INTERDISCIPLINARY RESEARCH ON COGNITIVE PROCESSES

Science Review
UDC 159.91
https://doi.org/10.21702/rpj.2024.1.2

# Using the Mobile Eye-tracking System in Sports

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## Abstract

**Introduction.** The study of the oculomotor activity of athletes is of interest to sports psychologists and sports training specialists. Oculomotor activity is an integral part of sports activity, and its training and optimization with the development of effective oculomotor strategies can contribute to the improvement of both sports performance and the health and functional state of the athlete. **Theoretical justification.** Research on athletes' oculomotor activity considers its various aspects, including visual search, the difference between eye movements of professionals and beginners. It also considers the relationship between effective oculomotor strategies and athletic performance success. Due to technology development, mobile eye-tracking technology has emerged that can be utilized in real-life sports activities. Mobile eye-tracking provides high ecological validity of research, combination with psychophysiological methods and virtual reality. The disadvantages of the mobile eye-tracking system include low, compared to stationary systems, measurement accuracy and the possibility of recording only macromovements of the eyes (fixations and saccades). **Discussion.** As a result of the theoretical analysis, the relevance and significance of studying athletes' oculomotor patterns have been outlined. In addition, the possibilities of using mobile eye-tracking in sports for these purposes to analyze athletes' oculomotor patterns have been described. Researchers may encounter problems when using mobile eye-tracking systems to record athletes' oculomotor patterns are highlighted. In particular, loss of eye-tracking data, difficulties selecting an optimal algorithm for data analysis, and ambiguity in interpreting the obtained information. In spite of the described problems, mobile eye-tracking systems represent an optimal means of recording eye movements in athletes for the purpose of further optimizing training and performance.

**Keywords**

sport psychology, eye-tracking, eye movement registration, eye macromovements, saccades, fixations, sport eye-tracking

**Funding**

The research was supported by RSF grant No. 19-78-10134

**For citation**

Yakushina, A. A., Bulaeva, N. I., Leonov, S. V., Polikanova, I. S., Klimenko, V. A. (2024). Peculiarities of using the mobile eye-tracking system in sports. *Russian Psychological Journal, 21*(1), 34–46. https://doi.org/10.21702/rpj.2024.1.2

## Introduction

Vision plays a major role at all stages of athletes' activity. During education and training, the athlete assimilates information visually provided by the coach (Gorovaya, Korobeinikova, 2013). During training, the ability to quickly analyze the sport situation and make optimal technical and tactical decisions based on the available visual information is improved (Hüttermann, Noël & Memmert, 2018; Brams et al., 2019). During motor skill development, visual information is essential for movement control and adjustment (Piras, Raffi, Lanzoni, Persiani & Squatrito, 2015). With experience, the athlete can anticipate events in a time-pressured situation based on available visual information (Kredel, Vater, Klostermann & Hossner, 2017). The athlete's tactical decision making in a sports situation is dependent on information received from sensory systems, and most often the vision system is the leading one (Hüttermann et al., 2018).

For many years, vision in sports has been studied from the perspective of various sciences, including ophthalmology, psychology, physiology, and biomechanics (Blinnikova & Ishmuratova, 2021; Menshikova & Pichugina, 2021; Pronina, Grigoryan & Kaplan, 2018; Smirnova, 2022). The undoubted importance of vision as a sensory system for the athlete was noted, but on the other hand, many studies were private, scattered, and isolated (Tambovsky, 2003). Scientific papers on eye-tracking technologies in sport appeared in the 1980s. Since then, many studies have been conducted on athletes' oculomotor activity using different eye-tracking technologies. These studies have examined aspects of oculomotor activity such as visual attention, oculomotor search, decision making based on visual information, the difference between eye movements of professionals and non-professionals, and the relationship between effective oculomotor strategies and athletic success (Mann, Williams, Ward & Janelle, 2007; Hüttermann, Noël & Memmert, 2018; Kredel, Vater, Klostermann & Hossner, 2017).

