Human as machine: A discussion on the transformations and exhaustion of a metaphor

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ABSTRACT

From Descartes' view of the body as machine, to Dennett's conception of the brain as a computer, our understanding of human beings is permeated with mechanical metaphors. Due to the history of failures of the machine metaphor to approach the complexity of human phenomena, and the availability of new scientific approaches to mind and body, we argue that the explanatory power of the metaphor has been exhausted. Contingency, diversity, non-linearity, self organization and the limits of the instruments for scientific inquiry, are highlighted as key factors to be considered in new perspectives in the scientific study of humans.

1. Introduction

Metaphors are cognitive representations through which we attempt to understand phenomena by the power of analogy, using one object or idea in place of another, ascribing properties to objects which they not literally possess (Childs and Fowler, 2006). In addition to this substitution in the objective contents of a metaphor, we find a mental dimension in which the discrepencies between the elements of a metaphor are processed and interpreted, and a new entity of meaning is infered. In the Aristotelian view for instance, the efectiveness of metaphors was regarded as their capacity to evoke mental images. Thus metaphors are creative devices, by which rather than merely expressing existing similarities, they create a new entity of meaning that resolves all discrepancies (Black, 1962). Prevalent in communication and decision-making, metaphors are not used as linguistic devices, but dramatically influence the way humans perceive themselves, as well as contributing to the formation of ideas, and playing a key role in defining a subjects' actions (Ricoeur, 1978; Lakoff, Lawler and Johnson, 1983).

One of the primary focus for metaphoric production is the human being. Reasonably since the moment of self-awareness and incrementally throughout a human's lifespan, comparisons and manipulations are attempted to understand the physical and the mental and the interaction with the environment. Although machine metaphors went back to early natural Greek philosophy, centuries of complex economic, scientific and social forces gradually turned the machine metaphor into the prevalent conception about human beings during the 17th century. In that technological and cultural context, it flourished with René Descartes and Thomas Hobbes among its central supporting figures. Over the next centuries, the machine metaphor remained a fundamental presupposition in the biological sciences and the study of human beings. As it increasingly bared fruit, it became central part in the consolidation of modern physiology and medicine. And then, with the development of psychiatry, psychology and neuroscience, the domain of mind was also accommodated to fit in the constraints of a mechanical model. During the 1950's, in the midst of the cold war, a new iteration of the old human machine model was fostered by the military-industrial context. Namely, the models of brain as a computing engine, and the conception of mind as software. Armed with new methods, instruments and data, academic fields such as cognitive neuroscience and artificial intelligence have been since pursuing the aim of proving that humans are machines. Computational models of human cognition have been developed, and corresponding machines endowed with instances of these cognitive models, in the hope that from the whole, a machine-consciousness comparable of that of humans will emerge.

However, under closer scrutiny, the human being and its interactions with the environment seem to be riddled with paradoxes that transcend the neatly compartmentalized, stable and predictable machine model. Relatively recent evidences from fields such as genetics, neurobiology and cognitive sciences have highlighted certain aspects of uncertainty, contingency and heterogeneity that are crucial for understanding organisms. Certainly, many elements of a human being can be empirically analyzed and characterized to the best of the instrumental capabilities to date. And hypotheses may be substantiated and confirmed, to therefore serve as the basis of relatively accurate prediction models. However, there is a history of failures of the strict machine model to grasp the complexity of a variety of human processes in real world conditions. And as scientific instrumental and theoretical capacities have matured, the mechanical metaphor has been proven insufficient and at times misleading. Nevertheless, the machine metaphor survived, largely because it provides a comforting notion of stability of being in the world. But, in the scientific study of any matter, including the study of human processes and their environment, no dogma should prevent from new empirical observations to be integrated into updated theories. In this article we argue that the achievements of the human machine model in providing empirical data and explanations of human phenomena not

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based on incorporeal forces, are endangered by strict interpretations of its metaphoric content. We review a variety of important physical and cognitive phenomena misinterpreted or simply not characterized by the mechanical models of humans. We consider the vast differences in scientific knowledge between now and the time when the machine metaphor first emerged. Specially the amount of new empirical data on previously unobserved physiological and cognitive phenomena. Also, the philosophical assumptions and scientific idiosyncrasies that the machine metaphor implies, which in this article are characterized as normative anthropocentric stance against nature and insufficient epistemic rationality.

In light of mounting evidence from a variety of scientific fields, the explanatory power of the machine metaphor seems to have been exhausted. As the machine metaphor has sustained the success of strategic fields, such as political and commercial persuasion, pharmaceutical and biotechnological industries, data sciences and artificial intelligence, a large transformative effort would be required from all domains of human society. It would not only imply massive changes from scientific areas related to the study of human phenomena: from updating some of its fundamental assumptions and methodologies, to articulating new ideas that include their latest hypotheses and empirical data. It would also require a conscious and sustained effort from policy makers and economic stakeholders.

