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Nima Rezaei *Editor*

Multidisciplinarity and Interdisciplinarity in Health

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Antonino Pennisi and Donata Chiricò

"Etenim, quid Corpus possit, nemo hucusque determinavit, hoc est, neminem hucusque experientia docuit, quid Corpus ex solis legibus naturæ, quatenus corporea tantum consideratur, possit agere, & quid non possit, nisi a Mente determinetur. Nam nemo hucusque Corporis fabricam tam accurate novit, ut omnes ejus functiones potuerit explicare [...]. Quod satis ostendit, ipsum Corpus ex solis suæ naturæ legibus multa posse, quæ ipsius Mens admiratur."

B. Spinoza, Ethica Ordine Geometrico Demonstrata, 1677

Summary

Cognitive sciences have a history of almost a century. The reflection on the nature of intelligence born in the cybernetic field has won the interest of all human, social, and life sciences. This process has certainly represented an enrichment and an important evolution. However, it was not painless. Initially the cognitive sciences have proved convinced that the activity of the mind can be entirely simulated by algorithmic procedures. After all, there is no doubt that this idea survives in neuroscience, neuropsychology, and much

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philosophy of the mind. In recent decades, cognitive neurosciences, on the one hand, have brought the naturalism of the brain–body to the center of the debate, but on the other, they have enhanced the cerebrocentrism that studies the brain in computational terms and completely neglects the role of non-brain–body. Yet, the natural sciences have taught us that the body is the protagonist of all the abilities of human beings, animals, and machines. On the contrary, the complex series of philosophies recognized today under the name of embodied cognition believes that understanding the brain means taking into account the fact that it is instanced throughout the living organism and that living organisms are instanced in communities of conspecifics. The great lesson of contemporary evolutionism and ethology is that natural selection transforms morphological and, subsequently, functional structures, gradually and filtered by the genetic pool. Knowing the brain, therefore, means studying its relationships with the whole set of structures and functions that characterize the fixation of a species.

Education: a rural school in Central Sicily
[Photography by Antonino Pennisi]
The code of this chapter is *01110100 01101111 01101100 01000011 01100101 01100011 01101100 01100101 01101001 01110110.*

Keywords

Body · Brain · Chronological causalism · Cognitive science · Embodied cognition · Evolutionism · Naturalistic models · Populational thinking

1 Introduction

The culture of the new millennium has opened up under the banner of cognitive science. There is no branch of scientific and even humanistic disciplines (as far as this distinction is still valid) has not been affected, positively or negatively, by the invasiveness of the cognitive paradigm. Today, neuroscience is the best example of team research: modular, interactive, effective because it is cooperative, the true science without borders. If we want to use a metaphor, we could compare a team of cognitive neuroscience to an integrated crime research department where organized information from specialized state bodies flows into a single database. As if by magic, by linking separate data from different intelligences, an increasingly accurate, likely, identikit of the culprit is reconstructed, probably resembling the real criminal.

The study of aphasia, for example, has been able to connect the specific knowledge of neurologists, linguists, neuropsychologists, language philosophers, rehabilitators, and speech therapists. The results have been surprising both theoretically and therapeutically: aphasia is no longer an irreversible catastrophic event but a starting point for reconstructing not only the physiological machine of language but the individual's linguistic life, the one that Heidegger called *das Haus des Seins* (*the house of being*).

Similar phenomena occur in robotics, where the application of artificial models of empirical knowledge makes it possible to create devices that are increasingly useful for work and interaction with humans, allowing them to engage in creative activities. Economics, marketing, and stock exchange trading also increasingly use the cooperation between artificial calculation models and cognitive psychology models and the reasoning developed by game theories. The potential of this method in deriving new homogeneous images from continuous comparisons between apparently heterogeneous data is therefore unimaginable.

Cognitive sciences, after all, are born with one of the most ambitious projects that have ever been advanced in the history of western culture. They investigate the nature and functioning of the mind in any *thinking system*, natural or artificial. It is a research program that aims to explain mental processes in such a transparent way that even a machine can then reproduce them, simulating the procedures of our activities: infer, deduce, argue, but also be aware, believe, imagine, and desire.

Different disciplines have occupied themselves with similar issues: philosophy, psychology, neurology, linguistics, and artificial intelligence (AI). The history of cognitive science, however, cannot be identified as the history of any of these disciplines. Rather than a general program of explanation, cognitive science is an interdisciplinary method that has the merit of having solved problems that had become insoluble, closed as they were, within isolated disciplines.

From not long ago, cognitive sciences began to have a respectable history of almost a century. The reflection on the nature of cognition, born in the cybernetic field, has now spread like wildfire on all human and natural sciences. From Turing, Simon, Newell, we have come today to Chomsky, Fodor, Dennett, Pinker, Gazzaniga, Kandell, and Damasio, but also, among others, to the anthropology of Dan Sperber, the philosophy of the mind of Ned Block, the psychology of neuromarketing by Daniel Kahneman and Vernon Smith, the neuroesthetics of David Freedberg and the studies on the performing arts, not to mention the decisive contribution that embodied cognition (EC) and the modern synthesis of evolutionary biology are making. It was an enrichment and a transformation, but not a painless process. The idea that all cognitive skills can be simulated by algorithmic procedures belongs, in fact, to the prehistory of cognitive sciences. However, this idea survives in other forms, both in neuroscience and in the philosophy of mind.

