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Principles of Nonlinear Pedagogy in sport practice

Structured Abstract

Background: There are deeply relevant questions concerning how to integrate and organise various nonlinear pedagogical strategies and methods in order to structure training in the professional development of Physical Education (PE) teachers and sport coaches. To promote the emergence and development of innovative and adaptive performance behaviours in sport, nonlinear pedagogy advocates the methodology of constraints manipulation to facilitate learning. Sport pedagogues have to manage and apply different constraint manipulations at varying times in practice contexts, that is, while planning before/following a learning session (i.e., designing the micro-structure of practice) and in interactions during the session. In nonlinear pedagogy, the design of practice micro-structure is predicated on the continuous, intertwined relationships between decision-making, action, perception and cognition in sport performance and learning contexts.

Purpose: Here, we present an analysis of the activities that pedagogues engage in to facilitate learning and performance in sport (i.e., the *micro-structure of practice*) during practical interventions in sport and exercise contexts, based on use of a Constraints-led approach by PE teachers and coaches.

Method: Based on data from illustrative studies on performance analysis and constraints manipulation, we exemplify some of the main principles and assumptions of nonlinear pedagogy. This synthesis, framed in a nonlinear pedagogy, aims to reveal how adopting a constraint led approach can straightforwardly enhance learning designs of sport practitioners.

Conclusions: This article shares insights from a nonlinear pedagogy that can frame the micro-structure of practice during interventions, compared to utilisation of traditional pedagogical practices. It is proposed that PE teachers and coaches are designers of learning environments and that both learning and performance improvement are seen as emerging from the interaction of key constraints (related to task, learner and environment).

Keywords: nonlinear pedagogy, learning design, micro-structure of practice, constraints.

Summary for practitioners

In this position statement, we propose that PE teachers and coaches are designers of learning environments, grounded on a nonlinear pedagogy approach for interventions in sport, physical activity and exercise. This approach advocates the methodology of manipulating constraints to design learning opportunities for athletes. In the process of learning design, we discuss PE teachers and coaches' decisions that emerge at different periods in practice contexts, that is, while designing the micro-structure of practice (i.e., planning before/following a session) and in interactions during the practice session. About designing the micro-structure of practice, we highlight some key aspects that influence the learning process such as: teachers and coaches' prior experience and knowledge, implementation of structure, diagnostic capacities of the teacher/coach, use of

methods such as goal setting, task simplification, constraints manipulation, group constitution, individualization of the learning process, representative design and variability. We also elaborate on key issues pertaining to quality of interactions during the micro-structure of practice, such as: use of instructional constraints, feedback provision and access, demonstrations and modelling, questioning, time spent in practice and observation.

Manuscript main text

Nonlinear pedagogy and a Constraints-led-approach

A key message of this article is that coaches and PE teachers are fundamentally *designers of learning environments*. In order to enhance preparation for sport performance, teaching and practice methodologies must be designed in ways that allow athletes to exploit learning opportunities that promote innovative and adaptive performance behaviours. Grounded in key concepts of ecological dynamics (e.g., Araújo, Hristovski, Seifert, Carvalho, and Davids 2017; Davids, Araújo, Hristovski, Passos, and Chow 2012), the framework of nonlinear pedagogy advocates the key methodology of *manipulating constraints* to facilitate learning (Chow, Davids, Button, Shuttleworth, Renshaw, and Araújo 2006; Renshaw, Chow, Davids, and Hammond 2010; Renshaw, Araújo, Button, Chow, Davids and Moy 2016). Chow (2013) highlighted the significance of the following design principles in nonlinear pedagogy: i) representative learning design – i.e., learning must take place in learning situations that simulate key aspects of a performance environment, which learners can use as information to regulate their actions; ii) developing relevant information-movement couplings – i.e., the circular relationship between perception and action must support goal-directed behaviours to emerge; iii) manipulation of constraints – i.e., learning designs should feature the interaction of conditions/boundaries that facilitate exploration for, discovery of and exploitation of functional movement solutions; iv) exploratory learning must leverage on functional variability – i.e., learning designs should account for variability that amplifies exploratory activity and adaptive behaviours and, consequently, the emergence of individualised functional solutions; and v) reducing conscious control of movement: a role for attentional focus – i.e., gradually focusing instructions on external movement effects, rather than internally, exploits available self-organizing processes, implicitly, rather than conscious control of movement.

When using a CLA in learning design, there are deeply relevant questions concerning how to integrate and organise various pedagogical strategies to structure practice interventions, as outlined in the remainder of this article. Here, we discuss how a CLA may be implemented in the design of what has been termed the *micro-structure of practice*, that is, the hourly/daily/weekly activities that pedagogues engage in to facilitate learning and performance in sport (Davids, Güllich, Araújo, and Shuttleworth 2017). Although guiding principles and assumptions of nonlinear pedagogy and CLA have been outlined previously (e.g., Chow, Davids, Button, and Renshaw 2016), their application in the micro-structure of practice in sport contexts requires continuous elaboration, clarification and empirical evaluation as argued by several authors (e.g., Moy, Renshaw and Davids 2016; Moy, Renshaw, Davids and Brymer 2015; Chow et al. 2014; Van den Berghe, Vansteenkiste, Cardon, Kirk, and Haerens 2014). This is the same for all pedagogical strategies which purport to support evidence-based practice.

