Brain in the Shell. Assessing the stakes and the transformative potential of the Human Brain Project

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Abstract

The "Human Brain Project" (HBP) is a large-scale European neuroscience and information communication technology (ICT) project that has been a matter of heated controversy since its inception. With its aim to simulate the entire human brain with the help of supercomputing technologies, the HBP plans to fundamentally change neuroscientific research practice, medical diagnosis, and eventually the use of computers itself. Its controversial nature and its potential impacts render the HBP a subject of crucial importance for critical studies of science and society. In this paper, we provide a critical exploratory analysis of the potential mid- to long-term impacts the HBP and its ICT infrastructure could be expected to have, provided its agenda will indeed be implemented and executed to a substantive degree. We analyse how the HBP aspires to change current neuroscientific practice, what impact its novel infrastructures could have on research culture, medical practice and the use of ICT, and how, given a certain degree of successful execution of the project's aims, potential clinical and methodological applications could even transform society beyond scientific practice. Furthermore, we sketch the possibility that research such as that projected by the HBP may eventually transform our everyday world, even beyond the scope of the HBP's explicit agenda, and beyond the isolated 'application' of some novel technological device. Finally, we point towards trajectories for further philosophical, historical and sociological research on the HBP that our exploratory analysis might help to inspire. Our analysis will yield important insights regardless of the actual success of the HBP. What we drive at, for the most part, is the broader dynamics of scientific and technological development of which the HBP agenda is merely one particularly striking exemplification.

Keywords

Neuroscience, Human Brain Project, simulation, ICT, neuromorphic computing, clinical data

Introduction

The "Human Brain Project" (HBP) is a large-scale European neuroscience and computing project which is one of the biggest funding initiatives in the history of brain research.[1] With a planned budget of 1.2 billion € over the next decade and building on the prior "Blue Brain Project", the project initiated by Henry Markram pursues the ambitious goal of simulating the entire human brain—all the way from genes to cognition—with the help of exascale information and communication technology (ICT). The HBP hopes to thereby produce new, brain-like computing technologies, so-called neuromorphic computers, which would be both highly energy-efficient and usable by the general public.

Despite the potentially enormous significance for both brain research and computer technology—as well as society and culture—the ambition and approach of the HBP has been a matter of substantial controversy from the beginning, both in the scientific community and the general public. Critics have claimed that the model-based bottom-up approach of the project is scientifically wrong-headed, have accused the project of not being managed transparently, and have attested that the aims of the HBP are too ambitious, such that the project is likely to waste valuable resources for research and infrastructure in Europe. It is currently – in mid-2015 – still a debated question whether the HBP in its current format and direction should be pursued *at all* (Bartlett 2015). The controversy has been fuelled in early 2014 by an open letter to the European Commission (EC) signed by over 750 European neuroscientists urging a reform of the HBP even before its operational phase was set to begin. They threaten to boycott the project in case no independent review panel is in place to assess whether the HBP meets the standards of excellence required for a "Future Emerging Technologies" (FET) flagship program (Open message to the EC, 2014; Nature, 2014; Marcus, 2014). The exclusion of the experimental cognitive neuroscience strand from the core project and the emphasis on building ICT infrastructures furthermore raised the question whether—despite the project's name—the human brain and neuroscience are actually at the center of HBP research (Fregnac and Laurent, 2014, Nature 2014). As a result, the HBP now increasingly risks losing support from the very scientific community it purports to serve. Most recently, the HBP board of directors responded to this criticism and to the report of a subsequent mediation committee by taking over the responsibilities of the project's three executive directors Henry Markram, Richard Frackowiak and Karl-Heinz Meyer (Abbott 2015; Enserink, 2015).

Taking a broader, critical perspective on the controversy surrounding the HBP, we ask the following questions: What is at issue and at stake in this controversy with regard to the project's potential mid- to long term impacts on the field of neuroscience and on neuroscience's role in society? How does the use of ICT and simulation in the HBP reconfigure the brain as a research object? By analysing the project's impact beyond its initial scientific or translational agenda, we argue that what is at stake in the HBP is not whether it is about the brain or ICT, but whether it can show how to create a "brain in the shell", by extending the neural domain beyond biological brains and into the computer. Hence our allusion to the society of "cyberbrains" in the science fiction manga "Ghost in the shell".

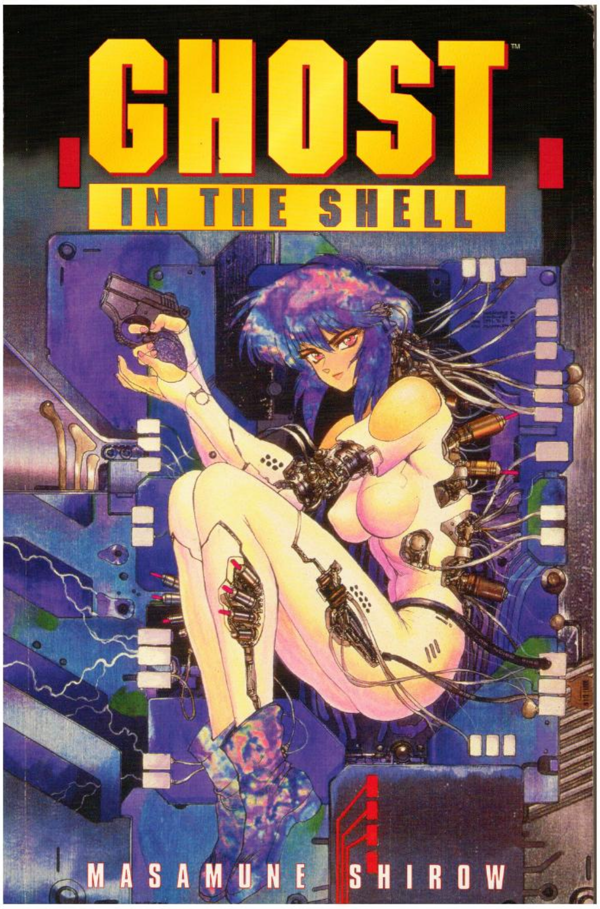

Fig. 1: Cover page of the first volume of Kōkaku Kidōtai: The Ghost in the Shell, by Masamune Shirow (1989), displaying the cyborg Motoko Kusanagi, protagonist and major of the counterterrorism force Public Security Section 9.

