Capturing group tactical behaviors in expert team players

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Over the last two decades there has been increasing interest in identifying properties of sport teams that are more than the sum of the properties of their members (Eccles & Tenenbaum, 2004; Salas et al., 1997). Team behaviors emerge from interactions of three or more players looking to cooperate and compete together to achieve common goals, while communicating through synergetic relations (Riley et al., 2011; Silva et al., 2013). Joint analysis of individual behaviors can translate to group behaviors as all players constrain and, in turn, are constrained by the dynamic, integrated system that they compose (Glazier, 2010). Expert teams are characterized by high levels of performance outcomes, achieved by the team's effective utilization of member expertise and mastery of group processes (Salas et al., 2006). Research on expert, non-sport team performance (see Salas et al., 2006) has revealed that: i) expert members are able to combine their individual expertise and coordinate actions to achieve a common goal, ii) the team as a whole creates a synergy, iii) expert teams solve problems quickly and accurately, iv) when faced with novel situations, members can predict events and create new procedures, and v) expert teams are adaptive.

Theories of expertise in team sports

Sport team performance has been extensively analyzed by a range of analytic performance indices (Hughes & Bartlett, 2002; James, 2006). Although some studies have investigated differences between expert and non-expert team ball players (Almeida et al., 2013), the vast majority of work has not examined the processes by which expert sport teams develop (e.g., the mechanisms proposed by Eccles & Tenenbaum, 2004 for sport teams were formulated on non-sport, expert team behaviors; see McGarry et al., 2013 for a complete overview).

A traditional approach to understanding the mastery of group processes that culminates in team effectiveness is predicated on the notion of group cognition. This concept is based on the premise that there exist shared mental models of the performance environment, internalized among all team members (Cannon-Bowers et al., 1993; Fiore & Salas, 2006; Salas et al., 2008). Shared cognition is typically referred to as a state of group coordination in which each individual's specific mental expectation and representation of a performance context is similar or identical to that held by other team members (Eccles, 2010; Eccles & Tenenbaum, 2004).

Although shared cognition has tended to dominate research on coordination in groups, the mechanism to explain re-formulations of a team member's representation when changes occur in the content of another member's representation has proved difficult to verify (Mohammed et al., 2000). Also, it is difficult to justify the existence of a brain that stores each player's representations (Shearer et al., 2009), and it is hard to consider that representations exist beyond the boundaries of an individual organism and can be somehow shared (Riley et al., 2011; Silva et al., 2013).

In contrast to assumptions of putatively shared cognition, an ecological approach proposes that knowledge of the world is based upon recurrent processes of perception and action through which humans perceive affordances (i.e., opportunities for action; see Gibson, 1979).

The concept of affordances presupposes that the environment is directly perceived in terms of what actions an organism can achieve within a performance environment (i.e., it is not dependent on a perceiver's expectations or mental representations linked to specific performance solutions) (Richardson et al., 2008). As in other collective systems, performers in sport teams often have to make decisions about where to move and which actions to perform in uncertain, dynamic environmental conditions (Davids et al., 2005). Affordances can be perceived by a group of individuals trained to become perceptually attuned to them (Silva et al., 2013). In collective sports, both teams in opposition have the same objective (i.e., to overcome the opposition and win). Hence, the perception of collective affordances acts as a selection pressure for overcoming opponents and achieving successful performances. In this sense, collective affordances are sustained by common goals of team members who cooperate to achieve group success. From this perspective, team coordination depends on the collective attunement to shared affordances founded on a prior platform of (mainly non-verbal) communication or information exchange (Silva et al., 2013). Through practice, players become perceptually attuned to affordances of others and affordances for others during competitive performance, and refine their actions (Fajen et al., 2009) by adjusting behaviors to functionally adapt to those of other teammates and opponents. This process enables them to act synergistically with respect to specific team goals (Duarte et al., 2012a). For example, Sampaio and Maçãs (2012), when studying the effects of a 13-week football training program on team tactical behavior, found that players showed more regular behavior with learning. This result suggests that inter-player coordination in pre-test seems to reflect individual affordances, and not shared affordances, among team players. However, post-test values showed that players became more coordinated with learning, reflecting attunement to shared affordances.

