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Learning design for Nonlinear Dynamical Movement Systems

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Abstract: Abstract: This paper discusses a theoretical basis for a sport pedagogy predicated on a conception of the learner as a nonlinear dynamical movement system. Here key ideas in ecological dynamics are elucidated before implications are considered for designing performance simulations to enhance learning in sport. It is argued that this approach to learning design in sport can provide practititioners with a relevant model of the learner and of learning processes. A key idea in ecological dynamics proposes that the relevant scale of analysis for understanding human behaviours such as learning is the person-environment relationship, not either entity considered separately. The paper concludes by discussing five principles of learning design implied by a commitment to an ecological dynamics approach to human behavior.

Keywords: learning design, motor behaviour, ecological dynamics, sport pedagogy.

INTRODUCTION

The design of practice and training tasks in sport require the construction of different simulations of the competitive performance environment to allow athletes to work on particular sub-phases or sub-components of performance, including specific skills, fitness requirements and tactical/strategical behaviours. An important task in sports science and performance analysis is to formulate rationale theoretical principles that underlie the design of these practice and training simulations in athlete development. Such principles need to be theoretically conceptualized and empirically verified to provide a valid basis for adopting specific pedagogical practices. For example, from a skill acquisition perspective, pedagogists and practitioners in sports science need to develop models of the learner and of the learning process to underpin the simulations of the performance environment that they create. Currently, there have been few attempts to produce a theoretical rationale to underpin learning design in sport, with the result that the development of novel, evidenced-based pedagogical practices may have been impeded [1, 2].

SOCIO-CULTURAL CONSTRAINTS ON TRADITIONAL EMPHASES ON OPTIMAL MOVEMENT PATTERNS

An impediment to the design and uptake of new pedagogical practices, founded on theory and evidence, is the tendency towards 'institutionalized inertia' that is inherent in performance domains like sport. For example, Moy and Renshaw [3] have argued that the experiences of successful performers in sport pre-dispose them to maintain a 'custodial' approach towards coaching and teaching practices, regardless of individual differences [4,5]. In sport pedagogy, models of occupational socialisation have explained how traditional teaching and coaching practices can become institutionalised by being perpetuated in sport development programmes [6]. Occupational socialisation consists of processes of acculturation, professional socialisation and organisational socialisation. In sport, acculturation is an ongoing socialisation process that includes past physical education and sports participation experiences of sport pedagogists. These powerful experiences not only influence individuals to enter the profession of sport pedagogy, but also provide a strong constraint on their perspectives for developing alternative pedagogical practices [7]. Many individuals who want to work in sport pedagogy have also enjoyed extensively high performance achievement levels in sport prior to entering the profession [8]. These positive experiences and associations with coaches and teachers help guide individuals' decisions to become sport educators and pedagogists. Consequently, developing professionals are likely to retain a custodial approach to sports pedagogy, and they are likely to practice in a manner similar to how they were taught/coached [9, 6]. Lawson's [6] model of occupational socialisation might help explain the continuity of the traditional 'reproductive' approach to practice in sport pedagogy since many practitioners have reported the predominant use of this style in their professional work [10].

On the other hand, processes of professional socialisation in coach and teacher education currently tend to involve some training in the sports sciences to provide a theoretical and evidence-based rationale for planning and organising

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programmes of athlete development. These programmes include training in exercise prescription, biomechanical analysis of performance and motor learning to understand how to design practice environments in sport. This aspect of professional socialisation can counter the powerful tendency to adhere to traditional learning practices in sport development programmes. The provision of such theoretical principles is important to ensure that, when designing a learning programme in sport, pedagogues and practitioners acquire an evidence-based model of the learner and of the learning process. Simply basing pedagogical practice on personal learning experiences is predicated on experiential knowledge only, and there is little consideration whether the methods adopted truly reflect the learning process. Merely 'coaching as one was coached', regardless of whether the methods may be appropriate for each particular learner in a specific activity context, is likely to overemphasize the importance of traditional reproductive pedagogical methods.