Online available at:
http://en.wikipedia.org/wiki/Ghost_in_the_Shell_%28manga%29#/media/File:Ghost_in_the_Shell.jpg

Analytical perspective and source material

The concept of "experimental systems" (Rheinberger, 1997; Rouse, 2011) figures in the background of the first three sections of this chapter. Experimental systems consist of technologies, scientific methods and institutional settings that allow scientists to study the unknown properties of the entity under investigation—i.e. the human brain in case of the HBP. The discussion of several proposed changes to neuroscientific practice, medicine and ICT will elucidate what kind of experimental system the HBP is planning to build. This analysis is valuable regardless of the actual success of the HBP in implementing its envisioned research architecture. As we will outline below, many of the proposed changes to neuroscience practice have far wider ramifications than those pertaining to this one single large-scale project. If it doesn't happen at this particular juncture and in the context of the HBP as currently constructed, many of the proposed measures will quite likely spring up elsewhere rather sooner than later.

The second analytical concept that we employ is that of an "experimental microworld" (Rouse, 1987). It is used to assess the larger transformative potential of a project like the HBP. Constituted by experimental systems, such microworlds allow entities to show orderly patterns of behaviour that lead researchers to new scientific insights. To successfully extend these insights beyond the isolated circumstances in which they were established, it is often necessary to change the material configurations of the world outside the laboratory so that the world itself begins to resemble the isolated circumstances of the experimental microworlds. Only then can scientific insights be used successfully in non-scientific contexts, and only then do they provide their non-scientific users with new possibilities of action—think of electrical power grids, light bulbs, batteries or power outlets that are available and usable for an ever-increasing portion of the public (Rouse, 1987, 199, 226ff.) We discuss below how the HBP's aim of building neuromorphic technologies may put such far-reaching material transformations on the agenda, and what impact these transformations could have on society and culture in case the HBP comes remotely close to fulfilling some substantial parts of its projected research plan.

The primary sources for our analysis are the "Overall Vision for the Human Brain Project" document (HBP, 2013) and the "Framework Partnership Agreement" (HBP, 2014a, hereafter FPA document), which to date are the most detailed, publicly available documents about the HBP that have been authored by the members of the project committee themselves (for the earlier official report to the EC see HBP, 2012). We discuss the most important of several proposed changes to neuroscientific practice, medicine and ICT. We furthermore amend our analysis with scientific research and overview articles from or on the HBP, official websites, newspaper articles, and blogpost commentaries. It needs to be noted, however, that there is to date rather little concrete information—let alone independent scholarly analysis—on how the HBP is supposed to operate, which and how many of the proposed plans of the Vision and FPA document are actually being pursued at the moment, and whether some of the issues we discuss in the following are even on the current internal agenda of the project or not. In fact, from what can be gleaned from recent reports, much in the organizational structure of the HBP seems to be in flux as a result of encompassing internal and external reviewing (see e.g., Nature 2014; Bartlett, 2015; Abbott, 2015; Enserink, 2015). The available body of source material therefore limits our ability to draw more than preliminary conclusions, which is why some of the following considerations have a slightly speculative flavour. We therefore chose a descriptive and analytical (instead of an overly normative and critical) approach to the sources available, which we hope can serve as a starting point for further critical analyses of the changing landscape of big-scale neuroscience in the years to come.

Scientific practice

A good starting point for discussion is the neuroscientific research agenda of the HBP, since one of its main goals is to ‘change the way neuroscience is done’ (Markram 2013, 146). The following five focal topics delineate the methodological approach and scientific practice that initiates the required infrastructure projects, motivates the forms and domains of future applications, and indicates the larger societal implications of the HBP – and potential other projects with comparable agendas – discussed in the rest of the paper.

Scaling up

Big Science projects investigating the brain move away from the common model of small, investigator-driven research groups that study the brain at one or a few levels of description and with one or a few instruments. Single-cell studies for instance, investigate action potentials at the chemical level of ion channels, Ca^{+} molecules and neurotransmitters. Functional MRI studies in humans correlate changes in blood oxygenation within whole cortical areas or networks to the level of cognitive tasks (e.g., counting numbers). These different levels are usually assumed to be parts of multilevel mechanisms (Craver, 2007), a view that the HBP also embraces with its multi-scale modelling approach (cf. HBP, 2013, 37; HBP, 2014a, 14 –15). But instead of studying each level individually, the HBP is planning to use most (if not all) laboratory-scale approaches (e.g., molecular, genetic, physiological or computational methods) simultaneously and on an industrial scale. It therefore attempts to bridge the enormous gap between microscopic and macroscopic neuroscientific evidence (such as from single-cell and fMRI studies), a task that is also tackled by other, small- and large-scale projects (Bohland et al., 2009; Grillner, 2014; Siero et al., 2014). The potential virtue of scaling up the existing approaches is expected to be a better *integration* of data from the many levels of brain organization (cf. HBP, 2013, 56; HBP 2014a, 187). Better integration can then be seen as the presupposition for a better understanding of the brain, which is why good neuroscience *ought* to become a large-scale and integrative effort.

It is this normative impetus of the agenda that in part stirred the recent controversy surrounding the HBP. The critics argue that although multi-level integration and a stronger funding is needed to better understand human brain organization, an industrial-scale project with a relatively fixed agenda may not be the best way to achieve such goals. Instead, they support a 'mechanism of individual investigator-driven grants', which would foster the analytic and creative capacities of small research groups with the overall funding level of the HBP (Open message to the EC, June 7 2014). Even some advocates of the HBP stress that developing new concepts or formulating interesting, specific questions about human brain organization will remain the task of small groups or individual neuroscientists (cf. P.M. Mathews in Kandel et al., 2013, 663; Grillner, 2014, 1211). Although the exact utility of the HBP for later research remains an open question, its initiation is already reshaping the global neuroscience landscape: since 2013, projects of a similar scale—although with different agendas—have been installed or pronounced in the US, Japan, China and Australia (Grillner, 2014, 1211; HBP, 2014a, 16).

Fewer experiments, more models

While the HBP plans to scale up and integrate existing approaches, it simultaneously moves away from acquiring experimental data. The HBP asserts that previous neuroscientific research has already generated most of the data necessary for understanding the human brain from genes to cognition (cf. HBP, 2014a, 2; HBP, 2013, 6). Besides the strategic collection of mouse and human data in the starting phase, the project therefore focuses on *multi-scale modelling*, *prediction* and *simulation* of brain structure and function (cf. HBP, 2014a, 3-5; HBP, 2013, 19f.). Through data-mining of existing studies and by using their own or data from other large-scale projects, the HBP aims to identify general principles of brain organization (cf. HBP, 2013, 6–17, Kandel et al., 2013, 662f.). Unifying the data and principles in multi-scale models would then allow researchers to predict, for instance, connectivity patterns at different spatial scales, plasticity changes at different time scales, or putative neural mechanisms of organismic behaviour. The predictions generated by these models could then be tested by simulating the brain on the HBP supercomputing platform (cf. HBP, 2013, 21; HBP 2014a, 20, 191-94).

