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2 **Movement in the philosophy of mind:**  
3 **traces of the motor model of mind in**  
4 **the history of science**  
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9 **1 The motor model of mind**

10 A new model of mind, the so called “motor model”, is gaining the scene  
11 within contemporary neurosciences, raising from a fertile “triangulation”  
12 [36] of data and from the acquisitions — theoretical, experimental and clinical —  
13 of different disciplines, from experimental psychology of cognitive  
14 processes to neuropsychology, from cognitive neurosciences “systemic” or  
15 “holistic” in the sense these terms are used by Kandel) [1] to mathematical  
16 modelling and to the most recent philosophy of mind. It is a model of the  
17 “incarnate” or “embodied” mind, rooted at the very intersection of these  
18 different disciplines (each endowed with specific conceptual and methodological  
19 tools, as well as with a specific level of complexity in the explanation  
20 of behaviour) and, departing exactly from their convergence, it aims at imposing  
21 a new concept of mind. A mind whose genetic roots are located far  
22 “below” and much “before” consciousness and will, in the organism’s vital  
23 drives and in kinesthesia. As a consequence, it is in the body and in the  
24 brain that the basic premises of the study of the cognitive functions are  
25 to be identified. The brain, within this theoretical framework, is specifically  
26 intended as an organ whose development was principally aimed at  
27 predicting the consequences of action rather than, in a classical fashion, as  
28 a generator of responses to stimuli coming to the organism from the more  
29 or less external environment. This new, action-based approach to the mind,  
30 in fact, attributes to body movement a basic and fundamental role in the  
31 development of consciousness and cognition [19, 6, 10, 7, 12].

32 Thus, with the aim of preserving the fertile epistemological interaction  
33 of a phenomenology of behaviour with the models of its underlying causal  
34 mechanisms, the new philosophy of mind aims at a philosophical foundation  
35 of the so called physiology of action. Choosing action as a cornerstone, as  
36 a theoretical lens through which to observe the behaviour in its wholeness,  
37 and therefore mind, naturally implies a stronger emphasis on the specificity

38 of the organism, on its being intrinsically goal-oriented and in an active  
39 and constructive interaction with its environment. The organism is, in fact,  
40 conceived as a sort of constant generator of hypotheses, that selects sensory  
41 information depending upon the aims of the action. In this theoretical  
42 perspective — biological, dynamic and integrated —, rather than as a bare  
43 motor expression of sensory computation, action is conceived as an active  
44 and goal-oriented “kinetic melody”<sup>1</sup>, a structured ensemble of co-ordinated  
45 movements in function of a specific aim.

46 Attributing to body movement a basic and fundamental role in the devel-  
47 opment of consciousness and cognition, allows a peculiar conceptual inver-  
48 sion, through which mind is interpreted as “moulded” by movements (which  
49 it traditionally plans and directs), and movement is no more the means to  
50 satisfy the needs of higher cerebral centres (mind): to the contrary, it is mind  
51 to be the tool to perform actions; thinking equals to decide what movement  
52 to perform next. Mind is intrinsically a motor system: thought, memory,  
53 cognition, perception, consciousness, motivation, meaning, in short, all that  
54 is mental, is a product of constructive motor capacities. Of course, strongly  
55 stressing the biological matrix of mental phenomena implies the overcoming  
56 of the Cartesian and universal epistemic subject, on which modern philos-  
57 ophy was based (a subject non-biologically conceived, thus separated from  
58 “external reality” that he aims at understand); it implies also the grounding  
59 of cognitive functions in evolution and history, in personal and interpersonal  
60 experience.

61 Hence it derives a model of the living being, of the environment and of  
62 the mind, aimed at finally overcoming the limitations of mechanism and  
63 of the metaphysical watershed that has kept body and mind separated for  
64 centuries. From the study of movement and form cognitive neurosciences, a  
65 new way to the embodiment of mind is thus taking form, based on a bodily  
66 and non-propositional concept of representation; in this sense the philos-  
67 ophy of action proposes itself as a theoretical route to the overcoming of  
68 the dichotomic contraposition between bodily mechanism and mental rep-  
69 resentation, between subject and object, mind and world. For an authentic  
70 understanding of cognitive functions it is in fact considered indispensable  
71 the fundamental relation between organism (with its aims, its needs, its  
72 history, etc.) and environment, between observer and phenomenon, within  
73 the scope of a concept basically grounded on an interactive constructivism.  
74 It incorporates the co-evolution of species and environment and the com-

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<sup>1</sup>Pierre Janet (1859–1947)— in open contrast with the reductionist, molecular ap-  
proach adopted in those very years by the American behaviorist psychology — developed  
the concept of “conduct”, intended as “global behaviour, intentional and intrinsically  
meaningful” [18] opposing it to the conception of behaviour in terms of mere Stimulus-  
Response associations.

75 plex interaction between the subject and the world in a theoretical frame  
76 characterized by a complex and dynamic interaction: of the organism with  
77 the environment (intended as *Umwelt*), of the body with the brain and of  
78 the “bodybrain” with the mind.