2. Cartesian machines

In the *Discourse on the Method* from 1637, René Descartes provided insight into one of the first articulations of the conception of humans as machines. Within the Cartesian universe, composed of res extensa or measurable things, res cogitans or mental things, and god as the divine designer, animal and human bodies were both automatons, but unlike animals, humans were connected to a thinking unmeasurable entity. Descartes explained these organisms in relation to the divine designer: "Every body is a machine and the machines made by the divine artisan are the ones that are best made (...) if only the body is considered there is no difference of principle between the machines made by men and the living bodies engendered by God, the only difference being that of perfection and complexity" (Descartes, 1999). Basic bodily processes associated with life, such as circulation, respiration, or digestion, were assumed to be produced by properly arranged matter functioning in accordance to the divine design. Notably, none of these material processes are caused by, or can cause mind. Descartes defined a sharp and mutually exclusive distinction between the radically distinct characteristics of mind and body: consciousness and spatial extension respectively. In this view, bodies are materials in space hence are essentially separated from mind, and one cannot act upon the other (Descartes, 1998). With this exclusive separation nevertheless, how the mind and body jointly execute voluntary acts was left unexplained (Baggini, 2002). In *The Passions of the Soul*, his final philosophical treatise completed in 1649, Descartes presented an updated view on the subject, in which a material interface, the pineal gland, supported the interaction between mind and body. Although this small gland located in the center of the brain is not exclusive to humans, Descartes argued that in humans its function is unique acting as the seat for the rational *soul* (Descartes, 1989). Descartes furthered the difference between a living body and a dead one from his mechanical perspective. The living body was compared with an automaton in operation, entirely governed by the criterion of its functionality as devised by the divine designer. Broadly, human bodies were God's machines. Material systems that unfold purely according to the laws of blind physical causation to which certain norms of correct functioning apply as dictated by a divine entity. But more precisely, the human machine was imagined as a functional device, following a specific teleological model of individual beings. Although the attribution of function and purpose to living systems is an ancient practice, the Cartesian metaphor crystallized a teleology of being individuated in complete independence of the nature of empirical objects, properties, or relations, excepting those in the individual's own body. And similarly, do not depend essentially on the natures of the minds or activities of other individuals (Burge, 1986). Before that time, teleology was either theologically grounded, or reliant on immanent essences that defined the final causes of organisms. In a process that comprised much of the 17th century, the soul was gradually replaced by concepts surrounding organization of individual entities, and by the idea that the complex activities of individual living beings emerged from the interaction of their component parts. A number of influential empirical and theoretical works of the time would serve as scaffolding for this turn. Let us consider examples such as Galen who presented in his *De usu partium* a functional analysis of the various parts of living organisms, in which organization and attributes of all the parts must be explained by reference to their functions in supporting the activities of the whole individual (Schiefsky, 2007). William Harvey's *De motu cordis* served too as a transition from vitalist to purely mechanistic explanations. His description of the circulation of blood through the veins and arteries in 1628, in which the heart was portrayed as a mechanical pump, and the circulation of blood as the result of the sequential motions of a machine (Wright and Wright, 2013). It is also noteworthy Andreas Vesalius' publication of *De humani corporis fabrica* in 1543. which included detailed illustrations of cranial nerves, glands, as well as the vascular supply to the brain, the spinal cord and the structures of the eye (Nutton, 2012; Denkler and Norman, 2012). And Thomas Willis's work *Cerebri Anatome* which presented in 1664 with enormous detail the anatomy of the brain and nerves, and where the term neurology was coined (Feindel, 1999). Agreement among these works gradually influenced the teleological compass to be exclusively centered on the individual and the mechanistic operations that insured its survival (Lennox, 2017). Following the Cartesian perspective, system features such as sensation or digestion serve the end of the mind–body composite with the sole function to suffice its survival. Specifically the survival of the body in a state suitable to allow the mind to continue to be in operation according to normative standards (Simmons, 2001).

3. Machine abstractions

The explanatory power of the Cartesian machine model reached out even further. Not only human bodies were conceptualized from a purely mechanistic perspective, but the entire Cartesian physical universe was idealized as one giant machine. A mechanical universe in which one event occurs after another through the relentless operation of physical causation following a set of divine rules. Just as at the scale of the individual scale the Cartesian model provided a set of goals and laws of correct operation, this universal machine was devised assuming a set of absolutely stable *laws of nature*. This represents another critical milestone, because at the time there had not been a consensus on such a notion of humans in the world and as part of the universe. Let us consider, influential philosophers of the time such as Sir Thomas Brown who discussed the idea of the entire universe as in disarray and that its dissolution was imminent. Or religious works such as Godfrey Goodman's 1629 Fall of Man which also supposed that the universe was in decay and slided daily towards its final dissolution (Poole, 2009). On the contrary, the Cartesian idea of timeless constants such as *laws of nature*, helped to shape and sustain a conviction of anthropocentric order, stability and equilibrium in nature, of which the machine metaphor of human beings is a crucial expression.

The all-encompassing machine metaphor of human beings in a mechanical universe consolidated then as the vehicle that provided the reductionist means for scientists to navigate otherwise uncharted biological landscapes during the next centuries (Urban, 2018). It also provided a goal-directed set of rules and a mechanical universe to fit into. In this sense, its influence was not restrained to the biological domain. As in the following centuries it also helped to devise types of social and labour organization with identical reductionist mechanistic approaches. A clear example is the invention of the assembly line in the mid 19th century, and its popularization in all types of manufacturing processes beyond its original place in heavy industries. Another example of this influence may be found in Taylorism and notions of scientific management that follow a machine-like ideal of human productivity and are up to this day seen as status-quo. Besides the fragmentation of complex processes into sequences of discrete steps, Taylorism argued for constant search for efficiency, and fine tuning of every step of the process with the purpose of generating more profit. This implied a hierarchical, mechanistic and strictly functional approach to human labour. Broadly, following the Cartesian division of humans into those who think and those who act. As a result, human contribution at each step of the manufacturing sequence may be reduced to its minimal expression. And importantly, it allows the rational interchangeability of any component of the industrial set-up, including human workers (Taylor, 1911). The quest for maximum profits even at the expense of human elements of the system rose up as sound method in scientific management. During the first half of the 20th century, these ideas of standard human bodies following universal rules had several other relevant revivals. For instance, the German architect, Ernst Neufert published in 1936 his seminal book *Architect's Data* which prescribed rules that sought to master space. Every object in space, including humans, would be standardised in a system of identical units. As a result, a universal industrial norm was born in the Nazi regime as the basis for the standardisation of German industrial and public architecture. A similar expression of totalitarian ethos was the *Modulor*. It was 1940's produce of the collaboration between the architect Charles Eduard Jeanneret-Gris -known as Le Corbusier- and the efforts of the Nazi-Vichy government in France to establish national standards for engineering buildings and industries. The *Modulor* which was supposed to regulate the spatial domain of humans, implied for instance that centimetres were to be replaced by a new system based on the height of the navel of a standard large man.

4. Machines matter

The definition of machine has shown not to be historically fixed. Etymologically the term machine comes from the ancient Greek mḗkhanẹ, which means set of pieces adjusted to each other, used to perform a specific job, specially tasks that challenge natural human capabilities (Walker, 1999). Importantly, machines are in essence goal-directed constructions, allowing manipulation of energy to achieve a vast diversity and scale of transformations (Kang, 2011). An example of machine capabilities to transform energy can be found in the solution to the problem of lifting heavy architectural elements. The earliest evidence for an understanding of composite pulley systems and cranes is found in the *Mechanical Problems* attributed to Aristotle's school at the beginning of the 3rd century BCE. Some decades later, Archimedes presented the principle of the mechanical advantage in the lever and his simple machines (Archimedes, 2009). The lever, the pulley and the screw, were used to obtain mechanical advantage and to modulate the direction of force. These basic machines transform human, animal energy or natural forces such as wind, river currents or gravity, into controlled gain of force and movement. A modern definition that accounts for this transformation of energy, is that a machine is a combination of resistant bodies arranged in such a way that the mechanical forces of nature can be manipulated, accompanied by certain movements (Hine and Mumford, 1968; Reuleaux, 1893). To achieve these movements and transformations, a machine must be comprised by a set of distinguishable material pieces, each of which should have a determined causal relationship with the movement of other pieces. Hence, recurrent, sequential and repetitive material operations account for the choreography in a machine. Every single piece plays a definitive role towards the goal of the machine. A modern description of these aspects of machines regards them as heterogeneous but intertwined sets of material fragments, gathered in conjunctions or cut through disjunctions, and in which the number of its parts and the complexity in their interrelation can give an account of the level of sophistication of the engineering used for its realization (Grosz, 2018; Uicker, Pennock and Shigley, 2003). These characterizations of the machine as goal-directed assembly of disparate material fragments that work to manipulate energy are interesting because they were contained in the Cartesian mechanical model of the 17th century. As we have reviewed, Descartes acknowledged the different relationships between organs in the body and accounted for the emerging properties of the assembly. In this sense, the Cartesian body machine was idealized as an integrated collection of special-purpose material subsystems, each capable of producing appropriate actions only within some restricted domain. And by working in coordination, these material subsystems perform several functions, of which they would not be capable if they were separated.

