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Canada
+15878858911
editorial-office@sciformat.ca

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EYE MOVEMENT AND PERFORMANCE IN PROFESSIONAL SPORT: A NARRATIVE REVIEW

Gabriela Kamińska (Corresponding Author, Email: gabrielakaminska066@gmail.com)

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0005-9454-8927

Szymon Chmiela

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0008-2901-615X

Julia Dzieciol

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0000-1394-2951

Kinga Dzioba

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0002-4549-8810

Julia Sawicka

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0004-0724-7839

Paulina Kisielewska

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0007-2028-1494

Zuzanna Banaś

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0003-9156-0221

Natalia Boltralik

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

Weronika Dmoch

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

ORCID ID: 0009-0004-2652-8011

ABSTRACT

Visual information supports anticipation, decision-making, and movement control in professional sport, yet visual performance comprises distinct optical, oculomotor, attentional, and perceptual-cognitive processes. This narrative review evaluated evidence directly linking eye movements or quantitative oculomotor measures with sport-specific performance in professional or international-level athletes. PubMed/MEDLINE, Scopus, and Web of Science were searched for studies published from 2015 to 2025, with backward and forward citation tracking. Eight eligible studies represented association football, Australian Rules football, baseball, cricket, and tennis. In football, more frequent and appropriately timed scanning was associated with a greater probability of successful passing, while in-situ eye tracking indicated that information was often acquired during brief scans without conventionally classified fixations. More successful Australian Rules football decisions were characterized by faster responses, fewer fixations, and greater allocation of viewing time to viable options. In baseball and cricket, smooth-pursuit accuracy, oculomotor timing, fixation stability, and composite visual measures were associated with plate discipline, competitive level, batting, and bowling outcomes. Tennis returners demonstrated individualized but adaptable visual search strategies centered on phase-specific kinematic information. Across sports, the findings support task-specific and context-sensitive gaze control rather than a universal expert pattern. However, the evidence is limited by predominantly observational designs, small male samples, heterogeneous devices and definitions, and limited external validation. Eye-tracking and oculomotor assessment may complement clinical, technical, and tactical evaluation, but training prescription and talent-selection applications require standardized methods, prospective validation, and demonstrated transfer to competition.

KEYWORDS

Eye Tracking, Gaze Behavior, Oculomotor Control, Sports Vision, Professional Athletes, Sport Performance

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Introduction

Vision is fundamental to how athletes identify opportunities for action, anticipate events, and regulate movement in dynamic environments. Professional sport often requires decisions within a few hundred milliseconds, while relevant information is distributed across moving objects, teammates, opponents, and space. Eye movements regulate when and where high-resolution information is acquired and help stabilize perception during movements of the eyes, head, and body. Gaze is therefore not a passive record of what an athlete sees; it is part of an active perception-action system in which information sampling and movement control are continuously coupled (Barbieri & Rodrigues, 2020; Gibson, 1979).

Several related constructs must be distinguished. Visual function refers to sensory and optical capacities such as visual acuity, contrast sensitivity, refractive status, stereopsis, accommodation, and vergence. Oculomotor function concerns the control of fixations, saccades, smooth pursuit, vergence, and gaze-stabilizing responses. Visual attention determines which information is prioritized and may be overt, at the point of gaze, or covert, away from it. Visual search describes the spatial and temporal organization of information sampling, whereas gaze behavior is the observable pattern produced by eye and head movements. Fixation location is therefore an imperfect proxy for attention because an athlete may monitor relevant information peripherally while maintaining central gaze elsewhere (Klostermann et al., 2020).

Foveal vision provides high spatial resolution for detailed cues, whereas peripheral vision is sensitive to motion and spatial relations. Skilled performers often anchor gaze at a useful central location while exploiting surrounding information rather than foveating every object. Consequently, fewer fixations may indicate efficient selection in one task but inadequate exploration in another. Likewise, greater scanning frequency is not inherently advantageous; its value depends on timing, location, and the information available (Klostermann et al., 2020; Kredel et al., 2023).

Saccades rapidly redirect the fovea but require time and are accompanied by reduced visual sensitivity. Smooth pursuit reduces retinal slip when tracking moving targets, although very fast objects can exceed the

velocity range of continuous pursuit. Interceptive athletes therefore combine early pursuit, predictive saccades, head movements, and trajectory estimation. Fixations permit detailed processing, but their measured duration depends on sampling rate and classification algorithm. Vergence aligns the eyes across viewing distances, while vestibulo-ocular responses stabilize gaze during head motion. These mechanisms collectively support exploration, stabilization, prediction, and action.

The quiet eye, usually defined as the final fixation or stable gaze period before the critical phase of movement, has been associated with expertise and performance, particularly in self-paced aiming tasks (Lebeau et al., 2016). It should not be treated as a universal explanation of expert vision. A golf putt, a football reception, a tennis return, and baseball batting have different information demands. Dynamic tasks may require repeated shifts, predictive saccades, and peripheral monitoring before any final stabilization. The relevant issue is whether gaze behavior is functionally matched to the evolving constraints of the task.