79 The tight intertwinement of motricity and thought is by now evident  
80 at a phylogenetic as well as at an ontogenetic level<sup>2</sup>. The incarnation of  
81 *cogito* emerges from neurosciences as the recognition of the capacity of the  
82 body to anticipate, imagine, mimic and forecast the actual body move-  
83 ment. The fundamental theoretical assumption, the unifying frame, is the  
84 constitutively temporal and material dimension of experience, the mutu-  
85 ally formative interaction between organism and environment. Experience  
86 is conceived as an anticipatory construction, insofar as it is considered the  
87 adaptive outcome of the essentially active nature of a subject that deter-  
88 mines by itself the object of possible experience. It is an important step,  
89 maybe nearly the goal, of a process of naturalisation of mind that from  
90 Darwin to contemporary neurosciences has aimed at arriving at symbols  
91 starting from matter, rather than looking at the latter, in our perception of  
92 reality, in terms of hypotheses and calculations, languages and symbols to  
93 decipher. Contrary to the 20th Century functionalistic approach, brain is  
94 not conceived as a computer, nor as any machine resembling an AI device,  
95 rather it is an original biological construction, the product of evolution,

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<sup>2</sup>Developmental psychology and contemporary neurosciences have clearly demon-  
strated that the embryo is primarily a motor organism, before than a sensory one; in  
the embryonic phase, in the phoetal one and in early infancy action precedes sensation,  
reflex movements are performed before any concept of them is developed (already Bain,  
in the mid-Nineteenth Century, had clearly expressed such a concept, conjugating philo-  
sophical reflection, coming from Anglo-Saxon associationism of empiricist tradition, with  
Darwinian intuitions and with the experimental acquisitions by the physiologists of the  
“Berlin Circle”, Helmholtz among them). Movement is a basic factor in infant develop-  
ment: it is through observation and motor action that the child operates a series of  
concrete learning actions that progressively develop into abstract concepts. The devel-  
opment of human mind unfolds along stages that are based on the concreteness of motor  
actions and sensations, instead than on the abstraction of language and logico-symbolic  
thought: we adjust to reality through forms of learning and generalisation. It will at  
this point be useful to recall the words of Piaget (1896–1980), to whom — as it is well  
known — consciousness is based on the concrete activity of the entire organism, in the  
sensory-motor coupling of mind, body and environment; cognitive structures emerge from  
recurrent schemes of sensory-motor activity, mostly unconscious basic capacities. Accord-  
ing to Piaget [26] biology and evolution, constructivism and history, have to lead research  
on the mind. Every kind of knowledge is linked to an action, and knowing an object or  
an event means using them, assimilating them to schemes of action. Knowing does not  
mean, in fact, copying reality, rather acting upon it and transforming it (apparently and  
actually), so as to understand it as a function of the systems of transformation to which  
those activities are linked. Sensory-motor intelligence consists in directly co-ordinating  
actions, without going through representation or thought. Perception has a meaning only  
inasmuch as it is linked to actions.

96 history and culture. Looking at the brain as a “proactive” rather than a  
97 “reactive machine”, perception and consciousness are fundamentally pre-  
98 dictive functions, insofar as they allow anticipation of the consequences of  
99 actual or potential actions.

100 In the progress of psychological research on perception, its projective  
101 character is testified by many experimental data on the capacity to “fill  
102 in the gaps”, integrating the missing information<sup>3</sup>. These data are made  
103 intelligible by the hypothesis that the brain operates as a simulator, con-  
104 stantly inventing models to project on a constantly changing outside world.  
105 In this perspective, emphasizing the plastic, flexible and adaptive character  
106 of biological mechanisms, in the context of an ecological approach to mind  
107 and behaviour<sup>4</sup>, the nervous system is conceived as a complex and dynamic  
108 generator of hypotheses and, consequently, the brain does not limit itself  
109 to produce responses to stimuli, to passively combine sensations and to or-

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<sup>3</sup>The obvious reference is here to the “revolutionary” acquisitions by Gestalt Psychology in the early 1900s. Considering the epistemological standards derived from mechanical physics and empiricist epistemology inadequate to the interpretation of some important mind-related facts, they stressed the necessity of keeping in mind the fundamental value of the experimental method, upholding at the same time the priority of a phenomenal dimension and the need for a holistic approach, aiming at the overcoming of the mind-nature dualism and at the eliminating of the distinction between sensation and perception, experience and “external” reality. The critique to the notion of alterity of environment with respect to mind is based on the fact that to each organism a behavioural environment inheres, and each organism is the centre of its own environment. To Kohler (1930), effects depend not only on given causes, but also on the characteristics of the system in which they come into being. And, according to a metaphor by Koffka (1935), the builder puts his own bricks together and builds the house: he forgets to have piled them within a gravitational field, without which no house could be built, just as it could not be built without bricks; but bricks are so much more tangible than gravity, that he only cares about them; so his concept of reality is forged.

