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Chapter 10

HOW DOES KNOWLEDGE CONSTRAIN SPORT PERFORMANCE? AN ECOLOGICAL PERSPECTIVE

Duarte Araújo [1], Keith Davids [2], Rita Cordovil [1,3], João Ribeiro [1] and Orlando Fernandes [4]

[1] Faculty of Human Kinetics, Technical University of Lisbon, Portugal
[2] Queensland University of Technology, Australia
[3] Lusófona University of Humanities and Technologies, Portugal
[4] University of Évora, Portugal

ABSTRACT

From an ecological perspective knowledge signifies the degree of fitness of a performer and his/her environment. From this viewpoint, the role of training is to enhance this degree of fit between a specific athlete and the performance environment, instead of the enrichment of memory in the performer. In this regard, ecological psychology distinguishes between perceptual knowledge or "knowledge of" the environment and symbolic knowledge or "knowledge about" the environment. This distinction elucidates how knowing how to act (knowing of) as well as knowing how to verbalize memorial representations (e.g., a verbal description of performance) (knowing about) are both rooted in perception. In this chapter we demonstrate these types of knowledge in decision-making behaviour and exemplify how they can be presented in 1 v 1 practice task constraints in basketball.

INTRODUCTION

This chapter addresses the question of how knowledge constrains (i.e., channels) athlete behaviour in sport performance and training. Different perspectives exist on how this may occur, including enrichment theories and ecological theories (Michaels and Carello, 1981). Enrichment theories hold, for instance, that skilled athletes outperform novices because of the knowledge they have added to their memories during the process of learning. It is proposed that the enrichment of memory allows skilled performers to make more accurate inferences for action from information available in the performance or training environment (examples in sport include McPherson and Kernodle, 2003, see also the other chapters in this section by Köppen and Raab, Chapter 9, Laurent and Ripoll, Chapter 11, and Williams and North, Chapter 8). Ecological theories, in contrast, hold that learning entails changes in properties of the environment to which perceptual systems become sensitive (Jacobs and Michaels, 2007, see Savelsbergh et al., 2004 for an example in sport). In the ecological view, the sophistication of expert performance derives from the improved fits of experts to their environments, rather than from an increased complexity of computational and memorial processes (see Shaw, 2003 for a detailed discussion about the differences between these views).

The ecological approach calls for a complete understanding of the informational aspects of the constraints of performance, as well as the behavioural consequences of such information. In this way, information closes the putative gap between perception and knowledge, with one process continuous with the other (Gibson, 1979). The traditional view that seeing something is quite unlike knowing something emerged from the old doctrine that the process of *seeing* involves a series of temporary sensations during each moment of time. *Knowing* has been proposed as storing permanent concepts in memory. However, perceptual *seeing* involves an awareness of persisting structure (Lee et al., 1982). Human knowledge emerges from experience of the affordances available to be picked up in performance and training environments. This process is based on perception but it enables humans to develop patterns of thought that go well beyond perception. *Knowing* is a process which resides neither wholly within the individual as an effect or response, nor wholly within the world as a cause or stimulus; rather, as an ecological concept, *knowing* stands astride the physical and psychological domains (Turvey and Shaw, 1995, 1999). Thus, to say that expert players "know" what needs to be done in a match, means that the player is sensitive to the events that convey information for his/her aims at any instance of the game (e.g., they understand how to find a path through opponents towards the basket or how to get a shot off despite the close attention of a defender). Through training, the player does not have to rely on constructing special mental representations about the game, but he/she has to learn how to use his/her body to adapt to the sources of information that will help make him/her successful. The development of this sensitivity to the competitive context occurs before the season, for example, through practice and training, and by schematically planning coordinated actions of the team for certain games. These schematic plans may represent the game but representations are not mentally constructed.

