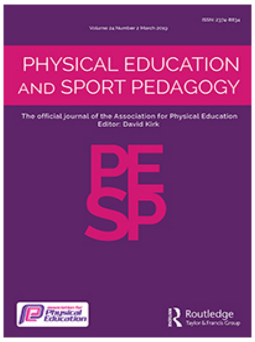

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A constraint-led approach to sport and physical education pedagogy

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ABSTRACT

Background: The Constraints-Led Approach (CLA) has emerged as a viable pedagogical option for teachers and coaches in the sport and physical education. The emergence of a CLA to teaching and coaching has paralleled a change in the current zeitgeist with many scientists embracing the ideas of complexity and a more ecologically driven agenda. The CLA articulates that through the interaction of different constraints – task, environment, and performer – a learner will self-organise in attempts to generate effective movement solutions [Renshaw, Ian, Keith Davids, Elissa Phillips, and Hugo Kerherve. 2011. "Developing Talent in Athletes as Complex Neurobiological Systems." In Talent Identification and Development in Sport: International Perspectives, edited by Joe Baker, Stephen Cobley, and Jorg Schorer. London: Routledge]. However, successful employment of a CLA requires an understanding of ecological dynamics as these underpinning concepts manifest themselves as guiding principles for the design of CLA practice environments.

***Findings*:** While some practitioners are adopting the ideas of CLA in their work, there is some concern that the often dense academic language often associated with the approach is acting as a key barrier in the take up of CLA and resulting in a limited understanding of the key underpinning concepts and hence poor implementation. It is therefore incumbent on advocates of CLA to provide pedagogues with the knowledge and tools to base learning design on the key principles of CLA.

Conclusions: In this paper, we walk the reader through the key theoretical concepts in CLA. We introduce the key ideas underpinning a CLA to provide guidelines as to how practitioners can implement a CLA in their practice. Wherever possible, we provide 'exemplars' from sport and pedagogy settings in an attempt to de-mystify the potentially confronting language of the ecological dynamics landscape. We make clear that simply adopting a CLA should not be seen as a panacea for practitioners and conclude by emphasising that effective CLA teaching and coaching practice is therefore subject to the same pedagogical requirements when designing learning activities as when providing more traditional approaches.

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Introduction

The Constraints-Led Approach (CLA) originated in the work of Newell (1986) and has emerged as a viable pedagogical option for teachers and coaches in the sport and physical education. At its simplest, the constraints-led approach would seem to be a straight forward model for pedagogues to adopt. The CLA articulates that through the interaction of different constraints - task, environment, and performer – a learner will self-organise in attempts to generate effective movement solutions (Renshaw et al. 2011). However, for successful employment of a CLA, an understanding of ecological dynamics (see Chow et al. 2015) is essential as these underpinning concepts manifest themselves as guiding principles for the design of CLA practice environments. Consequently, it has been suggested that a key barrier in the take up of CLA by practitioners is the combination of dense academic language and a resultant lack of depth in understanding the key underpinning concepts (which perhaps can lead to confusion or misinterpretation of ideas and knowledge). It is therefore incumbent on advocates of CLA to provide pedagogues with the knowledge and tools to base learning design on the key principles of CLA.

Additionally, although CLA is gaining traction and numerous empirical investigations demonstrate its efficacy in motor learning studies, there is minimal evidence of its effectiveness in applied settings such as schools and sports coaching environments. Furthermore, when a CLA is embraced by practitioners, anecdotal feedback suggests that it is not being implemented correctly; a problem that appears to be common in the implementation of other 'new, alternative' pedagogical approaches (Reid and Harvey 2014). Importantly, an incorrect implementation may lead to negative perceptions of CLA and its potential adoption by practitioners in P.E. teachers and sports coaching. There is, therefore, a clear need for research in authentic settings, over realistic time-frames.

These challenges highlight to us the need for a more targeted approach to (a) explain the key concepts and provide guidelines; (b) explore the efficacy of CLA based interventions in pedagogical settings and (b) the challenges and issues facing new or experienced P.E teachers and coaches when attempting to implement CLA into their practice. This special issue aims to address these challenges and deliberately targeted current academic and practitioner teams who were working in 'the real world' of P.E. teaching and sports coaching at developmental and elite levels. The response to the call was overwhelming and we had to make our final choices from over 25 studies/research projects undertaken by research groups across the world.