5. Unitary and stable

But, in the last decades of the 19th century a new conception of the material world emerged and with it new ideas that began to question the withstanding model and the conception of a neatly sub-divisible human machine. *Process philosophy* for instance, primarily associated with the work of philosophers such as Alfred North Whitehead or Henri Bergson, was concerned with the dynamic processes of material being and becoming, the conditions of spatial and temporal existence, and the importance of the relations between matter rather than matter itself (Robinson, 2009; Mesle and Dibben, 2017). In parallel, evidence from the emerging sciences dealing with quantum phenomena, provided interpretations that challenged the concept of matter itself. For instance, in the first decades of the 20th century works on the fundamental constituents of matter from Max Planck, Albert Einstein and later Louis Victor de Broglie helped to transform the notion of stable, unitary nature of matter. Evidence showed that matter at a subatomic level has coexisting particle and wave like properties, which was named *wave particle duality* (Lochak, 1984). These and other key discoveries and theories of quantum scale were assembled into a coherent mathematical framework called *quantum mechanics* (Primas, 1983). Furthermore, the results from the 1927 conference *Copenhaguen interpretation of quantum mechanics* posited that matter at subatomic level does not possess absolute properties of its own (Jammer, 1966). Rather its properties arise from the interaction between the observer and the observed. The implications of such scientific agreements were enormous. This means that matter in quantum world does not becomes until it is observed, a notion far closer to Kant's idealism and *Process philosophy* than to Cartesian reductionism. The contemporary view holds that all the fundamental constituents of quantum physics are fields rather than particles, and that there are no particles but only particle-like phenomena caused by field quantization. Field-particle duality exists only in the sense that quantized fields have certain particle-like appearances, but quanta are not particles; they are excitations of spatially unbounded fields. Photons and electrons, along with atoms, molecules, and apples, and human bodies would ultimately be disturbances in fields (Hobson, 2013). The assumptions about unitary and stable nature of matter that supported the modern machine conception of humans were critically challenged by the -multiple, distributed and heterogeneous- emergent conception. In showing that the idea of solid matter may be only an incomplete snapshot of what are really wave patterns of probabilities at the subatomic level, quantum physics questioned the deep reductionist assumption of matter being infinitely divisible into clearly defined and stable compartments. Instead it gave way to the notion of a complex web of relations between heterogeneous parts that, while distributed, act as a whole. In unexpected accordance to *Process philosophy*, and similar philosophical views concerned with dynamic becoming of beings, quantum discoveries allowed a glimpse into a new landscape in which no machines or bodies existed, but only distributed fields of interconnecting processes. In agreement, *New Materialism* has conceptualized matter as an active agent, with its own properties and capacities (Delanda, 2015), with morphogenetic powers of its own without having to invoke eternal natural laws (Lowney, 2011). A notion of matter with kinds of memory that exceed any individual instance, and fields of influence over other material structures (Sheldrake, 1992). This implied a change from a purely anthropocentric perspective into a view that considers space and time scales beyond that of humans. It also implied a shift from linear to non-linear causality, considering not only an entity's capacity to affect but also another entity's capacity to be affected at multiple levels. These transformations have led to the formation of new perspectives of embodied, situated human beings, constantly negotiating with the changing environment, influenced by material and genetic pursuits that extend beyond any single lifetime.

New materialism has generated a renewed interest in intrinsic elements of Darwinian approach to evolutionary processes of organisms. Specially the key factors of contingency, diversity, non-linearity, and self-organization, and a notion of humans as DNA-driven biological machines. However the old promise of stability afforded by the Cartesian perspective remains in the background of part of current genetic investigations. After groundbreaking conclusions about the composition of DNA were reached in the mid 20th century, with key contributions by Oswald Avery, James Watson and Francis Crick among others, confident expectations built up around the idea of novel genetic approaches to health and medicine (Portugal and Cohen, 1977). Understanding the workings of DNA would provide a map that would guide the discovery of the most intricate mechanisms of human species, and the particularities of each individual's genetic makeup. With these, the idea of a new stage in human development rose up in which inherited biology was available for manipulation and no longer invariable destiny (Venter, 2014; Collins, 2010). The follow-up to the human genome project, has nevertheless had limited success (Hall, 2010; Watson, 2003). There are some evidences highlighting that even current understanding of genetics is far from complete. For instance, there has not been a clear explanation about how so many heritable distinctions in organisms may be produced by the limited collection of DNA variety. Many genes are polyphenic, in that many phenotypes arise from one genotype. And most physical traits are polygenic, which means that are the result from more than one gene. Consequently, the relation between genotype and phenotype is utterly heterogeneous (Choi and Kim, 2020; Hahn and Wray, 2002). Despite dramatic advancement in genomics, the dynamism and complexity of the molecular world is still far from being completely understood. Other examples related to the complexity of genetics emerged from the study of behaviours that involve knowing things that were not previously learned by an individual, and the scientific examination of Hyperthymesia, a condition of highly superior autobiographical memory. Crucially as they are innate conditions, both had great expectations in finding an exclusive DNA explanation. However, after having pored over DNA for the last decade, scientists have found essentially no genetic specifics to work out a clear explanation for the innate differences that would rule over behaviours that were never learned. Schizophrenia's heritability has been a similar line of genetic inquiry for several years. Despite the efforts made at finding DNA-basis for the susceptibility to develop schizophrenia, it has been very difficult to pinpoint specific genes and no unequivocal DNA connection has been found (Balter, 2017).

Nowadays, the gene is not viewed as a fully identifiable entity and many its aspects are still unknown. It is not discrete, and any noticeable effects a gene may have are highly variable in a process that is enormously dynamic. The image of the gene as an isolated entity that only self-replicates has been abandoned. Instead, the idea of a so-called *promiscuous gene* has taken prevalence, highlighting the diverse relations in which a gene is engaged, and the variety of areas and ways of interrelation (Christopher, 2019).