Important to this discussion is Gibson's (1966) distinction between knowledge of the environment (perception based on information to control action, which constrains actual action, "what do I do to achieve a certain goal when I'm acting on a task" – exemplified by tactical decision-making) and knowledge about the environment (perception mediated by language, pictures and other symbols, which constrains future action "what can I do to achieve a certain goal before I can act on it" – exemplified by strategic decision-making). We move now to discuss further this notion.

GIBSON'S CONCEPTION OF KNOWLEDGE

Gibson (1966, 1979) argued that virtually all theories of perception had assumed that the objects of which we are immediately aware are based on sensations. These subjective objects give us knowledge about the external world, but only after a complex process of inference, association and interpretation is applied to them. In other words, most theorists held that what are directly perceived are mental symbols or representations, and it is only indirectly, through the mediation of these representations, that we perceive the external world (e.g., Fodor and Pylyshyn, 1981).

Gibson's theory that the perception of environmental objects, places, and events is based on ecologically available information challenged this widespread consensus. Gibson noted that his theory was a form of direct realism, in that it maintained that the surrounding environment could be perceived directly, on the basis of information, and not indirectly, on the basis of sensations and mental representations. Importantly, Gibson never argued that indirect (mediated) perception (or awareness) was impossible, but he made a strong distinction between perception based on information and perception based on language, pictures and other symbols. In 1966 (p. 91) he wrote: "In this book, a distinction will be made between perceptual cognition, or knowledge of the environment, and symbolic cognition, or knowledge *about* the environment. The former is a direct response to things based on stimulus information; the latter is an indirect response to things based on stimulus sources produced by another human individual".

For Gibson the process of detecting information is carried out by a functional system distributed throughout an individual's nervous system. Adjustments of peripheral organs, such as turning the eyes and head, play as significant a role in direct perception as the activity of the higher brain centres. Awareness of the environment is based on the adjustment of the performer's entire perceptual system to the information surrounding it. This adjustment includes a range of processes, all of which may be described as the simultaneous extraction of persisting and changing properties of stimulation, invariants despite disturbances of the array of information (Gibson, 1979). Performers can perceive themselves, their environments, and the changing relationship between themselves and their surroundings.

Gibson introduced the notion of affordance, a term that simultaneously captures and couples objects and events of the world with an individual's behaviour (Turvey and Shaw, 1995). An affordance is a combination of invariant properties in the environment, taken with reference to an organism that specifies an opportunity for action (Turvey, 1992). Consistent with Gibson's (1979) ecological notion of perception-action, affordances are properties of the environment whose actualization requires an individual with reciprocal effectivities; an effectivity is the dynamic actualization of an ability by the individual taken with respect to a particular opportunity for action (Shaw and Turvey, 1981). For an affordance to be a successful goal of an action there must be an affordance-effectivity fit of organism and environment. For example, an unmarked team mate located near the basket opens a passing line as an affordance for the player with the ball. But for the pass to be successful, the player in possession of the ball must have the reciprocal effectivity, i.e., the conjunction of strength (fitness) and accuracy (skill) to move the ball rapidly from the hands to the team mate.

The fundamental hypothesis of Gibson's ecological approach to perception and action is that where specific information about environmental objects, places, events and people is available and picked up, performers will perceive these entities to support their actions. This is what Gibson meant by the term direct perception, or "knowledge *of*" the environment. This type of knowledge is not formulated in pictures or words, because it is the knowledge that makes the formulation of pictures and words possible. However, even though it is tacit, this knowledge of the environment obtained through direct perception is not personal, subjective or private. Information is available in the environment, and it can be picked up by many observers. On the other hand, according to Gibson (1979) these "images, pictures, and written-on surfaces afford a special kind of knowledge that I call *mediated* or *indirect*, knowledge at second hand" (Gibson, 1979, p. 42). This kind of knowledge is intrinsically shared, because it involves the displaying of information to others. In all these cases the information on which direct perception can be based is selectively adapted and modified in a display, exemplified here by a schematic presentation of the disposition of two teams in basketball. The value of these pictures with selected samples of information lies not in the displays themselves, but in what they refer to or *represent*. These mediators are representations; they do not have affordances as objects do, but rather have 'referential meaning' (Reed, 1991). They consolidate gains of perception by converting tacit knowledge into explicit knowledge (Reed, 1991). The role of explicit knowledge, and the processes that make knowledge explicit, is not to create knowledge out of merely potentially meaningful input, nor even to select meanings to assign to inputs. The role of indirect forms of cognition is to make others aware and to share knowledge.

