Understanding constraints on sport performance from the complexity sciences paradigm: An ecological dynamics framework

SEIFERT, Ludovic, ARAÚJO, Duarte, KOMAR, John and DAVIDS, Keith <http://orcid.org/0000-0003-1398-6123>

Published version

SEIFERT, Ludovic, ARAÚJO, Duarte, KOMAR, John and DAVIDS, Keith (2017). Understanding constraints on sport performance from the complexity sciences paradigm: An ecological dynamics framework. Human Movement Science, 56 (A), 178-180.

Copyright and re-use policy

Understanding constraints on sport performance from the complexity sciences paradigm: An ecological dynamics framework

Ludovic Seifert, CETAPS EA3832, Faculty of Sport Sciences, University of Rouen, France

Duarte Araújo, CIPER, Faculty of Human Kinetics, SpertLab, University of Lisbon, Cruz Quebrada Dafundo, Portugal

John Komar, CETAPS EA3832, Faculty of Sport Sciences, University of Rouen, France

Keith Davids, Centre for Sports Engineering Research, Sheffield Hallam University, Sheffield, United Kingdom

Glazier's suggestion for the constraints-led approach as a GUT for sport performance is a worthy proposal. A proposal for a GUT has appeared in the area of Sports Medicine in recent years (i.e. 'GUTSME), but its focus on a 'unified theory for soft tissue injury causality or management' (Hamilton, 2013, p.2), supports its interpretation as an argument for greater theoretical and empirical underpinning of practical activities to understand 'the three traditional cornerstones' of the profession: prevention, treatment and enhancement. This limited conceptualisation of a GUT was later exemplified by Luxton's (2015) proposal of how systems biology could be used to explain lactate thresholds in sport performance. What is missing from these preliminary insights is a principled basis, in the form of pillars, for understanding the cornerstones of the sports medicine profession, and this lack of an *overarching* theoretical framework is also somewhat of a limitation in Glazier's initial ideas, as we argue later.

Clearly, however, Glazier's proposal is intended to be more far-reaching than these calls for a greater recognition of the relations between theory and practice in sports medicine, focused instead on developing a theoretical framework for understanding the many diverse, but interrelated, aspects of sport performance. Here we suggest that his preliminary proposal would benefit from considering a more comprehensive ontological positioning within the complexity sciences paradigm to benefit from conceptualising athletes and sports teams as complex adaptive systems. We argue that ecological dynamics provides a more encompassing rationale than the constraint-led approach because it is a multi-dimensional theoretical framework shaped by many relevant disciplines (including but not limited to physics, biology, evolutionary sciences, mathematics, psychology, and the social sciences). Ecological dynamics has the potential to provide an integrated explanation for human behaviour in sport predicated on a theory of constraints on dynamical systems (Kelso, 1995; Newell, 1986), ecological psychology (Gibson, 1979), and a complex systems approach in neurobiology (Edelman & Gally, 2001; Price & Friston, 2002). Glazier has drawn attention to some of the main roots of the constraint-led approach in his argument (e.g., non-equilibrium thermodynamics, homeokinetics, synergetics). Although this approach has some relevance and merit in avoiding the pitfall of a biased 'organismic asymmetry' that cognitive orientations promote (Davids & Araujo, 2010), it focuses on extending physical explanations of athlete-environment relations, and neglects the specificities of human behaviour (needed to understand performance) captured in psychology (especially ecological psychology), biology (for example systems biology, evolutionary biology, neurobiology, neuro-anatomy) and the social and cultural sciences. What is needed is a GUT which can reposition physics to understand athlete and team behaviours at many diverse levels in sport. We propose that ecological dynamics provides an interdisciplinary conceptualisation beyond the physical description of constraints. For this reason, it might be more suitable to postulate a grand unified theory of sports performance at the level of ecological dynamics instead of at a worthy component level of the framework i.e. the constraint-led approach with its application in dynamical systems.

