# The Rise of the Posthuman Brain: Computational Neuroscience, Digital Networks and the 'In Silico Cerebral Subject'

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## I. Introduction

To say that the brain has become a "major icon of contemporary culture," as Francisco Ortega and Fernando Vidal claim in the introduction to their book on "Neurocultures" (Ortega and Vidal 8), seems to be a common rhetoric today. Against the backdrop of a tendentious belief that all humans are essentially their brains, as we can witness in contemporary neuroscience as well as in its cultural surroundings, the understanding of the brain can be equated with an understanding of the human as such. What is often attacked as "Neuromania" (Legrenzi and Umiltà; Tallis) apparently proves to be very robust to further criticism. Moreover, the *Critical Neuroscience* (Choudhury and Slaby) have well-tried interdisciplinary reflections on the achievements and capabilities of neuroscience itself to support a more modest approach. But even the Critical Neuroscience project "examines the ways in which the new sciences and technologies of the brain lead to *classifying people in new ways*, and the effects this can have on social and personal life" ("Critical Neuroscience" italitcs mine). The neuroscientific endeavour in its shimmering facets tries to re-conceptualize our notions of the laws and functions of the human brain and, en passant, the human subject in its entirety. This can be observed in science as well as in broader social and political contexts.

From George H. W. Bush's Presidential Proclamation on a "Decade of the Brain" (1990–99) to the "Blue Brain Project" and the "Human Brain Project," founded by the European Union, and to Barack Obama's "BRAIN Initiative," the brain is the centre not only of a scientific but also a public eye. On the backwash of these financially strong enterprises the high-performance media technologies shape the regime of knowledge of the brain in late modern time.

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The coloured brain images of the functional magnetic resonance imaging (fMRI), for instance, have become quite prominent in science as well as in popular culture. Evidence of what happens when the "mind is at work" (Hagner) are attributed to these images and their imaging procedures. But as Edward Vul, Christine Harris, Piotr Winkielman and Harold Pashler have examined, the correlations between brain activities and personality measures based on "blood oxygenation level dependent (BOLD) signal measures" (278) in fMRI studies strongly rely on statistical computational procedures that base on selected sets of voxels and thresholds to create a feasible but highly artificial 'model' of brain activations. These images do not *show* the 'mind at work' *per se*, but, to a greater degree, statistical computations. Thus, evidence of brain activation has to be re-attributed rather to the 'algorithm at work.' This becomes much more apparent in efforts in "Computational Neuroscience," in which *difficult algorithmic or implementational questions are intimately related to the data of the nervous system*. The interplay of neural data and of computation and applied mathematics define the scope" (Schwartz x). Indeed, computational neuroscience is commonly defined as an interdisciplinary field of research that combines diverse fields such as neuroscience, cognitive science, computer science, physics, psychology and biology and that has steadily evolved as a vital and dynamic field. Nevertheless, the major focus is the development and evaluation of digital computer models:

> Computational neuroscientists use mathematical models for the description of experimental facts, borrowing methods from a wide variety of disciplines, such as mathematics, physics, computer science and statistics. Investigations of hypotheses with the aid of models leads to specific predictions that have to be verified experimentally. The comparison of model predictions with experimental data can then be used to refine the hypotheses and to develop more accurate models, or even models that can shed light on different phenomena. The studies in computational neuroscience can also help to develop applications such as advanced analysis of brain-imaging data, technical applications that utilize brain-like computations, and ultimately, better treatment of patients with brain damages and other brain-related disorders. (Trappenberg 3)

In so doing, computational neuroscience tries to understand the brain at a very 'functional level' by integrating all relevant information "from different levels of investigation into a coherent [digital] model of how the brain works" (Trappenberg 2). Or to put it another way, above all it is about the exploration of *computational principles and potentials*.[1] From this perspective, the "algorithmic intermediation" (Urrichio 25), as I will show in the following, leads to a corresponding regime of knowledge of the human subject in the neuro- and information-driven "century of the brain" (Hagner and Borck 507), a regime of knowledge that I will refer to as 'posthuman.' That is because the algorithm does not only re-configure the relations between the "viewing subject and the object viewed" (Urrichio 25) against the backdrop of a new computational impelled visual system, as William Urrichio has put it in a different context. The ascendancy of information patterns and digital algorithms in computational neuroscience strengthens a *modification* of the *epistemology of the brain,* a transformation of the human into a posthuman brain. In order to investigate opportunities for classifying human conditions in new ways the "algorithmic turn" (Uricchio) in computational neuroscience reveals itself as a 'posthuman turn.'[2]

I would like to discuss the following theses: I) There has been a shift in the epistemology of the brain in late modern neuroscience from a life science approach (biology and medicine) to a computer science approach in order to perpetuate a techno-rationality that concentrates rather on engineering than on representing nature. II) At this, such a shift in the epistemology of the brain *updates* and *preserves* the "posthuman view" (Hayles, *Posthuman* 2) in the field of computational neuroscience to render a proper regime of knowledge in the 'information age.'[3] III) The posthuman regime of knowledge in computational neuroscience leads to an understanding of the (post-)human being as an 'in silico cerebral subject'[4] that is implemented in a digital network environment.