In Russian sports science, the need for a comprehensive approach to the study of the visual system in sports was stated in the nineties of the last century. This was when the foundations of sports ophthalmology direction in the system of training athletes were laid. In this connection, a system of analysis and optimization of athletes' oculomotor patterns was developed to improve technical and tactical skills (Tambovsky, 2003). The first attempts to clarify the nature of the athlete's vision revealed visuokinematic pictures of the sports situation (VKKSS), which are certain trajectories of the athlete's eye movements during visual perception of the picture of the sports situation. VKSSS is formed by the coordinated work of the eye and ciliary muscles. It depends on the type of sport, the athlete's fitness level, psychological state, experience, role, level and peculiarities of thinking. However, the VKSSS parameters are often far from optimal, which entails many mistakes made by the athlete. The reason for this can be explained by the intuitive nature of VKKSS formation, as well as the lack of knowledge in this area by both the coach and his pupils (Tambovsky, 2003).

Training athletes in the optimal oculomotor strategy (optimal visokinematics) during the performance of sports activities leads to reduction of fatigue of the visual system, to increase the efficiency of technical and tactical actions, and to increase the speed and efficiency of tactical thinking of athletes (Tambovsky, 2003; Jin & Tambovsky, 2017; Polikanova, Leonov, Yakushina, Chertopolokhov & Isaev, 2022). With the growth of sportsmanship of an athlete (with all the variability of sports situations), the formation of several (from 2 to 5 variants) stable visokinematic pictures of a sports situation is observed. It is critical to note that the effectiveness of such training will be higher if it takes place in natural, dynamic sports conditions. In this regard, it is especially relevant to use modern eye-tracking systems, which register eye movement data under real training conditions.

Thus, the main **aim of this review** was to study the advantages and disadvantages of using modern eye-tracking systems to analyze athletes' oculomotor patterns.

## Theoretical Justification

### *Use of modern eye-tracking systems in sports*

Modern eye-tracking systems provide opportunities for studying athletes' oculomotor activity while performing sports activities (Grushko & Leonov, 2013; Espino Palma et al., 2023; Sáenz-Moncaleano, Basevitch & Tenenbaum, 2018; Menshikova, Kovalev, Klimova & Barabanschikova, 2017). Mobile eye-trackers, which have advantages over stationary ones and allow natural studies, have found wide applications in the field of sports training.

The operation of modern non-contact mobile, i.e. head-worn, eye-tracking systems, is based on a methodology based on the principle of video registration of eye movements in the infrared radiation range and determination of gaze direction by the vector of displacement between the centers of the pupil and corneal glare (Barabanshchikov & Zhegallo, 2014).

Mobile eye-tracking systems used to investigate athletes' oculomotor activity can be categorized into two types:

1. Eye-tracking systems worn on the subject's head (usually in the form of goggles or caps). They consist of a mini-video camera that records the actual situation in front of the subject and an infrared light source.
2. Eye-tracking systems embedded in virtual reality helmets (Leonov, Polikanova, Bulaeva & Klimenko, 2020). In virtual reality helmets, an eye-tracking module usually consists of cameras and a light source placed in a ring-shaped structure between the user's eyes and the display. Algorithms interpret the cameras' data and generate a real-time stream of eye-tracking data (such as pupil size, gaze vector, and eye openness).

## *Opportunities of mobile eye-tracking systems*

The reasons for choosing mobile eye-tracking systems for sports research are related to their capabilities and advantages over fixed systems.

Thus, mobile eye-tracking systems allow a high degree of ecological validity of the experiment: they make the conditions of the experiment close to the conditions of the studied sports activity (Tambovsky, 2003; Barabantschikov & Zhegallo, 2014; Gorovaya & Korobeinikova, 2013). Also, mobile eye-tracking systems (especially glasses) have minimal impact on the studied athlete's activity and on the recorded oculomotor activity parameters. During sport-specific tasks, the subject should be able to move freely in space, including head movement, which is possible only using mobile eye-tracking systems (Tambovsky, 2003). The obtained eye-tracking data make it possible to analyze and compare the peculiarities of oculomotor activity of athletes of different sports and skill levels (Leonov & Grushko, 2015). For example, based on the data recorded using an eye-tracking system, characteristic patterns of eye movements in professional baseball players have been identified (Houze, Spaniol & Paulison, 2023), identified differences in the number and location of fixations among volleyball players of different skill levels (Afonso, Garganta, McRobert, Williams & Mesquita, 2012), and noted a variety of gaze fixation points in soccer players depending on the phase of play (Aksum, Magnaguagno, Bjørndal & Jordet, 2020). The obtained data allow the optimization of oculomotor activity to reduce fatigue of the visual system, increase the efficiency of technical actions and improve tactical thinking in athletes (Tambovsky, 2003; McGuckian, Cole, Jordet, Chalkley & Pepping, 2018; Kredel et al., 2017; Martell & Vickers, 2004).

