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Visual Skills and Athletic Performance: The Role of Vision Training in Sport - A Narrative Review

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Abstract

Background: Visual abilities play an important role in athletic performance by supporting movement execution, perception, and decision-making during competition. Growing interest in perceptual-cognitive factors has increased attention to vision training as a potential method for improving sports performance.

Aim: To review the role of visual abilities in sport, evaluate the effectiveness of vision training methods, and discuss their practical applications.

Material and methods: A narrative review of the literature was conducted using PubMed, Scopus, Web of Science, and Google Scholar. Studies examining visual skills, vision training, and their relationship with sports performance were included.

Results: Elite athletes generally demonstrate better-developed visual and perceptual-cognitive abilities than less experienced performers. Vision training methods, including Quiet Eye training, stroboscopic training, 3D Multiple Object Tracking, and virtual reality-based interventions, may improve selected visual functions. However, evidence for their transfer to competitive sports performance remains inconsistent because of methodological differences between studies.

Conclusions: Vision training may be a useful addition to sport-specific training, although its effectiveness depends on the intervention and sporting context. Further high-quality studies are needed to establish its practical value.

Keywords: vision training; sports vision; athletic performance; visual skills; perceptual-cognitive skills; sport performance.

1. Introduction

Vision is one of the most important sensory systems involved in achieving high athletic performance. During training, athletes constantly receive and process visual information, which supports movement control, spatial orientation, anticipation, and decision-making. In many sports, success depends not only on physical fitness and technical skills but also on the ability to effectively perceive and respond to rapidly changing visual stimuli ^{1,2}.

For many years, visual performance in sports was primarily associated with static visual acuity. However, modern research indicates that athletic success depends on a much broader range of visual abilities. These include dynamic visual acuity, peripheral vision, depth perception, visual tracking, visual reaction time, and hand-eye coordination ². These skills enable athletes to identify relevant visual stimuli, track moving objects, judge distances, and adapt motor responses under time pressure. Their importance varies depending on the specific sport. For example, dynamic visual acuity is particularly important in sports requiring the tracking of fast-moving objects, while peripheral awareness and visual scanning are crucial in team sports, where constant monitoring of partners and opponents is necessary ^{3,4}.

Numerous studies have demonstrated differences in visual performance between athletes and non-athletes. High-level athletes often performed better on tasks assessing motion perception, reaction time, peripheral awareness, and hand-eye coordination ⁵. These results suggest that visual abilities develop as a result of long-term participation in sports.

The growing interest in vision in sports has led to the development of various visual training methods aimed at improving perceptual and visual-motor skills. The most commonly used methods include stroboscopic training, quiet eye training, multi-object tracking exercises, and virtual reality programs. These interventions are designed to stimulate the visual system and increase information processing efficiency during the performance of tasks specific to a given sport ^{2,6}.

Despite the growing popularity of vision training, its effectiveness remains a matter of debate. While some studies have demonstrated improvements in visual abilities and selected parameters related to athletic performance following the use of vision training programs, others indicate limited or inconsistent effects of such interventions ⁷. Additionally, significant differences exist in training protocols, outcome assessment methods, and research designs, making it difficult to formulate clear, evidence-based recommendations. Therefore, questions remain about which visual abilities are most important for athletic performance and whether improvements in laboratory vision tests translate into actual benefits during athletic competition ^{7,8}.

The aim of this review is to analyze the role of visual abilities in achieving sports performance, discuss the most commonly used visual training methods, and assess the current scientific evidence regarding their effectiveness in modern sports.

2. Research results

2.1. Key Visual Skills Associated with Athletic Performance

Efficient processing of visual information is one of the factors supporting an athlete's effective performance during competition. During both training and competition, athletes must constantly analyze changing environmental conditions, identify important visual stimuli, and make quick and appropriate motor decisions based on these cues.

One of the visual functions most frequently discussed in the literature is dynamic visual acuity (DVA). It is responsible for recognizing and identifying details of a moving object. Unlike traditional visual acuity tests, which assess vision using stationary stimuli, DVA reflects visual performance under conditions more similar to real-world sports situations ⁹. Athletes in sports such as tennis, baseball, cricket, and table tennis must constantly track moving objects and accurately assess their trajectory, speed, and direction. A limited ability to perceive moving objects can delay motor responses and negatively impact performance during competition ¹⁰. Previous studies have shown that elite athletes often achieve better dynamic visual acuity than untrained individuals, suggesting a relationship between this ability and the level of athletic advancement ¹¹.

