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Interpersonal Coordination and Visual perception of information for Decision-Making in Futsal

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Abstract

This study investigated how futsal players visually perceived information on angular interpersonal coordination relations when deciding to shoot. Experienced players (n=180) participated in eighteen videorecorded futsal matches, during which 32 participants wore an eye tracking device. Forty-five sequences of play were edited from the moment a teammate passed the ball to the shooter, until the moment a shot was undertaken. Independent variables included the following angular measures: (1) the angle connecting the shooter to their closest defender and goalkeeper; (2) the angle linking the shooter to the goalkeeper and left post of the goal; and (3), the angle connecting the shooter to the goalkeeper and right post. These angular values were also considered in relation to their rates of change (velocity and variability). Information on the goalkeeper, the shooter's closest marking defender, ball, and court floor were registered when they were focused only by the foveal vision, only in the peripheral vision, by both vision systems, and when they were out of the visual field. Findings revealed that: (i) futsal players' decision making to shoot was underpinned by four visual patterns, emerging from the interaction of gaze fixation and peripheral vision separately and in conjunction; (ii) such patterns are dependent on the characteristics of the final angle connecting the shooter to the closest marking defender and goalkeeper; and (iii), while utilisation of both vision systems allows futsal players to use the greater and growing angles, only foveal or peripheral vision does this based on the smaller and diminishing or stable angles.

Keywords: Angular relationships, Visual search, Team sports, Ecological dynamics, interpersonal coordination.

1. Introduction

Decision-making has been one of the most investigated phenomena in psychological research, in different areas of knowledge, including Sport Science (e.g., Raab et al., 2019). Its importance arises whenever performance outcomes, paths, or processes depend on choices. The search for understanding decision-making in performance began in the last century, when interaction tendencies started to be considered for explaining emergent phenomena (von Bertalanffy, 1950). An important example of this work is von Neumann and Morgenstern's (1944) theory of games and economic behavior, which provided mathematical modelling for understanding decisions made in social, political and economic contexts involving interactions between individuals, whether competing or cooperating. These types of interactions that have been considered a key aspect for decision-making research in team sports (Corrêa et al., 2014; McGarry 2009; McGarry et al., 2002; Passos et al., 2009). For instance, in the team sport of futsal, players constantly have to make decisions on actions (e.g., controlling the ball, shooting, passing, intercepting and tackling or dribbling) during performance .

Over the last few years, how players make decisions in different team sports has been the focus of numerous studies developed from an ecological dynamics perspective (e.g., Bourbousson et al., 2010; Clavijo et al., 2018; Correia et al., 2011; Denardi et al., 2017; Pinho et al., 2020). From this perspective, players make decisions based on their perception of relevant information for action (e.g., affordances) emerging from ball location, co-positioning of competitors and player displacements. Since players act to cooperate and compete within the laws of the game, information from the environment enables access to the spatiotemporal measures of these interpersonal coordination tendencies (Bourbousson et al, 2014; Passos et al., 2014). For instance, studies have revealed that, in futsal, players make decisions to shoot at goal, based on many key performance variables including: (a) the distance of each player in relation to the ball's trajectory (interception point); (b) the velocity of ball displacement; (c) the velocity of the goalkeeper's movement to intercept the ball; (d) the angle between the attacker, the closest defender and the goal; (e) the distance between the attacker and the center of the goal; (f) the distance between the closest defender and the center of the goal; (g) the distance between the attacker and the nearest defender; and (h), the relative velocity of the shooter and the closest defender (Vilar et al., 2013, 2014a, 2014b).

The current study sought to contribute to understanding of performance by considering the players' visual behaviors when making decisions to shoot at goal. If players make decisions by picking up and using information on the action alternatives emerging dynamically from interpersonal coordination, it is important to attempt to understand how they visually perceive information variables to regulate their decision making and actions. For instance, considering the use of vision during interpersonal coordination, a recent study by Corrêa et al. (2020) showed that futsal players vary their point of fixation to obtain a functional relative angle of shooting at goal. This relative angle was compounded by the relationship between the shooting player, their nearest defender, and the goalkeeper. A functional value provided information on an opportunity to successful shoot at goal (a mean value of 29.28°, which emerged through 8.30 °/sec of velocity and rate of variation of 0.33).