The selection of papers to cover as wide a range of pedagogical settings and activities as possible aims to address criticisms from some academics who have mistaken CLA for being 'just' another game-centred approach (GCA). However, in contrast to GCAs which emerged as a practical solution developed to address key issues such as failure to play games intelligently, or to meet the basic psychological needs of young learners (see Renshaw et al. 2015), CLA differs in that it is built from a theoretical model of motor behaviour. In fact, CLA does not just focus on games but is able to provide a principled approach to skill learning across *all sports and in all pedagogical settings*. We would point out that we do not intend to deride GCAs by making this comment, which is an approach we believe has much to offer pedagogues and has some common ground (Renshaw et al. 2015). We are also not saying that CLA is the only or best way to approach teaching and coaching. The focus is on raising awareness among scientists and practitioners on the need to account for the dynamic interactions (and thus nonlinearity that occurs in learning) as we explore how practices can be designed.

The emergence of a CLA to teaching and coaching has paralleled a change in the current zeitgeist with many scientists embracing the ideas of complexity and a more ecologically driven agenda (see Chow et al. 2015; Ovens, Hopper, and Butler 2013). In pedagogical settings, one notable attempt to explain and study teaching and learning from a CLA was in the 'teaching experiments' of Rovegno and colleagues (Rovegno, Nevett, and Babiarz 2001; Rovegno et al. 2001). This work provided a promising base upon which to build for those interested in applying CLA in authentic pedagogical settings, sadly, this has not happened to any great degree. Perhaps, the lack of empirical evidence and the complexity of implementation, highlighted in Rovegno's findings has impacted the uptake of CLA by practitioners. Additionally, as highlighted earlier concepts can be challenging for practitioners and consequently, our aim in this paper is to attempt to walk the reader through the key theoretical concepts and ideas underpinning a CLA as well as to provide guidelines as to how practitioners can implement a CLA in their practice. Wherever possible, we provide 'exemplars' from sport and pedagogy settings in an attempt to de-mystify the sometimes dense and confronting language of the ecological dynamics landscape.

An ecological definition of skill

Before discussing how to develop skill, we need to clarify what constitutes skilled behaviour. Traditional definitions have focused on the enrichment and acquisition of mental representation that lead to changes in internal states that underpin the development of accurate and consistent actions through practise in specific performance domains (Araújo and Davids 2011a). In brief, these definitions refer to how there is a representation of a mental model of what a skilled action is and how it is important to replicate the same successful action on a regular basis. Practice is therefore aimed at strengthening motor programmes that can be 'run-off' as required (Schmidt and Lee 2006), eliciting pedagogical approaches such as part-whole learning where the task is broken down into its constituent motor programmes before being 'added' back together (i.e. task decomposition). Alongside this, variable practice is seen as a useful way of parameterising general motor programmes (Schmidt 1975). Despite the popularity of such approaches, the supporting evidence is limited and a number of concerns have emerged, not least from key proponents of such approaches (Schmidt and Young 1986; Renshaw and Moy 2018).

An alternate ecological view and one we will use to frame a CLA is that skill acquisition may be better to not be seen as an entity but rather as the emergence of an adaptive, functional relationship between an organism and its environment (Araújo and Davids 2011a). Skill learning is, therefore, better described as the process of adapting or attuning to the environment. Thus, the aim of the practitioner changes from the pursuit of perfect technique to one which facilitates the emergence of greater functional relationships between the learner and the performance environment. Adopting this focus in learning design provides opportunities for learners to attune to the key affordances (see later) and develop functional solutions in line with the current status of each individual. Learning design is, therefore, more about giving learners the space to search, explore, and ultimately exploit performance environments to facilitate stable yet adaptable movement solutions (Chow et al. 2015).

Skill acquisition refers to the emergence of an adaptive, functional relationship between an organism and its environment … , the terms 'skill adaptation' or 'skill attunement' might be more suitable to describe this process (Araújo and Davids 2011a, 7).

The theory behind a constraint-led approach

On a superficial level, it could be argued that a CLA is a relatively straight forward and simple approach to understand, however, the underpinning theoretical concepts can be very challenging and for some practitioners steeped in unfathomable jargon. In this section, we will attempt to explain the key concepts of Ecological Dynamics by keeping our discussion as simple as possible. However, we believe that for the interested practitioner who may wish to delve deeper into the literature, there is a need to use the language of the topic. The ideas underpinning CLA are based on complexity theory and consequently there are a number of key interacting concepts and choosing the order to introduce them is moot. To that end, we have chosen one pathway; other educators may well have chosen others. Just like the concept of degeneracy in ecological dynamics, there is more than one solution and we will leave it to you (after sound guidance from reviewers) to decide if this one is functional! We will begin our discussion by building on the fundamental ideas of James Gibson (1966, [1979]

1986) who is often viewed as the founder of *Ecological Psychology*. Our first focus will be on the basic foundation of ecological psychology; the interwoven relationship between the individual and the environment.