The 'information paradigm' of cybernetics in the 20th century[5] has become

1. Cf. Dayan, Peter, and L. F. Abbott. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. Cambridge: MIT Press, 2001. Print.
2. For the requirements of a 'posthuman turn,' see N. Katherine Hayles' *Posthuman*. Furthermore, I will discuss my use of the term 'posthuman' in section II of the article.
3. Cf. Castells, Manuel. *The Rise of the Network Society.* Malden: Wiley-Blackwell, 2010. Print.
4. For a broader discussion of the concept of the "cerebral subject" in the history of neuroscience, see Vidal.
5. Cf. Wiener, Norbert. *Cybernetics: Or Control and Communication in the Animal and*

a strong epistemic logic nowadays, not only because of the massive impact of digital media as such, but because of the expansion of digital networks as the "core organizational structure" of the 21st century (Galloway and Thacker). With this in mind, the boundaries in computational neuroscience between working on 'in silico brains' and 'virtual genes' to find new ways of treatment for diseases and to enhance the brain in order to match it to the environmental system of the digital age are getting more and more blurred.

I will proceed as follows: In the first step, I will analyse the "Human Brain Project" to highlight the epistemic shift from the human to the posthuman brain in one of the most influential research projects in computational neuroscience at present. In the second step, I will discuss the concept of the "Human Brain Project" in order to emphasize the rise of the posthuman brain on the backwash of visions between *treatment* and *enhancement*. The attempt to realise 'in-silico brains' in the "Human Brain Project" to develop techniques for modifications of the biological brain moves this cutting-edge research closer to actual transhumanist-impelled concepts such as the "Substrate-Independent Mind Project." In the third step, I will draw attention to current media theory in the context of digital network technologies to expose some broader transformations of the posthuman subject in the 'century of the brain' in terms of the 'information paradigm.' Finally, I will give some provisional conclusions.

## Ⅱ. From the Human to the Posthuman Brain

The 'posthuman' is a highly ambiguous term that is used differently in the discourses on posthumanism (in its philosophical and culturally-critical manifestations), transhumanism (and its different forms, e.g. extropianism or liberal transhumanism), metahumanism, antihumanism or the so-called new materialisms.[6] Since I am referring to post- and transhumanist approaches

*the Machine*. Cambridge: MIT Press, 1948. Print. Cf. Bense, Max. "Kybernetik oder Die Metatechnik einer Maschine." *Kursbuch Medienkultu. Die maßgeblichen Theorien von Brecht bis Baudrillard*. 1951. Ed. Claus Pias, Joseph Vogl, Lorenz Engell, Oliver Fahle, and Britta Neitzel. 2nd ed. Stuttgart: DVA, 2000. 472–83. Print.

6. Francesca Ferrando has recently published a very well written article about the differences and relations between these concepts, and between the posthumanist and the transhumanist movement in particular. I will not go into detail about that again.

throughout the article a short discussion is needed. Roughly speaking, in the context of transhumanist discourses the posthuman can stand for the enhancement of 'human nature' with the help of advanced technologies such as nanotechnology, biotechnology, robotics and information and communications technology. Nick Bostrom, for instance, claims that transhumanists understand "human nature as a work-in-progress, a half-baked beginning that we can learn to remold in desirable ways" ("Transhumanist Values" 4). Thus, humanity in its current state is not considered as the endpoint of evolution. "Transhumanists hope that by responsible use of science, technology, and other rational means we shall eventually manage to become posthuman, beings with vastly greater capacities than present human beings have" (4). The scope of enhancement and augmentation includes "radical extension of human health-span, eradication of disease, elimination of unnecessary suffering, and augmentation of human intellectual, physical, and emotional capacities" (3). In addition, the transhumanist agenda also comprises "space colonization and the possibility of creating superintelligent machines, along with other potential developments that could profoundly alter the human condition" (3). In a similar way Max More, founder of the extropianist movement, writes:

> Transhumanists regard human nature not as an end in itself, not as perfect, and not as having any claim on our allegiance. Rather, it is just one point along an evolutionary pathway and we can learn to reshape our own nature in ways we deem desirable and valuable. By thoughtfully, carefully, and yet boldly applying technology to ourselves, we can become something no longer accurately described as human—we can become posthuman. (4)

In this sense, the posthuman occurs as a further developed human being with immensely greater physical and cognitive capabilities. "Becoming posthuman means exceeding the limitations that define the less desirable aspects of the 'human condition'" (More 4).

In the context of posthumanist discourses the posthuman appears as a different construct particularly with regards to the entanglements of humans and technology, such as in the concept of technogenesis, "the idea that humans and technics have coevolved together" (Hayles, *How We Think* 10). Technology is seen as an integral element of the human in the sense of a "continuous reciprocal causation" (10).[7] Therefore, posthumanism, as Francesca Ferrando points out, investigates technology "as a mode of revealing, thus re-accessing its ontological significance in a contemporary setting where technology has been mostly reduced to its technical endeavors.… Posthumanism is a praxis" (29). In contrast, 'the posthuman' can also stand for a 'philosophical construct' such as in philosophical posthumanism that tries to re-think the human being in the light of different theoretical approaches within the history of philosophy (e.g. post-structuralism, feminist post-anthropocentrism) to emphasize a so-called process ontology.[8]

However, if I am speaking of 'the posthuman' here, I understand it in terms of a (computational) regime of knowledge meaning the ascendency of information patterns, and digital codes and network structures in order to investigate and to understand the human brain at a (computer-based) functional level. Therefore, my notion of the 'posthuman brain' roots in the theoretical area of cybernetics (as it occurs in the field of computational neuroscience) and is highly influenced by N. Katherine Hayles' approach in *How We Became Posthuman*.

