findings suggests that Advanced athletes for both serves attended to the most appropriate visual information through the top-down approach, their knowledge and past experiences. For gender differences, the results show that the female athletes employed fewer fixation points in receiving float serves, however the employment of fewer fixation points during the top spin jump serves was due to receiving serves characterised by easily identifiable trajectories and lower speeds. The contradicting finding of the Advanced athletes employing more fixation points for the top spin jump serve may be due to task complexity demands. Thirteen areas of interests were also identified. The combined results for both gender and advancement levels suggest that the athletes fixated on

similar areas of interests, primarily the upper body and secondary on the ball (flight), serve reception phase, arrival at target and contact point.

The aim and objectives of this study were achieved in that both absolute and relative values for number of fixations, duration of fixations and areas of interest fixated on, were established. However the outcome of comparisons made, were not all expected particularly that of the Advanced group for the top spin jump serve. Possible explanations were offered, but further research is required in this regard.

KEY WORDS: volleyball, serve-reception, gaze behaviour, eye movements, expertse, gender differences

CHAPTER ONE

PROBLEM STATEMENT

1.1 INTRODUCTION

Volleyball has been played around the world for over a century. As of 2010, it is estimated that over 800 million participants are involved worldwide, making it one of the most popular participant sports in the world (Briner & Kacmar, 1997). Volleyball thus has become more and more a competitive sport with high physical and technical performance demands. Individual and team performance through match analysis has contributed significantly to the development of volleyball (Eom & Schutz, 1992; Coleman, 2002; Marelic, Resetar & Jankovic, 2004; Barzouka, Nikolaidou, Malousaris & Bergeles, 2006; Zetou, Moustakidis, Tsigilis & Komninakidou, 2007; Bergeles, Barzouka & Grigoris, 2009; Costa, Ferreira, Junquera, Afonso & Mesquita, 2011; Palao & Ahrabi, 2011).

On the basis of the analysis of volleyball matches, coaches, match analysts and researchers have investigated the characteristics of volleyball at club, national and international levels, assessing the quality of team play and the contributions of each player in terms of playing position and skill performed. A chain of factors determine success or failure in volleyball matches and it has been identified that the measurable parts of these factors are related to the indicators of efficient performance of technical and tactical elements of game phases during the match (Marelic et al., 2004).

At the highest levels of volleyball, the most crucial aspect of the game lies in a team's ability to serve effectively and receive the opposing team's serve successfully (McGrown, Fronske, & Moser, 2001; Papageorgiou & Spitzley, 2003). The effectiveness of the serve can be quantifiably measured based on the receiving team's ability to receive their opponent's serve. The pass (forearm or overhead) is most commonly used in serve reception, is the most essential skill in the game and accounts for approximately 16% of the total volleyball match play (Papageorgio & Spitzely, 2003). Furthermore, the reception's quality can be analysed based on the number of attacking options the receiving team's setter will have in his or her

offense. Therefore, each impending contact is dependent on the previous, and similarly has an effect on subsequent contacts.

With all of the abovementioned, one particular area for scrutiny in match play is therefore the Complex I (also known as side-out) game phase. The Complex I, can be defined as the sum of actions that one team realizes to neutralise the opponent's serve in order to gain serve possession, and comprises of the serve reception, the set and the attack (Monteiro, Mesquita & Marcelino, 2009). Within this particular game phase, current volleyball success is often dependent, at least in part, on serve reception ability. Lendberg (2006) stated that the serve receive is the single most important component in the overall offensive scheme of a volleyball team, regardless of level or gender. Since the serve and Complex I game phase are such integral factors in successful volleyball it can be stated that should a team be unable to receive the opposing team's serve and transition into an effective attack, the coach and the team will not be able to progress. With the widespread use of rally point scoring system, a breakdown in receiving the serve is truly the precursor to defeat. Therefore the importance of successful serve reception, as well as reducing the number of serve reception errors highlights the need for coaching correct passing techniques, correcting individual deficiencies in passing skills and updating current rules around the serve reception to enhance performance.

According to the *Fédération Internationale de Volleyball's* **(**FIVB) (2008a) World Cup 2007 results the Top 10 best male receivers in the world have serve reception efficiency percentages ranging between 60.39% and 72.40%. The female cohort ranges from 53.94% to 68.38%. Attack efficiency percentages for the Top 10 males range from 51.81% to 59.56%, while females range from 43.33% to 52.53 %. These statistics on serve reception efficiency demonstrate the positive impact improved reception skills could have on a match outcome. It has been theorised that the components and factors upon which volleyball success depends are related to a core set of visuo-motor skills (Kluka, 1987).

It can therefore be deduced that skilled visual perception and subsequent motor response are critical to successful performance in a game such as volleyball, and are important determinants of sport expertise.

These visuo-motor skills, when integrated with quick action plans such as decision making, enable volleyball athletes to anticipate impending actions so that their responses and reactions are timed appropriately (Kluka, n.d). For the volleyball serve reception, a player must gather relevant cues from the server's motion and the ball's flight to make a decision to receive.

The detection of ball speed and direction has been considered important factors of performance in volleyball (Abernethy, Wann & Parks, 1998; Williams, 2000). Thus, what volleyball players do with their eyes during the serve reception is very important. 'Keep your eyes on the ball' and 'positioning is everything', are common volleyball instructions and always include some advice on what to look at before and during the execution of the skill as this informs the service action. An intrinsic view of what the player is looking at during the various stages of the preparation, and execution of a serve reception justifies the need for this research.

1.2. PROBLEM CLARIFICATION

Extensive and contemporary research has been conducted regarding the statistical analysis of volleyball team performance (Eom & Schutz, 1992; Coleman, 2002; Barzouka et al., 2006), and the use of performance indicators in performance analysis, such as technical and tactical elements of game phases (Hughes & Bartlet, 2002; Marelic et al., 2004, Papadimitriou, Pashali, Sermaki, Mellas & Papas, 2004; Palao, 2004; Laios & Kountouris, 2004; Mesquita, 2005; Joao, Mesquita, Sampaio & Moutinho, 2006; Lirola, 2006; Jager & Schollhorn, 2007; Lames & McGarry, 2007; Marcelino, Mesquita & Afonso, 2008), but little research on vision-in-action studies in volleyball has been conducted (Vickers & Aldolphe; 1997 Lee, 2010).

A review of available research on vision revealed that no research in this regard has been conducted in Norway, and neither at a junior level. No relevant data concerning junior players' visual search and monitoring of the eyes could be found. It is therefore important to explore the phenomenon of vision-in-action, particularly gaze behaviour patterns of receivers, and identification of interventions to deal with this most fundamental skill that also carries the greatest potential for success or failure of teams. This research study aims to fill the research gap of vision-in-action and amongst junior players which is relevant in an international context.

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The primary aim of this research is to identify the gaze behaviour of the Advanced and Not Advanced junior volleyball athletes during successful serve reception.

1.3.2 Objectives

The following objectives were addressed in order to achieve the research study aim:

1. To describe and compare Advanced and Not Advanced junior volleyball players with respect to the following during the reception of a top spin jump serve and accurate pass to the setter:
    - number of fixations;
    - duration per fixation; and
    - area of interest.
2. To describe and compare Advanced and Not Advanced junior volleyball players with respect to the following during the reception of a float serve and accurate pass to the setter:
    - number of fixations;
    - duration per fixation; and
    - area of interest.
3. To describe and compare male and female junior volleyball players in respect of the following during the reception of a top spin jump serve and accurate pass to the setter:
    - number of fixations;
    - duration of fixation; and
    - area of interest.
4. To describe and compare male and female junior volleyball players in respect of the following during the reception of a float serve and accurate pass to the setter:
    - number of fixations;
    - duration of fixation; and
    - area of interest.

1.4 SCOPE OF STUDY

The present study is exploratory and quasi-experimental in nature and followed a quantitative methodological approach in its acquisition of data. The research sample consisted of Norwegian Volleyball female and male players, aged 16 to 19 years, currently studying at ToppVolley Norway. ToppVolley Norway is an academic institution, a High School for athletes specialising in volleyball. In total 50 participants, of which 38% of the students were at an advanced level and 62% were not at an advanced level (comprising of 14% beginners and 48% intermediate level athletes) were assessed. Data was collected by evaluating all athletes' ability to receive served volleyballs based on their ability to pass the ball to the setter's position. The athletes performed the task wearing a mobile eye tracking system. An additional questionnaire to extract biographical information, including a section on vision (20/20 vision test and eye dominance) and sporting history was disseminated. The collected data was then analysed to describe and compare the gaze behaviour patterns of Advanced and Not Advanced volleyball players during successful serve reception.

1.5 TERMINOLOGY

In order to ensure clarity, the following key terminology has been explained for the purposes of this study.

AREA OF INTEREST (AOI) - The area of a display or visual environment that is of interest to the researcher or design team and thus defined by them (*ASL*, 2001).

EYE TRACKING- A technique allowing researchers to determine eye movement and eye fixation patterns by using the eye tracker (*ASL*, 2001).

GAZE BEHAVIOUR–A gaze is a series of consecutive fixations. Thus, gaze behaviour is defined relative to the locations, objects and persons within a scene (*ASL*, 2001).

SERVE RECEPTION – The phase of the game where the team receives a serve from the opposition or the first contact with the ball with the intent to control the ball to the setter or setter zone (Selinger & Ackermann-Blount, 1986).

TOP SPIN JUMP SERVE – A serve where the server tosses the ball into the air and then jumps up and hits the ball as it descends. The ball is struck at the peak of jump height using an arm action that imparts topspin (MacKenzie, Kortegaard, LeVangie and Barro, 2012).

FLOAT SERVE - is an overhand ground serve where the ball is hit with no spin so that its path becomes unpredictable. A float serve requires a sharp contact with an open palm so as to impart no spin to the ball (Huang & Hu, 2007).

SETTER ZONE - Area on the volleyball court known as positions II and III (Selinger & Ackermann-Blount, 1987).

VISION - Primary sensory experience, also defined as the ability to see; a physiological sense of sight by which the form, colour, size, movements, and distance of objects are perceived (Kolb & Whishaw, 2004).

ADVANCED VOLLEYBALL PLAYERS - the more experienced athletes in their age group.

NOT ADVANCED VOLLEYBALL PLAYERS - the less experienced athletes comprising of both beginners and intermediate group of athletes.

JUNIOR VOLLEYBALL PLAYERS - athletes in the category of 16 to 19 years old.

1.6 SIGNIFICANCE OF STUDY

Because eye movement directly affects volleyball performance, measuring an athlete's attentional focus and trajectory, coincidence anticipation, as well as estimation of skills can play a vital role in talent development and coaching. Coincidence-anticipation is defined as the ability to make a motor response at the same time that a moving object arrives at a designated intercept point (Stadulis, 1971). Estimation on the other hand is defined as the ability to estimate the time remaining before an object reaches a player or particular place, therefore its time to arrival or time to contact (Tresilian, 1995). With the above definitions, eye tracking analysis can immediately reveal an athlete's search patterns that can facilitate efficiency and effectiveness of incoming data. By determining efficiency and effectiveness, a coach can arrange practices that enhance environments for most conducive presentations. More aspects about the key factors in sports can be understood by comprehending how players perceive their surroundings on the field.

To summarise, the study of gaze behaviour can reveal valuable information as it allows for:

a) Testing in sporting situations, as the eye-movement apparatus places participants in experimental conditions similar to real ones;
b) selection and identification of the most informative cues;
c) quantification of the amount of information gazed at; and
d) establishing a visual search strategy to reveal the vital importance of the participant's view.

1.7 LAYOUT OF THE DISSERTATION

The research study is divided into five chapters as follows:

Chapter One: Introduces the background to the proposed study, the research aim and outlines the objectives, and includes a brief overview of the research design and methodology applied.

Chapter Two: Reflects an overview of available literature on volleyball, gaze behaviour and the phenomenon of eye tracking in sport.

Chapter Three:	Motivates and explains the research design and methodology adopted for this research study.
Chapter Four:	Presents a narrative and visual description of the research findings.
Chapter Five:	Discusses and evaluates all findings of the study, and presents the limitations experienced in the study, along with conclusions and recommendations for future studies.

1.8 CHAPTER CONCLUSION

This chapter placed the study in context by presenting an orientation to the topic, describing the problem statement, the aim and objectives of this investigation, and clarifying terminology used.

It also provided a research methodology summary to the study. The next chapter focuses on building a case on the scope of vision in sport, specifically the gaze behaviour of volleyball athletes.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The aim of this particular study was to focus on one of the critical factors of successful volleyball play, namely visual perception. This study focuses specifically on the visual gaze behaviour of Advanced and Not Advanced volleyball players when performing a volleyball pass and compares these in terms of efficacy. In order to achieve this aim and objectives of the present study the key factors that underpin the research are reviewed. First, an overview of the game characteristics of volleyball and the main volleyball skills involved in performing successful serve reception, namely the serve and serve reception and their interaction are presented. Furthermore, the importance of these skills and their value in the winning or losing of matches is explained.

Secondly, this chapter presents an overview on the basic knowledge of how information, movement and skill level interact leading to successful performance. Cutting (1986:3) pointed out that "it is largely through vision that we know our environment and our physical place within it". Schmidt (1988:147) called vision "the most critical receptor system for supplying information about the movement of objects in the outside world". Therefore, central to this research are concepts related to the visual sensory system and its role in guiding successful movement responses with respect to sport in general and volleyball specifically. Relevant theories and research pertaining to visual search strategies and gaze behaviour are also reviewed in order to highlight the relevant implications these may have for the assessment methods and procedures applied in this study, as well as to provide background against which the results of this study could be interpreted.

2.2 GAME CHARACTERISTICS

Volleyball is an international sport played by two teams of six players on a playing court divided by a net. The regulation height of the net at the center is 2.43 metres for men and 2.24 metres for women. A volleyball court measures 18 metres long and 9 metres wide and is divided into two halves by the net (9 m × 9 m). Each half-court is usually divided into six court positions. The three in the front court are referred to as positions IV, III, and II from left to right, and the three back court positions are V, VI, and I (Bahr, Lian & Øvrebro, 1994). The objective of the game is to send the ball over the net in order to ground it on the opponent's court, and to prevent the same effort by the opponent (Bahr et al., 1994). Volleyball players perform a variety of maneuvers that are unique to the sport. According to Bahr et al. (1994) this game is considered to consist of six basic skills: serve, pass (serve reception), set, attack, block, and defense (see Figure 2.1). A team can touch the ball three times (in addition to the block contact) on its side of the net. The ball is put into play with an overhead serve, delivered jumping or standing. The opposing team usually starts offensive play with a standard dig-set-spike pattern. With arms extended and the hands held together below the waist, a player will dig or bump or pass the serve by playing the ball off both forearms or alternatively played with the overhead pass. The ball is then "set" by a teammate who, with both hands overhead, directs it toward the net, where another teammate jumps and attacks or spikes the ball, using an overhead arm swing. The goal of spiking is to generate a powerful hit into the opponent's court.

Volleyball is a rebound sport. In many sports, players can control the ball by retaining possession and moving with it. In volleyball, however, it is forbidden to catch or hold the ball; every contact must be a rebound action. Because of this rule, it is essential for the player to be in the right place at the right time if the ball is to be played in a controlled manner. Therefore, good anticipation and movement skills should be taught to participants.

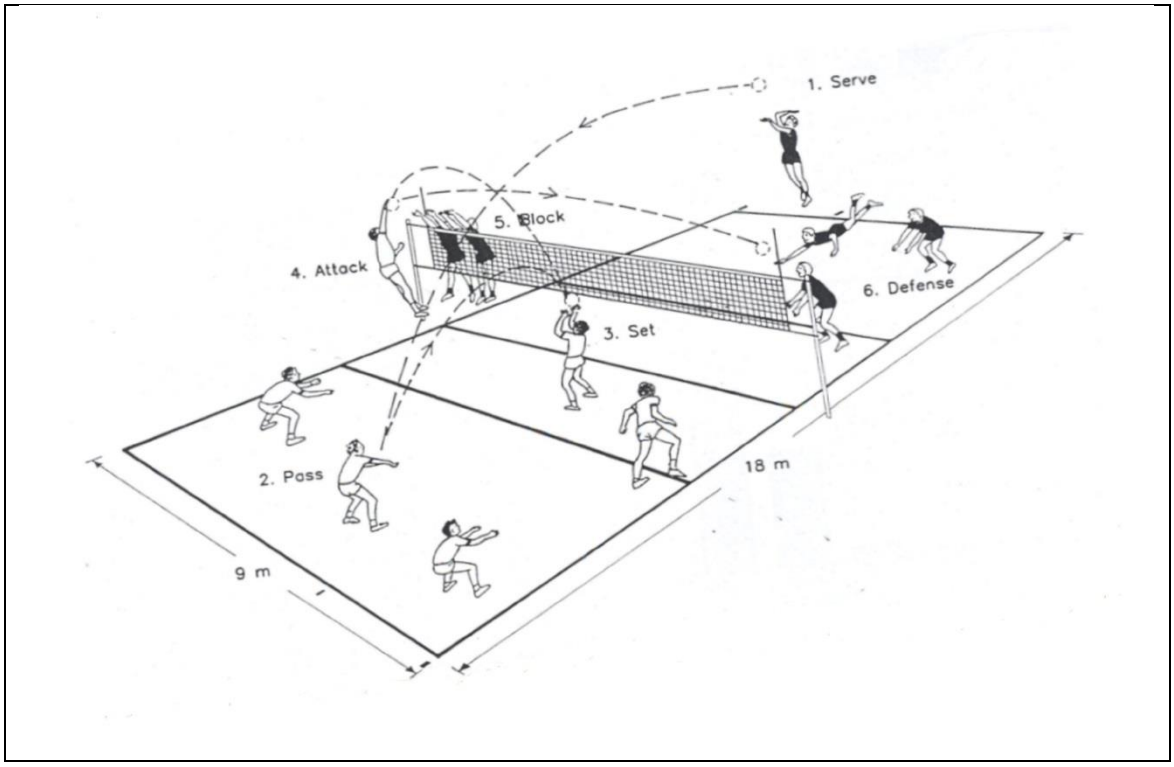

Figure 2.1: Illustration of a volleyball court and the six basic skills of volleyball in the most common playing order; serve, pass (serve reception), set, attack, block and defense (Volleyball South Africa Handbook, n.d).

As illustrated in Figure 2.1, the game is initiated by receiving a served ball, passing the ball to the setter and then attacking the ball. The ball is hit (if hit hard enough the ball travels at velocities up to 130 km/h over the net). This means the receiver must assess the incoming angle, decide where to pass the ball and then control the pass extremely quickly.

Prior to Sydney 2000 the FIVB introduced a new specialist role: the libero (FIVB, 2011). This player wears a different coloured uniform from the rest of the team and can be substituted in the back court for any player on the team. The libero cannot serve, spike the ball over the net nor rotate into the front line positions, but plays a vital role for the team in serve reception and back court defense. It was found that the libero added an extra dimension to the back court defense in, improving the reception of teams, lengthening the rallies and giving a vital role to shorter players (FIVB, 2011).

2.3 VOLLEYBALL SKILLS

The focus of this section is on volleyball skills; a presentation of factors that contribute to the dynamics of the game, gender differences in the game and determinants of winning or losing matches. This framework provides a simpler way of understanding the role of serve and serve reception in the game of volleyball.

2.3.1 Skill importance in Volleyball

A chain of factors determine success or failure in any sport match, but the measureable part of it is related to indicators of efficient performance of technical-tactical elements or game phases during matches. The monitoring of play in team sports such as volleyball, and its analysis, are based on the evaluation of the effects of situation-related parameters. The evaluation can be using volleyball game official records, video recordings such as data volley or various analysis of players' efficiency during the game (Marelic et al., 2004).

A broad scope of research has been conducted in order to understand the dynamics of the game of volleyball. After the rule changes in volleyball in 1999, the game experienced a complete renovation in the technical-tactical sense (Zadraznik, Marelic & Resetar, 2009). In order to facilitate the evaluation of team performance and analysing the logic of the game, the elements that play a key role in the way each team's game is organised should be weighed in regard to Complex I (also known as side out), which comprises of serve reception, setting and attack, or Complex II, which comprises of serve, block/defense and counter-attack (Frohner & Zimmermann, 1996). In the volleyball game complex analysis, it is observed that the side-out possesses more stable initial organization conditions, as the ball is recovered from the most predictable action of the game, the serve, thus creating favourable conditions to the offensive organisation (Mesquita, 2005).

According to Complex 1, the team tries to gain a point by direct first attack. It is therefore crucial for the team to play an offensive and effective game. During the series of actions, serve-reception, set and attack, every action aims at exerting pressure on the opponents by using all available weapons in attack (winning the point), at gaining the advantage by winning a direct ball or pressing the opponent's defense to save the ball and creating a counter-attack. The aim of gaining the point is achieved by restricting the attacking

possibilities of the opponent so as to enable the forming of a strong and effective block (Costa, Ferreira, Junqueira, Afonso & Mesquita, 2011).

Zetou et al. (2007) explains how the statistical evaluation of a team's performance helped considerably with the development of the game of volleyball. Their study shows that in terms of serve-reception skill, the best predictor of a win was the receiver's ability to receive the serve effectively for the setter to set for a first tempo attack or set a high set to the outside hitter in position four or two. The results concluded that a score of 'best' and a 'good' serve reception remained the main condition for a setter, in organising a powerful attack and thus winning the point.

Zetou, Tsigilis, Moustakidis and Komninakidou (2006) through video analysis using discriminant analysis, presented the playing characteristics of the teams in Complex II and attempted to determine which of these characteristics led to victory and to the final ranking of the teams. The results concluded that an 'ace' in the serve and in counter-attack are powerful aggressive tools for high level teams and were predictors to a win.
Laoios and Kountouris (2005) using video analysis, compared the effectiveness of the five principal skills in men's Volleyball, namely serve, reception, attack, block and dig, between the Sydney and the Athens Olympic Games and found that the observed changes in game patterns were connected to the implementation of the new rules in Volleyball. The findings revealed an increase in reception faults as a result of the improvement of the service effectiveness. The above changes reflect the teams' shift of tactics to win more points from their own serve.

Hughes and Daniel's study (2003) focused on understanding the playing patterns of elite and non-elite volleyball teams. Their analysis show that elite teams were significantly better at serving and receiving than non-elites. The study also showed that the quality of attack was dependent on the quality of the set, and that the quality of the set was dependent on the quality of the defense or the reception of the serve.

Yiannis and Panagiotis (2005) compared the effectiveness of key skills in 10 men's volleyball matches that occurred between Sydney 2000 and Athens 2004 Olympic Games and showed that there was a general trend of decreasing the proportion of mistakes performed on

all skills. In the 2004 Olympic Games, Brazil, the gold medalist, performed their reception and attack skills far better than the teams they competed against (Laios & Kountouris, 2005). Eom and Schultz (1992) noted that the quality of the first touch provided better conditions for setting and, consequently, favourable conditions for finalisation.

In summary, this section highlights the observed importance and implications of the serve-reception phase in the game, and notes that the quality of strategic and tactical play or winning is highly dependent on this aspect.

2.3.2 Gender differences in the volleyball game

Published studies show some differences between the men's and women's game. The primary differences are that men use more powerful jump serves (Agelonidis, 2004; Rocha & Barbanti, 2004; Palao, Santos & Urena, 2009), quicker attack tempos (Afonso et al., 2005; Castro & Mesquita, 2008), stronger attacks (Costa et al., 2011) and play less often in Complex II. On the other hand, women predominantly use float (ground) serves (Palao, Santos & Urena, 2005; Costa et al., 2011), develop slower attack plays (Palao, et al., 2004; César & Mesquita, 2006), use placed attacks more often (Costa, Mesquita, Greca, Ferreira & Moraes, in press) and provide longer rallies, therefore playing more often in complex II (Bergeles et al., 2009).

Zetou et al. (2006) found tendencies that in top level men's volleyball, serve aggressiveness was highly related to point scoring and diminishing the likelihood of the opponents being able to run quick attack play. On the contrary, Palao, Manzanares and Ortega (2009) found that the float serves in matches had the most occurrence (87.9%). Females induced smaller risks with this type of serve action, therefore resulting in tactical play with this type of serve, investing more effort in defense and counter-attack.

In a study on youth volleyball, three variables showed significant differences between males and females, namely serve type, attack type and attack tempo (Costa, Afonso, Brant & Mesquita, 2012). For the serve type, game characteristics for the youth level were similar to that of the senior level. The literature review shows that game features are substantially divergent according to gender with implications for technical and tactical preparations (Costa et al., 2012).

2.3.3 Determinants of winning or losing sets or matches in volleyball.

In a case study by Marelic et al. (2004) of discriminant analysis of sets won and sets lost by one team in the A1 Italian Volleyball League, the results revealed that the variable spike in the phase of attack proved to have the highest predictive value. The explanation for such a high predictive value was found in the fact that spike in the phase of attack is mostly executed after an ideal serve reception, upon which the setter has opportunity to organise a fast and combined attack. The study proved that the base of a well organised attack was a good service reception which required well-practiced receivers, especially a capable libero, and also the attacker's ability to attack all the balls effectively. Among coaches, the importance of serve reception is indisputable. A wish to elicit the best possible response to dangerous serves has resulted in the introduction of a new player in the body of rules. A player specialised only for receiving either the serve, or playing defense. Therefore the introduction of a libero was for a more precise serve reception and a more efficient organisation of attack (Marelic et al., 2004).

In a study conducted to answer the question as to whether the effectiveness of skill in Complex I predicted a winning outcome in men's Olympic volleyball, the researchers recorded every skill of the Complex I of the game for each team (Zetou et al., 2007). There was a five level scale protocol used according to the effectiveness of the skill. Among the five variables of serve reception were the two variables best reception, first attack, and good reception, high set attack. The results of this Zetou et al. (2007) study concluded that best, and good reception and the ace-point in the attack remain powerful aggressive tools for high level teams and are predictors of winning. Also, the Athens gold medalist team (Brazil) showed remarkable reception effectiveness which led to an outstanding attack capability, thus reestablishing attack as the most important skill in volleyball (Zetou et al., 2007). In a study by Costa et al. (2011) they too found the attack to be the most decisive procedure for the competitive success of the teams; along with its associated with the serve-reception effect leading to attack tempo and varied attack types.

2.3.4. The Serve

The serve, in modern volleyball is the first offensive action (FIVB, 2011). The serve initiates play and has two primary objectives, firstly to hinder the opponent's serve- reception attack by slowing it down (thereby making it more predictable to block), and secondly to score a direct point (Papageorgio & Spitzley, 2003). The serve is the only time in the game when a player completely possesses the ball and can choose the moment to initiate the action. The serve can also be used effectively to regulate the rhythm of the game and disrupt the opponent's concentration.

In high (club, national or international) levels of volleyball it is invaluable for a team's strategy to have good servers and serve specialists. In the modern game of volleyball the effectiveness of the serve and its impact on the match is pivotal. The following are goals for the serve: (Papageorgio & Spitzley, 2003)

- To directly score a point or force a poor first pass;
- To put pressure on the service reception formation, thus weakening and forcing the opposition to change their service reception;
- To move the starting position of the front court service reception as far back as possible;
- To make the running distance of the setter longer; and
- To allow the hitters less time to prepare for the attack.

Serves are divided into two broad categories, according to the ball movement after it has been struck: float serves and spin serves (the jump serve).

2.3.4.1. The Float Serve

The float (ground) serve (figure 2.2) is an overhand serve where the ball is hit with no spin so that its path becomes unpredictable. A float serve requires a sharp contact with an open palm so as to impart no spin to the ball (Huang & Hu, 2007). This is to minimize spin on the ball and float with the erratic air currents before dropping sharply into the opposite court. The nonsymmetrical lateral forces act on a non-spinning volleyball as it travels through the air resulting in unpredictable movement patterns. This unpredictable flight pattern makes it a very difficult serve to pass although the unpredictable trajectory increases.

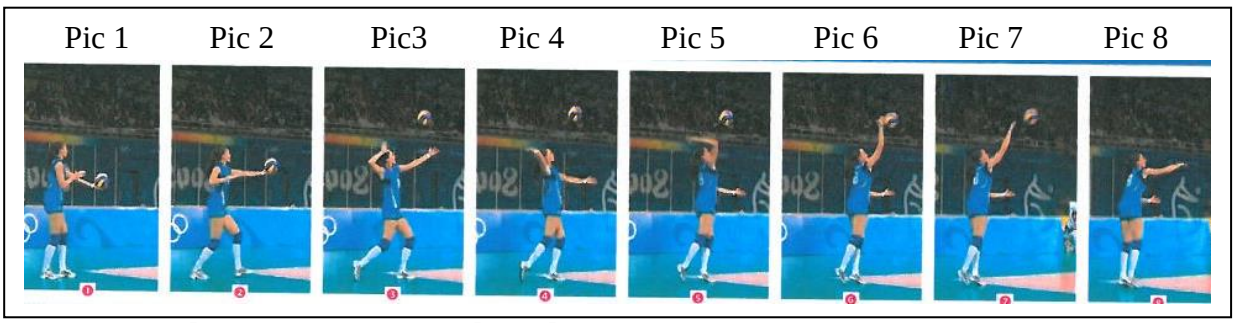

Figure 2.2 Float serve (FIVB Technical Posters)

According to Selinger and Ackermann-Blount (1986) to produce a float serve, the force of impact must pass through the ball's center of gravity in the direction of the desired flight. It is generally considered that the ball's floating and wavering action is due to what is known as Bernoulli's effect. This theory states that when a flying stream of gas speeds up, its pressure decreases, and vice versa. A volleyball ball has a shape of a three dimensional foil and therefore, when traveling through the air, it creates a funnel or tunnel of low pressure around it. If the low-pressure areas around the ball are exactly balanced, the ball will fly with no wobbling effect. However, if the air pressure in the tunnel is not perfectly balanced, consequently the ball wobbles from one low pressure to another. The turbulence behind the ball creates even more sinking and wobbling action. The greater the horizontal velocity of the ball the greater the wobbling effect. Therefore, it is recommended that the float serves be served from a relatively long distance behind the endline (6-9 metres) (Selinger & Ackermann-Blount, 1986).

2.3.4.2. The Top Spin Jump Serve

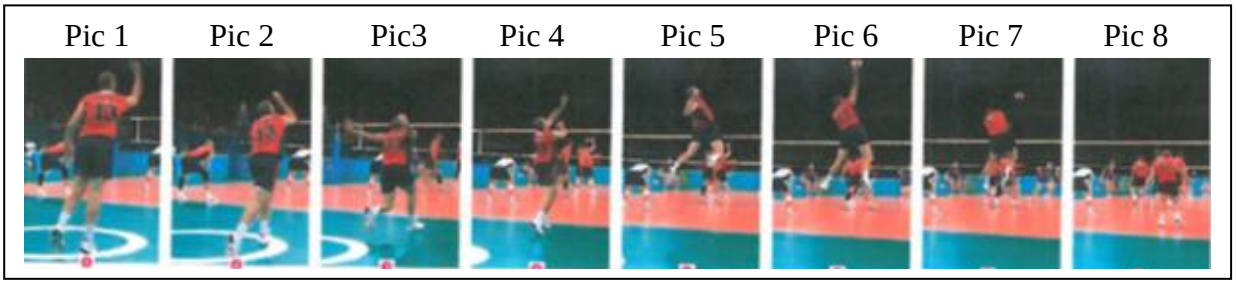

Figure 2.3 Top spin jump serve (FIVB Technical Poster)

One of the most dramatic skills in modern volleyball is the spike serve, also known as the top spin jump serve (shown in figure 2.3). Papageorgio and Spitzley (2003) explained that the top

spin jump serve has become a dangerous offensive weapon for the top volleyball teams of today, as a great jump server can produce a number of aces over the course of the match. MacKenzie et al. (2012) described the jump spin serve as being characterised by a high toss, multistep approach, and near maximum jump, including full use of both arms. The ball is struck at the peak of jump height using an arm action that imparts topspin. When traveling through the air with topspin, the ball experiences a primarily downward lift force, causing the ball to 'drop' earlier than the trajectory of a ball would without spin. Mackenzie et al. (2012) explained that the top spin jump serves to generate the greatest ball speeds and because the ball is contacted higher above the court relative to other current serve types, a flatter initial projection angle can be imparted to the ball. The lower initial projection angle and increased projection speed both results in a reduced flight time. Together, these factors increase the difficulty of the serve for the receiving team. However, the characteristics of the jump spin serve approach, and toss, make it easy to identify, and the spin imparted to the ball promotes a stable and predictable trajectory relative to a float serve.

