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CURRENT OPINION

Shared Knowledge or Shared Affordances? Insights from an Ecological Dynamics Approach to Team Coordination in Sports

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Abstract Previous research has proposed that team coordination is based on shared knowledge of the performance context, responsible for linking teammates' mental representations for collective, internalized action solutions. However, this representational approach raises many questions including: how do individual schemata of team members become reformulated together? How much time does it take for this collective cognitive process to occur? How do different cues perceived by different individuals sustain a general shared mental representation? This representational approach is challenged by an ecological dynamics perspective of shared knowledge in team coordination. We argue that the traditional shared knowledge assumption is predicated on 'knowledge about' the environment, which can be used to share knowledge and influence intentions of others *prior to* competition. Rather, during competitive performance, the control of action by perceiving surrounding informational constraints is expressed in 'knowledge of' the environment. This crucial distinction emphasizes perception of shared affordances (*for* others and *of* others) as the main communication channel between team members during team coordination tasks. From this perspective, the emergence of coordinated behaviours in sports teams is based on the formation of interpersonal synergies between players resulting from collective actions predicated on shared affordances.

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1 Introduction

In everyday life, individuals coordinate movements with behaviours of others in order to achieve simple task goals like walking and talking to friends [1]. The ability to coordinate actions with those of others is often paramount for succeeding in specific performance contexts [2], such as competitive team sports.

A traditional approach to understanding team coordination in sports involves the idea of group cognition grounded on the premise of shared knowledge of the performance environment internalized among all team members [3, 4]. These ideas are rooted in a key principle of cognitive science that performance (whether individual or collective) is predicated on the existence of a representation or schema, responsible for the organization and regulation of behaviours [5, 6]. Alternatively, an ecological dynamics perspective of team coordination focuses on the available informational constraints that afford possibilities for controlling goal-directed activity in individuals, often with others [7, 8]. This theoretical paradigm has underpinned several recent studies investigating interpersonal coordination tendencies of sub-groups and teams in several sports [9–12].

Despite relying on different premises, both theories have been used arbitrarily to evaluate coordination during team performance. For example, Bourbousson and colleagues [13–15] used both dynamical systems and social-cognitive conceptual approaches to study coordination tendencies in basketball teams.

Here, we challenge the concepts of shared knowledge and team cognition and propose that team coordination is, rather, predicated on shared affordances, substantiated by theoretical ideas of ecological dynamics.

2 Team Cognition Models and the Concept of Shared Knowledge

Group functioning involving multiple cooperating individuals has traditionally been conceptualized to be based on social and cognitive processes [16], suggesting that understanding skilled team performance in sport could be developed by studying internalized processes of cognition in collective systems [17]. This idea has been predicated on the assumption of shared knowledge between individuals in collectives, viewed as crucial for successful team performance [18, 19]. The concept of shared knowledge has been addressed in cognitive, social and organizational psychology [16], and a key aim has been to understand how shared knowledge can be represented in groups of coordinating individuals. Its central assumption hypothesizes that individuals belonging to the same group or team maintain some kind of representation of shared knowledge or understanding in common [3, 4, 17, 19–21]. It is typically referred to as a state of group coordination in which each individual's specific representation of a performance context is similar or identical to that held by team members [16, 20]. The assumption of shared knowledge results from the possession by team members of complementary goals, strategies and relevant tactics, providing a basic shared understanding of desired performance outcomes. Shared knowledge underpins how each team member, individually, and the team globally, aims to achieve performance goals [17, 20]. Team members form clear expectations about each other's actions, allowing them to coordinate quickly and efficiently in adapting to the dynamic changes and demands of competitive performance environments, like sport, by selecting appropriate goal-directed actions to execute at appropriate times [16, 18, 19, 22]. In this context, the processing of information is considered to play a crucial role in understanding how shared cognitive entities putatively provide the basis of players' decision making in team sports [18].

