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Spatiotemporal coordination behaviors in futsal (indoor football) are guided by informational game constraints

B. Travassos [a,b,*], D. Araújo [a], R. Duarte [a], T. McGarry [c]

[a] *Faculty of Human Kinetics, Technical University of Lisbon, Portugal*
[b] *Department of Sport Sciences, University of Beira Interior, Portugal*
[c] *Faculty of Kinesiology, University of New Brunswick, Canada*

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ABSTRACT

This report investigated the behavioral dynamics of teams in futsal game practice when the goalkeeper of the attacking team is substituted for an extra outfield player. To this end, the lateral and longitudinal displacements of the ball and both teams, as well as their kinematics expressed in angles and radial distances from the goal center, were obtained and subjected to relative phase analysis. The results demonstrated (a) stronger phase relations with the ball for the defending team than the attacking team for both coordinate systems, (b) phase relations between each team and ball, and, to a lesser extent, between teams themselves, produced greater stabilities in the lateral (side-to-side) direction than the longitudinal (forward-backward) direction, and (c) phase attractions were most pronounced for the defending team and ball when using angles as a measure of association, indicating ball position and goal location as key informational constraints for futsal game behavior. These findings advance understanding of self-organizing sports game dynamics with implications for sports practice.

1. Introduction

Team sports behaviors are predicated on the competing aims of the two teams, with the attacking team looking to keep ball possession and make a score (e.g., a goal, a basket, a point, etc.) and the defending team seeking to protect against a score and win ball possession. The playing behaviors that

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* Corresponding author at: Sport Sciences Department, University of Beira Interior, Convento de Sto. António, 6201-001 Covilhã, Portugal. Tel.: +351 275329153; fax: +351 275329157.

E-mail address: bruno.travassos@ubi.pt (B. Travassos).

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characterize these types of sports contests has been proposed to emerge as a self-organizing process consequence of the cooperating and competing coordination tendencies of players (see McGarry, Anderson, Wallace, Hughes, & Franks, 2002). This idea of game behavior as self-organizing means that ordered behaviors emerge from within the sports contest as a result of information exchanges among the players, instead of regularity being imposed on game behavior by any outside agency (e.g., a coach). This position does not deny the influence of coaching practice on game behavior however, which provides an important informational constraint by shaping individual and team objectives.

In sports contests, players and teams must constantly make decisions and actions based on changing game information derived from spatial-temporal relations with other players (teammates and opponents), positions on the field of play, ball kinematics and goal location, a continuous process regulated by localized dynamical interactions (McGarry et al., 2002). Thus, self-organized coordinated behaviors emerge under a variety of individual, task, and environmental constraints as players and teams seek to accomplish their game objectives (Araújo, Davids, Bennett, Button, & Chapman, 2004; Davids, Kingsbury, Bennett, & Handford, 2001). Self-organizing behaviors produce stable coordination patterns at the expense of other possible coordination states and offer a useful means for characterizing and investigating complex systems behavior (Beek, Verschoor, & Kelso, 1997).

Game dynamics has been investigated in various sports (Araújo, Davids, & Hristovski, 2006; Davids, Araújo, & Shuttleworth, 2005; McGarry et al., 2002; Palut & Zanone, 2005; Passos et al., 2009; Reed & Hughes, 2006) at various levels of analysis. As noted by McGarry et al. (2002), the emergent coordination patterns of team sports may be investigated from interactions between individual players (Bourbousson, Sève, & McGarry, 2010a) to interactions between teams (Bourbousson, Sève, & McGarry, 2010b; Frencken & Lemmink, 2008; Lames, Erdmann, & Walter, 2010). Previous research of game behavior at the team level has used relative phase to assess spatiotemporal coordination (Bourbousson et al., 2010b; Lames et al., 2010), with findings demonstrating general tendencies of synchronized displacements of teams in the lateral (i.e., side-to-side) and longitudinal (i.e., forward-backward) directions, particularly the latter. Noted already, these coordinated team dynamics are the hypothesized result of information exchanges between players and teams acting under game constraints (Marsh, Richardson, Baron, & Schmidt, 2006; McGarry et al., 2002).

The primary game objectives of team sports noted at the outset of this report necessitate that ball location with respect to the scoring targets (e.g., basketball hoops, football goals) constitutes an important constraint when considering dynamical game behavior, the ball furthermore providing a principal means for information exchange between players and teams (McGarry, 2009). In this study, we advance previous research by accounting for these important game constraints when investigating team dynamics produced in futsal game practice. Furthering understanding on game constraints and team dynamics may help coaches in designing appropriate tasks in sport practice by managing informational constraints with specific learning aims in mind, such as promoting self-adaptive behaviors within players and teams.

Futsal is a FIFA regulated five-a-side indoor association football game. In futsal competition, a common game strategy is for the trailing team towards the end of a game to substitute the goalkeeper for an extra outfield player when in possession of the ball. This game strategy, hereafter referred to as 5-v-4+GK, gives the trailing team a numerical advantage of outfield players, and is designed to increase the likelihood of generating goal scoring opportunities. In the final four of the UEFA Futsal Cup in Lisbon, 2010, half of the goals scored in the last five minutes occurred using this 5-v-4+GK game strategy, thereby demonstrating its importance to futsal competition.