After the "Blue Brain Project" (the simulation of the rat neocortex)[9] the "Human Brain Project" is one of two in the European Union's FET Flagship Program inaugurated in 2013.[10] The major goal of this project is to create a massive supercomputer to simulate the crucial areas and processes in the human brain — maybe even the whole brain someday — to gain deeper knowledge of the causation of mental disorders and brain diseases Western societies are struggling with (e.g. depression, burn-out, anxiety, schizophrenia and Alzheimer's disease).

In so doing, they investigate large volumes of data from various multiomics levels (like genomics, proteomics, channelomics and so forth) to define the *computational principles* of the functional and structural organization of the brain. After having the maximum amount of information (not all the information) of the brain the information gaps will be interpolated — a

7. Cf. Clark, Andy. *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*. Oxford: Oxford University Press, 2011. Print.
8. Cf. Braidotti, Rosi. "Posthuman, All Too Human: Towards a New Process Ontology." *Theory, Culture & Society* 23.7–8 (2006): 197–208. Print.
9. Cf. Markram, Henry. "The Blue Brain Project." *Nature Reviews Neuroscience* 7 (2006): 153–60. Print.
10. See Fig. 1.

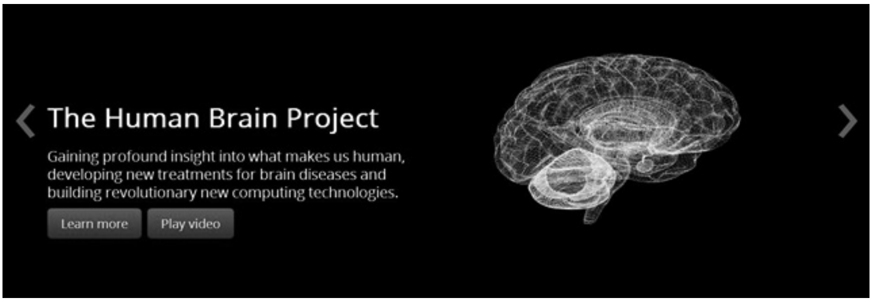


Fig. 1. The Human Brain Project

procedure Henry Markram calls "Predictive Reverse Engineering."

> This *Predictive Reverse Engineering* will allow us to predict how different patterns of gene expression produce neurons with different morphologies expressing different molecules, and different synaptic connections. Other generalizing rules will predict the way neurons migrate into position and grow their arbors and the way they connect with each other to form micro-, meso-, and macro-level circuits. Models of non-neuronal cells and blood vessels, integrated in the overall model, will allow simulation of metabolism and nutrition. Data collected with non-invasive methods will further constrain the model. This kind of *Multiomic Model Integration* will enable ever more accurate models of the human brain, providing a focus for the project's integration strategy.[11] (Markram et al. 40)

While we are moving close to a so-called 'society of depression and burnout'[12] new ways are needed to treat diseases and disorders. Brain research in the last couple of decades, as Markram writes, has been fragmented in various ways. But,

11. For an overview of the similar workflows in "The Blue Brain Project," see Fig. 2.
12. Cf. Ehrenberg, Alain. *The Weariness of the Self: Diagnosing the History of Depression in the Contemporary Age*. Montreal: McGill-Queen's University Press, 2010. Print. Cf. Rosa, Hartmut. *Social Acceleration: New Theory of Modernity*. New York: Columbia University Press, 2013. Print.

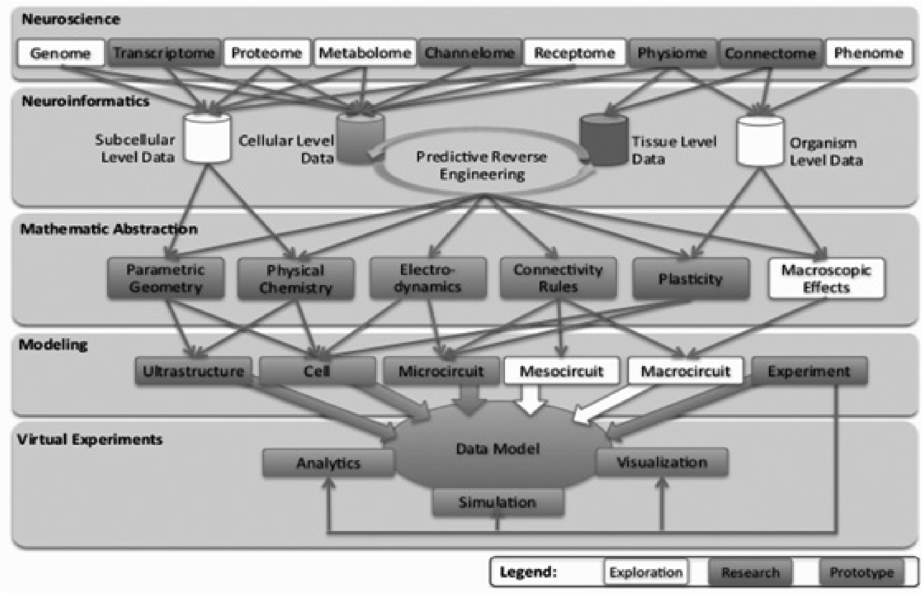


Fig. 2. Workflows in "The Blue Brain Project"

> [n]ew technologies are providing a flood of data about genes and gene expression, the production and distribution of proteins, protein interactions, cells, the connections between cells, and the fiber tracts that connect different regions of the brain. To exploit this knowledge, we need a strategy to put it all together. (Markram et al. 39–40)

Hence, the "Human Brain Project" seems to be capable of providing such a new strategy by integrating "everything we know in multilevel brain models" (40).

