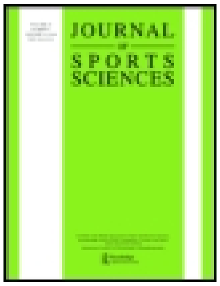

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Proximity-to-goal as a constraint on patterns of behaviour in attacker–defender dyads in team games

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Abstract

The aim of this study was to determine whether spatiotemporal interactions between footballers and the ball in 1 vs. 1 sub-phases are influenced by their proximity to the goal area. Twelve participants (age 15.3 ± 0.5 years) performed as attackers and defenders in 1 vs. 1 dyads across three field positions: (a) attacking the goal, (b) in midfield, and (c) advancing away from the goal area. In each position, the dribbler was required to move beyond an immediate defender with the ball towards the opposition goal. Interactions of attacker–defender dyads were filmed with player and ball displacement trajectories digitized using manual tracking software. One-way repeated measures analysis of variance was used to examine differences in mean defender-to-ball distance after this value had stabilized. Maximum attacker-to-ball distance was also compared as a function of proximity-to-goal. Significant differences were observed for defender-to-ball distance between locations (a) and (c) at the moment when the defender-to-ball distance had stabilized (a: 1.69 ± 0.64 m; c: 1.15 ± 0.59 m; $P < 0.05$). Findings indicate that proximity-to-goal influenced the performance of players, particularly when attacking or advancing away from goal areas, providing implications for training design in football. In this study, the task constraints of football revealed subtly different player interactions than observed in previous studies of dyadic systems in basketball and rugby union.

Keywords: *Constraints, ecological dynamics, decision-making, field position, football*

Introduction

Performance in sub-phases of team sports has been investigated in previous research with the aim of describing emergent decision-making and actions of performers from an ecological dynamics perspective. Research in basketball (Araújo, Davids, Bennett, Button, & Chapman, 2004; Bourbousson, Sève, & McGarry, 2010), rugby union (Passos et al., 2008), and association football (Davids, Araújo, & Shuttleworth, 2005; Duarte et al., 2010) has shown how localized interpersonal interactions of individual players within team game sub-phases have the potential to influence a match on a macroscopic scale, revealing how team sports are complex systems composed of a number of smaller sub-systems (Davids et al., 2005; Gréhaigne, Bouthier, & David, 1997; McGarry, Anderson, Wallace, Hughes, & Franks, 2002). In these studies, selected performance sub-phases were modelled as attacker–defender dyadic systems, typically comprising a player in possession of the ball, a defending player, and a goal/target area that provided some context for the task (Araújo, Davids, & Hristovski, 2006; McGarry et al., 2002). Studying behaviours of attacker–defender dyads provided the opportunity to observe interpersonal coordination tendencies in team games, revealing emergent decision-making behaviours as performance constraints changed.

When conceptualizing sub-phases of team games as complex systems, the relationship between the performer(s) and the performance environment is the relevant scale of analysis to understand decision-making for action. An ecological dynamics approach encompasses concepts from dynamical systems theory and ecological psychology to observe and describe the actions of system components (i.e. players) based on their interactions with each other and key environmental objects and events (Davids, Button, & Bennett, 2008; Handford, Davids,

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Bennett, & Button, 1997). In ecological dynamics, the decisions and actions of individual performers cannot be understood without reference to key information sources such as field markings and locations of other individuals on the field (Davids, Button, Araújo, Renshaw, & Hristovski, 2006). From this perspective, the concept of affordances underpins performer–environment relationships (Gibson, 1979). Affordances are opportunities for action provided by specific configurations of the environment, such as objects and surfaces, perceived with respect to the performer's own characteristics, such as physical attributes. The affordances available to an individual for completing a task arise under the influence of constraints, which are separated into three categories (Kugler & Turvey, 1987; Newell, 1986). Organismic constraints involve the individual characteristics a person brings to a task such as physical and psychological features. Environmental constraints take the form of physical (temperature, light) and social (norms, cultural factors) variables. Task constraints are specific to the task including rules, equipment, and size of playing area in sport (Newell, 1986). A key individual constraint is intentionality of performers, which interacts with task constraints to provide context for the performance, such as specific performance instructions given to basketball players (Araújo et al., 2006; Cordovil et al., 2009; Shaw & Turvey, 1999). Thus, intentionality is an important constraint to be investigated, since it influences the specific tactics, decisions, and actions that emerge during performance.

