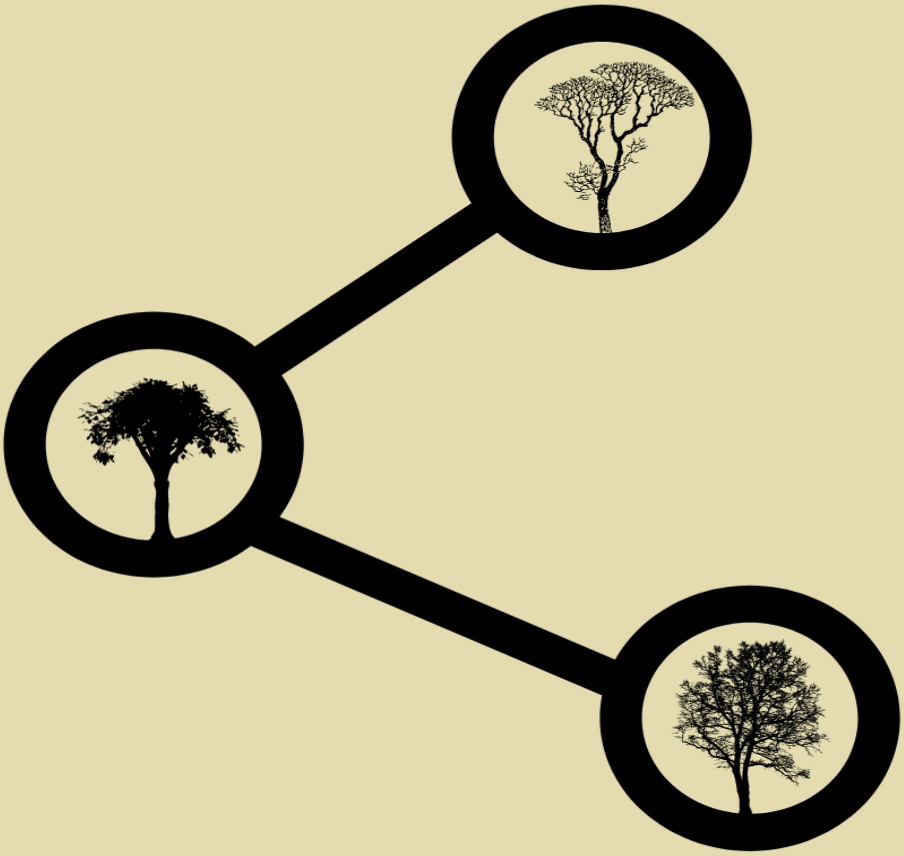

THE FOREST THROUGH THE TREES

MAKING SENSE OF AN ECOLOGICAL DYNAMICS APPROACH TO MEASURING AND DEVELOPING COLLECTIVE BEHAVIOUR IN FOOTBALL

WILL SHEEHAN, RHYS TRIBOLET, MARK WATSFORD, & JOB FRANSEN

The forest through the trees: Making sense of an ecological dynamics approach to measuring and developing collective behaviour in football.

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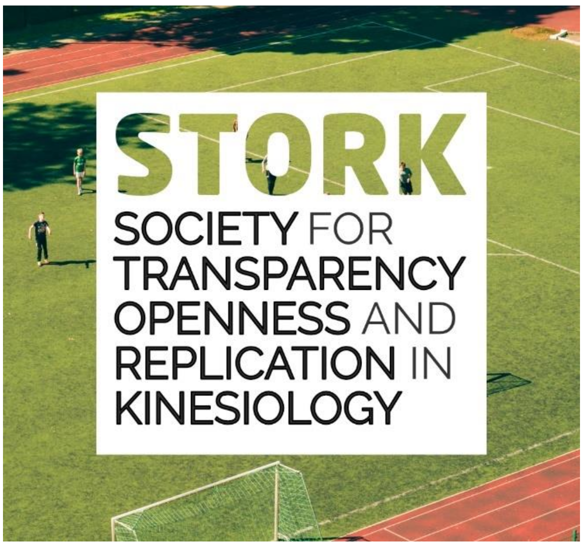

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Foreword by the authors

In 2019 we embarked on this project to try and make sense of the complexity that is inherent in team sports. Collectively, we had over thirty years of experience working as sport practitioners and scientists in team sports. Still, we had a gnawing feeling that while individual factors related to sport performance, such as injury or physical fitness, are omnipresent in research and practice, aspects related to how teams behave collectively are less understood. This book presents the actualisation of the first step of our journey into the area of collective behaviour and provides a detailed overview of the available research at the time of writing on measuring and developing collective behaviour (i.e. team tactics and team cooperation) in association football.

We have a strong sense of responsibility to the sports science and coaching community that has enabled us to do the work we love for so many years. As such, we made the decision to make this book freely accessible to all. It is our hope that this book reaches scientists and practitioners with an interest in and a passion for team sport science. We also intend this open–source book to be a conversation starter encouraging practitioners in the area of team sport, such as coaches, strength and conditioners, performance analysts or team managers, to reach out.

Throughout the text, we have cited works by referencing the relevant articles between round brackets, for the purpose of brevity. These references can be found in the reference list at the end of this book. It is however important to note that while this work is based on the most recent references at the time of writing, new research may have since been published that was not incorporated.

We hope you enjoy this book and find it useful, and we look forward to discussing this further with you.

Acknowledgements

We would like to acknowledge the contributions made by friends and colleagues who have, somewhere along the way, directly or indirectly, made suggestions to improve aspects of this work. Importantly, we would like to acknowledge the contribution of Dr Andrew Novak. Dr Novak, while not being directly involved in the writing of this work, has made substantial contributions to our knowledge and understanding of this research area over the years. We would also like to thank Dr Zachary Zenko at the Society for Transparency, Openness and Replication in Kinesiology for all the help formatting this book. Finally, we would like to recognise the role played by the Sydney Swans Football Club and its staff and players in supporting this work.

Overview

In this book, we interpret the literature that has analysed football performance from a tactical standpoint using an ecological dynamics perspective. This approach focuses on the performer–environment relationship and provides a basis for understanding the dynamic nature of performance in collective team sports (1) and will be explained in detail throughout. The first section of this text will provide a brief description of association football as well as commonly used methods to analyse football performance. The next section will briefly introduce common theories and practices used to measure team behaviour, decision–making, and performance enhancement in team sport, which are then used to introduce the ecological dynamics framework. This framework will then be used to aid the application of these findings for tactical analysis in team sports such as football. Finally, we will introduce some of the scientific literature on improving team performance, particularly in reference to team coordination and decision–making. The following sections of this book will deal specifically with how small–sided games can be used to develop tactical behaviour in football. A small–sided games approach was chosen as these modified games allow for the simultaneous development of players' technical skills, conditioning, and ability to solve and overcome tactical challenges through coordinative behaviour and effective decision–making (2–5). Small–sided games provide an environment that mimics the perception–action couplings of in situ performance, which should, in theory, improve the transferability of learned behaviours to in–game performance (4, 6). As a result, small–sided games are often used by coaches and form an integral part of this text. Finally, we conclude with some recommendations for future research, and some practical considerations for coaches interested in applying the research discussed in this book.

General introduction

Association football (from here on called *football* but also referred to as *soccer*) is a collective team sport played between two opposing teams, both containing 11 players, that compete to score by moving a ball with their feet into the opponent's goal (7). As such, both teams must coordinate their own actions to recapture, conserve, and move the ball to bring it within the scoring zone to score a goal (8). This behaviour is commonly referred to as 'attacking'. There are two basic ways of attacking: either by moving a ball individually or by kicking and receiving a ball between members of the same team (7). When a football team is attacking, the players must maintain possession of the ball, moving and passing through and into empty pitch regions in the direction of the goal to create scoring opportunities (9). As a result, players on the attacking team must decide whether to dribble, pass, or shoot at the goal (10). When a team is not in possession of the ball, it is defending. In defence, the players must move and coordinate to protect their own goal and attempt to recover possession of the ball (9).

Football shares similarities with other collective team games such as field hockey, water polo, Australian Rules Football, basketball and rugby union. The 360–degree nature of the sport, in that the ball can move in both a forward–backward and side–side direction, is similar to that of many other collective team games. However, in football, with the exception of the goalkeeper, all players use their feet to move the ball. Furthermore, other team invasion games requiring collective behaviour, such as rugby and Australian Rules Football, are considered contact sports, which are characterised by frequent collisions in an attempt to stop the attacking team from progressing. Regardless of these differences, the principles behind the scientific analysis of team sport performance in many team invasion games remains the same and aims to advance understanding of game behaviour and subsequently improve future outcomes (11). In recent years, notational analysis, which mainly records the occurrence of specific match events such as goal–scoring opportunities, passes, or counter–attacks, has been utilised to help teams improve their performance and achieve the aim of scoring more points/goals than their opposing team (12). In collective team sports, this form of analysis has specifically been used to examine passages of play where both an initiative or opportunity to score (attack) and an opportunity to prevent the opposing team from scoring (defence) are present (12).

Traditionally, in an effort to deepen the level of understanding of match performance, notational analysis has been used to subjectively audit and describe the behaviours of performers during different sub–phases of play, i.e. attack and defence, to provide additional information for practitioners (13, 14). This has typically occurred through verbal descriptions of lived experiences or game observation (15). While these processes may offer insight, such methods are not objective and are less systematic, relying on subjective impressions and procedural knowledge of expert performers (16). In contrast, in an attempt to objectively quantify the underpinnings of successful performance, analysts have focused on identifying associated physiological demands such as workload and total distance covered or distances covered at different intensities as measured by a global positioning system (GPS) (17). Furthermore, the assessment of discrete on–field actions such as the number of completed passes, time spent in possession of the ball, or the amount of tackles made, have endeavoured to provide reliable technical descriptions of game demands as predictors of success (18). However, inconsistencies and discrepancies exist between indicators of successful and unsuccessful performance. For example, in football, some studies have revealed that successful teams maintain ball possession for longer than unsuccessful teams (19) while others demonstrated that during the 1990 and 1994 FIFA World Cup finals over 80% of goals were scored from a total of four consecutive passes or less (20). The excessive emphasis placed on performance outcomes in these analyses presents an underlying issue. This approach fails to provide a meaningful understanding of the processes that bring about successful performance and exemplifies the need for a theoretical rationale of performance behaviours (21, 22).

Implementing tactical analysis in team sports may offer further insight into ‘why’ or ‘how’ certain behaviours emerge (15, 23). A more in–depth analysis of tactical performance is necessary as the ability to effectively make decisions and coordinate one’s actions with those of others is important for success in collective performance contexts. Research in football has been able to discriminate between different levels of opposition (24, 25) and positions (26) by analysing tactical performance where distance, speed, and physiological variables have failed to do so. In collective team sports, expert performance is distinguished from novice performance by the achievement of higher levels of task outcomes with more effective and adaptive interactions between teammates (21). It is evident that experts integrate their relevant individual expertise when coordinating behaviour collectively to form functional linkages, known as synergies, between players to achieve a common goal (27). Through effective coordination and adaptability, groups of proficient players exploit these functional couplings to quickly and accurately solve tactical problems as they emerge from variable situations (27). For example, skilled defenders will coordinate their behaviours in time and space to set an off–side trap for an unsuspecting attacker by adapting to the behaviour of the attacker whose aim it is to not be caught off–side. This all happens without overt communication, which would warn the attacker to the joint actions of the defenders. In an attempt to measure and quantify such synergistic behaviour, it has been suggested that technological advancements, such as an increase in sensitivity of GPS devices and improved application of their output, could be used. Additionally, novel statistical approaches now allow practitioners to use these data to quantitatively model, infer, and predict performance outcomes in team sports, particularly during critical in–game events (18). However, the complexity associated with the reporting of these methods, and a lack of clarity regarding which theoretical framework can appropriately contextualise and describe behaviour, often makes the practical application of these types of tactical analyses to measure or improve team sport performance difficult. Therefore, there is a need for a framework that can guide its application. Ecological dynamics has been considered as such a framework as it actively focuses on a malleable performer–environment relationship, and may subsequently provide a basis for understanding the dynamic nature of performance in team sport (1). Utilisation of these novel methods within this framework may upgrade the understanding of currently used methods of analysis, thereby acknowledging the 'how' and 'why' of successful behaviour as opposed to just 'when' it occurs (13). Therefore, ecological dynamics provides an alternative to traditional frameworks that have attempted to provide insight into team behaviour in collective team sports.

An ecological dynamics approach to skilled performance

A brief introduction to ecological dynamics

The term ecological dynamics combines ecological psychology, the study of the cyclical, lawful relations between any individual and the environment in which they function (28), and dynamical systems theory, the study of neurobiological coordination at multiple levels with roots in thermodynamics and synergetics (29). As such, an ecological dynamics approach uses the concepts and tools of dynamical systems theory to understand phenomena that occur at an ecological scale (29). The most relevant information for decision–making, regulation of action, and coordination arises from the continuous performer–environment interaction (1). Within the performer–environment, humans are surrounded by banks of energy flows or arrays that act as specifying information variables when perceived by performers (30). This critical information augments decision–making and collective organisation and consequently shapes behaviour during goal–directed activity (1). The influence of environmental information and ensuing behaviour has been demonstrated in nature. For example, amidst insect fauna, a colony of millions of insects avoid random behaviours (coordinate), and guide the decisions of others, by exploiting information in the environment. This information is presented through pheromones that the insects secrete into the earth to guide their cooperative nest–building activity (31). Through the analysis of an organism and its environment, or similarly a performer in their environment, it becomes apparent as to how ecological dynamics can provide information, as well as predictions, about which conditions will produce favourable, coordinative movements. Furthermore, this framework can help identify features of a situation that will facilitate or disrupt interpersonal as well as collective coordination in goal–directed activity (15).

The scale of analysis is an important consideration when identifying key information variables that influence decision–making and coordination. The lowest dimension of coordination is evident on a macroscopic scale, representing the global synergy between all individuals within a performer–environment system. This system is a product of all complex non–linear subsystems and their non–linear interactions within the environment (32). It is imperative to first understand the global dynamics at the behavioural level of analysis (32). Subsequently, this global system can be decomposed and examined at a mesoscopic level (subsystems/functional units) and, ultimately, a microscopic level to provide specific in–depth information regarding functional linkages between specific individual components (*dyadic* relations). In a sporting context, the inter–team relationship between two opposing teams might represent the global, macroscopic scale, while the intra–team relationships between players in their respective teams would signify the mesoscopic level. Exploring even further, *dyadic* relations between two cohesive teammates, or an attacker and a defender, would represent the microscopic level. Utilising this approach, researchers can work in a hierarchical manner to examine the impact of relevant variable components on the overall dynamics of the sporting environment (12).

Central tenets of ecological dynamics

Perceiving affordances for action

Contrary to alternate theories, such as those based on discriminating between desired movement solutions prior to action, decision–making from an ecological dynamics perspective is centred around the perception of, and attunement to, environmental properties or energy arrays (30, 33). In his theory of direct perception, Gibson (30) proposed that humans perceive and act on substances (e.g. grass), surfaces (e.g. a football field), places (e.g. a stadium), objects (e.g. a ball) and events (e.g. a football game) in the environment. These components provide opportunities for action, known as affordances (30). At each subsequent moment, an individual must choose, from all available affordances, to act in a way that will facilitate the achievement of an intended goal. However, as an individual continuously moves within the environment, other affordances continuously persist, emerge, and dissolve, providing a dynamically changing perceptual landscape of opportunities for action (33). Moreover, the varying intrinsic dynamics of everyone, shaped by past experiences, beliefs, knowledge of the game, etc. will afford different responses or solutions to different situations (34). For example, while a teammate may be 40 metres away and situated in open space, free of a defender, a ball carrier may pass only if they believe they are capable of performing a pass over that distance. Conversely, another individual may not pass and choose to dribble instead if they believe they cannot pass the required distance. Through continual perception of affordances, humans have the ability to regulate actions and adjust movements relevant to their environment (28). It is the perception of affordances that consequently controls behaviour (35). Additionally, the ability of an individual to perceptually attune to persisting or changing affordances can often help distinguish between novice and expert performers, with the latter possessing an ability to better attune their movements and actions in the context of the information embedded in the environment that surrounds them. This theory of direct perception may be preferred over traditional indirect theories (i.e. indirect theories argue that any information in the environment must be made sense of before it can be acted upon) as the decision–making process in this context limits or negates the cognitive processing required for the vast amount of sensory information a performer interacts with. In contrast, this theory emphasises that it is the implicit spatial and temporal coupling of perception and action that leads to emergent behaviour. As a result, this theory provides a basis for understanding how individuals coordinate their actions with those around them, despite constant dynamic changes in their performance environment.

Just as affordances guide individual actions, we could consider that collective affordances guide collective actions in team sports. These collective affordances can be viewed as similar affordances or opportunities perceived by team members who are linked as part of the same coordinative unit (e.g. the same team or positional group) and allow synergistic behaviours that are sustained by shared goals and objectives to emerge (21). In a game of football, for example, both teams have the same objective to overcome the opposition and win. Synergistic team behaviour is dependent on the ability of players to be collectively attuned to shared affordances. As a cooperative unit, players need to be attuned to affordances 'for' others (affordances an individual can provide for others under given environmental conditions) and 'of' others (affordances a fellow player can provide a perceiver (23)). As a result, successful teams are composed of players who have learned to perceive shared affordances 'for' and 'of' other players (12, 23, 36). These shared affordances may appear and disappear instantaneously, leading to constant fluctuations in the state of system organisation (21). For example, a disorganised defensive formation after a sudden loss of possession in the opposing team may briefly afford the attacking team to counterattack, but this opportunity rapidly disappears and changes into the need to retain ball possession once the defending team regains its organised defensive formation. Collective affordances are also shaped by surrounding constraints within the performance environment that guide and shape the emergence of coordinated team behaviours (13). For example, in football the relative position of a defensive line in the opposition team constrains passing opportunities. More specifically, a subtle positional displacement of a defender nearest to an attacking ball carrier can be collectively perceived by both the ball carrier and their teammates (37, 38). As the defender approaches the ball, attacking teammates position themselves in such a way that it offers a passing affordance 'for' the ball carrier while, simultaneously, the ball carrier needs to move and deviate in a way that opens up passing lines, allowing them to perceive the affordance provided 'of' a fellow player (37, 38). The collective perception of the defender's positioning allows teammates to coordinate in a way that provides opportunities for action prior to the resultant action being performed.

Constraining affordances

Contrary to traditional information processing theories, movement is not a pre–determined entity stored in the central nervous system, but rather is a dynamically changing process resulting from the interaction between environmental constraints and the internal resources of the performer in light of the task at hand (39). Constraints are either intrinsically (within the player or team) or extrinsically (within the environment) bound and can be considered as boundaries governing behaviour, or as design features that shape affordances and therefore guide action and ensuing organisation of the components within an individual or sub–system (22). In other words, constraints can either inhibit or encourage behaviours through altering the information embedded in the performance environment and which movements they invite. For example, a football coach who encourages her players to only have two touches on the ball before passing in a possessional game will encourage a first touch that pushes the ball into space and off–the–ball running behaviours of teammates who create passing options for the player in possession of the ball.

There are two key classifications of extrinsic constraint:

i) Environmental constraints relate to the structural and physical properties of the current environment, such as temperature, surface, altitude and external information available to the performer (1).

ii) Task constraints are implied constraints or restrictions, such as gameplay rules, which must be met within some tolerance range in order for the movement to produce a successful action (22).

Action goals are a special type of task constraint. Action goals guide behaviour by taking the form of a rule that determines how an individual should act to achieve a certain outcome. This rule asserts that a performer should seek specific information, presenting relevant affordances, that are specific to a desired outcome (33). For example, in football one of the primary objectives is to prevent conceding a goal. This shared goal affects the emergence of coordinated behaviour, with players of the defending team positioning themselves between their goal and the opposition team to limit goal–scoring opportunities (40).