Individual-environment mutuality

Perhaps, understandably, skill acquisition research has traditionally focused on the individual; that is, how do we help this child or athlete to become more skillful? Such an approach has often led to practices that fail to represent the task to be achieved. For example, on a recent trip to Coogee beach (in Australia by the way!), I observed a coach delivering a beach volleyball lesson to beginner level adults. The coach spent some time teaching the group to 'dig' the ball by mimicking the correct technique in response to an imaginary ball. Once they had 'got it', the ball was brought into the practice, however, the expected transfer to efficient digging failed to materialise, with the coach shocked to discover the well-practiced movement patterns were not replicated when a ball actually required intercepting. These de-composed approaches with a focus on developing perfect technique are a strong focus of practitioners across sports and other examples include unopposed shadow play in invasion or net-court games or learning to swing bats or golf club without a ball in striking and fielding games. Indeed, P.E.teachers apparently spend most of their time (up to 78%) engaging in such teaching strategies (Curtner-Smith, Hasty, and Kerr 2001). However, the lack of transfer in such tasks to the 'real thing' (Renshaw and Moy 2018) emphasises the importance of practitioners considering the individual *and* the environment when designing skill learning activities.

In line with Gibson, here we argue that the appropriate level of analysis to describe and examine 'ways of life' (i.e. P.E. teaching or sports coaching) is to consider the individual *and* the environment as one system; an inseparable pair where each term implies the other (Gibson 1986). In pedagogical settings, the idea of mutuality of the individual and environment is significant, as it highlights that the range of emergent abilities of learners (e.g. perception-action skills, mental skills, fitness) is determined by the environments created by practitioners. We will return to these ideas later.

The importance of the environment in providing the context in which skill is learned can be seen by the reported importance of physical and cultural environments as being significant factors in the development of many sporting champions across the world. For example, the importance attached to street football in Brazil (see a paper by Claudio and colleagues in this special issue), the backyard games of Australian cricketers and basketball in the parks of American cities highlight that local environments act as resources to develop specific sporting abilities. Individuals see locales in terms of what they perceive it offers and are therefore framed in terms of size or action capabilities. For example, is this hoop too high for me to shoot into? Can I use this wall to make up a game? What does this full playground allow me to do? Is this tree climbable? Can I lift the log? Can I jump the stream? Can I join in with this group of street footballers? (Gibson 1986). In essence, while individuals may not consciously ask these questions, through their involvement in such play contexts, they acquire the relevant affordances.

Taking Gibson's ideas further, the mutuality of the individual and environment emphasises that the individual is a perceiver *of* the environment and a behaver *in* the environment. Hence, what we see in our environment, determines what we do. What we see is dependent on what resources (i.e. parks, courts, empty spaces) are available in that environment and then upon our ability to pick-up that information. This is a key concept for practitioners as it highlights the importance of designing learning environments that provide learners with opportunities to attune to information from the environment to which they can couple their actions. A simple example would be to consider teaching tennis. If ultimately, being able to play a game of tennis requires hitting a ball over a net into a court, the learning environment must involve providing opportunities to learn to couple hitting actions to the perception of the moving ball. These ideas are captured in the following sections on affordances and perception-action coupling. Summarising this section, from an ecological dynamics perspective, the CLA should be described as an athlete-environment centred approach, rather than an athlete-centred approach and practitioners should always consider learners in the context of the environment (Araújo et al. 2014; Gibson 1986).

Affordances

Gibson proposed that the surroundings of the individual is his or her 'niche' and is composed of a set or landscape of affordances for a particular animal (Chemero 2003). *Affordances* consist of environmental properties that *afford* 'opportunities for action' for each individual. In fact, certain information sources in a performance environment may actually invite actions (Withagen et al. 2012, 2017). Affordances surround the individual's habitat; it is where it lives and is what it offers, and as highlighted in the previous section, consists of a range of resources that constrain the range of functional abilities individuals can exploit in attempts to get a 'grip' of their environment. In learning situations, the environment offers possibilities or invites actions in the pursuit of goal-oriented abilities. Environmental features such as mediums (i.e. air, water in swimming pools or rivers), substances (i.e. field characteristics, sand, mud, court surfaces, synthetic tracks, sprung wooden floors); objects such as the paraphernalia or tools of coaching (i.e. cones, markers, manikins, small goals, bats, balls, sticks, cones, agility poles); places (sports halls, playing fields, gymnasia) and events (lessons or after school clubs), offer different possibilities for individual learners as they are framed in terms of body scaling and action capabilities. For example, for an average size 12-year old, a size 4 basketball affords a 3-point shooting opportunity, whereas a size 6 ball does not. Similarly, a full-size netball court affords the opportunity to pass the ball from the defensive net to the attacking net in 3 passes, whereas, for 12-year olds, it takes a minimum of 5 passes.

