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An Ecological Dynamics Approach to Skill Acquisition: Implications for Development of Talent in Sport

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Abstract: This paper proposes how ecological dynamics, a theory focusing on the performer-environment relationship, provides a basis for understanding skill acquisition in sport. From this perspective, learners are conceptualized as complex, neurobiological systems in which inherent self-organisation tendencies support the emergence of adaptive behaviours under a range of interacting task and environmental constraints. Intentions, perceptions and actions are viewed as intertwined processes which underpin functional movement solutions assembled by each learner during skill acquisition. These ideas suggest that skill acquisition programmes need to sample information from the performance environment to guide behaviour in practice tasks. Skill acquisition task protocols should allow performers to use movement variability to explore and create opportunities for action, rather than constraining them to passively receiving information. This conceptualisation also needs to characterize the design of talent evaluation tests, which need to faithfully represent the perception-action relationships in the performance environment. Since the dynamic nature of changing task constraints in sports cannot be predicted over longer timescales, an implication is that talent programmes should focus on developing performance expertise in each individual, rather than over-relying on identification of expert performers at specific points in time.

Keywords:
ecological dynamics, representative design, skill acquisition, talent development

An important task in sport science and performance analysis is to understand the relationship between skill acquisition and the development of talent and excellence. The development of theoretical principles to guide the design of skill acquisition programmes can also provide an informed basis for organising evaluation tests for talent identification and development in sport (Phillips, Davids, Renshaw, & Portus, 2010; Renshaw, Davids, Phillips, & Kerhevé, 2012). In this paper we elucidate principles of the multi-disciplinary *ecological dynamics* approach to skill acquisition (Warren, 2006; Araújo, Davids, & Hristovski, 2006; Araújo & Davids, 2011), and examine implications for learning design and performance evaluation tests in talent development programmes in sport.

Theoretical Principles of Ecological Dynamics

Ecological dynamics has been influenced by key ideas from scientific sub-disciplines including ecological psychology, the sciences of complexity, nonlinear theormodynamics, and synergetics. Complexity sciences provide a description and explanation of the rich patterns formed in multi-component systems such as animal collectives, weather systems, brain and behavior and movements in team sports (Duarte, Araújo, Correia, & Davids, in press). In such systems it has been empirically verified that functional patterns emerge from the interactions between system components or agents (for comprehensive reviews, see Kauffman, 1993; Warren, 2006). The concept of emergence of order under constraints

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has been imported into the study of human movement from a complexity sciences perspective, in which expert performers in sport have been conceptualized as complex neurobiological systems, composed of many components or degrees of freedom on many system levels (e.g., neurons, muscles, joints, segments, perceptual systems; Phillips et al., 2010). The potential for interaction between these system components is a challenge when acquiring expertise in sport but provides a platform for creative patterns of behaviour to emerge from the dynamical interactions of individuals with their performance environments.

In the study of human movement, abundant evidence has demonstrated how coordination emerges in complex neurobiological systems (i.e. between muscles, joints and limbs of the body) during learning and performance (e.g., Kelso, 1995; Kugler & Turvey, 1987; Shaw & Turvey, 1999). These investigations verified that human movement systems can be modelled as complex systems able to exploit surrounding constraints, allowing functional patterns of behaviour to emerge in specific performance contexts. Particular empirical and theoretical impetus was provided by studies of Kelso and colleagues on bimanual coordination in establishing the role of key constructs like self-organization, attractors, order and control parameters, as well as transitions between stable states of neurobiological organization (for a review of these early studies see Kelso, 1995). The construction and adaptation of movement patterns has been successfully modeled and investigated by means of synergetic theoretical concepts since Haken, Kelso and Bunz (HKB) first applied them in investigations of brain and behavior (Haken, Kelso, & Bunz, 1985; Kelso, 2012). In their pioneering HKB model, abrupt changes in multi-limb oscillatory movement patterns were explained by a "loss of stability" mechanism, which produced spontaneous phase transitions from less stable to more stable states of motor organization with changes in values of critical control parameters. Together, these theoretical and empirical advances have contributed to an ecological dynamics explanation of how processes of perception, cognition, decision making and action underpin intentional skilled movement behaviors in dynamic performance environments (e.g., Araújo, Davids, & Hristovski, 2006; van Orden, Holden, & Turvey, 2003; Turvey & Shaw,1999). In ecological dynamics it has been revealed that the most relevant information for decision making and the regulation of action in dynamic environments is emergent during continuous performer-environment interactions (Travassos, Araújo, Davids, Vilar, Esteves, & Correia, 2012). From this viewpoint, neurobiological systems exhibit purposive adaptive behavior from the spontaneous patterns of interactions between system components. Abundant empirical evidence and mathematical modeling have provided strong support for an ecological dynamics interpretation, demonstrating the existence of key properties of complex, neurobiological systems in coordination of multi-articular goal-directed behaviours like learning the pedalo (Chen et al., 2005), cascade juggling (Beek & van Santvoord, 1992; Haibach, Daniels, & Newell, 2004), simulated ski-ing (Hong & Newell, 2006), hitting a punch bag in boxing (Hristovski et al., 2006), basketball shooting (Button et al., 2003; Rein et al., 2010), starting a regatta in sailing (Araújo et al., 2006) and kicking a football over a horizontal bar (Chow et al., 2008, 2009).