<sup>4</sup>In Gibson’s (1904–1979) “ecological perspective”, the world we perceive is not the world of physics, or of geometry, in which space is an abstraction and the position of an object is specified by the co-ordinates of given axes in an isotropic space. The world, or, better, the environment, is the eco-system in which the organism is immersed, in a dialectical complementary relation. From this holistic, dynamic and integrated theoretical assumption, Gibson derives a critique to classical analysis of perception, which distinguishes sensory data from the meaning they would receive by means of an intellectual act. Perception is, instead, an active process depending on the organism/environment interaction and it is always fundamentally gained in relation to the percipient body’s position and its activities. The ecological theory of perception therefore postulates that the act of perception directly gathers information, without implying any involvement of conscience or any mechanisms for the elaboration of stimuli in a sort of “internal theatre”. Gibson (1979) proposes instead to critically re-consider perception and cognition in the light of direct realism and affordance. An affordance transversally cuts the subjective/objective dichotomy; it is directed in both directions, towards environment as well as towards the observer. The idea of an interface between us and the world is useless and unintelligible and, with regard to this relational aspect of affordance, Gibson recognises the Gestaltic origin of the term.

110 ganise perceptions in view of successive transformations. Instead, it bases  
 111 itself on an internal repertoire of actions, that make it a simulator capable  
 112 of evaluating the interaction among goal-directed actions and their conse-  
 113 quences.

114 As it is evident, contemporary researches have produced a lot of hy-  
 115 potheses and data, clearly hinting at the possibility to isolate a single ex-  
 116 plicatory principle in the motor model of cognitive functions. A reference  
 117 frame comes into vision, unitary enough for the study and explanation of  
 118 phenomena, but within a plurality of approaches, theoretical assumptions  
 119 and research perspectives. It is only fair to remember, however, that, on  
 120 the one hand, science itself is often subject to fashion (and the contempo-  
 121 rary emphasis on the motor component of mind certainly runs the risk of  
 122 becoming one); on the other hand, that stressing the complex, integrated  
 123 and dynamic dimension of living being always runs the risk of being per-  
 124 ceived as a "mystic permeation" of organism and environment, and that the  
 125 "top-down" approach runs the risk of being assimilated to a holism that has  
 126 had in the past strong anti-scientific tones (the Gestaltists themselves, as  
 127 it is well known, were in some sense accused of this by critics). This would  
 128 rather seem an instance of the developmental dynamics of scientific knowl-  
 129 edge, characterized by the re-surfacing — this time in an evidence-based  
 130 fashion, at the experimental as well as the clinical level — of a theoretical  
 131 frame and approach to the living being that in the course of history, with  
 132 varying fortune, has importantly contributed to the scientific understanding  
 133 of mind, starting from mid-1800s.

## 134 **2 Movement as a cognitive factor in a historical** 135 **perspective: from reflex to action**

136 The historical and interdisciplinary dimension of the motor theory of mind  
 137 stems clearly from the analysis of different aspects of scientific and philo-  
 138 sopherical thought in the 1800s and 1900s: it hints hypotheses and models  
 139 which have been more or less abandoned or included through re-definition  
 140 by the contemporary cognitive sciences. The above sketched concept of  
 141 "perception-action-cognition" is based on the idea that all the organism's  
 142 resources, used in action as well as in perception, substantially share the  
 143 character of motor anticipation, and that the understanding of actions rests  
 144 on "a sort of [species-specific] vocabulary of actions related to prehension"  
 145 [30, p. 220].

146 What characterizes action and differentiates it from a movement is the presence of a  
 147 goal. Action is accompanied by the creation of an expectation that the goal will be  
 148 met. Thus, an individual performing an action is able to predict its consequences.  
 149 He knows what to expect. Objects, as pictorially described by visual areas are  
 150 devoid of meaning. They gain meaning because of an association between their

151 pictorial description (meaningless) and the motor behaviour (meaningful). The  
152 starting process is motor and is based on the expectations about the final outcome  
153 of progressively more and more complex actions. The neurophysiological data pro-  
154 vide a new insight about the neural mechanisms that might subserve the process of  
155 object categorization and action understanding. Both these processes in our per-  
156 spective seem to be deeply grounded in the bi-directional relationship between agent  
157 and environment. This relationship is basically dependent upon action execution.  
158 Action appears to represent the founding principle of our knowledge of the world  
159 [30, pp.221–227].