Other individuals are considered as features of the environment and are the most complex objects of perception for the individual. Fajen et al., (2009) describes other individuals such as coaches, teachers, team-mates and opponents or referees or umpires as social affordances. Social affordances can, therefore, be classed as (1) prey (a weak defender) or predator (i.e. a strong defender), (2) someone who affords co-operating or competing with (i.e. a team mate or opponent) or (3) who can provide nurturing (learning) opportunities (i.e. a teacher or coach). In a performance setting, what another individual affords is specified by his or her permanent features and their temporary states (Gibson 1986). That is, while the size of an opponent may not change over the course of a game, their action capabilities will. Consequently, at the beginning of a rugby match, a narrow space between two fresh defenders may not afford running through for an attacker, but later in the game when the defenders are more fatigued, the gap may be exploitable. Individual team-mates provide opportunities to develop inter-individual couplings (or interactions) to solve game related problems. For example, a packed defence in football may be de-stabilised by running at defenders with the ball while team-mates make runs off the ball to pull defenders out of position. Opponents may also act as affordances that constrain actions. For example, when running at a defender in basketball, the attacker can learn to exploit the body orientation of the defender by attuning to any foot that is more 'forward'; and hence attacking them on that side (Esteves, de Oliveira, and Araújo 2011). These examples highlight the importance of understanding the concept of affordances for those responsible for designing learning and performance environments as affordances act as constraints on the emergent self-organising perception-action couplings that may emerge in learners in pedagogical settings.

Perception-action couplings and co-adaptability

From an ecological perspective, the theory of affordances is predicated on the premise that the environment consists of energy flows that act as *information* that regulates the movements of individuals (Davids, Button, and Bennett 2008). In physical activities and sport, this information is directly perceivable to be picked-up by individual learners and performers to constrain their actions

(Gibson 1986). Perception is, therefore, a process of searching for the key, or 'specifying' information that can be used to guide movements. It is an active process with the basic idea that 'action-relevant information is both generated and reciprocally used to regulate movement' (Warren 2006, 23). Gibson (1979) sums this up by highlighting that 'we must perceive in order to move, but we must also move in order to perceive' (223); a coupling described as a perception-action cycle. The perception-action cycle generates, and at the same time utilises information to coordinate and control behaviour:

When an observer moves relative to the environment, a global pattern of optical flow is generated at the moving point of observation and corresponds to the class and direction of observer movement. Reciprocally, this information can be used to regulate the forces applied by the observer in controlling subsequent movements, which in turn generate a new flow field, and so on in a circularly causal cycle (Warren 2006, 23).

The study of the regulation of fast bowler's run ups has provided us with practical examples of how the environmental information available to be perceived by performers acts to shape their actions. For example, a recent study showed that removing an umpire from the performance environment influences the run-ups of fast bowlers (Greenwood, Davids, and Renshaw 2016). While the removal of the umpire did not result in an inability to regulate gait, it did result in the emergence of different run-ups. Significantly, variability in run-ups was lower across multiple steps in the umpire condition, compared to the no-umpire condition. Interestingly, in a case study where we manipulated the presence of umpire and wickets, the absence of vertical information in the form of an umpire or umpire and stumps led to more no-balls being bowled with final foot placements being much closer to the batter (Renshaw et al. 2003).

These studies highlight that learning to pick up or 'attune' to the 'useful' information available in performance environments is only possible if the information is actually designed-in. The emergence of functional perception-action couplings through practice is predicated on practitioners ensuring that key sources of information are present in practice environments and tasks. To emphasise this point, performers will only become attuned to specific affordances within practice and performance environments through continued exposure to them.

Self organisation under constraints

Central to the ideas of a CLA is the concept that the organisation of a system is influenced by the constraints that act upon it and any changes in constraints may lead to changes in the organisation of the system. Constraints are the boundaries that shape self-organisation and can be separated into categories, namely, individual, environmental and task constraints (Newell 1986). Self-organisation is a fundamental property of complex, biological systems composed of many independent but interacting subsystems. Self-organisation is ubiquitous in nature as seen by the flocking of birds, the behaviour of termites or in schools of fish and is also a key property found in individual learners and sports teams in competition (Renshaw et al. 2010).

For example, if an individual is asked to walk on a treadmill set to 3kmh^{-1} and the speeds increased to 4kmh^{-1} the individual will continue to produce a walking pattern. However, if the speed is increased by one kmh^{-1} at a critical value, which is generally around 10-11kmh^{-1} a transition from walking to running is likely to occur (see Raynor et al. 2002). Put simply, the increase in treadmill speed at the higher speed led to instability in the walking pattern (i.e. walking did not meet the new constraints) and the emergence of a new more functional pattern (i.e. one that met the new task demands).

