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Learning design to facilitate interactive behaviours in Team Sports

Diseños de aprendizaje para favorecer las interacciones en los deportes de equipo

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Abstract

This opinion piece aims to describe the process of learning in team sports, with a rationale in ecological dynamics sustained on the interactive nature of performance in that context. The first part of this article focuses on the information variables that discriminate affordances (invitations for action), supporting the emergence of anticipatory behaviours. Here we note that affordances emerge at different time scales of performance, with clear implications for planning and designing practice sessions. Acquiring interactive skills in team sports and perceiving information variables of relevance during performance is strictly connected to the concept of representative task design. In the applied section of this paper we show how the constraints-based approach is a suitable tool to create representative learning environments that produce changes in players' interactive behaviours over short and long time scales.

Key words: Ecological dynamics; affordances; interpersonal interactions; coordination tendencies; representative learning design.

Resumen

Este artículo de opinión tiene como objetivo describir el proceso de aprendizaje en los deportes de equipo fundamentado en una dinámica ecológica, sustentada en la naturaleza interactiva del rendimiento en ese contexto. La primera parte de este artículo se centra en las variables informativas que discriminan las *affordances* (invitaciones para la acción) que permiten la aparición de conductas anticipatorias. Observamos que las *affordances* emergen en diferentes escalas temporales del rendimiento, con claras implicaciones para la planificación y el diseño de sesiones de práctica. La adquisición de habilidades interactivas en los deportes de equipo así como la percepción de las variables informativas relevantes durante la acción está estrechamente vinculada con el concepto de diseño de las tareas representativas. En la sección aplicada de este trabajo se muestra cómo el enfoque basado en las rstricciones es una herramienta adecuada para crear ambientes de aprendizaje representativos que producen cambios en los comportamientos interactivos de los jugadores en escalas de tiempo cortas y largas.

Palabras clave: dinámica ecológica; affordances; interacciones interpersonales; tendencias de coordinación; diseño de aprendizaje representativo.

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Introduction

A key feature of success in team sports is the need to learn how to interact with teammates and opposing players. This process of interaction is predicated on co-adaptation (Passos et al., 2013) and players' co-adaptive behaviours are constrained by information emerging from task constraints, such as field locations and boundaries and rules, all influenced by changes in relative positioning of teammates and opponents. However, while field boundaries and rules remain unchanged during competitive performance, players' relative positioning is a key variable that continuously alters due to the location and presence of significant others. For example, defenders change their positions due to changes in attackers' locations. Attacking players in turn adapt their positions in response to the positional changes of defenders and teammates. These continuous adaptations in positioning of players on field emphasise the systemic nature of the relationship between competing and cooperating team games players. The continuous interactions of team games players are characterized by system nonlinearity signifying that it is not possible to completely predict in advance what other players will do in the immediate future during performance (Strogatz, 2004). In ecological dynamics, collective behaviours in team sports are characterized as a soft-assembled, dynamical system (i.e., a temporary coordination coalition between system components) sustained by players during nonlinear interactions (Eiler, Kallen, Harrison, & Richardson, 2013). Nevertheless, players have the ability to anticipate the actions of other performers. For instance, a defender can intercept a shot on goal or a pass from a ball dribbler to a supporting player in spite of the nonlinearity that characterizes these social interactions. This is because there are information sources that players can actively explore to predict what other performers will do which affords anticipative behaviours. Thus, information created within a performance context is crucial for players' perceptions, anticipation, decisions and actions.

Information variables, prospective control and anticipation

Schmidt and colleagues revealed that interpersonal coordination between individuals is typically achieved through the use of visual information that is locally created (Schmidt, Bienvenu, Fitzpatrick, & Amazeen, 1998). Visual information supports different perceptual motor strategies for the control of interceptive actions, such as receiving a pass or tackling an opponent. At this point it should be acknowledged that actions play a critical role in perception and that perception is critical for players' assembly of decisions and actions (Fajen, Riley, & Turvey, 2009). Thus, it seems relevant to pursue a formal description of the information that specifies action-relevant properties of the performance context. In that sense the performance of interceptive actions is strongly influenced by temporal constraints. The *time to contact* of an approaching object (e.g., ball; opposing player), when accurately perceived, affords successful actions such as anticipating and intercepting a pass between players or tackling a ball dribbler. As a variable that describes player – environment interactions, *time to contact* can be optically specified as "…the ratio of an approaching object's size in the optic array to its rate of optical expansion…" (Fajen, et al., 2009, pp. 83). *Time to contact* was termed *tau* (τ) (Lee, 1976).

Despite its relevance to team games performance, *tau* has a few limitations. The first is that *tau* it is not the only optical variable that individuals use to intercept objects. Also some studies have revealed unexpected effects of object size and approach speed that should not be observed if *tau* was an exclusive variable for the control of interceptive actions (Fajen & Devaney, 2006; Michaels, Zeinstra, & Oudejans, 2001). Further, the accelerating feature of an object's trajectory has also raised some questions regarding the use of *tau* for intercepting those objects (Michaels, et al., 2001). In sum, *tau* is specific to time constraints, and as such cannot be the only variable for the control of interceptive actions which also requires the use of spatial constraints. The emphasis is not only on when a ball must be caught, but where in space it should be intercepted.

