Understanding Skilled Adaptive Behavior: The Role of Action, Perception, and Cognition in an Ecological Dynamics Perspective

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Abstract

This chapter presents an ecological dynamics approach to conceptualizing affordances in the context of sports to understand the acquisition of skilled behaviors. Ecological dynamics is a multidisciplinary framework anchored in the sciences of complex systems, framed by concepts in ecological psychology and nonlinear dynamics, for analyzing behavioral adaptations (i.e., coordination and control) to surrounding constraints, predicated on processes of perception and action. We emphasize how the continuous regulation of human behavior is founded on information that guides the behaviors of each individual–environment system. The role of information is to support perception of affordances which can solicit and constrain behaviors in a specific performance environment. We highlight how affordances are body- and action-scaled, meaning that affordances are relative to the abilities of each individual. Environments in sports offer a rich landscape of multiple affordances, supporting skilled behaviors to emerge as sports performers engage in goal-directed actions based on perception of nested affordances. Explanations of skilled behaviors are enriched by the integration of tools and concepts from nonlinear dynamics to highlight how information is embedded in the dynamics of a performer acting in a performance environment, signifying how sports contexts can afford multiple modes of action for athletes during the performance.

Reference:

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Glossary

eco-physical variables: behavior variables which capture how performers coordinate with the circumstances of performance in a given performance environment.

field of affordances: affordances that stand out as relevant for use by a particular individual in a specific performance context, soliciting interactions with the environment

inviting affordances: in a given field of affordances there are some affordances that are salient and demand an acceptance or a declination from the perceiver.

degeneracy and functional equivalence: the capacity of elements in a complex adaptive system that are structurally different to achieve the same function or yield the same output, which could be summarized as a 'many structures-to-one' functional relationship

attractors and action modes: the different stable states of organization in a system. In dynamical movement systems, these states form coordination tendencies in an individual's movement when performing a given task in dynamic environments

perceptual attunement: learned ability of individuals to better use information sources for guiding actions

nested affordances: the multiple, inter-related affordances that co-exist in any given context providing an obligation for individuals to concatenate them when performing complex actions.

cognition: how performers negotiate the environment and regulate performance, as expressed by action, in a given performance environment.

decision-making: transitions, by means of bifurcations between attractors, in a course of action.

What do we understand by the term *affordance*?

> *Perhaps the composition and layout of surfaces constitute what they afford. If so, to perceive them is to perceive what they afford. This is a radical hypothesis, for it implies that the "values" and "meanings" of things in the environment can be directly perceived.*
>
> — James J. Gibson (1979, p. 127)

Gibson (1979) proposed that humans perceive action possibilities or affordances offered by the environment. His ideas imply that, in sports, performers perceive objects, surfaces, or events by what they may offer an athlete in terms of opportunities for action. In ecological psychology, affordance is not an independent *entity* but a property of the environment related to the organism that results in the emergence of behaviors. For example, environmental surfaces offer different actions for different people due to, among other constraints, their distinct physical properties, such as limb lengths (see Fajen et al., 2009, for critical features of affordances discussed in the context of sports). For instance, does a surface afford stepping on with the feet or climbing on with the legs and arms (in the case of a young child), given the key physical properties of the individual?

For Gibson (1979), affordance is a central concept of psychology, which captures the complementary relationship of an organism with its environment. Gibson pointed out a fundamental criticism of indirect theories of perception, stating that "psychologists assume that objects are composed of their qualities… what we perceive when we look at objects are their affordances, not their qualities" (p. 134). Perceiving the environment in terms of affordances leaves dispensable those intermediate processes required to transform action-independent perceptions into action-oriented perceptions. In the process of (direct) perception, there is no integration and combination of cues involved. The primary objects of an individual's perceptual experience are the action possibilities that the environment affords. Those action possibilities offered by the environment are relative to an individual's properties (e.g., body characteristics) and abilities. For example, Warren (1984) found that the maximum riser height of a step that was perceived to be climbable was 0.88 times adult participants' leg length and that this ratio was invariant between tall and short adults. Warren, therefore, concluded that the ability to perform an action such as stepping onto an obstacle is *body-scaled*. Further to the seminal work of Warren, the study of body-scaled affordances have been shown to form the basis of a range behaviors, including reaching (Carello et al., 1989), sitting (Mark et al., 1990) and aperture perception (Warren and Whang, 1987). Building on the concept of body-scaled affordances, Warren (1984) proposed a more functional conceptualization of affordances being *action-scaled*. This more functional proposal signifies that affordances are dynamically predicated on the action capabilities of an individual relative to the environment in which an action is performed (Fajen, 2005). For instance, Konczak et al. (1992) emphasized that affordance perception for step height is best understood as scaling relative to leg flexibility and strength (i.e., action-scaled relative to an individual at any moment) rather than leg length (i.e., body-scaled).

