Angular relationships regulate coordination tendencies of performers in attacker–defender dyads in team sports

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Angular relationships regulates coordination tendencies of attacker-defender dyads in team sports

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Abstract

This study examined the continuous interpersonal interactions of performers in dyadic systems in team sports, as a function of changing information constraints. As a task vehicle, we investigated how attackers attained success in 1v1 sub-phases of basketball by exploring angular relations with immediate opponents and the basket. Four basketball players performed as an attacker and defender in 1v1 sub-phases of basketball in which the co-positioning and orientation of participants relative to the scoring target was manipulated. After video recording performance behaviours, we digitized participant movement displacement trajectories and categorized trials as successful or unsuccessful (from the attackers' viewpoint). Results revealed that, to successfully dribble past a defender, attackers tended to explore the left hand side of the space by defenders by increasing their angular velocity and decreasing their angular variability, especially in the centre of the court. Interpersonal interactions and goal-achievement in attacker-defender dyads appear to have been constrained by the angular relations sustained between participants relative to the scoring target. This study extended previous understanding on effects of informational constraints on coordination tendencies in dyadic systems in invasive team ball sports. Results revealed the functionality of exploratory behaviours of participants attempting re-align spatial relations with an opponent in 1v1 sub-phases of team games.

Keywords: Constraints, interpersonal interactions, collective systems, decision-making, angular relations, dyads

1. Introduction

Research on collective systems has shown that patterns of behaviour of individuals remain continuously co-dependent over space and time (Araújo, Davids, Bennett, & Button, 2004; Davids et al., 2006; Schmidt & Richardson, 2008). For example, Schmidt and O’Brien (1997) used a visual wrist-pendulum task to investigate unintentional interpersonal coordination in dyads. They found that when visual information from one participant was available, particular coordination modes were more frequently observed than others, suggesting how the interpersonal interactions between individuals in a social collective were coupled by perceptual information.

In team sport collectives, competing individuals continuously interact to achieve specific performance goals such as when a ball carrier strives to pass a ball to a teammate before a defender moves close enough to intercept it (Travassos et al., 2012). An ecological dynamics approach is a viable theoretical framework to understand how evolving constraints influence transitions in coordination tendencies between individuals in collective systems like team sports (underpinning actions and decision making behaviours) (Araújo & Davids, 2009). According to this rationale, an individual’s performance behaviours are dependent on use of specifying information within particular performance environments (Araújo, Davids, & Hristovski, 2006).

A major task for movement scientists is to provide further understanding of the effect of key information constraints on the continuous interpersonal interactions of individuals in social systems (Vilar, Araújo, Davids, & Button, 2012). For example, research has begun to identify relevant informational constraints that support performance behaviours of attackers and defenders in 1v1 sub-phases of team games. In typical 1v1 sub-phases, values of interpersonal distance in basketball (i.e., distance between attacker and defender) (Cordovil et al., 2009) and relative velocity in association football (i.e., velocity differential between attacker and defender movement displacements) (Duarte et al., 2010), have been shown to influence the performance behaviours of attackers attempting to move past defenders and approach the scoring target. In fact, the relative position of performers to the scoring target has been identified in previous research as a paramount feature for studying collective and dyadic system dynamics in team sports (Araújo et al., 2004; Travassos, Araújo, Duarte, & McGarry, 2012). To exemplify, a recent study in basketball showed that interpersonal coordination tendencies (i.e., the dynamics of the relationship between an attacker and defender) were shaped by manipulation of the relative position of attacker-defender dyads to the basket, suggesting that attackers preferred to move past the defender on the left (Esteves et al., 2012). In futsal (a five-versus-five indoor football game), it was reported that the angular relations between an attacker, defender and the goal constrained success in shooting at goal by the attacker (Vilar et al., 2012). Another investigation of 1v1 sub-phases of rugby union examined running angles of an attacker and a defender in relation to the scoring line (i.e., the try line) (Passos et al., 2009). However, the method of computing the dependent variable in that study did not enable the investigators to differentiate between a leftward or rightward move by the attacker (i.e., an attacker positioning himself to the left or right of the defender returned a value of 0°, meaning that the attacker-defender vector was parallel to the try line). In addition, the try line in rugby union is a scoring zone that stretches across the whole width of the field, while in many other team sports the scoring target is located in a specific location in the middle of the court end line (e.g., basketball, netball or korfball).