Due to the demands of satisfying time and space constraints during performance, players need to be flexible in using different sources of information to perform an action. This requires a degree of perceptual flexibility which can be achieved through the process of *attunement* (Fajen, et al., 2009). This is where learning might make a difference. Thus we may suggest that the difference between experts and novices in team sports is grounded on the informational variables that each athlete actively explores to support decisions and actions (Araujo, Davids, & Hristovski, 2006). Practice enhances the perceptual attunement of expert performers to specifying variables which allows them to adapt their behaviours, satisfying system fluctuations in time and space constraints. Thus, an important issue for practice is to know which factors influence the informational variables that provide the basis of predictive or prospective strategies of interceptive actions that players use to decide and act in the ever-changing context of team sports (Fajen, 2005; Fajen, et al., 2009).

Predictive control strategies for intercepting a target in space assume that either the *place of* or *time to contact* with the moving target (e.g., ball; opponent; teammate) is known in advance and players will act accordingly, signifying that information to perform interceptive actions is known in advance. On the other hand, prospective control strategies allow players to continuously adapt their behaviours when seeking successful task performance (Fajen, 2005; Fajen & Devaney, 2006; Montagne, 2005; Chardenon et al., 2002). Research has revealed the predominance of prospective information for regulating interceptive actions (Bastin, Craig, & Montagne, 2006; Correia, Araujo, Craig, & Passos, 2011). These data signify that players mainly use information that is locally created, such as ball flight trajectories or opposing players' movements, to adapt to performance constraints. Indeed, Chardenon et al. (2002) revealed a high level of movement accuracy in performers when intercepting a moving object, but these same individuals lacked insights on the information they used to attain accuracy and guide their actions when they were required to make perceptual judgments, rather than act.

A recent study of rugby union performance assessed whether players' decision making for pass selection was constrained by the spatio-temporal variable *tau* (expressing time to contact between an immediate attacker and defender). Results revealed a predictive value of *tau* for pass duration. This finding suggested that the time motion gap (measured with *tau*) between an attacker and defender, when an attacker received a pass from a teammate, explained the temporal duration of a pass made by that attacker to another team mate (Correia, et al., 2011). Thus, an attacker – defender time motion gap provides the prospective visual information that sustains the decision making of a ball carrier regarding the type of pass to be performed. Nevertheless, the use of predictive strategies should also be relevant when an adjustment to player-environment couplings is required. According to Bastin and colleagues, the complementary role of prospective and predictive strategies for performing interceptive actions is a relevant issue that requires further work (Bastin, et al., 2006).

Information variables are tightly coupled with affordances, which are opportunities for action provided by the environment to each individual (Gibson, 1979). Perceptual attunement influences the affordances that are available to each individual player, consequently shaping the prospective control of players' behaviours (Turvey, 1992).

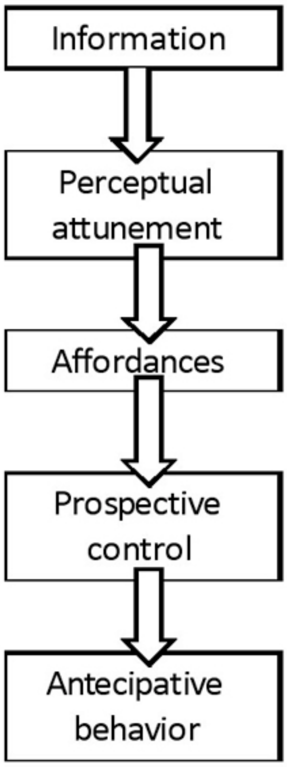

Figure 1. Prospective control strategies imply that players' decisions and actions are grounded on information about future 'states of affairs' in a performance environment which allows adaptive and anticipatory behaviours to emerge (Fajen, et al., 2009).

Anticipatory behaviours need to satisfy demanding time and space constraints that are continuously changing on different time scales. Practitioners should be aware that players' behaviours are mutually and reciprocally constraining, over fast and slow time scales. For instance dyadic co-adaptive behaviours of a ball dribbler and support players in rugby union emerge over slow time scales from the fluctuations emanating during the interactions of their movements at fast time scales (Eiler, et al., 2013). Rugby union attacking subunits are formed when a ball dribbler and support players coordinate actions as a single entity on field forming a 'diamond' shape structure. During performance this collective structure is achieved and remains over a long time scale due to continuous minor adjustments in players' relative positions and velocities at short time scales. In other words, support players are continuously adjusting relative positions among themselves and also with regard to the ball carrier's movements, achieving outcome solutions that cannot be achieved by each individual player, performing as a single entity (Passos, et al., 2011).

Learning in team sports emerges from the continuous interactions of players competing and cooperating with one another, at different temporal and spatial scales. Players' adjustments during each performance sequence (i.e., changes over fast and short time scales) will constrain their perceptual attunement to the behaviours of other performers (teammates and opponents), which can lead them to learn how to anticipate the movements of other performers at slow and long time scales. Perceptual attunement is a general principle of learning in sports related activities (Fajen, et al., 2009). Practice at fast and short time scales drives players to converge toward relevant information variables at slow and long time scales. Thus the core idea is that learning how to interact with significant others occurs at slow and long time scales sustained by performance sequences that occur at fast and short time scales. On the other hand, performance sequences that occur at fast and short time scales are constrained due to learning that occurs over slow and long time scales.