Given that affordances reflect the relational nature of many properties of organisms and the many properties of environments, they are proposed to be nested in the context of other affordances (Wagman and Stoffregen, 2020). According to Wagman et al. (2016), nested affordances refer to the multiple affordances that exist in any given context, providing an obligation for individuals to concatenate them when acting. Affordances are nested over several different spatial and temporal scales (Wagman et al., 2016; Wagman and Morgan, 2010) and can be exploited sequentially, simultaneously, or in parallel (i.e., simultaneously but independently of one another; Mark et al., 2015). Contemporary perspectives have subsequently proposed that skilled athletic experience influences the perception of nested affordances (Higuchi et al., 2011; Hove et al., 2006; Weast et al., 2011). van Dijk and Rietveld (2021) suggested that nested affordances invite skilled performers to act further as one situation develops into the next via these embedded invitations. For instance, in a climbing task, Seifert et al. (2021) showed that skilled climbers use a handhold as a transition (to chain movements) rather than as an isolated event. In skilled climbers, multiple holds are collectively perceived as a single nested climbing opportunity to transit vertically (Boschker et al., 2002; Seifert et al., 2021b, 2017). Indeed, evidence shows that expert climbers better perceive the functional properties of holds than less experienced climbers. Conversely, less experienced tend to exploit the structural properties of individual holds, leading to an emerging *hold-by-hold* climbing sequence instead of an interconnected chain of movements (Boschker et al., 2002; Boschker and Bakker, 2002). To exemplify, when beginners performed a climbing task in a learning programme of 13 sessions, results showed that the route afforded more learning opportunities as their visual-motor exploration became more efficient (Hacques et al., 2021). However, when skill transfer was assessed on three new routes (varying either in distance between holds, i.e. between 15-20 cm , hold orientation, i.e. holds were turned by 90°, or varied in shape ; see Figure 1), results suggested that learners transferred their skill to the route with an increased distance between handholds, but not to the other two routes (Hacques et al., 2021). In fact, the 'distance'-manipulated route induced lower-order behavioral changes as learners needed to recalibrate a similar hand grasp. In contrast, the 'orientation'- and 'shape'-manipulated routes induced higher-order behavioral changes, since those routes required different grasping patterns and postural orientation, suggesting that learners did not transfer their calibration and that calibration is posture-specific (as observed in motor development studies by Adolph et al., 2008 ; Kretch and Adolph, 2013).

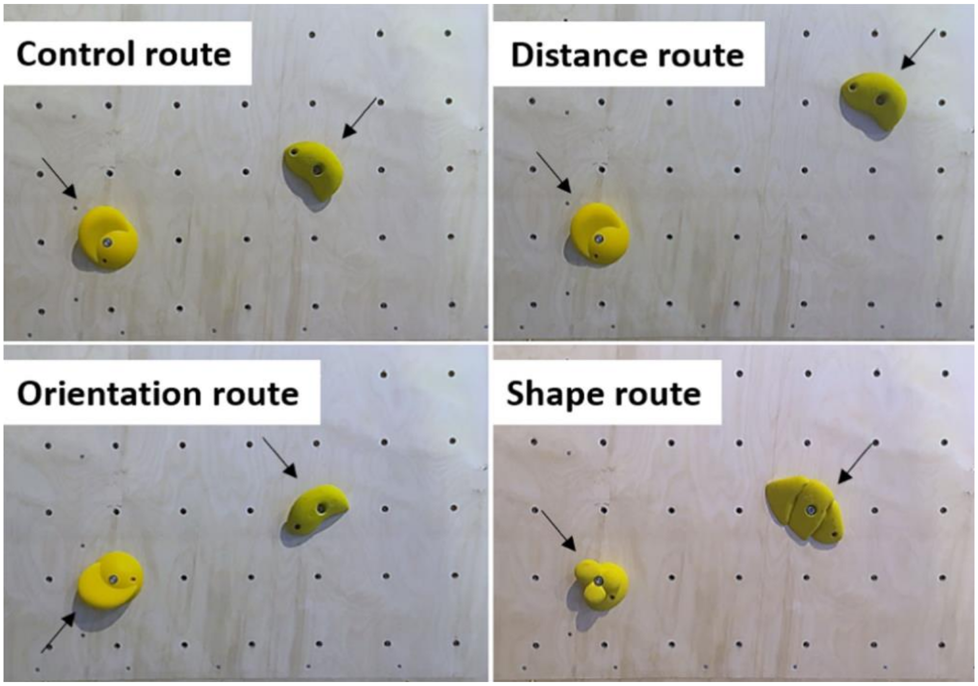

Figure 1. Illustration of the handholds characteristics for the control route of the learning protocol and for the three routes of the transfer test. The arrows indicate the preferential grasping enabled by the handhold (reproduced from Hacques et al., 2021 with permission).