The pedagogical framework of the CLA does not advocate a cognitive asymmetry (biased emphasis in practice on developing cognitive capacities and functions) (Davids, and Araújo 2010), endorsing instead a continuous, intertwined relationship between decision-making and action, perception and cognition in sport (e.g., Davids, Araújo, Vilar, Renshaw, and Pinder 2013). This deeply integrated relationship between cognition, perception and action needs to underpin learning design in sports coaching and physical education. Use of the CLA methodology to manipulate interacting task, personal and environmental constraints during practice and training, needs to be shaped by the intentions or goals of learners. To exemplify: (i) to maintain balance and ascend a climbing wall safely (intentions) using specific holds and grips which may be gripped with 2 or 3 fingers and reachable or not depending on scale of arm length (interaction with personal and task constraints), (ii) to maintain a posture in space (goal) having the leg strength and flexibility to leap over a vaulting box (interaction of task and personal constraints), (iii) to accurately hit a specific location on a moving target (goal) with the dominant or non-dominant hand (interaction of task and personal constraints), and (iv), to dribble with a ball through a specific gap between defenders (task goal) in a spatially-defined playing area using perceptual information from the area markings, the location of the moving defenders and the trajectory of the ball (interaction with task constraints). Thus, cognition, in the form of intentionality, shapes performance and, in turn, is continuously shaped by actions and perceptions of performers. Learners should be guided to use perception and action to achieve a task goal, by interacting with relevant affordances of objects, surfaces, events, terrains, features and significant others during performance. Activities in the micro-structure of practice should, thus, be continuously focused on individual-environment interactions (including interpersonal interactions between competing and cooperating athletes). Learning design entails identification of key constraints on successful performance behaviours, and their manipulation, in order to promote learners' search for functional action solutions. Opportunities for action can be designed by coaches/teachers into a landscape of affordances (i.e., composed of fields of possibilities) that invite learners to select and utilise them to achieve their intended goals during performance (Rothwell, Stone, Davids, and Wright 2017).

Design of the micro-structure of practice

Aligned with the sentiments of Gibson's (1979) well-known ecological maxim "we must perceive in order to move, but we must also move in order to perceive" (p. 223), pedagogues also must design to interact and interact in practice to design. To explain further: designing practice micro-structure and (inter)actions in learning environments may also be viewed as based on a continuum and a cyclical process. Accordingly, pedagogues need to design learning contexts to interact with learners and facilitate interactions between them. In turn the interactions allow us to better design future interactions.

Prior Experience and Knowledge

Both planning and its evaluation benefit from having prior experience **and** knowledge and being framed by scientific evidence (Renshaw et al. 2010). Sport training and performance have become more and more challenging and interdisciplinary (Buekers, Ibáñez-Gijón, Morice, Rao, Mascret, Laurin, and Montagne, 2017). Accordingly, it is evident that a coach or a PE teacher cannot behave simply as a highly experienced ex-performer, mentoring less experienced athletes and assuming a master-pupil relationship. To meet the demands of creating learning opportunities for elite and developing athletes in sport, the design of practice micro-structure would benefit from insights from various domains of sport science such as motor learning, physiology and psychology (e.g., Renshaw et al. 2010). It is also important for practitioners to master sport-specific and pedagogical content knowledge (Ward and Ayvazo 2016), and to develop and maintain a critical thinking attitude and continuously interpret the potential value of advances in scientific knowledge. Empirical knowledge on sports performance can be obtained from published research that has investigated the implementation of key task constraints in different sports (see Table 1).

INSERT HERE TABLE I

Table I. Illustrative empirically tested task constraints in different sports.

Planning and Structuring Sessions

According to a CLA, planning entails a process-oriented approach in designing the micro-structure of practice. This type of planning can include the prediction of which affordances learners may select and their potential movement solutions and elaborating on how these may be developed to potentiate further performance behaviours. These predictions (i.e., creating conditions for emergence of functional movement solutions) may be based on the perceived strength of couplings of athletes with affordances in a practice workspace (see Withagen et al. 2017). It entails the definition of performance behavioural goals, promoting the design of constraints manipulations that facilitate this exploratory activity. Decisions on manipulations must be also based on prior analysis by practitioners. It is important to gather general information related to task and personal constraints, such as what materials and spaces are available, athletes' general characteristics (e.g., number and groupings of learners, their age and past practice experiences, competitive experiences and skill level), the equipment and technology and scientific support teams available.

