EDITORIAL:

The study of decision-making behavior in sport

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Research on decision-making in sport has received increasing attention by sport scientists during the last decade (Araújo, 2011). In fact we see that different theoretical perspectives, methodologies (García-Gonzalez, Araújo, Carvalho & del Villar, 2011; Williams & Abernethy, 2012), and applications to training (Ibáñez-Gijón, Travieso, Jacobs, 2011; Carvalho, Araújo, García-Gonzalez & Iglesias, 2011; Causer, Janelle, Vickers & Williams, 2012; Davids, Araújo, Hristovski, Passos & Chow, 2012) are consolidated. In the next lines we emphasise the ecological dynamics approach. This approach avoids the "organismic asymmetry" (Davids & Araújo, 2010), i.e., looking only to the organism's interior, between input and output, but aims to capture the reciprocal interaction between individual and environment.

Skilled behaviour consists of intentional adaptation to the constraints imposed by the environment during task performance (e.g., Araújo & Davids, 2009). In ecological dynamics, for a given task, a performer and the performance environment are treated as a pair of dynamical sub-systems that are coupled and interact mechanically and informationally. Their continuous interactions give rise to behavioural dynamics, a vector field with stable, avoided and changing system states. Sudden transitions in behaviours indicate that decisions emerge in the 'intending-perceiving-acting cycle'. These ideas imply that there should be a strong emphasis on the specificity of the relations between the individual and environment, in designing representative settings both for experiments and practice in sport (Davids et al., 2012).

Perception and action coupling during sport performance

Perception refers to how humans can be aware of their surroundings. For example, during locomotion, a performer can visually regulate their actions by perceiving information from the optic flow. Optic flow is created by patterns of light available at a point of observation, structured by particular performer-environment interactions. In optic flow particular reliable patterns of optical structure, called invariants, are relevant to guiding activity. Outflow and inflow are distinct forms of optic flow that inform the performer whether he/she is moving forward or backward. Flow is structured by the texture and objects that we encounter as we move around a performance environment (e.g., terrain, people) that allows us to discover invariants to regulate activity (Carello & Turvey, 2002). In order to effectively guide their activities, performers need to know more than just what they're approaching (i.e., perception for object identification). They also need to know how they're approaching (i.e., the spatio-temporal characteristics of how they are addressing a feature of the performance environment).

Optical structure relevant to negotiating the environment has been identified and provides examples of quantitative invariants. The optical quantity tau (t) is specific to when a point of observation will contact an upcoming surface. For instance, as an attacker approachesthe defenders, their optical projection on the retina magnifies. The speed of approach affects this rate of retinal image expansion, regulating the change in optical area per unit of time. The quantity τ is given by the inverse of the relative rate of the retinal expansion—how long will it take until there are no units of time left (Lee, 1998). These descriptions of global optical structure capture situations when an observer is approaching a surface. But they are also relevant to a surface or object, such as a ball, approaching the point of observation. Local disturbances of optical structure are relevant to the guidance of interceptive behaviours and can be described in terms of τ and its derivative, providing specific information to the performer on when and how the interception of an object, individual or surface will occur (see Correia et al., 2011, for an example on Rugby). But to understand how perception is "individualized" the concept of affordance is needed.

Affordances are possibilities for action in a particular performer-environment setting (Gibson, 1979). Whether a hurdle, for example, is a 'running over' place or a 'jumping off' place is not determined by its absolute size or shape but how it relates to a particular performer, including that individual's size and agility and style of locomotion. The assumptions central to Gibson's (1979) theory of affordances are that: (a) actor-scaled properties of the environment allow a given behaviour to a performer; (b) informational invariants in energy arrays specify an individual-specific action; and (c) given that observers have perceptual systems sensitive to this information, they are able to perceive an affordance (Gibson, 1979; Withagen & Michaels, 2005). The theory of affordances is based on the interdependence of perception and action, where affordances are the primary objects of perception, and action is the realization of affordances (see Esteves, Oliveira & Araújo, 2011, on affordances in basketball).

Reed (1996) argued that skilled behaviour requires subtle resource usage, asserting that behaviour is not intrinsically mechanical, but functional. He argued that in the course of evolution, selection pressures gave rise to different action systems, enabling performers to establish new functional relationships with their performance environments. During performance in sport, resources can emerge from the performer (e.g., height, velocity) or from the environment (e.g., adherent floor, jumpable obstacle). Thus an action should not be considered as a simple displacement of anatomical parts of the body, because complex biological systems exhibit the capacity for stable and unstable patterned relationships to emerge between system parts through self-organisation (Davids, et al., 1994).

