The Body in Medical Imaging between Reality and Construction

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Introduction:

Medical Imaging has provided insight into the living body that were not possible beforehand. With these methods a revolution in medical diagnosis and biomedical research has begun. But as always the benefits also oppose problematic side effects and epistemic developments, which need critical reflection and correctives.

Problems arise from the epistemic property of these visualization technologies which are highly constructed, more so than classical photography or drawings. These images are constructed differently according to specific goals of visualisation. They are highly complicated combinations of technology and contingently chosen algorithms. In addition, image construction follows properties of the human visual and cognitive system to allow for the discrimination of the desired categories. It is no wonder that the visualizations referring to the body also show effects which have no physiological correlation within the body.

But there are deeper epistemological problems, such as the normative effects of such images and their cartographic derivations within atlases. These result in new definitions of the normed healthy body, sickness or pathologies, maleness and femaleness and in determinism as opposed to plasticity, e.g. of the brain. Moreover the constituents of these images are data sets, which are subject to data agglomeration and further computation. And last not least these virtualized data can be materialized again, together with tissue or blood engineering and other life material technologies to be computed into economic value.

Within history different epistemological methods have served to deduce scientific explanations, e.g. the viewing, or analogies not yet differentiating between the sign and the designated, empirical evidence, the experiment, simulation and construction. On the other hand different media have been used as scientific trading methods, like speech and orally traded indigenous knowledge, representations like drawings and substitutes, symbolic representations like signs, numbers, text, mathematical formulation and finally the materialization of symbolic representation within electric logic. The latter includes digital images and visualization by IT-devices, on the representational side now ruling out the difference between image and sign. From point of view of the viewer this difference is nevertheless important, giving different kinds of evidence: the immediate holistic impression of an image at one glance, or the slower explicit understanding of text or mathematical formulation. As the complexity of our scientifically meshed world rises, the role of visiotypes (Pörksen 1997), like tables, diagrams, curves and images has become crucial for quick understanding of complex interconnections. Images allow a quick comprehension, but they are also alleging objectivity, because the image “speaks for itself”. Especially in science, technology and medicine visiotypes are heavily used as scientific explanations[1]. This epistemic change from text to image is called iconic or pictorial turn (see also Böhm 2001; Mitchell 1997). Moreover the impressive impact of today's scientific images has enabled the victory of science over the text bound humanities (Jäger 2003).

As a third category of epistemological means the models used for scientific explanations can be considered: these range from natural and analogical models, mechanistic models, up to abstract models, like mathematical, statistical or algorithmic computer models. Through the use of mathematical and computational models as well as of information technological means in a lot of diverse ways very different kinds of episteme are meshed together. Instead of taking the image giving machine as black box the engineers and programmers have to substantiate their specification, modelling and construction of the digital images, as all this is subject to their subjective view of the task.

In the following the emphasis is laid on the constructive properties of medical imaging methods and the impacts of these images. In particular, the use of these images as standardizing instances is discussed, in contrast to the variance of their reference bodies, both in time and space, inter- as well as intra-individually.

I. Epistemic turn from text to image

Images and symbols always have served as vehicles for conveying information and concepts since the beginnings of human culture. In early modern Europe, initially, textual scholarship struggled against image based ideologies, leading to text based sciences and written documents, sometimes augmented by pictures. However, the relationship between text and image has extremely changed since the eighteenth century, and today especially due to the computers image production. According to Flusser (1995), "Presently, the most abstract conceptualization is to be found in conceptual images (for example in computer images) and the most supreme imagination is to be found in scientific texts". Science nowadays must be able to deal with the growing particularization, differentiation and complexity of its discoveries. Means of conveying information via images can make abstract and complex concepts possible and easier to ascertain, even when the price is paid by a loss in conceptual precision. A lot of technical measurements and data agglomerations can no longer be cognitively comprehended but with depictions and illustrations. Computer science inverts its own development: the dispossession of ostensive view from mathematics by dint of formalization (as an opposing term of 'view'), to which computing owes its thanks for its nascency, conversely brought back visual representation into scientific scholarship for the sake of understanding complex contexts. The visualization of dynamic and complexity is performed in adaption to the cognitive potentialities of human beings (see also Heintz 1995). The present visualization of natural scientific, medical or mathematical findings is the result of cognitive incomprehensible complexities of produced amounts of data and interconnections that require a recall in the visual perception. These tendencies in visualization do not necessarily mean a recurrence of the view of the natural, but a visual perception of virtual things. As concerns medical images, complicated