These studies highlighted the importance for the attacker to manage interpersonal distance values and create a velocity differential to move past an opponent, or to misalign their positioning with an immediate defender to shoot at a target. However, no data or explanation has been provided on how attackers attempt to break the stability of their alignment with opponents to convert a shot according to the relative positioning of the dyad to the scoring target

In this paper we aimed to extend current knowledge on how an attacker in a 1v1 dyadic system attempts to break stable alignments with an opponent in creating scoring opportunities, by considering their co-positioning relative to the location of the basket. We sought to achieve this aim by examining how an attacker explores the angular relations with an immediate defender and the basket in the team sport of basketball. In line with some previous work, we hypothesized that to successfully dribble past a defender, an attacker would tend to explore the left side of the dyad by generating a large angular velocity. Results from this study are also expected to provide insights on how coaches might design learning tasks for enhancing performance in 1v1 sub-phases of team sports like basketball.

2. Methods

Four (N=4) male, right-handed, intermediate level basketball players, aged 15 years, with an average of ten years of basketball practice (SD = .82), participated in the experiment. For each participant parental written informed consent was obtained. We chose athletes at this developmental stage as participants to study because we did not want the lack of skill of novices to confound our data.

The experimental task consisted of a 1v1 sub-phase played on half-court of basketball. Each attacker faced 3 defenders who took turns defending. The attacker was instructed to shoot at the basket after attempting to dribble past the first defender within the performance area. The first defender aimed to prevent the attacker from dribbling past him and shooting within the same area. Second and third defenders were instructed to maintain a prescribed static position, in order to constrain the attacker from dribbling outside the performance area (see Experimental setup).

A basketball half-court was divided into 9 different performance areas corresponding to a specific angular positioning to the basket: from p1 to p9 with an increment of each 20° (Figure 1, left). The 1v1 sub-phase began with an attacker positioned 1.15 m apart from the 3-point line and with the first defender 0.85 m in front (i.e., aligned with the first defender and the basket). The 3-point line limited backward movements of the first defender in direction to the basket (Figure 1, right).

********Insert Figure 1 about here********

A bounce-pass from the first defender to the attacker signalled the beginning of the 1v1 sub-phase that ended when the ball was intercepted by the defender or shot by the attacker. Each participant performed three trials in each performance area, for a total of 27 trials. The overall relative positions were presented to the participants in two sequences, increasing (p1 to p9) and decreasing (p9 to p1), comprising a total of 162 trials.

Our criterion for considering sample size was based on Brunswik's (1956) conceptualization of representative experimental design. More than simply referring to the number of participants involved in a study, Brunswik (1956) argued that sampling should consider the degree of generalization of experimental task constraints to performance settings. From this perspective, sampling in experimental research needs to also consider the situations and behaviours in a performance environment for the purpose of study, and not just the individuals or the environment, separately, per se (Araújo, Davids, & Passos, 2007). This proposition is intimately related to the richness of ecological constraints inherent to many sports performance contexts used as experimental tasks. As in the present study (e.g., Araújo, Davids, & Hristovski, 2006; Travassos, Araújo, McGarry, & Vilar, 2011), utilisation of these performance constraints may help to clarify distinctive processes in adaptive behaviours such as perception and actions (Davids et al., 2006).

A digital video camera placed at an angle of 45° to the mid-court line, in a superior plane, recorded the performance of participants at 25 Hz. Video footage of participants' performance was trimmed to consider the beginning and end of each trial, and we digitized their movement displacement trajectories with TACTO software 7.0 (Duarte et al., 2010; Fernandes, Folgado, Duarte, & Malta, 2010). This procedure consisted of following the vertical projection of the working point of the attacker and first defender on the floor, in each film clip, with a computer mouse. The obtained virtual coordinates were transformed into real coordinates using the direct linear transformation method

(2D-DLT) and subjected to a 6 Hz low pass filter (Winter, 2005). Intra-rater reliability for the digitization, over four consecutive days, of an exemplar trial of participant displacement movement trajectory was $\alpha = .99$, $p < .01$.

