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The Neurotechnological Cerebral Subject: Persistence of Implicit and Explicit Gender Norms in a Network of Change

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Abstract Under the realm of neurocultures the concept of the cerebral subject emerges as the central category to define the self, socio-cultural interaction and behaviour. The brain is the reference for explaining cognitive processes and behaviour but at the same time the plastic brain is situated in current paradigms of (self)optimization on the market of meritocracy by means of neurotechnologies. This paper explores whether neurotechnological apparatuses may—due to their hybridity and malleability—bear potentials for a change in gender based attributions that have been historically legitimized by apparently natural differences between women and men. Or, in contrast, which gendered ascriptions are (again) produced in theories and applications according to the normative demands for the bio-techno-social cerebral subject situated in neoliberal power relations. An exploration of three main fields of current developments, the neurotechnological apparatus of brain-computer-interfaces, the technologies for brain tuning and the discourses in neuroeconomics, reveals first insights on these gender aspects in reliance with the ethical/political debate. Moreover, this paper concretizes questions for further research on gender and ethical aspects in the field of neurotechnologies.

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Neurotechnologies for Optimizing the Bio-Techno-Social Cerebral Subject: Underlying Concepts and Potentials of Gender Research for Ethical Questioning

Brain research has become a leading science by enabling visual access to the living brain and the illustration of bodily matter and its communicative acting by dint of modern computer tomography. With reference to the neuroscientific knowledge production for explaining individual cognitive processing and behaviour, decision-making and emotional responses, sexual orientation [1] or religiousness [2] (to name only some examples), we witness a whole scope of emerging neurocultures (neuropedagogy, neuroeconomics, neuromarketing, neurotheology, neuroaesthetics, ect.) at the intersection of different disciplines. Francisco Ortega and Fernando Vidal used the term of the *cerebral subject* [3] to describe how thinking, acting and identity amalgamate with the brain's biology in these discourses. The cerebral subject emerges more and more as the central category defining the self, socio-cultural interaction and behaviour.

However, these discourses become detached from a pure deterministic perspective that has argued for an

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inherent brain matter by means of evolutionary concepts. Due to the emergence of *plasticity concepts* in the neurosciences the brain is not addressed any more as a determined, unchangeable matter. Instead, it is conceptualized as continuously changing in structure and function with experience. This holds particularly for cortical activity and its underlying structures aligned with complex human cognitive processing. Some current brain imaging studies have outlined the dynamics of synaptic networking in the cortex, constantly being conformed by individual learning and social interactions: for example the development of differentiated language networks according to language biographies [4], the changes in hippocampal synaptic density along with navigational experience [5], or effects of training on neuronal networks in cortical motor areas within 3 months [6]. Consequently, we are not only determined by our brains; we modulate our brains, its cortical structure and function in particular, continuously through thinking and acting.

Based on these notions of convertibility and modifiability of the 'brain's nature', "feasibility rather than fate" has become an imperative for the cerebral subject in the neoliberal societal and economic order. The subject is not only enabled, it is even more forced to use and to optimize his/her brain as a resource for successful positioning in societal hierarchies and for self-marketing in modern meritocracy. In line with notions of individualization, rationalisation and commercialisation of one's own employability technologies of brain modification emerge in the bio-medical field as well as in societal contexts. With the help of *neurotechnologies as instruments for optimization* the cerebral subject should become more efficient, more concentrated, more flexible and more self confident.

However, neurotechnologies are no neutral instruments that can be applied for optimization without impacts on the brain. Instead, technologies as brain-computer interfaces, transcranial magnetic stimulation or even pharmacological treatment are embodied in the brains bio-materiality. Consequently, the modern cerebral subject is not only defined bio-socially, as Ortega and Vidal stated; it becomes a *bio-techno-social subject*.

With the brain conceptualized in such a network of nature-culture-technology, a current change in the epistemology of brain research has to be stressed here as it fundamentally influences the neurotechnological endeavours. A *modern neurobiological determinism* again characterises all processes of thinking and acting, those explainable by the current biological structures and processes in the brain at the time of measuring [7]. However, this concept of determinism does not care whether brain structures and functions are innate or formed by experiences during lifetime, or by technologies, respectively. It is irrelevant whether the individual brain at a certain point in time is as it is by nature or by nurture, but its current status should predict all processes of thinking and action, e.g. [8]. However, independently of notions of plasticity these paradigms remain based on essentialist notions of the brain. Brain materiality has to be essential at the point of intervention; otherwise it cannot be modulated, manipulated or controlled.