In a kinematic charateristic study of the float serve versus the top spin jump serve, Huang & Hu (2007) showed that the jump serve has greater values than the float serve because of the ball being played in the air. Therefore, jump serves produce greater ball velocities and spike height which in turn increase the serve power. The results revealed that ball velocity was significantly correlated with horizontal velocity at take-off and spike height correlated with vertical velocity of the body in cm at take-off to contact point.

2.3.4.3. Serve Reception

Serve reception refers to that particular phase of the game when the team receives a serve. The term serve reception encompasses passing, which is the individual skill used in serve receiving, as well as the arrangements of players on the court or 'serve-reception formations' (Selinger & Ackermann-Blount, 1986). The serve reception is the single most important component in the overall offensive scheme of a volleyball team, regardless of expertise level or gender (Lenberg, 2006). If a team cannot receive the opposing team's serve and transition into an effective attack, the coach and the team must be prepared to lose the match. With the widespread use of rally point scoring, a breakdown in receiving the serve is truly the precursor to defeat (Lenberg, 2006).

The serve receiver and the passer are one and the same because the serve receiver's primary task is to pass the ball to another player (the setter); thus they are frequently called a passer rather than a serve receiver. Lenberg (2006) gives an explanation of what is required to produce a successful serve reception. First and foremost, an effective serve receiver must have proper visual skills to be able to track the ball from the exact moment it leaves the opposing server's hand to the time it reaches his or her arms. According to Lenberg (2006) a good serve receiver must have:

- excellent distance vision, which is the ability to see clearly at a distance of 16 feet or more,
- very good depth perception, which is the ability to judge distance from self to others and objects;
- visual pursuit, which is the ability of the eyes to follow smoothly, easily and accurately when tracking an object; and
- visual concentration, which is the ability to concentrate on an object while dealing with other visual stimulation occurring within range of sight.

In volleyball three types of trajectories can be defined, as illustrated in Figure 2.4 below.

Type One 	Type One is characterised by low speed and an easily identifiable peak point. This trajectory is easiest to judge.
Type Two 	Type Two is characterised by high speed and flat trajectory. This is considered moderately difficult to judge and should not be used with beginners.
Type Three 	Type Three is characterised by very high speed and downward trajectory. This is considered very difficult to judge and controlling this type of shot is an advanced skill.

Figure 2.4: Types of serve Trajectories (Volleyball England Handbook)

In addition to the abovementioned visual skills, it is has been determined that in serve reception a number of mental skills are important (Lenberg, 2006). The most desirable mental skills and traits include confidence, competitive focus, mental preparation and quality of training. In short, mental preparation or the ability to think in the present is paramount. A good passer must be able to move on from past mistakes and not worry about future performances. Confidence translates into the ability to trust one's own skills, thus invoking the ability to perform automatically without hesitation or second thoughts. Finally, according to Lenberg (2006), a good receiver must have the ability to get the job done. A player's ability to move efficiently to the ball determines the serve-receive success rate. When receiving a serve, passers should attempt to get the ball in three steps or fewer. They should be able to move to the point at which they can actually intercept the ball before it gets there. In other words, an effective passer should be waiting for the ball to arrive. A major fault that serve receivers display is waiting until the ball actually reaches them before taking the first step (Lenberg, 2006).

2.3.4.4. The Pass

The pass is the first contact with the ball after the serve. The main objective of the pass is to direct the ball to the setter in a specific, predetermined target area. The ability of a team to execute an effective attack following serve reception depends largely on the accuracy and the quality of the pass. If the pass is not precise, then the setter's options are reduced, creating an attack that is slow and predictable.

Usually the pass is executed with the forearms, however, it is legal and commonly more effective with slow serves to pass the ball with the fingers overhand, a motion that is similar to setting and is called 'finger passing'. In emergency situations, a player can even pass with one arm.

Passing is the most important skill in volleyball (Selinger & Ackermann, 1986). It is an attempt by the players of a team to receive the ball from the opponent and prevent it from touching the ground. There are two main types of passing in volleyball: the forearm passing and the overhead passing. While the players use their forearm to create a flat platform that directs the ball to a teammate in a controlled manner during a forearm pass, overhead passing

involves hitting the ball to a teammate using fingers and an overhead setting action (Selinger & Ackermann, 1986).

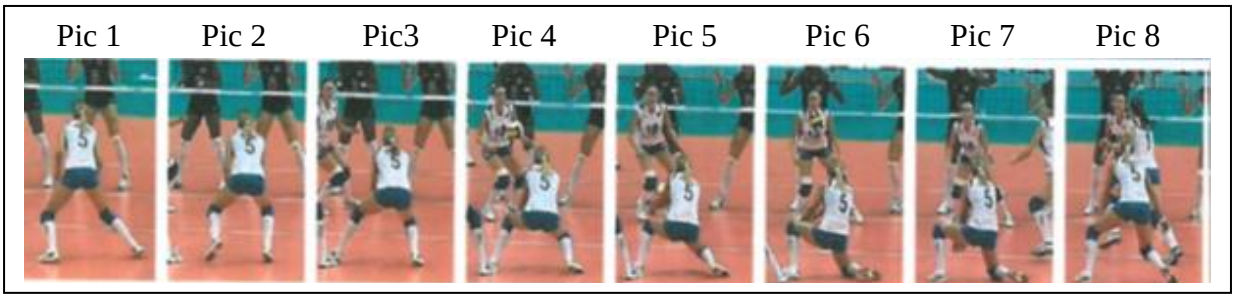

Figure 2.5 Forearm passing in serve reception (FIVB Technical Poster)

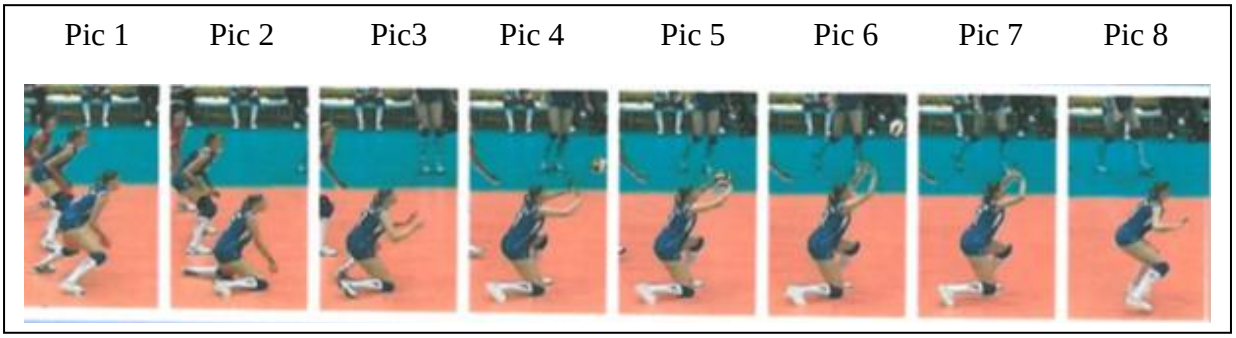

Figure 2.6 Overhand passing in serve reception (FIVB Technical Poster)

In summary, pivotal volleyball skills (serve and serve reception) have been defined and presented. Factors that contribute to successful volleyball performance and how the relationship between the serve and serve reception contributes to the game for both females and men were elucidated. The next section highlights the context of teaching and learning to acquire and perform these important skills.

2.3.5 Method of teaching volleyball skills

2.3.5.1. The ToppVolley Norway Program

The ToppVolley Norway program of the Norwegian Volleyball federation is based on a three year school program that facilitates deliberate practice in stages based on the Canadian long term athlete development (LTAD) model. Volleyball Canada (2006) defined LTAD as a training, competition, and recovery program that establishes guidelines for coaches, athletes, administrators, and parents in all these areas. Furthermore, it takes into account the ever-

changing competitive program and the overall demands on the athletes. Long-term athlete development is also about identifying potential and providing appropriate developmental pathways for that potential to be fully realised.

An early start and attendance at ToppVolley Norway exposes the athletes to three years of structured, organised and quality training/practices with professional coaches. Therefore the program is athlete centered and coach driven. Furthermore, players are grouped by skill, not by age. At ToppVolley Norway, the average amount of practice increases each year/grade along with the program content. Figure 2.7 below reflects the design of the teaching programme.

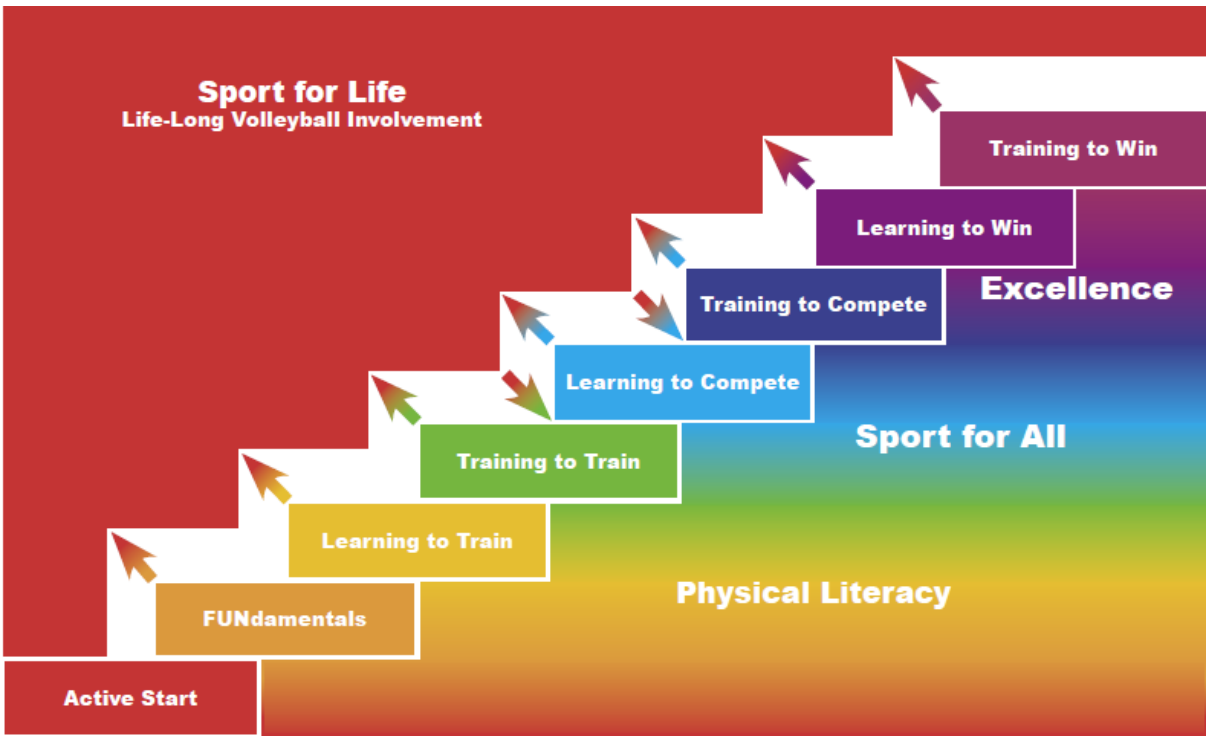

Figure 2.7: Steps to athletic success (Volleyball Canada, 2006).

In grade one instruction focus is on developing physical capabilities and volleyball skills. Skills are taught and performed under easy and stable conditions in order for the athletes to demonstrate consistency, control, and precision. In grade two, focus is on 'training to compete' and the introduction to specialisation practice. Specialisation refers to sport-specific and position-specific technical and tactical development. In summary, there is development of playing skills performed under more stable and complex conditions. Furthermore, movement control, synchronisation, and rhythm are stable when performing the skill under more complex conditions. Finally, in grade three, focus is on 'training to win'. This involves

movements being executed similar to the ideal model in terms of form and speed. Therefore refining the skills of the athletes and advanced mental preparation is highly important.

2.3.5.2. The Framework for teaching techniques

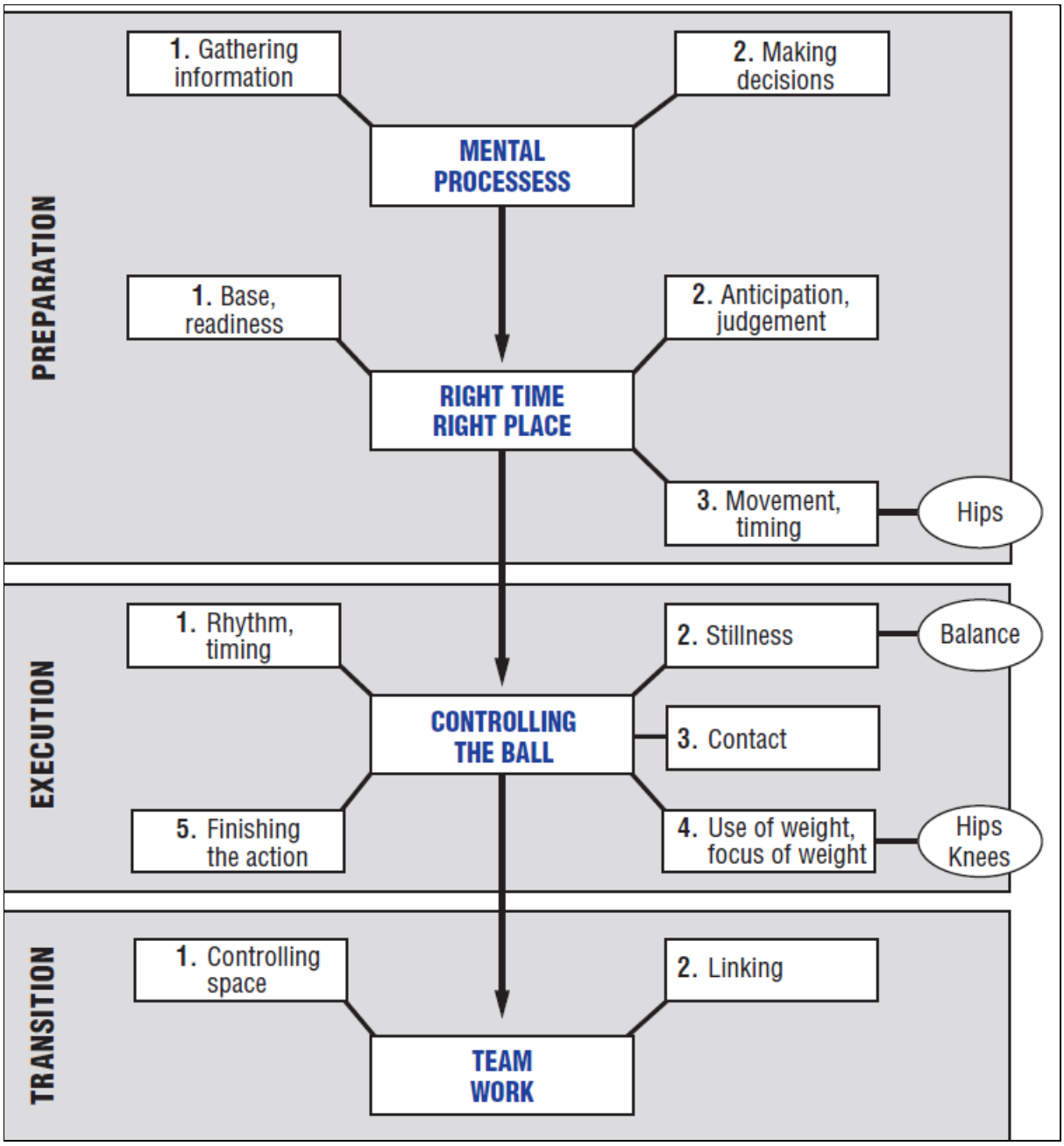

Figure 2.8: The framework for teaching volleyball skills (Volleyball England Model, Volleyball England Handbook, n.d)

There are many different factors which contribute to the successful execution of volleyball skills. These factors are fundamental and underpin the teaching of techniques and skills of the

game and therefore integrated into the teaching program at ToppVolley Norway. Figure 2.8 above illustrates a framework for performing an action and shows how the fundamentals of volleyball fit into each stage of the cycle to make a coherent model.

The rationale of the framework adopted from Volleyball England is that all actions start with a mental process and this involves the gathering and processing of information. Before a player can perform, the player must decide what action is required, and then how to achieve it. For example, a player would read and assess the ball flight and then decide whether to use a volley or forearm pass.

The key to the consistent execution of the skills in volleyball is being in the right place at the right time. Several components that contribute to being in the right space at the right time are: base readiness, anticipation and judgement, and movement and timing. Because volleyball is a rebound sport, the player cannot compensate for being out of position as this results in a lack of control of the ball. Therefore, much of the teaching must be aimed at helping the player to get to the optimum point of contact with the ball. A player must be in a position which affords the best chance of getting to any ball which might fall in their area of responsibility. Furthermore, a readiness posture is an indication of both physical and mental alertness. Also, fundamental to all ball sports is the ability to be able to anticipate and judge the flight of the ball. This is especially critical in a sport such as volleyball and should be addressed as part of a young player's sports education (Volleyball England). It is also critical to link movement within a time frame; ascertaining whether the ball is moving quickly or slowly prompting the decision of whether to react by moving more quickly or more slowly. Volleyball has specific movement and footwork patterns which are taught and these movement skills are based on principles of balance and control of body weight (Volleyball England). Finally, upon execution of a skill, controlling the ball is paramount. Equally important to this aspect is the combination of rhythm (correct timing), stillness (stability and preparation to play to intercepting), contact point (intercepting the ball precisely), body weight (to control the direction and pace of ball) and finishing/execution (a player must finish the action both physically and mentally). For example, the server not only needs to finish the serve with the hand pointing directly to target, but must also "see", in the mind's eye, the correct execution of the shot. It is important that each action should have a specific intention (Volleyball England).

In summary, the framework model highlights and depicts concepts that are important to this present study, especially within visual search, perception and visual-motor processing and performance. These concepts are reviewed later in this chapter.

2.4 THE VISUAL SYSTEM AND SPORT PERFORMANCE

The term "vision" and the growing field of "sport vision" apply to more than having 20/20 eyesight. Wilson and Falkel (2004) defined "vision" as the ability to see, and refers to "sport vision" as the stressing or loading of the visual perceptual, visual motor, and visual proprioceptive systems during sport-specific training in order to prepare athlete's for competition. Visual perception is the ability to interpret the surrounding environment by processing information that is contained in visible light. The resulting perception is also known as eyesight, sight, or vision and is the means with which humans extract information from images and the environment and how that information is used guides decision-making and actions. Most coaches think that if their athletes can see 20/20, nothing more is needed in the visual arena. This misconception has been found to be common in youth sport and professional sports as well (Wilson & Falkel, 2004). The visual system is like any other motor system in the body and responds to overload and progressive increases in the demands that the athlete places on it just as the rest of the musculoskeletal system responds to the demands and overloads it faces in training (Wilson & Falkel, 2004).

Fast ball games such as volleyball predominantly involve the so-called 'open' sports situations. An open skill situation is externally-paced and performed in dynamic environments that vary in terms of speed, direction, and levels of uncertainty; where one's movements vary depending on what is taking place in one's immediate environment, and so movements have to be continually adapted (Gallagan, 2000). For example playing or receiving a serve from a server (opponent) in a serve receive formation (on the court). Therefore, these situations may be influenced and are characterised by perceptual uncertainty and time pressure particularly in information processing. These characteristics together make the ball catching, hitting or receiving procedure difficult and determine the visual search strategies (Ripoll, 1991; Abernathy, 1991). Therefore in sports where participants and objects frequently move on complex and rapid trajectories, the need for efficient vision is paramount

(Williams, Davids & Williams, 1999). On the other end of the continuum are the so-called closed sport situations, these are defined as skills which take place in a stable, predictable environment and the performer knows exactly what to do and when (Gallagan, 2000). A characteristic is that they are self-paced and one can decide when to start or finish, for example serving a ball (float or jump serve). The serve is the only closed sport situation in the volleyball game.

Kluka and Love (1991) describe that the movements which the eyes exhibit are necessary functions of visual perception which assist in the selection and execution of appropriate motor responses during performance. Furthermore, in a later study, Holland, Patla and Vickers (2002) provided evidence that neural control of head and eye movements, guided by vision, play a key role in coordination of the trunk, arms and legs during the steering of the body.

Rosenbaum (1991) described that the maximum velocity of eye movements is around 100 degrees per second and that the eye's tracking ability begins to deteriorate at an angular velocity greater than 30 degrees per second. The fact that some sports performers can control a volleyball struck at speeds approaching above 100 kilometres per hour producing angular velocities greater than 500 degrees per second is intriguing as the constraints of competent play apparently exceed the known operational capability of the visual system (Williams et al.,, 1999).

The paradox identified by Williams et al. (1999) of having to see, yet able to perform competently without being able to see well, has brought about a division of emphasis in research in the role of vision in sporting action. For instance, there are those who propose that performance, particularly in high speed ball games, is a function of the quality of the individual's visual system. On the other hand, there are those who contend that perceptual skill is more a function of the expert knowledge gained through experience than the quality of the system that registers the various signals. The two viewpoints are often referred to as 'hardware' (system quality) and 'software' (knowledge structures) perspectives (Williams et al., 1999).

In order to further place the present study into context the discussion begins with the basic anatomy of the eyes and then moves to the functional issues related to the types of eye movements and gaze control which play an important role in gaze behaviour.

2.4.1 The Eye

The ability to see is dependent on the actions of several structures in and around the eyeball. Figure 2.9 below lists many of the essential components of the eye's optical system.

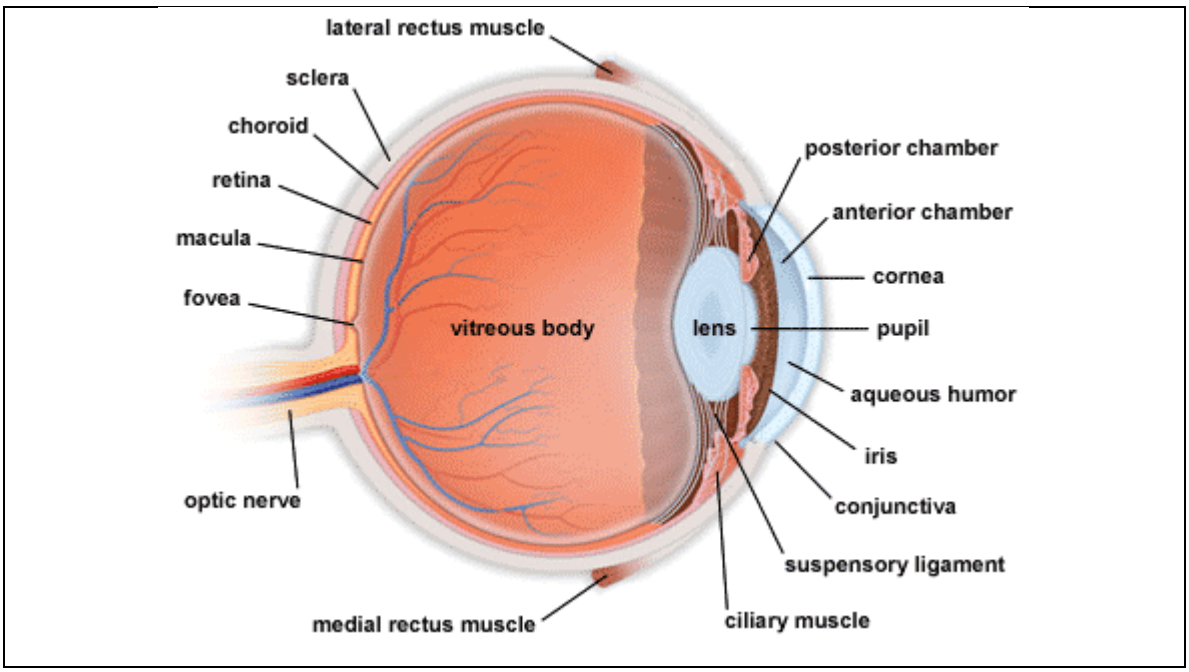

Figure 2.9 Cross sectional view of the eye (an optic chamber) (http://www.larsoneyecenter.com/chicago/patient-education/anatomy-of-the-eye.htm).

The eyes are the peripheral organs of vision and the primary sensory outpost of the brain. When you look at an object, the light rays are reflected from the object to the cornea. The light rays are bent, refracted and focused by the cornea, lens and vitreous. Bending the light positions objects or locations of interest on the fovea, an area at the back of the eye in the retina that is responsible for visual acuity, presents the ability to resolve small details and thus see objects or locations clearly. The lens's job is to make sure the rays come to a sharp focus on the retina. The resulting image on the retina is upside-down. The retina converts the light rays to electrical impulses which are transmitted through the optic nerve, to the brain, where the image is translated and perceived in an upright position (Vickers, 2007).

2.4.1.1 Anatomy

The visual system comprises of three principal structures within the central nervous system (CNS) and a multitude of the other connections which enable 'seeing' to become 'perceiving'. Figure 2.10 schematises the three structures relative to the environment and events within it, in this case, a baseball player catching the ball. The basic purpose of this illustration is to show the relationship between a sports action, which is heavily dependent on visual information about the object as it moves within the environment, the position of the eyes and the brain within the skull at the cross-sectional level of the visual pathway. Ultimately, this information is further converted and used for muscular contractions (for reaching and grasping the ball). Depicted are the eyes (peripheral organs of vision), lateral geniculate nuclei (mid-brain) for processing located within the thalamus, the optic chiasm (cross-over paths which enable sense data received on the retina of both eyes to be integrated as a complete image, and visual centres in the cortex.

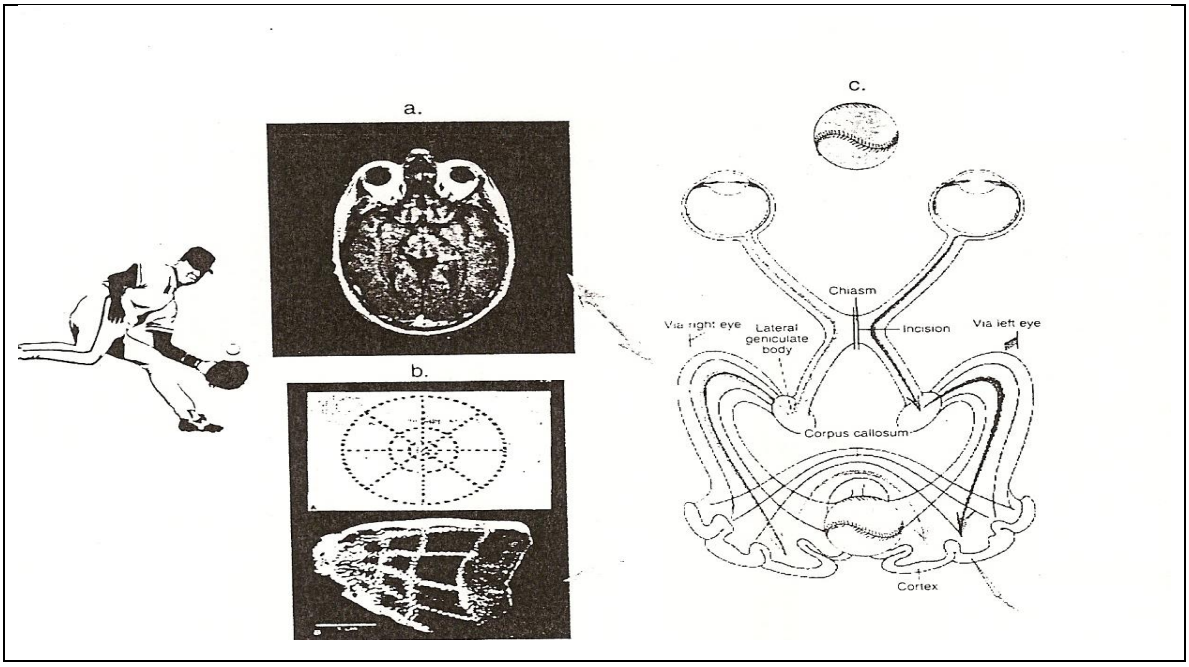

Figure 2.10 Schema of the central nervous system (CNS) and a myriad of the other connections. The pattern of neural activation in the visual cortex is influenced by the stimulus material (upper section) (Williams et al.,, 1999).

According to Williams et al. (1999), and illustrated in Figure 2.10 above, the pattern of neural activation in the visual cortex is influenced by the stimulus material (upper section). The anatomical components which enable seeing to become perceiving are comprised of multi-

layered, multi-laned pathways from the eyes to the brain. The catching action depicted above left is heavily dependent upon vision and perception-in-action. The MRI section (a) is the approximate level at which the pathway (c) is located. The upper image of (b) is stimulus material and the lower image being the pattern of neural activation in the visual cortex.

2.4.1.2. Visual field and the line of gaze

The total amount of light that stimulates your eyes at any moment in time is called the visual field. In Figure 2.11 below Vickers (2007) shows the visual fields of each eye, the line of gaze from the right and left eye, the optic system, including radiations from each eye to the primary regions at the back of the brain.

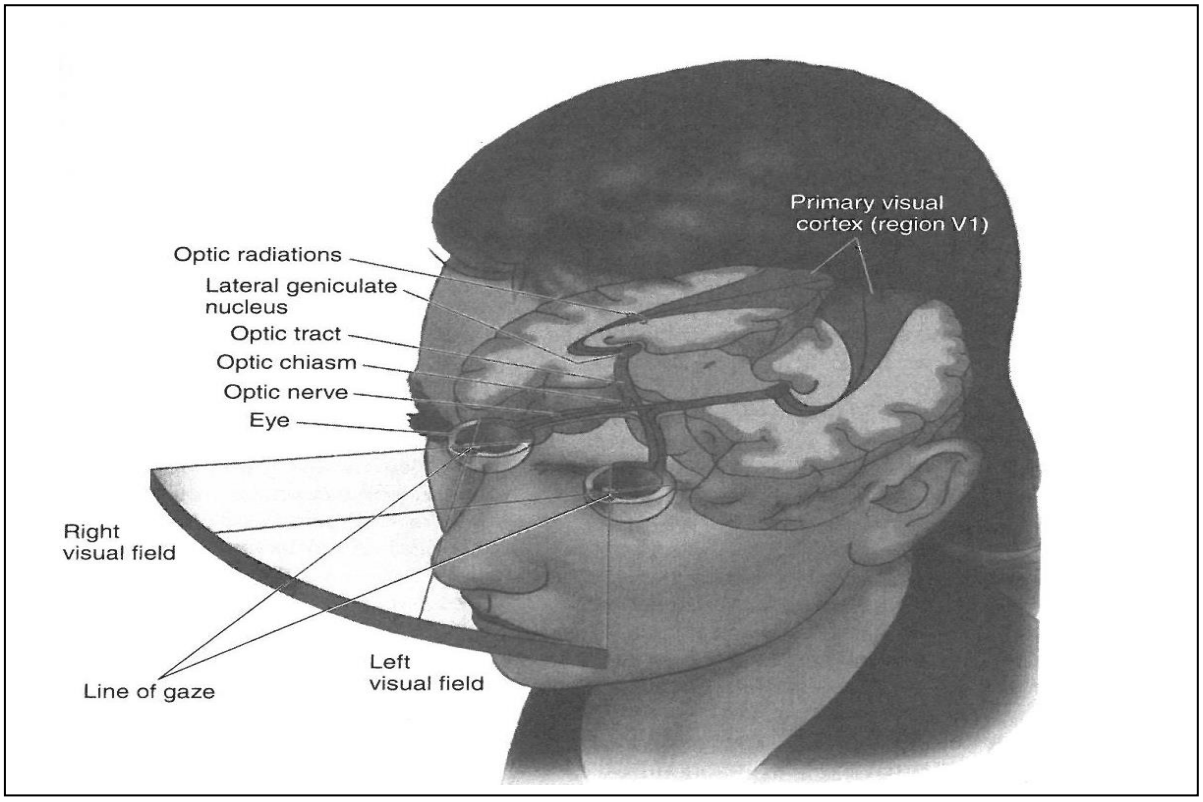

Figure 2.11: The visual system, field and line of gaze (Vickers, 2007)

As seen in Figure 2.11 above the passage of visual information along this route between the eye and the brain is continuous, and constant processing occurs within many parts of the brain. A line of gaze originates from each eye, passes through the appropriate field, and intersects in front. The line of gaze is defined as 'the absolute position in orbit and head position in space' (Vickers, 1996: 342). Gaze control is defined as the process of directing the gaze to objects and events within a scene in real time and in the service of the ongoing

perceptual, cognitive and behavioural activity (Vickers, 2007). The gaze system is responsible for locating and fixating task-relevant objects and the visual system supplies information and provides feedback as to what is being fixated on along with directional guidance to the motor system. In this way the eyes act to gather information necessary for successful performance.