On the other hand, neurosciences have developed a tendency to become the fulcrum of all causal explanations: with a prevalent word in recent decades, they have become "cerebrocentric." The cerebrocentric theories focus only on the computational function of the brain–body and overlook the significant contribution of the non-brain–body to all the capacities of humans, animals, and machines, downgrading performances to a mere executive function.

Hurley [1] resorts to "the sandwich model" metaphor to outline this idea. The traditional description for the mind, the "highest" function, emphasizes the role of the mind in elaborating information, while perception is limited to carrying inputs, and action transforms these inputs into output. It is exacerbated when, in the *philosophy of language*, Chomsky depicts the morphology and semantics of language as "externalization devices" [2] independently of the cognitive nature of language itself. In a recent book, Chomsky claimed: "the externalization of narrow syntax like the printer attached to a computer, rather than the computer's CPU" [3, 4] has named "separability thesis" the main idea permeating the field of cognitive neuroscience, according to which "from knowledge of mental properties it is impossible to predict properties of the body. Therefore, a human like mind could very well exist in a nonhumanlike body" (cfr. p. 167): this is the opposite of what happens in evolution, and it is a position alarmingly close to Putnam's hypothesis of "the brain in a vat" [5].

With these artificial and anthropocentric residues, both the set of new philosophies of the mind that go by the name of EC and the evolutionary biology that has promoted the position of the brain are being measured in the last twenty years—the ascending *metaphor of the current cognitive sciences*—within *the living organism*. The greatest in the topics of contemporary evolutionism is, in fact, "organisms and individuals fit, and not their structures in isolation, as if they were self-sufficient" [6]. Therefore, "to study the asymmetrical brain of a species means to study also its relations with the feet and hands, with the muscle-skeletal system, with the structure of the circulatory, respiratory, digestive, nervous systems: in short with all the patterns that have set during the evolutionary history of the physiological type of the species. The same is true in terms of functions. An animal that is able to speak not only communicates differently but also perceives in differently, thinks and remembers in a different way, wants, gets excited and acts in a different way, is differently related with its conspecifics: he came to this condition through the inexorable interplay between chance and natural selection" (ib.).

2 What Does "Naturalism" Mean Today

The ever-wider expansion of the field of cognitive sciences, which we have just seen in its young twentieth-century history, has led to serious identity problems within it. When not only the traditionally "hard" sciences but also a good part of the human sciences began to explore the virtues of interdisciplinarity, it seemed to many that the nature of the cognitive method could reveal cracks and contradictions. If we wanted to identify three fundamental identifying principles on which one cannot but agree by practicing any "content" meaning of the cognitive sciences, we could identify them in: i, heuristic principle instead of the descriptive principle; ii, monistic principle instead of the dualistic principle; and iii, experimental principle instead of the speculative principle.

The first point comes back to the founding act of cognitive sciences. In fact, they were born as a reaction to the behaviorist hegemony of the mid-twentieth century. In Skinner's famous review of Verbal Behavior (1959), Chomsky affirmed for the first time in linguistics the idea that describing language behaviors and ways of functioning does not mean explaining them. More precisely, he affirmed the idea that a linguistic theory cannot explain its object of study through the recognition and recording of speakers' stimuli and responses, but that it is necessary: *"To know in depth the internal structure of the organism and the ways in which it processes information and organizes its behaviors (…): a complicated product of an innate structure, a genetically determined maturation process and past experience"* [7].

The cognitive change impressed, not only on linguistics but on the whole culture of the twentieth century, since the end of behaviorism, is one of those points of no return that characterize the history of science. In this birth certificate of cognitive sciences, there is already expressed; however, the fundamental contradiction between an internalist philosophy (which presupposes—therefore—only the existence of mental rules) and computationalism of the mind (the black box that processes information algorithmically) and the biological and evolutionary nature codified through the phylogenetic structure and realized in individuals through ontogenetic development.

The second point has even older reasons. Already in the seventeenth century, Spinoza had caught in the dualism between res cogitans and res extensa the most evident contradiction of the Cartesian idea of science: "he had conceived mind as so distinct from body that he could assign no one cause either of this union or of the mind itself; and found it necessary to have recourse to the cause of the entire universe, that is, God" [8]. The Spinozian heritage cannot be denied not only by the cognitive sciences but by all the contemporary epistemology of science. Anyone who believes in doing science cannot suppose the existence of two different substances in any way they are identified. The extension should not be confused with the "visibility" of a substance. Visibility can always emerge with technology that changes our idea of the infinitely large and infinitely small (Lovejoy). Especially in the field of cognitive sciences, it is the brain's neuroelectric activity that generates the organization of information that we call the "mind." The human brain contains more than one hundred billion neurons, emerging into *a combination of mental states* that exceeds *the number of particles* elementaries of *the known universe* [9]. Ultimately, the complexity of the mind must be attributed to the infinity combinatorics of neural connections, that is, to the unlimited creativity that only one substance can be capable of.

Finally, the third point concerns the method, which in cognitive sciences are always experimental and never speculative (in the sense of not being based on the evaluation and comparison of the data collected). Also, in this case, the relationship between the principle of the experimental method and the potential of the analysis enters into a direct relationship with the technologies. Technologies constitute not only the eye with which we can look at data but also the procedures with which we can produce it. Is respect for these three principles enough to make cognitive sciences a chapter of natural sciences? Or to justify an entirely naturalistic approach to the scientific knowledge of cognition? The answer to this question lies in the meaning we give to the term “naturalism.”

