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Interpersonal coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer

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Abstract
This study investigated the influence of interpersonal coordination tendencies on performance outcomes of 1-vs-1 sub-phases in youth soccer. Eight male developing soccer players (age: 11.8 ± 0.4 years; training experience: 3.6 ± 1.1 years) performed an in situ simulation of a 1-vs-1 sub-phase of soccer. Data from 82 trials were obtained with motion-analysis techniques, and relative phase used to measure the space-time coordination tendencies of attacker-defender dyads. Approximate entropy (ApEn) was then used to quantify the unpredictability of interpersonal interactions over trials. Results revealed how different modes of interpersonal coordination emerging from attacker-defender dyads influenced the 1-vs-1 performance outcomes. High levels of space-time synchronisation (47%) and unpredictability in interpersonal coordination processes (ApEn: 0.91 ± 0.34) were identified as key features of an attacking player’s success. A lead-lag relation attributed to a defending player (34% around 7 ± 30° values) and a more predictable coordination mode (ApEn: 0.65 ± 0.27, P < 0.001), demonstrated the coordination tendencies underlying the success of defending players in 1-vs-1 sub-phases. These findings revealed how the mutual influence of each player on the behaviour of dyadic systems shaped emergent performance outcomes. More specifically, the findings showed that attacking players should be constrained to exploit the space-time synchrony with defenders in an unpredictable and creative way, while defenders should be encouraged to adopt postures and behaviours that actively constrain the attacker’s actions.

Keywords: Performance analysis, interpersonal coordination tendencies, relative phase, approximate entropy, soccer

Introduction
For some time, it has been known that the interpersonal interactions between two players during team game performance can occur in both physical (e.g., when players form a defensive wall in free-kicks or dispute ball possession) and non-physical processes of coordination (Schmidt, O’Brien, & Sysko, 1999). Previous research on coordination in social neurobiological systems has shown that non-physical interpersonal coordination occurs as individuals subtly adapt movement variables such as movement displacement trajectories and personal velocity levels to create space and time. Non-physical interpersonal coordination tendencies are based on the establishment of information-based links between individuals in pursuing specific performance goals (Marsh, Richardson, Baron, & Schmidt, 2006; Richardson, Marsh, & Schmidt, 2005), such as penetration or defence of critical scoring areas.

An extensive body of work has attempted to investigate the interpersonal coordination tendencies that emerge within attacker-defender dyads in team sports (e.g., a competing pair of athletes with opposing aims to score or prevent goals or points). Dyadic systems have been studied in different sport performance contexts like tennis (Lames, 2006; Palut & Zanone, 2005), squash (McGarry, 2006; McGarry, Khan, & Franks, 1999), 1-vs-1 sub-phases in rugby union (Passos et al., 2008), basketball (Bourbousson, Sève, & McGarry, 2010), and also in
Association Football (known as soccer around the globe) (Duarte et al., 2010a). Results from these studies have revealed that different patterns of interpersonal coordination emerge in different sports, due to the nature of the specific task constraints shaping these processes in different performance contexts. At the same time, identified spatiotemporal patterns of coordination have been in line with the universal principles of dynamical self-organising systems (Glazier, 2010; McGarry, 2009). McGarry, Anderson, Wallace, Hughes, and Franks (2002) considered that competing performers in team sports forged and broke interpersonal relations that emerged in space and time in the pursuit of mutually exclusive performance goals. From this perspective, analysis of dynamical patterns of interpersonal relationships between individuals is an important research task that can reveal the preferred modes of coordination that characterise dyadic system interactions in sport (Araújo, Davids, & Hristovski, 2006).

For example, previously, Passos et al. (2008) and Duarte et al. (2010a) have reported how initial dyadic system stability was broken by interpersonal coordination patterns influenced by specific values of key variables like interpersonal distance and relative velocity of attackers and defenders. Consequently, different performance outcomes emerged in 1-vs-1 sub-phases of team sports. Furthermore, Bourbousson et al. (2010) used relative phase analyses to assess dyadic relations between performers during a basketball game. They observed in-phase attractions between players in longitudinal (basket-to-basket) directions, especially for attacker-defender dyads, and both in-phase and anti-phase coordination patterns in lateral (side-to-side) directions. Further research that characterises the relation between performance behaviours and performance outcomes in specific game settings has been called for (McGarry, 2009). Specifically, an understanding of the modes of relations that characterise different performance outcomes in team sports under different task constraints, such as 1-vs-1 sub-phases of soccer, needs to be developed.

