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NEWCOMBE, Daniel J, ROBERTS, William M, RENSHAW, Ian and DAVIDS, Keith <http://orcid.org/0000-0003-1398-6123>

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The Effectiveness of Constraint-led Training on Skill Learning in Interceptive Sports: A Systematic Review (Clark & Christie) – A Commentary.

D. Newcombe, W. Roberts, I. Renshaw & K. Davids

Introduction

Clark and Christie's systematic review (2016) offers a timely examination of current literature assessing effects of a constraint-led approach to training on 'technical and cognitive outcomes', in comparison to traditional training methods. They concluded that, currently, there is a lack of sufficient evidence to advocate for the effects of training interventions that espouse benefits of constraint-led training on acquiring skill in interceptive actions. Clark and Christie reported that 14 studies satisfied their proposed inclusion criteria and, of these studies, only 57% provided evidence of the effectiveness of the constraints-led approach (CLA). Consequently, Clark and Christie argued that a "precise position on the implementation of the approach could not be made" (p.x). This is a revealing insight, which supports their claims that this finding "provides the opportunity for researchers to collect more compelling evidence to answer the question: '*Does constraint-led training assist with the development of technical skills within interceptive sport*?'". While we support their call for more empirical evidence on the effectiveness of a constraints-led approach (CLA) to practice and training design, we qualify it by highlighting some of the limitations of Clark and Christie's systematic review.

In this commentary on the paper by Clark and Christie we discuss key issues including: lack of a complete assessment of methodological validity of the reviewed papers; the inherent difficulties with the research methodologies employed in the studies; theoretical understanding to ensure that constraint-led approaches are better understood and distinguishable from other pedagogical approaches and their associated theoretical foundations; veracity of the intervention in each study; sampling of the environment (Brunswik, 1955) and assessing performance; sample

size (students versus elite populations); intervention length; and further areas of research that need to be addressed.

Risk of bias and procedures for assessing methodological validity of studies

We start by discussing the challenge of assessing putative constraint-based methodologies in interventions which may not have been clearly aligned with the theoretical principles of ecological dynamics, underpinning CLA. There is little evidence presented that the reviewed studies clearly adhere to the philosophical and theoretical underpinnings of the CLA, especially with respect to how practitioners and researchers have applied the key concepts and ideas to their experimental design. It was established by Clark and Christie that they used the Cochrane Collaborations tool for evaluating the risk of bias (Higgins & Altman, 2008). Domains of assessment include sequence generation, allocation concealment, blinding of participants, personnel and outcome assessors, incomplete outcome data, selective outcome reporting and other sources of bias. Summary outcomes of all studies for a particular domain need to be categorised as “low risk of bias”, “high risk of bias” and “unclear risk of bias”. However, as part of this procedure, there was no evidence provided that the studies sampled actually originated in a constraints-based theoretical rationale of ecological dynamics. Table 1 shows our assessment of the abstract and keywords of the sample studies. Of the 14 studies, only one, by Reid and Farrow, mentioned the word 'constraints' in the keywords and abstract, and that was in isolation from other key concepts of ecological dynamics, rendering some doubts about its selection. Importantly, none of the 14 studies mentioned constraints in relation to other key concepts from the theory of ecological dynamics which underpin a constraints based approach, such as: affordances, perception-action coupling, task, organismic or

environmental constraints, self-organisation, co-adaptation, metastability, or system dynamics. It is essential that researchers and practitioners alike are consistent with their understanding and application of CLA based interventions, predicated on key concepts in ecological dynamics (Davids et al., 2008).

Insert Table 1 here

Manipulation of interacting constraints in an intervention or manipulation of independent variables in an experiment?

What does this initial statistical/methodological criticism imply practically? The implication is that the high risk of bias with regards to assessing study methodology in the systematic review of Clark and Christie might have led to the selection of articles that did not investigate 'technical development' from a CLA that is embedded in the theoretical framework of ecological dynamics. Essential to the evaluation of studies purporting to adopt the CLA is ensuring that each study assessed is not merely manipulating experimental variables but rather that the key principles of CLA underpin an intervention. For proper assessment with regards to a relevant theoretical rationale in ecological dynamics, the term 'constraints' needs to be used in a highly specific way to refer to the boundaries which shape the emergence of coordinated behaviours (Newell, 1986) or to refer to information that leads to spontaneous self-organisation in system dynamics (Kugler & Turvey, 1987; Kelso, 1995; Jirsa & Kelso, 2004).