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[1] Visiotypes and images even can serve for getting deeper insight into scientific material, like in mathematics, for getting examples, new hypotheses and deduced insights.

constructed artefacts are visualized, whose correspondence with the “original” being depicted, relies on theses, modelling and plausibility suppositions and not (yet sufficiently) on empirical evidence. The different methods to view into the inside of the body all are following a long, complex and contingent road of elaborately produced and calculated data constructs and their visualizations. New methods have lead to unforeseen opportunities in diagnosis and research. However, the optical invasion of the human body brings along various problem complexes: the methods of image creation work with huge amounts of data and carry out extremely complex transformation algorithms, segmentation, glazing and cleaning and so forth, which already imply interpretation. The increasing distance of the image from its bodily source, that is, the complicated character of the image production increases the chance for misinterpretation with each step in abstraction, statistical derivation and integration. In a paradox inversion of this fact, these representations and further image producing methods, like cartography of the body, that are based not only on reproduction but also on further reduction, interpretation and resulting fabrications, insinuate that these images present an objective view of the standard body. The more complicated and deduced elements there are, the more elements will there be that will not be constitutive for the “living original”. In other words, there is the potentiality of creating image artefacts that have no physiological counterpart. Which constructs are used is not only “technically” but culturally and contingently determined as well, beginning with the use and selection of technical instruments, as here mentioned with methods that process images and visualization techniques. Because they reduce complexity, the danger of reductionism, one-sidedness and inadequate standardization is increased, as well as an easily made implication of naturalization of bodily realities, which are in truth contingent. This eventually leads to essentialism (Schmitz 2001), which will be discussed in more detail in Chapter IV.

II. Epistemic changes in science and medicine concerning imaginations about the body

Not until the Renaissance and its attendant preoccupation with humanism, rationalism and secularism were illustrations of the inner parts of the body permitted, empowering the inquiring humans to inspect their own body. Since in the 16th century anatomical theatres showing sections were opened to the public their pictorial representation through images as well as through anatomical atlases helped to make the shape and location of the organs inside the body increasingly better known. However, the inside of the living human was only accessible via invasive intrusions into the body. The invention of x-ray, later followed by a variety of sophisticated medical imaging technologies opened new alternatives per “optical invasion” into the living body, overcoming the limitations of the impermeable layers of skin, tissue, organs and bones.

With the anatomical representations also the symbolic meanings of the body surface changed: until the 18th century the body was mixed and meshed/netted into the world, the skin was considered as porous three-dimensional connection organ. Later the body became a closed entity, enclosed by the thin skin marking the border between the individual and the environment (Benthien 1999). This individualization and demystification was the presupposition to allow anatomy to open the human body again by sections (Duden 1991). Today though still

individualized, the borders of the body have become transparent again, by the new optical means.
After having modelled the body anatomy in the 19th century, medicine concentrated more on the pathological body. This in turn allowed the imagination of a fixed norm, of a „normal” body as counterpoint. The tendency to represent scientific or clinical facts visually converges with representing the standard body in atlases, but also opening the vista into the individualized body, as well as into the collective one. The body’s borders are becoming increasingly porous, symbolically, pictorially and also in reality: the projects of life prolongation by protheses and reproduction technologies, encroachments into the body’s regulation mechanisms like the immunity suppression, and finally the utilization of biological materials in a free combinatorics of biological raw materials and biological designs (cloning of germ cells, gene design, tissue engineering, stem cells) are shifting the definitions of humanness and of the individual. Human raw substance of biomaterials are circulating continuously as de-individualized raw materials, by which the borders of identity and biographical unities again are abolished.