2.4.1.3. A model for visually guided movements

Gaze, vision and action are the three systems responsible for visually guided movements and these systems are overseen and managed by a fourth system, namely the schema system (Figure 2.12). The schema represents an internal representation of the task that is used to guide action in a step-by-step manner, so that a coherent and timely action is produced. Researchers have described the schema as a basic top-down control action unit responsible for carrying out a set of instructions that determine where gaze will be directed, what information the visual system will pick up and what motor action will be executed (Chun & Jiang, 1998; Corbetta & Shulman, 2002; Land, 2009; Wood, 2010). Furthermore, the top-down control unit is an attentional unit that is directed and influenced by current goals, expectations and knowledge.

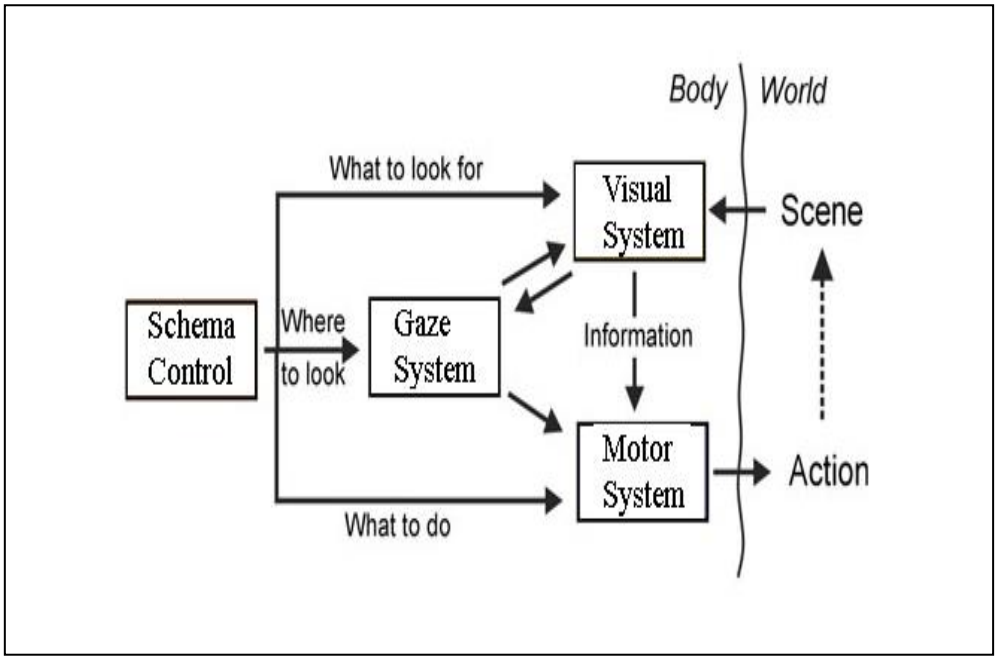

Figure 2.12 An illustration of the relations of the schema, gaze, visual, and motor systems during the performance of a visually controlled action. (Adapted from Wood, 2010).

One study that aptly shows how gaze, vision, action and the schema interact in natural environments was carried out by Land, Mennie and Rusted (cited in Wood, 2010). The study involved asking participants to make a cup of tea whilst wearing an eye tracker. This specific task was utilised to illustrate the many separate actions involved, and the transition of these actions could highlight how the schema system monitors and manages components of the three systems for successful performance. A scan path analysis revealed that saccadic eye movements were almost exclusively made in a systematic fashion preceding motor movements; and reflected the step-by-step requirements of the task and the level of manipulation that each object (kettle, tap, mug, amongst others) required. In fact, a third of all fixations were linked to locating objects, directing the hand to a new location, guiding the approach of one object to another (for instance, kettle and lid), and checking the state of some variable (for instance, water level). The authors concluded that the eyes closely monitored every step of the process and suggested that this type of unconscious, top-down, attentional control must be a common phenomenon in everyday life (Wood, 2010). It is evident from this body of research that in everyday environments, top down attentional control (even if unconscious), drives the eyes to lead and subsequent motor actions to follow.
This evidence has clear implications for performance in sport and in particular sports requiring the coordination of eye and limb movements, such as delivering a successful serve reception to the setter.

2.5 EYE MOVEMENTS IN SPORT

There are four major types of eye and head movement that are important for gaze behaviour and must be simulated by the gaze behaviour system, namely saccades, visual fixations, vestibulor-oculor and smooth pursuit eye movements. These types of eye movements are used to view moving objects and are important in understanding what events in sports may and may not be seen (Kluka, 1991). Therefore, integration of eye movements to match the relative motion of an object being tracked is a very complex phenomenon.

2.5.1. Saccadic eye movements

The most frequent eye movements in time-constrained contexts, such as sport, appear to be saccades. The eyes are moved about three times each second via rapid eye movements (saccades) to reorient the fovea through the scene (Henderson, 2003). These are conjugate eye movements which are responsible for the jumps that bring a new part of the visual field into foveal vision. Volleyball requires visual angular velocities in excess of 500 degrees per second to track the trajectory of a spiked ball (Ridgway & Kluka, 1987). In sport, saccades are the gaze behaviours that move the eyes from one location to another within the visual scene, meaning a performer uses saccadic eye movements to scan quickly from one player to another or from a ball to a target, and play an important role in moving gaze to locations of perceived importance so that such information can be foveated with maximal acuity or sharpness for optimal informational gathering (Vickers, 2007). Therefore, saccades are the rapid movements of the eyes towards a new fixation point, enabling another informative area of the display to be fixated on.

Saccades play no role in the extraction of visual information, therefore all visual information is suppressed during saccades. Saccades can reposition eyes at angular velocities exceeding 700 degrees per second (Carpenter, 1988), but the eyes essentially 'turn off' as they saccade to the next fixation (Cambell & Wurtz, 1978). The turning off suggests that there is a dramatic decline in visual sensitivity during saccades. Ditchburn (1973) found that visual sensitivity declines during saccades because when the saccade occurs the eyes move quickly and are therefore not able to foveate on specific areas, meaning that meaningful visual information cannot be acquired during the saccade. This reduction in visual sensitivity is referred to as saccadic suppression, and can be explained by either central or peripheral limitations. Theoretically, because of the suppression of information processing during saccadic eye movements, a search strategy which involves fewer fixations and consequently, a reduced need for saccadic eye movements, is assumed to be more effective (Williams et al., 1999).

2.5.2 Visual fixations

Henderson (2003) defined gaze control as the process of directing the gaze (head and eye movements) to specific objects or events within a scene in real time and in the service of the ongoing perceptual, cognitive and behavioural activity. Furthermore, as a performer looks at a scene, the gaze naturally fluctuates between periods of stability, where gaze is fixated, and

periods of rapid movement between objects and locations. A fixation is defined when gaze is stable on an object or location within three degrees of visual angle for a period equal to, or longer than 100 milliseconds (Vickers, 2007). This duration is thought to be the minimum amount of time that is needed to recognise and extract information from stimuli in the environment.

Visual fixations enable the performer to stabilise an informative area of the display, such as the served ball in the context of this research or a player in foveal vision, enabling more detailed processing to occur. The duration of the fixation period has been assumed by researches to signal the relative importance and complexity of the display area to the observer. The more information which has to be processed, the longer the fixation duration. For this reason fixation duration varies markedly depending on the nature and difficulty of the task and on the visual display presented to the observers. In sport, relatively high fixation durations (850-1500 ms) have been reported in complex viewing circumstances in team games like soccer, whilst values as low as 100 milliseconds are typical for highly practiced performers or those viewing familiar stimuli (Williams et al., 1999).

2.5.3 Smooth pursuit eye movements

Smooth pursuit movements enable the visual tracking of a moving object within the visual field. This system uses visual feedback and prediction to generate coordinated eye and head movements stabilising the image of the object on the retina. The maximum velocity of these eye movements is around 100 degrees per second, although the eye's tracking ability begins to deteriorate at an angular velocity greater than 30 degrees per second (Williams et al., 1999). Thus, the success of the visual system achieving a stable retinal image depends on the speed of the moving target which the eyes are required to follow. Pursuit eye movements are therefore restricted to situations, such as watching the ball after a shot in golf, following a floating serve in volleyball, or tracking the movements of distant players. It is reported that changes in the visual array typical of most sports, such as squash and ice hockey, make it difficult to visually follow an object using pursuit tracking eye movements. In fact, at excessive speeds, it has been demonstrated that experienced sport performers do not attempt to track a ball during its entire flight path but instead use saccadic eye movements to predict the future position of the ball (Williams et al., 1999).

2.5.4 Vestibular-ocular eye movements

Vestibular-ocular eye movements function to stabilise gaze and ensure clear vision during head movements (Williams et al., 1999). It utilises information from the balance system to move the eyes in an opposite direction to the head. Primarily, it serves to maintain visual clarity during dynamic sport situations. For example, the volleyball player attempting to pick up information from the server or opponent can achieve this either by initiating saccadic eye movements to bring the player to foveal vision, or alternatively by keeping the eyes fixed, but moving the head. The vestibular-ocular reflex comprises a number of structures located within the inner ear, which register motion of the head within each movement plane. These structures enable the player to produce compensatory eye movements much more rapidly (about 16 ms) than changes associated with the use of the visual system alone (about 70ms). Therefore, the head, the body and oculomotor control system function as one closely coupled system during skilled performance (Williams et al., 1999).

2.5.5 Blinks

According to Vickers (2007) blinks occur when the eyelids cover the pupils and prevent most light from reaching the retina. Furthermore, this action may occur voluntarily or involuntarily and is essential for refreshing the cornea and lens and for maintaining vision, however during this action information is also suppressed (Vickers, 2007).

This section presented the types of eye movements required and responsible for gaze control. The next section focuses on previous research of these eye movements and their role in vision in sport.

2.6 MEASUREMENT OF EYE MOVEMENTS

2.6.1. Eye Tracking Technology

Automatic recordings of orientations of the eye in the head, thus the direction of gaze were made as early as 1936 (Scott & Findlay, 1993). The primary goal of eye tracking was to support research in human visual data acquisition, but as instrumentation technology continued to evolve, it eventually lead to applications in a variety of settings where understanding of human perception, attention, search, tracking and decision-making were of great importance.

A number of techniques have been researched to assess visual search strategy. The main strategies used, according to Williams et al. (1999), include temporal occlusion, spatial occlusion, verbal reports and eye tracking. Temporal occlusion involves the selective editing of film footage to remove different points in time to give the participants variable extents of information (William et al., 1999). Spatial (or event) occlusion involves selectively occluding specific cue sources for the duration of the trial to determine areas of importance within the footage (Williams et al., 1999). Verbal reports have also been used to examine visual behaviour through the use of interviews.

Eye tracking techniques have gradually improved in the 20th century. Recently, eye tracking techniques have become quite non-intrusive, and portable, such as the corneal-reflection eye trackers that record the participant's eye movements on a video using a camera mounted on a headband or glasses. Eye trackers today have been specifically developed for field studies (use outside the laboratory): for measuring many properties of visual behaviour in terms of informative cues, for the quantification of information selected and for the establishment of a visual search strategy. Many studies (Williams & Davids, 1998; Williams & Elliot, 1999; Moreno, Reina, Luis & Sabido, 2002; Vickers, 2006) used the Applied Science Laboratory (ASL) mobile eye tracker system, which is known as appropriate for use in sport contexts (Williams et al., 1999).

Eye trackers are devices used in eye movement recording techniques. These recordings have been used to identify information processing operations involved in complex sport situations, such as measuring visual fixations. Fixations in terms of number, duration, location, also

known as area of interest (AOI) are obtained which allows identification of visual search patterns including scan paths. Under normal viewing conditions, eye movements are automatic in that individuals commonly look at stimuli that attract attention resulting in shifts in gaze positions. The objective of eye tracking methodology is to calculate the intersection of the gaze vector with the observed scene, so that elements in a visual scene that are being fixated upon by the subject can be determined. Head-mounted eye tracking systems are the preferred choice for researching vision in sporting settings (Yu & Eizenman, 2004). Information about how athletes use their eyes on the sporting field is fundamental to a basic understanding of their environment. Eye movements and scanning patterns are indicators of thought and mental processing involved during visual information extraction. In the sporting environment, eye tracking can be used to differentiate and objectively describe visual behaviour differences between expert and novice, or less skilled, athletes revealing effective eye movement behaviour that may be difficult to verbally describe, observe, or diagnose by others (Wetzel, Krueger-Andersen, Poprik & Bascom, 1996). Therefore, the use of eye tracking technology allows eye position estimates to be superimposed on the images of the scene, enabling real-time viewing of the subject's gaze (Yu & Eizenman, 2004). This type of eye movement measurement offers deep insights into man machine interaction and the associated mental processes (Flemisch, 2000).

2.6.2. Visual-search paradigm

The process by which one locates a target in a cluttered scene is defined as visual search (Vickers, 2007). Therefore, visual search is a type of perceptual task requiring attention that typically involves an active scan of the visual environment for a particular object or feature (the target) among other objects or features (the distractors). Many visual search paradigms have used eye movement as a means to measure the degree of attention (Shelga, Riggio & Rizzolatti, 1994) and these eye movements are recorded while viewing video tapes, photographs, or computer simulations, providing valuable insights about sport expertise and perceptual and cognitive characteristics of elite performers compared with novices. Vickers (2007) noted, however, that it presents two main limitations in that it does not identify the specific characteristics of gaze control under task constraints, nor does it identify the gaze and attentional characteristics that are found when an athlete is successful or fails.

In visual search studies of this nature, participants are required to look straight ahead at displays presented directly in front of them, as illustrated in Figure 2.13 (Vickers, 2007). The figure illustrates an example of a environment that has been used extensively in many sport activities where the goal is to identify differences in eye movements, attention, and decision making between non-elite and elite performers.

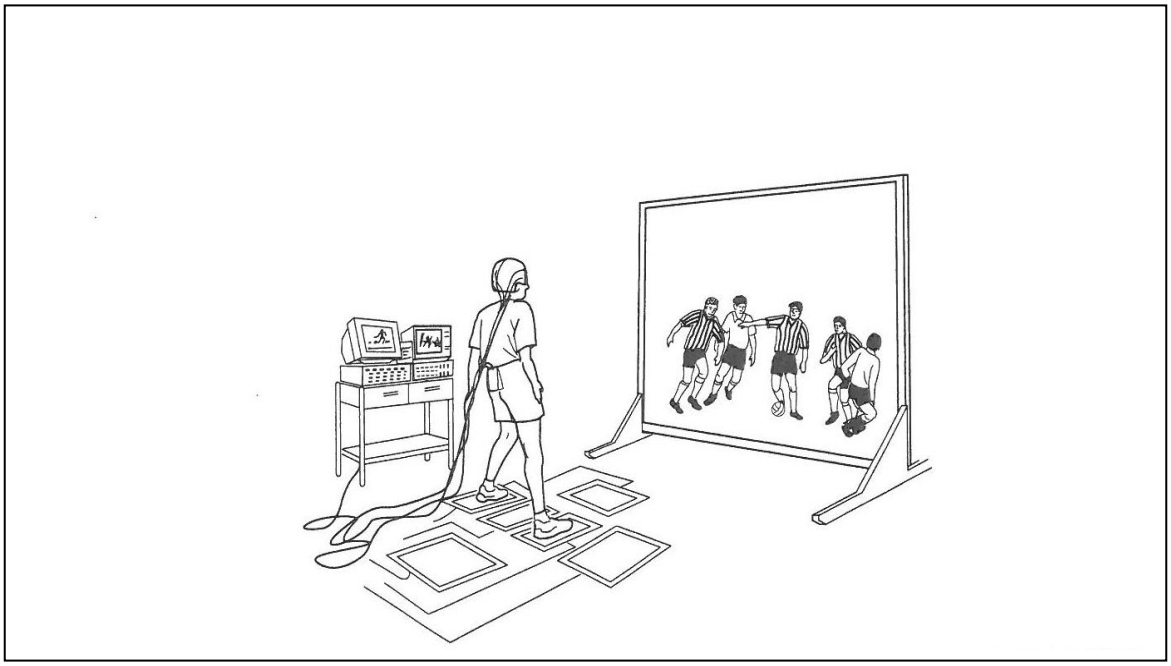

Figure.2.13 Visual-search paradigm as used in soccer (Vickers, 2007)

2.6.3. Vision-in-action paradigm

The vision-in-action paradigm is a perspective that differs from the visual-search paradigm in several ways (Vickers, 2007). Firstly, the gaze of the participants are recorded while they perform in real-world sport settings; thus ensuring a coupling between perception and action. Coupling is defined as the reciprocal relationship between how we take in sensory information and produce an appropriate action (Gibson, 1979). Secondly, the athlete performs a well-known task that has published standards of achievements (for example, race times, shots made, goals saved). In this way athletes can be grouped into skill categories based on objective standards of achievement. Thirdly, the athlete performs the task until an equal number of successful and unsuccessful trials are accomplished.

In vision-in-action studies, the nature of the task and the athlete determine the field of view as the task is performed. With this method, the gaze according to Vickers (2007) is recorded in

three dimensional space. Therefore, the participant's gaze behaviours are studied regarding full length, breadth and depth. Since the ability to handle depth is important in all sports, the vision-in-action approach reveals how the athlete acquires information in all three dimensions.

Vision-in-action data according to Vickers (2007) provide a rich source of coupled gaze and motor data that is analysed in a series of steps. Firstly it is most important to determine when the trial begins and ends. Secondly, the different motor phases are defined and their temporal durations recorded. Thirdly, the gaze is coded in terms of the type of gaze used (fixations, pursuit tracking, blinks, and other). Fourthly, the locations and objects of interest to the athlete are coded as found in the visuo-motor workspace. Fifthly, statistical analyses are carried out on the coded data and skill, and performance differences are determined for trial duration, motor phase duration and percent of gaze to specific locations or objects, and for frequency of gaze, duration of gaze, and other variables of interest.

A flurry of eye tracking studies have emerged. In the next section relevant gaze behaviour research is reviewed.

2.7. GAZE BEHAVIOUR RESEARCH IN SPORT-RELATED CONTEXT

Is this section, gaze behaviour research is presented that has been derived from current gaze research in sport. In the gaze framework model, three major categories of gaze control are presented, introducing the gaze control characteristics. Furthermore, a brief introduction to gaze control in open and closed skills, a closer look at the visual search strategies and expert-novice research paradigms is discussed.

2.7.1. Gaze control framework

The gaze control framework is a framework developed by Vickers (2007) specifically to aid researchers to objectively determine the relationship between the athlete's gaze and motor behaviour within specific sport-task environments. This framework provides a much simpler way of understanding how gaze and attention function in sport compared with treating each task separately in terms of gaze and attentional requirements needed to perform at the highest level. Current researchers show that gaze and attention are controlled in distinct ways within

three main categories of tasks: targeting tasks, interceptive timing tasks, and tactical tasks (Vickers, 2007). Within each of these categories, not only is gaze directed to the most important locations and objects in the performance space, it is also timed so that the critical cues underlying optimal performance are perceived and attended to at the right time.

The three categories are displayed as overlapping circles and illustrated in Figure 2.14. The arrangement shows that all three types of gaze control are found within a single sport, namely targeting, interceptive timing and tactical tasks. The framework further outlines the primary purpose of gaze within each of the three categories, the subcategories found within each category, the number of visuomotor workspaces, the spotlights for the attention that are normally found, as well as examples of sports where research has been conducted. In targeting tasks, the function of the gaze and attention system is to locate a target in space and control the aiming of an object to the area. Klein (cited in Vickers, 2007) stated that in tactical tasks it is imperative that the performer understands the meaningful relationships between locations and objects that contain expectancies, relevant cues, plausible goals, and actions. The interceptive timing task category involves object recognition, tracking, delivery and control (Vickers, 2007). The category relevant to this study is the interceptive timing task and is reviewed in the next section.

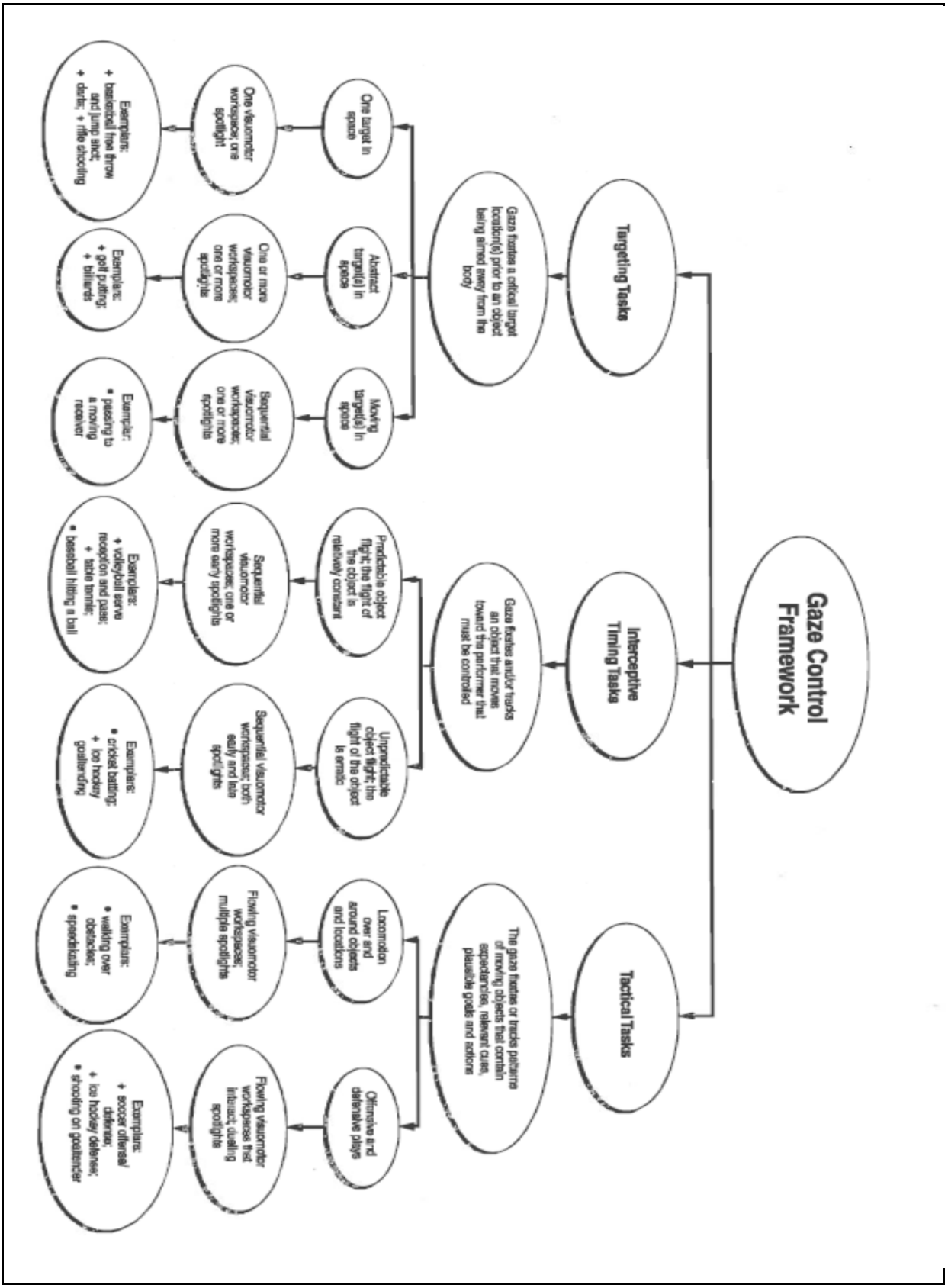

Figure 2.14 The gaze framework (Vickers, 2007)

2.7.2 Gaze control in interceptive timing skills

According to Vickers (2007) in interceptive timing tasks, an object travels towards a performer and the gaze and attention systems are used to read the object as it is delivered, track it as it approaches, and then control it as it is received to a secondary target at contact. Interceptive timing tasks have three sequential phases in common: object recognition, object tracking and object control (Vickers, 2007). During the object recognition phase, fixations and pursuit tracking are used to study the movements of the object. During the object-tracking phase, a smooth pursuit-tracking gaze is used to maintain the image of the object on the fovea in order to detect if it spins, accelerates or decreases in speed, changes direction, or is affected by wind or a host of other factors that can occur. During the object-control phase, the object, the volleyball ball in the context of this research, is served, received and passed to the setter.

Savelsbergh and Bootsma (1994) identified three task constraints that need to be satisfied in order to obtain successful performance in interceptive actions:

- ensure that they contact a desired object (typically a ball or surface) in the environment;
- contact it with the intended velocity; and
- contact it with an intended spatial orientation to satisfy (usually) accuracy requirements of the task.

Furthermore, in order to satisfy these constraints, the athlete needs to perceive the time-to-contact (Tc) information so that the motor segment (the athlete in this regard) intending to carry out the interception is moved into the right place at the right time. This capacity to precisely coordinate the movements of the whole body or parts of the body in relation to important external events, objects and surfaces has been termed as extrinsic timing. Extrinsic timing is dependent on the observer being able to perceive the ratio of the distance (d) at which an object is currently located and the velocity (v) of its relative approach. This *d/v* ratio provides the observer with Tc information about when the interception will occur(Savelsbergh & Bootsma,1994).

Sport tasks, such as receiving a serve (in volleyball, tennis, baseball, and badminton) require short latency information in the processing of vision. The above-mentioned skills have been identified to have in common a detection phase, a tracking phase and aiming phase (Vickers & Adolphe, 1997). During the detection phase, it has been found that the athlete attempts to

determine the flight of the object being served or hit towards them. It is unclear whether this phase is enhanced when athletes direct their gaze to the arm or body movements of the opponent or only to the object being propelled toward them (Vickers & Adolphe, 1997). Bahill and LaRitz (1984) earlier found that highly skilled baseball hitters could not sustain tracking on a pitched ball closer than 1.8 metres to the plate. However, Ripoll and Fleurance (1988) in a later study found an alternative view, that the subject's eye movements varied by ball flight characteristics. When the ball flight was predictable the eye movements of elite table tennis players "seemed to stop during the last part of the trajectory before the ball was hit", however, when ball flight was unpredictable tracking to contact occurred in 28% of the trials. As is evident, uncertainty surrounds the role of visual behaviour during all three phases namely detection, tracking and aiming skills (Vickers & Adolphe, 1997).

2.7.3 Gaze control in closed and open skills

Research has been carried out to determine the gaze behaviours of sport performers in both closed and open sport skills. Given these two definitions (referred to in Section 2.4), different gaze behaviours have been identified that are distinct to each category. In closed skills, since the primary object of interest does not move, a stable gaze should be found due to the unchanging nature of the object, while in open skills a more complex type of gaze control would be required due to the search for objects within the evolving environment.

Volleyball as open-skill sport is characterised with time-stress and uncertainty. This characteristic demands the athletes to process visual information in order to analyse, interpret and execute a motor response with maximum accuracy. According to Ripoll, Papin and Simonet (1983) in 'open' sports, vision plays a dual role, that of the 'semantic' and 'sensorimotor' visual function. The semantic visual function serves to identify and interpret the situation in ball games. In this context, the visual cues picked up from the opponent are used to predict hisor her behaviour and the kind of response he or she will make. The role of the 'sensorimotor' visual function is to carry out the response, which involves calculating the time of contact needed to initiate the response and coordinate the visual and motor systems involved with the response (Ripoll, 1991).

In open skills of an interceptive timing nature it has been found that when the flight of the object is predictable, pursuit tracking is directed early to the object and over the first part of flight, but when the movement of objects is unpredictable then the gaze adapts to deal with late changes in object flight and it is the elite performer who is better at adapting the gaze so that the rapidly changing conditions can be perceived in time to effectively adjust the action (Bahill & LaRitz, 1984; Shank & Haywood, 1987; Ripoll & Fleurance, 1988; Vickers & Adolphe, 1997; Rodrigues, Vickers & Williams, 2002; Vickers, Rodrigues & Brown, 2002; Williams & Ward, 2003).

2.7.4 Visual search strategies- Expert/Novice paradigm

This section is aimed at understanding visual search strategy that sport performers adopt within the expert-novice paradigms. The classification of 'expert' and 'novice' has been a topic of debate for many decades. Despite this, there is no disagreement amongst researchers as to the necessity of years of task-specific practice to acquire skilled performance (Hodges, Starkes & MacMahon, 2006). Ericsson, Krampe and Tesch-Romer (1993) suggested that the difference in sport performers were closely related to the accumulated deliberate practice hours and as a result 'expert' performance is a result of intense practice extended over at least 10 years which has been suggested to equate to 10,000 hours of practice. Some visual search research have used the term league status ranking or professional versus amateur classification of the individuals as their measure of expertise (Allard & Starkes, 1980; Abernerthy & Russell, 1984; Abernerthy, 1990; Ripoll, Kerlizin, Stein, & Reine, 1995). Studying the differences between "Advanced" (those with expert traits) and "Not Advanced" (those participants not yet as competent at the particular task) in respect of visual gaze behaviour research is therefore an acceptable practice and hence a justification for applying such an approach in the present study. The literature to date investigating visual search suggests that the number, location and duration of fixations are indicative of the perceptual strategy used by the performer (Vickers, 2007). A review of the research pertaining to the number, duration and location of fixations that performers use as perceptual strategy is now discussed.

2.7.4.1 Number of fixations

A fixation is an eye movement variable that gives insight as to the dynamics of where and how many times a subject acquires visual information. Ditchburn (1973) found that visual sensitivity declines during saccades because when the saccade is taking place the eyes moves quickly and therefore is unable to foveate on specific areas. Theoretically, the greater the number of fixations, the more saccades the eyes have to produce. Therefore a search strategy that involves fewer fixations is assumed to be more effective (Williams et al., 1999; Mann, Williams, Ward & Janelle, 2007) as less time is spent in saccadic eye movement where individuals are not able to use the information in the display. The proposal that experts produce significantly fewer fixations than novices is supported in studies by Bard and Fleury (1976), Helsen and Pauwels (1992, cited in Allard & Starkes, 1980), Ripoll et al. (1995), Singer, Cauraugh, Chen, Steinberg and Frelich (1996), Vickers (1996), Moreno et al. (2002) and Savelsberg, Williams, Van Der Kamp & Ward (2002). These studies collectively suggest that experts employ more refined search patterns as evidenced by the limited number of fixations. In contrast, a number of studies found that there were non-significant trend differences indicating experts produced fewer fixations than novices.

The suggestion that experts employ more efficient visual search patterns than novices also has not been supported in all research (Goulet, Bard & Fleury, 1989; Williams, Davids, Burwitz & Williams, 1994; Williams & Davids, 1998; Williams & Elliot, 1999; Moran, Byrne & McGlade, 2002); however these studies have found that expert performers produced more fixations than novices. Williams et al (1999) found discrepancies in findings in terms of the complexity of the display. They suggested that displays that contain more information could be considered more perceptually complex, for example in soccer an 11 on 11 situation would provide greater complexity compared to a one on one situation. Williams et al. (1999) argued that the numbers of fixations for both expert and novices would increase in relation to the perceptual complexity of the display and the cognitive complexity required for the task. Therefore, the more information that is present within the display and the more choices a performer has to make, the more fixations they would produce. The latter suggestion has implications regarding the types of visual display that performers see when performing. Note, that the mentioned studies required differing levels of cognitive complexity and motor skill demands, such as identifying types of serves (Goulet et al., 1989), moving in response to filmed offensive sequences in football (Williams & Davids, 1998), and anticipation of pass

destination from filmed soccer sequences (Williams et al., 1994). Therefore, the complexity of the task in terms of the display and cognitive demands could be considered as varied. Bard and Fleury (1976) concluded that the number of fixations reflected the complexity of the display, however they did not statistically relate the finding to fixation duration and task complexity. Thus, the assumption made by Williams et al. (1999) that the number of fixations are linked to the complexity of the task warrants more research including appropriate statistical analyses to link the number of fixations variable to the complexity of the trial.