Anticipation links visual sampling with rapid decision-making. Athletes combine advance kinematic information, situational probabilities, opponent tendencies, and the current state of play before an outcome is fully visible. The Model of Information Use During Anticipation in Striking Sports proposes that contextual and kinematic information are weighted differently over the course of an unfolding action (Runswick et al., 2020). Active-inference theory similarly describes gaze as sampling that reduces uncertainty and supports action selection (Harris et al., 2022). Expertise therefore involves both efficient visual evidence gathering and effective use of prior knowledge.

The validity of sport-vision research depends on representative design. Laboratory tasks permit accurate stimulus control, but passive observation of images or two-dimensional video may remove movement responses, depth cues, pressure, and information-action coupling. Representative learning design requires preservation of the informational variables and action possibilities that regulate behavior in the target environment (Pinder et al., 2011). Research has consequently shifted toward mobile eye tracking, virtual reality, synchronized motion capture, and integration of gaze with event data. Naturalistic recording, however, introduces calibration drift, head motion, variable illumination, missing data, occlusion, and labor-intensive coding (Kredel et al., 2023).

Pressure and fatigue may further modify gaze. Competitive anxiety can reduce goal-directed attentional control, while physical or mental fatigue may alter fixation stability, response latency, and search behavior. Quiet-eye training has shown some capacity to protect performance under competitive stress, although evidence is stronger for selected aiming tasks than for complex team sports (Vine et al., 2011; Wilson et al., 2009).

From a clinical perspective, refractive error, binocular anomalies, accommodative dysfunction, ocular disease, and clinically meaningful oculomotor deficits should be identified and treated. Nevertheless, normal acuity does not guarantee effective sport-specific information use, and superior performance on an isolated test does not establish that training that test will improve competition outcomes. Sports-vision assessment should begin with a task analysis, use reliable measures corresponding to the sport, and determine whether they explain meaningful performance variance beyond physical, technical, and tactical factors (Erickson, 2021; Laby & Appelbaum, 2021; Lochhead et al., 2024a).

Much sport-vision research has involved children, recreational athletes, collegiate samples, or expert-novice comparisons. Such studies provide mechanistic knowledge but do not directly answer whether visual measures differentiate performance among already highly skilled professionals. The present review therefore synthesizes evidence published from 2015 to 2025 that links eye movements, visual search, scanning, or quantitative oculomotor performance to match statistics, season outcomes, competitive level, validated decisions, or closely coupled practice outcomes in professional or international-level athletes.

The terms professional, elite, and expert are also not exact synonyms. Professional status may derive from employment, elite status from competition at the highest national or international tier, and expertise from accumulated knowledge and consistently superior performance. The included studies use these labels differently, ranging from English Premier League and Major League Baseball players to national-level tennis competitors. This heterogeneity should be considered when findings are compared across sports.

Methodology

This study was designed as a structured narrative review. Reporting was informed by the principles of the Scale for the Assessment of Narrative Review Articles, particularly the explicit presentation of the review question, search approach, scientific reasoning, and relevant outcome data (Baethge et al., 2019). Because the aim was an interpretive synthesis of heterogeneous observational and applied studies rather than a systematic estimate of a common intervention effect, the review was not registered and no meta-analysis was planned.

Searches were conducted in PubMed/MEDLINE, Scopus, and Web of Science and were supplemented by backward and forward citation tracking of key publications and relevant review articles. Eligibility was restricted to studies published between January 2015 and December 2025. Search concepts covered four domains: athletes and competitive level; vision and eye movement; perceptual-cognitive behavior; and performance. The main combinations included athlete*, player*, professional, elite, international-level, eye movement*, eye tracking, gaze, fixation*, saccad*, smooth pursuit, oculomotor, visual search, visual attention, scanning, peripheral vision, quiet eye, anticipation, decision making, performance, match statistics, season statistics, and key performance indicators. Boolean operators and database-specific field tags were adapted for each database.

The target population comprised professional or elite athletes. Professional athletes were defined as players contracted to a professional league or organization. Elite athletes were defined as senior international competitors or athletes competing at the highest national level when the sport did not operate through a conventional professional league. Studies containing mixed groups were eligible when data for the professional or elite subgroup were reported separately or when the study directly compared that subgroup with lower-level athletes or non-athletes.

To be included in the principal results, studies had to assess an eye-movement behavior or quantitative oculomotor variable and report a performance endpoint with clear relevance to the sport. Eligible endpoints included in-game technical outcomes, season statistics, competitive level attained, validated sport-specific decision accuracy, expert-rated tactical performance, or practice outcomes closely coupled to the competitive skill. Observational match analysis, cross-sectional comparisons, predictive cohort analyses, and applied laboratory or field studies were eligible. Studies were excluded if they were limited to recreational or youth samples, reported only clinical or device outcomes without a sport-performance link, evaluated a visual-training intervention without a performance endpoint in a professional cohort, or measured only static visual function without an eye-movement or oculomotor component.

Screening proceeded from titles and abstracts to full-text assessment after duplicate removal. Eight studies met all criteria. Reference details, sample characteristics, outcome definitions, and reported statistics were cross-checked against the full text or publisher record before synthesis.

