Europäische Akademie

zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen
Bad Neuenahr-Ahrweiler GmbH

Direktor:
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Newsletter

Akademie-Brief ▪ No. 52 (January 2005)

The Europäische Akademie has recently published the 25th volume of the book series "Wissenschaftsethik und Technikfolgenbeurteilung" (Ethics of Science and Technology Assessment) which is published in the Springer Verlag (Berlin, Heidelberg, New York). The series serves to publish the results of the Europäische Akademie's work and make it available for public and the scientific community as well as support political decision makers. Beside the final reports of the project groups the series includes volumes on general questions of the Ethics of Science and Technology Assessment as well as other monographic studies. The 25th volume published the results of a conference the Europäische Akademie held on the topic "On the Uniqueness of Humankind". In 2004 the Europäische Akademie published four more volumes: "Sustainable Development and Innovation in the Energy Sector" (translation of volume 5 of the series), "Bridges between Science, Society and Policy. Technology Assessment – Methods and Impacts", "Low Dose Exposures in the Environment", and "Bioethics in a Small World". At least nine more volumes are planned to be published in the following two years.

Further information about the book series as well as the opportunity to order volumes can be found at www.europaeische-akademie-aw.de where there are also links to the publishing company Springer Verlag.

The Newsletter will report regularly about the recent publications of the book series.

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Focus

Getting wired. Electronic Implants connecting to the Human Central Nervous System

Steffen Rosahl

When in 1790 Luigi Galvani discovered that electrical stimulation causes contraction of muscle fibres, he could not possible foresee a technological development that today is about to give machine-like capabilities to intelligence, asking the brain to accommodate synthetic devices, and learning how to control those devices much the way we control our arms and legs. Nor could Alessandro Volta, when he experienced a hearing sensation by injecting an electrical current into his water-filled ear canal in 1812, anticipate that 170 years later men would be bold enough to stick ball electrodes in a human brainstem in order to restore hearing in a deaf patient. So how can we, in 2005, predict the future possibilities of human electronic implantation? Picture a time when humans see in the UV and IR portions of the electromagnetic spectrum, hear ultrasound; or communicate by thought alone. Imagine a time when the human brain has its own wireless modem so that instead of acting on thoughts, people have thoughts that act.

Pure speculation? A scientific program! Two years ago, the Defense Advanced Research Projects Agency (DARPA) – the central research and development organization for the U.S. Department of Defense – spent $26 million on a contract with Duke University (Durham, North Carolina) to create brain-machine interfaces (BMI). The projects seeks to develop new technologies for augmenting human performance by accessing the brain in real time and integrating the information into external devices.

In their first human studies on the feasibility of using electrical brain activity to operate such devices, in March 2004 researchers at Duke University Medical Center (ranked among the top ten hospitals in the U.S.A.) reported that arrays of electrodes can indeed provide useable signals. A German research team has shown recently, that electrodes do not even have to penetrate the brain to provide the signals required for operating "neuroprosthetic" and other external devices.

Artists have clearly been fascinated about the integration of the organic and the technological for a long time. One of the first incarnations of the artificial human was the robot or android, which first made its appearance in the movie *Metropolis* in the 1920s. At that time, robots were purely electronic devices molded into a humanoid form; there was no organic component. By the 1960s, when the Cochlear Implant for the restoration of hearing in the deaf began its triumphal march into routine medical practice, science fiction writers had turned to a more interesting, imaginative construct: the cyborg. This being was a sort of hybrid, a mesh of flesh and steel, neurons and wires, blood and circuits. It was a human being partially transformed into a machine.

From the *Six Million Dollar Man* to *Robocop*, the question posed by all these depictions of the cyborg was, how much of a human being could you replace and still preserve its essential humanity? While some of this technology remains the domain of science fiction, some of it is appearing here and now today, in the form of artificial limbs and prostheses, biological implants, and electronic devices for restoring vision to the blind.

The challenges and consequences of progress in the fields of neuroprosthetics and neuromodulation stimulate human fantasy and global fears at the same time. The term "neuroprosthetics" summarizes technologies for the restitution of lost neural function (e.g. hearing and vision) while "neuromodulation" refers to technologies that are either aimed at the amplification of diminished neural function (e.g. parkinsonism) or at influencing erroneous function in neuronal networks (e.g. pain, mood disorders). Primarily, all electronic devices have been developed to supplant malfunctioning neural circuitry. The disorders to be treated are either caused by degeneration or a localized lesion – like a tumor or a trauma.