An important feature of a synergy is the ability of one of its components (e.g., a player) to lead changes in others (Riley et al., 2011). Decisions and actions of players forming a synergy should not be viewed as independent, and can explain how multiple players act in accordance with dynamic performance environments in fractions of a second. Therefore, the coupling of players as independent degrees of freedom into integrated synergies is based upon a social perception-action system supported by perception of shared affordances.

This view has major implications for designing experimental research for studying team performance behaviors. For example, it implies that team tactical behaviors may not be articulated in verbal reports. There is an interdependence between perception and action, with clear differences between verbalizing and acting (Araújo et al., 2010). Experimental designs need to focus on player-player-environmental interactions that can be elucidated in compound variables specifying functional collective behaviors of sport teams (e.g., geometrical centers), underpinned by interpersonal synergies created between players. In the next section we highlight ways of capturing group-based characteristics in team settings from existing research.

Capturing group-based characteristics in team settings

Group-based measures can be categorized by the following variables: i) team center (centroids and "weighted" centroids), ii) team dispersion (stretch index, team spread, surface area, team length per width ratio), iii) team synchrony (relative phase, cluster phase), iv) labor division (Voronoi, dominant regions, heat maps, major ranges, player-to-locus distance), and v) team communication networks (social networks).

Team center

A team's center (also termed centroid, center of gravity, or geometrical center) is obtained by computing the mean lateral and longitudinal positional coordinates of each performer in a team (each player contributes equally to this measure). It has been used to evaluate intra- (e.g., Gonçalves et al., 2013) and inter-team coordination processes in team sports (e.g., Frencken et al., 2011). Teams' centers represent the relative positioning of both teams in forward-backward and side-to-side movement displacement (see Figure 19.1 for an illustration), revealing important insights into team tactics.