2.7.4.2. Fixation duration and location

According to Williams et al (1999) fixation duration is assumed to be indicative of the visual perceptual strategy used by the performer to extract meaningful information from the display (Williams et al., 1999). The duration of fixation period would therefore reflect the time spent at a specific part of the display. Singer et al. (1996) found that highly skilled tennis players spent longer times fixating on the knee than beginners and less time fixating on the head and the ball. This reflects a difference in selective attention with experts looking to different places for different amounts of time to make their decisions. This may be a reflection of differences in perceived pertinence or knowledge bases between expert and novice performers. Ripoll, Papin, Guezennec and Verdy (1985), Ripoll et al. (1986), Helsen and Pauwels (1992, 1993), Vickers (1992, 1996), Savelsbergh et al (2002), and Williams et al (2002) have carried out gaze control research studies in closed skills, such as the golf putt, basketball shooting, pistol and rifle shooting, and billiards. It has been found that performers orient their gaze to a fixed target or target(s). Furthermore, it was found that experts produced longer fixations and the duration of this fixation has been shown to be longer on successful than unsuccessful trials. Other studies have found that experts produce shorter fixations than novices (Williams et al 1994; Williams & Davids, 1998). Williams et al (1994) found that experienced soccer players produced significantly shorter fixation durations than inexperienced players, suggesting that experienced players require less time to produce a coherent representation display. This may qualify also to be a reflection of the complexity of the display, for example, the greater number of people within a display may result in more fixations of shorter durations in order to produce coherent decisions. In addition, Abernethy and Russell (1987), Abernethy (1990b), and Williams and Elliot (1999) all found no significant differences in fixation duration between experts and novices, suggesting that in

some sports, such as badminton and karate, fixation does not appear to be a limiting factor. Furthermore, the equivocal findings suggested that perhaps the limiting factor in the perceptual performance of the novices is not an inappropriate search strategy, but rather an inability to make full sense of the information available from fixated display features (Abernethy, 1990a).

2.7.4.3. Fixation Area of interest

Areas of interest (also known as fixation location) is perceived to be the most important area of display in decision making as determined by the performer (William et al., 1999) and the featured location is of more importance at one phase in time than another. This object-oriented type of gaze control has been termed a "quiet eye" (QE) and expert performers differ from non-experts in having an earlier onset and a longer duration of this gaze suggesting a sustained focus on one location or object is required prior to the initiation of the final movement (Vickers, 1996; 2007). Vickers (1996) suggests that the QE allows for a period of cognitive registration of movement parameters, such as force, direction and velocity while minimizing distraction from other environmental or internal cues. This explanation may provide optimal attentional control and is also in theoretical alignment with Corbetta and Shulman's (2002) top-down, goal directed attentional system.

Furthermore, the QE illustrates the location-suppression hypothesis which states that during the location phase of motor performance, the athlete focuses on the most critical location on the target for about one second before the execution of skills. The fixation is therefore held at that location until an object enters the athlete's visuomotor workspace during which vision is suppressed in order for the task to be performed successfully (Vickers, 2007).

A free throw performance in basketball (Vickers, 1996) illustrated this phenomenon and described that initially a long fixation duration is required on the hoop, followed by a second phase which requires that the movement should be initiated slowly so that the fixation can be maintained. Finally fixation offset should occur early, followed by suppression of vision, and at this stage experts either blinked or diverted their gaze to areas other than the hoop, the ball, or their hands during the shooting action to avoid interference.

Considerable progress has been made in defining how novices and experts differ based on vision-in-action research findings. William and Ward (cited in Vickers, 2007) summarise some of the major findings as follows:

• Experts have superior recall and recognition of sport-specific patterns of play;
• Experts are faster in detecting and recognising objects, such as a ball within the visual field.
• Experts are more efficient and use more appropriate visual-search behaviours;
• Experts have an enhanced ability to effectively pick up advanced (pre-event) visual cues, particularly from an opponent's postural orientation;
• Experts have greater attunement to relative motion information when presented in the form of a coherent display; and
• Experts have more accurate expectations of likely events based on the refined use of situational probabilities.

2.8 ATTENTION AND VOLLEYBALL

Visual attention is the cognitive process of selectively concentrating on one object or location in the environment while ignoring other irrelevant aspects. One important theoretical consideration of all gaze-based research is the question of whether measuring where a person is looking is actually where their attention is being directed. Early research that explored this important question has focused on the association between the direction of gaze in terms of overt and covert attention. It has been described that during overt attentional processes, both the direction of gaze and location of attention have been found to be associated. For example, a server will look towards and concentrate on the location to which he wishes to serve. During covert attention, gaze and attention have been found to be dissociated and as a result the player may look to one side of the court (position 1) while striving to serve to the opposite side of the court (position 5).

Therefore, in volleyball, it has been described that the focus of attention is affected by certain characteristics of the athlete, such as interest, motivation, game awareness, knowledge and past experience. The visual selective attention theories concern the role of vision in motor skill performance, specifically directing visual attention to environmental information that influences the preparation or performance of an action (Magill, 2001). The processes by which people orient their attention have been the focal point of many attention-based theories. In the next three sections relevant attention theories are discussed.

2.8.1. Attention and direction

According to Eriksen and St. James (1986) selective attention is based on a spotlight metaphor, in which a mental beam illuminates a given target either internally or to an external cue. Posner, Snyder and Davidson (1980) added that the spotlight is said to enhance the efficiency of detection of events within its beam. As such, knowing and having a blue print of the relevant cue(s) stored in long term memory (LTM) allows performers to move to the central beam of their spotlight in order to attend to what is relevant. LTM refers to information stored in the brain and which is retrievable over a long period of time, often over the entire life span of the individual (contrasted with short-term memory). Alternatively, Eriksen and St. James (1986) proposed the zoom-lens model which suggests that while attention is directed to a given area of the visual field, the span of this area can be increased or decreased as necessary. This means athletes can adjust their attentional vision span based on the demands of a task. Additionally, both the zoom-lens model and the spotlight metaphor suggest that attention is limited to one area of a visual field at a time and therefore based on serial processing. The role of serial processing for volleyball athletes and coaches therefore is assumed to highlight the important features within a display that enhances decision making (Posner et al., 1980; Eriksen & St. James, 1986).

Most of the information that must be processed and responded to by athletes is gathered through the visual system and the perception process (Abernerthy, 1991). The ability to highlight relevant cues through the spotlight or zoom lens is dependent on a number of factors, such as a number of allocatable resources, background noise, use of advanced cues and pattern recognition. To understand the impacts of these factors on attention, the theory of guided search must be considered.

2.8.2. Theory of guided search: Treisman's Feature Intergration Theory

Treisman and colleagues (Treisman & Gelade, 1980; Treisman, 1988) introduced the Feature Integration Theory (FIT), a visual search model that suggests two differing visual search and attentional stages, namely parallel and serial search. Firstly, it highlights the pre-attentive stage (parallel stage) for the detection of simple feature aspects of the scene, such as orientation, width, size, colour, brightness, and movement direction in order to form a feature map. For these basic features to be perceived as objects in the world they have to be 'integrated' in the attentive stage and serial search is the result. The resultant serial search process checks the total amount of activity anywhere in the feature map. Parallel processing

is the ability to process several bits of information simultaneously, whereas serial processing is more attention-demanding and involves processing one bit of information at a time in a sequential manner (Wolfe, 1994) and bringing the stimuli into the more sensitive foveal region of the retina (Williams et al., 1999). How efficient the search process is depends on many factors including whether the target is defined, the similarity of the distractors and target, the nature of the distractors (whether they are all the same or different) and the size of the distractors. The FIT suggests that if features are detected in the parallel search then flat visual slopes are produced indicating very quick search times. Detecting these features would not be affected by the display size presented to the participants. Alternatively, serial search occurs when the target is not significantly different from the distractors (in shape and size) and each object has to be attended to separately in the form of selective attention. Detecting these features is affected by the display size presented to the participants.

2.8.3. Nideffer's Theory (1981)

Focus of attention, or focus of concentration shifts along two dimensions, a dimension of width (broad to narrow), and a directional dimension (internal or external). Conceptually, these can be seen as two intersecting dimensions which result in four different attentional styles of focus (Nideffer, 1976). These are shown in Table 2.1 which illustrates volleyball attentional demands during play. The ability to shift rapidly from one type of attention to another must be acquired by all volleyball players because no one can demonstrate more than one type of attentional focus at any given time. This shifting of attention helps players to adopt the appropriate attentional demand when it is needed.

Table 2. 1. Volleyball attentional demands during play (Nideffer, 1976**)**

Situation	**Broad-External**	**Narrow-Internal**	**Narrow-External**	**Broad-Internal**
1. Serve			X	
2. Pass			X	
3. Setting			X	
4. Spike/Tip			X	
5. Block			X	
6. Movement before above skills	X			
7. Coverage	X			
8. Anticipation	X			
9. Reading combination attack	X			

Nideffer (1981) says there are at least four different types of attention which athletes must be able to develop in order to function effectively:

- Broad-internal: The athlete must be able to integrate and organise a large number of internal thoughts and perceptions. This is the type of attention used to analyse and make plans, to anticipate the future and recall past information.
- Broad-external: The athlete must be able to rapidly scan a large number of external stimuli. This is the type of attention used to read complex volleyball situations, assessing the environment and anticipation.
- Narrow-external: Athletes must be able to focus attention on one thing, avoiding distraction. This is an action-oriented focus. Once a plan is made, attention is narrowed in order to execute, for instance hit a ball or react to an individual opponent.
- Narrow-internal: Athletes must be able to focus attention internally, for instance, on one line of thought. Again, this is action-oriented attention. It is this kind of attention athletes use to center and calm themselves and to rehearse a particular skill or move mentally.

2.9 VISUAL PERCEPTION AND DECISION MAKING IN VOLLEYBALL

Perception has been a focus within the sport science literature through the mechanism of visual search patterns, which are thought to represent elements of a performer's perceptual strategy (Moreno, Reina, Luis & Sabido, 2002). It has been theorized that there are at least nine factors that contribute to an individual's relative inability to successfully learn volleyball skills. Of the nine factors, four involve the visual perceptual system and decision making: 1) lack of recognition (reading), 2) late recognition (reading), 3) lack of inner focus, and 4) poor selection of inner options that can result in inappropriate motor program execution. These components and factors on which volleyball success depends (in large measure), are themselves related to a core set of visual and perceptual skills which include static and dynamic visual acuity, convergence and divergence, central and peripheral awareness, glare recovery, contrast sensitivity function, fusion, color perception and total reaction time. These skills or abilities, when integrated with quick action plans (decision making), enable volleyball athletes to anticipate impending events so that their actions and reactions are timed properly (Kluka, nd).

The construction of perception approach by Helmholtz (1925) follows an information processing framework. Firstly, this philosophical approach argues that inferential support is necessary for adequate perception of environmental stimuli because of the ambiguous nature of sensory input. In its entirety, it attempts to explain what processes are involved in between sensing, consciously perceiving events or objects in the environment and there is a supportive role for the knowledge of the individual. Therefore it can be defined that perception is a process of constructing meaning and an approach that places a significant emphasis on the cognitive processes which precede motor output, meaning that perception precedes decision and action. The ability to appropriately interpret what is perceived has been identified as a learned skill and it is, therefore, logical to suggest that visual information is a source on which athletes rely.

2.9.1. The role of knowledge

Volleyball involves a variety of complex movement patterns and the athletes therefore engage in extensive information processing related to the movement patterns observed. In essence, volleyball skill learning requires stored memory of volleyball elements, divided and selective attention, as well as the detection and identification of complex movement patterns. Therefore, the need to know what it is that athletes should attend to and then process this effectively in order to perform are important skills. Differences in information processing in terms of stored knowledge, resultant visual search patterns, and interpretation of information may explain any discrepancies in movement performance.

The most leading studies concerning the skillful management of perception provide much information through comparison of experts and beginners (Bard & Fleury, 1976; Abernethy 1987; Abernethy & Russell, 1987; McMorris & Colenso, 1996; Kim, 2000; Savelsbergh et al., 2002; Park & Kim, 2004; Kim, Lee & Park, 2005). The conclusions of these studies are that experts have enhanced perceptual cognitive skills and are superior to a beginner in using broad knowledge concerning the situational possibilities by perceiving, recalling and analysing organised sport situations. It has been found that the beginners mainly utilised the information obtained from the visual circumstances for the response primarily through the focal vision thereby fixating one's gaze on an optic clue. On the other hand, experts have the ability to obtain information through peripheral vision system while also fixating the gaze on an optic clue. In this way, it has been found that differences in the strategies used to obtain information influences the data processing ability for making decisions and withdrawal and structured information (Kim & Lee, 2006). Potential differences between experts and novices can be explained through differences in stored knowledge in long term memory and the use of knowledge.

2.9.2 Use of knowledge

Cognitive structures are related to the knowledge base of athletes or individuals and therefore this knowledge serves as a source of top-down guidance, which has been referred to as directing attention to the likely locations of the desired object (Chun & Jiang, 1998). Knowledge is commonly categorised into declarative, procedural, strategic and contextual knowledge. Declarative knowledge, according to Moran (1996), is also known as semantic knowledge; and Ste-Marie (1999) refers to it as "knowledge about factual rule-based

information". For the volleyball athlete, the abovementioned relates to the specific guidelines and criteria for performing volleyball skills. Ste-Marie (1999) further described procedural knowledge as pertaining to both decision-making and execution of pre-and-post movement(s) within a specific domain. Procedural knowledge has been applied by coaches and performers whose primary role is to correct movements; thus knowing how to perform each element of a skill is empirical and will undoubtedly assist performance development. Strategic knowledge refers to "concepts and strategies of generalisable form that may be applied within a variety of domains, including different control processes used to remember information" (Ste-Marie, 1998). Lastly, contextual knowledge refers to the knowledge that is learned, therefore giving a meaningful (coherent) display related to the visual context in order to facilitate the detection and identification of component objects and events. This implies that through contextual knowledge, the visual display can aid the process of visual search through the learned associations between the target location or areas of interest, and contexts stored in LTM, and as a result can help spatial attention (Chung & Jiang, 1998). In relation to volleyball performance, contextual knowledge serves as a link between knowing what the essential visual cues are involved within display and the interpretation of the visual cues. Furthermore, seeing a familiar context has been shown to automatically activate the representations of consistent objects within a scene, as well as their locations (Henderson & Hollingworth, 1999). Findings suggests that when observers search an object that is contextually consistent with the environment their eyes fall on the object faster than when they are searching for a contextually inconsistent object (Henderson, Weeks & Hollingworth, 1999). Furthermore, the researchers concluded that when observers explore a scene, details of information about the previously fixated objects are retained in LTM and used to plan further exploration of the image. Thus, previous fixations held in LTM should guide future search processes to similar locations of the scene.

Many studies have suggested expert athletes have superior knowledge of rules, therefore, the sport-specific cognitive attributes that were predicted to lead to expert advantage found that experts showed significantly greater depth and breadth in their declarative, procedural and contextual knowledge bases (Williams, 1999; Gobbo & Chi, 1986). The above findings suggest that declarative and contextual knowledge may be fundamental for improving in sport. An advantage of having procedural and declarative knowledge may be that it guides visual attention in a more selective manner through the top-down cognitive processing.

Ste-Marie (1999) found that novice performers showed an inability to cope with excessive information processing demands. With the visual systems' inability to fully process all input, the visual system can adapt itself in two ways. The first is to discard input at the periphery, and the second is to process information selectively (Wolfe, 1994).

2.9.3. Task complexity

Task complexity refers to how many parts or components are present and the intellectual demands of the task. Therefore, in task complexity, an individual's focus of attention may have a detrimental effect on motor performance and learning. It has been demonstrated that performing and learning of motor skills can be enhanced if the individual's attention is directed to an external focus (the movement effect), for example, on a ball or apparatus rather than to an internal focus (the body movements). This effect has been found in a variety of tasks including balancing, performing volleyball serves and soccer passes (Wulf, Gärtner, McConnel & Schwarz, 2002).

Earlier Wulf, McNevin and Shea (2001) proposed the constrained action hypothesis to explain the benefits of an external focus of attention. They suggested that an external focus of attention improved performance and learning relative to an internal focus by promoting automatic processing and reducing conscious processing. An internal focus on the other hand was proposed to increase conscious control of the task, thereby disrupting the automatic processing that might otherwise occur. Evidence for the lower cognitive demand associated with an external focus was obtained by Wulf et al. (2001) by having learners complete a probe reaction time task while learning a balance task. Those who learned the task with an external focus of attention had shorter reaction times than those given an internal focus, suggesting the cognitive demand of the balance task was reduced by the external focus.

Learning and performing a skill is determined by the functional difficulty of the task, not the nominal difficulty. Nominal 'general' difficulty relates to the complexity of a skill relative to other skills (for example jump serve vs. float serve) and functional 'individual' difficulty relates the complexity of a skill relative to the context (for example expert vs. novice). Figure 2.15 illustrates the latter explanation. For the same athlete, different skills will have different functional difficulties, that is, individual strengths and weaknesses. Therefore, task

complexity in the context of this study looks at receiving the two serves (float and top spin jump serve) and also the groups (Advanced and Not Advanced athletes; and gender).

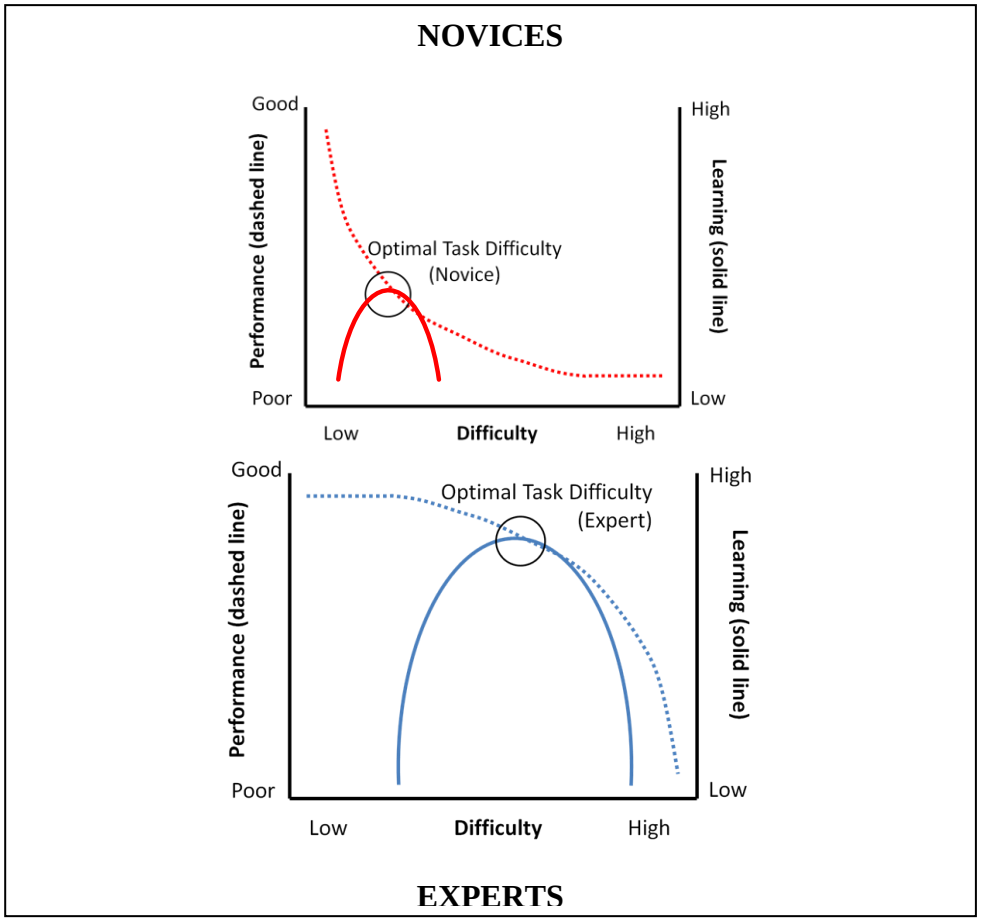

Figure 2.15 Expertise changes functional difficulty (Lohse & Hodges, n.d)

2.10 SUMMARY

In conclusion, this chapter has attempted to set out the theoretical considerations concerning volleyball, the visual system and sport performance and the measurement of eye movements. By linking current theoretical knowledge concerning vital visual volleyball skills, such as gaze behaviour in a sport-related context, highlighting the function of attention and perception processes, and their effect, it is hoped that this is a strong grounding established upon which the research within this thesis can now draw and expand upon.

CHAPTER 3

METHODS AND PROCEDURES

3.1 INTRODUCTION

The present study was undertaken at ToppVolley Norway, a school and academy of volleyball for scholars aged between 16 and 19 years, situated in Sand, Norway. In recognising the importance and immeasurable value of cultivating talented volleyball players, and possibly providing scientifically proven interventions, the need for the study emerged. As ToppVolley Norway serves as a base for youth development programmes and national team activity, it needs to fast track and bridge the gap between itself and other leading European volleyball nations. As mentioned in the previous chapter, serve and serve reception are two skills that most teams and coaches train as these skills play pivotal roles in match outcomes.

The present study aimed to identify the gaze behaviour patterns of volleyball players during successful serve reception. The focus of this chapter is on describing in detail the methods and procedures employed to achieve the aim of the study. Firstly, the research and study design adopted for the purpose of this study is described, followed by the characteristics of the participants involved in the study sample. An explanation of the processes used in conducting the data collection, as well as a full description of the methods and procedures of assessments are included. This chapter concludes with a discussion on the ethical considerations relevant to the study.

3.2 RESEARCH DESIGN

This study is quantitative in that it uses a descriptive, exploratory and quasi-experimental methodology in answering the research questions of how the gaze behaviour effects a volleyball player's serve and service reception. This research also uses a quantitative approach in that it uses a questionnaire to extract data on biographical information, schooling and volleyball background, and the athlete's visual abilities. Quasi-experimental designs are conducted in naturalistic settings, incorporating authentic conditions (Thomas, Nelson & Silverman, 2005). Since this is a vision-in-action research study about sporting techniques, it demands that the testing be conducted in a sport setting. In this case testing took place on the volleyball court. Given the quasi-experimental nature of this research and that limited information in this regard exists, the research design and findings are considered exploratory in nature.

As this research study searches for variables that differentiate between groups (Advanced and Not Advanced; male and female), an ex post facto design approach was followed. Thomas et al (2005) describe the ex post facto design as a static group comparison. In this study, the gaze behaviour patterns of Advanced and Not Advanced and male and female volleyball players during serve reception were compared. This design approach provides an alternative to investigating how independent variables affect dependent variables and allows the investigator to observe independent variables.

3.3 PARTICIPANTS AND SAMPLING TECHNIQUE

3.3.1 Participant recruitment

Participants recruited for this study were all from the ToppVolley Norway (Norway) High School and had to meet the following inclusion criteria:

- Be a registered student of ToppVolley Norway (Norway) High School;
- Be between the ages of 16 and 19 years; and
- Be a participant in volleyball practices and competitions.

A total number of 69 students volunteered to participate in the study. They all met the inclusion criteria and were tested, However of the 69 initial participants, only 50 had their eye tracker data successfully analysed. The other 19 participants' results were lost due to the inability to calibrate the ASL mobile system. The eye tracker needs delicate handling and specialised training to operate the system. In all, 64% of the students were male, and 36% were female. Of the participating students 16% were enrolled as Grade 1students, 36% were Grade 2 students and 48% were Grade 3 high school students. Grade one, two and three are Norwegian equivalents to Grades 10, 11 and 12 in South Africa. More than half (56%) of the sample have participated at a national team level and the remaining 44% have participated at club level (first or second division). Of the national team members, 32% have represented Norway at Under 17 level (U/17), 57% at U/19 and only 10% at senior level. This demographic information for the students was obtained via self-report questionnaires prior to the onset of testing (see Appendix G).

3.3.2 Participant categorisation according to volleyball advancement

For analysis purposes it was initially planned to divide the participants into three groups according to their volleyball advancement level applying the following criteria:

- Beginner:
  - Grade 1: First year in the ToppVolley Norway Programme
  - Club competition experience in their age group (2nd division)
- Intermediate:
  - Grade 2: Second year in the ToppVolley Norway Programme
  - Club competition experience (1st division)
  - National team representation at U17 and/or U19
- Advanced:
  - Grade 3: Third year in the ToppVolley Norway Programme
  - Club 'open' competition experience (1st division and Mizuno League (no age group)
  - The more experienced athletes in their age group
  - National team representation at U19 and/or Senior level.

The categorisation of the sample resulted in seven Beginners, 24 Intermediate and 19 Advanced participants. To meet the minimum sample size requirement for statistical

inference, the Beginner and Intermediate groups were combined into a single Not Advanced group of 31 participants. Thus a total of 19 (38%) of the final sample were at an advanced level and 31 (62%) were not at an advanced level (comprising of 14% beginners and 48% intermediate level athletes).

3.3.3 Sampling Method

Based on the above it can be deduced that the sampling method used for this study was purposive and criterion-based. Purposive sampling is a judgmental sampling that involves the researcher's conscious selection of subjects (Burns & Grove, 1999), and criterion-based sampling enables the identification of specific criteria for inclusion in the sample (Polit & Hungler, 1993). Choosing participants that share the same characteristics and experiences makes it possible for the gathering of in-depth information about the phenomenon being investigated (Halloway & Wheeler, 1996).

3.4 MEASURING INSTRUMENTS

Five measuring instruments were used to gather data for the purpose of this study.

3.4.1 Questionnaire

The first measuring instrument utilized was a short demographic questionnaire. Its purpose was to collect data on biographic, volleyball and vision history of athletes prior to testing (See Appendix G).

3.4.2 Vision test

The second assessment involved static vision testing. The purpose of the vision test was twofold, one was to test whether the athletes had 20/20 static vision and the other was to test eye dominance. The 20/20 test was performed first. The test measures static visual acuity of the eyes, which is a measure of the spatial resolution of the visual processing system (Watt, 2003; Kniestedt & Stamper, 2003; Erickson, 2012). The visual acuity test was conducted using an eye chart called the Snellen Chart (See Appendix H), requiring the person whose vision is being tested to identify characters on the chart from a set distance. The chart characters are represented as black symbols against a white

background (for maximum contrast). The distance between the person's eyes and the testing chart is set at a sufficient distance to approximate infinity in the way the lens attempts to focus. For the purpose of the test, the distance was twenty feet (equivalent to 6.10 meters), which is an essential infinity from an optical perspective. The metric equivalent of 20/20 vision is 6/6 vision**.** At 20 feet or 6 meters, a human eye with normal performance is able to separate lines that are one arc minute apart (equivalent to lines that are spaced 1.75 mm apart). A vision of 20/20 is considered normal performance for human distance vision. A vision of 20/40 is considered half as good as normal performance. A vision of 20/10 is considered twice as good as normal performance (Watt, 2003).

Secondly an eye dominance test was conducted to assess far vision. The method used is called the distance hole-in-the-card. The athletes were instructed to put both hands straight ahead at arm's length making a diamond shape. The diamond shape was big enough to allow viewing with both eyes of a letter X marked on the wall letter at 3 meters away. The athlete was instructed to cover the left eye and asked if he or she could see the letter. The athlete was then again instructed to cover the right eye and asked again if he or she could still see the letter. The eye that could see the letter was recorded as the dominant eye (right or left). If the athlete was able to see the letter with both the right and the left eye, the dominant eye was recorded as "neither."

3.4.3 Luxmeter

The third instrument used was the luxmeter. A luxmeter is a device for measuring illumination in work places or sporting settings. Illumination is a measure of the total "amount" of visible light present and the intensity of illumination on a surface. The official rules for lighting by the FIVB world and official competitions require the lighting on the playing area to be 1,000 to 1,500 lux measured at 1 meter (39 inches) above the surface (FIVB, 2011). For the purpose of the study, lighting was checked for each participant. The lighting in the hall ranged from 1,400 to 1,450 lux.

3.4.4 Jugs Professional Sports Cordless Radar gun

The fourth instrument used was a Jugs Professional Sports Cordless Radar gun. It is specifically designed to measure the pitch-release speed of balls in softball and baseball. It incorporates high performance, precision, and versatility, with many leading features. Determining an object's speed begins with the radar gun transmitting and directing a beam of microwave energy at an approaching (receding) target. When energy from this beam strikes the target, a small amount of energy is reflected to the antenna in the radar device. The reflected signal frequency shifts by an amount proportional to the speed of the target. This is known as the Doppler effect. The radar device then determines the target speed from the difference in frequency between the reflected and transmitted signal. Whereby the frequency of the returned signal is increased in proportion to the object's speed of approach if the object is approaching, and lowered if the object is receding (Jugs User's Manual: 3). For the purpose of this study, the radar gun was used to determine the speed of the served balls in the measurement unit of km/h. The measurement would in turn help indicate the range of speeds for the float and top spin jump serves respectively.

3.4.5 Applied Science Laboratories (ASL) mobile eye system

The fifth and final measuring instrument used for data collection was the Applied Science Laboratories (ASL) mobile eye system as illustrated in Figure 3.1. The mobile eye tracker was designed specifically for applications in which lightweight, completely un-tethered eye gaze tracking is required. This specific design is well suited in most sport settings including the present study as it has been used in similar volleyball eye tracking studies by Vickers (1997) and Lee (2010).

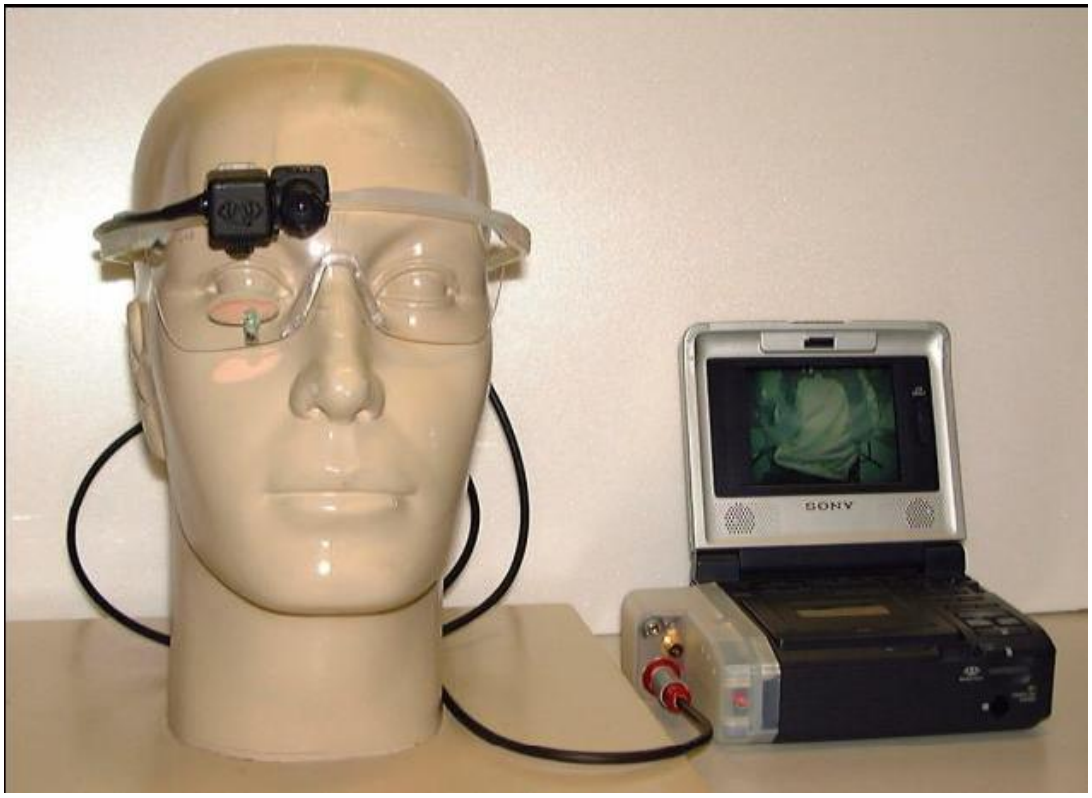

Figure 3.1: The ASL Mobile Eye system (ASL, 2008)

The ASL mobile eye tracking system uses a technique of eye tracking known as dark pupil tracking. This method uses the relationship between two eye features, the pupil and a reflection from the cornea, to compute gaze within a scene. A set of three harmless near infra-red lights are projected on the eye by a set of LEDs in the spectacle mounted unit (See Figure X 3.2). The near infra-red lights are not visible to the player or participant, so they cannot cause any form of distraction during testing or a task, however they are visible to the eye camera on the spectacle mounted unit. A portion of these three lights is reflected by the cornea and appear to the camera as a triangular pattern of three dots, called the spot cluster, at a fixed distance from each other.