To achieve these objectives the project is segmented into three milestones. Firstly, in neuroscience the researchers will use neuroinformatics as well as computer simulations of the brain to accumulate and to integrate data within the process of Predictive Reverse Engineering. Secondly, in medicine they will use medical informatics for tagging the biological signatures of diseases in the brain. This should allow a diagnosis at a very early stage before irreversible damage has been caused. Thirdly, in computing they will create and realize new methods of supercomputing "driven by the needs of brain simulation….

Devices and systems, modelled after the brain, will overcome fundamental limits on the energy-efficiency, reliability and programmability of current technologies, clearing the road for systems with brain-like intelligence" ("Overview").

The convergence of biology and information and communications technology (ICT) leads to an understanding of the (human) brain that is, first and foremost, determined by high-performance computer technology. The brain becomes fragmented into data and stored in a database of a supercomputer which can be accessed from various locations within a networked scientific research environment thus shaping scientific practices and thinking processes in sustainable ways.[13] The data, along with the hypothesis about brain circuits, need to be integrated into a "unified picture of the brain as a single multi-level system" to "realise a new 'ICT-accelerated' vision for brain research" ("Overview"). Far from being able to reproduce the whole human brain — because even the newest generation of supercomputers will be unable to simulate the complexity of the whole web of neurons and their connections — the claim is to model a virtual brain based on a still incomplete knowledge of cells and synapses. So, as long as they can have all the 'available data' and the up-to-date hardware and software, "The Human Brain Project" aims to render 'wetware,' formerly known as the human brain, as fast as possible. In the end the scientists will rather work on a high definition posthuman brain than on its biological counterpart.

> Once our brain simulator has been built, researchers will be able to set up *in silico experiments* using the *software specimen* much as they would a biological specimen, with certain key differences.… With the *in silico brain*, they will be able to knock out a *virtual gene* and see the results in 'human' brains that are different ages and that function in distinctive ways.… What we learn from such simulations will also feed back into the design of computers by revealing how evolution *produced a brain* that is *resilient*, that *performs multiple tasks rapidity and simultaneously* on a massive scale — while consuming the same amount of energy as a lightbulb — and that *has a huge memory capacity.* (Markram, "The Human Brain Project" 39; italics mine)

13. Cf. Gramelsberger, Gabriele, ed. *From Science to Computational Sciences: Studies in the History of Computing and its Influence on Today's Sciences*. Zürich: diaphanes, 2011. Print.

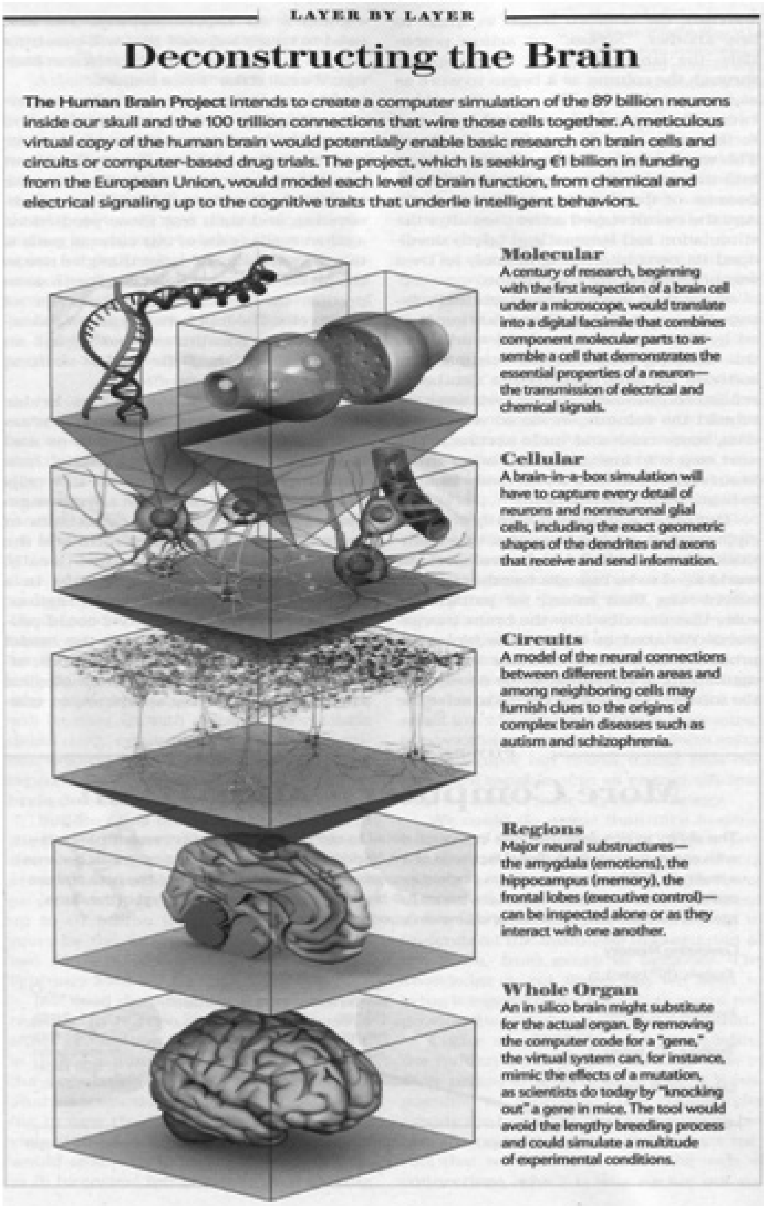


Fig. 3. The development of the "in silico brain"