Neurotechnological developments are strongly associated with bio-political discourses as technologies of power and market economy are implemented into technologies of the self, with the individual (or even more his/her brain) in the centre of mending and manipulation. This emergence of a *neurogouvernementality* has already been situated in the ethical debate including questions of impact assessment and adverse aspects, questions of social equity, equal access and distributive justice, to the point of identity debates or the tension between the seemingly autonomy of the subject against the gouvernemental pressure to perform, e.g. [9–11]. In this paper I will focus in particular on ethical questions that derive from the interconnection of human brains with neurotechnologies and on how norms and definitions that are related to the paradigm of neurotechnological enhancement impact the cerebral subject. I explore three main fields of current developments, the neurotechnological apparatus of brain-computer interfaces, the technologies for brain tuning and the discourses in neuroeconomics, all of which are deply embedded in the discourses on the cerebral subject in neoliberal societal orders and power relations.

This approach is strongly connected to the questioning of gender aspects combined with neuroethical questions in the emerging field of neurotechnologies. For the purpose to concretize this interconnection it is important to outline first some basic insights gender research can offer on the processes of knowledge production in the brain sciences.

Potentials of Gender Research

During the last decades analyses of *Gender & Science Technology Studies* have dismantled dichotomous attributions of female/male skills, attitudes and behaviours that have been explained essentially by brain based sex differences, see [12] for review. The assumed clear cut differences and the homogeneity within the two sex groups (women's brains in opposition to men's brains) has been proved to be unsustainable on the level of findings, showing a higher variation within the groups than between male/female boundaries. This holds for language processing [13, 14], for spatial orientation and environmental cognition [15, 16], for mathematic performances [17, 18], and even for structural aspects of the corpus callosum [19]. In-depth analyses have outlined methodological distortions that influence the assessment of findings and challenge the transfer of results between studies or the drawing of simplified generalisations over the sex categories [20, 21].[1]

With respect to brain plasticity studies the variability of results within gender groups as well as their overlapping across gender boundaries can be discussed against the experience based formation of the individual brain, concerning both its materiality and its functionalities. Inter- and intra-individual brain diversity emerges throughout lifetime at the intersection of gender, age, class, ethnicity and further cultural categories. However, some similar experiences during socialization may also lead to similar brain structures and functions. Following this perspective, the brain is not only marked with gendered significations, it is also formed by gender-affected experiences, and the brain itself reciprocally influences cognition and behaviour. This concept of embodiment draws a connection between socio-cultural constructions and the constitutions of corpo-realities of gender without making tendentious deductions regarding cause and effect, and without dichotomising sex (as biological part) and gender (as socio-cultural part) [22]. The gendered brain, then, has to be discussed within a network of permanent and mutual biological, social and cultural interchanges. Consequently, images of brain activation during problem-solving at a certain point in time (in brain imaging, adults are usually tested) are only snapshots of the subject's continuously changing corpo-reality. They allow for both interpretations: the brain as cause or as result of cognition and behaviour. Theses empirical phenomena are underdetermined for the one or the other theory (nature versus nurture), to speak in terms of Sciences Studies [12].[2]

Gender & Science Technology Studies (STS) have also outworked the constructive nature of brain images per se, e.g. [23–25]. Without question, brain imaging has turned out to be an important technique to improve knowledge of brain processes. However, brain images are no direct copies of the inside of the brain because they are constructed with the assistance of a whole set of IT-supported calculations and computer-graphical methods. Over the course of the construction process a multitude of decisions are made regarding what will be included in the image and what is left out, what will be accentuated and what remains in the background. These approaches illustrated how decision processes during image construction are influenced by background theories, research questions and aims, technological prerequisites, economic and political aspects, as well as by popular discourses on gender attributions. This notion of the constructive nature and of the inscriptions that are aligned with the apparantly neutral neuroscientific technologies will gain importance also for the analyses on gender and neurotechnologies.

Gender research and feminist technoscience stressed another important perspective. Brains that before were determined by arguments of naturalization as being seemingly fixed and fateful, have become conceptualized as malleable and this can also be attributed to discourses about gender and the brain. If neurotechnologies fragment the border between brains and technologies, and if technologically upgraded brains become hybrids between nature, culture and technology, mutually intra-acting, influencing and changing each other, these cyborgs or bio-socio-techno apparatuses, as Donna Haraway [27] or Karen Barad [28] have conceptualized them, may bear the possibility to overcome the historically

[1] More and more, this type of reflective analysis enters high-ranked neuroscience journals, as for example [20] in *Brain Research Reviews* or [21] in *Brain and Language,* and it improves the discussion about influences of the empirical setup, of the techniques of data acquisition and data analysis, or of the use of statistical procedures on research findings concerning brain and gender.

