Exploring niche construction in sport coaching: an ecological dynamics analysis.

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Exploring niche construction in sport coaching: an ecological dynamics analysis

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ABSTRACT

In this article we challenge deterministic practices on learning and development, biased towards individual properties of learners (e.g., genetic endowment) and knowledge acquisition (e.g., internal representations). These traditional approaches typically fail to account for environmental influences which may interact in unique ways with relevant personal characteristics of learners. To challenge these deterministic approaches, we present a conceptual framework that combines niche construction theory and ecological dynamics, positioning behaviour at the ecological level of analysis where highly skilled behaviour emerges from the individual-environment system. To substantiate this conceptual framework, we investigate the insights and experiential knowledge of professional sports coaches on their practice designs. Results revealed how athletes and coaches value the capacity to modify athlete-environment interactions influencing opportunities for action in a practice context. This novel conceptual framework can inform the designs of contemporary learning and development practices that positively influence the evolution of skilled behaviours in different individuals.

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Introduction

A goal for coaches and practitioners in performance contexts like education and sport, is to provide meaningful and contemporary learning approaches that support the development of functional and adaptable behaviours (Avner, Denison, Jones, Boocock & Hall, 2020; Rudd, Pesce, Strafford & Davids, 2020). However, traditional education practices typically focus on what has been termed the *knowledge acquisition* metaphor (an influence traceable back to Plato's dialogue *the Meno*), where learning is focused on acquiring facts or skills, measured by assessment procedures using standardised performance tests (Barker, Barker-Ruchti, Rynne & Lee, 2012). In this

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sense, learning is believed to occur by enriching internalised representations between the brain and the goal to be achieved that support permanent behavioural changes (e.g., Schmidt & Wrisberg, 2004).

Araújo and Davids (2011) have raised concerns over this deterministic explanation of learning in contexts like sport, suggesting that these ideas emanating from the psychological sciences have developed an *organismic asymmetry* (i.e., an organism-centred view of behaviour). This view of human behaviour has promoted a genocentric view of athlete learning and development that has been criticised for objectifying athletes' bodies and over-emphasising the physiological, anthropometric, genetic, and psychological profiling that seeks to dominate debates on the foundations for athletic performance (Barker-Ruchti & Tinning, 2010). This perspective on learning is synonymous with biological determinism and models of human behaviour in the evolutionary sciences, where, as in education and sport, predetermined inherent properties are conceptualised and tested because they have been deemed important for progress or adaptations (Denison, Mills & Konoval, 2017).

An alternative view of athlete learning and development, that positions the learner as an active agent capable of self-regulating to interact with multiple opportunities for action offered by the environment (i.e., affordances), is ecological dynamics (Button, Seifert, Chow, Davids & Araujo, 2020). A key tenet of ecological dynamics is Gibson's (1979) theory of affordances. Gibson (1979) argued that humans inhabit ecological niches (i.e., a talent development programme or coaching setting) replete with available *affordances* which continually invite actions from them. When individuals are consistently exposed to ecological niches that are rich in information, they are likely to develop the *effectivities* (skills, knowledge, and capacities; Gibson, 1979) to seek and use available affordances to guide skilled actions (Araújo, Dicks & Davids, 2019).

Rothwell, Davids, Stone, Araújo and Shuttleworth (2020b) have suggested that creating an ecological niche to promote self-regulating, functional, and adaptable athletes, who develop a tightly knit relationship with the environment, should be the cornerstone of learning and development programmes in sport. However, the idea of sport practitioners creating an ecological niche that strengthens the athlete-environment system might be at odds with the norms of a specific sport and can (for an example in athletics see Mills et al., 2020), therefore, be problematic to develop in some social and cultural contexts (Ross, Gupta & Sanders, 2018). The reasons for this challenge can be twofold. First, sociocultural factors can assert a powerful influence on coaches' professional practice (Banwell, Kerr & Stirling, 2020). Second, sport practitioners who are not familiar with the idea of strengthening the athlete-environment system might find the term somewhat abstract, inhibiting coaches from being able to support this

ecological notion of learning in practice. Therefore, the overarching goal of this article is to provide sport coaches who are interested in moving away from deterministic models of learning and development, with a conceptual framework that supports the notion of niche construction and situates the learning process within an ecological dynamics rationale of the athlete-environment system.

To develop the conceptual framework, we combine niche construction theory (NCT) (Lewontin, 1983; Odling-Smee, Laland & Feldman, 1996) with concepts in ecological dynamics. This combination is appropriate because their shared assumptions and reciprocal foundations are aligned to tenets of ecological psychology, particularly the theory of *affordances* referring to the action possibilities that the environment offers an individual for "good or ill" (Gibson, 1979, p. 119). The basic premise of NCT is that living organisms, through their "metabolism, activities, and choices" can modify environmental conditions to shape and influence selection pressures (Matthews et al., 2014, p. 245), positioning the reciprocity between an individual and their environment (i.e., athlete-environment system) as the basis for human development, learning, and evolution Odling-Smee, Laland & Feldman, 2013). In sport, a selection pressure relates to how coach or athlete modified environments can preference certain performance behaviours over others (e.g., in boxing, coach informed practice can support boxing on the front or back foot).

To evaluate the extent to which organism-mediated environmental modifications evolve in natural populations, Matthews et al. (2014) proposed a criterion to test for the presence of niche construction (Criteria 1 & 2) and determine when niche construction affects evolution (Criterion 3) (Table 1).

Table 1. Combining Matthews et al. (2014) criteria for niche construction and ecological dynamics can provide sport practitioners with a conceptual framework to design practice environments that strengthen the athlete-environment relationship.

Niche construction theory and ecological dynamics can strengthen the learner-environment relationship		
	Criteria for Niche Construction	Ecological Dynamics concept
Criterion 1	An organism (i.e., a candidate niche constructor) must significantly modify environmental conditions.	Although athletes and coaches can and do modify conditions at the micro (i.e., practice tasks) and macro (system level changes) levels of development. Modifications must be for the benefit of athlete improvement. The concept of *representative co-design* in ecological dynamics can facilitate the collaborative design of learning environments.
Criterion 2	The organism-mediated environmental modifications must influence selection pressures on a recipient of niche construction.	Coaches and athletes can bring about changes in the practice landscape by influencing selection pressures on the utilisation of specific affordances.
Criterion 3	There must be a detectable evolutionary response in a recipient of niche construction that is caused by the environmental modification of the niche constructor.	Detectable evolutionary responses in athletes may be manifest in the environmental constraints (socio-cultural) that athletes experience on micro and macro timescales.