In this context, it is important to recall some principles of degeneration and regeneration in the human nervous system. If a receptor organ (e.g. eye, ear) is destroyed, the secondary neurons in that sensory pathway may remain intact over a long period of time. This is probably effected by interneurons that keep on nurturing the modality-specific neurons even if the complete sensory channel has lost its function. An implant to restore function may well work even when placed at the level of the second neuron just behind the destroyed receptor organ.

It will – of course – also work when its electrodes are placed over the cerebral cortex where perception and recognition are mediated. Due to the immense parallel processing occurring at this level, however, implants have to be much "smarter" to provide meaningful stimulation. They also incorporate a much higher potential for interference with personality traits.

If there is damage to a nerve, a process that is called "Wallerian degeneration" is initiated, which causes the portion of the nerve between the lesion and the target neurons or the effector organ to break down rapidly.

Therefore, it does not make much sense to stimulate the damaged nerve itself in order to restore function. In these circumstances, a neuroprosthesis would have to be connected to the effector organ (e.g. a muscle in the motor system) or to the higher neuron in a sensory pathway (e.g. cochlear nucleus in the hearing system).

If central nervous tissue is destroyed, regeneration is blocked by formation of a scar and by the release of substances from the central myelin. While an elegant way of nature is to prevent the formation of tumors, this is also the reason why a patient remains hopelessly paraplegic after traumatic sectioning of the spinal cord. Electrical stimulation to restore function would have to be established below the level of the lesion in the CNS – or directly in the disconnected muscles.

Finally, most central nervous systems are redundant. If a population of neurons in a specific system fails due to degeneration (e.g. the dopaminergic system in the basal ganglia in Parkinsonism), other neurons increase their output to make up for this malfunction. This, however, will only work up to a point. If degeneration becomes overwhelming, the counterpart of the dopaminergic system will dominate and cause the clinical picture.

Stimulation can either be applied to increase the production of dopamine or to suppress the action of the disinhibited countersystems. The concepts in neuromodulation for other movement disturbances (e.g. dystonia), for pain, and for mood disorders basically work on the same principles.

In general, sensory neuroprosthetic and neuromodulatory devices today work like a switch that by turning on electrical stimulation initiates a naturally pre-programmed sequence in a pre-wired neuronal system. Currently, concepts are being devised that work more interactively. For instance, one of the ideas that are just about to be transferred into medical practice is drug-delivery through pumps implanted over the cerebral cortex in relation to (intracortically measured) changes in the electroencephalogram (EEG) of epilepsy patients. It will also be possible to electrically stimulate a cortical brain area upon EEG changes in order to prevent a generalized seizure.

Interactive devices also play a role in experimental concepts of memory restoration and enhancement in neurodegenerative disorders. For obvious reasons, restorative medicine has taken the lead in human electronic implantation. Not only is the loss of a complete sensory channel a terrible disaster for the individual patient, the bridging of the gap – even though it may be only partial – is a highly prestigious, at times heroic endeavour.

With more than 70,000 carriers worldwide, Cochlear Implants (CI) certainly constitute the most successful human sensory artificial devices at present. The implants are placed in patients with intact hearing nerves and damage to the receptor cells in the inner ear. If the hearing nerves are damaged, too, a similar implant can be placed at the hearing centres of the brainstem – the so-called Auditory Brainstem Implant that has been fitted to less than 300 patients until now. Despite temporal resolution and dynamic features that are very similar to the Cochlear Implant, the clinical results with respect to speech comprehension did not meet early expectations and still do not significantly exceed the performance of single channel CI's. Only about 10% of the patients are able to understand words and short sentences on the telephone. However, lip reading is facilitated, voice of men, women and children can be distinguished, everyday sounds such as doorbells and cars can be perceived and many patients return to their previous occupation.

The attempts to restore vision in blind patients have been less fruitful until now, although the first research studies do also date back to the 1950s. This is probably due to the considerably higher complexity of the visual compared to the auditory system. While the auditory nerve of a young, healthy, normally-hearing individual contains approximately 30,000 nerve fibers originating from the same number of receptor cells, the visual pathway begins at 130,000,000 photoeceptors in the retina.

In the 1960s and 1970s it was attempted to restore vision by placing electrodes directly onto the surface of the visual cortex of the brain. The implants, however, did not provide any useful images, partly because of limited spatial resolution, but mainly because the spot-like sensations of light – the "phosphenes" – the patients perceived tended to fade out rapidly and to occur in a different location independent of the site of stimulation.