While task and environmental constraints are extrinsic to the performer, individual constraints are intrinsic, or belonging to the performer or performing entity (in the case of a team). Individuals possess unique intrinsic dynamics that act as constraints on behaviour (34). They are the structural and functional characteristics of performers and include aspects related to their physical, psychological, cognitive, and emotional make–up (34). Individual variations in intrinsic dynamics allow unique, functional solutions to emerge. Furthermore, as an individual develops, these dynamics will diversify and change (41). For example, a player that possesses exquisite ball control will push the ball into space when under defensive pressure, while a physically strong player with less control may use their body to shield the ball from the opposition.

Collectively, it is the confluence of interacting constraints, both intrinsic and extrinsic, that shape perceived affordances and determine subsequent coordination and behavioural outcomes. Often small changes in one constraint can have a large influence on ensuing coordination patterns (22). For example, adding one player to each team in a small–sided football game, i.e. from 4v4 to 5v5, results in an increase in separation between the two teams, as measured through the average geospatial position of all players in both teams (42). These interacting constraints are described in Newell's model of interacting constraints (Figure 1) (43).

This interaction of organismic, environmental and task constraints forces performers, both individually and cooperatively, to become attuned to the changing dynamics of the performer–environment. Effective attunement allows performers to seek stable and effective patterns of behaviour that successfully satisfy constraints and aid goal achievement (1, 34). Expertise can be defined as the ability of an individual or team to functionally interact with imposing constraints and exploit them to successfully achieve performance outcomes on an individual and team level (1). This concept may also highlight why experts may, or may not, be selected in the best sporting teams. While an individual may possess superior performance at an individual level, failing to interact cohesively at an intra–team level may jeopardise team performance and hence the respective player's selection into that team.

In collective team sports, functional patterns of behaviour develop through a process of self–organisation and co–adaptation. As a result, beneficial, functional movement solutions emerge to problems posed by the performance environment (Figure 1) through performers' interactions with each other, the environment, and associated constraints (21).

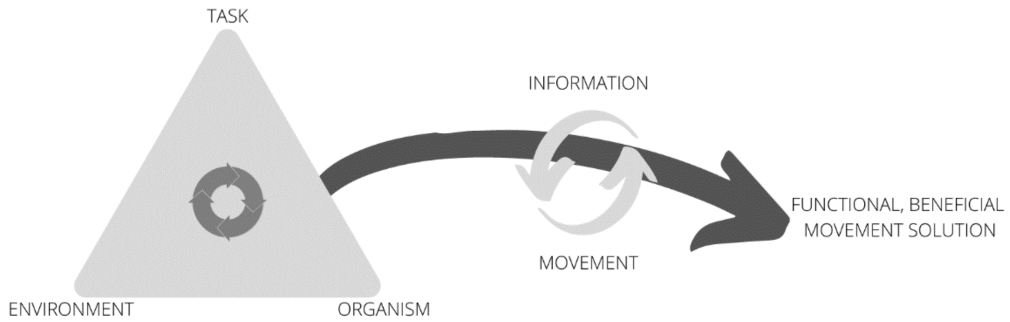


Figure 1: Interacting constraints alter the coupling between information and movement, resulting in the emergence of functional, beneficial movement solutions, adapted from (21) and published under the Creative Commons Licence (CC–BY 4.0). This conceptual framework is build on Newell's Model of Interacting Constraints (43) and forms the basis for the ecological dynamics view on skill acquisition and performance analysis

Stability, variability and self–organisation

Changes in informational constraints give rise to potential attractors (favourable affordances) and repellers (unfavourable affordances) which subsequently guide behaviour. An attractor or attractive state can be classified as a stable, functional linkage or movement solution. Conversely, states to be avoided are known as repellers and are associated with dysfunctional movement outcomes that hinder task achievement (33). As new affordances continually arise and dissipate, new, non–linear behaviour emerges as a result of the continual interaction between attractors and repellers at *bifurcation points* (33). Bifurcation points are associated with changes in affordances and, consequently, the available number of attractors and repellers impact transitions in behaviour (33, 44). At these points, performers are required to undertake the functional and emergent process of decision–making. In training and game contexts, manipulation of relevant constraints can either increase or decrease the number of available attractor/repeller states (45). For example, in football, providing numerical superiority in attack, such as a 5v3 format, will likely provide additional passing attractors as the uneven number of players will leave fellow attacking players in open space free to receive a pass. Conversely, providing an even format, such as a 5v5, may present relatively more repellers that need to be considered in the decision–making process as each player will likely be marked by a defender, resulting in difficulty finding players in free space. The ability to be attuned to relevant attractors and repellers in the performer–environment landscape through direct perception underpins successful decision–making in sporting environments and allows organised, functional patterns to emerge (13, 33).

Bifurcation points can lead to fluctuations in the organisational state of the team sporting environment. When fluctuations are powerful enough to perturb existing balance, a *stability–breaking* process occurs, transiting the game into a new dynamic state of organisation (13). For example, in a 1v1 drill, when an attacking player decides to reduce the relative distance to the goal against a defender, the system enters a transition phase (40, 46). The system will then transition into one of two states: 1) The defender maintains stability and remains between the goal and the attacker, minimising scoring affordances or 2) The attacker successfully breaks *stability* and passes the defender towards the goal providing a scoring opportunity (40). In team–based sports, stability is often linked with favourable coordination between players, i.e. players move cohesively to achieve a common goal, while *instability* is associated with the loss of coordination (13). Analysis from an ecological dynamics perspective can help distinguish between successful and unsuccessful performances and patterns of play by examining the stability–breaking processes that emerge throughout the functional interaction between players, teams and environmental affordances and constraints (13). This form of analysis can be used to identify the distinct properties that contribute to the stability or variability in emergent behaviour in collective team sports.

Adapting to change

The ability to perceptually attune to affordances and favourable attractors is linked to superior levels of expertise (33). This is particularly important when multiple affordances/attractors are perceivable by the performer, and where certain affordances may be more valid than others in order to achieve an intended goal (33). At this instant, performers enter a region of *metastability* where multiple stable, functional states (*multi–stability*) become available and an inherent decision is required (41). Within this region, individuals have the ability to exploit coexisting coordination tendencies in order to maintain stability at bifurcation points (29). For example, in football, when players are required to pass to a moving teammate at increased distances, lofted passes are preferred. When required to pass into a stationary goal at similar distances, while players may use a lofted pass to achieve the task goal, they often utilise a low trajectory pass as this is perceived as a superior option (10). This highlights that, while different performance solutions are available, a specific solution may be better suited to the task at hand. Individuals can transition between multiple states (*multi–stability*) of organisation under different constraints, subsequently aiding the achievement of successful performance (29). This has been demonstrated in cricket where batsmen were able to successfully hit the ball, pitched at the same length, using either front– or rear–foot batting strokes (47). Conversely, shorter pitched deliveries afforded rear–foot attractors, resulting in strokes being played off the rear–foot while fuller deliveries, alternatively, afforded front–foot attractors (47). With experience and practice, coordination and behaviour converge towards stable states of movement and *synchrony* through effective decisions made at bifurcation points between attractors and repellers. Through continuous exposure to sufficiently variable training environments, players are afforded the opportunity to exploit multiple problem–solving strategies allowing multiple movement solutions to emerge (47).

Performers adapt in numerous ways to achieve stability and are able to assemble functional coordinative patterns from an abundance of degrees of freedom (45). In pursuit of stability, a system or performer with many degrees of freedom can act as if it were a simpler system if sufficient constraints, or linkages, are established among its components by coupling them into a synergy (33, 48). In human movement, the wide array of peripheral degrees of freedom, represented by the many interacting aspects related to motor behaviour (i.e. physiological, anatomical and biomechanical), allows the assembly of varying movement solutions. Similarly, in a collective team environment, coordination and stability can emerge as a result of dimensional compression, where independent degrees of freedom (e.g. players in a team) are coupled so that a synergy is created with fewer degrees of freedom (12). Dimensional compression allows the reduction of system dimensionality into smaller, coordinative synergies or sub–units (23). In football, players have demonstrated coordinative behaviour with their own position–specific teammates (i.e. defenders synchronise with fellow defenders), acting as a cohesive synergy (49). This coupling is based upon a social perception–action system supported by shared affordances (e.g. the movements of opposition attackers or the opposition team's ability to counter–attack quickly) and has the capability for varied patterns of coordination due to the numerous degrees of freedom (27).

In contrast, while freezing, or dimensionally compressing, specific degrees of freedom can be utilised to develop desired movement solutions or coordination, abundant degrees of freedom may allow individuals to achieve specific performance goals and adapt to metastable regions in a variety of ways (1, 44). An ecological dynamics approach recognises degeneracy, or functional equivalence, in human subsystems and refers to the ability of structurally different components, or degrees of freedom, to coordinate in a way that allows the achievement of the same behavioural goal (41). As noted, cricketers have the ability to produce the same performance outcome (hitting the ball) utilising different movement patterns (47). In team systems, reciprocal compensation allows coordination and stability to persist. Certain components, or players, have the ability to adjust their respective contributions or efforts, so that task performance goals can still be achieved despite variation in the contribution from other components (12). Through analysis of synergistic linkages (dimensional compression), reciprocal compensation, and degeneracy in collective team sports, practitioners can effectively explain how successful, stable performance outcomes emerge despite different movement solutions or tactical patterns (13). With reference to these concepts, it can be inferred that *variability* in movement solutions may not be the expression of a dysfunctional, noisy system, as commonly thought in practical applications, but an essential component of flexible and stable behaviours (32). In learning environments and game situations alike, it may be appropriate to promote decision–making tasks that allow for degenerate solutions to emerge, enabling individuals and teams to appropriately adapt to dynamically changing environments, which are implicitly linked with collective team sports (29).

Applying the principles of ecological dynamics to measuring and developing sport performance

Skilled behaviour predicated by effective decision–making is defined as the capacity of a performer to select functional actions from a number of affordances at bifurcation points to achieve a specific task goal (50). Traditional approaches to decision–making tasks and evaluation tests for skilled behaviour, such as those used in talent identification, player scouting or performance monitoring, incorporate a limited number of constraints, restricting possibilities for action (29). These tasks have exposed performers to constraints and affordances that would not normally be available in an in situ environment (51). For example, some of these paradigms have incorporated slide images or video presentations, as opposed to in situ stimuli. Furthermore, many of these assessments coupled visual presentations of information on a screen or slide with verbal or micro–movements (pressing buttons, moving a joystick), as opposed to sports specific action responses (18). These assessments lack representability by removing functional perception–action couplings that would otherwise be present in competition conditions (52), and by not allowing assessments to sample the same constraints present during competition (1). Additionally, traditional designs also fail to recognise the importance of variability in the environment and performer, which are both essential for improving performance (29), by assessing players in mostly static, rather than dynamic contexts (1).

An ecological dynamics approach to improving decision–making and collective team performance requires a setting that is representative of the original performance environment, possessing all the associated information (33). Furthermore, decision–making tasks must be designed in a manner that is eminently anticipatory and cyclical, allowing the performer to perceive dynamically changing information sources that have changed as a result of their own actions within the external environment. This additional information then consequently triggers new affordances for action. Furthermore, these settings must allow performers to utilise movement variability as they explore and create opportunities for action (1, 33). Through this exploration, new affordances and ensuing patterns may emerge due to adaptive processes such as dimensional compression, degeneracy or reciprocal compensation. Task designs utilising in situ environments, coupled with specific action responses, may more readily capture the skill capabilities of an individual, as they provide performers with the opportunity to perceive in order to act, as well as act in order to perceive, both in a way that is specific to the intended generalisations of the sport (51).

Task designs utilising a representative design framework (i.e. representative task design) have been able to distinguish between novice and expert performers, as well as improve performance (i.e. representative learning design) (18). Engagement in in situ performance tasks, coupled with relevant constraints and environmental information, may improve individual performance through an enhanced attunement to relevant and valid affordances, consequently allowing the performer to satisfy the unique set of imposing and interacting constraints (29). In practice design therefore, constraints can be manipulated to progressively direct individuals to specific or favourable affordances that support the achievement of a task goal or allow the stabilisation of an intended performance outcome (1). Similarly, in team sports, appropriate designs may allow players to become perceptually attuned to affordances 'of' and 'for' others, providing individuals with the opportunity to refine and adjust behaviours in a way that allows functional adaptation to those teammates and opponents (15).

Training tasks that provide performers with metastable regions in which they can explore affordances and associated attractors and repellers at bifurcation points may allow individuals and synergies to develop healthy variability in movement organisation and performance output (29). While expert performance is characterised as stable and consistent over time, as well as resistant to perturbations, it is also flexible and adaptive (or 'degenerate') (29). Highly proficient players and teams have the ability to appropriately control variability, adapting to unexpected task–specific constraints (32). Davids et al. (1) identified five key components for consideration when designing representative assessment tasks, yet these can similarly be applied to representative practice design from an ecological dynamics perspective. According to Davids et al. (1) these tasks should possess:

i) Noise: Promote noisy and messy tasks that encourage performers to search and assemble functional movement patterns in adverse situations.

ii) Predicated perception–action responses: Enable and facilitate the perception of information that specifies favourable, or superiorly valid, affordances or attractors in a performance environment.

iii) Open–system qualities: Avoid discrete sequences and design tasks that are ongoing and can evolve over different time scales.

iv) Representative affordances: Provide possibilities for action that are relevant to the intended performance environment (i.e. competition).

v) Components scaled to the performer: Acknowledge individual differences (i.e. intrinsic dynamics) and variation in movement solutions.

Additionally, for appropriate task design, Araujo et al. (44) highlighted that coaches and performance analysts need to identify primary constraints to be manipulated, or considered, during practice as well as desired movement patterns and outcomes, effectively advocating for an inter–relatedness of performance analysis and skill acquisition departments. To identify desirable patterns and behaviours, and track improvements associated with practice, *order parameters* and *control parameters* need to be identified. These parameters can effectively describe behaviour and allow the validation of control laws that regulate action (33). Existing literature analysing pattern formation in sports has identified *order* parameters, which refer to collectively stable and reproducible relationships among a system's components, and control parameters, which move the system through its many different attractor/coordinative states (22). Temporal, non–linear changes in order parameters have been observed with systematic changes in control parameters and stability is often observed in the order parameter in low control parameter values (22). For example, in a football attacker–defender dyadic subsystem, the interpersonal distance between the two players acts as a control parameter while the relative distance to the goal acts as an order parameter. As the control parameter changes, manipulated by the attacker trying to pass the defender, the order parameter changes as the attacker gets relatively closer to the goal. If the system is sufficiently perturbed, e.g. the attacker misaligns the opposing player, and the defender's stability is broken, the attacker may move past the defender and closer to the goal, relative to the defender (40). It is therefore evident that a change in the control parameter can induce a change in the collectively defined order parameter. There is a need to identify relevant control and order parameters that specify functional collective behaviour, as these underpin interpersonal synergies between performers (15, 33). This can subsequently act as a starting point for designing relevant tasks and setting functional goals as they have the capacity to identify favourable patterns of behaviour. Ensuing the successful development through appropriate training modalities, these behavioural patterns can then be coordinated and exploited tactically to achieve success.

Tactical performance in football

A viable framework that can provide a basis for understanding performance in team sport is essential to provide an upgrade to more operational methods of analysis, acknowledging 'how' and 'why' behaviour emerges. An ecological dynamics approach has been applied to provide a better understanding of the tactical behaviour of teams and players within these teams. Whilst existing literature has examined performance in this context, current research examining tactical behaviour in team sport is scattered and the adoption of a 'foreign' framework means that associated terminology and concepts are often not interpretable by researchers and practitioners. Therefore, using football as an example, this review will present an ecological dynamics approach to better understand tactical performance in team sport. The ensuing sections will identify current methodological approaches to tactical analysis on an inter–team (macroscopic), intra–team (mesoscopic) and inter–personal (microscopic) level in football, followed by a review of tactical findings and associated applications. Accordingly, to gather literature for this review, electronic databases PubMed and Google Scholar were used. Search terms included 'ecological dynamics', 'football', 'tactics', and 'tactical analysis', with combinations of search terms also applied. Additional sources were obtained through the reference lists of reviewed articles. Following the screening of titles and abstracts for relevance, 93 articles were used for further review.

Methodological approaches

Table 1 identifies previously employed order and control parameters which, when used appropriately, offer insight into the tactical behaviours demonstrated by individuals and teams. These variables help identify 'why' and 'how' patterns of coordination and functional behaviour emerge (12, 13, 18). Through analysis of attacking and defending phases of play, these parameters are capable of recognising favourable patterns of behaviour that may assist teams in their attempt to score more points/goals than their opposing team (12). From an ecological dynamics perspective, football is a performance environment sub–system where players and teams perceive affordances that guide decision–making and coordinative behaviour. Football teams can utilise key ecologically bound strategies such as degeneracy, dimensional compression, reciprocal compensation, and interpersonal linkages to maintain system stability (53–58). These aspects can be objectively identified and analysed using relevant statistical approaches, with the variables identified in Table 1.

Statistical procedures

Parameters identified in Table 1 have often been used in association with specific statistical procedures. *Running correlations* are often applied over time series data to examine the spatiotemporal interactions between teams (e.g. two centroids) or respective participants (attacker–defender dyad) during attacking and defending sequences (59). Utilising this technique, it is possible to identify stable/symmetric and unstable/non–symmetrical patterns (59). Conversely, a lower *coefficient of variation*, demonstrating lower values in a given parameter, may be associated with regularity and stability (60). While the coefficient of variation may offer insight, it has been suggested that a non–linear metric, such as entropy, should be utilised as it can provide additional information about the structure of the variability in a non–linear system that evolves over time (61). Similar to the coefficient of variation, lower values represent more predictable or regular patterns, often associated with less chaotic data point sequences (62). Finally, studies have sought to identify specific patterns or values at which individuals, or systems, enter a period of criticality. For example, in a 1–on–1 football drill, when an attacking player is within 1–2.5 metres of the defending player, the system enters a transition phase whereby changes in relative velocity determine the outcome. When the relative velocity remains low, the defender maintains stability and remains between the goal and the attacker. Alternatively, when relative velocity supersedes a certain threshold in the attacker's favour, the attacker breaks the stability and moves closer to the goal, providing a scoring opportunity (40, 46). In this transition region, sub–systems may be forced to transit from one state of organisation to another (either stability or variability), potentially allowing one team or an individual to gain tactical advantage over the opposition (33).