2.1 Physicalist Naturalism

Throughout the twentieth century, the term “naturalism” almost always coincided with a physicalist orientation. The main coordinates of this orientation must be inscribed in a complex cultural matrix that intertwines the great season of the epistemology of science—which culminated in the sixties with the works of Popper and Khun—the primacy of analytical philosophy, in particular with the Quine’s approach, the first computational season of cognitive sciences and generative-transformational grammar. Each of these scientific battleships has helped to dictate a piece of that great philosophical paradigm that has imposed its hegemony for the whole last century. The philosophy of science has traced the perimeter within which it had to move: a forced synchronic, formal, analytical-deductive paradigm. The “linguistic turn,” began with Wittgenstein, has given him the chrism of logical-formal self-reference. The “linguistic turn,” which began with Wittgenstein, has provided him with the chrism of logical-formal self-reference, Turing with the cognitive efficiency of recursive and decidable systems and Chomsky with the mentalistic and biologic nature. All the pieces of this mosaic have often interacted with each other and, together, have been inspired, as far as possible, by philosophical traditions of the past: Platonic essentialism, the mathematical philosophy of the Pythagoreans, the Galilean-Newtonian method, Boolean logical laws, Cartesian dualism and iatromechanics, and, in some cases, the epistemological circularity of idealistic rationalism.

In what sense can this coherent philosophical paradigm consolidated throughout the twentieth century be defined as “naturalistic”?

Firstly, because the knowledge produced within it is modeled as “natural laws,” which tend to be analogous to those of physics. Therefore, general laws, controlled on an experimental and repetitive basis, formalized in a falsifiable theory, and expressed in a mathematizable language. In the linguistic field, for example, Fregean semantics, formal grammars, generative rules of rewriting, and very abstract ones of universal grammar are some examples, differently graded, of theories that express “natural laws” in a physicalist sense.

Secondly, which is the one covered by the so-called Chomskyan “biology,” physicalism can be interpreted naturalistically because its laws would conform to human nature in the very specific sense of innate devices, genetically predisposed and which manifest themselves without exception (pathologies apart) in human ontogenesis. Every child, ad., e.g., would manifest a constant pattern of language acquisition, of reaching specific stages such as motor learning, the appearance of syntax, etc.

Finally, this approach can be defined as naturalistic because it is based on a method traditionally attributed to the Galilean idea of “nature,” assimilated to a language of knowledge in which all terms are previously linked to deductive definitions, “in the language of mathematics” whose characters are “triangles, circles and other geometric figures, without which means it is impossible to understand humanly words, without these it is a wandering around for a dark labyrinth” (Galileo Galilei 1564–1642). From this idea derives the exclusion of any other scientific form that is not a specific mold of mechanics: the only known model of science in which it is possible to reduce knowledge to calculations without residues.

Taking on such a strong epistemological statute led to very high prices to be paid in terms of the empirical adequacy of the theories. For example, to always remain in the field of linguistics, expose yourself to the continuous reformulation of an entire theory because it cannot explain a given form that manifests itself in a certain language and that comes to conflict with its axiomatic principles bring to a devaluation of linguistic variability.

A second price paid to physicalist naturalism is purely philosophical. From Descartes onwards, in fact, the clear separation between totally mechanizable and mathematizable sciences and holistic and non-deterministic sciences has been able to establish itself through the specific philosophical stratagem of dualism. The res extensa would concern the components reducible to mechanistic analysis, and the res cogitans would remain the ontologically distinct domain of psychic reality. In computational hypotheses, this solution has proved to be perfectly suited to the distinction between hardware and software. The first models of AI, however, proved unsuitable to explain even the simplest semantic uses, and the state of the linguistic simulations of the artificialist models has never exceeded the stochastic level of the syntactic parsing of the sentences.

In the philosophy of the mind, the physicalist approach has even prevented us from tackling central problems of linguistic cognition, starting from the relationship between consciousness and language. It seemed completely intuitive to those who had taken on the onerous task of proposing a hybrid hypothesis on conscience to take refuge in some form of “naturalistic” [10] or “attributive” dualism [11]. In Chomsky, the dualistic assumption—very strong since Cartesian linguistics—ended up taking the forms of the epistemological distinction between problems and mysteries of language [12].

2.2 The humanistic Naturalism of Evolutionary Biology

There is a second form of naturalism: the "humanistic" form of evolutionary biology. To one of Darwin's most trusted heirs, Ernst Mayr, this possibility had not only not escaped but, at the end of his career, in a testament book written more than a hundred years old, it had seemed like a founding awareness: "Considering how similar evolutionary biology is to historical science and how different it is from physics in conceptualization and methodology, it is not surprising that drawing a definite line between the natural sciences and the humanities is so difficult, indeed nearly impossible" [13].

What is this similarity of biology-based more on *Geistenswissenschaften* than on exact sciences (id.: 34) from an epistemological point of view? What kind of naturalism is Darwinian, and why would it be so pertinent to cognitive studies so that a "part of the philosophy of humans can therefore by merged with biophilosophy" (id.: 55)?