Planning also entails structuring practice. The planning of warm-up, main exercises and final exercises should be designed around the goals for each session. For instance, the warm-up must help players attune to the task environment and should involve activities that enable them to calibrate their actions to that specific performance environment. For example, in any ball team sport the warm-up should include the ball preventing players from spending the first minutes of performance calibrating their actions to the use of the ball. Furthermore, there could be some common or individualised stretching exercises and final instructions - physiological reasoning, motivational advice, i.e., reminders linking the athletes to previous practice sessions and drawing attention to key information sources and possible performance solutions that may be explored in a following session.

Furthermore, according to traditional pedagogical practices, to plan a session implies deciding beforehand on specific manipulations of: time, verbal instructions, constitution of sub-groupings, materials and space, practice atmosphere, rules and conditions of practice tasks. Nonlinear pedagogy also involves those functions but takes a more emergent, adaptive and individualised approach in which pre-planning only initiates a session, rather than dictating it in great detail from the outset. This implies monitoring planning and flexibility to adapt online.

Diagnostic Capacities

Practitioners can use diagnostic capacities to identify which performance behaviours need to be improved and why, which constraints can be manipulated and when, so that learners can explore, discover and exploit effective performance solutions. As Brymer and Davids (2014) argued “educators need to be skilled at understanding each individual’s needs in order to manipulate the specific task (or environmental) constraints to best draw out the intended learning process” (p.111). It is fundamental to observe and carry out an analysis of the athlete or team's performance history prior to planning as “the challenge for teachers is not just to understand how to manipulate constraints, but to identify key individual constraints that can be presented to students to encourage learning” (Renshaw et al. 2010, p. 134). This analysis need might, at first sight, seem contradictory, after all: *Since performance behaviours are emergent, how can we know, a priori, how to define the constraints that will be manipulated?* This issue is resolved by understanding the relations between intentions and perception and action in learning. What is needed by a learner, initially, is 'soft-assembled' plans: conditions of practice that facilitate exploration around a potential target behaviour, verified by needs of other learners with similar characteristics. Beyond planning sessions, practitioners can design more specific manipulations of task constraints, once they have gained a better understanding of specific learner needs. In structural terms, "conditions for realization of actions" should not be defined *a priori* as in linear pedagogies, but are mostly identified by practitioners as they are allowed to emerge during initial stages of practice design. As each learner engages with a task problem, the link with relevant affordances will emerge more robustly, driving their intentions in practice.

Goal Setting

Intentionality of learners is framed by goal setting. In line with nonlinear pedagogical principles, goal setting must be representative, individualised and nonlinear in approach. Goals designed by athlete(s) and coach(es) should involve the search for functional action modes to solve a particular/typical problem in a performance context. In team games this approach could involve an opponent-team pattern of action, confirmed by performance analysts. Or in the sport of climbing goals could emerge from a preview of the surface (prior to beginning), which can get updated as climbers actually negotiate surface features such as holds, ledges, cracks and edges, during the traversal (see e.g., Seifert et al. 2017). Irrespective of sport modality, a coach /PE teacher observes performance, detects what must be improved, and designs the practice session. The learners, collaboratively with the coach (depending on their experience level), can inclusively identify what is needed for improving their performance through learning. For example, this might include the information that they struggle to find and use to regulate their actions, but which is perceived by the coach as relevant. Together they can set new goals and co-design tasks that suit each individual's needs and representatively replicate specific performance situations in practice. For example, consider a rugby player learning to time his/her interception to grab the legs of a running ball carrier in order to tackle him/her in a run towards the try line. Both the player and the coach might video record and analyse games and practice situations in which that tackle affordance might emerge. Together they could co-design tasks that simulate the opportunities to successfully achieve the performance goal, respecting principles of task representativeness and functional variability. This might involve a learner standing near a player with the ball before tackling, with distances between the attacker and defender increasing gradually to enhance the challenge. Different ways of tackling the ball carrier may be explored in practice, culminating in a conditioned game for learners to implement the newly learned skill of tackling. In learning designs under a nonlinear pedagogy, periods following the micro-structure of practice are not as reflexive in mental rehearsal as in traditional pedagogical approaches. There is little focus on strengthening mental representations or on reinforcing explicit knowledge of an activity. Rather, practice time can be spent in continuously co-adapting to refinements in the manipulations of key task constraints entailed by subtle variations in spacing and co-positioning of attackers and defenders. Using 'off the field' time, practitioners and athletes could deliberate on goals defined, tasks designed, observed behaviours and maintain a continuous evaluation of individual needs. The aim is always to enhance the skill adaptation of learners (Araújo and Davids 2011) by elaborating the constraint manipulation strategies that help athletes to self-regulate in search for more functional and innovative performance solutions.