In this report, we extend on an earlier investigation of the dynamical behaviors observed between players and ball, and between players themselves, in 5-v-4+GK futsal game practice (Travassos, Araújo, Vilar, & McGarry, 2011). As with player behaviors, we expect the team behaviors produced in 5-v-4+GK futsal game practice to conform to dynamical self-organizing principles, for the reasons outlined by McGarry et al. (2002). Furthermore, we account for game context by assessing positions of ball and teams with reference to goal location by using polar coordinates (i.e., angles and radial distance). The expectation is that ball dynamics and goal location are important constraints on game behavior, and, as such, are deserving of attention for advancing understanding of game behavior. The purpose of using polar coordinates, then, is to investigate the phase relations between each team and ball, and between teams, using displacement measures derived from specific reference to goal position.

2. Method

This study was approved by the research ethics committee of the Faculty of Human Kinetics, Technical University of Lisbon, and followed the guidelines specified by the American Psychological Association.

2.1. Participants

Fifteen male senior players of the National Futsal University Team in Portugal were invited to participate in this study (mean value 23.25 years, *SD* = 1.96 years), with each player providing informed consent before data collection. Participants were grouped into three teams of five players each.

2.2. Data collection

Nine 5-vs-4+GK game condition practice sessions of five minutes duration were undertaken, with each team competing against each other in round robin fashion on three separate occasions. Thus, each team played two consecutive game sessions interspersed with five minutes rest to offset fatigue (Castagna, D'Ottavio, Granda-Vera, & Barbero-Alvarez, 2009). The practice sessions were performed according to the Official Futsal Rules (FIFA) with the defending (4+GK) and attacking (5) teams trying to prevent and score goals, respectively. The nine practice sessions were recorded at 25 Hz using a digital camera placed in the superior plane and positioned 45° to the middle field line. Thus, all the movements of the ball and players were made available for analysis.

2.3. Data analysis

Twenty one (21) trials, or game segments, without transition in ball possession were selected from the ongoing practice session game data. Each trial contained data beginning with the attacking team obtaining ball possession and ending with a shot at goal, the length (time duration) of trial therefore being determined by game performance. For each trial the movement trajectories of ball and players were digitized in slow motion (half normal video velocity) by the first author using TACTO software. Previous research has reported measurement error of less than 5% using TACTO (see Fernandes, Folgado, Duarte, & Malta, 2010).

The spatial resolution of the video device was 1280 × 800 pixels, and the trajectory of each player and ball was followed using the mouse cursor. The half-way distance between the two feet was used for digitization of player position on the reasoning that this location best approximates projection of the center of gravity (see Duarte et al., 2010). The center of the ball was used to digitize ball position on similar reasoning. The data were smoothed using a second-order 6 Hz Butterworth low pass filter to reduce signal noise associated with manual digitization (Winter, 2005). The virtual coordinates obtained from the digitization were then transformed to pitch coordinates for data analysis using a bidimensional direct linear transformation method (2D-DLT) (see Duarte et al., 2010; Kwon, 2008).

Two separate coordinate systems were used for data analysis. Zero data were assigned to the bottom left corner of the half-pitch using Cartesian coordinates, and zero data assigned to the center of the goal line using polar coordinates (see Fig. 1). In both coordinate systems, position of the ball and the geometric center of both teams, obtained from the arithmetic mean of the five players per team, were obtained for all time samples after filtering, thereby yielding measures of lateral and longitudinal displacements (Cartesian coordinates), and angles and radial displacements (polar coordinates). Consistent with the underlying thesis of coupled oscillators being responsible for the self-organizing behaviors produced in sports contests (McGarry et al., 2002), visual inspection of the time series data revealed well-expressed peaks and troughs in approximately periodic fashion, as expected. Subtracting the mean value from the time series data (signals) ensures the resultant trajectory data circle the origin, a necessary step when subjecting data to relative phase analysis using the Hilbert transform (Palut & Zanone, 2005; Rosenblum, Pikovsky, Kurths, Schäfer, & Tass, 2001).

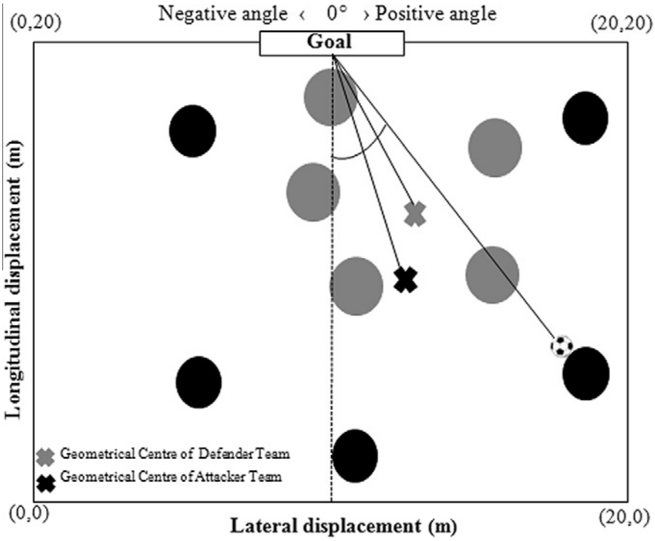

Fig. 1. Half-pitch representation using Cartesian and polar coordinates of the players (large circles) and team geometric centers (×) and ball. The datum coordinates are located bottom left (Cartesian) and top middle (polar). The defending team is represented in grey and the attacking team in black.