In ecological dynamics, Warren (2006) captured the link between perception and action systems by describing how interacting constraints support the information-based regulation of action. According to Gibson (1979) humans are surrounded by banks of energy flows or arrays that can act as specifying information variables (e.g., optical, acoustic, proprioceptive) to constrain the coordination of actions with a performance environment. Critical information sources continuously shape intentions and enhance decision-making, planning and organization, during goal-directed activity. For example, data from studies of dribbling a football (Headrick et al., 2012), running to cross a football to a team mate (Orth et al., 2012), dribbling a basketball (Cordovil et al., 2009) and running with the ball in rugby union towards a gap between two defenders (Correia et al., 2012) have clearly demonstrated how decision making and the coordination of action in sport are adapted to changing task constraints provided by critical information from the relative positioning of defenders, morphological and instructional constraints on performers and even the field location for a performance activity. Despite specific task instructions being provided, participants were observed to adapt key performance parameters such as running velocity and gait over trials as their perceptual processes shaped their intentions and constrained their subsequent actions in different ways. These ideas from ecological dynamics propose that, as expertise in sport is enhanced, informational constraints designed into practice tasks can progressively direct an individual to the specifying information sources that support the organisation of actions and enhance the capacity to adapt to changes in a performance environment (Esteves, De Oliveira, & Araújo, 2011).

A key goal of learning is to educate the intentions of learners so that they understand the information sources that can be harnessed to support an action. For example, Seifert and Davids (2012) showed how climbers of varying expertise differed in the movements they used with ice picks and crampons to climb the surface of the same ice fall. In their study, expert ice climbers displayed a greater *dependence* on the (specifying) properties of frozen water falls when climbing, compared to unskilled climbers. The experts were attuned to environmental constraints in the form of functional holes in an ice fall which could facilitate system *multi-stability* (see Kelso, 2012), leading to the emergence of different movement patterns required to move quickly up the frozen water fall. Functional movement variability emerged as they perceived stochastic variations in key properties such as ice fall shape and steepness, and temperature, thickness and density of ice. Expert climbers exhibited greater levels of adaptive variability in upper and lower limb organisation tendencies, which varied in horizontal, oblique, vertical and crossed angular locations, by swinging their ice tools to create different anchorages and by hooking existing holes in the ice fall. Conversely, unskilled climbers tended to show greater levels of movement stability and fewer exploratory activities. They only tended to use horizontal and oblique angles of the upper and lower limbs and their ascent pattern resembled climbing a ladder. Their main intention was to maintain stability on the ice fall and they could not detect the affordances for climbing offered by the ice fall properties. The novices believed that a functional anchorage was often synonymous with a deep anchorage and they tended to swing their ice tools and kick with their crampons more frequently than experts, instead of exploiting existing holes in the ice fall. Therefore, when designing learning tasks or skill evaluation tests in talent development programmes, it is most important that task protocols sustain the link between intentions and available specifying information to regulate actions, to support the assessment of an individual's performance dynamics (Phillips, et al., 2010; Araújo, Fonseca, Davids et al., 2010).

