Chapter I

INTRODUCTION

As the face is the image of the soul so the eyes are its revealers.

(Cicero [106–43 BC], The Orator)

Sports of modern times have become a fierce competition and there are dramatic advances in the use of technology not only in everyday life but also in sport for performance enhancement. Athletes and coaches are using various advance technical gadgets like biofeedback, virtual reality, neurofeedback trainer, neurotracker, reaction time trainer, wearable technology and numerous software’s for enhancing the performance. By using technology there might be a very small performance gains but that makes a difference between winning and losing thus changing the life of an athlete.

There are a whole lot of researchers like Peter Fadde and Leonard Zaichkowsky explore available technologies to measure and improve athletes’ perceptual-cognitive skills, including visual occlusion, virtual reality, and 3D multiple object tracking. Further Aidan Moran, Mark Campbell, and Danilla Ranieri conclude with potential uses, considerations, and evidence for how eye tracking technology can be used to enhance cognitive training in applied sport psychology.

Eye tracking as a tool in sports research helps to optimize athletic performance by detecting flaws linked to attentional focus, trajectory estimations, visual search strategies and eye-hand-foot coordination. Even misalignment of the eyes is not detectable by an individual while looking in the mirror. This condition may affect as many as two out of three athletes. Research indicates that if this condition is not detected and then corrected, it can cause extreme problems throughout life and with sports performance and sports injuries. Scientific studies indicate that an athlete’s ability to read the movements of a ball is important to the outcome of a play.

Eye tracking has been an important source of information about perception and cognition for more than 50 years as reviewed by McCarley and Kramer (2007). It has been utilized to study a diverse number of topics such as the patterns of fixations and saccades while reading text (Rayner, 1998), the workload of pilots during
different phases of flight (Di Nocera, Camilli, & Terenzi, 2007), and the effectiveness of visual advertisements (Wedel & Pieters, 2008), among many, many others. However, research including eye tracking in sport has not been as commonplace as it could be.

**Sport Psychology**

In the current era while an athlete wins or achieves his best of performance it is not only due to perfection of his skills or best of physiological status but his psychological status too. Thus in this world of perfection to create, understand and bring about the best of performances from a sport person a unique field of psychology is pushed forth called the Sport Psychology. In 1996 the European Federation of Sport Psychology (FEPSAC) defines the term sport psychology as the study of psychological basis, processes and effects of sport. Jarvis (2005) further explains/ed that in broad sense, including any physical activity for the purpose of competition, recreation, education or health. Gill and Williams (2008), defines sport and exercise psychology as the scientific study of people and their behavior in sports and exercise contexts and the practical application of that knowledge. Specializing in the subject provides mainly three careers prospective, that is as a researcher, because of the wide range of knowledge it has yet to be discovered and understood. The teacher; to the athletes and coaches to teach the importance and its application and as the consultant; for solving problems that may or is hampering the athlete to bring out his best as an individual or as a team.

To gain in depth insight for the enrichment of human life through sports and exercise and enhancement of the performance the subject sport psychology came into being. It follows the principle of psychology in a sport or exercise setting (Cox, 2007). Sport and exercise as described by Gills and Williams (2008), is the scientific study of people and their behaviors in sport and exercise context and their practical application of that knowledge. While Sport psychology is the study of psychological basis, processes and effects of sport (Jarvis, 2005).

The sport psychology can be traced back in time since the ancient Olympic Games (Kermer and Moran, 2008). At the end of the nineteenth in century 1898, Norman Triplett the North American psychologist performed a study on the phenomenon of social facilitation, he was himself a bicycle racing enthusiast and had
a keen interest to understand the reason of why a cyclist rode faster in presence of the other cyclist? He first tried to understand this phenomenon by conducting an experiment with young children making them reel in fishing line as fast as possible; here he found that children reeled more in line in the presence of other children. Thus carrying forth his search he explained the social facilitation. Coelman Griffith also contributed a lot to the growth of the Sport Psychology with his research works thus was called the father of American Sport Psychology, in short span of a decade from 1921 to 2931 he published as many as 23 articles about the subject (Weinberg and Daniel, 2015). So on as the year went by the researchers kept making immense contribution, some of the important names to be remembered are Franklin Henry, Dorthy Yates, Warren Johnson, Bruce Ogivie, Dorthy Harris and few more.

Weinberg and Daniel in their book called Foundation of Sport and Exercise Psychology (2015, 6th edition) mentions three major orientations; first, the Psychophysiological Orientation which talks about how understanding and studying the human physiology to understand the psychological changes one undergoes during a physical activity. These psychologists typically use brain wave activity, heart rate, muscle action potential determining the positive relation between those psychological measure and sport and exercise behavior.