The relative phase quantifies the position relations between two sinusoidal signals (time series data) by measuring the phase differences between signals in their respective cycles. For example, in-phase (0°) represents signals at the same point in their respective cycles, and anti-phase (180°) denotes signals that are a half-phase displaced from each other, with other phase relations between in-phase and anti-phase likewise expressed with values between 0° and 180° (or between 180° and 360°). The relative phase data were inspected using frequency phase histograms and phase attractions noted from observations of peak frequency (Palut & Zanone, 2005).

Relative phase frequency data were subjected to a 12 (phase bins) × 3 (phase association) × 4 (coordinates) ANOVA with repeated measures on the first factor. The phase bins factor comprises the 12 relative phase (30°) bins, the phase association comprises the phasing relations between the defending team and ball, the attacking team and ball and between the two teams themselves, and the coordinates factor comprises the lateral, longitudinal, angle and radial distance measures. Analysis of variance was subjected to Mauchly's sphericity test and, when necessary, the Greenhouse-Geisser correction procedure was used to adjust the degrees of freedom. Significant ANOVA results were followed up with Bonferroni post hoc analyses.

2.4. Reliability

One of the 21 trials was selected at random and the data trajectories of the ball and players re-digitized by the first author. The data were assessed for accuracy and reliability using technical error of measurement (TEM) and coefficient of reliability (R), respectively (Goto & Mascie-Taylor, 2007). The intra-TEM yielded values of 0.19 m (1.75%), 0.25 m (3.65%) and 0.24 m (2.36%) for defenders, attackers and ball, respectively. These results indicate good accuracy, and therefore agreement, between trials. The coefficient of reliability produced data for the defenders ($R = .96$), attackers ($R = .97$) and ball ($R = .99$) demonstrating good reliability between measurements.

3. Results

Analysis of variance results revealed a main effect of phase bins, $F(2.96, 711.10) = 278.4$, $p < .001$, but no significant main effects for the phase association or coordinates factors. Significant interactions between phase bins and phase associations, $F(5.93,711.10) = 9.05$, $p < .001$, and between phase bins and coordinates, $F(8.89,711.09) = 9.05$, $p < .001$, and between phase bins, phase associations and coordinates were observed, $F(17.78,711.09) = 7.98$, $p < .001$. The remaining interaction between phase association and coordinates was not significant. Post hoc analyses of the phase bin data (i.e., the relative phase histograms) were undertaken as appropriate for purposes of identifying phase attractions.

3.1. Cartesian coordinates

3.1.1. Phase relations between the defending team and ball

Phase bin analysis of the defending team and ball on both lateral and longitudinal directions showed significant differences in the −90° through 0° phase relations and the other coordination patterns (see Table A1a). Visual inspection of the relative phase histograms (upper panels, Fig. 2) demonstrated −30° phase attractions for both lateral and longitudinal directions, with markedly stronger attractions observed for the lateral direction than the longitudinal direction.

3.1.2. Phase relations between the attacking team and ball

Post hoc analysis of relative phase data for the attacking team and ball for both lateral and longitudinal directions produced significant differences between the −30° through 30° phase bins and the 120° through 210° phase bins (see Table A1b). (Note. −180° and 180°, and −150° and 210°, represent the same phase relations by virtue of the circular statistics.) Visual inspection of the relative phase histograms (lower panels, Fig. 2) demonstrated phase attractions of −30° and 0° for the lateral and longitudinal directions, respectively. The phase attractions with the ball for the attacking team were much less pronounced than those demonstrated by the defending team.

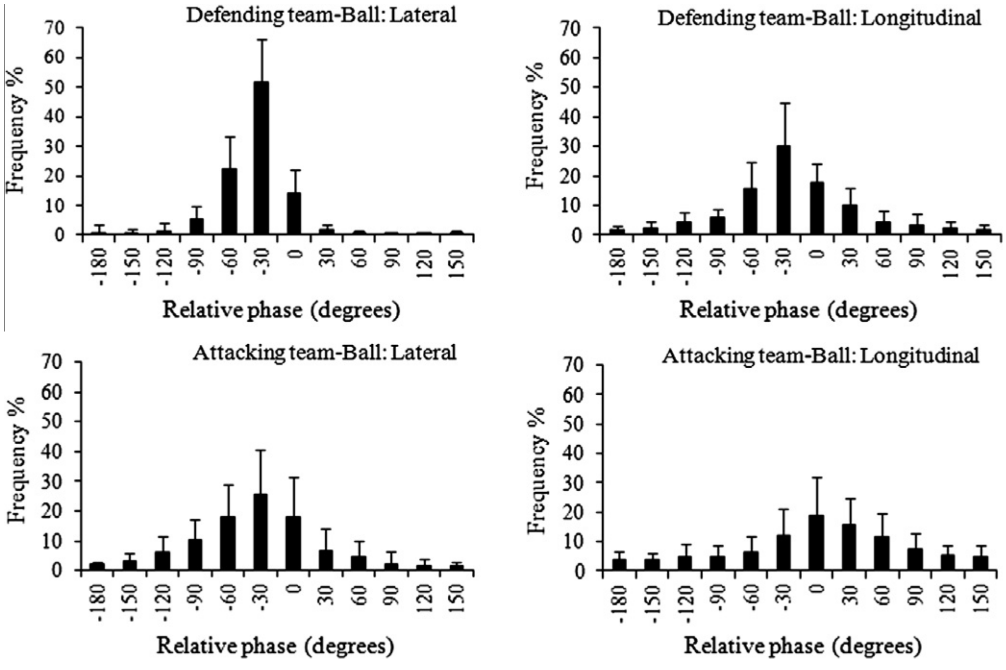

Fig. 2. Relative phasing between the defending and attacking teams and ball for lateral (left panels) and longitudinal (right panels) directions: Upper panels – Frequency histograms for the defending team and ball with error bars representing standard deviation; Lower panels – Frequency histograms for the attacking team and ball with error bars representing standard deviation.