[2] Nonetheless, brain images do not loose their seemingly objective power in scientific and even more in popular discourse, but this analysis would go beyond the scope of this paper, for overview see [26].

deeply embodied gendered connotations of female versus male skills, attitudes or behaviours, of female nature versus male technology, or of male rationality versus female emotionality. However, these degendering potentials can only be stated on an epistemological level until now. If embodiment processes in neurocultures are situated in scientific, socio-cultural, political and economic power relations it has also to be questioned whether gendered attributions persist, and maybe even become stronger in line with the emerging field of neurotechnologies.

This paper presents an approach to detect comprehensive lines across the field of neurocultures intertwined with neurotechnologies that can help to asses the facets of gendering and/or degendering processes in its discourses and applications. With my screening of the fields of brain-computer interfaces, neuroenhancement technologies and neuroeconomics I extract gendered and neuroethical aspects that should gain importance for a set up of a combined neuroethical and gender research agenda. More than presenting final results I aim to characterise the assemblage points for further detailed analyses in these issues.

The Neurotechnological Apparatus of BCI

I start my exploration in the bio-medical sector of brain-computer and brain-machine networks. By means of some examples I aim to work out first how the seemingly independent biological matter of the brain and the technological components of computers and neuroprostheses, in fact, are deeply intertwined within these neurotechnological networks. This leads to a set of questions on how the actors in these networks impact each other and how hierarchies and power relations in these apparatuses have to be analysed under a neuroethical perspective. On this background, I will proceed to some neurotechnological applications in the non-medical field of human enhancement to outline gender aspects that call for further detailed research in this area.

Deconstructing the Outside-Inside Dichotomy in Human-Computer-Communication

For the development of brain-computer interfaces (BCI) in the bio-medical sector the point is superficially a matter of facilitation of the communication between the brain and the environment. A BCI is designed to catch signals from the brain, to decode them and to convert them into signals that control connected technological devices. Under this perspective the 'enabling' or (re-)gaining of human capabilities (impaired by illness or injury) for communication with the environment is conceptualized as a linear process from the inside of the brain to the outer world, e.g. [29].

Paralyzed humans or locked-in patients (who have lost muscular control, speech and even mimic consecutively in case of Amyotrophic lateral sclerosis) can, for instance, learn to raise or lower their slow cortical potentials. These changes are detected by EEG-electrodes on the scalp and are computed into a binary coding to select or reject letters, to choose websites or e-mail functions on a computer interface. Thus, from a perspective 'from inside to outside' the control of a computer cursor with the own EEG changes allows the patient to communicate with the outside world [30]. Upon a closer look, however, this 'communication' requires long-lasting training phases: in the case of the cited study it took the patient 1 year of training to be able to write a text with 2 letters per minute [31]. Most important in the training phase was the visual feedback for the patient as his brain had to learn to communicate with the machine. Instead of a seemingly linear process, the partners in the neurotechnological network, i.e. the brain and the computer, start to interact.

A similar breaking up of boundaries and directions between the brain and the technological components holds for invasive BCI. In the project BrainGate [32] a paralyzed patient was implanted with a sensor in his motoric cortex, in particular in those brain areas that regulate arm and hand movements. This sensor was connected to a signal receiver in the skull; the latter was wired to a computer. Through the imagination of an arm movement the patient at a given point in time tried to move a cursor on the computer in different directions: to surf the Internet, to check e-mail, to choose television programs, or to conduct computer games. The advantage of invasive BCIs, in general, is proposed for multidimensional scaling of more degrees of freedom and for navigation of a cursor in close time with movement associations of the subject. In this case as well, the patient's success was a result of intensive training. Moreover, not only the brain had to learn how to interact with its incorporated technological equipment; the computer and the technical system, in turn, also had to be calibrated to the current brain status of the patient before every trial.

Invasive BCI technologies, additionally, comprise the development of neuro-prosthetics. Through brain implants the activation pattern aligned with movement regulation in motoric brain areas should be decoded and converted into direct control of external arm- or leg-prostheses. It took the research group around Miguel Nicolelis and Michael Lebedev 5 years to extract the relevant information for navigation control of a robotic arm from the highly complex neuronal patterns within apes' motoric cortical areas with the help of IT-processing and learnable algorithms [33, 34]. The authors highlight brain plasticity as prerequisite on the apes' side to develop new brain activity pattern for the control of the robotic arm, and they point to the necessity of a multiple feedback system that supplies the apes with visual, senso-motoric feedback, and with feedback by reward. Otherwise, the ape-computer communication does not function effectively.

These examples show that brain-computer and brain-machine interfaces themselves break up the apparently focused direction from the inside of the brain to the outside of the world. BCI-scenarios change the notions of the subject's brain as a sender, of the computer as a neutral transmitter, and of the technical devices as receivers of information. Instead, human-machine-communication is to be processed in a so called *closed loop* [35] with continuous feedback between both subject and machine. The communicative network requires the plastic and learning brain on the one side and learnable algorithms as a counterpart in the computer. Both, brain and computer have to 'harmonize' their codes for communication. Consequently, brain, computer and technical devices intra-act and change each other permanently.