It is a deconstruction of the brain layer by layer into a virtual system of network connections.[14] The "'ICT-accelerated' vision of brain research" alters the epistemology of the brain in late modern science. It forces a shift from biology and medicine to informatics and from genetics to patterns and digital algorithms. The nexus of the computer and the brain, as it was taught by scientists of cybernetics in the 20th century like Norbert Wiener and others, *experiences an update and development*.[15] Cybernetics has changed the archive of (scientific) knowledge in profound ways thus feedback control systems of information patterns, digital codes and networks define the scope of the epistemological regime[16] the "Human Brain Project" rely on. Within this context the shift from the human to the posthuman as the key concept for a corresponding regime of knowledge in the information age is being updated as well. The "posthuman view," as Hayles writes, "privileges information patterns over material instantiation" and "configures human being so that it can be seamlessly articulated with intelligent machines. In the posthuman, there are no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals" (*Posthuman* 2–3). In other words, such an understanding outlines the world in general as dynamic, flexible and open to computational manipulation. Systems of evolving, dynamic and distributed digital networks with the capacity of self-organization and on-going reinvention constitute a strict ontological and epistemological foundation.[17] This, as Hayles made clear, has significant consequences for an understanding of embodiment.

14. See Fig. 3.
15. Actually, the attempt to investigate and to understand the human brain in such a way has its very roots in the core of cybernetic theory. Moreover, the study of the 'nature of mental states' by using computational principles has flourished since the 1960s as well and is associated with scientific movements such as "(computational) functionalism." Within the concept of 'functionalism' mental states are defined as computational states of the brain: "we simply postulate that desires and beliefs are 'functional states' of the brain (i.e. features defined in terms of computational parameters plus relations to biologically characterized inputs and outputs)" (Putnam 7).
16. Cf. Pias, Claus. "Zeit der Kybernetik. Eine Einstimmung." *Kybernetik. The Macy-Conferences 1946–53. Vol. 2: Essays & Documents/Essays & Dokumente*. Ed. Claus Pias. Zürich: Diaphanes, 2004. 9–41. Print.
17. Cf. Weber, Jutta. "Die kontrollierte Simulation der Unkontrollierbarkeit. Kontroll- und Wissensformen in der Technowissenschaftskultur." *Unsichtbare Hände*. Ed. Hannelore Bublitz et al. München: Fink, 2011. 93–110. Print. See p. 94.

But the privileging of patterns over material instantiation does not necessarily mean, as she claims, "that embodiment in a biological substrate is seen as an accident of history rather than an inevitability of life" (*Posthuman* 2). As Eugene Thacker emphasises, the strategic notion of information in cybernetics "does not exclude the body or the biological/material domain from mind or consciousness, but rather takes the material world as information" (80). By analysing information theory and cybernetics Thacker highlights that the major point about the question of embodiment roots in an understanding of an 'informatic essentialism.'

> In short, when the body is considered as essentially information, this opens onto the possibility that the body may also be programmed and reprogrammed (and whose predecessor is genetic engineering). Understood as essentially information, and as (re)programmable, the body in informatic essentialism increasingly becomes valued less according to any notion of materiality or substance … and more according to the value of information itself as the index to all material instantiation—a kind of source code for matter. (86)

He claims that within this 'strategic move' informatic essentialism "does not necessarily deny materiality or the body," but simply "interprets materiality and body in terms of an informational pattern" (86). That indicates, Thacker continues, "[t]he key to informatic essentialist thinking is not disembodiment, but something more along the lines of file conversions and data translation" (87). Applied to the "Human Brain Project," such an 'informatic essentialism' within the context of a posthuman position (as Thacker outlines) is the basic epistemic mode and vis-à-vis the *stratagem* to seek information patterns and digital codes on a deeper level. If all humans are essentially their brains, and if all brains are re-conceptualized within in silico experiments, then the posthuman literally determines the human (condition) in the 'century of the brain.'

From this perspective and with respect to the history of neuroscience, the "cerebral subject," as it was described by Fernando Vidal in his historical analysis of the condition of "brainhood" as the "anthropological figure of modernity" in industrialized and medicalized societies since the mid-20th century, becomes a virtual fabric.

## Ⅲ. The 'In Silico Cerebral Subject' and Digital Networks

The ideology of the cerebral subject can be encapsulated as follows: "As a 'cerebral subject,' the human being is specified by the property of 'brainhood,' i.e. the property or quality of *being*, rather than simply *having*, a brain" (Vidal 6). In the field of neuroscience, the *brain* and the *self* do not only *became consubstantial*, but the brain in a not too distant future, as some neuroscientists proclaim, "seriously gets ready to know itself" (Elger et al. 37).[18] On the backwash of relatively assessable evidence (and a revolutionary rhetoric) questions on knowledge, consciousness and self-experience are about to be answered by a universal neuroscientific brain theory. A brain theory that is to be dictated by algorithms. Further, the coessential 'brain/self,' which will be able to know itself, became 'functionally independent' of a biological substrate in computational neuroscience in an informatic essentialist way of thinking. The flexible modern self—reframed within the notion of brainhood[19]—turns into a posthuman subject "as an amalgam, a collection of heterogeneous components, a material-informational entity" (Hayles, *Posthuman* 3) under the conditions of *virtual brainhood*. Especially when the 'in silico cerebral subject'—a bundle of digital data—needs to be connected to its technological environment on behalf of the development of artificial intelligence:

> We will need to build the machinery to allow the [computer] model to change in response to input from the environment. The litmus test of the virtual brain will come when we connect it up to a virtual software representation of a body and place it in a realistic virtual environment. Then the in silico brain will be capable of receiving information form the environment and acting on it. Only after this achievement we will be able to teach it skills and judge if it is truly intelligent. (Markram, "The Human Brain Project" 39)

To push the vision further, in the 'century of the brain' the ICT-accelerated 'in silico cerebral subject' in computational neuroscience—and particularly in the "Human Brain Project"—can easily be synchronized with the requirements of its media technological environment. In this point of view, the "Human

18. See Fernando Vidal's "Brainhood: Anthropological Figure of Modernity," p. 10.
19. See Fernando Vidal's "Brainhood: Anthropological Figure of Modernity."