Information variables and opportunities for action

Team sports are highly dynamic performance contexts due to the interactive nature of players' movements, and opportunities for action that may emerge are limited in time and space. For example, a ball can be ‘interceptable’ at a certain moment and no longer ‘interceptable’ the next moment or the space between defenders may open up, but as attackers move closer, that gap may close. These ideas suggest that affordances change over short time scales. For instance, in football a support player's positioning might afford receiving a pass from a ball dribbler, only for a short period of time. At the next moment, the pass affordance may no longer exist for the ball dribbler. A suitable example of the linkage between perceptual attunement, affordances, prospective control and anticipation is the '*alley oop' manoeuvre* in basketball (when a support player receives a pass in the air and dunks the ball immediately). For the ball dribbler the support player's trajectory in the air towards the basket affords an ‘alley oop’ movement, but only for an instant in time. Performing such a joint action demands perceptual attunement of a ball dribbler to an affordance of passing the ball to a teammate moving in the air. To make such a pass requires prospective control that requires anticipation of where the teammate is likely to be (in the air) at a future moment. This dynamic feature of affordances implies that players must be fine tuned to information invariants in order to anticipate the next tactical move.

But due to learning effects, affordances also change over longer time scales. Learning implies changes in perceptual, cognitive and motor skills that remain across time. The acquisition of these skills implies that players will explore the performance context in a different way. Examples of athletes exploring new affordances include: a rugby player who learns how to perform a long distance (cut out) pass; a cricketer who learns how to switch hit; football players learning a new manoeuvre in front of a defender (such as a Cruyff or Maradona turn). In this way, perceptual-motor learning drives performers to explore affordance changes over longer time scales, which influence how a player will explore affordances over short time scales (e.g., opportunities for action that emerge during competitive performance).

Due to the sort of information created within learning environments, practice will influence players’ perceptual attunement and shape the affordances that become available for a player or a set of players. A question of relevance in understanding team games performance is: What are the factors that influence the information that sustains players’ interactive behaviours? Seeking an answer to this question will place sport scientists and coaches in a better position to design learning environments that lead to successful outcomes.

Methods that capture and describe players’ interactions in team sports

During the past decades there has been a significant amount of research attempting to describe players’ interactive behaviours in team sport performance. Use of video based methods and digitizing procedures to capture players’ movements in a continuous fashion allow the calculation of coordinative variables that accurately describe players’ collective behaviours (e.g., the formation of dyads to pattern formation in entire teams).

Variables like relative angles, interpersonal distances, relative velocity, and centroids have been used for that purpose (Corrêa, Vilar, Davids, & Renshaw, 2014; Folgado, Lemmink, Frencken, & Sampaio, 2014; Passos, Araujo, Davids, Gouveia, Milho & Serpa, 2008; Passos, et al., 2009; Passos, Milho, Fonseca, Borges, Araujo & Davids, 2011). For example, angles between players have been used to describe attacker – defender dyads in rugby union as a single unit (Passos, et al., 2009). This variable provides a description of critical fluctuations in the balance of an attacker-defender system, which define critical regions where players’ behaviours become mutually dependent. Within these critical regions, other variables, such as relative velocity, become relevant to increase their explanatory power over the final performance outcome. Thus, increasing relative velocity values signify an attacker's advantage in a competing dyad, whereas decreasing values signify an advantage for a defender (Passos et al., 2008; Passos, et al., 2009).

Angular relations between attackers and defenders have also been studied to explain affordances for passing direction in futsal. Spatial and temporal variables related to the angular dynamics of the positioning of a ball dribbler, relative to other players (teammates and closest defender) on field, have been observed to constrain passing direction during performance in competitive futsal (Corrêa, et al., 2014). These angular relations were analysed by calculating: i) a vector from the ball dribbler to a teammate with a vector from the ball dribbler to the nearest defender; and ii) a vector from the ball dribbler to the teammate with a vector from the ball dribbler to the teammate's nearest defender. Concerning spatial constraints, when having three teammates to pass to (and consequently three dyads), data revealed that the ball dribbler decided to pass the ball in the direction of the dyad with the greatest angular values (i.e., with larger distances between a teammate and the nearest defender). Concerning temporal constraints, data showed that the ball dribbler decided to pass the ball to the teammate whose angle with the closest defender displayed higher velocity values (i.e., angles that took more time to close). Results revealed that changes in angular values, due to the movements of teammates, afforded passing opportunities to which the ball dribbler needed to be attuned (Corrêa, et al., 2014). In sum, the findings revealed how ball dribblers needed to be attuned to changes in spatial and temporal constraints emerging from their interactive coordination tendencies with teammates and opponents. These interactions provide crucial informational variables for prospective control that afford anticipatory actions during performance.

Players' relative positioning can also be assessed through recording values of interpersonal distances between individuals, as well as their positioning relative to key task constraints as such as shooting targets and field markings. Previous research on 2v1 situations in rugby union described affordances for ball carriers available in values of interpersonal distances, relative velocities, and defender positions relative to the sidelines on field (Passos, Cordovil, Fernandes, & Barreiros, 2012). Results revealed that the ball carrier's decision making to dribble forward towards the score line or pass the ball to a teammate was influenced by a correlation between values of players' interpersonal distances with both players' relative positioning to the sideline (i.e., termed the 'inter-individual distance to the sideline'). Data displayed a tendency for the ball carrier to pass the ball at higher values of interpersonal distances from the tackler (i.e., sooner), when the event was located further from the sideline. From this study it is worth noting the influence of temporal constraints on the ball carrier's decision to move forward and score a try. The moment that the ball carrier decided to advance was strongly influenced by the variability of the value of inter-individual velocity to the sideline (i.e., the rate of change of both players' positioning to the closest sideline). The higher the variability values, the sooner the ball dribbler decided to move forward. The data from this study reinforced the importance of the influence of spatial and temporal informational variables, emerging from interpersonal interactions, on players' opportunities for action.