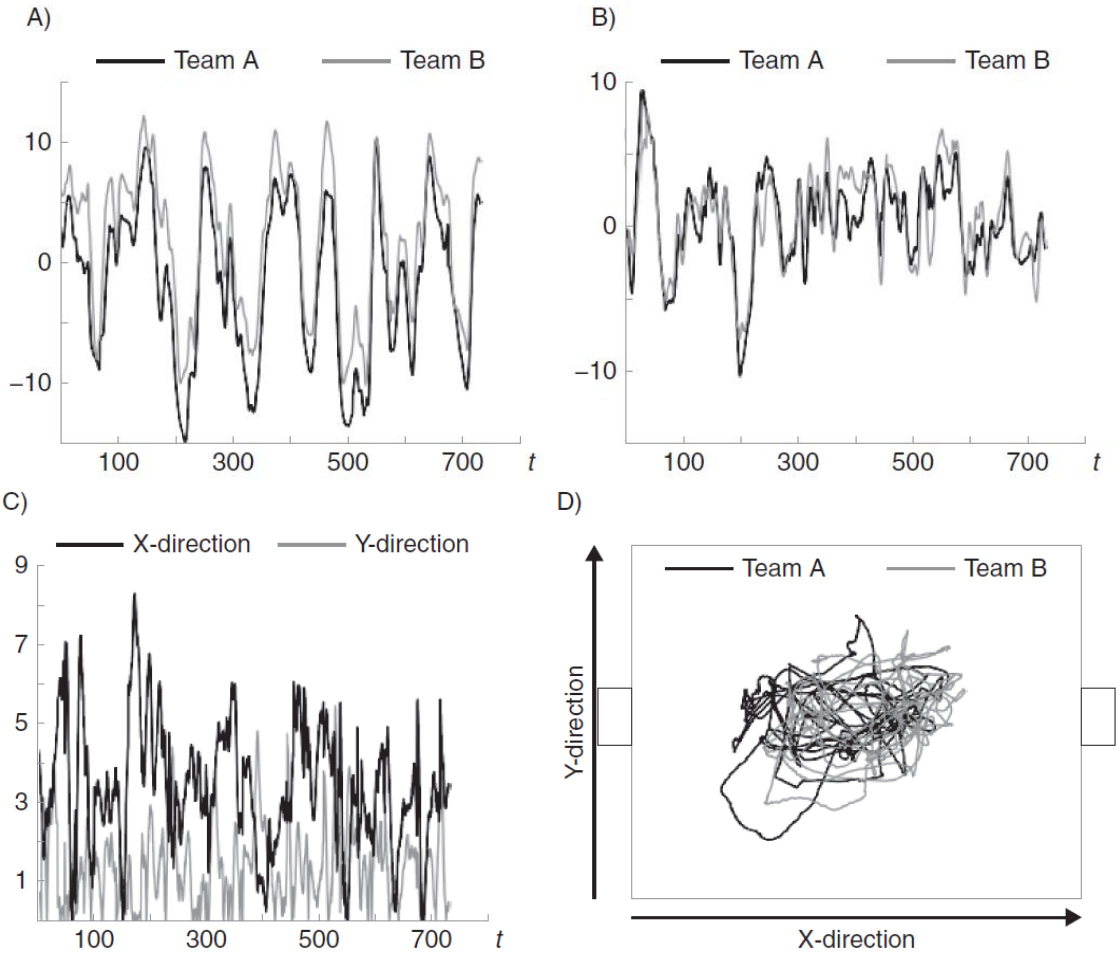


Figure 19.1 Upper panels depict the centroids' coupled oscillations of two teams during six-a-side, small-sided games in: A) X-direction, and B), Y-direction. Oscillations are more pronounced for the goal-to-goal direction. Lower panels illustrate: C) centroids' absolute distances in the X- and Y-direction and D) centroids' trajectories on the field. Distances are greater for the X-direction.

Analysis of inter-team coordination processes has considered the distance between the two teams' centroids in small-sided games as a measure of proximity between competing teams.

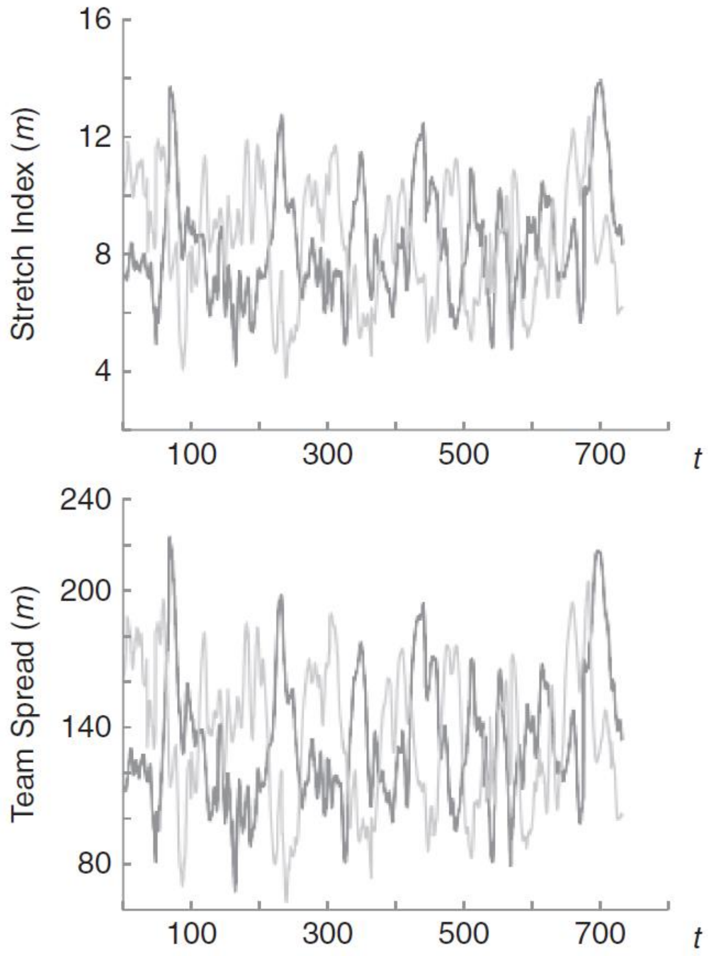
For example, Frencken et al. (2011) observed that the centroid of an attacking team crossed the centroid of a defending team in several plays, ending in a goal being scored, during small-sided games. They argued that this might be a prerequisite to increase the probability of scoring. However, different results were reported by Bartlett, Button, Robbins, Dutt-Mazumder, and Kennedy (2012) in regular matches. They found no clear convergence of the teams' centroids during several plays ending with goals in 11 versus11 football matches, likely because the positioning of players farthest from the ball compromised the influence of players nearer the ball.
Analysis of a "weighted" centroid echoes the distance of each player to the ball according to his/her influence on the play. Clemente, Couceiro, Martins, Mendes, and Figueiredo (2013b) found pronounced oscillations of both teams' weighted centroids in a lateral direction, interpreted as efforts by the team with the ball to destabilize the defensive organization of opponents by changing the flank of attack (Clemente et al., 2013b). The extent to which the crossing of weighted centroids represents the creation of scoring opportunities is still to be verified.