The second is the Social-Psychological Orientation; they assume that the behavior of the athlete is determined by a complex interaction of the environment and his individual coping ability. Examining how a leader’s style and strategies foster group cohesion and influence participation in an exercise program is an example of task of a Social Psychologist (Caron and Spink, 1993).

The last one is the Cognitive- Behavioral Orientation. It is believed that thought is central in determining behavior. It is concerned with the internal processes involved in making sense of the environment, and deciding what action might be appropriate. We can define cognitive psychology as involving the attempt to understand human cognition by observing the behavior of people performing various cognitive tasks (Eysenck and Keane, 2010). How the sense organ gathers information passes on to the brain for interpretation and sent back as a respond was understood as the cognitive processing.
Understanding the reasons behind how and why human behaves the way they do, in a given situation if different individuals respond in a common way, or is it by birth that an individual acquires the certain trait of behavior etc. are the few questions that has been revealed by the experts through the subject called psychology. It has been defined as: “the science of mind and behavior” (Gross 1966). Further the complexity of human brain have been studied through many means and measures while studying or observing anything about the abstract form of mind still has its challenges.

**Cognitive psychology**

The cognitive psychology initiates to study and propose ideas about the vast concept and functioning of such issues. Cognitive psychology refers to all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used (Neisser, 1967). We can also define cognitive psychology as involving the attempt to understand human cognition by observing the behaviour of people performing various cognitive tasks (Eysenck, 2010).

Many contributions of cognitive psychology has been infused into various other modern disciplines of psychology such as cognitive science and of psychological study, including educational psychology, social psychology, personality psychology, abnormal psychology, developmental psychology, and economics. While ‘Cognitive psychology’ can also be used to refer to activities in a variety of other disciplines and sub-disciplines in cognition. Some sub disciplines, like cognitive neuropsychology, developmental cognitive neuropsychology, cognitive neuropsychiatry, and cognitive neuroscience, include the cognitive signifier in their own titles. It is concerned with the internal processes involved in making sense of the environment, and deciding what action might be appropriate (Braisby & Gellatly 2005).

**Cognitive Processes**

Like we can see the definition given by Neisser (1967), says cognitive psychology is the processes by which the sensory input is analyzed and used for further implications. Thus this process is further explained by Thompson (2013) as; cognitive processes are everything that goes on in our mind that affects our
environment. These processes include attention, perception, learning, memory, language, problem solving, reasoning, and thinking, while many of these processes are still performed in an unconscious state, for instance if an athlete is about to take a block start he has his eyes on the route to be taken at the same time he can here the firing sound and respond accordingly. It is the ability of the brain to process all the information received from various senses and perform or follow up with a response. This also works independently for example, a deaf and dumb individual could process information well if it is received from other senses like tactile input etc. With time understanding the brain and its working improved, the technology Neuroimaging or brain imaging stated around the 1970’s gave images of living, functioning brains. The number of applied research studies grew exponentially after the appearance of neuroimaging devices, as did the number of new medications and psychological and neurological treatments.

Despite all studies performed so far, till some extend it is found that it is still controversial whether cognition is brain-bound (Adams and Aizawa 2008) or extended (Clark and Chalmers 1998; Menary 2010), embodied (Gallagher 2005), embedded (Robbins and Aydede 2009) or enacted (Hurley 1998; Noe 2004): Newen Albert (2015). Studies has been done time and again solving these questions, the transition of the idea that it was a philosophical concept to a scientific one has made its long journey and has yet many gap of knowledge to be filed.

In 1997, Salmon et al performed a study on “Development of an Instrument to Assess Cognitive Processes in Physical Education Classes” where they constructed a set of questionnaire called the Cognitive Processes Questionnaire in Physical Education (CPQPE), with 819 participants. The results indicate the CPQPE is a valid and reliable instrument that can provide valuable information about the teaching and learning process.

Back in 1970’s the idea of information processing approach was highly accepted by the cognitive psychologists. According to the version it was assumed that the information received by the senses would go to the brain processed and sent back as response, that too only one at a time. But eventually with deeper studies and research it was found that unlike the previous approach information is not processed only in the serial manner but also performed as bottom-up processing and that too
more than one information can be processed unlike the serial processing called the parallel processing. After many years of work researchers have accomplished to reveal the process involved in attention, memory, reasoning, perception, learning, and so on (Eysenck and Keane, 2010). Such major contribution has led to simplifying and sinking the anchor to the shallow bottom of the deep and wide knowledge of the matter/subject. The flow chart in figure 1 gives a clear visual of the information processing system.

![Figure 1. Information processing cognition flow chart (2018)](image)

**The Eyes**

The eyes are the dominant sensory organs of the brain (Hubel & Weisel, 1968). Out of all the senses humans have, eyes which ultimately help to gain the majority of information for further analysis and not only the external vision, the ability of inner visual perception contributes immensely to the understanding of the environment and further respond to it. Human since infant manifest the understanding of the world through his eyes. The understanding of his surrounding, recognizing his loved ones, sensing danger and emotional expressions are all done using one of the most complex sense organ: the eyes.