Team ball sports modelled as complex systems have allowed interactions between players in a performance environment to be understood in terms of fluctuations (i.e. instabilities) and phase transitions (Araújo et al., 2004; Passos et al., 2008). As players are drawn together as a functioning system by their individual task goals, it has been proposed that they enter a critical region where their coordination tendencies emerge: their actions are no longer independent of each other (Adami, 1995). If an attacking player is able to pass a defender and assume a position closer to the goal area, the original order of an attacker–defender dyadic system is broken. The change in order indicates that a phase transition has occurred, whereby the system has undergone self-organization from one state to another due to a change in the value of a critical variable (Haken, Kelso, & Bunz, 1985; Kelso, 1984, 1995).

Previous team sport dyadic systems investigations have focused on sub-phases where the player in possession of the ball was positioned in close proximity to the goal or target area, such as the free-throw line in basketball or 10 m from the try line in rugby union (Araújo et al., 2004; Passos et al., 2008). Araújo et al. (2004) identified interpersonal distance as a physical variable useful for explaining interpersonal interactions of performers in dyadic systems in basketball. Passos et al. (2008) concluded that an interpersonal distance of less than 4 m combined with a relative velocity of at least $1 \text{ m} \cdot \text{s}^{-1}$ was influential in predicting the attacker passing the defender in 1 vs. 1 rugby union dyads. Cordovil et al. (2009) also investigated 1 vs. 1 basketball dyads, but in their study the players were given specific instructions (neutral, risk taking or conservative) on how the task of scoring a basket should be attempted. When the instructions were conservative, the attacking players were observed to take significantly more time to cross into the attacking half of the court with the ball. Previous research has revealed how performance location (proximity to try line) and specificity of instructional constraints influenced the intentionality, decision-making, and actions of players in relation to performance of a given task.

Attacker–defender dyads in football differ from those studied previously in other team sports, like rugby union and basketball, due to the unique task constraint of controlling the ball on the ground with the feet. The importance of considering the role of the ball in football was highlighted by the experimental design of Duarte et al. (2010), who manipulated starting distance between the ball and a defender in 1 vs. 1 dyads located 15 m from the attacker's scoring goalmouth. Due to the ball being located on the ground and between opposing players, there is potential for player-to-ball and player-to-player interactions to influence performance outcomes. Duarte et al. (2010) reported no statistical differences relating to the different ball–defender starting positions, although higher player-to-player relative velocity and lower interpersonal distance values were found to accompany a phase transition. Taking into account the design of Duarte et al. (2010), an interesting question concerns how each player interacts with the ball in *different locations* of the field, since this information could capture how intentionality can be constrained by the inherent risks and rewards associated with performing in distinct areas of the field. Raab and Johnson (2004) identified that basketball players displayed individual differences in risk-taking behaviour and they suggested that the influence of task and situational variables needs to be investigated further to characterize risk-taking performance in team sports.

Notational/performance analysis of football matches has indicated that possession and movement of the ball in certain areas of the field leads to critical events such as goals and/or shots at goal (Hughes, 1996). For example, Reep and Benjamin (1968) concluded that 50% of goals originated from possession gained in the attacking third of the field. Similarly, Bate (1988) found that 50–60% of shots on goal originated in the attacking third. Therefore, gaining possession of the ball when approaching the goal scoring area seems to facilitate more potential rewards than in midfield or defensive regions. In contrast, possession in the defensive region of the field carries greater risk because any loss of possession provides the opposition with increased chances of scoring. Hence, the investigation of attacker–defender dyads in different areas of the field has the potential to reveal varied emergent patterns of behaviour without the influence of specific task instructions.

The main aim of this study was to identify whether decision-making behaviour captured by the player-to-ball distance variable in 1 vs. 1 football dyads could be influenced by manipulating proximity-to-goal of the participants. In the absence of specific performance instructions, it was predicted that attacker–defender dyads positioned closer to either the attacking or defensive goal of the ball dribbler would reveal different strategies and distinct player-to-ball distance patterns than trials in a midfield position due to the constraint on performance imposed by the importance of these goal areas.