However, notwithstanding the important role of gaze fixation in focusing and identifying the relevant information for action, peripheral vision has also been recognised to be essential for decision-making in team sport contexts (Runswick et al., 2021; Ryu et al., 2013; Schwab et al., 2012; Vater et al., 2019a; Willians et al., 2004). Peripheral vision is the part of vision that allows picking up information (e.g., players and ball position and displacement) outside focal vision (the center of gaze) (Ryu et al., 2013; Williams & Davids, 1998; Davids & Stratford, 1989; Davids, 1988). Interestingly, most of the eye-tracking technologies used to assess gaze behavior in team sports have allowed the advancement of knowledge, mainly in relation to gaze fixation; therefore, peripheral vision has not been properly considered (Erickson, 2021; Vater et al., 2017). In addition, to the best of our knowledge, few studies have considered the interaction between the functioning of vision and interpersonal coordination information at an ecological level of analysis, i.e., a real futsal match (Schumacher et al., 2020).

Based on the foregoing, we sought to extend the previous findings by identifying the information in the futsal players' visual field during decision-making on shooting. For this purpose, the information focused by foveal vision, peripheral vision, or both was investigated, considering a real scenario of angular interpersonal coordination of shooting in the sport of futsal.

2. Method

2.1 Participants

One hundred eighty young adults with normal visual acuity who played eighteen matches of futsal following rules set by FIFA voluntarily participated. From them, thirty-two players (average age =19.27 yrs; SD = 1.95 yrs) played for periods of a game while wearing an unobtrusive eye tracking device. For this purpose, based on the coach's knowledge of the team, a player with a tendency to perform many shots during the game was chosen to wear the glasses in the first half of the game, and another player wore it during the second half. Participation required the volunteers' written consent, and the experimental protocol was given ethical approval by the local Institutional Review Board.

2.2 *Data collection*

The players' movement displacement values were captured at a frequency of 25 frames per second by using three cameras (Canon-SX170, Gopro hero 3 black edition and Sony DSC-W830). Two of them were placed behind the goals (*x* coordinate), between 10 and 15 m high, and the other was positioned at the same height, but on the lateral court line (*y* coordinate) (Denardi et al., 2017). Forty-five sequences of play ranging from 0.36 to 5.28 sec were selected and edited from the moment a teammate passed the ball to the shooter (initial moment), until the moment this shooter performed a shot at goal (final moment). Regarding interpersonal coordination, the following angles were captured frame by frame using KINOVEA 8.27 software (http://www.kinovea.org): (1) angle connecting the shooter to their closest defender and the goalkeeper; (2) angle linking the shooter to goalkeeper and the left post of the goal; and (3), angle connecting the shooter to goalkeeper and the right post. Such angles were also analysed in relation to rates of change, through calculating the angular velocity value, considering $v\Theta = (\Theta I - \Theta F)/t$, where v refers to the velocity, I is the initial angle (when a teammate performed the passing), F is the final angle (when the shooting was performed), and t was the duration of the sequence of play. In this case, a positive value of angular velocity means that the angle of interpersonal coordination increased from the initial to the final moment, while a negative value means that it decreased. to the rate of change in angular variability was also calculated, using $CV = \sigma/\mu$, where CV refers to the coefficient of variation, σ refers to the standard deviation and μ is the arithmetic mean.

A set of glasses, with dedicated software, and a recording unit composing an eye tracking system (TOBII PRO: Figure 1 - Tobii pro, Danderyd, Sweden) were used for data collection on participant visual search tendencies, considering the following informational variables in participants' visual field during the sequence of play: shooter's closest defender, goalkeeper, ball, and court floor. The visual field refers to the external world that can be seen without a change in fixation (Erickson, 2021). It has been suggested to cover approximately 190°, with foveal vision covering approximately the central 1.7° eccentricity of the visual field (Anderson, 1987; Rosenholtz, 2016). Due to the limitation of the technology used, the visual field captured covered 90° (TOBII AB. Product Description Tobii Pro Glasses 2. US. v.1.95, 2018; https://www.tobiipro.com/siteassets/tobii-pro/product-descriptions/tobii-pro-glasses-2-product-description.pdf). During sequence of play, the following information was (i) focused only by the foveal vision (FV); when they were not focused by the foveal vision but were in the visual field, that is, when such information was only in the peripheral vision (PV); (iii) when they were focused by the foveal vision and were also in peripheral vision (FV/PV); and (iv) when they were out of the field specified above (OVF).

The synchronization of the information from the eye-tracking system and sequences of play from the video footage was made through the Adobe Premiere PRO 13.0 software (Adobe, Boston, USA). Finally, the KINOVEA software 8.27 (http://www.kinovea.org) made possible the access and record of both foregoing in the same interface. The interrater reliability was obtained by the Pearson correlation test ($r = 0.92$, $p < 0.01$).