With time humans undertook a way of understanding the human eye and the composite system of vision through multiple research works. The German physicist Hermann von Helmholtz well explained the mathematics of the eye who also gave a
number theories of vision, ideas on visual perception of space, color vision research and empiricism in the physiology of perception around the 19th century. The Human eyes help to provide a three dimensional, moving image, normally colored in daylight. Rod and cone cells in the retina allow conscious light perception and vision including color differentiation and the perception of depth. This light is focused upon fovea of the retina and it is relatively small in size. This size allows one to achieve clear and detailed images only from two to three degrees of the visual angle (Land, 2016). The term gaze control is termed to the situation when one produces purposive movements of the eyes, head and the body to place image upon fovea. Further for proper and quality imaging more precise movements called saccades and to attain steadiness fixation and pursuit tracking is used (Panchuk & Vickers, 2015). These movements are mandatory for optimum functioning of the eye and ultimately perceiving and using the information for further psychological analysis.

The bodily movement at the same time is associated to the musculo skeletal functioning but its precision is acquired only through correct perception using the sense organs especially the eyes.

In sports it is seen that every skills and technique acquisition and execution requires a high quality of visual interpretation. Seeing clearly is important, but it is only a part of a well-functioning visual system. Athletic performance at a competitive level demands a host of other visual skills: eye movements, focus flexibility, depth perception, contrast sensitivity, visual reaction time, visual processing, eye-hand coordination, dynamic visual acuity; as well as static visual acuity makes 20/20 eyesight (Vinny, 2018).

**Eye tracking**

Sport optometrist gains immense understanding and diagnosis using the eye tracking device for further enhancement of the athlete’s performance. Where we fix our eyes (gaze), and how we move eyes is associated with where we pay attention to. Eye tracking uses sensor technology to follow an individual’s gaze and eye movement. This enables the eye tracking device to identify where our eyes are focused at exactly. It also determines our presence, attention and focus (Pramodini, Mukti & Ramesh, 2017). The advancement in this technology along the 19th century
gave rise to the eye tracking technology, its origin dates back to 1879 when Louis Émile Javal the French ophthalmologist for the first time noticed, that readers’ eyes do not skim smoothly through the text while reading, but makes small quick movements, now known as saccades, mixed with short pauses called fixations. These studies were based on observations by naked-eye. Then the first device for eye tracking was built by 1908 by Edund Huey, much later around the 1970’s and 1980’s its research flourished. In sport, the first eye tracking studies were conducted in the 1970s (Bard & Fleury, 1976). Some of the early methods of eye tracking included electrooculography systems, (placing electrodes around the eye to monitor vertical and horizontal eye movements) and the magnetic search coil method (placing small coils of wire embedded in a modified contact lens onto the eye, usually after administering an anesthetic, which can then track the movement of the eye (Discombe et al., 2015).

In the early 1900s, a breakthrough in eye tracking research was the development of the first non-invasive eye tracking device, based on photography and light reflected from the cornea (Wade & Tatler, 2005). This system can broadly be considered as the forerunner of contemporary video-based, corneal reflection eye tracking systems. Today 95 per cent of all modern eye trackers use a video-based pupil and corneal reflection system (Holmqvist et al., 2011). These systems are considered the most user friendly and practical devices available (Duchowski, 2007).

There are three main types of corneal reflection eye trackers available: Table/desk-mounted, head-mounted, and remote systems, each of these systems has its own benefits and drawbacks. Much later with the advancement in head-mounted eye tracking technology the door have opened towards a broad range of more ecologically valid field based sport and exercise research projects and performance-focused interventions (Discombe et. al., 2015). Also the mobility and instant nature of the feedback provided from head-mounted eye tracking systems, has led many sport psychologists and researchers to attempt to design vision-based training programs. One such training program, which has proven useful, is the Quiet Eye approach. Quiet eye refers to the final fixation or tracking gaze that is located on a specific location or object (Vickers, 2009). Today the importance of such devices is felt in many fields for its precision and contribution for filling the gap of knowledge about the visual system.
Professor Aidan Moran and his team at University College Dublin says he uses those eye trackers to look at the differences between expert sports people and beginners in order to find out what’s going on in their mind as they look at something. The eye tracker gives us a pattern of fixations that the eyes display, but the psychology begins when we start analyzing those fixations to see the knowledge that lies behind them. Sport is played by the body but won mainly in the mind (Morgan, 2013).

To understand the working of the eye and its tracking system one must be clear about few basic ideas of the concepts these have been illustrated further.