The first point we should address to answer these questions is the Darwinian concept named by Mayr "populational thinking:" a notion that has been mainly ignored, so far, by those who work in the field of cognitive sciences, and instead deeply explored "by biologists who have applied the Darwinian thought to population genetics to reconstruct the bottom layer of knowledge about the speakers of historical-natural languages" [14, 15]. Actually, this topic is mostly unfamiliar and too philosophical for those interested in a naturalistic perspective rather than in a physicalist one. How populational thinking is in essence and defined by the biological and philosophical terms is summarized in Table 1.

3 The Neo-naturalistic Model of Cognitive Sciences

Undoubtedly, the cognitive sciences can be considered naturalistic sciences. However, the history of their naturalistic status must be considered as a sway with a progressive shift from physicalism to biology. The beginnings are all skewed toward the computational paradigm, the cornerstone of mid-century physicalism.

3.1 The Computational Paradigm

In 1936, Alan Mathison Turing, in the famous article—*On Computable Numbers, with an Application to the Entscheidungsproblem*—proposed a virtual machine whose operating rules appear simple but capable of simulating any calculable function. Its reliability is very high because it operates through deterministic procedures. Its operating principles are recursion (i.e., the possibility of applying rules that recall themselves for an indeterminate number of times) and the finiteness of the number of logical states in which it can be located and the tape on which it writes and reads the results of the elaborations. To function, however, it is essential

Table 1 How is populational thinking in essence and defined by the biological and philosophical terms

	Populational thinking
In essence	Populational thinking indicates that evolution always occurs within population: it is the effect of reception accorded by the environment to individual mutations, also helped by chance, which are advantageous for the individual in which they manifest themselves. Thus, it allows selection to be directed not toward the idealization of the best "essences" (as in the platonic-cartesian paradigm) but toward processes specifically related to reproductive success
Current biology	Populational thinking coincides with the concept of a "gene pool" that has taken the place of the classification of species based on morphological characteristics, similarities, or affinities of any kind. It is the set of all alleles of the genes belonging to all individuals of a population p at a given time t. A genetic pool, therefore, always contains an inherent possibility of very high variation that—associated to events caused by mutations, drift, gene flow, and by innumerable randomness factors related to the concrete realization of chromosomal transformations (for example, crossing over in meiosis)—basically makes regular but non-deterministic the reproductive process of individuals and entirely connects the affirmation of progressively adapted populations to natural selection
Philosophy	Populational thinking opens a new epistemological model to naturalism. It is no longer a typological universe of eidos, essences, formally defined classes treatable through reductionist formal processes that tend to be predictable, as in several physicalist paradigms, but it consists in events strongly constrained by structural trends and even more conditioned by concrete performance

that the problems submitted to it are solvable: that is, that the calculations necessary to find the solutions are made up of a number, perhaps very high, but nevertheless finished with steps.

The problem of the halting problem of a Turing machine is, however, Turing undecidable; that is, it cannot be predicted a priori. That the halting problem of a Turing machine is undecidable appears equivalent to limiting theorems of the formal systems of Kurt Gödel. Both tell us a very simple story at the end: not all human knowledge can be subjected to formalization processes. But we have to trust that part that we can formalize.

A few years later, Turing tries again. In *Computing Machinery and Intelligence,* published on "Mind" in 1950, he challenges the world to demonstrate his ability to distinguish only from external manifestations (the answers given to certain questions by an agent A to an agent B places in separate rooms) if reasoning comes from a machine or a human. In that important article, he demonstrates the impossibility of solving the problem with logical methods. The Turing test thus becomes the symbol of the first phase of cognitive sciences that in which the idea triumphs that everything we can preach about human intelligence can also simulate it through computers. Modern AI is born.

Today, AI is a mainly computer science discipline that seeks to develop algorithms that allow machines (computers or robots) to perform practical tasks performed up to now by human agents but no longer attempting to imitate the logic of human thought (a striking example is the use of *Deep Learning* [16]). By the mid-twentieth century, many thinkers had, however, cultivated the hope that by studying these procedures, cognitive scientists could identify the formal principles that govern the whole human reasoning and behavior (the so-called AI-strong principle). Turing was agnostic on this point. He showed neither skepticism nor optimism. Alongside the awareness that problems—still debated—such as self-awareness, but also transcendence ("theological objection"), common sense, naïve psychology, etc. (id.: 129–147) play in the formation of human thought without being able to be addressed in the context of an explicit mechanistic theory of the mind. Turing also has a clear understanding of the problematic nature of the real discriminating question for AI: the biological dimension of human cognitiveness.

Neurology, physiology, and morphogenesis have been some of his major interests since the late 1940s. In 1952, he published *The Chemical Basis of Morphogenesis* in which he tried to apply his formal models to the development of embryos. These are problems of "formidable mathematical complexity" [17], in which the guiding idea of the role of simplification, idealization, and, therefore, of the potential application of reductionist methods to biological reality is strengthened. The development of embryos, as well as the evolution of individuals, seems to Turing an event that can be simulated by machines that learn: "there is an obvious connection between this process and evolution" [18] as schematically presented in Fig. 1.

The limit of this assimilation between the machine–child and the biological child becomes, however, the insurmountable limit, in the first phase of the cognitive sciences, of the specificity of the cognitive embodiment: "to understand the Turing model of the brain, it was crucial to realize that it considered the physics and chemistry, including all the arguments of quantum mechanics (…), as essentially irrelevant. (…) The claim was that whatever a brain did, it did it by virtue of its structure as a logical system and not because it was in the head of a person, or is a spongy tissue made up of a particular type of biological cell formation" [19].