As highlighted above, any qualitative change in co-ordination depends on the relative stability of the system at any moment in time and means that a small change in a constraint may or may not perturb the system. The treadmill example demonstrates how systematic manipulation of a specific constraint (this is called a control parameter in CLA) can be used by practitioners to deliberately create the conditions that lead to changes in co-ordination. Newell and Valvano (1998) identify the practitioner as a key constraint on emergent behaviours as they are the ones responsible for designing the environments that channel the emergence of new movements and actions. When designing a learning intervention it is incumbent on the practitioner to be able 'to identify the appropriate physical or informational constraint that induces an efficient and effective search strategy for task-relevant qualitative and quantitative change towards functional output in the movement dynamics' (Newell and Valvano 1998, 51). However, at present there are limited sport-specific examples of control parameters in sport and going forward, the first steps will be to educate practitioners about the key processes and then for researchers and practitioners to work together to identify and eliminate or verify candidate constraints. The second stage will be to work out how much to change a constraint by in order to create instability and promote transitions to new intentions, perception and action solutions. We will return to this idea in the section on repetition without repetition below, however, we will now focus on providing examples of constraints.

Constraints

We have described constraints at length in previous articles in PESP (e.g. Renshaw et al. 2010; Tan, Chow, and Davids 2012), however, we will discuss them again here with specific examples for practitioners. Identifying the constraints that potentially influence performance in sports is a good starting point for practitioners, as is then separating them into those that they have no control over and those that they can deliberately design-into practice and then manipulate. For example, individual constraints such as growth or deterioration in eye sight, environmental constraints such as a changes in wind direction, or the temperature, or task constraints such as a rule change imposed by a governing body or the opposition you play against in a competition may all have an impact on the emergent performance but are outside the practitioner's control. Of course, just because these types of constraint cannot be controlled does not mean they should be ignored and practitioners can design-in opportunities to learn to explore and exploit such constraints. An often overlooked constraints that can be manipulated by practitioners is intentions. We start our discussion there.

Individual constraints

Despite misconceptions on the part of some that cognition plays no role in a CLA, *intentions* could be viewed as the most important individual constraint (Kelso 1995). Learner's intentions have the power to act as a specific informational constraint related to their overarching goals and could lead to stabilisation or destabilisation of existing system organisation. Intentionality is, therefore, a central constraint for practitioners to consider and frames the selective openness and responsiveness of learners to search for and select from the rich landscape of available affordances (Rietveld and Kiverstein 2014).

When working with children, anthropometric factors such as body size and physical factors such as strength or flexibility are always important constraints to consider. For example, ensuring games that look and feel like the 'real' *adult* game to develop movement and decision-making skills that will be useful as part of long-term athlete development requires a principled approach to modifying children's games. For example, Gorman et al. (Forthcoming) found that the basketball size that had a hand-ball ratio most similar to that of adult players was a size 4 rather than the size 6 they currently use (in Australia). Subsequent performance analysis revealed that playing with a smaller ball led to more 3-point shots as the affordances of the ball allowed the young players to shoot the ball from further away from the basket. While this might seem a minor point, it has a significant impact on the defensive and offensive play as it meant that the defending team need to come out to pressure this shot and hence leave more space inside the key.

Practitioners also need to consider psychological factors such as emotions and confidence. Session design can impact learner's motivation to 'have a go' at tasks where failure is a possibility. For example, if a session involves high levels of surveillance by teachers and class mates (e.g. where individuals are called out by the teacher to play against each other in front of the rest of the group) it may inhibit or even embarrass less confident or nervous children. When they do not feel as though their every movement is being monitored and scrutinised, it can give children the freedom to explore and fail without worrying about the potential negative consequences. Practitioners should, therefore, look to devise learning environments that promote exploration and promote motivational climates that encourage 'having a go' rather than 'avoiding' showing incompetence (Renshaw, Oldham, and Bawden 2012).

Environmental Constraints. Constraints in this category can be separated into Physical and Socio-Cultural Constraints. Physical environmental constraints include gymnasiums, school halls; sports halls; playing fields, school-yards and courts. Socio-Cultural constraints include teacher expectations, school values, the ethos of the physical education department and individual teacher, family support and access to available facilities. On a more macro level, the sports that have high cultural capital in countries states or regions act as significant constraints on the sports that children value (Araújo and Davids 2011b).

For the learner, teacher intentions act as an environmental constraint as they will determine how they shape learning environments. For example, a teacher may compromise learning how to play team invasion games to meet his goal of making sure every player is involved. This typically involves a rule such as everyone must touch the ball before a team can score; a rule that does nothing to promote game understanding or solving game related problems. Similarly, teachers may initially adopt teaching practices that are more about meeting the need to demonstrate behavioural control and gain the respect of the class in terms of showing that she is a 'good' teacher. Once this is established, the focus can move more towards learning. (Refer to paper in this special issue by Orth, Button, and van der Kamp (This issue) on adaptive learning across coach-athlete system for more discussion).