2.3 Data analyses

First, from the identification of how the shooter visually handled the information involved in the interpersonal coordination scenario, it was plotted into its respective shotting to characterise the visual pattern of shooting performance. For instance, the sequence of play of shooting 1 involved the following visual pattern for goalkeeper, shooter's closest defender, ball, and court floor, respectively: PV – FV/PV – FV – PV. From the plotted data on all 45 shots, a cluster analysis using Ward's minimum variance method with Euclidean distance was run (Johnson & Wichern, 2014). The output of this analysis was a tree diagram named dendrogramme for 45 shots. It shows the similarity level (distance) between the visual pattern of shooting performance on the *y*-axis, while the cluster of shooting is presented on the *x*-axis. From the dendrogramme, a cut-off level of 25% of its overall height was assigned based on the distinctness, compactness, and weight of the clusters (Everitt et al., 2011; Kaufman & Rousseeuw, 2009). These procedures allowed us to identify different visual patterns used in shooting performances.

Second, a one-way analysis of variance (ANOVA) was run to compare each of those three initial and final angles of interpersonal coordination and their respective velocities and variabilities in relation to the identified visual patterns. In this case, the $Fisher_{LSD}$ test was used as a post hoc test. The foregoing analyses were developed by *Statistica® 13.0* software (StatSoft Inc., Tulsa, OK, USA).

Finally, to identify the main characteristics of the shooting's visual patterns showing significant effects, we run a test of multiple comparisons through the Trend Module (Trend Analysis and Multiple Comparisons) of PEPI software (Gahlinger & Abramson, 2005). For this, the relative frequencies of FV, PV, FV/PV, and OVF in the different shooting visual patterns were compared. For all analyses, the level of significance was set at $p \leq .05$.

3. Results

Table 1 presents the relative frequency of the visual patterns of each type of information. It shows that the goalkeeper was more in PV and PVF, and the closest defender was more in PV. In contrast, the ball and court floor were more focused by FV. It is interesting to note that the ball was not in the PV during the sequence of play.

Insert table 1 about here

As Figure 1 shows, statistical analysis (Ward method with Euclidean distance) revealed four visual patterns in the shooting (P1, P2, P3, and P4). P1 occurred in shots 13, 16, 18, 22, 23, 24, 25, 26, 27, 28, and 29; P2 was performed in shots 2, 4, 10, 11, 15, 19, 21, 33, 36, 37, 38, 39, and 41; P3 occurred in shots 5, 6, 7, 9, 42, 43, 44, and 45; and P4 was performed in shots 1, 3, 8, 12, 14, 17, 20, 30, 31, 32, 34, 35, and 40. It also shows there was no major tendency for goals to be scored in these visual patterns, since they were scored in the shots 1, 6, 7, 8, 12, 13, 21, 22, 24, 25, 27, 31, 36, 38, 39, 40, 42, and 44.

Insert figure 1 about here

The ANOVAS results revealed effects only for the final angle connecting the shooter to his/her closest defender and the goalkeeper (Table 2). The post hoc test pointed out that this angle in P3 was greater than in P1, P2, and P4 ($p < 0.05$) (Figure 2).

Insert table 2 about here

Insert figure 2 about here

Table 3 shows that the Trend Analysis and Multiple Comparisons revealed differences for all informational variable (goalkeeper, shooter's closest defender, ball, and court floor). P3 was characterised by a smaller relative amount of this information focused by FV/PV than PV and OVF (goalkeeper), FV (shooter's closest defender and ball), FV and PV (court floor) ($p \leq 0.05$).

Insert table 3 about here

4. Discussion

This study investigated how futsal players handled visually with information compound an angular interpersonal coordination scenario to make decision on shooting. It has been remarkable what technological advances in eye-tracking systems have contributed to understanding the role of the visual sense in sport contexts, including the locus and time of gaze fixation. In fact, studies have pointed out gaze fixation as an essential mechanism for athletes' perception of relevant information for successful decision-making and action (e.g., Mann et al., 2019; Savelsbergh et al., 2006; Vickers, 2016). Notwithstanding the advancements on this subject, it has also been assumed that complex and dynamic environments such as those of team sports, which involve several players interacting in different ways over time, also demand complex and dynamic visual behavior (Ericson, 2021; Williams et al., 2004). In this vein, this study's results showed that futsal players performed four visual patterns by interacting gaze fixation and peripheral vision on goalkeeper, shooter's closest defender, ball, and court floor, separately and in conjunction. Therefore, it appears there were four sets of shooting whose informational demand implied different visual resources for decision-making. One could say that this has occurred because the visual information demand for decision-making changes as a function of the teammates, opponents, and ball positions (Vater et al., 2019a).