Another visual ability often associated with effective performance in sports is peripheral vision. While central vision allows for detailed observation of a specific object, peripheral vision allows for the detection and interpretation of information appearing beyond the direct line of sight. This skill is particularly valuable in team sports, where players must simultaneously monitor the position of teammates, opponents, and available space without losing focus on the ball or another key object. For example, a football player receiving a pass can use peripheral vision to assess defenders' positioning without having to look away from the ball. Well-developed peripheral awareness can support tactical decision-making and shorten reaction times in dynamic match situations ¹².

Perception and stereoscopic vision are also crucial aspects of visual functioning in sports. They enable accurate assessment of distance and spatial relationships between objects. This allows athletes to determine an object's location and predict its movement relative to their own position. This information is crucial when performing activities such as catching a ball, passing, intercepting an opponent, or striking a moving target. In highly dynamic disciplines, even small errors in distance estimation can affect movement timing and the quality of technical execution. Therefore, stereoscopic vision and depth perception are often included in the assessment of athletes' visual abilities and are considered important components of visual-motor skills ¹³.

Another element closely linked to athletic performance is reaction time. In many sports situations, athletes must react almost immediately upon noticing a visual stimulus. The time between recognizing relevant information and initiating the appropriate motor response can be crucial to their success. Research indicates that trained athletes often achieve better reaction times than untrained individuals. This is particularly noticeable in disciplines requiring rapid changes in the situation and high perceptual abilities. A shorter reaction time can facilitate faster decision-making and more effective responses to unexpected events during competition ¹⁴.

In addition to the functions mentioned above, eye-hand coordination and visual tracking also play a crucial role in many sports. Eye-hand coordination refers to the ability to transform visual information into precise and controlled motor actions. This process is essential when passing, catching, throwing, or striking the ball. Visual tracking, in turn, enables the continuous observation of moving objects and the updating of information regarding their speed, direction, and trajectory. Together, these abilities contribute to greater precision in movements and better anticipation of events occurring during the game. They are particularly important in racket sports, team sports, and combat sports, where athletes must react to rapidly moving objects and opponents ^{8,15}.

Studies comparing athletes of different levels of advancement indicate that elite athletes achieve better results in terms of dynamic visual acuity, movement perception, reaction time and eye-hand coordination than amateurs and untrained individuals. However, it is not clear whether this advantage results from many years of sports training or whether people with better developed visual abilities have greater predispositions to achieve high sports results ¹¹.

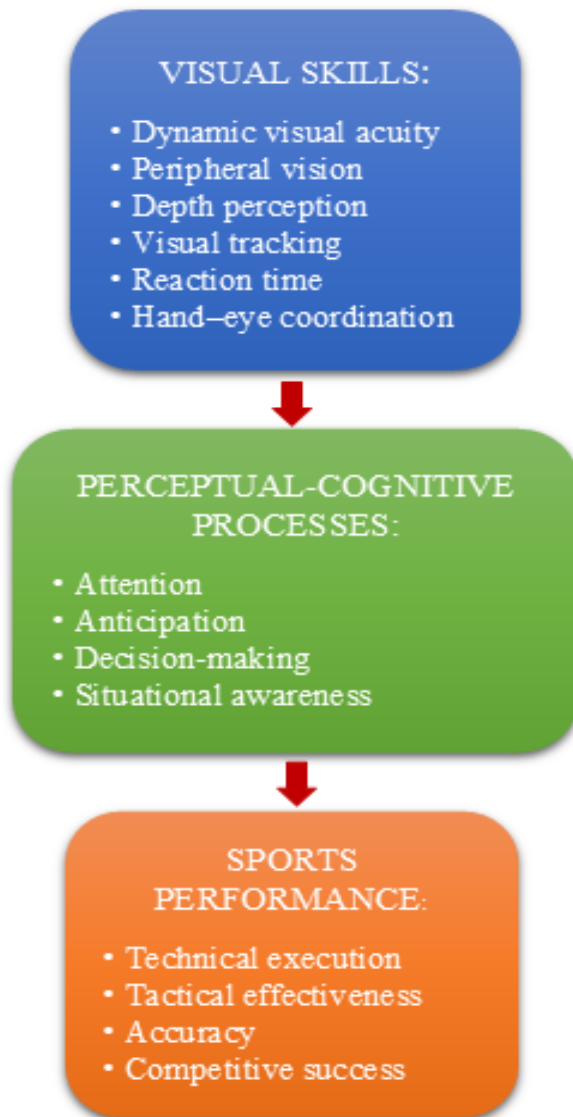


Figure 1. Conceptual relationship between visual skills, perceptual-cognitive processes, and sports performance. Source: Authors' own elaboration based on the reviewed literature.