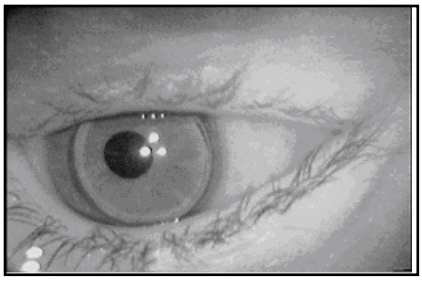

Figure 3.2: Three harmless near infra-red lights projected on the eye (ASL, 2008)

The ASL mobile eye tracking system operates as the eye turns, the centre of the pupil will move relative to the head. However, due to properties of the cornea, the corneal reflection remains approximately in the same position relative to the head. Therefore, by comparing the vector (angle and distance) between the pupil and the cornea, the eye tracking system can compute the angle that the eye is pointed. By teaching the system how these angles relate to an image on a second camera that is viewing the environment, the scene camera, the eye tracker can compute in which direction the eye is pointed relative to the scene camera. Thus, the gaze direction is documented output as a point of gaze marker superimposed on the scene video image.

With the above-mentioned eye tracking basics described, the function of the Mobile Eye System is to record data at 60Hz by interleaving images taken from two cameras. The eye camera records the eye being tracked while the scene camera records the environment being observed by the player. Both image streams are then recorded on the same digital videotape medium by alternating frames.

The ASL mobile eye hardware (Figures 3.3 to 3.8) interfaces recording operations with a stand-alone control computer or laptop (Figure 3.9) for data processing. The laptop runs ASL EyeVision version 2.2.7 software for these operations.

3.4.5.1 ASL mobile eye hardware

The Sony GV-D1000 Digital Video Cassette Recorder (Figure 3.3) is attached to the ASL recorder mounted unit. It is used to record and play video from the field and interfaces with the control computer (ASL, 2008).

Figure 3.3: Sony GV-D1000 digital video cassette recorder (ASL, 2008)

The recorder Mounted Unit (Figure 3.4) is attached to the digital video cassette recorder and contains an ASL circuit board and connects to the spectacle mounted unit (ASL, 2008).

Figure 3.4: Recorder mounted unit

The Spectacle Mounted Unit (Figure 3.5) contains the scene camera, the eye camera, and a short distance audio microphone. It mounts onto the spectacle above the eye and connects to the recorder mounted unit. Also located in the eye camera housing is the infra-red illuminator (ASL, 2008).

Figure 3.5: Spectacle mounted unit (ASL, 2008)

The eyewear is fitted with an adjustable hot mirror (monocle), dovetail mount for attachment of spectacle mounted unit, and tightening headband. A ventilation hole is located in the spectacles (Figure 3.6) to eliminate condensation (ASL, 2008).

Figure 3.6: Spectacles (ASL, 2008)

The monocle (Figure 3.7) is a mostly transparent mirror that is partially reflective in the near infra-red and infra-red range. Its purpose is to reflect the eye image and corneal reflections between the eye and the eye camera. It is attached to the spectacles by a ball joint to allow for adjustment of the image. The monocle is larger than the ventilation hole to keep it from contacting the wearer in the case of a forceful impact (ASL, 2008).

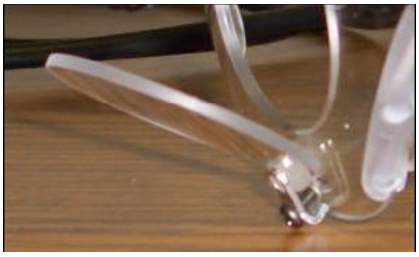

Figure 3.7: Monocle (ASL, 2008)

The Sony GV-D1000 Digital Video Cassette Recorder uses ^{Mini}DV DVC 60 tapes (Figure 3.8) for recording video (ASL, 2008).

Figure 3.8: ^{Mini}DV DVC 60 **Tape (ASL, 2008)**.

The digital video cassette recorder connects to the control computer (Figure 3.9) for real time calibration or post-collection data processing. The computer comes preinstalled with the EyeVision software (ASL, 2008).

Figure 3.9: Control computer (ASL, 2008)

3.4.5.2 Scene calibration

Because of the effects of parallax, the physical distance of the objects being used to calibrate will affect the accuracy of the eye tracking. Therefore, for accuracy, the suppliers recommend that objects are about the same distance away from the participant as those in the participant's task to calibrate the ASL Mobile Eye Tracker System. For the present study, the testing was conducted on a 18 x 9 metre volleyball regulation court, and the distance between the server and receiver was approximately 12.7 meters.

The point of gaze must be calibrated every time the player puts on the Mobile Eye since even small differences in spectacle or optics placement can result in degradations in data accuracy. The scene calibration maps the point of gaze onto scene data by relating the positions of eye features (pupil and corneal reflection cluster) to known positions within the scene image. For the purpose of this study recording was begun after setting up the optics.

A short calibration record was created by asking the player to look at a nine point-calibration screen. Figure 3.10a illustrates the calibration screen used. This point-of-gaze calibration procedure displays individual parameters of each participant relative to gaze directionality and eye movements within the scene. Participants were asked to focus their point-of-gaze on each dot before moving on to the next dot. Dots were moved (from right

to left) in the same plane while the participant maintained a still head position on the server (Refer to Figures 3.10b and c).

Figure 3.10a: Zoomed in picture of the calibration screen

Figure 3.10b: Test participant instructed to look at the dot in the middle of the volleyball court.

Figure 3.10c: Test participant instructed to view the dot on the left side of the volleyball court.

The ASL Mobile Eye Tracker System standards include the use of five to10 points during calibration. For the purpose of this study, nine calibration points were used. To ensure accuracy of pupil mapping the investigator watched the monitor in order to ensure that the pupil boundary between the pupil and the iris was well defined and the spot cluster was clearly visible during calibration.

Eye motion patterns are at the centre of this work. Patterns of eye movement are comprised of a sequence of points representing the locations of the eye fixation points over time. While research has been performed on patterns of object selection to infer user intention and state, this work explores a new direction: the use of patterns of eye fixations. Several advantages can be gained from analysing patterns of eye motion in eye tracking interfaces. The technique of analysing eye movement on the pattern level can have three significant effects on current eye tracking systems that this section proposes and discusses. Such a technique can offer speed, reliability and a better understanding of user attention and each of these three effects are individually discussed below.

3.5 DATA COLLECTION AND TESTING PROTOCOL

Testing was conducted over a two-year period. A total number of 20 non-successive testing days were used to collect data. Table 3.1 depicts the steps followed in gathering data from the participants.

On the day of testing, participants arrived at the testing venue and were welcomed by the researcher and assistants. The study, the equipment and the testing procedure were explained by the researcher and any questions by participants were answered. The participants then completed the informed consent form (Appendix E), as well as a questionnaire (Appendix G) on their sporting and visual history.

Table 3.1: Data collection procedure

Step	Step Description
1	Welcome the test participants
2	Brief the participants. • Introduce the observers. • Show and explain the equipment. • Explain the skill/product being evaluated. • Explain the task/ process. • Ask to give verbal comments after task completion.
3	Administer forms. • Consent and disclosure forms
4	The participant conducts three to five trials in order to familiarise themselves with passing the ball while wearing the spectacles and recorder mounted unit.
5	Calibration of equipment.
6	Conduct the test. • Record eye tracking data • Record video and audio information • Log participant activities • Save data files after the test
7	Debrief the participants
8	Thank the participants

3.5.1 Eye tracking protocol

Once the relevant questionnaires and forms were completed, each participant was fitted with the ASL Mobile Eye Tracker System and calibrated accordingly. Figure 3.11 illustrates the set-up in the testing venue and the movements of the ball from the server on the right hand serving the ball and the receiver standing on the left hand side on a regulation volleyball court wearing an eye tracker and passing the volleyball to a target score area 4, the setter area.

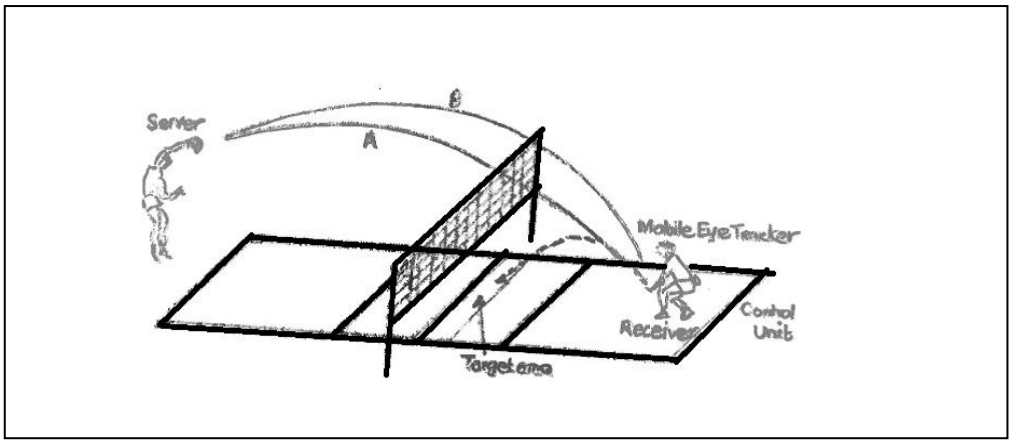

Figure 3.11: Illustration of Top Spin jump Serve set up in testing venue for both male and female players at the respective regulation heights for gender/sex. Ball flight A represents the ball trajectory of the float serve and the B represents the trajectory of the top spin jump serve. The reception area remained at the same place. (Source: Diagram supplied by researcher).

The participants were required to perform four successful serve receptions, of which two serves were ‘top spin jump’ serves and two were ‘float’ serves. The task was to detect the ball as it was delivered by the server, track it over a distance, receive the ball with the forearms or fingers (overhead pass) and make an accurate pass to a target area (Figure 3.11). The gaze patterns of the receivers were recorded using the ASL Mobile Eye Tracker System. A limitation to the testing protocol was that we were unable to record whether the athletes passed using an overhead pass or the forearm due to lack of an external synchronised video camera setup. The participants had an unspecified number of trials, meaning the test stopped after four successful serve receptions, two from the top spin jump serve and two from the float serve. The data were recorded for each participant on every

trial (Appendix I). Once the testing was complete, the participant was thanked for their participation.

3.5.2 Speed of serve test protocol

For the purpose of collecting the speed of serve data, a speed radar gun located to the rear of the receiver was used. Positioning the radar gun for optimum reading of a volleyball serve speed was crucial (see Figure 3.12 below). In order to achieve maximum accuracy, the radar unit on a tri-pod was aligned in the direction of travel of the ball. The protocol used for the test was simple. For every ball served and type of serve served, the speed gun automatically tracked the speed and the speed in turn was recorded.

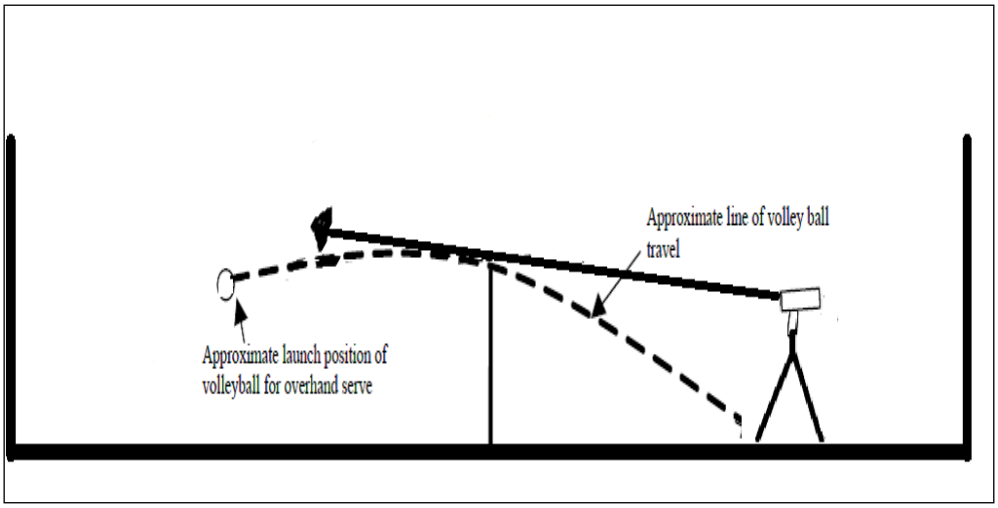

Figure 3.12: Side view of speed gun set up. (Source: Supplied by researcher).

3.5.3 Data coding protocol

INTERACT 8 software version 2008: 8.4.7 is a software package that operates as a professional and flexible analysis tool used to collect, manage, and analyse all types of observational and behavioural data (INTERACT 8, 2009). The system combines all required components for efficient high-quality eye movement and scene video recording into a single high performance control computer workstation. Real-time image processing, calibration, built-in data analysis and data and video recording are some of the components combined into one application. In this study, the analysis of the receivers' eye movements were of interest, in terms of determining the predefined areas of interest (AOI) of where the receiver's

gaze was directed. Furthermore, the duration and frequency of fixations in those areas of interest were extracted, coded and analysed. Table 3.2 shows an outline of all possible areas of interest. Table 3.2 below provides a time line with a start-and-end time code built up as HH:MM:SS:FF (hours:minutes:seconds:frames) (See Table 3.3).

Table 3.2: Table of all possible areas of interest (AOI)

Area of Interest
Ball (Serve Stance)
Ball Tracking (Toss)
Upper Body
Lower Body
Anticipated Contact Point
Contact Point
Ball Tracking (Flight)
Serve Reception
Ball (Return)
Anticipated Point of Arrival
Arrival at Target
Blink
Other

Table 3.3: Example of INTERACT 8 event and time codes for 16 frames

Time Code		**Event Code**
Start	**End**	**Predefined Area of Interest**
00:00:00:00	00:00:00:04	Ball Tracking (Toss)
00:00:00:05	00:00:00:09	Upper Body
00:00:00:10	00:00:00:11	Contact Point
00:00:00:12	00:00:00:16	Ball (Tracking Flight)

3.6 STATISTICAL ANALYSIS

A combination of descriptive and inferential statistics were used to delineate the results. Descriptive statistics are generally used to present quantitative descriptions in a manageable form (Babbie & Mouton, 1998) and facilitates organisation and interpretation (Cozby, 1993; Dane, 1990). Descriptive statistics, such as the mean, standard deviation and frequency distribution have been calculated to describe the observed data of volleyball players in the study and specifically to describe the eye tracking measure variables, such as 1) number of fixations, 2) duration of fixations, and 3) the AOI visited. The following eye tracking results are presented with the applicable variable name suffix in parentheses:

1. Number of fixations (N) - the number of fixations/times visited.
2. Number of fixation percentage (N%) - the percentage of the number of fixation/times visited.
3. Duration (D) - the period of time spent during a fixation.
4. Duration percentage (D%) - the percentage of time spent during a fixation.
5. Average duration per fixation (D/N).

It should be noted that certain non-integer statistics for the number of fixations, such as minimum and maximum was used due to the fact that during the data processing stage, the observed eye tracking data scores used for data analysis were the average values of the one to four successful serve reception attempts.

Inferential statistics, such as ANOVA, t-tests and Chi-square tests were used to compare Advanced with Not Advanced and male with female volleyball players in respect of the above-mentioned eye tracking measure variables. The inferential statistical techniques were conducted at the five percent level of significance. Furthermore, where statistically significant differences were observed, Cohen's d and Cramer's V statistics were used to determine practical significance. Cohen's d values were interpreted as follows: $0.20 <= d < 0.50$ small, $0.50 <= d < 0.80$ moderate and $d >= 0.80$ large practical significance. For Cramer's V, the value of 0.10 was used as the minimum for suggesting practical significance. Graphic illustrations are also used to furthermore facilitate the understanding of the results.

3.7 ETHICAL CONSIDERATION

Broadly, ethics can be described as a set of moral principles which is suggested by an individual or group, and subsequently widely accepted. In research one is bound to consider the ethical implications and repercussions of research, especially when dealing with human subjects. Thus ethics considerations offer rules and behavioural expectations about the most correct conduct towards experimental participants and respondents, employers, sponsors, other researchers, assistants and students (De Vos et al., 2005).

As the study required human participants, the researcher was concerned about any circumstances in the research setting or activity that could harm the participants. Harm should be interpreted to mean to frighten, embarrass or negatively affect the participants (Thomas et al., 2005). Thus a number of ethical issues were considered in order to prevent harm to the participants. They were as follows:

- The right to privacy and nonparticipation – the researcher did not ask unnecessary information or force participation in the study. Respondents signed consent or forms and were informed of their right to leave the research study without prejudice;
- The right to anonymity – the researcher promised anonymity to the participants and that the study focused on group data. To record data preference numbers were assigned rather than names of participants;
- The right to confidentiality – the researcher informed the participants that all information would be confidential and only used for the present research purposes. Furthermore, participants would have access to the final study.
- The right to expect experimenter responsibility – the researcher was well-meaning and sensitive to human dignity and adhered to an ethical code of research conduct.

Permission to conduct the study was sought from the Nelson Mandela Metropolitan University (NMMU) Research Ethics Committee (Human) as the participants involved in the study were mostly under the legal age of 18 years (Appendix F). Permission was granted and

informed consent forms were obtained from all selected participants. See Appendix A, B, C, D and E for copies of the Consent and Assent Forms respectively.

3.8 SUMMARY

This chapter highlighted the descriptive, explorative and quasi-experimental nature of the study, the inclusion criteria for the participants and the sampling technique utilised. The measuring instruments were introduced, the calibration process, the data collection including the testing procedures, the data capturing and analysis were discussed.

The following chapter describes the results obtained in this study.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

The research methodology utilised to determine and compare the gaze behaviour of Advanced and Not Advanced junior volleyball players during successful serve reception was discussed in the previous chapter. In this chapter, the focus is on describing the findings extracted from the quantitative data. Descriptive and comparative data is provided to establish the serve efficacy of Advanced and Not Advanced players, as well as to compare the techniques between the male and female cohorts in respect of the variables assessed. The results obtained were statistically analysed and are reflected in five sections, namely the biographical information, volleyball background, vision data, serve speed data and finally the eye tracking data.

The results are presented and then interpreted with reference to mean values, standard deviations and frequency distributions for the variables assessed. Differences were regarded as significant if results were both statistically and practically significant. If a variable did not prove to be statistically significant, the redundant practical significance statistic is not reported.

4.2 BIOGRAPHICAL INFORMATION

The biographical information of the respondents was collected by means of the questionnaire and is reflected below.

4.2.1 Age

The descriptive statistics of the participants' age are depicted in Table 4.1.

Table 4.1: Descriptive statistics - Age (in years) by gender and advancement level

Frequency Distribution	**Female** n = 18		**Male** n = 32		**Not Advanced** n = 31		**Advanced** n = 19		**Total** n = 50	
16 years	3	17%	4	13%	7	23%	0	0%	7	14%
17 years	7	39%	8	25%	9	29%	6	32%	15	30%
18 years	5	28%	7	22%	8	26%	4	21%	12	24%
19 years	3	17%	13	41%	7	23%	9	47%	16	32%
Statistic	**Female**		**Male**		**Not Advanced**		**Advanced**		**Total**	
Mean	17.44		17.91		17.48		18.16		17.74	
S.D.	0.98		1.09		1.09		0.90		1.07	
Minimum	16.00		16.00		16.00		17.00		16.00	
Quartile 1	17.00		17.00		17.00		17.00		17.00	
Median	17.00		18.00		17.00		18.00		18.00	
Quartile 3	18.00		19.00		18.00		19.00		19.00	
Maximum	19.00		19.00		19.00		19.00		19.00	

Table 4.1 above shows that no significant differences in age distribution were found between the Not Advanced and Advanced players (Chi^2 (d.f. = 3, n = 50) = 6.69; p = .083). Similarly, there were no significant differences found between gender and age (Chi^2 (d.f. = 3, n = 50) = 3.12; p = .374).

4.1.2 Gender

The gender distribution of the participants by advancement level is presented in Table 4.2. It should be noted that the majority of the participants were male. The gender composition of the Not Advanced group was particularly disproportionate with 71% male and 29% female. However, the gender distribution of the Advanced group was more equal 53% male and 47% female. No significant differences by gender were found between the Not Advanced and Advanced players (Chi^2 (d.f. = 1, n = 50) = 1.72; p = .190).

Table 4.2: Frequency distribution - Gender according to advancement level

Gender	Not Advanced n=31		Advanced n=19		Total n=50	
Female	9	29%	9	47%	18	36%
Male	22	71%	10	53%	32	64%

4.3 SCHOOLING AND VOLLEYBALL BACKGROUND

This section will present the results based on the questionnaire schooling history and volleyball background.

4.3.1 Grade Attended (school level)

Table 4.3 reflects the grades attended by the players, showing that more females (61%) in the study attended either grade 1 or 2 [1] compared to males (47%). For the male players there was a more even distribution between grades 1 or 2 (47%) and grade 3 (53%) compared to females (61% and 39%). Most Not Advanced players (61%) were in grades 1 or 2, and most Advanced players (63%) were in grade 3[2]. However, no significant difference between that of grade levels were found between the frequency distributions of Not Advanced and Advanced players (Chi^2 (d.f. = 1, n = 50) = 2.82; p = .093) nor between those of females and males (Chi^2 (d.f. = 1, n = 50) = 0.94; p = .333).

Table 4.3: Frequency distribution - Grade attended by gender and advancement level

	Female n=18		Male n=32		Not Advanced n=31		Advanced n=19		Total n=50	
Grades 1 or 2	11	61 %	15	47%	19	61%	7	37%	26	52%
Grade 3	7	39%	17	53%	12	39%	12	63%	24	48%

4.3.2 Advancement level

Table 4.4 reflects the frequency distribution of the advancement level categories of the participants by gender. The largest portion of the participants (62%) were classified as at a Not Advanced level compared to 38% Advanced. Whilst there was a larger portion of the

[1] Equivalent of grade 10 and 11 in South Africa
[2] Equivalent of grade 12 in South Africa

males (62%) classified as Not Advanced, the distribution for females were equally divided between the Not Advanced and Advanced categories. However, no significant differences were found between the gender groups with regard to advancement level distribution (Chi^2 (d.f. = 1, n = 50) = 1.72; p = .190).

Table 4.4: Frequency distribution – Volleyball advancement level by gender

Advancement Level	Female N=18		Male N=32		Total N=50	
Not Advanced	9	50%	22	69%	31	62%
Advanced	9	50%	10	31%	19	38%

4.3.3 Playing position

Table 4.5 reflects the frequency distribution of the primary positions of the participants. The main positions that require good to excellent serve reception abilities are the libero and outside hitter positions. Note that column totals do not add up to a 100% total for a particular group because some players indicated that they played in more than one primary position.

Table 4.5: Frequency distribution – Player position by gender and advancement level

Position	Female n = 18		Male n = 32		Not Advanced n = 31		Advanced n = 19		Total n = 50	
Libero	4	22%	6	19%	4	13%	6	32%	10	20%
Middle Blocker	2	11%	10	31%	7	23%	5	26%	12	24%
Outside Hitter	10	56%	14	44%	14	45%	10	53%	24	48%
Setter	4	22%	5	16%	6	19%	3	16%	9	18%
Diagonal	2	11 %	6	19 %	6	19 %	2	11 %	8	16%

Table 4.5 reflects that the majority of participants in the study were either outside hitters (24 respondents) or libero players (10 respondents). Of the total outside hitters, 53% fall in the Advanced group compared to 45% in the Not Advanced group. For the libero position, there were more players represented in the Advanced category (32%) compared to the Not Advanced category (13%).

Table 4.6 below reports a summary of the significance levels for the various playing positions that utilise serve reception skills.

Table 4.6: Significance of player position differences by gender and advancement level

Position	Chi²(d.f. = 1, n = 50) results			
	Gender		Advancement Level	
	Chi²	p	Chi²	p
Libero	0.09	.768	2.57	.109
Middle Blocker	2.56	.109	0.09	.764
Outside Hitter	0.64	.423	0.26	.608
Setter	0.34	.560	0.10	.750
Diagonal	0.50	.479	0.68	.409

Table 4.6 displays that no noteworthy differences were found between either the gender or advancement groups for any of the playing positions.

4.3.4 Highest level of participant achievement

The highest level of participants' volleyball achievement is presented in Table 4.7, indicating that 28 players in the study have played at national level, comprising of 56% female and 44% male participants. 79% (15 respondents) of the Advanced players had participated at national level, while the majority of the Not Advanced players (58%) had participated at club level only.

Table 4.7: Frequency distribution - Highest level of volleyball achievement by gender and advancement level

Highest level	Female		Male		Not Advanced		Advanced		Total	
Club	8	44%	14	44%	18	58%	4	21%	22	44%
National	10	56%	18	56%	13	42%	15	79%	28	56%
Total	18	100%	32	100%	31	100%	19	100%	50	100%

There was a significant statistical and medium practical difference found between the Not Advanced and Advanced groups in respect of highest level achieved (Chi² (d.f. = 1, n = 50) = 6.55; p = .010; V = 0.36). Significantly more volleyball players had played for a national team in the advanced group than the non-advanced group. However, no significant differences were found between gender and competitive level (Chi² (d.f. = 1, n = 50) = 0.00; p = .962).

4.3.5 National Team Category

Table 4.8 depicts the distribution of the various categories of national team representations by the participants.

Table 4.8: Frequency distribution - National teams represented by gender and advancement level

National Team Category	Female		Male		Not Advanced		Advanced		Total	
U17	3	30%	6	33%	7	54%	2	13%	9	32%
U19	7	70%	9	50%	6	46%	10	67%	16	57%
Senior	0	0%	3	17%	0	0%	3	20%	3	11%
Total	10	100%	18	100%	13	100%	15	100%	28	100%

It shows that most players have played for Norway at U/19 level, accounting for 70% of the females compared to 50% of the males. In the Not Advanced group, 54% of the players participated at U/17 level and interestingly in the Advanced group, 67% played at U/19 and 20% at the highest level, senior. No significant differences were found between gender and the national team category (Chi^2 (d.f. = 2, n = 28) = 2.14; p = .343). Unfortunately, no further analysis in order to find significant differences between the groups and national team category could be conducted due to the small sample involved in the study.

4.3.6 Years of Volleyball Experience

Descriptive statistics for the number of years of experience in playing volleyball is represented in Table 4.9. Furthermore, the table visually depicts the frequency distribution of the number of years' experience in volleyball for the two experienced groups and by gender.

Table 4.9: Descriptive statistics of volleyball experience (in number of years) by gender and advancement level

Frequency Distribution	Female n=18		Male n= 32		Not Advanced n=31		Advanced n=19		Total n= 50	
2 to 4 years	9	50 %	5	16 %	7	23 %	7	37 %	14	28 %
5 to 6 years	6	33 %	17	53 %	17	55 %	6	32 %	23	46 %
7 to 10 years	3	17 %	10	31 %	7	23 %	6	32 %	13	26 %
Statistic	**Female**		**Male**		**Not Advanced**		**Advanced**		**Total**	
Mean	4.75		5.97		5.52		5.55		5.53	
S.D.	1.59		1.62		1.69		1.77		1.7	
Minimum	2		3		2,5		2		2	
Quartile 1	4		5		5		4		4	
Median	4.5		6		5		6		5	
Quartile 3	5.75		7		6,25		7		6.88	
Maximum	8		10		10		9		10	

These results show that the male players in the study cumulatively are more experienced players with a mean number of years of 5.97 ± 1.62 years compared to females with a mean of 4.75 ± 1.59 years. The Advanced players in the study had slightly more volleyball experience with a mean of 5.55 ± 1.77 years compared to the Not Advanced group with a mean of 5.52 ± 1.69 years. Interestingly, 55% of the Not Advanced players have played volleyball between five and six years compared to the Advanced players with 32%. No significant difference in the distribution of volleyball playing experience was found between the Not Advanced and Advanced groups (Chi^2 (d.f. = 2, n = 50) = 2.61; p = .271). However, a medium significant difference was found for gender (Chi^2 (d.f. = 2, n = 50) = 6.78; p = .034; V = 0.37) with males having more experience than females.

4.3.7 Number of years attended at ToppVolley Norway

Descriptive statistics for the number of years attended at ToppVolley Norway are presented in Table 4.10. Both female and males players had attended ToppVolley Norway for a mean time of 2.22 ± 0.73 and 0.79 years respectively. The Advanced players attended the longest with a mean 2.58 ± 0.51 years and 58% of the respondents were in their third and final year.

Table 4.10: Descriptive statistics of the number of years attended at ToppVolley Norway

Frequency Distribution	**Female** n = 18		**Male** n = 32		**Not Advanced** n = 31		**Advanced** n = 19		**Total** n = 50	
One year	3	17%	7	22%	10	32%	0	0%	10	20%
Two years	8	44%	11	34%	11	35%	8	42%	19	38%
Three years	7	39%	14	44%	10	32%	11	58%	21	42%
Statistic	**Female**		**Male**		**Not Advanced**		**Advanced**		**Total**	
Mean	2.22		2.22		2		19		2,22	
S.D.	0.73		0.79		0.82		2.58		0.76	
Minimum	1		1		1		0,51		1	
Quartile 1	2		2		1		2		2	
Median	2		2		2		2		2	
Quartile 3	3		3		3		3		3	
Maximum	3		3		3		3		3	

Table 4.10 also shows that there was a relatively equal distribution of players in the Not Advanced group across year one to three; whereas in the Advanced group the respondents were only found to be in year two and three. There was a statistical and medium practical significant difference in the frequency distribution of the number of years attending ToppVolley Norway among the Not Advanced and Advanced players (Chi^2 (d.f. = 2, n = 50) = 8.11; p = .017; V = 0.40) with the latter group having the longer attendance. There were no significant differences found between gender and the number of years attended at ToppVolley Norway (Chi^2 (d.f. = 2, n = 50) = 0.53; p = .768).

4.3.8 Number of weekly practice hours

Table 4.11 indicates the weekly training hours accumulated by the players, reflecting that Advanced players practice the most.

Table 4.11: Frequency distribution of the amount of training hours spent per week for Not Advanced and Advanced volleyball players

Nr of Hours Practice/Week	Female		Male		Not Advanced		Advanced		Total	
11 to 15	4	24%	4	13%	7	24%	1	5%	8	17%
16 to 20	7	41%	12	39%	13	45%	6	32%	19	40%
21+	6	35%	15	48%	9	31%	12	63%	21	44%
Total	17	100%	31	100%	29	100%	19	100%	48	100%

The majority (63%) of the Advanced players practice 21 hours or more per week whilst the largest portion (45%) of the Not Advanced practice between 16 and 20 hours per week. No statistical significant differences were found, though in the frequency distribution of number of hours trained per week between the Not Advanced and Advanced players (Chi^2 (d.f. = 2, n = 48) = 5.67; p = .059) a strong tendency for the Advanced Group to train longer per week was observed. No significant differences between the gender groups with regard to the number of practice hours per week were found either (Chi^2 (d.f. = 2, n = 48) = 1.19; p = .551).

4.4 VISION DATA

This section will present the results of the vision tests conducted.