All trials were categorized as successful or unsuccessful (from the attackers' point of view) according to the performance outcomes in the 1v1 sub-phase. First, an experienced basketball coach, (with 18 years of officiating experience) visual inspected video images of participants' performance to identify fouls (i.e., violations to basketball rules) and ball interceptions by the defender to classify them as unsuccessful trials. We also examined if the movement displacement trajectories of the attacker proceeded outside the lateral limits of each performance area to classify them as unsuccessful trials. For that purpose, the distance of the attackers' position (point-by-point in the time series) to the lateral limits of the performance area was computed. A total of 44.4% of trials were categorized as successful for the attacker and 55.6% as unsuccessful. Intra and inter-reliability for the categorization process, completed with the advice of an experienced basketball referee (12 years experience), was respectively $\alpha = .85$, $p < .01$ and $\alpha = .81$, $p < .01$.

To capture angular relations between the attacker and defender in relation to the basket we computed the attacker-defender-basket angle (ADB), assigned as β. Initially, we calculated the angle θ formed by the defender-attacker (DA) vector, with respect to the MC vector (orthogonal to the lateral limits of the performance area). Then, we performed a rotation of -90°, clockwise, of angle θ so that the referential of 0° for the ADB (β) would be coincident with the BM vector (orthogonal to the end line of the court) (Figure 2).

********Insert Figure 2 about here********

This procedure allowed us to identify when the attacker: (i) was facing the defender in front of the basket (0°); (ii) attempted to dribble past the defender on the left side (90°); and (iii), attempted to dribble past the defender on the right side (-90°). We computed the angular velocity of ADB (rad·s-1) by considering the variation of angular displacement as a function of time (0.04 s). We also determined the regularity of the ADB time series by using the approximate entropy (ApEn), which provided a quantification of its structure of variability (Stergiou, Buzzi, & Kurz, 2004). Interpersonal distance (m) was computed according to the Cartesian distance between the positions of an attacker and defender on court.

Our dependent variables (ADB, angular velocity of ADB and ApEn of ADB) were computed in the time series from the moment when the attacker received the ball from the defender (i.e., beginning of the sub-phase), to the moment when the attacker reached the second and third defenders or lost ball possession (i.e., at 4.6 m from the basket). For statistical purposes all variables were normalized with respect to time by taking the shortest trial as a reference, which was further divided into equal intervals from 0% to 100% of time. Following the same reasoning, dependent variables were also grouped for all trials, participants and sequences (i.e., increasing and decreasing sequence), for the first (0% to 49%) and second half (50% to 100%) of the normalized time series.

We submitted the mean percentages of successful trials to a two-way factorial ANOVA, with the factors being relative positioning and presentation sequence of relative positions to the basket. ADB and angular velocity of ADB data were subjected, in the second half of the normalized time series, to a two-way mixed- model ANOVA, having two levels of success of the drive (successful and unsuccessful) and nine levels of relative positions to the basket (p1 to p9) as, respectively, between- and within-factors (i.e., independent variables). A Bonferroni adjustment was used for pairwise comparisons of the interaction relative positions to the basket*success of drive. Violations of the sphericity assumption for within-participant variables were analysed using Mauchly's test. When a violation of this assumption occurred, the Greenhouse-Geisser correction procedure was used to adjust the degrees of freedom. Finally, we submitted the ApEn values of ADB, separately for successful and unsuccessful trials of the complete time series, to an independent samples t-test for parametric distributions. The level of statistical significance was set at $p < .05$. All statistical analyses were computed using SPSS® 20.0 software (IBM SPSS Inc., Chicago, USA). This study was conducted within the guidelines of the American Psychological Association (6th Edition) and a local university ethics committee approved the protocol.

3. Results

3.1. Exploration of attacker-defender alignment according to success of the drive and relative position to the basket

Analysis of angular relations between attackers and defenders in dyads and the basket (ADB) revealed significant interaction effects between the success of the drive of the attackers and the relative position of the dyads to the basket, F(2, 97) = 19.39, $p < .01$, $\eta^2 = .29$. This observation suggests that ADB was significantly affected by the relative positioning of the dyads to the basket and by the success of the drive of the attackers. Specifically, there were larger values of ADB for successful trials in p6 (M = 87.76, SD = 58.39), and smaller values of ADB, for unsuccessful trials, in p3 (M = -33.53, SD = 23.78). A Bonferroni adjustment for pairwise comparisons of the interaction effects showed significant differences in the ADB, in unsuccessful trials, between p3 and p7 (p = .01), p3 and p8 (p = .04) and p6 and p7 ($p < .05$). For successful trials, significant differences were found between p2 and p6 ($p < .05$). In line with our hypotheses, these results suggested that the successful achievements of the attackers depended more on exploring the left side for moving past the defender, preferentially near the centre of the court.