3.1.3. Phase relations between the teams and ball

Post hoc analyses of phase bins of the teams and ball reported significant differences for lateral displacements between the −90° through 0° phase relations and other coordination patterns (see Table A2a). Significant differences were also observed for longitudinal displacements between the −60° through 0° phase relations and other coordination patterns (see Table A2b). Visual inspection demonstrated that phase attractions with the ball for the defending team, for both lateral and longitudinal directions, were much more pronounced than those demonstrated by the attacking team (Fig. 2).

Single trial analysis: Relative phase data for each team and ball from a single trial are presented for both lateral and longitudinal directions, as well as the standard deviation of relative phase for that same trial obtained using a one second moving window (Fig. 3). In this trial, stable in-phase relations with the ball for the defending team was observed in both the lateral and longitudinal directions. The phase shifts (from 0° to 360° to 720° etc.) observed in both directions represent the same (in-phase) relation and are attributed to an inserted or missing cycle in one of the two signals being compared. As expected, the standard deviation values confirm in-phase stability as the standard deviation spikes attributed to each phase shift return to approximating zero after each single spike. The attacking team likewise produced stable phase relations with the ball in the lateral direction but, unlike the defending team, produced unstable phase relations in the longitudinal direction for the first half of the trial. Instability in phasing relations is observed in the straight line with constant slope before stabilizing in-phase (−1800°) as also demonstrated in the high and varied standard deviations.

3.1.4. Phase relations between the defending and attacking teams

Post hoc analyses of phase bins reported significant differences between the −30° through 30° phase relations and other coordination patterns (see Table A3). Visual inspection of these data demonstrated −30° phase attractions for the lateral direction and in-phase (0°) attractions for the longitudinal direction (Fig. 4).

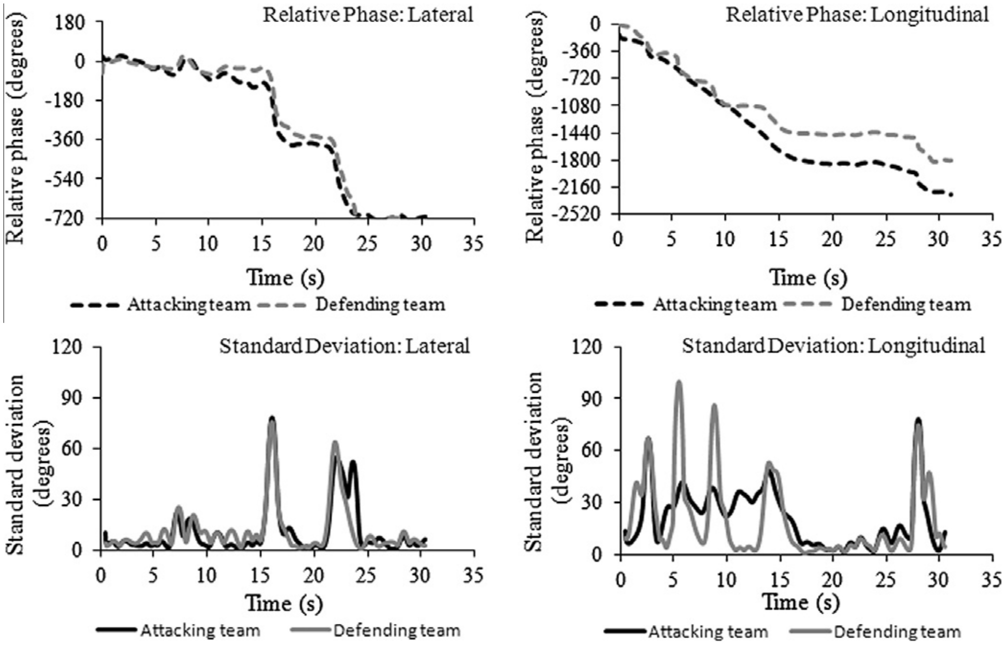

Fig. 3. Relative phase between the defending and attacking teams and ball for lateral (left panels) and longitudinal (right panels) directions. Upper panels – Single trial relative phase dynamics of both teams and ball. Lower panels – Standard deviation of the relative phase dynamics of both teams and ball (same trial).