6. Computer brains

One of the chief obstacles that all mechanistic theories have faced is providing a purely mechanistic explanation of the human mind. The traditional Cartesian view endorsed dualism in spite of supporting a completely mechanistic conception of the material world because Descartes argued that mechanism and mind were logically incompatible. Thomas Hobbes similarly in the 17th century conceived the human mind as purely mechanistic, completely describable in terms of the effects of perception and the pursuit of desire. Hobbes held a mechanical causal perspective about perception, which is largely the view of a chain of motions, completely caused by the materialistic operations of the nervous system. He was convinced that mental contents are derived directly or indirectly from sensation. The experience of objects in the environment would excite human senses and cause resonances in the particles that compose mind, resulting in motions that synchronized brain and hearth (Mill, 2001; Tuck, 1989). Importantly, in *De Corpore* Hobbes articulated the view that reasoning is computation: "By reasoning I understand computation. And to compute is to collect the sum of many things added together at the same time, or to know the remainder when one thing has been taken from another. To reason therefore is the same as to add or to subtract" (Hobbes, 1656). Reasoning was for Hobbes a form of computation in which mental symbols representing concepts, are added or subtracted in processes similar to those of arithmetic. These simple operations would then give way to networks that form more complex ideas. Hobbes gave some initial examples of adding ideas together to form more complex ones: "from the conceptions of a quadrilateral figure, an equilateral figure, and a rectangular figure, the conception of a square is composed" (Hobbes, 1656). Hobbes was not alone in this computational account for mental processes as symbolic manipulations. In 1644 the French philosopher Blaise Pascal had designed a mechanical calculator that could perform addition and subtraction based on symbols materialized as independent metallic gears. By the time of Hobbes' *De Corpore* was finished, more than 50 of Pascal's calculators had been manufactured. In the 1670s Gottfried Leibniz continued the development of the mechanical calculator and attempted the implementation of new operations of multiplication and division (Morar, 2014). Although these were early examples of symbol manipulation machines, they were still specialized devices, dedicated to carrying out a narrow range of arithmetic tasks. The first general purpose programmable symbol manipulator, and as such a candidate for computer brain model, came almost 200 years later. By mid 1830's The British mathematician Charles Babbage designed his *Difference Engine* purposed for calculating mathematical tables, and his *Analytical Engine* which was described as a general purpose calculator. Designed as a steam powered machine, the *Analytical Engine* featured some common elements with any modern computer, such as the idea of a central processing unit and a memory. Unlike Pascal's calculator it was not devoted to a single task, as it could be programmed to perform different sequences of operations. The programs were to be encoded as holes punched on cards that were fed into the machine, initiating then a sequence of gear-defined operations. This machine was never built partly because nineteenth-century engineering would not match the precision needed for producing the required pieces. Although the *Analytical Engine* was intended as a numeric calculator, Babbage acknowledged it could be programmed to operate on other kinds of symbolic data. He accounted for the foreseeable influence of machinery in economics and manufacturing (Babbage, 1832). Speculation arose on whether such a machine might be candidate for a model of the brain thus giving place to an *intelligent machine*. However Babbage made clear the *Analytical Engine* could only do whatever it was instructed to perform, uncapable of originating anything new, in concordance with Descartes' argument that matter, and therefore machines, cannot reason since reasoning involves the creation of new ideas (Bowden and Halsbury, 1953).

The development of early computer models of the brain thrived on and became one of the prevalent devices in the interpretation of empirical data from a variety of physical and mental phenomena. For example, in 1843 Emil du Bois-Reymond demonstrated the electrical nature of the nerve signal, and put forward a general conception that a living tissue, such as muscle, might be regarded as composed of a number of electric molecules (Finkelstein, 2015). In a few years, these laboratory models and speculations found opportunity for real world application in large scale populations, attracting much public interest. At Pitié Salpêtrière hospital, Jean-Martin Charcot produced a complete clinical description of around 3000 patients, coupled with the record of pathological changes associated with a variety of neurological diseases. The hospital context allowed Charcot to conduct one of the pioneering and widest pathological classification and post mortem study of neurological diseases (Zalc, 2018).

From an observational science, neurology gradually developed into a systematic way of approaching the nervous system and possible interventions in neurological disease. Studies of the brain and nervous systems became more sophisticated after the invention of the microscope and the development of cellular level identification procedures by Camillo Golgi during the late 1890s. Golgi's techniques were used by Santiago Ramon y Cajal and led to the hypothesis that the functional unit of the brain is the neuron. For this approach, Golgi and Ramon y Cajal shared the Nobel Prize in Physiology or Medicine in 1906 (Bock, 2013). In parallel, the study of aphasia and the work with brain-damaged patients by Paul Broca suggested that certain regions of the brain were responsible for certain functions, specifically supporting the importance of the frontal lobe in speech (LaPointe, 2013). As the understanding of neurons and nervous system functions became increasingly precise during the first decades of 20th century, neuroscience consolidated as a distinct academic discipline in its own right. Increasingly, quantitative work gave rise to numerous biological neuron models and models of neural computation that furthered fueled the computer brain dream (Finger, 2005).

The discovery of electroencephalography was a milestone for the advancement of neuroscience, especially in the study of consciousness, learning and treatments for patients with seizures. German psychiatrist Hans Berger made the first electrocorticogram recording in 1924 and reported on the topic in 1929 using the terms alpha and beta waves. A few years later in 1934, Wilder Penfield became the first Director of McGill University's Montreal Neurological Institute. Penfield's intellectual approach to the nervous system was derived from his studies with Ramon y Cajal, and others. Penfield made important observations on electrical stimulation to map the cortex in conscious patients during surgery for the treatment of focal epilepsy at the Montreal Neurological Institute. With his colleague Herbert Jasper, invented the *Montréal Procedure* in which patients with severe epilepsy were treated by destroying nerve cells in the brain where the seizures were thought to be originated. Interestingly, to accurately locate the borders of the region responsible for the epilepsy the procedure involved intervening on the brain of conscious, speaking subjects on the operating table. Under local anaesthesia, they received electrical stimulation on the surface of their brains while responding to questions from the operating staff (Guenther, 2016; Prkachin, 2021). The *Montréal Procedure* allowed Penfield and colleagues to create maps of the sensory and motor cortices of the brain showing the most likely portions of brain tissue which connect to the various limbs and organs of the body. They published this work in *Epilepsy and the Functional Anatomy of the Human Brain* in 1951 (Penfield and Jasper, 1954), and practically unaltered, these maps are still used today.