Task Simplification

Traditional pedagogical practices typically tend to structure meticulous and detailed learning situations, elaborating progression-drills (e.g., Rick, 1993) predicated on 'if-then' propositional statements using *task decomposition.* This is intended to manage information loads for learners but decouples relevant information-movement relations (see Handford 2006; Renshaw et al. 2010). Traditionally, pedagogues tend to determine beforehand criteria for success (expected to support the feedback given to performers during practice) to advance between progression-drills. These strategies, based on part-task training and adaptive verbal instructions/feedback, assume that performing a set of task components, in isolation, will lead to successful performance of the entire task, when re-integrated. This traditional pedagogical approach follows a logic of progressing from unknown to known, simple to more complex and easy to more difficult, as the task components are mastered (Wickens 1989, 1997). However, analytically decomposing a movement into separate components needs to be handled very carefully since it might disrupt the information that establishes "coherence" between parts of a coordinated action during performance. In contrast to the *task decomposition* characteristic of linear pedagogical approaches, nonlinear approach advocates (representative) *task simplification* (Renshaw, et al. 2010). Using simplification procedures could avoid undermining the coherence between the parts of a coordination pattern to support the use of information to regulate action. On the other hand there are modalities such as in sports like gymnastics and ice skating in which the main task goal can be the movement form itself, the style with which a manoeuvre is performed. In this type of exploitation, strategies are used to "block or unblock" the degrees of freedom, the sensory information (visual, auditory and proprioceptive), used to perform the target movement. It may seem to make sense to divide the movement into parts (a more analytic - closed strategy), in which simplification seeks to decrease the involvement of degrees of freedom, then progressively increasing involvement of more system degrees of freedom, in approaching the global movement pattern. In sports where the form of movement is not evaluated, goals and task conditions can be created that allow the emergence of a more efficient (functional) motor solution. For example, in tennis, if we constrain the height that the ball must be driven over the net, and/or the spatial area on court in which the ball should strike the ground, we can guide the learner's exploration of the amplitude of the backswing movement and / or the zone of contact of the ball and racquet or even of the power with which the ball is struck. These examples illustrate the importance of information in regulating actions. This is why the decoupling of movement and information in practice task designs lacks coherence. Learning design should be regarded as a dynamical process, even at elite and advanced stages of learning, and there is a need for athlete-coach collaborations to collectively develop innovative and creative means to manipulate interacting constraints to continuously enhance performance. The individualised nature of performance development and the range of affordances in a landscape require continuous adaptations of practice task designs that enhance effectivity in athletes and teams. For this reason, the use of the term 'drills' conveys the wrong impression that practice task designs remain stable, repetitive and stagnant throughout a pedagogue's career. In fact, practice task designs should be viewed as dynamic, innovative and emergent, depending on the needs of each learner or group of learners.

Constraints Manipulation

As we have argued before, intervention results from manipulation of key constraints that help learners to achieve their intended goals. By "constraints" we mean the demands or conditions placed on emergent actions that may delimit or inhibit certain actions, while potentiating or channelling others. CLA practitioners must learn to innovate practice settings characterized by manipulation of relevant task constraints that interact and bound the exploration and emergence of functional movement solutions (Renshaw et al. 2010, see also Handford, 2006; Ranganathan and Newell 2013). Key questions for practitioners are: *What are the relevant task constraints* or *How do we know that the manipulation of certain constraints guide/facilitate learner' exploration of a target behaviour?* It is necessary to know the essential aspects of each sport movement, or condition of a performance environment, what "factors" can constrain emergent behaviours and what is the effect of manipulating those constraints in the exploration of action solutions. However, given that exploration is also an individualised process, the course of exploration may not emerge along an intended route, which implies that the teacher / coach must adjust or introduce new constraints in order to guide exploration towards an intended goal. The relevant constraints are those that most influence the course of exploration, derived from knowledge of the relevant performance factors. Constraints can be conceptually organized in task, individual and environment constraints.

Examples of **task constraints** are goals, rules, space and materials used in practice. For example, in tennis, preparation time for a stroke or zone of contact of the racket with the ball constrains performance functional efficiency. As already mentioned, the preparation time to perform the ball strike can be constrained by manipulating different parameters of the ball trajectory, using balls of different compression values, higher or lower trajectory feeds, varying spin or by placing the ball at different distances from the performer. These manipulations can influence the learner to adapt positioning depending on ball location and invite the performance to strike the ball in front or behind current positioning, or higher or lower than its centre of mass. The learner may even be constrained from running around the ball to play a forehand instead of a backhand shot. Another good example of this methodology in CLA involves the use of small-sided and conditioned games (SSCGs) during practice (e.g., 2v2 or 6v4) (e.g., Davids, Araújo, Correia, and Vilar, 2013; Vilar, Esteves, Travassos, Passos, Lago-Peñas, and Davids 2014). Group constitution and individualization refers to the composition of the SSCGs and is a pedagogical strategy that can be used in the micro-structure of practice, prior to but also during interactions with learners and athletes. Traditionally group constitution can be reduced to strategies aiming at differentiating learners by gender, performance level, performance role or by learning goals. According to a CLA, the criteria used to constitute groups should be closely linked to the constraints manipulated and the fields of affordances they promote for learners to utilise. For example, because affordances are body and action scaled, some combination of constraints manipulations might afford specific action possibilities for some individuals, while not for others. This approach allows individual differences (e.g., height, speed, strength, experience, skill level) to be exploited during learning. For instance, practice in a 1v1 rugby union task involving players of the same physical dimensions (e.g., height and limb length) will not necessarily promote the same opportunities as a 1v1 task involving players of significantly different heights. Practitioners must track emerging action solutions in each learner, identifying key constraints that could allow them to potentiate those action solutions (i.e., seeing them as invitations for coupling actions to affordances in the performance environment), or helping them to explore and find others. This process is inherently individualized (due to specific capacities or effectivities and body and action characteristics). In individual sports (such as climbing, athletics, diving, gymnastics) individualisation can be more straightforward, but in team sports (such as the rugby codes, basketball, volleyball, football) the individualization of practice can be shaped by using group constitution, individualising the constraints manipulated in sub-groups. The importance of unstructured small-sided and conditioned games in practice design even at elite performance level in preparation for competition has been noted (Mckay & Connor, 2018).