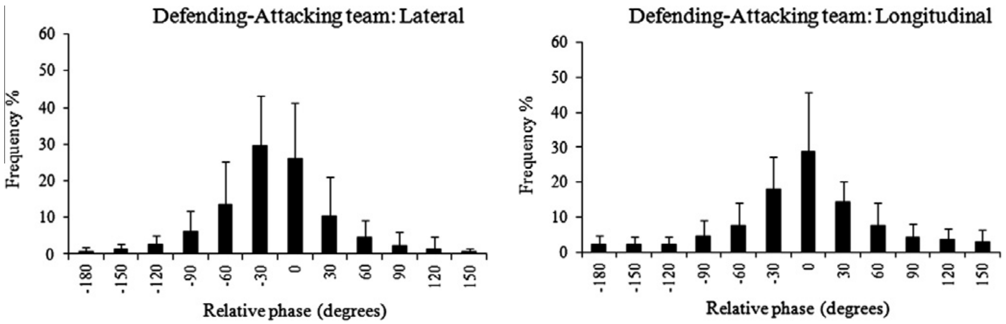

Fig. 4. Frequency histograms depicting relative phase between the defending and attacking teams for the lateral (left panel) and longitudinal (right panel) directions, with error bars representing standard deviation.

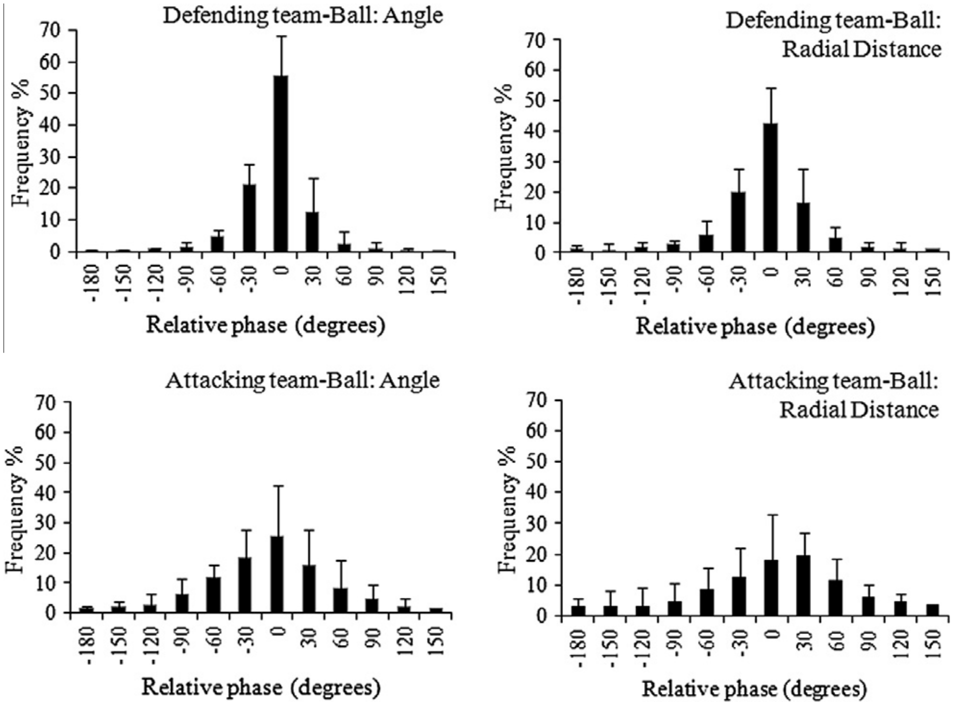

Fig. 5. Relative phase between the two teams and ball using polar coordinates (angle and radial distance) with error bars representing standard deviation: Frequency histograms for the defending team and ball (upper panels); attacking team and ball (lower panels).

3.2. Polar coordinates

3.2.1. Phase relations between the defending team and ball

Post hoc analyses of the phase bins indicated significant differences between the −30° through 30° phase relations and most other coordination patterns (see Table A4a). In-phase attractions were observed for both angle and radial distance, with stronger attractions observed for angles than for radius (upper panels, Fig. 5).

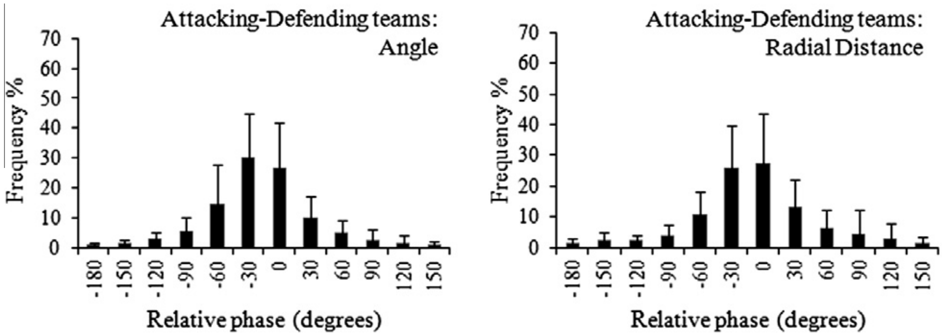

Fig. 6. Frequency histograms depicting relative phase between the defending and attacking teams for degrees (left panel) and radial distance (right panel), with error bars representing standard deviation.

3.2.2. Phase relations between the attacking team and ball

Post hoc analyses produced significant differences between the −30° through 30° phase relations and other values (see Table A4b). In-phase and 30° phase attractions were observed for angles and radial distances, respectively (lower panels, Fig. 5). The phasing attractions of the ball for the attacking team were much weaker than those demonstrated by the defending team.