**Saccade**

It is a ballistic eye movement that brings the point of maximal visual acuity onto the fovea so that an object can be seen with clarity (Thilo et al., 2004). Saccadic eye movements are said to be ballistic because the saccade-generating system cannot respond to subsequent changes in the position of the target during the course of the eye movement. They range in amplitude from the small movements made while reading, for example, to the much larger movements made while gazing around a room. Saccades can be elicited voluntarily, but occur reflexively whenever the eyes are open, even when fixated on a target (Purves et al., 2001). For example while reading a book our eye movements are not smooth across the line but instead our eyes jump and pause generating a number of saccades (Pramodini, Mukti & Ramesh, 2017).

**Fixation & fixation Sequence**

A fixation is the maintenance of steady gaze to allow processing of visual information from that location. A fixation typically ranges from one to three degrees of visual angle for 80–150 ms (Carpenter, 1988; Vickers, 2007) and enables performers to stabilize an informative area of a scene on the fovea so that complex processing can occur. In sporting tasks, fixations allow attention to be directed to specific details from the scene, in order to guide decision-making or motor control skills (Panchuk et al., 2015).
Fixation sequence can be generated based on fixation position and time information. It depends on where a respondent looks and for how long. We can build an order of attention where the respondent looked first, second and so on. This parameter is used in research as it reflects salient elements in the display or in an environment that catch much attention. AOIs that respondents look at first are visually more salient and hence are of more interest (Pramodini, Mukti & Ramesh, 2017).

**Figure 2. Gaze plot of fixation and fixation sequence**

Figure 2 shows the gaze plot of the fixation, where the circles indicate the fixation in that particular point. Along with fixation, this figure highlights the fixation, where the sequence of the gaze point is indicate in numbers and the size of the circle represent the duration of fixation on the particular point, the bigger circle indicates the longer fixation duration.

**Smooth Pursuit Movement**

Smooth pursuit movements are much slower tracking movements of the eyes designed to keep a moving stimulus on the fovea. Such movements are under voluntary control in the sense that the observer can choose whether or not to track a moving stimulus (Purves et al., 2001). It is a skill that is particularly useful in high-
speed sporting tasks maintaining a steady gaze on a moving object or target. It demands a minimum stability of 80-150 ms on the target to process information. For example, imagine watching a slow moving train from a distance. Here, our eye movements are quite opposite as our eyes follow moving objects steadily.

**Scan paths**

The scan path was first defined by David Noton and Lawrence Stark in 1971. The sequence of fixation-saccade fixation is referred to as scan path (Pramodini, Mukti & Ramesh, 2017).

**Heat maps**

The static or dynamic or static aggregations of gaze points and fixations generate the distribution of visual attention are represented through a heat map. Heat maps serve as an excellent method for visualization; it shows maximum attention area of the stimulus Heat maps use easy to read color coded scheme. A high number of gaze points are indicated by Red area and shows an increased level of interest, yellow and green area point toward less visual attention (Pramodini, Mukti & Ramesh, 2017).

Figure 3 shows the visualization of eye in the form of heat map where the warmer colour (red/orange/yellow) in the snapshot represent more gazing time, and cooler colour (green) indicates less gaze time.

*Figure 3. Heat Map*
Area of Interest

Area of interest (AOI), are sub regions of a stimulus object displayed on screen defined by user. Metrics to separate AOIs are evaluated with the performance of two or more specific areas in the same picture, website or any program interface (Pramodini, Mukti & Ramesh, 2017). Areas of Interest (AOIs) enable numerical/statistical analysis based on regions or objects of interest in the snapshot images. AOIs are drawn around objects in the snapshot that the researcher would like to analyze further in third party software such as SPSS, Matlab or Excel as shown in figure 4. AOIs can be of any shape. Once an AOI has been drawn onto a snapshot, and there is data mapped onto the snapshot, the data export output file will include data on whether the participant’s gaze point is inside or outside the AOI.

![Snapshot of Badminton Court](image)

*Figure 4. Snapshot of Badminton Court*
Respondent Count & time Spent

This metric allows to extract more information about the number of respondents had gaze direction towards a specific AOI. Higher respondent count indicate that fixations and gaze points are driven by some external aspects in the stimulus. Time spent specifies the amount of time that respondents have spent on a specific AOI. It often indicates motivation and conscious attention because long prevalence at a region points to a high level interest (Pramodini, Mukti & Ramesh, 2017).