Understanding learner intentions is of significant importance for practitioners to ensure that their respective learning design goals are aligned. For example, performers can often be resistant to attempts by coaches to change well-established techniques that has been somewhat successful for an individual (a point supported by research from motor learning; Jacobs, Michaels, and Runeson 2000). People tend to stick with things that they believe are working. Consequently, attempts to change movement co-ordination by manipulating task constraints or providing instructional constraints can be 'over-ridden' by individual intentional constraints (Kelso 1995) and coaches need to convince their charges that this new way is going to be better. Often, it takes failure for this to happen and practitioners may sometimes manipulate constraints to deliberately create such an outcome. Of course, adopting such an approach can be high risk and practitioners need to ensure that the right psychological support is provided at these times (see Renshaw, Oldham, and Bawden 2012 for some ideas here).

Task Constraints. As we stated in our 2010 article in PESP (Renshaw et al. 2010), task constraints are the most important constraint for PE teachers as they are the easiest to manipulate as part of their practice (Tan, Chow, and Davids 2012). Task constraints include instructional constraints, rules of the sport and any modified rules added on by the practitioner, modifications of equipment such as racket sizes or ball size or composition (Buszard et al. 2016). Manipulating the size of practice areas is a common strategy, however, initial pitch size is often based on 'best guesses' of the right level of challenge for a group of learners. For the beginner level practitioner, a more objective methodology to manipulate these task constraints would aid practice. To that end, we recently developed the Game Intensity Index for use in invasion games (Chow et al. 2013). GII is a mathematical tool, which is a function of the size of an area divided by the number of players in that area. GII can be used to provide a 'value' for the time and space players get and provide practitioners with a way to (a) create game demands representative of the competition environment, (b) compare game forms, (c) control the difficulty level for players, and (d) assess skill levels. Research is ongoing to study the skilled behaviours that emerge in different GIIs.

Constraints interact

While we have described examples of the different categories of constraints, the principles of self-organisation highlight that behaviours emerge through the interaction of constraints. As discussed by Warren (2006) (see below), the constraints of the environment, the individual and the task constraints all constrain the emergent behaviour. This is essentially the crux of the concept of self-organisation with learner's actions being adapted to the multiple boundary constraints associated with specific task demands.

Specifically, the structure and physics of the environment, the biomechanics of the body, perceptual information about the state of the agent– environment system, and the demands of the task all serve to constrain the behavioural outcome. Adaptive behaviour, rather than being imposed by a pre-existing structure, emerges from this confluence of constraints under the boundary condition of a particular task or goal (Warren 2006, 358)

Understanding how self-organisation emerges under the influence of interacting constraints processes should inform the design of learning environments to enable young learners to develop functional co-ordination solutions. When working with children, task demands need to consider body and action scaling which would allow learners of different stages of growth and development to learn functional movement solutions that would endure over developmental time frames. For example, when teaching hurdling in an athletics lesson, teachers may wish to provide lanes with hurdles of different heights and with different hurdle-hurdle distances to match with leg lengths and enable the development of 'ball-park hurdling techniques' (i.e. hurdling that looks like hurdling). In netball, the court length (a task constraint) could be shortened for younger players with less arm strength, so that they can still pass the ball down the court in three passes. Use of a small lighter ball added to a lowered net would also enable them to learn to shoot with a technique similar to those seen by adult netballers.

As we discussed above, learning how to manipulate constraints is a key skill for practitioners who wish to implement a CLA and there is some anecdotal evidence that teachers and coaches have intuitively tended to use the method of identifying and manipulating key constraints on learners (Renshaw et al. 2010). However, the key to successful application of a CLA is dependent on an understanding of the key processes that take place when constraints change due to uncontrolled factors (e.g. changes in the weather) or are deliberately manipulated by practitioners (e.g. changing task constraints or creating higher levels of emotion). Consequently, ensuring that constraints are manipulated in a principled manner is essential to prevent over constraining or providing inappropriate tasks in this special issue on a discussion on how CLA can promote Physical Literacy in children's play). In this final section, we will consider how to apply the key concepts of ecological dynamics in practice through the implementation of a CLA. We will propose a CLA Session Design Builder (Renshaw et al. 2019) which we suggest that practitioners could use to design CLA sessions.

The CLA Session Design Builder

The key principles in this practical framework are (1) Constrain to Afford; (2) Representativeness Learning Design including (3) Purpose and Consequence and (4) Repetition without Repetition which is framed around manipulating (5) Variability to increase or decrease (In)stability. We will unpack each principle in turn using the CLA Session Design Builder provided in Figure 1.