Ecological dynamics offers a rich, unifying perspective to understand and explain sport performance, based on theoretical assumptions on human behaviour, which roots in complexity sciences paradigm, such as *self-organization, emergence, synergy, non-linearity and non-proportionality, embodiment-embedded cognition, sense-making, experience, information-movement coupling* and *affordances* (for a review on this proposal, see Davids et al., 2014). There are three main pillars of ecological dynamics, which makes it richer than a constraints-led approach as a GUT for sport performance.

The first pillar is viewing athletes and sports teams as *complex adaptive systems* which exhibit properties such as *non-linearity* and *non-proportionality*, questioning whether the causality between patterns of coordination and the performance outcome is linear *vs.* non-linear, unidirectional *vs.* circular. In this regard, recent investigations of the movement-performance relationship showed evidence that (i) there is a non-proportionality between improvement of coordination and performance outcome (for example, see Delignières et al., 1998; Nourrit, Delignières, Caillou, Deschamps, & Lauriot, 2003), and (ii) studying coordination by itself is not enough to account for a specific performance level (for example in soccer kick, ski simulator, breaststroke swimming, basketball free throw, see Chow et al., 2009; Hong & Newell, 2006; Komar, Chow, Chollet, & Seifert, 2015; Rein, Davids, & Button, 2010). For instance, coordination patterns can differ, although a similar functional performance outcome is observed, which corresponds to the "*principle of functional equivalence*" (Kelso, 2012, p. 907), and is also identified under the concept of degeneracy defined as "*the ability of elements that are structurally different to perform the same function or yield the same output*" (Edelman & Gally, 2001, p. 13763). The same perspective has been highlighted in skill acquisition by Seifert, Komar, Araújo & Davids (2016), illustrated in sport by research in swimming, climbing and team games. For example Delignières et al. (1998) showed that changes in coordination and performance are neither proportional, nort linear. In a balancing task in gymnastics, novice participants were able to improve their performance with practice (i.e., the amplitude of the swing) without any qualitative change in their behaviour. The authors suggested that, despite the gradual change in performance with practice, a discontinuity needs to occur in the behaviour of novices in order to gain access to expert coordination (Delignières et al., 1998). This non-proportionality between behaviour and performance has been related to the concept of sensitivity to initial conditions (a.k.a. *butterfly effect*), when at some point during practice, a small change in behaviour can lead to a drastic increase or decrease in performance and conversely a big change in behaviour can lead to a marginal increase of performance. This example demonstrate that coordination and the performance outcome do not share the same dynamics, promoting the need for studying sports performance at different levels of analysis, with an integrative perspective that could be supported by ecological dynamics theoretical framework.

The second important pillar is that brain and behaviour must be considered together to analyse sport performance, as suggested in ecological dynamics (Davids, Araújo, Hristovski, Passos, & Chow, 2012), and in other theories, such as the enactive perspective (Stewart, Gapenne, & Di Paolo, 2010; Thompson & Varela, 2001; Varela, Thompson, & Rosch, 1991). The enactive perspective proposes a complementary focus on biology and phenomenology to understand not only emergence, self-organization and embodiment phenomena but also sense-making and experience processes and the complexity between those phenomena that shape the way behaviour is dynamically patterned (De Jaegher & Di Paolo, 2007; Froese & Di Paolo, 2011; Froese, 2012). Glazier argues that dimensional compression "*simplifies the problem of regulating movement since the central nervous system only has to macro-manage the collective, not micro-manage its constituents*" (p.5). An ecological dynamics perspective does not place an inordinate emphasis on the role of representations in the central nervous system, or on any other internal structure of the organism. Rather functional behaviours emerge from each organism-environment system. This more symmetric view focuses on individual adaptability in evolutionary functional contexts (Seifert et al., 2014). From this perspective, athletes are active individuals engaged in ongoing dynamical transactions with their functionally defined environments. A movement is not an entity stored by an individual in the central nervous system, but rather a dynamically varying relationship captured by the constraints imposed by the environment and the resources of a performer (Araújo & Davids, 2011). Consequently, the individual-environment system forms the minimal ontology for describing sport performance for which an ecological dynamics perspective is well placed to provide a more comprehensive rationale. Individuals and contexts co-determine each other during ecological interactions (Barab & Plucker, 2002). Both individual and environment (physical or social) have the potential to be impacted and transformed by these interactions.

