Movement in the philosophy of mind: traces of the motor model of mind in the history of science

Carmela Morabito

1 The motor model of mind

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

Thus, with the aim of preserving the fertile epistemological interaction of a phenomenology of behaviour with the models of its underlying causal mechanisms, the new philosophy of mind aims at a philosophical foundation of the so called physiology of action. Choosing action as a cornerstone, as a theoretical lens through which to observe the behaviour in its wholeness, and therefore mind, naturally implies a stronger emphasis on the specificity of the organism, on its being intrinsically goal-oriented and in an active and constructive interaction with its environment. The organism is, in fact, conceived as a sort of constant generator of hypotheses, that selects sensory information depending upon the aims of the action. In this theoretical perspective — biological, dynamic and integrated —, rather than as a bare motor expression of sensory computation, action is conceived as an active and goal-oriented “kinetic melody”[1], a structured ensemble of co-ordinated movements in function of a specific aim.

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

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

[1]Pierre Janet (1859–1947)— in open contrast with the reductionist, molecular approach adopted in those very years by the American behavorist 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.

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

The tight intertwinement of motricity and thought is by now evident at a phylogenetic as well as at an ontogenetic level[2]. The incarnation of *cogito* emerges from neurosciences as the recognition of the capacity of the body to anticipate, imagine, mimic and forecast the actual body movement. The fundamental theoretical assumption, the unifying frame, is the constitutively temporal and material dimension of experience, the mutually formative interaction between organism and environment. Experience is conceived as an anticipatory construction, insofar as it is considered the adaptive outcome of the essentially active nature of a subject that determines by itself the object of possible experience. It is an important step, maybe nearly the goal, of a process of naturalisation of mind that from Darwin to contemporary neurosciences has aimed at arriving at symbols starting from matter, rather than looking at the latter, in our perception of reality, in terms of hypotheses and calculations, languages and symbols to decipher. Contrary to the 20th Century functionalistic approach, brain is not conceived as a computer, nor as any machine resembling an AI device, rather it is an original biological construction, the product of evolution,

[2]Developmental psychology and contemporary neurosciences have clearly demonstrated 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 philosophical 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 development: it is through observation and motor action that the child operates a series of concrete learning actions that progressively develop into abstract concepts. The development 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. According 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.

history and culture. Looking at the brain as a "proactive" rather than a "reactive machine", perception and consciousness are fundamentally predictive functions, insofar as they allow anticipation of the consequences of actual or potential actions.

In the progress of psychological research on perception, its projective character is testified by many experimental data on the capacity to "fill in the gaps", integrating the missing information[3]. These data are made intelligible by the hypothesis that the brain operates as a simulator, constantly inventing models to project on a constantly changing outside world. In this perspective, emphasizing the plastic, flexible and adaptive character of biological mechanisms, in the context of an ecological approach to mind and behaviour[4], the nervous system is conceived as a complex and dynamic generator of hypotheses and, consequently, the brain does not limit itself to produce responses to stimuli, to passively combine sensations and to or-

[3]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 methaphor 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.

[4]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 immerged, 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 intellective 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.

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

As it is evident, contemporary researches have produced a loto of hypotheses and data, clearly hinting at the possibility to isolate a single explicatory principle in the motor model of cognitive functions. A reference frame comes into vision, unitary enough for the study and explanation of phenomena, but within a plurality of approaches, theoretical assumptions and research perspectives. It is only fair to remember, however, that, on the one hand, science itself is often subject to fashion (and the contemporary emphasis on the motor component of mind certainly runs the risk of becoming one); on the other hand, that stressing the complex, integrated and dynamic dimension of living being always runs the risk of being perceived as a "mystic permeation" of organism and environment, and that the "top-down" approach runs the risk of being assimilated to a holism that has had in the past strong anti-scientific tones (the Gestaltists themselves, as it is well known, were in some sense accused of this by critics). This would rather seem an instance of the developmental dynamics of scientific knowledge, characterized by the re-surfacing — this time in an evidence-based fashion, at the experimental as well as the clinical level — of a theoretical frame and approach to the living being that in the course of history, with varying fortune, has importantly contributed to the scientific understanding of mind, starting from mid-1800s.