In addition to the enormous possibilities opened by the imaging methods also the problems shall be discussed: the selection of bodily properties that can be visualized versus those which are not locally and distinguishably representable within a picture. The abstract and complex character of data extraction and processing leading to images with realistic appearance are putting the original bodies into distance from their visualizations, i.e. the referential tie between body and image is very loose. In addition their use for standardizations and normative effects are problematic for many reasons, the more as the contingent construction methods are easily considered as producing objective 1-1 correspondences between images and the originals. The use of these technologies and images are characterizing epistemic changes in the sciences and medical diagnosis and care.

III. Medical imaging technologies

For getting images of the inner structure of objects, acoustic (ultrasound) or electromagnetic waves (for the other medical imaging technologies mentioned) are used. Magnet-Encephalographic images (MEG) are capturing the electromagnetic waves of neuronal activity, by measuring the evoked potentials. Computer Tomography uses radial X-rays within a plain to receive tomographic slices from dispersed or from absorbed vs. through-flowing rays from which the form of the organs can computed back. For Magnet Resonance Imaging (MRT) and functional Magnet Resonance Imaging (fMRI) an external strong magnetic field is used together with radio waves to receive induced electromagnetic waves within the body radiating outside onto the tomographic wall. In other cases (Single Photon Emission Computed Tomography = SPECT, Positron Emission Tomography = PET and also with fMRI) Gamma-rays producing radioactive substances are introduced into the body, allowing deductions about the blood flow on micro level, which in turn can be used to image production.

All of these methods, except for X-ray, do not map directly, i.e. the resulting images are not reproductions, produced by collecting waves shaped by objects directly, but originating from complex images fabricating processes. In other words, they are visualizations that are created using complicated means of data production and following computational transformations that result in computed constructions that are complex as well. For example for ultrasound, MEG and CT-Imaging the image reconstruction resulting from the data collected at the wall needs to computationally identify the regions where the waves have been absorbed or dispersed. The mathematical task of area reconstruction, called the „inverse dispersion problem" e.g. is the task of designating the shape and location of the inside boundary surfaces based on such measurements. Similarly for MEG the computation of the location and strength of activity of the distant origin neurons measured by the electromagnetic field at the head surface is a so called ill posed numerical problem. Even though numerical methods exist to solve the inverse dispersal problem in the 3-D acoustical dispersal theory none exist as yet for electromagnetic waves (represented by a system of hyperbolic differential equations with boundary constraints). The problem is solvable under the constraints that the physical medium is homogenous and not absorbable - a condition never occurring within real bodies. Because there are no satisfactory complete numerical solutions to the inversion of the differential equations that occur here, mostly numerical methods to determine the shape of the dispersed bodies are born out of repeated use of simulation calculations, where in every step the tentative dispersed bodies are accordingly modified. The multitudinous simulations entail a high calculating time. Furthermore, the unknown field must be well assessable and the boundary conditions must be known so that the procedure can stabilize. Also these conditions are sufficed seldom, resulting in a tentative breaking point of the simulation process, directed by modelling probable solutions and comparing them with the last solution, which might be inadequate. From this tentative solution the image is generated, again through a contingent computational process. Therefore in MEG the localization information need not be correct or is fuzzy and in CT images the image information may contain artefacts, i.e. both false positively indicating pathological and false negatively indicating normal physiological areas.