Data extracted from each included study comprised sport, sample size, competitive level, study design, assessment environment, eye-tracking or oculomotor method, principal visual variables, performance endpoint, and main statistical finding. Methodological appraisal was narrative rather than numerical. Particular consideration was given to sample size, the number and independence of observations, task representativeness, device and sampling characteristics, operational definitions, appropriateness of the performance endpoint, adjustment for contextual variables, and whether predictive models were validated. The findings were grouped by functional domain and sport. Quantitative pooling was not appropriate because the studies differed substantially in exposure variables, fixation definitions, devices, statistical models, and performance outcomes.

Eye-movement variables and performance outcomes were retained using the terminology of the source studies. Potentially misleading terms were clarified; for example, a millisecond outcome was described as target-acquisition time rather than angular eye-movement velocity.

The narrative appraisal also considered whether statistical analyses respected the dependence of repeated observations. Studies based on many possessions, returns, or video scenarios were examined for hierarchical or mixed modeling, because event counts can overstate effective sample size when observations are clustered within a small number of athletes. Findings were interpreted conservatively when models included many candidate predictors relative to the number of independent participants.

Results

Characteristics of the included evidence

The eight included studies represented five sports. Association football was examined through a season-long video analysis of scanning in 27 English Premier League players and an in-situ mobile eye-tracking study of four elite Norwegian midfielders (Aksum et al., 2021; Jordet et al., 2020). Australian Rules football was represented by a video-based eye-tracking study of 27 professional players (Kassem et al., 2022). Baseball contributed a preseason assessment linked to pitch-by-pitch data in 71 professional batters, a mobile eye-tracking study of preparatory fixation shifts in 58 professionals, and a comparison of cardinal-gaze responses in 17 Major League Baseball players, 160 amateur prospects, and 128 non-athletes (Kubitz et al., 2020; Liu et al., 2020; Hunfalvay et al., 2017). The remaining studies assessed 59 professional Twenty20 cricket players and 17 national- or international-level tennis players (Murray et al., 2021; Rosker & Majcen Rosker, 2021).

The studies differed substantially in representativeness, measurement, and outcome. Field studies preserved natural information-action relations but had limited control and, in one case, only four players. Video tasks standardized the display but required verbal rather than sport-specific action. Standardized oculomotor batteries allowed prediction of season statistics but raised questions about proprietary composites and similarity to competition. These differences prevented quantitative pooling but supported comparison of recurring functional principles.

Five studies measured gaze or scanning during a sport-specific task, whereas three used standardized screen-based oculomotor batteries. Performance endpoints also differed in proximity to competition. Pass completion and pitch-by-pitch plate discipline were direct event outcomes; league level and season statistics were longitudinal but influenced by exposure and role; expert-rated decisions and batting-practice measures were closely coupled proxies. This gradient of outcome validity was considered when conclusions were drawn.

Exploratory scanning and peripheral information in association football

Jordet et al. (2020) defined a scan as an active head movement in which the player's face was temporarily directed away from the ball to collect information before subsequent involvement. Twenty-seven male players from one English Premier League club were filmed during 21 home matches in the 2017/2018 season, producing 9,574 possessions.

Scanning varied with position and context. Central midfielders and central defenders scanned more frequently than forwards, and scanning was reduced under tight pressure, in wide areas, and closer to the opponent's goal. Players also scanned more before passing than before dribbling or shooting. These findings show that scanning is not a context-free personal trait; it changes with information density, available time, orientation, and the action being prepared.

Scanning frequency before reception was higher when possession was retained rather than lost and before completed rather than unsuccessful passes. The standardized differences were small, approximately $d = 0.20$ and $d = 0.15$, respectively. A Bayesian hierarchical model accounting for individual differences and pass difficulty still indicated that higher scanning frequency was associated with a greater probability of pass completion. The contribution should therefore be described as small but positive, not deterministic.

Causality cannot be inferred. Easier situations may permit both more scanning and better execution, while tactically skilled players may create additional time through positioning. Video-coded head turning also does not reveal the exact point of gaze or prove that a particular object was attended. It is best understood as an orientation behavior that creates an opportunity for information pickup.

Aksum et al. (2021) used Tobii Pro Glasses 2 during two 11-versus-11 matches to examine 869 scans by four central midfielders from the Norwegian top league. Scans were longer when the ball was airborne and during passes between players, situations in which its future location may have been more predictable and temporary disengagement less costly.

Only 20 scans, or 2.3%, contained a fixation under a 120-ms threshold. Scans with a fixation were markedly longer than those without one. The rarity of classified fixations does not imply that most scans were uninformative: rapid head movement complicates classification, and information may be obtained through brief stabilization, motion cues, or peripheral vision. The scan stop point contained the largest number of visible players and was the most information-rich phase according to the study's operational measures.

Together, the studies indicate that timing and organization matter more than scanning frequency alone. Effective exploration must occur when direct ball information can briefly be sacrificed, sample a useful region,

and finish early enough to guide action. Future work should combine head orientation, point of gaze, player tracking, pressure, and technical outcome.