A constraints-led approach is a well-promoted framework for understanding how humans acquire and organise the necessary actions to successfully engage with sport

and exercise contexts (Renshaw *et al*., 2011; Davids *et al*., 2008; Araújo *et al*., 2004; Handford et al., 1997). The CLA articulates that, through the interaction of different constraints - task, environment, and organism -, individuals will self-organise actions, perception and cognitions in an attempt to generate functional movement solutions (Renshaw *et al.,* 2011). Ecological dynamics is a theoretical framework that has evolved by interlacing the theories of dynamical systems and ecological psychology, which inform principles of a nonlinear pedagogy, in which the methodological nuances of a CLA are captured in learning design (Chow *et al*., 2016). The fundamental relationship between theory and practice is not a trivial issue for philosophical reflection only, as James Gibson (the founder of ecological psychology) pointed out in drawing inspiration from the words of the Gestaltist, Kurt Lewin: "There is nothing so practical as a good theory" (Gibson, 1967, p. 135). The ecological dynamics framework illuminates the essential relationship between the learner and the environment as a key foundation of practice design and a theoretical tenet on which to consider the processes of skill acquisition. Adopting an ecological dynamics approach drives practitioners to conceptualise learners as complex, adaptive dynamical systems, co-adapting with events, objects and significant others in an ever-changing performance environment. Through the practical articulation of key theoretical ideas of ecological dynamics, guiding principles for the design of learning environments have been inferred, with relevant research still required to 'frame' the design of constraints-led practices. Philosophical and theoretical clarity has been provided by the extensive literature in the area of nonlinear pedagogy (cf. Handford et al., 1997; Davids et al., 2008; Renshaw *et al.,* 2009; Chow *et al.,* 2016). Without a comprehensive assessment of the methodological quality of studies in adhering to a

CLA, the conclusion remains that Christie and Clark's systematic review is at high risk of bias.

Comparison of effects of traditional pedagogies and constraints led training approaches

Clark and Christie proposed that a significant reason for their systematic review was, that "Currently, there is a lack of sufficient evidence to advocate whether the manipulation of specific task constraints benefit individuals more so than traditional training regimes." Yet in their review, this comparison was not undertaken with respect to carrying out a separate systematic review of what could be defined as studies investigating the efficacy of traditional pedagogies. Indeed, in their review, no attempts were made to provide rigorous definitions of traditional skill learning practices, nor to compare these characteristics with constraints based learning designs. This is an important challenge for future researchers in skill acquisition and sport pedagogy. First, clear definitions are needed to characterise different approaches and only then can rigorous assessment methodologies be undertaken to compare effectiveness of studies in different categories (traditional vs. CLA). The inherent intricacies in 'measuring' complex, emergent, adaptive, behaviours in skill performance should not serve as rationale for rejecting appropriate research methodologies, or indeed, serve as a rationale for rejecting an approach altogether. That we currently cannot effectively measure something, speaks more to the issue of methodological design and appropriate frameworks for representing a theoretical approach rather than it does for rejecting that approach as inappropriate for a field of study.

Representative Learning Design

Regardless of constraints manipulation, a major omission in the systematic review was the lack of evidence that studies were high in what Egon Brunswik (1955) termed *representative design.* This is a major principle of ecological dynamics for ensuring that task designs for learning and experiments contain relevant informational constraints to elicit the emergence of functional behaviours, as performers are drawn to exploit affordances available (Fajen *et al*., 2009). This key concept is founded on the idea of representative task design (Brunswik, 1955), advocating the need to maintain action-fidelity (Stoffregen *et al*., 2003). Brunswik's (1955) work has been adopted by ecological dynamicists (e.g., Pinder et al., 2011; Araújo et al., 2012), especially his request to sample performance contexts in the same way as researchers have traditionally considered the sampling of participants. Consequently, researchers and practitioners need to sample practice and experimental environments to ensure they have similar information) flows to a performance environment, making them more representative and maintaining greater action-fidelity. As result, any actions that emerge in interventions, via the processes of attunement and calibration generated, are more likely to transfer to a performance context (see van der Kamp and Renshaw, 2015). The concept of representative learning design (RLD) calls into question the value of practice task designs that are decontextualized through artificiality and reductionism (potentially breaking the coupling of perception and action systems) in a performance environment. To exemplify, in practical learning interventions, it is important not to design an environment that requires learners to dribble around cones or manikins – with the aim of creating realism – as this lacks the subtle informational constraints that authenticate valid practices, thus rendering a practice as lacking