Here, we argue that these criteria are important to provide an operational framework that emphasises the learner-environment relationship for coaches, teachers, trainers, educationalists, and sport practitioners who are challenged with designing learning environments (i.e., an ecological niche). The combination with concepts of ecological dynamics is important because it provides an explanation of how NCT-informed learning environments support functional, adaptable, and emergent behaviours in response to opportunities for action (i.e., affordances) available in dynamic contexts.

To achieve the overarching goal of developing a conceptual framework that supports the notion of niche construction, we recognise, as Cooper and Allen (2018) did, the value and importance of drawing on the experiential knowledge of experienced coaches to ensure that the development of a conceptual coaching framework is realistic and meaningful. With this in mind, we sought the qualitative insights of experienced sport coaches working across different sports who were informed by an ecological dynamics framework. Crucially, this approach was adopted to establish if experienced coaches' everyday assumptions about coaching and learning align to the NCT-ecological dynamics coaching framework, to provide a better understanding of its application in future practice. Therefore, the specific aims of this paper are to: 1) draw on the experiential knowledge of professional sports coaches' activities and choices when modifying environmental conditions (for example, manipulating task constraints) in the microstructure of practice designs. and 2), collect and analyse coaches' qualitative insights of the microstructure of practice design with respect to tenets of a combined NCT and ecological dynamics framework.

Combining niche construction theory and ecological dynamics can enhance our understanding of the athlete-environment system

To complement the criteria proposed by Matthews et al. (2014), and to enrich our understanding of how ecological and evolutionary dynamics interact to develop athlete performance, we first overview key concepts and assumptions of Gibson's theory of affordances in ecological dynamics theory. Ecological dynamics is a contemporary theory of skill acquisition aligned with NCT's complementary view, in advocating the mutuality of the athlete-environment system (for more details see Button, Seifert, Chow, Davids & Araujo, 2020). In athletes and sports teams, conceptualised as complex dynamical systems, behaviour is understood to self-organise under constraints, continuously shaped by a range of individual, environmental, and task constraints, impacting on each athlete, seeking to achieve their intended task goals. Expanding on Matthews et al.'s (2014) criteria for NCT can help us highlight how the complementary nature of key concepts in

ecological dynamics and NCT can provide an interdisciplinary perspective that could enrich understanding of athlete- and coach-modified practice environments on athlete development and learning.

An organism must significantly modify environmental conditions

Aligned with insights of James Gibson (1979) on reciprocity of organism and environment interactions, the biologist Richard Lewontin (1983) suggested that living organisms have the capacity to actively construct and modify environmental conditions (sociocultural practices) for their benefit. This is an important concept for understanding athlete development and performance, because in the same way that many biological species create nests, holes, or webs for ecological and evolutionary importance (Odling-Smee, Laland & Feldman, 2013), sport coaches modify environmental conditions to facilitate (or not) a productive, evolving relationship between an athlete and their environment. This point is supported by data from Roca and Ford (2020) examination of 53 top-division European professional youth football coaches. They highlighted that Portuguese (68 ± 9%) and Spanish (67 ± 10%) youth players spent a significantly greater percentage of session time in active decision-making activities (i.e., uni-directional games, small-sided and conditioned games, possession games, and phase of play). In comparison, they observed that German (57 ± 10%) and English (56 ± 8%) youth players experienced more coach-prescribed repetition of passive drills (Roca & Ford, 2020).

The idea of organisms modifying environmental conditions has been instrumental in the theory of ecological dynamics, where the challenge for sport coaches and scientists is to manipulate task constraints in a re-conceptualised role of *learning designers* (Chow, Davids, Hristovski, Araújo & Passos, 2011; Davids, 2012). However, the careful manipulation of task constraints (e.g., rules, training area dimensions, or equipment) in practice design by coaches are not always based on sampled information sources that are *representative* of a performance environment. As we discuss throughout this paper, how sport practitioners and athletes modify environmental conditions is of great significance for developing adaptable and skilled athletes who need to cope with the demands on modern sport. NCT can support sport practitioners, working within an ecological dynamics framework, to consider how the ecological niches they modify influence an athlete's engagement with the environment.

Individual-mediated environmental modifications must influence selection pressures on a recipient of niche construction

The idea that individuals can perceive their environments primarily in terms of opportunities for action (i.e., affordances), with the agency to accept or reject, is highly pertinent from an evolutionary perspective. This is because conceptualising behaviour through an ecological realism perspective means that intended behaviours may emerge through the development of perceptual and action systems, while others do not (Withagen, de Poel, Araújo & Pepping, 2012). Although the idea that affordances can enrich our understanding of evolutionary biology has been previously considered (see Reed, 1996), these conceptualisations have tended to adopt a selectionist view aligned to traditional positions in evolutionary sciences, seeking to describe why some affordances may be selected for utilisation by an individual and others ignored. This view has been criticised for viewing the animal and environment system as separate entities under adaptationist theorising (Heft, 2007).

Withagen and van Wermeskerken (2010, p. 499) re-examined the role of affordances in the evolutionary process from a NCT perspective to counter the selectionist view of the changing animal-environment system, arguing that not only do "affordances constitute the context of selection, but also that animals' destruction and construction of affordances change this context". Withagen and van Wermeskerken (2010) "*interactionist*" conceptualisation of affordances is relevant for understanding the evolutionary consequences of NCT on athletes' performance behaviours. In the same way that animals create and destroy affordances through modifying environmental conditions, coaches and athletes can bring about changes in the practice landscape by influencing selection pressures on the utilisation of specific affordances. In this way, pedagogical practice can potentiate athlete readiness for action through the co-design of specific, relevant "fields" of affordances during practice (for examples in team sports see Otte, Davids, Millar & Klatt, 2020; Rothwell, Stone & Davids, 2020a; Woods, Rothwell, Rudd, Robertson & Davids, 2021). An ecological conceptualisation of direct perception is integral to this interactionist perspective in sport because it emphasises the importance of exploratory behaviours to develop what Gibson (1979, p. 242) termed *knowledge of the environment*. He elaborates:

Knowledge of the environment, surely, develops as perception develops, extends as theobservers travel, gets finer as they learn to scrutinise, gets longer as they apprehend moreevents, gets fuller as they see more objects, and gets richer as they notice more affordances.Knowledge of this sort does not "come from" anywhere; it is got by looking, along withlistening, feeling, smelling, and tasting.

This analysis of knowledge as emerging from *active perception* and *engagement* with the environment to achieve intentions and tasks goals is relevant to the current discussion of practice design in sport. Practice experiences, designed from an ecological dynamics perspective, should aim to solicit opportunities for athletes to continually explore, directly perceive, and select from a range of available information to regulate behaviours immediately and prospectively (Rudd, Pesce, Strafford & Davids, 2020). Through the continuous exploration of practice landscapes, athletes can develop deep *knowledge of the environment* and learn to use perception of information to continuously reorganise actions, to utilise affordances during sport performance (Araújo & Davids, 2018).