Thanks to mobile systems of eye-tracking, fixation of athletes' oculomotor activity can be combined with registration of various psychophysiological indicators, including electroencephalography, skin-galvanic response, heart rate measurement by biofeedback, stability of the vestibular system (Anisimov, Ermachenko, Ermachenko, Tereshchenko, Latanov, 2012; Ermachenko, Ermachenko, Latanov, 2011; Isaev, Isaichev, 2015; Calabrò et al., 2017; Janelle, Hillman & Apparies, 2000; Fujiwara et al., 2009; Mann, Coombes, Mousseau & Janelle, 2011; Barfoot, Casey & Callaway, 2012). In addition, mobile eye-tracking systems can be used in virtual reality research (Menshikova, Kovalev & Klimova, 2014; Pastel et al., 2020; Wirth et al., 2021; Heilmann & Witte, 2021) and tracking human movements in space (Helsen & Starkes, 1999; Kishita, Ueda & Kashino, 2020).

### *Limitations of mobile eye-tracking systems*

However, despite the many advantages of using a mobile eye-tracking system in sports practice, limitations can also be highlighted.

Thus, in studies using mobile eye-tracking systems, oculomotor activity is analyzed by such indicators as fixations and saccades, i.e., eye macromovements (Piras, Lobietti & Squatrito, 2010; Di Russo, Pitzalis & Spinelli, 2003; Aoyama et al., 2022). This is due to the fact that mobile eye-tracking systems have certain limitations and experiments are conducted under conditions that approximate real-world conditions. The study of eye micromovements (tremor, drift, microsaccades) is possible only in stationary conditions, in the laboratory, where the subject's head is rigidly fixed during the experiment, and the equipment has a high frequency and accuracy of eye position registration. In addition, mobile eye-tracking systems have low temporal and spatial resolutions compared to stationary systems. The data obtained with a mobile eye-tracking system allows analysis of oculomotor activity only at the fixation sequence level.

It is also worth noting that mobile eye-tracking systems have low, compared to stationary systems, measurement accuracy, temporal (registration frequency) and spatial resolution capabilities declared by the manufacturer. Mobile eye-tracking systems register video at 30–60 Hz (fixed systems – 500–1250 Hz). Most modern eye-trackers have an accuracy of about 0.5–1 angular degrees (stationary systems – 0.25 – 0.5 angular degrees) (Barabantshchikov & Zhegallo, 2014).

In addition, the quality and stability of eye movement registration depend on various factors: room illumination, makeup, wearing glasses (Barabanshchikov & Zhegallo, 2014; Holmqvist, Nyström & Mulvey, 2012), as well as individual facial features (e.g., thick eyelashes or large brow arches (Turitsyn, Anokhin, Volovod, Gerasimchuk, Mashkovtseva, 2016). The quality of data received from eye-tracking systems embedded in a virtual reality helmet can be affected by motion sickness (vertigo), neck muscle fatigue from the helmet, visual focus-accommodation conflict, loss of focus, and fogging of helmet screens (Clay, 2019; Holmqvist et al. 2012).

## Discussion

To minimize the above-mentioned disadvantages and to improve the quality of recording oculomotor patterns of athletes at the stage of preparation and carrying out eye movement registration, it is necessary to calibrate the eye-tracker before each measurement, to set the position of trackers relative to the eyes correctly and to monitor the stability of the position of the participant in the experiment.

However, difficulties may arise not only at the stage of eye-tracking data registration, but also when analyzing them.