2 Movement as a cognitive factor in a historical perspective: from reflex to action

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

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

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

In relation to this concept, the historical perspective emphasizes how, in the course of time, through different theoretical routes, the development of both philosophy and scientific knowledge has led to a process of naturalization and progressive embodiment of mind, deeply changing the traditional concept of cognitive functions and rooting them in the organism's development and in its interaction with environment. In the historical development of the knowledge on mind and behaviour, produced in the last two Centuries, it would be possible to choose several different case studies, in order to reconstruct a sort of map, to facilitate orientation within the complex theoretical landscape of the progressive naturalization of mind Here I will only consider one single 'chapter' of this dense and stimulating theoretical route[5], promising in terms of heuristic value and developments, the so-called "Physiology of Activity" developed within the Russian physiological community in the second half of the 1900s as a deepening, a critique and, finally, an overcoming of the reflex concept. The analysis will be especially focussed on Bernstein's theory and on the complex motor model of mind he develops exactly as an attempt to theoretically overcome the simple S/R account of behaviour. The deepening of the reflex concept — initially conceived as an arc, a linear and sequential connection between sensation and movement — has led Bernstein to question the neat distinction between stimulus and response, posture and voluntary activity (traditionally conceived as a sum of complex motor sequences made up of simple reflex "building blocks").

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

[5]With Kuhn, historical reconstruction becomes an essentually selective and interpretative activity, but data can retroact back on expectations.

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

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

In the mid-1800s, Secenov (1829–1905)[34] had first tried to trace the whole behaviour back to reflex, and to reduce mental processes to physiological mechanisms. He demonstrated that the brain can produce inhibitory influences on the reflex activity (developing an intuition already put forward by Weber in the 1840s), so he employed the concept of"inhibitory action" in the nervous system as a means to overcome the clear limits of any attempt to account for behaviour exclusively in terms of reflexes. In his thought we can recognise the premise of the whole theoretical horizon of Soviet Reflexology, which has in Pavlov and Bechterev its most outstanding representatives. At the dawn of 1900s, Pavlov (1849–1936),who recovered and developed Secenov's intuitions, was among the founders of the so-called "Reflexologic School" and proposed a more dynamic conception of reflex, enriched by the effects of experience (conditioning).

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

The reflex concept retains therefore its validity in accounting for the complex and dynamic way in which the animal's behaviour adapts to the environment. Pavlov's conditioning shows the reflex to be plastic and modifiable by experience, thus plausibly conceivable as the basic neurophysiological mechanism of learning and of all the 'higher functions' of the nervous system. In the same years, Bechterev (1857–1927) viewes these functions in terms of coupling of reflexes, or progressively more complex integrations thereof, the so-called "associative reflexes". To Bechterev's opinion, Reflexology consists in examining from a rigorously objective standpoint not only the most elementary, but also all the higher human functions that in everyday language are called psychic activity. Thus, the investigation has to be limited to the external features of human actions and it is necessary to undertake a naturalistic observation of the subject in its social environment, with the aim of defining the relations between man and the surrounding physical, biological and, especially, social world [3]. Around the half of the XXth Century it is Anochin (1908–), the most famous pupil of Pavlov, to call the attention of neurophysiologists on the need to finally overcome the reflex bottleneck, in order to concentrate on the complexity and on the integrated and unitary dimension of action. Studying conditioned reflexes under Pavlov's guidance, Anochin came to a radical critique of the traditional physiological culture: to his opinion, in fact, one of the most meaningful aspects of the history of brain research has been the complete exclusion of the results of action from the physiological concepts. This obviously has been a serious methodological limit in the study of the integrated activity of the brain, since it is the very results of action that constitute the final goal of behaviour. The reflex arc concept holds nervous processes as linear by nature, leading the physiologists' attention on the accomplished fact, lying thus down an impenetrable barrier between the act itself and the evaluation of the obtained results, which are an intrinsic consequence of action. "The behavioural act (conceived as a functional system) has a harmonious structure, an integral unity the behavioural act constitutes the link between neurophysiology, higher nervous activity and psychology" [2]. Thus, from within experimental neurophysiology, deeply rooted in the quest for the simplest elements, the presumed minimal units of behaviour, the necessity had grown to acknowledge the integrative, goal-oriented, dynamic and unitary nature of behaviour. Anochin is, with Bernstein, one of the great representatives of the Physiology of Activity, the Soviet "School" that between the 1930s and the 1960s implemented a qualitative shift in physiological and psychophysiological investigation, from the acknowledgment of the bare fact of integration to a real systemic perspective. Once the mechanism has been abandoned, to embrace the concept of 'process', it is not sufficient to just assume the integration among reflexes: one must recognise the specific organisation of the system itself. Bernstein's theory brings to completion the critique of the reflex arc, as well as of the traditional rigid concept of the relation between stimuli and responses; conversely, the fundamental value of the motor component for the development of mind and the organisation of behaviour is emphasized.