This paper highlights a theoretical basis for a sport pedagogy predicated on a conception of the learner as a nonlinear dynamical movement system. This theoretical rationale proposes how learning design in sport might be based on an ecological dynamics perspective. Here key ideas in ecological dynamics are elucidated before implications are considered for designing performance simulations to enhance learning in sport.

AN ECOLOGICAL DYNAMICS MODEL OF THE LEARNER AND THE LEARNING PROCESS

A key point in developing a model of the learner and of learning processes in ecological dynamics concerns the proposal that the relevant scale of analysis for understanding human behaviours such as learning is the *person-environment relationship* [11,12]. A misconception of traditional motor learning theories to be avoided is the tendency towards an 'organismic asymmetry' in modelling processes of learning [13]. Dunwoody [14] lamented the traditional bias in psychology towards personal attributions in explanations of human behaviour and the failure to recognise situational attributions in the form of interactions of individuals with their behavioural environments. This inherent bias in traditional psychology tends to overemphasize the acquisition of enriched internal states, such as movement templates, for explaining behaviour regulation [13,14,16]. Organismic asymmetry in traditional psychology reflects a preference for internal mechanisms, such as representations, to explain how the processes of perception, action and cognition may be regulated. This organismic asymmetry has led to a biased theoretical focus on internal mechanisms to explain the acquisition of movement skill from a cognitive neuroscience perspective, ranging from abstract, symbolic representations (such as motor programmes and schemata) to groupings of neuronal cells functioning in the vertebrate motor system. These dominant themes in psychology have underplayed the role of the environment as an additional cause of behavioural adaptation. This assymetry has subserved the overriding emphasis on the acquisition of similar optimal movement patterns in all learners in the reproductive nature of traditional pedagogical practice.

Ecological dynamics avoids such a bias by assuming a performer-environment mutuality and reciprocity, in which both combine to form a whole ecosystem [12]. Under this synergy, biology and physics come together with psychology to define sport science at a new scale of analysis – the ecological scale [1,13,16]. In ecological dynamics a major challenge is to understand the ability of each individual to perceive information from the performance/learning context which can regulate actions. Sport environments tend to be complex and dynamic, with information emerging from the ongoing interactions of performers with key objects (projectiles to catch or hit), surfaces (take off boards, diving platforms, ice falls), events (tactical changes) and significant others (teammates, opponents). Since this information is emergent, it follows that actions also need to be emergent to take advantage of ongoing changes to the information present in performance/learning environments and can rarely be planned and prescribed well in advance. The significant relationship between emergent information and emergent actions in sport suggest how the ecological scale of analysis can benefit understanding of sport performance and learning. These ideas are instrumental in modelling the learner and learning processes in sport. A critical point in ecological dynamics is that each individual learns to perceive information from the surrounding layout of the performance environment in the scale of his/her body and action capabilities [17]. From this perspective, the role of information and intentionality in cognition and action needs to be understood in physical terms, not as part of internally-located inferential mechanisms (i.e., there is a need for a law-based understanding of discrete and dynamic aspects of human behaviour) [17].

How is successful performance in sport characterized and what does an ecological dynamics approach imply for designing learning environments to enhance skill acquisition? Successful performance in sport is characterized by the patient assembly of stable and reproducible low-dimensional patterns of behaviour, which are functional, consistent with respect to performance outcomes and resistant to perturbation [11]. Although successful actions in sport exhibit some regular morphologies, it has become clear 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 [1,13]. Due to the 'emergent information-emergent actions' relationship, learners need to adapt their actions successfully to dynamically changing performance environments that characterise competitive sport. This need characterises 'functionality' in sport performance and such requisite flexibility is tailored to current environmental conditions and task demands, and implicates ongoing perceptual regulation of action [12]. So, if more functional movement patterns emerge to fit the circumstances and context of performance, fluctuations created by dynamic instabilities in the system will provide a platform for the performer to discover and explore them.