Previous research in basketball by Bourbousson and colleagues (Bourbousson, Seve & McGarry, 2010a) has reported players' movement displacement trajectories in lateral and longitudinal directions to analyze intra- and inter-team dyadic behaviours. Dyadic system coordination tendencies were measured using relative phase analysis. Results revealed that longitudinal displacements (i.e., towards the basket) provided the emergence of stronger interpersonal coordination tendencies between attackers and defenders. This finding suggests that, due to weaker interpersonal coordination tendencies in a lateral direction, longitudinal displacements may create more affordances for attackers to break existing attacker-defender symmetries. Following the same reasoning, Travassos and colleagues (Travassos, Araujo, Vilar & McGarry, 2011) also used relative phase analysis to investigate defenders' interpersonal coordination tendencies in the lateral and longitudinal directions relative to ball dynamics and displacements of attackers in futsal (i.e., indoor football). Contrary to the findings of the study by Bourbousson and colleagues, results of Travassos and co-workers (Travassos et al., 2011) revealed higher coordination tendencies for defenders' lateral movements regarding ball dynamics, compared to attackers' movements (Travassos et al., 2011). As suggested by the investigators, these effects may have been due to defenders attempting to close available gaps for attackers that afforded shooting at goal. An interesting issue emerged from the data of both studies concerning the coordination variable selected for analysis during performance in basketball and futsal. Both studies revealed insights on which plane of motion affordances might emerge during competitive performance. These results reinforced the relevance of task constraints on players' perception of affordances. For team sports with differing task constraints, like basketball and futsal, players' affordances seem to emerge on different planes of motion. This might be a crucial issue for planning and designing training sessions in team games. The information variables that specify players' affordances are highly related to specific task constraints. The implication is that if coaches design a training session by manipulating task constraints, other than those available during competitive performance (e.g., field markings and interpersonal distance values of attackers and defenders), practising athletes may be forced to become perceptually attuned to other affordances which may not be functional during performance (for an example involving use of ball projection machines for practice, see Pinder, Davids, Renshaw & Araujo, 2011).

Findings from a similar study involving use of the statistical methods, running and cross correlations, with rugby union attacker-defender dyads reinforces this suggestion (Correia, Passos, Araujo, Davids, Diniz & Kelso, 2014). Dyadic system coordination tendencies were measured by calculating running correlations of players' lateral displacements (i.e., players' velocity towards and away the sideline). Results suggested that, in situations when tries were scored, affordances were only available closer to the end of the sequence of play, when attackers' evasive manoeuvres created instabilities in existing attacker defender coordination tendencies. When sequences of play ended in a successful tackle, defenders were able to maintain dyadic system stability. They achieved this goal by maintaining coordination tendencies in the lateral direction which afforded a tackle, also closer the end of a sequence of play. These results reinforced the importance of the concept of 'critical regions' in dyadic systems, raised in previous studies of dyadic system interactions in rugby union (Passos et al., 2013). Thus, it seems that the rate of change of players' relative positioning (in the lateral plane of motion) is a crucial information variable for performance in 1v1 situations in rugby union. It is likely that perceptual attunement to that information variable may allow prospective control of action within critical performance regions (close the end of a sequence of play in 1v1 situations) that allows players to explore affordances (such as instantaneous gaps emerging and disappearing during interpersonal interactions between an attacker and a defender).

Previous research on perceptual variables emerging from interpersonal interactions between attackers and defenders in team sports has also sought to analyze intra- and inter-team collective behaviours. This body of work has attempted to examine how a sub-group of players coordinate actions to perform as a single unit during performance, achieving what is not possible to achieve as individual performers. Such sub-groups might represent a defensive unit in association football or an attacking unit of backs in rugby union. The empirical description of collective actions in such sub-groups involves the same principle of identifying coordinative variables that describe players' interactive behaviours, functioning as a system

(Kelso & Engstrom, 2006; McGarry, Anderson, Wallace, Hughes, & Franks, 2002). For that purpose previous research in football (Frencken & Lemmink, 2008; Frencken, Lemmink, Delleman, & Visscher, 2011) and basketball (Bourbousson, Seve, & McGarry, 2010b) have successfully identified coordinative variables such as a team's centroid, stretch index or surface area. These variables have captured fluctuations in the patterns of a team's longitudinal and lateral movement directions characterising intra- and inter-team interactions. As previously stated, in team sports players continuously co-adapt their actions to the movements of the other players in the vicinity. These continuous interactions constrain the positional changes of each individual player and, subsequently, changes in team's centroid positioning. The suggestion is that centroids may be a suitable measure to describe intra- and inter-team collective behaviours in team sports.

Research results so far seem to indicate that, in team sports, players' behaviours are constrained by local information rules. Players' behaviours are influenced by information variables that emerge due to interactions with other players in the vicinity on field. Previous research during competitive performance in rugby union, seeking to record the behaviours of attacking sub-units of players, before and after they encounter defensive sub-groups, sustains this assumption. Data from a 4v2+2 situation in rugby union revealed how attackers' coordination tendencies in a sub-group, captured by recording their mean values of interpersonal distance, changed during performance. The evidence suggests that these changes in coordination tendencies emerged to satisfy task constraints of playing before the first defensive line and between the first and the second defensive line. After breaching the first defensive line, attackers need to reposition themselves relative to each other, the ball carrier's position and that of the closest defenders. Thus, local information provided by changes in the nearest vicinity relative positions afforded the attackers spreading out (i.e., increasing interpersonal distances) which is an expression of co-adaptive behaviours over short timescales due to changes in task constraints (Passos, et al., 2011).