7. Control

The military-industrial complex formed in the World War II and the years after influenced academic understanding of body and behaviour, as enthusiastic supporter of the cybernetic view of human brain as an electronic, information processing machine. This alliance popularized the idea that the same electronic circuits and communication networks that controlled radar systems and the firing of missiles were the best model for understanding neural activity and predicting human behaviour. Between 1946 and 1953, the Macy Foundation in New York sponsored a series of conferences that united many disciplines under the cybernetic program: engineering, physics, biology, psychology, neuroscience. These conferences constituted a landmark as they were the first to develop a cohesive theory of systems that approached human body and behaviour, as well as social and economic processes, from a strict machine perspective (Nyce, 1992). Feedback was the main concept that differentiated cybernetics from other mechanistic explanations. Feedback is defined as the circular linking of causally connected elements in a system, making these systems non-linear. Thus cybernetics was born out of the marriage of military research and the attempts to express neural mechanisms of psychological phenomena in mathematical language (Capra, 1997). Moreover, the cybernetic program was popularized by many of the most influential scientists of the time such as Wiener, Von Neumann, Ashby, Shannon and McCulloch who were employed directly in the war efforts. A great part of the scientific advances regarding the machine brain model were directed towards strategic decision making and prediction of the opponent strategy, and the development of new *thinking* weapons systems. Another crucial branch of research was directed toward manipulations of the brain machinery and developing clinical applications for the relief of illnesses produced in war. Considering this, Penfield together with other scientists and institutions, such as the Allan Memorial Institute in Montreal, had at their disposition vast amounts of new data in the form military veterans suffering from neurological and psychological illnesses product of the war (Reif, Strzelczyk and Rosenow, 2016). To this end, known surgical methods such as the *Montréal Procedure*, and electric stimulation such as electroconvulsive therapy were used in coordination with newly developed techniques. In the Allan Memorial Institute with Ewen Cameron as its director since 1943, psychic driving techniques, the forced administration of drugs, sensory deprivation, and the manipulation of sleep and hunger were seen at the vanguard of treatments of neurological and psychological disorders. Some of these techniques remain currently in use both for clinical and law-enforcing applications (Cameron, 1957; Loo, Katalinic, Mitchell and Greenberg, 2011). For instance, the techniques of psychic driving involved incessant administration of persuasive messages to the individual during both wake and sleep cycles aiming to overwrite the patterns of the diseased mind. Further, Cameron and colleagues also attempted to use these techniques to write brand new mental patterns, just as if it were to replace a strip of film, or record a new file in a computer's memory. However, the mechanisms of mind and memory proved to remain beyond the predictions of the mechanical models, in spite of the reckless enthusiasm of the scientists of the time (Meerloo, 1956). The military industrial complex supporting academy and applied research institutions played a catalytic role in the use of these techniques, and pressured to go further as far as to implant new human memories. Memories were strategically seen as potent sources of motivated behaviour, shaping the nature of thinking and acting. And with memory implantation the conception of non free human agents with military purposes. However, these experiments were only partially successful in wiping memories from individuals, leaving important physical and psychological scars. They were largely not successful in deleting selective pieces of memory to help psychological diseases. Much further away remained the military dream of implantation of memories that could fuel coherent tactical actions. The radical methods used, reduced patients to an almost vegetable state in which just like children had to re learn their world, thus failed as both a therapeutic tool and an instrument for control of memory and behaviour (Sadowsky, 2019). The techniques that confidently aimed to brake down the brain machinery to then be re assembled into righteous individuals, allowed scientists glimpses into the irrational, unpredictable forces that form an important part of human behaviour and are dismissed by the traditional machine model. Among these unsolved paradoxes, irrationality. For instance motivated biased belief including self-deception, weakness of will and deficient self-control. Also, the degrees of influence of unconscious drives in current behaviours. The image of programmable machines which could be returned to *a natural state of equilibrium* was false. However, the search for stability and equilibrium, of which the human machine models are a crucial expression, remained embedded in therapeutic culture and scientific thought. And many of the assumptions regarding humans brains as computers helped to shape the empirical study of mental processes during the next decades.

As an alternative to the dream of a programmable human, the fields of cognitive science and artificial intelligence directed their efforts towards building machines with human-like thinking capabilities of their own (Haenlein and Kaplan, 2019). The Cold war had accelerated the translation of human cognitive abilities into machines, first in the fields of communication and decision making, and later in machine perception. Moreover, the bet on such machine models was encouraged by the overwhelming military success of their developers in the wars of the 20th century. Since the invasion of Iraq in 1991, a new set of revolutionary weapons materialized these efforts to instantiate human-like problem solving in machines. A large wealth of mathematical models and their computational instantiations already assisted strategic and tactical decision-making, as well as corporate management (Usselman and Edwards, 1996; Campbell, Lotmin, DeRico and Ray, 1997). The concepts of autonomous and precision weapon systems grew from fragments of the old metaphors of the computer brain and bared fruit in the promise of a new type of *intelligent* war that captured the public's attention almost immediately (Hiebert, 2003). As most destruction was witnessed only by machines and a few soldiers on the ground, the psychological scars of war that Penfield, Cameron and other scientists failed to erase were largely avoided. Moreover, by expanding the cybernetic communication networks of the military institutional body into society, and using the well tested psychological driving techniques on a mass scale, war scientists succeeded in developing a clean, coherent and heroic history of their military campaigns (Galliott, 2021).

8. Software minds

Artificial intelligence (AI) is currently seated at the centre of a vast enterprise to build computational models of intelligence. Its main assumption bares in some ways the heritage of old computer brain metaphor, which portrays intelligence in terms of symbol structures and symbolic operations which can be programmed in a digital computer (David, Miclea and Opre, 2004). In the prevailing view, human intelligence is essentially goal-directed. As stated by John McCarthy a foundational AI researcher: "Intelligence is the computational part of the ability to achieve goals in the world" (Sutton, 2020).