By avoiding a mechanistic conceptualization of affordances (i.e., affordances can constrain behaviors but do not cause them; Gibson, 1979), ecological psychology emphasizes the important role of individuals to self-regulate their behaviors in achieving intended task goals. These ideas shape our understanding of individual differences in affordances that people may use and explain why people can accept or reject affordances available to them *invitationally* (Withagen et al., 2012).

What role does affordance play in perception? Is it the entity organisms perceive, or is it the means through which organisms perceive? Are affordances the only perceptual dependent variables?

Since the ecological dynamics perspective construes goal-directed behaviors in sports as emanating from the hard-assembled (physical) and soft-assembled (informational) links between performers and their performance environments (Kugler and Turvey, 1987), processes of cognition, perception, and action can be captured by eco-physical variables (Araújo and Davids, 2018). These variables express the fit between the physics of the environment and a performer's continuous adaptations. Environmental properties directly inform what an individual can and cannot do (Withagen et al., 2017, 2012). Therefore, the emphasis on eco-physical variables avoids a representational tendency to search for variables inside the organism that are deemed to "cause" behaviors. It sidesteps the *organismic asymmetry* needed in explaining the brain driving cognition, perception, and action through neural or symbolic activity (Davids and Araújo, 2010).

Affordances are not only perceptual variables but entail action components, emphasizing that perception and action cannot be separated. Perception-action coupling obliges mutuality and reciprocity between an individual and the environment, with the individual-environment system being the most appropriate unit of analysis captured by eco-physical variables. An *in situ* example is the eco-physical variable GDD (goal-directed displacement) index developed to study dyadic system behaviors in tennis rallies (Carvalho et al., 2014). Using eco-physical variables in research and practice enables understanding of how cognitive processes might be predicated on continuous, emergent, performer-environment interactions in sports. In particular, athlete decision-making can be analyzed with eco-physical variables, which entails that behaviors can be understood as self-organizing, emerging from the continuous interactions of environmental, individual, and task constraints. From the performer's point of view, the task is to exploit surrounding physical (e.g., field characteristics as determined by sports rules) and informational (e.g., the movement of the ball and other players) constraints to continuously (re)organize behaviors. Constraints reduce the number of configurations available to a dynamical movement system at any time. In a performance environment, behavior patterns emerge to satisfy constraints as less functional organization states are dissipated. Changes in performance constraints can lead a system towards bifurcation points where choices emerge as more specific information becomes available, ever constraining the environment-athlete system to switch to a more and more functional path of behavior (such as running with the ball into a larger gap on the field, rather than another which is smaller (Araújo et al., 2006).

An account of affordances inspired by the philosophical ideas of Wittgenstein views them as embedded in socio-cultural practices of an organization, club, community, or society, for example, with performers being historically dependent on socio-cultural skills to use specific affordances which are always available but selectively used (O'Sullivan et al, 2021). Thus, affordances exist in a performance environment but are selectively used, dependent on one's expertise. Therefore, expert cognitive and perceptual activity can be considered selective engagement with an affordance available in a rich landscape. This idea can be exemplified by footballers being adaptive enough to pick up and utilize affordances for action in different performance contexts. When a performer changes from one action mode in team games (running with the ball) to another (passing the ball when a defender is approaching to tackle), a transition in the course of action is expressed. Transitions among stable behavioral states (i.e., action modes) emerge due to dynamic instabilities, providing a universal decision-making process for switching between distinct patterns (Kelso, 1995). Such stabilities and instabilities in a performance environment do not exist *a priori* in the structure of the player or the surrounds. However, they are co-determined by the confluence of constraints and information, exemplifying how control lies in the performer–environment system. Emergent behavioral patterns can be formally modeled using differential equations and potential functions to describe the long-range dynamics underlying interactions of system components. From this viewpoint, athletes search in a sports performance context to arrive at a stable, functional solution. A viable option selected is the strongest attractor for an individual at a given moment, with other options having less strength of attraction. This selection only emerges from the continuous interactions of an individual and a performance environment. Ignoring other options is a dynamical consequence since if a system relaxes to one attractor, it concomitantly ignores the remaining options (attractors). The fact that there is a stronger attractor does not eliminate the influence of other attractors in the sports context (e.g., Araújo et al., 2013). Under dynamic performance conditions, other attractors (i.e., other options) may emerge and exert their attraction in the system's dynamics, emphasizing the performer-environment reciprocity.