4.4.1 Visual Acuity

Over 80% of the athletes across gender and advancement level had normal vision (20/20) as depicted in Table 4.12. Those athletes found without 20/20 vision had corrected vision in terms of contact lenses and glasses.

Table 4.12: Frequency distribution - Visual acuity by gender and advancement level (outcome of the 20/20 vision test)

Visual Acuity	Female		Male		Not Advanced		Advanced		Total	
20/20 vision	15	83%	28	88%	26	84%	17	89%	43	86%
Visual impairment	3	17%	4	13%	5	16%	2	11%	7	14%
Total	18	100%	32	100%	31	100%	19	100%	50	100%

No significant differences were found between the Not Advanced and Advanced players in terms of the frequency distribution of participants with impaired vision and subsequently presenting with corrected vision (Chi^2 (d.f. = 1, n = 50) = 0.31; p = .579). No significant differences were found between the gender groups with regard to visual impairment (Chi^2 (d.f. = 1, n = 50) = 0.17; p = .684).

4.4.2 Eye dominance

The frequency distribution of eye dominance is presented in Table 4.13. Eye dominance was evenly distributed for both female and male participants. While 55% of the Not Advanced players were right eye dominant, 58% of the Advanced players were left eye dominant.

Table 4.13: Frequency distribution - Eye dominance by gender and advancement level

Dominant Eye	Female		Male		Not Advanced		Advanced		Total	
Left	9	50%	16	50%	14	45%	11	58%	25	50%
Right	9	50%	16	50%	17	55%	8	42%	25	50%
Total	18	100%	32	100%	31	100%	19	100%	50	100%

Thus, no significant differences in respect of eye dominance distribution were found between the Not Advanced and Advanced players (Chi^2 (d.f. = 1, n = 50) = 0.76; p = .382) and gender groups (Chi^2 (d.f. = 1, n = 50) = 0.00; p = 1.000).

4.5 SERVE DATA

Table 4.14a describes the speed of serve statistics. The mean recorded speed was 58.72 km/h for the float serve and 70.28 km/h for the top spin. Table 4.14a reveals that the speed for the float serve ranged between 42 km/h to 89.99 km/h. The top spin jump serve ranged between 50 and 99.00 km/hr. Furthermore, 70% of the float serves reached speeds ranging between 50 and 59.99 km/h.

Table 4.14a: Descriptive statistics - Serve speed (in km/h) for the float and top spin jump serve types

Frequency Distribution Km/h	**Float** **n = 40**		**Top Spin** **n = 40**	
42.00 to 49.99	2	5%	0	0%
50.00 to 59.99	28	70%	4	10%
60.00 to 69.99	8	20%	15	38%
70.00 to 79.99	0	0%	17	43%
80.00 to 89.99	1	3%	4	10%
90.00 to 99.99	0	0%	1	3%
Statistic				
Mean	58.72		70.28	
S.D.	8.34		8.14	
Minimum	47		55	
Quartile 1	55.5		64.75	
Median	56.88		70.13	
Quartile 3	59.63		78	
Maximum	88		99	

For the top spin jump serve, an even distribution of serves was detected, whereby 43% of the serves reached speeds between 70 to 80 km/h and 38% accounted for speeds between 60 and 70 km/hr. Of the two types of serves, the top spin jump serve produced the higher frequency of the faster speed recordings. Table 4.14b below highlights that the mean speed of topspin jump serves was significantly greater than that of the float serve ($t = 5.90$, d.f. = 39, $p = <.0005$, $d = 0.93$, Large).

Table 4.14b: Descriptive statistics - Serve speed (in km/h) differences between the Top Spin and Float Serve types

Frequency Distribution Km/h	**Difference Top Spin Minus Float** n= 40	
[-43 to -30)	1	3 %
[-30 to -15)	0	0 %
[-15 to 0)	4	10 %
[0 to 15)	17	43 %
[15 to 31]	18	45 %
Statistic		
Mean	11.56	
S.D.	12.39	
Minimum	-43	
Quartile 1	7,75	
Median	12.75	
Quartile 3	19.21	
Maximum	30.5	

Note that for the purpose of the study, speed was recorded to gain a range for the speed of serves, therefore 40 trials were recorded.

4.6 EYE TRACKING DATA

This section will present the eye tracking results for both the float and top spin jump serves.

4.6.1 Eye tracking data for the float serve

4.6.1.1 Number of fixations, fixation duration and average duration per fixation for the float serve

The descriptive statistics relating to the number of fixations, fixation duration (in sec) and duration per fixation (in sec) by gender and advancement level for the Float Serve are shown in Table 4.15.

Table 4.15: Mean number of fixations, fixation duration (seconds) and average duration per fixation (seconds) by gender and advancement level - Float serve for the total group (n = 50)

	Female		Male		Not Advanced		Advanced		Total	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number of fixations	9.19	1.55	11.02	3.37	10.77	3.63	9.70	1.14	10.37	2.97
Duration	15.63	1.04	16.00	1.09	16.02	0.96	15.61	1.22	15.87	1.08
Duration/fixation	1.76	0.29	1.62	0.27	1.60	0.34	1.64	0.20	1.62	0.29

The eye tracking statistics in Table 4.15 show that Advanced participants had on average fewer fixation points (9.70 compared to 10.77) and shorter fixation duration (15.61 compared to 16.02) than the Not Advanced participants. The average duration per fixation for the Advanced participants was longer (1.64s compared to 1.60s) than the Not Advanced cohort. Male athletes had on average more fixations (11.02 compared to 9.19) and longer fixation duration (16,00s compared to 15.63s) than female participants. One of the reasons for the differences between the male and female scores (Table 4.20) for the number of fixations and duration may be the difference in net height. The significant differences were determined by ANOVA and the results are reported in Table 4.21(a) and (b).

4.6.1.2 Area of interest (AOI) eye tracking data for the float serve

Tables 4.16, 4.17, 4.18, 4.19 and 4.20 for the AOI eye tracking data are combined results for both gender and Advancement levels. The abovementioned tables show the results for the

mean number of fixations, relative number of fixation (%), fixation duration and duration per fixation for the 13 AOI's when participants received float serves.

Table 4.16: Descriptive statistics for the number of fixations per AOI for the total group (n=50) for the float serve

	Mean	S.D.
AOI.Ball (Serve Stance).N	0.01	0.04
AOI.Ball (Toss).N	0.69	0.42
AOI.Upper Body.N	1.58	1.48
AOI.Lower Body.N	0.91	0.61
AOI.Anticipated Contact Point.N	0.33	0.34
AOI.Contact Point.N	0.96	0.17
AOI.Ball (Flight).N	1.06	0.19
AOI.Serve Reception.N	1.00	0.00
AOI.Ball (Return).N	0.83	0.74
AOI.Anticipated Point of Arrival.N	0.96	0.44
AOI.Arrival at Target.N	0.99	0.08
AOI.Blink.N	1.03	0.73
AOI.Other.N	0.03	0.10

Table 4.16 reflects the mean values for the number of fixations per AOI indicating the amount of interest in a visual area. The region with the highest average fixation frequency was the upper body (M = 1.58). Other AOI's deemed important and fixated on during the serve reception include ball (flight), serve reception, arrival at target and contact point.

Table 4.17: Descriptive statistics for the relative number of fixations per AOI for the total group (n=50) for the float serve

	Mean	S.D.
AOI.Ball (Serve Stance).N%	0.05	0.33
AOI.Ball (Toss).N%	6.83	4.38
AOI.Upper Body.N%	14.05	7.78
AOI.Lower Body.N%	8.90	5.71
AOI.Anticipated Contact Point.N%	2.98	2.98
AOI.Contact Point.N%	9.68	2.34
AOI.Ball (Flight).N%	10.64	2.32
AOI.Serve Reception.N%	10.10	1.85
AOI.Ball (Return).N%	7.62	4.34
AOI.Anticipated Point of Arrival.N%	9.25	3.07
AOI.Arrival at Target.N%	9.94	1.99
AOI.Blink.N%	9.71	5.76
AOI.Other.N%	0.26	0.97

Table 4.17 reflects the mean values for the relative number of fixations (%) per AOI. These data suggest that a greater percentage of fixations and or relative importance were placed on the upper body region (14.05%), followed by an almost equal number of fixations for the phases of the ball flight (10.64%), serve reception (10.10%), arrival at target (9.94%) and contact point (9.68%).

Table 4.18: Descriptive statistics for the fixation duration per AOI for the total group (n = 50) for the float serve

	Mean (seconds)	S.D.
AOI.Ball (Serve Stance).D	0.00	0.01
AOI.Ball (Toss).D	1.20	0.98
AOI.Upper Body.D	2.24	1.35
AOI.Lower Body.D	1.42	1.19
AOI.Anticipated Contact Point.D	0.42	0.53
AOI.Contact Point.D	0.73	0.38
AOI.Ball (Flight).D	3.83	0.89
AOI.Serve Reception.D	1.34	0.87
AOI.Ball (Return).D	1.72	1.47
AOI.Anticipated Point of Arrival.D	1.54	0.81
AOI.Arrival at Target.D	0.04	0.03
AOI.Blink.D	1.36	1.09
AOI.Other.D	0.03	0.15

Table 4.18 reflects the mean value for fixation duration per AOI, showing that the longest fixation duration took place in the ball flight phase (M = 3.83±0.89), followed by the upper body area (M = 2.24±1.35) and ball return phase (M = 1.72±1.47). Longer fixations imply the participants are spending more time interpreting or processing the information in the specific location or identified AOI.

Table 4.19 reflects the mean relative value for the fixation duration (%) per AOI.

Table 4.19: Descriptive statistics for the fixation duration percentage per area of interest for the total group (n = 50) for the float serve

Float (n=50)	Mean	S.D.
AOI.Ball (Serve Stance).D%	0.01	0.06
AOI.Ball (Toss).D%	7.51	6.09
AOI.Upper Body.D%	14.13	8.43
AOI.Lower Body.D%	8.83	7.30
AOI.Anticipated Contact Point.D%	2.65	3.34
AOI.Contact Point.D%	4.60	2.37
AOI.Ball (Flight).D%	24.15	5.58
AOI.Serve Reception.D%	8.44	5.48
AOI.Ball (Return).D%	10.87	9.59
AOI.Anticipated Point of Arrival.D%	9.76	5.06
AOI.Arrival at Target.D%	0.28	0.22
AOI.Blink.D%	8.59	6.90
AOI.Other.D%	0.19	0.97

Table 4.19 shows that most time is spent fixating on the ball (flight) phase (24.15%) and on the upper body area (14.13%).

Table 4.20: Descriptive statistics of the average duration per fixation ratio per area of interest for the float serve

	n	Mean (seconds)	S.D.
AOI.Ball (Serve Stance).D/N	1	0.28	-
AOI.Ball (Toss).D/N	40	1.73	0.86
AOI.Upper Body.D/N	48	1.64	0.87
AOI.Lower Body.D/N	42	1.57	0.95
AOI.Anticipated Contact Point.D/N	28	1.30	0.73
AOI.Contact Point.D/N	49	0.77	0.38
AOI.Ball (Flight).D/N	50	3.68	0.98
AOI.Serve Reception.D/N	50	1.34	0.87
AOI.Ball (Return).D/N	43	2.04	0.85
AOI.Anticipated Point of Arrival.D/N	48	1.65	0.69
AOI.Arrival at Target.D/N	50	0.05	0.05
AOI.Blink.D/N	46	1.43	0.90
AOI.Other.D/N	4	1.51	1.83

Table 4.20 reflects the eye tracking data for the average duration per fixation. The ball flight phase, serve reception phase and arrival at target were the three main identified AOI with the longest durations per fixation. This happened for all serves. The longest duration per fixation took place in the ball flight phase (M = 3.68).

4.6.1.3 Significance of eye tracking data differences by gender and advancement level for the float serve

A two-way analysis of variance (ANOVA) was conducted to determine the statistical significance of the differences between the gender groups and advancement levels with regard to eye tracking data for the various areas of interest when participants received float serves. Table 4.21a and 4.21b indicate the descriptive and inferential statistics related to the ANOVA results, showing the relevant significant differences by gender and advancement level.

Table 4.21a: Descriptive and inferential statistics for statistically significant differences by gender found by means of ANOVA for the float serve

	Female		**Male**		**ANOVA**	**Cohen's**
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Upper Body.N	0.97	0.67	1.93	1.69	.037	0.67
AOI Anticipated Point of Arrival.N	0.78	0.31	1.07	0.48	.027	0.68
AOI Upper Body.N%	10.01	5.90	16.32	7.86	.003	0.87
AOI Contact Point.N%	10.73	1.66	9.08	2.48	.016	0.74
AOI Serve Reception.N%	11.16	1.81	9.50	1.6	.003	0.99
AOI Arrival at Target.N%	10.85	2.24	9.43	1.67	.025	0.75
AOI Upper Body.D	1.54	1.32	2.63	1.22	.001	0.86
AOI Upper Body.D%	9.93	8.46	16.49	7.08	.002	0.83
AOI Serve Reception.D%	10.75	7.08	7.13	3.9	.042	0.69
AOI Average.D/N	1.74	0.29	1.52	0.27	.015	0.8

Table 4.21b: Descriptive and inferential statistics for statistically and practical significant differences by advancement level found by means of ANOVA

	Not Advanced		Advanced		ANOVA	Cohen's
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Ball (Toss).N	0.79	0.38	0.52	0.43	.029	0.68
AOI Upper Body.D	1.34	0.93	0.98	1.04	.045	0.38
AOI Ball (Toss).D%	8.33	5,9	6.16	6.48	.046	0.36
AOI Upper Body.D%	13.2	8.35	15.65	8.56	.035	0.29

The results in Tables 4.21a and 4.21b show significant differences($p<.05$, $d> 0.2$) between the gender groups and advancement levels in respect of the following variables respectively:

- Number of fixations (N variables) on the:
  - Upper body - more fixations for males (M = 1.93) than females (M = 0.97);
  - Anticipated point of arrival - more fixations for males (M = 1,07) than females (M = 0.78); and
  - Ball toss - more fixations for Not Advanced (M = 0.79) than Advanced (M = 0.52).
- Relative number of fixations (N% variables) on the:
  - Upper body – a greater percentage of fixations for males (M = 16.32%) than females (M = 10.01%); and
  - Contact point, serve reception and arrival at target - a greater percentage of fixations for females (M = 10.73; M = 11.16 and M =10.85) than males (M = 9.08; M = 9.50 and M = 9.43).
- Duration (D variables) of fixation on the:
  - Upper body - longer time spent fixating on this region by males (M = 2,63) than females (M = 1,54);
  - Upper body- longer time spent fixating on this region by Not Advanced (M = 1,34) than Advanced (M = 0.98); and
- Relative duration (D% variable) of fixation on the:
  - Upper body – greater percentage of time spent fixating on this region by males (M = 16.49) than by females (M = 9.93);
  - Serve reception - greater percentage of time spent fixating on this region by females (M = 10.75) than by males (M = 7.13);

- Ball toss - greater percentage of time spent fixating on this region by the Not Advanced (M = 8.33) than Advanced participants (M = 6.16); and
- Upper body - greater percentage of time spent fixating on this region by Advanced (M = 15.65) than Not Advanced (M = 13.20).

- Duration per fixation (.D/N variable) on the:
  - AOI (Total) - This is the cumulative or the total amount of fixation time on an AOI. It was found that females (M = 1.74) spent more time per fixation than males (M = 1.52).

4.6.2 Eye tracking data for the top spin jump serve

4.6.2.1 Number of fixations, fixation duration and average duration per fixation for the top spin serve

The descriptive statistics relating to the number of fixations, fixation duration and duration per fixation by gender and advancement level are shown in Table 4.22 below.

Table 4.22: Mean number of fixations, fixation duration and average duration per fixation by gender and advancement level - Top spin jump serve (n = 50)

	Females		**Males**		**Not Advanced**		**Advanced**		**All**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Means**	**SD**
Number of fixations	11.36	1.69	12.26	2.46	11.83	2.17	12.11	2.40	11.94	2.24
Duration	18.87	1.48	18.15	1.85	18.56	1.94	18.17	1.39	18.41	1.74
Duration/fixation	1.73	0.28	1.56	0.32	1.65	0.34	1.57	0.26	1.62	0.32

The eye tracking statistics in Table 4.22 show that Advanced participants had on average more fixation points (12.11 compared to 11.83) and shorter fixation duration (18.17 compared to 18.56) than the Not Advanced. Male athletes had on average more fixations (12.26 compared to 11.36) and also shorter fixation duration (18.15 compared to 18.87) than female participants. The duration per fixation remains shorter for the males compared to the females (1.57 compared to 1.65).

4.6.2.2 Area of interest (AOI) eye tracking data for the top spin jump serve

Tables 4.23, 4.24, 4.25, 4.26 and 4.27 in this section are combined (total) results for both gender and Advancement levels for the AOI eye tracking data. The abovementioned tables also show the results for the mean number of fixations, fixation duration and duration per fixation for the 13 areas of interest (AOI) when participants received top spin jump serves.

Table 4.23: Descriptive statistics of the number of fixations per area of interest for the total group (n=50) for the top spin

	Mean	S.D.
AOI.Ball (Serve Stance).N	0.04	0.16
AOI.Ball (Toss).N	0.88	0.42
AOI.Upper Body.N	1.96	0.87
AOI.Lower Body.N	1.10	0.90
AOI.Anticipated Contact Point.N	0.96	0.54
AOI.Contact Point.N	0.99	0.07
AOI.Ball (Flight).N	1.02	0.22
AOI.Serve Reception.N	1.00	0.00
AOI.Ball (Return).N	0.80	0.89
AOI.Anticipated Point of Arrival.N	0.93	0.34
AOI.Arrival at Target.N	1.00	0.00
AOI.Blink.N	1.18	0.65
AOI.Other.N	0.10	0.24

Table 4.23 reflects the mean values for the number of fixations per area of interest. These data suggest that the participants fixate most frequently on the upper body region (M=1.96) lower body (M=1.10), ball (flight) (M=1.02), serve reception (M=1.00), arrival at target (M=1.00) and contact point (M=0.99) areas.

Table 4.24: Descriptive statistics of the relative number of fixations per area of interest for the total group (n=50) for the top spin

	Mean	S.D.
AOI.Ball (Serve Stance).N%	0.31	1.42
AOI.Ball (Toss).N%	7.48	3.46
AOI.Upper Body.N%	16.07	5.60
AOI.Lower Body.N%	8.88	6.81
AOI.Anticipated Contact Point.N%	7.97	4.24
AOI.Contact Point.N%	8.59	1.66
AOI.Ball (Flight).N%	8.74	1.94
AOI.Serve Reception.N%	8.64	1.51
AOI.Ball (Return).N%	6.38	5.35
AOI.Anticipated Point of Arrival.N%	7.81	2.76
AOI.Arrival at Target.N%	8.64	1.51
AOI.Blink.N%	9.80	5.09
AOI.Other.N%	0.68	1.61

Table 4.24 reflects the mean relative values for the number of fixations (%) per AOI. These data suggest that a greater percentage of fixations are more frequent on the upper body area (16.07%), followed by a relatively equal percentage of fixations in the areas: lower body (8.88%), ball (flight) (8.74%), serve reception (8.64%), arrival at target (8.64%) and contact point (8.59). Note that the athletes spend 9.80% of the time blinking.

Table 4.25 reflects the mean value for fixation duration per area of interest.

Table 4.25: Descriptive statistics of the duration per area of interest for the total group (n=50) for the top spin

	Mean (seconds)	S.D.
AOI.Ball (Serve Stance).D	0.08	0.46
AOI.Ball (Toss).D	2.11	1.35
AOI.Upper Body.D	3.11	1.62
AOI.Lower Body.D	1.57	1.43
AOI.Anticipated Contact Point.D	1.26	1.01
AOI.Contact Point.D	0.78	0.28
AOI.Ball (Flight).D	2.86	0.65
AOI.Serve Reception.D	1.23	0.90
AOI.Ball (Return).D	1.48	1.40
AOI.Anticipated Point of Arrival.D	1.69	0.83
AOI.Arrival at Target.D	0,04	0.00
AOI.Blink.D	2.02	1.46
AOI.Other.D	0.17	0.47

Table 4.25 shows that the longest duration took place on the upper body region (M = 3.11), followed by the ball flight (M = 2.86), the ball (toss) (M = 2.11) and in the phase of blinking (M= 2.02).

Table 4.26 reflects the mean value for the fixation duration (%) per AOI.

Table 4.26: Descriptive statistics of the duration percentage per area of interest for the total group (n=50) for the top spin

	Mean	S.D.
AOI.Ball (Serve Stance).D%	0.48	2.79
AOI.Ball (Toss).D%	11.34	7.23
AOI.Upper Body.D%	17.05	9.35
AOI.Lower Body.D%	8.38	7.49
AOI.Anticipated Contact Point.D%	6.89	5.55
AOI.Contact Point.D%	4.26	1.57
AOI.Ball (Flight).D%	15.46	3.39
AOI.Serve Reception.D%	6.67	4.72
AOI.Ball (Return).D%	8.08	7.54
AOI.Anticipated Point of Arrival.D%	9.16	4.32
AOI.Arrival at Target.D%	0.22	0.02
AOI.Blink.D%	11.10	8.04
AOI.Other.D%	0.92	2.55

Table 4.26 shows that more time is spent fixating on the upper body region (M = 17,05%), followed by the phases of the ball flight (M = 15.46%), the ball toss (M = 11.34%) and blinking (11.10%). The interest in ball flight phase indicates the need for early information about the trajectory of the served ball and the ball toss phase suggests the participants' interest in tracking the served ball leading to the contact point phase (the ball and the server's hand).

Table 4.27 reflects the eye tracking statistics for the average duration per fixation.

Table 4.27: Descriptive statistics of the duration per fixation per area of interest for the total group (n=50) for the top spin

	n	**Mean (seconds)**	**S.D.**
AOI.Ball (Serve Stance).D/N	3	2.67	3.27
AOI.Ball (Toss).D/N	45	2.42	1.14
AOI.Upper Body.D/N	49	1.72	0.97
AOI.Lower Body.D/N	38	1.52	0.88
AOI.Anticipated Contact Point.D/N	44	1.28	0.72
AOI.Contact Point.D/N	50	0,79	0.28
AOI.Ball (Flight).D/N	49	2.86	0.55
AOI.Serve Reception.D/N	50	1.23	0.90
AOI.Ball (Return).D/N	41	2.05	1.22
AOI.Anticipated Point of Arrival.D/N	48	1.85	0.67
AOI.Arrival at Target.D/N	50	0.04	0.00
AOI.Blink.D/N	48	1.83	1.16
AOI.Other.D/N	9	1.92	1.33

Table 4.27 shows that the contact point, serve reception and arrival at target phases were the three AOI's where most subjects' gaze was fixated. The area with the longest duration per fixation was the ball flight phase (M =2.86).

4.6.2.3 Significance of eye tracking data differences by gender and advancement level for the top spin jump serve

A two-way analysis of variance (ANOVA) was conducted to determine the statistical significance of the differences between the gender and advancement level with regard to eye tracking data for the various areas of interest when participants received top spin jump serves. Table 4.28a and 4.28b indicates the descriptive and inferential statistics relating to the statistically significant ANOVA ($p<.05$) and practical significant (using Cohen's d analysis) ($d> 0.2$) differences by gender and advancement level.

Table 4.28a: Descriptive and inferential statistics for statistically and practical significant differences by gender for the top spin jump serve

	Female		Male		ANOVA	Cohen's
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Anticipated Point of Arrival. N	0.81	0.35	1.00	0.31	.033	059
AOI Blink. N%	11.86	5.75	8.64	4.35	.021	0.66
AOI Blink. D	2.98	1.63	1.49	1.05	.000	1.16
AOI Blink. D%	15.87	8.88	8.41	6.18	.000	1.03
AOI Ball (Flight). D/N	3.08	0.45	2.73	0.56	.026	0.67
AOI Blink. D/N	2.41	1.31	1.47	0.91	.004	087
AOI Average D/N	1.69	0.27	1.53	0.31	.045	0.54

Table 4.28b: Descriptive and inferential statistics for statistically and practical significant differences by advancement level for the top spin jump serve.

	Not Advanced		Advanced		ANOVA	Cohen's
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Contact Point. D	0.83	0.31	0.69	0.2	.049	0.5
AOI Contact Point. D%	4.51	1.73	3.85	1.17	.047	0.43
AOI Upper Body. D/N	0.37	1.25	-0.27	1.03	.047	0.55

The results in Tables 4.28a and 4.28b show significant differences ($p<.05$, $d< 0.2$) between the gender groups and experience levels with regard to the mean:

- Number of fixations (N variables) on the:
    - Anticipated point of arrival - more fixations for males (M = 1.00) than females (M = 0.81);

- Relative number of fixations (N% variables) on the:
    - Blink - a greater proportion of fixations for females (M = 11.86) than males (M = 8.64);
- Duration (D variable) on the:
    - Blink - longer time spent blinking by females (M = 2.98) than males (M = 1.49);
    - Contact point- longer time spent fixating on this region by Not Advanced (M = 0.83) than Advanced participants (M = 0.69).
- Relative duration (D% variable) on the:
    - Blink- greater portion of time spent blinking by females (M = 15.87) than by males (M = 8.41);
    - Contact point- greater portion of time spent fixating on this region by Not Advanced (M = 4.51) than by Advanced participants (M = 3.85).
- Duration per fixation (D/N variable) on the:
    - Blink- females (M = 2.41) spent longer time blinking per fixation than males (M = 1.47);
    - Ball flight- females (M =3.08) spent longer time per fixation than males (M = 2.73);
    - Average AOI- females (M = 1.69) spent longer time per fixation than males (M = 1.53);
    - Upper body- Not Advanced (M = 0.37) spent longer time per fixation in this region than Advanced participants (M = 0.27).

4.6.3 Eye tracking data for the comparisons between the top spin jump serve and float serve

4.6.3.1 Differences between serve types with regard to number of fixations, fixation duration and average duration per fixation

The descriptive statistics relating to the number of fixations, fixation duration and duration per fixation by gender and advancement level are reported in this sub-section and shown in Table 4.29. Note that in all instances the differences were calculated as the top spin value minus the float serve value.

Table 4.29: Mean number of fixations, fixation duration and average duration per fixation by gender and advancement level - Differences between top spin jump and float serves (n = 50)

	Females		Males		Not Advanced		Advanced		All	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Number of fixations	2.17	1.93	1.27	3.28	1.06	3.14	2.40	2,24	1.57	2.88
Duration	3.24	1.70	2.15	1.83	2.53	1.75	2.56	2,04	2.57	1.84
Duration/fixation	-0.03	0.35	0.02	0.35	0.05	0.37	-0.07	0,30	0.00	0.35

The eye tracking statistics in Table 4.29 depicts the differences between the top spin jump serve and the float serve. Both Advanced and Not Advanced players look longer at the topspin jump serve (2.56 vs 2.53), but Advanced players change the object of gaze more often (2.40 vs 1.06). Therefore, Advanced players use slightly more time (0.07) per fixation during a float serve than during a top spin jump serve. The opposite holds for inexperienced players who use slightly less time (0.05) during a float serve than during a top spin jump serve. Female athletes had on average almost one more fixation point (2.17 compared to 1.27) per serve and also a longer recording of above one second fixation duration difference (3.24 compared to 2.15) than male participants. The significance of these differences was determined by ANOVA and Cohen's d statistics and the results are reported in Table 4.35a and 4.35b.

4.6.3.2 Differences between the top spin jump serve and float serve with regard to the area of interest (AOI) eye tracking data

Table 4.30 reflects the statistics relating to the differences between the serve types with regard to the AOI eye tracking data. One sample t-tests were conducted to determine the statistical significance of these differences, with the null-hypothesis being that there are no differences between the two serve types. Note that in all instances the differences were calculated as the top spin value minus the float serve value.

Table 4.30: Statistics for the differences between the serve types with regard to the number of fixations per area of interest (n=50)

Variable	Mean	S.D.	t	d.f.	p	d
AOI.Ball (Serve Stance).N	0.030	0.165	1.29	49	.204	n.a.
AOI.Ball (Toss).N	0.193	0.551	2.48	49	**.016**	**0.35**
AOI.Upper Body.N	0.380	1.348	1.99	49	.052	n.a.
AOI.Lower Body.N	0.183	0.850	1.52	49	.134	n.a.
AOI.Anticipated Contact Point.N	0.627	0.596	7.43	49	**<.0005**	**1.05**
AOI.Contact Point.N	0.030	0.120	1.77	49	.083	n.a.
AOI.Ball (Flight).N	-0.045	0.275	-1.16	49	.253	n.a.
AOI.Serve Reception.N	0.000	0.000	-	-	-	-
AOI.Ball (Return).N	-0.030	0.535	-0.40	49	.693	n.a.
AOI.Anticipated Point of Arrival.N	-0.033	0.503	-0.47	49	.642	n.a.
AOI.Arrival at Target.N	0.015	0.078	1.35	49	.182	n.a.
AOI.Blink.N	0.153	0.789	1.37	49	.176	n.a.
AOI.Other.N	0.068	0.265	1.82	49	.074	n.a.

Table 4.30 shows that the ball toss and anticipated contact points' AOI are looked at significantly more often during a top spin serve as opposed to a float serve.

The differences between the two serves with regard to the mean relative number of fixations are indicated in Table 4.31.

Table 4.31: Statistics for the differences between the serve types with regard to the relative number of fixations per area of interest (n=50)

Variable	Mean	S.D.	T	d.f.	p	d
AOI.Ball (Serve Stance).N%	0.26	1.46	1.28	49	.207	n.a.
AOI.Ball (Toss).N%	0.65	4.84	0.95	49	.349	n.a.
AOI.Upper Body.N%	2.02	8.06	1.77	49	.083	n.a.
AOI.Lower Body.N%	-0.01	6.42	-0.02	49	.987	n.a.
AOI.Anticipated Contact Point.N%	4.99	5.01	7.04	49	**<.0005**	**1.00**
AOI.Contact Point.N%	-1.08	2.16	-3.54	49	**.001**	**0.50**
AOI.Ball (Flight).N%	-1.90	2.56	-5.25	49	**<.0005**	**0.74**
AOI.Serve Reception.N%	-1.45	1.92	-5.35	49	**<.0005**	**0.76**
AOI.Ball (Return).N%	-1.24	4.77	-1.84	49	.072	n.a.
AOI.Anticipated Point of Arrival.N%	-1.44	3.79	-2.68	49	**.010**	**0.38**
AOI.Arrival at Target.N%	-1.30	2.14	-4.28	49	**<.0005**	**0.61**
AOI.Blink.N%	0.08	6.05	0.10	49	.921	n.a.
AOI.Other.N%	0.42	1.97	1.50	49	.140	n.a.

The anticipated contact point was the only AOI for which the mean percentage of fixations was significantly greater (4.99%) for the top spin serve than for the float serve. The contact point, ball flight, serve reception, anticipated point of arrival and arrival at target were the AOI that recorded significantly greater percentages of fixations for the float serve compared to the top serve.

Table 4.32 indicates the mean duration differences between the two types of serve.

Table 4.32: Statistics for the difference in duration (sec) per area of interest between the two types of serve (n=50)

Variable	Mean	S.D.	t	d.f.	p	d
AOI.Ball (Serve Stance).D	0.082	0.465	1.24	49	.221	n.a.
AOI.Ball (Toss).D	0.903	1.351	4.72	49	**<.0005**	**0.67**
AOI.Upper Body.D	0.869	1.794	3.42	49	**.001**	**0.48**
AOI.Lower Body.D	0.152	1.441	0.75	49	.459	n.a.
AOI.Anticipated Contact Point.D	0.837	1.116	5.30	49	**<.0005**	**0.75**
AOI.Contact Point.D	0.051	0.352	1.03	49	.310	n.a.
AOI.Ball (Flight).D	-0.967	0.694	-9.86	49	**<.0005**	**1.39**
AOI.Serve Reception.D	-0.101	1.013	-0.71	49	.484	n.a.
AOI.Ball (Return).D	-0.237	1.468	-1.14	49	.260	n.a.
AOI.Anticipated Point of Arrival.D	0.148	1.006	1.04	49	.302	n.a.
AOI.Arrival at Target.D	-0.003	0.034	-0.71	49	.484	n.a.
AOI.Blink.D	0.668	1.143	4.13	49	**<.0005**	**0.58**
AOI.Other.D	0.140	0.506	1.96	49	.055	n.a.