Whereas for MEG and CT-imaging the localization problem refers to an ill posed, unsolved mathematical problem, for MRI and fMRI the local information is directly contained within the data measured at the tomographic wall. This does not make these imaging processes simpler. First of all the physical mechanisms underlying the magnetic resonance technologies are working on atomic level, using the magnetic moment of the spins of the protons of the Hydrogen-atoms within the body. Within a strong homogeneous magnetic field these spins are oriented according to this field and they are additionally excited by high frequency radio waves. Differences between the relaxation times of these magnetizations, where electromagnetic waves are emitted, the impulses of which are collected at the tomographic wall and the resulting data are used for image giving. Thereby the fraction of water within tissue can be measured, and it can be differentiated between water and fat, i.e. the chemical binding of hydrogen within the molecule: the hydrogen atoms within fat are bound more strongly and therefore are relaxing more quickly than those in water. Moreover the radio wave impulse sequences can be varied in duration of the rerun time in order to enhance the contrast and/or for questioning variable tissue properties. But between these data collected on the wall, interpreted as grey or colour level pixels, and the final images a lot of computational steps and algorithms have to be performed, many of which are already interpreting steps. These include corrections of the inhomogeneous strength of the magnetic field, corrections of different kinds of noise, stemming from the apparatus as well as from the patient's tissue, up to the selection and preparation of parameters according to which varied images can be produced from the data set of one and the same person. Tissue noise on the molecular level is ruled out using physiological models, won by empirical experience. As the molecular tissue properties are varying not only according to the kind of tissue (organ differences, normal or pathological tissue), but also individually, it is not sure that the uniform modelling is adequate in every individual case.

Even more sophisticated is the use of MRT technology and physical-chemical effects to visualize blood flow and the brain through fMRT. Following Hennig (2002) it rests upon an indirect effect, the haemo-dynamic coupling between neural activity and local blood flow. Neural activity requires energy, which is delivered by converting glucose to oxygen. According to the prevalent hypothesis, there is a bottleneck in the transportation of oxygen from the capillaries to the neurons where it is utilized. In succession to a neural activity affording more oxygen to be pressed into the tissues, the local blood flow is increased as a buffer to prevent undersupply of oxygen. The change in activation offsets the balance between oxygen-rich and oxygen-deficient blood and this can be observed using MRT. The deoxidised haemoglobin possesses via its iron nucleus a strong magnetic moment that is discharged during the connexion of oxygen. According to an idea of Ogawa (1992) such local microscopic interplays between the magnetic field during activation or in quiescence can be measured via MRT as a signal reduction or an increment in signal. But functional MRI is neither precise enough to measure minuscule magnetic fields of neural currents nor can it directly observe neural metabolisms. Because the measurable effects are multi-factorial and inferences can only be contingently allowed, an fMRI experiment is set up such that the data exposure is repeated several times and such that the activation constraints concerned are changed several fold for the entire duration of the experiment. These experiments can set up parameters to measure cortical activation per presentation of a stimulus such as light, mental exercises or tactile stimuli, or can consist of the through-flow of a contrasting agent that measures perfusion, etc.

Again the computational investment is enormous and within this framework the complexity of these calculations is hardly even hinted at. It is not in the least possible to sight the assimilated data by hand. Moreover, the activation effects vary only by a few percentage points and thus in comparing images are the effects barely perceivable to the human eye. The effects can only be extracted using computer based interpretations. For fMRI the problem arises that there are a large number of possible psychological processes, which create temporally variable signals that – coincidentally or not – can show a certain correlation with the effects to be measured. New programs attempt to record such additional effects in the modelling of data – for example for periodical signal changes caused by the pulsing blood flow, or effects that are contingent on breathing, in the hopes of differentiating between activation effects. As Hennig (2002) writes, “the astonishing fMRI representations of brain activity can belie the fact that a long chain of data processes and evaluative steps are necessary to elicit these images from quantified data.”

Influencing quantities onto medical image giving methodologies apart from the body from which the photons on the wall are stemming, are at first contained in the technological apparatus. Technology has to cope with human tissue, organs and bones in general, but has to be able to differentiate individual (sane) deviations, and again to differentiate them from pathological deviations.

Secondly the technical apparatus determines the kind of images and the possible information obtained within. This includes the physical effects used, the specific blurring and correction necessities caused by the physical effects as well as of the technological solution. In addition the very individual specialities of the complicated apparatus (each one is slightly different from the other and medical doctors have to adapt to them) have to be taken into account.