Previous reviews addressing social cognition models have emphasized shared knowledge believed to be associated with team effectiveness [23, 24] and collective efficacy [25] by proposing, for example, that "the more teammates have a shared understanding of their situation, the more cohesive the team will be" [18], with higher levels of cohesion signifying higher degrees of coordination. In this case, team efficacy may increase when a sophisticated, global and comprehensive representation of a collective action is linked to a mental representation of a performance context, somehow shared by all players and put into practice. An asynchrony between the goals of individual performers and those of the team implies that a shared state has yet to be achieved, with resulting difficulties in coordination between players [16].

The role of explicit memorized knowledge is emphasized in each individual player for successful team functioning. Practice and experience are deemed important for enhanced encoding of domain-specific information in, and retrieval from, long-term memory structures [22]. They are also relevant for the formation of new and more elaborate representations or schemas, developed by performers for regulating behaviours in task-specific situations [16, 17, 22]. The shared awareness of 'who knows what' is seen as complementing the knowledge possessed by each individual player and is considered to form a transactive memory network responsible for underpinning each team member's awareness of that unique performance knowledge [20, 23, 24].

Several studies have attempted to understand how team members exchange and share knowledge during performance, assuming that this accounts for team coordination in competitive sport events like doubles in tennis [26] and table tennis [27–30] as well as in basketball [13, 31]. These studies have mainly used videotaped and audiotaped matches and/or verbal reports and questionnaires during post-match interviews as methods for coding and categorizing communication exchanges between teammates. Using such methods, Bourbousson and colleagues [13] reconstructed the courses of action of each of five players in a basketball team and then synchronized them. They found that players were only able to verbalize about all their teammates' behaviours when they were outside the match while they focused on only one or two teammates to coordinate their actions during the match. It was concluded that basketball players coordinate their actions by making local adjustments and enhancing their interactions with a single teammate, and not by grasping the full game situation.

2.1 Challenges for Team Cognition Models

Criticisms and questions about models of team cognition, and the key concept of shared knowledge, have emerged from within the field itself. Although shared knowledge has tended to dominate research on mental models in collective systems, and is still accepted as a necessary pre-condition for the emergence of team coordination, some investigators claim that it needs to be conceptually reformulated and much more carefully defined [17, 23, 25]. It is argued that players possess different types of knowledge [32] (e.g., declarative, procedural and strategic knowledge) [24] that account for different knowledge of the game (e.g., knowing 'how' to do and knowing 'what' to do). Further, perceptual cues are likely to be used differently by each individual, according to their skill level, type of practice engaged in or simply due to the relatively distinct contribution of each team member to each phase of play [17]. Thus, knowing 'who knows what' at each moment of a match would involve a tremendous cognitive load.

Particularly, the mechanism to explain re-formulations of a team member's schema, when changes occur in the content of another member's schema, has proved difficult to verify [32]. In some cases, decision making in sports might seem to depend upon the execution of a plan and a contingency in which shared knowledge of plans might be useful [17]. Consider, for example, Association Football, when some players combine in advance the way they are going to execute a set piece such as a free kick. Yet, during the set piece itself, a predefined decision might become infeasible due to last minute constraints imposed by the actions of opposing team players. The mechanism through which a group of expert players adapts to the new conditions within seconds is still to be demonstrated by team cognition models. Several studies have failed to find significant relationships between measures of convergence of mental models and various dimensions of team performance [24]. From a biological point of view, the existence of a brain that stores each player's representations is utopian [25] and it is hard to consider that representations exist beyond the boundaries of an individual organism and can be somehow shared [33].

Social cognitive models are grounded on rational models of decision making, which assume that athletes possess the necessary knowledge to mentally evaluate the costs and benefits of every specific performance solution. By admitting the existence of an equally accessible inference for every person, which differentiates between correct and incorrect decisions (regarding a specific performance goal in a given context), there is no room for response variability [34]. This is because rationality is only viable in closed systems (e.g., computers) where specific outcomes are triggered through linear processes, ignoring the constraints continuously imposed on performers [34–36].