From an ecological point of view, knowledge should be understood in direct and deep connection with dynamic principles (Turvey and Shaw, 1995). From this ecological perspective, characteristic cognitive capabilities are what they are by virtue of laws and general principles. Within this approach, dynamics (involving laws of motion and change) and dynamical systems (involving time evolution of observable quantities according to law) can help us to understand knowledge in sport in line with the work initiated by Kugler, Kelso and Turvey (e.g., 1980, 1982; see also Araújo et al., 2006, for a development of these ideas in sport). The link between the ecological approach to perception and the dynamical systems approach to action is expressed in its most developed state to date in the work of Warren (e.g., 2006). He characterized the agent and environment as a pair of dynamical systems, coupled by both mechanical forces and informational flow fields. The behaviour that emerges from this interaction is referred to as *behavioural dynamics*. Briefly, functional behaviour can often be described by changes in a few key variables. Observed behaviour corresponds to trajectories in the state space of behavioral variables (i.e., the hypothetical totality of all the possible states of order which are achievable by a system). Goals correspond to attractors or regions in state space toward which trajectories converge. Conversely, states to be avoided correspond to repellers, regions from which trajectories diverge. Sudden changes in the number or type of these fixed points are known as bifurcations, which correspond to qualitative transitions in behaviour. In other words, they express decisions. A central theme of Warren's framework is that behaviour is not commanded by a central controller. Rather, the agent learns mappings from information in (e.g., optic) flow to movement that bring about desired states (i.e., goals). Knowing what patterns of flow can and cannot be brought about allows the agent to perceive affordances. Next, we present an illustration of these types of knowledge in the team sport context of basketball.

EVIDENCE FOR THE DISTINCTION BETWEEN KNOWLEDGE OF AND KNOWLEDGE ABOUT IN THE SAME TASK (1VS1 IN BASKETBALL)

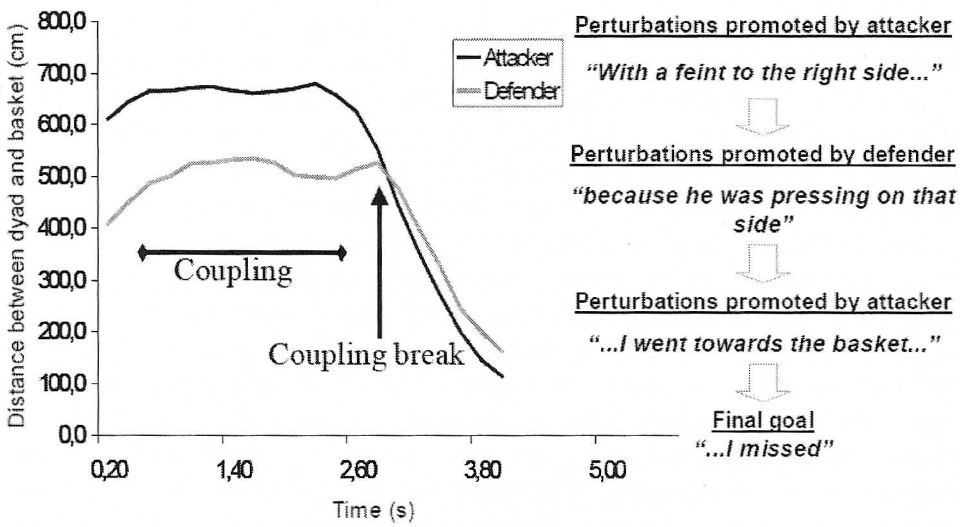
In dynamic environments such as a basketball game there is typically not one stimulus to trigger a reaction in a player (such as when a sprinter reacts to the starter's gun), but a constant flux of stimulation available to be picked up from the environment in support of action (Reed, 1996; Whiting, 1991). Therefore, although possible, an explanation for a particular aspect of a complex interaction in an attacker-defender dyad, such as a response to a fake move by one player, cannot easily be explained by relationships like Hick's law (the relation between the number of stimulus-response alternatives and reaction time), stimulus-response compatibility, or the psychological refractory period (although see Schmidt and Lee, 2005). Also, the fact that both players in the dyad are linked by information indicates that one player is not merely responding to the other, but that there is a coupling effect as an emergent property, as predicted by the ecological dynamics systems approach (Davids et al., 2006). An ecological dynamics analysis of the coupling and decoupling of the players in a basketball dyad needs to begin with a measure of order in the stable interpersonal pattern formed by the position of the attacker and defender with respect to the ball and the basket.