Methods

Twelve male footballers (age of 15.3 ± 0.5 years) provided informed consent to participate in the study after ethical clearance was gained from a university ethics committee. All players were members of the Queensland Academy of Sport U-19 state football development squad and reported a mean of 9.5 ± 1.0 years of formal football experience and training. Both right and left foot dominant players were included, representing all playing positions apart from goalkeepers. Each participant was asked to perform in the role of a ball dribbler (attacker) and defender at three field locations against two different opponents, thereby completing twelve 1 vs. 1 trials. Attacker–defender dyads competed in an area 10 m (length) × 5 m (width) positioned to represent the following locations under competitive performance conditions (see Figure 1):

(a) *Attacking the goal*: The playing area positioned so the defender began on the edge of the penalty area directly in front of goal while the ball dribbler began 10 m further from goal. This scenario represented a performance sub-phase with a single attacker versus a single defender on the edge of the penalty area.
(b) *Midfield*: The two players were positioned 5 m either side of the half-way line within the centre circle of the football field, representing a defensive midfielder versus a lone dribbler.
(c) *Advancing away from goal*: The playing area was the same as for condition (a), but the dribbler began on the edge of his own penalty area while the defender began 10 m further from goal. The player in possession represented a lone defender in front of his own goal versus a single opposing player.

The dribbler and defender began at opposite ends of each area, with the dribbler aiming to move from one end of the performance area to the other, in the process destabilizing the dyad by passing the

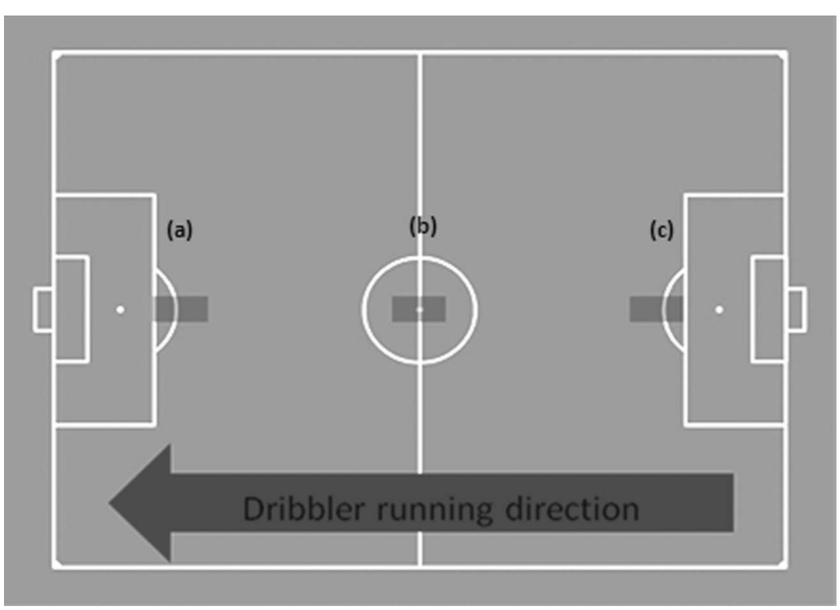

Figure 1. The three field positions represented by the dark shaded boxes: (a) attacking the goal, (b) midfield, and (c) advancing away from goal.

defender with the ball. In contrast, the defender aimed to maintain dyad stability by preventing the dribbler from advancing with the ball, within the laws of the game. It is important to note that no specific instructions were given to participants on how to act and they received only general verbal information (as in a–c above) regarding the task constraints of the performance sub-phase. The aim of the dribbler was to move with the ball beyond the defender and cross the opposite end line of the performance area. Each trial began with a signal from a research team member with the ball at the dribbler's feet and ceased once the ball left the playing area or if the ball dribbler was dispossessed.

Data on participant and ball displacement trajectories were collected using a digital video camera (Sony HVR-V1P) positioned in a grandstand side-on to the field and 40 m above ground level, orientated at approximately 50° to the central point of each playing area. The stationary camera was positioned as far from the action as possible and a zoom lens used to maximize the field of view (Bartlett, 2007). Captured video footage was transferred to a computer via a fire wire cable and saved in AVI format. One trial was excluded due to an excessive length of 24 s (average trial length 5.1 $\pm$ 2.6 s), leaving 71 trials for analysis.