On a finer level a lot of decisions for data processing, computation, algorithms and their combination have been taken by the constructors, which include interpretations for the image giving. These are performed on the level of technical data correction, like ruling out inhomogeneous lighting, on the level of interference of physical and/or physiological effects, like the apparatus' and tissue noise in MRI and fMRI, etc. Other models are used for capturing the properties of tissue, for separating regions by drawing lines and for constructing the images for cognitive adequacy. Modelling is interpretation, and therefore it is never innocent. Here models are used for many different purposes, from different sciences: mathematical, algorithmic, computational or physiological models, e.g. how tissue is expected to behave on a molecular level, etc. These models may not hit reality in certain cases, and if so this may result in the representation of artefacts, of visual items that have no correspondence within the original body. Computer scientific image processing methods, the end of the data manipulation process to gain good images recur to the possibilities of human cognition as well as to experiences of image interpretation. Eliminating blurring requires to know the qualities of a clear picture in advance; filtering to differentiate between dirt and essential spots; interpolation to guess the difference between two level images; segmentation to decide through algorithm selection in which sequence to reduce or to highlight and where to draw a line; and finally rendering to decide how to triangulate a flat or a three-dimensional manifold to allow surface representation, deformation, transparency, etc. It becomes clear that all these processes, modelling, selections and combinations are contingently designed and built together, also if they are fixed within the apparatus itself. Even if the constructors have put emphasis in building or choosing optimal algorithms for particular solutions and adequate combinations of such solutions these may not be optimal or even adequate for every person in every situation of medical investigation.

Moreover the image representation is selective, because on the macroscopic level of showing a whole brain slice in a picture localized dots and regions are preferred to netted structures.

IV. The use of these images

The representation of medical facts, sensorimotor and cognitive performance of the individual brain in images creates the collective brain along with it, since abstraction is possible due to the concretisation of the individual into an image, to objectivization. No wonder the optical opening of individual bodies converges with the compilation of the normalised body into atlases. Efforts or endeavours to standardise the depiction of the body are problematical, because situation dependent snap-shots from selected individuals are generalized into standards.

Projects such as the Human Brain Project[2] attempt to place the brain and its functions in increasing detail under the scientific gaze. HBP aims to grasp as much data as possible, „from gene to behaviour“, integrated into and made available through databases; furthermore, HBP tries to construct a generalised anatomical 3D-standard brain, but also functional atlases and disease specific atlases, in order to come to a comprehensive understanding of “normal” and “abnormal” brain functions.

There are various averaging procedures available to anatomically standardise and to conduct the comparative ascertation of areas: landmark oriented (on the cranial bone), true to volume or via linear, affine and transformations of a higher order. Since the anatomical relations are strongly inter-individually variable, all averaging procedures have problems when used as normalisation instance. Therefore algorithmically deformable atlases or graphic illustrations of statistical characteristics are employed upon the anatomical contours in probability and variability atlases (Thompson et al. 2000b). This method, according to Masanneck (2001), prescribes as norms variation borders defined by calculation instead of descriptive findings or socio-cultural conventions, which should not be confused with laws of nature. In her critical analysis of the HBP project she identified how cultural definitions of the healthy and the sick mind are compounded with setting existence in brain anatomical cause.

The assumed correspondence between function and anatomy brought about aspiration towards a functional cartography which then led to the creation of standard systems of functional neuro-anatomy, like the Talairach atlas (from one female body), the ECHBD or MNI (by mapping from a group of bodies). With “faulty” brain functions due to illness, also these and correspondences between pathological structures and defective functions were set into pictures. Some neurological illnesses such as Parkinson’s, multiple sclerosis, Alzheimer’s but also psychological illnesses appear in functional brain images as physiological deviations. For endogenous depression or schizophrenia both neuro-anatomical, neuro-physiological and functional atlases were created (Narr et al. 2001). For some of these, e.g. schizophrenia even gender differentiated atlases were given. Further atlas differentiations, by grouping according to sex, age or also (in the USA) ethnicity, aim to identify specific illness archetypes for each group.