We also found a main effect of angular velocity of ADB, F(1, 48) = 45.43, $p < .01$, $\eta^2 = .49$, indicating that in successful trials, attackers dribbled past defenders with greater angular velocity values (M = 76.16, SD = 72.12). In unsuccessful trials attackers tended to present smaller values of angular velocity (M = -18.40, SD = 142.66). No main effect was observed for the relative position of the dyads to the basket, F(3, 48) = .42, p = .75, and no interaction effects observed between the success of the drive and relative position of the dyads to the basket on the angular velocity of ADB, F(3, 48) = 1.38, p = .25.

Analysis of the success of the drive of the attackers showed no main effects of relative position of the dyads to the basket, F(1, 8) = 1.35, p = .26, and its sequence of presentation, F(1, 1) = 3.82, p = .06.

3.2. Dynamics of the exploration of attacker-defender alignment

An exemplar successful trial for the attacker (Figure 3, left) shows a relative stability in the dyad with the attacker facing the defender near 1 m of interpersonal distance (ADB of 0° and angular velocity of ADB close to -0.52 rad·s-1). Between 1 m and 0.5 m of interpersonal distance, ADB decreased to -20° with an angular velocity close to -0.70 rad·s-1, suggesting that the attacker was moving with small angular velocity on the right, while approaching the defender and the basket. Then, angular velocity increased to 5.24 rad·s-1 along with an increase of ADB to 90° near 0.5 m, suggesting that the attacker was moving with a large angular velocity on the left. From this point onwards until -0.5 m of interpersonal distance, ADB slightly increased to 93° while its angular velocity increased again to 3.49 rad·s-1. These findings suggested that the attacker successfully dribbled past the defender on the left with large angular velocity, as a function of enclosing interpersonal distance.

An exemplar unsuccessful trial for the attacker (Figure 3, right) exhibited values of ADB between 0° and -70°, mainly within 0.5 m and 1 m of interpersonal distance. Concurrently, the angular velocity of ADB varied between 1.75 rad·s-1 and -3.49 rad·s-1.These findings suggested that the defender prevented the enclosing of interpersonal distance (small than 0.5 m) together with the increasing of angular velocity (more than 1.75 rad·s-1) by the attacker that could permit its approach to the basket (i.e., ADB close to 180°).

********Insert Figure 3 about here********

Analysis of the variability of angular relations, using ApEn of ADB, showed significant differences between successful and unsuccessful moves by the attackers, $t(47) = 3.51$, $p < .01$, $r = .44$, respectively, $M = .29$, $SD = .13$ and $M = .18$, $SD = .09$. These results suggested greater variability in the angular relations between attacker-defender dyads relative to the basket when the defenders prevented a successful move of the attackers.

4. Discussion

In this study, we sought to examine the functional exploratory behaviours of individuals in social collective systems seeking to achieve specific performance goals. To achieve this aim, we investigated how attackers and defenders performed in 1 v1 dyads in the team sport of basketball by manipulating their co-positioning and orientation relative to the location of the basket. In line with our hypothesis, we noted that in successful trials the attacking player explored more specific spatial areas of performance, such as the left side of the defender to move past him, with greater angular velocity, especially in the centre of the court.

We observed that ADB angles were significantly greater for successful trials and smaller for unsuccessful trials, mainly near the centre of the court (p6). This finding suggests that the attackers' exploration of spatial area of the left side of the dyad, to break the alignment with a defender and basket, emerged as a more functional solution to approach the target, according to specific court locations. This decision might have emerged from the interaction of dyad location with specific personal constraints since defenders may have tried to limit right-handed attackers from using their dominant (right) hand to dribble to the right. This solution was likely to provide greater opportunities in 1v1 sub-phases for attackers to achieve their performance goals against the defending opponents. Accordingly, to successfully move past an opponent, attackers may have resorted to the solution of exploring more the left side to break the alignment with the defender and basket when shooting at the target.

Furthermore, significantly greater values of angular velocity of ADB were observed for successful trials of the attacker in the 1v1 sub-phase. It appears that the goal achievement of the attacker depended not only on exploring the alignment with the defender and the basket, but also on changing this angular relation quickly enough to move past the opponent. Previous research has already indicated that other interacting agents provide relevant sources of information (e.g., posture-related information of the opponent) that constrain actions of an individual in social systems such as team sports (Marsh, Richardson, Baron, & Schmidt, 2006; Esteves, de Oliveira, & Araújo, 2011).