Whether such model-based predictions will be of scientific value, however, crucially depends on the biological data put into the simulations. It is here where the HBP's vision to create biologically meaningful whole-brain simulations within a decade has been criticized as premature and overly ambitious. Despite large-scale projects mapping human brain connectivity (e.g., Bohland et al., 2009), community consensus suggests that, so far, the data required to properly constrain the multi-scale models or simulation-based hypotheses is largely missing (Denk et al. 2012; Fregnac and Laurent, 2014).

Notwithstanding the questionable turn away from data acquisition, the HBP proposes several strategies for validating brain models against experimental data. By mining data in common atlases, or using strategic imaging and behavioural data, researcherso8 could validate 'knowledge gaps' about brain organization or multi-scale simulations of neural function (cf. HBP, 2013, 12, 61; HBP 2014a, 186–90). One-level 'snap-shot models' could also be initially validated against biological data, before they are trained to display behaviour and cognition (cf. HBP, 2013, 21). This co-existence of biological and computational validation strategies indicates that the HBP does not principally distinguish between the brain as being materially realized in biological tissue or within a computer (see also Parker, 2009). Nevertheless, the methodological primacy of simulation and modelling over experimentation seems to imply that the *focus* of the HBP is not the biological brain *per se*. Rather, invasive or non-invasive laboratory experiments on actual biological brains would only be the occasion for enabling various theoretical, mathematical and computational scientific activities, which can be pursued independently within the fully operating HBP. Since the majority of neuroscientists regard experimentation with biological brains as the key procedure towards understanding the brain, it comes as no surprise that the computational focus of the HBP deeply challenges current neuroscientific practice.

Virtualizing the lab – cerebral technoscience goes in silica.

The HBP plans to implement or develop a number of technological innovations that, if successfully realized, would move the entire neuroscientific experimental practice into the ICT domain. Once the first principles are identified from the data and the first predictions can be inferred from the models, the Brain Simulation Platform of the HBP would allow researchers to perform *in silico* experiments. The final outcome would be a closed loop between brain models in virtual bodies (or virtual neurorobots) that are interacting with a virtual environment, which can in turn be manipulated by the scientists in their *virtual laboratories* (cf. HBP, 2013, 32, HBP 2014a, 8, 11). Such laboratories would include virtual versions of instruments like fMRI or EEG, or eDrugs for simulating the mechanisms of brain diseases.

The virtue of virtualization is that researchers might gain access and control over the biological processes of the brain which are difficult to manipulate in material laboratories. By stressing these virtues, the HBP approach defines the main role of *in silico* experiments as providing computational manipulations of multi-scale brain models. In contrast, the comparison of simulation results to *in vivo* or *in vitro* experiments seems to be of less interest, especially since the limited experimental data acquisition is unlikely to produce laboratory counterparts to all virtual experiments over the course of the project. This change in priority also provides the HBP with a productively provocative answer to those who criticize its simulations as insufficiently constrained by biological data: if computational manipulations trump laboratory manipulations, the lack of comparison with experimental data can be reinterpreted as a *success* over the limits of access and control in traditional experiments.

Standardization

One apparent drawback of current neuroscientific practice is the enormous variety of experimental protocols, data analysis methods and modelling algorithms. The outcome is that results are only partially comparable, or even worse, that the high number of possible choices leads to false positive results, independently of the quality of the individual experimental design (for the case of imaging, see Carp, 2012). Current efforts to standardize neuroscientific research tools (e.g., the Allen Brain Atlas) will likely allow neuroscientists to compare results across different laboratory sites more accurately. The HBP's specific contribution to that effort would be six remotely accessible ICT platforms (Neuroinformatics, Brain Simulation, Medical Informatics, High Performance Computing, Neuromorphic Computing, and Neurorobotics, cf. HBP, 2013, 17; HBP 2014a, 4, 3–9).

If the ICT platforms can be sufficiently developed in the 30 month ramp-up phase, researchers are expected to use them during the operational phase to mine experimental or clinical data, build brain models and interact with them in real time via a human-supercomputer interface, build virtual robots based on the insights of the models, and implement some version of these robots into neuromorphic computing systems (cf. HBP 2013, 17, 53ff., HBP 2014a, 23f.). In order to make the platforms accessible for non-expert scientific users, the HBP also plans to provide standardized versions of experimental protocols, data pipelines and modelling algorithms (cf. HBP 2013, 19, 29, 37f., HBP 2014a, 184, 196). While it would increase access and comparability, the encompassing standardization of the platforms also comes with a loss of experimental flexibility. Many proponents of open science, for instance, do not only share their data but also share their code for data analysis, so that other researchers can further develop it according to their own needs, geared to their specific experimental situation.[2] It is currently unlikely that scientists from outside the project will have that option, since the use of the HBP platforms is allocated via a partnering project mechanism (initially:

a Competitive Calls programme, cf. HBP 2013, 36) based on the milestone-driven approach of the HBP core project (HBP 2014a, 13, 212). Although the HBP publicly supports open source and community-driven approaches to scientific inquiry (cf. HBP 2013, 19, 61, HBP 2014a, 9, 25–29, 184), its current institutional and funding structure places strong constraints on experimental flexibility.

Iteration

Another essential feature of the HBP could be its ability to switch iteratively between many modes of scientific inquiry. The idea is that principles extracted from the gathered data can be used for new model algorithms, and by using the models for predictions which are themselves tested in *in silico* experiments, new principles might emerge which can in turn be used to create more powerful algorithms, leading to better predictions, and so on. This methodological iteration is ideally accompanied by the co-evolution of neuromorphic computers that implement the principles of brain organization identified so far, and thereby accelerate the iterative process through an increase in computing power. The ultimate vision of the HBP is to let methods and technology evolve into an exascale supercomputer which is capable of simulating the entire human brain. The iterative approach therefore raises the question whether the real goal is to understand the human brain (technology being the proxy) or to build the next generation of supercomputers (the brain being the proxy).

In response to the aforementioned controversy, the EC and the HBP directors stressed that the project is primarily concerned with the development of new ICT infrastructure (HBP, 2014b; Madelin, 2014a). According to some commentators, the HBP now appears to be a 'costly expansion of the Blue Brain project, without any further evidence that it can produce further [neuroscientific] insights' (Fregnac and Laurent, 2014, 28, see also Bartlett 2015). For reasons that will be elaborated in the section "world making" below, we believe that it is inappropriate to contrast ICT development with the neuroscientific research conducted within the HBP, because the iterative approach that the project pursues blurs the distinction between computer and brain, making them effectively inseparable in practice.