Ferrario and colleagues [37] provided evidence of inter-trial variability in a team coordination task that challenges this view. They analysed the within-team positional variability of semi-professionals and amateur football players while performing two pre-planned and rehearsed offensive patterns of play. The coefficients of variation found in the relative players' positioning across trials highlighted the implicit variability characterizing every performance task and the impossibility to re-create, a priori, the exact movement actions in a rehearsed task.

There are other important questions to be considered. Is there enough time for the processing of a significant amount of information between individual members of a team during performance (15 vs 15 in Rugby Union and 18 vs 18 in Australian Rules Football)? In most sports there is no time for team members to plan deliberately during performance, which leads to no other option than ongoing adaptation of behaviours without explicit communication. According to team cognition models, this adaptive process would be based on pre-existing knowledge about the task, involving implicit coordination [38]. But, then, how would players cope with uncertainty when facing emergent, unpredictable and novel situations during competitive performance?

3 An Ecological Dynamics Perspective of Team Knowledge in Sport Performance

In contrast to assumptions of shared internalized knowledge, an ecological approach proposes that knowledge of the world is based upon recurrent processes of perception and action [39] through which humans perceive affordances (i.e., opportunities for action) during sport performance [40].

The concept of affordances presupposes that the environment is perceived directly in terms of what an organism can do with and in the environment (i.e., it is not dependent on a perceiver's expectations, nor mental representations linked to specific performance solutions, stored in memory) [41]. Gibson [42] proposed that humans can perceive the features of the environment as possibilities for action. Thus, players can detect information from patterned energy arrays in the environment in terms of their own characteristics (e.g., individual height, in basketball) [43] or in terms of their action capabilities (e.g., perceiving a defender's most advanced foot invites the attacker to drive an attack to that side) [44]. This information constrains behaviour by providing affordances or behavioural possibilities for decision making [45].

In relation to the role of knowledge, Gibson [46] distinguished between two types—'knowledge of' and 'knowledge about' the environment. 'Knowledge of' the environment refers to the ability to complete an action by detecting the surrounding informational constraints in order to regulate behaviours, specifically through the perception of affordances. This is possible because key properties of the environment can be perceived directly, on the basis of information available, and not indirectly, on the basis of organizing internal mental representations of the world [40].

Previous empirical work has provided some examples of adaptive behaviour during competitive and dynamic sporting contexts. Passos et al. [47] showed that the co-adaptive behaviours emerging between teammates in a sub-phase of Rugby Union was predicated on context-dependent informational fields such as relative positioning to nearest defenders. The interpersonal distance found between attackers was significantly different according to their distance to the defensive line. Lower values of distance to opponents constrained the attackers to attain higher values of interpersonal distances. Travassos et al. [48] demonstrated that the interception of a passing ball in futsal (indoor football) was constrained by spatial relations between key features of the environment, like the defender's distance to the ball trajectory and the kinematic properties of the ball. Both examples highlight how successful coordination, whether at team or individual level, was supported by perception of relevant information that provides affordances, or, in Gibson's words, 'knowledge of' the environment.

'Knowledge about' the environment refers to the perception of language (e.g., from the coach), pictures and videos (e.g., from the opponents) or other symbols that facilitate access to absent information sources [39, 40]. It constitutes an indirect perception [40] because the perception of the word 'ball', which is a representation of an actual ball, is a medium to talk about a to-be-directly-perceived ball. An example of this kind of knowledge might involve the verbal explanation of one player about how and when to act in a given game situation during a team meeting. This is a typical situation in team sports preparation where knowledge is shared, presupposing the notion of collective internalization, with a coherent sharing of the same mental representations between all teammates to underpin coordination. However, the role of this type of knowledge is to make others aware and to constrain action initiation [40], but only prior to actual competitive performance, before perception of information and action occurs. Moreover, tactical skills cannot be captured by verbal reports [49, 50]. Previous research in cricket and baseball showed that performers can actually do more than they can tell [41, 51] and that when asked to describe past performances they are usually inaccurate [40]. Other examples have highlighted existing differences between making verbal judgements about affordances and actually acting on them [52]. There is an interdependency between perception and action [53] and clear differences between verbalizing and acting [50].