Session Aims: Careful assessment of the current skill level of the learners underpins session goals and the commensurate design of the session. Here we propose an adaptation of Newell's (1985) 3-stage stages of learning model (Co-ordination, Control, Skill) to just 2 stages. Stage 1 is a Learning to Co-ordinate Phase (as per Newell) whilst Stage 2 is an Adaptation Phase (a collapsing of Control and Skill from Newell's model). Stage 1 is therefore about *searching* and *exploring* to develop intra-individual-environment or inter-individual-environment co-ordination patterns (Renshaw and Moy 2018). Learners who have developed basic co-ordination patterns move into the Adaptation Phase.

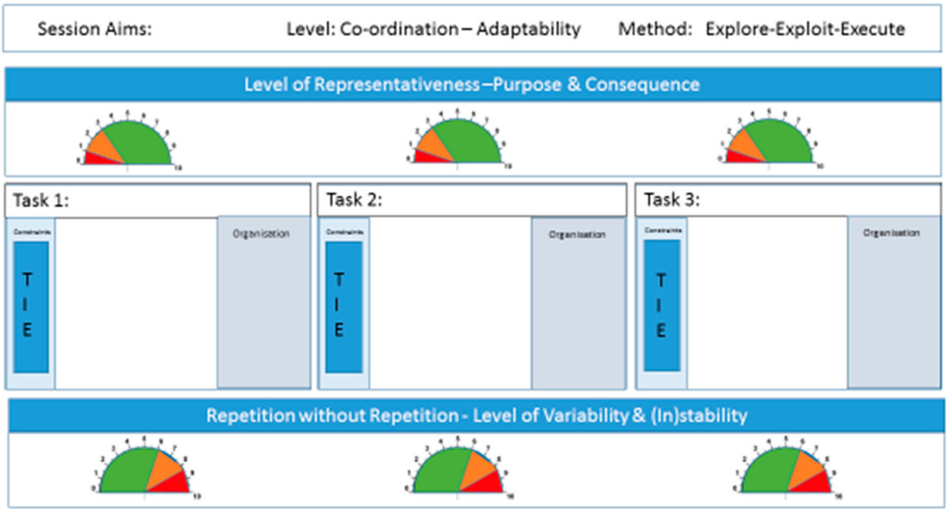

Figure 1. An example template of a CLA Session Design Builder.

This phase is concerned with optimising performance through developing stable yet flexible co-ordinative structures based on the emergent ability to *exploit* the individual-environment system (i.e. passive, inertial, and mechanical properties of limb movements (Davids, Button, and Bennett 2008)). Learners in the adaptive phase educate their intentions and attention through attunement to more specifying information sources that enhance their capacity to use the information to predict future events (Davids, Button, and Bennett 2008). The greater adaptability resulting from this tighter fit between the individual and his environment enables instantaneous adaptations to minute environmental changes and greater smoothness and fluidity in movements (Davids, Button, and Bennett 2008; Newell 1996).

Constrain to Afford: The traditional P.E models based lesson (Kirk 2013) has focussed on acquiring skill in the form of enhanced cognitive structures such as generalised motor programmes (Schmidt 1975). In contrast, the CLA session is designed to specifically provide opportunities for learners to become more attuned or adapted to the environment (Araújo and Davids 2011a). Learning is therefore aimed at enabling knowing how to perceive and act via a process of increased attunement to the affordances for action (Chow et al. 2015). This approach requires practitioners to design-in constraints that will channel the learner toward the desired task related outcomes (Chow et al. 2015). Providing the constraints to afford by adding in or manipulating constraints means that practitioners become 'problem setters' and learners are invited to move beyond 'what' they must do, and allow them to construct for themselves the 'how, why, where and when' to utilise affordances in sport performance. Knowing when one 'ought' to use an available affordance is perhaps just as important as being able to use it (Heft 2003). In practice, helping players to learn to recognise the affordances, when and why and ultimately how to use them requires sampling of 'the landscape of affordances' from performance and ensuring that the most important affordances are available in practice. It is essential that the practice environment not only provides the learners with opportunities to attune to a range of possible affordances but solicits those actions. A useful strategy to aid this process is adopting the principles of exaggeration (See Bunker and Thorpe 1982; Renshaw et al. 2015; Tan, Chow, and Davids 2012). For example, a badminton coach may use a long thin court to encourage the learner to recognise when the space is in front of or behind their opponent.

A final point when considering the principle of 'constrain to afford' is that the desired action should not be forced towards a solution by over-constraining the learning environment. Functional behaviour emerges as the learner searches through the dynamically available affordances within the environmental and task constraints. Examples of over-constraining include the ubiquitous 2-touch rule or by forcing players to make a specific number of passes before they can score. Designing in-affordances that invite actions, but provide choice is, therefore, an essential feature of 'constrain to afford'. An analogy from an urban design perspective would be that an architect guides walkers through a park by creating a series of concrete paths through grassed lawns. While the paths invite walking on they do not force walking on and some park dwellers may choose to walk on the grass.