The two studies are complementary rather than interchangeable. The season analysis offered strong event coverage and contextual modeling but inferred information gathering from head orientation. The mobile eye-tracking study measured gaze more directly but included only four players and short observation periods. Together they show why a single method cannot fully characterize visual exploration: video analysis scales to many matches, whereas eye tracking provides detail about gaze-head coordination and visible information.

A possible nonlinear relationship should also be considered. More scans may be helpful only until they interfere with ball monitoring or action preparation. The functional target for training is therefore an appropriate scan at the appropriate moment, not the highest attainable scan count.

Visual search and decision-making in Australian Rules football

Kassem et al. (2022) examined whether gaze behavior distinguished more and less successful decisions within a single professional Australian Rules football club. Twenty-seven male players viewed 14 game-based video clips selected from match footage. Each clip presented an attacking situation with three to five possible options and paused at a critical decision point. Three experienced coaches had previously ranked the most appropriate passing options. Participants verbally selected an option within four seconds while wearing Tobii Pro Glasses 2, and their responses were categorized as skilled or less skilled according to agreement with the expert rankings.

The correction of the statistical description is important. Decision time and fixation duration were separate variables. The skilled decisions were made faster, with a mean response time of 2.21 $\pm$ 0.76 s compared with 3.71 $\pm$ 1.92 s for less-skilled decisions. Skilled decisions were also associated with a shorter overall fixation duration and fewer fixations: mean fixation duration was 2.21 $\pm$ 0.84 s versus 2.75 $\pm$ 0.93 s, and the mean number of fixations was 4.59 $\pm$ 2.20 versus 5.99 $\pm$ 2.84. At the same time, successful decision-makers allocated relatively more fixation time to viable teammates or options. Thus, the pattern was not simply shorter looking. It combined faster response, reduced sampling of the entire display, and selective investment in the information most relevant to the decision.

This pattern is consistent with information-reduction accounts of expertise. Experienced athletes may use structured knowledge to identify high-value locations and reject irrelevant alternatives more efficiently. Fewer fixations can therefore coexist with greater task-relevant processing. The results also illustrate the value of distinguishing total fixation behavior from fixation distribution. A player who spends less time overall but directs a greater proportion of that time toward useful options may be more efficient than one who continues to inspect noncritical areas.

However, the design did not reproduce the full perception-action demands of match play. Participants watched two-dimensional footage, remained in a laboratory, and produced a verbal response after the video paused. They did not move into space, execute a kick or handball, or experience direct opponent pressure. The expert-derived response criterion was defensible but not infallible: the best tactical option for one player may depend on individual kicking range, role, or team strategy. In addition, individual responses were repeatedly sampled across clips, and the labels skilled and less skilled referred to decision instances rather than immutable categories of athlete ability. The study therefore supports the assessment of perceptual-cognitive efficiency but does not establish that the observed gaze pattern directly causes better decisions in competition.

The classification procedure also deserves attention. Skilled and less-skilled observations were defined by agreement with a coach-derived option ranking, not by career status, because all participants belonged to the same professional cohort. The study therefore demonstrated meaningful within-elite variation. This is important for applied work: comparisons between professionals and novices may reveal broad expertise effects, whereas within-professional designs address whether gaze metrics discriminate the smaller performance differences relevant to coaching and selection.

The 50-Hz sampling rate was adequate for fixation-based analysis but limited detailed characterization of saccade kinematics. Manual assignment of fixations to areas of interest achieved high inter-rater agreement, although dynamic scenes and ambiguous player boundaries remain sources of classification error.

Oculomotor assessment and professional baseball performance

Liu et al. (2020) linked preseason visual assessment with season-long professional performance. Seventy-one minor-league batters completed quantitative eye tracking, visual-motor testing, and autorefraction during spring training. Subsequent TrackMan data generated plate-discipline propensities: O-Swing, swinging at pitches outside the strike zone; Z-Swing, swinging at pitches inside the zone; and Z-Miss, swinging and missing at pitches in the zone. The highest league level attained was also analyzed.

Smooth-pursuit accuracy and processing-speed variables were associated with O-Swing and Z-Swing, whereas none of the visual measures predicted Z-Miss (Liu et al., 2020). General oculomotor speed contributed to prediction of the highest attained league level. Selected models explained approximately 22% to 28% of outcome variance, indicating meaningful but incomplete prediction.

Smooth-pursuit accuracy represented the proportion of time gaze remained near moving targets across several trajectories. General oculomotor latency, speed, and processing speed were composite timing measures from tasks requiring central fixation, acquisition of peripheral targets, and a manual response. Oculomotor speed therefore described target-acquisition time, not peak saccadic velocity. Classical measures such as refractive error did not improve the selected models to the same degree.

The results suggest that dynamic control and rapid processing may discriminate among athletes whose basic optical function is adequate. They remain exploratory, however. The sample was modest relative to the candidate predictors, data were collected in one organization, and model selection may capitalize on chance. Plate discipline is less dependent on fielding than batting average but remains influenced by pitch quality, count, league, and tactical role. The models require external validation before clinical or selection thresholds are proposed.