The theoretical efforts of the newborn cognitive sciences have thus been oriented toward making explicit systems, relations, and operative processes of the mind, relegating their bodily implementations to any kind of hardware, artificial or biological, in the background.

3.2 The Hegemony of Neuroscience and the Resilience of the Philosophy of the Mind

The basic idea that accompanied the conversion from the computational origins of cognitive sciences toward the neuroscientific approach is the naturalization of the mind. The computational mind is, in fact, an artificial mind. In a sense, however, no scholar, even among the most extremist supporters of strong AI, has ever truly believed that the computer metaphor could be anything but a method, a philosophy. On the contrary, in the neuroscientific paradigm, mind and brain really coincide.

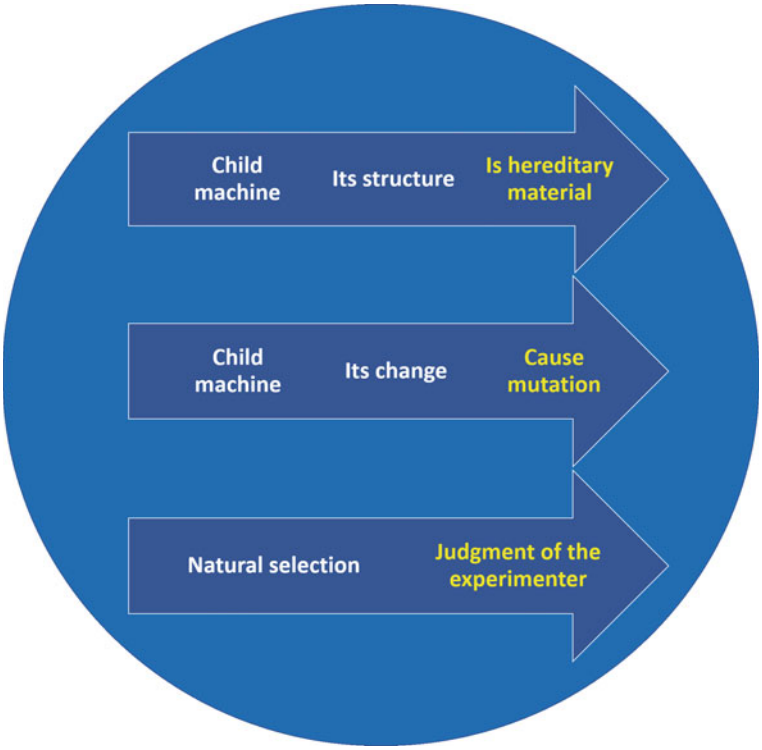

Fig. 1 Evolution and learning [18]

The brain is no longer a metaphor for the mind. In a sense, "it is" the mind itself. Although full of technical problems, the neuroscientific hypothesis is finally radically monistic: the mental process is resolved entirely in the brain process.

It is now a matter of *"simply"* mapping the correspondences between brain processes and mental events, associating neuronal sites with behaviors. The tendency to naturalize all the knowledge related to cognitive sciences is rooted in this hypothesis. In general, it can be said that the relationship with the two main naturalistic approaches that we have previously described varies with the type of cognitive investigation carried out, with the researcher's "job."

For those who deal exclusively with studying and measuring body phenomena, this statement is quite obvious: a neuroscientist studies the brain through histological, neurobiological, biochemical, neurophysiological, and instrumental analysis (brain imaging). His method is linked to meticulous and procedurally very rigorous experimental activity. In very different ways, even for the psychologist, the naturalization of the field is nothing more than an implementation of the experimental method applied to the attempt to identify the relationship between behaviors and neuropsychological hypotheses. The specificity of psychology, however, already complicates the transparency of cognitive analysis operations. In fact, how can we identify behavior if not as sets of observations on what subjects perform in terms of more or less complex functions that need, first of all, to be pre-defined in order to be considered falsifiable constructs? Finally, linguists also operate in a domain in which it is not excessively problematic to adopt a knowledge naturalization program. Linguists are also called to monitor the relationship between observable material phenomena (phonemes, words, sentences, speeches) and categorical classifications (such as the definition of grammatical, syntactic, and semantic competencies). However, the latter are connected to brain activities; therefore, they are, at least in theory, experimentally demonstrable.

The integration of neuroscience, neuropsychology, and neurolinguistics is today, in fact, completely satisfactory in the research practice of cognitive sciences. It operates through a true methodological synergy: the circumscription of the "sub- and neo-cortical areas in neuroscientific topography would have been impossible without the identification of actual behaviors, linguistic (or not), and their "intangible" interpretation—i.e. purely deductive—in terms of an explanatory theory of the interconnected functioning of systems of competencies (inference, mind reading, perception, syntax, semantics, etc.)" [20, 21]. Finally, it is particularly important that this type of integration produces relevant application results: the whole sector of cognitive and linguistic rehabilitation therapies is a clear example.

But if the rule is that as you move away from a craft centered on the material nature of your object of study, the application of the term naturalism appears increasingly problematic, what happens in the philosophical context in which you have to do directly not with the material substrates of ideas and concepts, but with the ideas and concepts themselves? It is the biggest problem of the philosophy of the mind and of all the collateral disciplines that revolve around cognitive neuroscience. What does it mean, in these cases, to consider mental behaviors natural behaviors?