Team dispersion

Tactics in invasion team sports are expressed by the stretching and expanding of attacking teams on the field and the contracting and reducing of distances between players of the defending team. Such collective movements are captured by specific measures of team coordination that quantify the overall spatial dispersion of players, such as the stretch index (or radius), the team spread, and the effective playing space (or surface area).
The stretch index is calculated by computing the average radial distance of all players to their team's centroid. It can also be calculated according to the axis expansion, providing distinct measures of dispersion in longitudinal and lateral directions. Using this index, Yue, Broich, Seifriz, and Mester (2008) and Bourbousson, Sève, and McGarry (2010b) highlighted the dynamics of attacking and defending, in football and basketball, by representing the intermittent expansion and contraction patterns of competing teams.
Team spread measures have been reported by Moura, Martins, Anido, Barros, and Cunha (2012), who calculated the square root of the sum of the squares of distance values between all pairs of players, except the goalkeeper. They observed a counter-phase relation between expansion in attack and contraction in defense, with greater dispersion values when teams had ball possession. However, further studies are needed to clarify how team dispersion measures are related to attacking and defending phases of play (Bartlett et al., 2012).
Independently, none of the aforementioned studies have accounted for the proximity of each player to the ball, in calculations of team dispersion. In the work by Clemente, Couceiro, Martins, and Korgaokar (2012), distances of each player to the weighted centroid have been considered in calculations of the stretch index. Clemente and colleagues were able to determine a weighted stretch index that accounted for the dispersion of players in relation to the game center containing the ball. They observed a negative relationship between both teams' stretch index values and lower values of this variable without possession of the ball, compared to being in possession of the ball, in seven-a-side, under-13 (years of age) football. It seems that the expansion and contraction properties of a team are constrained by proximity of players to the ball.

The effective playing space (or surface area) is defined by the smallest polygonal area delimited by the peripheral players, containing all players in the game. It can also provide information about the surface that is being effectively covered by opposing teams, and informs how the occupation of space unfolds throughout performance and how stretched both teams are on the field. The effective playing space may also be computed as a function of attacking and defending, discriminating the surface areas of both teams in competition while representing positioning in the overall team (Frencken & Lemmink, 2008). Similar to the stretch index and team spread, the relationship between offensive and defensive surface areas can highlight the balance of the opponents' relationship during matches (Gréhaigne & Godbout, 2013). Putatively, the attacking team may occupy a larger surface area than that of the defending team, by virtue of being more stretched in the field. The suggestion is that these three variables share a similar nature (see Figure 19.2).

Capturing group tactical behaviors



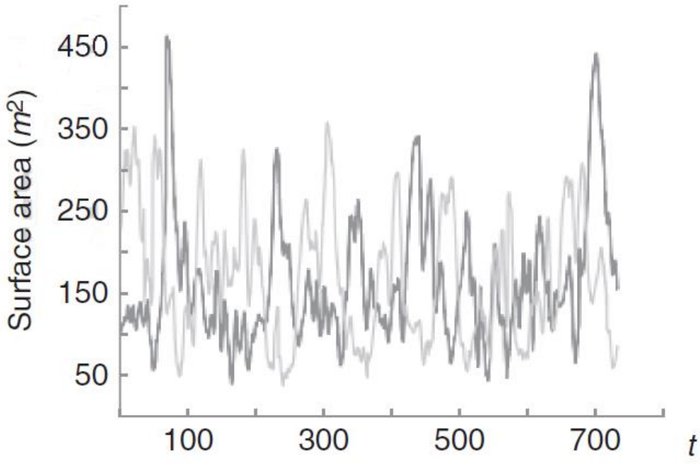


Figure 19.2 Stretch indices, team spreads, and surface areas time series of two competing teams during five-a-side games. All three quantities exhibit similar counter-phase oscillation patterns between teams.