2.2. Evidence for Vision Training Intervention

The growing body of research demonstrating a link between visual abilities and athletic performance has prompted researchers and practitioners to investigate whether these skills can be developed through targeted training programs. Although training protocols vary significantly across studies, most interventions focus on increasing the efficiency with which athletes perceive, interpret and utilize visual information presented during athletic competition.

One of the most frequently described visual training methods is stroboscopic training. It uses special glasses that periodically limit visual stimuli by periodically darkening the field of view. In such conditions, the athlete performs standard exercises specific to their sport, such as receiving the ball, making passes, or reacting to an opponent's movement. Because the image is not continuously available, the athlete must rely more on predicting the next course of action and quickly processing available information. Previous research suggests that stroboscopic training can contribute to improving reaction time, visual attention, and selected sporting skills, but the results are not entirely uniform across all disciplines ^{7,16}.

Quiet Eye training is also gaining significant popularity. Unlike many other methods, it focuses not on training the eyes themselves, but on how visual attention is directed during a motor task. This training is based on extending the final visual fixation on the most important element of the task before initiating movement. For example, a basketball player shooting a free throw maintains their gaze on the rim for a specified period before taking the shot, instead of repeatedly shifting their gaze between the ball, the basket, and the surroundings. Similar strategies are also used in golf, archery, and target shooting. Numerous studies indicate that maintaining a steady gaze on the target can promote better concentration, more accurate movement execution, and more effective decision-making in situations requiring high precision ^{17,18}.

In addition to stroboscopic and Quiet Eye training, researchers have also focused on methods utilizing digital technologies. One such method is 3D Multiple Object Tracking (3D-MOT) training, also known as NeuroTracker. This method involves simultaneously tracking several moving objects displayed on a three-dimensional screen. During training, the athlete observes a group of identical objects, some of which are initially designated as tracking targets. Then, all the objects move simultaneously in different directions, and the athlete's task is to identify the tracked objects after completing the test. This exercise engages visual attention, working memory, and the ability to process multiple information simultaneously. According to available research, regular 3D-MOT training can improve decision-making speed and the ability to monitor multiple stimuli simultaneously, which may be particularly important in team sports ^{19,20}.

Virtual reality (VR) also holds a significant place among contemporary visual training methods. Its main advantage is the ability to create environments resembling real-world sporting situations while maintaining full control over the training process. Athletes can

perform tasks requiring decision-making, tracking objects, and reacting to opponents' actions without having to be on the field or training room. For example, players can repeatedly practice reacting to specific match situations that rarely occur during standard training. Available research suggests that VR-based training can support the development of perceptual and cognitive skills and serve as a valuable complement to traditional training methods, although the number of high-quality studies remains limited ^{21–23}.

Despite the differences between the methods described, their common goal is to improve how athletes perceive, analyze, and utilize visual information. However, research findings to date remain ambiguous. Some authors observed improvements in selected visual abilities and athletic performance parameters, while other studies indicated minor or short-lived effects.

2.3. Transfer of Vision Training to Sports Performance

The ultimate goal of visual training is not solely the development of visual functions, but primarily the translation of these effects into the athlete's performance during competition. Therefore, researchers are increasingly focusing on the concept of transfer. It is defined as the degree to which the effects achieved during training translate into athletic performance. In the literature, near transfer and far transfer are most commonly distinguished. Near transfer refers to improved performance in tasks similar to those performed during training, while far transfer refers to improved actual athletic performance during training or competition. Although the evidence supporting the occurrence of near transfer is relatively strong, the existence and extent of far transfer remains a matter of debate ⁸.

