



LJMU Research Online

Ballet, C, Barreto, J, Hope, E and Casanova, F

What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A pilot study [version 2; peer review: 1 approved with reservations]

<http://researchonline.ljmu.ac.uk/id/eprint/20876/>

Article

Citation (please note it is advisable to refer to the publisher's version if you intend to cite from this work)

Ballet, C, Barreto, J, Hope, E and Casanova, F (2023) What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A pilot study [version 2; peer review: 1 approved with reservations]. F1000Research. 12. p. 679. ISSN 2046-1402

LJMU has developed [LJMU Research Online](#) for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact researchonline@ljmu.ac.uk

<http://researchonline.ljmu.ac.uk/>



RESEARCH ARTICLE

REVISED What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A pilot study [version 2; peer review: 1 approved with reservations]

Charles Ballet ¹, Joana Barreto², Edward Hope ³, Filipe Casanova ²

¹Institute Cognitive Neuroscience, University College London, London, England, WC1N 3AZ, UK

²Educação Física, Universidade Lusofona de Humanidades e Tecnologias, Lisbon, Lisbon, 376, Portugal

³Rehabilitation and Exercise Sciences, University of Essex, Colchester, England, C04 3SQ, UK

V2 First published: 15 Jun 2023, 12:679
<https://doi.org/10.12688/f1000research.134231.1>
 Latest published: 21 Aug 2023, 12:679
<https://doi.org/10.12688/f1000research.134231.2>

Abstract

Background: Visual perception has been defined as the first step to a football player's decision-making process and it plays an important role in performance in sport. The skill of focussing to prioritize relevant cues has been also considered crucial in sport. This pilot study aims to explore the visual behaviour and attentional effort of three football players (mean age 19 ± 0 years old) in specific-role positions; Right-winger (RW), Centre-Midfielder (CM) and Left-Back (LB), in the five seconds before receiving the ball from their teammate.

Methods: Twenty-two male football players performed an 11v11 game, where 24 game sequences (trials) from which 166 fixations were recorded and analysed *via* the Tobii Pro eye-movement registration glasses and software. The gaze behaviour dependent variables were the mean of fixation duration (FD), time to first fixation (TTF), both measured in milliseconds (ms), and the number of fixations (NF) on eight areas of interest (AOIs). AOIs include teammate with and without the ball, opponent without the ball, space around teammate with and without the ball, space around opponent without the ball, ball and undefined. The mean pupil diameter (PD) correlates to the attentional effort and was measured in millimetres (mm).

Results: Descriptive statistics showed nonregular search rate data between the participants in FD, TTF, NF on the AOIs. Mean FD on the ball: (CM, 270 ms), (RW, 570 ms), (CM, 380 ms). They also presented differences in the mean PD during play; (CM: $2.90 \text{ mm} \pm 0.26$), (RW: $2.74 \text{ mm} \pm 0.30$), (LB $2.77 \text{ mm} \pm 0.27$).

Conclusions: Albeit the sample size was small, the findings demonstrated a promising way to measure the on-field perceptual-cognitive abilities of football players according to their specific positions, since different playing roles revealed to present distinctive

Open Peer Review

Approval Status ?

1

version 2

(revision)

21 Aug 2023

version 1

15 Jun 2023

?

[view](#)

1. **Vicente Luis-del Campo** , University of Extremadura, Caceres, Spain

Any reports and responses or comments on the article can be found at the end of the article.

visual and attentional patterns.

Keywords

Football, player-role, perceptual-cognitive skills, eye-tracking, decision making



This article is included in the [University College London](#) collection.

Corresponding author: Charles Ballet (charles.ballet.17@alumni.ucl.ac.uk)

Author roles: **Ballet C:** Conceptualization, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Writing – Original Draft Preparation; **Barreto J:** Formal Analysis, Writing – Review & Editing; **Hope E:** Writing – Review & Editing; **Casanova F:** Methodology, Resources, Supervision, Validation, Visualization, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2023 Ballet C *et al.* This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Ballet C, Barreto J, Hope E and Casanova F. **What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A pilot study [version 2; peer review: 1 approved with reservations]** F1000Research 2023, **12**:679 <https://doi.org/10.12688/f1000research.134231.2>

First published: 15 Jun 2023, **12**:679 <https://doi.org/10.12688/f1000research.134231.1>

REVISED Amendments from Version 1

The introduction has been revised to provide a more seamless flow of concepts, addressing the reviewer's recommendations. The phrase "when talking about" has been appropriately replaced with "for" to enhance clarity, ensuring the discussion of spatial awareness is more cohesive. Additionally, the suggestion to insert "up" after "picked" has been integrated, reinforcing the description of how visual information is processed.

In response to the comment of the reviewer, we have added a more comprehensive explanation of the rationale behind choosing on investigating the participants' visual search, the five seconds (instead of ten seconds) before receiving the ball from a teammate during 11v11 games.

We emphasized our aim to use concisely this type of data as part of a multi-disciplinary team supporting a football coaching staff.

In the method section, we have also included the total amount of hours of our participants' football practice. These insights contribute to a better understanding of participants' exposure to football-related training.

Lastly, the discussion has been enriched with the inclusion of findings from the recent study by Luis-del Campo and colleagues (2023), which focused on evaluating mental load through ocular metrics and saccadic features. This addition allows for a more robust comparison of findings and enhances the overall discourse on attentional effort.

Any further responses from the reviewers can be found at the end of the article

Introduction

Over the last twenty years, perceptual-cognitive skills of athletes in sports have been studied extensively to understand the mechanisms behind anticipation, decision-making, and expertise in sport.¹ Perceptual-cognitive skill of an athlete in team sports refers to their ability to use human perception; seeing, hearing and awareness to pick up cues during play.¹ Those would be then integrated and processed with existing (tactical) knowledge so that the right sporting decision could be actioned.² It has been clearly demonstrated that athletes with higher perceptual-cognitive skills have better anticipation and decision-making abilities.³

Research has shown that attention in sport is as important as perception for performance.⁴ Indeed, visual attention (focus) and visual perception are distinct, yet closely linked.^{4,5} From a coaching and professional perspective, visual perception is defined as the first step of football players' decision-making process.⁶ A player scans the field during a specific style of play to decide their next action accordingly.⁷ Visual attention is what enables this player to pick-up all important cues and ignore the less relevant before making their decision.⁴

When discussing attention, it is important to distinguish between covert and overt attention.⁸ The covert is characterised by the attention following the movements of the eyes (linked to central vision).^{8,9} Overt attention are directed elsewhere than where the eyes are fixating (linked to peripheral vision).^{8,9}

A football game is characterised by 22 athletes whose movements, speed, body, and positioning, vary continuously.¹⁰ As a result, football players would use their visual perception and attention differently to pick-up cues such as spaces, teammates, opponents to intend to make the right decision at the right time.⁹ As a result, we believe it is important for coaches to be aware of individual players' visual patterns and attention.