The push towards hybridization is already apparent in the active collaborations between the HBP and European exascale computing projects (e.g., CRESTA in the UK, DEEP in Germany and Mont-Blanc in France) to create ICT that meets the specific demands of whole brain simulations (cf. HBP, 2013, 25; HBP 2014a, 193). Independently of specific simulation outcomes, these collaborations could turn neuroscience into the next major player in a series of simulation-focused research programs—from nuclear weapons research to climate science—that shaped the development of supercomputing technologies (Elzen and MacKenzie, 1994). Somewhat parallel to the limited flexibility created by the standardized ICT platforms, the goal of building a neuromorphic supercomputer furthermore indicates that the HBP approach works with a *closed* type of iteration. Whereas interactions among the elements of the iterative chain (modelling, algorithms, predictions, simulations) are possible, interaction with elements from the outside (e.g., exploration and conceptual development, question generation, see. O'Malley et al., 2010) is only possible *insofar* as they contribute to the overall goal of the HBP. *Open* iteration within HBP's own methodology seems not to be possible, or is at least not explicitly intended in a milestone-driven approach.

These five projected and expected changes that the HBP is set to bring to neuroscientific practice can be summed up in the following slogan: *The HBP sets out to standardize iterative modelling and virtual experimentation on a large scale, thereby aspiring to move neuroscientific practice successively away from interacting with actual biological brains.*

Infrastructure

A goal that is perhaps even more fundamental than simulating the human brain—and certainly also more likely to be achieved—is to 'build a completely new ICT infrastructure for neuroscience […] medicine and computing' (HBP, 2013, 3). Building (Big Science) infrastructures is more fundamental than specific scientific goals because the platforms, institutions and facilities will outlast the project's relatively short duration of ten years, even if the goal of simulating the entire human brain will not have been achieved by then.[3]

From experiment to database, from laboratory bench to remote access

The common training as a neuroscientific practitioner requires students to learn principles of data acquisition, experimental design and how to skilfully use laboratory instrumentation (Harrington, 2010). The ICT platforms of the HBP would instead provide *databases* as the initial starting point of neuroscientific inquiry. While the standard interfaces of the platforms can be also used to upload further experimental data from different levels of brain organization, the main task of an HBP practitioner would be to use the existing evidence to create a new *kind* of data, describing simulated brain behaviour on multiple levels. The use of such data within virtual laboratories also implies that in principle, no *material* laboratory would be required to conduct a wide range of neuroscientific activities (e.g., generating and testing hypotheses, designing *in silico* experiments or identifying causal mechanisms, cf. HBP, 2013, 5, 28, 56; HBP 2014a, 3, 11, 22, 170, 168, 187). The same logic also applies to neurologists working within the HBP, for the Medical Informatics platform allows them to federate clinical data, i.e. to mine them for biological disease patterns without physically removing them from the hospital site of recording (cf. HBP 2013., 27; HBP 2014a, 195). Here, too, medical scientific inquiry (e.g., disease classification, drug testing or personalized diagnosis) would be possible in principle without requiring researchers to actually enter a material clinic (cf. HBP 2013., 38f.).

The computer with a remote internet access to the ICT platforms could therefore become the actual workplace of the next generation of neuroscientists working in the HBP, even if most or all efforts to build neuromorphic supercomputers fail. In that case, there would still remain a less encompassing database for experimental and clinical data, accessible via conventional computers. Finally, the existence of new simulation facilities implies that the HBP is also a massive data *generation* project (cf. HBP 2013, 57), albeit of a different sort: the data are the outcome of computer simulations, not of invasive or non-invasive studies of biological brains. Big Science projects often produce more data than the scientists working on them are able to analyse immediately, and at times further retrospective analysis leads to surprising discoveries.[4] Here, another novel possibility of working as a neuroscientist emerges, perhaps closer to archaeological research than to experimental laboratory practice. Scientists trained on the ICT platforms of the HBP could specialize in large-scale data analysis using different parameter values and pattern recognizers without having to conduct their own (laboratory or virtual) experimental work, and again independently of whether the HBP goal of building a working human brain simulation is ever achieved.

User environments for neuroscientists

A broader infrastructural change follows from the creation of multiple interfaces to make the supercomputing and simulation technology of the HBP accessible to the broader scientific community (e.g., the Brain Simulation and the Neurorobotics Cockpit, cf. HBP 2013, 22, 34; called Virtual Neurorobotics Laboratory in the FPA document, cf. HBP 2014a, 206). Moving neuroscientific practice onto ICT platforms thereby creates two types of researcher that are not specific to any particular subdiscipline. The first type is the *developer*, i.e. a researcher, engineer or technician who builds, develops and maintains the platforms themselves (including, besides technical apparatuses, the interfaces, data pipelines, implemented algorithms, standard models etc.). The second type is the *user*, i.e. a neuroscientific or medical practitioner who conducts, tests and compares her research through the ICT platforms provided by the developer.

How separate these two roles will be within the HBP will depend on the feedback loops built into the project's institutional structure during the operational phase (the iterative approach already indicates that a dynamic feedback model would be easily possible). The separation seems to be quite sharp, however, once researchers outside the project will access the platforms, for they will neither have the knowledge nor the skills to maintain supercomputers or large databases.[5] The user-developer distinction furthermore runs orthogonal to more traditional divisions of scientific labour such as experimenter-theoretician or basic and applied scientist. What unites both the developer and the user, however, is that the ICT platforms establish the computer as the primary object of interaction with the neuronal domain, both in the form of commercial devices and specific (neuromorphic) supercomputers.

The two infrastructural changes, then, can be again summarized in a slogan: *The HBP developer generation aspires to create remotely accessible databases and user environments for scientist-supercomputer interactions.*

Application

Given that the success of the HBP's ambitious aim to simulate the entire human brain from genes to cognition cannot be guaranteed, there are two kinds of potential application outside neuroscientific practice but within the project. *Immediate* applications are independent of simulating human brains with (neuromorphic) supercomputers, while *intermediate* applications are dependent on at least a partial success of this endeavour. Although not sharp, this distinction allows us to assess the likelihood of whether certain transformative potentials of the HBP will be actualized over the next decade(s).