TACTO 8.0 software (Fernandes & Caixinha, 2003) was used to manually digitize the displacements of the players and ball at 25 frames per second using the position of the mouse cursor. Players were tracked using a working point between the feet on the ground, while the dribbled ball was tracked using the point where it was touching the ground. Four known reference points were also digitized and saved as "virtual coordinates" in pixels and as "real world coordinates" representing their known distances apart in relation to the 10 $\times$ 5 m box. The digitized data files were then fed into a two-dimensional direct linear transformation (DLT) via a MATLAB routine to transform the digitized player and ball coordinates into "real world" displacement trajectories relative to the known reference points. Displacement trajectories were then entered into Microsoft Excel (version 12, 2007) spreadsheets for analysis.

The digitization process was evaluated by determining accuracy and reliability measures following 9 days of training with the digitization software. The errors between known participant positions within the performance area and the digitized coordinates were established as: x (3.4 $\pm$ 0.6 cm) and y (3.1 $\pm$ 0.6 cm). These errors related to 0.68% and 0.31%, respectively, of the total performance area dimensions. Intra-class reliability measures of the digitization process returned high correlations for x ($r = 0.823$) and y ($r = 0.996$) coordinates, while inter-class correlations of measures obtained by two trained researchers were x ($r = 0.856$) and y ($r = 0.994$).

To identify player behaviours within the different field locations, the following dependent variables were observed:

1. Defender-to-ball (D-Ball) distance: the distance (Euclidian) between the defending player and the ball.
2. Attacker/dribbler-to-ball (A-Ball) distance: the distance between the attacking player and the ball.
3. The success rate of the dribbler reaching the other end of the performance area in each field position.

Displacement plots were produced to view the relationship between the ball and players over time and identify emergent patterns of behaviour. After observing player-to-ball distance plots, a pattern emerged regarding the moment when D-Ball distance first stabilized at a constant value. The constant state of this dependent variable was determined manually from player-to-ball distance plots and data spreadsheets to find three consecutive frames where D-Ball distance remained stable. The onset of stabilization followed a period where D-Ball distance had decreased as a result of the players being drawn together and their behaviour becoming coordinated. Statistical analyses were employed to determine performance differences according to the three field locations. A one-way repeated-measures analysis of variance (ANOVA) with pairwise comparisons (alpha level < 0.05) was performed to identify significant differences in times at which the D-Ball distance became constant in the three field locations. Bonferroni corrections were used to control for Type I errors and the Huynh-Feldt method employed to correct for violations of the sphericity assumption (Field & Hole, 2003). The same statistical methods were performed to test for significant differences for the maximum A-Ball distance between the three field locations.

Results

Representative trials from each field position are presented in Figure 2, demonstrating the emerging player-to-ball distance patterns. Figure 2A (attacking the goal) shows the D-Ball distance decreasing until 2.08 s after trial initiation where the plot begins to level out, before assuming a constant D-Ball distance of approximately 2 m. Defender-to-ball distance remained constant until 2.92 s, when the attacker was successful in beating the defender and advancing closer to goal. Figure 2B (midfield) shows a similar trend, although D-Ball distance was constant at a smaller value (< 1 m) before being destabilized. Figure 2C shows an advancing away from goal trial