representativeness. Without the information of opposing defenders, spatial (line markings) or temporal (tempo of a ball feed) informational constraints (to exemplify). there will be little strengthening of the perception-action couplings required in skilled performance. Whilst it is clear that further work is needed in developing clarity for practitioners in representative learning design, it is a key theoretical construct that should not be overlooked when considering criteria for reviewing effectiveness of interventions in research.

Choice Of Interceptive Actions Only

An interesting question concerns the choice of interceptive actions by Clark and Christie as the research domain for their systematic review, rather than sports in general such as sprinting, weightlifting, rowing and climbing. The issue of assessing the effectiveness of specific approaches to learning is important for the study of skill acquisition more generally, not just in interceptive actions, and not just when using constraints based methodologies. The framing of the systematic review around studies of interceptive actions needs a comprehensive rationale for its selection. Clark and Christie's choice to include interceptive actions resonates with the argument that it is integral to look beyond studies that only involve performance of dynamic interceptive actions in ball games and invasion game activities. Additionally, interceptive actions include a much wider range of activities than those covered in the systematic review to include all sporting activities as highlighted by the large number of studies (not intervention studies) that have ecological dynamics as the underpinning theoretical model (e.g. athletics hurdling - Moy, Renshaw & Davids, 2015; cricket bowling - Renshaw & Davids, 2004; Greenwood, Renshaw & Davids, 2016; diving - Barris et al, 2014; rock climbing - Seifert et al, 2013; swimming - Seifert et al, 2013). Perhaps,

Clark and Christie have confused the CLA with other Games Based pedagogies – which is a point we addressed in another paper, as a result of an uninformed reviewer's comment (see Renshaw *et al*., 2015). It is important to re-iterate our argument that studies purporting to use a CLA need verification of methodology by assessing that the theoretical principles of ecological dynamics underpin the rationale in a study. Although the sample of only 14 papers in this systematic review is not a methodological issue, it does draw attention to the lack of literature available on interventions and it is, therefore, surprising that Clark and Christie chose not to widen their range of analysis beyond interceptive actions. Regardless, it is worth reiterating a key finding of this paper that future research is required to determine the effectiveness of constraint-led training - not just on performance of a limited range of interceptive actions - to all areas of skill learning in a range of different sports. Significantly, this is not just of relevance for a CLA but is a major issue for developing our understanding of traditional approaches to learning sport skills, as well as frameworks like TGfU, schema theory, closed-loop control, variability of practice, contextual interference and the specificity of learning hypothesis, for which there have been no recent systematic or quantitative reviews conducted.

Further, it is not clear that quantitative reviews of experimental studies are the most appropriate way to engage with evidence on effectiveness of learning interventions, which is a major assumption behind the paper by Clark and Christie. The inherent belief seems to be that a classical experimental design is best for examining skill acquisition in sport using constraints based methodologies. It is worth challenging this ideology. A positivist approach to experimental design is employed by all of the studies reviewed in their systematic review. With the aim of establishing reliable

results, a reductionist approach to the control of methodological research design is common, but not necessarily appropriate in all instances. By removing the inherent representative variability required in studies from the measurement of key dependent variables, researchers attempt to ensure that the experimental conditions are similar between the pre- and post- intervention trials. The key driver behind employing a constraints-based methodology is to create training environments that are representative of a specific performance environment in order to enhance the transfer of skill learning between practice simulations and performance. This foundational idea in ecological dynamics raises questions on measuring the impact of a constraints-led intervention in an environment designed for the control of experiments, and which, consequently, may not be representative of a performance environment, as it might diminish the purposefulness of the training intervention itself. A paradigm shift towards the use of methods to access more qualitative information, in combination with quantitative methods (Camerino *et al*., 2012) may best suit the purposes of methodological evaluation in sport pedagogy. Future studies should explore the use of action research methodologies with the aim of capturing skill acquisition processes and the thorny issue of transfer to a performance environment.