Research on visual perception evidenced that 80% of the information taken from the environment is done through the eyes.¹¹ This allows a player to analyse the game situation and recognised patterns of play.¹¹ Therefore, visual perception is crucial for spatial awareness.¹¹ Visual perception has been previously studied *via* "scanning", which is the amount of time a player moves their head towards and away from a ball, teammate, or opponent; not considering their gaze behaviour.^{10,12} Although, visual exploration can also be done through body movements, it is ultimately through the eyes that the information is mainly picked up and processed.¹⁰

When it occurs, the eyes move and fixate at a specific cue, this process is characterised by the steadiness of the gaze at a point of interest.¹³ It is commonly associated to central vision since it enables individuals to see details clearly and sharply.¹³ For example, fixation happens when a player keeps their eyes (and therefore gaze) on the ball to get a clearer vision of it.¹¹ Fixation has been previously linked to football performance since its duration can vary depending on the skill level of an athlete and task constraints existing in the sport environments.¹⁴ An increase in fixation duration can suggest that the player may have more interest in what is fixating at, and/or processing the information.¹¹ Although there has been a general assumption that the players attention is where they fixate, it has also been evidenced otherwise.¹⁵ As an

example, a player can look at the most obvious free teammate but pass the ball to another teammate they spotted using their peripheral vision.¹

Most visual perception studies explored gaze behaviour following Gibson's theory of perception-action coupling, which explains the mechanism behind the coordination between what we see and what we do.¹⁶ During a football game, players are confronted with ever-changing dynamic situations and constraints which they need to consider constantly before their next actions. For example, a player who is in possession of the ball would have to decide to either shoot at goal, pass to a teammate, or dribble the ball depending on how far the goal is and how his/her teammates and opponents are positioning and moving themselves on the pitch.¹⁷

Aksum *et al.*¹⁰ conducted an on-field observational study investigating eye movements of midfield players during a 11v11 match play. They analysed visual fixation when the ball was at play, during both defence and attack phases. Moreover, the forementioned authors measured fixation duration and the total time spent (as a percentage) of viewing each fixation's location, categorising the locations as ball, teammate, opponent, space and other.¹⁰ They provided valuable insight from their experiment showing that elite midfield players use longer fixation duration (242.49 ms) when facing several cues such as space, teammates, and opponents.¹⁰ Furthermore, midfield players fixate more at the player in possession of the ball during a defensive phase of play than during an attacking phase.¹⁰

Although their experiment provided an understanding into the gaze behaviour of midfield players, more research is needed, as it could be argued that football players, including backs and forwards, have different roles on the pitch and therefore might use different gaze strategies.¹⁸ Another limitation of their research lays on the fact that they did not explore visual attention.

As previously stated, visual perception and attention are closely linked and integrated within the decision-making process of a football player.⁴ Therefore, our intention was to investigate visual perception by studying our participants gaze behaviour but also their attention by measuring their pupil size during play.

A laboratory study investigated attentional effort of expert and novice horse riding athletes by measuring pupil diameters using video simulations.¹⁹ The results found evidenced that the expert group displayed a higher increase of their pupil size diameter than the novice group.¹⁹ Conversely, another study highlighted that a player owning a higher amount of tactical knowledge requires less cognitive effort during a laboratory video test.²⁰ This difference could be pointed because football is a team sports with complex situations compared to horse riding.^{10,19}

The aims of this pilot experiment were to study the differences of the gaze behaviour and attention of three male footballers playing as a left-back (LB), right-winger (RW) and a centre-midfielder (CM), during the five seconds before receiving the ball from a teammate on 11v11 game. Which means that visual data including search rate and order will only be analysed during when the team of the player investigated had possession of the ball. Since different football player positions come with different tactical demands, we hypothesised that there would be different gaze behaviour used between the players.¹⁸ Secondly, we predicted that there would be dissimilar values in the attentional effort between the players by showing different pupil size diameters.¹⁸

Methods

Participants

Twenty-two male football players (mean age 19 ± 0 years old; 6.67 ± 3.79 years of football practice, which correspond to a total 1334 hours) who play as amateurs in the Portugal National University Championships were recruited. We contacted football coaches of the Lusófona University *via* email who forwarded our invitation letter to the players to voluntarily take part to the experiment. They all took part in a 15-minute pre-competitive football game, which were separately recorded the visual behaviour of three of those participants who played as a LB, CM and RW were each analysed and recorded at different moments of an 11 v 11 football game. Participants reported normal or corrected-to-normal levels of visual function. The study complied with the safety guidelines of the Tobii eye tracking devices and was approved by the Ethics Committee of Lusófona University (protocol number M25A21), and the UCL Research Ethics Committee (project identification number 7067/001) which are in accordance with the Declaration of Helsinki. All participants provided voluntary written informed consent, where all procedures were explained in detail, from the data collection to the publication stage.

Apparatus

The Tobii Pro Glasses 2[®] (Tobii Pro AB, Stockholm, Sweden) eye-movement registration system was worn by each participant during an 11 v 11 football pre-competitive match on a full-size pitch. The Tobii Pro Glasses 2[®] is a binocular

eye tracker that records the point-of-gaze onto a video image of the scene, measuring the relative position of the pupil and corneal reflection. The image recorded was then analysed *via* the Tobii Pro Lab software (Version X, Tobii Pro AB, Stockholm, Sweden). The Tobii Pro Lab Software was utilized on a Dell Venue 11 Pro 7130, Windows 8/8.1 Pro tablet at a rate of 50 Hz. It is important to highlight that players were not recorded simultaneously. The visual behaviour and attentional effort of three football players were investigated in the five seconds before receiving the ball from their teammate. Jordet *et al.*¹² previously investigated the scanning frequency (players looking over their shoulders) per seconds in the last ten seconds of a team possessing the ball. We chose to analyse our data in the five seconds before the player receive the ball since it might help the coaches and players to interpret another understanding of visual strategies used during a short period of time.

Procedure

The procedures were carefully explained to the participants before the beginning of the experiment. The eye-tracking glasses were well fitted onto the participant's face who also worn a vest holding the recording unit in a small pocket between the shoulder blades. To ensure high gaze data quality, calibration procedures were carried out by asking the participants to focus on the center-point of the calibration card held in front of them for five seconds. Each investigated participant practiced for five minutes playing football while wearing the eye tracker to ensure familiarity with the testing protocols. In the experiment, our three investigated participants took part in a 20-min 11v11 pre-competitive football game. Each of them worn the Tobii eye tracker for about 5 minutes.