Much previous research has described collective behaviours and changes in those behaviours due to task constraints, such as values of interpersonal distance to defenders and teammates, players' locations on field, or even differences in players' levels of expertise (Frencken, et al., 2011; Frencken, Van der Plaats, Visscher, & Lemmink, 2013; Passos, et al., 2011; Sampaio & Macas, 2012). These interactions in the collective systems of team sports are mainly nonlinear. Continuous interactions between players lead to co-adaptations that may provoke fluctuations in the strength of the coupling between the players. An interesting issue concerns how to measure the strength of coupling between teammates over time. Two studies of interpersonal interactions in rugby union investigated this issue by using running correlations measures to capture the strength of the coupling between the players during performance. In the first study, Passos and colleagues examined the strength of coupling between players in attacking subunit of 4 players running towards the try line (Passos, et al., 2011). Data revealed initial coupling strengths between attacking teammates of close to 90%, but decreasing values of interpersonal distances to defenders provoked fluctuations in correlations, which reinforced the notion of co-adaptation sustained by locally created information sources. Findings revealed how the presence of other players created affordances that invited co-adaptation.

Other previous work in rugby union sought to describe how intra-team coordination patterns influenced successful performance outcomes. Running correlations of players distance to the score line were used to measure intra-team coordination patterns within attacker and defender dyadic subunits closest the ball dribbler. Results revealed that fluctuations in correlation values within a dyadic subunit (either attackers or defenders; e.g., ball dribbler with left side support player; ball dribbler closest defender with left side support player closest defender), created affordances for opposing subunits to perform successfully. Alternatively, high correlation values in players' distance to the score line (meaning that players are running at the same pace in the same direction), indicated the existence of strong levels of intra-team coordination tendencies within a subunit, leading to a successful performance outcome (Rodrigues & Passos, 2013). These results suggest that strong intra-team coordination tendencies need to emerge to achieve successful performance outcomes in team sports, especially when opposing subunits (of attackers or defenders) demonstrate reduced coupling tendencies. However, when both teams maintain high levels of coupling tendencies, signifying that the players are not influenced by the presence of opponents, high levels of within sub-group coordination tendencies remain.

Representative learning tasks

Initially in the introduction we emphasized the importance of manipulating task constraints to create learning environments where players can develop their perceptual attunement to key information sources that support their active exploration of emergent affordances during performance. The acquisition of a strong coupling between information variables, perceptual attunement, affordances and prospective control requires attention to the concept of representative task design by pedagogists in team sports.

The concept of representative experimental design was proposed by Egon Brunswik (Brunswik, 1952, 1956) to refer to the participant-environment interaction. It "refers to the arrangement of conditions of an experiment so that they represent the behavioural setting to which the results are intended to apply" (Araujo, Davids, & Passos, 2007, pp. 72; Hammond & Stewart, 2001). Brunswik's (1952, 1956) main argument was that participants should encounter in experimental tasks the natural variability of performance settings. Removing natural variability of task constraints will alter experimental outcomes. Applying this concept to practice environments in team sports implies the need to create representative learning designs (Pinder et al., 2011). In representative learning design, task constraints need to faithfully represent the ecological constraints of a specific competitive performance environment so that players maintain perceptual-motor relations with significant others (i.e., opposition and teammates), events (e.g., coaches' instructions) and objects (e.g., a ball). Without representative learning design, different patterns of interpersonal coordination within- and between-individuals are likely to emerge (Pinder, et al., 2011). Moreover a consequence of a lack of task representativeness is that players will tend to rely on non-specifying information (especially if that information source affords some level of success in outcomes). Consequently, players during practice might attune to information variables other than those which specify affordances in competitive performance settings (Jacobs, Runeson, & Michaels, 2001). Therefore, training in team games must faithfully represent the dynamic circumstances of performance by including plenty of variability that naturally occurs in specific competitive performance environments (Araujo, et al., 2007). Without representative task design the behaviours that emerge from practising athletes may not be functional for competitive performance in team sports contexts (Davids, Hristovski, Passos, & Chow, 2012; Dicks, Davids, & Araújo, 2008; Pinder, et al., 2011). Thus, a significant challenge inherent to learning contexts is that task design should be grounded on task constraints manipulation that is representative of specific competitive performance environments. A key issue is to consider how affordances (i.e., opportunities for action) designed into learning environments can correspond to those affordances that exist in competitive performance environments.

In sum, the notion of task representativeness in team sports learning is predicated on what a specific task affords a participant grounded on the information variables that can vary due to the typical interactive behaviours of competing athletes. Affordances require that a performer regulates his/her activity according to information variables from objects (e.g., ball flight path), other performers (e.g., defender's relative positioning) or events (e.g., the deceptive actions of an opponent) (Araujo, et al., 2007). Hence, information variables, perceptual attunement, affordances and prospective control of behaviour, as well as task representativeness, are likely to change, being shaped by continuous interactions between performer, task, and environmental constraints (Kugler, Kelso, & Turvey, 1982).