The depiction of illness brings some epistemological problems, like the question whether an individual’s image that has similarities with the illness atlas shows that he/she really has that illness, or is in danger to get it. Making diagnoses and decisions about a therapy in preference of visual evidence instead of on clinical findings could consequently occur. Another epistemological question is whether the deviation shown is cause or effect of a possible sickness (see also Schmitz and Schinzel 2004).

Concerning sex/gender differences Schmitz (2004) und Nikoleyczik (2004) examined the following publications of neuro-scientific functional language tests: Using fMRI for rhyme identification Shaywitz et al. (1995) found that 19 test persons showed a strong activation on the left side of the frontal lobe, and that 11 of the 19 test persons showed marked activation on both sides. However, in these tests no parallel differences in performance were found. This much cited

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[2] http://nessus.loni.ucla.edu/icbm/index0.html

study is put out as evidence for women's strong bi-laterality of general (!) language processing in contrast to men's uni-laterality. In a study by Frost et al. (1999) though, „under 100 test persons, no gender differences were found neither in language performance nor was activation-asymmetry identified in the examined brain areas." Moreover, the Frost research group compared the sex/gender group differentiation with one that split-up the test images at random into two groups, with analogical outcome. But this work, in contrast to that of Shaywitz et. al., is seldom cited, because there is a desire to find and to publish differences. In a recent study Kaiser (2004) was able to show that a small variance in the setting of fMRT-measuring had an influence on the illustration of lateralised language performance: once for the same persons gender differences were visible, with other parameter values not, and yet with other values even the sides in mens' pictures became interchanged.

In fact there is an often stated publication bias concerning statistically evaluated population studies[3]: those with significant difference are considered as interesting, whereas such without mostly are not considered worth to be published (see Easterbrook et al. 1991; Moscati et al. 1994)

Moreover Schmitz (2004) criticizes that in such studies it is left unconsidered that the current image of brain structure or brain function represents the result of an individual's life history, as explained by brain plasticity (). For this reason there is no scientific evidence for a biological determination of the effects cited. Rather structures and functions are fluent according to a person's experiences and remain variable through the permanent production of new neurons and dendrites, as well as through enhancement of nervous tracts within the nervous system, and this during the whole life time.

Nevertheless, conscious of plasticity or not, cognitive scientists and pedagogical researchers have acquired the possibilities of functional imaging into their methodology, stating that the images indicate the locations of thought and learning processes in the brain. This is problematic for several reasons: For functional images of cognitive skills the subtraction method is used, assuming that the image of a not specifically activated brain could be subtracted pixel wise from the activated one, showing the very locus of the function activated. But it is not clear whether the activity shown on the non activated brain is not constitutive for the function activated as well - the mistake can be made clear by stating that an inactive brain is dead. In addition Burri (2003) has criticized the very artificially constructed examination constraints, not only concerning the cognitive tasks to be unhinged. The production process assumes specifically formed and operating bodies, and for this reason, disciplined bodies. The creation of "instrumental bodies" is the prerequisite so that these bodies can be visually represented at all. In this process the procedures that discipline the body and instrumentally regenerate it, are following an implicit structuring mechanism, geared towards the visual representation of the body and thus do the preliminary work for instrumental fabrication of biomaterial flow.

There are hardy any fields and sciences that deal with cognition and human behaviour that have not adopted the use of the prefix neuro-, which signifies the

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[3] Let alone the fact that statistical population studies mostly are wrongly interpreted by taking the Ioannidis, J.P.: Why Most Published Research Findings Are False, PLoS, Medicine, August 2005.

use of functional imaging of the brain. Musicologists and aestheticians are trying to identify musical and artistic activities in the brain for improving their didactics. Advertising specialists use the methods to test the rise of alertness in specific brain areas via advertising media (Mc Clure and Li 2004). Neuro-theologists (Newberg et al. 2001) observe the localities of religious experiences in the brain, even as far as to locate the proof of God's existence and the existence of angles, and psychologists have recently suggested the use of fMRI as a lie detector (Wolpe et al. 2005).