160 In relation to this concept, the historical perspective emphasizes how, in  
161 the course of time, through different theoretical routes, the development of  
162 both philosophy and scientific knowledge has led to a process of naturaliza-  
163 tion and progressive embodiment of mind, deeply changing the traditional  
164 concept of cognitive functions and rooting them in the organism’s develop-  
165 ment and in its interaction with environment. In the historical development  
166 of the knowledge on mind and behaviour, produced in the last two Cen-  
167 turies, it would be possible to choose several different case studies, in order  
168 to reconstruct a sort of map, to facilitate orientation within the complex  
169 theoretical landscape of the progressive naturalization of mind Here I will  
170 only consider one single ‘chapter’ of this dense and stimulating theoretical  
171 route<sup>5</sup>, promising in terms of heuristic value and developments, the so-called  
172 “Physiology of Activity” developed within the Russian physiological com-  
173 munity in the second half of the 1900s as a deepening, a critique and, finally,  
174 an overcoming of the reflex concept. The analysis will be especially focussed  
175 on Bernstein’s theory and on the complex motor model of mind he develops  
176 exactly as an attempt to theoretically overcome the simple S/R account of  
177 behaviour. The deepening of the reflex concept — initially conceived as an  
178 arc, a linear and sequential connection between sensation and movement  
179 — has led Bernstein to question the neat distinction between stimulus and  
180 response, posture and voluntary activity (traditionally conceived as a sum  
181 of complex motor sequences made up of simple reflex “building blocks”).

182 By the end of the 1800s, already Dewey (1859–1952), thinking about the  
183 reflex arc as a possible key to understand motor behaviour, states the inad-  
184 equacy of an elementary approach in psychological investigation and, more  
185 at large, for a biological understanding of the organism, whose activities,  
186 of whatever nature, are always global and continuous processes. Dewey  
187 pointed out that the very distinction between sensation and movement,  
188 sensory stimulus and motor response, is but an abstraction if applied to  
189 behaviours other than simple automatisms. The distinction has of course  
190 been of great importance as a heuristic principle to investigate the func-  
191 tioning of the nervous system, but it overlooks the bare fact that in the

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<sup>5</sup>With Kuhn, historical reconstruction becomes an essentially selective and interpre-  
tative activity, but data can retroact back on expectations.

192 organism's actual behaviour there always is a fundamental circular connec-  
193 tion, so that response actually acts back on stimulus. This lets the observer  
194 appreciate some aspects previously not adequately evaluated, to produce,  
195 as a consequence, a new, more effective response that will in turn trigger a  
196 new circular process, and so on. In Dewey's own words, it would be more  
197 appropriate to look at the reflex arc as a "reflex circle": "The circle is a  
198 coordination It is the coordination which unifies that which the reflex arc  
199 concept gives us only in disjointed fragments. It is the motor response which  
200 assists in discovering and constituting the stimulus. It is the holding of the  
201 movement at a certain stages which creates the sensation, which throws it  
202 into relief" [11, p. 370].

203 Few years later, Sherrington (1857–1952) conceived the reflex not as a  
204 simple reaction elicited by a specific organ, better as an already co-ordinated  
205 movement, depending on the excitement of a given region of the organism,  
206 whose effects are also determined by the organism's global state. "A simple  
207 reflex arc is probably a pure abstract conception, because all parts of the  
208 nervous system are connected together and no part of it is probably ever  
209 capable of reaction without affecting and being affected by various other  
210 parts, and it is a system certainly never absolutely at rest". In other words,  
211 the reflex movement, even in its most simple, analytical aspects, is a form of  
212 behaviour; it is the reaction of an organic whole to a change in its relation  
213 with environment [31, pp.7–8]. Beyond these important changes in perspec-  
214 tive produced, on one hand, by the functionalist and pragmatic American  
215 philosophy/psychology and, on the other hand, by British neurophysiol-  
216 ogy, I consider the development of Soviet "Physiology of Activity" as a  
217 paradigmatic example of the production of a drastically different conception  
218 of mind, still from within an undoubtedly reductionistic and experimental  
219 theoretical framework which originally conceived the reflex as a constitutive  
220 "building block" of nervous activity, the minimal unit to account for mind  
221 and behaviour in neurophysiological terms.

222 In the mid-1800s, Secenov (1829–1905)[34] had first tried to trace the  
223 whole behaviour back to reflex, and to reduce mental processes to physio-  
224 logical mechanisms. He demonstrated that the brain can produce inhibitory  
225 influences on the reflex activity (developing an intuition already put forward  
226 by Weber in the 1840s), so he employed the concept of "inhibitory action" in  
227 the nervous system as a means to overcome the clear limits of any attempt to  
228 account for behaviour exclusively in terms of reflexes. In his thought we can  
229 recognise the premise of the whole theoretical horizon of Soviet Reflexology,

230 which has in Pavlov and Bechterev its most outstanding representatives.  
231 At the dawn of 1900s, Pavlov (1849–1936), who recovered and developed  
232 Secenov’s intuitions, was among the founders of the so-called “Reflexologic  
233 School” and proposed a more dynamic conception of reflex, enriched by the  
234 effects of experience (conditioning).