With the advent of penetrating multichannel arrays integrating 38 or even 100 electrodes, the results have been improved slightly. Another approach is to stimulate the optic nerve by a cuff electrode with a few stimulating electrodes. With this implant, a blind patient could localize single bright spots of light, although the spatial resolution of such an electrode array could not be expected to be satisfactory.

In the 1990s, the focus of research had shifted to prostheses that can be directly implanted into the retina. Basically, two concepts have been advanced: the subretinal and the epiretinal implant. The epiretinal implant works on similar principles as the auditory brainstem implant. Visual input is received by a field sensor acting like a camera that is positioned either outside the eye or within an intraocular lens that replaces the natural lens. It is then transformed into a series of electrical impulses by a microprocessor and this train of stimuli is delivered via electrodes attached to the cells whose neural processes eventually form the optic nerve. The problem with these implants is that the electrical impulse reaches the visual pathway at a stage where in the retina the natural light stimulus has already passed through a network of preprocessing neural cells.

The subretinal implant relies on the anatomical and functional integrity of the intra-retinal neural network and connects at its input level, thus "merely" replacing the photoreceptors themselves. It basically consists of a very tiny microchip that contains light-sensitive elements on one side and stimulation electrodes on the other. The chip needs to be placed in between the retinal layers. Major challenges for function of the subretinal implant are biodegradation of the silicon and power boosting to arrive at stimulation intensities reaching the electrical threshold of the retinal cells. A clinical trial with eight blind patients is being prepared in Germany for this year.

As long as electronic implants are established for the **treatment** of a specific lesion and their effect is directed at restoring lost neuronal function – ethical considerations mainly concern side effects. If **augmentation or enhancement** of human capabilities for the pursuit of happiness, personal advantage or external manipulation of an individual person come into play – traditional ethical boundaries are likely to be overrun.

The year 2002 has brought but a taste of this when Kevin Warwick, professor of cybernetics at the University of Reading, U.K., had an advanced computer chip connected to a nerve and implanted into his arm. The nerve signals transmitted by the chip when Warwick bends the index finger can be used, for instance to remote control a robot. A science fiction scenario – a being part human, part machine – has become reality.

A retinal implant is not confined to detect only the visible spectrum of light. Once the technology works, it may well be used to transform infrared light waves and provide its recipient with night vision. Ultraviolet light may also be "seen" by a retinal implant user as well as ultrasound be "heard" by means of an auditory implant. Blinding effects by bright light or extreme noise may be controlled by the electronic circuitry in a sensory implant, providing Mr. Superhuman with a clear advantage over his non-implanted fellows. Moreover, any implant that is interfaced with the human nervous system can possibly work both ways: to remote control technical devices (telekinesis) and to manipulate human brain activity.

The brain's performance is dynamic and amazing. It contains perhaps as many as 100 trillion connections; vastly more than the 55 million transistors on a Pentium 4 chip. In our time, we have a very limited understanding on how these connections are used to process information and control behavior. The current electronic implants in the central nervous system simply bridge lost elements in a chain of neural signal transmission or re-initiate such a chain when its first element is malfunctioning. This is somewhat like replacing the co-processor of a computer by a sheet of aluminum foil. The resulting neglect of side effects of central nervous system implants is one of the reasons for clear ethical guidelines in the clinical application of this technology.

An attempt at augmentation of human capacities beyond therapeutic and restorative intentions is yet another one.

Priv.-Doz. Dr. med. Steffen Rosahl is Vice Chairman of the Department of Neurosurgery at the Albert Ludwigs Universität Freiburg. Furthermore, he is member of the project group "Intervening in Psychic Capacities" of the Europäsiche Akademie.

Working Groups

Environmental Noise

On its regular meeting on 15 and 16 November 2004 the project group invited two experts to discuss specific technological issues of traffic noise and its abatement. Professor Dr. M. Hecht (TU Berlin) gave insights from the railway branch, which is generally favoured by environmentalists due to its relatively low cumulative pollution. Nevertheless, noise loads from railroads are considerably serious for the affected people and therefore, they need for significant mitigation. However, short-term innovations of corresponding noise emitting sources – although technically feasible – seem to be economically challenging because of the relatively long lifetime of the respective technical elements. This problem seems to be less severe for the motorway branch: It offers therefore a variety of specific technical noise reduction options for their implementation in the near-term, as Dipl.-Ing. Heinz Steven (RWTÜV, Würselen) pointed out. Among them, noise mitigation by improvement of yet "noisy" wheel tires and/or road coatings seems to be primarily promising. However, any innovation for substantial reduction of environmental noise will have to be fostered by appropriate incentives.