To control for possible learning biases, no feedback was provided during performance.

Visual search behaviours

Search rate

The measurement of visual search rate comprised those of the number of fixations (NF); characterising how often each player looks at each of the eight areas of interest (AOI), as per Casanova *et al.*¹¹: the ball (B), an opponent without the ball (ONB), the space around opponent without the ball (Space around ONB), any space around a teammate without the ball (space around TNB), space around a teammate with ball (space around TB), teammate with ball (TB), teammate without the ball (TNB) and undefined (U). The "undefined" category is characterised by any gaze data which would not fall into any of the other areas.

The search rate was measured *via* the fixation duration (FD) (in milliseconds; ms) which reveals how long each player looks at each of the eight AOIs.

The gaze data were measured *via* the Tobii Pro lab software *via* metrics analysis and tracking pursuit analysing data frame-by-frame using a sampling rate of 50 Hz. The velocity-threshold identification (IV-T) algorithm was used to classify the different eye movements depending on their velocity, measured in visual degrees per second ($^{\circ}/s$). This threshold enables the categorization of the raw gaze data into different eye movements as saccades and fixations.²¹ For instance, if the velocity is above the threshold, it would be categorised as a saccade. On the contrary, if the velocity turns out to be below the threshold for a minimum duration of 120 ms, the eye movement data would be classified as a fixation. In this experiment the IV-T filter was set up so that a fixation presents with a minimum threshold of 120 ms, with velocity below the threshold of 100 visual degrees per second ($^{\circ}/s$). The filter was set up with those values because the subjects, targets and objects would be constantly moving under dynamic situations.²²

The analysis of the eye tracking data *via* the Tobii Pro lab software was done *via* assisted mapping of the gaze data point (gaze circle) on to a fixation location and into new coordinate system. In the study conducted by Aksum *et al.*¹⁰ the gaze circle was set at 100% so that it could comprise more than one object of interest. For instance, one fixation could include three different areas such as the ball, teammate, and opponent.¹⁰ In the present study, we choose to set the gaze circle at 1% to contain only one object of interest, so to make the results more precise.

Search order

Search order also defined as fixation order is characterised by the search sequence or order used by the players.²³ The search order was measured by analysing the mean time to first fixation (TFF), indicating when each player looks at each AOI.²⁴ A smaller mean time to first fixation value on a specific AOI would indicate that the player looks at this specific AOI earlier in comparison to other AOIs.²⁴

Attentional effort

Measure of pupil dilatation

We measured the size of the pupil of each of three players which is meant to reflect their attentional effort.²⁵ Pupil data often carries “noises” which are data that cannot be interpreted.²⁶ As a result, the moving average noise reduction filter of the Tobii Pro software was used to filter our data. It produces an output data by creating an arithmetic mean of several data points from the input data.²⁷ The moving average filter also makes an average of the right and left eye data, even in the event of only one eye being recorded.²¹

To demonstrate changes in attentional effort, previous studies measured a baseline (at rest) and a “*post-stimulus*” mean value of a participant’s pupil diameter.¹⁹ Subsequently, the baseline of the pupil data of each player investigated was obtained by measuring the mean of the pupil diameter during the calibration of the eye tracker. The “*post-stimulus*” value of the pupil dilatation of each player was also measured during the five seconds before receiving the ball, as per the gaze behaviour measurements.

Reliability

Test-retest reliability comprised a 20-day interval for re-analysis to avoid any familiarity effects with the task performed using the Cohen’s Kappa test.²⁸ Moreover, reliability was verified through the reassessment of more than 25% of trials, as suggested in the literature.³

Statistical analysis

The distribution of data sets²⁹ was analysed using Shapiro-Wilk tests. Only descriptive statistics for the results analysis was used since this pilot study had a small sample size and, therefore, is statistically underpowered.³⁰ Descriptive analyses were performed using the Statistical Package for Social Sciences software V24.0 (IBM SPSS Statistics for Mac, Armonk, NY: IBM Corp.) (RRID:SCR_002865).

Results

Fixation duration (FD)

Descriptive analysis revealed that the mean FD of the CM was the highest and accounted for 530 ± 509.42 ms, with minimum and maximum values being 140 ms and 1420 ms, respectively (see [Table 1](#) and [Figure 1](#)). The mean FD of the RW was the second highest at 332.50 ± 143.10 ms, with a minimum value of 130 ms and a maximum value of 570 ms. Finally, the mean FD of the LB was the lowest and accounted for 306.25 ± 149 ms, with a minimum value of 130 ms and a maximum value of 480 ms.

Table 1. Mean (m) and standard deviation (\pm sd) of search rate; fixation duration (ms) and number of fixations obtained in centre-midfielder (CM), right winger (RW) and left back (LB) players.

(Search rate)	Player role					
	Centre midfielder		Right winger		Left back	
	Fixation duration	Number of fixations	Fixation duration	Number of fixations	Fixation duration	Number of fixations
AOIs						
(Ball)	270 \pm 509.42	25 \pm 8.07	570 \pm 143.10	19 \pm 5.04	380 \pm 149	16 \pm 4.41
(Opponent No Ball)	150 \pm 509.42	2 \pm 8.07	310 \pm 143.10	6 \pm 5.04	240 \pm 149	6 \pm 4.41
(Space Opponent No Ball)	550 \pm 509.42	3 \pm 8.07	430 \pm 143.10	4 \pm 5.04	130 \pm 149	7 \pm 4.41
(Space Teammate No Ball)	210 \pm 509.42	2 \pm 8.07	130 \pm 143.10	9 \pm 5.04	160 \pm 149	7 \pm 4.41
(Space Teammate Ball)	1420 \pm 509.42	6 \pm 8.07	320 \pm 143.10	7 \pm 5.04	480 \pm 149	12 \pm 4.41
(Teammate No Ball)	270 \pm 509.42	2 \pm 8.07	270 \pm 143.10	6 \pm 5.04	460 \pm 149	8 \pm 4.41
(Teammate Ball)	1230 \pm 509.42	2 \pm 8.07	190 \pm 143.10	5 \pm 5.04	440 \pm 149	7 \pm 4.41
(Undefined)	140 \pm 509.42	1 \pm 8.07	440 \pm 143.10	3 \pm 5.04	160 \pm 149	1 \pm 4.41