There must be a detectable evolutionary response in a recipient of niche construction that is caused by the environmental modification of the niche constructor

Matthews et al.'s (2014) final criterion for niche construction suggests that there must be a detectable evolutionary response in a recipient of niche construction in the form of genetic or ecological inheritance (i.e., sociocultural practices). We recognise that genetic changes can and do occur in respect of NCT and gene-culture co-evolutionary theory (Feldman & Laland, 1996). However, in sport, this perspective may be problematic because: 1) the practice of gene profiling presents ethical and practical issues, regarding athlete consent and power relations in a sports organisation, which can lead to prioritising the role "nature" is believed to play in athletic performance (Baker & Young, 2020), 2) it neglects aspects of niche construction that are influenced by acquired knowledge and shared practices resulting from sociocultural influences, and 3), testing for genetic changes linked to environmental modification is highly problematic, having little supportive evidence for its validity (Davids & Baker, 2007). Rather, detectable evolutionary responses in athletes may be manifest in the culturally inherited practice settings that athletes experience on micro and macro timescales (Rothwell, Davids, Stone, Araújo & Shuttleworth, 2020b).

Cultural inheritance concerns the knowledge and skills that are transmitted between multiple organisms across generations, in shared ecosystems. Odling-Smee and Laland (2011, p. 226) were keen to clarify culture, typically an ambiguous term, as information shared in a reciprocal manner between organisms and environments, which influences human evolutionary responses when acquired through "learned knowledge, beliefs, values, and attitudes, which are expressed in behaviour, artifacts, and technology". This conceptualisation positions cultural inheritance as a central component by which human evolutionary responses occur in niche construction.

In sport, cultural inheritance, and associated social and historical constraints, continually influence practice designs that shape athletes' self-organising tendencies in either global (i.e., sociocultural constraints) or local (i.e., performers cooperating to achieve a common performance goal) directions (Ribeiro et al., 2019; C. Woods, Rudd, Robertson & Davids, 2020). This idea is exemplified by Uehara et al.'s (2020) exploration of how sociocultural constraints operating at a *global to local* direction influence emergent coordination tendencies in Brazilian football players (for a theoretical explanation see Ribeiro et al., 2019). The findings of Uehara and colleagues (Uehara et al., 2020) suggested that global macro influences emanating from the late 1800s, such as slavery, socioeconomic inequalities, corruption, and unemployment supported novel and creative behaviours for survival, known as *Malandro*. In football, this direction of influence, operating as a macrosystem to guide and shape in-competition behavioural characteristics are still evident today, where deception, creativity, body sway, and feints form the fabric of the highly skilled Brazilian football style (known as *Ginga*).

Method

In line with previous research designs that have aimed to construct or develop knowledge about individuals and the social world in which they reside (i.e., coaching settings), qualitative inquiry in the form of semi-structured interviews, was adopted to elicit information from participants (Smith & Sparkes, 2016). Specifically, our research study was conducted through an interpretivist research paradigm because this is appropriate for achieving our aim of constructing knowledge through a subjective and shared (i.e., researcher and participant) process (Markula & Silk, 2011).

Participants

Participants were purposefully sampled, based on their extensive experience as professional sport coaches and their alignment to an ecological approach to coaching. The authors were aware of the participants' philosophy for creating practice environments, based on prior interactions at academic conferences, coach education events, and sharing of knowledge on applied practice. To ensure their anonymity, participant specific roles are not outlined. However, they were all experienced individuals working within national level sports teams, coaching Olympic level athletes, and being employed within professional sports organisations. The sample level of coaching experience, defined temporally, at the time of the interviews, ranged from 9 to 28 years. Seventeen, experienced professional sports

coaches (14 males; 3 females), from a range of countries worldwide (Australia, Netherlands, Portugal, Sweden, UK, USA), working in individual and team sports (n = 1 Athletics, 1 Australian Rules Football, 1 Field Hockey, 1 Figure Skating, 1 Golf, 2 Rugby League, 3 Rugby Union, 3 Soccer, 2 Swimming, 1 Tennis and 1 Volleyball), volunteered to be interviewed. This study was approved by the host Institutional Research Ethics Committee and all interviewees provided informed consent prior to participation.

Data collection

Individual semi-structured interviews with each participant were conducted face-to-face by the first author who had previous experience of qualitative interviewing. Interview lengths ranged between 35 and 99 minutes (mean 52 min) in length and were recorded on a digital voice recorder and transcribed verbatim. The content of the interview guide was generated based on the authors' inductive logic of coaching, ecological dynamics, and Matthews et al.'s (2014) criteria for niche construction. In this way, the interview guide was developed to explore relevant research aims, with open-ended questions, including: 1) how the coaches and athletes modified environmental conditions through their practice designs (e.g., "Can you tell me about the type of activities you use in practice sessions?"), 2) the influence of practice designs on athletes responsiveness to opportunities that emerge in practice (e.g., "How do the athletes respond physically and cognitively to the practice sessions you deliver?"), and 3), the evolution of athletes through exposure to the practice setting (e.g., "what sort of attributes do you feel the athletes develop after continuous engagement with practice?").

Data analysis

Thematic analysis was used to identify themes across the dataset and the research team did not adopt an "either or approach" (i.e., inductive or deductive). Rather, a more pragmatic line was followed that included inductive and deductive approaches (Braun, Clarke & Weate, 2016; Robertson et al., 2013), where a two-staged thematic analysis was employed to analyse the collected data set. The first coding stage followed deductive analysis to organise the data into one of Matthews et al.'s (2014) three criteria for niche construction. Once the data set was organised into the three areas and accepting that theory-free knowledge cannot be achieved (Guba & Lincoln, 2005), both inductive and deductive analysis were used. For example, during the analysis, some points expressed by the participants provided very clear and

Table 2. Thematic map.

Themes	Sub themes
Coach and athlete modified environmental conditions	Representative co-design Exploratory behaviour Athlete ownership Constraints on behaviour
Coach and athlete mediated environmental modifications must influence selection pressures on athletes	Affordances for action Self-organisation
There must be an evolutionary response in at least one athlete caused by the environmental modification	External focus of attention

appropriate meaning without the use of a theoretical framework to interpret the findings (inductive) (i.e., athlete ownership). Conversely, other experiences were interpreted from a theoretical position (deductive), due to the findings representing relevant meaning regarding NCT.