On pages 138–39 of his book, Gibson (1979) considered choice behavior more broadly as the environment consisting of affordances of objects, surfaces, events, and other people that have value or not for each individual (and this can change over time for the same individual. A great example is given of a letterbox having an attraction for an individual when he/she has a letter to post and lives in an environment where there is a postal system, but not when there is no letter to be posted. In emphasizing the value and meaning of things, affordances can repel or invite actions. These ideas form the basis of the person-environment interactions that affordances underpin. The metaphor of a field is helpful here: some affordances stand out more than others in a whole landscape of affordances that are available to be utilized. Bruineberg and Rietveld (2014) distinguished a field from a landscape of affordances: A landscape of affordances corresponds to the "affordances available in an ecological niche" (p. 2), which relate to the whole spectrum of abilities available in our socio-cultural practices. A field of affordances relates to the "affordances that stand out as relevant for a particular individual in a particular situation; i.e., the multiplicity of affordances that solicit the individual" (Bruineberg and Rietveld, 2014, p. 2). Some affordances are experienced as soliciting immediately, others are experienced as soliciting on the horizon, and still, others are entirely ignored (only the latter leave us cold). We can distinguish between an affordance, i.e., a possibility for action available at a specific location, and a solicitation. A *solicitation* is an affordance that stands out as relevant in a specific situation lived by an animal. A solicitation is the experiential equivalent of a bodily action readiness: the readiness of the affordance-related ability (Rietveld, 2008). In deriving this conceptualization, Gibson (1979) drew upon Kurt Lewin's concept of valences as either pushing an agent towards or away from an object, event, or another person. The value of an object perceived by an individual agent is changed by the experience and a person's needs.

The affordance is not changed, but the value or meaning changes for each person-environment relationship. The value and meaning of an affordance will change as a function of an individual's effectivities and needs. So, skills, capacities, and experience will influence whether an affordance is more or less soliciting for an individual, especially when understood with respect to their needs in dynamic performance contexts like sports. Relatedly, Withagen et al. (2017) sketched a dynamical model of the agent-environment relationship where the agency is conceptualized as the capacity to modulate the coupling strength with the environment. This model explained how the agent could intentionally influence how they are influenced by the different affordances, which may be more or less soliciting. By modulating the coupling strength, the agent simply alters the dynamics of the performer-environment system, thus shaping the behavior that emerges. This model opens to ecological dynamics the challenge of understanding how a performer's changes (e.g., psychological, biological) influence their intentions and the modulation of the coupling strength with the environment. Following the same logic, it opens the possibility to understand how immediate changes in an environment (e.g., social, normative, rule-based, task, implements) also exerts constraints on the modulation of the coupling strength with the performer through differences in the solicitation.

Why is affordance any better than stimulus? What does a theory of affordance suggest that stimuli cannot; how has it moved the needle past Gibson 1960's recognition of how little we can define stimuli?

A theory of "stimulus" implies that the stimulus conditions a response. This relation implies automaticity through conditioning, whereas an affordance implies an invitation (Withagen et al., 2012), highlighting the importance of agency incorporating decision-making and problem-solving, not separately from action, and framed by intentionality. To explain how humans and other animals establish perceptual contact with their environment, Gibson (1966) introduced a radical new theory of the "stimulus information available to the receptors." He argued that the assumption of impoverished stimulus information, on which most inferential theories of perception are based, is fallacious. Traditional information-processing theories argue that, for perceivers to be informed about sources of stimulation, they must store a large set of alternatives in memory that are selected according to those stimulating conditions. In other words, stimulation of the receptors does not directly inform about its sources. For example, one cannot know from the raw energy of the light ray itself whether its source is near or distant. Receptors in an eye stimulated by a ray of light can only be informed of the presence of the ray of light. For stimulation to act informatively, a perceiver may be said to have some means of interpreting or decoding such stimulation according to a limited set of memorized possibilities.

Contrary to this classical viewpoint, Gibson argued for a very different conceptualization of information that he considered was a more appropriate way to understand perception and cognition amongst living organisms. From this ecological view, the structure of light, for example, could be intrinsically informative. Gibson's theory implies that sensitivity to information structure must exist in a perceiver but that there does not have to be an added interpretation process (Richardson et al., 2008). For Gibson (1979, 1966), perceptual information resides in the ambient energy arrays and flows and can directly inform an individual about the environmental properties of our world. Notably, Gibson also stressed the importance of an individual's movement in detecting and discovering specifying information. In his view, perceivers are not passive: to detect information, perceptual systems scan the ambient arrays to detect information actively.