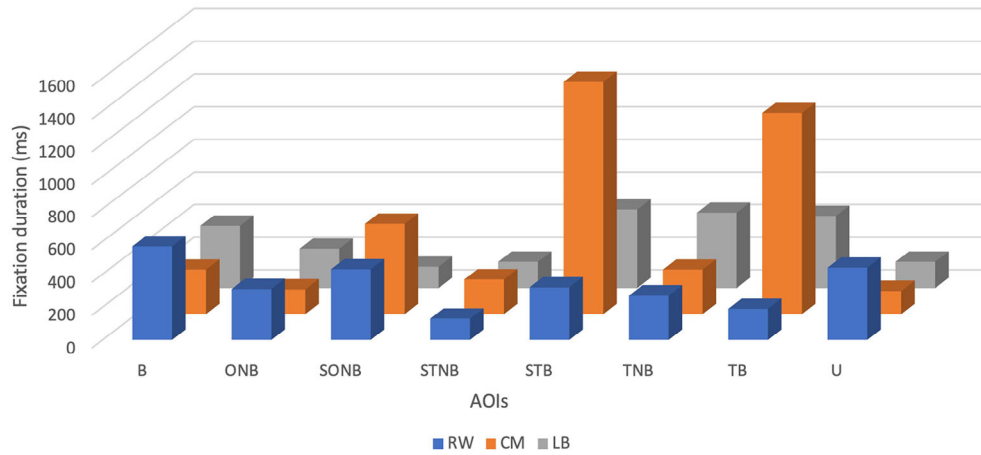


Figure 1. Fixation duration (ms) of players (right winger (RW), centre midfielder (CM) and left back (LB)) by their position during the five seconds before receiving the ball.

Total (TNF) and average number of fixations (NF)

The highest TNF was for LB which accounted for 64, associated with a mean value of 8 ± 4.41 , a minimum value of 1 and a maximum of 16.

The second highest TNF was for the RW which was 59, with a mean value of 7.37 ± 5.04 and minimum and maximum values of 3 and 19, respectively.

We found that the TNF for the CM was 43 and the mean value of 5.36 ± 8.07 . The minimum and maximum of NF were 1 and 25, respectively.

Time to first fixation (TFF)

Descriptive statistics showed that across the explored plays the mean TFF of the LB was the highest and accounted for 22770 ± 18441.24 ms, with a minimum value of 620 ms and a maximum value of 53900 ms.

The mean of TFF of CM was the second highest and accounted for 10211.25 ± 7000.32 ms, with a minimum value of 0 ms and a maximum value of 20960 ms (see Table 2 and Figure 2).

The mean TFF of the RW was the lowest (5078.75 ± 6289.68 ms) with a minimum value of 0 ms and a maximum value of 19360 ms.

Table 2. Mean (m) and standard deviation (\pm sd) of search order; time to first fixation (ms) obtained in centre-midfielder (CM), right winger (RW) and left back (LB) players.

(Search order)	Player role		
	Centre midfielder	Right winger	Left back
	Time to first fixation	Time to first fixation	Time to first fixation
AOIs			
(Ball)	0 ± 7000.32	4790 ± 6289.68	3120 ± 18441.24
(Opponent No Ball)	15000 ± 7000.32	1330 ± 6289.68	4860 ± 18441.24
(Space Opponent No Ball)	5000 ± 7000.32	7970 ± 6289.68	30950 ± 18441.24
(Space Teammate No Ball)	14850 ± 7000.32	3570 ± 6289.68	31890 ± 18441.24
(Space Teammate Ball)	3340 ± 7000.32	1110 ± 6289.68	28770 ± 18441.24
(Teammate No Ball)	10230 ± 7000.32	19360 ± 6289.68	620 ± 18441.24
(Teammate Ball)	12310 ± 7000.32	0 ± 6289.68	28050 ± 18441.24
(Undefined)	20960 ± 7000.32	2500 ± 6289.68	53900 ± 18441.24

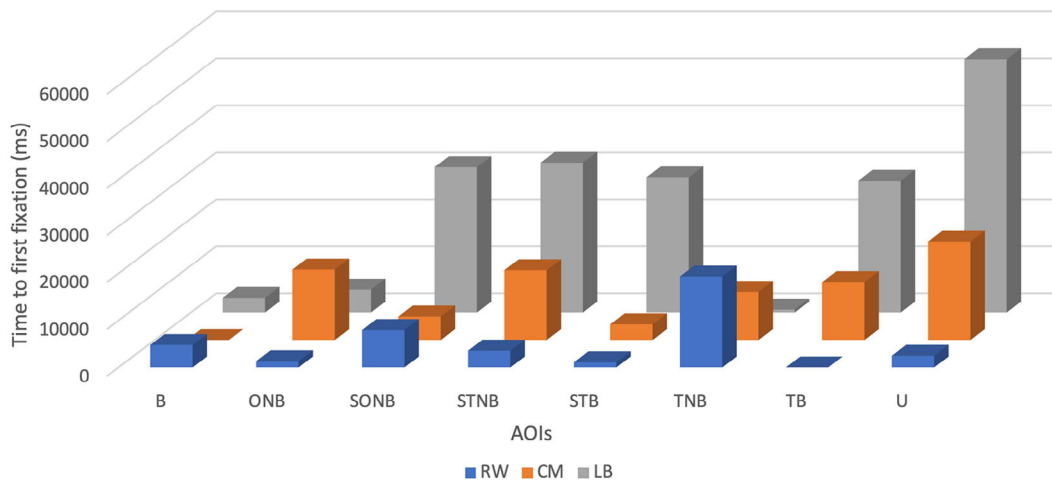


Figure 2. Time to first fixation (ms) of players by their position (right wing (RW), centre midfield (CM) and left back (LB)) during the five seconds before receiving the ball.

Pupil diameter

The mean pupil size of the CM at baseline was 2.50 ± 0.20 millimetres (mm), with a minimum value of 2.21 mm and a maximum value of 3.34 mm. During play, the CM’s mean pupil size increased by 0.40 mm to 2.90 ± 0.26 mm, with a minimum value of 2.34 mm and a maximum value of 3.63 mm (see Table 3 and Figure 3).

Table 3. Mean (m) and standard deviation (\pm sd) of attentional effort; pupil diameter (mm) obtained in centre-midfielder (CM), right winger (RW) and left back (LB) players.

	Player role		
	Centre midfielder	Right winger	Left back
Attentional effort			
	Pupil diameter	Pupil diameter	Pupil diameter
Baseline	2.50 ± 0.20	2.64 ± 0.18	2.59 ± 0.35
During play *	2.90 ± 0.26	2.74 ± 0.30	2.77 ± 0.27

*During the five seconds before receiving the ball from a teammate.