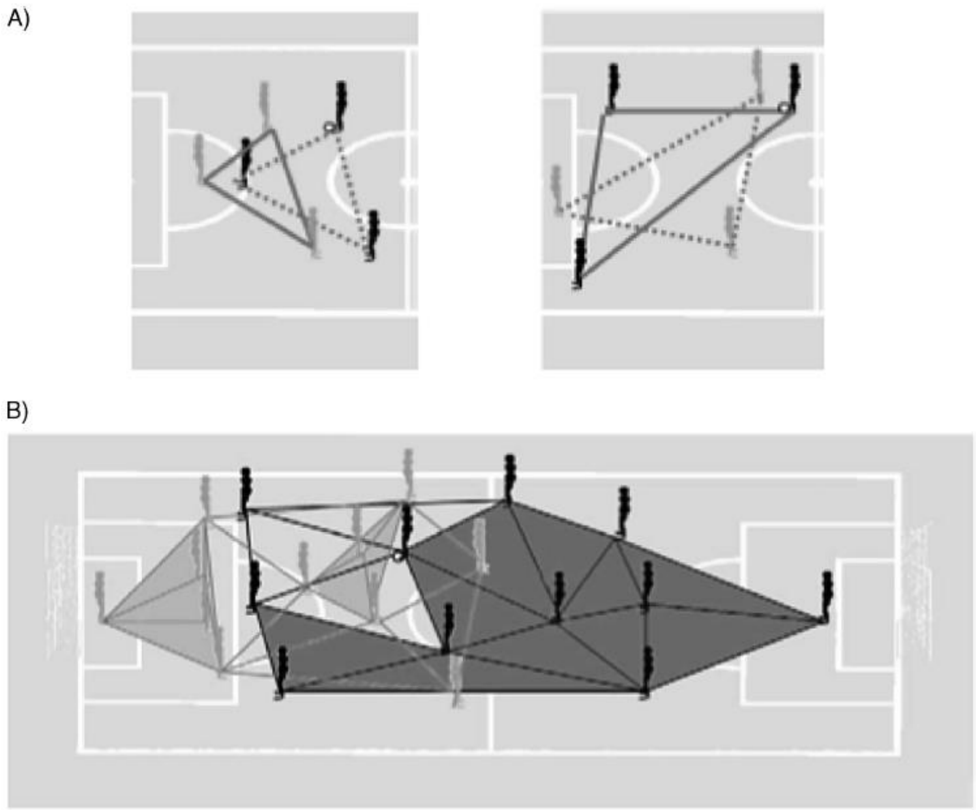


Figure 19.3 A) Examples of triangles interception. B) Effective surface area with offensive (dark grey) and defensive triangles (light grey). From Clemente, Couceiro, Martins, and Mendes (2013), reprinted with permission of the authors.

A different conceptualization of the effective playing area was proposed by Clemente, Couceiro, Martins, and Mendes (2013a), based on the assumption that it is important to assess the area that a team covers without intercepting the effective area of the opposing team. To

this effect, Clemente and colleagues have calculated the non-overlapping triangles formed by the players of each team and the total area delimited by these triangles for the attacking and defending teams (Figure 19.3).
They showed that the attacking team, in general, showed higher values of triangulations (i.e., higher number of triangles not annulled by the opponent team's triangles) and effective playing area, whereas the defending team displayed lower effective surface areas. A negative correlation between the areas of both teams was also found, indicating a counter-phase relation between both teams' effective playing areas, which did not happen in other studies that measured surface areas by the above-described means.

Team synchrony
Several tools have been used to assess coordination between two oscillatory units (e.g., the coupling of two centroids, or the phase relations of two players in a dyad). For instance, the phase synchronization of two signals has been previously studied in team sports through relative phase analysis (Bourbousson et al., 2010a, 2010b) and running correlations (Duarte et al., 2012b; Frencken et al., 2013).
A cluster phase method has been recently proposed to analyze synchrony in systems with a small number of oscillatory units (Frank & Richardson, 2010; Richardson et al., 2012). It is based on the Kuramoto order parameter conceived to examine the phase synchronization of a large set of coupled oscillators (Kuramoto, 1984), like neural synchronization in the brain. Frank and Richardson (2010) adapted this algorithm to describe the collective phase of a smaller number of oscillators into one single measure, and used it to assess group synchrony in a non-sport task. In team sports, Duarte et al. (2013) applied this measure to the movements of 11 football players from two teams during an English Premier League match to assess whole team and player-team synchrony. They found large synergistic relations within each team, particularly in the longitudinal direction of the field. Whole team synchrony revealed superior mean values and high levels of stability in the longitudinal direction, compared with the lateral direction of the field. Player-team synchrony revealed a tendency for a near in-phase mode of coordination. However, the cluster phase method might be useful to measure group synchrony only when it is expected that players exhibit synchrony by performing symmetric movements on the field (e.g., during a counterattack in football or a turnover in basketball). More research is needed to determine the utility of this method when players perform coordinated, but non-symmetric movement behaviors (e.g., when players switch positions).