Since different sources of perceptual information allow different possibilities for action (i.e., affordances) (Fajen et al., 2009), a crucial issue in designing learning environments is to represent the information available for action in competitive performance contexts. For instance the use of static (i.e., with no manipulation; e.g., cones or passive defenders) or dynamic (i.e., with task constraints variability; e.g., attackers need to perform under defensive pressure) tasks constraints differs in availability of affordances. According to Pinder and colleagues, static task constraints (e.g., use of cones and passive defenders) in sport training typically lacks functionality (i.e., perceptual attunement to other players as affordances) and consequently are not representative of performance constraints of dynamic competitive environments (Pinder, et al., 2011; Vilar, Araujo, Davids, & Renshaw, 2012).

To be representative any training exercise must frame continuous time and space constraints. Space constraints can be easy to address, usually represented in the relative positioning of players, changes in distances to goal or manipulations of field dimensions. Time constraints require that the way that space changes in competitive settings is represented during training. For instance the velocity of a closing gap between defenders, the rate of change of attacker – defender interpersonal distances or the rate of change of an angle that affords a shot at goal rate of change, exemplify situations that requires players' perceptual attunement to information for successful performance. Players can only attune to these relevant information variables if they are designed into practice tasks during training. Ensuring representative learning design implies providing the same affordances that players will encounter in competitive performance environments. For that purpose the constraints based approach seems to be a suitable tool to fulfil this task (Davids, Button, & Bennett, 2008).

Planning and designing learning environments

The interactive nature of team sports requires designing learning environments that develop players' ability to solve problems by using a motor repertoire with different task outcomes (rather than specifying a single solution). This capacity for functional variability during performance is crucial to develop players' adaptive performance behaviours.

The Constraints Based Approach (CBA) has been previously suggested as a theoretical framework to support the design of learning environments that encourage players to actively explore available task solutions for achieving the same performance outcomes (Araújo, Davids, Sainhas, & Fernandes, 2002; Davids, et al., 2008; Davids, Handforf, & Williams, 1994; Passos, Araujo, Davids, & Shuttleworth, 2008; 2010).

The CBA is a theoretical framework that stipulates planning supported by the manipulation of three types of constraints which display a mutual and reciprocal interaction (for further information see Newell, 1986). These constraints bound a perceptual-motor workspace where performance can emerge during practice. The three types of constraints are: i) individual constraints (e.g., technical skills; tactical skills; problem solving); ii) task constraints (e.g., interpersonal distances between opponents; angles between ball dribbler and closest defender); and iii), environmental constraints (e.g., weather; presence of an abusive crowd).

The perceptual-motor workspace created with the CBA contains time and space information variables that constrain players' behaviours. A major task is to build representative practice sessions which replicate the same task constraints that players face in competitive performance environments. Practice sessions need to provide similar affordances to those that will be explored in a competitive environment. Continuous exposure to such contexts during practice will create learning environments where players develop the required perceptual attunement that can lead to the prospective control of actions and consequently to the emergence of anticipation.

Learning provides opportunities for changes in the affordances over long time scales, with consequent changes in short time scale affordances explored by the players. However, changes in short time scale affordances, due to players' interactive behaviours, will constrain changes in long time scale affordances. A suitable example is the functional asymmetry issue in motor learning and performance. In rugby union a scrum half should be able to accurately perform a pass to both sides (i.e., left hand pass; right hand pass); a football player should be able to perform a dribble or shot at goal with both feet. Nevertheless, individuals have a dominant side (hand) which they prefer to use to perform motor tasks (Gurd, Schulz, Cherkas, & Ebers, 2006; Sainburg, 2002). Learning to accurately perform a pass, a dribble or a kick with either feet (or hands) is a functional change that occurs over long and slow time scales which can only happen due to performance under task constraints that affords players to practice with limbs on both sides of the body (i.e., fast and short time scale). Long time scale achievements due to learning will in turn drive the players to explore other affordances within a match. This dynamic interactive feature of affordances over different timescales requires changes in the framework of practice sessions; otherwise players' actions can become ‘too’ stable reducing their capacity to adapt. Concerning the planning of training sessions the following question emerges: With which frequency should coaches manipulate task constraints? Here we suggest that when players’ behaviours remain ‘too’ stable, players might lose opportunities for exploring different task solutions when facing opponents. Manipulating task constraints that change over long time scales will induce variability in practice, driving players to explore different task solutions to successfully interact with relevant others (over a short time scale). These exploratory behaviours will lead to changes over long timescales in players' co-adaptive behaviours, supporting learning

References

Araujo, D.; Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, 7(6), 653-676. http://dx.doi.org/10.1016/j.psychsport.2006.07.002

Araujo, D.; Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioral setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology*, 19(1), 69-78. http://dx.doi.org/10.1080/10407410709336951

Araújo, D.; Davids, K., Sainhas, J., & Fernandes, O. (2002). Emergent decision-making in sport: A constraints-led approach. Paper presented at the International congress "movement, attention & perception", Poitiers, France; Université do Poitiers.

