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Review Article

Sports Vision: Influence on Athlete's Performance

Patrícia Rodrigues*

Optometrist and Sport Vision Specialist, Portugal

***Corresponding Author:** Patrícia Rodrigues, Optometrist and Sport Vision Specialist, Portugal

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Abstract

The ability to see and then create an appropriate motor response is central to optimal sports performance. Elite athletes face intense visuo-motor demands requiring millisecond-level decision making to convert vision into action. Some crucial skills in competition are directly linked to the visual process. It is helpful to classify the areas of assessment in order to better understand how the factors affect performance. It is analyzed a routine check in sports vision consultation, which involves the evaluation plan routine of primary and secondary skills with direct influence on sports performance. These abilities are assessment with an approach to direct correlation with the sporting skill that interferes; the way it should be evaluated and the instruments available on the market. Sport vision training aproaches provide another opportunity for the athlete to enhance vision and visual performance factors that are importante for their sport. In most sports, vision is critical element for sucessful performance and an eyecare professional should be proficient in assessing and training athletes' high-performance vision skills.

Keywords: Sports Vision; Vision Motion; Sports Vision Evaluation; Sports Vision Training; Athletic Performance

Abbreviation

SVT: Sport Vision Training

Introduction

The ability to see and then create an appropriate motor response is central to optimal sports performance. The ability to see the target, determine its motion wheter being an oponente, a moving object, or the goal is required for optimal performace. How we achieve optimal performance, and what role and to what extent our visual systems participate in performance is yet an entirely different question. In the past, many have attempted to describe and define the role of vision, leading to a motor response [1].

Labby et all, present a paradigma based on a pyramidal structure to explain the visual function on motor response (Figure 1). In this model, the concept of a pyramid is used in order to highlight the theory that build a stable, long - lasting pyramid each level must be built on a solid preceding foundational level. Should one lower level be weak, or of less width in the case of a geometric pyramid, the pyramid will not be stable and will not function properly. In this model, dedicated to the visual system, the authors describe the basic monocular visual functions of visual acuity and contrast sensitivity as forming the pyramid base. Above, and wholly dependent on the preceding monocular abilities, is the binocular visual function of stereoscopic vision. Without optimal function of each monocular ability, binocular function cannot be optimal. The next level of the sports vision pyramid utilizes the now binocular visual input to make a "go" vs. "no-go" decision. Lastly, sitting above the decision level of the sports vision pyramid is the motor effector level. Here, with a "go" decision, the previous visual information

Figure 1: Pyramidal struture pruposed by Labby to explain the visual function on motor response.

must be coordinated into a rapid, efficient, and precise motor action. This motor action and its success will be directly related to the previous information provided by lower levels of the pyramid, highlighting the importance of the previous binocular and monocular levels of the pyramid. With optimal function of each and every level below the apex of the pyramid, successful sports performance can be obtained [2].

In fact, elite athletes face intense visuo-motor demands requiring millisecond-level decision making to convert vision into action. Actually, elite athletics falls into a small class of human behaviors in which the perception-action cycle is required to function under intense temporal demands but with an incredibly high level of decision-making accuracy and action execution [3].

The professional literature demonstrate that high-achieving athletes perform better than non-athletes or lower-performing athletes on various measures of visual, perceptual, cognitive, and motor abilities. Several studies have concluded that higher-achieving athletes are better able to detect perceptual cues, make more efficient eye movements, and perform better on measures of processing speed and attention, as compared to less accomplished athletes or non-athletes [4-7]. And these abilities vary depending on the sport they practice and the specific need in each sport [8]. Additionally athlete`s superiority on beginners in elementary visuo-motor tasks, such as visual acuity, saccadic eye movements, depth perception, and oculomotor reaction time, has been widely investigated but results cannot be generalized to all sports [9-12].

Some crucial skills in competition are directly linked to the visual process, like anticipation that is an important part in sport expertise, it refers to the event itself. This ability to "read the play" is essential in sport where the speed of the game means that decisions must typically be made in advance of an opponent`s. Key factors behind anticipation in sport include visual abilities and perceptual and cognitive skills [13].