235 The inborn reflexes by themselves are inadequate to ensure the continued existence  
236 of the organism, especially of the more highly organized animals. The complex  
237 conditions of everyday existence require a much more detailed and specialized cor-  
238 relation between the animal and its environment than is afforded by the inborn  
239 reflexes alone. This more precise correlation can be established only through the  
240 medium of the cerebral hemispheres; and we have found that a great number of  
241 all sorts of stimuli always act through the medium of the hemispheres as tempo-  
242 rary and interchangeable signals for the comparatively small number of agencies of  
243 a general character which determine the inborn reflexes, and that this is the only  
244 means by which a most delicate adjustment of the organism to the environment  
245 can be established. I have termed this new group of reflexes conditioned reflexes  
246 to distinguish them from the inborn or unconditioned reflexes. Compared with the  
247 inborn reflexes, these new reflexes actually do depend on very many conditions,  
248 both in their formation and in the maintenance of their physiological activity. We  
249 might retain the term ‘inborn reflexes’, and call the new type “acquired reflexes”;  
250 or call the former “species reflexes” since they are characteristic of the species, and  
251 the latter “individual reflexes” since they vary from animal to animal in a species,  
252 and even in the same animal at different times and under different conditions [24,  
253 p. 17].

254 The reflex concept retains therefore its validity in accounting for the  
255 complex and dynamic way in which the animal’s behaviour adapts to the  
256 environment. Pavlov’s conditioning shows the reflex to be plastic and mod-  
257 ifiable by experience, thus plausibly conceivable as the basic neurophysio-  
258 logical mechanism of learning and of all the ‘higher functions’ of the nervous  
259 system. In the same years, Bechterev (1857–1927) views these functions  
260 in terms of coupling of reflexes, or progressively more complex integrations  
261 thereof, the so-called “associative reflexes”. To Bechterev’s opinion, Reflex-  
262 ology consists in examining from a rigorously objective standpoint not only  
263 the most elementary, but also all the higher human functions that in every-  
264 day language are called psychic activity. Thus, the investigation has to be  
265 limited to the external features of human actions and it is necessary to un-  
266 dertake a naturalistic observation of the subject in its social environment,  
267 with the aim of defining the relations between man and the surrounding  
268 physical, biological and, especially, social world [3]. Around the half of the  
269 XXth Century it is Anochin (1908– ), the most famous pupil of Pavlov,  
270 to call the attention of neurophysiologists on the need to finally overcome  
271 the reflex bottleneck, in order to concentrate on the complexity and on  
272 the integrated and unitary dimension of action. Studying conditioned re-  
273 flexes under Pavlov’s guidance, Anochin came to a radical critique of the  
274 traditional physiological culture: to his opinion, in fact, one of the most



275 meaningful aspects of the history of brain research has been the complete  
276 exclusion of the results of action from the physiological concepts. This obvi-  
277 ously has been a serious methodological limit in the study of the integrated  
278 activity of the brain, since it is the very results of action that constitute the  
279 final goal of behaviour. The reflex arc concept holds nervous processes as  
280 linear by nature, leading the physiologists' attention on the accomplished  
281 fact, lying thus down an impenetrable barrier between the act itself and  
282 the evaluation of the obtained results, which are an intrinsic consequence  
283 of action. "The behavioural act (conceived as a functional system) has a  
284 harmonious structure, an integral unity the behavioural act constitutes the  
285 link between neurophysiology, higher nervous activity and psychology" [2].  
286 Thus, from within experimental neurophysiology, deeply rooted in the quest  
287 for the simplest elements, the presumed minimal units of behaviour, the ne-  
288 cessity had grown to acknowledge the integrative, goal-oriented, dynamic  
289 and unitary nature of behaviour. Anochin is, with Bernstein, one of the  
290 great representatives of the Physiology of Activity, the Soviet "School" that  
291 between the 1930s and the 1960s implemented a qualitative shift in physio-  
292 logical and psychophysiological investigation, from the acknowledgment of  
293 the bare fact of integration to a real systemic perspective. Once the mech-  
294 anism has been abandoned, to embrace the concept of 'process', it is not  
295 sufficient to just assume the integration among reflexes: one must recognise  
296 the specific organisation of the system itself. Bernstein's theory brings to  
297 completion the critique of the reflex arc, as well as of the traditional rigid  
298 concept of the relation between stimuli and responses; conversely, the fun-  
299 damental value of the motor component for the development of mind and  
300 the organisation of behaviour is emphasized.