Due to the failure of classical binary logic as an appropriate model for human decision making, a departure from the traditional deduction paradigm began taking place in the 1990s. It saw reasoning as mainly probabilistic, rejecting the traditional binary logic as too limited for a comprehensive model of human thinking. Instead of the monotonicity of classical logic, the new paradigm embraced the update and revision of beliefs as new evidence becomes available (Oaksford and Chater, 1991, 2007). In decision theory the normative formula for belief revision is Bayes' theorem, which specifies how base rates should be integrated with new evidence to produce posterior probabilities. Essential theoretical aspects of Bayesian approach deal with the relationship between inductive and deductive ways of thinking, and with the interpretation of probability (Savchuk and Tsokos, 2011). This Bayesian turn would not only have implications for renewing the statistical methods used in empirical study of mind. Indeed Bayesian statistics provided a rational solution to the problem of making inferences about structured hypotheses based on sparse and noisy data. But it would also serve as inspiration for a new generation of models of human cognition, which shared the view of the human mind as essentially problem solving, operating according to the principles of Bayesian inference. This new paradigm of human cognition might be characterised by a number of features inspired by Bayesian models. It shares an emphasis on subjectivity, both subjective probabilities and degrees of belief, and subjective utilities and psychological values. It claims a descriptive stance in the face of uncertainty, and thus rejects superimposing expectations or normative criteria onto observed phenomena (Elqayam and Over, 2013). Considering that one of the defining features of the Bayesian statistical approach is the use of probability distributions to represent uncertainty, this Bayesian approach would attempt to build models that adapt to the observed phenomena, attempting to represent all that is and is not known about the models and its uncertainties (Lindley and Smith, 1972). However a more strict Bayesian view also exists in this new paradigm of human cognition. In this perspective, the goal-directed nature of humans is inexorably linked with normative rationality, which depends on conforming to normative criteria. In contrast, in what is known now as a soft Bayesian view, Bayesian models are used precisely for its approach to subjectivity, uncertainty, and degrees of belief which represent clear benefits specially for researching human phenomena, specially in the cognitive domain. This soft Bayesian stance would promise a more accurate perspective, allowing a descriptivist approach to behaviour, not based on how standard subjects ought to behave. A view in which instrumental rationality is not defined neither justified by normative models (Elqayam, 2012).

A variety of computational architectures of human cognition have been developed in the last decades, following both strict and soft Bayesianism, with varying degrees of success in their real world instances. One of the computational models of cognitive processes built implementing these ideas is known as Intelligent Distribution Agent (IDA) (Franklin and Graesser, 1996). Specifically, IDA was developed for the United States Navy to manage a rather complex set of tasks resolving the requirements and assignments of each sailor's tour of duty. It must allocate resources considering that the Navy's needs are satisfied while adhering to Navy policies, to then proceed to authorize and write the sailor's orders. Although IDA was not initially developed to test cognitive models, it is nonetheless based on psychological and neurobiological theories of human cognition and does put to test hypotheses and predictions about different cognitive aspects including consciousness (Baars and Franklin, 2003). For instance IDA's flexible cognitive cycle has been used to analyze the relation of consciousness to working memory at a fine level of detail, offering explanations of classical image-based working memory tasks, or the rehearsal of telephone numbers (Franklin, Baars, Ramamurthy and Ventura, 2005). But more importantly, IDA successfully implements much of one theory of human cognition, namely *global workspace theory* (Baars, 1988, 2002).

The *global workspace theory* postulates that human cognition is implemented by a variety special purpose processors, which are almost always unconscious. Coalitions of such processes find their way into into consciousness in function of the demands of real world contingencies. Consciousness in this theory is seen as a workspace that serves to transmit the message of the coalition to all available unconscious processors in order to recruit them to join in handling the current real-world situation. Consciousness is argued to have evolved in humans to allow dealing with novel or problematic situations that cannot be dealt with efficiently, or at all, by habituated unconscious processes. In 2009, Raphael Gaillard and colleagues provided empirical evidence for this view, by showing that conscious, but not unconscious, visual information is rapidly and widely distributed across the brain, provoking a synchronized brain activity that is the hallmark of conscious processing (Gaillard, Dehaene, Adam, Clémenceau, Hasboun, Baulac, Cohen and Naccache, 2009). It was then argued that in order to become conscious, information must first be represented by networks of sensory neurons long enough to gain access to a second stage of processing, specially involving the prefrontal cortex which is believed to be a major center for associating multiple kinds of information. And crucially, in order to reach consciousness, this combination of bottom-up and top-down information propagation must reach a state of reverberating, coherent activity among many different brain centers.

Following the *global workspace theory*, the higher level of IDA architecture is modular, having borrowed names from psychology for modules such as perception, working memory, auto biographical memory, action selection, constraint satisfaction, language generation, and consciousness, among others. In the lower level of IDA, the processors postulated by the *global workspace theory* are implemented by *codelets*, small pieces of code running as independent expectant threads, each of which is specialized for some relatively simple task. Codelets perform a variety of functions, most of them serving some high-level process such as a behavior. However, some codelets work permanently on their own, performing such tasks as watching for incoming e-mail and instantiating the goals of the system. An important type of codelet that works on its own is the attention codelet, whose purpose is to bring information to IDA's consciousness.

A number of other important cognitive theories and architectures share the view of conscious and unconscious interplay related to signal coordination. Francis Crick and colleagues hypothesized that synchronous firing at 35 - 75 Hz in the cerebral cortex is the hallmark frequency for observing consciousness. It has been argued that in such synchronous firing, pieces of information regarding different aspects of an entity are brought together, and thus consciousness emerges (Crick and Koch, 1990). Antonio Damasio's model also describes a constellation of unconscious processes that become consciousness once a reverberating threshold is achieved (Damasio, Damasio, Tranel and Brandt, 1990). The model hypothesizes the existence of many *sensory convergence zones* that integrate information from individual sensory modalities through forward and backward synaptic connections and the resulting reverberations of activations. Damasio also hypothesized the global *multimodal convergence zone* which integrates information across modalities also through reverberation. Once signal reverberation is achieved, all the information about an entity stored in different places of the brain becomes available as consciousness. The role of signal reverberation is captured in the cognitive architecture proposed by Ron Sun called *Connectionist Learning with Rule Induction ON-line* (CLARION) (Sun, 1997; Sun and Franklin, 2007). CLARION is focused on the integrated effect of top-down and bottom-up learning applied to a variety of domains, for example, navigation and decision making (Sun, Merrill and Peterson, 2001). CLARION implements recurrent connections within modules at the bottom level and through multiple top-down and bottom-up information flows across the conscious and unconscious levels. This leads to a space of synthesis of all the information present which would be consciousness (Baars, 1988). Some resonance may also be observed between the ideas of the *global workspace theory* and the views of the philosopher Daniel Dennett on consciousness. Dennett has argued that the phenomena of consciousness is the result of a vast amount of calculations occurring in the brain almost simultaneously. For Dennett consciousness is collaborative - competitive interaction between temporary coalitions of mental processes. In his *Multiple draft theory* Dennett outlines a form of *virtual governor* that is not located anywhere, but it seems to control the whole system (Dennett, 1991, 2018). By virtue of discovering how consciousness related computations operate in the human mind, it would be possible for computer programs to achieve consciousness. In Dennett's view consciousness has evolved genetically and culturally in humans, in order to act as a system of higher-level cooperation and mutually enforcible constraints to facilitate coexistence. Consciousness would be then unique to humans, because they coexist in a world orders of magnitude more complex and full with opportunities than that of any other living thing.