Analysis of coaching literature reveals that an order parameter (i.e., a collective variable that synthesizes the relevant coordinated parts of the system as a whole) to describe the organization of an attacker-defender system could be the distance between the basket and the dyad (i.e., medium point of the distance between the attacker and defender) during a 1 v 1 sub-phase of the game (e.g., Bain et al., 1978). Araújo et al. (2002; 2004; Davids et al., 2006) examined whether the distance from the attacker-defender dyad to the basket would become less stable (i.e., not maintaining a similar distance from the dyad to the basket) until some critical value of interpersonal distance was reached. This was even more evident when we decomposed the order parameter (distance between the medium point of the dyad to the basket) showing each player's distance to the basket (see figure 1 for illustration of this decomposition). This investigation considered whether changes in interpersonal distance were associated with dribbling success by attackers. By tracing in the horizontal plane trajectory the mass centre of each player in the dyad, and then computing the values of the described order parameter, we observed that during the initial part of the dyadic entrainment there is a stable state of the order parameter, meaning that the players are coupled. This state was followed by an abrupt change in the system due to an attacker's success in de-stabilizing the dyad and de-coupling the players (see arrows in figure 1). In the case of success by the attacker, the attacker-defender system exhibited initial coupling, which was broken during transition to a new state at a critical value of the control parameter. In other words, the attacker was trying to dribble past the defender, but the defender was attempting to maintain the initial steady state of the dyad. The attacker increased the variability of dribbling actions (deciding what to do) in order to force the emergence of a system transition (deciding when to move past the defender). Suddenly (when dyad was broken), the decision emerged in the 'intending-perceiving-acting cycle' (Kugler and Turvey, 1987), suggesting that it is possible to interpret the dynamics of player interactions in dribbling as emergent properties under constraints.

Similar results were obtained by Ribeiro and Araújo (2005), with top national junior players, where besides analysing the ecological dynamics of the basketball dyad, concorrent verbal protocols were applied. These verbal protocols were carried out immediately after the attacker had finished competing in the 1vs 1 practice task, since it was almost impossible to apply these protocols concomitantly in such a fast moving task (timescale of 1 to 5 seconds) (Ericsson and Simon, 1993). Ericsson and Simon (1993) proposed that there are many types of behaviour where participants spontaneously report concurrent and retrospective thoughts. They suggested that when appropriate verbal reporting procedures are used, participants can report on the information they were attending without changing the structure of the underlying processes. They argued that researchers have now accepted that participants provide valid concurrent verbal reports on their cognitive processes matching other evidence for the associated performance and process-trace data. Interestingly, the ecological psychologist Reed (1996) argued that verbalization is a relevant means of selecting and making information available to others, and that "it refers not to inner representations but to environmental situations and states of affairs" (p. 156). Thus, there is clear support for the circumscribed use of verbal protocol analysis techniques by sport psychologists within different theoretical frameworks in studying cognition, perception, and action.