Ecological Dynamics of Skill Acquisition

According to Bernstein (1967) the acquisition of movement coordination is viewed as "...the process of mastering redundant degrees of freedom of the moving organ, in other words its conversion to a controllable system" (p. 127). This is why the theory of ecological dynamics advocates that the relevant scale of analysis for understanding behaviour is the performer-environment relationship, and not the description of the environment or the activities of the learner, separately (Araújo & Davids, 2011). The most relevant information for performance and learning in dynamic environments arises from continuous performer-environment interactions (Araújo, et al., 2006; van Orden, Holden, & Turvey, 2003; Travassos et al., 2012).

Key features of the performer-environment system that constrain skill acquisition include the structure and physics of the environment, the biomechanics, morphology, emotional and psychological characteristics of each individual and specific task constraints. Adaptive, goal-directed behaviours emerge as each individual attempts to satisfy these continuously interacting constraints. Expertise can be defined as the individual's capacity to functionally interact with key constraints (i.e., task and environmental; Newell, 1986) in order to exploit them to successfully achieve performance aims. To achieve specific performance goals, multiple means are available to sport performers, due to the inherent *degeneracy* of their perceptual and action systems (Edelman & Gally, 2001; Mason, 2010; Withagen & Michaels, 2005). Degeneracy describes how functionally equivalent actions in sport can be achieved by structurally different movement system components. Neurobiological degeneracy in sport has been empirically demonstrated in studies of football kicking (Chow, Davids, Button, & Koh., 2008) and the basketball hook shot (Rein, Davids, & Button, 2010) demonstrating how individuals used lower and upper body joints and limb segments, respectively, in very different ways to perform successfully, as key task constraints (such as height of a football chip and distance to basket for a shot) were changed. These studies have demonstrated that assembly of functional actions in skilled performance is a dynamical process, dependent on relevant sources of perceptual information (specifying variables such as distance to a target) related to key properties of the performer (e.g., haptic information from muscles and joints) and the performance environment (e.g., vision of a nearest defender; for a review of empirical examples see Vilar et al., 2012; Headrick et al., 2012; Orth et al., 2012). Such studies have provided important knowledge about the kinematic relationships between limb segments during learning and how motor system degrees of freedom are re-organized over time as a function of practice in sport.

Skill acquisition programmes in sport, therefore, should aim to develop an enhanced coupling of an individual's perception and action sub-systems to achieve intended task goals. Learning leads to changes in relational properties, captured by key events, objects and inter-individual interactions, to which a learner's perceptual systems become attuned (Jacobs & Michaels, 2007). Although skilled actions exhibit some stable characteristics, it is also apparent that skilled performers are not locked into rigidly stable solutions (e.g. technical, tactical), but can modulate their behaviours to achieve consistent performance outcome goals (Araújo, Davids, Chow, & Passos, 2009). This characteristic of skilled behaviour in sport was exemplified in a study of cricket batting by Pinder et al. (2012). Their data on meta-stability (functional switching of skilled batters between forward and backward strokes in cricket, when ball pitching locations were varied) demonstrated the rich and varied patterns of interceptive actions that emerged during performance. When participants were forced into the meta-stable region of cricket batting performance, task goals were achieved in a variety of ways (for an example in basketball shooting see Rein et al. (2010) and hitting a boxing heavy bag see Hristovski et al., 2006). These data illustrated that, harnessing inherent neurobiological degeneracy, skilled performers could functionally adapt the organisation of interceptive actions, resulting in higher levels of variability in movement timing in meta-stable performance regions, in order to maintain quality of performance outcomes. Such requisite flexibility is tailored to current environmental conditions and task demands, and implicates ongoing perceptual regulation of action (Araújo et al., 2006).

The powerful role of informational constraints on emergent performance behaviours has also been demonstrated frequently in research studying interactions between skilled attackers and defenders in team sports (e.g., Correia et al., 2012). Studies in team sports like basketball and futsal have shown the constraining effects on participant movement behaviours of task instructions (Cordovil et al., 2009), the feet positioning of nearest defenders (Esteves, Oliveira, & Araújo, 2011), as well as the location of key objects such as the ball (Travassos, Araújo, McGarry, & Vilar, 2011) and the goal (Vilar, Araújo, Davids, & Travassos, 2012). Knowledge, in the form of instructions and pre-determined strategies of play also contribute to constrain performance behaviours. For example, despite no specific instructions being provided, in 1v1 sub-phases of basketball when attackers play conservatively to retain ball possession, different movement trajectories emerge than when they play with risk and attack the basket (Araújo, Davids, Cordovil, Ribeiro, & Fernandes, 2009; Cordovil et al., 2009).