The approach to data analysis went some way to addressing the challenge of the first author's (who is a practising coach himself) past experiences and biases, which may have led to the misinterpretation and distortion of data (Baur & Ernst, 2011). In addition to the pragmatic approach to data analysis, the first author adopted a reflective and analytically detached perspective during analysis, allowing theory and reflection to provide a more objective view of the social environment under study (Elias, 1956). In addition to this, all three authors engaged in an evaluative process of critical dialogue to challenge the interpretations made and to provide a sounding board for reflection and exploration of multiple and alternative explanations of the data (Smith & McGannon, 2018).

Results and discussion

The results and discussion have been organised and presented according to Matthews et al.'s (2014) three criteria for niche construction and evolution but have been renamed to reflect the coach and athlete interactions in a performance sport context (Table 2).

Criterion 1 – Coach and athlete modified environmental conditions

Congruent with the notion of NCT, each participant's description of practice design demonstrates how the symbiotic relationship between coaches and athletes served to modify environmental conditions. These may not be modifications in the physical sense, but rather, the shared sociocultural practices that are situated in the everyday practices, varying affordances perceived by individuals in their ecological niche (Van Dijk & Rietveld, 2017). Therefore, analogous to the way a colony of beavers can affect the surrounding ecosystem through constructing a dam in a river to modify water flow, participants described how their role was to co-design the ecological niche, with athletes, to evolve opportunities for action within the athlete-environment system (Araújo & Davids, 2016). This Australian Football League (AFL) coach emphasised the importance of co-designing practice tasks and described how players' game knowledge is instrumental in identifying important information sources to shape task constraints:

We would constantly design in that information not just through our own perceptions butthrough discussions with the players themselves so we actually were able to understandwhat they perceive, what information they perceived was important to educate theirdecision making and subsequently the resultant behaviour. AFL coach

Through co-designing learning environments to enhance athlete development, coaches also emphasised the importance of engagement and athletes taking ownership of their own learning and performance enhancement. The value of coaches modifying the environment in this way was demonstrated by Hodge, Henry and Smith (2014) case study that examined the motivational climate created by the New Zealand All Blacks rugby union coaches Graham Henry and Wayne Smith. Henry and Smith suggested that supporting athlete ownership and empowerment can enhance player problem-solving and self-reliance. However, it should be noted that adopting athlete-centred approaches is a complex challenge embedded in "operations of power" that have sociocultural dimensions (Denison, Mills & Konoval, 2017, p. 773). This type of athlete ownership is described in the current study by a swimming coach who aims to support athletes to "take ownership":

What I try to do, is help athletes learn how to coach themselves so you give them these concepts of what needs to happen when swimming. And, basically you need to create a bodyline that creates no resistance and you need to create a propelling, use your arm or your leg to propel yourself and you want as much surface area and you need to hold that surface area as long as possible. You know those are the only real rules. And you can start to shape their behaviours a little bit by asking questions and it's less instructional and it forces them to take ownership. Swimming Coach 1

Another feature of the coach- and athlete-modified environmental conditions were the opportunities presented to performers to explore a range of task solutions through the careful manipulation of learning tasks. Hacques, Komar, Dicks and Seifert (2020) have suggested that sport practitioners who are tasked with developing skilful performers should facilitate exploratory movements and perceptual behaviours, not reducing these activities at the expense of more rigid training practices and methods that focus on adherence to rehearsing "optimal" performance techniques. An ecological niche in athlete programmes, that supports the exploration of practice landscapes, can help learners to become perceptually attuned to information in the environment. In ecological dynamics, attunement involves the process of learning which sources of information need to be perceived to regulate actions and when (Renshaw et al., 2015). Modifying the learning environment to highlight regulatory sources of information can facilitate a tighter coupling between perception and action for performers in practice. This pedagogical approach can support the search for a tighter coupling of perception and action in practice, even leading to innovative connections between these sub-systems (Davids, 2012). The idea of performers exploring a range of task constraints is demonstrated by this athletics coach, who manipulated hurdle spacing, to provide a performer with opportunities to attune to relevant specifying information sources. The coach explains:

XXX (young performance athlete) is progressing to a longer race as his age group has moved up, so he will be eventually running 10 hurdles in his race. We are around seven hurdles at theminute, so I had seven hurdles set up last night and they started at five and a half metres, six,six and a half, seven and then I fixed the rest of the run at seven metres. The idea there is I amtrying to encourage XXX (young performance athlete) to think about how he comes off thehurdle, sets up how he goes into the next hurdle, which is a fundamental part that I believe he needs to learn.

Manipulating hurdle spacing also required the athlete to satisfy a range of task solutions, facilitating experience and exposure to "any scenario that may emerge in a race". Experiences of this nature can support athletes to differentiate between *specifying* (relevant and useful) and *non-specifying* (less relevant and useful) information sources available to facilitate their effective regulatory engagement with the environment (McCosker, Renshaw, Polman, Greenwood & Davids, 2020). The coach continues:

. . . . . .because if he learns that, if he works out how to land off the hurdle and how that will set up his next hurdle I can then present him almost with any scenario in a race, getting it wrong, clipping a hurdle, being fast, being slow, head winds, etc. So I set that landscape and get him to explore it. Athletics Coach

Along with providing opportunities for athletes to refine their perceptual attunement to surrounding information, participants also felt that facilitating exploration of practice environments supported athletes to develop creative and new movement solutions. Orth, van der Kamp, Memmert and Savelsbergh (2017) conceptualised how the emergence of creative and adaptive motor solutions can emerge from athletes exploring varied practice conditions, while satisfying a mix of ecological constraints. This soccer coach explains how applying a task constraint to a simple 4 v 4 game exposes players to variability in movement organisation redundancy (using multiple ways to coordinate a movement to achieve the same task goal), while exploring different (potentially useful) movement patterns within a dynamic practice environment. The coach elaborates:

How can I teach you how to balance and how to fall without saying now we are going to roll and now stay with your feet? No, I start bringing in the element when it is safe for everybody to take off your shoes or keep on your shoes or we double extra socks around your soles and then I give you another ball, then we play four against four, with goalkeepers and we mix in the goalkeeper. So the skills of the goalkeeper is also your skill,

The coach then continues to describe the creative movements that this type of activity can develop: .and then I start training balance, stability, learning to fall, because I believe that if you learn to fall you make different choices in your balance activities, so it is a creativity boost. In that way you are not afraid for the floor anymore and for contact. Soccer Coach 2

Ranganathan and Newell (2013) have argued that practice of this nature can enhance motor learning, provide alternative ways to achieve the same outcome, address current movement organisation, and lead to performance advancements. To exemplify, during the 1974 soccer World Cup finals, the Dutch player Johan Cruyff displayed a novel approach to beating a defender by dragging the ball behind his standing leg, turning 180 degrees, and accelerating away. This innovative move became known as his signature "Cruyff turn".