3.2.3. Phase relations between the teams and ball

Post hoc analyses of phase bins of the teams and ball reported significant differences for angle measures between the −60° through 60° phase relations and other coordination patterns (see Table A5a). Significant differences were also observed for radial distance between the −30° through 30° phase relations and other coordination patterns (see Table A5b). Once again, visual inspection demonstrated much stronger phase attractions with the ball for the defending team, for both angle and radial distance, than for the attacking team (Fig. 5).

3.2.4. Phase relations between the defending and attacking teams

Post hoc analyses of phase bins reported significant differences for −30° through 30° phase values and other coordination patterns (see Table A6). Visual inspection identified −30° and in-phase attractions for angle and radial distance, respectively (Fig. 6).

4. Discussion

The patterned behaviors observed in the data are considered as emergent features of game behavior produced under various constraints, including the player configurations, the ball kinematics, and the goal being attacked and defended. The competing aims of the two teams lead to a priori expectations of different associations with the ball, as both teams try to achieve their different game objectives. Indeed, despite similar phase attractions (−30°) with the ball for both defending and attacking teams, markedly stronger attractions were produced by the defending team than the attacking team (see Fig. 2). In a 5-vs-4+GK game situation, the defending team tries to counter the numerical outfield player advantage of the attacking team by using zone defence. This game strategy seeks to limit goal scoring opportunities by reducing the spaces afforded to the attacking players in the region of the goal being defended, resulting when successful in collective synchrony between defending team and ball. In contrast, the attacking team seeks to increase the number of action possibilities for goal scoring opportunities by probing constantly the defensive structure resulting in increased phase variability (i.e., less phase stability). Thus, the attacking team explores continually the spatiotemporal relations that underpin game structure, with the express purpose of disrupting the defending team behavior for generating goal attempts. This view is akin to the notion of perturbations that have been proposed to change the behavioral stabilities of sports games (McGarry, Khan, & Franks, 1999), as well as the notion of "functional variability" which describes the various action possibilities for biological systems (Davids, Glazier, Araújo, & Bartlett, 2003). These action possibilities underscore the varied coordination patterns essential for adaptation and function in socio-biological systems (Kelso & Engstrøm, 2006), including sports contests.

Stronger −30° phase attractions of the defending team and ball were observed for the lateral direction than the longitudinal direction (see Fig. 2), a finding that may be attributed to the zonal strategy used to defend the goal in the 5-v-4+GK condition. In general, the defending team may be more responsive to ball kinematics in the lateral direction, and less responsive in the longitudinal direction when doing so would draw them from the defensive zone, for example when the ball is being displaced away from goal by the attacking team. On similar reasoning, differences between the defending and attacking teams in their −30° phase attractions with the ball in both directions may likewise be explained by increased responsiveness of the defending team to ball kinematics. For example, an attacking player in position to receive a pass from a teammate consequently draws a defender towards that position when the pass gets made. Given their opposing aims, both teams constantly adjust positions on the basis of game context, namely the changing positions of other players and ball. These general findings of different strengths of phase attractions with the ball for the defending and attacking teams are consistent with the view that the ball dynamics, goal location and game objectives constitute important constraints on playing behavior.

In team sports like futsal, the attacking team tries to get past the defending team in attempt of scoring a goal while the defending team tries to prevent the attacking team from achieving this aim. With these team objectives in mind, the attackers look to generate time and space for themselves by breaking synchrony with the defenders at opportune times whereas the defenders attempt to restrict the time and space of the attackers by achieving synchrony with them (McGarry, 2005). In breaking synchrony, then, the attacking team will destabilize the phase relations of one or more of the playing (attacker-defender) dyads, so producing behavioral perturbation in the defensive organizational structure. In contrast, in achieving synchrony the defending team will contain the attacking team within a reasonably balanced game state thereby reducing the prospect of the attacking team generating a goal scoring threat. These competing objectives produce varying phase attractions between playing dyads and between teams. Thus, the coordination dynamics between the defending team, attacking team and ball emerge from the information available, including the individual and collective objectives of the players and teams. The suggestions above are consistent with the results of Travassos and colleagues (2011) who analyzed the 5-v-4+GK futsal game data at the level of playing dyads. In the present study, stronger phase attractions between the teams and ball were observed than those between the players and ball reported by Travassos et al. (2011), a finding consistent with statistical considerations. From behavioral considerations, increased variability in phase relations observed for the playing dyads may be the result of players continually engaging with their surrounds so as to produce functional adaptive behaviors at the team scale, as noted for other biological systems (Beek et al., 1997; Kelso & Engstrøm, 2006).

The defending team and attacking team demonstrated −30° and 0° phase attractions in the lateral and longitudinal directions, respectively (Fig. 3). These results indicate general tendencies for both teams to move together in lockstep, possibly as a means of the defending team seeking to maintain spatial-temporal pressure on the attacking team. Equally strong phase attractions observed between teams in the lateral and longitudinal directions in this report are contrary to results reported previously, both for basketball contests (Bourbousson et al., 2010b) and small-sided soccer games (Frencken & Lemmink, 2008). These differences are attributed primarily to the different nature of the game conditions investigated and the different strategies used by the defending teams. (For basketball and soccer, the teams comprised of 5-v-5 and 4-v-4, respectively, with individual defending strategies used by both teams in both investigations.) These differences notwithstanding, the various team sports investigated conform to a common description consistent with theoretical principles of dynamical self-organizing systems, primarily the presence of non-prescribed stable coordination patterns brought upon by coupled information exchanges between players and teams, as proposed by McGarry et al. (2002).