Individual constraints include, for instance, the athlete(s) characteristics, related to combination skills and tactical awareness development with teammates and opponents, conditioning, and ball skills in small confined spaces. It is important here to highlight the notion of **rate limiters** (Davids et al. 2008). Rate limiters are constraints that can stop learners showing the skills they have acquired. For example, a young child‘s lack of arm strength may limit his/her capacity to climb quickly up a climbing wall because he/she cannot currently pull her/his body weight up to the next hold on the wall. Or a young tennis player may not be able to show that he/she has learned a backhand drive in tennis due to current limitations in arm strength. For this purpose we may use scaling of equipment and space (smaller rackets and tennis balls with lower compression) to help individuals cope with current, temporary limitations, which are acting as *rate limiters* (Davids et al. 2008; Fitzpatrick, Davids & Stone, 2017). Rate limiters can be regarded as properties (related to the individual, environment or task) which may be temporarily hampering the evolution of learning or the stabilization of functional solution (Brymer and Davids 2014). A useful analogy is that rate limiters may be a personal and temporary 'handbrake' on learning in an individual. In CLA, identifying individual rate limiters (e.g., atmosphere conditions, coordination, physical fitness, coping skills, functional capacities) is pivotal in learning design and the PE teacher/coach must be able to identify and manipulate constraints to reduce the influence of rate limiters. In terms of child's motor development, Davids and colleagues (Davids, Bennett, Kingsbury, Jolley & Brain, 2000) showed that upright postural control could be a rate limiter on young children's one-handed catching performance, as they verified that these children could not control their posture while standing upright, creating instability and perturbing their catching performance. But when participants were required to reduce the number of degrees of freedom they had to regulate by sitting down to catch the ball, requirements to stand upright while catching a ball were avoided and their catching performance improved.

Environmental constraints may involve physical and social characteristics of the performance environment (Davids, Button and Bennett, 2008). Physical constraints include, for example, playing surface characteristics and weather conditions. In windsurfing, for instance, the existence of wind strength and direction may influence the exploitation of a targeted behaviour (balancing on the board) or a particular tactical solution (turning the board around in the water by exploiting wind). The PE teacher/coach could ensure that the wind surfing area is protected against wind speeds above a critical threshold value and use starting locations in lakes and lagoons which favour the learner's use of the wind, or use adapted equipment (i.e., a lighter and smaller board). Social constraints include audience involvement and atmosphere. This environmental constraints' manipulation can be prepared in advance, for example, by exploiting the presence of 'others' during practice, when parents of youth players or senior players are present, or when they train on a court or field near the main stand.

Representative Design

The concept of representative design (proposed by Brunswik 1956; see also Hammond and Stewart, 2001) advocates that task constraints should be *representative* of a performance context, to which behaviours are intended to be generalized. Representative task constraints are essential for the design of training and learning tasks meant to improve performance of athletes and teams (Araújo et al. 2006; Davids 2008; Davids, Araújo, Button, and Renshaw 2007; Araújo and Davids 2015). This consideration in the design of practice task constraints highlights the functionality of performance behaviours, and the potentiation of perception-action couplings used to achieve task goals (e.g., Hristovski, Davids, Araújo, and Button 2006). Complex coordination patterns, which are functional in a sport, are maintained and supported by the coupling of information and movement in representative practice designs (Renshaw et al. 2010). In contrast to traditional practices that commonly decrease uncertainty of performance contexts and prescribe decision-making for learners under more static task constraints, nonlinear pedagogical practices seek to facilitate learners' search for functional performance solutions (Passos, Araújo, Davids, and Shuttleworth 2008). When correctly designed, manipulation of constraints poses questions of learners which they answer with actions. For example, in the context of pre-school physical education, if a teacher aims to facilitate jumping ability, the learning situation could be designed in a play form placing arcs on a surface floor to be conceived as "big stones in the middle of a river". This imaginative play design could challenge children to reach the other bank of a river, stepping only on those stones as quickly they can to avoid getting wet (c.f. Cordovil and Correia 2012). Placing the targets too close to each other will not invite the children to jump, but rather to step. If the targets are placed too far away from each other, they will not invite a jump, losing opportunities to learn to jump. So teachers must be able to perceive the personal capacities of each learner (effectivities), in this example, *their jump possibilities,* and manipulate task constraints accordingly.