For Quine [22], Goldman [23], and Dretske [24]—to whom we owe the first complete formulation of philosophical naturalism—it meant practicing philosophical euthanasia: philosophy must only dissolve in scientific knowledge by adopting the methods of the same natural sciences, especially physics. A more moderate formulation supports a gap between the philosophical problems that can be treated through the methods of the natural sciences and those that do not appear reducible to them. Supporters of this "liberal naturalism," including McDowell, Millikan, and Sellars, tend to place themselves at the ideal center of the dispute but risk using a blanket that leaves both the feet and the head of the debate uncovered.

Opening up to a dimension of thought inaccessible to naturalistic methods can mean, in fact, returning to dualistic solutions. However, such a hypothesis cannot coexist with the cognitive science program, at least from its second phase onwards.

There are two possible loopholes that the philosophy of the mind could take to avoid or mask the dualisms implicit in untreatable problems. The first would consist in the reduction of non-treatable problems to treatable problems. For example, consider the problem of the soul, subjectivity, consciousness, etc., as linguistic-conceptual problems. The second is to replace much more simplified versions of these problems with the problems themselves; for example, to replace the study of neurophysiological automatisms with that of the problem of extended consciousness, that of states of epileptiform alteration in mystical crises with that of the problem of religious sense (see Newberg and d'Aquili [25]), etc. For the purposes that we propose here, it is sufficient to say that only a few scholars have taken the first road, while most have poured on the second.

Complicating the tasks of the philosophy of the mind is the thorny question of the nature of language and its role in human cognition, which emerged above all with the "linguistic turn" in the philosophy of the first half of the twentieth century. The expression is of the American philosopher Richard Rorty, who in the 1960s advanced the idea according to which the analysis of language constitutes the method for solving all philosophical problems. This hypothesis, in addition to highlighting a lack of confidence in the autonomy of the physical and biological sciences, has also led to a sort of anthropocentric resilience which, by denying language to non-human animals, has contributed to amplifying its cognitive distance with humans and disadvantaging thus attempts to naturalize the history of evolution.

In many respects, therefore, the naturalistic program of neuroscience encounters resistance and generates problems, especially in the philosophical component of cognitive sciences, that is, in the philosophy of mind and language. At the same time, however, these philosophies pose a challenge to the development of cognitive naturalism, relaunching those problems which today seem to go beyond the threshold of scientific knowledge but which Turing considered, as we have seen, potentially solvable.

Could there, however, exist a naturalistic philosophy of cognitive science that transforms these challenges into a significant new step forward? In other words, is it possible to go beyond the neuroscientific phase that is currently dominating the scene in a naturalistic direction? According to Nobel Prize winner Gerald Edelman, this is possible only if cognitive sciences become definitively hinged in the theoretical and methodological contexts of contemporary biology. It is his program for the third phase of the new paradigm: "we must incorporate biology into our theories of knowledge and language. (…) We must develop what I have called a biologically based epistemology—an account of how we know and how we are aware in light of the facts of evolution and developmental biology" [26].

3.3 The Embodied Cognition and the Neo-naturalism of Contemporary Cognitive sciences

Edelman was one of the first to glimpse the crisis of the cognitivist paradigm at the very moment when it seemed to have reached its most successful point: "the blend of psychology, computer science, linguistics, and philosophy known as cognitive science." As with all vigorous efforts, ill-founded or not, much has emerged that is of great interest to scientists and non-scientists. Not the least of the positive results has been the routing of simple-minded behaviorism, but at the same time, "an extraordinary misconception of the nature of thought, reasoning, meaning, and of their relationship to perception has developed that threatens to undermine the whole enterprise" [26]. He reproaches at early cognitive sciences an exaggerated hyper-formalism that reduced representations of meaning to a logical-syntactic combinatorics. To tell the truth, animal cognitive systems are biological in nature. A genuine return to Darwin, therefore, means, for Edelman, the adoption of a populational and empirical biological conception. Therefore, not only "the mind is in the body," but "certain dictates of the body must be followed by the mind" (ibid. p 239).

EC is a set of theories recently developed as a reaction to the "cerebrocentrism" crisis denounced by Edelman. Its general principles can be summarized in the following points:

1. It is impossible for cognitive sciences to neglect the involvement of body structures in cognitive processes [27, 28].
2. Different body structures correspond to different cognitive systems [4].
3. Cognitive processes are not confined to the brain but involve wide-body structures and interaction with the environment [29–32].

Beyond these extremely important merits, however, the embodied perspective has soon split into different positions, to the point that Shaun Gallagher and Mark Rowlands coined the term "4E cognitions," that is: embedded, embodied, enacted, and extended (Fig. 2).