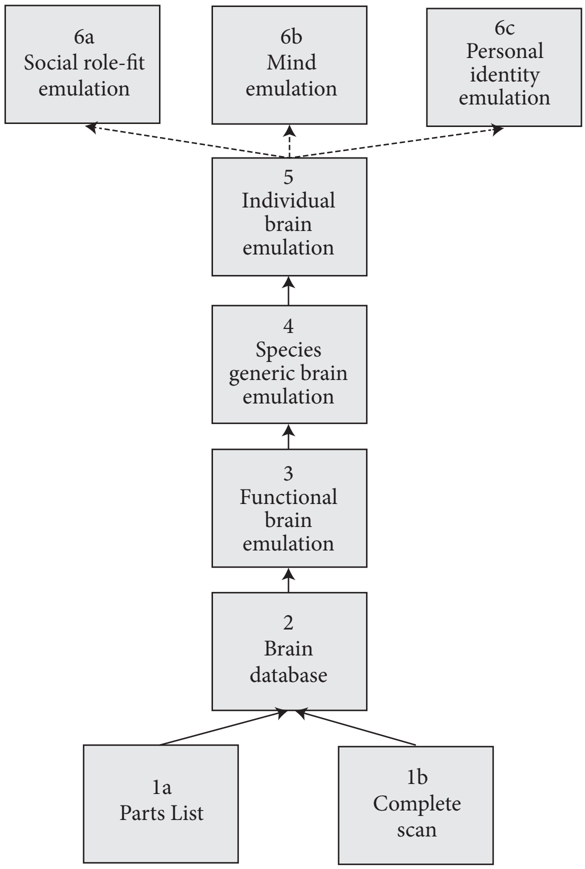


Fig. 4. "Success levels for WBE"

Brain Project" moves closer to transhumanist-impelled ideas in the field of neuroscientific brain research that focus rather on *enhancement* than on treatment.

"Whole Brain Emulation"[20] is a hypothetical process of "one-to-one modelling of the function of the human brain" (Sandberg and Bostrom 5)[21]

20. See Randal A. Koene's "Achieving Substrate-Independent Minds: No, We Cannot 'Copy' Brains" and "Uploading to Substrate-Independent Minds."
21. See Fig. 4.

and it is strongly connected to the idea of uploading a human mind. Hans Moravec's provocative publication on *Mind Children: The Future of Robot and Human Intelligence* is now more than 20 years old, but the fantasy on 'Mind Uploading' still thrills contemporary research not only in robotics, informatics and artificial intelligence, but in computational neuroscience as well. As neuroscientist Randal A. Koene puts it, they are not able to copy the whole human brain in order to upload it into a computer or the internet ("Achieving Substrate-Independent Minds"). On the one hand the computing methods are still struggling with the problem of divergence in information theory. The computational processes and the activities in the biological brain are not exactly the same in time and space. "We cannot," Koene admits, "do better than the physical elements that are carrying out their *own natural processes* (or computations, if you like)" ("Achieving Substrate-Independent Minds"). But on the other hand, he points out, the claim in research on what Koene and others prefer to call "substrate-independent minds" is to carry out *functions* of the brain that represents *thinking processes* which can by transferred between different physical (biological or non-biological) substrates based on the method he refers to as "whole brain emulation" (Koene, "Uploading" 147).

Unlike common practices in computational neuroscience, information in the context of brain emulation is related to an individual brain: "We call the stochastically generated models simulations and the faithful copies emulations" (148). Hence, the 'emulated' neural circuitry, according to the theory, "is identical and represents the same result of development and learning" (148). Creating a "substrate-independent mind" by "whole brain emulation" leads, as Koene writes, to the development of tools for *adaptability and enhancement* of *thinking processes*:

> Imagine a mind that can think many times faster than we do now, and can access knowledge databases such as the Internet as intimately as we access our memories now. In addition to minds that are copies of a human mind, we are interested in man-machine merger, or rather in the ability of man to keep pace with machine and share the future together. ("Achieving Substrate-Independent Minds")

Today Koene and his colleagues are still at the very beginning of such a journey. But once the emulation will provide much more—or maybe even full—evidence of the structure and function of the human brain they seem to be able to invent techniques for modifications and augmentations of the biological brain based on operations on the posthuman model. The 'conceptual aspect' of independence of a biological substrate—in the "Human Brain Project" as well as in the "Substrate-Independent Minds Project"—combines both projects against the backdrop of the epistemic mode in computational neuroscience that designs the in-silico or posthuman brain as an amalgamation of software, hardware and wetware. In other words, it is the survival of information patterns over genetics:

> A shift from gene survival to pattern survival is a necessary preparation for the competition between our own emergent intelligence and intelligence of another origin. That other origin could be machine intelligence without the same set of intrinsic drives, or intelligence emergent in thinking entities elsewhere in the cosmos.[22] (Koene, "Pattern Survival")