Furthermore, by moving, performers can create spatiotemporal energy patterns specific to environmental properties. The moving body of an (embodied) observer contributes to the structure of an array at any observed place. Because performers exploit spatiotemporal energy patterns specific to the to-be-perceived or to-be-acted-upon properties of the environment, inferential processes are dispensable, and direct perceptual contact with a performance environment is possible.

Since Gibson wanted to understand perception of the environment, instead of working with primitives such as points, lines, planes, and projections, he began with the ambient optic array. The ambient optic array is structured light surrounding a point of observation. It consists of multiple reflected light rays filling a medium (in this case, the air). This physical characterization means that there must be light sources, reflecting surfaces, and a medium. The same set of reflecting surfaces that make the light-filled medium possible also accounts for differences in intensity in different directions from any point of observation. These differences exist by differences in arrangement (layout) relative to one another and the illumination, differences in texture, and differences in pigment structure. In the case of light, the optic array (i.e., information) just exists; it is not coming to the eye. Gibson (1979) referred to the fact that animals with compound eyes, as well as animals with chambered eyes, show visually-guided behavior (such as avoidance behaviors in the presence of an expanding shadow specifying a looming object) as evidence that they are designed to use optical information in the array, even though they have no retinal images. Thus, retinal images are not necessary for vision, but the information is (Mace, 1986). Gibson maintained that such optical changes (variants) and non-changes (invariants) in the surrounding array are used by perceivers to regulate their movements relative to the dynamics of the environment. As a structure surrounding a performer, patterned ambient energy (e.g., optic array, sound waves) can be explored or observed actively. When this occurs, the patterned energy flow changes in some ways, but not all. For example, an important way that the optical array of an idealized frozen environment changes occurs when an observer moves. Everything in the array flows, and there are regular exchanges of array components revealed and hidden. But within the flow, some relations of components to one another stay invariant. These invariants specify (i.e., inform an individual about) stable features of the environment. The changes, or variants, specify the observer's movement relative to the stable environment. Because invariants are defined only with respect to variants, it follows that change is necessary to reveal non-change. It also follows that coordinated movements of an observer can be specified only relative to the invariant structure of the surrounding energy arrays (Mace, 1986). Importantly, variants and invariants of the ambient optic array allow for the separation of that which belongs to the environment from that which belongs to the performer. As the performer's point of view changes, one can perceive when the point of view is changing and when the environment is changing. When the point of view changes in a stable environment, the persistence of that environment is specified by invariants (Gibson, 1979). A consequence of the optics of occlusion is that as one uncovers new surfaces by exploration, one is extending the amount of connected, concurrently existing surfaces that one has detected.

One of the most closely studied invariants in the informational array is an optic variable known as *tau*, which has been proposed to specify the time to contact (T_c) information (Lee, 2009). Since its conceptualization and operationalization by David Lee in the 1970-the 80s, it has generated a significant amount of research and debate in the literature. When a non-deforming object, such as a ball, moves toward an observer, the contours of the ball form a solid visual angle. This optic flow is perceived over time as a nested hierarchy of solid angles that expands symmetrically on approach to the observer. The optical information specified by the relative rate of expansion of the solid visual angle enclosed by these contours is *tau*. *Tau* provides the individual with direct information about the remaining time T_c between the point of observation and an approaching object (Lee, 1976). Assuming that an approaching object has a constant velocity and is traveling toward the point of observation, there are considerable advantages of being able to perceive T_c. For instance, the individual does not need to indirectly process ambiguous cues on distance, object size, and velocity and perform mental calculations to compute the object's time of arrival. Not needing to rely on indirect processing of cues is particularly beneficial when performing dynamic activities such as playing tennis. In these activities, performers may have little time to react and need not spend time calculating the time of arrival of an object or surface while interpreting events in the environment.

Travassos et al. (2012) developed an interesting application of the *tau* concept to study team sports performance. They studied how Futsal defenders intercept the trajectory of a ball (passed between attackers) by comparing how they regulated their actions using critical information sources, such as time to intercept the ball, in successful and unsuccessful interceptions of a pass. Time to ball interception was measured via the difference between the time of each defender to reach an interception point in ball trajectory and the time of the ball's arrival at the same interception point. Results showed positive values of time to ball interception when passes were not intercepted and negative to zero values when passes were intercepted. Furthermore, analysis of defenders' adaptations to the visual information available in the environment revealed that continuous changes in participants' movement velocities towards the ball constrained their exploitation of these informational variables and the success of their interceptive actions.

What is the connection between affordances and behavioral scale and intention? How distant or reluctant can a perceiving-acting system be before affordances come into play? Do affordances exert their role only when the system is close or willing enough?