Verbalizing and reflecting about their own performance may help individuals to become more attuned to important informational constraints that they may encounter in future competitive performance. However, there is still little firm evidence to conceive this type of knowledge as a collectively internalized mechanism explaining how all team members represent the unique and specific actions-to-be-performed (as well as an opponent's actions), in correspondence with their unique perceptions of the competitive performance environment.

3.1 Shared Affordances as an Information Network for Team Coordination

Alternatively, the control of action can be regulated through perception of affordances in a performance context [45]. Examples of affordance-based coordination have been reported in studies of performance in basketball [44, 54], futsal [48, 55], Rugby Union [56, 57] and Association Football [58, 59]. Affordances can be perceived because they are specified in patterns of energy available to perceptual systems [42, 45, 60], allowing performers to explore and detect the relevant information to support action [36, 41].

Reed's conception of affordances [61] is most important in an ecological approach. He argued that affordances are resources in the environment, properties of objects that might be exploitable by an individual. These resources in the environment have incurred selection pressures on individuals, causing them to evolve perceptual systems to perceive them. Those resources, that some group of individuals evolve the ability to perceive, are *affordances for members of that group*.

From this viewpoint, affordances are collective environmental resources that exist prior to the individuals that came to perceive and use them. Collective affordances can be perceived by a group of individuals trained to become perceptually attuned to them. In collective sports, both teams in opposition have the same objective (i.e., to overcome the opposition and win). Hence, the perception of collective affordances acts as a selection pressure for overcoming opponents, and achieving successful performance. In this sense, collective affordances are sustained by common goals between players of the same team (i.e., they are team-specific) who act altruistically to achieve success for the group.

Collective affordances can be specified by generated information sources from the positioning of teammates and opponents, motion directions and changes in motion, used to govern a team's coordination tendencies [57, 62, 63]. Thus, players can communicate by presenting affordances for each other [8] (whether consciously or not) by performing actions like passing the ball or running into an open space. These include the affordances another actor can provide under a given set of environmental conditions (i.e., affordances *for* others) and the affordances another actor's actions afford a perceiver (i.e., affordances *of* others) [64]. Therefore, by perceiving and using affordances *for* and affordances *of* others, players can share affordances and this helps to explain how teammates are able to control their actions in a coordinated way.

There is evidence supporting the idea that humans can be very accurate at perceiving another person's action capabilities [65, 66] and even the intentions of others [67, 68]. Examples of controlled action by perception of shared affordances in team ball sports have been reported in research in Rugby Union. Passos and colleagues [64] showed that the precise moment of a pass was decided according to the position of a tackler and to his possibilities of tackling the ball carrier. This study exemplified the perception of affordances from an opponent. The same rule can be applied for the perception of affordances from a teammate who, for example, has occupied a clear space providing the ball carrier with an opportunity to pass. Correia and colleagues [69] showed how the decisions of running, passing short or passing long for an attacker were constrained by self-affordances and affordances available *for* his teammates.

From this perspective, team coordination depends on being collectively attuned to shared affordances founded on a prior platform of communication or information exchange. Through practice, players become perceptually attuned to affordances *of* others and affordances *for* others during competitive performance and undertake more efficient actions [70] by adjusting their behaviours to functionally adapt to those of other teammates and opponents. This enables them to act coherently with respect to specific team task goals [62].

3.2 Establishing Interpersonal Synergies for Team Coordination

So far, we have provided explanations on how the decisions and actions of players continually constrain and are constrained by the actions of their teammates and opponents towards the goals of the collective.