Quite Eye

The Quite Eye (QE) refers to a gaze behaviour observed immediately prior to movement in aiming task, this term was first proposed by Professor Joan Vickers of Calgary University. For example during a service in badminton when a skilled individual prepares for their service, they generally pause with their eyes steady on or around the target before initiating the movement of the shot. The final pause where their gaze remains steady on a single location before the movement is defined as the QE in this task. Joan Vickers defines the quiet eye as ‘the final fixation on a location that is within 3° of visual angle for a minimum of 100ms’ (Vickers, 1996). Research examining QE tends to involve performers of varying levels of expertise executing skills while their gaze behaviors are recorded. In order to determine the attributes of a QE fixation that correlate with sporting expertise, athletes are often asked to perform under experimental conditions in which task complexity, pressure/anxiety, and physiological arousal are manipulated. The QE is a variable that examines the complex relationship between perception and action, and has been adopted in more than 100 published studies (Vickers, 2007; Vine et al., 2014).

The major reason that drives the study of eye tracking in sport is the relationship between eye movements, attention, and motor performance. While attention can move independent of eye movements, or without being discovered (Posner, 1980), there is evidence that eye movements coincide with a mandatory shift of attention (Deubel & Schneider, 1996; Shepherd et al., 1986).

Studies show that eye movement recordings have demonstrated how eye movements differ between experts and novices across a range of skills (Vickers,
The majority of these studies has used cross-sectional designs and, thus permits us only make assumption that there are differences between groups, there is evidence that the movement of eyes change over the course of skill learning as well (Sailer et al., 2005; Vine & Wilson, 2010, 2011; Vine et al., 2012). Such research also permits us to make predictions about the underlying structure of the task, like we can determine which sources of information are relevant for performance and how the sources of information that are relevant for performance change with the development of expertise (Land, 2009). Expert performers, through constant commitment within a task domain, develop the unique ability to attend to relevant information at the time when it is most necessary for task performance (Hayhoe et al., 2007). Experimental studies have also demonstrated the importance that specific gaze behaviors, such as the QE, play important role in the performance of motor skills. Williams, Singer, and Frehlich (2002) found that when QE duration was experimentally manipulated in a billiards task to 50 per cent and 75 per cent of participants’ normal QE durations, the accuracy of both experts and novices suffered, showing the superior motor system of the elite players did not protect them from the effects of their lower than normal QE durations. Finally, insight into expert gaze behaviors can be used as a training tool to guide the behavior of novices and hasten the learning process (Harle & Vickers, 2001; Vine et al., 2011).

**Eye Tacking in Sports**

Talking about the use of eye tracking in sports, we can simply start by putting up the questions: where does the sports person look at while performing his skills, what are the thoughts running in his mind, is seeing around very important? In sports with very fast ball a player cannot always continue looking at the ball constantly, does that affect the performance? Some coaches in these fast-ball sports tell their players to ‘keep their eye on the ball’; yet how helpful is this advice? And is it even possible to ‘keep one’s eye on the ball’? Eye tracking technology allows us to investigate these questions and explore a topic that has intrigued sport researchers for decades (Vickers, 2009). In fast-ball sports such as cricket, tennis, squash, hockey and baseball, the time on constraints upon perceiving and acting are extremely severe. For instance, if a cricketer were to bat successfully, they would need to filter relevant information, select the most appropriate course of action, and execute the action
precisely within a time window of a millisecond. This process often occurs within an environment where the opponent deliberately attempts to deceive and confuse the performer (Müller, Abernethy & Farrow, 2006). Elite level athletic performance can be readily observed by the observer however the perceptual-cognitive mechanisms that contribute to advantage of the experts’ are much less evident (Mann et al., 2007).

The majority of sport is performed in a dynamic, ever-changing environment, under conditions of extreme pressure where the limits of human capability are continually challenged and extended (Ericsson, 2003).

Amongst the victory achieved in sports using the highest contribution of the vision is the racket sports, they demand high quality imaging both external and internal for accessing the speed, movement, anticipation and depth perception for an elite level performance. Amongst these badminton is currently one of the most demanded multidisciplinary skilled game, thus grabs attention both as a player and a spectator. The sport has gained immense name and fame over the last 20 years. It has not only reached its heights in techniques and tactics but in technology as well. As the standard of the game has risen it is seen that the elite players come across newer and bigger challenges. Thus latest equipment’s, technologies, strategies and trainings are all in high demand. Researchers with collaboration with elite athletes all over the world too are contributing through major minor findings.

We see scientists like Eysenck, Keane, Weinberg and Daniel emphasizes and highlights how the cognitive aspect of an individual includes the process of decision making, problem solving, anticipation, attention, dealing with tactics etc. Sports offers as a very huge platform for an individual to learn, practice and develop the cognitive skills. Decision making is one such aspect where the stage of sports gives immense opportunity for the player, the coach and the referee to make decisions in and out of pressure resulting in a victory or a defeat. Johnson (2006) highlights three characteristics of decision-making in the field of sports. First, he claim that they are naturalistic which means decision-making agents (mainly coaches and athletes) naturally always encounter the decision in sport environment with some degree of task familiarity. The researchers address several important points that the difference between the study of decision making in the laboratory and the ‘‘real world’’ is an
important distinction that has only recently been appreciated in decision research (Orasanu & Connolly, 1993).