And this epistemic mode, as it is evident, operates on a principle of rather engineering than of representing nature. In informatic essentialist thinking *optimization*—in order to find ways to cure brain diseases as well as to enhance the brain—implies the *improvement of data processing*. At best, nature becomes a toolbox to modify the 'in silico cerebral subject' within a technorational regime of combinatorics and (digital) re-design in a digital media environment.[23] The boundaries between working on 'virtual genes' to find new ways for treatment and to enhance the brain in order to fit it to the environment of the computational system of the 'information age' are becoming fuzzy. Koene makes it explicit in the context of brain emulation. Nick Bostrom's reflections on so-called "differently constituted minds" ("Why I" 38)—with reference to questions on *posthuman well-being* (primarily because of the merging of the human being and the technological world)—are strongly connected to the idea of brain emulation and enhancement. And even Markram disguises it in an argument about ethical issues:

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22. Ray Kurzweil's "pattern recognition theory" goes in the same direction as well. See Kurzweil, Ray. *How to Create a Mind: The Secret of Human Thought Revealed*. New York: Viking, 2012.
23. Cf. Weber, Jutta. "Die kontrollierte Simulation der Unkontrollierbarkeit. Kontroll- und Wissensformen in der Technowissenschaftskultur." *Unsichtbare Hände*. Ed. Hannelore Bublitz et al. München: Fink, 2011. 93–110. Print. See p. 104.

> Even if a tool that simulates the human brain is a long way off, it is legitimate to ask whether it would be responsible to build a virtual brain that possessed more cortical columns than a human brain or that combined humanlike intelligence with a capacity for number crunching a million time greater than that of IBM's Deep Blue, its chess-playing computer. ("The Human Brain Project" 39)

With this in mind, questions of 'how the brain works' and even 'how we think' as posthumans come into view in a different light. Because these questions do not only rely on a co-evolution of humans and technics as "continuous reciprocal causation," as Andy Clark as well as N. Katherine Hayles argue within the notion of the "technogenetic spiral,"[24] but, *first and foremost*, on the accomplishments of digital data processing. Moreover, in the information-driven 21st century (of the brain) the accomplishments of digital data processing are strained by digital network technologies, as Alexander Galloway and Eugene Thacker claim:

> Networks are elemental, in the sense that their dynamics operate at levels 'above' and 'below' that of the human subject. The elemental is this ambient aspect of networks, this environmental aspect—all the things that we as individuated human subjects or groups do not directly control or manipulate. The elemental is not 'the natural,' however (a concept that we do not understand). The elemental concerns the variables and variability of scaling, from the micro level to the macro, the ways in which a network phenomenon can suddenly contract, with the most local action becoming a global pattern, and vice versa. (157)

This elemental aspect of networks that defines the essential entanglements and scaling between the macro level and the micro level, between the world and the subject, is dictated by the 'agency of the non-human.' "Networks, generally speaking, show us the unhuman in the human, that the individuated human subject is not the basic unit of constitution but a myriad of information, affects, and matters" (Galloway and Thacker 155). To sum up, if digital

24. Cf. Clark, Andy. *Supersizing the Mind: Embodiment, Action, and Cognitive Extension*. Oxford: Oxford University Press, 2011. Print. See N. Katherine Hayles' *How We Think: Digital Media and Contemporary Technogenesis*.

networks characterize the 21st century, if they are constituting the 'ambient conditions' of what it means to be human in a technological world by, in the end, *exposing the non-human* as elemental, the status of the human subject needs to be reconsidered. Information patterns and electronic codes replace the 'individuated human subject' to establish digital networks as the driving force in the contemporary technological world.

Therefore, agency in the media culture of the 21st century, as Mark Hansen proclaims in a different context, seems to be no longer related to privileged (individual) actors. Agency is the effect of global activity of complex digital networks. Because of the essential impact and the connectedness of digital networks, as Hansen continues, the human subject nowadays needs of be understood as a fabric of 'dispersed agency' across different scales and operative contexts that are *inherent to the media environment of digital networks* (367). "We" are being (self-)constructed through operations of myriads of "multi-scale procedures." Within such an approach in media theory human agency is replaced by the authority of digital technology to uphold a media philosophy of cybernetic augmentation. As a consequence, the boundaries between "humans and technical object, specifically networked and programmable machines" (Hayles, *How We Think* 86) are vanishing. The posthuman 'being' itself becomes a programmable and networked subject fully immersed into a dynamic system of evolving, distributed digital networks.

This is comparable to research in the field of neuroscience concerning its conception of the human. In computational neuroscience the (individual) biological substrate does not matter any more. What matters is big data of the 'quantified in silico brain' that has transformed into a huge database of information "about genes and gene expression, the production and distribution of proteins, protein interactions, cells, the connections between cells, and the fiber tracts that connect different regions of the brain" (Markram et al. 39–40). The holistic view on digital networks and the understanding of (human) agency as effect of global activities of complex digital networks is quite similar to the holistic view on the 'in silico cerebral subject' as effect of the evaluation of data in a networked environment. The 'in silico cerebral subject' is the product of various operations in the sense of multi-scale procedures as well; if we think, at least, of the large volumes of data from various multiomics levels and the process of so-called Predictive Reverse Engineering. Thus, the 'in silico cerebral subject' is a digital fabric (of 'dispersed agency'), a flood of data within a digitally connected research environment; a network within a network. With the "emergence of [these] new relationships between human and machine, biology and technology, genetic and computer information" (Thacker 81) as well as a media constitution characterised by networked computation, the 'in silico/post-human cerebral subject' turns into a programmable and networked model of/for human properties within the conditions of virtual brainhood in the information-driven century of the brain. This model is the main epistemic object in computational neuroscience to apprehend the posthuman brain as an amalgam of software, hardware and wetware, and to re-conceptualize human agency out of a multi-level system with brain-like artificial intelligence.