Affordances are inviting or soliciting but do not compel individuals to behave in a certain way (Withagen et al., 2012). Behavior is not only composed of the action we observe but also incorporates perception, emotions, cognitions, intentions, and social dimensions (e.g., shared affordances in collective task performance). Intentions are not *causes* of action but constraints on the action; they are not mental as opposed to physical but are embodied in the kinds of performance behaviors typically observed in performers. Reed (1993) argued that these intentional organizational patterns emerge in situations where different affordances can be utilized to enhance performance in contexts like sports. This performer-environment basis of conceptualizing behavior indicates that affordances can be used, motivating an organism to act, but they are not to be viewed as causes of behavior because a person may not act on a perceived affordance (Withagen et al., 2017). Adaptive behavior can emerge continuously from the confluence of constraints under the boundary conditions of intentions embedded within task goals. Perceiving is an activity of the whole body acting on and in the environment to obtain information (Gibson, 1966; Reed, 1996) and requires coordinated movement. For example, the leg's function by bringing one perceptually-guided way to a place where nested adjustments of head turning, eye movements, lens accommodation, hand positioning, finger movement, and so forth can perform their functions in a coordinated act. Perceiving is guided by the practical requirements of a person's intended goals, achievements, and circumstances. A person has to perceive enough of the environment to accomplish intentional goals, but that's all. There are no right or wrong perceptions.

Moreover, perceiving can improve. If there is always more structure that can be clarified with more exploration, then the possibility for enhanced perceiving is always present. Perceiving involves guiding the complex adjustments of the body and performing goal-directed activities in the environment (Mace, 1986). Perception, like action, is a coordinated activity, an *achievement* of the performer-environment system (Guignard et al., 2017). Swimming is an excellent example to consider, as any displacement in the water is highly dependent on fluid characteristics. Swimmers use these properties to propel themselves through the water in different ways. Traditionally, biomechanical research has focused on swimmers' actions without exploring perturbations to fluid flows.

Conversely, fluid mechanics research has sought to record fluid behaviors, isolated from how the swimmers cope with the environmental constraints (e.g., in some experiments, fluid flows are passively studied on mannequins or robot effectors). When a swimmer moves in the water, they create continuous specific changes in fluid motions, providing action information. When swimming in outdoor aquatic environments (such as oceans, rivers, and lakes), swimmers can gain information on fluid motion when interacting with waves, rips, and currents to decide how to exploit aquatic flows to move in context (Guignard et al., 2020). For Gibson (1979), movement generates information which, in turn, supports further movements, leading to a cyclical relationship between information and movement. The interdependency between the detection of information and the generation of movement implies that perception and action cannot be studied separately (Araújo et al., 2006). Only in practice contexts where perception and action processes are expressed within representative environments may we observe the smartness of evolutionary-designed perceptual mechanisms (Davids et al., 2012). In this context, *smartness* refers to the dedicated function for which a perceptual mechanism has evolved.

This understanding of intentionality can be extended to team cognition and decision-making in a team sport. During the competitive performance, the organization of action by perceiving surrounding informational constraints is expressed in "knowledge of" the environment. This idea emphasizes that the perception of shared affordances underpins the main communication channel between team members during team coordination tasks (Araújo and Davids, 2016). Predicated on the key ideas of Reed (1996), we argued that affordances are collective environmental resources that have existed prior to the upskilling of the individuals that came to perceive and use them. Ecological dynamics predict that the presence of others extends action possibilities that are realizable by individuals to action possibilities realizable by groups. Indeed, Gibson (1979) argued that "behavior affords behavior" (p. 135) and that it was important to note that the "richest and most elaborate affordances" (p. 135) of all are affordances of other people in social contexts. The suggestion is that affordances can be perceived by a group of individuals trained to become perceptually attuned to them (Silva et al., 2013). Through practice, players can become perceptually attuned to the affordances *of* others and affordances *for* others during the competitive performance. They can refine their actions (Fajen et al., 2009) by adjusting behaviors to functionally adapt to those of other teammates and opponents.