Secondly, Johnson (2006) argues that since the majority of sports decisions are dynamic, decisions in sports reveal over time. The impact of this dynamic aspect is double. There are internal dynamics, meaning there is not so much a single point of decision as there is a course of deliberation. Information is not immediately gathered and processed; rather a decision maker must accrue information over time, and subsequent processing of this information takes additional time. On the other hand, sports situations and decisions possess external dynamics, meaning that the situation itself changes over time. Thirdly, the author places emphasis on decisions which are often made online during the tasks or intense timely stressful situation which is related to, but distinct from, the dynamic nature of sports decisions. So, most decisions made by athletes, coaches, and referees are made while the play is in motion. He concludes that an element of variability must be realized when studying sports decisions (Kaya, 2014).

**Nature of Badminton**

Badminton like other sports, has important motor skills involved. Forehand smash shot, drop shot, attack clear shot and lob shot are of the major and almost common attack skills. It requires a great deal of accuracy to send shuttlecock to suitable places in the competitive court (EL-Gizawy, 2007; Grice, 2004; Paup & Fernhall, 2000).

The game is one of the fastest games in the world with shuttle speed going upto 426 kmph, also it is the most exciting and interesting sports, credit to its fast playing rhythm, the constant interaction between attack and defense shots throughout the match and the large points number per game. Therefore, players remain in a constant struggle throughout the game in order to win a largest number of points since winning is the final outcome point that players are looking for (El-Kholi, 2001; Saber, 2008).

Badminton would constitute information creating system at a certain time. As the eye provides information to brain which explains the information and after that sends signals that make hands, legs and other body parts move that happens in a split
second. If this message inaccurate, incomplete, or introduced at an inconvenient time, this leads to incorrect performance (EL-Gizawy, 2015).

Badminton being a fast game demands high accuracy in visual abilities especially in the elite level. Not just to judge the speeding shuttle but also to estimate the path of trajectory, to place the racket accordingly and analyze its impact, check the position of the opponent, to push the opponent in utmost uncomfortable position forcing him a weak or no return are major challenges one must overcome positively through good interaction of one’s visual and motor skill. The highly complex role played by vision and hand-eye coordination in almost all the sports is as important as fitness and skill training, and can make or break a professional’s game.

According to Calder, “the role of vision is usually undermined and yet it plays a huge role”. She says although games are played during the day mostly and night games are played under bright lighted stadiums, vision has nothing to do with eyesight but rather what you see and how to process it and the way you respond. It is important to realize the role of good vision and hand-eye coordination in sports and how this can make a difference in a person’s performance. Hand-eye coordination, says Calder, “is what you see and how accurately and rapidly you respond.” She says mastering this technique depends entirely on the individual. Hand-eye coordination skills involve the input of visual information to the brain and the interpretation of that information by the brain to coordinate movement.

Badminton requiring the visual skills definitely needs more attention on its training too. Like Clader focuses the importance on the link between what a player sees or perceive visually and how he processes it to perform an outcome is equally necessary. It is evident that all sports involving a projectile, for example badminton, tennis, cricket, football, rugby, hockey etc and many more require excellent hand-eye and/or hand-foot coordination in order to catch, hit or kick the object.

"Keep eyes on the ball", the phrase we hear constantly from many coaches. Nothing happens until eyes guide hands what should be done. Nearly 80% from start signals in almost all of sports are through sense of sight. Visual accuracy and abilities have great importance. Therefore, via visual processing athlete can see the thing clearly and its place in air or how fast it moves or if this thing is going to change its direction (Abdul-Qadir, 2001).
It is a fact that only the small area right in the center of where one is looking is seen in clear, high resolution. The rest of the scene, in the peripheral vision, is blurry, low resolution. Therefore, we need to move our eyes around a lot. There are few specific terminologies which is given to understand the basic movement of the eyes or pupil which will be used often to explain its workings.

In the concept of badminton while the shuttle moves the players try to glide his gaze along with its flight, but in natural condition if the shuttle is moving fast the gaze point really does not smoothly skim along. They form a small pause and points of fixating its gaze choosing from whole of center and peripheral view. This is called the fixations. Studies have shown that an elite player has the ability to retain longer and fewer fixation points on the moving shuttle. In soccer for example, in 2002 Savelsbergh and colleagues found that expert soccer goalkeepers employed a more efficient search strategy while the novice usually tend to have a scattered and short fixations. The way in which we move from fixation to fixation depends on what we are doing and is called our visual search strategy. In fact in some cases, the purpose of fixating on a location is not to use central clear vision but rather to anchor the eyes so that the important peripheral cues can be seen.