Taken together, this body of empirical research reveals that expertise in sport derives from an improved functionality of expert performers in their environments, in which they are able to achieve consistent performance outcomes in dynamically changing performance contexts (Araújo & Davids, 2011). From the developing athlete's viewpoint, the task is to become expert at exploiting physical and informational constraints to stabilize intended performance outcomes. An emergent performance solution may rely more or less on physical or informational regularities, depending on the nature of the task. Within given task constraints there are typically a limited number of varied but stable performance solutions that can be achieved for a desired performance outcome. These ideas have important implication for talent identification in sport since more functional movement patterns can emerge to fit changing contexts of performance as sports evolve through rule changes, enhanced technological equipment design or new performance strategies developed by clever opponents and coaches.

Acquiring expertise in sport involves learning how to identify and use affordances or opportunities for action to achieve performance goals. The concept of affordances provides a powerful way of combining perception and action, since "within the theory of affordances, perception is an invitation to act, and action is an essential component of perception" (Gibson, 1979, p. 46). Affordances capture the fit between key properties of the environment and the personal constraints of a performer, defining the complementary relations between objective and physical properties in the performance environment (Scarantino, 2003; Turvey & Shaw, 1999). An affordance-based mode of control suggests that, in order to establish functional perception-action couplings and successfully control behaviours, performers should be able not only to identify specifying information variables (i.e. be perceptually attuned to constraints of the performance environment), but also have the ability to scale information to their own action capabilities including key body dimensions, such as limb sizes (i.e. calibration; Fajen, 2007; Jacobs & Michaels, 2007). Notably, the invitational character of affordances in performance environments emphasizes the role of agency (Withagen, de Poel, Araújo, & Pepping, 2012). Affordances are perceived in relation to relevant properties of an individual including the scale of key body dimensions (e.g., limb sizes), or action capabilities (e.g., speed, strength). These ideas have important implications for those working with developing athletes whose body dimensions and action capabilities are changing as they go through growth spurts, for example during adolescence (see Abbott, Button, Pepping, & Collins, 2005). An important issue that we consider next concerns the design principles of skill acquisition programmes in ecological dynamics for sport performance development. These principles also have significant implications for the design of performance evaluation tests in talent development programmes.

Representative Learning Design in Sport

From an ecological dynamics perspective, intentional goal constraints regulate how performers should act if a particular performance outcome is intended (Kugler & Turvey, 1987; Shaw & Turvey, 1999). Given the epistemic role of action in human perception, it is important to design pedagogical programmes that permit individuals to act upon the performance environment to obtain information to enhance performance (Warren, 2006). Representative design (Brunswik, 1956) was acknowledged as the generalization of task constraints in experimental designs to the constraints encountered in specific performance environments, such as sport (Araújo et al., 2006; Davids, 2008). *Representative learning design* is a new term which theoretically captures how skill acquisition theorists and pedagogues might use these insights from ecological dynamics to ensure that practice and training task constraints are representative of a particular sport performance context toward which they are intended to generalize (Chow, Davids, Hristovski, Araújo, & Passos., 2011; Pinder, Davids, Renshaw, & Araújo, 2011).