According to Warren [11] stable performance solutions correspond to attractors in the behavioural dynamics of the performer-environment system, and transitions between behavioural patterns correspond to bifurcations. System bifurcations provide a selection mechanism, the means to decide when one mode of behaviour is no longer functional and to switch to more functional behavioural solutions [18]. It is worth re-iterating that such stabilities are not located internally *a priori* in the performer's system but are emergent, shaped by the specific confluence task and environmental constraints for each specific individual. These ideas are congruent with Gibson's [19] proposition that behavioural control lies in the actor–environment system. This idea implies that behaviour can be understood as *self-organized and emergent under interacting constraints*, in contrast to organization being imposed by an internal mechanism located within.

The key to the learning process in ecological dynamics is for each learner to exploit physical and informational constraints to stabilize an intended behaviour. An emergent functional performance solution is lawfully predicated on physical and informational regularities, depending on the nature of the task, and within given constraints there are typically a limited number of varied but stable performance solutions that can be achieved for a desired outcome. An ecological view suggests that the structure and physical properties of the performance environment, the physical and mental capacities of each individual, perceptual information and specific task demands, all serve to constrain the motor learning process in an embedded way [11,12].

From this viewpoint, successful learning results in behaviours that are adaptable to a range of varying performance contexts. In an ecological dynamics approach, the nature of the performer-environment relationship is not the same for beginners and experts, since experts are more capable of exploiting information about environmental and task-related constraints in order to (re)organize the multiple degrees of freedom of the body [20]. Thus, the greater adaptability of experts to a variety of interacting constraints, such as personal, environmental and task constraints [21], has emphasized the functional role of adaptive movement variability [1]. Learning design should, therefore, provide advanced learners with dynamic representative tasks to explore movement variability and find a functional relationship between their actions and the performance environment. The design of dynamic, representative practice tasks will allow the performer to explore variable motor patterns, facilitating the discovery of functional patterns of coordination and is supported by neurobiological system degeneracy [22,23] and multi-stability [24]. The use of static practice task drills in sport or severely constrained practice tasks may not provide a viable platform for performers to exploit these inherent tendencies and for adaptive movement patterns to be acquired during learning.

Adaptive behaviour is important because constraints like the environment, task requirements, and an individual's intentions and motivations can alter every time an action is performed. Adaptive movement behaviour, rather than being imposed by a pre-existing structure, emerges from this confluence of constraints under the boundary conditions of a particular task or activity context [1,11], even under relatively stable task constraints such as experienced in sports like diving, gymnastics and synchronised swimming. A major challenge for sport scientists is to understand how each individual learns to adapt their movement behaviours in complex and challenging sport performance environments in order to consistently achieve a particular task outcome and to design learning environments accordingly.

COGNITION IS PREDICATED ON PERCEPTION AND ACTION

In ecological dynamics perception and action are very cognitive matters, illustrating an organism's knowledge of the environment [13,15,19]. An important consideration is how properties of the environment are perceived by each individual. How do we gain knowledge of our world so that we can produce skilled behaviour? The answer to that question is literally that *knowledge of* the world is predicated on perception and action. Gibson [19] advocated a functionalist approach by arguing that biological organisms perceive and act on relevant substances (exemplified in sport by wind and currents in sailing and kayaking), surfaces (e.g., running or biking terrains), places (e.g., locations on court or on field in team games), objects (e.g., sticks, bats, oars, balls) and events (e.g., an approaching opponent) in the environment.

KNOWLEDGE OF AND KNOWLEDGE ABOUT THE PERFORMANCE ENVIRONMENT

Pertinent to understanding the learning process is a helpful distinction by Gibson [25], between *knowledge of* and *knowledge about* the environment. He proposed that *knowledge about* the environment involves perception which is indirect or mediated by language, symbols, pictures, instructions to facilitate analogical reasoning and cognition of what an information source means. In physical activity and sport this type of knowledge is exemplified by a dance teacher's instructions or feedback captured in a verbal description of a dance sequence. *Knowledge of* the environment, on the other hand, captures the ability of a biological organism to perceive properties of the surrounding layout of the performance environment in the scale of its body and action capabilities. [17] According to Gibson [25], *knowledge of* the environment facilitates knowing how to regulate action because it involves perception of invariants used to control action directly. *Knowledge of* the environment involves the pick up of perceptual variables that directly constrain functional behaviours like balancing on a surface, intercepting a projectile, locomoting towards a surface or object in space, and manipulating equipment. Through exploration in the learning process, perceptual systems become progressively more "attuned" to the invariants in the environment through direct experience in specific contexts. The information variables picked up by learners become more subtle, elaborate, and precise with task-specific experience and become successfully coupled to actions through the process of direct learning [26].