Players, just before they begin moving or performing their skill or make a move, seem to lock their eyes on one thing in their environment (for example the net when putting it closest to the net during net play, especially the novice players) and keep it there. The less movement of the eyes during this period tosses its name; the Quiet Eye period coined by Joan Vickers. This effect has also been demonstrated in sports including ice hockey, archery, shooting, billiards and tennis.

It is seen in research on following a moving object, like a smashed shuttle with your eyes is impossible to do for its entire flight because object moves faster than we can move our eyes. Thus instead, in many cases, elite players seem to follow the ball for a while then make a quick jump of their eyes to where they predict it will be is called a saccade.

In this era of science and technology sports provides one of the widest platforms for its growth and development. At every stage of learning there is a unique demand of interventions. Thus sports science since past many decades have understood and started working on inventions that has overcome the major minor
challenges it has faced over time. Keen Sports scientists and researchers have made many major contributions for its rise, to enhance the level of performance through scientific training programs, invention of various training and competition equipment, scientific testing machines etc.

Bloom's Taxonomy was created in 1956 under the leadership of educational psychologist Dr Benjamin Bloom in order to promote higher forms of thinking in education, such as analyzing and evaluating concepts, processes, procedures, and principles, rather than just remembering facts (rote learning). It is most often used when designing educational, training, and learning processes.

The Three Domains of Learning (Bloom, et al. 1956):

- **Cognitive:** mental skills (knowledge)
- **Affective:** growth in feelings or emotional areas (attitude or self)
- **Psychomotor:** manual or physical skills (skills)

The cognitive domain involves knowledge and the development of intellectual skills (Bloom, 1956). This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. There are six major categories of cognitive processes, starting from the simplest to the most complex: knowledge, comprehension, application, analysis, synthesis & evaluation (Old Taxonomy) and creating, evaluating, analysing, applying, understanding & remembering (new taxonomy).

Being the windows to the soul, eyes reveal information about individuals' feelings, emotions and behaviour, affecting various cognitive tasks, such as focus of attention, spatial cognition and navigation, cognitive load, etc. With the increased use of computer systems, complex information is visualized and communicated through visual interfaces as a mean of information presentation to and processing by the users. However, people differ regarding the way they seek, retrieve, process, comprehend, organize and recall information, based on their individual perceptual characteristics, cognitive skills, abilities and styles. Therefore, the point and the motion of the eye movement could reveal behavioural patterns related to individual cognitive differences; patterns that are extracted using eye tracking tools which quantify and provide compelling data regarding eye movement.
Keeping in mind the necessity of the cognitive domain in the game badminton, this study aims at finding the major differences in the visual abilities between the elite and the novice badminton players. Sports optometrists can definitely be of great help for players who would need his attention for bringing out a constantly effective visual system.

It is known that the effective control of eye movements (which is an aspect of visual system) does seem to be a crucial factor in badminton, thus convincing more and more research work to be carried out so as to distinguish athletes of different abilities and bring about new trainings to improve sports performance.

A crucial feature of this research is that the study will in detail show how, why and when are the elite and novice players different visually and what lessons can be learnt for the novice to break the barrier of performance and develop along with the growth in fitness and the skills.

**STATEMENT OF THE PROBLEM**

The purpose of the study was to analyze the cognitive process through eye movement among badminton players of different levels.

The subordinate purpose of the investigation was to look into:

- The difference in the eye movement (visual-attention) among senior, junior and sub-junior badminton players in selected badminton skills of (a) forehand overhead clear; (b) forehand drop, (c) drive and (d) forehand smash.

- The difference in the eye movement (visual-fixation) among senior, junior and sub-junior badminton players in the selected badminton skills of (a) forehand overhead clear; (b) forehand drop, (c) drive and (d) forehand smash.
RESEARCH QUESTION

❖ Is there any difference in the eye movement (visual-attention) among senior, junior and sub-junior badminton players while executing various badminton skills?
❖ Is there any difference in the eye movement (visual fixation) among senior, junior and sub-junior badminton players while executing various badminton skills?

OBJECTIVES OF STUDY

❖ Research scholar wants to investigate the difference in the eye movement (visual-attention) among senior, junior and sub-junior badminton players in their badminton skills.
❖ Research scholar wants to investigate the difference in the eye movement (visual- fixation) among senior, junior and sub-junior badminton players in their badminton skills.

DELIMITATIONS

❖ The study was delimited to male badminton players only.
❖ The subject of the study was further delimited to the age group of senior, junior and sub-junior players. The age ranged between 20-24 years for senior (mean & SD 21.75 ± 1.28); 15-18 years for junior (mean & SD 17.00 ± 1.41) and 10-14 years for sub junior (mean and SD 12.58 ± 1.68) respectively.
❖ The study was further delimited to analysis of eye movement of visual attention and fixation of badminton players.
❖ The eye movement was measured only in four badminton skill, i.e., forehand overhead clear, forehand drop and drive, forehand smash.