When designing learning tasks and performance simulations, the manipulation of key task constraints by practitioners (particularly perception-action constraints) should allow functional movement behaviours to emerge during learning in specific sports and physical activities. The term 'functional' here signifies that varied movement behaviours are oriented towards task goals relative to an individual's action capabilities. The traditional tendency to design simplistic and highly controlled evaluation or practice tasks is reductionist and will not provide the requisite level of representative design to enhance learning in specific sports. This weakness was highlighted in a recent study examining the effectiveness of training drills to replicate the lower limb coordination patterns in the sport of triple jumping (Wilson, Simpson, Van Emmerik, & Hamill, 2008). Results indicated that coaches should focus on dynamic, rather than static, training drills that more closely replicate the coordination patterns representative of competitive triple jumping performance, a finding that has intuitive implications for the initial identification and development of talent in such sports (Vilar et al., 2012). These data highlight that static tests may lack functionality and may not successfully represent the constraints of performance environments. Indeed, so intimately bound are perception and action sub-systems, that it has been shown that merely adopting an intention to act in a certain way (for example to catch a ball with one hand) can influence how perceptual processes are implemented to achieve an action, regardless of whether the action is correctly executed or not (Cañal-Bruland & van der Kamp, 2009). To attain representative learning design, skill acquisition specialists should *sample* informational variables from specific performance environments and ensure the *functional* coupling between perception and action processes in the design of specific practice tasks (Pinder et al., 2011). Functionality would ensure that: (a) the degree of success of a performer's actions are controlled for and compared between contexts, and (b) performers are able to achieve specific performance goals by regulating behaviours in learning contexts (movement responses, decision making) with comparable information sources to that which exist in the performance environment (Araújo, Davids, & Passos, 2007; Pinder et al., 2011).

These ideas imply that representative learning design needs to be captured in practice tasks and skill tests which simulate aspects of the competitive performance environment in sport. Simulations of the performance environment need to be high in action fidelity (in much the same way that video designs in studies of anticipation are intended as simulations of a performance context which is the subject of generalization; Stoffregen, Bardy, Smart, & Pagulayan, 2003). For example, key measures of sport performance, such as time taken to complete a task and observed kinematic (coordination) data during action, would be imperative in assessing action fidelity of simulated training, practice and learning environments (Araújo, Davids, & Passos, 2007; Pinder et al., 2011). The purpose of action fidelity is to examine whether a performer's responses (e.g., actions or decisions) remain the same in two or more contexts; for example, when sampling a sports performance environment to design a talent identification test. Fundamentally, task design which does not represent the performance environment may: a) not support the correct diagnosis of the critical aspects of performance which are required to be evaluated, trained or enhanced; and b), not support the development of functional evaluation, intervention or training tasks which achieve these goals.

Implications for Talent Development Programmes in Sport: Representative Evaluation Test Design

Developing a rationale for identifying and manipulating the major constraints on learners provides a principled basis for the design of performance evaluation tests in talent programmes (Vilar et al., 2012). For example, Russell, Benton and Kingsley (2010) suggested an association football skills test comprising three different tasks to evaluate players' performance. Passing and shooting tasks required players to kick a moving ball, delivered at a constant speed, towards one of four randomly determined targets (identified by a bespoke lighting system). Passing distances in the tests were designated as short (4.2 m) and long (7.9 m), while the dribbling task required players to dribble around seven marker cones placed 3 m away from each other over a course of 20 m (cones 1 & 7 were 1 m away from the ends of the course). Vilar et al. (2012) argued that the skills tests designed in the study of Russell et al. (2010) were not representative of competitive performance in football because they did not include critical perceptual variables that performers typically use to control their actions during performance. For example, research in ecological dynamics has shown that the relationship between the time for a ball and a defender to arrive at an interception point (the nearest point of a defender to the trajectory of a ball being passed between two attacking teammates) acted as informational constraints for attackers to successfully organize the passes (Travassos et al., 2012) and shots at goal in futsal (Vilar, Araújo, Davids, & Button, 2012). Additionally, the relative velocity of an attacker and a defender was shown to constrain the emergence of dribbling behaviours when values of interpersonal distance were 4 m or less (Passos et al., 2008; Duarte et al., 2010). While the test data reported by Russell and colleagues (2010) may have been able to differentiate between skilled and less skilled performers on *test performance*, the absence of relevant perceptual variables to specify actions in the skills test may have led the players to use information that was non-specifying of the competitive performance environment, supporting emergence of different behaviours (Pinder, Renshaw, & Davids, 2009) . This argument is based on compelling empirical evidence in sport showing that, when informational constraints of a task are altered, *different* patterns of movement coordination tend to emerge (Dicks, Button, & Davids, 2010; Pinder et al., 2009).