Most studies on visual training indicate positive changes in laboratory measures of visual and perceptual-cognitive functioning. Athletes participating in visual training programs often perform better on tests assessing reaction time, motion perception, visual attention, visual tracking, and eye-hand coordination. These results suggest that visual skills can be developed with appropriate interventions, and many of the skills discussed in previous chapters are amenable to training ^{8,15}.

From a practical perspective, however, a more important question is whether improving these skills influences a player's behavior in situations specific to a given sport. Supporting evidence has been found for several training methods. One of the most frequently cited examples is 3D Multiple Object Tracking (3D-MOT). In a study of soccer players, players participating in the 3D-MOT program demonstrated greater accuracy in passing decisions

compared to a control group ²⁰. In team sports, where the athlete must simultaneously observe partners, opponents and the course of the action, more efficient processing of visual information can facilitate making accurate tactical decisions.

Positive results have also been obtained in studies involving Quiet Eye Training. This method is based on optimizing visual behavior immediately before making a move. In a study conducted among golfers, a two-week Quiet Eye Training program led to improved putting performance in pressure situations and increased visual fixation time on the target.. Similar observations have been previously reported in basketball and shooting sports. These results indicate that gaze control can influence both movement precision and performance in situations requiring rapid assessment ^{17,18,24}.

Evidence supporting transfer has also been reported with stroboscopic training. By periodically restricting visual information through specialized eyewear, athletes are forced to process incomplete information and rely more on anticipation. In several studies, this method has been associated with improvements in reaction time, visual processing efficiency, and selected sporting skills ⁷. Although the exact mechanisms responsible for these effects have not yet been fully elucidated, it is hypothesized that repeated exposure to intermittent visual stimuli may enhance the ability to predict movement patterns and respond more effectively to dynamically changing situations.

Despite these favorable results, the overall magnitude of training effects appears modest. One recent meta-analysis, encompassing 27 studies and 669 athletes, demonstrated a positive effect of visual training on decision-making and selected performance indicators. However, the observed effects varied significantly across sports disciplines and training methods. The authors emphasized that interventions that most closely resembled real-world sporting situations produced better results than isolated visual training exercises performed in a laboratory setting. This suggests that training that is as close as possible to real-world competition conditions yields the greatest benefits ²⁵.

However, not all researchers agree that improving visual function automatically leads to significant improvements in athletic performance. Controversy regarding the effectiveness of visual training centers primarily on the issue of long-range transfer. One study noted that many training programs effectively improve performance in perceptual and cognitive tasks, but evidence confirming the translation of these effects into actual athletic performance remains limited. The study's author emphasized that numerous technologies used in sports are based on

the assumption of long-range transfer, even though the available scientific data do not clearly confirm such a relationship ²⁶.

This position, however, has been criticized. Another study indicated that while the evidence is still limited, this does not mean that visual training is completely ineffective. The authors emphasized that some studies demonstrated improvements in selected elements of athletic performance, particularly when the exercises used were closely related to the demands of a specific discipline ²⁷. This dispute shows that the current discussion is no longer about whether visual training affects perceptual functions, but rather about the extent to which these effects can translate into performance during sports competition.

Training method	Evidence for improvement in visual skills	Evidence for improvement in sports performance
Quiet Eye	Strong	Moderate to strong
Stroboscopic	Moderate	Limited
3D-MOT	Moderate	Limited to moderate
VR-based training	Emerging	Emerging
Eye-tracking-based interventions	Emerging	Insufficient

Table 1. Summary of evidence regarding vision training effectiveness. Source: Authors' own elaboration based on the reviewed literature

3. Discussion

3.1. Practical Applications in Modern Sports

The results presented in this review indicate that visual abilities are an important element of sports performance and can influence both the implementation of technical actions and the decision-making process during sports competition ^{8,15}. At the same time, they do not justify replacing traditional sports training with vision training. Current research suggests that

vision training should be considered a complementary element of athlete development, supporting selected perceptual and cognitive functions that are important for performance ²⁵.

One of the most consistent findings from the literature is that the effectiveness of visual training is largely dependent on its specificity. Training programs that closely mirror the perceptual and decision-making demands of competitive sports appear to yield more significant effects than isolated visual training performed without the context of a given sport. This finding has particular practical significance, as it suggests that visual training should be integrated with existing technical and tactical training rather than functioning as a completely separate form of preparation ^{8,20,25}.