Bastin, J.; Craig, C., & Montagne, G. (2006). Prospective strategies underlie the control of interceptive actions. *Human Movement Science*, 25(6), 718-732. http://dx.doi.org/10.1016/j.humov.2006.04.001

Bourbousson, J.; Seve, C., & McGarry, T. (2010a). Space-time coordination dynamics in basketball: Part 1. Intra- and inter-couplings among player dyads. *Journal of Sports Sciences*, 28(3), 339-347. http://dx.doi.org/10.1080/02640410903503632

Bourbousson, J.; Seve, C., & McGarry, T. (2010b). Space-time coordination dynamics in basketball: Part 2. The interaction between the two teams. *Journal of Sports Sciences*, 28(3), 349-358. http://dx.doi.org/10.1080/02640410903503640

Brunswik, E. (1952). Conceptual framework of psychology. Chicago: University of Chicago Press.

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

Chardenon, A., Montagne, G., Buekers, M. J., & Laurent, M. (2002). The visual control of ball interception during human locomotion. *Neuroscience Letters*, 334,13-16. http://dx.doi.org/10.1016/S0304-3940(02)01000-5

Corrêa, U.; Vilar, L., Davids, K., & Renshaw, I. (2014). Informational constraints on the emergence of passing direction in the team sport of futsal. *European Journal of Sport Science*, 14(2), 169-176. http://dx.doi.org/10.1080/17461391.2012.730063

Correia, V.; Araujo, D., Craig, C., & Passos, P. (2011). Prospective information for pass decisional behavior in rugby union. *Human Movement Science*, 30, 984-997. http://dx.doi.org/10.1016/j.humov.2010.07.008

Correia, V.; Passos, P., Araujo, D., Davids, K., Diniz, A., & Kelso, J. A. (2014). Coupling tendencies during exploratory behaviours of competing players in rugby union dyads. *European Journal of Sport Science*, 1-9. http://dx.doi.org/10.1080/17461391.2014.915344

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

Davids, K.; D., A., Hristovski, R., Passos, P., & Chow, J.-Y. (2012). Ecological dynamics and motor learning design in sport. In A. M. W. N.Hodges (Ed.), Skill Acquisition in Sport: Research, Theory & Practice (2nd ed.). London: Routledge.

Davids, K.; Handforf, C., & Williams, A. M. (1994). The natural physical alternative to cognitive theories of motor behaviour: An invitation for interdisciplinary research in sports science? *Journal of Sport Sciences*, 12(6), 495-528. http://dx.doi.org/10.1080/02640419408732202

Dicks, M.; Davids, K., & Araújo, D. (2008). Ecological psychology and task representativeness: implications for the design of perceptual-motor training programmes in sport. In Y. Hong & R. Bartlett (Eds.), The Routledge Handbook of Biomechanics and Human Movement Science (pp. 129-139). London: Routledge.

Eiler, B. A.; Kallen, R. W., Harrison, S. J., & Richardson, M. J. (2013). Origins of Order in Joint Activity and Social Behavior. *Ecological Psychology*, 25(3), 316-326. http://dx.doi.org/10.1080/10407413.2013.810107

Fajen, B. R. (2005). Perceiving possibilities for action: on the necessity of calibration and perceptual learning for the visual guidance of action. *Perception*, 34(6), 717-740. http://dx.doi.org/10.1068/p5405

Fajen, B. R., & Devaney, M. C. (2006). Learning to control collisions: the role of perceptual attunement and action boundaries. *Journal of Experimental Psychology Human Perception and Performance*, 32(2), 300-313. http://dx.doi.org/10.1037/0096-1523.32.2.300

Fajen, B. R.; Riley, M. A., & Turvey, M. T. (2009). Information, affordances, and the control of action in sport. *International Journal of Sport Psychology*, 40(1), 79-107.

Folgado, H.; Lemmink, K. A., Frencken, W., & Sampaio, J. (2014). Length, width and centroid distance as measures of teams tactical performance in youth football. *European Journal of Sport Science*, 14 Suppl 1, S487-492. http://dx.doi.org/10.1080/17461391.2012.730060

Frencken, W., & Lemmink, K. (2008). Team kinematics of small-sided soccer games: a systematic approach. Paper presented at the 6th World Congress on Science and Football, London.

Frencken, W.; Lemmink, K., Delleman, N., & Visscher, C. (2011). Oscillations of centroid position and surface area of soccer teams in small-sided games. *European Journal of Sport Science*, 11, 215–223. http://dx.doi.org/10.1080/17461391.2010.499967

Frencken, W.; Van der Plaats, J., Visscher, C., & Lemmink, K. (2013). Size matters: Pitch dimensions constrain interactive team behaviour in soccer. *Journal of Systems Science & Complexity*, 26(1), 85-93. http://dx.doi.org/10.1007/s11424-013-2284-1

Gibson, J. (1979). The ecological approach to visual perception. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gurd, J. M.; Schulz, J., Cherkas, L., & Ebers, G. C. (2006). Hand preference and performance in 20 pairs of monozygotic twins with discordant handedness. *Cortex*, 42(6), 934-945. http://dx.doi.org/10.1016/S0010-9452(08)70438-6

Hammond, K., & Stewart, T. (2001). The essential Brunswik: Beginnings, explications, applications. New York: Oxford University Press.

Jacobs, D. M.; Runeson, S., & Michaels, C. F. (2001). Learning to visually perceive the relative mass of colliding balls in globally and locally constrained task ecologies. *Journal of Experimental Psychology Human Perception and Performance*, 27(5), 1019-1038. http://dx.doi.org/10.1037/0096-1523.27.5.1019

Kelso, J. A., & Engstrom, D. A. (2006). The Complementary Nature. Cambridge, MA: Bradford Books.