That due to the yet insufficient knowledge about the tissue in focusable scales and about micro structural processes in the brain, it is not known, what these images really show, how they are to be interpreted and what would be allowed to be gathered from them, does not disrupt the flood of tests and the still empirically poor substantiated and seemingly scientific publications one bit. Obviously for the scientific editing practice in the respective fields it suffices to be situated at the foremost front of research by means of the newest technology.

Visualisations of the thinking brain proffer themselves as a result of neutral technical-natural scientific workmanship that is built upon natural scientific objectivity using effects delivered by physics to enlarge human sensory perception. Digital images of the body, its organs and their functions should objectively represent unaffected truths. However, it has been shown how contingent the production methods are and which differing results they could show, both from identical data collections, as well as in a temporal process involving an individual, and the more inter-individually.
Moreover deeply rooted changes in the viewing of human beings of themselves, in the body and in “humanness” have been established, like the assumption that it is possible to locate illnesses and human characteristics topographically in the material body; that they are supposedly capable of being pictorially represented, and that the human being as subject in living images of the body is professedly revealed (see Schmitz 2004). The new, momentary neurologically founded debate concerning free will (Geyer 2004) is one consequence of this new self-image of concretisation of human beings into the neuro-chemical and neural-physiological.

References:

Benthien, Claudia(1999): Haut. Literaturgeschichte, Körperbilder, Grenzdiskurse, Reinbek bei Hamburg.

Böhm, Gottfried (2001): Zwischen Auge und Hand: Bilder als Instrumente der Erkenntnis, in: Heintz, Bettina; Huber, Jörg (Hg.): Mit dem Auge denken. Strategien der Sichtbarmachung in wissenschaftlichen und virtuellen Welten, Zürich, S. 43-54.

Burri, Regula (2003): Digitalisieren, disziplinieren. Soziotechnische Anatomie und die Konstitution des Körpers in medizinischen Bildgebungsverfahren. Technical University Technology Studies Working Papers 3-2003. Berlin. [http://www.tu-berlin.de/fb7/ifs/soziologie/Tuts/Wp/TUTS_WP_3_2003.pdf] (19.07.2004)

Easterbrook, Philippa; Berlin, Jesse; Gopalan, Ramana; Matthews, David (1991): "Publication bias in clinical research," Lancet. 1991; pp. 867-872.

Flusser, Vilém (1995): Lob der Oberflächlichkeit. Für eine Phänomenologie der Medien, 2., durchgeseh. Aufl., Mannheim

Frost, Julie; Binder, Jeffrey; Springer, Jane; Hammeke, Thomas (1999): Language processing is strongly left lateralized in both sexes: Evidence from functional MRI. Brain 122 (2), pp.199-208.

Geyer, Christian (2004): Hirnforschung und Willensfreiheit, Frankfurt: Edition Suhrkamp.

Heintz, Bettina (1995): Zeichen, die Bilder schaffen; in: Johanna Hofbaue r, Gerald Prabitz, Josef Wallmannsberger (Hrg.): Bilder, Symbole, Metaphern. Visualisierung und Informierung in der Moderne, Wien, S. 47-81.

Hennig (2002): Chancen und Probleme bildgebender Verfahren für die Neurologie. Freiburger Universitätsblätter 153 (3): 67-86.

Jäger, Ludwig (2003): Die Verfahren der Medien: Transkribieren - Adressieren – Lokalisieren, in: Fohrmann, J., Schüttpelz, E. (Hrsg.): Die Kommunikation der Medien. Tübingen: Niemeyer.

Kaiser, Anelis; Kuenzli, Esther; Nitsch, Cordula (2004): Does sex/gender influence language processing? Men show bilateralization in a language production task. Poster. Human Brain Mapping Conference 2004, Budapest, Session Language.