The practical application of visual training can therefore vary depending on the sport. In team sports such as soccer, basketball, or handball, players must constantly monitor the positions of teammates and opponents, the movement of the ball, and the available space, while making quick decisions under time pressure. In such conditions, visual attention and the ability to simultaneously process multiple sources of information become particularly important. Training methods such as 3D Multiple Object Tracking (3D-MOT) can be useful in developing perceptual and cognitive skills that support tactical decision-making during play ²⁰.

Different priorities may exist in sports requiring a high level of precision. In golf, archery, target shooting, and in certain basketball match situations, such as free throws, performance often depends on the athlete's ability to maintain stable visual focus immediately before making a move. Quiet Eye training appears particularly useful in these sports. Research has shown that optimizing visual behavior can improve movement accuracy and support sustained performance under pressure, especially in tasks where small differences in visual focus can impact the final outcome ^{17,24}.

Stroboscopic training can be particularly useful in sports characterized by a dynamically changing visual environment, such as racket sports, baseball, and team sports. By periodically restricting visual information through specialized eyewear, athletes are encouraged to utilize their ability to anticipate and anticipate events. Instead of functioning as a standalone exercise, this type of training can be incorporated into technical drills, allowing them to perform sport-specific tasks under modified perceptual conditions ⁷.

Many authors emphasize that the greatest benefits can be achieved when perceptual training is embedded in sport-specific practice. For example, exercises developing visual tracking can be implemented during small-scale task-based games in soccer, while gaze control

strategies can be incorporated into free throw training in basketball. This approach may increase the likelihood of transferring training effects to situations occurring during actual sports competition ²⁵.

Advances in technology have significantly expanded the possibilities of implementing vision training in sports practice. Virtual reality systems, eye tracking devices, and digital performance analysis tools allow coaches to assess athletes' visual behavior and recreate situations typical of sports competition in controlled conditions ²³. These technologies can support the individualization of training programs and provide objective feedback on athletes' perceptual and cognitive functioning. Similar trends have been discussed in recent publications, which emphasize the growing role of technology-enhanced monitoring and individualized training methods in contemporary athlete development ²⁸.

Despite its potential, vision training should not be considered a one-size-fits-all solution for improving athletic performance. Athletic success is determined by the interaction of many factors, such as physical fitness, technical skill level, tactical preparation, psychological readiness, and competitive experience ²⁹. Therefore, vision training should be viewed as one element of a comprehensive training process, and not as an independent factor determining sporting success ^{8,15}.

3.2. Limitations and Future Directions

Despite the growing popularity of visual training in sports, several significant limitations exist that complicate the interpretation of available scientific evidence. One of the most frequently cited problems is the significant methodological heterogeneity of studies. Interventions used to date vary significantly in terms of training duration, session frequency, participant characteristics, visual skills trained, and outcome measures used ^{8,15}. As a consequence, studies examining completely different training methods are often discussed under the umbrella term “vision training,” which makes direct comparisons of results difficult and limits the ability to make clear evidence-based recommendations.

An additional complication is the lack of a universally accepted definition of visual training. The term currently encompasses a wide range of interventions, such as traditional visual exercises, Quiet Eye training, stroboscopic training, perceptual-cognitive programs, multiple-object tracking tasks, and virtual reality-based methods. Although all of these approaches involve visual processes to some extent, they affect different mechanisms and may

lead to different adaptations. Hadlow et al. emphasized that future research should be based on a more consistent classification system to facilitate comparison of results and synthesis of available evidence ³⁰.

Another significant limitation is the sample size of the study groups. Many intervention studies were conducted on relatively small samples of athletes, often with fewer than 30 participants ^{8,15}. For example, the study by Romeas et al., analyzing the effect of 3D Multiple Object Tracking training on soccer players' performance, included only 32 players ²⁰. Similarly, many studies on Quiet Eye training were based on small groups of athletes representing a single discipline or a specific level of advancement ^{17,24}. These types of research designs limit the statistical power of the analyses and increase the risk that the obtained results will not reflect the effects observed in larger populations of athletes.

Assessing training effectiveness poses another challenge. Most studies use laboratory-based outcome measures such as reaction time, visual attention, visual tracking, or perceptual-cognitive tasks ^{8,31}. While these measurements provide valuable information about the functioning of the visual system, they do not fully capture the complexities of athletic competition. As noted by Broadbent et al., improvements observed in controlled laboratory conditions do not necessarily translate into better performance in competition. This issue is particularly relevant in the context of far transfer, which remains one of the most debated issues in the field ³².