Kugler, P.; Kelso, J. S., & Turvey, M. T. (1982). On the control and co-ordination of naturally developing systems. In J. S. Kelso & J. Clark (Eds.), The development of movement control and coordination (pp. 5–78). New York: Wiley.

Lee, D. N. (1976). A theory of visual control of braking based on information about time-to-collision. *Perception*, 5(4), 437-459. http://dx.doi.org/10.1068/p050437

McGarry, T.; Anderson, D. I., Wallace, S. A., Hughes, M. D., & Franks, I. M. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences*, 20(10), 771-781. http://dx.doi.org/10.1080/026404102320675620

Michaels, C. F.; Zeinstra, E. B., & Oudejans, R. R. (2001). Information and action in punching a falling ball. *Quarterly Journal of Experimental Psychology A*, 54(1), 69-93. http://dx.doi.org/10.1080/02724980042000039

Montagne, G. (2005). Prospective control in sport. *International Journal of Sport. Psychology*, 36, 127-150.

Newell, K. M. (1986). Constraints on the Development of Coordination. In M. W. H.T.A.Whiting (Ed.), Motor Development in Children: Aspects of Coordination and Control (pp. 341-360). Dordrecht, Netherlands: Martinus Nijhoff.

Passos, P.; Araujo, D., Davids, K., Gouveia, L., Milho, J., & Serpa, S. (2008). Information-governing dynamics of attacker-defender interactions in youth rugby union. *Journal of Sports Sciences*, 26(13), 1421-1429. http://dx.doi.org/10.1080/02640410802208986

Passos, P.; Araujo, D., Davids, K., Gouveia, L., Serpa, S., Milho, J., et al. (2009). Interpersonal pattern dynamics and adaptive behavior in multiagent neurobiological systems: conceptual model and data. *Journal of Motor Behavior*, 41(5), 445-459. http://dx.doi.org/10.3200/35-08-061

Passos, P.; Araujo, D., Davids, K., & Shuttleworth, R. (2008). Manipulating Constraints to Train Decision Making in Rugby Union. *International Journal of Sports Science & Coaching*, 3(1), 125-140. http://dx.doi.org/10.1260/174795408784089432

Passos, P.; Araújo, D., Davids, K., & Shuttleworth, R. (2010). Manipulating Tasks Constraints to Improve Tactical Knowledge and Collective Decision Making in Rugby Union. In K. Davids, G. Salvesbergh & I. Renshaw (Eds.), Motor Learning in Practice: A Constraints-Led Approach (pp. 120-130): Routledge.

Passos, P., Milho, J., Fonseca, S., Borges, J., Araujo, D., & Davids, K. (2011). Interpersonal distance regulates functional grouping tendencies of agents in team sports. *Journal of Motor Behavior*, 43(2), 155-163. http://dx.doi.org/10.1080/00222895.2011.552078

Passos, P.; Cordovil, R., Fernandes, O., & Barreiros, J. (2012). Perceiving affordances in rugby union. *Journal of Sports Sciences*, 30(11), 1175-1182. http://dx.doi.org/10.1080/02640414.2012.695082

Passos, P., Araújo, D., & Davids, K. (2013). Self-organization processes in field-invasion team sports: implications for leardership. *Sports Medicine*, 43(1), 1-7. http://dx.doi.org/10.1007/s40279-012-0001-1

Pinder, R. A.; Davids, K., Renshaw, I., & Araujo, D. (2011). Representative Learning Design and Functionality of Research and Practice in Sport. *Journal of Sport & Exercise Psychology*, 33(1), 146-155.

Rodrigues, M., & Passos, P. (2013). Patterns of Interpersonal Coordination in Rugby Union: Analysis of Collective Behaviours in a Match Situation. *Advances in Physical Education*, 3(4), 209-214. http://dx.doi.org/10.4236/ape.2013.34034

Sainburg, R. L. (2002). Evidence for a dynamic-dominance hypothesis of handedness. *Experimental Brain Research*, 142(2), 241-258. http://dx.doi.org/10.1007/s00221-001-0913-8

Sampaio, J., & Macas, V. (2012). Measuring tactical behaviour in football. *International Journal of Sports Medicine*, 33(5), 395-401. http://dx.doi.org/10.1055/s-0031-1301320

Schmidt, R. C.; Bienvenu, M., Fitzpatrick, P. A., & Amazeen, P. G. (1998). A comparison of intra- and interpersonal interlimb coordination: coordination breakdowns and coupling strength. *Journal Experimental Psychology Human Perception and Performance*, 24(3), 884-900. http://dx.doi.org/10.1037/0096-1523.24.3.884

Strogatz, S. (2004). Sync: The Emerging Science of Spontaneous Order. Penguin Press Science.

Travassos, B.; Araujo, D., Vilar, L., & McGarry, T. (2011). Interpersonal coordination and ball dynamics in futsal (indoor football). *Human Movement Science*, 30(6), 1245-1259. http://dx.doi.org/10.1016/j.humov.2011.04.003

Turvey, M. T. (1992). Affordances and prospective control: An outline of the ontology. *Ecological Psychology*, 4, 173-187. http://dx.doi.org/10.1207/s15326969eco0403_3

Vilar, L.; Araujo, D., Davids, K., & Renshaw, I. (2012). The need for 'representative task design' in evaluating efficacy of skills tests in sport: A comment on Russell, Benton and Kingsley (2010). *Journal of Sports Sciences*, 30(16), 1727-1730. http://dx.doi.org/10.1080/02640414.2012.679674