To achieve representative design, skill evaluation tests should be predicated on the same *specifying* information variables that performers use to control their actions in specific performance contexts, such as team games or outdoor activities (Araújo, et al., 2007; Dicks, Davids, & Araújo, 2008; Pinder, et al., 2011; Vilar et al., 2012). Although all information variables can induce some kind of behavioural response from individuals, only specifying information variables support the requisite behaviours needed for success in a particular task. Consequently, representative design might be measured not only by assessing product (performance outcome) variables (e.g., time to complete the task, number of points scored, number of trials to achieve criterion), but also by evaluating process variables (kinematics of behaviour, stability of behaviour, changes in spatio-temporal relations between performers during interactions; Araújo, et al., 2007; Pinder, et al., 2011; Vilar et al., 2012). Important criteria to develop an operational definition of "representative test evaluation design" in ecological dynamics are summarized in figure 1, and should include the following (see Chow et al., 2011; Pinder et al., 2011):

(i) *Designing noisy tasks and evaluation tests.* Tests of talent should provide athletes with opportunities to show how they can harness the inherent degeneracy of their movement systems. Representative performance evaluation tests need to allow developing experts to explore adaptive variability in decision making and actions. The 'search and assemble' process that characterizes skilled performance in sport can be enhanced by ensuring that variability is present in a battery of evaluation tests which amplifies the exploratory activity of developing experts. Intrinsic movement pattern variability enlarges the area of search for a functional movement solution in a developing expert (Newell et al., 2008). Indeed, in skill acquisition, Schöllhorn and colleagues have advocated a 'Differential Learning' approach, in which learners experience a variety of movement patterns (thus providing a 'noisy' learning environment), to encourage development of an individualized movement pattern that best fits the task dynamics of the performance context (Schöllhorn et al., 2006; Schöllhorn, Mayer-Kress, Newell, & Michelbrink, 2009. Their work suggests that challenging developing experts to perform refined adaptations of a movement skill, in order to achieve the same performance outcome, should comprize a basic principle of representative performance evaluation tests.

(ii) *Designing performance evaluation tasks predicated on information-based control of action.* This aspect of representative test design would enable perception of information that specifies an affordance in a performance environment (e.g., in 1v1 sub-phases of team sports, using information about an individual attacker's movement capabilities to constrain information about the time needed for an individual defender to make contact with that attacker specifies distinct affordances (clear action opportunities) such as dribbling/running with the ball or passing the ball (Correia et al., 2012; Orth et al., 2012). In order to design tasks to evaluate skills in sport, performance analysts and practitioners should use their knowledge to sample the key information variables that players use to guide successful skill performance in the competitive environment. During development, movement may be coupled to a specific source of information that supports action, but it may be a source that does not guide the performer towards the goal he/she wants to achieve. Performers use exploratory activity in simulated performance environments (practice tasks) to reveal what environmental properties are informative in relation to a specific intention. Evaluation test design should allow developing experts to show their ability to make reliable judgements and adapt their actions relative to environmental properties such as interpersonal distance between an attacker and a defender in a 1v1 sub-phase of team games (Vilar et al., 2012).

(iii) *Ensuring continuous context-dependent decisions and actions.* Performance evaluation tests need to be composed of ongoing tasks which evolve over time, requiring interrelated decisions and actions. Discrete tests should be avoided since they may be reductionist and not representative of dynamic performance environments in sport, where continuous context-dependent decisions and actions are needed (Vilar et al., 2012).

(iv) *Designing evaluation tasks with representative affordances.* This test design principle would require developing experts to act in context in order to pick up specifying variables that provide affordances for achieving their performance goals (Araújo, et al., 2006; Hristovski, et al., 2006). For example, previous work on 1vs1 sub-phases of team ball sports has shown that players are highly attuned to information from the movements of an immediate opponent to regulate their passing, shooting and dribbling behaviours. In the team sport of futsal, the time needed for a specific defender to intercept a moving ball has been shown to yield information for passing possibilities of attacking players (Correia, Araújo, Craig, & Passos, 2010). Also, in futsal, it has been demonstrated that successful shooting is precipitated by sudden transitions in the angles to the goal of an attacker and a defender (Araújo, et al., 2004; Cordovil, et al., 2009), and by the angle of the attacker-defender vector to the try line (Passos, et al., 2009), respectively. Finally, successful dribbling in team sports have been shown to be highly constrained by the interpersonal distance and relative velocity of an attacker and a marking defender in association football and rugby union (Duarte, et al., 2010; Passos, et al., 2008).