The interconnection and malleability of the brain-computer-networks and their openness towards reciprocal constructions lead to a set of questions from a neuroethical perspective that go beyond the ethical debate of medical damages or the question of informed consent, e.g. [11]. If the brain is to intra-act with the mathematical-logical machine, it has to be analysed in more detail how the processes of intra-action dynamically progress. What are the 'data', what are the kinds of information, what are the codes that are centred in these forms of communication? How far is the brain—or more precisely the cerebral subject—able to articulate autonomously, or how far does the computer dictate the particular form of communication? Which shortenings are due to the reduction of complex brain activity pattern to the binary code of the computer?

Even the notion of a closed loop may be misleading as it gives the impression of BCIs being self-contained and independent from the surroundings in which they are constructed. Hence, the ethical discussion has to be extended to a debate on the situatedness of the neurotechnological apparatus within scientific, economic, societal and political processes and discourses. Who are the actors in these networks, how do they intra-act, and are they all on equal footing? Which role and influence do researchers and investors (e.g. from the medical, the economic or the military field), social institutions and discourses about the neurotechnologically interconnected cerebral subject gain in this interrelation?

With respect to some applications of these neurotechnologies in the societal field for the improvement of 'normal' human capabilities, I will sharpen some of these neuroethical questions in alignment with gendered aspects.

BCI on the Market: Extracting Gender and Ethical Aspects

Developments of brain-computer interfaces for the commercial market mostly comprise non-invasive neurotechnologies. The Graz-BCI group, for example, presents an image of a user moving through a virtual urban environment: a street surrounded by modern buildings populated with virtual subjects [36, 37]. This scenario promotes strongly the impression of an application for the modern human. With another application, a so-called 'smart home technology', a user can operate home facilities (light switches, door openers, television or hi-fi systems) from somewhere outside of the building by wearing an EEG-cap that is connected to a computer [38, 39].[3] These examples match with analyses of Cecile Crutzen [40], who

[3] This BCI technology uses changes in particular brain signals (P300) to be transformed into control signals for the devices.

outlined gendered attributions in the development of smart home technologies for the very busy manager (who is therefore able to pay) to facilitate and rationalize his activities before arriving at home, tired from work at the office. They also match with applications that promise a faster, more effective communication in using mobile phones via EEG-interfaces.

Another set of examples refer to non-invasive BCIs on the market of computer games: EEG-caps are advertised that shall enable the engagement in a computer simulation of a ping-pong game via ‘thoughts’ [41]. This application is presented with images of two technologically upgraded male players in a competitive scenario. More advanced systems even promise the control of avatars in computer games such as “World of Warcraft”. The so-called “Emotiv-System” (EPOC), for example, is advertised especially with the possibility to ‘implement’ the own emotions (anger, pleasure, astonishment) in the actions of the subject’s avatar by wearing an EEG-application. Beside the fact, that the promise of a detection and transmission of complex emotions through changes in EEG waves has to be questioned, an exploration of the advertisements of EPOC showed an interesting result with respect to gendered attributions. The images in the advertisements present a high amount of females or coloured people wearing the ‘emotive cap’ [42], thus intertwining emotions with the categories of gender and race.

A third arena of research and neurotechnological applications cannot be disregarded: the military field. The DARPA (Defence Advanced Research Projects Agency) aims at—as Hanna Hoag has already shown [43]—developing neurotechnological facilities for the faster, harder, fit-for-action, always ready-for-operation soldier. In this domain, medical and non-medical applications cannot be distinguished sharply. For example, the “Revolutionizing Prosthetics Program” [44], launched in 2007 and prolonged in 2009, should enable injured soldiers to control an artificial arm via neuronal interfaces. Rehabilitation and operation readiness are not clearly separable. Another application of the DARPA, the “Cognitive Threat Warning System”, is interesting because it refers directly to mutual modulations in the brain-technological network: the CT2WS should promote an ‘intelligent’ neuro-optical system that is to be trained via EEG. In principle, the computer should learn algorithms from the soldier’s brain (his unconscious detection of dangerous stimuli), the algorithms then should process the information faster than the solder can detect dangerous stimuli consciously, and, finally, the technical system should return warning signals into the soldier’s brain; all this to give “the U.S. starfighter as much as a 20-minute advantage over his adversaries” [45].

Some *goals of neurotechnological optimization* for the healthy subject can be extracted from these approaches: enhancement of connectedness, operational readiness and flexibility, improvement of mobility and communication. These are optimizations for the ‘modern human’ who aims at effective self-marketing in modern information society. Thus, neurotechnological enhancement in the non-medical field seems to focus on particular target groups and to overtake current discourses with notions of economizing the social sphere, commercialization, individualization, rationalization and globalization.