The purpose of this study was to investigate whether interpersonal coordination tendencies emerging between opposing players influence the performance outcomes of 1-vs-1 sub-phases of soccer. In this process, the emergence of two possible performance outcomes was studied: (i) the attacker’s success in de-stabilising the dyadic system, and (ii) the defender’s success in stabilising the system and recovering ball possession. Specifically, we investigated how different patterns of interpersonal coordination might influence the emergence of the different performance outcomes in this sub-phase of play, with a special emphasis on its variability. We hypothesised that different patterns of interpersonal coordination should characterise distinct performance outcomes.

Methods

Participants

Eight male, developing soccer players (age: 11.8 ± 0.4 years; weight: 39.3 ± 4.5 kg; height: 1.46 ± 0.1 m) participated in the study. They were deliberately selected to participate in this study due to their intermediate level of skill (training experience: 3.6 ± 1.1 yrs; weekly training volume: 90 min x 3, in addition to competitive experience), to avoid too experienced soccer players with idiosyncratic behaviours, or inexperienced individuals who could not execute actions skilfully. All players and their parents were informed about the procedures, according to the guidelines of the local university ethics committee. All parents signed an informed consent attesting the voluntary participation of their children in the study.

Experimental task

The experimental setting consisted of a simulation of a 1-vs-1 sub-phase of soccer performance on a grass surface, where the attacker tried to destabilise a dyad formed with a defender to move into the free space behind him and create shooting opportunities. Conversely, the defender tried to maintain dyadic stability, recover the ball and attack the opposite goal. Based on expert knowledge of experienced coaches in soccer and in a pilot study, the experimental task was performed in a space of 10 x 8 m beyond which there was a 15 m scoring zone in which players could shoot at a goalkeeper positioned in goal to ensure a representative task design (see Figure 1, left panel) (Davids, Button, Araújo, Renshaw, & Hristovski, 2006). Each participant performed four series of five trials as an attacking player, while the other five participants took turns to act in one trial as a defender. The experiment resulted in a total of 120 trials. Only 82 trials (n = 55 successful attacks and n = 27 successful defensive trials), in which one of the players successfully crossed the end line of the central square and got into the scoring/target zone with the ball, were selected for further analysis.

Procedures

Participants’ movement displacement trajectories were captured by a digital video camera placed in an elevated plane (4 m in height), forming an angle of approximately 45° with the longitudinal axis of the performance area. Video recordings were transferred
and divided into 82 video files (.avi format), corresponding to the plays selected for further analysis. For image processing and to obtain positional data from players’ displacement trajectories, we used a dedicated software package - TACTO 8.0 - with validity reported as superior to 95% (see Fernandes, Folgado, Duarte, & Malta, 2010). The procedure consisted of following with a computer mouse cursor a working point located between the feet of each participant. This working point was used because it represents the projection of the player’s centre of gravity on the ground. Camera calibration was made by comparing virtual (pixels units) and real measures (metric units) of six control points. Next, the x and y virtual coordinates of the players were extracted with a data sampling rate of 25 Hz. To transform the virtual into real coordinates we used the bi-dimensional Direct Linear Transformation method (2D-DLT) (Abdel-Aziz & Karara, 1971). The x and y coordinates were subsequently filtered with a Butterworth low pass filter of 3 Hz cut-off frequency (Winter, 2005). To ensure appropriate quality control of measurements, the digitising researcher undertook seven days of a digitisation-training programme. Intra-digitiser reliability was assessed using the ‘variation accounted for’ measure (VAF) (Moorhouse & Granata, 2007), which revealed high consistence both for x- and y-component of motion (VAF always > 99.98%) (for further details about these time-motion analysis procedures see Duarte et al., 2010b).

Considering a 1-vs-1 sub-phase of team sports as a dyadic system, the players can be regarded as two components oscillating in relation to a target zone (i.e., the offensive space which an attacker intends to penetrate, see right panel of Figure 1). Thus, to capture the different modes of relations between players in approaching/protecting the target zone, time-series data of the minimum distance of each player to the end line of the central square was calculated for all trials. Matlab® R2008a software (The MathWorks Inc, Natick, MA, USA) was used for all computing procedures.

**Statistical analysis of the data**

Relative phase calculations with Hilbert transform (Palut & Zanone, 2005; Rosenblum & Kurths, 1998) were used to measure the phase relations of the minimum distance of each player to the end line over the entire duration of each trial. These measurements were used to capture the interpersonal coordination tendencies established between the players. The relative phase data were then forced into − 180° and 180° limits for frequency analysis using histograms.