We also observed smaller levels of variability in ADB for successful trials of the attacker, in line with other studies (Araújo et al., 2006; Davids et al., 2006). The detection and use of contextually relevant information for moving past a defender may have narrowed the range of possible solutions and led to the emergence of a final performance solution. In contrast, larger levels of variability in successful trials for the defender suggested exploratory behaviours of the attacker to use information to break the alignment with the opponent, which may have been ineffective. Our findings showed how informational constraints may have shaped functional behaviours of attacker-defender dyads by reducing the possible configurations (i.e., spectrum of possible actions) of the performer-environment system (Davids, 2009).

Exemplar data from successful and unsuccessful trials in the 1v1 sub-phase supported these arguments: (i) the attacker successfully dribbled past the defender and approached the basket on the left hand side by breaking the alignment to the defender with a large angular velocity of ADB, while varying interpersonal distance; (ii) the attacker was unsuccessful in dribbling past the defender and approach the basket because he was not able to break the alignment with the defender and basket and increase the angular velocity of ADB enough, while varying the distance to the defender. It is apparent that ADB, together with angular velocity of ADB, captured the dynamics of behaviour in these attacker-defender dyads. Stable and unstable organizational states of the system appeared to be constrained by discontinuous changes in ADB and angular velocity of ADB according to the closing distance between an attacker and defender. This transition from one previously stable state to another represents a qualitative change in the organization of a dyadic system. Functional decisions occurred at these transition points, where the use of specifying information (i.e., attacker-defender alignment) prompted at the environment-individual scale, the emergence of ultimate solutions to achieve task goals (Araújo et al., 2006).

Interestingly, we did not find significant differences in the success of the drive of the attacker according to the relative positioning of the dyad to the basket. These findings suggest an adaptation of the attackers to the evolving constraints that may have led to a constant efficacy level in their performance, despite the process of goal-achievement being markedly different, as we have reported before. Adaptive neurobiological systems (here, basketball performers) consistently demonstrate their ability to achieve similar goals with different action patterns, exploiting their evolutionary tendencies for system degeneracy (Edelman & Gally, 2001; Mason, 2010).

To summarize, this study added empirical evidence to support outcomes of previous investigations on effects of informational constraints, such as values of interpersonal distance and relative velocity on dyadic system interactions in invasive team ball sports (e.g., Cordovil et al., 2007; Duarte et al., 2010). Here we showed that interpersonal interactions of attacker-defender dyads in the 1v1 sub-phase of basketball were dependent on exploration of the alignment between opponents and a scoring target, and an association with a large angular velocity.

Future research on interpersonal interactions in social collective systems in human movement science needs to consider the effects of additional interacting agents and other potential information constraints on participant behaviours. For instance, in the study of team sport collectives, an interesting question concerns how an attacker might manage the alignment to a closest defender, and to an additional defender positioned near the target, when striving to move closer to the scoring target and completing a shot. In addition, future research could also consider comparing the influence of relevant informational constraints on emergent functional exploratory behaviours in elite and sub-eliteperformers.

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Figure captions

Figure 1

Half-court of basketball with 9 different areas correspondent to different relative positions to the basket where the 1v1 situation should take place: p1, p2, p3, p4, p5, p6, p7, p8 and p9 (left). Starting positions of attacker (1), first defender (2), second defender (3) and third defender (4) in the 1v1 sub-phase correspondent to 80° to 100° (p5) of relative position to the basket (right).

Figure 2

Representation of attacker-defender-basket angle (β). External limits of the performance area in grey dashed lines. MC vector is orthogonal to the external limits of the performance area and BM vector is orthogonal to the end line of the court. Angle θ is formed by the defender-attacker (DA) vector, with respect to the MC vector. A further rotation of -90°, clockwise, was computed such as the referential of 0° for the ADB angle (β) would be coincident with the BM vector.

Figure 3

Successful (left) and unsuccessful (right) exemplar trials, from the attackers' point of view, in the 1v1 sub-phase. The black and grey lines are time-series that display, respectively, attacker-defender-basket angle (ADB) and angular velocity of ADB related to the decreasing interpersonal distance (x-axis).