LIMITATIONS

❖ Tobii-Pro Glasses 2 has its own limitation.
❖ Thought process of the subject was beyond the control of the researcher.
❖ Athletes perception towards own behavior may be different. It might be considered as another limitation of this study.
The impact of coaching or training technique of the coaches for various players might influence the task of the players they were asked to perform, which might be considered as another limitation of this study.

**HYPOTHESES**

On the basis of literature reviewed, available research findings, expert guidance and scholar’s own understanding the following hypothesis are formulated:

**Hypothesis 1**: There would be significant difference in the eye movement (visual-attention) among senior, junior and sub-junior badminton players in their badminton skills:

(a) forehand overhead clear (b) forehand drop (c) drive & (d) forehand smash.

**Hypothesis 2**: There would be significant difference in the eye movement (visual fixation) among senior, junior and sub-junior badminton players in their badminton skills:

(a) forehand overhead clear (b) forehand drop (c) drive & (d) forehand smash.

**DEFINITION AND EXPLANATION OF TERMS**

**Eye Movement**: Eye movement includes the voluntary or involuntary movement of the eyes, helping in acquiring, fixating and tracking visual stimuli.

**Eye tracking**: Eye tracking is the process of measuring either the point of gaze ("where we are looking") or the motion of an eye relative to the head. An eye tracker is a device for measuring eye positions and eye movement. Eye trackers are used in research on the visual system, in psychology, in cognitive linguistics and in product design. There are a number of methods for measuring eye movement. The most popular variant uses video images from which the eye position is extracted.

**Fixation (visual)**: Fixation or visual fixation is the maintaining of the visual gaze on a single location. Humans (and other animals with a fovea) typically alternate saccades and visual fixations, the notable exception being in smooth pursuit, controlled by a
different neural substrate that appears to have developed for hunting prey. There are three categories of fixational eye movements: microsaccades, ocular drifts, and ocular microtremor.

**Visual attention:** Visual attention is a process that directs a tiny fraction of the information arriving at primary visual cortex to high-level centers involved in visual working memory and pattern recognition (Neurobiology of Attention, 2005). When our eyes fixate to different locations in a visual field, they do not process every single piece of information available. Instead, the eyes will go through a process to select different aspects to retrieve.

**Gaze:** Gaze means "to look steadily, intently, and with fixed attention.

**Quite Eyes:** It refers a gaze behavior observed immediately prior to movement in aiming tasks.

**Saccade:** An extremely fast voluntary movement of the eyes, allowing them to accurately reflex on an object in the visual field.

**SIGNIFICANCE OF STUDY**

*Eye tracking* study is one of the fascinating fields of research to understand human behaviour. Recently the information gleaned from eye tracking is applied in the profession of web designing, content writing, conversion optimization expert, etc. Eye tracking basically measures where people look and for how long they persist. Eye tracking data is presented visually, overlaid on the screen that the subjects were looking at. With eye tracking, you can discover where a person looked first, second, third, and so on. You can find out what the user considers to be the most interesting part of the screen and how long he or she looked at certain areas.

According to Jacob and Karn (2003), eye tracking has remained a very promising tool for research, but it has never been as widely utilized as it potentially could be. Those authors provide a cogent treatment of the factors potentially inhibiting wider adoption of eye tracking methodologies, including limitations and challenges associated with eye tracking hardware and software, and with the resultant data related to volume, extraction, and interpretation.
An additional consideration not specifically mentioned by Jacob and Karn (2003) is the cost of an eye tracker. Especially in the field of sport in India this concept has come now as very few departments are having this equipment. Hence, the present research is an eye opener and a learning tool for the researcher himself and for others who could take up research on athletes in this equipment. There are more than ten different type of software for eye tracker and one has to know what would be better for what kind of sport. There are high cost and low cost eye tracker too. Based on the work one is willing to take up, one should try to procure the same.

In the last thirty years (1987-2016), an increasing interest in sport sciences regarding the analysis of expert athletes’ gaze behavior has become apparent in high performance sport.

The study will be significant in the following ways:

- This study will help the coaches to understand the eye movement of badminton players while executing the different strokes.
- This study will help coaches to understand the importance of visual attention in order to raise the performance.
- This study will help to assist the players to understand worth of visual attention so as to improve the badminton playing ability.
- This study will help the players to enhance and developed cognitive processes involved in playing the game of badminton.
- This study will help the coaches and experts to design training program for developing and enhancing the cognitive aspect involve in the game of badminton.
- The present work also would help to understand the different kind of eye tracker being used for different kind of sport activities. Further to help a researcher to apply the right kind of eye tracker for his/her research and analysis purpose.