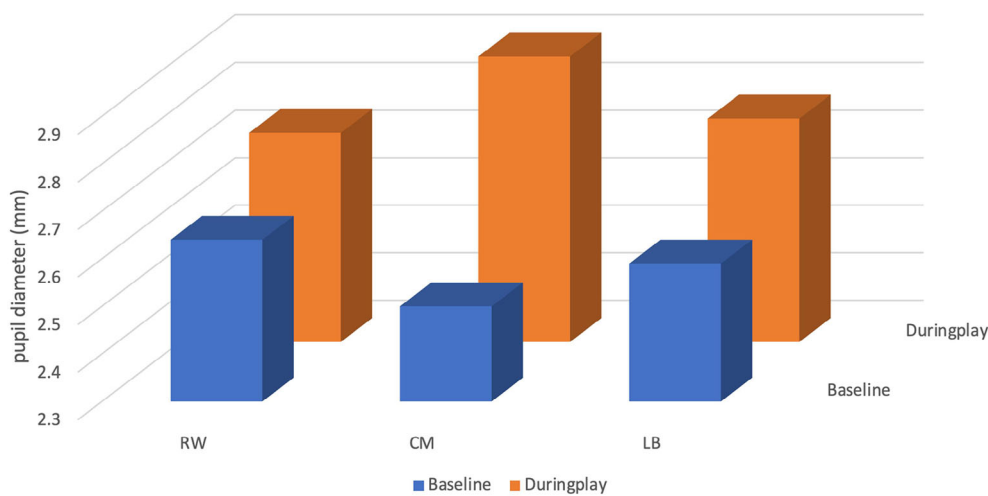


Figure 3. Pupil diameter (mm) of players (right winger (RW), centre midfield (CM) and left back (LB)) by their position during the five seconds before receiving the ball.

The mean pupil size of the RW at baseline was 2.64 ± 0.18 mm, with a minimum value of 2.22 mm and a maximum value of 3.04 mm. During play, the RW's mean pupil size increased by 0.10 mm to 2.74 ± 0.30 mm, with a minimum value of 2.22 mm and a maximum value of 4.59 mm.

The mean pupil size of the LB at baseline was 2.59 ± 0.35 mm, with a minimum value of 2.38 mm and a maximum value of 5.70 mm. During play, the RW's mean pupil size increased by 0.18 mm to 2.77 ± 0.27 mm, with a minimum value of 2.35 mm and a maximum value of 3.89 mm.

Discussion

This pilot experiment was carried out to explore gaze behaviour and attentional effort of football players from LB, RW and CM during the five seconds before receiving the ball from a teammate on 11v11 game. As expected, in the present study we observed dissimilar gaze behaviour and attentional effort from each football player (*i.e.*, CM, RW and LB).

Visual search behaviours

The mean FD of the CM was the highest of all the specific positions analysed (530 ± 509.42 ms). It can be argued that the CM tends to fixate for longer periods of time than the other players, in which is associated with previous studies which explained that the CM players display higher value of mean FD since they usually act as a link between attack and defence.¹⁸ Hence, CM players must process more information because they consistently need to scan their surroundings. The RWs, who can be considered as attacking midfielders, displayed the second highest mean value of FD (332.50 ± 143.10 ms). This contradicts previous research which suggested that attacking players display a lower scanning rate because they usually operate against temporal and spatial in critical areas.¹⁸ Likewise, players located at the peripheries have also restricted use of their vision field since they do not need to gather information from outside the side line.¹² Lastly, the mean FD of the LB accounted for 306.25 ± 149 ms which could be caused by the fact that players having proximity to the goals would have the lowest scanning frequencies.

Analysis of the mean FD on AOIs showed that CM spent more time looking at spaces, particularly at STB (1420 ms) than ONB (150 ms). This reveals that the CM player had more spatial awareness before receiving the ball, which has been evidenced to enable a player to analyse different options and increase the chance of success of their next tactical action. During the five seconds before receiving a pass, it seemed that the RW was more fixating at the ball (570 ms) than the spaces taking individually (STB- 320 ms; STNB- 130 ms; and SONB- 430 ms), which might indicate that the RW player tended to do more “ball watching”. Ball watching has been commonly associated with lower league and amateur players' lack of spatial awareness and technical experience which led them to focus solely on the ball.^{3,9} Interestingly, the LB spent most of time fixating at STB (480 ms) and least time on SONB (130 ms). This could be interpreted that the LB somewhat fixates also at spaces. Nevertheless, it is important to highlight that LB longest mean FD on AOIs, including 480 ms on STB, still remains lower than that of CM and RW's. This could also be explained by his position on the field, as previously mentioned.

It can be observed that despite CM looking 25 times at the ball, the player did not spend as much time fixating at it (270 ms) but rather fixated longer at STB (1420 ms). FD and its relation to cognitive process has been deemed as intuitive.¹⁹ Nevertheless, it has been conjectured that FD appears to be longer with more a complex task and situation.² As a result, it can be argued that CM tends to fixate longer at STB because he needed to process more complex information. Moreover, it is important to mention that STB could entail the space surrounding two different teammates who might have possessed the ball during the five seconds before CM received a pass. Contrary to the CM, the RW had the tendency to fixate more often at the ball (19 times) and longer on the ball (570 ms), while less fixating at STNB (9 times) for 130 ms. Indeed, RW used 49 times fixations during five seconds and the highest number of them were used solely on the ball.²⁰ The same pattern could be observed for LB, who used 64 fixations with a high number of them used on ball (16 times). Those findings could be explained by the fact that our participants are all university level, who are known to do more “ball watching” than their elite counterparts.^{3,9}

The benefits of using TTF as an outcome measure include communicating the visual pattern order of each player.²⁴ Interpretation of TTF on (U) category was not included because it would provide no relevant information in that specific analysis. Subsequently, it can be put forward that during the five seconds before receiving the ball, the CM tends to look first at the ball, then STB followed by SONB, TNB, TB, STNB, and ONB. RW would look at the TB, STB, ONB, STNB, B, SONB and TNB, in order. The LB presented with a different visual search order characterised by firstly fixating at TNB then B followed by ONB, TB, STB, SONB, and STNB.

Attentional effort

As far as we are aware, only a few research studies¹⁹ in sport have used pupil diameter measurements to provide information on player's focus. As a result, it may be difficult to debate our findings to other research studies. Nevertheless, the CM showed a higher increase in pupil size diameter by (0.40 mm) compared to RW (0.10 mm) and LB (0.18 mm), which could be seen regarded as a trait of expertise. Conversely, another study presented that their players with the lowest attentional effort had the highest tactical knowledge.²⁰ For instance, lower and higher tactical knowledge players displayed mean pupil diameter $3.13 \text{ mm} \pm 1.24$ and $3.09 \text{ mm} \pm 1.39$, respectively during verbalization of their gameplay decision.²⁰ This contradicts our previous statement since CM presented with the highest cognitive effort during play ($2.90 \text{ mm} \pm 0.26$). Those differences between theirs and our results could be explained by the fact that their study was done with academy players from a higher league (Brazilian first division soccer club) watching a video on a screen.²⁰ Aksum *et al.*¹⁰ also highlighted discrepancies when comparing their findings to those found in laboratory studies, showing that players investigated in those studies presented on average with longer fixation duration (467 ms to 1,002 ms) while had shorter duration (249.29 ms).