The categorization of verbalizations in Ribeiro and Araújo's (2005) study was made including three broad topics: i) verbalizations without reference to the context ("I went to the right because is my best side"), ii) verbalization with reference to the context (referring to what the defender did – perturbations promoted by the defender, and action opportunities detected in the situation – perturbations promoted by the attacker), iii) and verbalizations concerning the goal of the attacker in that 1vs 1 situation (i.e., about the shot or the result). Then the number of elements of each protocol was counted, i.e. the number of categories verbalized sequentially by the performer. The researcher used probes such as "what happened in this situation that you just performed?", and then "could you be more detailed?".

The results clearly showed that what the player stated about his actions clearly differed, although it was complementary to what he really did during the task (figure 1).



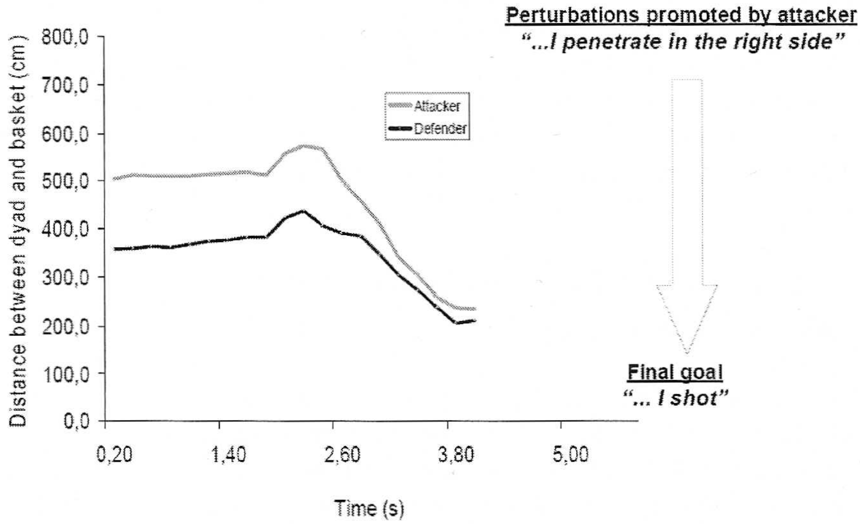


Figure 1. Expressions of player's knowledge in 1vs 1 situations in basketball. Right and left graphs illustrate the two types of knowledge (*knowledge of*, *knowledge about*).

More compelling was the fact that in the top graph of figure 1, the retrospective verbalizations that described the player's *knowledge about* the situation was more detailed than in the bottom graph of figure 1, but their *knowledge of* the situation was equally detailed in both situations. Importantly, the examples in figure 1 were selected since they involved two players playing at the highest national junior level, in similar positions in the attacking system of the team. Their performances ended with a similar result (both shots touched the ring but the ball did not go through the basket), however their expressions of *knowledge about* their performance were quite different.

These results showing individual differences in 'knowledge about' the practice task can be interpreted with reference to Gibson's (e.g., 1979) theorizing. Indeed, Gibson (1979) did not deny the existence of physical objects or individual differences in terms of perceptions of the world; rather, he conceptualized how they could be coupled. Postulating this 'knower-known' coupling, and the importance of grounding it within the context in which the knowing occurs, Gibson avoided a 'knower-known' dualism. Through experience with various environments and their nested affordances, the individual becomes apprised of what changes and what remains the same. In this way, it is possible to account for individual perceptions of change (variance) and permanence (invariance) without the postulation of further mental processes. Subsequent interactions are not dictated by the individual or environment; they emerge out of the dynamics of the interaction itself – an affordance-effectivity fit (Barab et al., 1999). From this view, meaning is not solely in the environment or solely in the individual but in the relation between them.