### *Problems arising at the stage of acquisition of eye-tracking data, and ways to solve them*

#### *Problem with loss of eye-tracking data*

As a result of the subject's blinking or due to the failure of the algorithm for pupil and corneal glare detection, skips of eye-tracking values may occur, i.e. frames with undefined eye position and unspecified gaze direction. In this case, all eye-related fields (gaze coordinates, pupil sizes, etc.) are filled with zeros. Missing values can affect the fixation detection algorithm by breaking one large fixation into separate shorter fixations. Various methods that include mathematical and empirical data recovery algorithms can be applied to solve this problem (Turitsyn et al., 2016). Also, an eye-tracker can lose sight of one of the two eyes and data is written from only one eye. If the binocular disparity is small, it is acceptable to fill in the gaps with data from the registered eye (Turitsyn et al., 2016).

#### *Selection of the algorithm and thresholds for detection of the sought events (fixations, saccades)*

The choice of an algorithm for detecting events (fixations and saccades) is a crucial consideration when analyzing raw eye-tracking data, as different algorithms based on the same data may produce different results (Salvucci & Goldberg, 2000). In addition, the choice of threshold values of the values used by a particular algorithm also affects the sensitivity and the results of the algorithm (Llanes-Jurado, Marín-Morales, Guixeres & Alcañiz, 2020).

The analysis of fixations and saccades requires preliminary separation of fixations as moments of visual information processing (and, accordingly, saccades between them as moments of rapid gaze movement when no information processing occurs) from the raw data set (Veraksa, Korobeinikova, Leonov & Rasskazova, 2016; Grushko, 2017). This approach allows us to simplify the analysis of eye-tracking data by highlighting their main characteristics, on the basis of which oculomotor behavior can be analyzed (Salvucci & Goldberg, 2000). The choice of specific thresholds depends directly on the goals and objectives of the study and the nature of the activity being studied (e.g., values for reading or looking at pictures will be one, while those for detecting and responding to a rapidly moving object will be different) (Widdel, 1984, Rayner, 1998).

### *Problem of interpreting received information about oculomotor activity*

Additional information is needed to correctly interpret the subject's oculomotor activity data. Not always the delay of gaze in the direction of an object indicates fixation of attention on this object. Saccades may be caused not by a visual stimulus, but by an auditory stimulus, etc. Interviewing the subject, videotaping the experiment, and collecting statistics can provide additional information for the experimenter.

It is necessary to study oculomotor activity at a higher level – the level of integral structures, patterns, which are determined not only by the objective characteristics of external stimuli, but also by the characteristics of the subject of perception himself (his past experience, intentions, peculiarities of the oculomotor system, etc.). This is due to the fact that quite often studies use such an indicator as the number of fixations in the selected area, which is associated with a number of cognitive aspects and can be interpreted in different ways: the number of fixations can indicate 1) the semantic significance of the image area, 2) the level of complexity of the search task, 3) the presence of experience in solving such tasks, and even 4) the presence of a number of psychiatric and neurophysiological diseases.

To improve the system of eye-tracking in sports, it is necessary to describe in detail the procedure of conducting the study: equipment specification, algorithm, threshold values, criteria for excluding data from the analysis, approach to processing omissions ("zero" values), the percentage of rejected eye-tracking data, detailed interpretations of the obtained data, taking into account the specifics of the conducted experiment and the characteristics of the sample.

### ***Conclusion***

Despite some limitations of mobile eye-tracking systems in sports, gaze tracking seems to be a possible method for investigating athletes' gaze behavior, provided it is used in a meaningful and correct way. In particular, working with mobile eye-tracking systems is a promising way to analyze cognitive aspects of athletes' professional performance and its impact on results. The eye-tracking system allows us to learn about athletes' attention and gaze direction at different stages of sportsmanship formation. This makes it possible to identify characteristic patterns of eye movements for beginners and professionals. This can help improve the technical and tactical components of skill and movement control. Taking these points into account can potentially lead to the development of specific training methods and improve competitive performance.

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Received: September 05, 2023
Revision received: November 28, 2023
Accepted: January 16, 2024

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**Sergey Vladimirovich Leonov** – research methodology, final approval of the article.

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## Conflict of Interest Information

The authors have no conflicts of interest to declare.