Criterion 2 – Coach and athlete mediated environmental modifications must influence selection pressures on athletes

Opportunities offered to individuals by the environment are dependent on the relationship between the normative practices that are influenced by key agents in a particular ecological niche (i.e., a sports organisation) (Van Dijk & Rietveld, 2017). This ecological view of human behaviour is congruent with the notion of selection pressures in niche construction theory, where living organisms can alter their environments and, in turn, influence selection pressures on their species (Odling-Smee, Laland & Feldman, 1996). This perspective was implicit within the coaches' description of practice

designs, where the interview data demonstrated how direct coach influence on environmental conditions (practice design) influenced an athlete's responsiveness to certain affordances (selection pressures). A soccer coach explains how they manipulated a "phase of play" to provide goalkeepers with opportunities to detect and act on affordances to achieve a functional defensive outcome (sustaining the continuous interactions between the athlete and coach modified environment): So when I'm doing a crossing session I try to make it look like a phase of play with all the goalies. The goalies in, they'll have four players on the outside, the goalie will clip the ball into them and then they'll start passing it. Any one of them can cross at any time. *He's constantly now having to readjust his position*, communicate to the back three in front of him all at once, *having to make sure he's checking his shoulders to see runners coming in*, balls on its way in. He's having to think about first of all *can I come and get it so that depends on are your defenders close enough to deal with it or is this my ball*. If he decides it is my ball he's *got to assess the flight of it*, he's got to communicate nice and early to let everybody know he is coming for it and then is it a catch? Is it a punch? How do I know if it's a catch or a punch because the pressures on me [emphasis added]. Soccer Coach 1

This practical coaching example elucidates a Gibson (1979) perspective of human behaviour, where it is considered that the performance environment is substantive in *meaning* to support individual interactions. Meaning consists of rich, available information sources that athletes can directly perceive to utilise affordances to support intended interactions with the environment. Drawing on this perspective, and in line with the work of Otte, Davids, Millar and Klatt (2020), the coaches discussed how their specific role was to manipulate variations in the task (constraints) goal to strengthen an athlete's relationship with the environment and facilitate engagement with affordances for skilled action. The importance placed on the athlete-environment relationship, by the coaches, aligns with an ecological dynamics rationale of sport expertise, outlined by Araújo and Davids (2011, p. 7) who argued that sport expertise is the emergence of an ever more "adaptive, functional relationship between an organism and its environment". This is an important conceptualisation for sport practitioners as designers, advocating that they should constantly (re)consider their modifications of environmental niches designed and implemented in programmes over days, months, and years.

Many examples from sport illustrate how highly functional athlete-environment relationships, developed over years of engagement in high quality athletic experiences, can lead to greater receptiveness to relevant affordances that guide skilful behaviour in performance contexts (see Button, Seifert, Chow, Davids & Araujo, 2020; Renshaw, Davids, Newcombe & Roberts, 2019). By way of example, Seifert, Dicks, Wittmann and Wolf (2020) demonstrated how novice and expert ice climbers used different

affordances while climbing an icefall (frozen waterfall). Data revealed that experts used a broader range of multi-limb coordination patterns to execute fewer exploratory movements with ice tools and crampons, suggesting that *existing* holes in the icefall structure were exploited since they provided affordances to regulate climbing behaviours. In contrast, novice climbers displayed lower levels of multi-limb coordination while repetitively swinging ice tools and kicking in crampons to achieve and maintain a deep anchorage. These repetitive actions suggested a lack of perceptual attunement and calibration to available affordances (ice properties) to support climbing performance. Differences between expert and novice ice climbers, in affordance utilisation, was predicated on action effectiveness and energy efficiency. The sentiments of Araújo and Davids (2011) and Seifert, Dicks, Wittmann and Wolf (2020), were evident within the coaches' description of practice, where there was a clear motivation to support athletes to develop *knowledge of* (Gibson, 1979) the environment to strengthen the quality of their interactions with the performance context. A swimming coach explains how he eschewed an instructional, coach-led approach, in favour of designing task modifications to promote a functional relationship between a swimmer and the water, he elaborates (note the emphasis on body awareness to reduce water drag):

It's like all these micro-adjustments that you've got to make to do it and like you know am I going to tell a kid to posteriorly tilt his pelvis by 5 degrees? Like they have no idea what that means and so you know how can I *create more awareness of the shape that their body's in so that they can move through the water better*. So I guess a couple of my solutions are make the feedback bigger and louder to them and so the idea is they swim with a t-shirt and they go fast with a t-shirt because now they've got all this extra drag and also their skin on their torso is not exposed to the water so it's probably they can't feel as much and then you *take the t-shirt off and hopefully now they have a whole lot more sensory information* and they can feel things better and that's one way that maybe they can hopefully *learn to adjust their body position to keep it skinnier so it feels like the waters flowing over their body better* [emphasis added]. Swimming Coach 1

In this sense, learning to be skilful is not the result of an athlete acquiring new *knowledge about* the environment (i.e., through verbose descriptions, visual representations of tactical play or coach-imposed technical models). Rather, a skilful athlete is one who develops deep *knowledge of* the environment to support active interactions, therefore, inhabiting a richer landscape of affordances (Rietveld & Kiverstein, 2014). An important consideration for sport practitioners, however, is to consider that affordances are not simply possibilities for action that exist in an ecological niche, but affordances are invitations which can invite or repel behaviours from individuals (Withagen, Araújo & de Poel, 2017). Therefore, the performance environment should not be viewed as a "collection of causes, but as a manifold of action possibilities"

that makes behaviour possible (Withagen, de Poel, Araújo & Pepping, 2012, p. 251). Accepting this position demonstrates how important it is for sport practitioners to consider how environmental modifications may influence selection pressures and can encourage coaches to evaluate athlete performance from an ecological perspective. This viewpoint is exemplified by a participant who constantly reviews practice designs to establish which affordances are rejected and which are accepted:

I guess the important part was that we explicitly designed information within theenvironment or opportunities, affordances for the players to, I guess, attune to. In a way that we really wanted to do so without being too explicit with our instructions towards them so again we really lived that concept of we're designing an environment and if we want a certainbehaviour to emerge we have to invite those behaviours, and if they're accepted fantastic if they're not we need to assess perhaps why they're not which is like what I said before we constantly review our activities to determine which affordances our players are accepting, which they're rejecting and perhaps why. AFL coach

Along with demonstrating how coach-mediated environmental modifications influence selection pressures on athletes, these examples also illustrate how individuals have the capacity to continuously modulate couplings with the environment's many solicitations (Withagen, Araújo & de Poel, 2017), positioning the athlete-environment relationship as the starting point for understanding how skilful athletic behaviour emerges.