Interestingly, a recent study which looked at evaluating mental load (attentional effort) in training sessions, showed that the pupil diameter of soccer players changes depending on the time spent training.⁵ Although this study had different objectives and methodologies, it presented that exploring attentional effort via pupil diameter could be a tool to monitor cognitive load during training sessions and possibly reduce the risk of mental fatigue.

Our findings revealed that players acting in different specific positions (roles) presented distinctive visual behaviours and attentional effort during the Football game. From a practical perspective, coaches and practitioners should consider how best to use and adapt their interventions to improve visual search behaviours and attentional efforts according to their role in the field.

Limitations

The biggest limitation of this pilot study is the small sample size and the amount of data collected, which do not enable us to demonstrate strongly evidences between the participants.^{30,31} Likewise, because we only had three participants, the results could not generalize to the players role but rather to individual variations. It would also be interesting to gather more data in different sporting settings (indoors vs outdoors football training sites) since pupil size diameters could vary depending on the brightness of an environment and coupling decisional actions, as well.³²

Future recommendations

It is proven that conducting pilot studies can assist in assessing whether research is possible on a bigger scale.³¹ Despite its limitations, the present pilot study gives a new oncoming on-field data that coaches could use to assess and improve their player's visual behaviour and attentional effort.

Ethics and consent statement

The studies involving human participants were reviewed and approved by the Ethical Committee of Lusófona University (protocol number M25A21) and University College London (protocol number 7067/001). The participants provided their written informed consent to participate in this study, including the data collection and publication.

Author contributions

FC and CB contributed to the conceptualisation, data collection, data analysis, and writing of the paper. JB contributed to the data analysis and writing of the paper. EH contributed to revising and writing the paper. All authors contributed to the article and approved the submitted version.

Data availability

Underlying data

Open Science Framework (OSF): Visual Behaviour and Attentional Effort of Football Players, <https://doi.org/10.17605/OSF.IO/WAEYJ>.²⁹

- (1) gaze behaviour of football players (Data).csv
- (2) Attentional effort of football players (Data).csv

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/) (CC-BY 4.0).

References

1. Ashford M, Abraham A, Poolton J: **Understanding a Player's Decision-Making Process in Team Sports: A Systematic Review of Empirical Evidence.** *Sports (Basel).* 2021; **9**(5).
[Publisher Full Text](#)
2. Williams MA, Jackson RC: *Anticipation and Decision Making In Sport.* New York, London: Routledge Taylor & Francis Group; 2019.
3. Roca A, Ford PR, McRobert AP, et al.: **Perceptual-cognitive skills and their interaction as a function of task constraints in soccer.** *J. Sport Exerc. Psychol.* 2013; **35**(2): 144–155.
[PubMed Abstract](#) | [Publisher Full Text](#)
4. Memmert D: **Pay attention! A review of visual attentional expertise in sport.** *Int. Rev. Sport Exerc. Psychol.* 2008; **2**(2): 119–138.
[Publisher Full Text](#)
5. Luis-Del Campo V, Morenas Martin J, Leon Llamas JL, et al.: **Influence of the time-task constraint on ocular metrics of semi-elite soccer players.** *Sci. Med. Footb.* 2023; 1–8.
6. World FN: *Coaching Football Intelligence: Scanning vs Situational Awareness.* Youtube; 2020.
[Reference Source](#)
7. World FN: *Michael Buel - Process of Learning From The Game to Design Scanning Training Drills.* Youtube; 2021.
8. Blair CD, Ristic J: **Attention Combines Similarly in Covert and Overt Conditions.** *Vision (Basel).* 2019; **3**(2).
[Publisher Full Text](#)
9. Williams MA, Williams JG, Davids K: *Visual Perception and Action in Sport.* USA and Canada: Routledge; 1999.
10. Aksum KM, Magnaguagno L, Bjorndal CT, et al.: **What Do Football Players Look at? An Eye-Tracking Analysis of the Visual Fixations of Players in 11 v 11 Elite Football Match Play.** *Front. Psychol.* 2020; **11**: 562995.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
11. Vitor de Assis J, Costa V, Casanova F, et al.: **Visual search strategy and anticipation in tactical behavior of young soccer players.** *Sci. Med. Footb.* 2021; **5**(2): 158–164.
[PubMed Abstract](#) | [Publisher Full Text](#)
12. Aksum KM, Pokolm M, Bjorndal CT, et al.: **Scanning activity in elite youth football players.** *J. Sports Sci.* 2021; **39**(21): 2401–2410.
[PubMed Abstract](#) | [Publisher Full Text](#)
13. Purves D, Augustine GJ, Fitzpatrick DKL, et al.: *Types of Eye Movements and Their Functions.* Sinauer Associates; 2001. Edition Nn, editor
14. Williams AM, Davids K: **Visual search strategy, selective attention, and expertise in soccer.** *Res. Q. Exerc. Sport.* 1998; **69**(2): 111–128.
[PubMed Abstract](#) | [Publisher Full Text](#)
15. Vater C, Williams MA, Hossner E-J: **What do we see out of the corner of our eye? The role of visual pivots and gaze anchors in sport.** *Int. Rev. Sport Exerc. Psychol.* 2019; **14**(1): 81–103. Taylor & Francis Online.
16. Lobo L, Heras-Escribano M, Travieso D: **The History and Philosophy of Ecological Psychology.** *Front. Psychol.* 2018; **9**: 2228.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
17. Paterson G: *Perception – action coupling and decision-making in sport.* Amsterdam: Vrije Universiteit; 2020.
18. Laakso T, Davids K, Luhtanen P, et al.: **How football team composition constrains emergent individual and collective tactical behaviours: Effects of player roles in creating different landscapes for shared affordances in small-sided and conditioned games.** *Int. J. Sports Sci. Coach.* 2022; **17**(2): 346–354.
[Publisher Full Text](#)
19. Moran A, Quinn A, Campbell M, et al.: **Using pupillometry to evaluate attentional effort in quiet eye: A preliminary investigation.** *Sport Exerc. Perform. Psychol.* 2016; **5**(4): 365–376.
[Publisher Full Text](#)
20. Cardoso F, Gonzalez-Villora S, Guilherme J, et al.: **Young Soccer Players With Higher Tactical Knowledge Display Lower Cognitive Effort.** *Percept. Mot. Skills.* 2019; **126**(3): 499–514.
[PubMed Abstract](#) | [Publisher Full Text](#)
21. Olsen A: **The Tobii I-VT Fixation Filter, Algorithm description.** 2012.
22. Tobii: **When do I use the I-VT Attention filter?** 2018.
[Reference Source](#)
23. Williams AM, Davids K, Burwitz L, et al.: **Visual search strategies in experienced and inexperienced soccer players.** *Res. Q. Exerc. Sport.* 1994; **65**(2): 127–135.
[PubMed Abstract](#) | [Publisher Full Text](#)
24. Tobii: 2022.
[Reference Source](#)
25. Campbell MJ, Moran AP, Bargary N, et al.: **Pupillometry During Golf Putting: A New Window on the Cognitive Mechanisms Underlying Quiet Eye.** *Sport Exerc. Perform. Psychol.* 2018; **8**: 53–62.
[Publisher Full Text](#)
26. Kret ME, Sjak-Shie EE: **Preprocessing pupil size data: Guidelines and code.** *Behav. Res. Methods.* 2019; **51**(3): 1336–1342.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
27. Tobii: **Tobii Pro Lab Gaze Filter 2023.**
[Reference Source](#)
28. Robinson G, O'Donoghue P: **A weighted kappa statistic for reliability testing in performance analysis of sport.** *Int. J. Perform. Anal. Sport.* 2017; **7**(1): 12–19. Taylors Francis Online.
[Publisher Full Text](#)
29. Ballet C, Barreto J, Casanova F, et al.: (Data set) What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game? A Pilot Study. [Data]. 2023.
[Publisher Full Text](#)
30. Field A: *Discovering Statistics using IBM SPSS Statistics.* 5th Edition. SAGE; 2018.
31. Van Teijlingen ER, Rennie AM, Hundley V, et al.: **The importance of conducting and reporting pilot studies: the example of the Scottish Births Survey.** *J. Adv. Nurs.* 2001; **34**(3): 289–295.
[PubMed Abstract](#) | [Publisher Full Text](#)
32. Klatt S, Noel B, Brocher A: **Pupil size in the evaluation of static and dynamic stimuli in peripheral vision.** *PLoS One.* 2021; **16**(5): e0250027.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)