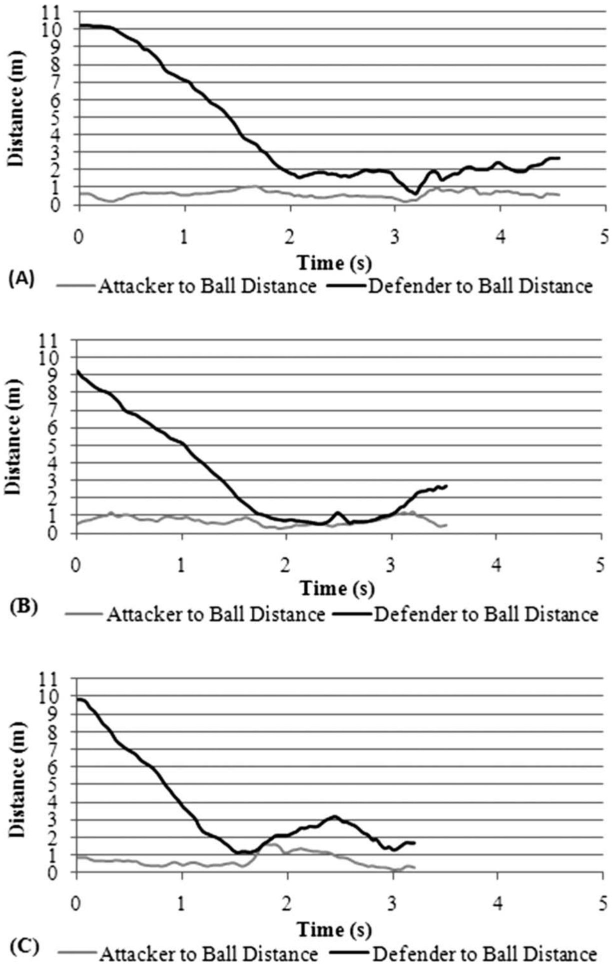

Figure 2. Representative plots of attacker-to-ball distance (grey line) and defender-to-ball distance (black line) over time in destabilized trials. (A) Attacking the goal, (B) midfield, (C) advancing away from goal.

with a brief constant state (0.2 s) occurring at a significantly lower D-Ball distance value (1.2 m) than attacking the goal trials. Analysis of variance revealed that field location had significant effects on D-Ball distance at the point where the D-Ball distance stabilized ($F_{1.77,38.8} = 4.11$, $P < 0.05$). Pairwise comparisons revealed that stabilization of D-Ball distances for attacking the goal (a) trials occurred at a significantly greater D-Ball distance value than advancing away from goal (c) trials (a: 1.69 ± 0.64 m; c: 1.15 ± 0.59 m; $P < 0.05$). No significant differences were found between either (a) or (c) and midfield (b) trials (1.49 ± 0.65 m). Maximum A-Ball values revealed no significant differences between all three field locations (a: 1.94 ± 0.97 m; b: 2.27 ± 0.91 m; c: 2.11 ± 0.79 m; $F_{1.88,41.35} = 0.91$, $P > 0.05$). The ball dribbler in the dyadic systems was found to be successful in 25% of trials when attacking the goal, 8.3% of trials when in midfield, and in 17.4% of trials when advancing away from goal.

Discussion

This study was designed to investigate the influence of proximity-to-goal as a constraint on the relationship between players and the ball in attacker–defender dyads in association football. Results revealed statistically significant effects of player–ball relations and provided representative plots of player-to-ball distance patterns for different field locations. Trials in location (a) were on average found to stabilize at a moment of constant D-Ball distance at a greater D-Ball distance than trials in position (c). The standard deviations reported in the Results section reflect the variability in the emergent behaviours through different player strategies to satisfy the performance task constraints. These data are similar to variability levels observed in interpersonal interactions of attacker–defender dyads in other team sports, such as basketball and rugby union (see Araújo et al., 2004; Passos et al., 2008). The constant period of D-Ball distance can be considered a critical region where the players have been drawn together and their actions become coordinated (Passos et al., 2008). In this critical region, the system order of the dyad could remain stable or become destabilized through interactions of the performers. The percentage of successful trials for the dribbler in each field position also revealed higher success rates for positions (a) and (c), which were located closer to goal. These success rates were not found to relate to player-to-ball distance values largely due to the emergence of individualized strategies for completing the task and the influence of the task constraints (i.e. performance area boundaries).

In location (a), the intentionality of players appeared to be conservative with both dribbler and defender assessing the available affordances for completing the task. The defending player could not risk an expansive attempt at dispossessing the attacker, since he was the last player defending the goal. Similarly, because only a single defender was between him and the goal, the attacker could wait for the optimal moment to manoeuvre beyond the defender to a position nearer the goal. When the attacker was able to pass the defender, the dyad experienced a phase transition due to the change in system organization (Kelso, 1984; Passos et al., 2008). In position (c), the period of constant D-Ball distance was brief and at a smaller value, suggesting that the players were more eager to complete the task. The lone dribbler would be expected to attempt and move the ball beyond the defender and further from goal as quickly as possible. Similarly, the defender, playing the role of a lone forward, could attempt to dispossess the dribbler at anytime with little risk due to being a greater distance away from the defended goal.