Representative learning design (purpose and consequence)

One of the most important concerns for practitioners who are interested in improving performance is the degree to which what one learns in 'practice' transfers to the competitive environment. In our framework, this is captured by Brunswik's (1956) notion of representative design. Representative *learning* design was a concept that was developed to focus on ensuring that practice and training task constraints are *representative* of a particular sport performance context (Chow et al. 2011; Pinder et al. 2011). More recently, we have introduced the idea of Affective Learning Design (Headrick et al. 2015), to highlight the interaction between emotion, intentions, perception and actions. In simple terms, the practitioners can check the representativeness of his practice session by asking 'does the practice look and feel like the real thing?' or 'does the environment offer the relevant opportunities for action, often, and that they are representative of the game with an optimum level of competition and difficulty?' Essential to this design process is ensuring that the task outcome has been given a purpose and that there are clear consequences. A failure to ensure this aspect of representative learning design may lead to athletes performing below competition intensity and create different intentions, emotions and consequently different emergent perception-action couplings (Maloney et al. 2018).

Repetition without repetition (including variability and in(stability))

A key feature common across sport is the belief of practitioners that we become 'good' by doing repetition after repetition, however, evidence in motor behaviour research has highlighted that repeating the same movement over and over again is an impossibility (Bernstein 1967). The term, Repetition without Repetition was coined by Bernstein to capture this idea. Bernstein suggested that repetitions were, therefore, more about repeating the search for a functional solution to a task problem. Providing opportunities for lots of repetition is therefore essential to allowing learners to search and explore effective adaptable movement solutions. However, contrary to the traditional view of motor learning, increased variability in movement patterns is an established trait of more skilled performers (Davids, Bennett, and Newell 2006) and the generation of functionally variable movement patterns is an important characteristic of skilled learners operating within a dynamic environment. Komar, Potdevin, and Seifert (2018) capture this discussion on the need for variability in practice to allow for exploitation and exploration in skill learning in this special issue.

Repetition without repetition can also refer to achieving a task goal in multiple ways and both repetition and variation should be designed-in to practice to facilitate this process. For example, in a football game as no two passes are ever identical the learner needs lots of opportunities to pass to different team members and require players to adapt to the many different situations (see Button, Davids, and Schöllhorn 2006).

An important question for practitioners is how much variability to build into session design through the systematic or random manipulation of constraints. As we discussed in the section on constraints, variability can be at an individual, environmental or task level. Orth, Button, and van der Kamp (This issue) address these ideas in this issue suggesting that practitioners can utilise systematic and unsystematic approaches by the manipulation of constraints (Ranganathan and Newell 2013). We discussed systematic manipulation earlier which is concerned with control parameters. The unsystematic manipulation of constraints involves practitioners constantly and randomly manipulating task and environmental constraints, for example, intentionally changing racquet sizes or ball types when teaching tennis (Lee et al. 2014) or even in Paralympic sports contexts (see Pinder and Renshaw 2018 in this special issue).

The amount of variability designed-in to a session needs to be matched to the learner. For the beginner level player, low task and environmental variability may be beneficial to guide exploration towards one or two functional solutions. In contrast, the more expert performer may be presented with greater variability in individual, task and environmental constraints to promote more adaptable behaviour. Knowledge of 'critical values' (i.e. the amount of variability that will lead to instability and the search for new solutions) is important for practitioners and needs careful management and awareness of the implications for placing individuals in these critical ('red') zones. Consequently, the CLA Session Design Builder is designed to encourage practitioners to move up and down the variability continuum across a session but be aware of spending too much time in the red zone and potentially creating negative psychological consequences (Renshaw, Oldham, and Bawden 2012). (See paper by Correia and colleagues on promoting and evaluating learning using Nonlinear Pedagogy in this special issue to gain some insights on designing practices).

Summary

On the surface, CLA is a straight-forward model and it could be argued is nothing new for teachers and coaches who have long used modified games as a basis for their work. However, achieving that goal can be challenging, as it requires an in-depth understanding of the intrinsic dynamics (ID) of each learner; which are shaped by their movement history. Consequently, the solutions individual comes up with in order to solve a performance problem is impacted by the relative fit between the ID and the new task constraints. Adopting a CLA approach is, therefore, more than just adding in random constraints especially when it is difficult to predict the expected and unexpected behaviours that are likely to emerge in learners who come from diverse historically different movement backgrounds (Reitveld and Kiverstein 2014). In effect, given that performance behaviours are emergent, how can practitioners know, a priori, to identify the constraints to manipulate (Correia et al. This issue)? It should be clear from the above examples that simply adopting a CLA should not be seen as a panacea for practitioners. Adopting a CLA in teaching and coaching practice that will lead to effective interventions is therefore subject to the same requirements when designing learning activities or when providing prescriptive instructions. Poor practice is still poor practice, irrespective of the approach utilised!

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