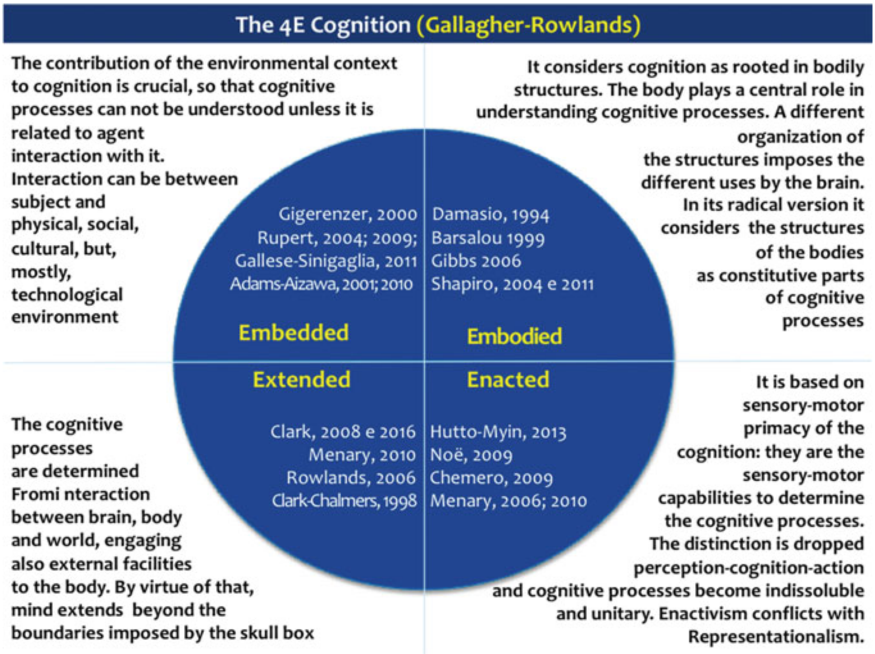

Fig. 2 4e cognition

Enactivism (enacted cognition), for instance, has often focused on the performing resources of biological organisms, their ability to carry out activities, starting with motor activity and also relying on an evolutionary perspective [32–35].

Even the theory of the embodied mind (EC) describes cognition as a function of biological structures. Therefore, as Shapiro attempted to show [4, 28], it is plausible that different body structures can result in different forms of intelligence. The presence or absence of certain structural features can lead to cognitive, mental, and cultural adaptations [6, 33, 34].

The cases of embedded cognition and of the extended mind are less directly addressed to the biological task. In particular, it is not so important to know the constitution of the "bodily technology" [35–37] that makes the development of certain cognitive abilities possible, but, if anything, to understand how digital technologies, developed from certain cognitive abilities, can extend and improve the body's powers [27, 30, 38–43].

All these variants of the embodied mind paradigm, however, can lead to epistemological problems. The first problem is the potential risk of going back to behavioral epistemologies. For instance, the most radical enactivist theses such as Chemero [29] dynamic approach to cognition or the post-artificialist models of Brooks [44, 45] support the idea that the self-organization of systems in perpetual dynamic interaction can account for the entire cognitive process.

The second potential risk is the denial of any form of representationalism as a result of the belief that cognition does not require internal semantic states. Gibson [46], for example, rejects any cognitive function of symbolic processing by attributing to perceptual systems the ability to grasp affordances directly from objects.

The third huge problem is the adoption of a naturalistic perspective centered on the subject and not on the species, which creates a tendency to explain the contribution of corporeality as "weak" or "lower" or "minimal" cognition [29, 47–49].

All these problems represent a price to pay for the EC perspective in cognitive science since they do not meet the fundamental principle of cognitive science: a theory must not describe behaviors, but he has to explain them. It is no accident that Gallagher wonders whether there is any point in conceiving enactivism as a science of mind. Enactivism is not a scientific research program, but a "philosophy of nature" [50, 51], a sort of "comment about the overall image of the natural world made by scientific and non-scientific research" [50] or "a form of naturalism, [which] does not endorse the mechanistic definition of nature" [51].

4 Conclusion

But if with the chiaroscuro of the EC, the critical picture is well defined, the constructive perspectives of a third "neo-naturalistic" phase of the cognitive sciences seem well underway but still need profound rearrangements in order to constitute a basic naturalistic model for the interdisciplinary approach to scientific problems. The abandonment of the mythical strong AI project and its transformation into a new computer science based on the intensive exploitation of big data, as in *deep learning*, has given rise to stunning results in some fields such as visual recognition [16, 52]. Abandoning any idea of simulating the way the human mind works, too different from artificial algorithmic solutions, AI seems to have found a completely adequate position in neo-robotics, in deep mind health, in-home automation, and in all the countless other sectors of “applied intelligence.” These developments seem to go precisely in the direction of an unexpected integration between theoretical and applied sciences, demonstrating the rules-free creativity of interdisciplinarity.

On the other hand, contemporary neurosciences, while deepening and perfecting more and more the refinement technologies of the investigation methods for clinical-diagnostic purposes and arriving at the ever-wider diffusion of neural interfaces, seem to have understood the theoretical importance of mitigating the tested internalist approach to embracing also the possibilities of the externalist. In particular, cognitive, affective, and social neurosciences have discovered the fruitfulness of making the relationship between the individual and the collective mind interact both on a psychological and ethological-social level. The extended mind model is no longer limited to assessing the possibilities of cognitive enhancement of individual subjects through the amplification of technological devices. It prolongs, however, to the analysis of the social management of emotions, feelings, primary conditions of aggression, cooperation, for the first-time crossing interaction with evolutionary psychology and with the ethological constraints of evolutionary and developmental biology (Evo-Devo).

Physicalist naturalism, in other words, is increasingly amalgamating in cognitive sciences with what we have previously called the humanistic naturalism of evolutionary biology, according to Ernst Mayr’s clear clairvoyant vision (2004) [13]. It is becoming increasingly clear to the entire research field that the decisive leap, which can transform cognitive science into a universal epistemological method, is its definitive metamorphosis into the unitary core-knowledge of the science without borders paradigm.