As participation couples knower and known, it takes on and imbues meaning, within context, through the function it serves. As the goal is met, the function served flows back on the action, imbuing it with contextualized meaning. This notion places meaning within context-embedded experience, where practice takes place in the context of meaningful relations (Barab et al., 1999). The particular meaningful relations that emerge are, in a very real sense, dependent on the performer-context relation in which particular constraints make certain meanings more functional, indeed more probable, than others; that is, context places boundary conditions on the particular meanings that emerge.

In order to further test these ideas we conducted research in which we manipulated perceptual knowledge and symbolic knowledge (Araújo, 2006; Cordovil et al., 2006; Cordovil et al., in press). For this purpose, we studied effects of task and individual constraints on decision-making processes in experienced basketball players.

CHANGES IN PLAYERS' BEHAVIOUR DURING 1VS1 DUE TO MANIPULATION OF KNOWLEDGE CONSTRAINTS

In order to manipulate symbolic/verbal knowledge or *knowledge about*, specific instructions (neutral, risk taking or conservative) were manipulated to observe effects on emergent behaviour of the dyadic system. Instructions were: i) Risk - the game will finish in 10s, the team is losing by 1 point and the player should risk possession to change the scoreline; and ii), Conservative - the game will finish in 20s, the team is winning by 1 point and the player should be conservative to prevent the opposition from changing the scoreline. In order to manipulate perceptual knowledge, or *knowledge of* the environment, body-scaling of participants was systematically altered by creating player dyads with different height and arm span relations. The anthropometric manipulation of dyads (height) was: i) Attacker much taller than defender (difference ranging between 6.7% - 15.4%); and ii) Attacker much shorter that defender (difference ranging between 6.7%- 15.4%). In the control group players had similar height levels (differences ranging between 0.2% - 2.7%) and received neutral instructions (try to score within the rules of basketball).

Data showed how decision-making behaviour could be differentially influenced by *knowledge of* and *knowledge about* the environment. The group with risky instructions and the group with shorter attackers were characterized by greater speed in crossing the mid-court line ($p \leq .001$), and by less variability in the path of the dyad towards the basket, over time ($p \leq .001$). However, the attackers with risky instructions also tended to lose possession of the ball more often. The group with taller attackers was characterized by a lack of coupling breaking ($p \leq .006$). Finally, the group with conservative instructions was slower in crossing the mid-court line ($p \leq .001$), and showed greater variability in the path of the dyad towards the basket, over time ($p \leq .001$), and greater variability in the attacker's trajectory on court ($p \leq .001$). Data showed that the manipulation of these kinds of knowledge created boundary conditions on the particular behaviours that emerged.

In figure 2, it can be observed that, during the initial part of the dyadic entrainment there was a stable state of the collective variables, followed by an abrupt change (de-coupling) in the state of the system due to an attacker's success in de-stabilizing the dyad. These dynamical properties were clarified with the use of statistics. The running correlation curve RC(t) is the time course of correlation coefficients obtained from a sliding rectangular window of waveform data centred at t. The correlation coefficient at each instant is the normalized sample covariance of the windowed waveforms $x'(t)$ e $y'(t)$: $RC(t) = <(x'-m_{x'})(y'-m_{y'})>/(s_{x'}s_{y'})$ where m and s are the amplitude mean and standard deviation across the duration of each windowed waveform (see Corbetta and Thelen, 1996; Meador et al., 2002). The running correlation RC(t) provides a measure of the degree of coupling of the players in the dyad. Each value of *r* represents the degree of coupling at each moment of the interactions. Interestingly, this coupling can be inverse (see the "conservative" graph), meaning that the players are not moving both to the same side at the same time, but that each player is moving to a different side at the same time.