This distinction in the different types of knowledge that individuals can acquire in human behaviour has some important implications for sports scientists. First, it suggests that learning processes in sport need to be based almost exclusively on movement and perception. The use of too much verbal information to constrain a learner's actions might inadvertently constrain them towards acquiring knowledge which is useful to describe a performance solution, rather than to functionally discover it for him/herself. Knowledge of a performance environment is predicated on a functional relationship between cognition, perception and action which is focused on achievement of movement performance goals. Some knowledge about a performance environment might be needed to complement the most influential knowledge of how to achieve performance goals in sport. But knowledge about a performance environment is most functional for a sports commentator who is not charged with creating information for action by movement. An implication that needs to be empirically verified from this assertion is that coaches and teachers may benefit from sufficient performance experience in a sport context to be able to design performance simulations in practice which encourage a cyclical relationship between action and perception in a direct form of learning.

Direct learning over time entails changes in the properties of the environment to which a learner's perceptual systems become attuned through experience [26]. In an ecological dynamics view of learning, skilled performance gradually derives from the increasingly improved (functional) fit of an individual and an environment, rather than from an increased complexity of acquired knowledge and associated computational and memorial processes. The focus is on how performers learn to take advantage of the informational richness of environmental properties that are present in specific performance environments. During learning, experts refine the environmental properties to which their perceptual systems are sensitive and need to be able to express this expertise through their actions in specific performance contexts [26].

This approach to the learning process suggests that skill acquisition should not be modelled as the acquisition of an internal state comprised of different movement invariants and parameters (e.g. acquiring a triple salto in ice skating). Rather it might be characterized as the refinement of adaptation processes, achieved by perceiving the key properties of the surrounding layout of the performance environment in the scale of an individuals' body and action capabilities. These properties are picked up and used as information to regulate action in specific performance environments (such as the surface texture of ice for ice climbers; see [5]). These comments suggest that the processes of "skill acquisition" involve becoming more skilled at negotiating a specific environment and concern changing the nature of the athlete-environment relationship, rather than as 'acquisition of something to be stored somewhere'. This conceptualization is not helped by the definition of a 'skill' as a particular act (an object or entity), which is undoubtedly correct. But the phrase "skill acquisition" may be somewhat misleading due to cognitive psychology's inherent organismic asymmetry, inducing the notion of skilled behaviour as an object, state entity to be acquired and maintained by the learner. In fact, skilled behaviour is traditionally considered to be a possession of an individual and not an outcome of person-environment interaction [13]. A commitment to this theoretical idea suggests that learning may be more about changing the relationship that an individual establishes with a particular performance context. Rather, processes of skill adaptation or skill attunement may be more unbiased terms for psychologists to consider.

REPRESENTATIVE LEARNING DESIGN IN SPORT

Ecological psychology's ideas on the symmetry of the organism-environment relationship dovetail well with Egon Brunswik's [27] conceptualization of representative task design, with clear implications for learning design in sport. The phrase *representative experimental design* refers to the organisation of experimental constraints so that they represent the behavioral context to which the results are intended to apply. With reference to the concept of representative design, Hammond and Stewart [28] noted that Brunswik used the term *represent* here in the same sense in which a sample of participants in an experiment might be said to *represent* individuals in some population that was not included in the experiment, according to the statistical theory of R.A. Fisher (e.g., sampling participants according to their level of experience or gender). Thus, Brunswik was arguing that the (statistical) logic of induction should hold for environments as well as participants. Brunswik's [27] notion of representative task design is important because it is predicated on the role of information in human behaviour as an adaptive process. Representative experimental task constraints reveal adaptation by human participants to environmental contexts and performance settings. The proposition in this paper is that these ideas, emphasising the performer-environment relationship as the relevant scale of analysis to understand human behaviour, can theoretically frame a functional model of the learner and of the learning process in sport