Criterion 3 – There must be an evolutionary response in at least one athlete caused by the environmental modification

The well-established sociocultural perspective of sport is synonymous with the evolutionary nature of NCT, where cultural inheritance is viewed as a key driver in the evolutionary responses of athletes (Uehara et al., 2020). In the current study, cultural inheritance influenced coach and athlete evolution, and was exemplified by the participants' motivations to reject a dualist, Cartesian philosophical worldview (i.e., the separation of mind and body). This command-style pedagogical approach is typically manifest in top down, coach-centred approaches in sport (i.e., an over emphasis on athlete control through direct instruction and feedback). Rather, participants' responses highlighted a desire to implement an ecological worldview (discussed in the previous sub-section) grounded in principles of self-organisation (Barab et al., 1999). Specifically, participants discussed the importance of contextualised learning experiences where performance problems were discussed with the athletes to facilitate functional levels of self-organisation. The intention of the participants to create learning opportunities that exploit self-organisation tendencies and promote athlete self-regulation was exemplified here in the aim: .to develop self-regulating

athletes that are able to regulate actions and behaviours relative to emerging problems in the game, so we really shifted our perspective from providing solutions to players to providing an environment in which the players could interact with and then regulate actions and behaviours based upon what they perceive within their environments. AFL coach In ecological niches, learning customs and practices can generate innovations that propagate through populations and serve to trigger evolutionary responses (Odling-Smee, Laland & Feldman, 2013). Athlete attempts to "evolve" their performance, described by the participants, appeared when striving to satisfy intentional or task goals to promote naturally emerging order, in the individual and/or collective, through athlete-environment integration (Araújo & Davids, 2018). A practical example of this intention is described here by this tennis coach: at the moment we're trying to get them to recover back to the middle after each shot. So they always run, they hit a shot and they just stand there watching the ball instead of preparing for the next shot. And getting back towards the middle of the court but instead of having a recovery box in the middle of the court, in the middle of the baseline, I've moved it slightly to the forehand side so they're more likely, the ball is more likely to go to their backhand on the next shot to encourage them to hit more backhands compared to forehands.

From a complex systems perspective, the concept of emergence under constraints described by the coach provides a platform for individual and team behaviours to emerge (Araújo & Davids, 2016; Shaw & Turvey, 1999). A consequence of this athlete-environment reciprocity is that functional athlete performance can be understood as self-organising while exploiting task (i.e., playing area, equipment) and informational constraints (i.e., surfaces to negotiate, opposition movement or formations) to stabilise intended behaviours (Seifert et al., 2014). The concept of self-organisation in ecological dynamics rejects the idea that skilful behaviour is best shaped by internal (i.e., the mind) or external (i.e., over-arching coach instructions) memorised representations or structures (Araújo & Davids, 2011). Instead, skilful behaviour emerges from the continuous re-organisation of body and brain with events in performance contexts (i.e., dynamic competition) while satisfying a range of constraints (Otte, Davids, Millar & Klatt, 2020). Consider this explanation of developing the vertical jump in figure skating, where movement competency is not inferred by internal or external structures, rather, the coach encourages attention to the *effects of the environment* on the emergent movement through an external focus, an approach shown to be more beneficial in skill learning (Wulf, 2007). The coach explains:

And so let's say I'm working for something technical, I'll use an example of a vertical jump. So traditionally we would work on all of the body parts. They're working on a vertical jump, you want to make sure you're pressing off with your ankles and you're pointing your toes andyou're extending this and

you're pressing with your hips and all that stuff. I don't talk about body parts anymore. I'm a big fan of external focuses, keeping the mind, keeping your thoughts off the body. So I'll use a concept say for a vertical jump or a jump take off on the ice of trying to look up over a fence. So tell a seven year old kid alright I want you to stand there, imagine that there's a big high fence in front of you and I want you to jump upand try to look over it and you'll see that their bodies extend and they push off with their toes.Figure Skating Coach

When athletes are exposed to specific practice settings, the experience can facilitate an enculturation process that supports certain evolutionary responses over others (Blackett, Evans & Piggott, 2020). In the previous example, prolonged exposure to enrichment through exploration can evolve athletes' intentions to actively search for information for self-organisation (individual or collective), resulting in the development of functional movement solutions to skilfully engage with the constraints of performance (Uehara, Button, Falcous & Davids, 2016).

Conclusion and future directions

The overarching goal of this article was to provide sport coaches, who are interested in moving away from deterministic models of learning and development, with a conceptual framework to design ecological niches to guide practice design, and to stimulate reflection on how the practice environments they modify may influence the evolution of performance behaviours in learners. Our paper has proposed a shift away from a *genocentric* view of athlete evolution as genetic adaptation and re-positioned a complementary view of how skilful performance within a Gibsonian framework is contingent upon an ever-evolving, tightly knit relationship between an active and autonomous athlete and their sociocultural context. We examined evidence from a sample of elite sport practitioners which may encourage researchers and sport practitioners to consider our reconceptualisation as a framework for future practice designs and research. Our reconceptualisation can inform the design of future studies to understand the influence of specific sport contexts on athlete evolution at micro and macro timescales. Although the challenge of investigating which properties of practice design contribute to athlete evolution is significant, a good start point could be to adopt an ecologically situated perspective to observe how responsive athletes are to the unfolding situations embedded within their ecological niche. One way to achieve this task and to address the limitations of the current study, is to integrate ecological realism theorising and ethnographic observations in real world athlete development settings to enhance our understanding of learning and development of skilled behaviour. In addition, phenomenological data can provide insights into athletes lived experiences of practice, to elicit rich information about key constraints placed on their development leading to

the design of more meaningful and empowering learning environments to enhance athletic performance.

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Ethics approval

Ethics was approved via Sheffield Hallam University Sport and Exercise ethics committee. The current chair is Mayur Ranchordas, Reader in Sport Nutrition.

References

Araújo, D., Dicks, M., & Davids, K. (2019). Selecting among affordances: A basis for channelling expertise in sport. In M. L. Cappuccio (Ed.), *Handbook of embodied cognition and sport psychology* (pp. 557–580). MIT Press.

Araújo, D., & Davids, K. (2011). What exactly is acquired during skill acquisition? *Journal of Consciousness Studies*, *18*(3), 7–23.

Araújo, D., & Davids, K. (2016). Team synergies in sport: Theory and measures. *Frontiers in Psychology*, *7*, 1449. https://doi.org/10.3389/fpsyg.2016.01449

Araújo, D., & Davids, K. (2018). The (sport) performer-environment system as the base unit in explanations of expert performance. *Journal of Expertise*, *1*(3).

Avner, Z., Denison, J., Jones, L., Boocock, E., & Hall, E. (2020). Beat the game: A Foucauldian exploration of coaching differently in an elite rugby academy. *Sport, Education and Society*, *26*(6), 1–16. https://doi.org/org/10.1080/13573322.2020.1782881

Baker, J., & Young, B. W. (2020). Talent development. In I. J. Sport, B. S. Cobley, & J. Schorer (Eds.), *Talent Identification and Development in Sport: International Perspectives* (2nd ed., pp. 19–33). Taylor and Francis.