Hunfalvay et al. (2017) examined preparatory gaze in 58 professional players wearing mobile eye trackers during batting practice. Players made multiple visual shifts between the pitcher and home-plate region before the pitcher's action. Cluster analysis indicated a positive relationship between a greater number of preparatory shifts and batting average or on-base percentage. These shifts may support oculomotor readiness, spatial calibration, or a consistent routine, but the study did not identify the mechanism and batting practice differs from competition.

After release, the ball travels too rapidly for continuous foveal pursuit over its full trajectory. Experienced batters combine early ball-flight information with predictive saccades and coordinated eye-head movements (Kishita et al., 2020; Mann et al., 2013). Laboratory pursuit tests may therefore index a broader capacity for motion processing and target acquisition rather than directly reproducing batting gaze. Future work should combine standardized batteries with high-speed in-task eye, head, ball, and bat tracking.

The direction of the plate-discipline associations should be reported carefully. Lower O-Swing generally represents better discrimination because the batter avoids chasing pitches outside the zone, whereas Z-Swing reflects willingness to attack pitches inside it. A visual measure can therefore relate differently to the two propensities without producing a simple global “better batting” score. The absence of an association with Z-Miss further suggests that contact after the swing decision depends strongly on motor execution and pitch characteristics not captured by the visual battery.

Hunfalvay et al. also illustrate the limitation of relying on a single end-stage fixation. Preparatory gaze shifts may establish spatial reference points before release, after which the batter must rapidly transition to pitch recognition and prediction. Future models should analyze the complete sequence rather than isolated averages.

Oculomotor predictors of professional cricket performance

Murray et al. (2021) assessed 59 male professional Twenty20 players, including 29 batters and 30 bowlers, using a standardized battery of pursuit, saccadic, fixation, reaction-time, and composite measures. These variables were related to batting strike rate and run production and to bowling runs conceded and wickets taken.

Selected models explained approximately 85% of variance in batting strike rate, 45% in runs conceded, and 85% in wickets. Significant contributors included pursuit quality, saccadic performance, fixation stability, processing speed, and global composite scores. The direction of the findings is consistent with the baseball evidence, but the very high R-squared values require caution. With fewer than 30 athletes per role, regression models containing several correlated predictors are vulnerable to overfitting and may not generalize to another league or season. Composite percentiles are also difficult to interpret when their reference population or weighting is not fully transparent.

Batting and bowling involve different visual functions. Batting emphasizes release recognition, trajectory prediction, gaze stabilization, and interception; bowling includes target control, run-up stabilization, and delivery precision. Strike rate, wickets, and runs conceded are additionally influenced by tactical role, opponent quality, playing conditions, and opportunity. The study provides important predictive evidence, but independent validation and role-specific mechanisms are needed.

The study's cross-sectional design also prevents separation of stable capacity from current form. Season statistics may reflect different numbers of innings and role-specific exposure, and a player selected more often has more opportunity to accumulate wickets or runs. Analyses using rate-based outcomes, minimum-exposure criteria, and adjustment for opponent and venue would provide stronger tests.

Replication should preferably use prespecified predictors rather than stepwise selection and should compare proprietary composite scores with transparent component measures. This would determine whether prediction comes from a specific oculomotor process or from a broad score that partially overlaps with reaction and manual-response speed.

Adaptive visual search during tennis serve return

Rosker and Majcen Rosker (2021) recorded on-court gaze during serve return in 17 male national- or international-level players. Participants returned approximately 90 serves while wearing mobile eye-tracking glasses. The serve was divided into phases and 25 areas of interest covering the server, racket, ball, and surroundings. Fixations of at least 100 ms were retained, and two coaches rated return quality.

Gaze was organized around phase-specific information. The tossing hand and ball-toss region were important early because they informed toss location and the developing action; body, racket, and ball cues gained relevance closer to contact. This temporal reweighting is consistent with anticipation models in which expectations are updated by kinematic and ball-flight evidence (Harris et al., 2022; Runswick et al., 2020).

Machine-learning analyses showed a strong individual gaze signature: returning-player identity was classified with an area under the curve of about 0.95. Gaze also reflected adaptation to the server, with more accurate server classification and return-quality classification in the international group. Expertise therefore appeared to involve flexible, opponent-specific search rather than one invariant scanpath.

High identity-classification accuracy demonstrates consistency, not superiority. Repeated returns were nested within a small number of athletes, and performance can be inflated if trials from the same player occur in training and testing sets. Return quality was expert-rated, and the fixation threshold affected retained events. The study nevertheless shows that aggregated fixation counts may obscure the temporal and opponent-specific organization of gaze.

The importance of adaptability is consistent with qualitative evidence from professional tennis players, who describe combining server-specific tendencies, score context, toss information, and racket kinematics rather than relying on one cue (Vernon et al., 2018). Gaze data should therefore be interpreted alongside probabilistic knowledge. An athlete may fixate the same location in two points while assigning it different meaning because expectations differ.