The division of labor within teams
The behavior of each individual in a team is constrained by several factors, such as his/her position on the field (in relation to the other teammates and opponents), strategic and tactical objectives, playing phases (i.e., attacking and defending), game rules, etc. Team behavior is thus the emergent result of many individual labors in interaction (Duarte et al., 2012b; Eccles, 2010).
The analysis of labor division in the field can be performed from a spatial perspective. Gréhaigne (1988) pioneered analysis of the division of individual areas, or action zones, of each player, in an attempt to assess the tactical characteristics of each player in a team. He

analyzed the effective covered space of football players by registering their position on the field every 30 seconds, according to their specific location on a pitch divided into 40 equal squares. Nowadays, the reconstruction of spatial distribution maps, also known as heat maps, provides a clear picture of the distribution of each player on the field. Heat maps highlight with warmer colors the zones where each player has spent larger periods of time during performance (e.g., Lames, 2008; see also Figure 19.4).

Based on this concept, Silva et al. (2014) produced heat maps of youth football players of different competitive levels performing in small-sided games. They calculated entropy measures of each individual's spatial distribution, providing a value that quantified the uncertainty of locating each player in a specific location on the field. They observed that the more skillful players displayed higher spatial unpredictability on the smaller fields, compared to less-skilled players. Both groups displayed identical levels of predictability in movement trajectories on larger fields.

Another approach to assess the division of labor in team sports is by measuring the area covered by each player. Yue et al. (2008) proposed the calculation of a major range, defined as an ellipse centered at each player's locus and with semi-axes being the standard deviations in the x- and y-directions, respectively. This measure identifies preferred spatial positions, major roles for each player, and playing styles.

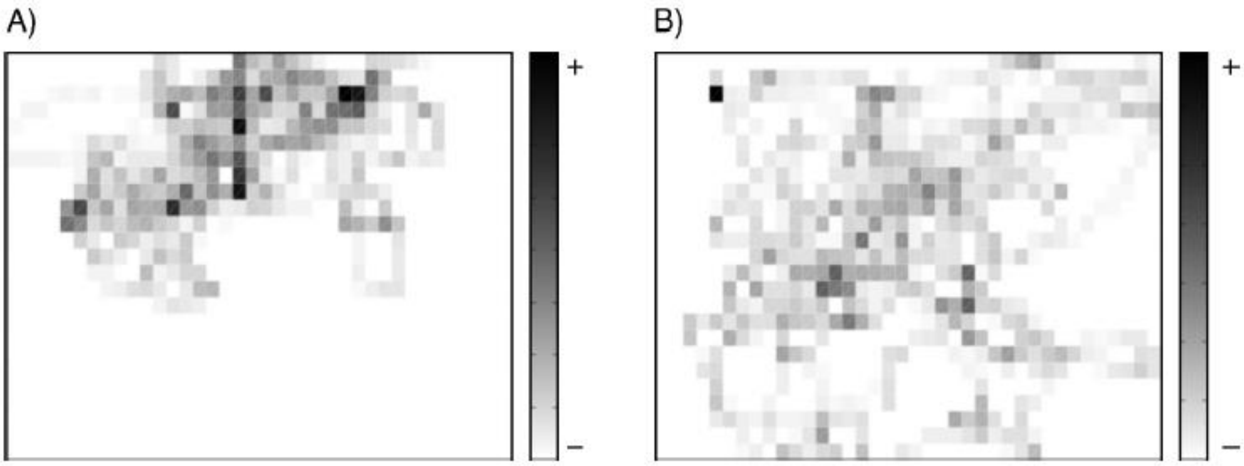


Figure 19.4 Exemplar spatial distribution maps of two players during a four-a-side game; A) regional player; B) national player. The national player presents more variability in space occupation in relation to the regional player.