Healthcare and medical diagnosis

The HBP considers improvements in diagnosing and treating brain diseases (i.e. neurogenerative diseases, but also anxiety or mood disorders etc.) to be 'the most immediate impact […] for European society' (HBP, 2013, 60, see also HBP 2014a, 199). The likelihood of fairly quick changes in medical practice initiated by the HBP is comparatively high, because the Medical Informatics Platform and its data federation system are set to function independently of other advances in the project. A central access point to physically remote clinical data could indeed provide new ways to tackle the challenge of developing novel and potentially more effective diagnoses of Alzheimer, Parkinson's or clinical depression. Even if the HBP will not produce an exascale supercomputer or a new powerful paradigm for predicting biological disease signatures in the next decade, the large-scale nature of the clinical database alone could still substantially transform neurology. To date, case-based reasoning and individual syndromic and histopathological tests constitute the most common practice for treating patients in this domain of medicine (cf. HBP, 2013, 38, HBP 2014a, 195).

It is peculiar that the proposal for a new, federated clinical database and nosology is repeatedly justified with the economic argument that brain diseases cost the European health economy 800 billion € per year (HBP, 2013, 55, Markram, 2013, 148; Kandel et al., 2013, 659). The attempt to tackle this economic burden scientifically implies a strong medical strand within a Big Science project like the HBP. Significantly, it is also said to require science and society to consider 'clinical data as a public good, rather than the proprietary information of health insurers and providers' (HBP

2013, 56). Together with stressing the economic burden of disease, the HBP is *ex negativo* construing the Medical Informatics Platform as an *investment in the public*, a rhetorical figure known from the presentation of previous large scale biomedical databases, such as the UK Biobank (Petersen, 2005).

The rhetoric of contrasting the health industry's private data policy with the open data policy of the HBP somewhat conceals that ultimately, the same logic is at work in both cases. Like health insurers and providers, the HBP's economic argument configures "health" to be primarily a commodity. Clinical data, then, are just the quantified, scientifically objective indicator for individual health, and clinical data can therefore be most easily traded in the health market. Biologically valid classifications of the data into disease categories are then also the most (cost-)effective way of treating personal suffering caused by neurological disorders. The suffering or the disorders themselves, however, are secondary to the goal of commodifying health more effectively, in about the same sense as the biological brain may be secondary to the goal of building neuromorphic computers.

Although the economic and social or personal effects of "health" cannot be neatly separated in contemporary societies, the bioinformatics approach of the HBP medical platform reflects how the current EU research agendas increasingly focus on the application of technological fixes to societal problems. Further sociological and anthropological studies need to critically investigate this linear policy approach from technological innovation to the expected increase in the well-being of citizens (Levidow and Neubauer, 2014).

Neuromorphic computers for the life world?

In the vision document of 2013 the HBP claims, in a characteristic display of its self-aggrandizing proposal rhetoric, that the development of neuromorphic computers for general purpose use could represent a 'disruptive technology with a potential social and economic impact comparable to that of the first commercial computer' (HBP, 2013, 59).[6] To construct such a "disruptive" technology as an intermediate application, HBP researchers would need to (i) identify organizational principles from mouse or human brain data, (ii) incorporate the principles into multi-scale brain models, (iii) validate the models and principles by successfully simulating of known brain processes and finally, (iv) export a simplified version of the validated model into the Neurorobotics platform, where it can be run as the control architecture of a virtual neurorobot on a supercomputer. If the supercomputer itself is neuromorphic, then implementing a brain-inspired hardware system with a brain-inspired control architecture into a standard size commercial device becomes an engineering problem.

Although mutual adjustments between (i) to (iv) are possible within the HBP methodology, the outcome of one of the elements is also interdependent upon the success of the others. Consider the case of building a neuromorphic device with the ability to 'predict the likely consequences of [its] decisions, and to choose the action most likely to lead to a given goal' (HBP, 2013, 58; cf. HBP 2014a, 165). The HBP would first have to produce a top-down model of this ability, validate the model through simulation, and then export a simplified version of it into the Neurorobotics platform. In view of the currently uncertain future of the cognitive neuroscience subproject within the HBP (Fregnac and Laurent, 2014; Madelin 2014b), it seems unlikely that human decision-making will be the first template for a neuromorphic control architecture (cf. also HBP, 2013, 54).

Given that there are no commercial applications of neuromorphic computers so far, and given that the interdependencies between the iterative elements make the complexity of a first application highly unpredictable, the disruptive nature of these technologies most likely does not lie in their immediate scientific, economic or societal impact.[7] It would rather lie in showing that it is *possible* to extend the neural domain—i.e. the principles governing the behaviour of neural entities—beyond the biological brain into a silicon-based computer.[8] The disruptive potential of the

HBP itself, its immediate impact, then, would derive from concretely exploring this space of possibilities over the next decade.

The proposed immediate and intermediate applications can be summarized in the following slogan: *The HBP medical database and nosology sets out to foster the commodification of personal health as a public good, while the successful construction of a neuromorphic device would show that it is possible to extend the neural domain beyond biological brains.*

World making

Combining these prospective changes to neuroscientific practice, infrastructure and domains outside of science, we now analyse a number of potential intermediate effects of the HBP (and/or comparable present and future initiatives) on the material, socio-economic and perhaps even political configurations within which human beings live. The process that is likely to lead to these larger implications can be described in three steps, roughly corresponding to the three slogans at the end of the previous sections.

The de-organ-ization of the brain

As described above, the HBP moves away from small-scale invasive animal studies, and from the correlational paradigm of imaging studies in cognitive neuroscience. By attempting to change the normative standards of neuroscience to multi-scale modelling, predictive neuroinformatics, simulation, and large-scale integration, the HBP also attempts to overcome currently unresolvable issues such as individual variability (Miller et al., 2012), measurement artefacts (Horton and Adams, 2005, 843) and identifying causal mechanisms in the human brain (Logothetis, 2008).

The HBP approach could in principle resolve these issues because the new norms of good neuroscientific practice also reconfigure the object of investigation, i.e. the brain *itself*. The move away from working on biological tissue de-*organ*-izes the brain: that is, it shifts the scientific significance away from characteristics typical for *biological organs*, such as its evolutionarily contingent organization, the variability of cells and areas, or the biochemical nature of signal transmission. What is highlighted instead are the brain's characteristics that become salient from the outlook of predictive informatics, modelling, and simulations, such as the statistical connectivity of neurons with different morphologies (Hill et al., 2012), or the electrical signatures around cells which can be simulated in a large-scale model (Reimann et al., 2013). While certainly biologically *informed*, these studies produce a non-biological kind of data (i.e. simulation results) which is then taken as evidence for the behaviour of the entities in question. In other words, the de-organ-ized brain is given the *possibility to behave in new ways*, if the neuroscientist studying it is able to 'monitor and control all states and parameters of the [*in silico*] experiment' (HBP, 2013, 33; HBP 2014a, 187). Once the HBP moves into its operational phase the biological characteristics would drop out of the iterative chain step by step, until models could be refined entirely by referring to the rapidly accumulating simulation data. But that implies that the new ways of brain behaviour enabled by the iterative simulation method of the HBP are themselves—in a strict sense—not biological, but *computational*, in the sense of computer processing steps run on silicon chips. The ICT platforms of the HBP therefore not only provide the neuroscientists with a virtualized experimental system to work with, but also create a *virtual microworld* for the de-organ-ized brain to live in. This world is also populated by virtual neurorobots and environments, or eDrugs, whose behaviour is governed by mathematical algorithms, and is scaffolded by, and probably ultimately built into, (neuromorphic) supercomputers.