To summarize, for designing performance evaluation tests in team sports, the interactions between opposing players and key performance constraints, such as the location of the ball and the goal, appear to be key issues in understanding the emergence of successful and unsuccessful performance. By neglecting the active role of opponents in task design (e.g., by using cones to simulate an obstacle to avoid), performance evaluation tests may not faithfully simulate the dynamic nature of the performance environment in team sports, which could significantly impact on the functionality of a skills evaluation test. Test environments that fail to provide relevant sources of information for performers to pick and use to regulate their actions can lead to the assembly of less functional performance behaviours (Vilar, et al., 2012). For example, practicing a shot in basketball without a defender can result in the development of a movement pattern that may be less functional (i.e. easily blocked) when a defender is present.

(v) *Recognising Individual Differences.* Expect a significant amount of individual variation as individuals seek to assemble their own performance solutions to satisfy the unique set of constraints interacting on them. Ecological dynamics provides a principled, theoretical framework for understanding individuality and applying the ideas in learning design (Chow et al., 2011; Davids et al., 2008; Phillips et al., 2010). Even if task and environmental constraints were considered as constant over some period, we can observe that the learning dynamics of each individual will be different since the interacting configurations

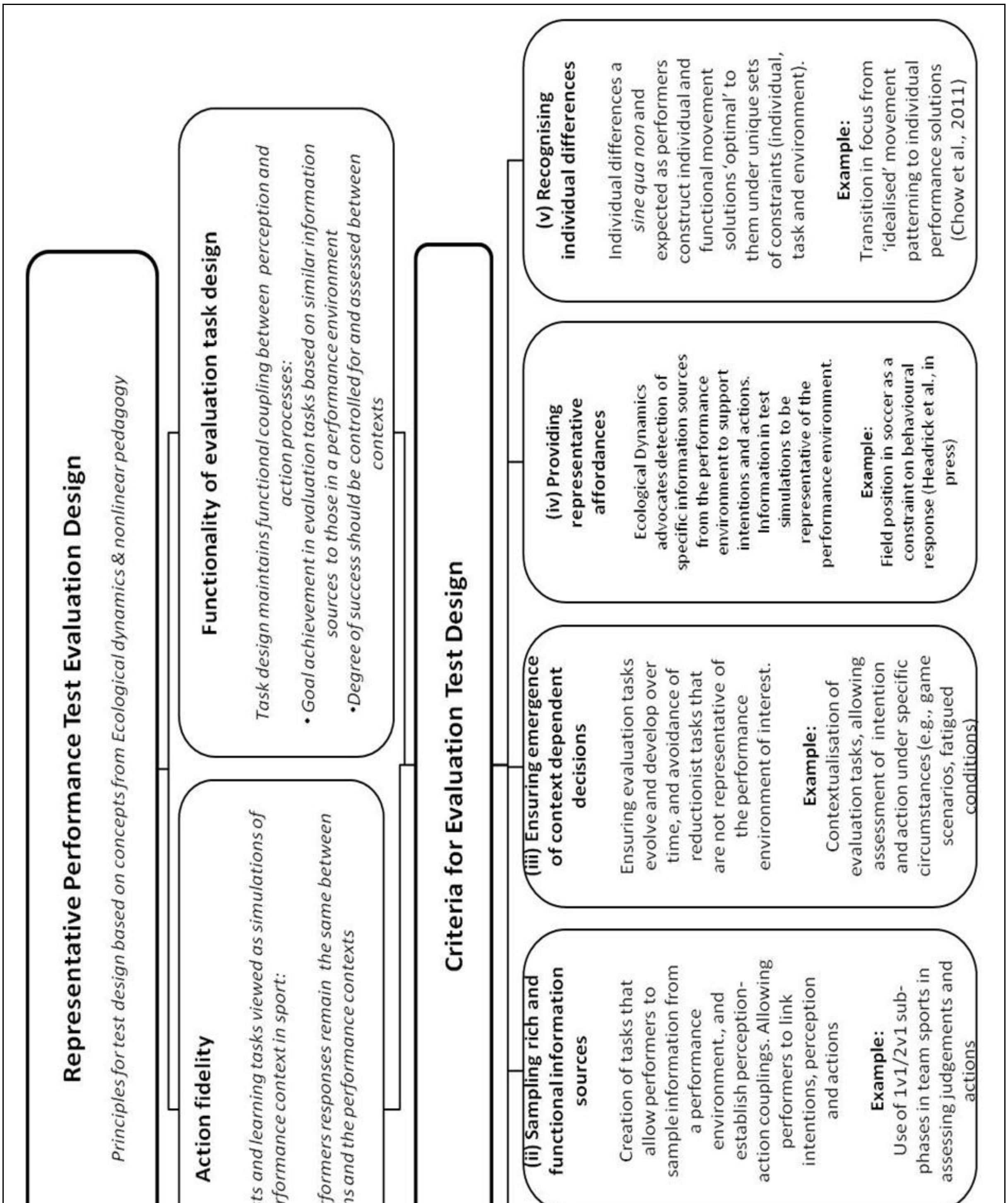

Figure 1: Principles for the design of representative performance evaluation tests for talent development programmes in sport, based on concepts in ecological dynamics.

of constraints will differ between learners. The distinctive configuration of constraints between learners supports how each individual detects and calibrates information to their own action capabilities at any one point in his/her personal development during practice. Hence, it is futile to expect all learners to produce a common, idealized motor pattern (e.g., a ‘classical’ technique for an action). Individual learners can often experience discontinuous, qualitative changes in their performance due to the presence of instabilities in their perceptual-motor landscape (i.e., the space of possibilities for interaction between a specific developing expert and his/her performance environment). These instabilities may be due to growth, development, maturation and learning across the lifespan. It is important to note that constraints act on learners along different timescales, from the immediate (at the timescale of perception and action) to the more long term (at the timescale of developmental change over months and years). In ecological dynamics the goal of learners is not to re-produce an idealized movement pattern, but to assemble a personal, functional, ‘optimal’ movement solution which satisfies the unique configuration of constraints impinging upon them at any instant in time (Chow et al., 2011).