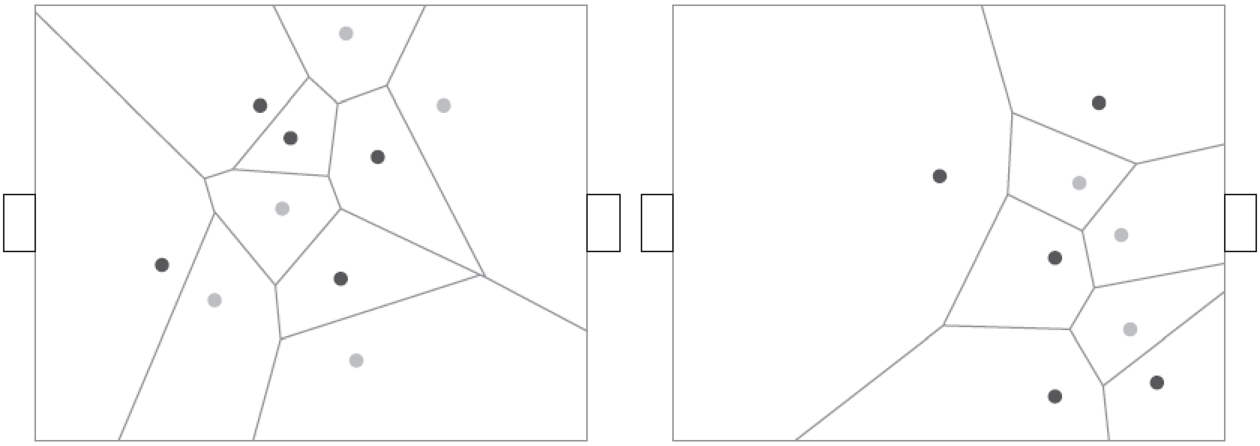


Figure 19.5 Exemplar players' Voronoi cells in two small-sided games (five versus five and five versus three) in single frames (goalkeepers excluded).

Other spatial measures emphasizing the individual playing areas attributed to each player on a team – the Voronoi diagrams – were revised by Fonseca, Diniz, and Araújo (2014). These studies indicated that this individual spatial representation could be used to measure teamwork by assessing the dominant regions of each team. Dominant regions reflect the creation and coverage of space by teams. Given a set of n points distributed in a plane, the Voronoi diagram divides the plane into n cells (Figure 19.5), each associated with one, and only one, point. In other words, each cell corresponds to a part of the plane that is closer to one of the points. For instance, in a soccer match, the points could be the position of the players, the plane the play area, and the cells the regions associated to each player. By measuring the total area of all cells from each team, it is possible to obtain a dominant ratio of one team over the other (Kim, 2004) (see Figure 19.5).

Fonseca, Milho, Travassos, and Araújo (2012) computed the Voronoi cells of two futsal teams to understand how players of both teams coordinated their locations on the court during attack and defense. They found larger covered areas by players in attacking teams and lower regularity (measured by approximate entropy) in the areas occupied by defending teams, revealing more unpredictable interactive behaviors between defending players (see also Fonseca et al., 2013 for the novel concept of superimposed Voronoi).

However, the assumption that all space inside a Voronoi cell is reachable in a shorter time by its designated player may be questioned. The position, speed, acceleration, and movement direction of the players may be determined to define which areas he/she can arrive at earlier than other players (Gréhaigne et al., 1997). Taki and Hasegawa (2000) took into account these factors to calculate the dominant region of each player on a football match. They calculated deformed Voronoi cells that weighted the players' positions, movement directions, and speeds, determining with higher accuracy each player's dominant region.