Adaptive Variability

Nonlinear pedagogy does not seek to restrict learners' adaptive variability but rather to potentiate it by encouraging the active (re)shaping of cognition, perception, decision-making and actions through constraints manipulation (Davids et al. 2012). Adaptive variability is seen as an important phenomenon underpinning emergent movement patterning which plays a functional role in learning and performance (Davids, Bennett and Newell 2006). To be clear, this does not mean that practitioners must follow a *laissez-faire* approach in which teachers and coaches simply offer 'free play' expecting that movement solutions will magically appear to support goal achievement, as constraints are manipulated (Renshaw et al. 2010). It needs to be understood that some learning designs may 'under-constrain', and others 'over-constrain', the actions of a learner. Two aspects should be considered in practice, regarding adaptive variability: a) it should be infused in practice to promote different ways of achieving the same task goal, i.e., helping learners explore the redundancy of the movement system; and b), it should emphasise practice conditions that promote the search for, exploration of, and exploitation the use of the same solution to respond to different problems. To exemplify in tennis, when the task goal is to force an opponent to return the ball in an unstable position (e.g., when an opponent is seeking to return the ball when over-reaching and unbalanced), the PE teacher/coach can achieve this by feeding the ball into areas away from the learner in seeking to manipulate the instability of the learner and, consequently, requiring the player to adapt positioning in order to hit the ball firmly. The speed of exit of the ball can be explored in various ways: amplitude of force application (amplitude of the backswing); greater acceleration of the kinetic chain and / or the arm in the forward swing; use of a greater number of degrees of freedom (e.g., use of the wrist, forearm pronation, etc.); combination of rotation with body translation, etc. - requiring exploitation of system redundancy. Different strategies can be used to target skill adaptations in learners, for example, using balls of differing compression values, increasing the tension of string racking, using smaller and / or lighter rackets, or playing on surfaces where the rebound is faster (requiring a shorter backswing time) in combination with the need to strike the ball to further distances. On the other hand, if learners' tactical adaptations are challenged, he/she may be required to hit the ball in an unstable position in different ways. Examples include: forcing him/her to move from side to side on court (e.g., adding a task constraint that when one of the players hits the ball twice on the same side of the court, the other loses a point); requiring the learner to move the opponent to one side of the court and then playing down the line (e.g., player A is the attacker and can vary down the line, player B defends and must always play cross court; point, if B does not touch the ball, A gains 2 points) or; through varying the speed of the ball (e.g., defining two on court zones where the ball can rebound, one next to the net and another near the baseline - the point is won whenever one of the players cannot respond after being moved from one zone to the other).

Practitioner-learner interaction during the micro-structure of practice

During interactions with learners in the micro-structure of practice, teachers and coaches can use several communication strategies that should also be focused on channelling exploratory behaviours of learners, rather than prescribing specific solutions to them. Interactions between practitioners and learners could include verbal and non-verbal modes of communication to shape goal-directed behaviours and informationally constrain learning activities. Intentionality and informational constraints in everyday interactions between coach and athlete play an important role in influencing the specific pathways of change for individual learners as they seek new preferred performance solutions (Chow, Davids, Button, and Rein 2008).

Instruction

It is well established amongst sport practitioners that instruction plays a fundamental role in teaching and coaching. In a nonlinear pedagogical approach instructions are conceived as a constraint to guide exploratory search activities of learners. Their greatest impact is not in telling learners which decisions to make and how to perform an action. Rather, instructional constraints can be kept to a minimum and direct a learner's search activities and frame their intentions during practice and performance. They can stimulate a learner's understanding of a task goal, rules of a sport or physical activity. Instructional constraints can also provide information for stabilising relevant perception–action couplings (ensuring that performance behaviours are regulated by information). As argued before, task constraints can be manipulated to enhance skill acquisition by designing tasks that allow learners; i) to explore degrees of freedom to achieve a task goal (search phase), ii) to explore task solutions and stabilize them (discovery phase), and finally iii), to exploit available perceptual-motor degrees of freedom (exploitation phase).

Traditional pedagogical practices assume a role for instructions as descriptive and prescriptive, providing a detailed explanation to learners on how to perform an action, or what decision to take in specific performance contexts. Instruction is traditionally used to indicate a desired, 'common optimal action' towards which all learners should aspire (Davids, Button, and Bennett 2008). In traditional pedagogies, verbal instructions are typically over-used by most coaches and even considered as a 'default' method for supporting a learner at all levels of performance (beginner, intermediate, advanced and elite). In a nonlinear pedagogy any verbal information provided by a practitioner, including instructions, feedback or stimuli, is a pedagogical constraint that interacts with task and individual constraints to shape emergent behaviours during exploratory practice (e.g., Chow, Davids, Button, Renshaw, Shuttleworth and Uehara 2009; Newell and Ranganathan 2010). Practitioners should be aware that instructions should be used carefully to facilitate, guide or potentiate intentionality and purpose during problem-solving activity, rather than prescribe a definitive function for a learner.