Future analyses should use leave-one-player-out or leave-one-session-out validation and report confusion matrices in addition to AUC. Such procedures would test whether a model generalizes to unseen athletes rather than recognizing an individual's repeated trials.

Cardinal-gaze response time in Major League Baseball players

Kubitz et al. (2020) compared the RightEye Cardinal Gaze Position test in 17 Major League Baseball players, 160 amateur prospects, and 128 non-athletes. Participants redirected gaze from central fixation toward targets in eight peripheral directions. Because the outcome was measured in milliseconds and represented target-acquisition time, cardinal-gaze response time is more precise than eye-movement velocity.

The MLB group averaged approximately 238 ms, compared with 341 ms in prospects and 337 ms in non-athletes. Differences between MLB players and both comparison groups exceeded 98 ms and were significant, whereas prospects and non-athletes did not differ. Downward responses were generally slower and rightward responses among the fastest.

The study demonstrates a group distinction but not a direct relationship with batting performance. Faster responses may result from training or selection, and age differed between professionals and prospects. The task combines stimulus detection, saccade initiation, movement, and target-arrival criteria and is not equivalent to a neurological examination of extraocular muscles or cranial nerves. Its practical value may lie in

longitudinal athlete-specific monitoring, but this requires test-retest reliability, standardized conditions, and meaningful change thresholds. Cross-sectional differences alone do not justify talent selection.

Directional differences may reflect target eccentricity, habitual gaze demands, measurement geometry, or biological asymmetries, but the study does not establish an evolutionary or muscle-specific explanation. Interpretation should remain descriptive until replicated with direct saccadic measures, matched age groups, and control for batting side, ocular dominance, and handedness.

The lack of difference between prospects and non-athletes is also informative. It suggests that the MLB result may not represent a gradual linear progression across competitive levels and may instead reflect high-level selection, accumulated professional practice, or sample differences.

Cross-study synthesis

Four functional domains emerged: exploratory orientation in team sport; selective visual search during decisions; quantitative oculomotor control associated with season or competition outcomes; and adaptive use of anticipatory cues. No single metric was measured consistently across sports.

The evidence does not support a universal expert pattern. Football performance was associated with appropriately timed scanning, successful Australian Rules decisions with fewer fixations and selective viewing, baseball preparation with repeated shifts, and tennis return with phase- and opponent-specific cue use. The common feature is functional efficiency: gaze is useful when it samples informative variables while they can still influence action.

Dynamic oculomotor measures were more consistently associated with professional outcomes than basic optical measures in baseball and cricket. This does not make acuity or refraction unimportant. Adequate sensory quality is a prerequisite, while restricted variance in screened professionals may reduce its statistical discrimination.

Certainty remains limited. Most studies involved fewer than 60 elite athletes, all samples were male, and repeated observations were often nested within few players. Devices, thresholds, tasks, and outcomes differed substantially. The studies provide convergent direction rather than interchangeable effect estimates.

A further pattern concerns the level of measurement. Scanning and fixation studies characterize strategies used during a task, whereas screen batteries characterize capacities available to support those strategies. Capacity does not guarantee effective deployment, and an apparently efficient strategy may depend on adequate underlying sensory and oculomotor function. A comprehensive model should therefore connect clinical input quality, oculomotor capacity, task-specific information sampling, decision processes, motor execution, and performance outcome.

This layered model also explains why an isolated test may show modest prediction: performance is multiply determined, and visual variables operate alongside physical, technical, tactical, and psychological factors.

Discussion

Principal interpretation

The evidence indicates that eye movements relate to professional performance through the organization of information sampling rather than through one generalized visual advantage. Athletes must determine when to stabilize gaze, when to redirect it, which sources require foveal analysis, and which relations can be monitored peripherally. These decisions occur within a perception-action loop: movement changes the information available, and sampled information changes the next movement.

In team sports, exclusive ball fixation would prevent monitoring of opponents, teammates, and space. Scanning allows the internal representation of the scene to be updated, but its value depends on timing and available action time (Aksum et al., 2021; Jordet et al., 2020). In Australian Rules football, better decisions were associated with faster responses, fewer fixations, and selective attention to viable options (Kassem et al., 2022), consistent with expertise-based information reduction.

In interceptive sports, continuous reactive tracking is insufficient. Batters and returners use early kinematic and ball-flight information to predict future events. Associations of pursuit, target acquisition, and processing speed with baseball and cricket outcomes may reflect this broader predictive system (Liu et al., 2020; Murray et al., 2021). Tennis players' opponent-specific gaze further supports the view that expert visual behavior is adaptable rather than fixed (Rosker & Majcen Rosker, 2021).

The findings also distinguish efficiency from speed alone. Faster target acquisition may be useful, but premature gaze shifts can remove useful information. More rapid decisions may reflect expertise, but impulsive responses can be inaccurate. Expert behavior balances information gain against the time and motor costs of looking. Accordingly, the most informative outcomes are those coupling gaze metrics with decision quality or subsequent action rather than reporting eye movement in isolation.