The cerebralization of the computer

It can now be shown why the respective aims of human brain simulation and building an exascale supercomputer are in fact inseparable in the practice of the HBP. Evolving multi-scale brain models and ICT into a neuromorphic supercomputer also changes the ability of computers to process data (in the same way that virtualization changes the space of possibilities for conceivable brain behaviour). In order to implement such changes, the HBP proposes to build neuromorphic computers by using heterogeneous and highly diverse parts, which behave stochastically, can switch between synchronous and asynchronous communication, individually 'interpret' received inputs, and are organized in a hierarchical and highly recurrent structure (cf. HBP, 2013, 56f.). The outcome of changing hardware and software architecture would be that the computer gets *cerebralized*, which is just the flipside of de-organ-izing the brain as described above. By providing a virtualized microworld for it, the HBP computers need to become more like the brain in order to fulfil their purpose of multi-scale simulation. In the more mature stages of the HBP, then, the cerebralized computer and the de-organ-ized brain would become practically indistinguishable for neuroscientists who simulate brain processes on the ICT platforms.

One possible effect of this indistinguishability is that the HBP reshapes the metaphor of "the brain as computer". Whereas it initially enabled neuroscientists to describe brains as serial or parallel information processors, hard-wired circuits etc. (Borck, 2012), the metaphor now implies that computers have to become more like brains, via an iterative convergence upon neuromorphic devices. It also implies that the brain *is* the better computer, since traditional computing reaches its technological limits without the ability to compute processes that match the complexity of neural behaviour. Therefore one might expect that retroactively, what the history of computing was *about* is changed once the first neuromorphic device can be built.[9] The HBP's major initiator and former spokesperson Henry Markram already wrote in 2006 that 'Alan Turing […] started off "wanting to build a brain" and ended up with a computer' (Markram, 2006, 153). In the context of brain simulation and neuromorphic computing Turing's aim gains the semantic force of a *factual* claim about the prospects of computer science which were back then technically impossible to achieve. From the perspective of the HBP today, it was already conceivable back then that computing as a field would progress into a stage where it becomes part of the neural domain itself.

Extending the microworld beyond the Human Brain Project

The final step of the transformative process beyond the initial HBP agenda involves the material transformation of the world outside the project's ICT infrastructure. Here, the history of computer development is again instructive. Initially a highly specific tool for academic and military purposes, the computer gradually evolved into a commercial device in the late 1980s and became the primary point of accessing information through the Internet in the 1990s. The widespread accessibility of the latter via Wi-Fi or smartphone technology coincided with the (material) transformation of public places (cafés, airports, libraries, classrooms), social and political issues (privacy in social networks, WikiLeaks, NSA surveillance), the economy (online shopping and banking, Dotcom Bubble, The Internet of Things), and of course, scientific research itself.

Processes of the kind just described are often inevitable because the material conditions in question were simply non-existent before the relevant scientific practice was established. Extending knowledge beyond the laboratory is therefore usually not an application to (applied to *what*?) but rather a *reconfiguration* of the world according to the principles embodied in experimental microworlds. As elaborated in the last two sections, the HBP is planning to build a virtual microworld that simultaneously enables new possibilities of action for neuroscientists, and new ways of behaviour for brains and computers. This microworld can be extended outside the HBP by reconfiguring the material conditions—and furthermore the economic, social, cultural and political conditions—so that they resemble the order maintained in the HBP itself. Needless to say, the commercial cerebral computer would be the primary interface between the virtual microworld that is materially realized in the ICT platforms, and the material macroworld of hospitals, family homes, offices, factories or sports stadiums.

The reconfiguration of the macroworld is indicated by the intermediate applications of neuromorphic devices to non-scientific contexts. Here, the promise is that such devices could contribute to the automation of labour in 'sectors requiring non-repeated actions that are difficult to standardize: for instance the construction industry, services and the home' (HBP 2013, 60; cf. HBP 2014a, 165). Promising such potential economic benefits falls firmly into the agenda of FET program of the EU. The FET's focus on ICT is itself connected to the "Digital Agenda for Europe" within the EU's "Horizon 2020" funding initiative launched in 2014. Crucial objectives of the "Digital Agenda" are the creation of a single digital market in Europe, maintaining European competitiveness in R&D of ICT, and fostering ICT-based economies, health and public services, as well as the "Digital Science" movement. Given that the EU-funded HBP obviously shares many of the aims with these larger policy initiatives, the crucial question is not *whether* the project aims to extend its insights from the micro- into the macroworld, but *how* it attempts to do so.

A possible model for interacting with general-purpose neuromorphic devices would be the neuroscientific user of the ICT platforms, albeit in a technically less sophisticated form. Such an "ordinary" user would have new possibilities of interacting with neuromorphic devices in the workplace (manufacturing neurorobots, neuromorphic controllers), through communication (mobile devices) or at home (neuromorphic computers or household appliances, cf. HBP 2013, 40; cf. HBP 2014a, 202). Of course, it seems highly unlikely that any of these devices will be built and developed into a marketable commodity in the near future, but the HBP puts at least the *possibility* of doing so on the horizon. It remains to be seen whether and how that possibility will get realized over the course of the project. But the preceding remarks should have made clear that Big Science projects like the HBP are *world making projects*: that is, they are in the business of materially reconfiguring the world we live in. They might have the potential to affect our lives in ways that are more profound, sustained, and potentially also less reversible than the isolated 'application' of this or that novel device.