Under the perspective of an ethical debate concerning equal access and distributive justice the impacts of neurotechnological enhancement on the formations of social inequality, on inclusions and exclusions that derive along the intersected lines of gender, class, age and ethnicity have to be questioned. Some gendered ascriptions have already shown up under this first screening. The flexible manager in an urban environment, connected via his mind-controlled mobile phone, using his smart home technology through EEG-interfaces or the male computer players, neurotechnologically connected and engaging in competitive endeavours: they all can be associated with maleness. On the contrary, the female computer player tries to implement her emotions in avatars. Even if military prosthetics are also built for female soldiers, the notion of a fit-for-action soldier reinforces the masculine image of a ‘universal soldier’, as Petra Cook has worked out in detail [46]. These first notions of inscribing (again) connotations of masculinities and feminities in the realization of neurotechnologically upgraded humans call for further analysis at the intersection of gender and neuroethics.

Brain Tuning Engendered

My second screening of neurotechnologies leads to the domain of *brain stimulation* that is initially conceptualized from the outside of the world to the inside of the brain. For purposes of improving performance via technological or pharmacological neuroenhancement, these developments are again intertwined with notions of the cerebral subject that should use his/her brain as recourse and instrument for optimization. Based on notions of brain plasticity enhancement techniques on the cognitive level and on the level of moods are promised for everyone. In consequence, the debate on brain tuning appears surprisingly degendered at first glance. However, it has to be questioned what notions of normalization go in line with the technologies of brain optimization. Do gendered attributions really vanish; or are gendered norms legitimized and manifested again in line with these developments and, if so, which?

Technological Brain Stimulation

In transcranial magnetic stimulation (TMS), for example, intense magnetic spools relay repeated impulses to certain brain regions that should influence the function and structure of nerve networks. In the 1980s, TMS was developed to medicate depression, but showed side effects such as headache, epilepsy, and fluctuations in cognitive capability [47]. The latter 'side effect' gained importance in neuro-technological approaches that aim to use TMS for improving skills in computing or detailed memory [48, 49]. It is important to point out here that brain plasticity again plays a central role as sustainable effects of magnetic brain stimulation cause and need changes in the functional brain networks. As in the field of BCI, the brain stimulation with TMS does not only connect technology and biology, instead, both change each other permanently.

My exploration of the research area of TMS with respect to neuroenhancement technologies leads to particular examples. So-called savants, often diagnosed with high functional autism (Asperger autism) are presented as having astonishing skills (beside social deficits). For example, Kim Peek was able to recall postal and phone codes for every US city, and to name the highways to get there. In addition, he was able to memorize the content of about 12.000 books. Orlando Serrell was hit by a basket ball at the age of ten, and since then he is said to remember every detail of his life. Daniel Tammett *c*an memorize 22.000 numbers in a row and he is able to learn a new language (e.g. Finish) within 2 weeks for conversation. Stephen Wiltshire, called 'the living camera', was diagnosed with autism at the age of 3 years. With his savant skills he became famous for drawing complete and detailed pictures of London, Rome or Frankfurt, after a single aero flight around.

Why are these subjects presented as so outstanding in the discussion of neurotechnological approaches to cognitive enhancement with TMS? Alan Snyder from the Center of the Mind/Australia [49] and Nils Birbaumer at the University of Tübingen/Germany [48] presumed that these skills for detailed memory capacities are 'hidden' in all humans. The storage of low-level information bits comprises the first steps of central nervous information processing, forming the basis for complex pattern recognition. However, 'normal' individuals filter relevant information and associations out of this flood of information bits into consciousness to prevent overload. People with Asperger autism, instead, recognise (consciously) every detail of information, but they are not able to separate important from unimportant information or to extract associations and patterns. In addition, they are even less able to connect rational and emotional processing, which is assumed to explain their social deficits.

Neurotechnological approaches that aim at turning savant like skills to profits for cognitive enhancement of the 'normal' subject with the help of TMS [49] enter the discussion in the recent years, see [50] for review. A blockage of the superior processes of pattern recognition with repetitive TMS should allow healthy subjects to memorize details and information bits of the first-step processing or to enhance mathematical and other cognitive skills.