Table 1: Methodological approaches for the analysis of tactical behaviour in soccer

Variable	Variable defined	Level of analysis	Studies
Centroid	Calculates the mean lateral and longitudinal position of each player in a team and can represent, in a single variable, the relative positioning of both teams in forward–backward and side–to–side movement displacement (12, 27). Weighted centroids account for the relative positioning of the ball, i.e. if the ball is closer to an individual, their position will be more relevant (63).	Macro–level Meso–level	28 studies – (6, 8, 16, 42, 49, 57, 59, 63–83)
Stretch index	Computes the average radial distance of all players to their team centroid and provides a distinct measure of dispersion in lateral and longitudinal directions (27). Weighted stretch index computes the average distance to the weighted centroid (27). Relative stretch index demonstrates how teams expand and contract relative to one another (80).	Macro–level Meso–level	28 studies – (6, 8, 9, 16, 24, 42, 49, 56, 57, 60, 64–70, 75–77, 80–87)
Length/Width	The displacement value between the two farthest players in either the lateral (width) or longitudinal (length) direction at a given time. Length per width ratio represents the relationship between the playing length and width and describes the preferable axis direction towards which the players from both teams are distributed (78).	Macro–level Meso–level	10 studies – (5, 6, 69–71, 75, 76, 78, 83, 88)
Surface area/Effective play space	Team surface area can be either rectangular (team length by width) (89) or by detecting all possible triangulations formed by team players. The combined area of all triangles is then computed providing the total area covered by a team (9).	Macro–level Meso–level	22 studies – (8, 9, 59, 62, 65–67, 69, 70, 72, 74, 75, 78,

	Effective play space is defined by the smallest polygonal area or convex hull delimited by the peripheral players, thereby containing all players in the game (9, 27).		81, 86, 88–94)
Voronoi diagram/Dominant region	Spatial constructions that allow a spatial partitioning of the field area into cells, each associated with each of the players, according to their positions (95), and interpreted as the respective dominant region of each player within the limits of the playing area (96). Superimposed Voronoi diagrams convey the maximum percentage of overlapped area of a team or two opposing cells, as well as the percentage of free area (96).	Macro–level Meso–level	5 studies – (6, 7, 95–97)
Heat map	Heat maps highlight, with warmer colours, the zones that each player has stayed in for longer periods throughout a match (12) and are used to identify most occupied areas for each individual (46).	Meso–level	3 studies – (46, 61, 92)
Cluster/relative—phase method	Quantifies the collective spatiotemporal phase synchronisation of oscillatory movement components (e.g. team players' movement displacement trajectories or velocities) in a single collective parameter (98). When players are moving in synchrony, they are 'in–phase' (0 degrees) and conversely are asynchronous (180 degrees) when players go in opposite directions (13).	Macro–level Meso–level Micro–level	15 studies – (3, 16, 25, 37, 40, 46, 56, 77, 79, 98–103)
Interpersonal distance	The straight line distance between two corresponding teammates or, alternatively, an attacker and a defender. Similarly, this may also include passing and shooting distances, which are calculated as if the ball would travel in a straight line. Interception variables may also include the perpendicular distance of each player to the ball's trajectory, the time for the ball to arrive at the same point, and the required movement velocity of the nearest defender and goalkeeper to intercept the ball (38). Team separateness is defined as the sum of distances between each team player and the closest opponent – a higher value symbolises freedom of movement (78).	Meso–level Micro–level	30 studies – (2–5, 10, 37, 38, 40, 46, 56, 57, 78, 79, 81, 84, 85, 95, 97, 100–102, 104–113)

Interpersonal angle	May represent the relative angle between two players with respect to the goal (13) or to another player or opponent (104). Also includes passing angles, which are formed by the ball carrier, his teammate, and an opponent; and shooting angle, which may be formed by the ball carrier, the goal, and the opponents (104).	Meso–level Micro–level	7 studies – (46, 79, 100, 102, 104, 111, 114)
Relative velocity	Velocity of one player, or centroid, relative to another.	Micro–level	7 studies – (38, 40, 46, 79, 102, 107, 108)
Displacement	Provides lateral and longitudinal movements of players (98). Can be measured using GPS devices (115).	Meso–level	3 studies – (25, 54, 116)
Cooperative network analysis	Conveys the local structure of organisation among players. In these networks, nodes represent players, and links are weighted according to the number of passes or positional changes completed between players (12). Includes measures such as network density, intensity, centrality, betweenness, in– or out–degree measures, closeness, reciprocity index, and transitivity index.	Meso–level	12 studies – (26, 55, 58, 97, 117–124)
Tactical strategies	Possession types (e.g. type of ball recovery, counter–attack vs elaborate attacks or balanced vs imbalanced defence), tactical patterns (risky vs conservative) and time scales (short vs long).	Macro–level Meso–level	4 studies – (125–129)

Coordinative behaviour in football

Inter–team

The lowest dimension of the assessment of coordination is evident on a macroscopic scale, representing the global synergy between all individuals within a performer–environment system. In a football context, macroscopic analysis occurs on an inter–team level whereby two opposing teams are inextricably linked, each acting in response to the other team's behaviour and patterning. This system is a product of all complex non–linear subsystems and their non–linear interactions within the environment or, in this case, a football game (32). It is essential to first understand the global dynamics at the behavioural level of analysis (32) so that ensuing functional linkages and patterns can be analysed at a mesoscopic level (subsystems/functional units) and then, subsequently, a microscopic level (dyadic relations). At the inter–team level of analysis, studies have methodologically utilised surface area/effective play space (Figure 2a), length and width (Figure 2b), centroids (Figure 2c), stretch indices (Figure 2d), Voronoi diagrams (Figure 3), phase analysis, and tactical strategies to help identify favourable patterns of behaviour that lead to successful attacking (goal–scoring opportunities) and defensive (preventing goal–scoring opportunities) sequences of play.

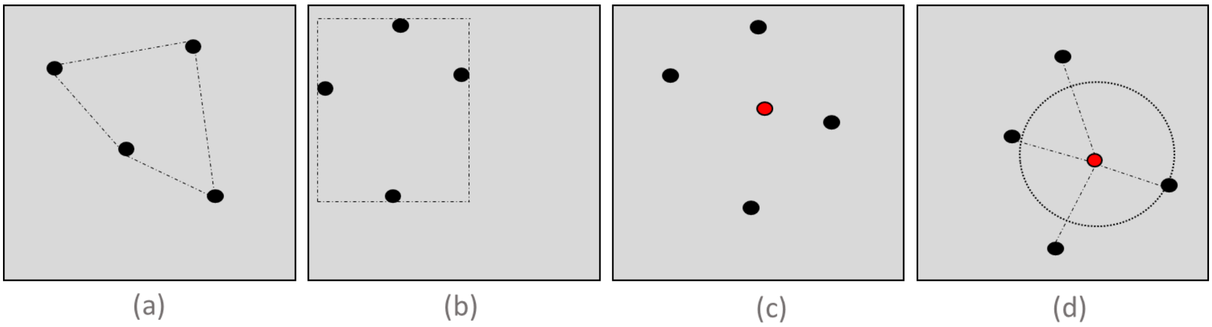


Figure 2: Variables for measuring tactical behaviour – (a) effective area, (b) length/width, (c) centroid, and (d) stretch index. The full black circles represent four players playing on the same team. The full red circle represents the team centroid (the average geospatial location of the four players) For more info consult Fonseca et al. (96)

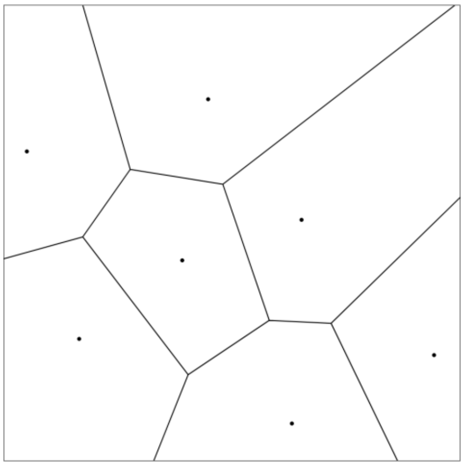


Figure 3: Example of Voronoi diagram derived from fictional data of six players demonstrating the dominant regions of players. For more info consult Fonseca et al. (96).

In general, centroid and cluster phase measures have demonstrated synchronous behaviour between opposing teams in lateral and longitudinal directions in both 5v5 (futsal) (57, 72, 78, 79) and 11–a–side (regular) (16, 63, 65, 73, 82, 99) football formats. Similarly, co–adaptive inter–team coordination patterns have been demonstrated in amateurs (57, 66, 72, 78, 79) and professionals (16, 63, 65, 73, 82, 99) alike, and in both younger (under–18) (57, 66, 72, 78) and older (over–18) (16, 63, 65, 73, 79, 82, 99) age groups. It is suggested that synergistic behaviour emerges as a result of the co–adaptation between the two opposing teams, each using the information of the other team's positioning to guide decision–making and behaviour (99). Furthermore, information conveyed via displacement of the ball through passing and shooting in both lateral and longitudinal directions may afford different action possibilities and appears to guide behaviour in those directions (73). In support of this concept, Frencken et al. (73) demonstrated that critical match periods identified via longitudinal and lateral inter–team centroid displacement, and their rates of change, were respectively associated with 93% and 87% of match events in which the ball was passed longitudinally or laterally. This may offer a possible explanation into Bartlett et al.'s (65) findings, which revealed a strong relationship, using correlation measures, between the geographical positioning of team centroids in plays leading to goals or shots on goal. It is evident that opposing teams, regardless of whether their possessional status is attack or defence, use the positioning of the ball as a key informational variable to guide behaviour (99). Further, a plethora of existing research indicates a higher level of synchronicity in the longitudinal direction than in the lateral direction (16, 63, 65, 72, 73, 78, 82, 99, 103). This may be due to off–side constraints, limiting attacker's positioning relative to the defenders, and the position of the goals (99), with the primary attacking objective to advance up the field to create goal–scoring opportunities (73). Lower synchronisation in the lateral direction may reflect a tactical strategy of the attacking team, with players deciding to keep a certain degree of asymmetry with the defence, passing the ball from side–to–side, aiming to increase affordances for scoring a goal by creating a misalignment between the opposition defenders (82). Conversely, a lack of synchrony may reflect defensive tactical behaviour as players may decide to use a conservative approach, adopting preferential symmetry in the longitudinal direction as opposed to the lateral direction attempting to protect their goal (82). In these instances, task constraints (off–side rules) and team strategies (score/prevent goal scoring) may align performers with specific information in the environment that provides affordances for outcome–directed action. Furthermore, greater inter–team synchrony has been demonstrated in the first half (16, 73) compared to the second half of a football match (99). This increase in variability in the second half may be due to changes in specific performance constraints, such as fatigue or other strategic (team formation) or situational changes (change in score line) (16, 73, 99). Changes that are due to fatigue may have implications for pre– and in–season physical preparation strategies. Alternatively, players may need to be exposed to varying situational factors in a training environment, potentially using vignettes, providing individuals with the opportunity to adapt to contextual changes.

For measures of team dispersion, it has been demonstrated that teams co–adaptively expand or contract together along the pitch in synchrony while lacking synchrony in the lateral direction (65). This may once again reflect the influence of off–side task constraints along with the primary goal constraint in the game: to progress up the field in order to increase the probability of scoring. Conversely, other studies revealed that dispersion of teams' players tended to follow a dynamical counter–phase relation where when one team contracted, the other dispersed (8, 82). This may reflect tactical strategies employed in both offense and defence. In offense, teams try to increase team dispersion to explore potential goal–scoring affordances while defensive teams contract to limit the available space and ultimately protect the goal and limit goal–scoring opportunities (66)**.** Interestingly, only a few studies examining dispersion via team surface area revealed no tendency for a positive (*in–phase*) or negative (*counter–phase*) synergistic relationship between teams (72, 74). However, these studies utilised a 5v5 small–sided game format which may be methodologically limited as the examined area is only formed by four outfield players where adjustments in one player's positioning may drastically effect the overall surface area (72). Furthermore, the presence of extra players in an 11–a–side format may provide sufficient information to guide synergistic behaviour and decision–making processes. Additional players may add relevant information and provide an opportunity for each team to optimally co–adapt to one another (85). Finally, freedom of longitudinal movement in the absence of the off–side rule may limit interpretation of results in relation to 11–a–side football as players in this format would normally impose a penalty (72). While dispersion measures offer useful insights, caution must be used when analysing surface area in an 11–a–side format as these measures only account for the most peripheral bound individuals, neglecting the influence of players within the given area (66). A more appropriate method may be the use of superimposed Voronoi diagrams (Figure 3). These have the ability to account for every player and can effectively describe spatiotemporal relationships at both an inter–individual and inter–team level (96). For example, when opposing players are tightly paired (such as in man–to–man defence), the percentage of free area among players and teams is small with limited free space for teams to explore affordances in offense (96). While this is yet to be examined in relation to successful and unsuccessful patterns of play, these variables, based on teams' overlapping areas and the relative position of players, may offer further insight regarding the spatial interaction and decision–making processes used by players and teams.

Such findings may need to be interpreted with caution as they may be limited by the global timescale of analysis. One study revealed higher values of coordination over longer sequences of play in a 5v5 format in contrast with shorter sequences of play (64). Furthermore, Frencken et al. (73) revealed that 51 of 242 critical match periods – instances commonly associated with phase transitions – detected in a professional football game were aligned with dead–ball situations**.** It may be more relevant to analyse synergistic behaviour over shorter timescales, such as a specific time period leading up to successful or unsuccessful scoring attempts (e.g. from the moment of a turnover until a subsequent shot on goal). This may offer supplementary insight into favourable patterns of play as larger timescales demonstrating higher degrees of synergy may subdue the variability otherwise observed in shorter sequences of play (73). Further, discretion is advised when interpreting results from centroid measures. Despite different displacements of players, centroids can remain in the same relative position. For example, each player four metres apart will have the same relative effect on a centroid measure as if they were eight metres apart (63). Additionally, while providing useful information on a global scale, utilising centroid measures neglects to provide a complete understanding of the strategic distribution of players on the field (65). For a deeper understanding of synergistic behaviour and emergent tactical patterns evident at a macroscopic level, it is necessary to examine dynamical behaviour on a higher dimensional scale that simultaneously observes dispersion and synchrony between teammates. A macroscopic or intra–team level of analysis may be sufficient to provide further insight regarding desirable patterns of play.

Intra–team

With the lowest (macroscopic) dimension of coordination identified, subsequent analysis on a mesoscopic scale can be undertaken to identify synergistic and co–adaptive behaviours that emerge on an intra–team level. At this level, parameters are often measured in isolation of the opposition team but still offer additional insight, especially when analysed with reference to successful and unsuccessful phases of play, i.e. goal–scoring opportunities or turnovers. Measures of dispersion, displacement and social connectedness, when effectively utilised, can reveal the patterns of behaviour and decision–making that emerge through degenerate adaptation, dimensional compression and reciprocal compensation, all afforded and governed by information in the performer–environment sub–system. This level of analysis may be deemed important for team performance and success as tactical coordination patterns revealed through collective positioning variables are superiorly sensitive to changes in constraints in comparison to physiological variables (24).

Aligning with the macroscopic scale of analysis, patterns of expansion and contraction in attack and defence, respectively, have been identified between players of the same team. In amateurs (67) and professionals (69, 76, 86) alike, studies have demonstrated an increase in team dispersion when in possession of the ball through measures of stretch index (67, 69, 76, 86), surface area (67, 69, 86), and length and width (69). Conversely, without possession, the same team revealed a decreasing tendency in dispersion measures (67, 76, 86). As identified on an inter–team level, these emergent patterns may align with the ambition of either dispersing in an attempt to explore potential goal–scoring affordances or contracting in an attempt to limit the available space and subsequently protect the goal and limit goal–scoring opportunities for the opposition (66). Furthermore, the half of a match appears to influence players' spatiotemporal relationships and, consequently, their ability to disperse in offense or contract in defence. Team dispersion measures typically reduce in the second half (i.e. in offence, players are less dispersed in the second than in the first half of a game), which could be attributed to the onset of fatigue in the second half of a game (67), demonstrating the inter–relationship between the physical and tactical domains of performance in football. With diminished physical capacities, the ability of players to explore the whole width and length of the field while trying to unbalance an opposing team is compromised (67). Furthermore, the speed at which players expand and contract their team formations during defending and attacking plays has also been investigated in relation to game time. Concurrent with the decrease in absolute dispersion values, the rate of change in dispersion measures has also demonstrated a decrease in the second half, once again implicating the potential effects of fatigue (9). While running demands were not concomitantly assessed with dispersion measures, previous studies have revealed a reduction in high–intensity runs by players in the second half (130), again reinforcing the inextricable link between physical and tactical parameters. Once again, the decrement in the above measures may be associated with increased fatigue and may limit the ability of a team to effectively respond to new emerging affordances and constraints (9).

To evaluate the space–time coordination tendencies between each individual player and their team as a singular unit, *relative phase analysis* may be incorporated. Once again, aligning with emergent synergistic behaviours between opposing teams, phase analysis between teammates has demonstrated that intra–team synchronicity is superior in the longitudinal direction compared to the lateral direction (25, 54, 99, 103). As identified earlier in the review, these patterns may emerge due to off–side constraints, positioning of the goals, and the primary objective to advance up the field and score (99). However, contrary to the macroscopic analysis, which demonstrated a decrease in synchrony between teams, individuals display greater synchrony within the team in the second half in comparison to the first half (99). This may be a result of developing shared affordances during games, allowing players to become increasingly attuned to affordances 'of' and 'for' others (23). Alternatively, this may be a result of the decrease in total dispersion values and rates of change in these values (i.e. players are less dispersed and disperse or contract at a slower rate in the second compared to the first half), as highlighted above, due to fatigue onset (9, 67). Additionally, during heavily congested fixtures, players experience a decrease in synchronicity in both lateral (at moderate intensities) and longitudinal directions (at low and moderate intensities) (54). In their study, Folgado et al. (54) revealed that players covered the same amount of distance at similar intensities, highlighting no changes in physical capacity in both congested and non–congested fixtures, and proposed that the reduction in synchronisation may be associated with an increased perception of fatigue and consequent adaptation strategies. Interestingly, players were able to maintain a higher level of coordination, as measured via synchrony, at higher speeds. This may be associated with critical game phases where opportunities are created. This suggests that players may decide to switch off mentally at lower intensities to preserve the limited capacity of cognitive resources (54) as this has been shown to adversely influence synchronicity and rates of dispersion in a football context (84).

The literature has revealed that the displacement of all players (defenders, midfielders, and forwards) was nearer and more coordinated with their own positional–group centroids than with the other centroids (49). Positional centroids appear to guide emergent, position–specific behaviour as the decision–making process and inter–player coordination is facilitated when inter–player roles are similar and distances between teammates are smaller (49). Furthermore, defenders (54, 103) and midfielders (49) spend more time in synchrony with each other and their own positional centroids than with forward players, meaning that positional groups move in a synchronised manner by matching their position with that of other members of the same positional group. An absence of synergistic behaviour in attack may be a consequence of the forward's role to be less predictable, or degenerate, while aiming to destabilise opponent defensive stability with sudden changes in speed and direction (49, 103). Dimensional compression, conveyed by stronger coupling between defenders and midfielders, is likely a result of the players' awareness of the risks of asynchronous behaviour in the defensive pitch, collectively trying to reduce open spaces and affordances for opposition scoring (49, 66, 103). Individually, midfielders are likely constrained by a common goal: to control the pitch's centre by maintaining effective inter–player spacing (49). Interestingly, positional centroid measures have revealed stronger in–phase relationships in the lateral direction (49), contrasting with inter–team centroid and intra–team displacement measures of synchrony in the longitudinal direction. Gonçalves et al. (49) suggested that this may be related to the need to reduce lateral spaces in defence to minimise oppositional attacking opportunites. This may be well justified as, in attack, the occupation of the lateral corridors in a synchronised manner is considered to be the greatest destabilising factor of opponents' organisation since the critical, or transitional, game periods appear to be associated with changes in lateral distance between teams (49).

While synchronicity measures can demonstrate dimensional compression, measures of *predictability* and *variability*, as determined through the analysis of *entropy* measures, may reflect stable or degenerate behaviour. These measures reflect the *regularity* in behaviours exhibited by players or teams. High predictability may indicate pattern maintenance by a team throughout a match or competition, signifying a high level of organisation (92). Conversely, significant changes in a team's structure or behaviour could yield unpredictability or a higher capacity to co–adapt to unexpected or variable situations during a match or championship. Through the use of different tactical solutions, teams may still be able to achieve task goals, despite demonstrating considerable amounts of variability in how these task goals are achieved (degeneracy) (92). Selected studies have demonstrated higher predictability in offense, potentially signifying that a standardised pattern of behaviour may be regularly utilised in an attempt to overcome the opposition's defence (89). Similarly, in defence, low entropy values (higher predictability) are evident, particularly near scoring zones, reflecting the need to regularly reduce the available space afforded to opponents, limiting consequential scoring opportunities (89). These low entropy values in defence and attack may represent the strategy or playing style used by a team to attempt to score goals or prevent the opposition from scoring, respectively. Entropy values have revealed a tendency to decrease during halves, signifying that teams become more regular and predictable in their organisational shape with ensuing time, potentially due to decreases in dispersion measures and concurrent increases in synchrony, perceptual attunement to teammate behaviour, fatigue, and performance–related stress (69, 70). This co–adaptation to fatigue as a performance constraint may push teams into their preferred attractor states (i.e. reverting to well–established learned and trained tactical behaviour), reducing coordination complexity and dimensionally compressing to stabilise performance and increase regularity in patterning (70). However, while entropy values may decrease throughout the match, critical periods characterised by larger entropy scores (decrease in predictability), that eventuate into scoring opportunities, may still be present later in the match, but may be less prevalent due to the onset of fatigue. The spatiotemporal examination of goal–scoring opportunities throughout the second half of the match, along with the prevalence of these opportunities, may provide further insight into behaviour, and the decay in entropy, that emerges as the game concludes.