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Intervening in Psychic Capacities

The third meeting of the project group, held on 26 November in Ahrweiler, was coordinated for the first time by its newly appointed chairman Professor Dr. Reinhard Merkel. Two experts had been invited to introduce themselves to the group by giving talks on their research. Dr. Bart Nuttin, neurosurgeon at the Catholic University of Leuven, reported on the results of the first attempts to treat obsessive-compulsive disorder (OCD) by means of Deep Brain Stimulation (DBS). Out of about 40 patients worldwide that have been treated this way up to now he himself implanted electrodes into the limbic system of 9 patients suffering from severe treatment-resistant OCD. The results of these first trials are altogether very promising. For some of the patients that prior to the intervention were close to committing suicide DBS is so successful that now they are able to lead more or less normal lives. Surprisingly enough, taking into account the deep impact of this intervention on the brain, no major adverse effects in terms of personality change or memory loss have been reported until now.

Dr. Gerard Boer from the Netherlands Institute for Brain Research, not only displayed the development and state-of-the-art of clinical neurotransplantation (NT), but also gave a thoughtful account of the relevant normative questions pertaining to this still highly experimental technique. Just like DBS NT has been predominantly applied to treat Parkinson's disease until now. Representing the principles of NT Dr. Boer enumerated the different sources that were used to obtain neural grafts. As attempts to gain neural xenografts from pigs have been abandoned by now, the main source for brain tissue are aborted foetuses. Summarising the ethical guidelines that Dr. Boer has drafted on behalf of the Network of European CNS Transplantation and Restoration (NECTAR) he explained the principle of separation pertaining to the usage of foetal tissue. According to this principle the process of NT shall be framed in such a way that neither the decision to become pregnant nor the subsequent decision to have an abortion get motivated by the need to obtain neural grafts.

Much to the satisfaction of all the project group members Dr. Nuttin and Dr. Boer decided immediately after their talks to join the project group.

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News

Ahrtalgespräch

Am 17. November 2004 fand zum zweiten Mal das „Ahrtalgespräch" statt, das der Verein der Förderer der Europäischen Akademie in Zusammenarbeit mit der Stadt Bad Neuenahr-Ahrweiler jährlich veranstaltet. Thema des Abends war die Frage nach der „Selbstbestimmung am Ende des Lebens". Professor Dr. Dieter Birnbacher (Philosophisches Institut, Düsseldorf), Professor Dr. Dr. h.c. Dieter Kettler (Zentrum für Anaesthesiologie, Rettungs- und Intensivmedizin, Göttingen) und Professor Dr. Eberhard Schockenhoff (Institut für Systematische Theologie, Freiburg) stellten die Perspektiven ihrer Fachdisziplinen vor. Anschließend diskutieren die Referenten mit dem Auditorium und unter Moderation von

Professor Dr. Dr. h.c. Carl Friedrich Gethmann das Thema. Anlass für die Diskussion ist der Umstand, dass durch den medizinisch-technischen Fortschritt das Ende des eigenen Lebens der Gestaltung durch den Menschen (wenn auch in Grenzen) zugänglich geworden ist. Dieser Fortschritt hat jedoch bei vielen Menschen eher Ängste als Befriedigung hervorgerufen. Zum einen befürchten viele Menschen, dass der medizinische Fortschritt zu einer Lebensverlängerung unter entwürdigenden Umständen führt. Zum anderen besteht der Verdacht, dass über die Beendigung des Lebens nicht der eigene Wille entscheidet, sondern Interessen anderer (z.B. zur Ermöglichung einer Organentnahme) eine Rolle spielen. Daher erwägen viele, durch mündliche oder schriftliche Verfügungen über die Umstände des eigenen Sterbeprozesses im Voraus Bestimmungen zu treffen. Abgesehen von den Unsicherheiten über angemessene Inhalte solcher Verfügungen, wird ihre Verbindlichkeit beispielsweise für Ärzte und Pfleger allerdings unterschiedlich eingeschätzt. Ferner stehen solchen Verfügungen religiöse Überzeugungen entgegen. Diese Gesichtspunkte waren Bestandteil der Diskussion. Zudem wurden die moralischen und rechtlichen Pflichten des Arztes in der Sterbephase kontrovers diskutiert.