With these assumptions in place, vision specialists should break the paradigms that seeing well equals having a good vision. Vision is a process that begins in the eye and ends in the visual cortex in order to produce an action in response to the observed stimulus. Consultations and offices must be adapted when assessing an athlete's vision, due to the characteristics inherent to their condition. Even if athletes have an eye exam every year, he or she can benefit from seeing an eye care specialist, who specialized in sport vision. The vision and perceptual skills often identified as important for sports include static and dynamic visual acuities, contrast sensitivity, stereopsis, color vision, accommodative and vergence facility, multiple object tracking, eye-hand-foot coordination, precision ocular motility, eye-hand reaction speed, and peripheral eye-hand response speed [14]. Some aspects of these visual skills are assessed as part of a routine vision exam, but many are not evaluated for various reasons. It is helpful to classify the areas of assessment in order to better understand how the factors affect performance.

Sports vision evaluation

Primary skills in sports vision

An eyecare professional that is proficient in evaluating and training the high performance vision skills of athletes, must do a minimum number of exams to verify that the athletes' visual abilities meet the normality criteria.

The author recommends a routine examination in sports vision consultation, which involves the evaluation plan routine of primary skills with direct influence on sports performance:

- **Static visual acuity:** Measure of the athlete's vision visibility. In fact it all starts with visual acuity, because that task measures visual acuity for fine details at a distance. Measurements should be collected monocular, binocular, far and near. Deficits in static visual acuity can cause an inability to see and recognize small objects clearly and rapidly. It is important not to limit acuity measurements until AV 10/10.
- **Dynamic visual acuity:** Measure the ability to see objects clearly while they are in motion. The act of seeing when motion is involved requires different and more demanding visual acumen than the act of viewing a stationary object. In fact, sports with ball involve greater speed for all players in competition, which the measurement of dynamic visual acuity is more appropriate than static evaluation. In fact, quantifying this ability allows the vision professional to understand if the athlete can follow all the movements in play in a quick and fluid way, with correct processing to that the brain can interpret it. Fluctuation of clarity can affect timing, depth perception, object detail variation, and many other facets of good vision. Equipment designed to quantify a person´s ability to maintain sharp vision when movement is introduced will play a valuable role in a complete high performance vision assessment. Some of the devices available on the market are Nike Sensory Station (Nike Inc, Beaverton, OR), moV and (Vision and Motor Performance Lab) and Bernell's Rotator Disc (422 E Monroe St, South Bend).
- **Retinoscopy/Refraction:** Evaluate the athletes' refractive system to identify and compensate for possible refractive error. An emmetropia is very difficult to find, and possible

low astigmatisms induce a feeling of good vision to athletes, but which can limit the constant and fluid sharpness during a competition. A recent study show that only one out of four athletes who needed to use correction for playing football actually used it [15]. The sport vision specialist must choose suitable compensations and allowed by the regulation of each modality, so as not to jeopardize the athletes' safety during the competition.

- **Eye motility:** It is necessary to evaluate smoothness, precision, extension and complete extension of movements like version, duction, pursuit, saccadic and vestibulo-ocular movements, in low and high amplitude, evaluations for distances in far and near vision. This assessment allows the professional to know if the athlete is able to make a correct fixing between teammates and opponents, such as following the ball with the eye, without needing to perform micro-corrections; that would be responsible for longer reaction times and decreased maximum performance. In non-dynamic sports such as precision target shooting, the ability to maintain steady fixation is a vital aspect of successful performance. Therefore, the assessment of oculomotor function can include evaluation of pursuit eye movements, saccadic movements and steadiness of fixation. An important aspect of oculomotor function is the physiologist time required for initiation of the requisite eye movement for the visual task. Eye tracking systems such as SensoMotoric Instruments (SensoMotoric instruments, GmbH), among others listed below, they can be of help in this analysis.