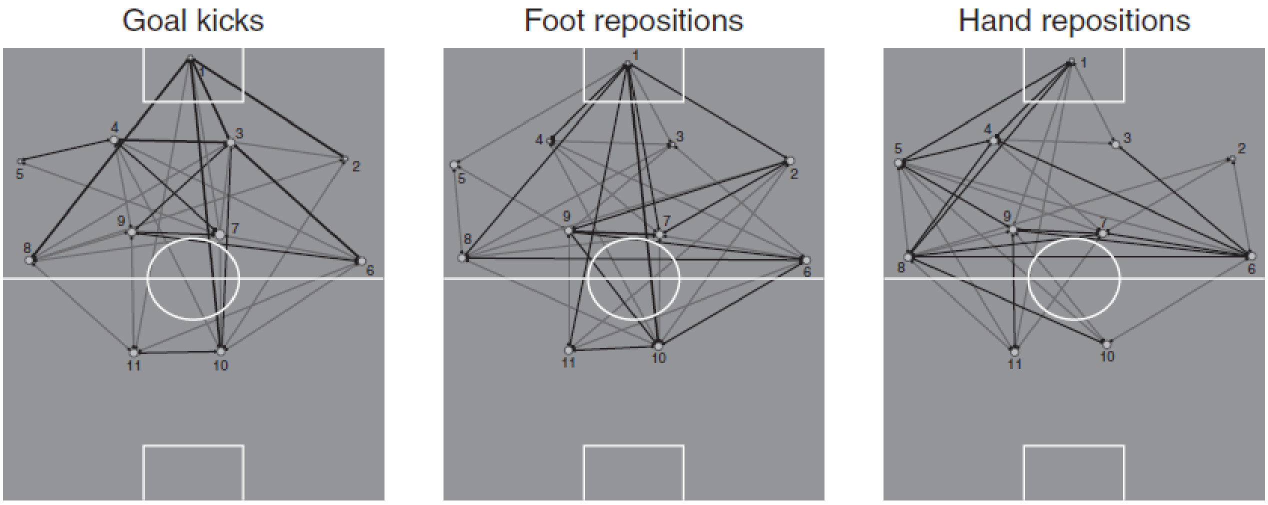


Figure 19.6 Playing patterns of one English Premier League team according to the goalkeepers' actions (courtesy of B. Travassos).

Team communication networks

A team ball game can be viewed as a small-world social system in which collective behavior is sustained by interpersonal interactions among system players (Passos et al., 2011). From a behavioral perspective, two players are considered to be linked when they exchange passes, or when they intentionally switch positions (Passos et al., 2011). Social networks are used to analyze the structure of such communication channels among players during subphases of play in team sports. In these networks, nodes represent players, and lines are weighted according to the number of passes or positional changes completed between players.

Using this tool, Travassos, Sá-Pinho, Marques, and Duarte (2012) analyzed the influence of different goalkeepers' actions on the attacking patterns of play of a football team. They found different patterns of play initiated by goal kicks, foot repositions, and hand repositions (Figure 19.6).

Players with major competitive roles may be easily identified through social networks, as they display a higher number and stronger connections. Additionally, different match networks can be compared to extract the general tactical and strategic features of a team (Duch et al., 2010; Passos et al., 2011).

Another approach to the analysis of networks focuses on density and centrality features, reflecting the formation of dyads between team members (Grund, 2012). Density refers to the interaction intensity of the players (e.g., passing rate), whereas centrality refers to the degree to which network positions are unequally distributed in a team. In association football it has been shown that better team performance is associated with high density and low centrality (Grund, 2012).

Conclusion

Recently, sport teams have been conceptualized as interacting social units benefiting from natural processes of self-organization among players, leading to the formation of functional group synergies, supported by perception of shared affordances. This ecological dynamics perspective has compelled sport scientists to search for measures of the behavioral expression of group processes. By means of tracked positional data, recent research has begun to reveal how players and teams continuously interact during competition (Correia et al., 2012). In this chapter we have discussed several variables that have been specifically developed to assess the tactical performance features of different teams.

From the perspective of space coverage, group variables can capture relative team positioning (team center), the degree of dispersion of players on the field (team dispersion), and the division of space into personal territories, conferring each team member specific tactical roles (division of labor). Networks expose synergies established between dyads within the team, through preferred linkages and communication channels, whereas the cluster-phase approach extended the concept of synergy to the group level.

Identification of individual key match events in time, like an assisting pass or a successful shot on target, may be crucial for understanding team behavioral changes, captured by some of the aforementioned variables, resulting in critical performance outcomes. Development of expert team analysis may benefit from approaches that contextualize and trace relevant performance processes of effective teams, as measured by time-evolving variables capturing interactions of the whole team, subgroups, individual players, or the ball and discrete events.

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