Interestingly, the results also revealed that while the ball and court floor were more focused by the foveal vision, the goalkeeper and shooter's closest defender floor were more in the peripheral vision. Regarding the ball, although it may be in the peripheral vision depending on its position and the position of the shooter's head, it demands gaze fixation at some point during the shooting performance because its success depends on the contact accuracy of the foot with the ball (Barbieri et al., 2008; Dicks et al., 2010; Quintana et al., 2007).

In relation to gaze fixation on points of the count floor, it can have occurred as a pivot or anchoring strategy (Vater et al., 2019a). This consists of the player fixing the gaze on a specific point to avoid the constant direct monitoring of other players. Specifically, gaze anchoring is suggested to occur on cues and free space, whereas the visual pivot is used to select the location for the next fixation to a peripheral cue (Vater et al., 2019b). This might explain why goalkeeper and shooter's closest defender have been more focused on peripheral vision. Therefore, peripheral vision can be useful to simultaneously monitor the movements of both opponents and teammates in team sports (Davis, 1984; Ryu et al., 2013; Schumacher et al., 2020) or, more specifically, information compounding angular interpersonal coordination.

In sum, in conjunction, these results provide support for the players' perceptive ability to deal with informational demands for decision-making through the interplay of central and peripheral visions. However, the results also showed that the final angle connecting the shooter to his/her closest defender and goalkeeper in the P3 visual pattern was greater than the remaining angles, and it was characterised by a smaller relative amount of information focused by foveal vision and peripheral vision during the sequence of play than other visual patterns. In other words, the smaller final angles of interpersonal coordination involved only using foveal vision or peripheral vision during the sequence of play.

It is interesting to note that P3 is the only visual pattern involving interpersonal coordination with a clear tendency to increase the angle over the sequence of play (Figure 2b). In contrast, P2 and P4 showed a decreasing tendency, and in P1, the angular tendency remained at the same magnitude. These tendencies in angular interpersonal coordination could afford different levels of opportunity for a shooting to be successfully completed (Corrêa et al., 2016;

Vilar et al., 2014b). Thus, it is possible that the utilisation of both vision systems has allowed futsal players to perceive the greater and growing angles of interpersonal coordination as opportunities for shooting, whereas only foveal or peripheral vision did so based on the smaller and diminishing or stable angles.

Finally, the findings of this study showed that (i) futsal players can make decision on shooting through four visual patterns by interacting gaze fixation and peripheral vision on goalkeeper, shooter's closest defender, ball, and court floor separately and in conjunction; (ii) such patterns are dependent on the characteristics of the final angle connecting shooter to his/her closest defender and goalkeeper; and (iii) while the utilisation of both vision systems allows futsal players to perceive the greater and growing foregoing angles, only foveal or peripheral vision does this based on the smaller and diminishing or stable angles. Obviously, these findings are closely related to the method. As part of the scientific endeavor, they need to be replicated to guarantee the consistency necessary for generalisation and transformation into instructional procedures. In this process, future studies need to reconsider the technological limitations of visual field capture.

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Tables and Figures Captions

Table 1 - Relative frequency (%) of visual patterns (FV, PV, FV/PV, and OVF) of the goalkeeper, shooter's closest defender, ball, and court floor.

Table 2 – Results of the one-way ANOVAS for (a) initial and (b) final angles linking the shooter to goalkeeper and the left post and its (c) velocity and (d) variability, (e) initial and (f) final angles connecting the shooter to goalkeeper and the right post and its (g) velocity and (h) variability, and (i) initial and (j) final angles connecting the shooter to his/her closest defender and the goalkeeper and its (k) velocity and (l) variability.

Table 3 – Results of Trend Analysis and Multiple Comparisons.

Figure 1 - Dendrogram showing four visual patterns for the shooting (P1, P2, P3, and P4) (Ward method with Euclidean distance) [◌ = scored goals].

Figure 2 - Means of final and emerging angles connecting the shooter to his/her closest defender and the goalkeeper in P1, P2, P3, and P4.