3 Bernstein on action and perception: movement and mind

"Reading Bernstein is somewhat like reading the Bible" [32, p. 22]. These words clearly express how Bernstein's work on motor control in the last decades of XXth Century was recognised as the starting point of contemporary movement sciences, providing a new understanding of the organization of movements. Nikolaj A. Bernstein (1896–1966) is actually considered "the father of motor control in humans" [20], with special reference to natural, voluntary, non-automatic (naturally occurring) movements. It must be underlined, however, that his contribution is mostly well known within the "human movement sciences" community (rehabilitation, sports training, sport medicine), whilst almost unmentioned by scholars interested in behaviour, mind and mind-brain relations. Even Lurija (one of the "fathers" of contemporary neuropsychology) defines him "a rare case of a scientist who practically devoted his whole life to one problem: the physiological mechanisms of human movements and motor actions", just overlooking Bernstein's interest in brain and mind, in the integrated models of behaviour and their epistemological value. It is instead of the utmost importance to underscore how Bernstein actually aimed at understanding the brain through the study of movement and, vice versa, how he used his knowledge of the brain to improve and develop knowledge on movement. By integrating different theoretical approaches and methodologies in his own research[6], he tried to correlate all the different levels of organisation of movement, with the aim of defining a new, ecological and integrated, concept of mind and behaviour. It is exactly this emphasis on the interaction among brain, motor system, natural and cultural environment, that should be acknowledged as his most relevant contribution. It is my opinion that the great heuristic value of his interdisciplinary approach and of his peculiar theoretical progression extend the relevance of his contribution well beyond contemporary movement sciences, making it a theoretical articulation of crucial importance to the development of a motor model of mind.

Starting with his works of the 1930s, and then with the collections of his most relevant works, appeared in the 1960s[7], Bernstein accomplished a powerful synthesis of neurophysiology, psychology and cybernetics, introducing in the study of motor system physiology new methods and concepts: action-perception cycle, "motor synergies", posture as "keeping oneself ready to action". The starting point of his experimental work are his researches on biomechanics and on the physiology of movement, within a clearly neuropsychological theoretical frame since the beginning.

With the aim of extending the knowledge of the brain through the study of movement, in fact, since 1924 he started a collaboration with Kornilov's Moscow Institute of Experimental Psychology. There Vygotskij and Lurija worked, who will become (together with Leontijev), the highest representatives of the "Psychology of Activity", a psychological model that emphasizes the role of action and experience in the development of mental functions, and the social dimension of human behaviour, conceived as a complex of essentially cultural 'higher functions' intrinsically different from the lower, 'natural' ones[8]. Without explicitly referring to this psychological approach,

[6]Starting from a mechanistic position, Bernstein adopted in the 1930s and 1940s a global dynamic approach; he went through a renovated mechanicism 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.

[7]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.

[8]In a game of reciprocal acknowledgements, Leontjev himself, in 1959, underlines the

in 1962 Bernstein will name his theoretical system "Physiology of Activity" to highlight his attempt to provide a non-idealistic alternative to Pavlovian Reflexology, based on a small number of basic pillars: movement, brain and mind, organism and environment. Developing a hierarchical conception[9] of nervous control of movement, based on evolutionism and clinical neurosciences, Bernstein proposes two basic concepts: 1) movement as structure; 2) motor regulation and control (hierarchically organised co-ordination). Movements are not to be seen as chains of details, rather as structures articulated into details; they are structural wholes, characterised at the same time by a high degree of differentiation of the elements and by differences in the relations among the parts.