Differences observed in player-to-ball patterns between field locations suggested that proximity-to-goal does provide a source of constraint on intentionality of individuals in 1 vs. 1 dyads. Previous research in basketball (Cordovil et al., 2009) attempted to manipulate intentionality through altering explicit time and scoring requirements for participants as instructional constraints. Further studies in basketball (Araújo et al., 2004), rugby union (Passos et al., 2008), and association football (Duarte et al., 2010) only investigated dyad performance in field positions where the player in possession of the ball was in close proximity to a goal-scoring/point-scoring area. The current study contributed to research by encouraging participants to explore the performance environment without the influence of specific instructions and in distinct field locations. Dyad design and general performance objectives at each location remained identical, hence differences in emergent decision-making behaviour could be attributed to interpersonal interactions of dyads based on the proximity-to-goal. The results showed that intentionality and emergent behaviour of players differed based on their distance to key reference points (goal, penalty area), reflecting the importance of understanding the player–environment relationship.

These findings reveal clear implications for design of practice tasks in relation to simulating performance contexts (Araújo, Davids, & Passos, 2007; Brunswik, 1956). For example, positions (a) and (c), which were nearest to goal, revealed differences in intentionality shaped by the effects of different performance locations on the participants. Midfield trials (b), equidistant from both attacking and defensive goals, did not reveal unique trends in behaviour and returned the lowest success rates for dribblers, suggesting that this field position did not provide strong contextual information for performance. Therefore, in a practice environment it is imperative to consider what subphase or situation of the game is being simulated and whether appropriate environmental information is available to replicate the desired performance context (Pinder, Davids, Renshaw, & Araújo, 2011). A key learning design feature involves positioning practice tasks/games to be constrained by relevant field locations, rather than employing generalized tasks that contain little scenario-specific information. Providing reference objects such as goals, corner flags, and line markings instead of ambiguous cones or poles also provides visual information relating to a specific area of the field and/or game scenario. Furthermore, giving players the opportunity to explore the environmental information for themselves (through enhanced movement variability) without preconceived task instructions is recommended. Encouraging the players to make decisions for themselves, without overly detailed prescriptive instructions, produces practice activities that are representative of the competitive performance environment.

Previous work with rugby union and basketball dyads identified the importance of critical variables such as interpersonal distance and relative velocity for describing player-to-player interactions (Araújo et al., 2004; Passos et al., 2008). Under the unique task constraints of football, this study identified a critical dyadic system performance variable: defender-to-ball distance. The identification of this variable warrants further research to determine the influence of player-to-ball relationships in other team games, such as field or ice hockey, where the ball is also controlled on the ground. Furthermore, player-to-ball relationships can be used to design practice tasks by positioning the players and ball within critical distances of each other. For example, a practice game could be designed with a D-Ball distance of 2 m, representing the range at which the stable state of D-Ball distance appeared in this study, signalling that performers' actions influenced each other. This element of training design is important, since team sport performers learn to perceive critical distances between each other and the ball that influence their intentionality and decision-making behaviours.

Conclusion

The findings of this study revealed that changes in proximity-to-goal of 1 vs. 1 football dyads influenced the decision-making behaviour and intentionality of players in relation to the ball. Therefore, field location, specifically proximity-to-goal, can be considered a primary task constraint that poses implications for representative design in team games practice. Subsequently, analysis of player-to-ball relationships revealed emergent coordination tendencies of performers in 1 vs. 1 sub-phases of association football, reflecting how the unique task constraints of team games shape performance.

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References

Adami, C. (1995). Self-organized criticality in living systems. *Physics Letters A*, *203*, 29–32.

Araújo, D., Davids, K., Bennett, S. J., Button, C., & Chapman, G. (2004). Emergence of sport skills under constraints. In A. M. Williams & N. J. Hodges (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 409–434). New York: Routledge.

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, *7*, 653–676.

Araújo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondance between experimental task constraints and behavioral setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology*, *19*, 69–78.

Bartlett, R. (2007). *Introduction to sports biomechanics: Analysing human movement patterns* (2nd edn.). London: Routledge.