- **Accommodative system:** Accommodation is the vision mechanism that par excellence allows the sports vision specialist to assess whether the athlete can maintain clear and smooth vision, while making eye changes between various distances; such as changing the fixation between the ball on the feet when shooting and the goalkeeper in goal. The underlying premise is that strength and flexibility in focusing ability provide better stability of visual information to the athlete, particularly when the athlete must deal with excessive fatigue and psychological stress. A correlation between rapid focusing and the visual judgments typically required in rapid-action sports has been assumed.

- **Binocular vision:** Eye alignment, at motor and sensory level, is maintained by a functional binocular vision system. Like others in the human body, this system is basically based on muscles and their strength and endurance. For an athlete to remain at best performance it will be expected that the binocular system must be compensated. If the binocular system, with phorias and reserves is under effort, it may not allow a clear and stable view with the course of the competition, additionally it will be very difficult to athlete keep both eyes locked in on a target, even when fatigued. Preliminary assessment with Maddox Rod (Laboratory Equipment Unlimited, Ambala, Haryana) can detect any anomalies.

- **Stereopsis:** Measure this ability quantify the capability to interpret the combined images from both eyes to correctly judge distances. Calculation of the athlete's distance from teammates, opponents, the ball and all elements in play. Through this correct calculation, it is possible for the brain to perceive the speed of moving objects, such as the ball's kick. With information like distance and speeds, spatial relationships will be rapidly and precisely. The relation between depth perception abilities and athletic performance as a logical correlation to explore because many sports tasks require judgments of spatial localization. Several studies have demonstrated that binocular vision can improve performance on certain tasks compared with performance by individuals using only one eye [14]. An assessment of depth perception is an almost universal element to sports vision evaluation and can be assessed and quantified by a simple use of the Titmus Stereo test (Paragon Care Group Australia Pty Ltd).

- **Contrast sensitivity:** As a rule, in-office visual acuity assessments are with maximum contrast from the Snellen table. However, there are many sports that are played in sports hall, where the contrast is not the maximum contrast that is measured with a Snellen table. In these athletes in particular, it is of paramount importance to assess their sensitivity to contrast, in order to understand how their visual system works in the real conditions in which they play. The assessment of this ability can be through Pelli-Robson Contrast Sensitivity Chart (DG Pelli and JG Robson) or more recently or latest with the evolution of the digital age with the smartphone-based Peek CS (https://www.peekvision.org).

- **Ocular health exams:** A complete assessment of ocular health is an obligatory portion of a sports vision evaluation. A complete assessment generally includes evaluation of external adnexa, anterior segment of the eye with biomicroscopy, pupillary response, intra-ocular pressure, and posterior segment of the eye with retinography. Sports that involve physical impact can cause eye injuries that are only discovered over the years.

- **Tear film evaluation:** The biomicroscopy is the complementary exam of choice to assess the condition of the tear film. The tear is the first refractive surface through which the observed image passes, changes in the defective structure or composi-

tion of some of the layers of tear film, will cause fluctuations in the sharpness of the image throughout a competition, which influences athletic performance. Sports vision specialist can assist with recommendations for eye drops that restore tear stability, or therapeutic plans to improve long-term tear quality and quantity.

- **Color vision:** A simple, economical and fast test like the Ishihara test (Kandiara Co. and LTD), allows the identification of anomalies in the color vision. The sports vision specialist can compensate or/and advise, being a great help in choosing colors and patterns of equipment and objects that will be in the field, to prevent situations difficulties in recognizing or observing the game.

- **Dominant eye:** It is important to assess the motor and sensory dominant eye, in order to correlate with other dominances and laterality of the athlete. These indications allow obtain indications of eye-hand-foot coordination, reaction time, imperfect techniques, improvement of techniques and tactics, among other factors that differentiate an effective team from an efficient team. Depending of sport´s modality, having crossed eye-hand-foot dominance could be advantage or disadvantage, to maximum performance. These facts were further inspired by findings of Coren and Porac, who found that information from the dominant eye is processed approximately 14 ms faster than information from the non-dominant eye [16]. Also magnetoencephatolography (MGE) and functional magnetic resonance imaging (fMRI) studies and further demonstrate a larger activation area in the primary visual cortex of the dominant eye [17,18]. With these data well established, the sports vision specialist can use visual training to create symmetries in the dominances and create a more functional athlete.