### 301 **3 Bernstein on action and perception: movement and** 302 **mind**

303 "Reading Bernstein is somewhat like reading the Bible" [32, p. 22]. These  
304 words clearly express how Bernstein's work on motor control in the last  
305 decades of XXth Century was recognised as the starting point of contem-  
306 porary movement sciences, providing a new understanding of the organiza-  
307 tion of movements. Nikolaj A. Bernstein (1896–1966) is actually considered  
308 "the father of motor control in humans" [20], with special reference to nat-  
309 ural, voluntary, non-automatic (naturally occurring) movements. It must  
310 be underlined, however, that his contribution is mostly well known within  
311 the "human movement sciences" community (rehabilitation, sports train-  
312 ing, sport medicine), whilst almost unmentioned by scholars interested in  
313 behaviour, mind and mind-brain relations. Even Lurija (one of the "fathers"  
314 of contemporary neuropsychology) defines him "a rare case of a scientist who

315 practically devoted his whole life to one problem: the physiological mecha-  
 316 nisms of human movements and motor actions”, just overlooking Bernstein’s  
 317 interest in brain and mind, in the integrated models of behaviour and their  
 318 epistemological value. It is instead of the utmost importance to under-  
 319 score how Bernstein actually aimed at understanding the brain through the  
 320 study of movement and, vice versa, how he used his knowledge of the brain  
 321 to improve and develop knowledge on movement. By integrating different  
 322 theoretical approaches and methodologies in his own research<sup>6</sup>, he tried to  
 323 correlate all the different levels of organisation of movement, with the aim  
 324 of defining a new, ecological and integrated, concept of mind and behaviour.  
 325 It is exactly this emphasis on the interaction among brain, motor system,  
 326 natural and cultural environment, that should be acknowledged as his most  
 327 relevant contribution. It is my opinion that the great heuristic value of  
 328 his interdisciplinary approach and of his peculiar theoretical progression ex-  
 329 tend the relevance of his contribution well beyond contemporary movement  
 330 sciences, making it a theoretical articulation of crucial importance to the  
 331 development of a motor model of mind.

332 Starting with his works of the 1930s, and then with the collections of his  
 333 most relevant works, appeared in the 1960s<sup>7</sup>, Bernstein accomplished a pow-  
 334 erful synthesis of neurophysiology, psychology and cybernetics, introducing  
 335 in the study of motor system physiology new methods and concepts: action-  
 336 perception cycle, “motor synergies”, posture as “keeping oneself ready to  
 337 action”. The starting point of his experimental work are his researches on  
 338 biomechanics and on the physiology of movement, within a clearly neu-  
 339 ropsychological theoretical frame since the beginning.

340 With the aim of extending the knowledge of the brain through the study  
 341 of movement, in fact, since 1924 he started a collaboration with Kornilov’s  
 342 Moscow Institute of Experimental Psychology. There Vygotskij and Lurija  
 343 worked, who will become (together with Leontijev), the highest representa-  
 344 tives of the “Psychology of Activity”, a psychological model that emphasizes  
 345 the role of action and experience in the development of mental functions,  
 346 and the social dimension of human behaviour, conceived as a complex of  
 347 essentially cultural ‘higher functions’ intrinsically different from the lower,  
 348 ‘natural’ ones<sup>8</sup>. Without explicitly referring to this psychological approach,

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<sup>6</sup>Starting from a mechanistic position, Bernstein adopted in the 1930s and 1940s a global dynamic approach; he went through a renovated mechanism and cybernetics in the 1950s, to finally reach in the 1960s an ‘ecological’ and again dynamic conception, that will allow a completely naturalistic account of behavioural planning, without recurring to any dualism whatever.

<sup>7</sup>Almost all the following quotes are taken from Bernstein 1967, a selection (and English translation) of Bernstein’s works, made by the author shortly before his death.

<sup>8</sup>In a game of reciprocal acknowledgements, Leontjev himself, in 1959, underlines the

349 in 1962 Bernstein will name his theoretical system “Physiology of Activity”  
 350 to highlight his attempt to provide a non-idealistic alternative to Pavlovian  
 351 Reflexology, based on a small number of basic pillars: movement, brain and  
 352 mind, organism and environment. Developing a hierarchical conception<sup>9</sup>  
 353 of nervous control of movement, based on evolutionism and clinical neuro-  
 354 sciences, Bernstein proposes two basic concepts: 1) movement as structure;  
 355 2) motor regulation and control (hierarchically organised co-ordination).  
 356 Movements are not to be seen as chains of details, rather as structures artic-  
 357 ulated into details; they are structural wholes, characterised at the same  
 358 time by a high degree of differentiation of the elements and by differences  
 359 in the relations among the parts.

360 Thus, he comes to underline the importance of an organisation in which  
 361 the same goal is reachable by different paths<sup>10</sup>, i.e., the “functional non-  
 362 univocality between impulses and effects: Changes in muscle tension bring  
 363 about a movement and the movement affects the condition of the muscles  
 364 by shortening or stretching them causing further changes in their tension.  
 365 Consequently, this form of interaction does not presuppose a one-to-one  
 366 correspondence between force and movement, that is, one and the same se-  
 367 quence of changes in forces may produce different movements on successive  
 368 repetitions” [4, p. 62]. This precludes the mechanistic idea of a central  
 369 signal “just striking a piano key” [4]. In motor control there is a circular  
 370 flux of information, aimed at assuring the overall co-ordination of move-  
 371 ment organs, conceived as complex systems. Such a position implies a shift  
 372 from purely descriptive biomechanics to the problems of central control and  
 373 regulation of movement, starting exactly from a critique of the reflex con-  
 374 cept, elaborated — it must be emphasized — from within a materialistic  
 375 perspective.