Table 4.32 indicates that the ball toss, upper body, anticipated contact point and blink are the AOI with significantly longer fixation durations for top spin serves compared to float serves. The ball flight phase was the only AOI looked upon longer on average during the float serve than during the top spin jump serve.

Table 4.33 indicates the mean relative duration (percentage) differences between the two types of serve.

Table 4.33: Statistics for the difference in duration percentage per area of interest between the two types of serve (n=50)

Variable	Mean	S.D.	t	d.f.	p	d
AOI.Ball (Serve Stance).D%	0.47	2.79	120	49	.237	n.a.
AOI.Ball (Toss).D%	3.83	7.62	3.55	49	**.001**	**0.50**
AOI.Upper Body.D%	2.92	10.80	1.91	49	.062	n.a.
AOI.Lower Body.D%	-0.45	7.98	-0.40	49	.691	n.a.
AOI.Anticipated Contact Point.D%	4.24	6.32	4.75	49	**<.0005**	**0.67**
AOI.Contact Point.D%	-0.34	2.23	-1.09	49	.280	n.a.
AOI.Ball (Flight).D%	-8.69	4.29	-14.32	49	**<.0005**	**2.03**
AOI.Serve Reception.D%	-1.76	6.00	-2.08	49	**.043**	**0.29**
AOI.Ball (Return).D%	-2.80	8.20	-2.41	49	**.020**	**0.34**
AOI.Anticipated Point of Arrival.D%	-0.60	5.59	-0.76	49	.450	n.a.

Table 4.33 indicates that participants were fixated for a significantly longer percentage of the time during a top spin jump serve on the ball toss, and anticipated contact point. On the other hand the ball flight, serve reception and ball return were AOI where participants were fixated a greater proportion of the time during the float serve.

Table 4.34 shows statistics for the mean differences between the float and top spin serves with regard to the mean duration per fixation.

Table 4.34: Statistics for the difference in duration (sec) per fixation per area of interest between the two types of serve (n=50)

Variable	**n**	**Mean**	**S.D.**	**t**	**d.f.**	**p**	**d**
AOI.Ball (Serve Stance).D/N	0	-	-	-	-	-	-
AOI.Ball (Toss).D/N	36	0.74	1.19	3.73	35	**.001**	**0.62**
AOI.Upper Body.D/N	47	0.12	1.20	0.71	46	.483	n.a.
AOI.Lower Body.D/N	36	-0.10	1.25	-0.46	35	.651	n.a.
AOI.Anticipated Contact Point.D/N	25	007	0.96	0.36	24	.720	n.a.
AOI.Contact Point.D/N	49	002	0.33	0.50	48	.618	n.a.
AOI.Ball (Flight).D/N	49	-089	0.82	-7.60	48	**<.0005**	**1.09**
AOI.Serve Reception.D/N	50	-0.10	1.01	-0.71	49	.484	n.a.
AOI.Ball (Return).D/N	38	0.08	1.39	0.35	37	.732	n.a.
AOI.Anticipated Point of Arrival.D/N	46	0.25	0.87	1.97	45	.055	n.a.
AOI.Arrival at Target.D/N	50	-0.01	0.05	-0.85	49	.399	n.a.
AOI.Blink.D/N	44	0.43	1.03	2.77	43	**.008**	**0.42**
AOI.Other.D/N	0	-	-	-	-	-	-

Table 4.34 shows that the significant differences for the duration per fixation were found in three areas: namely the ball toss (medium), ball flight (large) and blink (small). The duration per fixation was found to be longer for the top spin serve with regard to ball toss and blink, while the ball flight was the only AOI where the duration per fixation was found to be significantly longer on average for the float serve.

4.6.3.3 Significance of eye tracking data differences between the top spin jump serve and the float serve by gender and advancement level

A two-way analysis of variance (ANOVA) was conducted to determine the statistical significance of the differences between gender and advancement level with regard to eye tracking data for the various AOI for the differences between the top spin jump serve and the float serve. Table 4.35a and 4.35b indicate the descriptive and inferential statistics relating to the statistically significant ANOVA results and Cohen's d analysis, showing significant differences by gender and the advancement level with regard to the abovementioned two serves.

Table 4.35a: Descriptive and inferential statistics for statistically and practical significant differences by gender between the top spin jump and float serves.

	Female		Male		ANOVA	Cohen's
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Blink. D	1.42	0.97	0.25	1.02	.001	1.17
AOI Ball (Toss). D%	1.40	6.13	5.20	8.11	.028	0.51
AOI Blink. D%	5.83	5.03	0.63	6.10	.006	0.91
AOI Blink. D/N	0.97	0.97	0.09	0.93	.037	0.93

Table 4.35b: Descriptive and inferential statistics for statistically and practical significant differences by advancement level for the top spin jump and float serves.

	Not Advanced		Advanced		ANOVA	Cohen's
Variable	**Mean**	**SD**	**Mean**	**SD**	**p**	**d**
AOI Ball (Toss). N	0.05	0.21	0.00	0.00	.034	0.29
AOI Upper Body. D	1.18	1.75	0.36	1.79	.005	0.47
AOI Ball (Toss). D%	2.57	7.43	5.88	7.66	.037	0.44
AOI Upper Body. D%	4.96	10.15	-0.40	11.27	.004	0.51
AOI Upper Body. D/N	0.37	1.25	-0.27	1.03	.004	0.55
AOI Contact Point. D/N	0.11	0.30	-0.12	0.35	.050	0.70
AOI Ball (Return). D/N	0.56	1.41	-0.66	1.02	.041	0.96

The results in Tables 4.35a and 4.35b show significant mean differences ($p<.05$, $d>0.2$) between the gender groups and advancement levels:

- Number of fixations (N variables) on the:
    - Ball (toss) - Not Advanced athletes had on average 0.05 more fixations on ball toss during the top spin jump serves than during the float serves; whilst there was no difference between these serves for the Advanced group. There was a small practical significant difference between the Not Advanced (0.05) and Advanced (0.00) groups.
- Duration (D variable) on the:
    - Blink - Female athletes spent on average 1.42 seconds longer on blinking during the top spin jump serves than during the float serves; whilst there was only a small difference (0.25) between the two serve types for the male group. There was a large practical significant difference between the female (1.42) and male (0.25) athletes in this respect.
    - Upper body- on average 1.18 seconds longer was spent fixated on the upper body region by Not Advanced players during the top spin serve than during the float serve; whilst there was no difference between these serve types for the Advanced group. There was a small significant difference between the Not advanced (1.18) and Advanced (0.36) athletes in this respect.
- Relative duration (D% variable) on the:
    - Ball (toss) - During the ball (toss) phase, males spend a greater percentage (5.20%) of time fixated on this AOI during the top spin jump serves than during the float serves; whilst there was no difference between the serve types for female athletes. There was a small practical significant difference between the male (5.20%) and female (1.40%) athletes in this respect.
    - Ball (toss) - Advanced athletes spent more than double the amount of time looking at the ball toss phase during the top spin jump serve than during the float serve. There was a small practical significant difference between the Advanced (5.88) and Not Advanced (2.57) athletes in this regard.
    - Blink - Female athletes spent a greater percentage (5.83) of time blinking during topspin jump serves than during float serves whilst there was a small practical difference (0.63) between these serve types for the male group. There

was a large practical significant difference between the female (5.83) and male (0.63) athletes in this regard.

- Upper body - Not Advanced athletes recorded a greater percentage (4,96%) of time spent looking at the upper body region during the top spin jump serve than during the float serve whilst there was a small (-0.40) practical difference between the two serves for the Advanced group. The difference between the Not Advanced (4.96) and Advanced (-0.40) athletes is of a moderate practical significance.

- Duration per fixation (D/N variable) on the:
  - Upper body - the results show that female athletes registered longer durations per fixation on the upper body region during top spin serves than during float serves, whilst there was a small practical difference recorded for the male counterparts between these two serves. The difference between the Not Advanced (0.37) and Advanced (-0.27) is of moderate practical significance.
  - Contact Point - During the contact point, Not Advanced athletes spent on average longer durations per fixation during the top spin jump serve than during the float serve, whilst there was the opposite finding for the Advanced athletes. There was a largely practical significant difference between the Not Advanced (0.11) and Advanced (-0.12) athletes.
  - Ball (return) – Not Advanced athletes had on average a longer duration per fixation during the top spin serves than during the float serve, whilst there was a reversed difference between these serves for the Advanced athletes. There was a largely practical significant difference between the Not Advanced (0.56) and Advanced (-0.66) athletes in this regard.

4.7 SUMMARY

Chapter 4 illustrated the results of the study. No significant differences were found for age, gender, or vision data between the groups Advanced and Not Advanced, and gender. In terms of advancement level, significant differences were found for volleyball experience including highest level of achievement, years of volleyball experience and number of years attending ToppVolley Norway. However, no significant differences were found for playing positions.

The eye tracking data revealed that Advanced athletes employed fewer fixations but longer durations per fixation for the float serve; and more fixations but shorter fixation durations for the topspin jump serve. Furthermore, the results revealed that female athletes employed fewer fixations for both float and top spin jump serves than the male athletes.

Thirteen (13) areas of interests were identified and the combined results for both gender and advancement levels for the float serve suggest that the athletes fixated primarily on upper body region and secondarily on the ball (flight), serve reception, arrival at target and contact point. Similarly, the upper body, lower body, ball (flight), serve reception, arrival at target and contact point were areas of interests frequently fixated on for the top spin jump serve. The blink was a common action of the eyes found while receiving both serves particularly for females.

The next chapter (Chapter 5), is the concluding chapter that provides a discussion of the findings of this study. Furthermore, the chapter describes the limitations of the study, draws conclusions and makes recommendations for further study.

CHAPTER 5

DISCUSSION, SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

In the sport of volleyball, an effective service reception is directly related to the athlete's capacity to identify and interpret relevant visual cues from the server and the ball. It is these visual cues that the athlete uses to predict where the ball will be served and where it will arrive. Indeed the essential key to passing to the setter is the ability to anticipate this action both efficiently and accurately. Part of this process of anticipation involves an athlete's visual search and gaze behaviour patterns, thus their eye movements and cognitive decisions are vital to performing this particular volleyball skill effectively.

In this chapter the eye tracking results gathered during the data collection phase of this research are examined. The results have been described thoroughly in Chapter four's list of findings and their visual representations. Now, the data is analysed and discussed in terms of addressing the aims and objectives of this study. To clarify the overall sample used the biographical factors (such as age, gender, advancement level as well as certain volleyball background and experience) of the respondents to commence this discussion.. As no eye movement studies conducted on young athletes (16-19 years) and concerning gender differences could be found, the literature reviewed is used wherever applicable to understand and substantiate the research findings. Ultimately summary of results, limitations of the study and conclusions drawn from the findings are presented before the chapter culminates in recommending possible future research.

5.2 BIOGRAPHICAL INFORMATION AND VOLLEYBALL BACKGROUND

To put the study into context the biographical information and volleyball background of the respondents, as elucidated from the questionnaire, is now discussed thoroughly.

5.2.1 Age, gender, skill level and vision data

The total sample of young volleyball players (mean ages of 17.75± 1.07 years) which made up the research sample consisted of 34 males and 16 females. The majority of the participants were 19 years old and made up 47% of the Advanced group. On the other hand only 23% of the Not Advanced group were in the 19 years category. On average the Advanced athletes (mean age of 18.16± 0.90 years) were over half a year older than Not Advanced athletes (mean age of 17.48± 1.09 years). Nevertheless according to Table 4.1 no stastisically significant ($p<.05$) difference in respect of age distribution between the Advanced and Not Advanced groups could be found. With regards to gender, the male athletes were older, with 41% in the age category of 19 years compared to 17% of their female counterparts. The mean ages of the male athletes was 17.91± 1.09 years which is slightly older than the mean age of 17.44± 0.98 for the females. The proportion of males to females in the Not Advanced category was unequal (71% male versus 29% female), while the gender distribution of the Advanced group was more even (53% male versus 47% female). Overall however, the results showed no significant ($p<.05$) differences between the Advanced and Not Advanced groups in respect of gender distribution. Age and gender can therefore be eliminated as factors that could have influenced the two groups' visual gaze behaviour.

Tests for visual acuity and eye dominance were conducted. The results show that the athletes' normal vision and eye dominance was evenly distributed. No significant differences were found between gender and groups, which is a desired result, as these two factors (visual acuity and eye dominance) could similarly be negated as having an influential effect on the visual search strategies and eye tracking gaze behaviour results.

5.2.2 Gender differences in the game

Zetou et al. (2006) and Palao et al. (2009) found that the game of volleyball presents diversified competitive demands according to age and gender, particularly concerning the efficacy of the game actions. The trend found was that females played more often in Complex II than in the side-out phase which is the opposite for the males. When these complexes were scrutinised between the genders, three significance discriminant variables namely, serve type, attack tempo and attack type (Palao et al., 2009) became evident. The differences explained in terms of serve type noted that men's volleyball relied on applying more powerful jump serves while women predominantly used the float serve. These researchers claimed that in men's volleyball, powerful serves were needed to diminish the likelihood of the opponent running quick attack plays and that females induced smaller risk with the float serve action, thus investing more effort in defense and counter-attack plays. With the aforementioned studies, the game features are substantially divergent according to gender with implications for tactical and technical preparations. In this study, experience in receiving float and top spin jump serves were not measured. Future studies should measure this variable. Nonetheless, from coaching experience at ToppVolley Norway, female players are more trained in receiving float serves and males more trained at receiving top spin jump serves.

The point with comparing gender is that we can compare the different experiences. Female players are experienced in receiving float serves, and therefore should be better at tracking these serves. Conversely, male players have more experience in receiving faster and more powerful serves. Therefore, they should be better at tracking top spin jump serves. It is thus notable that in this study, the female players were able to track both the float and top spin jump serves employing fewer fixation points than their male counterparts during serve reception. This is discussed in section 5.5 later in the chapter.

5.2.3 Volleyball experience and advancement level

5.2.3.1 No significance differences found

In comparing experience in volleyball and advancement level, Advanced players were found to have slightly more volleyball experience (mean 5.55±1.77 years) including participation at highest level (either U17, U19 or some senior national team) and specialisation in serve reception specific positions (libero or outside hitter). It should be noted that the number of years of experience account for both attendance at ToppVolley Norway and past volleyball exposure. However, no significant ($p<.05$) differences in the distribution in advancement level between experienced and less experienced players were found. In this regard, it can be generalised that experience has no effect on advancement level. Although this study shows results of the male athletes with between seven to ten years' experience, research shows that the age at which performers typically reach their highest level (elite status) in many sports is the mid-to-late 20s (Ericsson et al., 2006). Furthermore research has shown that even for the most talented individuals, ten years or 10 000 hours of experience is necessary to become an expert (Ericsson et al., 2006). In the present study, the Advanced athletes were really at an intermediate skill level, however they possess traits of expert performers.

There were no significant differences found between advancement level and playing positions (Table 4.6). The majority of participants in both groups were from the positions that usually receive serves (outside hitter and libero) and no significant ($p<.05$) difference between the two advancement groups in this respect were found. Therefore, playing positions have no bearing in this study. Though no relevant differences between positions were found, it should be noted that those athletes who play in specialised serve receive positions have advantage in experience of receiving the served ball.

Furthermore, no significant ($p<.05$) differences were found for gender and advancement level, gender and national team representation, and gender and number of years attending ToppVolley Norway. Firstly, with regards to gender and advancement level, a greater number of male players were Not Advanced (Table. 4.4). The ratio for females on the other hand was balanced. Secondly, male players were more experienced and had representation in all three national team categories (U17, 19 and senior) compared to their female counterparts which held representation in two categories (U17 and U19). Lastly, both female and males had attended ToppVolley Norway for a mean of 2.22± 0.73 (female) and 0.79 (male) years. These findings may indicate that there is an interaction between advancement level, national

team representation, number of years attending ToppVolley Norway and gender, nonetheless, gender was not found to have a statistical significant ($p<.05$) effect.

Overall these factors were found to have no effect on visual gaze behaviour for this present study.

5.2.3.2 Significant differences found

The statistics emanating from this study show that male athletes are more experienced than females, however this had no bearing on their playing ability and was thus not evident in the analysis between gender and advancement level. However, among the male cohort the differences were significant ($p<.05$). This was due in part to the fact that the sample size for the male cohort was larger, thus making it more likely that medium differences would reach statistical significance.

However, based on the results (Table 4.8) it can be deduced that more seniors and u/19 national team volleyball players were in the Advanced group than in the Not Advanced group. However, no analysis in order to find significant differences between the groups and national team category could be conducted due to the small numbers involved.

A statistical and medium practical significant ($p<.05$) difference was found for the number of years in attendance at ToppVolley Norway among the Advanced and Not Advanced groups. Both female and male participants in the study had attended over 2 years (mean 2.22±0.73 (female) and 0.79 (male) years), with the Advanced athletes having attended the longest (mean 2.58±0.51 years). The distribution of ToppVolley Norway attendance over year 1-3 was significantly ($p<.05$) different between the Not Advanced and Advanced groups with the Advanced group having larger representation of participants in year 2 and 3 at the specialised school.

Therefore, there is a relationship between skill level of groups and attendance, and also an affective factor, such as accumulated practice time. At ToppVolley Norway, the average practice time increases each school year and for each advancement level which involves deliberate practice (structured and quality training sessions by professional coaches). Another difference found was that the Advanced players practiced up to 21 or more hours per week,

while the Not Advanced players practiced less (between 11 to 20 hours per week, depending on which grade they attended). The program content for each level and grade differs. Focus on grade one is on the instruction of basic volleyball techniques and skills. In grade two is on position-specific specialisation and grade three focuses on refining skills and simulating game-like conditions.

With regards to this type of structured learning, it allows the opportunity for learning and developing optimal visual strategies and visual-motor performance. In several expert-novice paradigm studies, it has been demonstrated that experts have superior visual abilities, that they possess superior abilities in 'software' perspectives based on the greater amount of knowledge in the sport specific field (Ste-Marie, 1999, Gobba & Chi, 1986). In particular, elite players are superior in the recognition and recall of structured play situations (Ste-Marie, 1999).

Therefore, for this study one could expect that the Advanced group of participants in the present study should have superior visual skills.

5.3 SERVE SPEED DATA- FLOAT SERVE VERSUS JUMP SERVE

The mean speed was 58,72 km/h for the float serve (ranging between 47 and 88 km/hr) and 70.28 km/h for the top spin (ranging between 55 and 99 km/hr). Seventy percent of the float serves reached speeds ranging between 50 and 60 km/h. For the top spin jump serve, an even distribution of serve was detected, whereby 43% of the serves reached speeds between 70 to 80 km/h and 38% accounted for speeds between 60 and 70 km/hr. Of the two types of serves, the top spin jump serve is the faster and more aggressive serve, the speed differences were found to be largely significant ($t = 5.90$, d.f. = 39, $p = <.0005$, $d = 0.93$).

In a kinematic characteristic study of the two volleyball serves, Huang's (2011) results showed that the top jump serve had greater speed than the float serve. The topspin jump serve demands that the player have a run-up approach with the player throwing the ball into the air from the baseline and jumping into the court to spike the ball toward the opponents. The ball is hit with a heavy topspin, which makes it difficult to receive the ball. While in the case of the float serve the preparation motion is at ground level demanding a low toss; the athlete

strikes the ball sharply and retracts the arm immediately after contacting the ball. This is done to minimize the spin and float with erratic air currents before dropping sharply into the opposite court. Therefore, the jump serve's difference in velocity compared to the float serve is derived from the approach, takeoff, jump height and spike height/contact point. It is clear that the biomechanical movement and execution of the two serves are different and the top spin jump serve may be viewed as difficult and therefore requiring the use of differing visual strategies, processing and decision-making.

There are two types of difficulty, namely nominal (general) difficulty and functional 'individual' difficulty (Lohse & Hodges, n.d). Nominal difficulty alludes to the complexity of a skill relative to other skills (for example the jump serve vs. float serve) (Lohse & Hodges, n.d) and functional complexity refers to the complexity of a skill relative to the context (for example Advanced vs. Not Advanced or Expert vs. Novice) (Lohse & Hodges n.d). For the purpose of this study, for the same athlete, different skills would have different functional or individual difficulties, therefore successful performance becomes heavily dependent on the athlete's capability to select the appropriate response in a given situation. Therefore, the application of attentional focus in task complexities is crucial. Slow speed serves (easy tasks) present less challenges, while faster speeds present complex challenges. Wulf, Gartner, McConnel and Schwarz (2002) found that when tasks are more complex, more attentional focus is required. This is because task complexity for a wide variety of motor tasks has been proposed to increase reaction time, leading to increased movement time and finally response variability. Another significant finding by Wulf et al. (2002) is that focusing on the effects of one's movements would improve performance in visual-motor processing. In the context of this study, reading an opponent's kinematics improves receiving the ball and this would perhaps reflect in improved visual-motor processing. One weakness in this study was not having a synchronised camera set-up to film the receiver's behaviour. Subsequent studies should therefore include the use of such a device because the biomechanics of the athlete could offer valuable information in similar studies.

5.4 EYE TRACKING DATA

To put the study into context the three main eye tracking variables and results are now discussed thoroughly.

5.4.1 Fixation Number

In vision-in-action studies, the nature of the task and the athletes determine the field of view as the task is performed (Vickers, 2007). Therefore, the orientation of the head and gaze exists as a function of both the task and the skill level of the athlete (Vickers, 2007). There were significant skill-based differences found in the number of fixations applied by participants in the present study. The gaze search behaviour of the Advanced participants involved fewer fixations (9.70±1.14) than the Not Advanced (10.77±3.63) participants (Table 4.15) when viewing the float serve. The phenomenon of fewer fixations being associated with more advanced performers is a finding common to numerous expert-novice paradigm research literature, such as that of Bard and Fleury (1976), Helsen and Pauwels (1992; cited in Starkes & Allard, 1983), Ripoll et al. (1995), Vickers (1996), Singer et al. (1996), Moreno et al. (2002) and Savelsbergh et al. (2002). For the top spin jump serve the Advanced participants produced more fixations than the Not Advanced participants (12.11±2.4 versus 11.83±2.17) also in line with studies by Goulet et al. (1989), Williams et al. (1994), Williams and Davids (1998), Williams and Elliot (1999), Moran et al. (2002) and Afonso et al. (2012).

The current study's two findings seem contradictory with the differences in fixation number between the two serves. However, this may be explained as a result of differing task complexities requiring different gaze behaviour. One must also take into consideration that each type of serve viewed and received may have had differing speeds, ball trajectory, flight path, direction, height, and so forth thereby contributing to the differing cognitive and perceptual complexities, which in turn may impact upon the visual search strategies employed. Cognitive complexity in this regard refers to the amount of decision making required during the task; and perceptual complexity refers to the degree of speed and noise, to name a few within the display. In summary, complex tasks may benefit from different visual strategies, accounting for larger numbers of fixations to several locations (Afonso et al., 2012). It is apparent that the nature of the task strongly influences and underpins the decision-making process.

The Not Advanced participants during the float serve in this present study were found to have more fixations, however search strategies that involved fewer fixations were found to be more effective, contributing to faster reading/information gathering and processing (Afonso et al., 2012). It has also been found that, the greater the number of fixations, the more saccades the eyes produces, leading to decreased/declined visual sensitivity. This is because when the saccadic eye movements take place the eyes move more quickly and are therefore not able to foveate on specific areas (Ditchburn, 1973).

There are several other factors to consider regarding advanced or superior performances of expert athletes, the first to mention is reading abilities. For example, reading experiments have lead researchers to the discovery and realisation that single fixation points do not always consist of single words, but rather that a single fixation point may include several words. The reason is due to the use of peripheral vision, where the reader has the ability to see some of the words or letters on both sides of a fixation point. This expanded use of the periphery is called the 'vision span' and can be determined to be either narrow or wide. Therefore, fewer fixations combined with increased vision span and multiple fixation points all add up to faster reading speeds. In summary, this is a possible reason for fixation points not being measured or captured as the eye tracker cannot actually measure peripheral vision. Another possible factor to consider is familiarity, therefore familiar tasks or skills will require fewer fixations. In unfamiliar tasks or situations, the eyes have been found to tend to stop more often because the brain has not created the necessary associations. Another factor to consider is that if the situation is familiar, one would naturally have more confidence and unfamiliar situations would similarly lead to anxiety and a lack of confidence. That being said, confidence and anxiety levels were not measured in this study, but could form the part of future research.

For the top spin jump serve, it was found that the Advanced participants produced more fixations. Williams et al's (1994) finding is reinforced by this study, where it was found that that the more information present within a display and the more choices a performer has to make, the more fixations they would produce and that this may qualify also to be a reflection of the complexity of the display. Afonso et al. (2012) found in their study that the visual search strategies employed by the highly-skilled players involved more fixations to a greater number of locations (areas of interests). Highly-skilled participants spent more time fixating on functional spaces between two or more display areas, while skilled participants fixated on the ball trajectory and specific players.

When investigating gender differences, the present study revealed that when viewing both the float serve and the topspin jump serve, the male athletes' search strategies involved more fixations for shorter durations per fixation than the female participants. A possible factor to consider for the more fixations employed by males during the float serves, is that of merely having less experience in receiving this type of serve. The female athletes' use of fewer fixations of longer duration suggest more efficient search strategies were employed. The latter corroborates with the fact that they are more experienced in receiving float serves than male athletes. A possible reason why the female athletes employed fewer fixations during the top spin jump serve reception may have been due to receiving serves of slower speeds recorded than received by their male counterparts (the range 50-69.99 km/h versus 70-99.99 km/h). Serves with slower speeds are viewed as easy to read and allow for the application of fewer fixations. On the other hand, the male athletes, with more experience in receiving top spin jump serves, used the same visual strategies found for the Advanced group in this study. Although having their experience in receiving such serves, it is important to acknowledge that the increased number of fixations produced are due to the nature of the top spin serve as a task. Influential factors are higher serve speeds.

5.4.2 Fixation Duration

The results of this present study suggest that the Advanced participants produced on average longer durations per fixation (1.64± 0.20 sec) than the Not Advanced (1.60±0.34 sec) (Table 4.15) group during the float serve. This finding is what was expected in accordance with existing literature as similar results were obtained by a number of research studies including that of Helsen and Pauwels (1993), Ripoll et al. (1995), Vickers (1996), Moreno et al. (2002) and Savelsbergh et al. (2002). The longer fixation durations produced by the Advanced participants suggest that they were better able to track specific areas of interest for longer periods of time. This increased duration of the fixation point may allow the Advanced participants to produce a more coherent representation of the display.

For the top spin jump serve, however the converse was found, namely, that the Advanced participants had shorter durations per fixation. This is consistent with the Williams et al. (1994; 1998) findings in their two studies of soccer, suggesting that experienced players require less time to produce a coherent representation of display and pointing out that fixation

duration requirements are task specific, and furthermore, that increasing the complexity of the visual scene increases the number of eye movements required.

The results for the Not Advanced athletes confirm that differences in visual behaviour, taking into account their level of expertise, exist. The longer duration scores for the Not Advanced participants found in this present study possibly reflect an increased search time needed by the Not Advanced players to be able to assimilate the necessary information and perhaps impacting on the decison-making process. The longer fixation duration times reflect that the Not Advanced participants spend more time searching among the perceived areas of importance, and perhaps less time fixated on the informative areas of interest in the display that would enhance their analysis of the ball trajectory. In some cases this could lead to exhaustive search patterns. Abernerthy (1990) suggested that the limiting factor in the perceptual performance of novices is not an inappropriate search strategy, but rather an inability to make full use of the information available from the fixated display features. Abernerthy's (1990) view may explain the present study's findings.

Another possible factor to consider is that serve reception is a time-stressed skill, therefore the search strategy employed by the Not Advanced athletes could be due to anxiety. And observations under high anxiety conditions are characterised by an increase in search rate and the amount of time spent fixating on the specific areas of interests. These factors could similarly cause some degree of peripheral narrowing (Williams, 1999). Although in this study the level of anxiety was not specifically searched for, it may be relevant to highlight this possibility.

5.4.3 Areas of Interest

In this section the variable (area of interest) will be discussed in two sections highlighting both general and significant results found between the two serves.

5.4.3.1 General results and comparisons

There were 13 areas of interest identified in this study. The combined results for both gender and advancement levels for the float serve suggest that the athletes fixated primarily on upper body region and secondary on the ball (flight), serve reception, arrival at target and contact point. Similarly, the upper body, lower body, ball (flight), serve reception, arrival at target and contact point were areas of interests frequently fixated on for the top spin jump serve.

Vickers and Adolphe's (1997) volleyball study classified the serve reception as an interceptive timing skill that involves complex tracking and aiming skills. Interceptive timing skills have been found to have a common detection phase, a pursuit tracking phase and an aiming phase. The general comparison of eye movements for the two serves indicate that the reception players gathered their initial and relevant cues from the server's motion (lower body, approach and ball toss) and the upper body (including the hip, shoulder, head, hitting arm) up until contact point representing the detection phase. In a recent volleyball study on gaze behaviour patterns of volleyball players during serve reception, Lee (2010) found that the shoulder and arm region were areas that experts fixated on the most and for longer durations than novices. Novices were found to fixate more on the head and ball areas for longer time than experts.

The contact point, the point where the ball is struck by the hitting hand (hitting hand stops on contact with the ball and should finish facing the target), determines the force applied to the ball and furthermore determines the ball speed and direction. Ball speed detection and direction are therefore important factors for influencing performance and are both indicators for the predictability of the flight of the ball. Eye movement studies by Goulet et al. (1989) in the badminton smash and tennis serve provide evidence to the fact that fixating on the movements of the opponent's arm contributed to better prediction of the ball flight. However in baseball, subjects were more successful in predicting the flight path of the ball when they

fixated only on the ball at release. These findings indicate and conclude that reading the body kinematics of the server (the upper body) may be the most important cue and reflects the most important cue used in decision making.

With regards to the ball flight phase, the ability of a player to predict the path of the ball, both in terms of space (where) and time (when) is critical to success in volleyball. This prediction must also be accompanied by a movement of the player to the point of interception, and by his or her preparation to play the ball. It is therefore essential that players are taught the fundamental skills of judging ball flight. In volleyball, three types of trajectories can be defined. Trajectories characterised by low speed and height have an easily identifiable peak point and are easiest to judge, however those with high speed and a flat trajectory are considered moderately difficult to judge and finally those with high speed and a downward trajectory are considered very difficult (Volleyball England n.d). In the context of this study, during the ball flight phase, it is suspected that the more experienced athletes nearly always maintained fixation on the ball via smooth pursuit tracking eye movements, while the less experienced players' eye movements could have been using a combination of smooth and saccadic eye movement behaviours. After the ball flight phase, it was also revealed that athletes were capable of predicting the ball to serve reception and then furthermore track the ball to the arrival point of the serve.

It is evident that the athletes utilised similar areas of the display as important areas for decision making, but the ways in which the information is used may be the key difference between the Advanced and the Not Advanced athletes. To substantiate the aforementioned, it has been found that Advanced athletes may fixate their eyes on these areas of interest through a top-down visual process, as past experiences have guided their visual search strategies and gaze behaviours as these areas present the crucial kinematic information for determining intended direction (Chun & Jiang 1998; Vickers, 2007). Furthermore, skill-based differences in anticipatory speed and accuracy depend on the ability to select and properly utilise the visual cues from the server's posture and body orientation. It has been confirmed in previous studies that expert athletes anticipate faster and more accurately their opponent player's actions and have more efficient visual search patterns for acquiring proper visual cues than less skilled athletes (Abernerthy & Russell, 1987; Ripoll et al., 1995, Starkes et al., 1995, Farrow et al., 1996; Williams & Elliott, 1999; Savelsbergh et al., 2002).

5.4.3.2 Differences found between the two serves

Interestingly, the differences between the two serves in terms of fixation points is that the ball (toss) and anticipated contact points are AOI significantly ($p<.05$) looked upon more often during the top spin jump serve as opposed to the float serve. In terms of time fixation (fixating on AOI), the findings indicate that the ball (toss), upper body, anticipated contact point and blink are AOI's with the significantly ($p<.05$) longer fixation durations during the top spin jump serve as compared to the float serve. The ball (flight) was the only AOI looked upon significantly ($p<.05$) longer on average during the float serve by the Not Advanced athletes.