9. Instruments and methods

A large wealth of critical hypotheses for computational theories of cognition and consciousness are derived from these and other implementations of synthetic cognitive systems (Petersen and Sporns, 2015). However, the key attributes of these architectures largely remain outside the reach of current capacity to produce empirical data. Consider that in the last decade, expensive efforts to construct a map the human brain using the most advanced neural technologies were put in place but have had limited success (Adams, Albin, Amunts et al., 2020).

For instance, bottom-up and top-down information propagation, and synchronization among many different centers, represent a critical challenge for current brain imaging techniques such as functional magnetic resonance imaging (fMRI). This technique was developed in 1990 by Seiji Ogawa and colleagues at Bell Laboratories and is considered the standard for in vivo imaging of the human brain. It is based in the assumed correlation of instantaneous hemodynamic changes to brain activity (Ogawa, 2013). But, the voxel-level resolution of fMRI results represent changes in hemodynamic parameters for groups of several millions of cells. Additionally, many cell structures are involved in multiple processes, and their hemodynamic parameters may change at many times irrespective of the explicit cognitive activity, hence it is impossible to make observations about specific structures of cells. Furthermore, the temporal resolution of fMRI even of most advanced systems is coarse in comparison to the speed in which neural processes seem to occur. Considering that each fMRI scan requires more than one second to be performed, thus allowing enough time for fields of neurons to fire several hundred times without being registered. It is currently not possible through fMRI alone to assess weather the activity of any single area causes activity in another area of the brain (Turner, 2016). The sparse information gathered through fMRI requires sophisticated statistical techniques to infer correlations between voxel change and cognitive activity. From the changes within each voxel generated by the subject in each scan, and relying on general models of correlations derived from previous patients, scientists attempt to make observations and point at specific areas of significant activity (Monti, 2011). During the last decades, several discussions have emerged regarding the accuracy of models and parameters used in these data collections and interpretations, and inflated correlations in fMRI analyses have been pointed out (Vul, Harris, Winkielman and Pashler, 2009; Yarkoni, 2009).

Another important aspect is the ecological validity of the tasks and environments used to collect neural and behavioural data. The tasks used to generate neural activity are generally heavily constrained to the environment of the fMRI apparatusses. After the discovery in 1992 that hemodynamic changes in brain cortex can be explored by near infrared spectroscopy, functional near infrared spectroscopy (fNIRS) appeared as a brain imaging technique that could resolve the portability and ease of task integration issues (Ferrari and Quaresima, 2012). Despite its advantages, fNIRS is also limited in spatial resolution, comparable to fMRI technique, making it equally difficult to distinguish neural responses from separate adjacent areas, while being prone to localization errors. The data acquired by fNIRS consists of a series of time-dependent signals measured between individual light source and detector pairs. Using general models that describe the light propagation in the underlying tissue according to its location, this technique reconstructs hemodynamic activity for each source-detector pair. A clear advantage of fNIRS is its high temporal resolution allowing for sampling rates up to 10 Hz. But despite this advantage, these recordings are still too coarse and may often represent the subject's averaged hemodynamic response to repeated stimuli or tasks. Another limitation of this technique is that near-infrared light diffuses rapidly while entering neural tissue, rendering fNIRS unsuitable for investigation of neural activation in structures deeper than about 1 centimeter below the surface of the brain (Cui, Bray, Bryant, Glover and Reiss, 2011). As with fMRI, fNIRS data interpretation is closely related to the nature and use of image reconstruction algorithms, and thus subject to similar discussions on non independent studies, biased models and inflated correlations. In this case this process includes models for localisation of brain tissue, an average path of light between each source and detector position, models for propagation of light and the tissue's standard absorption and scattering properties, among others Carlo and Stevens (2013). And from these models an image of the underlying hemoglobin changes in the brain is constructed.

However, in order to test assumptions related to situated, embodied models of cognition, in which the coordination of multiple centers across the entire body play a significant role, a new set of test methods and instruments would have to be developed Seth (2012). The necessity for registering data points at sufficient temporal resolutions would have to be clearly resolved. Moreover, these processes closely interact with environmental influences over time, therefore it would be of critical importance for techniques to integrate as transparently as possible into the experimental environments. The statistical approaches to interpretation of fMRI or fNIRS data, are evidences of the large differences in scope and resolution between the neurocognitive phenomena and the available instruments for their empirical study. Due to this limited scope and resolution of available techniques and lack of ecological validity of current methods, most of the hypotheses held by most current computational models of mind remain untested.

10. Discussion

The machine metaphor succeeded in articulating a majority of the knowledge and imagination regarding the scientific study of human beings during the 17th century, and since, became the most accepted approach. Along with the evolution of scientific and philosophical thought, the traditional mechanistic approach underwent numerous adaptations to ensure its survival and may be found up until today embedded deep into popular culture, as well as in philosophical and scientific thought. From modern physiology and medicine, up to recent theories of brain as computer and mind as software, the mechanical metaphor took on many forms to explain a vast variety and scale of complex phenomena. Many aspects of human body and mind are certainly susceptible to be observed and probed and most have had their operating principles modeled with a variety of degrees of certainty. In the ideal sense in which metaphors are neutral devices, the use of metaphors would have been useful to help communicate observed phenomena and scientific facts to the best of instrumental capabilities of each epoch.

However, the metaphoric construction of human as machine has bridged the gaps between known and often sparse facts, carrying a variety of unfounded assumptions and expectancies along its centuries-long life. Rather than just expressing some existing similarities, this metaphor has developed into an entity with meaning of its own. In this case, metaphorical meaning which is not merely the result of a semantic friction between the entities human and machine. But, by projecting the rather recent human ability to construct machines onto natural organisms, a crystallization of a set of specific philosophical viewpoints and scientific idiosyncrasies into a highly transmissible communication device. Namely, a strict normative anthropocentric stance in the universe, which possesses categorical force to bind nature and any rational agent. We consider this stance an expression of the endless search for stability and equilibrium in nature, specially the desire for control and predictable human beings. When transposed from the study of humans to entire societies, the machine metaphor has provided the fundamental assumptions such of stability and linearity of natural processes, their categorical separability, and the need for hierarchical organization. As such, the machine metaphor contributed to shape entire disciplines of corporate management. First, in industrial and military bodies, and later in design of policies for social and economic management.

Furthermore, the machine metaphor is no representative of current scientific knowledge. During the last decades, an increasing amount of empirical evidence from fields so diverse such as physics, astronomy, social sciences, biology and genetics, and the neural and cognitive sciences, have begun to replace normativism with descriptivist accounts that consider contingency, diversity, non-linearity, and the instrumental limits of scientific knowledge as key aspects. Additionally, the views of *Process philosophy*, and *New materialism* which hold matter as an active agent engaged in its own open-ended evolution, have helped to replace the tradition of anthropocentric order in the study of natural phenomena, rejecting natural eternal laws or directions given by a divine designer.