Task specificity and the absence of a universal optimal gaze pattern

A universal expert gaze pattern is unlikely. Longer final fixation may support golf, shooting, or free throws, whereas repeated scanning supports orientation in football. A tennis returner shifts the relative value of toss, body, racket, and ball information; a baseball hitter combines preparatory shifts, early tracking, and predictive saccades.

Quiet eye remains valuable, especially in self-paced aiming tasks, and is associated with expertise and performance (Lebeau et al., 2016). It should nevertheless be embedded in the wider visual sequence. In externally paced tasks, preparatory search, pursuit timing, head movement, and peripheral monitoring may be equally important. This task-specific view explains why expert-novice studies sometimes report fewer and longer fixations and elsewhere more frequent shorter fixations. Counts and durations must be interpreted with location, temporal phase, and action outcome.

Representative validity and measurement

The included studies illustrate the trade-off between control and representative validity. Video tasks provide standardized stimuli and clean recordings but weaken perception-action coupling. In-situ recordings preserve movement and spatial geometry but increase missing data and reduce control. Representative learning design requires preservation of the information-action relations regulating the target behavior rather than literal replication of every competitive feature (Pinder et al., 2011).

For decision research, responses should preserve the relevant motor action where possible. A verbal response to paused video measures option selection but not ball control, body orientation, or execution. Virtual reality may improve immersion, although transfer depends on latency, field of view, depth cues, and movement freedom. Mobile eye tracking offers ecological access but requires transparent reporting of sampling frequency, calibration, accuracy, fixation classifier, missing data, and head-motion handling.

Small professional samples remain a major limitation. Thousands of possessions or returns improve within-player precision but do not replace independent athletes. Hierarchical models are preferable when trials are nested within players, matches, servers, or scenarios. Commercial composite scores also require published algorithms and reference populations. Predictive studies should report adjusted fit, confidence intervals, predictor-to-sample ratios, cross-validation, and external validation (Kredel et al., 2023).

Researchers should additionally distinguish accuracy from precision. Accuracy indicates how close recorded gaze is to the true location, whereas precision describes sample-to-sample stability. Both can deteriorate during vigorous movement, and calibration quality may vary across the visual field. Dynamic areas of interest should be defined using reproducible procedures, and analysts should report how ambiguous or missing samples were handled. These details materially affect fixation counts and dwell times.

Clinical and ophthalmological implications

Sports-vision practice should begin with clinical adequacy. Refractive correction, ocular health, binocular alignment, accommodation, vergence, visual field, and contrast sensitivity should be assessed according to symptoms and sport demands. Basic optical measures may fail to predict differences within professionals because clinically significant deficits have already been treated or because variance is restricted; they remain prerequisites for reliable information pickup.

After clinical needs are addressed, assessment should follow a visual task analysis. Erickson (2021) recommends matching tests to sport demands rather than administering an undifferentiated battery. A football midfielder may require functional peripheral awareness and gaze-head coordination; a batter may require motion prediction, target acquisition, and rapid discrimination; a precision athlete may depend more on fixation control.

Performance profiling and clinical diagnosis must remain distinct. Oculomotor changes may occur after concussion and other neurological or vestibular disorders, but they are not specific to one diagnosis (Cochrane et al., 2019). A changed score should prompt clinical interpretation, not an automatic conclusion about talent or readiness.

Longitudinal within-athlete monitoring may be more useful than ranking against non-athletes. It requires reliable hardware, standardized conditions, learning-effect control, and predefined change thresholds. Current evidence does not justify using one eye-tracking test as an independent talent-identification instrument. Any selection application must demonstrate prospective, incremental prediction beyond age, prior performance, technical skill, and physical capacity.

Clinical screening should also consider sport-specific correction. Contact lenses, spectacles, protective eyewear, lighting, glare, and contrast can alter usable vision without changing the athlete's underlying perceptual expertise. Symptoms such as intermittent diplopia, blur at changing distances, headache, motion sensitivity, or difficulty after concussion require diagnostic evaluation before performance training is contemplated.

Where a performance battery is used, clinicians should communicate the construct actually measured. A response-time score combining ocular and manual components should not be presented as a pure measure of an extraocular muscle or cranial nerve.

Visual training and transfer to competition

Assessment and trainability are separate questions. A measure can correlate with performance without being modifiable, and improvement on a device does not prove competition transfer. Generic brain- or vision-training programs commonly produce near transfer but inconsistent far transfer (Abernethy & Wood, 2001; Simons et al., 2016).

Transfer is more plausible when training preserves sport-specific information, timing, and movement. Gray (2017) reported transfer from virtual-reality baseball practice to real batting, while the systematic review by Lochhead et al. (2024b) found more consistent gains on trained visual tasks than on robust competitive outcomes. Strong trials require active controls, preregistration, retention tests, and objective sport endpoints.

Gaze training should therefore guide information pickup rather than isolate eye exercise. Football practice can manipulate pressure, ball travel, orientation, and passing options while preserving ball control. Tennis training can vary servers and cue availability without prescribing one rigid scanpath. Quiet-eye training may suit stable target tasks but should be tested under pressure. Because athletes may use different effective strategies, interventions should identify late or missed information and evaluate change against individual baseline and real performance.