These developments require an analysis under the *perspective of gendered inscriptions* in the complex of TMS-enhancement and Asperger autism. Autism is diagnosed four times more often in males than in females [51]. The dominance of male savants is explained by an effect of testosterone, conceptualized as a male hormone. Testosterone is said to improve the processing of single information und to explain extreme male savant skills for detail memory, computing or spatial performance. Testosterone should lead to a stronger asymmetry of brain hemispheres in males, and—as savant skills are related to the right hemisphere—this could explain male savant dominance [52]. These gendered attributions are mostly taken over uncritically as a fact, without referencing to the results of reflective gender analyses in brain sciences that have been outlined in the first section of this paper. Rebecca Jordan-Young [53] has currently outworked the complexity of hormonal regulation on the brains organizational level as well as on activation processes of cortical networks. Her detailed analyses of contradictory findings, conflicting theories and gender biased interpretations speaks against the binary separation of male (testosterone) versus female (estrogens, progesterone) steroid hormones, and it speaks against essential explanations of sex-typed cognitive skills and behavioural dispositions as simple results of these hormonal effects. Notwithstanding that hormones influence the materiality and functionality of the brain, Jordan-Young stresses the overlapping and similarities between gender groups more than the differences between them. Consequently, simple drawings between testosterone and apparently masculine superior performance have to be handled with care.

This critical reflection also holds for Simon Baron-Cohen's theory of males' S(ystematic)-brains versus females' E(motional)-brains [54] as it follows the same principles in setting up a dichotomy between male brains associated with rationality by means of the influence of prenatal testosterone, contrasted to female brains that should be hormonally directed to empathic and social dispositions. Nicole Karafyllis has deconstructed the associations of high functional autism with male systematic brains in Baron-Cohen's *extreme male brain theory* [55]. Moreover, she worked out how the rationalized male is taken responsible for solving future demands of the technologized society and how the female is (again) signified as responsible for emotionalized care work.

One of the rare women with Asperger autism who is presented in public media is the professor of biology Temple Grandin. Her savant skill, it is said, lies in her outstanding ability to feel empathy with animals. Even though Temple Grandin also shows superior spatial skills (following Baron-Cohen, she should have a male brain), media representations, as Karafyllis has shown, construct her image predominantly in association with rural environments, empathy and animals. In contrast, male savants are rationalized and associated with technologies and computers in media representations [51].

The approaches on brain stimulation with TMS are in the fist place in a developmental state until now. However, the underlying gendered connotation of a masculine rationality that is presented as the requested goal of enhancement has to be taken seriously. Although medical damage as seizures that may be induced by TMS applications are stated with minor ethical concerns, there are other hints on impacts of TMS stimulation on brain materiality and functionality with respect to the regulation of social cognition, see [50] for overview. Several studies point to a decrease of empathic and moral judgement capabilities after exposure to TMS in parallel with an increase of egoistic cost-benefit judgements of behavioural decisions. These first hints strongly call for a combination of gender research with the ethical debate. In particular, the valuating of rationality superior to emotionality/empathy as a discursive normative formation of leading qualities in a technologized society seem to go in line with some particular foci of this form of technological enhancement. Feminist theoretical concepts as Haraway's material-semiotic node points [56] or Barad's intra-active apparatus [28] could provide a useful guidance for analysing the TMS field under these perspectives.

Pharmacological Brain Stimulation

The most intensive discussion on interventions in the brain in order to influence skills and performances is concerned with pharmacological neuroenhancement. Neuropharmaceuticals that are to improve memory (e.g. Modafinil), concentration (e.g. Ritalin) or mood (e.g. Prozac) all function via brain plasticity. They sensitize or inhibit biochemical information processing at the synaptic contacts between nerve cells in such way that they influence the release or uptake of transmitters. Not only affecting the functional sensitivity of synapses, some groups of neuropharmacological enhancers have been researched for influencing the activity of neuronal genes [57], the latter coding for the creation of new synapses or for strengthening the synaptic network. Although brain pills are advertised with the message to have only short-term effects, they especially focus on long-term potentiation (LTP). As LTP is the prerequisite for learning processes on the central nervous level, pharmacological enhancement implies permanent changes in the plastic brain structure and function. This thwarts recent discussions on the use of neuropharmacological enhancement, in the academic field in particular, which is legitimized along the argumentative line of non-lasting side effects [58, 59]. Long-term consequences on identity formation or on changes in personality have been already discussed widely under the neuroethical perspective, as well as the problematic aspects of use and abuse of pharmacological neuroenhancers, or questions concerning equal opportunities and equal access within societal power relations, e.g. [60–64].

In addition, I will concentrate here on some *gendered facets* in the discourse that are again related to attributions of male rationality and female emotionality. I pick two examples out of the plenty of so-called ‘smart drugs’ for neuropharmacological enhancement. *Ritalin* contains the drug methylphenidate (an amphetamine), and this neuropharmaceutical was originally developed for the treatment of the ADHS syndrome; Ritalin increases attention and concentration capabilities and reduces anxiety. Pharmacological treatment is applied mostly to 6–18 year old consumers, mainly males [65]. *Prozac* (in Germany marketed as Fluctin) is based on the active ingredient fluoxetine, a serotonin reuptake inhibitor. Approved inter alias for the treatment of severe depression, obsessive-compulsive disorder and bulimia, it is advertised as well with the promise[4] to improve mood in moderate depression and to encourage self-confidence even for healthy subjects. The company Lilly reported about 40 million consumers in over 100 countries since its approval in 1987 [66].