Buenos Aires Declaration on the Ethical Dimensions of Global Warming

On 9 December an international consortium of experts released the above mentioned White Paper on the occasion of a corresponding side event to the 10th Conference of the Parties to the Framework Convention on Climate Change of the UN. Contributions to the event were also made by inputs from the academy's project "Reasoning Goals of Climate Protection". The released Declaration announces a project that was started in Buenos Aires but will now continue through an international programme that will examine important ethical issues entailed by climate change. The initiative is coordinated by Donald Brown, Director of the Pennsylvania Consortium for International Environmental Policy, Harrisburg (USA).

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Arbeitskreis Medizinethik

Im Rahmen des Mediziner-Arbeitskreises des Fördervereins der Europäischen Akademie referierte am 13. Dezember 2004 der Direktor der Europäischen Akademie, Professor Dr. Dr. h.c. C. F. Gethmann, über „Ethische Grundlagen eines dauerhaften Gesundheitssystems". In seinem Vortrag stellte er die Ergebnisse einer Arbeitsgruppe der Berlin-Brandenburgischen Akademie der Wissenschaften BBAW vor, die vor kurzem ihr Memorandum zur Reform des Gesundheitssystems unter dem Titel „Gesundheit nach Maß?" vorgelegt hat.

Conferences

Netzwerk TA (NTA)

Am 24. November 2004 wurde in Berlin ein Netzwerk TA (NTA) gegründet. Es soll den im Bereich Technology Assessment arbeitenden Institutionen und Forschern eine Kommunikationsplattform bereitstellen. Im Anschluss fand eine von drei Mitgliedern des Netzwerkes organisierte Tagung zum Thema 'Technik in einer fragilen Welt' statt, die die Diversität der im Netzwerk verbundenen Ansätze und Interessen deutlich machte. Die Europäische Akademie GmbH ist Gründungsmitglied des Netzwerkes und war mit vier Beiträgen auf der Tagung vertreten (vgl. Rubrik „Lectures").

Lectures

Thorsten Galert

25.11.04 "Inwiefern können Eingriffe in das Gehirn die personale Identität bedrohen?". Konferenz „Technik in einer fragilen Welt", 24.–26. November, Berlin.

Gerd Hanekamp

25.11.04 „TA und Governance in einer robusten Welt". Konferenz „Technik in einer fragilen Welt", 24.–26. November, Berlin.

Stephan Lingner

25.11.04 „Umgang mit Klimarisiken. Handlungsstrategien und ihre Implikationen". Konferenz „Technik in einer fragilen Welt", 24.–26. November, Berlin.

Personalities

Jürgen Mittelstraß studied philosophy, German literature and protestant theology at the universities of Bonn, Erlangen, Hamburg and Oxford from 1956–1960. In 1961 he finished his Ph.D. in philosophy at the Universität Erlangen and in 1968 he performed his habilitation. Since 1970 Mittelstraß is Professor of Philosophy and Philosophy of Science at the Universität Konstanz and since 1990 he is also Director of the Center for Philosophy of Science. Professor Mittelstraß refused several calls from universities in Germany and the USA. 1985–1990 Member of the German Science Council; 1992–1997 Member of the Senate of the German Research Society. 1995–1998 Member of the German Chancellor's Council for Research, Technology, and Innovation; since 2003 Member of the Austrian Science Council. 1997–1999 President of the German Philosophical Association. Member of the Berlin-Brandenburgische Akademie der Wissenschaften BBAW (Berlin), of the German Academy of Scientists Leopoldina (Halle), of the Academia Europaea (London, 1994–2000 Vice-President, since 2002 President), of the Pontifical Academy of Sciences (Rome) and the Austrian Academy of Sciences (Vienna).

Since 1994 Professor Dr.phil. Dr.phil. h.c. mult. Dr.-Ing. e.h. Jürgen Mittelstraß is member of the Scientific Advisory Board of the Europäsiche Akademie.

Publisher: Europäische Akademie zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen Bad Neuenahr-Ahrweiler GmbH, Wilhelmstraße 56, D-53474 Bad Neuenahr-Ahrweiler
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Print: Warlich Druck Ahrweiler GmbH, Bad Neuenahr-Ahrweiler
ISSN 1432-0150, frequency of publication: 8 – 10 times per year, 2.700 copies, reproduction is permitted with reference to the source, please send two voucher copies.