The evolutionist perspective, contrary to what the most important exponents of twentieth-century physicalism and even of early cognitivism thought, does not use the historical-diachronic axis as an instrument of pure (and useless/idle) description on the origins. On the contrary, the reference to the gradualism of the structures and the constraints of natural selection and the development of form (introduced by Evo-Devo) constitutes *the only form of causalism admissible in natural explanatory processes*. Elsewhere [53, 54], we have called it the principle of “chronological-logic-causalism,” meaning by it the indisputable fact that every variation always and obligatorily derives from the previous forms.

In a "disembodied" cognitive science, this type of causalism would be a negligible event. In fact, gradualism operates on structures and not on functions. Functions are never taken for granted in the evolutionary steps; anything can happen, as the numerous cases of exaptation demonstrate [55] and, of all, that of language, decisive for human cognitive ethology [6, 54].

But if we use, as we have tried to show in this essay, a naturalistic-biological perspective, there can be no doubt about the importance of the chronological causalism of the structures. The cognitive science of the new millennium must take for granted that applying a naturalistic perspective means, first of all, always basing cognitive evolution on morphological (anatomical-physiological) evolution that cannot undergo leaps. While the functional jump can produce transformations that we call "emergencies," the evolution of structures does not; all matter is transformed on the basis of its previous forms. A cognitively emergent state is reached, however, only at the conclusion of a very slow anatomical-physiological revolution. Chronological causalism and populational thought explain for themselves the reasons for any change that has proved decisive in the evolutionary history of a species.

The relationship, therefore, no longer between mind and body but between what Alva Nöe and Daniel Hutto call brain–body and non-brain–body (or neural body and non-neural body) is overturned from this neo-naturalistic perspective. As Spinoza had already taught in the seventeenth century, the substance is always one, but it is the non-brain–body that triggers changes in the brain–body. The brain is, as André Leroi-Gourhan happily said, "the tenant of the body" [53, 56]. According to Leroi-Gourhan, in fact, "human evolution did not begin with the brain but with the feet" [57]. With this expression, he summarized the long history of structural transformations in hominids, each derived from the previous one: bipedal mutation ─► standing upright ─► enlargement of the cranial fan ─► vocal tract formation with two 90° intersecting pipes ─► possibility of proffering articulated sounds ─► language training ─► rapid cognitive and cultural evolution Fig. 3

From the first to the last of these stages, seven million years pass. Almost all engaged in slow, gradual transformations of the physio-anatomical structures filtered by selecting the genetic pool. Only the very last part of this path was utterly unpredictable and took place in a brief time (57 thousand years) at the end of an enormously long cycle of structural transformations. If we admit, therefore, that this history of consequential structural transformations has determined the turning points of cognitive evolution that we analyze today with the typical forms of the experimental cognitive method, then we will also have to recognize that the evolutionary perspective is not a useless historical reconstruction without practical applications, but it is the foundation of a new naturalistic causalism on which the idea of science without borders could rest entirely.

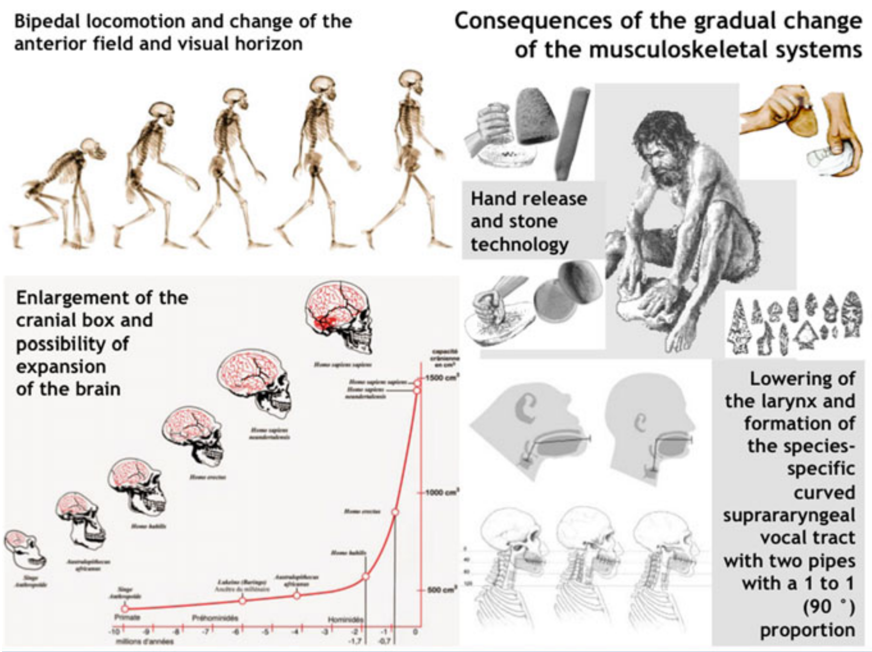

Fig. 3 Consequences of the gradual change of the musculoskeletal system

Core Messages

- Recent developments in cognitive science integrate life sciences, and AI, demonstrating the rules-free creativity of interdisciplinarity.
- Contemporary neuroscience seems to understand the integration of an externalist and an internalist approach to the mind.
- Cognitive neuroscience has discovered the fruitfulness of making the relationship between the individual and the collective.
- The model of the embodied mind is not limited to the cognitive level but at both the psychological and ethological-social levels.
- An evolutionary cognitive perspective is the foundation of a new naturalistic causalism of science without frontiers could rest entirely.

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