The final slogan that summarizes this section is as follows: *The HBP is a world making project, because it plans to build a microworld for de-organ-ized brains and cerebralized computers, and shows how it is possible to extend this microworld through reconfiguring the macroworld via non-scientific neuromorphic devices and a new type of ordinary user.*

Ethics and Society

A project division that requires particular critical attention is the HBP's Ethics and Society Programme, whose level of funding with about 3% of the overall budget roughly mirrors the proportion of relevance accorded to ethics and society in the Human Genome Project. Given such a massive section dealing with foresight, social impacts, ethics, and public engagement (HBP, 2013, 43f.; HBP 2014, 208ff.), it might be objected that the kind of external analysis we conduct here is superfluous, as the project's own researchers might be considered to be in a better position to analyse and evaluate the initiative. We reject both parts of this objection, because the available Vision and perspective documents are not putting any relevant emphasis on the issues we have addressed in this chapter. Besides the usual programmatic of scientific research ethics, the documents mostly raise rather classical (neuro-)philosophical questions—such as freedom of the will, the biological basis of consciousness or psychiatric illness, etc.—questions that are considerably less relevant when it comes to understanding the impacts *specific* to the HBP's agenda. The issues regarding the potential formatting effects exerted by novel technologies and research procedures, medical practice, personal computing, or various data management policies do not figure prominently in the documents. What has been slightly modified between the 2013 and 2014 versions, however, is the ratio of emphasis between narrowly ethical and broader societal and public acceptance issues, where the latter have gained increasing prominence. This can be considered a step in the right direction – particularly given the fact that the Ethics and Society Programme initially seemed at risk of adopting little more than a standard neuroethics approach to brain research. This would have amounted to little more than unabashed advertising campaigns for specific lines of research (cf. de Vries, 2007). Refocusing on issues of technology assessment, foresight and public participation, while taking into account normative factors tacitly at work in those sectors of society into which potential innovations are set to be introduced (HBP 2014, 209), are steps that should be welcomed, although not without critical caution.

While the potential for forms of intensified critical engagement within the project might also be gleaned from a recent paper by HBP Foresight Lab leader Nikolas Rose (Rose, 2014), project initiator and former spokesperson Henry Markram had a quite different vision for this segment of the HBP. To Markram, the task of the Ethics and Society program was chiefly one of 'building public support' (Markram, 2013, 150). Apparently, he construed the public's understanding of the HBP as one of entirely ungrounded fears that arise with regard to the project's impact on matters diffusely perceived as relevant to our humanity. Accordingly, the task of a neuroscience initiative would be to 'recognize these fears, lay them to rest and actively build support for neuroscience research': for instance through education and trust building (ibid.). Drawing on the our analysis above, it almost seems like Markram wanted the HBP's Ethics and Society Programme to prepare and condition the wider public for future transformations of the macroworld to come, rather than to engage in critical studies that would have the potential to impact the HBP's agenda, let alone unsettle it in as of yet unforeseeable ways.[10] In stark contrast to this perspective, our assessment here should have made clear that further independent and critical analyses by STS and 'neuroscience-in-society' scholars are needed in order to prevent that the HBP agenda will influence or, at worst, even monopolize scholarly assessments of the project's likely impacts on neuroscience and society. **Elsification here**

However the future of the HBP will play out, it is crucial that the potential impacts of the projected agenda on the technical and informational infrastructure of science, medicine, education and personal computing are subjected to thorough independent scrutiny from multiple perspectives. This being said, it must also be noted that this task calls for a certain amount of patience and also for a dose of hermeneutic charity in one's assessments some aspects of the scientific agenda, including those that may at first glance seem fantastically exaggerated. Before us appear the initial stages of what will likely be a long game of piecemeal restructuring of several sectors of science and society, with far wider implications than those pertaining to the fate of this one particular project. We risk missing out on relevant issues if we jump on the first opportunity to enter the familiar reflex currents of academic critique. What is called-for instead is the more difficult task of staying closely attuned to a large number of developments in order to grasp what will likely remain a highly complex and fluid situation. In the present paper we could do no more than outline very first steps of what will hopefully become a sufficiently broad and informed assessment of transformations whose full extent and full range of consequences have only just appeared on the horizon.

Conclusion

How does our analysis help understand the larger stakes of the current controversy about the place of neuroscience in the HBP? To date, it seems like the critics' demands are going to be fulfilled, since the EC announced an independent review of the project in early 2015, and promised to biennially evaluate the scientific and organizational agenda before approving further funding (Madelin, 2014b). With the decision to not publish the complete first interim report, however, the

HBP continues its restrictive information policy (Abbott 2015).[11] Thus, there are very good reasons to remain cautious, since the project's basic institutional structure of an EU-funded core project and regionally funded partnering projects, as well as the scientific direction of ICT infrastructure building and whole brain simulation, will likely remain unchanged. Based on our analysis, we would add that the construction of standardized ICT infrastructures—perceived as a positive development by the majority of the neuroscience community—could have wide-reaching impacts on neuroscientific practice independently of the HBP's aim of whole-brain simulation. With regard to the disciplinary effects of integration, standardization and iteration, paired with the HBP's potential impact on society and culture that we call "world making", one could speak of a massive *lateral agenda* of the HBP which demands critical scrutiny.

Perhaps the most persistent force contravening these expected effects remains the currently fragile support of the HBP by the neuroscientific community. Even in disciplines where standardization is widely supported, heated debates remain over the reliability and proper use of the shared methods and tools (Leonelli, 2012). It is here where neuroscientific practitioners critical of the HBP could remain an active force of resistance that reaches beyond the current dispute over transparency and scientific excellence. With regard to the prospects of reform, however, it is crucial to see that the power relations between the HBP and its critics are asymmetric. The HBP has now gained a material and intellectual *gravitas*—with hundreds of researchers, collaborators, buildings, an education programme etc.—which could make it 'too big to fail', even if the bottom-up simulation approach towards the brain turns out to be scientifically unfruitful (Schatz, 2013).

Besides the analysis of the current issues and future stakes of the HBP, our remarks should also be seen as first steps towards more encompassing critical studies of the HBP. They could serve as outlines for various questions that might be investigated from different science studies perspectives:

- *HPS and STS of computer simulation:* How does the large-scale, standardized, multi-level simulation practice of the HBP bear on discussions about the relationship between experiments, simulations, and theories (Winsberg, 2003)? More specifically, what are the epistemological and ontological implications of the aim to create a non-biological target system for human brain simulation in the form of a neuromorphic supercomputer (Parker 2009)? More broadly, what are the (institutional and economic) implications of the simulation- and ICT-based approach for neuroscientific research culture, and how do they differ from simulation in astrophysics, meteorology, and nanotechnology (Johnson, 2006; Sundberg, 2010) or in-silico experimentation in molecular biology (Moretti, 2011)?

- *Medical anthropology and medical humanities*: How could the data-federation system and clinical database of the HBP transform local and global medical practice and health care? How does the commodification of "health" as a public good (in the form of clinical data) relate to the concept of "venture science" and capitalized bio-power (Sunder Rajan, 2006; Cooper, 2008)? How do medical clinical databases relate to the discussions surrounding E-health and the Patient 2.0 (Jensen, 2005; Langstrup et al., 2013)?