Francis Fukuyama (professor for politics at the John Hopkins University in Washington and advisor of the US-Bioethic Council until 2005) said in an interview in the German journal *The Spiegel* in 2002: “More and more women use ‘Prozac’, an antidepressive that emerged in the US to a feminist medicine…Thus Ritalin and Prozac bring both sexes to similar patterns of behaviour: males become less aggressive, females more self-confident.” [67: 122, translated by author]. Petra Schaper-Rinkel notes with reference to this quote that it would be alluring to get “Prozac as a means to deconstruct prevalent gender relations” [68: 94, translation by the author]. But under her more detailed analysis it turned out that changes should only be possible within existing hierarchies: On the one hand is the use of Prozac addressed to middle and upper class women who should conform to the masculine notion of assertiveness in management. On the other hand is Prozac associated with the optimization of capabilities to combine work and family duties, without questioning the structural manifestation of power relations in which family and care work remains associated with feminity. Similar lines in this discourse have also been outlined impressively by Linda Blum and Nena Stracuzzy [66] in their analysis of gendered associations with the use of Prozac in US popular literature.

A Short View on Gendered Neuroeconomics

The third exemplary field I take into consideration is less concerned with neurotechnologies as instruments for optimization. However, it also touches the gendered notions of rationality and emotionality embedded in the discourses of the neoliberal societal order.

Neuroeconomics references to brain research—to brain imaging studies in particular—to explain individual economic decision-making. The concepts of neuroeconomics are based on the re-conceptualization of the ‘homo oeconomicus’: not only in terms of rationality or egoistic behaviour along cost-benefit ratios, but also as emotionally affected in his/her decision making. Game theory provides the experimental settings in which a participant has to take investment decisions dependant on the fair or unfair respond of a counterpart. If an unfair respond is rejected by the provider, none of the players will get any money. The acceptance of an unfair respond would reflect acting along the egoistic cost-benefit model of pure rational choice (less money is better than none), whereas the rejection of an unfair respond speaks for emotional involvement in the decision-making.

With brain imaging technology the concrete brain areas are characterized that are activated in rational choice behaviour in relation to those neuronal substrates that are involved in the processing of emotional responses [70]. A detailed analysis of the findings and empirical methods in neuroeconomic research uncovered that the processing of rational control and emotional evaluation are not seen in a

[4] I use the term ‘promise’ here in reference to the review of Irving Kirsch and colleagues [69], who stated that Prozac only shoes placebo effects in cases of moderate depression. Nevertheless the Prozac market seams to be more or less unaffected by these results until now.

network of mutual interchange but are separated and allocated to distinct brain areas. This separation, however, is not independent from brain image construction that extracts separated areas out of the brain network of information processing by subtraction methods (task-baseline activity, task1-task2 activity, men-women activity and vice-versa procedures of computation), thus neglecting connectivity compared to localisation [71]. This separation between brain networks of rationality and others of emotionality forms the basis for conceptualizing emotions as a necessary counterpart to prevent rationality from losing control. Emotional processing is often associated with unconsciousness whereas rational control is connected to conscious processes [72], and, additionally, rationality is considered superior to emotions.

The focus of neuroeconomics on rationality versus emotionality again calls for questioning possible *gendered aspects* in these concepts. One could assume that the inclusion of emotions as important part in economic behaviour combined with the notions of emotional capital as a prerequisite for successful professionals in the new management discourse could foster a degendering of these attributions. However, Eva Illouz has stressed that the inclusion of emotional work as a human resource at the level of management accounts for a differentiation between female/male connotations of attributes (emotionality/rationality) and their adoption by women and men, who can take over both categories for professional success. Nevertheless, the categories of emotionality versus rationality seem to remain gendered labels on the labour market [73]. Gotlind Ulshöfer has outworked in detail, how gendered stereotypes are re-signified and manifested in neuroeconomic research [74]. Empathic influence in decision-making is stated to be more prominent in females whereas cognitive control and feelings of revenche are rated higher for male decision-making. Ulshöfer pointed out, that "sexual stereotypes and traditional gender roles are written ahead in the structure of these experiments" [74: 206]. As this neuroeconomic discourse is developing rapidly gender research has to continue in analysing the permanence or the possible changes according to these gendered connotations and to witness their impact on in- and exclusions on the labour market.