Variability of interpersonal coordination tendencies was assessed using standard deviation (s) of the mean relative phase value (Schmidt, Richardson, Arsenault, & Galantucci, 2007), and approximate entropy (ApEn) (Harbourne & Stergiou, 2009). Whilst s measured the magnitude of the deviation around the mean tendency, ApEn evaluated the structure of coordination variability (i.e., examining the regularity with which certain patterns of coordination varied over time) (Pincus & Goldberger, 1994). Values of ApEn typically range from 0 to 2, with values closer to 0 indicating greater regularity (i.e., periodicity), values from 0.5 to 1.5 representing chaotic behaviours, and values nearing 2 corresponding to greater irregularity (i.e., more randomness) in pattern variations within a time-series (Harbourne & Stergiou, 2009). Due to the different length of the time-series from each trial, ApEn random ratio values were computed using Matlab. These normalised values comprised a ratio calculated from the ApEn value for the original time-series divided by the average of the ApEn values calculated from 100 normally distributed random time-series (Fonseca, 2009).
Milho, & Passos, 2009; Passos et al., 2009). The $m$ (i.e., the length of the vector to be compared) and $r$ (i.e., the tolerance factor) input parameters were set at 2 and 0.2 standard deviations, respectively (Stergiou, Buzzi, Kurz, & Heidel, 2004). In order to compare mean values of ApEn for successful outcomes for both attackers and defenders, a Mann-Whitney U test was performed, while comparison of $s$ values was made using an F-test. Both analyses were performed in MedCalc<sup>®</sup> 11.5.1 software (MedCalc Software bvba, Belgium). Alpha levels were maintained at $P < 0.05$ for both statistical procedures.

**Results**

**Interpersonal coordination tendencies**

A strong in-phase mode of coordination (47%) was observed for the plays ending in attacking success (see left panels of Figure 2). For the plays ending in success for the defending player, the values of preferred mode of coordination decreased and shifted to negative values (34% around $-30^\circ$, see right panels of Figure 2), meaning that defender is leading the relationship.

In order to improve understanding of the lagged relationships for successful outcomes in defending, the plays with clearly demarcated performance success for the defending player were selected and subjected to further analysis. Figure 3 displays the relative phase frequencies for the plays with only one crossover between players (i.e., only one reversal in the relative positioning of players), which ended in a successful outcome for a defender.

In this type of play, the lead-lag phase relations observed in the right panel of Figure 2 were emphasised for a $-90^\circ$ mode of coordination (near 28% of the time) with an increase in negative modes of coordination. Negative values showed that, in these types of plays, defenders clearly led the interpersonal interactions.

**Variability of interpersonal coordination tendencies**

In order to assess the variability that underlies interpersonal coordination tendencies between players, measures of $s$ and ApEn were calculated for the two possible performance outcomes (see Figure 4).

No differences in $s$ values were identified between successful outcomes of attackers and defenders ($F(26,54) = 1.5, P = 0.18$). However, values of ApEn were different between the trials in which attackers and defenders succeeded ($0.91 \pm 0.34$ and

![Figure 2. Interpersonal coordination tendencies of 1-vs-1 sub-phases. Upper panels show relative phase histograms for successful trials of attackers (left panel, $n = 35$) and defenders (right panel, $n = 27$). Bottom panels display exemplar trials of relative phase time-series for each performance outcome.](image-url)
Data showed that interpersonal coordination tendencies observed in successful outcomes for attacking players displayed significant higher levels of irregularity (less periodicity) over time.

Discussion

The specific purpose of this study was to investigate the influence of interpersonal coordination tendencies on the performance outcomes of 1-vs-1 subphases in youth soccer. Results clearly revealed different trends in interpersonal coordination between players in the two performance outcomes, indicating that different mode relations within a dyad tended to influence the final outcome of this sub-phase of play. While successful outcomes for attackers were related to a high level of spatiotemporal synchronisation between players, the success of the defenders was distinctly associated with their ability to lead the relationship (i.e., the to-and-fro movement displacements of defenders preceded the moves of the attacking player).

McGarry (2006) also reported the existence of a lead-lag phase relation (of 135°) within dyads of opposing squash players for radial distances to the T-position (i.e., the central point of the court), with the lag phase being attributed to the movements of the serving player. This type of lagged phase relations evidenced time delays between players’ movements. In the successful outcomes for the defending players, the predominant lead-lag phase relations were observed as near in-phase (−30°) for 34% of the time in all trials. These outcomes also depicted a more distributed frequency of values over the entire spectrum of relative phase. In the coordination dynamics literature this phenomenon has been termed ‘relative coordination’ (Kelso & Engstrom, 2008). These findings suggest that a higher number of coordination modes were associated with performance success of defending players. Additionally, in plays with clearly demarcated performance success of the defending player, the predominant mode of coordination involved a shift in the phase relations lag to a quarter phase (−90°). This type of change in mode relations was observed in trials where the defender maintained system stability, and recovered ball possession to move past the opponent. Thus, the present findings suggest that trials in which performance was controlled by the defending players were associated with larger time delays in the phase relations led by these players.

