



Bernstein's levels of movement construction: A contemporary perspective

Vitor L.S. Profeta^{a,*}, Michael T. Turvey^{a,b}

^a Center for the Ecological Study of Perception and Action, University of Connecticut, Storrs, CT, USA

^b Haskins Laboratories, New Haven, CT, USA

ARTICLE INFO

Keywords:

Bernstein
Control
Coordination
Synergy
Movement construction

ABSTRACT

Explanation of how goal-directed movements are made manifest is the ultimate aim of the field classically referred to as “motor control”. Essential to the sought-after explanation is comprehension of the supporting functional architecture. Seven decades ago, the Russian physiologist and movement scientist Nikolai A. Bernstein proposed a hierarchical model to explain the construction of movements. In his model, the levels of the hierarchy share a common language (i.e., they are commensurate) and perform complementing functions to bring about dexterous movements. The science of the control and coordination of movement in the phylum *Craniata* has made considerable progress in the intervening seven decades. The contemporary body of knowledge about each of Bernstein's hypothesized functional levels is both more detailed and more sophisticated. A natural consequence of this progress, however, is the relatively independent theoretical development of a given level from the other levels. In this essay, we revisit each level of Bernstein's hierarchy from the joint perspectives of (a) the ecological approach to perception-action and (b) dynamical systems theory. We review a substantial and relevant body of literature produced in different areas of study that are accommodated by this ecological-dynamical version of Bernstein's levels. Implications for the control and coordination of movement and the challenges to producing a unified theory are discussed.

1. Introduction

Nicolai Bernstein's essay *Levels of Construction of Movements* was written some 70 years ago. An English translation from the original Russian by Mark L. Latash was published in 1996. The publication was in a volume entitled *Dexterity and its Development* (Latash & Turvey, 1996) that included contributions by a dozen contemporary movement scientists. At the core of *Levels of Construction of Movements* is a hierarchical neural model. The model is framed in terms of the evolution of the nervous system in the phylum *Craniata* (see Margulis & Schwartz, 1998). It proposes that each level of the hierarchy evolved to solve a particular class of movement problems.

Anatomically, the hierarchy is built bottom-up with older levels at the base of the hierarchy. Functionally, the hierarchy operates top-down with the upper and younger of any two levels taking advantage of the functional capabilities of the lower and older level so as to decrease the upper level's involvement. Any movement requires at least two levels, establishing a relationship of leading and background levels. The “leading” refers to the upper level that controls the given movement and the “background” refers to the level or levels that provide the necessary support for the given movement.

* Corresponding author.

E-mail address: vitor.da_silva_profeta@uconn.edu (V.L.S. Profeta).

The neural-based treatment that Bernstein gave to the construction of movement was necessary to bring different movement demands into a common language. Despite Bernstein's efforts to apprehend the wholeness of the system of movement organization, the enterprise, both past and present, has been to study the levels independently. Considerable progress has been made in this endeavor. In our opinion, it would be fruitful (a) to summarize this progress and (b) to identify, as Bernstein did, a means to reconcile the levels of movement construction in terms of a single and coherent model.

In this essay, we present what might be termed an ecological-dynamical perspective on Bernstein's model of movement construction or assembly. An ecological perspective is grounded in the assumption of mutuality between an animal and its environment. More specifically, understanding any given animal's behavior requires an appreciation of what behaviors the animal's environment affords (Gibson, 1979): the animal-environment system constitutes the unit of analysis. In turn, a dynamical system approach to movement relies on mathematical concepts of nonlinear dynamics to describe and interpret coordination (e.g., Kugler, Kelso, & Turvey, 1980), which is understood as an emergent state produced by self-organizing processes (Kelso, 1995; Kugler & Turvey, 1987). The ecological and the dynamical perspectives seek lawful regularities in behavior and advocate parsimony in the promotion of local executive control.

Our goal is to establish the state of the art at each of Bernstein's levels from the ecological-dynamical perspective. More than offering definitive answers, we offer a viewpoint and suggest (to movement scientists in general and, in particular, those abiding an ecological-dynamical perspective) a way to grasp the big picture of the coordination and control of movement.

The remaining of this essay is organized in four sections. In Section 2, we revisit *Levels of Construction of Movements* identifying its primary themes. In Section 3, we present the bulk of the essay, a re-examination of each of Bernstein's levels in the light of contemporary conceptual advances and experimental results. In Section 4, we offer some thoughts towards reconciliation of the levels as a modern version of Bernstein's original attempt. In Section 5, we conclude presenting an agenda to push further the ecological-dynamical perspective presented in this essay.

2. Bernstein's hierarchy of movement construction

Fig. 1 shows schematic relations among the levels comprising Bernstein's hierarchical account of how movements are constructed. The first level is the Level of Tonus. This level establishes the communication between the neural and muscular systems. In Bernstein's words, this level speaks the "muscle language". Residing in the spinal cord, the first level's function is to prepare the movement apparatus to respond adequately to commands (influences, instructions, constraints) coming from upper levels of movement construction by changing the excitability of sensory and motor cells. Consequently, it is never a leading level in the performance of a purposive movement. It is always strictly a background level. The form that a movement takes in solving a particular movement challenge is never defined at the Level of Tonus. Without the Level of Tonus, however, the movement apparatus would be unprepared to respond adequately to upper-level commands and the intended movement form would never be made manifest.

The Level of Synergies (or the Level of Muscular-Articular Links) is the second level of movement construction in Bernstein's hierarchy. Residing in the middle brain, it constrains the degrees of freedom of the motor apparatus and guarantees coherence in movements by controlling large choirs of muscles. Synergies are shaped by the inflow of proprioceptive information about the whole body. Besides its relevance and unique function, the Level of Synergies happens to be, like the Level of Tonus, a background level when one performs any movement oriented to an external goal. Its function is to correct the details of movements. That is the case because the Level of Synergies is not informed by (does not receive afference from) either the visual or auditory systems, thus it is not

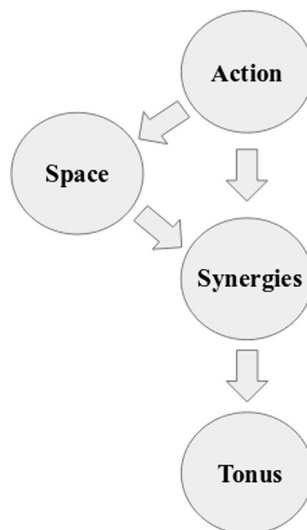


Fig. 1. Schematic representation of functional interaction among Bernstein's levels of construction of movements. Arrows indicate directions of dominance between levels, from leading to background levels. See text for details.

Download English Version:

<https://daneshyari.com/en/article/7290948>

Download Persian Version:

<https://daneshyari.com/article/7290948>

[Daneshyari.com](https://daneshyari.com)