Near transfer, intermediate transfer, and far transfer should be reported separately. Improvement on the practiced visual task is near transfer; improvement on a related sport simulation is intermediate transfer; improvement in competition statistics is far transfer. Conflating these levels produces overly strong claims. The most persuasive evidence would demonstrate a retained change in gaze behavior during representative action together with an independent improvement in performance.

Training dose and adverse effects also require reporting. Intensive visual practice can produce fatigue, discomfort, or reduced adherence, while head-mounted virtual environments may cause cybersickness. Practical feasibility is therefore part of effectiveness.

Effects of pressure, fatigue, and context

The included studies rarely examined anxiety or fatigue. Pressure may reduce goal-directed attentional control and alter quiet-eye behavior, while quiet-eye training has improved performance under competitive stress in selected aiming tasks (Vine et al., 2011; Wilson et al., 2009).

In team sport, pressure may reduce the time available for scanning. Jordet et al. (2020) observed less scanning under tight opponent pressure, but this can represent rational adaptation rather than failure. Training must also create time through positioning, body orientation, and first touch.

Physical and mental fatigue may affect pursuit, saccadic latency, fixation stability, head control, and decision speed. Future studies should record workload, sleep, and fatigue state and examine whether visual markers identify temporary degradation when competitive demands are highest.

Limitations of the evidence and of this review

The evidence is concentrated in male ball sports. No eligible study directly linked eye movements with performance outcomes in professional female cohorts, combat sport, motorsport, winter sport, aquatic sport, or para-sport. Most studies were observational, often from one organization, and cannot establish whether visual characteristics caused performance, developed through practice, or reflected experience and selection. Small samples, multiple predictors, and limited external validation increase uncertainty.

Measurement was heterogeneous: studies used different fixation thresholds, devices, head-scanning definitions, tasks, and outcomes. Some analyses involved commercial systems and composite scores. These differences precluded meta-analysis and make conceptual convergence more defensible than pooled effect estimation.

This review was narrative rather than fully systematic. SPORTDiscus was not part of the original database set, a complete numerical search log and formal risk-of-bias score were unavailable, and only accessible English-language records were considered. The 2015-2025 window excluded older primary studies, although selected earlier literature informed theory. Publication bias may favor positive findings.

Several studies also relied on outcomes that can be statistically noisy across short periods. A batting average, wicket count, or promotion decision is affected by opportunity and organizational context. Confidence increases when visual measures predict repeated or context-adjusted outcomes across multiple seasons. Null findings should be reported with the same detail as positive models to reduce selective emphasis.

Priorities for research and practice

Future studies should be prospective, preregistered, multisite, and sufficiently powered. Models should be developed in one professional cohort and validated in another, with repeated testing across seasons to separate stable traits from fatigue, form, and measurement noise. Female athletes and underrepresented sports require priority.

Gaze should be integrated with synchronized performance data. Football studies can combine eye tracking with player position, ball events, pressure, and body orientation. Batting studies can synchronize eye and head behavior with ball and implement kinematics. Machine-learning studies should split data at athlete or session level to prevent leakage and report external validation.

Interventions must test transfer using active controls, retention, and competition-relevant endpoints. For practice, a cautious sequence is recommended: establish ocular health; analyze role-specific visual demands; select reliable measures; collect an individual baseline; assess gaze in representative practice; intervene only when a plausible limitation is identified; and verify transfer through real performance. Interpretation should be multidisciplinary.

Consensus reporting standards would facilitate comparison. At minimum, studies should provide device model, sampling rate, calibration and validation procedure, fixation algorithm and threshold, data-loss rate, number of independent athletes, number of repeated trials, full model specification, uncertainty intervals, and conflicts of interest. Deidentified gaze and event data should be shared when contractual and privacy constraints permit.

Conclusions

Eye movement is associated with professional sport performance, but the relationship is task dependent. In football, appropriately timed scanning makes a small positive contribution to successful passing, while in-situ eye tracking shows that information may be acquired through rapid head-eye coordination and peripheral monitoring rather than prolonged fixation. In Australian Rules football, successful decisions are characterized by faster responses, fewer fixations, and selective viewing of viable options. In baseball and cricket, pursuit accuracy, target-acquisition time, fixation stability, and processing speed are associated with selected performance outcomes, although predictive models require external validation. Tennis returners demonstrate individualized and adaptable search, emphasizing phase- and opponent-specific cue use.

The evidence is promising but insufficient for universal thresholds, causal claims, or selection decisions based on isolated scores. Most studies are observational, use small male samples, and apply heterogeneous methods. Clinical visual adequacy remains a prerequisite, while performance assessment should focus on how visual capacities are deployed in the sport environment. Eye tracking is most informative when combined with task analysis, real movement, contextual data, and longitudinal outcomes.

Future work should standardize measurement, validate models across independent cohorts, include female and underrepresented sports, and test transfer to competition. Until then, gaze and oculomotor assessment should complement rather than replace technical, tactical, physical, and clinical evaluation.

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