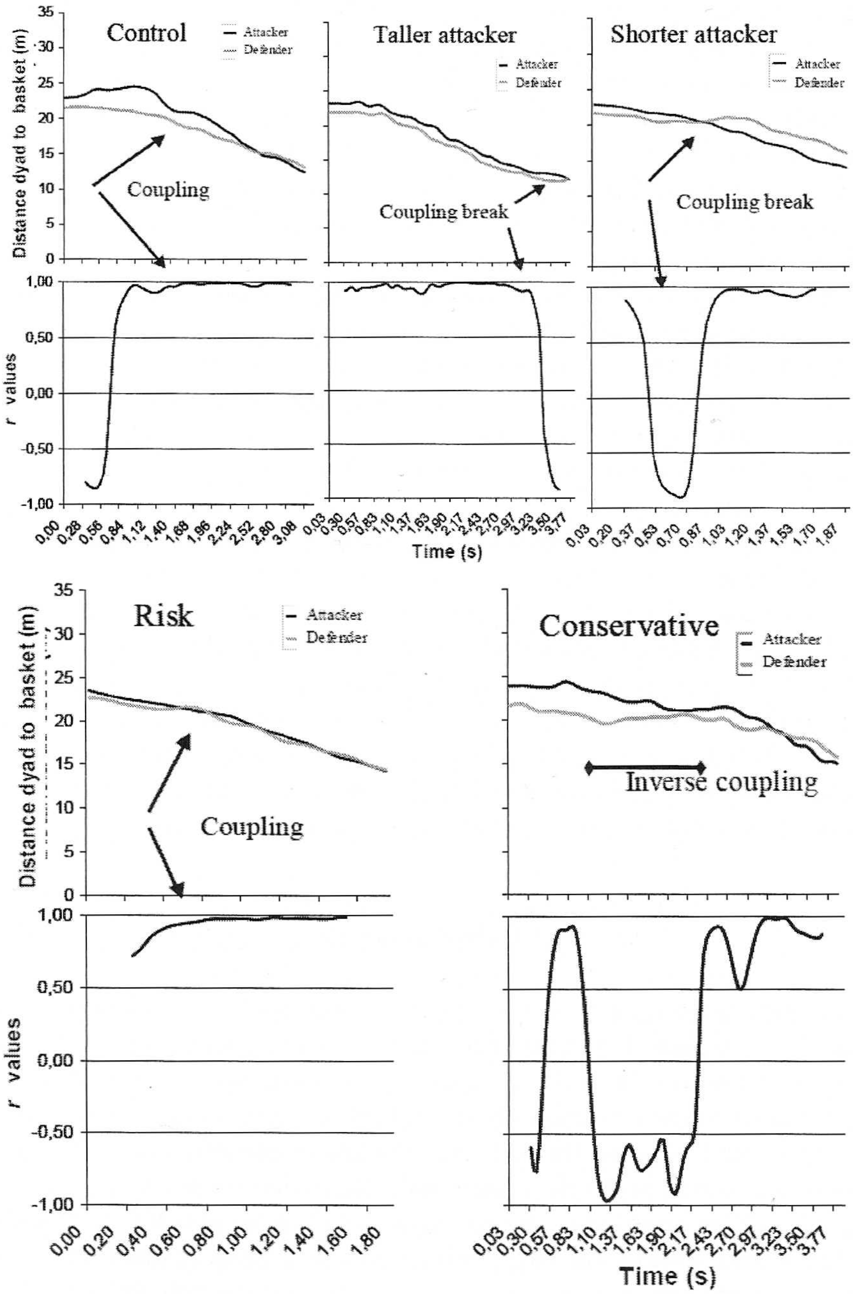


Figure 2. Example of five organizational states of the system formed by the "attacker-defender-basket" in a 1vs 1 situation (Control, Taller attacker, Shorter attacker, Risk and Conservative). The graphs on the top of each of the two ensembles indicate the distance run by the players from the starting point to the basket. The bottom graphs show the corresponding running correlation function.