Secondary skills in sports vision

The previous listings are core skills necessary for optimal performance. Winton [19] consider are secondary skills that incorporate these core skills with information processing and motor control of the muscular system when the body is in action:

- **Eye-hand/eye-foot/eye-body coordination:** Eye-hand/foot/body coordination refers to the precise and accurate control of body in response to visual information and is the center of athletic ability. Eye-hand-foot coordination involves the integration of the eyes and the hands and the feet as a unit. The eyes must lead and guide the motor (movement) system of the body. How quickly and accurately the body responds to visual input of information separates elite athletes from average ones. There is a multitude of equipment that has been developed to evaluate and train this critical skill for athletic success. Several large electronic boards designed for this purpose are available. They have such varied names as the Action Coach (Perceptual Testing Inc), the Sanet Vision Integrator (Gold Canyon, AZ), the Wayne Saccadic Fixator (Wayne Engineering, Inc), DynaVision (West Chester, OH), NeuroTracker (NeuroTracker Inc) and Nike SPARQ System (Nike Inc, Beaverton, OR). They all concentrate on assessing and improving visual-motor performance by asking the athlete being tested to touch randomly illuminated lights within a predetermined time limit. Devices such as the Reaction Plus and Multi Operational Apparatus for Reaction Time - MOART (Lafayette Instrument, USA) also incorporate eye-to-foot reaction tests [20].

- **Eye tracking:** it is possible to analyze the eye movement at each instant of the training, game or specific situation through eye tracking system. These systems typically consist of two cameras mounted on an eyeglass-type frame: one to monitor eye position and another to monitor motor performance characteristics. The data collected by the mobile eye tracker are then synchronized with elements of motor performance using software programs that can operate in real time. The objective is to understand the constancy and latency of the athlete's ability to focus when observe an opponent´s pathway while moving across the playing field, or how observe different body parts of an opponent player, or the precision of the eye in focusing the ball or if it may lead to fixing wrong areas of interest; among others. The study of eye movements during performance of motor skills can yield important information to understand how individual athletes control their actions [21]. Several companies market complete mobile eye tracking systems such as SensoMotoric Instruments (SensoMotoric instruments, GmbH) and Tobii Pro (Falls Church, VA) and depending on the purpose of the assessment that must be carefully chosen, as studies report [22].

- **Motor response time and visual-motor reaction time:** Motor response time, also know as motor reaction time, is the time required to complete a simple, predetermined motor movement. For other side visual-motor reaction time refers to amount of time that elapses between the initiation of a visual stimulus and the completion of a motor response to the stimulus. This is the full completion of response time reflex, including the period required for the retinal cell information to the visual cortex, and time required for the neuromuscular system to send the information to the muscles that need to be stimulated to make the appropriate motor response. Visual

reaction times have been shown to be impaired by factors such as reduced IQ, cold, fatigue, and restriction of peripheral visual fields with protective eyewear [23]. The measure of reaction time reflex represents the minimal amount of time required to process visual stimulus presentation and performs a simple motor response to that stimulus. There are several instruments on the market that allow quantifying this capacity in athletes, like the Wayne Saccadic Fixator (Wayne Engineering, Inc), Visual Choice Reaction Time Apparatus (Medicaid Systems, Chandigarh), Multi-Operational Apparatus for Reaction Time - MOART (Lafayette Instrument, USA); or more recently free APP to Android and IOS systems like: Reaction Time, from Hackman or Ewefo.

- **Speed of recognition:** The ability to process visual information rapidly has been considered an essential element for success in fast-action sports. Speed of recognition refers to an athlete's ability to make quick visual decisions on the playing field. The processing speed can be measured psychophysically as inspection time. Shorter inspection time allow accurate decisions to be made from shorter stimulus duration than from longer inspection times. The tachistoscope is the device of choice to test and train the speed with which an athlete makes visual choices, with good test-retest reliability and correlate with measures of cognitive abilities, according to Erickson [14]. It can expose images of realistic playing situations at on-hundredth of a second to prompt an accurate response. In the testing mode, numbers may be shown on a screen in various sequences, with the subject asked to report these number sequences correctly. The faster an athlete can make visual decisions about the sports challenge and hand, the more he will have a competitive edge over his opponent.