Feedback

Like traditional pedagogical perspectives, in nonlinear pedagogy, feedback is also an important tool, acting as an augmented informational constraint on learners' search for task solutions (Newell, Morris and Scully 1985). In CLA feedback is not prescriptive and, like instructional constraints, is meant to help the learner in exploring an effective / efficient performance solution. This conceptualisation raises important questions, such as: *Is providing more feedback better for learners? What kind of feedback should be provided and when is it expected to use more feedback?*

In traditional perspectives, verbal feedback is regarded as a default method to help learners to develop a movement template and correct their errors. It is traditionally held that frequency should decrease as learners begin to rely on their own "cognitive feedback" processes to evaluate and correct their actions (Davids, Button and Bennet, 2008). On the other hand, advanced learners, opposed to beginners, are believed to better deal with more detailed instructions (Davids, Button, and Bennett 2008).

Feedback should be used to help educate the attention of a learner to perceive and utilise relevant information sources, to regulate actions and support the search for functional performance solutions for their specific task goals. It can direct learners to a ball park area (field) of an affordance landscape where they can explore opportunities for action. For example, in the sport of climbing, practice on an indoor wall can be shaped by the design of holds on the wall. These holds can facilitate exploration of learners with the fingers, hands and/or feet. Performance feedback is provided by the learner traversing quickly up the wall (saving time and energy) using specific configurations of fingers (1, 2 or 3 fingers) and hands (right, left or both hands), or remaining stationary on the wall, while using other less effective configurations (using both feet to maintain balance)(Orth, Davids and Seifert 2018).

As seen, feedback is instrumental during search activities in practice, for instance, to reinforce the route of exploration, to incite the search for different solutions, to demonstrate other possibilities for action, and to highlight a source of information. In tennis, for example, one could ask a learner what position in court was his/her opponent when he/she performed a shot? What needs to happen after the shot is performed and before the opponent's return to facilitate better spatial coverage of the court? After an unsuccessful shot (e.g., ball out, into the net) feedback could be focussed on getting the player to reflect by asking what he/she could have done differently.

It is important to note that the specific nature of instructions and feedback can differentially impact the performance solutions that emerge (Chow et al. 2016). The attentional focus of instructions can be external (i.e., effect of the action performed on the environment) or internal (i.e., focusing the parts of the body used in an action) (Wulf, Lauterbach, and Toole, 1999). Although directing attention to external sources has been shown to support the inherent self-organisation tendencies in learners (Renshaw, Oldham, and Bawden 2012), at very early stages of learning a functional action pattern may not exist and instructions with an internal attentional focus may direct learners to the specific part of an affordance landscape which needs to be searched in practice to help them explore relevant functional performance solutions (Peh, Chow, and Davids 2011). For instance, a tennis learner who performs the backhand volley much at the expense of flexion extension of the arm, could be asked to seek to keep the arm in extension in front of the trunk and perform the backswing essentially through rotation of the trunk.

Whether feedback should be provided in verbal, visual, proprioceptive, haptic forms, or a combination of them, depends on the key constraint practitioners aim to manipulate and the characteristics of the task and the learner, i.e., the type of feedback used should help learners seek and utilise an affordance. Feedback should be understandable and meaningful for the learner who receives it, effectively helping him/her to perceive the information from the environment that specifies an effective performance solution.

Demonstration

Both instruction and feedback can involve use of demonstrations, which is augmented information. Traditionally demonstration provides a visual model that assists in a prescriptive way the development of a mental representation of a movement solution (Bandura 1977). CLA views demonstrations, provided by a coach or another athlete, as another instructional constraint to guide the search activities of a learner. Demonstrations and other forms of feedback can restrict their search activities or expand them, depending on their needs. Instead of using demonstrations to seek to reduce perceived differences between a learner's movements and those of a model, the focus of modelling strategies should be on promoting attunement to information in the available landscape of affordances. In a performance environment, the most significant information sources that constrain athlete behaviours are affordances, and attuning learners to the information they convey by demonstrating actions to enhance their search of the landscape, is an effective way of enhancing learning (Seifert, Araújo, Komar, and Davids 2017). In CLA, demonstrations provide examples of action possibilities for exploration, including a range of different possibilities in order to invite an athlete to find a functional performance solution from those that have been modelled. Yet this can be a challenging task in sport pedagogy, since essentially, the goal of a practitioner is to highlight affordances for achieving a task goal. As we know, one is not easily attracted to do what one perceives one cannot do (i.e., moving from known to unknown or easy to difficult performances). In learning design, practice task constraints could be manipulated, based on actions that athletes can perform. The purpose of manipulation of constraints is to challenge learners to add something to their current actions or to adapt their behaviours to achieve an intended performance goal (i.e., learning designs must attract learners towards a new mode of action). In this sense the learning task could draw learners out of comfort zones into less comfortable performance situations, considering though that in the later the learner might fall back in previous "intrinsic" behaviours (Davids, Güllich, Araújo, and Shuttleworth 2017). This is precisely how a progression drill can be described from a nonlinear pedagogical perspective. The key point here is that learners can be guided to explore and discover performance solutions from affordances of different parts of the landscape.