In figure 2, it can be observed that all the graphs, except the one involving the group given conservative instructions, showed a symmetric coordination pattern between the players. It is clear that typically both players in a dyad approached each other or moved apart almost simultaneously, with the correlation function displaying high positive values. The two graphs with two examples of system dynamics constrained by conservative task instructions, showed that after starting uncoupled, the players formed a system which exhibited symmetry (coupling with $r > .80$) , with changes to uncorrelated states, and with anti-symmetric states (inverse coupling with $r < -.80$).

The example of a situation with risky instructions revealed several zero-crossings (symmetry-breaking occurrences) but maintained a high degree of coupling during the whole trial. The graphs depicting the control group, as well as the example with the taller attackers showed a similar pattern of coordination, with the moment of transition to the antisymmetric state distinguishing most situations.

Note that in the example of the group with shorter attackers, the system changed from symmetry to antisymmetry and returned to symmetry, in synchronization with the zero crossing shown on the upper graph (the distance of the players to the basket).

Symmetry states were broken when correlations between players in a dyad stopped. At that point a zero crossing tended to occur, with the positioning of the players being inverted, but the positive correlation persisted. But in the antisymmetric states, due to its instability, this attractor was visited only when the system transited between symmetries, an infrequent event, perhaps due to the greater amounts of metabolic energy that the players needed to use to maintain this kind of coordination (in comparison to the conservative instruction group in figure 2). It is interesting to note that only the trials of the control group and the conservative instruction group exhibited non-correlated states of interaction. In sum, this macro perspective (compared to perspectives that merely analysed cognitions based on organismic constraints, such as preferences, desires, eye movements) of the coordination states of the dyadic system influence by different constraints showed unique properties, which cannot be observed at other levels of analysis. These observations strengthen the argument that cognition and knowledge of performers in sport should be analysed at the ecological scale.

CONCLUSION

In this chapter, we have used the context of basketball to show how cognition and knowledge can be explained in terms of the relations between performers and the properties of specific environments in sport. In sport, as in other specific performance settings, knowledge is described as fundamentally situated, emerging in context (Barab et al., 1999). It becomes impossible to separate the performer, the task to be performed or the material to be learned, and the context in which training and competition occurs. From this perspective, "knowing of" and "knowing about" are no longer conceived of as static structures residing in an individual's head; instead, knowing of/about refers to an activity that is distributed across the knower, the environment in which knowing occurs, and the task which the performer is attempting to perform - a dynamic unfolding of the perception-action cycle. *Knowing of* as well as *knowing about* are deeply embedded in active participation within the social/material world. Skill development is therefore context dependent, and there is a relation between knowing of/about the world and the world that is being known. Is it possible to scientifically identify a world-class basketball player outside of a basketball context? The answer is clearly no (but confront with Ripoll, Chapter 7).

A full account of cognitive activity in team sports like basketball (as opposed to a static conceptualisation of cognition), knowing about (as opposed to static knowledge), and meaningful relations (as opposed to a collection of symbols in a representation) must include an account of ongoing change, and of the emergence of new order. Emergence is a key aspect of cognition and learning that has not been handled well by information-processing theories.

One implication of these ideas for practice in sports such as basketball is that knowledge transmitted by coaches to performers is at best second hand, since instead of having to be extracted by the performer from the environment, this knowledge is typically communicated in verbal descriptions to the performer. This indirect knowledge transmission process relies on the coach's skill in verbalising concepts and ideas in basketball and on the player's ability to interpret verbal instructions to become more aware of the information in the performance environment. This is not an impossible task. But it is much more challenging than the process of selecting and manipulating task constraints in order to help the performer increase direct awareness of key information sources to obtain knowledge about specific performance circumstances (Davids et al., 2008). To conclude, both direct and indirect cognition constrain performance, but the *expression* of a player's *knowledge of* the environment is perhaps the main purpose of competition (and training).

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