- **Peripheral field of vision and peripheral awareness:** In many sports situations, especially team sport, processing of information from peripheral visual fields is a beneficial element to successful performance. Because the focus of the visual field is so small (focus ability is limited to 3 degrees), peripheral vision becomes very important, for these information needs to be processed quickly to facilitate the detection of motion so that visual focus be directed to other events [24]. The peripheral field of vision is defined as the full range of vision extending to 180 degrees while eyes are focused on a centrally fixed target. For other side, peripheral awareness is the ability to perceive and react to a peripheral stimulus without moving your eyes. It's important to distinguish between the concepts of peripheral vision and peripheral awareness. The peripheral field of vision is genetically determined and unchangeable (exceptions for various eye diseases and other health conditions that may reduce), while peripheral awareness may be trained and enhanced. Testing of peripheral vision is typically accomplished through computerized peripheral field-mapping analyzers, like Humphrey (Carl Zeiss Meditec). The Awareness Trainer (Wayne Engineering, Inc) measures the peripheral speed of reaction in milliseconds, corresponding to evaluation for peripheral awareness. In this case of sports evaluation, the factors involved in assessment of peripheral vision include the extend of visual fields, the sensitivity of the visual fields, the visual response speed to peripheral information, and spatial localization accuracy of peripheral stimuli. Previous studies demonstrated, that athletes have a larger extent of horizontal and vertical field than non-athletes and better recognition at more peripheral locations [25,26].

- **Visual memory:** Is the ability of eyes and brain to recognize patterns on the field or court and be able to process that information quickly and efficiently. This is a valuable tool for athletes and is a skill that is developed over time and can be trained and improved.

According Teig this sport-related battery of tests can take anywhere from ninety minutes to two hours to complete. The primary skills procedures are conducted on every type of athletes. In addition, secondary skills allow doctors to pinpoint abilities that are most relevant to a particular sport [20].

Sports vision training (SVT)

As previously mentioned, athletes have better visual abilities so it is expected that the results obtained in this battery of exams are above average. Despite having more developed visual and physical abilities, studies show that it is possible to improve them [27-29].

There are many factors that influence sports performance, and one fundamental area of extreme importance is training. Athletes commonly train their muscles, their understanding of the game, and their strategies to outperform their opponents. But relatively little attention has been dedicated to training visual and attention abilities within the sports world [14].

Might athletes be able to gain a competitive edge by directly training vision and attention? Buys and Ferrira attribute acquisition of 80% of sportive environment information through sight [30], so is expect further improvements in sports performance with the training of visual skills, demanding visual perceptual, mo-

tor and sensory tasks programs; as it is one of the most sensorial means of providing information.

There is approaches to SVT that using the same diagnostic methods presented in the previous topics, modified traditional programs vision therapy, and combined with increasing integration of other sensory, motor and cognitive demands; to better simulate the visual performance demands that may be encountered in sports. These approaches are limited because their isolate component visual performance factors (e.g. vergence, accommodation, pursuit, and saccadic eye movements) and create a motor pattern repetition of these SVT activities.

With the evolution of the times, new SVT approaches have appeared, with greater recourse to the digital age, with visual reality simulations that can recreate an augment sporting context to promote certain sports-specific visual-cognitive abilities. Also SVT approaches have been advanced greatly by training programs that use information about the structure and function of the visual system combined with recent innovations in perceptual learning paradigms to engender more specify and robust learning.