Open Peer Review

Current Peer Review Status: ?

Version 1

Reviewer Report 17 July 2023

<https://doi.org/10.5256/f1000research.147268.r178912>

© 2023 Luis-del Campo V. This is an open access peer review report distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



Vicente Luis-del Campo

Faculty of Sport Sciences, University of Extremadura, Caceres, Spain

*Comments to the Authors:

The submitted manuscript entitled "What is the visual behaviour and attentional effort of football players in different positions during a real 11v11 game?" describes an interesting study about the visual and attentional demands that young athletes in football have when played some specific game sequences in the playing field.

Firstly, I appreciate your submission on various accounts. To exemplify, it is an innovative study because there are few studies in the literature about visual perception in sport collecting visual fixations of athletes with portable eye trackers in the playing field. Therefore, this study allowed to evaluate the visual behaviours and attention of football players with an in situ approach during real 11 vs 11 sequences of the play. As a result, the ecological validity of this study was guaranteed because authors used representative tasks for the study of visual behaviours in a naturalistic environment. Additionally, I argue that the rationale of the study is well-focused towards the relevance of the perceptual-cognitive skills and visual attention on the athletes' performance (e.g, anticipation and decision-making). I also agree with the decision of authors of starting the exploration of footballers' visual and attention activity with a pilot study because this type of studies would: i) provide an initial tendency of the data, ii) enhance a better replication of the same study in further attempts (e.g., improving reliability of research tools and/or designs, etc.), and iii) achieve a higher external validity of the data if a large sample of participants may be recruited.

Nevertheless, I have two main concerns that require contemplation and appropriate attention in revising the document if it is to contribute appropriately to the extant literature. These two concerns are related to the selected time to analyse fixations and the lack of integration between visual fixations and other behavioural measures of movement:

1. Why did the authors decide to collect and analyze the five seconds before receiving the ball from a teammate on 11v11 games? What is the rationale for this decision? The authors claim that Jordet et al. used a temporal window of 10 seconds for the team possessing the

ball, then, why did the authors consider that five seconds would be enough to scan correctly and sufficiently the visual activity of the football players?

2. The existing studies about visual perception in sport have usually used not only visual variables but also other motor outcomes due to the strong relation between perception-action loops. However, there is an absence of measures related to the motor behaviour of athletes in this study. Why did the authors not include this type of behavioural variables when players performed their specific actions on-field? (e.g., decision-making, number of correct passes performed, etc.). The combined analysis of visual information and movement would offer a better understanding of the underlying cognitive processes supporting performance of the players for this tactical sport.

These reservations should be clarified and justified throughout the manuscript before a decision can be made on publication.

Introduction

In my opinion, the background of the paper offers a general viewing of the state-of-the art about visual perception and attention in sport. However, it would be interesting to add more existing studies in football that used variables related to visual performance to address sport performance in controlled laboratory settings. This point would strengthen the need of accumulating more evidence using on-field studies with representative procedures and designs to test visual and motor behaviours of footballers.

After reading this section, it seems clear that there is a lack of studies assessing visual behaviours in the playing field. For an exception, the authors highlight the observational study conducted by Aksum et al. (2021) with midfield footballers while playing a real 11v11 match. This is a similar study compared to Ballet and colleagues, but these last authors have now included the gaze behaviours of footballers with different roles and visual attention. I would also encourage authors to introduce another recent published paper driven by Luis-del Campo and colleagues (2023)¹ because they used ocular metrics and saccadic features as biomarkers of the mental load suffered by football players when performed a training session with manipulation of the available time to complete the goals of the tasks. This study would provide authors some interesting results to compare with your data, for instance, of pupil size.

Luis-Del Campo, V., Morenas Martín, J., León Llamas, J. L., Ortega Morán, J. F., Díaz-García, J., & García-Calvo, T. (2023). Influence of the time-task constraint on ocular metrics of semi-elite soccer players. *Science & medicine in football*, 1–8. Advance online publication. <https://doi.org/10.1080/24733938.2023.2172203>

Additionally, the authors should include other studies that used ocular metrics in footballers. For example, lower pupil diameter was associated with higher values of tactical knowledge (Cardoso et al. 2019)² and better tactical behaviour efficiency (Cardoso et al. 2021)³.