Table 1

Visual Pattern	Goalkeeper	Closest Defender	Ball	Court Floor
FV	8,9	8,9	75,6	60,0
PV	37,8	55,6	0,0	40,0
FV-PV	15,6	15,6	0,0	0,0
OVF	37,8	20,0	24,4	0,0

Table 2

Interpersonal Coordination	SS	df	MS	F	*p*	Partial eta-squared	Noncentrality	Observed power
(a)	1994.86	3	664.95	1.42	0.251	0.09	4.26	0.35
(b)	1952.12	3	650.71	1.54	0.218	0.10	4.62	0.38
(c)	0.00	3	0.00	0.98	0.412	0.07	2.94	0.25
(d)	0.27	3	0.09	0.47	0.704	0.03	1.41	0.14
(e)	738.82	3	246.27	2.01	0.128	0.13	6.02	0.48
(f)	450.59	3	150.20	0.89	0.457	0.06	2.66	0.23
(g)	0.00	3	0.00	0.20	0.895	0.01	0.60	0.08
(h)	0.25	3	0.08	0.66	0.583	0.05	1.97	0.18
(i)	5525.40	3	1841.80	0.71	0.549	0.05	2.14	0.19*
(j)	16235.52	3	5411.84	2.25	0.050	0.14	6.74	0.53
(k)	0.01	3	0.00	0.45	0.721	0.03	1.34	0.13
(l)	1.15	3	0.38	1.05	0.380	0.07	3.16	0.26

*Significant difference

Table 3

Information	CO3
Goalkeeper	$\chi^2 = 42.91$, $df = 3$, $p \leq 0.01$*
Closest Defender	$\chi^2 = 30.15$, $df = 3$, $p \leq 0.01$*
Ball	$\chi^2 = 21.67$, $df = 2$, $p \leq 0.01$*
Court Floor	$\chi^2 = 37.54$, $df = 2$, $p \leq 0.01$*

* Significant difference

Figure 1

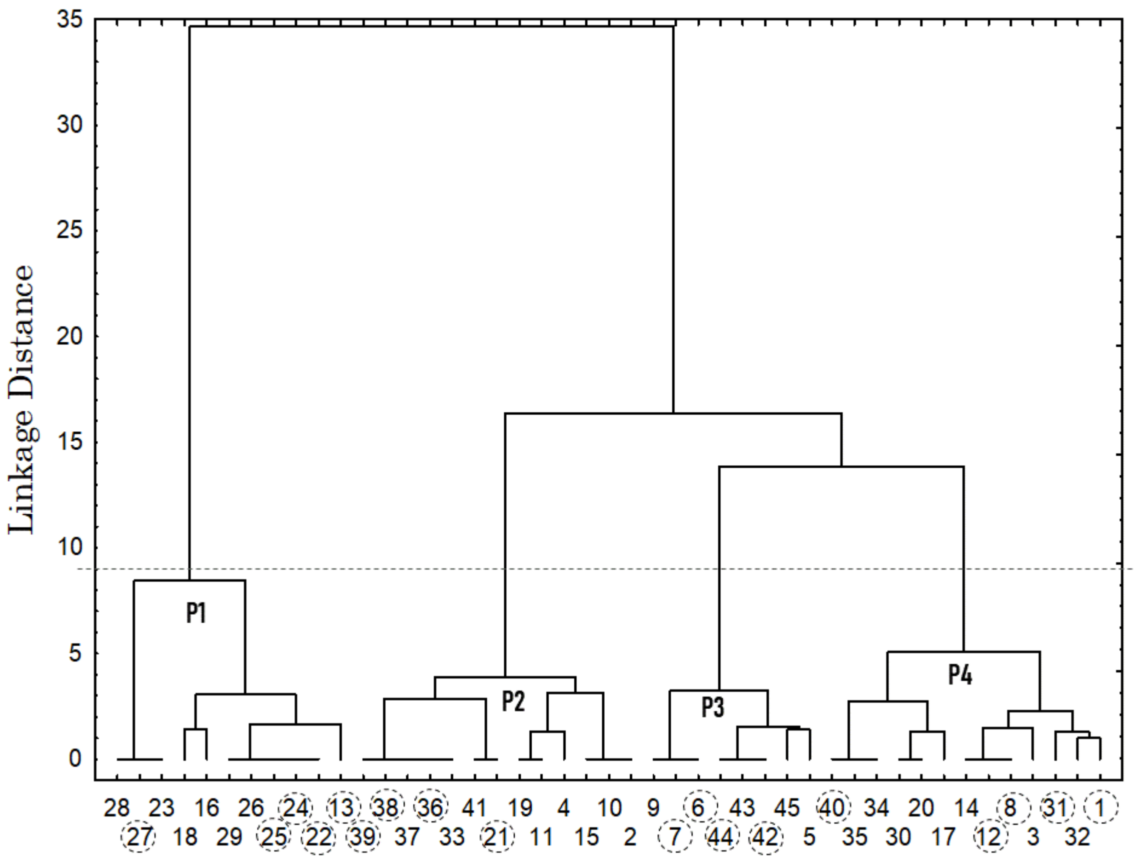

Figure 2