Position–specific *entropy* measures have offered insight into the value of fostering *stability* or *unpredictability*. Forwards have demonstrated more *irregularity* in comparison to other players, potentially as a consequence of their need to be less predictable in offence in an attempt to deceive and destabilise the defence (49, 61). Conversely, greater regularity has been displayed in midfielders, whose role is to control the pitch's centre and act as a communicator, and defenders, who coordinate and stabilise patterning in an attempt to minimise affordances for the attacking team (16, 49). Furthermore, defenders need to stabilise coordinative behaviours and maintain their trajectories within their specific regions to ensure the possibility of recovering the ball during offensive attempts by the opponent team (61). However, in contrast, Moura et al. (92) revealed that external midfielders and external defenders demonstrated the greatest variability in spatial distribution throughout the 2012 UEFA

European Championship. This outcome may reflect these players' tactical roles and the changes within these roles with the introduction of modern football tactics. While central players have a well–defined role (to either solely attack or defend) during a match, the external defenders not only act as defenders but also support the midfielders during attacking phases (92), while midfielders act as a link between the defenders and attackers (61). Additionally, in modern football, these positional groups often cross multiple 'lines', where lateral defenders often run to the opposition goal line to deliver a cross in front of goal. Lastly, goalkeepers are the most predictable players, likely due to their positional constraint, spending the majority of time in the defensive square (61). It appears that player roles and tactical intentions act as a determining constraint on emergent behaviour and need to be considered when analysing player–specific regularity measures.

A further way to gauge intra–team synergy is through implementation of a cooperative network analysis that conveys the local structure of organisation among players. In these networks, nodes represent players, and links are weighted according to the number of passes or positional changes completed between players (12). By analysing passes and kicks made within a team, practitioners are able to map the relationships between players during a game. Through analysis of professional players in an 11–a–side format, *scaled connectivity* measures (117) revealed that all players usually cooperate in attack. On an individual level, scaled connectivity represents the connectivity of a player in which higher values represent a higher cooperation, as demonstrated by a player being connected with more players. On a global scale, *centralisation* values represent the distribution level of the network whereby larger values signify a network's dependence on one player. Similar to scaled connectivity, through the use of centralisation measures, Clemente et al. (118) revealed that in professional football there are generally no focal players, i.e. each player had nearly the same connectivity. A higher level of connectedness between players, along with lower centralisation, may allow degenerate or multiple stable patterns of play to emerge with multiple passing options available between multiple players (117). However, values of centrality increased in the second half, showing a decreasing participation of all players at the same level, with the emergence of a number of focal player(s). This increase in centrality was accompanied by a decrease in network density, an indicator of global connectivity among players with higher values suggesting that players interact with each other, and an increase in *network heterogeneity*, quantifying the variability in the level of connectedness between different players, revealing that as time ensued, intra–team clusters of players at different levels emerged (118). This may implicitly occur or represent a decision to tactically decrease the number of players involved, allowing players to rest. Alternatively, deciding to change to a direct style of play, favouring certain players due to skill, or the existence of ambiguous relationships to create offence plays, may give rise to the apparent changes between halves (118).

It is also possible to identify social centroid players who are the most highly connected in the network (117). Due to their tactical roles, it has been revealed that defenders and midfielders are centroid players (117–119, 124). These players are often responsible for recovering possession, particularly in the defensive zone, which would increase participation in offensive plays. Additionally, if a team decides to adopt a building style of offense, as opposed to a direct style, in an attempt to attract the opponents out of their defensive zone to provide offensive affordances for attackers, midfielders and defenders will display higher centralisation (117). *Topological dependency*, identifying players who are heavily depended–upon, highlighted that midfielders are the players that connect most easily with any other player and are also the players that interact most with remaining teammates (117). This was supported by Clemente et al. (26) who revealed superior *degree prestige*, a variable that considers the inbound links from other players in midfielders in comparison to defenders and goalkeepers. This superior dependency is likely due to the role of midfielders to connect offensive play from the defensive zone to the offensive zone (26). Further, attackers require players to recover the ball in defence and generate offensive plays (117). Alternatively, Gama et al. (55) highlighted that professional football teams prioritise circulation and maintenance of ball possession, by passing to the centroid player/s several times. Additionally, these players may play a pivotal role in the self–organisation processes of the team, exhibiting a higher level of quality during both execution and reception of passes, contributing to an increase in social intensity and density within the network (55). In amateur football, Clemente et al. (55) revealed that higher performing players with lower fatigue who had previously performed better in dribbling tasks demonstrated high *betweenness centrality* in matches. Such values signify that a player is often situated between teammates. This may indicate that players with excellent technical ability, and the ability to maintain excellent performance throughout the entirety of the game, might be considered references for improving cooperation among teammates (26). Additionally, expert central defenders and midfielders have demonstrated superior *closeness*, which indicates the ease of connectivity with a player, and *betweenness centrality* values than other positional players emphasising the pivotal role of these positions in fostering cooperation among teammates (124).

Further utilising cooperative network analyses, *clustering coefficients* indicate which players contribute the most to the generation of team clusters, with a higher value signifying that the greatest cooperation among teammates occurs around these players (117). In general, average clustering coefficient values revealed the emergence of clusters within the team and have been associated with success in the 2010 FIFA World Cup (123). Additionally, the players with the highest values were the wing midfielders and the forwards, suggesting that these players participate in more attacking plays that involve a large number of teammates (117). Clemente et al. (117) revealed that players with a higher clustering coefficient also tended to have lower connectivity values. These results suggest that these players participate in offensive plays with teammates that have a higher level of interaction with each other. The higher interaction between centre midfielders and defenders may indicate adaptation through reciprocal compensation for the lack of involvement from lateral and forward players. Gama et al. (120) demonstrated that emergent compensatory behaviours can emerge in football when one of the regularly key players has fewer interactions in a game, thus requiring other players to emerge to replace them (120). The results revealed by Clemente et al. (117) may once again be a result of an offensive building style whereby central and defending players increase passing between themselves until the appropriate opportunity is afforded to the forward players. These positions have also revealed superior betweenness and closeness values indicative of their role in controlling and distributing possession (124). To explore these relationships further, and the mechanisms behind intra–team coordination, collective parameters and co–adaptive tendencies can be observed on a dyadic level as different situations may afford varying emergent behaviour between players.

Inter–player

Behavioural analysis on a microscopic scale can further rationalise and clarify behaviours that emerge on a lower dimensional scale, i.e. meso– and macroscopic level. Literary findings have adequately identified how interpersonal coordination tendencies constrain decision–making, performance, and inter–player patterns in professional (25, 54) and amateur (97) 11–a–side football as well as, to a larger degree, in futsal (5–a–side) (37, 38, 78, 101, 102, 104, 108–111, 114). Through the measurement of inter–player distance, velocity, synchronicity, regularity, and angular displacement, coaches and practitioners can identify emergent patterns of coordination and behaviour that precede successful phases of play to subsequently guide decision–making processes. Furthermore, these parameters allow practitioners to transpose these findings into a training context, ensuring the availability of representative constraints and affordances for players.

In an 11–a–side context, only measures of synchronicity and regularity have been assessed and analysed, with particular reference to positional differences. Studies have revealed that dyads consisting of backs attain superior levels of synchronisation (54) and regularity (97), as opposed to dyads consisting of forwards, who are generally further apart. Dyads engaged in offensive match–play demonstrated a lower percentage of the game in synchrony (54). In a similar alignment with emergent behaviour on a mesoscopic scale, enhanced synchronicity may reflect the presence of a common objective between defending players, i.e. to remain between the attackers and the goal, contracting to minimise goal–scoring affordances (8, 63, 65). Conversely, lower synchronicity and regularity between forward attacking dyads may reflect a significant amount of time attempting to destabilise the defence with sudden changes in speed and direction, consequently altering displacements (49). The associated levels of synchrony on a microscopic scale further clarify and explain why and how specific levels of synchronicity emerge on a lower dimension of analysis in an 11–a–side football game.

Similar synchronicity has been observed in professional futsal (5v5). Defensive positioned dyads have demonstrated strong in–phase attractions with the ball and each other in the lateral direction while forwards have revealed weaker phase attractions (101). As per the traditional format of the game, similar aims may be present as defenders attempt to maintain stability while attackers probe oppositional defensive stability (101). Backs may also use the positioning of fellow defenders, and the displacement of the ball, as key informational variables that guide decision–making and constrain behaviour or provide affordances for action (73, 99). Furthermore, intra–team dyads between forwards and backs have revealed weak in–phase patterns of coordination. This may reflect the different positional intentions and goals, as well as variable linkages between different players forming different sub–systems within the mesoscopic system (101). Conversely, between opposing attacker–defender dyads, stable in–phase patterns of coordination have emerged between inter–player distances (37, 102, 110) and angle (102) to the goal and ball. The distance and angle of attackers to the goal and ball, and the distance of ball carriers to defenders, seem to be coupled in a specific manner to guide interpersonal coordination tendencies between players during competitive performance in the team sport of futsal (37). However, it is important to contextualise and examine behaviour in conjunction with successful and unsuccessful patterns of play as this ultimately guides the decision–making process.

Patterns for performance

Inter–team

When looking at individual phases of play, recent investigations have identified common inter–team tactical behaviours that emerge over time in both attack and defence. Centroid analysis in professional football games has demonstrated that, when in defence, teams tend to move closer to their defensive zone in an attempt to ensure that their centroid is nearer to its goal than the offensive team's centroid (65). Furthermore, teams that consistently allocate more players in certain areas of the field closer to their own goal exhibit numerical dominance during defensive phases of play (93). This numerical dominance may contribute to the observed defensive centroid positioning and reflect an attempt to protect the goal, one of the primary task constraints in football (6, 8). This same study also revealed that winning teams demonstrate greater regularity in corresponding centre–back sub areas of play in regard to numerical dominance, implying that, for successful defence, numerical dominance must be consistently present in defensive areas (93). It has also been highlighted that winning teams maintain a greater separation between their own centroid and that of the opposing team when in defence (63). This separation decreases the imposed pressure on the defensive team and allows more time to modify behaviours relative to that of the attacking team, allowing minimisation of the number of affordances available to the offense (8, 63, 65, 81).

Focusing on specific defensive and offensive strategies can be utilised to alter behaviour as it provides a modified task constraint. In defence, implementing zone strategies leads to superior distance and variability between centroids compared to man–to–man defence (75). In zone, defensive teams function collectively as a compact block between the ball and the goal with the increased distance and variability, with respect to man–to–man defence, attributed to a shared focus on fellow teammate positions as well as ball displacement information. In contrast, with the utilisation of man–to–man defence, the emergent behaviour of players is constrained by the task of perceiving and acting in accordance with a specific opposing player (75). In training, incorporating specified defensive strategies may force attacking teams to search for new affordances in the performer–environment landscape, potentially leading to alternative solutions enabling the scoring of goals. Alternatively, in attack, teams utilising counter–attacks (direct play) have been more effective than elaborate (possession play) attacks when playing against an imbalanced defence. Tenga et al. (129) revealed that 94% of goals were scored against an imbalanced defence while only 2.5% were scored against a balance defence. The main objective of counterattacking is to exploit imbalances in the opponent's defence to achieve penetration (129). While this study neglected quantitative tactical measures, a direct style of play may sufficiently perturb defensive lines as it does not provide the defending team with enough time to modify their synergistic behaviours relative to the ball or the attacking team's movements (81).

Additionally, in assessing the synchronicity in professional 11–a–side football utilising a *cross–correlation* in spread measures between teams, Moura et al. (87) demonstrated that opposing teams have a tendency to present in–phase coordination with a short time lag, suggesting that one team has the ability to lead the other and influence emergent behaviour (87). This study revealed that in the preliminary stages of offensive sequences that ended in a shot at goal, a greater anti–phase in coordination was present than those ending in a tackle. These results suggest that the attacking team may seek to present a contrary behaviour to its opponent (or may lead the adversary behaviour) in the beginning of the attacking play, regarding to the distribution strategy, to increase the chances of a shot on goal (87). Further, the only main difference was in the initial stages, and not the final stages of the attacking play. This highlights the importance of breaking the usual in–phase coordination between teams and may also explain why counter–attacks are an important strategy for scoring goals (87). Tactical strategies imposed by coaches should be carefully considered as they have the potential to constrain player behaviours as well as coordinative outcomes. Coaches may incorporate different strategies or playing styles in a bid to enhance attunement to specified affordances and, consequently, promote multi–stable regions of performance that allow players and teams to achieve relevant goals (29). This may better prepare teams for the tactical patterns used by opposing teams.

Contrary to traditional thoughts on defensive success, Bartlett et al. (65) utilised measures of dispersion to reveal that smaller *stretch index* values (contraction) in defence relative to larger values in attack (expansion) were associated with more successful attacks, i.e. goal–scoring opportunities (65). This contradicts original ideas that defensive teams need to contract to protect the goal and limit goal–scoring opportunities for the attacking team (66). However, the results demonstrated by Bartlett et al. (65) may not acknowledge the offensive team's ability to perturb the coordinative behaviours of defensive lines. In attack, this ability to disrupt the stability of the defensive team has been shown to be an influential factor for creating goal–scoring opportunities which, when capitalised upon, are necessary for success (129). Contrary to the conflicting defensive patterns demonstrated in this study, the evident offensive patterns concur with original idea in that teams need to increase team dispersion, relative to the defence to generate potential goal–scoring affordances (66). This is reinforced in the literature as numerous studies have shown that effective area (67), surface area (70), length/width (70) and dominant regions (95) increase when teams regain possession and transition to offense. Concurrent analysis of inter–team dispersion measures, along with intra–team variability, may further clarify the importance of relative measures of dispersion.

Evidence suggests that the ability of an offensive team to perturb opponent inter–team stability is important for success (16, 66, 129). Utilising centroid measures, an unbalancing of phase coupling between opposing teams in the lateral direction has preceded the scoring of a goal (66). More specifically, utilising positional centroids, a crossing of attacking– and defensive–line centroids was evident in the lead–up to goals and goal–scoring opportunities in professional football (16). Additionally, increased variability between attacking– and defensive–line centroids has been identified in the lead–up to goal–scoring opportunities with a continual increase in this variability up until the critical moment (goal attempt) (16). These studies reinforce the notion that offensive teams need to utilise positional information to destabilise their defensive counterparts and subsequently exploit imbalances in the defence, leading to more opportunities for goal–scoring actions (129). This may be deemed necessary as successful defensive shadowing, where defensive teams effectively organise and create triangles towards the ball (effective area), can limit the spaces and opportunities with which an attacking opponent can pass or dribble (Figure 4) (132). This intra–team coordinative behaviour will consequently limit goal–scoring opportunities, which are pivotal for game success (12).

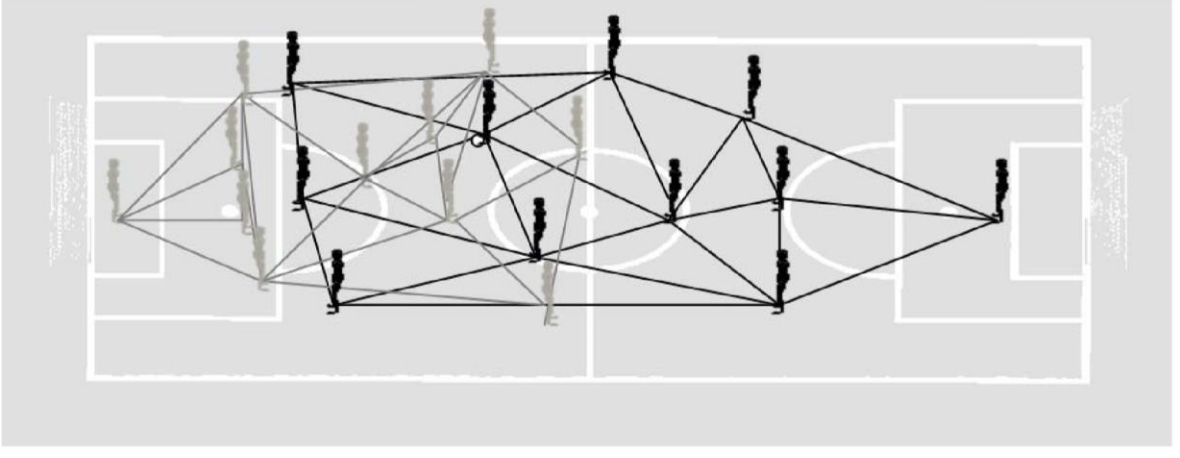


Figure 4: Defensive (grey) effective area that limits the space and passing opportunities for attacking opponents (black) (66), published under the Creative Commons license.

Intra–team

Aligning with the macroscopic level of analysis, investigation of intra–team coordination has revealed behavioural patterns associated with in–game success. Through the analysis of dispersion (86, 89, 98), displacement (103) and cooperative network measures (97, 121, 123), favourable patterns in both professionals (86, 89, 103, 121, 123) and amateurs (7, 97) can be identified and consequently used as a reference to guide the decision–making process or for training prescription and attempts to optimise team performance.

Despite the limitation of being examined in isolation of the opposing team, mesoscopic analyses of dispersion have revealed similar patterns of success to those of a macroscopic level analysis. This would be expected as, even though no opposition measures were recorded, players are presented with similar task and goal–directed constraints. Moura et al. (86) revealed that when a team in defence presented a greater area and spread, they were required to defend against more shots on goal. In contrast, with smaller dispersion, they successfully performed more tackles (86). The presence of task constraints, along with the need to protect the goal and limit goal–scoring opportunities for the opposition, appear to guide defensive behaviour, leading to the emergent decision to contract dispersion (63, 65, 66). Furthermore, aligning with inter–team patterns, superior measures of dispersion, as revealed through the use of Voronoi diagrams, have been associated with successful attacking phases of play. Taki & Hasegawa (7) revealed that attacking teams cooperatively increase their dominant regions, leading to goal–scoring opportunities. It is suggested that an increase in dominant regions will afford favourable passing opportunities for teammates, as passes made within a teammates dominant region will increase the chances of the pass being successful (7). While successful patterns of play were not directly analysed, stronger teams demonstrated greater offensive length, width and surface area in an attempt to move forward into the score zones and create shot opportunities when playing against weaker teams as determined by competition rank (89). Conversely, weaker teams displayed greater defensive length, width and surface area against stronger teams. Greater dispersion by superior teams may be related to an enhanced ability to effectively disperse to create scoring affordances. Conversely, more dispersion in defensive patterns exhibited by weaker teams may reflect an ineffective co–adaptation to the stronger offensive team, mirroring their movements in attack (89). While superior teams may demonstrate distinguishable behavioural patterns, the absence of contextual information, as provided through reference to successful and unsuccessful patterns of play, may limit the interpretability of conveyed information.

When examining intra–team player displacement, one study revealed that winning teams demonstrate superior values of synchrony over a match compared to losing teams (103). These larger values may highlight the importance of defensive success in influencing match outcome, as this study also demonstrated superior defensive dyadic synchrony relative to attacking dyads (105). Defensive synchrony, and the association with match success, may reflect the ability of players to coordinate their actions and remain between the attackers and the goal to minimise goal–scoring affordances (8, 63, 65). This may be a priority over the lower synchronicity and regularity commonly demonstrated by forward attacking dyads who often attempt to destabilise the defence with sudden changes in speed and direction (49). However, an absence of relevant contextual information, such as the amount of time spent in offensive or defensive phases of play, was not quantified. A larger amount of time spent defending may inherently lead to a greater proportion of the match spent in synchrony as this is deemed necessary for defensive success. While this research failed to account for specific phases of play, global movement synchrony may be considered as a measure of a team's tactical performance throughout the season (103).