The visual-motor reaction-time is the ability tinning more common of component SVT because many sports situations require an athlete to quickly make motor response. Several instruments have been created to evaluate and improve visual-motor reaction speed, including the Dynavision D2 (https://info.dynavisioninternational.com, Figure 2), Vision Coach (www.visioncoachtrainer.com), Wayne Saccadic Fixator (www.wayneengineering.com), SVT (www.sportvision.com.au), Batak (Horley, Surrey, UK, www.batak.com), Sanet Vision Integrator (www.svivision.com), and FITLIGHT Trainer (Aurora, ON, Canada, www.fitlihtraining.com). These instruments each consist of a 2-dimensional panel or setup with an array of illuminated buttons. The athlete is required to press a randomly lit button as rapidly as possible with one hand, then another button is lit in a random position on the instrument and the reaction-time reflex cycle is repeated for an established period [31].

In addition to visual performance assessment, a variety of computerized training programs are also available on the Senaptec Sensory Station (http://senaptec.com) and Vizual Edge Performance Trainer (http://vizualedge.com).

Also exist the training platform of CogniSense NeuroTracker (http://neurotracker.net) entails an immersive 3-dimensional multiple object tracking program to increase cognitive load. This approach has been studied at various ages, and has been correlated with actual game performance in professional basketball players and soccer players [32-36]. Based on the same fundamentals of multiple object tracking was developed the NeuroTrainer (http://neurotrainer.com), in which athletes are given a series of dual tasks that simultaneously challenge attention and peripheral vision [31].

Figure 2: DynaVision 2.0 device.

Other way to train vision and attention for sports is to practice and train in suboptimal conditions, and this general strategy is often employed; baseball players take warm-up swings with weights on their bats, runners train in high altitudes to perform better in low altitudes, and swimmers practice with weights on their ankles during practice. Moreover, many training regimens are designed on the premise that training in extreme and restrictive conditions can produce enhanced performance (e.g. over speed treadmill training, resistance throwing cord training, and stretch shortening cycle work such as box jumps prior to competition in the long jump). Here sport vision specialist can apply this same logic to the training of vision and attention, through the use of or stroboscopic vision [37]. The most common device used for stroboscopic athletic training has been the Nike Vapor Strobe (Nike Inc, Beaverton, OR) eyewear. However, it has been discontinued. Similar devices are available from Senaptec eyewear (http://senaptec.com) and VisionUp strobe glasses (Appreciate Co, Lta, Kyoto, Japan), that also allow control of transition frequency and ratio of image. The products all use battery-powered liquid crystal liftered lenses that alternate between transparent and opaque states. Studies involving stroboscopic training suggest that it can enhance accuracy, consistency and visual memory; improved abilities to detect subtle motion cues and identify briefly presented stimuli; also reduces errors in antecipatory timing, and decrease reaction time [38-42]. Mitroff report an18% improvement in on-ice skill performance from pre-training to pos-training, whereas the control group´s performance did not improve [43].

Conclusion

The role of visual performance factors in sports has received a fair amount of attention over the years, but many athletes still have limited access to evaluation and enhancement approaches. Competitive athletes are continuously searching for ways to elevate their performance in their sport. Most of the focus is on the development of requisite physical abilities, such as strength, speed, agility, and endurance. The other major focus is on skill development for specific sport applications, often requiring significant repetition with feedback about optimal biomechanics. Depending on the sport, athletes also may work on the psychological issues that can impele or enhance performance. This article highlighted the existing options on the market to help vision professionals and athletes to increase sports performance through the use of sensory vision methods, based on previous scientific evidence.

The first step is the assessment of primary and secondary visual performance abilities inherent and fundamental in visual demands and sport that the athlete practices. Consultations and offices must be adapted when assessing an athlete's vision, due to the characteristics inherent to their condition, and perform techniques adapted to the demands of sport, making associations between vision and sports techniques. Athletes have better physical, motor and visual abilities than non-athletes; and these skills are amenable to training and improvement through visual sports training. So finally, SVT aproaches provide another opportunity for the athlete to enhance vision and visual performance factors that are importante for their sport. In most sports, vision is critical element for sucessful performance.

Conflit of Interest

The author claims any comercial interest in any brando of devices mentioned, or is, in any way related to the manufacture ror distributor of these or any other brando f products of this type.

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