To consider learning at an ecological scale of analysis there is a need for studying behaviour in representative tasks, that is those tasks in which the information from a performance environment has been sampled and integrated into a practice simulation [27]. Representative learning designs in sport can be achieved through the implementation of key ideas in ecological dynamics. These ideas suggest how sport scientists and pedagogists might aspire to design representative learning contexts [1,2,29,30]. The tendency to design simplistic and highly controlled practice tasks in a reductionist approach will not accomplish the requisite level of representative design to enhance learning in specific sports. The next section discusses how the model of the learner and the learning process in sport from ecological dynamics could provide the principles for a nonlinear pedagogy. The paper concludes by exemplify how pedagogical practice in sport may be shaped by the adoption of this model.

NONLINEAR PEDAGOGY: KEY CONCEPTS AND ASSOCIATED PRINCIPLES FOR LEARNING DESIGN

Nonlinear pedagogy is predicated on the conceptualisation of the performer/learner in sport as a complex neurobiological system exemplifying a nonlinear dynamical system in nature. These theoretical ideas imply a commitment to learning design based on a nonlinear dynamics explanation of how processes of perception, cognition, decision making and action underpin intentional movement behaviors in dynamic environments [e.g., 17, 31] . This perspective proposes that the most relevant information for decision making and regulating action in performance environments is emergent during performer-environment interactions [12,31]. Nonlinear pedagogy proposes that athletes, considered as neurobiological systems, exhibit purposive adaptive behaviors from the spontaneous patterns of interactions between system components. The notion that skill acquisition is predicated on the use of functional adaptive movement patterns in sport implies that simulation tasks during learning needed to be designed with carefully considered 'noise' [32-34]. Noisy simulations of the performance environment during practice provide learners with important opportunities to explore adaptive variability in decision making and actions. These ideas have been well exemplified in the work of Schöllhorn and colleagues in Differential Learning [32-34]. Their work suggests that variability can be designed into learning tasks in order to enhance skill acquisition. However, it is not clear whether the addition of random variability to a movement task will benefit skill acquisition in individuals at the different stages of Newell's [35] motor learning theory (e.g., coordination or control stage) since no formal criteria were provided in those studies for categorising participants. The categorisation of participants is not a straightforward task and there are dangers in using 'proxy' measures such as age or formal training of participants in this process. Therefore, it is not clear whether randomly added variability is more likely to benefit more advanced learners, particularly those at the control stage of learning [35]. This is an important issue for research since at the previous coordination stage of motor learning, individuals need to discover a stable movement pattern that can provide a functional solution to a task problem. Initial added variability may help them to discover their own functional states of coordination, which can then be stabilised through practice. Variability can create fluctuations and instabilities in practice environments which can act as a platform for learners to discover and explore more refined movement patterns.

PERCEPTION-ACTION COUPLING IN PRACTICE SIMULATIONS

An important feature of complex neurobiological systems is the emergent relationship that develops between perception and action as such systems coordinate their actions with respect to the environment. The mutual interdependence between perception and action in stressed in nonlinear pedagogy suggests that these processes should not be allowed to function separately in learning design [e.g. 12]. Gibson's [19] insights reveal why practice tasks in sport need to be carefully structured and managed in order to maintain relationships between key sources of information and action for learners and performers during practice. These ideas are exemplified in the long jump run-up where the idea of information and movement coupling suggests that learners should be encouraged to run towards a take-off board to jump or to practice a ball toss with a service action when serving a ball in tennis and volleyball. These tasks should typically not be broken down into separate components during practice because this strategy might effectively de-couple perception and action, which is likely to result in a weakly established relationship between these processes. Different sources of perceptual information present different affordances for performers to execute specific actions in sport and for this reason care should be taken in designing learning environments. This important principle of nonlinear pedagogy is termed perception-action coupling. It implies that learning design should emphasise keeping information and movements together to allow athletes to couple their actions to key information sources which are available in performance and practice environments. Experiential knowledge of coaches intuitively agrees with the viewpoint of keeping tasks whole, and not separating them into their smaller parts during practice, known as *task decomposition* [36].