Thus, he comes to underline the importance of an organisation in which the same goal is reachable by different paths[10], i.e., the "functional non-univocality between impulses and effects: Changes in muscle tension bring about a movement and the movement affects the condition of the muscles by shortening or stretching them causing further changes in their tension. Consequently, this form of interaction does not presuppose a one-to-one correspondence between force and movement, that is, one and the same sequence of changes in forces may produce different movements on successive repetitions" [4, p. 62]. This precludes the mechanistic idea of a central signal "just striking a piano key" [4]. In motor control there is a circular flux of information, aimed at assuring the overall co-ordination of movemement organs, conceived as complex systems.Such a position implies a shift from purely descriptive biomechanics to the problems of central control and regulation of movement, starting exactly from a critique of the reflex concept, elaborated — it must be emphasized — from within a materialistic perspective.

Thus Bernstein succeeds in deeply penetrating the structure, organisation and programming of goal-oriented motor acts and comes to focussing on the crucial concept of 'co-ordination' as "overcoming excessive degrees of freedom of our movement organs, that is, turning the movement organs into controllable systems" [5, p. 41]. "The reflex arc cannot exist — he claims — and the organization of movement requires reflex rings" [4]: "The period of struggle towards the recognition of the biological importance, the reality and the generality of the principle of cyclical regulation of life processes is 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.

[9]Clear, in this respect, is the influence of Jackson [17] and of Weiss' hierarchical organicism (1928).

[10]On this matter, Bernstein also quotes Lashley (1929) ed Held (1920).

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

Mastering the very many degrees of freedom involved in a particular movement, reducing the number of independent variables to be controlled, the organization of movement, coordination, emerges as the reciprocal attunement of several simultaneous kinetic and informational processes. An interdisciplinary and integrated approach, and a new concept of movement, call then for a new theory, both of behaviour and of brain organisation. Conceiving co-ordination as a patterning of body and limbs motions relative to the patterning of environmental objects and events, Bernstein views it both as a process and as a structure showing itself in the "motor field", i.e. the space in which movements take shape[11]. Hence he develops his notion of localization in the brain, in clear accordance with what will be Lurjia's theory of diffused localisation in a functional system[12]: the brain is the centre of diffused and parallel processses, the central signal is written in terms of the overall structure of movement and not in terms of its spatial details. Thus, from the study of motor co-ordination Bernstein obtains an insight into the "true categories" [4] of the organization of movement and of the brain itself.

This conception implies a harsh critique to the Reflexology of Pavlov, who "failed to understand the brain because he failed to understand its most important function, that is, the organization of movement" [5][13]. In this theoretical position the influence is clear of the XXth Century German thought and of its search for alternatives to the mechanism/vitalism counterposition[14]. So, by developing a comparative and evolutionary approach (based on what he calls "interphyletic awareness"), in the early 1900s Bernstein proposes himself as "an exception to the overall distinction be-

[11]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]

[12]Lurija 1962, 1973.

[13]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].

[14]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).

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

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

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

[15] 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].

[16] 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.

Integrating, through an accurate philosophical and psychological elaboration, the laws of control and regulation of the whole organism's movements into a wider concept of "living being's activity", based on biological, cultural and social factors and cybernetic principles, Bernstein formulates in the 1960s a fully naturalistic — neurobiological and psychological — account of goal-oriented behaviour. Such a conception clearly shows many important common features with the ecological psychology being developed more or less at the same time by James Gibson[17], centered on the basic tenet that one must move in order to perceive, but also perceive in order to move, its ground assumption being the mutuality of an animal and its environment.

In conclusion, a historical reconstruction of Bernstein's thought shows how, through a conception of organism as a self-regulating system, that actively accomplishes the genetically-and environmentally-determined goals of its action, a decisive qualitative shift is produced, from within the materialistic-dialectical analysis of the relation between organism and environment. So, the limits set by classical physiology and reflex theory (the Pavlovian concepts, as well as the S/R model of the behaviourists, which were dominant, as it is well known, in the mid-1900s) are overcome. Bernstein's 'poor orthodoxy'[18], his daring and pragmatic theoretical and methodological eclecticism, are thus determinant factors which led him, who studied movement with an eye on brain and mind, to develop hints, intuitions and suggestions that represent important premises to, and meaningful theoretical elements of, the contemporary motor model of mind.

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

[17]Gibson 1966, 1979.

[18]He had no official position and many limits to his scientific activity during all his life

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