In addition to the measures of team dispersion and displacement, network analyses have exposed favourable social characteristics within teams. Through examination of player interactions in the English Premier League and the number of goals scored, Grund (121) revealed a clear network intensity effect demonstrating that increases in passing rate lead to increased team performance. This study revealed that lower centralisation values, where a team is not dependent on single or selected players, are associated with superior performance. This was also demonstrated in higher performing amateur teams (97). It is suggested that decentralised teams, where all players are equally central, or are equally likely to receive the ball, fosters interdependence, which encourages coordination and cooperation. This may also provide teams with more flexibility and foster degeneracy, allowing multiple effective scoring affordances and solutions to emerge (121). Furthermore, through analysis of the 2010 World Cup, Peña & Touchette (123) revealed that Spain, the tournament winner, had the highest number of passes, high edge connectivity, and a low betweenness score. This aligns with Grund's (121) findings, as edge connectivity is defined as the number of edges one needs to remove to make a network disconnected, while betweenness indicates how the ball–flow between other players depends on a selected player. This suggests that a large number of passes would need to be intercepted to disrupt the team's preferred ball movement patterns and that this team does not rely on certain players (123). Additionally, Spain demonstrated the largest clustering and clique values (123). Clustering represents the percentage of all possible triangles containing a specific node while clique values represent a subset of players that are all pairwise–connected by direct passes (123). The superior values demonstrated by the Spanish team signifies that most players interact with each other. This further suggests that successful performance relies on degeneracy, allowing team co–adaptation to different game situations or constraints, which consequently fosters task achievement.

As noted, caution must be taken when interpreting intra–team measures in isolation as most studies examine behaviour in one team only. While the reasoning behind emergent behaviour can be inferred in relation to a lower dimensional level of analysis, i.e. inter–team literature, future research should incorporate concurrent examination of similar variables in both teams, similar to those utilised in inter–team analysis. This may offer further insight as to how the actions and tactical patterning of opposition teams afford unique opportunities and constraints. Further, while there is a plethora of research on intra–team coordination, many studies examined emergent behaviours without reference to successful and unsuccessful passages of play, such as goal scoring or turnover sequences (9, 16, 26, 49, 54, 55, 61, 66, 67, 70, 71, 89, 92, 99, 117–119, 121, 123). Whilst these studies provide useful information, future research should assess tactical behaviour with contextual reference to both favourable and unfavourable outcomes as this may assist training intervention and enable the establishment of performance guidelines for intra–team coordination. Subsequently a deeper analysis can then occur between selected individuals of the same, or opposing, team.

Inter–player

In contrast to the macro– and mesoscopic scale of analysis, microscopic coordination patterns have rarely been explored in 11–a–side football. Despite neglecting concurrent analysis of successful and unsuccessful phases of play, selected studies have identified patterns of synchronisation that may be favourable for superior performance. One study revealed that a higher percentage of time was spent in dyadic synchronisation against superior teams (25). This may be explained by the increase in match demands imposed by higher–level teams. These demands might require an increase in collaborative work in order to gain advantage over the higher–level opponents, in both attacking and defensive phases (25). Alternatively, the increase in synchronicity may be a result of tactical mechanisms whereby the weaker team follows the superior team’s lead. Folgado et al. (54) revealed that players spent a greater amount of time in dyadic synchrony during non–congested fixtures (games six or more days apart) compared to congested fixtures (games played three days apart). Despite players covering the same amount of distance at similar intensities in both types of fixtures, the reduction in synchronisation may be associated with an increased perception of fatigue and consequent resultant effects of congested fixtures. While successful patterns of play were not concurrently assessed with respect to performance outcome, synchrony may serve as a performance indicator of the interaction process between teammates (54).

In contrast to 11–a–side football literature, there is a plethora of literature in futsal regarding favourable dyadic synchrony patterns for successful performance. Examination of interpersonal distances between players, and interception lines, have revealed common associations. Instances where time or distance to ball interception for a defender was positive, i.e. they could not reach the ball in time, resulted in passes that were not intercepted, while negative or zero values resulted in intercepted passes (38, 109, 111). This indicates that a pass could be successfully performed if the defender was far enough away from the closest interception point or if the ball carrier decided to pass outside the reach of the defender (38). Additionally, for intercepted passes, the closest (109) and second closest (108) defender were positioned further away from the attacker, but were closer to the ball's trajectory in intercepted passes. The greater distance between the defenders and the ball carrier may afford the defending player more time to intercept the ball. Both attackers and defenders must utilise perceptual information pertaining to their opponents positioning and movement to implicitly act in a way that will result in a successful outcome, i.e. completing a pass to a teammate (attack) or intercepting a pass (defence). Interestingly, there are no differences in interpersonal distances between attackers for successful and unsuccessful passes (108, 109). This may be due to the continuous co–adaptation in displacements and ball trajectories as attackers explore spatial–temporal relations with defenders and fellow teammates in an attempt to afford shooting and passing opportunities (108). It is suggested that defenders should try to limit passing and shooting affordances by remaining in synchrony with one another (81) and by coordinating their movements with the ball and the opponents' displacement trajectories, actively decreasing passing lines and the available space for attackers to pass or shoot in (37, 108). Conversely, attackers should move in order to 'pull' opponents away from passing and shooting lines (38). This research reveals that, at the moment of pass initiation, the interpersonal distances between defenders, attackers, and ball trajectory act as an information–specifying variable that constrains the decision–making process and reveals possibilities for successful passing or interception (109). The results highlight the importance of conceiving both distance and time to interception when trying to successfully pass/shoot (attackers) or intercept (defenders) (38) and have major implications for the prescription of training. Additionally, these studies highlight that critical values attained in specific parameters can be used to predict successful or unsuccessful outcomes.

In conjunction with distance, intercepted passes seemed to be influenced by the continuous regulation of a defender's velocity relative to the ball's trajectory (109). Vilar et al. (38) demonstrated lower required velocities for the nearest outfield defender and the goalkeeper to intercept a ball, while Travassos et al. (109) revealed that the second closest defender had a smaller velocity for intercepted vs non–intercepted passes. This reduced velocity may be a result of a pre–emptive decision and movement, positioning the defender, or goalkeeper, closer to the passing or shooting line, leaving enough time to intercept the ball (109). Travassos et al. (109) also identified an increase in the second defender's velocity if the initial defender failed to intercept the ball. This highlights how defenders need to continuously co–adapt to the surrounding environmental information, i.e. teammate and ball positioning, in order to sufficiently constrain attacking passing behaviour as well as optimise opportunity for interception (109). The combination of distance to, and required velocity for, interception emphasises that the time to ball interception is a variable capable of capturing the emergent functional behaviours of players attempting to intercept the trajectory of a pass in futsal (109).

Concurrent analysis of both an order and control parameter may offer further insight, allowing coaches and practitioners to identify desired behavioural tendencies that emerge in a dynamically changing dyadic sub–system, such as a one–on–one interaction in football. The relative distance of an attacker and the opposing defender to the goal may act as an order parameter while interpersonal distance may provide a suitable control parameter. At the moment of shooting, the mean values of relative distance to goal decrease significantly in plays ending in a goalkeeper save compared to in plays ending in a goal (111). This suggests that the defender may have constrained the attacker's shooting opportunity, applying defensive pressure and forcing the player to shoot sooner than necessary (111). Further, through analysis of a control parameter, interpersonal distances between the moment of ball reception and the subsequent shot on goal between the shooter and attacker decreased less in plays ending in a goal (111). Vilar et al. (111) revealed that in goal–scoring trials an attacker was able to reduce the distance to the goal while simultaneously increasing the distance to the nearest defender. This highlights that favourable concurrent changes in both an order, i.e. approaching closer to the goal, and a control parameter, i.e. increasing the distance to the nearest defender, can be identified in collective team sports and, in this context, may be ideal for promoting goal–

scoring affordances. Training strategies to enhance these elements of match–play may be beneficial for team success and should be sought.

Vilar et al. (37) additionally revealed that when there is a decrease in distance between the ball carrier and defender, the distance between the ball carrier and surrounding teammates decreases. It is suggested that teammates tend to approach the location of the ball carrier to afford a passing opportunity, increasing the chances to maintain ball possession (37). With this reduction in attacking–dyad distances to provide passing opportunities, support players should concomitantly focus on increasing values of interpersonal distance between themselves and the nearest defenders. This was made apparent by Vilar et al. (111), demonstrating that receiving shooters were further from their nearest defender at the moment of pass initiation from the ball carrier suggesting that fellow attacking teammates who can create separation from their opposing defender provide a more favourable affordance for passing. Furthermore, Grehaigne, Bouthier & David (116), through an analysis of 110 dynamical configurations in an 11–a–side context, highlighted that 102 configurations respected the principle of passing the ball into an open space, emphasising the importance of creating sufficient distance between teammates and their nearest defender. While defenders should try to reduce their distance to attackers to apply defensive pressure (111), surrounding teammates should make decisions that provide favourable affordances for the ball carrier, especially when under pressure, by advantageously positioning themselves in open space. Interestingly, while a tendency for greater ball velocity was present, studies have revealed no differences in ball velocity for successful and unsuccessful passes (108, 109). This emphasises the importance of spatiotemporal information, as provided by teammates and defenders, in providing affordances for a ball carrier.

While it is apparent that interpersonal distance and relative distance to goal afford opportunities to the ball carrier and attacking teammates (37), the analysis of relative angles may provide additional information for successful passing and shooting at an inter–player level. Literature has demonstrated that as well as remaining close to the goal, defenders tend to remain at the same relative angle to the ball and goal as the immediate attacker (Figure 5a), with the included vector angle from the defender to the attacker and goal increasing in plays ending in a defender’s interception (Figure 5b) (102, 111). This positioning allows the defender time to anticipate the attacker’s actions while remaining as close, in a stable fashion, as possible to the likely trajectory of a shot towards the goal (102). Conversely, a reduction in the included vector angle between the defender, attacker, and the goal affords successful goal–scoring opportunities (111).

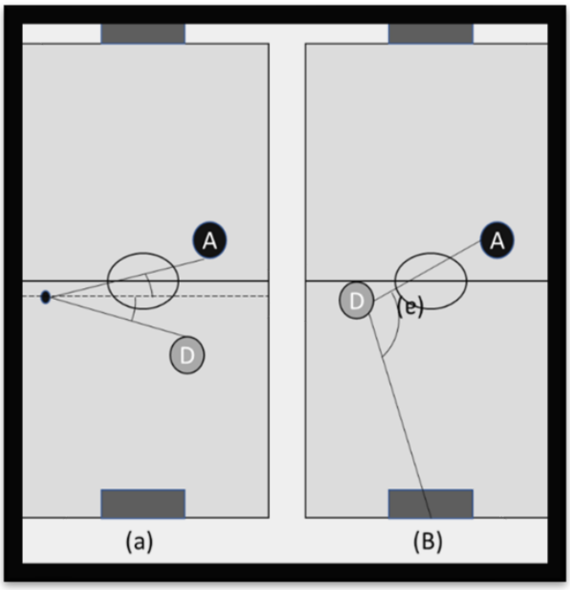


Figure 5: (a) Relative angle of the attacker (A) and the defender (D) to the ball (102) and (b) nearest defender's angle (ɐ) to the attacker and the centre of the goal (111)

Additionally, Corrêa et al. (114) identified that the included vector between ball carrier, nearest defender, and ball receiving teammate (Figure 6a) increased from ball reception to pass initiation. Further, in successful passes, this vector was greater and less variable than the included vector angle between the ball carrier, ball receiver, and the ball receiver's nearest defender (Figure 6b) (114). In essence, attacking players should explore the positional misalignment of the defenders in relation to the goal, in order to gain favourable goal–scoring affordances (102, 111). Furthermore, the literary findings imply that supporting teammates should continuously move to increase the passing vector angles to the ball carrier's nearest defender vector and the ball carrier's teammate's nearest defender vector (114). These results highlight how interpersonal angles can act as an informational specifying variable that collectively describes dynamically changing behaviour that emerges over time.

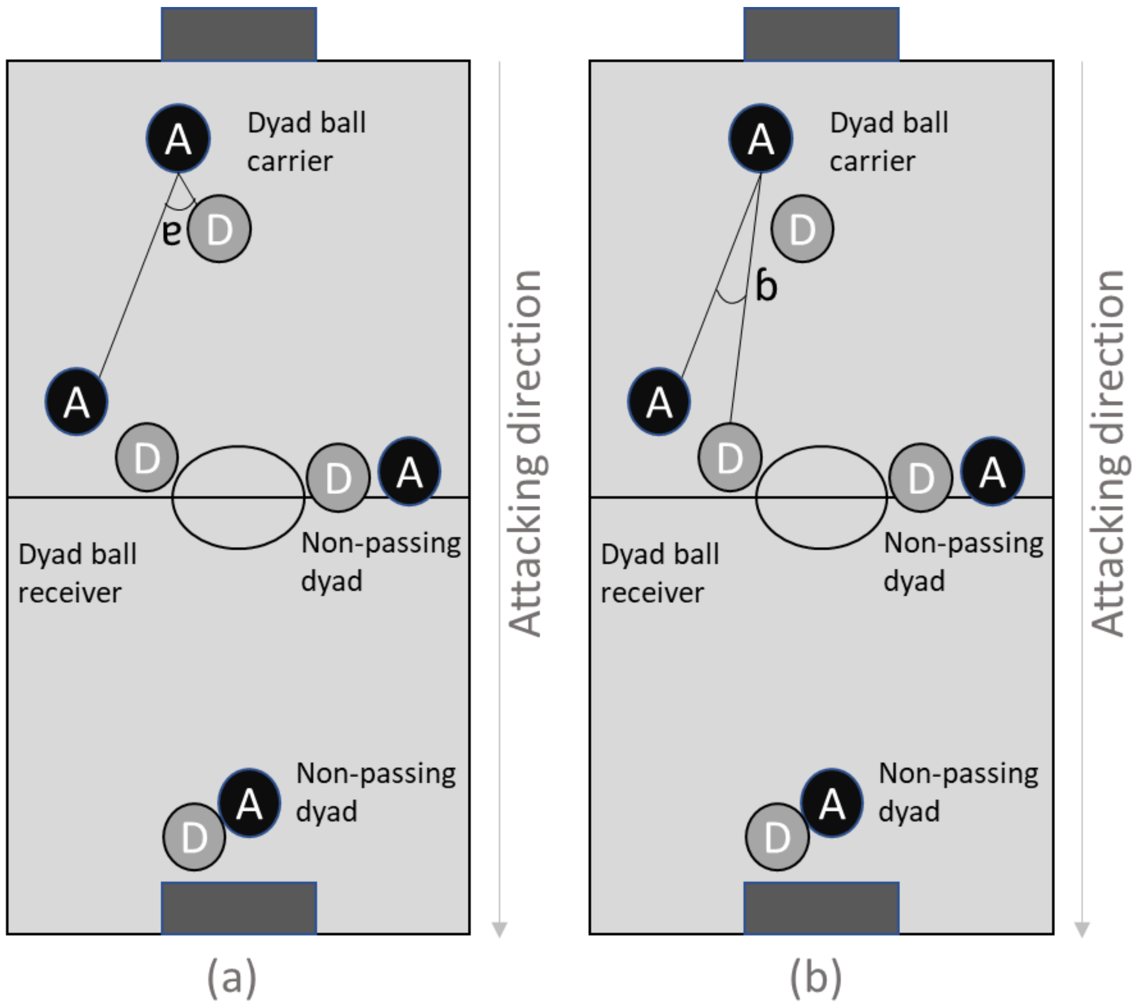


Figure 6: (a) Included vector between ball carrier, nearest defender, and ball receiving teammate and (b) included vector angle between the ball carrier, ball receiver, and the ball receiver's nearest defender. Figure adapted from (114)

The *variability* in spatiotemporal parameters may also act as a constraint on passing success. Research has revealed that there is a decrease in the *coefficient of variation (%)* in interpersonal distances from the moment at which a ball carrier passes to a teammate, to the proceeding moment of pass initiation by that individual to a fellow player (108). This temporary stability in the interpersonal distances within a team up to the moment of pass initiation signifies that interpersonal distances between players converge to a specific time window where a passing action emerged (108). Additionally, while large, favourable angles and distances to a teammate and goal were present, Corrêa et al. (104) revealed that there was greater variability in these measures when a ball carrier opted to dribble rather than pass or shoot. This demonstrates that even when there is a possibility to score a goal, the game's most desired target, or pass to a fellow teammate, the variability constrained the ball carrier to make a decision to dribble instead of pass (104). The research regarding variabilty in futsal is delimited to amateur players. As identified, professionals may better be able to harness variability, degenerately adapting to collectively achieve task outcomes. Playing ability may have constrained decision–making as amateurs may be less able to capitalise on positional variability of surrounding players. However, further research is required in a professional context, particularly in an 11–a–side format, to add clarity about the impact of variability on performance. If deemed as a determinant of performance, coaches may be able to design training drills that expose players to variable and noisy situations, much like the conditions evident in an in situ environment. For example, use of small–sided games, which are inherently noisy and variable (1), may be beneficial in providing the opportunity for players to co–adapt and harness this variability to achieve favourable outcomes.

Through the examination of behaviour at the macro–, meso–, and microscopic level of analysis, general patterns and behavioural trends between and within teams have been well identified. Throughout the match, teams positionally mirror each other, particularly in the longitudinal direction, whilst demonstrating a counter–phase relationship in measures of dispersion. During attacking phases of play, teams tend to expand, increasing interpersonal distances, moving in an unpredictable manner; conversely, during defensive phases, players tend to contract and move in synchrony, collectively positioning themselves between the opposition team and their goal. Of particular interest is that these patterns re–emerge with the concurrent examination of behaviour and performance outcomes (i.e. winning/losing or goals scored/goals prevented). The expansive, unpredictable behaviour that emerges in attack is deemed necessary to perturb defensive stability and consequently create goal–scoring opportunities. Additionally, winning teams demonstrate well–connected passing networks with decentralised tendencies where there are no focal players, i.e. each player has nearly the same connectivity. In contrast, when defending, the collective positioning of the team's centroid between that of the opposition and the goal while remaining in a synchronous, contracted state is required for defensive success. Similar patterns also emerge at the microscopic level of analysis, with attacking players moving unpredictably in an attempt to misalign their opposing defender to provide an opportunity to pass to a fellow teammate or score a goal. Alternatively, defenders remain between the attacking player and the goal and coordinate their actions with surrounding defenders to either intercept the ball or prevent these opportunities. Regardless of the phase of play, players need to move and act in a way that provides favourable affordances, or opportunities, for themselves and their teammates as it is the subsequent perception of, and attunement to, these affordances that allows players to co–adapt and achieve performance success. Accordingly, it is important to provide teams and individuals with an opportunity to create, perceive, attune, and act on different affordances prior to competition. Within a practice environment, appropriate manipulation of small–sided games may provide this opportunity and allow coaches to promote and develop favourable patterns of coordination on all levels of behaviour. The use of small–sided games provides an environment that mimics the perception–action couplings of in situ (match–play) performance and allows superior transferability of learned behaviour in this context to in–game performance (4, 6).

Tactical intervention using small–sided games

Quantifiable tactical information gathered from research can be utilised to appropriately design training tasks that promote similar, and favourable, behaviours to those seen in an *in situ* environment. Small–sided games are modified games played on reduced pitch dimensions, often using adapted rules and involving a smaller number of players than traditional games (2, 3). When designed appropriately in accordance with Pinder et al.'s (133) three key considerations for representative learning design (Table 2), small–sided games are considered a valuable tool to promote adaptive decision–making and coordination at all levels of the performer–environment sub–system.

Table 2: Three key considerations for designing representative tasks (133).

Consideration 1	Design dynamic interventions that consider interacting constraints on movement behaviours
Consideration 2	Adequately sample informational variables from the specific performance environments
Consideration 3	Ensure the functional coupling between perception and action processes

Practitioners and coaches have utilised small–sided games as a modality to improve performance through the development of an individual or team's ability to solve and overcome tactical challenges (2–5). The effective use of small–sided games allows performers to develop in a spatiotemporally varying training environment that reflects the formal and functional structure of a football game, with relevant informational constraints that reflect those of an official match (2, 4, 5, 112), despite being represented in a more manageable format in small–sided games. It is believed that small–sided games allow players to adjust their tactical behaviours, both individually and collectively, due to perceived information and opportunities for action (4, 6). This format of training facilitates the transfer of action and decision–making from the training process to the competitive context as it provides attractors and repellers, along with associated bifurcation points, that are representative of the traditional 11–a–side format of the game (4, 6). Small–sided games allow coaches to design and manipulate specific constraints (environmental, task, and goal) which guide players' exploration and discovery of solutions in metastable regions. This occurs through the continual perception and adaptation to a dynamically changing environment (2, 4, 6). The effect of these constraint manipulations on emergent behaviour is evident on three different scales of analysis – the macro–, meso– and microscopic level.