These ideas and data imply the need to design simulations so that learners can perceive information that specifies a property of interest for them to use in regulating their actions through a coupling process. A simple example exists in sports that involve a run-up. Principles of ecological dynamics suggest that learning design should involve a nested task to be performed at the end of an approach phase. For example, athletics training should include creating learning tasks in long jumping in which individuals learn to use information from a take-off board to regulate their approach run. These tasks should always involve the learner performing a jump (the nested task) after placing the front foot on the take-off board. The tempo of the run up can be varied but the task goal should remain unchanged: 'Run to jump from the board'. This is because a key aspect of the task involves the learner picking up information from a target in space to regulate their gait during the approach phase to perform the nested action. Similar examples exist in running to perform a gymnastic vault, running to cross a ball in football and running to the popping crease in cricket to bowl at a batter. The information-movement coupling principle should not be ignored in learning design. This issue poses a problem for the use of ball projection machines in sport, a common practice. The problem is that in the ball games performance context, the speed of projectiles is so great that performers have to use anticipatory information from the body orientation of individuals projecting a ball in space (through throwing, pitching, bowling, hitting and kicking actions) to successfully perform an interception. Projection machines only provide learners with access to ball flight information and not the specifying information from a deliverer's actions [30], therefore limiting their role in the design of ball skill acquisition tasks.

The constraints of training and practice need to adequately replicate the performance environment so that they allow learners to detect affordances for action and couple actions to key information sources within those specific settings. This critical requirement 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 [37]. Findings 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. Similar issues with static task constraints have been highlighted in the design of performance analysis tests to assess skilled movement or decision-making behaviors [38,39]. Static tests lack functionality and do not successfully represent the constraints of performance environments. For example, Ali *et al.* [38] attempted to overcome recognized limitations of previous 'closed' soccer skill tests, claiming to have 'enhanced ecological validity' by designing tests for the assessment of ball passing (that required players to pass soccer balls to specific targets on benches arranged in a square in a gymnasium). The shooting skills tests required targeting specific goal areas when faced with a static plywood goalkeeper in a 'set' position. Furthermore, the consequences of not adequately representing the key variables in that performance environment can be directly applied to sport psychology research. Abouzekri and Karageorghis [40] adopted this passing test in the assessment of a pre-competition state anxiety intervention on performance timing and accuracy.

These ideas on how to dynamically organise skill and conditioning assessments also have implications for designing learning environments in team games where it has been found that small-sided games are excellent simulations of the competitive performance environment [2,41]. The notion of designing opportunities for learners to pick up affordances for action through movement in practice tasks has implications for acquiring movement and tactical skills in team sports. Creating learning tasks that include situations which evolve over time, requiring interrelated decisions and actions (e.g., the movement interactions between an attacker and defender specifies affordances (clear action opportunities) such as dribbling into a gap or moving to close a gap defensively). This aspect of learning design should allow learners to make reliable judgements and actions about environmental properties such as interpersonal distance between an attacker and a defender [41]. Practice tasks should enable learners to act in simulated performance contexts (e.g., 1v1 or 4v4 subphases of team games) in order to detect affordances to support achievement of their performance goals. Indeed research is beginning to reveal a number of key variables that can be picked up from interpersonal interactions between attackers and defenders in team game performance to specify decision-making affordances [e.g. see 42,43]. These studies suggest that small-sided games provide an excellent informative vehicle as the basis for learning design in team sports since they successfully simulate these performance environments. In contrast, traditional training drills in ball skill acquisition are too static and lack representative learning design [43,30].