Conclusions and Implications

This paper has described key ideas in ecological dynamics which underscore that successful learning design is based on a sound understanding of: i) the expertise level of the performer on the task, ii) the intentions/goals to be understood, and iii) the primary constraints (organismic, task and environmental) to be manipulated during learning. A major challenge is to consider the functional representativeness of training exercises (Pinder et al., 2011), i.e., to evaluate the correspondence of a learner’s behaviour in training and competition. Without such established correspondence, performance evaluation tests may lack representative design. Traditional talent identification models tend to be operationalized by assessment of a small number of heavily weighted variables typically measured in isolation from the performance context. These isolated performance evaluation tasks are reductionist and lack representative design, implying significant consequences for developing athletes (Vilar et al., 2012). For example, in a study investigating the transfer of talent from a deliberate programming perspective (Bullock et al., 2009) in skeleton, a winter sport in which athletes slide face-down on an ice track, initial pilot data indicated that up to 50 % of the variance in skeleton performance was attributable to the push start. Previous research showed that elite skeleton performers were able to approach their best upright sprinting performance in a crouched position. The assumption was then made that the fastest upright sprinters would also be the fastest in a crouched position, which was not empirically verified. The findings showed that push time and overall performance were only marginally related, reflecting the problems with a reductionist approach (Bullock et al., 2009). Such reductionism is understandable as part of an operational approach to talent identification, but is not based on a principled theoretical model of the relationship between expertise and talent development (Phillips et al., 2010). Crucially, this sort of test design failed to provide information on performance of the ‘drive’ component in the skeleton. This type of design fails to capture the continuous interactions of athletes with their performance environment, as well as the need to ensure the presence of specifying information in performance evaluation tests which performers use to regulate their actions (Jacobs & Michaels, 2007).

Recent trends in the reductionist design of evaluation tests may have become prevalent because current identification of talent is based on structured and mechanistic attempts to maximize limited resources (e.g., physical, logistical, operational and financial). The prevalence of these ‘snapshot’, uni-dimensional approaches, allied to an absence of a principled theoretical framework for understanding expertise and talent development (see Phillips et al., 2010), might explain why there is such a large number of performers being unsuccessful in transfer or being de-selected from talent development programmes (see also Abbott, Button, Pepping et al., 2005).

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