Macroscopic–level intervention

Small–sided games have demonstrated representative features at the inter–team level of coordination. The utilisation of numerical and spatial constraints, manipulated via the number of players (2v2, 3v3, 4v4, 5v4 and 5v5), as well as relative space per player, enable small–sided games to demonstrate similar patterns to those of the traditional 11–a–side format (8, 57, 59, 72, 79, 81, 83, 95). Similar to normal football match–play, centroid measures have demonstrated synchronous behaviour in both lateral and longitudinal directions (57, 59, 72, 79, 81, 83) as well as a converging or crossing of centroids prior to goal–scoring opportunities (8, 72). Further, utilising Voronoi diagrams, larger dominant regions for attacking teams have been demonstrated relative to the defending team (95), aligning with conventional notions that offensive teams attempt to increase team dispersion in order to explore potential goal–scoring affordances while, conversely, defensive teams contract to protect the goal and limit goal–scoring opportunities (66). It therefore appears appropriate, on a macroscopic scale, that incorporating this form of training may present teams with similar informational variables to those demonstrated in 11–a–side football. From an inter–team perspective, small–sided games may promote and/or preserve inter–team coordinative behaviour and decision–making as the presence of an opposition and ball provide relevant information that guides co–adaptive behaviour (73, 99). However, the precise constraints that are implemented in small–sided games and that act on and guide emergent behaviour require more extensive research to determine how manipulating small–sided games task–constraints, such as rules, line markings, etc., affect tactical behaviour on a macroscopic scale.

A common task constraint used in small–sided games is the manipulation of the number of players, or the relative (dis)proportion of attackers versus defenders. It has been demonstrated that from a 2– to 4–a–side format, distance between centroids decreases followed by an increase again within a 5–a–side format (42). For coaches attempting to encourage similar offensive patterns to those of an 11–a–side match, it is postulated that the utilisation of a 3– or 4–a–side format, as opposed to a 2– or 5–a–side, may be more appropriate to emulate the patterns that emerge in the traditional format. Additionally, as demonstrated in 11–a–side, a decrease in inter–team centroid positioning is associated with the primary attacking objective of the game, to advance up the field to create goal–scoring opportunities (73). Shorter distances between team centroids have been linked with higher pressure (8) and, from an attacking perspective, this may lead to a disruption in defensive stability. Conversely, using a 2– or 5–a–side format may promote effective defensive patterning as defenders conventionally try to preserve a greater distance between teams, minimising pressure and positioning themselves between the goal and the offensive team (8, 63, 65). Further, Almeida et al. (125) demonstrated that the majority of regained possessions occurred when two or more defenders were between the attackers and the goal in a 4v4 format. Additionally, using a 3–a–side format, Duarte et al. (59) revealed an increase in surface area of the offensive team as they approached the scoring zone, which was coupled with a decrease in centroid inter–team distances. Again, this aligns with traditional offensive patterns as attacking teams attempt to disturb defensive stability by increasing team dispersion, relative to the defence, and applying pressure to explore potential goal–scoring affordances (59, 66). It is apparent that a small manipulation in the number of players may adequately alter perceivable information in the performer–environment, creating significantly different co–adaptive behaviours.

Small manipulations in numerical inferiority and superiority can constrain or afford different offensive/defensive behaviours. Centroid analysis demonstrated increases in inter–team distances with numerical superiority in defence (5v5, 4v5 and 3v5) (6). Despite a numerical advantage, defending teams may still decide to prioritise the protection of their own goal and the minimisation of pressure, maintaining positioning between their goal and the attacking team, allowing enough time to co–evolve with offensive patterning (6, 8). Additionally, when numerically inferior in defence with one less player (5v5 vs 5v4) (81) or in the presence of two side–line floaters on the offensive team (7v7 + 2 floaters) (5), increases in centroid distances and team separateness have been demonstrated (see Table 2 at end of section). These findings may indicate an adjustment that affords the defending team more time to modify their individual and collective behaviours according to changes in ball and/or attacking movements (81). Further, numerical inferiority has also been associated with reductions in surface area in defence, signifying a relative contraction to protect the goal (81). It is suggested that defending players restrict space between themselves, and, consequently, the occupied area in front of goal, thereby restricting space for external kicks, such as diagonal or longitudinal passes to free players (81).

When faced with numerical inferiority in offense, attackers may also contribute to the increased separation evident between defending and attacking teams as the additional distance may allow more time and space for the attacking team to coordinate and search for attractors in the performer–environment landscape (6). Alternatively, numerical superiority in offense appears to afford decreases in inter–team distances along with heightened values of distance between the lateral lines of the overloaded team and the lateral lines of the underloaded team (Figure 7) (6). This decrease in inter–team distance may allow the attacking side to perturb the defensive line through additional pressure while greater *width* provides more relative dispersion, potentially affording further goal–scoring opportunities (6). It is clear that manipulation of the number of players reveals synergistic patterns and tactical behaviours that closely align with traditional patterns seen in the 11–a–side format of the game. In attack, providing teams with numerical superiority may facilitate a learning experience that allows players to become perceptually attuned to the shared affordances available as a result of overloading in specific spatial areas (6). Conversely, when inferiorly loaded, players may have to search metastable regions for alternative ways to stretch and perturb defensive *stability* to create goal–scoring opportunities. Similarly, in defence, despite being either over– or underloaded, the aim of defenders remains constant: to collectively position oneself between their own goal and the offensive team, often contracting to minimise goal–scoring opportunities (63, 65). Through the perception of affordances 'for' and 'of' others, defending teams can learn to coordinate and adapt to numerical differences, attuning to informational variables that may be present in an 11–a–side context.

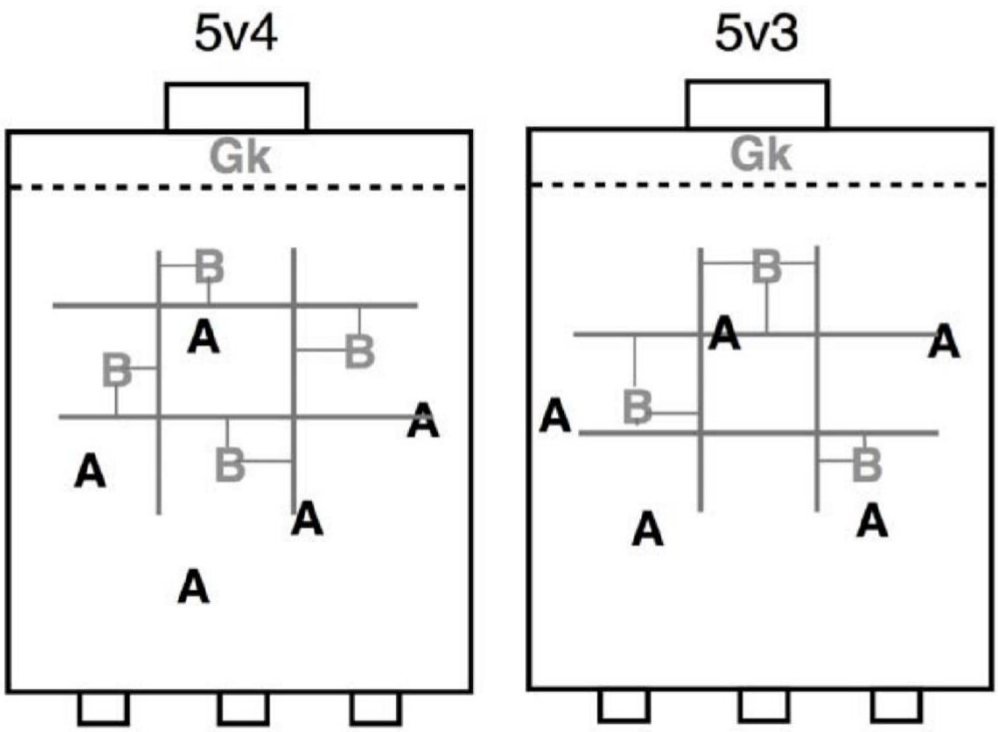


Figure 7: Heightened distance between lateral lines of the overloaded team (A) and underloaded team (B) (6), published under the Creative Commons license.

While varying the number of players can influence the relative space per player (57), manipulating pitch size can also alter this variable and consequently the affordances available to teams. Increases in pitch size have led to an elevation in team separateness which may favour defensive coordination (78). This separation allows the defending team additional time to modify positioning and movements relative to that of the attacking team (81). Alternatively, relatively narrower (30 x 16 m vs 30 x 20 m), and shorter (24 x 20 m vs 30 x 20 m), pitches have decreased inter–team distance which may favour attacking teams, providing more opportunities to perturb defensive lines (74). This attacking advantage is further exemplified through a decrease in centroid coupling in both lateral and longitudinal direction in shorter pitches and a decrease in the lateral direction in narrower pitches, with significantly more irregularity in distances to nearest opponents in smaller fields (74). This irregularity and instability between teams' centroids is synonymous with offensive success as it affords the attacking team with the opportunity to disrupt the defensive line, potentially leading to goal–scoring opportunities (16). However, it is important to note that effective decision–making is still required by offensive teams as they select affordances and attractors that lead to goal–scoring opportunities (15, 23).

Altering the goal–scoring modality can also guide inter–team synergistic behaviour. Increasing the number of goals, from one to upwards of three at each end, has concomitantly led to an increase in distance between team centroids (80) as well as team separateness (5). Use of multiple goals may force defenders to create distance between themselves and the offending team and, conversely, be harnessed by the attacking team in an attempt to stretch the opposition defenders and promote the creation of free spaces (5). However, contrary to traditional central goal–scoring modalities, Travassos et al. (80) found small decreases in relative stretch index, more time spent in left corridors and more time spent in defensive zones with the use of additional goals. While time spent in the defensive zone is expected, as defenders remain between the goal and attackers, the wider distribution may reflect tactical co–adaptation in defending teams. The use of multiple goals, as opposed to a single central goal, decreases the odds of regaining possession with elongated playing shapes, implicating the need for broader playing patterns (125). Players can defend more efficiently if they are able to cover and press most of the possible passing lines available for an opponent, implying that their ability to spread out and cover the width of the field is of importance in small–sided games with multiple goals (125). The use of additional goals potentially expands players' breadth of attention and perceived stimuli and has implications for improving tactical performance as defending teams coordinate and search for new affordances to cope with modified scoring modalities while attackers try to break defensive stability and search for scoring opportunities (80). Alternatively, the use of additional goals may be primarily used to augment relevant information for attacking players as they co–adapt and make decisions that will stretch and perturb the defensive line, providing more free space for passing and shooting opportunities.

While manipulating the number of players, pitch size, scoring modality, and tactical strategies can influence inter–team coordinative behaviour, external influences such as match status, location, quality of opposition and vignettes can also constrain emergent patterns of behaviour and should be considered when designing small–sided games. Tactical analysis in 11–a–side football has revealed that, when losing, there is a tendency for teams to defend in more advanced pitch zones (Figure 8). This may be to apply defensive pressure by decreasing inter–team distances, attempting to force a turnover (8). A similar pattern also emerges when teams are playing at home (90). It was suggested that home crowd support is associated with an increased functional aggressive response, which, consequently, enhances the effectiveness of defensive actions such as interceptions and tackles (134). Further, independent of these factors, higher ranked teams have proven to be more effective at applying defensive pressure in more advanced pitch zones and have dominated ball possession, as identified through notational analysis, demonstrating more stable patterns of play independent of the evolving score line (90). While traditionally it has been thought that greater inter–team distance is necessary for successful defensive performance, the findings of this study, despite no *centroid* or macroscopic–level measures, suggests that defensive strategies implemented by relatively superior teams utilise more intense and organised collective processes to pressure the opposing team, particularly away from their own goal (90). Superiorly ranked teams may not require extensive amounts of time and space to modify their behaviours relative to those of the attacking team as previously thought due to an elevated ability to collectively, and efficiently, attune to relevant environmental information that affords goal–directed activity (81). Identifying the impact of these external influences may appropriately guide training design as the emulation of these specific factors may afford teams, and players, with an opportunity to coordinate and co–adapt to specific situations in a representative environment.

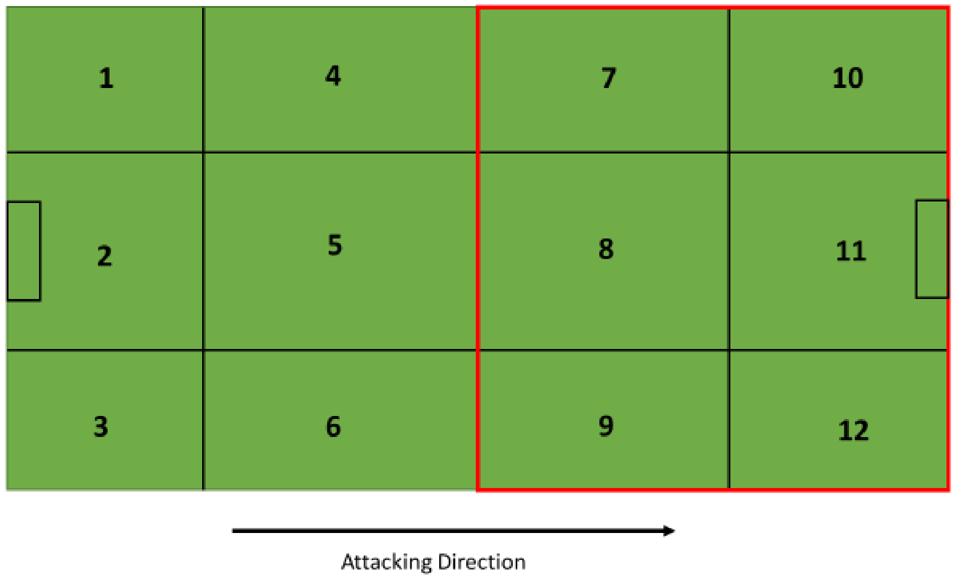


Figure 8: Red square signifying advanced pitch zones (zone 7–12)

Coaches and practitioners can incorporate vignettes or manipulate games with specific scenarios, such as a team initially starting behind on the scoreboard, to promote different adaptive behaviours (135). In sport, performers must adapt to constraints and conditions whilst concurrently performing under different emotional states that in turn constrain player perception and action (135). Traditional models generally view emotions as negative or detrimental in performance and have accordingly attempted to remove this aspect from practice task contexts until desired skills have been established. However, this reductionist approach may inadequately challenge performers from a cognitive perspective, subsequently rendering performers unprepared for the emotion–laden experiences that are inevitable in a sporting context (136). Implementing vignettes or scenarios, such as being in front or behind on the scoreboard with a specific amount of time remaining, within a training context may allow performers to experience the emotional feelings associated with specific match–contexts in a learning environment that simulates the external task demands of a new environment (135). This style of representative learning may promote effective development of skill and expertise in sport, allowing performers to achieve functional task outcomes in a variety of different scenarios under different affective constraints. However, further research is required to elucidate the impact of affective constraints and learning on cognition, perception, and resultant team and player behaviour in a football context (135). Further examination of the influence of these components on intra–team behaviour, in a training environment, may provide insight as to why specific behaviour emerges between two opposing teams in certain situations.

Mesoscopic intervention

Intra–team coordination can improve with appropriate training utilising 11–a–side training. One study revealed an improvement in team ability to reciprocally compensate as demonstrated by the readjustment delays between the co–positioning of team members, consequently enabling faster regulation of coordinated team actions (56). This highlights that intra–team coordination is a trainable phenomenon and warrants further investigation into different modalities that coaches and practitioners can implement to induce co–adaptive improvements at this level. Similar to the macroscopic scale, small–sided games appear to be an appropriate format of intervention on the mesoscopic level. Providing a format with fewer players than the traditional 11–a–side format (42, 57, 58, 60, 62, 71, 77, 78, 94, 98, 122), along with the manipulation of levels of inferiority or superiority (4, 6, 79, 81, 85, 95, 128), pitch size (57, 60, 62, 94), and goal type (5), coaches and practitioners can improve coordinative behaviour in a training environment that enables performers to act and perceive in a way that is representative of an 11–a–side match.

Similar to 11–a–side training implementation (56), adopting a 5–a–side training format over a 13–week period in amateur players has induced improvements in intra–team coordination as indicated by increases in longitudinal synchronicity, regularity in player displacements and dispersion measures (77). Equal manipulation in the number of players on each team appears to afford relevant mesoscopic coordinative behaviours. Increasing the number of players from 2– to 10–a–side (particularly 3– to 5–a–side) appears to promote an increase in dispersion measures (42, 57, 94) along with regularity (42, 94) (see Table 2 at the end of the section).

Whether there is an increase in the number of players with a concomitant increase in pitch size (42) while keeping relative space per player the same, or a decrease in relative space per player with an increase in player numbers on the same sized pitch (57, 94), dispersion and regularity increase. With a smaller number of players, participants need to move continuously and often irregularly in close proximity to the ball to create passing opportunities for teammates. Conversely, a format with more players requires players to harness degeneracy to enable co–adaptation to new spatiotemporal constraints in the form of less relative space per player (57). As players need to develop their activity in a larger area, roles become more specific and are not always involved or required to be in close proximity with the ball (42). Further, the increase in tactical dispersion is representative of that found in offense in an 11–a–side format whereby players spread in search for goal–scoring affordance (66). Additionally, via manipulating of relative space per player using the number of players on field, i.e. 7v7 to 9v9, Silva et al. (94) revealed superior measures of dispersion and regularity than when space was manipulated by dimensions. The increase in regularity and dispersion with the number of players infers that training stable tactical coordination requires the use of a higher number of players, suggesting that 4– or 5–a–side formats appear to be adequate to promote team–related emergent and self–organised behaviour. However, the smaller formats (2– and 3–a–side) associated with game unpredictability (42), may allow players to harness irregularity in an attempt to destabilise defensive teams. This intra–team unpredictability has been associated with offensive success in an 11–a–side format (16, 66, 129).

Manipulating numbers to promote offensive or defensive superiority/inferiority can encourage favourable intra–team patterns of performance (see Table 2 at the end of the section). When numerically superior in a 5v3 (6), 5v4 (6, 81, 85, 95), 4v3, 7v4 (85) format, or with floaters (4+2 floaters v 4) (4), teams in possession of the ball tend to increase dispersion while numerically inferior teams contract in defence (4, 6, 81, 85, 95). The use of additional players may provide players with an opportunity to create numerical advantages in offense by selectively picking up shared affordances that consequently lead to passing and goal–scoring attractors (6). Alternatively, defending in numerically inferior situations may promote team defensive stability as teams decrease space between players during defensive organisation in an attempt to reduce passing and shooting affordances available for the opposition (4). Furthermore, an increase in the number of opponents has revealed stronger in–phase relations between defending players and the ball (79, 81), indicating that, when faced with a numerical disadvantage, defenders prioritise the protection of the goal against ball displacements rather than against movements of the attackers. On the contrary, attacking teams have demonstrated greater phase variability between players and the ball. This may reflect an emphasis being placed on the constant probing as a result of playing against an organised defensive structure in an attempt to increase action possibilities for goal scoring (79).