Concepts from application of dynamical systems theory to the study of movement coordination contribute to this alternative framework for understanding team coordination. Insights from Bernstein suggested that independently controllable movement system degrees of freedom (dof) could be coupled to form synergies that regulate each other without the need for individuals to control each single dof separately [33, 71–73]. This idea is mirrored in team sports, viewed as dynamical systems composed of many interacting parts (e.g., players, ball, referees, pitch dimensions) [74, 75]. The numerous linkages between the players as collective system dofs (regarded as the numerous individual possibilities for action that emerge during competitive performance) requires the reduction of system dimensionality by harnessing the capacity for system re-organization into structures that are specific to a particular task [76–78]. These structures, also known as coordinative structures or synergies [79, 80], allow individuals in a team to act as collective sub-units [33, 80, 81] at the level of *interpersonal interactions* [77].

Specific constraints like the players' individual characteristics, a nation's traditions in a sport, strategy, coaches' instructions, etc., may impact on the functional and goal-directed synergies formed by the players to shape a particular performance behaviour. These informational constraints shape shared affordances available for perceptual systems, viewed as crucial for the assembly of synergies, that support the reduction of the number of independent dofs and enable fast, regulating actions [76]. Another feature of a synergy is the ability of one of its components (e.g., a player) to lead changes in others [33, 81]. Thus, the decisions and actions of the players forming a synergy should not be viewed as independent. In this context, social interpersonal synergies can be proposed to explain how multiple players can act in accordance with changing dynamic environments within fractions of a second. Let us re-consider the example of performing an indirect free kick in football. If, during the run-up to the ball, the player perceives that his teammates are undertaking different moves from those previously rehearsed (due to unpredictable constraints like an effective blocking movement by opponents), he/she might choose to shoot directly at goal instead of crossing the ball.

Therefore, the coupling of players' dofs into interpersonal synergies is based upon a social perception-action system that is supported by the perception of shared affordances.

Bourbousson and colleagues [15] reported examples of interpersonal synergies emanating from patterned behaviours of two basketball teams. They observed differences between defending teams in values for distances to immediate opponents by analyzing stretch indexes, valid compound measures that capture interpersonal interactions of teammates. Paradoxically, in a companion study of the same basketball contexts, fewer spatial-temporal couplings between players' displacements (assessed by measuring the relative phase of all possible intra-team dyadic relations) were identified, supporting data from the associated study discussed earlier in Sect. 2 [82]. However, these two studies appeared to present contradictory rationalization of the same phenomenon, with two contrasting conceptual approaches to team coordination used. While we agree that couplings between teammates may differ in strength during performance, it is not possible that players' actions can be independent in teams that exhibit co-adaptive behaviours. Further investigations need to clarify the merits of their interpretation of shared team coordination.

4 Conclusions and Practical Implications

In this article we have highlighted some inconsistencies in the conceptualization of the idea of shared knowledge for understanding coordination in sports teams. Alternatively, we proposed an ecological dynamics approach as a useful theoretical framework to explain coordination in collective systems. We argued that team coordination is guided through perception and use of shared affordances, not by products of a mind, the environment or a stimulus [76].

This view has major implications for designing experimental research in the field of team performance. Task designs need to focus on the *player-player-environment* interactions that can be captured through compound variables specifying functional collective behaviours of sports teams (e.g., geometrical centres, stretch indexes, etc.) [62] underpinned by interpersonal synergies created between players. Variations in such measures may express intra-team coordination processes as a consequence of cooperative goal-directed behaviours [63]. Interpretations in light of a shared affordances approach can explain how the intertwined perception-action processes of team members may form the basis of collective behavioural patterns under a specific set of constraints.

Training methods in team sports should promote the exploitation of constraints and the development of shared affordances through exploration of performance solutions. Small-sided and conditioned games may represent an excellent vehicle for the acquisition of shared affordances during practice [83].

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