- *History and philosophy of neuroscience and technology:* How will large ICT platforms in the HBP impact the relation between users and developers in scientific practice (Millerand and Baker, 2010)? More generally, how does it relate to the historical emergence of "the user", i.e. the type of person interacting with a computer (Stadler, 2014)? Moreover, how does neuromorphic computing reconfigure the long history of technomorphic metaphors of the brain—from the telegraph to the network (Borck, 2012)? And finally, how does the need for computing power for whole-brain simulations reshape the socio-technological development of supercomputers (Elzen and MacKenzie, 1994)?

- *Historical ontology / political theory of future technologies*: Perhaps less emphasized in our paper is how the notions of de-organ-ized human brains and cerebralized computers relate to the question of what it means to be human in the 21st century. Do policy agendas about the use of "converging technologies" that aim to increase human performance (or public science reports about the impact of neuromorphic technologies on society) make it legitimate for scholars to announce the dawn of a "trans-human" society (Fuller 2011, 2012), or are such announcements premature? At stake here is an assessment of the intensifying debates about issues such as human enhancement, life extension, or technological singularity in the context of the political, economic, and social orientations that inform them.

Obviously, this list is incomplete and just points to some of the links between our analysis of the HBP and prevalent themes in science studies that strike us as potentially fruitful for further investigation. Our hope is that we can thereby motivate researchers from disciplines including, but not restricted to the ones mentioned above, to consider the HBP as a significant research topic for critical inquiries into contemporary science, technology and society.

Notes

1 See the official website of the project: http://www.humanbrainproject.eu.

2 A good example is the community driven, open-source software development system NeuroDebian (Halchenko and Hanke, 2012).

3 For reasons of space we have to omit a discussion of the large-scale educational programme of the HBP (cf. HBP, 2013, 44f.). We would note, however, that the plan to educate 5,000 PhD students within a decade could foster the simulation-based approach to neuroscience independent of the specific outcomes of the HBP (the precise number of PhD's is not provided in the FPA document, cf. HBP 2014a, 28f). The education programme also represents a form of institutional reproduction commonly found in Big Science projects—see also the analysis of the remote access site "Nanohub" within the US Network for Computational Nanotechnology by Johnson (2006), 46f.

4 An example of such a discovery is provided by the Fermi National Accelerator Laboratory, where the decay pattern of Higgs bosons was identified in the data long after the Tavatron particle accelerator had already been shut down (Fermilab, 2012).

5 Depending on the project phase, the HBP could also exemplify aspects of Sundberg's (2010) organizational typology of simulation code collectives. In the ramp-up phase, the HBP seems to function internally like a "code of the centre collective", where development (and use) of the ICT platforms is tied to HBP membership. During the operational phase, it could resemble a "code spread all around collective", where HBP members are internally split into "core developers" and periphery developers or users respectively, while nonmembers could take up the position of external developers in the Competitive Calls program or to maintain the community driven Wiki "Brainpedia" (HBP, 2013, 19, 34).

6 Neuromorphic computing was developed by Caltech electrical engineer and computer scientist Carver Mead in the 1980s as an alternative to ICT that relies on "Moore's law", i.e. the conjecture that the number and density of transistors doubles roughly every two years. Neuromorphic computers could therefore provide a promising, low-energy alternative to meet the increasing demand of computing power in the future. Only recently, it has become possible to build large-scale neuromorphic systems (e.g., in the SpiNNaker group, UK, the EU FACETs program, or the DARPA SyNAPSE program, USA), although these systems currently do not meet the desired energy efficiency of 10 million Multiply Accumulate Operations per second and Watt (Hasler and Marr, 2013, 19f.). The HBP crucially builds upon further improvements of these technologies in order to run its multi-level human brain simulations on exascale supercomputing technology (cf. HBP 2013, 23ff., HBP 2014a, 191ff.). Note that the use of the

word 'disruptive' was derived from the initial call for the FP7 program of the EC, but has been subsequently dropped in later official reports of the HBP.

[7] In August 2014, the SyNAPSE team has built the first neuromorphic chip called "IBM TrueNorth" that could be used for commercial application (Merolla et al., 2014). It runs with 769 times less energy than the SpiNNaker microprocessor. While this energy reduction seems to be an enormous step forward for neuromorphic computing, it remains to be seen how fast IBM can transfer this prototype into applicable commercial devices, and how TrueNorth may influence the neuromorphic agenda of the HBP.

[8] We consider the extension of inquiry beyond an initial domain to be an integral aspect of scientific research (Rouse, 1987, 2011). As a comparison, consider how in 19th century physics, electricity and magnetism were considered two independent phenomena, until the laboratory practices of Oersted, Ampère, Faraday and others established new concepts to study the interaction between electrical wires and magnets (Steinle, 1997). It is similarly a trademark of how the HBP understands the brain conceptually that it recognizes a shared boundary between the neural domain and the domain of computing. Implementing ICT platforms that serve as interdisciplinary "trading zones" (Galison, 1996) between both domains is therefore a practical consequence of that conceptual understanding.

[9] Our claim here draws on Rheinberger (1997), who argues that the initial target of scientific inquiry—what it is 'about'—can retroactively change depending on the further directions an experimental system subsequently takes. Rheinberger's example is Peyton Rous' chicken sarcoma system, which initially seemed to be about the link between viral entities and cancerous cell growth, but subsequently became a means to study normal cell physiology with the help of ultracentrifuges. Only after WW II (in part through the introduction of electron microscopy into molecular cell biology) did viruses re-appear as a determinate entity within the sarcoma system. Rous' conjectures about the viral origin of cancer were therefore retroactively supported, after being largely ignored by the research community for 40 years (Rheinberger 1995, 56ff., 76f.).

[10] The HBP therefore neatly follows the Horizon 2020 research agenda, which for the most part diminishes the role of the social sciences and humanities in the guidance—if not reinforcement—of 'capital-intensive technoscientific solutions' to the 'grand challenges' of European society (Levidow and Neubauer, 2014).

[11] Abbot's claim that the report was not published is not entirely true, since a summary of it is available (Digital Agenda for Europe 2015). Many of the recommendations made in this summary resemble the critical points that we mentioned above (e.g., stronger involvement of the neuroscientific practitioners outside the HBP in the early use and adjustment of the ICT platforms, and a more open exchange between experimental and computational subprojects, cf. ibid., 2, 4). Note however, that the summary of the report mainly concerns issues of transparent communication and the better integration of the subprojects within the overall structure of the HBP. It therefore does not deal with what we have called above the *lateral agenda* of the HBP. For the different kinds of rhetoric surrounding the report, compare the above document to Van der Pyl (2015).

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