Furthermore, when looking at manipulations of superiority and inferiority in the design of small–sided games, differences are apparent between professionals and amateurs. In high inferiority scenarios, amateurs generally reduce distances to their own centroid. A lower degree of contraction in professionals may reflect an anticipation of the importance of optimising collective decision–making and may be linked to improved decisions based on opponents' positioning information (85). Elite players may make improved decisions based on affordances perceived at an earlier stage in the decision–making process. Additionally, the superior skill levels of experts may also afford them the ability to defend relatively larger areas of 'individual space'. Furthermore, amateurs reveal a greater increase in regularity with higher teammate numbers. It is suggested that the presence of more teammates is associated with the self–organisation process and the effect of this is amplified in amateur players (85). Professional players have also demonstrated similar area distributions and stretch indices in balanced (5v5) and numerically inferior (5v4) scenarios, indicating that dropping a player isn't enough to disturb coordination tendencies (6). Additionally, in these scenarios, professional players have demonstrated dispersed dominant regions to a greater extent, compared to those of amateurs, which were more superimposed (Figure 9) (6). The above examples highlight that professionals are able to maintain a more balanced distribution, degenerately adapting to different numerical constraints allowing the maintenance of intra–team coordination (6). Gradually increasing inferiority, or increasing superiority, may also probe the stability of their coordinated behaviour. It is apparent that varying the number of opponents to elicit numerical inferiority may be more suitable to improve professional collective decision–making tactical performance as this induces increased team–related functional adaptations. Alternatively, manipulating the number of teammates to provide numerical superiority might emphasise the amateur players' local perceptions, augmenting relevant environmental information and affordances (85).

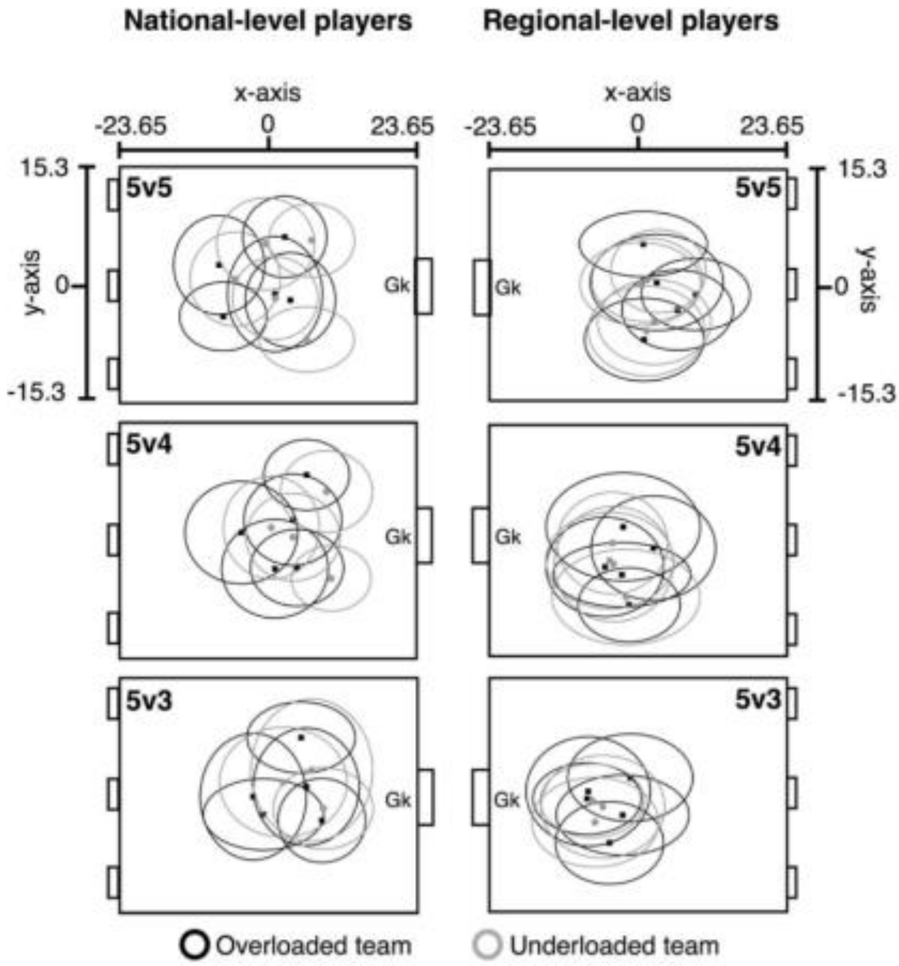


Figure 9: Comparison of dominant regions demonstrated by professional and amateur players under different numerical constraints (6), published under the Creative Commons License.

When considering pitch size, Silva et al. (60) demonstrated that U18 players in a 5v5 game increased dispersion from their preferred zone in a more regular manner with an increase in pitch size. This study also revealed that national league players demonstrate higher variability, as evidenced by the higher coefficient of variation in movement trajectories. On larger pitches, the increase in dispersion and regularity may be explained by the need for players to self–organise into specific roles and positions to ensure a balanced occupation of the full playing field (60). Furthermore, the increase in the coefficient of variation highlights the need for players to move more and explore space on smaller fields to promote affordances (60). Conversely, on smaller pitches, national league players revealed less regularity and variability in comparison to regional players (60). Lower levels of regularity may reflect the higher frequency of perturbations with more tackles, shots, challenges, and changes in ball possession occurring due to the reduced playing area or, alternatively, the degenerate ability of higher–level players to co–adapt with less relative space per player (60). Further, the lower variability demonstrated by skilled players may reflect their superior ability to search for and move to more variable areas of the pitch to cope with the constraints imposed by smaller spaces, while simultaneously maintaining higher consistency in the distances to their preferred zone (60). Accordingly, coaches can manipulate field dimensions to afford learning opportunities for professionals and amateurs alike as both appear to respond similarly to changes in field size. However, this may be more appropriate for amateur players. Despite demonstrating similar tendencies to those of elite players, these behaviours may be less pronounced or prevalent. Utilising a large field (57.8 x 37.4 m) may force attacking players to search for affordances resulting in highly variable behaviour, while, conversely, a small field (36.8 x 23.8 m) may promote more stable patterns of behaviour (60).

As pitch size provides different affordances for coordinative behaviour and decision–making, it appears that area of occupancy during team possession influences the shape of dispersion. Rectangular surface area measures in a professional 11–a–side format were analysed to guide modifications in pitch dimensions for small–sided games (91). This study identified that the rectangular surface area width, covered by players on the field, was generally greater than the length, with the exception of when the ball carriers were in the zone closest to either goal, with length equalling the width. While the above information did not consider measures with respect to successful and unsuccessful patterns of play, it is suggested that the midfield area is where play is established with a transition from defensive to offensive patterning. Players therefore disperse laterally to deal with the concentration of players, attempting to provide passing affordances for teammates in this area (91). Interestingly, one study revealed that playing length per width ratio increased with pitch size for national league players but remained relatively constant for regional players (78). This may reflect an offensive strategy to approach the goals more quickly in larger areas by playing preferably outstretched in the goal–to–goal direction, affording longer passes for teammates (78). Based on 11–a–side area measures, Fradua et al. (103) suggested that pitch sizes with individual areas between 70–110 m^2 with a length to width ratio of 1:1 should be utilised for training offensive build–up and finishing phases of play, while practitioners and coaches should incorporate smaller individual playing areas to train transitioning (65–95 m^2) with a L:W of 1:1.3 (91).

Goal type and defensive strategy need to be considered when designing small–sided games. Castellano et al. (5) revealed that team shapes were more elongated in defence except for a small goal condition (two small goals at each end measuring 2.5 m wide and 1 m high at either end of the goal line) (Figure 10), where players were more dispersed laterally. While utilising two smaller goals at each end induces favourable patterns of dispersion in offence, allowing attacking players to spread in search for goal–scoring affordances, this format may be detrimental to defensive patterning. Defensive dispersion may be contraindicative to the desired 11–a–side formation as, with only one goal, teams in the defensive phase often accumulate players to defend one goal situated on the goal line on the central axis of the pitch (5). As noted, increasing the number of goals may primarily benefit attacking passages of play as it augments a favourable situation whereby the defending line is perturbed and dispersed. Additionally, when utilising a zone defence over man–to–man defence, players spend more time in synchrony, particularly in the lateral direction (98). This lateral synchrony may be beneficial as Gonçalves et al. (49) suggested that there is a need to reduce lateral spaces in defence as the occupation of the lateral corridors by attackers is considered to be the greatest destabilising factor of defensive organisation since the critical game periods appear to be associated with changes in lateral distance between teams (49). On the contrary, man–to–man defence entails following an opposing player who is trying to create space and perturb the system (98). Inherently, following variable attackers will likely lead to asynchronous behaviour in defence. These differences provide the opportunity for coaches to optimally prescribe training drills in order to promote desired defensive behaviour. Further, from an offensive perspective in a 5v5 format, when facing a conservative defence such as zone defence, professional football teams have revealed increases in the number of passes between field zones, higher levels of reciprocal passing between different areas, superior closeness centralisation values and higher betweenness (58). This signifies that incorporating a conservative defensive pattern in small–sided games may force attacking players to explore different areas of the field with greater dispersion of ball passing trajectories in the search for goal–scoring opportunities (58).

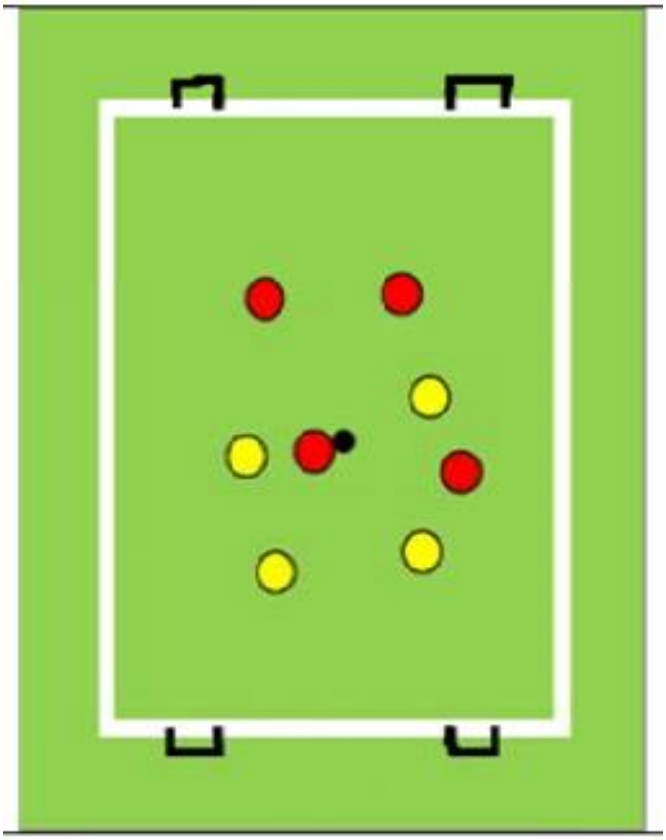


Figure 10: Small–sided game format utilising small (2.5 x 1 m) goals at either end of a 40 x 20m pitch (5), published under the Creative Commons license.

Lastly, the timescale used for small–sided games is important. Over shorter periods, play is characterised by high intra–team variability while, conversely, longer periods allow enough time for players to co–adapt to one another, resulting in superior levels of synchronicity (64, 128). This may be particularly important for younger players, as older players have demonstrated less variability in dispersion measures (71, 88). However, despite differences in dispersion measures, analysis of cooperative network variables from U12s through to U16s revealed no difference in centrality measures in a 5v5 format. Additionally, Costa et al. (138) revealed no systematic advantage for U11–U17 players born early in the selection year vs those born later when considering tactical aspects (126). It was observed that players with birthdays across the span of the selection year had similar movement patterns and tactical performance indexes (126). From this, it can be inferred that players of different ages should benefit in a similar capacity independent of the timescale employed within a small–sided game.

While small–sided games and tasks are often governed by time, a player–driven criterion approach, whereby players decide what the goal or outcomes of the small–sided game/drill should be, can be adopted. This approach requires players involved to agree about the basic assumptions such as what the situation is, what can be done about it, and what should be done about it (137). Collectively, players then agree upon what the desired outcome will be and the best way to achieve this. This process fosters intra–team coordinative behaviour via collective intelligence where initially independent agents, or players, develop a unified approach to solving a shared problem. Upon the agreeance of a desired outcome, all players involved implicitly become attuned to desirable affordances for action that will allow the achievement of the agreed upon outcome. This collective action provides many functional advantages and has led to superior performance of groups over single organisms in a wide array of human social phenomena (138). As an example, in football, a criterion approach can be incorporated within a small–sided game with vignettes whereby a team (team A) initially begin the game losing to the opposition team (team B) by one goal. As the overarching goal of soccer is to score more goals than the opposition team, team A as a collective group may decide that in order to achieve this, they need more possession of the ball whilst concurrently limiting team B's scoring opportunities. This subsequently leads to the common agreement that when in defence, they need to force more early turnovers. As a result, team A decide they need to force five turnovers in order to provide themselves with the opportunity to score. The drill then continues until five turnovers have been achieved, regardless of the amount of time that has passed. This process whereby players agree on an outcome solution will result in the implicit attunement to specific affordances that allow players to coordinate behaviour at an intra–team level, resulting in the achievement of goal outcomes.

Microscopic intervention

Small–sided games may provide a suitable environment for guiding emergent behaviour and decision–making on a microscopic level. Manipulating pitch size (2, 78) and incorporating superiority and inferiority scenarios (81, 85, 95, 112), as well as zone constraints (106, 107), can influence inter–player co–adaptation. Similar to mesoscopic intervention, improvement in inter–player lateral and longitudinal synchronisation has been demonstrated following a 9–a–side, half–pitch, pre–season training protocol with professional football players (105). This highlights that the use of small–sided games is an appropriate choice to promote the simultaneous development of physical, technical, and tactical skills for football players (105).

On a smaller scale, in an isolated 1v1 attacker–defender dyadic drill context, specific inter–player distances (40, 46), velocities (40), and relative angles (100) may act as control parameters that identify when players enter a transition phase (40). This phase precedes the perturbation of the system stability that exists between two players. Through co–adaptation to new emergent affordances and constraints, one of two qualitative states emerges: 1) The defender maintains stability and minimises attacker scoring affordances, remaining nearer to the goal than the attacker or 2) The attacker breaks system stability and passes the defender towards the goal providing a scoring opportunity (40). When beginning in a 5 m (width) x 10 m (length) area in the defensive zone, defenders have maintained a distance of on average two metres between themselves and the opposing attacker before being destabilised. This distance may reflect the intentions of opposing players. Defenders cannot afford to risk positioning, attempting to remain between the attacker and the goal, while attackers can afford to wait for an opportunity (3). Conversely, when defending in the opposition's defensive area in a 5 x 10 m area, only a brief interpersonal distance of 1.2 m is maintained before being destabilised. Similarly, this may reflect conflicting intentions with attackers attempting to move away from their goal as quickly as possible while defenders try to take advantage of the field position (3). Evidently, while different stable patterns of interpersonal distance emerge, these distances appear to be constrained by the proximity–to–goal as well as the intention of the players (3, 100) and such elements should be considered by coaches when prescribing training.

Furthermore, for attacking players, the proximity–to–goal affords different relative angular opportunities between the defender and the goal. In the midfield, for example, larger relative angles to the goal have been observed (100). This increase in angular amplitude reflects an attempt of the attacker to overtake the defender in this transition zone (40, 46). Further, in the lateral part of the attacking zone, the relative angle to the goal is affected by foot preference, i.e. either left– or right–footed (100). On the left–hand side of the attacking zone, a left–footed attack trying to shoot will likely be afforded with a lower relative angle, hindering scoring opportunities. This reduced angle occurs as they orientate and move laterally to the left, away from the centre of the goal, in an attempt to misalign the defender to kick with their left foot. Conversely, a right–footed attacker in the left–hand side attack zone will be afforded with a larger relative angle, as this player can orientate and move towards the central parts of the pitch to afford a misalignment and a consequential scoring opportunity (100). Once again, in a 1v1 contest, the relative position to the goal is a key informational variable that sustains participants' behaviours for dribbling and shooting (100). Lastly, Clemente et al. (46) revealed an increase in relative velocity as an attacker attempts to overtake the defender. This speed increase is harnessed in an attempt to destabilise dyadic stability (46). This aligns with Duarte et al. (40), who revealed that at critical interpersonal distances between 1–2.5 metres, the relative velocity determined the outcome of phase transitions, with superior attacking velocity associated with destabilising the attacker–defender dyadic synchrony (Figure 11). For coaches and practitioners, it is important to consider the relative velocities, distances and angular positioning along with the proximity–to–goal when designing practice tasks.

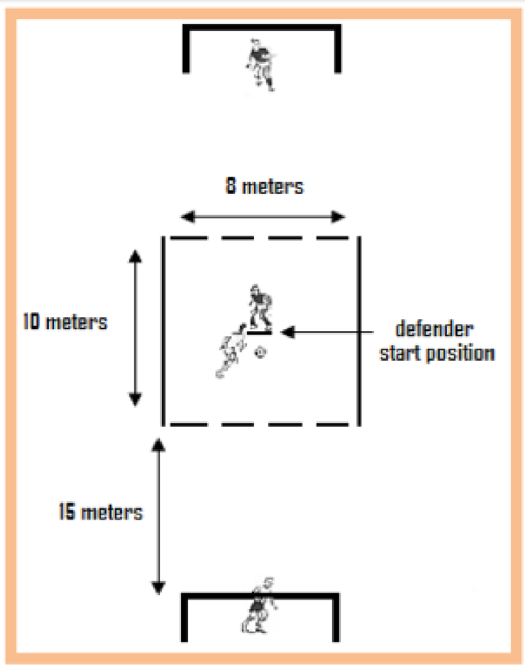


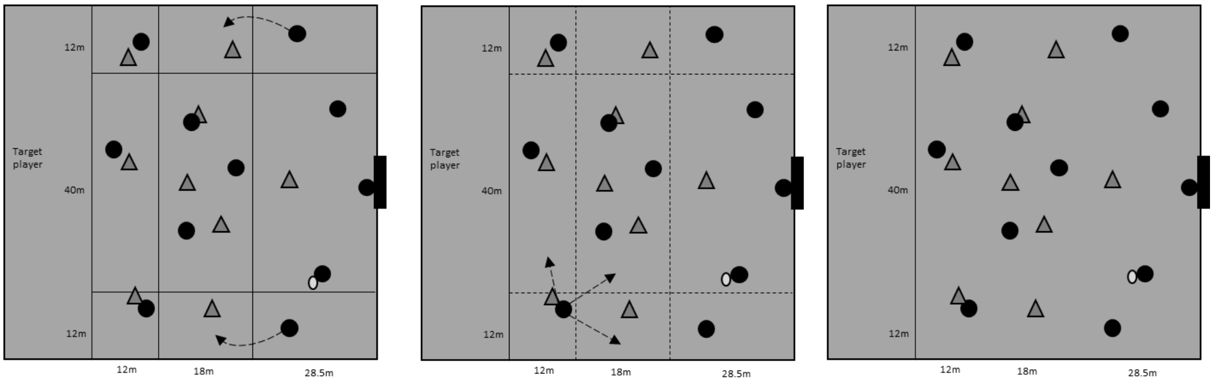
Figure 11: (a) Starting position of two players at a distance of 1–2.5m apart in a 1v1 contest drill (40), published under the Creative Commons License.

Numerically manipulating the degree of superiority or inferiority can constrain inter–player coordination. Mean values of relative distance of a defender to an interception line, which is the distance needed to intercept the trajectory of a shot or pass, were higher in inferior defending scenarios (5v4 and 5v3 compared to 5v5) (112). Due to the defensive inferiority task constraint, an increase in interpersonal distance between interacting attackers was also apparent, allowing an increase in opportunities for attackers to maintain ball possession. Further, four passing opportunities with only three defenders (5v3) makes it difficult for defenders to simultaneously remain close to all ball trajectories and fewer defenders may make it difficult for the defending team to remain between attackers and the centre of the goal to prevent scoring opportunities (112). The spatial variation on field, due to numerical inferiority, also leads to an increase in the attacking team's affordances to perform passes and shots at goal (112).