10.1. Normativism

A search for order and stability in nature is expressed in the machine metaphor. It bares at its center the perspective of the engineer, superimposing onto biological lifeforms the normative way mechanisms ought to operate, be designed, constructed and organized. The concept of human machine is intertwined with a biologically correct way of behaviour, and even, a biologically correct social integration.

As we have reviewed, several times in history, the machine metaphor has played the role of the regulatory device preceding the empirical observation of behaviour and the filter for its interpretation. This allowed the fabrication of an apparently clear homogeneity from the rather disparate and unstable reality of humans beings. In the realm of the machine body, models have been grounded on a fundamentally goal-directed, comparative concept of operation. When instead, it could be possible to approach body not in terms of goal directed functionality, but in terms of gradations of experience and relative instrumental standards (Schroeder, 2013). We now know that biology runs on a motor of unpredictable mutations that generate the variability seen across individuals in a species and interact with the environment to drive evolutionary change through natural selection. Neurons are also known to be noisy elements, generating action potentials that are far from perfectly predictable events. In machine engineering, an ideal of perfection is the guide for design and operation. Errors are avoided, and operation glitches quickly fixed. In part, the comfortable stability predicated by the mechanical metaphor has prevented from rational epistemological stance in face of uncertainty in nature and the complex processes of human beings.

This may be in part why modern medicine has been directed in a large degree only towards control and palliation. Unlike machines that may have their discrete parts replaced and thereon continue to perform the exact same function, it seems evident that although the critical operations of important organs are understood, there is a variety of processes beyond the scope and resolution of the traditional human machine model. For instance, while it is true that heart transplant procedures have saved numerous lives since the the late 1960s, it is also true that nearly none of these cases are able to return to the operational standards as a machine would do. Only 57 per cent of patients live 10 years beyond their operation, and only with great pharmacological efforts (Politi, Piccinelli, Poli, Klersy, Campañá, Goggi, Viganó and Barale, 2004). Moreover, decades-long reports of changes in heart recipients' behaviours have not been explained. For instance, the emergence of behaviours in recipients that parallel behaviours of anonymous donors, as well as cases of sensory experiences that resemble experiences lived by corresponding anonymous donors (Pearsall, Schwartz and Russek, 2000; Liester, 2019). It seems reasonable to inquire the possibility of alternative explanatory approaches sensible to new scientific discoveries, and attempt new theories that do contemplate these interesting and perhaps crucial human phenomena. In this sense, in the study of mind, a clear distinction between normativist and descriptivist approaches to rationality has gained interest. Normativist approaches accept an *oughtness* in regard to human thinking, postulating that thinking should reflect predetermined absolute normative standards. When such approaches also argue that thinking empirically conforms with normative standards, the result is Panglossism, the view that thinking is inherently normatively rational (Stanovich, 1999; Elqayam and Evans, 2011). The human machine heritage expressed in strict Bayesian approaches tends to be normativist-Panglossian. It would be then reasonable to favour a descriptivist approach as that proposed by soft Bayesianism, according to which models follow observation of phenomena, and are open to uncertain evolution.

10.2. Instrumental limits

Provided that a descriptive Bayesian approach would be the best approach to address the fields of complexity and uncertainty in the study of human phenomena, efforts should be directed to reach a stage in which the instrumental and methodological limits are also accounted for. Invasive and non invasive current techniques offer coarse and partial correlations of brain activity and cognitive processes that help scientists to make inferences about systems (Alivisatos, Chun, Church, Greenspan, Roukes and Yuste, 2012). As so, the localised scope of these instruments, and the lack of sufficient spatial and temporal resolution, remain major challenges for certainty in neurocognitive studies. Moreover, a vast majority of these methods work in artificial conditions far from ecological validity, thus lacking the complexity afforded by real-world interaction. From these data, brain scientists assert with varying degrees of confidence the role of systems in various functions and states. But these correlations are fragile and provide only glimpses in a vastly complex landscape of interactions. As we have reviewed, a variety of models of cognition and neurocognitive data have highlighted the instantiation of cognitive functions not in a single cell or even a well discernable group of brain cells, but by complex networks of collaborating and competing structures across the body. It is now understood that specialized cell structures become active or inhibited non-linearly, following a variety of complex patterns and communications, which in turn affect the state of other structures. A number of interesting resonant frequencies have been found during specific cognitive operations pointing to synchronized multi focal processes (Solomon, Kragel, Sperling, Sharan, Worrell, Kucewicz, Inman, Lega, Davis, Stein, Jobst, Zaghloul, Sheth, Rizzuto and Kahana, 2017). This top-down and bottom-up coordination of the human body seems critical to understand a diversity of cognitive processes, as well as the phenomena of consciousness as various influential models of consciousness now agree. Moreover, at least some of these cell networks distributed throughout the body gradually build material modifications to facilitate repeated environmental responses and behavioural states, reflecting vast possibilities for variety between individuals.

By using a descriptivist approach all of this knowledge has yet to inform the future models of human phenomena. But numerous critical advancements in the development of experimental methods and new instruments would still be necessary to be created. Due to the fact that currently available techniques for key phenomena at a fine-grained level, such as fNIRS, fMRI and electrodes implantation, lack either in scope, or in spatial and temporal resolution, most of the interventions procured by neural fields specialists critically rely on partial and coarse images of the functioning body, allowing enormous biases and misinterpretations. In a similar way, a majority of the assumptions related to computational models of mind face serious challenges for producing significant evidence to guide speculations speculations and verify hypotheses. Further still, lies the possibility of outlining a general theory of consciousness which would determine what sort of physical systems generate conscious states, whether other organisms possess consciousness and in which degree (Ramos, Grady, Greely, Chiong, Eberwine, Farahany, Johnson, Hyman, Hyman, Rommelfanger, Serrano, Churchill, Gordon and Koroshetz, 2019).

In light of these issues, and the growing availability of new scientific instruments and knowledge, it seems reasonable to consider that the metaphor of human as machine has been exhausted. As it has been so disparately employed by different fields throughout its lifespan, and as it has been superseded to such degree by current scientific and philosophical thought, it seems now contributes more confusion than insight. The lack of a unified view to replace the comfortable machine metaphor may be interpreted as an expression of maturity in scientific stance in history. A descriptivist stance in which uncertainty, diversity, nonlinearity, self-organization and instrumental limits for scientific inquiry would be crucially considered before blind adherence to any ideal model.

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