376 Thus Bernstein succeeds in deeply penetrating the structure, organisation  
 377 and programming of goal-oriented motor acts and comes to focussing on  
 378 the crucial concept of ‘co-ordination’ as “overcoming excessive degrees of  
 379 freedom of our movement organs, that is, turning the movement organs into  
 380 controllable systems” [5, p. 41]. “The reflex arc cannot exist — he claims  
 381 — and the organization of movement requires reflex rings” [4]: “The period  
 382 of struggle towards the recognition of the biological importance, the reality  
 383 and the generality of the principle of cyclical regulation of life processes is  
 384 now behind us” [4]. The organisation of motor apparatus control, typical

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importance of Bernstein’s theory of the multilevel and hierarchical motor co-ordination,  
 and of the fundamental role it attributed to the relation between ‘moving organism’ and  
 environment, as a theoretical input towards the development of his own theory of activity.

<sup>9</sup>Clear, in this respect, is the influence of Jackson [17] and of Weiss’ hierarchical  
 organicism (1928).

<sup>10</sup>On this matter, Bernstein also quotes Lashley (1929) ed Held (1920).

385 of biological systems, implies afference as well as efference, perception as  
 386 well as action. In the action, “a whole sequence of movements that together  
 387 solve the motor problem all the movements are related to each other by the  
 388 meaning of the problem” [5, p. 146].

389 Mastering the very many degrees of freedom involved in a particular  
 390 movement, reducing the number of independent variables to be controlled,  
 391 the organization of movement, coordination, emerges as the reciprocal at-  
 392 tunement of several simultaneous kinetic and informational processes. An  
 393 interdisciplinary and integrated approach, and a new concept of movement,  
 394 call then for a new theory, both of behaviour and of brain organisation.  
 395 Conceiving co-ordination as a patterning of body and limbs motions rela-  
 396 tive to the patterning of environmental objects and events, Bernstein views  
 397 it both as a process and as a structure showing itself in the “motor field”,  
 398 i.e. the space in which movements take shape<sup>11</sup>. Hence he develops his  
 399 notion of localization in the brain, in clear accordance with what will be  
 400 Lurjia’s theory of diffused localisation in a functional system<sup>12</sup>: the brain  
 401 is the centre of diffused and parallel processes, the central signal is written  
 402 in terms of the overall structure of movement and not in terms of its spatial  
 403 details. Thus, from the study of motor co-ordination Bernstein obtains an  
 404 insight into the “true categories” [4] of the organization of movement and  
 405 of the brain itself.

406 This conception implies a harsh critique to the Reflexology of Pavlov,  
 407 who “failed to understand the brain because he failed to understand its  
 408 most important function, that is, the organization of movement” [5]<sup>13</sup>. In  
 409 this theoretical position the influence is clear of the XXth Century Ger-  
 410 man thought and of its search for alternatives to the mechanism/vitalism  
 411 counterposition<sup>14</sup>. So, by developing a comparative and evolutionary ap-  
 412 proach (based on what he calls “interphyletic awareness”), in the early 1900s  
 413 Bernstein proposes himself as “an exception to the overall distinction be-

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<sup>11</sup>Bernstein stresses that the motor field has a global topology rather than a specific metrics; here he explicitly refers to Kurt Lewin for a “non-Euclidean, non-rectilinear geometry” [4]

<sup>12</sup>Lurija 1962, 1973.

<sup>13</sup>The clash between politics and science in the Soviet Union is one of the most important factors in Bernstein’s biography: his idea that motor behaviour never replicates itself identically is in fact incompatible with the neo-pavlovian theory of conditioned reflexes. Bernstein is therefore considered a public enemy, and is fired from his job on the grounds of his “displayed adoration of foreign scientists neglected the importance of the work of Pavlov” (cited in [13]). Only after Stalin’s death (1953) he will be gradually “rehabilitated” [8].

<sup>14</sup>Consider the new approaches to the organism as a whole (Gestalt, with K’ohler 1924, 1933), as a functional system organized through hierarchical levels and dynamical processes (Von Bertalanffy 1933, Weiss 1928).

414 tween the domain of neuronal control and that of motor behaviour [...] his  
 415 research integrated concepts deriving from the behavioural field with neu-  
 416 rophysiological, neuromuscular and biomechanical data, especially in the  
 417 study of locomotion [...]. While the two domains (behavioural/neuronal  
 418 study of movements) were progressively integrating in Russia, this was not  
 419 happening in the USA or Great Britain, where most of the studies on move-  
 420 ment were taking place” [32]. Self-determining goals and trying to find ways  
 421 to solve motor problems are functional properties of the cortex; however —  
 422 Bernstein holds — neurophysiology is by itself not sufficient to explain these  
 423 higher phenomena; it is necessary to develop a sort of motor model of mind,  
 424 in-between neurosciences and psychology, adopting action as a theoretical  
 425 framework to the study of mind: “every skill arises in answer to a particular  
 426 motor problem” [4].