Gonçalves et al. (85) also revealed a decrease in distance to nearest opponent, with a concomitant increase in regularity with increases in the number of opponents (4v5 and 4v7 compared to 4v3) in both professional and amateur players (see Table 2 at the end of the section). It is suggested that the increase in regularity may be linked to improved decisions emphasised in opponents' positioning information (85). Further, amateurs demonstrated greater distances and less regularity in distance to nearest opponent in comparison to professionals. This aligns with Vilar et al.'s (112) finding that amateur players demonstrate greater interpersonal distances in inferior game situations (5v3 and 5v4 compared with 5v5). These higher distances may reflect retrieval towards goal and contraction to protect the goal where professionals can continually press to apply pressure (71). Conversely, when numerically superior (7v4 and 5v4 compared to 3v4), only professional players demonstrated increases in distance and regularity to nearest opponent. This highlights that professional teams could be more effective when playing against fewer opponents through anticipating the need to optimise collective behaviour and effectively exploiting unpredictable behaviours to attack and disrupt the opponents' organisation (71). Superiority may not be adequate to provide amateurs with an adequate stimulus to be more irregular and to solve the tactical problem (71). As identified through analysis of patterns for performance on a microscopic scale, occupation of available open space may be favourable for breaking opponents' structure organisation and affording passing and shooting opportunities for others (71). These findings emphasise how numerical constraints in small–sided games can be manipulated to vary values of key spatial and temporal performance variables which, consequently, influence the nature of interpersonal interactions between competing players during practice (112).

When appropriately manipulated, pitch size can also constrain emergent behaviour and induce desirable movement patterns. It is clear that the implementation of smaller pitches (28 x 14 m, 40 x 20 m and 52 x 26 m) results in smaller interpersonal distances, affording attacking players few opportunities to maintain ball possession (2). Conversely, pitch size does not appear to influence opportunities for players to shoot at goal, or to perform passes to other teammates (2). Furthermore, national league players have demonstrated greater irregularity in distance to nearest opponent in small (36.8 × 23.8 m) and intermediate (47.3 × 30.6 m) fields in comparison to large (57.8 × 37.4 m) fields (78). Increased irregularity demonstrated by national league players on relatively smaller pitches may be related to a heightened ability to perform 'off–the ball' movements more often in an attempt to evade their defender and create free space in order to maintain or receive ball possession (78). Furthermore, as identified in patterns for performance, amateur players only pass under conditions where variation is minimal. This may reflect the increased regularity displayed by lower–level players on smaller pitches, unable to utilise variability to degenerately achieve task outcomes. Appropriately manipulating pitch dimensions of small–sided games might enhance opportunities for amateurs to utilise variability and to acquire specific movement and decision–making skills (2). For example, when trying to improve an amateur's ability to utilise variable behaviour in attacking sequences of play, it may be appropriate to begin with a 5v5 drill design utilising a large (52 x 26 m) field and gradually progress to an intermediate (40 x 20 m) sized field as their ability to harness degenerate behaviour improves (2). Following this, a small (28 x 12 m) field may be used to further challenge players. In contrast, due to the enhanced ability of professionals to utilise degenerate behaviour, coaches may initially utilise a 5v5 small–sided game on a small field.

While the manipulation of pitch dimensions can alter dyadic relationships, constraining players to certain areas of the pitch may hinder the emergence of favourable inter–player coordinative behaviour (see Table 2 at the end of the section). Gonçalves et al. (106) revealed higher levels of synchronisation between dyad displacements for contiguous– (any player, one at a time, can move to adjacent areas of field) and free–spacing (no–restriction) conditions in comparison to restricted spacing (limited to one single area of nine in the field) (Figure 12). Further, a higher coefficient of variation, accompanied by greater regularity, in teammate inter–dyad distances were evident in contiguous– and free–spacing conditions in comparison to the restricted condition. Greater variability of behaviour has been viewed as an important means to understand players' ability to explore the environmental opportunities for action, while higher regularity signifies the collective co–adaptation to environmental constraints and affordances (106). Ric et al. (107) also revealed greater instability in free–spacing conditions with a concurrent decrease in the time in possession in comparison to contiguous– and restricted–spacing conditions. This study revealed that players' long–term exploratory behaviour increases in free–spacing conditions while, conversely, short–term exploration increases in restricted–spacing conditions (107). It appears that the effects of limiting players' spatial exploration greatly impairs the effective regulation of behaviour between teammates' positioning due to less variability and predictability in players' behaviour (106). Interestingly, the researchers also revealed an increase in physical and physiological parameters, along with player exertion, with the reduction in spacing restrictions. Considering the similarity of tactical results between contiguous– and free–spacing scenarios, coaches and practitioners may promote similar collective behaviour in practice, while eliciting different physical and physiological demands. From the workload perspective, using pitch area restrictions may be useful to manage the physical and physiological stimuli while highlighting specific positioning role demands and maintaining the tactical focus (106).



(a) (b) (c)

Figure 12: (a) Restricted–spacing constraint with the pitch divided into nine playing areas and players assigned according to their specific playing position and not allowed to move out during the game with exception made to the two lateral defenders from the 10 player team; (b) contiguous–spacing constraint with the pitch divided into nine playing areas where any player (but only one for each team) is allowed to move to a neighbouring area; and (c) free–spacing constraint where players have no restrictions in space occupation (106)

Tactical intervention summary

Table 3 below reveals ensuing patterns of coordination preceding the implementation of varying constraints in small–sided games. When utilised with reference to favourable, or desired, performance outcomes, small–sided games appear to effectively guide players towards specific behavioural outcomes. The appropriate imposing constraints can actively challenge players to adapt to variable situations, allowing the achievement of task outcomes in a variety of ways. Table 3 also reveals a variety of shortcomings in the small–sided games literature. The blank spaces in the table identify areas that, at the time of writing (anno 2020) require clarification or further research regarding emergent tactical behaviour in football.

Table 3: Review summary of tactically induced patterns using small–sided games

Scale	Macroscopic (Inter-team)										Mesoscopic (Intra-team)								Microscopic (Inter-player)														
Status	Attack					Defence					Attack				Defence				Attacking Dyads					Defending Dyads					Opposing Attacker-Defender Dyads				
	TS	Disp	CSyn	Reg	CVar	TS	Disp	CSyn	Reg	CVar	Disp	Sync	Reg	Var	Disp	Sync	Reg	Var	ID	Ang	Sync	Reg	Var	ID to intercept	Ang	Sync	Reg	Var	ID	Ang	Sync	Reg	Var
↑ in players 2-4	↓					↓					↑		↑		↑		↑																
↑ in players 5-10	↑					↑																											
↑ inferiority	↑					↑	↓					↓		↑	↓	↑		↓						↑					↓			↑	
↑ Superiority	↓	↑				↑					↑			↑			↑		↑										↑			↑	
↑ Pitch Size	↑		↑	↑	↓	↑		↑	↑	↓	↑		↑	↑	↑		↑	↑						~					↑			↑	
↑ in goals	↑	↑				↑	↑				↑				↑																		
↑spatial restriction																					↓	↓	↓			↓	↓	↓					
Winning v Losing	↑					↑																											
Home v Away	↓					↓																											
Playing High vs. low ranked team	↓					↓					↓				↑						↑					↑							
1st vs 2nd half			↑		↓			↑		↓	↑	↓	↓		↑		↓	↓															
Zone Def v Man-on	↑		↓		↑	↑		↓		↑						↑																	
Non-congested vs congested												↑				↑					↑					↑							
↑ Drill time												↑		↓		↑		↓															

Note: TS = Team separation, Disp = Dispersion, CSyn = Centroid Synchrony, Reg = Regularity, CVar = Centroid Variability, Sync = Synchronicity, Var = Variability, ID = Interpersonal Distance, Ang = Interpersonal angle

Directions for future research

Each of the studies included in this review used a male cohort, making it difficult to transpose findings into a female context. The expansion of this research using female cohorts is essential given the some of the differences in match–play styles between genders. At the professional level, males have demonstrated superior running demands and pass completion rates throughout a match along with fewer turnovers in possession, all of which are likely to influence, or be influenced by, emergent coordinative behaviour (139). Additionally, while few studies offer superior insight through analysis of behaviour in relation to successful and unsuccessful performances, i.e. goal–scoring opportunities or ball turnovers, most research failed to contextualise performance in relation to tactical intent. For example, analysis of zone and man–to–man defence both reveal conflicting effects on synchronicity and variability (98). A man–on–man defensive style will often result in defensive asymmetry and lack of coordination, as the defending team's emergent behaviour is guided by the opposition's displacement (98). However, through the analysis of goal–scoring opportunities, the disruption in defensive stability, as marked by changes in synchronicity and variability, has been associated with attacking success (129). Whether this defensive disruption is a result of attacking behaviour, sufficiently perturbing the defence, or if it was tactically intended by the defending team, is rarely clarified in the studies reviewed here. If a defending team is utilising a man–on–man defence, this asynchrony may be deemed favourable as this signifies that players may be using the offensive team to guide behaviour. In contrast, if the intention was to use a zone defence where success is marked by synchronistic behaviour, then the disruption in stability, likely due to offensive perturbation, may be deemed unfavourable. Likewise, in offense, if the intent or coaches' instruction is to be unpredictable and asynchronistic, then tactical analysis revealing this will signify offensive success. Alternatively, if the attacking team are trying to move as a singular entity, moving in a coordinated way, then increases in variability or unpredictability may be counter to performance outcomes. Therefore, it is important to identify or contextualise tactical intent regarding attacking or defending behaviour as this constrains and guides emergent behaviour (3).

On a macroscopic scale of analysis, while the potential to provide further understanding has been recognised, Voronoi diagrams are yet to be implemented in an 11–a–side context and associated with performance. This tool has the ability to account for every player and can effectively describe spatiotemporal relationships at both an inter–individual and inter–team level (96). Incorporating this method of analysis may clarify existing ideas surrounding effective patterns of dispersion in attack and defence. Furthermore, a link between relative dispersion measures and the associated variability in these measures is also required. While increases in dispersion accompanied by heightened variability have been associated with attacking success at an intra–team level, this was observed in isolation of the opposing team's behaviour patterns. Incorporating these measures on an inter–team scale may offer further insight regarding how players should collectively move and disperse or contract to promote opportunities for success. From a tactical intervention perspective, while different defensive strategies have been analysed, i.e. zone vs man–on–man defence, future research should examine tactical analysis of a variety of offensive strategies, such as penetration/counter–attack vs possession play strategies, as these will both likely lead to different observable outcomes. Further, while different contexts such as home vs away, winning vs losing or superiority vs inferiority lead to variations in emergent behaviour, research designs examining these components have typically failed to do so with reference to successful and unsuccessful performance outcomes.

At the mesoscopic level of analysis, while fatigue is suggested to be a confounding influence on second–half tactical performance (9, 67), future studies should examine relevant tactical variables in association with running demands, skill performance, team cohesion metrics, and perceptual measures. This will provide an enhanced understanding of the influence of fatigue on tactical performance. Further, linking these associated changes with opportunities for success, i.e. goal–scoring or turnover affordances, may offer insight regarding the effect of fatigue on match outcome. As noted, a substantial amount of intra–team literature has also been analysed in the absence of an understanding of successful and unsuccessful patterns of play, or without context, neglecting to provide tactical intent as defined by the coaches' instructions. While examination with reference to critical match events has proven useful, contextualising outcome measures with associated intent may provide an additional marker of tactical success. Selected studies examining the effect of small–sided games manipulation on intra–team coordination did so on a general scale, failing to distinguish between attacking or defensive phases. While this may provide relevant detail when comparing two teams, i.e. one team demonstrated less synchrony in the second half, potentially signifying a greater onset of fatigue, it is necessary to distinguish between attacking and defending passages of play. This is important when examining a team in isolation, as possessional status has revealed significantly different tactical tendencies on an 11–a–side scale. This is likely due to different task–specific goals, as well as varied environmental information available for perception.

To date, only measures of dyadic synchrony and regularity have been examined during an 11–a–side football format, neglecting specific measures of interpersonal distance, angles, velocities, passing distances, interception distances, and distance to goal within this context. The presence of additional players likely affords individuals with more behaviourally specifying information than that provided in a 5v5 (futsal) or small–sided game format. Furthermore, identifying emergent patterns of behaviour on a microscopic scale in an 11–a–side context may elucidate behaviour demonstrated at a meso– (intra–team) and macroscopic (inter–team) level. Finally, as identified, Table 3 highlights existing gaps or areas that require further clarification in a small–sided games context on not only a microscopic scale, but also meso– and macroscopic scale. Moreover, research into the effect of different constraints on emergent tactical behaviour and decision–making at all scales of analysis may enhance training design and subsequent performance.

Finally, few studies have examined the effects of training interventions on emergent team tactical behaviour over a specified training period. While the effect of different small–sided games manipulations on acute coordinative behaviours has been assessed an analysed in a football context, additional research is required to elucidate the chronic effects, particularly assessing whether these changes in behaviour persist and appropriately transpose to the 11–a–side context.

Conclusion

Traditionally, to distinguish between successful and unsuccessful performances, i.e. winning vs losing, practitioners have focused on associated physiological demands, such as distance covered at certain speeds or workloads, or discrete on–field actions, such as time in possession or number of passes preceding a goal. However, inconsistency and discrepancies exist between indicators of successful and unsuccessful performance. Additionally, a shortcoming of these approaches is their focus on performance outcomes rather than the underlying processes, lacking explanation as to 'why' or 'how' certain performance outcomes emerge. Furthermore, for the vast majority of performance analyses in sport, the unit of analysis remains on the individual, the positional group, or the team. However, there is a need to analyse performance at the interaction level rather than the individual level, making the smallest unit of analysis not one player's output, but the output of one player's interaction with another. With recent advances in technology, in conjunction with novel statistical approaches, researchers and practitioners have been able to examine tactical performance in collective team sports with reference to an ecological dynamics framework, offering an unfamiliar perspective on the mechanisms behind sporting success.

Borrowed from ecology psychology and dynamical systems theory, an ecological dynamics framework, when effectively incorporated, can provide a useful tool for describing 'how' and 'why' certain behaviours emerge over time. Additionally, this framework has the potential to distinguish between non–expert and expert performers, the latter having an enhanced capability to achieve higher levels of task outcomes, with effective and adaptive interactions between teammates. From an ecological dynamics perspective, football is a performance–environment sub–system where players and teams perceive affordances that guide decision–making and subsequent actions. Football teams can utilise key ecologically bound strategies, such as degeneracy, dimensional compression, reciprocal compensation, and interpersonal linkages, to satisfy imposing constraints and successfully achieve task–objectives (53–58). Implementing a hierarchical approach, researchers and practitioners can examine coordinative behaviour that emerges initially on a macroscopic level, followed by a mesoscopic level and, finally, on a microscopic level. This top–down form of analysis provides an all–encompassing framework that describes 'how' and 'why' certain behaviours emerge as a result of inter–player, intra–team and inter–team decision–making and coordination.

At all levels of analysis, i.e. macro–, meso–, and microscopic, players rely on information afforded to them by surrounding players, opponents, as well as the displacement of the ball. Furthermore, specific task–constraints, such as field dimensions and specific limitations, for example off–side and handball rules, provide additional information and boundaries that guide behaviour. On a macroscopic scale of analysis, it is apparent that teams tend to move in synchrony throughout the match, with this attractor state governed by positioning information of the other team. When in possession of the ball, however, disruption of this synchrony, or attractor state, potentially affords new goal–scoring opportunities for attacking teams. Additionally, relative dispersion measures signify that attacking teams tend to spread out to provide scoring opportunities while defending teams contract, positioning themselves between the goal and the attacking team trying to minimise goal–scoring affordances. It is the reciprocal exchange of information that drives synergistic, or antagonistic, cooperation between two opposing teams, both with the same objective: to overcome the opposition and win.

While inter–team analyses can adequately describe the dynamic relationship between two teams over time, a higher dimensional level of analysis can be undertaken to identify synergistic and co–adaptive behaviours that emerge on an intra–team level. Often measured in isolation of the opposing teams, in defence there is a tendency for players to utilise afforded information provided by surrounding players to maintain synchrony and stability, consequently minimising goal–scoring opportunities for the offending team. Conversely, aligning with patterns of centroid coupling at an inter–team level, attacking players trying to perturb this stability by dispersing and moving in a variable, unpredictable manner, drawing players away from their goal to provide scoring opportunities. Furthermore, position–specific analysis offers further insight, as defenders and midfielders spend more time in synchrony with their own position–specific centroids than attackers. These emergent stable states (defenders and midfielders) and variable states (attackers) may reflect tactical roles as defenders remain dimensionally compressed to protect the goal while attackers remain unpredictable or degenerate to perturb the opposing defensive line. Additionally, cooperative network analyses have revealed common tendencies in successful teams, with minimal reliance on focal players being a common characteristic associated with successful performances. Further, the ability for teams to offensively co–adapt and reciprocally compensate when one or two key players are removed, or unavailable to pass to, is important for attacking success, allowing teams to achieve task outcomes by fostering different relationships between players. When correctly utilised, a cooperative network analysis can reveal centroid players, i.e. those who are the most highly connected with in a team. These players appear to be midfielders and this may be linked with their positional role as they are often responsible for recovering possession, particularly in the defensive zone, which would increase participation in offensive plays. Further, being centrally located, these players play a transitional role, often linking defenders and attackers.

The most complex level of analysis occurs at the microscopic or inter–player level. The dyadic relationship between two players is guided by task constraints, intrinsic dynamics of the performers, ball displacement, and either the movement of a fellow teammate (attacker–attacker or defender–defender dyad) or an opposing player (attacker–defender dyad). In an attacker–defender dyad, defenders try to remain between the goal and the attacker, maximising opportunity for interception and minimising opportunity for the opposition player to shoot or pass in free space. Alternatively, attackers focus on misaligning their opposing defender, affording a passing or shooting opportunity, trying to satisfy the game's primary constraint: to score a goal and win. Additionally, fellow attacking teammates provide affordances for the ball carrier by positioning themselves in a way that allows reception of a pass in open space. Further, defender dyads, aligning with defensive coordination patterns displayed on a mesoscopic level, remain tightly coupled, which reflects the presence of a common objective between defending players: to remain between the attackers and the goal, contracting to minimise goal–scoring affordances.

Small–sided games appear to be an appropriate representative modality of training that allow coaches and practitioners to train and guide desirable behaviour at all levels of coordination by manipulating the task and environmental constraints that act upon small–sided games. The effective use of small–sided games allows performers to develop in a spatiotemporally varying training environment that reflects the formal and functional structure of a football game, with relevant informational constraints that reflect that of an official match. As highlighted in Table 3, manipulating games by imposing specific constraints can guide players towards specified attractor states through enhanced attunement to relevant perceptual information and affordances that allow favourable patterns of behaviour to emerge. This format of training facilitates the transfer of action and decision–making from the training process to the competitive context as it provides attractors and repellers, along with associated *bifurcation points*, that are representative of the traditional 11–a–side format of the game. Further, this format of training provides an open, noisy environment that can be actively scaled to fit the requirements of performers.

As highlighted, further research is still required regarding tactical analysis in football at each level of coordination. Female players are yet to be incorporated in studies utilising these forms of analysis and a wide array of existing studies lack contextual background regarding observed tactical patterning. Finally, as ecological dynamics is conceptually based in ecological psychology and dynamical systems theory, difficulty arises in the interpretation and understanding of associated ideas and terms. Consequently, appropriately applying relevant concepts to help explain team sporting performance in a concise manner has proven difficult. A challenge for practitioners is to familiarise coaches and relevant stakeholders with the appropriate terminology and concepts, allowing an enhanced understanding as to 'how' and 'why' coordinative behaviour emerges in collective team sports. Subsequently, practice tasks and drills can then be designed accordingly to promote favourable patterns of coordination.

Afterword

It was our intention to write a book that would be useful for researchers, students and practitioners with an interest in team performance. Despite the great strength that lies in applying the ecological dynamics framework as a conceptual framework to better understand team behaviour and performance, its recent popularity has also led to its rushed and under–researched implementation in a variety of domains, as well as its implementation as a causal framework in sport, which we believe it is not (yet). This is echoed in Araújo et al.'s seminal work (33) work who concluded empirical research is now needed to underpin some of the central hypotheses of the ecological dynamics framework. Nonetheless, we hope that this book can act both as a detailed perspective on assessing and developing team–tactical behaviour, as well as an introduction to the ecological dynamics framework for those intending to apply it to a specific context, or for those starting their research journey in sport. We are by no means contending we 'got it right', but by opening up our perspectives and study of the ecological dynamics literature to the wider sport science community, we hope they can learn from, and build upon, our work.

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