The third pillar of ecological dynamics relates to the role of *information-movement coupling* in sport performance in which athlete behaviours and interactions in a competitive performance environment are considered to be regulated by the information available. Such information needs to be used by performers as they become perceptually attuned to affordances, which specify actions in competitive sport performance contexts. In ecological dynamics an individual's expertise can be explained without postulating internal controlling structures. This approach emphasizes understanding of the transaction between affordances (opportunities for action) and how performers become attuned to perceive those affordances that specify goal achievement (Gibson, 1979; see Davids & Araújo, 2010 specifically about sport performance). Affordances, perceived in 'animal-relevant' terms, can be more than mere opportunities for action, and invite or solicit actions from an organism (Withagen, de Poel, Araújo, & Pepping, 2012). Interestingly, from the perspective argued in Glazier's target article, James Gibson (1979), who created the concept of affordance, considered that affordances *constrain* behaviours (p.411). Indeed, "*within the theory of affordances,* *perception is an invitation to act, and action is an essential component of perception*" (Gibson, 1979, p.46). Through exploratory actions in specific contexts, perceptual systems become progressively attuned to invariants in the environment (Vicente & Wang, 1998). With task-specific experience, each individual's abilities become more attuned to the used information (Jacobs & Michaels, 2007). Successful performance in sport, therefore, derives from an increasingly functional fit between an individual and a performance environment (Davids & Araújo, 2010). For instance, a recent study about learning in a climbing task showed that a relevant performance indicator might be the ability of performer to functionally explore the environment (Seifert, Boulanger, Orth, & Davids, 2015). In other words, high sports performance could be reflected by being able to use many different coordination patterns while keeping contact with his environment and maintaining high efficiency/effectiveness (i.e. being highly adaptable).

In conclusion, we welcome the proposal of a GUT predicated on constraints to understand sport performance. Such a framework is much-needed but a constraints-led approach is only part of the necessary comprehensive rationale that ecological dynamics can contribute to develop from complexity sciences paradigm.

References

Araújo, D., & Davids, K. (2011). What Exactly is Acquired During Skill Acquisition? *Journal of Consciousness Studies*, *18*, *3*(4), 7–23.

Barab, S., & Plucker, J. (2002). Smart people or smart contexts? Cognition, ability, and talent development in an age of situated approaches to knowing. *Educational Psychologist*, *37*(3), 165–182.

Chow, J. Y., Davids, K., Button, C., Rein, R., Hristovski, R., & Koh, M. (2009). Dynamics of multi-articular coordination in neurobiological systems. *Nonlinear Dynamics, Psychology, and Life Sciences*, *13*(1), 27–55.

Davids, K., & Araújo, D. (2010). The concept of "Organismic Asymmetry" in sport science. *Journal of Sports Sciences*, *13*(6), 633–40. doi:10.1016/j.jsams.2010.05.002

Davids, K., Araújo, D., Hristovski, R., Passos, P., & Chow, J. Y. (2012). Ecological dynamics and motor learning design in sport. In N. J. Hodges & A. M. Williams (Eds.), *Skill acquisition in Sport: research, theory and practice* (2nd Editio., pp. 112–130). New York, NY, USA: Routledge (taylor and francis Group).

Davids, K., Hristovski, R., Araújo, D., Balague Serre, N., Button, C., & Passos, P. (2014). *Complex systems in sport*. London, UK: Routledge, Taylor & Francis Group.

De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making: An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, *6*, 485–507. doi:DOI 10.1007/s11097-007-9076-9

Delignières, D., Nourrit, D., Sioud, R., Leroyer, P., Zattara, M., & Micaleff, J.-P. (1998). Preferred coordination modes in the first steps of the learning of a complex gymnastics skill. *Human Movement Science*, *17*, 221–241.