Beside these gendered aspects even more general ethical considerations have to be taken into account. Not only is neuroeconomics harnessed to explain individual economic decision-making; current discourses in Germany about the global financial crisis have taken neuroscientific arguments to explain financial greed of managers by genetic and brain based defects, see [71] for overview. This argumentation has to be taken under critical response, not because of its reference to personal greed per se, but because of its *only* reference to individual failures, thus leaving socio-political structures and processes of the neo-liberal market uncritically out of the discourse.

Neuromarketing is another area where neuro-findings emerge as a leading source of reference in combination with a strong prevalence of stereotypical gender notions, as in the conceptions of testosterone-driven male brains versus estrogen-regulated female brains in explaining differences in consumers' preferences. With reference to the apparently objective facts from brain imaging experiments, products should be advertised by means that address the unconscious and biologically determined preferences of women and men. Testosterone-controlled men would need associations of adventure, thrill, discipline, technology, etc. Estrogene-controlled women would need balance, the social, partnership, fashion, etc. [75]. Moreover, neuromarketing strategies aim at influencing the brain itself by addressing the brain plasticity concept in order to incorporate requested preferences for the market: 'from store branding to brain branding' is the current phrase in this area [76]. Influencing consumer decisions by marketing strategies is not new. However, the flip-flop of arguments ranging from biological determination of group preferences to plasticity conceptualizations of the brain calls for further analyses. Who uses which arguments for promoting certain developments? Not only gendered connotation but their intersections with class, age and ethnicity have to be taken into account in this domain.

Gender-Ethics Questions the Bio-Techno-Social Cerebral Subject: First Insights and a Call for Further Research

Nature was never an innocent and passive counterpart of culture/technology. Our relation to nature is characterized by inscriptions of meanings and powerful actions. Artifactual nature—a term developed by Donna Haraway—is and has always been "made in world-changing technoscientific practices by particular collective actors in particular times and places" [77: 297]. However, the necessary prerequisite for the development of manipulative power relations of the western civilized society was the dichotomization of active culture over passive nature. The control over nature and the exploitation of nature needed arguments of nature as *the Other*, as passive object and exploitable resource that can be possessed by civilized subjects with the help of technologies. This polarization was and is interwoven with gendered attributions of nature and femaleness versus culture-technology and maleness. Analyses of gender research in science have outlined these and other related gender-codes: maleness, rationality, status as subject and power to the side of culture; femaleness, emotionality, reproduction, status as object and repression to the side of nature.

Donna Haraway used the metaphor of the cyborg for reflecting on possible transgressions of the borders between nature, culture and technology [27]. Via their transgressions cyborgs are hybrids in which nature and culture, the organic and technology, matter and information are so thoroughly cross-linked and interwoven that they can be no longer traced back to their separate origins. If, following Haraway, nature, culture and technology *hybriditizise,* then gendered dichotomies and attributions could implode.

By means of neurotechnologies cerebral subjects can acquire new and networked communication abilities, motor skills, mindsets, and enhancements of cognitive skills and moods. However, they not only use neurotechnological upgrades as templates, which they take off like worn clothing. Instead, they incorporate them as bio-techno-social cerebral subjects. Following Haraway, the opening of the plastic brain towards the socio-cultural environment and its interconnection with technology may dissolve gendered ascriptions. The exploration of different neurotechnological fields, however, has shown that despite the thoroughly interwoven networks that constitute the neurotechnological cerebral subjects the classical gendered Cartesian dualism, i.e. the separation into a male-connoted rationality against a female-connoted emotionality seems to remain comprehensively.

The persistence of these gendered ascriptions may be due to the norms that are set up for improvable skills, which indicate a certain direction of the desired enhancement. These normative demands coherently go together with the compatibility between capitalist labor market needs, ideologies of individual responsibility and medical-technical feasibility. The outlined brain technologies match the ideas of the project-oriented polis as a 'new spirit of capitalism', to use the term of Luc Boltanski and Eve Chiapello [78]. Accordingly, individuals should plan and organize their lives strategically, purposefully, as a succession of projects. Brain optimization has to be performed at any time, recalled per button push: spontaneous, flexible, situated and predictable.

Rationality turns out to remain valuated superior to emotionality in this endeavor. Although the optimization paradigm targets all subjects irrespectively of gender, this hierarchy still seems to structure gendered power relations under the neoliberal regime in society. Thus, not only has the ethical debate to question the impacts of neurotechnological enhancement with respect to the subject's autonomy to engage or disengage in these technologies of the self (beside the already outlined ethical questions on access, justice, safety, personality and identity). Based on these preliminary results the linkage between ethical and gender aspects have to be further researched in detail with respect to the manifold developments in the domain of neurotechnologies. This has to be work in progress.

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