From this perspective, if the 'cerebral subject' refers to the idea that being a human means being a brain, then current projects in computational neuroscience aim to re-enunciate this 'anthropological figure' as a networked digital fabric. On this, Claude Shannon's "Mathematical Theory of Communication" becomes the blueprint for the epistemological framework and Alan Turing's "Universal Computing Machine" seams to provide the theoretical model for a corresponding 'posthuman anthropology.' What it means to be human is defined by digital information patterns and complex algorithms of computational brain simulations.[25] The human subject dissolves into a web of dispersed agency within a networked database capable of displacing individual subjectivity and turning them into codes (of no body); commonly called the posthuman.

## IV. Conclusion

The conception of the human condition in computational neuroscience has changed in a significant way. All human properties are attributed to the brain or, to a greater degree, brain-like computer simulations. Questions concerning cognition, intelligence and behaviour will be investigated and explained from a perspective of 'non-conscious agents of cognition.'[26] In so doing, they "will

25. In a similar way this is the main argument of the (posthuman) media theory established by Friedrich A. Kittler. Cf. Kittler, Friedrich. A. *Grammophon, Film, Typewriter*. Berlin: Brinkmann & Bose, 1986. Print.
26. By 'non-conscious agents of cognition' I am referring to an interpretation given by N. Katherine Hayles on a lecture in 2013 based on her reading of the work of the Polish science fiction author and philosopher Stanislaw Lem (Hayles, *The Lights Are On*). Cf. Hayles, N. Katherine. *The Lights Are On but Nobody's Home: The Cost of Consciousness*

connect brain models to robots functioning in real or virtual environments, test their capabilities on 'benchmark problems,' and trace the causal chain of events leading to these capabilities" (Markram et al. 40). As Kevin Warwick has depicted for artificial intelligence systems from a different angle, the work on A.I. needs to be pushed much further in the direction of the 'integrative design' of agent autonomy, distributed information processing, embeddedness and forms of sensory motor coupling with the environment (69) that is beyond the scope of the "Human Brain Project." But what appears to be significant is that the 'ICT-accelerated' vision for brain research produces a notion of human condition (as 'in silico cerebral subject') that stands in the tradition of cybernetics and that upholds and accelerates the posthuman within the 'strategic move' of informatic essentialism.

In computational neuroscience the computer as "the 21st century's *epistemology engine*" (Ihde 79) re-ascribes the quality of an "efficient knowledge-acquiring system" (Zeki 54) from the biological brain to complex digital simulations and the regime of the algorithm, or, to put it another way, from the human to the posthuman.

From a standpoint of posthuman media theory this leads to a more far-reaching perspective than media as extensions of man.[27] Notably the increasing authority of digital networks causes alterations not only concerning the social, political and economic, but also, and moreover, the epistemological entanglements between humans and digital (network) technologies. Within a networked scientific research environment computational practices and procedures constitute an ICT-accelerated approach in brain studies that displaces the vision of biological 'brainhood' to solidify the 'in silico cerebral subject' as a more appropriate epistemic object. And the quantified 'in silico cerebral subject' can be seamlessly implemented into digital network technologies to merge properties or qualities of the human brain with features or capabilities of algorithmic operations. By doing so, anthropology appears to be overridden within the horizon of informatics to reach the status of the posthuman.

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27. Cf. McLuhan, Marshall. *Understanding Media: The Extensions of Man*. Reprinted. London: Routledge, 2001. Print.

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Fig. 2: “Workflows.” *The Blue Brain Project*. N.p., n.d. Web.
Fig. 3: Markram, “The Human Brain Project” 38.
Fig. 4: Sandberg and Bostrom 10.

## Abstract

The purpose of this paper is mainly diagnostic. It investigates current research projects in computational neuroscience to emphasize a shift from a life science approach (biology and medicine) to a computer science approach in the epistemology of the human brain. This shift updates and preserves the "posthuman view" (N. Katherine Hayles) to render a proper regime of knowledge of the brain in the digital age. Moreover, the massive impact of digital media and digital networks in particular cause essential modifications of the concept of the (post-)human subject in the 21st century. At first, the paper will present an analysis of the "Human Brain Project" to highlight the shift from the human to the posthuman brain in one of the most influential projects in computational neuroscience at the moment. What follows is a discussion of the relations between the "Human Brain Project" and the transhumanist-impelled "Substrate-Independent Mind Project" to emphasize the rise of the posthuman brain between visions of treatment and enhancement. Finally, the paper draws attention to recent theory of digital networks to expose some broader transformations of the concept of the (post-)human subject. In the information-driven 'century of the brain' that is dominated by (computational) neuroscience, the human as a "cerebral subject" (Fernando Vidal) turns into an 'in silico cerebral subject.' As a programmable and networked model of/for human properties the 'in silico cerebral subject' becomes the main epistemic object in computational neuroscience to re-conceptualize the human (brain) out of a multi-level system with brain-like artificial intelligence.


**Keywords:** computational neuroscience, The Human Brain Project, substrate-independent minds, in silico cerebral subject, posthuman turn, digital networks

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