I am not sure if it would be appropriate for a pilot study to drive hypotheses with specific predictions about the impact of role position on visual behaviours when the authors show no previous studies for a different visual exploration of the playing field regarding the specific role in

the team. Thus, the number of total fixations collected (n=166) seems scarce to conclude these initial assumptions. Indeed, the authors state at the statistical analysis that only descriptive statistics were used. What is the authors' opinion about this issue?

Method

It would be fine to add more specific information about the visual and motor experiences of footballers (e.g., the average of hours training by week, or the average of hours watching football matches on TV or in the field).

Again, I find lost a scientific approach to decide that the five seconds before receiving the ball from their teammate were sufficient to fully understand the visual behaviours of the three footballers during 11 vs 11 sequences of play. What do the authors mean when refer to "...interpret another understanding of visual strategies used during a short period of time"? Please, clarify this point.

Again, the authors did not include any variable related to decisional and/or motor behaviours. The authors should clarify those reasons that prevented them the use of these variables while participants wearing the eye tracking glasses during five minutes of the 11v11 pre-competitive football game. In my opinion, this should be stated as another limitation of the study.

I guess that the number of calibration points was 1 when the authors stated "...participants to focus on the center of the calibration card held in front of them for five seconds", didn't they? If true, they should specify this technical detail.

The specifications showed by the authors were robust for the identification of fixations and search rate. For the search order of fixations, I would recommend authors to use the Graphos software for a better understanding of this type of analysis of fixations. This software would also help readers to better interpret the relevance of certain AOIs and the order in which the footballers moved their gaze from one AOI to another one.

The pupil size has showed sensitiveness to different light conditions (Wyatt 1995)⁴ but also to cognitive states of participants (Beatty, 1982; Mahanama et al., 2022; Mathôt et al., 2015)^{5,6,7}. Taking into consideration that the pupil dilation showed responsiveness to different external and/or internal variables, I wonder if the three participants had the same conditions to measure the attentional effort, at the baseline and at a "post-stimulus", because their visual fixations were collected at different moments of the 20-min 11v11 pre-competitive football game. I would like to know the opinion of the authors about this issue, and I ask them if they consider that the impossibility of measuring simultaneously would be a limitation of the study.

Statistical analysis and results

During the writing of the results, I would add the information about what participant achieved the highest or lowest values for fixation durations, number of fixations and time to first fixation at the different AOIs.

To exemplify, for the fixation durations, the RW participant displayed longer fixations on B, ONB and U, compared to the CM and LB participants. The CM participant showed fixations of longer duration on SONB, STB and TB, compared to RW and LB ones. The LB participant made longer fixations only on the TNB, compared to RW and CM ones. For the time to first fixation, the LB participant showed the highest values for the most AOIs, compared to RW and CM ones (e.g., SONB, STNB, STB, TB, U). The RW participant displayed the highest values for B and TNB, compared to CM and LB. Contrary, the CM participant achieved the highest values only for the ONB, compared to RW and LB ones. Finally, to highlight that the CM participant was the footballer who more increased the values for pupil diameter variables from “baseline” to “duringplay”, compared to the RW and LB participants.

This information would help to understand that each participant explored differently the playing field, and what AOIs were more or less relevant for the participants regarding their role in the team. Contrary, I would not specify the values found in the tables during the wording because the authors may duplicate information for readers or be redundant during the presentation of their results.

Discussion

The authors have provided different explanations for their results found, also comparing them to other previous specific studies. I congratulate them because they found well-focused accounts in this attempt.

Again, the authors should use the results of Luis-del Campo et al. (2023)¹ to compare them with those found for their attentional effort variable. This comparison would enrich the discussion section and may show how the pupil diameter shows a similar or different responsiveness regarding the skill level of footballers.

I would recommend authors more specification when talked about the practical perspective. In this vein, it would be fine that the authors could show some examples of modifications during 11 vs 11 play games to improve visual behaviours of footballers regarding their player role.

*Specific comments to the Authors:

Introduction

The authors refer to decision-making as an “ability”. Are they suggesting that decision-making could not be learned (i.e., natural or innate), or aimed at achieving a goal, as opposed to a “skill”?

I would recommend authors to delete the last “,” at the next phrase: “....body, and positioning, vary continuously”.

I would recommend authors to change “when talking about” by “for” at the next phrase: “Therefore, visual perception is crucial when talking about spatial awareness”.

I would recommend authors to add “up” after the verb “picked”, at the next phrase: “...is mainly

picked and processed”.

I would recommend authors that in this phrase “....can vary depending on the skill level of an athlete”, they would add this: “.....can vary depending on the skill level of an athlete and task constraints existing in the sport environments”.

I would recommend authors to change “fixate on” by “fixate at”. For example: “Furthermore, midfield players fixate more on the player in possession of the ball during a defensive phase of play than during an attacking phase”. Please, change throughout the document if necessary again.

Discussion

I would not introduce the specific vales for the variables at this discussion section.

I hope that these comments will serve you well in your efforts to improve your manuscript.

References

1. Luis-Del Campo V, Morenas Martín J, León Llamas JL, Ortega Morán JF, et al.: Influence of the time-task constraint on ocular metrics of semi-elite soccer players. *Sci Med Footb.* 2023. 1-8 [PubMed Abstract](#) | [Publisher Full Text](#)
2. Cardoso FDSL, González-Villora S, Guilherme J, Teoldo I: Young Soccer Players With Higher Tactical Knowledge Display Lower Cognitive Effort. *Percept Mot Skills.* 2019; **126** (3): 499-514 [PubMed Abstract](#) | [Publisher Full Text](#)
3. Cardoso FDSL, García-Calvo T, Patrick T, Afonso J, et al.: How Does Cognitive Effort Influence the Tactical Behavior of Soccer Players?. *Percept Mot Skills.* 2021; **128** (2): 851-864 [PubMed Abstract](#) | [Publisher Full Text](#)
4. Wyatt H: The form of the human pupil. *Vision Research.* 1995; **35** (14): 2021-2036 [Publisher Full Text](#)
5. Beatty J: Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin.* 1982; **91** (2): 276-292 [Publisher Full Text](#)
6. Mahanama B, Jayawardana Y, Rengarajan S, Jayawardana G, et al.: Eye Movement and Pupil Measures: A Review. *Frontiers in Computer Science.* 2022; **3**. [Publisher Full Text](#)
7. Mathôt S, Van der Stigchel S: New Light on the Mind's Eye: The Pupillary Light Response as Active Vision. *Curr Dir Psychol Sci.* 2015; **24** (5): 374-378 [PubMed Abstract](#) | [Publisher Full Text](#)

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Visual perception and action in sport

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research