In summary, the differences found between the two serves on where and how much time is spent on an area of interest purely highlights the biomechanical differences. It is not surprising that the ball (flight) phase in the float serve is of paramount importance as it represents the detection phase.

5.5 SUMMARY OF RESULTS

The following summary draws together the final findings of the study:

- The findings suggest that Advanced athletes employed fewer fixations for longer durations per fixation for the float serve and more fixations but shorter fixations durations for the topspin jump serve. Although, the findings are different and contradictory, it is presumed that the Advanced athletes for both serves attended to the most appropriate visual information via the top-down approach, knowledge and past experiences.
- The findings suggest that the gaze behaviours and search patterns of Advanced and Not Advanced are different but bear common characteristics of fixating on the 13 identified areas of interest.
- However, the similarities in fixation location in terms of the areas of interest, suggest that the Not Advanced may not be able to make full sense of the information available from the fixated display features.
- The findings suggest that while the two serves received are significantly different the entire serve from reception to arrival at target path, the float serve requires fewer

fixations and the top spin jump serve requires more fixations. This is a result of the nature of the task's demands (type of serve served and degree of difficulty), leading to differing cognitive and perceptual complexities, which in turn may impact upon the visual search strategies employed.

- The upper body is the area of interest where all athletes spend most of their time fixating their attention and is therefore a region that tells the about the receivers server's body kinematics from approach to contact which influences the ball flight/trajectory and eventually serve reception.

5.6 LIMITATIONS OF THE STUDY

This study used the ASL mobile eye tracker as the main testing tool. However, to retrieve and gain additional information to help interpret the results, it would have been useful if a video camera was used and synchronised with the eye tracker during the serve reception. Within this context, seeing the reception player's body kinematics in relation to the server's movements, would provide additional insight into when and how they approach intercepting the served ball.

It is reported that a major limitation is that eye tracking can be misleading because it does not capture peripheral vision. The eye tracker records and displays foveal fixations, which reflects the small part of the visual field that makes for the sharpest and finest vision. By not recording peripheral vision, eye tracking misses around 98% of our visual field. This results in a significant loss of the visual field, as peripheral vision is used to choose where one's vision fixates next. However the task investigated, namely the serve reception, consists of object movement mainly in the sagittal plane and in line with the foveal vision.

Furthermore, the ASL recommends using five to ten points during calibration. In the present study, in some cases only the absolute minimum number of calibration points (5) could be used which may have affected the accuracy. However, the minimum recommended points were at least adhered to. It is reported that more calibration points could make the point of gaze calculation more robust and give leeway in the case that some points are not useable due to loss of pupil or corneal reflection, or there was not enough time spent looking at the object.

Since this study was undertaken in a live volleyball court setting, the head-mounted device would slip over the course of a task, therefore requiring recalibration to avoid data loss. In the first round of testing in January 2011, this equipment's instability resulted in the valuable loss of data of 40 athletes. However, more volleyball players at the relevant school were tested seven months later to ensure that at least 50 participants were tested for the purpose of this study.

5.7 CONCLUSIONS

This research aimed to identify the gaze behaviour of Advanced and Not Advanced volleyball athletes during the serve reception and to add to the literature regarding the role of gaze behaviour and eye movement in visual perception studies. The results found suggest the following:

1. Advanced participants produced on average fewer fixations and for longer durations per fixation than the Not Advanced participants when viewing the float serve.
2. Advanced participants produced on average more fixations and for shorter durations per fixation than the Not Advanced participants when viewing the top spin jump serve.
3. Male participants produced on average more fixations and for shorter durations per fixation than the female participants when viewing both the float serve and the topspin jump serve.
4. The combined results for both gender and advancement levels for the float serve suggest that the athletes fixated primarily on upper body region and secondarily on the ball (flight), serve reception, arrival at target and contact point. Similarly, the upper body, lower body, ball (flight), serve reception, arrival at target and contact point were areas of interests frequently fixated on for the top spin jump serve. The blink is found to be a common action of the eyes produced while receiving the serve and is of importance.

5.8 RECOMMENDATIONS

The following recommendations are made for future studies:

- The ASL eye tracking system should be used in synchronisation with an external camera in order to capture the kinematic movements of athletes while receiving the serve.
- Develop an eye tracking system that can accommodate both foveal and ambient vision systems.
- Revise the testing protocol. Conduct more trials (10 float serves and 10 top spin jump serves) for comparisons per athlete in order to determine their visual-search strategies and gaze behaviours.
- Revise the testing protocol by collecting data from both successful and unsuccessful serve receptions utilising both serves.

The importance of service reception in volleyball is well established. Statistical data has consistently confirmed the close correlation of serve reception and winning. From the findings of this study, it is evident that the most basic elements of success in serve receive is the ability to read the server's body kinematics, cues and predict the flight of the ball and intercept the ball. The outcome of effective visual pattern recognition is the capability to prepare a response in advanced based on the information picked or provided. Thus, developing young players with the reading and visual skills to accurately predict the flight of the ball during the serve receive phase of the game should be a high coaching priority. In sum, the result of being an expert decision maker is to create the apprearance of having all the time in the world with which to prepare and execute a response.

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LIST OF APPENDICES

Appendix A: Letter to the participant

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Faculty of Health Sciences
Department of human Movement Science
Tel: +27 (0)41 504-4544 Fax: +27 (0)41-504-2770
E-mail: Bonolo.Ramphomane@nmmu.ac.za

May 2011

Dear Participant

You are being asked to participate in a research study. We will provide you with the necessary information to assist you to understand the study and explain what would be expected of you (participant). These guidelines would include the risks, benefits, and your rights as a study subject. Please feel free to ask the researcher to clarify anything that is not clear to you.

To participate, it will be required of you to provide a written consent that will include your signature, date and initials to verify that you understand and agree to the conditions.

You have the right to query concerns regarding the study at any time. Immediately report any new problems during the study, to the researcher. Telephone numbers of the researcher are provided. Please feel free to call these numbers.

Furthermore, it is important that you are aware of the fact that the study has to be approved by the Research Ethics Committee (Human) of the university. The RECH consist of a group of independent experts that has the responsibility to ensure that the rights and welfare of participants, in research are protected and that studies are conducted in an ethical manner. Studies cannot be conducted without RECH's approval. Queries with regard to your rights as a research subject can be directed to the Research Ethics Committee (Human) you can call the Director: Research Management at (041) 504-4536.

If no one could assist you, you may write to: The Chairperson of the Research, Technology and Innovation Committee, PO Box 77000, Nelson Mandela Metropolitan University, Port Elizabeth, 6031.

Participation in research is completely voluntary. You are not obliged to take part in any research. If you choose not to participate your choice will be respected.

If you do partake, you have the right to withdraw at any given time, during the study without penalty or loss of benefits. However, if you do withdraw from the study, you should return for a final discussion or examination in order to terminate the research in an orderly manner. Should you fail to follow instructions or for administrative reasons, your participation may be discontinued.

Although your identity will, at all times remain confidential the results of the research study may be presented at scientific conferences or in specialist publications.

This informed consent statement has been prepared in accordance with current statutory guidelines.

Yours sincerely

---	---
Bonolo Ramphomane	Prof. R. Du Randt
Researcher	Supervisor
Tel: (041) 504-4544	Tel: (041) 504-2499

Appendix B: Letter to ToppVolley Norway

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Faculty of Health Sciences
Department of human Movement Science
Tel: +27 (0)41 504-4544 Fax: +27 (0)41-504-2770
E-mail: Bonolo.Ramphomane@nmmu.ac.za

November 2010

ToppVolley Norway
Sports Manager/Principal
Mr. Øyvind Marvik

Dear Sir

My name is Bonolo Ramphomane, and I am a Sport Science Masters student at the Nelson Mandela Metropolitan University (NMMU). I am conducting research on the gaze behaviour of volleyball players in successful serve reception under the supervision of Professor Rosa Du Randt (NMMU, South Africa) and Professor Darlene Kluka (Kennesaw State University, USA).

In order to achieve the aim of the research, I would like to invite the senior men's team to participate in the study. Before approaching the relevant players individually, I would require your permission to conduct the research.

Aim of the Research:
To identify the gaze behaviour of ToppVolley Norway (scholars) volleyball athletes during the serve reception.

Significance of Research Project:

The research will be significant in the following ways:

1. It will provide information about the gaze behaviour patterns of female and male volleyball athletes as they receive the float and top spin jump serve and perform an accurate forearm or overhead pass to the setter zone.
2. It will provide information about whether Advanced and Not Advanced volleyball receivers differ in their gaze behaviour, control and accuracy while receiving a topspin jump serve and perform an accurate forearm or overhead pass.
3. It will provide information to assist volleyball coaches to improve serve reception of players at various levels of participation.

Benefits of the Research:

1. Dissemination of results to ToppVolley Norway and relevant Journals.

Research Plan and Method:

Data will be collected using the ASL mobile eye tracking device. Permission will be sought from the players and their parents prior to participation in the research. Only those who consent and whose parents consent will participate. The testing will be administered by a research team from NMMU and will approximately take 4-5 days to complete. All information collected will be treated in strictest confidence
and no player will be identifiable in any reports that are written. Participants may withdraw from the study at any time without penalty.

ToppVolley Norway involvement:
Once I have received your consent to approach the players to participate in the study

- I will arrange for informed consent to be obtained from participants and participants' parents for those under 21 years of age.
- I will arrange a date and time for testing and data collection to take place.

Further information:
Attached for your information are copies of the parent information and consent form and also the participant information statement and consent form.

Thank you for taking the time to read this information

Yours sincerely

---	---
Bonolo Ramphomane	Prof. R. Du Randt
Researcher	Supervisor

Appendix C: Consent form to ToppVolley Norway

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Nelson Mandela Metropolitan University
for tomorrow

Consent Form

I give consent for you to approach the ToppVolley Norway players to participate in the research project.

I have read the project information statement explaining the purpose of the project and understand that:

- The role of the school is voluntary
- I may decide to withdraw the school's participation at any time without penalty
- Players will be invited to participate and that permission will be sought from them and also their parents
- Only players who consent and whose parents consent will participate in the project
- All information obtained will be treated in strictest confidence
- The names will not be used and individual players will not be identifiable in any written reports about the study
- Players/participants may withdraw from the study at any time without penalty
- A report of the findings will be made available to the federation
- I may seek further information on the project from Bonolo Ramphomane on (0027) (41) 504-4544.

_____ _____
Principal Signature

_____
Date

Please return to: Bonolo Ramphomane
Skulevegen 22
4230
Sand
Norway

Appendix D: Letter to parents

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Nelson Mandela Metropolitan University

for tomorrow

Dear Sir/Madam

My name is Bonolo Ramphomane, and I am a Sport Science Masters student at the Nelson Mandela Metropolitan University (NMMU). I am conducting research on the gaze behaviour of volleyball players in successful serve reception under the supervision of Professor Rosa Du Randt (NMMU, South Africa) and Professor Darlene Kluka (Kennesaw State University, USA). The NMMU has given its approval for the conduct of the study. ToppVolley Norway has given approval the players from the school can participate in my research.

I am seeking your consent for your child to participate. I will also seek the consent of your child. Only children who consent and whose parents/guardians consent will participate in the study. I ask that you discuss participation in this study with your child.

The study will be used to provide information about:

1. The gaze behaviour patterns of female and male volleyball athletes as they receive the float and top spin jump serve and perform an accurate forearm or overhead pass to the setter zone.
2. Whether Advanced and Not Advanced volleyball receivers differ in their gaze behaviour, control and accuracy while receiving a topspin jump and float serve and perform an accurate forearm or overarm pass.
3. How to assist volleyball coaches to improve serve reception of players at various levels of participation.

The testing will be administered by a research team from NMMU and will approximately take 4-5 days to complete. All information collected will be treated in strictest confidence and no player will be identifiable in any reports that are written. Participants may withdraw from the study at any time without penalty.

Please discuss participation in this project with your child. To give consent for your child to participate, please complete the attached form and return it to your child's coach.

Thank you for taking the time to read this information.

Yours sincerely

Bonolo Ramphomane
Researcher
Tel: (0027) (41) 504-4544

Prof. R. Du Randt
Supervisor
Tel: (0027 (41) 504-2499

Appendix E: Information and informed consent to players

Nelson Mandela Metropolitan University

for tomorrow

NELSON MANDELA METROPOLITAN UNIVERSITY

INFORMATION AND INFORMED CONSENT FORM

(Please delete any information not applicable to your project and complete/expand as deemed appropriate)

Title of the research project	Gaze behaviours of volleyball players in successful serve reception
Reference number	
Principal investigator	Bonolo Ramphomane
Address **Postal Code**	Nelson Mandela Metropolitan University Department of Human Movement Science Summerstrand 6001
Contact telephone number (private numbers not advisable)	(041) 504-4544 (W)

A. DECLARATION BY OR ON BEHALF OF PARTICIPANT (Person legally competent to give consent on behalf of the participant)	***Initial***
I, the participant and the undersigned……(name) I.D. number …… in my capacity as participant of…… ……(address)	
A.1 I HEREBY CONFIRM AS FOLLOWS:	
1. I, the participant, was invited to participate in the above-mentioned research project that is being undertaken by **Bonolo Ramphomane** of the Department of Human Movement Science in the Faculty of Health Sciences of the Nelson Mandela Metropolitan University.	
2. **The following aspects have been explained to me, the participant:** 2.1 **Aim:** To identify gaze behaviour of Advanced and Not Advanced volleyball athletes during the serve reception. 2.2 **Objectives:** 2.2.1 To identify gaze behaviour patterns of female and male volleyball athletes as they receive the float and top spin jump serve and perform an accurate forearm or overhead pass to the setter zone. 2.2.2 To determine whether Advanced and Not Advanced volleyball receivers differ in their gaze behaviour, control and accuracy while receiving a topspin jump serve or a float serve and perform an accurate forearm pass. The information will be used to assist volleyball coaches to improve serve reception of the players at various levels of participation.	

2.2 **Procedures: See attached protocol**	
2.3 **Risks:** There are no risks involved, as the project does not require invasive procedures	
2.4 **Possible benefits:** 1. Results of the research will be presented to Volleyball South Africa (VSA) and ToppVolley Norway (TVN). 2. There is however no remuneration for participating in the study.	
2.5 **Confidentiality:** My identity will not be revealed in any discussion, description or scientific publications by the investigators.	
2.6 **Access to findings:** Any new information/or benefit that develops during the course of the study will be shared with VSA and TVN.	
2.7 **Voluntary participation/refusal/discontinuation:** My participation is voluntary ☐ YES ☐ NO My decision whether or not to participate will in no way affect my present or future volleyball careers. ☐ TRUE ☐ FALSE	
3. The information above was explained to me/the participant by Bonolo Ramphomane in English and I am in command of this language. I was given the opportunity to ask questions and all these questions were answered satisfactorily.	
4. No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation.	
5. Participation in this study will not result in any additional cost to me.	

A.2 I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT

Signed/confirmed at……..on……2006

Signature or right thumb print of participant	Signature of witness Full name of witness

B. STATEMENT BY OR ON BEHALF OF INVESTIGATOR(S)

I, **Bonolo Ramphomane** declare that

- I have explained the information given in this document to……..

  (name of participant)

- he/she was encouraged and given ample time to ask me any questions;
- this conversation was conducted in English and no translator was used

Signed/confirmed at ……on……..2006

Signature of interviewer	Signature of witness
	Full name of witness

C. IMPORTANT MESSAGE TO PATIENT/REPRESENTATIVE OF PARTICIPANT

Dear participant/representative of the participant

Thank you for your/the participant's participation in this study. Should you require any further information with regard to the study, kindly contact **Bonolo Ramphomane** at telephone number(0027) (41) 504-4544 (w)

Appendix F: Ethics approval request

Nelson Mandela Metropolitan University
for tomorrow

NELSON MANDELA METROPOLITAN UNIVERSITY

APPLICATION FOR APPROVAL FROM NMMU RESEARCH ETHICS COMMITTEE (HUMAN)

(ETHICAL STANDARDS: RESEARCH PROTOCOL)

1. Any project, in which humans are the subjects of research, requires completion of this form and submission for approval to the ETHICS COMMITTEE.
2. The faculty through the Faculty Research Committee **and** Head of Department should approve research proposals before submission to the Ethics Committee.
3. Each faculty should have the primary responsibility for ensuring that human subjects used in social research in their faculties are protected adequately by the application of the appropriate code applicable to the relevant profession.
4. The application form, after **being** completed in **typescript**, to be handed in at the Department of Research Management.

FOR OFFICE USE ONLY		**REF NO:**	
DEPARTMENT		***DATE RECEIVED***	
DATE SUBMITTED TO THE RESEARCH ETHICS COMMITTEE (HUMAN)		**DATE APPROVED BY THE RESEARCH ETHICS COMMITTEE (HUMAN)**	
AUTHORIZED Chairperson of the Research Ethics Committee (Human)			

1.	**GENERAL PARTICULARS**
a)	**Name of principal investigator/researcher**: Bonolo Ramphomane
b)	Gender of principal investigator/researcher: Female
c)	**Contact number of principal investigator/researcher**: (041) 504 4544
d)	**Type of research**: Exploratory, descriptive and comparative in nature

STAFF						STUDENT					
Multinational [MN]		National [N]		Local Research [LR]		Multinational [MN]		National [N]		Local Resea rch [LR]	
Undergraduate [U]		Honours [H]		Master's [M]		Undergraduate [U]		Honours [H[		Maste r's [M]	√
Doctoral [D]		Other [O]				Doctoral [D]		Other [O]			

e) **If medical research**:

Therapeutic Research [TR]		Non-therapeutic Research [NTR]	√

f) **Funding**

External Grant [E]		NMMU Research Grant [RG]	√
Privately Funded [P]		Not specifically funded [N]	√

If external funding, state source of funds:

- Vodacom

Are there any restrictions or conditions attached to publication and/or presentation of the study results?

- No

Does the contract specifically recognise the independence of the researchers involved?

- Yes

g) **Summary of research**

(i) What is the purpose of the research?

The primary aim of this research is to identify gaze behaviour of elite volleyball athletes during the serve reception. Gaze behaviour will be assessed as the athletes receives a top spin jump and a float serve by using a forearm pass to the setter zone while wearing a head-mounted eye tracker.

(iii) Briefly state the methodology and the procedure in which subjects will be asked to participate (attach protocol)

The proposed research method will be primarily exploratory-descriptive and comparative in nature. The study population will comprise of 30 subjects who are squad members of the South African (SA) national men's team. The team members will be divided into two groups, and classified as expert (E) receivers (n=15) and as near-expert (NE) receivers (n=15) based on serve reception statistics. Testing will be conducted over a period of four (4) to five (5) days. Approximately ten (10) athletes will be tested per day. Each participant will be fitted with an eye tracker helmet which will be calibrated accordingly.

The task will be to detect the ball as it is delivered by the server, track it over a distance, receive the ball on his forearms and make an accurate pass to a target area. Only 20 trials/ consecutive serves (balls) will be delivered to each participant. Each participant will receive 3-5 practice trials. The number of trials will depend on the participant's readiness. No more than 5 practice trials will be given.

The eye tracker system iView X will be used to conduct the data collection. This system integrates input from the HED with an external video to specifically collect the coupled gaze and behaviours of the receivers. The HED is a head-mounted, monocular eye-tracking system that uses corneal reflection to measure eye-line-of-gaze with respect to the field of view.

h) **Name of the investigator/researcher (whether student or staff member) mostly involved in this project**:

Bonolo Ramphomane-Aandahl

i) **Name(s) of co-investigator/assistant researchers**: Bonolo Ramphomane-Aandahl	
j) **Name(s) of supervisor/co-supervisor or promoter/co-promoter**: Prof. Rosa du Randt Prof. Darlene Kluka Mr. Danie Venter	Nelson Mandela Metropolitan University

2. INFORMATION TO PARTICIPANT	
a)	What information will be offered to the participant before he/she consents to participate? (Append both the written and any oral information given) ➢ See attached consent form
b)	Who will provide this information? **Bonolo Ramphomane**
c)	Will the information provided be complete and accurate? [√] **YES** [ ] **NO** If NO, describe the nature and extent of the deception involved and explain the rationale for the necessity of this deception. (If necessary, attach separate schedule)

3. TARGET PARTICIPANT GROUP			
		Answer YES or NO	**If necessary, explain in space provided or attach appendix**
a)	Are particular characteristics of any kind required in the target group? (e.g. age, cultural derivation, background, physical characteristics, disease status etc.)	YES	Specify the characteristics: The athletes must be national players.
b)	Are participants drawn from NMMU students?	NO	
c)	Are participants drawn from specific groups of NMMU students?	NO	Identify the group:
d)	Are participants drawn from a school population?	NO	Identify: (State whether pre-primary, primary, secondary, etc.)
e)	Are participants drawn from an institutional population? (e.g. hospital, prison, mental institution)	NO	
f)	Will any records be consulted for information?	NO	Specify source of records:
g)	Will each individual participant know his/her records are being consulted?	N/A	State how these records will be obtained:
h)	Are all participants over 18 years of age?	NO	

State the minimum and maximum number of participants involved (Minimum number should reflect the number of participants necessary to make the study statistically viable)	**Minimum**	**24**	**Maximum**	**50**

4. RISKS AND BENEFITS OF PROJECT			
		Answer YES or NO	**If necessary, explain in space provided or attach appendix**
a)	Is there any risk of harm, embarrassment or offence, however slight or temporary, to third parties or to the community at large?	NO	If YES, specify:

b)	Are all risks reversible?	N/A	If NO, specify:
c)	Are remedial measures available?	N/A	
d)	Are alternative procedures available?	NO	
e)	Has the person administering the project previous experience with the particular risk factors involved?	N/A	
f)	Are any benefits expected to accrue to the participant personally? (e.g. improved health, mental state, financial etc.)	YES	If YES, specify: PERFORMANCE IMPROVEMENT
g)	Will you be using equipment of any sort?	YES	If YES, specify: EYE TRACKER AND VIDEO CAMERA
h)	Will any article of property, personal or cultural be collected in the course of the project?	NO	If YES, specify:

5.	**CONSENT OF PARTICIPANTS**		
		Answer YES or NO	**If necessary, explain in space provided or attach appendix**
a)	Is consent to be given in writing?	YES	If YES, attach consent form. If NO, state reasons why written consent is not appropriate in this study:
b)	Are any participant(s) subject to legal restrictions preventing them from giving effective informed consent?	YES	If YES, justify: PARENTS OF PARTICIPANTS UNDER 18 WILL ALSO HAVE TO GIVE CONSENT FOR THEIR SON TO PARTICIPATE IN THE STUDY
c)	Do any participant(s) operate in an institutional environment, which may cast doubt on the voluntary aspect of consent?	NO	If YES, state what special precautions will be taken to obtain a legally effective informed consent:
d)	Will participants receive remuneration for their participation?	NO	If YES, state on what basis the remuneration is calculated:
e)	Do you require consent of an institutional authority for this project?	YES	If YES, specify: TOPPVOLLEY NORWAY

6.	**PRIVACY, ANONYMITY AND CONFIDENTIALITY OF DATA**		
		Answer YES or NO	**If necessary, explain in space provided or attach appendix**
a)	Will the participant be identified by name in your research?	NO	
	b) Are provisions made to protect subject's rights to privacy and anonymity and to preserve confidentiality with respect to data?	YES	Specify: NAMES WILL BE CODED
c)	Will mechanical methods of observation be used? (e.g. one-way mirrors, recordings, videos etc.)	YES	VIDEO
d)	Will participant's consent to such mechanical methods of observation be obtained?	YES	
e)	Will data collected be stored in any way?	YES	If YES: (i) By whom? BONOLO RAMPHOMANE (ii) How many copies? 2

			(iii) For how long? DURATION OF RESEARCH (iv) For what reasons? ANALYSIS (v) How will participant's anonymity be protected? CODE NAMES
f)	Will stored data be made available for re-use?	NO	If YES, how will participant's consent be obtained for such re-usage?

g)	Will any part of the project be conducted on private property (including shopping centers)?	NO	If YES,
h)	Are there any contractual secrecy or confidentiality constraints on this data?	NO	If YES, specify:

7.	**FEEDBACK**		
		Answer YES or NO	**If necessary, explain in space provided or attach appendix**
a)	Will feedback be given to participants?	YES	FEEDBACK WILL BE GIVEN TO ALL THE PARTICIPANTS IN A GROUP SETTING AFTER ENTIRE PROJECT
b)	If you are working in a school or other institutional setting, will you be providing teachers, school authorities or equivalent a copy of your results?	YES	If YES, specify: VOLLEYBALL SOUTH AFRICA

8. STATEMENT ON CONFLICT OF INTEREST

The researcher is expected to declare to the Committee the presence of any potential or existing conflict of interest that may potentially pose a threat to the scientific integrity and ethical conduct of any research. The Committee will decide whether such conflicts are sufficient as to warrant consideration of their impact on the ethical conduct of the study.

Disclosure of conflict of interest does not imply that a study will be deemed unethical, as the mere existence of a conflict of interest does not mean that a study cannot be conducted ethically. However, failure to declare to the Committee a conflict of interest known to the researcher at the outset of the study will be deemed to be unethical conduct.

Researchers are therefore expected to sign either of the two declarations below.

a) As the principal researcher in this study…**BONOLO RAMPHOMANE**……(name)
I hereby declare that I am not aware of any potential conflict of interest that may influence my ethical conduct of this study.

Signature:…….…….…….
Date:……..……..

b) As the principal researcher in this study……(name)
I hereby declare that I am aware of the following potential conflicts of interest which should be considered by the Committee:

Signature:……..…….…….
Date:……..……

9.	ETHICAL AND LEGAL ASPECTS
The Declaration of Helsinki version 2000 to be included in the references.	

10.	DECLARATION
If any changes are made to the above arrangements or procedures, I will bring these to the attention of the Chairperson of the Research Ethics Committee (Human).	
SIGNATURE OF PRINCIPAL INVESTIGATOR/RESEARCHER	**DATE**
SIGNATURE OF SUPERVISOR	**DATE**
SIGNATURE OF HEAD OF DEPARTMENT	**DATE**
Noted application **SIGNATURE OF CHAIRPERSON: FACULTY RESEARCH COMMITTEE**	**DATE**

Appendix G: Self-report questionnaire

Nelson Mandela Metropolitan University

for tomorrow

PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Faculty of Health Sciences
Department of Human Movement Science

Kindly note that the information that you have provided will be used for research statistics only. Your name will be kept confidential.

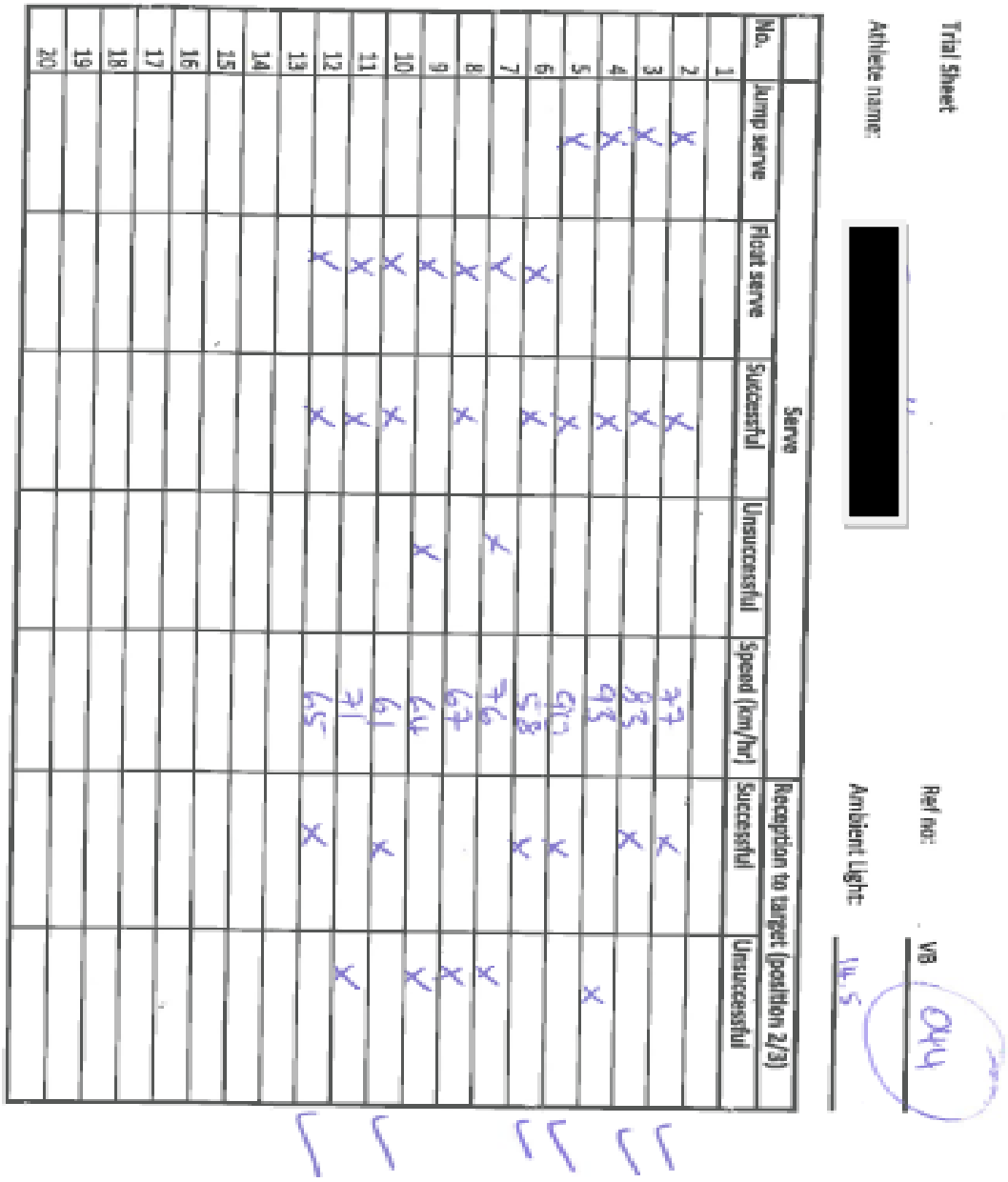
Today's date	07.06.2010				
Personal Information					
Name	[redacted]				
Surname					
Date of Birth	Date	Month	Year		
	05	February	1993		
Age	17 yrs				
Gender	Female				
Grade/Class	1				
Anthropometric Data					
Standing Height	1 m	72 cm			
Standing Reach	2 m	28 cm			
Spike Jump	2 m	86 cm			
Block Jump	m	cm			
Sport History					
What positions do you play?	(OH)	MB	Utility	Libero	Setter
What is the highest level you have achieved?	Club	Provincial	(National)		
How many year's have you been playing volleyball?	6 years				
How many year's have you attended TVN?	9 Months	yrs			
How many hours per week do you practice volleyball? (non-TVN players)	0 to 5	6 to 10	11 to 15	16 to 20	21 + more
Eye History					

Do you have any visual impairements?	Yes	No	20/20
If so, what?			
What is your dominant eye?	Left	Right	
Do you wear contact lenses or glasses?	Yes	No	
If so, are you near or far sighted?	Near	Far	

Thank you for your co-operation!

Appendix H: Snellen Chart for 20/20 (visual acuity) testing

Appendix I: Trial recording sheet for serve reception



Trial Sheet

Athlete name: [redacted]

Ref no: VB 044

Ambient Light: 14.5

Serve							
No.	Jump serve	Float serve	Successful	Unsuccessful	Speed (km/hr)	Reception to target (position 2/3)	
						Successful	Unsuccessful
1							
2	X		X		77	X	
3	X		X		83		
4	X		X		93	X	
5	X		X		90		X
6		X	X		90	X	
7		X	X	X	58	X	
8		X	X		76		X
9		X	X		67		X
10		X	X	X	64		X
11		X	X		61	X	
12		X	X		71		X
13		X	X		65	X	
14							
15							
16							
17							
18							
19							
20							