A COMMITMENT TO INDIVIDUAL DIFFERENCES

Nonlinear pedagogy involves manipulating key interacting constraints for each individual learner under specific practice tasks designed to simulate performance in sport. These simulations are designed to facilitate the emergence of functional movement patterns in each athlete, regardless of skill level or experience. Nonlinear pedagogy promotes the creation of realistic performance simulations to enhance learning in individual athletes, presenting opportunities for them to discover unique performance solutions in representative practice contexts [1,2,29,30]. As distinct from more traditional approaches to coaching, which favour the provision of detailed verbal instructions, prescriptive explanations, and repetitive practice, nonlinear pedagogy facilitates athletes in finding their own performance solutions to satisfy unique constraints impinging upon them. In nonlinear pedagogy, practice is viewed as a process of searching a perceptual-motor landscape composed of interacting personal, task and environmental constraints. Therefore, instead of attempting to change athlete behaviour through highly prescriptive instructions, which might short-circuit the discovery and exploration process of learning, the coach becomes a facilitator, responsible for designing training and learning tasks to instigate functional changes in athlete behaviour. In this process the athlete is guided to search appropriate areas of the perceptual-motor landscape during practice, not instructed to form a specific movement pattern considered to be optimal by a coach. A key distinction of performance simulations in nonlinear pedagogy is that athletes are presented with practice task constraints which pose them problems to resolve through performing, rather than being presented with ‘ready-made’ solutions to repeat by an authority figure such as a coach or teacher [5].

The individual constraints of the athlete are an important consideration within nonlinear pedagogy, and refer to the unique physical, physiological, cognitive and emotional characteristics of the individual learners, which shape how an athlete solves performance problems [12]. The perspective of elite coaches has stressed the importance of individuality within the learning set-up since they understand that individuals respond differently to different task and environmental constraints faced [36]. The concept of individuality extends beyond learning, to athletes achieving the goal of a specific task. The concept of individual constraints implies a shift away from the assumption that there is a ‘one size fits all’ optimal movement pattern towards which all athletes are working, towards a more individualised approach which encourages the emergence of unique performance solutions in order to achieve desired task goals.

Performers have the potential to solve specific movement problems with a variety of methods, and if encouraged to, they will naturally seek out a solution which satisfies their individual constraints and the task constraints. The process of searching for functional performance solutions during training creates an adaptable athlete better able to handle the unpredictable settings of performance environments since their movement patterns have been self discovered [1]. Despite this awareness of individual expression and the existence of individual solutions to specific tasks within both experiential and experimental knowledge, many researchers still favour analysing group mean data in an attempt to generalise findings to wider populations. The use of group mean data in sport science studies has the potential to mask individual, intrinsic dynamics which are especially important in the acquisition of skill [29], and whilst this type of analysis may have a place in scientific research, the role of individuality needs to be understood and given the emphasis it deserves to ensure scientific understanding of sport performance moves forward.

CONCLUSION

This paper proposed how the design of simulated practice environments to provide learning opportunities in sport by sport scientists requires a commitment to developing a model of the learner and of the learning process. Without such a commitment, acculturation and occupational professionalization processes in sport pedagogy have a bias towards maintaining the ‘status quo’, which typically involves adherence to a traditional, reproductive style of practice, emphasising repetition of putative common optimal movement patterns. An ecological dynamics perspective of learning was discussed and key theoretical issues were highlighted to illustrate some potential key principles of learning design in sport. It was argued that ecological dynamics presents a viable platform for learning design in sport because of its commitment to understanding behaviour at the level of the performer-environment scale of analysis. This scale of analysis suggests the need for principles of sport pedagogy to be framed around: (i) the relationship between perception and action in goal-directed performance; (ii) the predominance of individualised performance solutions over 'movement templates' to fit all learners; (iii) the notion that skilled behaviour is predicated on functional adaptive movement pattern variability at all levels of experience, but especially at the intermediate and elite levels; (iv) the idea that practice tasks should be ongoing and dynamically organised to allow continuous movement and the conditioned-coupling of later behaviours on earlier decisions and action; and (v), a fully encompassed representative learning design as the key principle of practice to faithfully simulate key information properties and constraints of the performance context.

Further work in sport science is needed to provide further empirical verification of these ideas and to extend the principled framework of nonlinear pedagogy as an alternative to traditional reproductive practice styles in sport.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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