Edelman, G. M., & Gally, J. a. (2001). Degeneracy and complexity in biological systems. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(24), 13763–8. doi:10.1073/pnas.231499798

Froese, T. (2012). From adaptive behavior to human cognition: a review of Enaction. *Adaptive Behavior*, *20*(3), 209–221.

Froese, T., & Di Paolo, E. (2011). The Enactive Approach: Theoretical Sketches From Cell to Society. *Pragmatics & Cognition*, *19*, 1–36.

Gibson, J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Hamilton B. (2013). Towards a “Grand Unifying Theory of Sports Medicine” (AKA “Guts Me”). New Zealand Journal of Sports Medicine, 40 (1), 2-3.

Hong, S. L., & Newell, K. M. (2006). Change in the organization of degrees of freedom with learning. *Journal of Motor Behavior*, *38*(2), 88–100. doi:10.3200/JMBR.38.2.88-100

Jacobs, D. M., & Michaels, C. F. (2007). Direct Learning. *Ecological Psychology*, *19*(4), 321–349. doi:10.1080/10407410701432337

Kelso, J. A. S. (1995). *Dynamic Patterns: the self-organization of brain and behavior*. Cambridge, MA: MIT.

Kelso, J. A. S. (2012). Multistability and metastability: understanding dynamic coordination in the brain. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *367*(1591), 906–18. doi:10.1098/rstb.2011.0351

Komar, J., Chow, J. Y., Chollet, D., & Seifert, L. (2015). Neurobiological degeneracy: Supporting stability, flexibility and pluripotentiality in complex motor skill. *Acta Psychologica*, *154*, 26–35.

Luxton, S.J. (2014). A response to: Towards a “Grand Unifying Theory of Sports Medicine” (AKA “Guts Me”). New Zealand Journal of Sports Medicine 41, 37-38.

Newell, K. (1986). Constraints on the development of coordination. In M. Wade & H. Whiting (Eds.), *Motor development in children: Aspects of coordination* (pp. 341–361). Amsterdam: Martinus Nijhoff Publishers.

Nourrit, D., Delignières, D., Caillou, N., Deschamps, T., & Lauriot, B. (2003). On discontinuities in motor learning: a longitudinal study of complex skill acquisition on a ski-simulator. *Journal of Motor Behavior*, *35*(2), 151–170.

Price, C. J., & Friston, K. J. (2002). Degeneracy and cognitive anatomy. *Trends in Cognitive Sciences*, *6*(10), 416–421.

Rein, R., Davids, K., & Button, C. (2010). Adaptive and phase transition behavior in performance of discrete multi-articular actions by degenerate neurobiological systems. *Experimental Brain Research*, *201*(2), 307–22. doi:10.1007/s00221-009-2040-x

Seifert L., Komar J., Araujo D., Davids K. (2016). Neurobiological degeneracy: A key property for functional adaptations of perception and action to constraints. *Neuroscience and Biobehavioral Reviews*. 69, 159–165.

Seifert, L., Boulanger, J., Orth, D., & Davids, K. (2015). Environmental Design Shapes Perceptual-motor Exploration, Learning, and Transfer in Climbing. *Frontiers in Psychology*, *6*, 1819. doi:10.3389/fpsyg.2015.01819

Seifert, L., Komar, J., Barbosa, T., Toussaint, H., Millet, G., & Davids, K. (2014). Coordination pattern variability provides functional adaptations to constraints in swimming performance. *Sports Medicine*, *44*(10), 1333–45.

Stewart, J., Gapenne, O., & Di Paolo, E. (2010). *Enaction: Toward a new paradigm for cognitive science*. Cambridge, MA: MIT Press.

Thompson, E., & Varela, F. (2001). Radical embodiment: neural dynamics and consciousness. *Trends in Cognitive Sciences*, *5*(10), 418–425.

Varela, F., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge, MA, USA: MIT Press.

Vicente, K., & Wang, J. (1998). An ecological theory of expertise effects in memory recall. *Psychological Review*, *105*, 33–57.

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