427 Motor Problems arise out of the external environment, upon which the organism  
 428 actively operates and from which it receives sensory feedback. Biological activity  
 429 implies the cognition of the surrounding world through action and the regulation  
 430 of action within it. Each meaningful motor directive demands not an arbitrarily  
 431 coded, but an objective, quantitatively and qualitatively reliable representation of  
 432 the surrounding environment in the brain. This also leads to knowledge through ac-  
 433 tion and revision through practice which is the cornerstone of the entire dialectical-  
 434 materialistic theory of knowledge and serves as a sort of biological context for Lenin’s  
 435 theory of reflection [4, pp. 114–120].

436 “Physiology of Activity” aims to be a non-metaphysical, naturalistic un-  
 437 derstanding of life: animals pursue aims which must have a natural origin.  
 438 If movements are goal-directed, they must be controlled by something “as  
 439 yet unrealized”, i.e. a sort of “model of the future” [4]. In their interac-  
 440 tion with the environment, organisms must “plan action through an active  
 441 sampling incorporating a measure of uncertainty into their motor acts. By  
 442 the way of a probabilistic extrapolation they predict the course of events  
 443 in the environment” [4]<sup>15</sup>. Since the 1930s<sup>16</sup>, then, Bernstein identifies the  
 444 key to understand movement of organisms in the goal of action and in the  
 445 formulation of the motor program. He considers Cybernetics insufficient for  
 446 a convincing account of the essential features of life: “the honeymoon of  
 447 this union between automatic processes and physiology is over cybernetics  
 448 may capture self-programming automata that are able to estimate what will  
 449 happen but cannot model what has to happen” [4].

<sup>15</sup>See the “proactive” model of the brain recently formulated by A. Berthoz: “The brain is above all a biological machine for moving quickly while anticipating. Evolution obviously selected receptors capable of predicting the future” [6].

<sup>16</sup>The problem of the relation between co-ordination and localization’ is published by Bernstein in 1935, at least twelve years before it was focussed upon by Wiener and the Cyberneticists.

450 Integrating, through an accurate philosophical and psychological elaboration,  
 451 the laws of control and regulation of the whole organism's movements  
 452 into a wider concept of "living being's activity", based on biological, cul-  
 453 tural and social factors and cybernetic principles, Bernstein formulates in  
 454 the 1960s a fully naturalistic — neurobiological and psychological — ac-  
 455 count of goal-oriented behaviour. Such a conception clearly shows many  
 456 important common features with the ecological psychology being developed  
 457 more or less at the same time by James Gibson<sup>17</sup>, centered on the basic  
 458 tenet that one must move in order to perceive, but also perceive in order  
 459 to move, its ground assumption being the mutuality of an animal and its  
 460 environment.

461 In conclusion, a historical reconstruction of Bernstein's thought shows  
 462 how, through a conception of organism as a self-regulating system, that ac-  
 463 tively accomplishes the genetically-and environmentally-determined goals of  
 464 its action, a decisive qualitative shift is produced, from within the materialistic-  
 465 dialectical analysis of the relation between organism and environment. So,  
 466 the limits set by classical physiology and reflex theory (the Pavlovian con-  
 467 cepts, as well as the S/R model of the behaviourists, which were dominant,  
 468 as it is well known, in the mid-1900s) are overcome. Bernstein's 'poor or-  
 469 thodoxy'<sup>18</sup>, his daring and pragmatic theoretical and methodological eclec-  
 470 ticism, are thus determinant factors which led him, who studied movement  
 471 with an eye on brain and mind, to develop hints, intuitions and suggestions  
 472 that represent important premises to, and meaningful theoretical elements  
 473 of, the contemporary motor model of mind.

474 In the most recent studies on the physiology of movement, and in the dis-  
 475 covery of mirror neurons, it is then possible to dig out the neurophysiological  
 476 evidence, the experimental grounding, of a model that has appeared, dis-  
 477 appeared and re-emerged over and over again in the development of behavioural  
 478 and mind sciences. And, without constraining historical analysis within  
 479 silly quests for precursors [9], recognising instead resemblances and "fam-  
 480 ily likeness" (à la Wittgenstein) among concepts and hypotheses developed  
 481 over time, with the aim to find the solution to a specific problem, can help  
 482 perceiving the actual historical dimension of the development of knowledge.  
 483 It can help to grasp the ways in which in the course of time a process of  
 484 naturalization of the mind has taken place on the basis of a functionally in-  
 485 tegrated approach to the organism-environment system. The minimal unit  
 486 of analysis is the perception-action cycle in intentional contexts, and the  
 487 unifying theoretical frame is the continuous dialectic relation between man  
 488 and its physical, biological, historical and cultural environment.

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<sup>17</sup>Gibson 1966, 1979.

<sup>18</sup>He had no official position and many limits to his scientific activity during all his life

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