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Bongers, R.

Published in:
Physics of life reviews

DOI:
[10.1016/j.plrev.2021.02.003](https://doi.org/10.1016/j.plrev.2021.02.003)

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Bongers, R. (2021). Action and perception manifolds have gradients that may play a role in learning Comment on "Laws of nature that define biological action and perception" By M. Latash. *Physics of life reviews*, 37, 5-6. <https://doi.org/10.1016/j.plrev.2021.02.003>

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Comment

Action and perception manifolds have gradients that may play a role in learning

Comment on “Laws of nature that define biological action and perception” By M. Latash

R. Bongers

University of Groningen, University Medical Center Groningen, Department of Human Movement Sciences, Groningen, the Netherlands

Received 15 February 2021; accepted 18 February 2021

Available online 22 February 2021

Communicated by L. Perlovsky

In his state-of-the-art overview, Latash [1] presents an original approach to unify action and perception that is based on physical laws grounded in physiological mechanisms of neural control of movement. This approach accounts for two distinguishing features of goal-directed actions; goal-directed actions are flexible, implying that the same goal can be reached in different ways, while at the same time they are stable to small perturbations. In his approach Latash proposes referent coordinates (RCs) at the task level, that organize the motoric degrees of freedom into a task-specific system using a type of control in line with the Equilibrium Point control and the Uncontrolled Manifold (UCM) hypothesis. Extending this with a so-called Iso-Perceptual Manifold (IPM), which is grounded in the same physiological mechanism as that explain motor control, accounts for a stable and flexible perception of body parts and their movement.

RCs at the task level are converted to RCs at lower levels, creating moments around joints and forces in muscles [1]. These RCs at all levels in the motor system create energy gradients in the high-dimensional space of relevant elemental variables (e.g. joint angles). These energy gradients imply that not all locations on a UCM for a given task are as likely to occur, but only a small portion of the UCM is occupied during repeatedly performing a task. For instance, when repeatedly holding the index finger at a certain position the posture in the arm will vary a little bit each time but the differences in the postures are not large. On the UCM an energy gradient specifies the posture with least energy for that particular task and the posture used varies around that position (i.e., flexibility). Note that task constraints affect the shape of these energy gradients, and thus the location on the UCM at which the task is performed. For instance, reaching to a target or intercepting an object at that same target location implies different task constraints and Tuitert et al. [2] showed that the joint angle configuration in the arm at the target was at a different location on the UCM for the two tasks. This indicates that different constraints affect the RCs at different levels and create energy gradients in spaces of elemental variables. It is likely that this idea of gradients also holds for the IPM.

The notion of gradients in high-dimensional spaces of elemental variables and in manifolds (i.e., UCM and IPM) in those spaces opens up possibilities for understanding how flexibility and stability are exploited during action and perception learning [3,4], extending the approach of Latash [1]. Learning a new coordinative pattern when the end-

DOI of original article: <https://doi.org/10.1016/j.plrev.2020.07.007>.

E-mail address: r.m.bongers@umcg.nl.

effector has to be in the same location, such as a modification of the fore-hand swing in tennis to play with more top-spin, implies a search on the UCM. Performing different types of fore-hand swing implies different task constraints and hence different gradients on the UCM with different locations of minimal energy. The change in the gradient on the UCM shifts the performance of the fore-hand swing over trials from a swing with less to a swing with a lot top-spin. Note that the gradients keep the performance stable while allowing for flexibility between different task performances. Learning a new task, such as a back-hand swing, destabilizes the UCM for the fore-hand swing and the new task constraints create gradients towards the UCM for the back-hand swing. Lastly, learning a new task not just involves new coordinative patterns but might also involve the use of different informational (i.e., perceptual) variables. Gradients in the IPM might guide the search for informational variables (cf. [5]), but understanding this search requires new experiments.

Several questions about the proposal in the review can be identified. For instance, on the UCM the co-variation over repetitions originates from a back-coupling mechanism [6]. However, it is unclear whether co-variation also occurs in the IPM and which underlying mechanism might account for it. Moreover, it is unclear how the IPM guides action and perception since the different axes in this space represent action variables or perceptual variables, creating a space that might not be fully commensurate. Finally, the RCs at task level are defined with respect to the organism and the environment, but at this time it is unclear on the basis of which informational variables aspects of the environment are specified in the IPM. Thus, we support the approach as proposed in the review and we see it provides new opportunities to understand exploration in learning while at the same time we see challenges that require addressing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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