Questioning

Questioning is also a methodology used in the micro-structure of practice to guide the way learners search for and discover effective performance solutions. It is also a way that coaches can move or direct a learner's search towards different fields of the affordance landscape for their search activities. For example, observing a tennis novice player driving the ball too high and out of court, the coach could ask "What can you do to keep the ball lower and drive it into court?" After further practice, if the learner has not found a functional performance solution, further questions can be addressed: e.g., "Why are you hitting the ball underneath? Where does it go when you hit it there?" Here, it is important to differentiate the role of questioning in CLA from other pedagogical approaches such as Teaching Games for Understanding (TGfU). In TGfU the learner only practises after understanding a possible solution (a declarative solution) guided by the questioning of the teacher. CLA uses questioning to help a learner to define a path of exploration to guide the discovery and exploitation process (Chow et al. 2016). Questions, as with all verbal and non-verbal communication interventions in learning, need to be used as a type of instructional constraint. They need to be carefully framed by a practitioner, who remains aware of their impact on the search activities of each individual learner. Questioning should be introduced when the PE teacher/coach seeks to attune a learner's attention to a source of information that can change the direction of the exploration of action. For example, if a tennis player is not recovering his/her position in relation to the court centre line quickly enough, the coach may question him/her about what position he/she was in and if there are possibly better positions on court.

Time spent on task

It has been assumed that measuring an athlete's time spent on task related-variables informs practitioners about learning and goal achievement itself (Siendentop 1982; Metzler 1989). Time management, according to a traditional perspective in physical education (PE), focuses on session management issues such as class time and practice time, transition and rehearsal and routines (Tinning, McCuaig and Hunter 2006). Some traditional pedagogists have strongly argued for the importance of certain temporal variables for the study of class quality, such as the potential learning time in PE, arguing that the greater this time is, the greater will be learning (e.g., Siedentop 1983; Metzler 1989). CLA does not absolutely disregard measures of time in practice as fundamental for learning to occur. If the learner does not get the chance to experience new action solutions during learning, it will not be observed. But the time spent in practice *per se* is not predictive of learning efficacy (as proposed by practice theories such as deliberate practice). A more fundamentally important aspect of practice is its *quality*, dependent on specificity of practice, affordance design (i.e., what the task design actually invites the learners to do) and value of task constraints manipulations that guide exploration and adaptation of athletes. Quality of manipulations in an individualised way is at the very heart of nonlinear pedagogical approaches.

Observation

Traditional pedagogical practices commonly regard long observation periods (periods only spent observing athletes practising the designed tasks) as a limited part of the role of the teacher/coach. According to nonlinear pedagogy constant verbal interventions are not always necessary for exploration and search activities in learning to occur. There is a greater emphasis in CLA on guiding learners towards specific fields in a landscape of affordances (to search and explore) during the learning process, rather than the teaching or instructing process which directs learners to a specific affordance to utilise. Long periods spent observing actions of learners may imply that the designed learning task is sufficiently assuming its role in promoting the exploration of effective action solutions in an affordance landscape. Observing is key to designing CLA practice in the sense that the coach /PE teacher seeks to detect what may be improved, identify which movement-perception couplings are functional for competitive performance, and monitor the process of search and exploration for potential performance solutions by the learner. Continuous observation allows and guides that process, by feeding instructions, questioning or demonstrating possible solutions. Furthermore, as noted previously, teachers and coaches must also be able to perceive the personal capacities of each learner and groups of learners to manipulate task constraints accordingly. Moreover, practitioners must observe learners' behaviours to become aware of the impact of task designs and manipulations.

Concluding remarks

To sum up, in planning, implementing and refining the micro-structure of practice, practitioners must continuously seek to innovate the unfolding interactions required of each learner in practice. Both practitioners and learners need to focus on the available affordances in a landscape, or boundaries of action solutions, that task designs are promoting (through the manipulation of constraints). Using a nonlinear pedagogy, practitioners need to continually assess and evaluate the needs of each learner to support them in the processes of seeking, discovering and exploiting their action solutions. Sport performance does not stand still and there is a need for innovative and creative actions to emerge as athletes co-adapt to the behaviours of other competitors. Learning design needs to help learners perceive what actions should be functionally adapted to satisfy new constraints in the form of rule changes, new equipment and technology and novel performance solutions from competitors. There is no pre-determined list of activities and task manipulations in the micro-structure of practice that practitioners can follow in coaching manuals or education courses, indicating which specific task designs lead to the emergence of specific performance solutions. A successful manipulation observed with one athlete or group, may not be successful with other learners or even with the same learner at a different stage. These ideas imply that practitioners are faced with the exciting challenge of being innovative and creative in their learning designs, understanding that planning must be flexible and adaptable, individualised and constantly monitored, occurring much more *in loco* (being emergent when needed).

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