In considering the movement behaviors of players, teams and ball in regard to location on the field of play referenced to goal position, the data were analyzed using polar coordinates. These coordinate data provided measures of direction (angle) and distance (radial) with reference to the center of the goal line, a principal and common focus of both teams. Thus, polar coordinates offer a different view of futsal game behavior from the Cartesian coordinates reported to date, with the "sway" of both teams and ball dynamics being expressed in relation to the goal. Indeed, analysis of variance reported significant interactions between phase angle and coordinates. Note the strong in-phase attractions of the defending team and ball as compared to the attacking team and ball when using polar coordinates (Fig. 5). Similar results were reported using Cartesian coordinates too (Fig. 2) but important distinctions in phase relations between the two coordinate systems are observed, as expected. The phase relations obtained using polar coordinates demonstrated game behaviors anchored on the competing game objectives of the attacking and defending teams specified in respect to goal location as follows.

The relative phase between the defending team and ball produced stronger in-phase attractions for angle measures than for radial distance (Fig. 5). These results are explained by the defending team seeking to guard space by positioning itself with respect to the changing ball position and the goal being defended. By way of analogy, the defending players (team) may be thought of as patrol agents anchored to the goal center on a "retractable leash" of some maximum length, their principal task being to intercept and prevent path access of ball and attackers to goal. This interpretation offers additional explanation for the earlier reported finding of weaker attractions with the defending team and ball in the longitudinal direction than the lateral direction. Since the attacking team is able to change the angle information of the ball with respect to the center goal line more effectively by lateral displacements than by longitudinal displacements, it would seem reasonable to expect the defending team to be more responsive to ball displacements in that same direction. This interpretation is reinforced further when considering that ball displacements in the longitudinal direction may generally be treated with varying degrees of attention by the defending players, depending in part on whether the ball is being displaced towards or away from goal.

The main contribution of using polar coordinates was to undertake game behavior analyses while accounting for the key game objectives, namely that of attacking and defending a given goal. Strong in-phase attraction between the defending team and ball was observed using polar coordinates (i.e., angles and radial distances), with much less strong phase attractions reported for the attacking team and ball as well as for between the two teams. In particular, the results from the defending team and ball produced stronger phase attractions when using polar coordinates instead of Cartesian coordinates, that is when their dynamics were measured in consideration of goal position. This finding demonstrates the importance of using variables that reflect the behavior of teams with respect to their functional aims (McGarry, 2009).

In summary, individual and team coordinated behaviors are the result of information exchanges among dyads whose varied compositions on different levels may be considered as cooperative and competitive. Within this context, the results of this investigation have shown that ball kinematics is a key constraint that influences the dynamical behaviors of the players and teams, with general attractions towards in-phase being reported for each team and ball, as well as between the two teams. The attacking team demonstrated weaker phase coordination patterns with the ball than the defending team, a result interpreted as consistent with the attacking team trying to break synchrony with the defending team. Other than ball kinematics, the goal line was also shown as a key informational constraint that influences coordination patterns, particularly for the defending team as demonstrated using angles and radial distances expressed with regard to the center of goal. Thus, the defending team attempts to develop and maintain spatiotemporal coordination patterns with the attacking team, and with the ball, but, importantly, it does so within the context of considering kinematic information with respect to the goal line. Identifying and developing new variables for describing coordination patterns that emerge in team sports as a result of ecological considerations and dynamical principles should aid future understanding of game behavior.

5. Practical applications

In this last section, we offer some brief and general considerations for sports practice on the premise that futsal game behavior is self-organizing with players and teams making decisions and actions under ongoing informational constraints. In this view, the importance of coaching influencing on game behavior is observed in coaching decisions (e.g., designing sports practice, deciding on team selection, identifying game strategies, making game substitutions, and so on) that add, remove and/or change the informational constraints that the players and teams are operating under. In designing sports practice, then, the coach may consider shaping informational constraints that allow for the players and teams to explore behavioral possibilities for achieving specific task objectives. In short, the general approach is to encourage individual and collective decision-making by the players in specific game contexts regulated by certain informational constraints shaped by coaching design. For example, a practice session may require players to attack and defend two separate goals located on the same line as opposed to a single standard goal, with the aim of promoting self-organized lateral coordination within the defending team – a fundamental issue for the defending team as observed in this report – instead of providing players and teams with prescribed behaviors to prescribed situations. This example illustrates promotion of self-learning (and self-organization) through design of deliberate practice sessions.

Acknowledgments

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Appendix A

Table A1
Relative phase post hoc results for (a) the defending team, and (b) the attacking team, both with respect to the ball in Cartesian coordinates.

	(a) Defending team													(b) Attacking team											
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12
1	—			*	*	*	*						1	—					*	*	*				
2		—		*	*	*	*						2		—		*		*	*	*				
3			—		*	*	*						3			—				*					
4	*	*		—	*	*			*	*	*	*	4		*		—			*					
5	*	*	*	*	—	*		*	*	*	*	*	5					—							
6	*	*	*	*	*	—	*	*	*	*	*	*	6	*	*				—					*	*
7	*	*	*			*	—	*	*	*	*	*	7	*	*	*	*			—		*	*	*	*
8					*	*	*	—					8	*	*						—		*	*	*
9				*	*	*	*		—				9							*		—			
10				*	*	*	*			—			10							*	*		—		
11				*	*	*	*				—		11						*	*	*			—	
12				*	*	*	*					—	12						*	*	*				—

Note. 1 = –180°, 2 = –150°, 3 = –120°, 4 = –90°, 5 = –60°, 6 = –30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.