The issue of long-range transfer deserves special attention. Although numerous studies demonstrate improvements in visual function or perceptual-cognitive abilities following training, significantly fewer studies document significant changes in actual sport-specific metrics. Fransen pointed out that many commercial vision training programs are based on the assumption that gains obtained during exercise automatically translate into improved sport performance, despite limited scientific evidence supporting such a relationship. According to this position, improvements achieved in isolated visual tasks should not be considered evidence of improved sport performance unless accompanied by objective, sport-specific performance metrics ²⁶.

An additional limitation is the short duration of most interventions. Many training programs last only four to eight weeks, and the effects are assessed immediately after the training ends ^{8,30}. As a result, little is known about the long-term sustainability of these adaptations. It remains unclear whether the improvements observed immediately after the

program are sustained throughout the entire athletic season, or whether regular training is necessary to maintain these benefits. Longitudinal studies examining the durability of these effects remain relatively rare and should be a priority for future research.

Current knowledge also focuses primarily on adult athletes. Considerably less attention has been paid to adolescent populations, even though perceptual and cognitive abilities continue to develop throughout adolescence ^{19,30}. Understanding the influence of age, biological maturity, and training experience on the effectiveness of visual training may have significant implications for long-term athlete development programs.

Future research should place greater emphasis on the ecological validity of the methods used. Instead of relying solely on isolated laboratory tests, researchers should analyze visual behavior in conditions that more closely resemble real-world athletic competition ^{32,33}. Advances in eye-tracking technology now enable detailed analysis of visual behavior during sport-specific tasks, while wearable sensors enable data collection in real-world training and match conditions. This approach can provide more reliable information on the true impact of visual abilities on athletic performance.

Technological advancements will likely play an increasingly important role in this area. Virtual reality platforms enable the creation of realistic, yet tightly controlled training environments where athletes can repeatedly experience situations specific to their sport without disrupting their standard training process ³⁴. Recent reviews indicate that VR-based interventions may be particularly useful in developing anticipation, decision-making and visual attention in dynamic sporting situations ^{23,34}. Similarly, the integration of artificial intelligence and wearable technologies can support the creation of personalized training programs and enable continuous monitoring of perceptual and cognitive functions ^{28,35}.

Another promising research direction is the identification of sport-specific visual profiles. Previous studies have shown that highly skilled athletes often employ different gaze strategies and visual field search patterns than less experienced athletes ^{33,36}.

In summary, the available literature suggests that visual training can improve selected perceptual and cognitive skills; however, significant methodological limitations still prevent drawing firm conclusions regarding its effectiveness. Future research should focus on larger participant groups, standardized intervention protocols, longer follow-up periods, and the use of sport-specific outcome measures. Wider use of eye tracking, virtual reality, wearable

technologies, and artificial intelligence may help narrow the gap between laboratory findings and actual athletic performance.

4. Conclusion

The growing interest in vision training reflects a broader shift in sports science toward viewing athletic performance as a result of the interplay of physical, technical, cognitive, and perceptual factors. The research reviewed in this paper indicates that visual abilities should not be considered in isolation from other elements of athletic preparation, but rather as part of a complex system supporting decision-making and movement execution during athletic competition^{8,15}.

Although numerous studies have demonstrated improvements in selected visual and perceptual-cognitive functions following various forms of training, the practical significance of these changes remains a matter of debate. The available literature suggests that the greatest benefits are observed when training tasks closely reflect the perceptual demands of a given sport and are integrated with technical and tactical preparation, rather than functioning as standalone exercises^{25,32}.

At the same time, contemporary research highlights a significant discrepancy between improvements in laboratory performance and actual improvements in athletic performance. This issue remains a key challenge for future research and partially explains the ambiguous results regarding the effectiveness of visual training in competitive sports^{26,30}.

Rather than focusing on whether visual training works in general, future research should focus on determining which methods are effective, for which groups of athletes, and under what conditions they yield the greatest benefits. Developments in technologies such as eye-tracking, virtual reality, artificial intelligence, and wearable devices can support this process by enabling more precise assessment of visual behavior in environments that faithfully replicate real-world sporting situations^{28,35}.

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