Sample Size and Participants

Clark and Christie questioned the low sample size in the studies in the systematic review with more than half of the studies having relatively small sample sizes of six to ten participants per group and suggested that this may have had an impact on the reliability of the results. Sample size is a key challenge, especially if we want to work in messy, noisy, real-world, competitive sporting environments and when traditional experimental designs are seen as the gold-standard for research, often leading to an

over emphasis on the use of laboratory conditions and undergraduate students as participants. For example, elite athletes or developing experts, by virtue of their talent in to adapting to challenging performance environments are few and far between. Of course they are worthy of study, despite obvious limitations in sample sizes. The challenge here is to design methods that are consistent with a theoretical model and the commensurate need to capture individual differences in response to interventions. Approaches that may be worthy of further scrutiny are single case study and multiple baseline designs. A good example here is the basketball study of Oudejans (2005) who adopted a group and single case study design to study sports performers over a complete season.

The good news for skill acquisition scientists is that advances in technology and also greater acceptance from the point of view of evaluating types of knowledge – a constant battle of the sciences - means we have moved beyond traditional research designs and we are now able to collect data in real world settings. The key concern then becomes what information to collect from the vast plethora of information that *can* be collected (Renshaw & Gorman, 2015). Collecting data in complex sporting environments often requires a *distinct* approach to traditional hypothesis-based, experimental designs and the utilisation of mixed methods may be entirely warranted (Camerino *et al*., 2012).

Intervention Length

The length of the training interventions employed in some of the reviewed studies is also questionable, but for some time this has been recognised as an inherent problem with the ubiquitous ‘6-week training study’ prevalent across all of the sport science

disciplines (see Miller *et al.*, 2006). Within skill acquisition research, intervention studies rarely use training periods longer than nine weeks (Oudejans, 2005). In the sample of the systematic review, the studies by Masters et al. (2008), Hagemann et al. (2006), and Williams et al. (2002) consisted of only a single session, while the longest study reviewed consisted of 45 sessions over a nine-week period in table tennis (Raab *et al*., 2005). Such short periods of training are unlikely to produce a change in performance, let alone a measurable one. Previous research within the ecological dynamics realm has highlighted that learning can take place over different time scales. For example, attunement to a key informational constraint can lead to almost immediate improvements in performance (e.g. the cricket batter who is suddenly able to identify the wrist spin bowler's *googly* from the changes in his or her bowling action (Renshaw & Fairweather, 2000)). Alternately, changes can be more medium or long-term, with varied learning trajectories (see Newell, 2009). In fact, the way athletes react to any intervention is likely to be specific to each individual and their developmental history. This point also highlights the limitations of traditional group designs where individual responses can be masked and emphasises the need to move to research methodologies more in tune with the key ideas of ecological dynamics and complex systems in general (see Renshaw & Gorman, 2015 for an extended discussion of how to capture expertise in real world settings).

The role of Experiential Knowledge in assessing effectiveness of learning designs

Elsewhere it has been argued that many coaches and sport pedagogues implement a version of a constraints-based approach in their practice task design, which might be enhanced by a greater understanding of the theoretical concepts of ecological dynamics (Phillips et al., 2010; Greenwood et al., 2014, 2016). These studies have

revealed the potential value of elite coaches' experiential knowledge in understanding how to design training interventions, an often-overlooked source of knowledge. We have made the call for the experiential knowledge of coaches to be acknowledged and emphasised the need for coaches and sport scientists to work together (see Renshaw & Gorman, 2015). The value and role of experiential knowledge of coaches has often been neglected largely because of the inability to 'collect' data through classical experimental designs because of the inherent complexity of expertise or knowledge in coaching. A number of programmes of work are emerging that have meshed qualitative and quantitative research findings to enhance our understanding of expertise in sport (see Plujms *et al.*, 2013) in sailing and the PhD programme of Sarah-Kate Millar (2013) in rowing and Dan Greenwood (2014) in sport run-ups. We call for a continuation of this excellent work. Future quantitative reviews need to also consider a range of different data sources, rather than simply sample experimental studies in the scientific literature. To exemplify, a blog recently highlighted how the coach (Swys de Bruin) of the South African Super 16s franchise, the Lions, encouraged his players to enhance their adaptive variability and seek affordances from the opposition ('what they offer') to decide emergent game strategies:

Figure 1. **How to Beat the Kiwis - Be Unpredictable**

Furthermore, what are we to make of the post on the blog, Connected Coaches, by Blake Richardson outlining evidence behind Coach of the Year, Danny Kerry's, success at the 2016 Olympic Games in leading Team GB to an unexpected gold medal in field hockey? Important 'watch words' in the successful pedagogical practice included a constraints-led approach (see Figure 2).

Figure 2. **How Danny Kerry Put the Great into British Hockey**

Perhaps questions about understanding the efficacy of a constraints based approach to skill acquisition need to also consider opinions in a football coaching blog by Richard Allen (see Figure 3) asking: Do we really know how to utilise the constraints-led approach?

Figure 3. **Do We Really Know How to Use the Constraints Led Approach?**

This criticism of Clark and Christie's restricted approach in focusing on evidence from scientists only, and ignoring the voices of practitioners as stakeholders in resolving the issue of skill acquisition effectiveness, does raise an interesting challenge for researchers: How to assess the value of information from blogs, podcasts and media articles expounding the effectiveness of constraints-based coaching approaches?

Conclusion and Recommendations for future learning studies utilising a CLA

Clark and Christie rightly, in our view, highlighted the need for more research examining the efficacy of constraints based interventions in sport training and practice. However, this is an issue challenging skill acquisition theories and sport pedagogical frameworks across the board. A systematic review will only provide an analysis of the quality of findings from experimental studies of skill learning, some of which may contain reductionist methods less suited to providing the quality of evidence needed on intervention efficacy from a range of different sources. These include experiential knowledge of elite practitioners and athletes, as well as information from action-based research in which researchers are embedded in sports

training environments. A particular challenge here is to also ascertain the quality of information evident in digital media such as blogs, websites and podcasts. With regards to the specific systematic review undertaken by Clark and Christie, there are a number of factors addressed in this commentary that highlight some of the potential limitations of the studies and the conclusions of their review. We identified how researchers interested in adopting CLA can address these issues to inform future directions of research, including the following:

- CLA is applicable to all sports and physical activities, not just those which contain interceptive actions. As CLA is based on an ecological dynamics theoretical rationale, the methodologies of the reviewed studies need to be assessed as embedded within that specific framework.
- Longitudinal Studies: Future research designs on the CLA need to track skill learning, not over days, weeks or months, but over seasons and years.
- Use of Individual or Multiple Baseline Methodologies: Traditional group based designs with control groups is not necessarily the most appropriate when implementing a CLA in terms of the theoretical concepts or the ethics of impacting athlete's careers. This is especially the case when it comes to assessing impact of CLA interventions on elite and developing expert athletes. It is simply not feasible to undertake experimental manipulations with such groups.
- Representative 'Testing': Appropriate measurement of interventions should be developed that utilises the knowledge of practitioners and scientists
- Participants and Sample Sizes: By definition, if we want to move away from 'student' populations and test the effectiveness of CLA in sports performance

settings, interventions need to take place in the messy, noisy world of competitive sports performance.

- Robust Environment Design: frameworks are required to bridge the gap between the theoretical understanding and its practical application. These will acts as a guidance tool for practitioners and researchers to ensure they are designing environments consistent with the underpinning principles of ED.

Whilst it is clear that the work of Clark and Christie is a timely and valuable introspection into the potential of the CLA, it is clear that much work is required by researchers and practitioners alike to better *frame* research on applications in the field of skill acquisition in sport. It is clear that further work is required to espouse the relevance and practical application of constraints-led approaches, but we must move beyond inappropriate and reductionist methodologies that *test* performance outcomes and instead seek to *understand* real world, messy, representative and authentic sport practice by designing appropriate *frameworks* for practical application and assessing methodological fidelity for *researching* pedagogical practice in the real world.

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