[*] $p < .001$.

Table A2
Relative phase post hoc results for the teams and ball for (a) lateral direction and (b) longitudinal direction.

	(a) Lateral displacements													(b) Longitudinal displacements											
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12
1	—			*	*	*	*						1	—				*	*	*					
2		—		*	*	*	*						2		—			*	*	*					
3			—		*	*	*						3			—			*	*					
4	*	*		—	*	*				*	*	*	4				—	*	*	*					
5	*	*	*	*	—				*	*	*	*	5	*	*		*	—						*	*
6	*	*	*	*		—	*	*	*	*	*	*	6	*	*	*	*		—			*	*	*	*
7	*	*	*			*	—	*	*	*	*	*	7	*	*	*	*			—		*	*	*	*
8						*	*	—					8								—				
9					*	*	*		—				9						*	*		—			
10				*	*	*	*			—			10						*	*			—		
11				*	*	*	*				—		11					*	*	*				—	
12				*	*	*	*					—	12					*	*	*					—

Note. 1 = –180°, 2 = –150°, 3 = –120°, 4 = –90°, 5 = –60°, 6 = –30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.
* $p < .001$.

Table A3
Relative phase post hoc results for the defending and attacking teams in Cartesian coordinates.

	1	2	3	4	5	6	7	8	9	10	11	12
1	—					*	*	*				
2		—				*	*	*	*			
3			—			*	*	*				
4				—		*	*					
5					—		*					
6	*	*	*	*		—					*	*
7	*	*	*	*	*		—		*	*	*	*
8	*	*	*					—	*	*	*	*
9		*					*	*	—			
10							*	*		—		
11						*	*	*			—	
12						*	*	*				—

Note. 1 = –180°, 2 = –150°, 3 = –120°, 4 = –90°, 5 = –60°, 6 = –30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.
* $p < .001$.

Table A4
Relative phase post hoc post hoc results for (a) the defending team, and (b) the attacking team both with respect to the ball in polar coordinates.

	(a) Defending team													(b) Attacking team											
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12
1	—					*	*	*					1	—					*	*	*				
2		—				*	*	*					2		—				*	*	*				
3			—			*	*	*					3			—			*	*	*				
4				—		*	*	*					4				—			*					
5					—	*	*	*					5					—		*					
6	*	*	*	*	*	—	*			*	*	*	6	*	*	*			—					*	*
7	*	*	*	*	*	*	—	*	*	*	*	*	7	*	*	*	*	*		—			*	*	*
8	*	*	*	*	*			—	*	*	*	*	8	*	*	*					—		*	*	*
9							*	*	—			*	9									—			*
10						*	*	*		—			10							*	*		—		
11						*	*	*			—		11						*	*	*			—	
12						*	*	*	*			—	12						*	*	*	*			—

Note. 1 = –180°, 2 = –150°, 3 = –120°, 4 = –90°, 5 = –60°, 6 = –30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.
* $p < .001$.

Table A5
Relative phase post hoc results for the teams and ball for (a) angle and (b) radial distance.

	(a) Angle													(b) Radial distance											
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12
1	—				*	*	*	*	*				1	—				*	*	*	*				
2		—			*	*	*	*	*				2		—				*	*	*				
3			—		*	*	*	*					3			—			*	*	*				
4				—		*	*	*					4				—		*	*	*				
5	*	*	*		—	*	*	*				*	5	*				—	*	*					*
6	*	*	*	*	*	—	*			*	*	*	6	*	*	*	*	*	—			*	*	*	*
7	*	*	*	*	*	*	—	*	*	*	*	*	7	*	*	*	*	*		—		*	*	*	*
8	*	*	*	*	*		*	—	*	*	*	*	8	*	*	*	*				—	*	*	*	*
9	*	*					*	*	—		*	*	9						*	*	*	—			
10						*	*	*		—			10						*	*	*		—		
11						*	*	*	*		—		11						*	*	*			—	
12					*	*	*	*	*			—	12					*	*	*	*				—

Note. 1 = −180°, 2 = −150°, 3 = −120°, 4 = −90°, 5 = −60°, 6 = −30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.
[*] $p < .001$.

Table A6
Relative phase post hoc results for the defending and attacking teams in polar coordinates.

	1	2	3	4	5	6	7	8	9	10	11	12
1	—					*	*					
2		—				*	*					
3			—			*	*					
4				—			*					
5					—							
6	*	*	*			—				*	*	*
7	*	*	*	*			—	*	*	*	*	*
8							*	—				
9							*		—			
10						*	*			—		
11						*	*				—	
12						*	*					—

Note. 1 = −180°, 2 = −150°, 3 = −120°, 4 = −90°, 5 = −60°, 6 = −30°, 7 = 0°, 8 = 30°, 9 = 60°, 10 = 90°, 11 = 120°, and 12 = 150°.
— = Diagonal cell.
[*] $p < .001$.

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