On the other hand, for successful attacking outcomes, the preferred mode of coordination did not reveal predominant lagged phase relations. A high level of synchrony between players was observed for 49% of the performance time. Thus, it seems the success of attacking players in destabilising dyads was based on creating a tight coupling with the defender. Bourbousson et al. (2010) have also reported strong in-phase relations for playing dyads in a longitudinal (basket-to-basket) direction during performance. However, these authors did not report the performance outcomes associated with these dyadic system relations. It is worth noting that, in the present study, the movements of the soccer players were not decomposed into lateral and longitudinal components of motion as in some previous work (e.g., Bourbousson et al., 2010; Palut & Zanone, 2005). In keeping with the idea of studying phase synchronisation of coupled chaotic oscillators (Rosenblum, Pikovsky, & Kurths, 1996), a single measure was used to express the movement oscillations of each player in the approach to the scoring zone. This measure consisted of the minimum distance of each player to the line that bounded the scoring zone and was similar to the radial distance measure used by McGarry (2006). This type of measure that integrates relevant task constraints such as target zones and/or goal locations, for instance, seems to more meaningfully capture the coordination tendencies that underlie goal-directed
behaviours in team sports (Davids, Vilar, Araújo, & Travassos, 2010; Travassos, Araújo, Vilar, & McGarry, 2011).

Concerning the stability of the interpersonal coordination tendencies that emerged from the interactions of the players, we examined the magnitude (s) and structure (ApEn) of system variability. While s measured the magnitude, or ‘amount’, of deviations around the mean tendency of interpersonal coordination values, ApEn revealed the predictability, or regularity, of the relative phase fluctuations over time (Harbourne & Stergiou, 2009). In the present study, only ApEn values significantly differed between performance outcomes. That is, the success of the attacker was associated with high ApEn values, while defensive success showed the opposite trend. This finding implies that the dyadic interpersonal coordination tendencies emerging in relation to the attacking player’s successful outcomes were characterised by a higher level of irregularity (less periodicity). This higher level of unpredictability seemed to be a key feature related to successful attacking performance in the 1-vs-1 sub-phases of play. In contrast, the success of the defenders seemed to be associated with higher levels of regularity and predictability in the interpersonal coordination tendencies that emerged. We acknowledge the possibility that our data might be considered as not completely independent from trial-to-trial, although outcome analyses of every attacker facing the same defender did not reveal any differences. The data from this study contrasted with the findings of Passos et al. (2009) who observed that successful performance outcomes for the attacking players in 1-vs-1 sub-phases of rugby union were related to lower values of ApEn, than observed in successful tackles by defending players. These differing results can be attributed to the different nature of the task constraints in both studies, especially the higher levels of physical contact between players allowed in the team sport of rugby union compared to soccer.

This study advanced understanding of 1-vs-1 sub-phases of soccer presented in earlier work by Duarte et al. (2010a), by demonstrating how different modes of interpersonal coordination emerged from attacker-defender dyads to influence performance outcomes in sequences of competitive play. High levels of space-time synchronisation and unpredictability in interpersonal coordination processes were identified as key features of an attacking player’s success in 1-vs-1 sub-phases of soccer. A lead-lag relation attributed to a defending player and a predictable coordination mode demonstrated the coordination tendencies underlying the success of defending players in 1-vs-1 sub-phases of soccer. These findings have important implications for learning and practice designs. Attacking players can be constrained and encouraged to develop a highly irregular and creative space-time synchrony with defenders which could abruptly change to atypical, creative and unpredictable behaviours. For instance, attacking players might perform explorative actions such as changing speed, direction and using deception to alter the interpersonal relations in their favour. These explorative actions can be promoted by manipulating some task constraints such as limiting the time to shot on goal, decreasing the area of play, or using additional goals. On the other hand, defenders need to adopt postures and movements suitable for actively influencing an opponent’s actions in spaces advantageous for recovering ball possession (e.g., channel the attacker to the side line or move closer to a defending teammate to ensure spatial and numerical advantage). Finally, it is possible that the particular values for dependent variables found in this study were related to specific characteristics of this sample. There is a need for additional work to examine the generality of the data to different samples such as older players or elite performers. The current data imply that interpersonal coordination tendencies may vary within specific ranges according to different levels of skill and experience in participants, but probably maintaining the same general trends observed in this study. It might be expected that skilled players would present small differences in interpersonal patterns of coordination for different outcomes but with larger values of ApEn (Davids, Glazier, Araújo, & Bartlett, 2003). Therefore, the use of longitudinal designs to assess intervention effectiveness in 1-vs-1 sub-phases of team sports remains a challenging, but important, task for future research.

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References


Davids, K., Vilar, L., Araújo, D., & Travassos, B. (2010). Ball and goal location as constraints on decision making in team sports. *Journal of Science and Medicine in Sport*, 12(Suppl. 2), 92.