Banwell, J., Kerr, G., & Stirling, A. (2020). Benefits of a female coach mentorship programme on women coaches' development: An ecological perspective. *Sports Coaching Review*, *10*(1), 1–23. https://doi.org/org/10.1080/21640629.2020.1764266

Barab, S. A., Cherkes-Julkowski, M., Swenson, R., Garrett, S., Shaw, R. E., & Young, M. (1999). Principles of self-organization: Learning as participation in autocatakinetic systems. *Journal of the Learning Sciences*, *8*(3–4), 349–390. https://doi.org/org/10.1080/10508406.1999.9672074

Barker, D., Barker-Ruchti, N., Rynne, S., & Lee, J. (2012). Olympism as education: Analysing the learning experiences of elite athletes. *Educational Review*, *64*, 369–384. https://doi.org/10.1080/00131911.2012.665846

Barker-Ruchti, N., & Tinning, R. (2010). Foucault in leotards: Corporal discipline and coaching practice in women's artistic gymnastics. *Sociology of Sport Journal*, *27*(3), 229–250. https://doi.org/10.1123/ssj.27.3.229

Baur, N., & Ernst, S. (2011). Towards a process-oriented methodology: Modern social science research methods and Norbert Elias's figurational sociology. *The Sociological Review*, *59*(1), 117–139. https://doi.org/org/10.1111/j.1467-954X.2011.01981.x

Blackett, A. D., Evans, A. B., & Piggott, D. (2020). Negotiating a coach identity: A theoretical critique of elite athletes' transitions into post-athletic high-performance coaching roles. *Sport, Education and Society*, *26*(6), 1–13. https://doi.org/org/10.1080/13573322.2020.1787371

Braun, V., Clarke, V., & Weate, P. (2016). Using thematic analysis in sport and exercise research. In B. Smith& & A. C. Sparkes (Eds.), *Routledge handbook on qualitative research in sport and exercise* (pp. 191–218). Routledge.

Button, C., Seifert, L., Chow, J. Y., Davids, K., & Araujo, D. (2020). *Dynamics of skill acquisition: An ecological dynamics approach*. Human Kinetics Publishers.

Chow, J.-Y., Davids, K., Hristovski, R., Araújo, D., & Passos, P. (2011). Nonlinear pedagogy: Learning design for self-organizing neurobiological systems. *New Ideas in Psychology*, *29*, 189–200. https://doi.org/10.1016/j.newideapsych.2010.10.001

Cooper, D., & Allen, J. (2018). The coaching process of the expert coach: A coach led approach. *Sports Coaching Review*, *7*(2), 142–170. https://doi.org/10.1080/21640629.2017.1361168

Davids, K. (2012). Learning design for nonlinear dynamical movement systems. *The Open Sports Sciences Journal*, *5*(1), 9–16. https://doi.org/10.2174/1875399X01205010009

Davids, K., & Baker, J. (2007). Genes, environment and sport performance. *Sports Medicine*, *37*(11), 961–980. https://doi.org/10.2165/00007256-200737110-00004

Denison, J., Mills, J. P., & Konoval, T. (2017). Sports' disciplinary legacy and the challenge of 'coaching differently'. *Sport, Education and Society*, *22*(6), 772–783. https://doi.org/org/10.1080/13573322.2015.1061986

Elias, N. (1956). Problems of involvement and detachment. *The British Journal of Sociology*, *7*(3), 226–252. https://doi.org/10.2307/587994

Feldman, M. W., & Laland, K. N. (1996). Gene-culture coevolutionary theory. *Trends in Ecology & Evolution*, *11*(11), 453–457. https://doi.org/10.1016/0169-5347(96)10052-5

Gibson, J. (1979). *The ecological approach to visual perception*. Lawrence Erlbaum Associates.

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin& & Y. S. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (3rd ed., pp. 191–216). Sage.

Hacques, G., Komar, J., Dicks, M., & Seifert, L. (2020). Exploring to learn and learning to explore. *Psychological Research*, *85*(4), 1–13.

Heft, H. (2007). The social constitution of perceiver-environment reciprocity. *Ecological Psychology*, *19*(2), 85–105.

Hodge, K., Henry, G., & Smith, W. (2014). A case study of excellence in elite sport: Motivational climate in a world champion team. *The Sport Psychologist*, *28*(1), 60–74. https://doi.org/10.1123/tsp.2013-0037

Lewontin, R. C. (1983). Elementary errors about evolution. *Behavioral and Brain Sciences*, *6*(3), 367–368. https://doi.org/10.1017/S0140525X00016538

Markula, P., & Silk, M. L. (2011). *Qualitative research for physical culture* . Palgrave.
Matthews, B., De Meester, L., Jones, C. G., Ibelings, B. W., Bouma, T. J., Nuutinen,V., van De Koppel, J., & Odling-Smee, J. (2014). Under niche construction: An operational bridge between ecology, evolution, and ecosystem science. *Ecological Monographs*, *84*(2), 245–263. https://doi.org/org/10.1890/13-0953.1
McCosker, C., Renshaw, I., Polman, R., Greenwood, D., & Davids, K. (2020). Influence of expertise on the visual control strategies of athletes during competitive long jumping. *Journal of Expertise*, *3*(3), 183–196.
Mills, J., Denison, J., & Gearity, B. (2020). Breaking coaching's rules: Transforming the body, sport, and performance. *Journal of Sport and Social Issues*, *44*(3), 244–260
Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (1996). Niche construction. *The American Naturalist*, *147*(4), 641–648. https://doi.org/10.1086/285870
Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2013). *Niche construction: The neglected process in evolution*. Princeton university press.
Odling-Smee, J., & Laland, K. N. (2011). Ecological inheritance and cultural inheritance: What are they and how do they differ? *Biological Theory*, *6*(3), 220–230. https://doi.org/10.1007/s13752-012-0030-x
Orth, D., van der Kamp, J., Memmert, D., & Savelsbergh, G. (2017). Creative motor actions as emerging from movement variability. *Frontiers in Psychology*, *8*, 1903. https://doi.org/10.3389/fpsyg.2017.01903
Otte, F. W., Davids, K., Millar, S.-K., & Klatt, S. (2020). When and how to provide feedback and instructions to Athletes? How sport psychology and pedagogy insights can improve coaching interventions to enhance self-regulation in training. *Frontiers in Psychology*, *11*, 1444. https://doi.org/10.3389/fpsyg.2020.01444
Ranganathan, R., & Newell, K. M. (2013). Changing up the routine: Intervention-induced variability in motor learning. *Exercise and Sport Sciences Reviews*, *41*(1), 64–70. https://doi.org/10.1097/JES.0b013e318259beb5
Reed, E. S. (1996). *Encountering the world: Toward an ecological psychology*. Oxford University.
Renshaw, I., Araújo, D., Button, C., Chow, J. Y., Davids, K., & Moy, B. (2015). Why the constraints-led approach is not teaching games for understanding: A clarification. *Physical Education and Sport Pedagogy*, *21*(5), 459–480. https://doi.org/10.1080/17408989.2015.1095870
Renshaw, I., Davids, K., Newcombe, D., & Roberts, W. (2019). *The constraints-Led approach: Principles for sports coaching and practice design*. Routledge.
Ribeiro, J., Davids, K., Duarte Araújo, J. G., Garganta, J.Garga, & Garganta, J. (2019). Exploiting Bi-Directional Self-Organising tendencies in team sports: The role of the game model and tactical principles of play. *Frontiers in Psychology*, *10*, 2213. https://doi.org/10.3389/fpsyg.2019.02213
Rietveld, E., & Kiverstein, J. (2014). A rich landscape of affordances. *Ecological Psychology*, *26*(4), 325–352. https://doi.org/10.1080/10407413.2014.958035
Robertson, S., Zwolinsky, S., Pringle, A., McKenna, J., Daly-Smith, A., & White, A. (2013). 'It is fun, fitness and football really': A process evaluation of a football-based health intervention for men. *Qualitative Research in Sport, Exercise and Health*, *5*, 419–439. https://doi.org/10.1080/2159676X.2013.831372
Roca, A., & Ford, P. R. (2020). Decision-making practice during coaching sessions in elite youth football across European countries. *Science and Medicine in Football*, *4*(4), 263–268. https://doi.org/org/10.1080/24733938.2020.1755051