Moreover, individuals in a team can act in a way to create competitive circumstances (the affordances) that are favorable to them. For example, by pressuring opponents in team games to play more in one zone of a playing area, this strategy can create affordances for attacking play by freeing other areas of the field. These processes enable a group of players to act synergistically with respect to specific performance circumstances. An important feature of a team synergy is the capacity of one individual (e.g., a player in a team) to influence the behaviors of others (Araújo and Davids, 2016; Riley et al., 2011). Decisions and actions of players forming a localized synergy should not be viewed as independent, explaining how multiple players synchronize activities per dynamic performance environments in fractions of a second (Silva et al., 2016). The coupling of players, as independent degrees of freedom, into local synergies, is based upon perception-action systems functioning in a social context, supported by the collective perception of shared affordances (Silva et al., 2013). Ecological dynamics analyses of team sports have attempted to explain how interactions between players and information from the performance environment constrain patterns of stability, variability, and transitions in organizational states of such team synergies. Research has demonstrated that inherent degeneracy (i.e., flexible behavior, like "many" structures to "one" function relationship; Mason, 2010) in perception-action systems provides the basis for the diversity of actions required to negotiate information-rich, dynamic social environments towards a task goal (Seifert et al., 2016). For instance, the goal for icefall climbers is to anchor their ice axes to the ice surface, which could be achieved by "swinging" ice axes against the icefall to create specific anchorages or by "hooking" the blade of the ice axes into existing holes in the icefall, supporting that expert climbers utilize functionally equivalent movements (i.e., the degeneracy of perceptual-motor system) during the realization of affordances (Seifert et al., 2014).

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How do systems engage with affordances as they move amongst tasks and intentions?

Tasks and intentions are not separated; in other words, tasks are not external, and intentions are not internal to an individual but strongly nested. Thus, considering an organism-environment system, affordances are not excluded from this system but are deeply part of it. The ecological dynamics approach stresses the primacy of performer-environment couplings by means of which problems, such as moving about, deciding with whom to create attachments, competing with adversaries, and so on, can be resolved in a performance environment. In this view, any system capable of performing such feats of behavior is a cognitive system. These problems can range from tasks derived from biology (e.g., goal-path decisions in a school of fishes) to abstract reasoning (e.g., deciding on the next move in a chess match), as long as it involves making a decision that solves the problem in an intelligent (functionally adaptive) way (Turvey and Carello, 2012). In the traditional view, the behavioral expression of those decisions is not at the heart of cognition because behavior is assumed to be a simple implementation of a mental plan. However, the regulation of behavior, as an expression of a cognitive process, should not be attributed to one part of the animal-environment system (i.e., the individual). Decision-making in activities like sports are examples of cognitive processes which are embodied, situated, and dynamic. For ecological dynamics, decision-making behavior is defined as transitions in the course of action and is a central issue for intelligent performance (Araújo et al., 2006). Thus, a significant challenge is to understand the ability of each individual to perceive the surrounding layout of the performance environment on the scale of their body and action capabilities (Fajen et al., 2009). As a performer moves with respect to their surroundings, opportunities for action persist, emerge and dissolve, even though the surroundings are analyzed as objects, and the relations among them, remain stable. Subtle changes of action can give rise to multiple and marked variations in opportunities for subsequent actions. The dynamic process implied in the perception of affordances provides the basis by which a performer can control their behaviors prospectively.

To interact meaningfully with the environment, performers must have complex interiors, an on-board (metabolic) potential capable of biogenic forces that may be used to cancel, modulate, or delay their immediate reaction to an external force (Araújo et al., 2006; Kugler and Turvey, 1987). This way, the agency is the capacity to modulate the coupling strength with the environment because an agent can influence to what extent they are influenced by different affordances in a performance landscape (Withagen et al., 2017). From this perspective, distinctive cognitive capabilities are what they are by laws and general principles (Profeta and Turvey, 2018), where dynamics (involving laws of motion and change) and dynamical systems (involving time evolution of observable quantities according to law) can offer the tools to understand cognitive processes. For example, research about attacker-defender dyads in team sports has revealed that these agent interactions could also be described in low-dimensional order parameter dynamics (Araújo et al., 2006). Previous work by Schmidt et al. (1990) proposed that two individuals might be considered a single system. Using the same gradient equation as the model developed by Haken et al. (1985), this work has suggested that a dyadic synergy can reveal nonlinear properties, namely entrainment and sustained periodic behavior, and specific modes of inter-personal coordination, that emerge under contextual, personal, and task constraints. Following this line of thinking, the study of the dynamics of attacker-defender dyads in team sports has shown that decision-making emerges from continuous interactions of team players (e.g., Araújo et al., 2013; Passos et al., 2008). In these social systems, attackers and defenders form closely interacting dyads in which individuals do not deliberately seek to coordinate actions since an attacker must avoid a stable dyadic organization with a marking defender. Cooperating and competing players do not share a standard neuronal system, so emergent coordination, and transition phases are solely based on the task constraints present in specific performance environments. Part of the attractiveness of such dynamic models is derived from the fact that they can explain different decisions using the same underlying process of originating and decaying attractors and without the need to use mental representations (see Araújo et al., 2013; Araújo and Davids, 2016).