In nonlinear dynamical movement systems, this type of self-organisation process can occur in several functionally appropriate ways. Non-linear dynamics is a branch of physics that provides a formal treatment of any system which is continually evolving over time, and which can be formally modelled as a numerical system with its own equations of motion (Araújo et al., 2006). Within this framework, the behaviour of any living system can be plotted as a trajectory in a state space: the set of all states attainable by the system, together with the paths to them. Resting states of the system are attractors. A physical system can have one or more attractors. The number and layout

of these attractors influence the overall functioning and behaviour of the system (Kugler, Shaw, Vincente & Kinsella-Shaw, 1990). In human movement systems, attractors are roughly equivalent to functional states of coordination of system degrees of freedom (Davids, et al., 1994).

Self-organization processes emerge from the dynamics of open systems that intrinsically and autonomously create and destroy such stable system states. Transitions between states of organisation (order-order transitions) occur at the timescale of perception and action, exemplifying interactions between athletes and the environment. These interactions initiate system trajectories from one marginally stable dynamic mode to another, providing the basis for athletes to select functional coordination modes. Structurally stable states of ordered behaviour are created or destroyed with reference to changes in the perceptual field (e.g., optic flow), allowing a performer to switch between different stable modes of behaviour.

The constant (re)structuring of system organisation and behaviour emerges under the influence of constraints, which can simultaneously limit and enlarge the system's range of behavioural possibilities. Bottom-up constraints are responsible for the initial formation of macroscopic order among system microcomponents (e.g., physiological processes of the athlete). While this is occurring, top-down constraints can "enslave" the microcomponents into the macroscopic whole (e.g., competing in a championship). In this way, human behaviour can be constrained by the specific performance context in such a way that states that emerge are those that contribute to the performer-environment system's desired behavioural goal (Kelso & Engström, 2006).

Intentionality and sport behaviour

The perceptual control of action and the enhancement of the quality of perception by exploratory activity are specified by initial conditions and constraints that are bounded by the goals aimed by the performer. Intentional constraints may be seen as goal-state attractors arising through the dynamic interplay of constant energy exchanges between a performer and the environment (Kugler et al., 1990). According to Kugler and Turvey (1987), internally-stored energy flows provide a source of force

and which can actively utilise or compete against external forces (e.g., a runner using or braking against gravitational forces when running down hill). Thus, internal forces can be directed to compete actively with external forces in achieving specific intentions. The intentional dynamics that emerge during performance are the consequence of a movement system's ability to use energy tactically, to anticipate outcomes, and to choose among options. Some aspects of intentional behaviour refer to an interior frame of reference (e.g., the biological systems of the attacker footballer), and others refer to an exterior frame (e.g., the situation of confronting an attacker, which includes the position of the goal and defender). To intend a performance goal a performer needs to select an initial condition that permits attainment of a specified final condition under the laws of physics. With each step closer to the goal, the information must become even more specific, narrowing the range of possible action paths, until ultimately, at the final moments of goal accomplishment, an emergent performance path becomes uniquely defined (Araújo et al., 2006).

The individual can use his or her internal potential only at choice points (Kugler et al., 1990). Decisions arise at those points along a trajectory at which the system must expend internal energy to keep moving in the same mode toward the same target, or where it can counter the work done on it by an exterior gradient. Structurally, these choice points in the field are bifurcation points that act as attractors. They imply choices because there is insufficient information in the field to define uniquely a future path (Araújo et al., 2006). In order to achieve a final goal, nonlinear behaviours will result if there is a competition between attractors (i.e., if there are multiple sub-goals to be satisfied). For example, Cordovil et al. (2009) studied effects of task and individual constraints on decision-making processes in basketball. When specific instructions were manipulated they observed effects on emergent behaviour of the dyadic system. Moreover, when body-scaling of participants was manipulated by creating dyads with different height and arm span relations, results indicated that height had a greater effect on emergent dynamics of decision-making in dyads. When attackers were considerably taller than defenders, there were fewer transitions than in other combinations.

In sum, the production of stable yet adaptive behaviours

implicates the coordination of action, where the individual selects action modes, and it implicates perception, where information is selected (picked up) from the environment in order to guide action. The problem of intentionality and decision-making is, thus, grounded on perception and action cycles (Araújo et al., 2006). The implication is that the structure of the environment, the biomechanics of the body, perceptual information about the state of the performer–environment system, and the demands of the task all serve to continuously constrain behaviours. Adaptive behaviours, rather than being imposed by a pre-existing structure (e.g., memory, brain area), emerge from this confluence of constraints under the boundary condition of a particular task. With this exposition I would like to call for a more holistic and integrated view on sport behaviour research, where psychology, physiology, biomechanics, neurosciences, and sociology address together sport phenomena.

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