Ross, E., Gupta, L., & Sanders, L. (2018). When research leads to learning, but not action in high performance sport. *Progress in Brain Research*, *240*, 201–217. https://doi.org/10.1016/bs.pbr.2018.08.001

Rothwell, M., Davids, K., Stone, J., Araújo, D., & Shuttleworth, R. (2020b). The Talent Development Process as Enhancing Athlete Functionality: Creating Forms of Life in an Ecological Niche. In J. Baker, S. Cobley, & J. Schorer (Eds.), *Talent Identification and Development in Sport: International Perspectives* (2nd ed., pp. 34–49). Taylor and Francis.

Rothwell, M., Stone, J., & Davids, K. (2020a). Investigating the athlete-environment relationship in a form of life: An ethnographic study. *Sport, Education and Society*, 1–16. https://doi.org/org/10.1080/13573322.2020.1815690

Rudd, J. R., Pesce, C., Strafford, B. W., & Davids, K. (2020). Physical literacy-A journey of individual enrichment: An ecological dynamics rationale for enhancing performance and physical activity in all. *Frontiers in Psychology*, *11*, 1904. https://doi.org/10.3389/fpsyg.2020.01904

Schmidt, R. A., & Wrisberg, C. A. (2004). *Motor Learning and Performance* (3rd ed.). Human Kinetics.

Seifert, L., Dicks, M., Wittmann, F., & Wolf, P. (2020). The perception of nested affordances: An examination of expert climbers. *Psychology of Sport and Exercise*, *52,* 101843. https://doi.org/org/10.1016/j.psychsport.2020.101843

Seifert, L., Wattebled, L., Herault, R., Poizat, G., Adé, D., Gal-Petitfaux, N., & Davids, K. (2014). Neurobiological degeneracy and affordance perception support functional intra-individual variability of inter-limb coordination during ice climbing. *PLoS One*, *9*, 1–22. https://doi.org/org/10.1371/journal.pone.0089865

Shaw, R., & Turvey, M. (1999). Ecological foundations of cognition: II. Degrees of freedom and conserved quantities in animal environment systems. *Journal of Consciousness Studies*, *6*(11–12), 111–123.

Smith, B., & McGannon, K. R. (2018). Developing rigor in qualitative research: Problems and opportunities within sport and exercise psychology. *International Review of Sport and Exercise Psychology*, *11*(1), 101–121. https://doi.org/10.1080/1750984X.2017.1317357

Smith, B., & Sparkes, A. C. (2016). *Routledge handbook of qualitative research in sport and exercise*. Routledge.

Uehara, L., Button, C., Falcous, M., & Davids, K. (2016). Contextualised skill acquisition research: A new framework to study the development of sport expertise. *Physical Education and Sport Pedagogy*, *212*, 153–168. https://doi.org/doi.org/10.1080/17408989.2014.924495

Uehara, L., Button, C., Saunders, J., Araújo, D., Falcous, M., & Davids, K. (2020). Malandragem and Ginga: Socio-cultural constraints on the development of expertise and skills in Brazilian football. *International Journal of Sports Science & Coaching, 16* (3), 622-635. https://doi.org/org/10.1177/1747954120976271

van Dijk, L., & Rietveld, E. (2017). Foregrounding sociomaterial practice in our understanding of affordances: The skilled intentionality framework. *Frontiers in Psychology*, *7*, 1969. https://doi.org/10.3389/fpsyg.2016.01969

Withagen, R., Araújo, D., & de Poel, H. J. (2017). Inviting affordances and agency. *New Ideas in Psychology*, *45*, 11–18. https://doi.org/org/10.1016/j.newideapsych.2016.12.002

Withagen, R., de Poel, H. J., Araújo, D., & Pepping, G. J. (2012). Affordances can invite behaviour: Reconsidering the relationship between affordances and agency. *New Ideas in Psychology*, *30*(2), 250–258. https://doi.org/doi.org/10.1016/j.newideapsych.2011.12.003

Withagen, R., & van Wermeskerken, M. (2010). The role of affordances in the evolutionary process reconsidered: A niche construction perspective. *Theory & Psychology*, *20*(4), 489–510. https://doi.org/10.1177/0959354310361405

Woods, C., Rudd, J., Robertson, S., & Davids, K. (2020). Wayfinding: How ecological perspectives of navigating dynamic environments can enrich our understanding of the learner and the learning process in sport. Sports Medicine, 6(1), 51. https://doi.org/org/10.1186/s40798-020-00280–9

Woods, C. T., Rothwell, M., Rudd, J., Robertson, S., & Davids, K. (2021). Representative co-design: Utilising a source of experiential knowledge for athlete development and performance preparation. *Psychology of Sport and Exercise*, *52*, 101804. https://doi.org/org/10.1016/j.psychsport.2020.101804

Wulf, G. (2007). *Attention and motor skill learning*. Human Kinetics.