Masanneck, Carmen (2001): Das Human Brain Project – Hirnforschung im 21. Jahrhundert, in: Schinzel, Britta (Hrsg.): Interdisziplinäre Informatik. Neue Möglichkeiten und Probleme für die Darstellung komplexer Strukturen am Beispiel neurobiologischen Wissens, Freiburger Universitätsblätter 149 (3), Freiburg, S. 87-104.

McClure, Samuel; Li, Jian (2004): Coke And Pepsi Advertising Effects Measurable In Brain Scans; Neuron, Vol. 44, No 2; 14, pp. 379–387.

Mitchell, William (1997): Der Pictorial Turn, in: Kravagna, Christian (Hrsg.): Privileg Blick. Kritik der visuellen Kultur, Berlin, S. 15-40.

Moscati, R; Jehle D; Ellis D; Fiorello A; Landi M.(1994): "Positive-outcome bias: comparison of emergency medicine and general medicine literatures," *Acad Emerg Med*. 1994; 1, pp. 267-271; [http://www.numberwatch.co.uk/publication_bias.htm].

Narr, K.L., Thompson, P.M., Sharma, T., Moussai, J.; Zoumalan, C.I., Rayman, J., Toga, A.W. (2001): 3D Mapping of Gyral Shape and Cortical Surface Asymmetries in Schizophrenia: Gender Effects. American Journal of Psychiatry 158 (2), pp. 244-255; [http://www.loni.ucla.edu/~thompson/SZ/schizo_atlas.html] (29.06.2004)

Newberg, Andrew; D'Aquili, Eugene; Rause, Vince (2001): Why God Won't Go Away: Brain Science and the Biology of Belief, New York: Ballantine Books.

Nikoleyczyk, Katrin (2004): NormKörper: Geschlecht und Rasse in biomedizinischen Bildern; in Schmitz, Sigrid; Schinzel, Britta (Hrsg.): Grenzgänge - Genderforschung in Informatik und Naturwissenschaften, Königstein: Ulrike Helmer Verlag, S. 133-148.

Ogawa, S., Tank, DW, & Ugurbil, K. (1992). Mapping the brain with MRI. Brain Imaging, 2(10), 525-528.

Pörksen, Uwe (1997): Weltmarkt der Bilder. Eine Philosophie der Visiotype, Stuttgart.

Schinzel, Britta (2004): Digitale Bilder: Körpervisualisierungen durch Bild gebende Verfahren in der Medizin. In Coy, Wolfgang (Hrsg.): Bilder als technisch-wissenschaftliche Medien, Workshop der Alcatel-Stiftung und des Helmholtzzentrums der HU Berlin. [http://waste.informatik.hu-berlin.de/Forschung/VisArg/2004]

Schmitz, Sigrid (2001): Neurowissenschaftliche Informationssysteme. Chancen und Grenzen in Datenmanagement und Wissensrepräsentation, in: Schinzel, Britta (Hrsg.): Interdisziplinäre Informatik. Neue Möglichkeiten und Probleme für die Darstellung komplexer Strukturen am Beispiel neurobiologischen Wissens. Freiburger Universitätsblätter 149 (3), Freiburg, S. 51-65.

Schmitz, Sigrid (2004): Körperlichkeit in Zeiten der Virtualität; ; in Schmitz, Schinzel: Grenzgänge - Genderforschung in Informatik und Naturwissenschaften, Königstein: Ulrike Helmer Verlag, S. 118-132.

Shaywitz, Bennet ; Shaywitz, Sally; Pugh, Kenneth ; Constable, Todd, Skudlarski, Pawel; Fulbright, Robert et al. (1995): Sex differences in the functional organization of the brain for language. Nature 373, pp. 607-609.

Thompson PM, Woods RP, Mega MS, Toga AW (2000b): Mathematical/Computational Challenges in Creating Deformable and Probabilistic Atlases of the Human Brain. Human Brain Mapping 9, pp. 81-92.

Wolpe, Paul; Foster, Kenneth; Langleben, Daniel (2005): Emerging Neurotechnologies for Lie-Detection: Promises and Perils; American Journal of Bioethics, Vol 5, 2, pp. 39 – 49.