Bate, R. (1988). Football chance: Tactics and strategy. In T. Reilly, A. Lees, K. Davids, & W. Murphy (Eds.), *Science and football* (pp. 293–301). London: E & FN Spon.

Bourbousson, J., Sève, C., & McGarry, T. (2010). Space–time coordination dynamics in basketball: Part 1. Intra-inter couplings among player dyads. *Journal of Sports Sciences*, *28*, 339–347.

Brunswik, E. (1956). *Perception and the representative design of psychological experiements* (2nd edn.). Berkeley, CA: University of California Press.

Cordovil, R., Araújo, D., Davids, K., Gouveia, L., Barreiros, J., Fernandes, O. et al. (2009). The influence of instructions and body-scaling as constraints on decision-making processes in team sports. *European Journal of Sport Science*, *9*, 169–179.

Davids, K., Araújo, D., & Shuttleworth, R. (2005). Applications of dynamical systems theory to football. In T. Reilly, J. Cabri, & D. Araújo (Eds.), *Science and football V: The Proceedings of the Fifth World Congress on Science and Football* (pp. 537–550). London: Routledge.

Davids, K., Button, C., Araújo, D., Renshaw, I., & Hristovski, R. (2006). Movement models from sports provide representative task constraints for studying adaptive behavior in human movement systems. *Adaptive Behavior*, *14*, 73–95.

Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: A constraints-led approach*. Champaign, IL: Human Kinetics.

Duarte, R., Araújo, D., Gazimba, V., Fernandes, O., Folgado, H., Marmeleira, J. et al. (2010). The ecological dynamics of 1 vs. 1 sub-phases in association football. *The Open Sports Sciences Journal*, *3*, 16–18.

Fernandes, O., & Caixinha, P. (2003). A new method in time-motion analysis in soccer training and competition. Paper presented at the *5th World Congress of Science and Football*, Lisbon, Portugal, 11–15 April.

Field, A., & Hole, G. (2003). *How to design and report experiments*. London: Sage Publications.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Hillsdale, NJ: Lawrence Erlbaum.

Gréhaigne, J. F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationships in collective actions in soccer. *Journal of Sports Sciences*, *15*, 137–149.

Haken, H., Kelso, J. A. S., & Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological Cybernetics*, *51*, 347–356.

Handford, C., Davids, K., Bennett, S., & Button, C. (1997). Skill acquisition in sport: Some applications of an evolving practice ecology. *Journal of Sports Sciences*, *15*, 621–640.

Hughes, M. (1996). Notational analysis. In T. Reilly (Ed.), *Science and soccer* (pp. 343–361). London: E & FN Spon.

Kelso, J. A. S. (1984). Phase transitions and critical behavior in human bimanual coordination. *American Journal of Physiology: Regulatory, Integrative, and Comparative Physiology*, *246*, R1000–R1004.

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Cambridge, MA: MIT Press.

Kugler, P. N., & Turvey, M. T. (1987). *Information, natuaral law, and the self-assembly of rhythmic movement*. Hillsdale, NJ: Lawrence Erlbaum.

McGarry, T., Anderson, D. I., Wallace, S. A., Hughes, M. D., & Franks, I. M. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences*, *20*, 771–781.

Newell, K. M. (1986). Constraints on the development of coordination. In M. G. Wade & H. T. A. Whiting (Eds.), *Motor development in children: Aspects of coordination and control* (pp. 341–360). Dordrecht: Martinus Nijhoff.

Passos, P., Araújo, D., Davids, K., Gouveia, L., Milho, J., & Serpa, S. (2008). Information-governing dynamics of attacker–defender interactions in youth rugby union. *Journal of Sports Sciences*, *26*, 1421–1429.

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport and Exercise Psychology*, *33*, 146–155.

Raab, M., & Johnson, J. G. (2004). Individual differences of action orientation for risk-taking in sports. *Research Quarterly for Exercise and Sport*, *75*, 326–336.

Reep, C., & Benjamin, B. (1968). Skill and chance in association football. *Journal of the Royal Statistical Society: Series A (General)*, *131*, 581–585.

Shaw, R. E., & Turvey, M. T. (1999). Ecological foundations of cognition: II. Degree of freedom and conserved quantities in animal–environment systems. *Journal of Consciousness Studies*, *6*(11/12), 111–124.