The second key idea is that tasks and intentions reveal affordances influencing behaviors at different time scales because the task an individual performs at the moment is temporary and nested in other tasks performed in parallel, feeding future tasks and intentions. Inviting affordances favor certain behaviors and select against others (Withagen et al., 2012). The constraints ... e and thus are not on ... ormer, such as their s ... define skilled intentio ... a rich landscape of af ... ailable in different prac

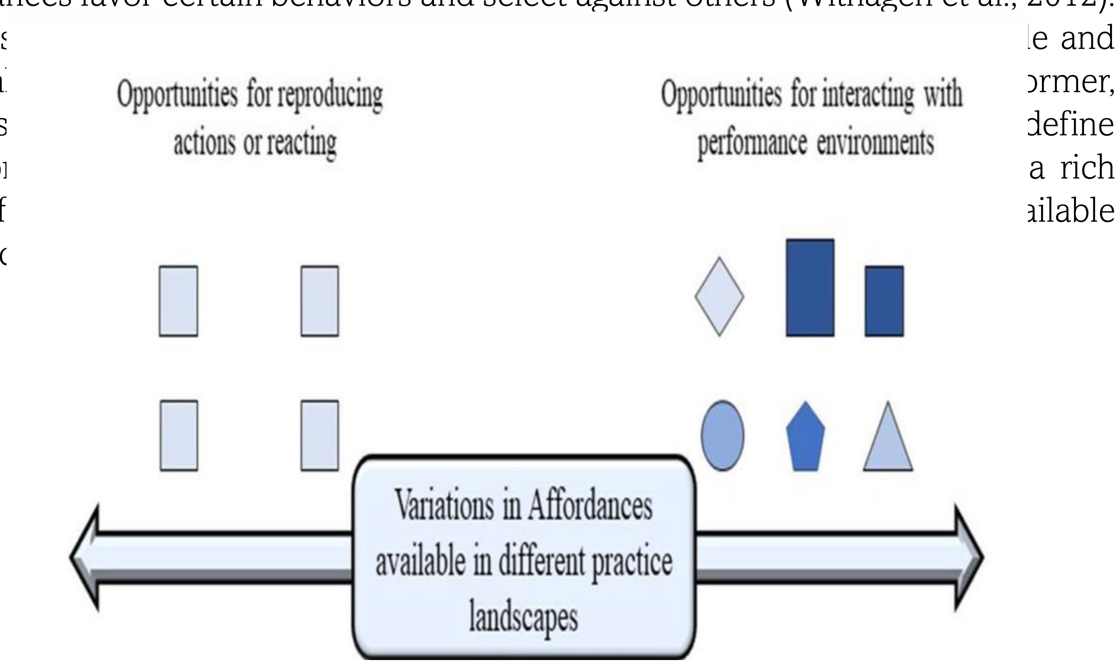

Figure 2. Affordances exist in a landscape surrounding individuals and soliciting their actions, as long as they have relevant effectivities that are functional for interacting with a specific performance environment. Note that individuals can interact with different affordances (here captured by different shapes and sizes of symbols) in unique and individualized ways.

This notion indicates that the everyday environment offers a range of more or less inviting affordances (Withagen et al., 2012). However, these affordances are only accessible to individuals with the necessary skills to act on them. For example, where one tennis player with an excellent backhand shot may perceive an opportunity to penetrate an opponent's court when using it, another player who is highly skilled at volleying may perceive every ball as an opportunity to approach the net. Thus, athletes interact with a surrounding environment through skilled engagement with the affordances that a performance environment offers them because of their unique skills. From this viewpoint, the process of perceptual attunement brings an 'openness' to affordances that, without skill, would not be accessible since it is a skill that opens possibilities for action to an individual. Importantly, subsequent actions are modulated by the individual, exerting their agency in the performer-environment system dynamics at appropriate points to yield a performance trajectory (Withagen et al., 2017). In turn, these dynamics are coupled to larger scale dynamics, guiding the formation of the behavioral trajectory over longer time scales. Reciprocally, the longer-term dynamics could influence the short-term interactions (thus highlighting specific affordances), for example, by altering environmental conditions (Araujo et al., 2019). Because a behavioral trajectory is assembled anew on each occasion, the action sequence is historically contingent and variable, allowing for the flexibility observed in ordinary action sequences. As Profeta and Turvey (2018) rightly argued, the continuity of the ambient optic array and the prospective nature of perception are essential assumptions that would allow the performance of a sequence of movements to be accomplished with the task specified in the act of perceiving. Wagman et al. (2016) showed empirical evidence for *means–ends* relations among nested affordances, where information arrangements about possible future states of affairs, once detected, constrain how states of affairs evolve.

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