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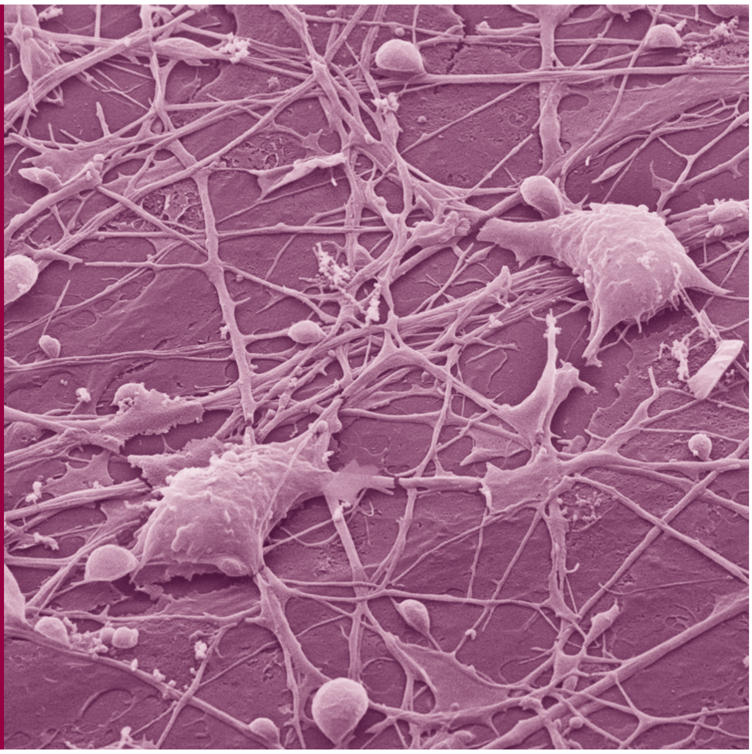
Brain research

Summary



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SUMMARY

The neurosciences, i.e. the investigation of the nervous system and its significance for perception, inner experience and human behaviour have made great strides in recent decades with regard to the understanding of the structure and function of the brain on the one hand, as well as concerning diseases and the development of various possible technical and pharmaceutical applications on the other hand. The neurosciences have in the meantime become one of the most highly regarded fields of research in the life sciences. The broad level of public attention accorded to them is also due to the fact that their central subject matter, the human brain as the biological foundation of our cognitive abilities and emotional modes of experience, constitutes so to speak the essence of being human.

THE STATE OF BASIC RESEARCH

Modern neuroscience makes use of a multitude of natural-scientific fields of work and methods and as a result does not represent a single discipline, but rather forms a multidisciplinary field of research. Through contributions and advances in understanding in various fields (classical neurology, genetic research, information science) as well as through the application of new methods (such as high-resolution imaging techniques), the data sets on the function of the nervous system have grown tremendously and along with these also the understanding of the biological foundations of cognitive abilities. Advances in basic neuroscientific research have for a long time been finding expression in sophisticated methods of treatment of not only neurological, but also psychiatric diseases including pharmacological and psychotherapeutic applications. In addition neuroscience is also triggering off the development of technological applications in computer science. It is contributing both to the optimisation of information processing systems as well as to the development of human-machine interfaces, which can for instance be used to support people whose sense organs are functionally impaired.

Generally the different approaches to and research topics of neuroscience are roughly classified into three descriptive levels: the sub-cellular and cellular level, a medium level of neural network associations as well as the functional systems level, encompassing the various mental capabilities of the brain. Advances made in recent years relate in particular to the sub-cellular and cellular levels as well as the (superordinate) level of functional systems. It is on the level of the functional systems (especially through imaging techniques) that success has been achieved in clearly refining the mapping of the brain, i.e. the assignment of different mental capabilities to specific regions of the brain. As a result it is unquestionable that there are functional specialisations in the brain; on the other hand, in the course of research it has become clear that complex cognitive functions are as a rule distributed across numerous, different regions of the brain, meaning that mention can be made of specialisations, but not of an exclusive function. On the cellular and sub-cellular level, the structure and electrophysiological functioning of as well as the cooperation between neurons has been clarified. Through molecular genetics it has been possible to provide a molecular characterisation of certain groups of neurons and to allocate certain capabilities to them. In the same way headway has clearly been made in the localisation and the clarification of the significance of neurotransmitters as chemical messengers and transfer agents between nerve cells, which has opened up new therapeutic options for psychological diseases.

The limits to the understanding of the biological foundations of mental capabilities and processes, and thereby the essential challenges for research are so far to be found on the so-called medium level of neural associations. It is here that the stimuli which are conducted by the sense organs into the brain are translated into information and meaningful mental content (emotions, ideas, thoughts). The cooperation between neural networks forms the level upon which consciousness is ultimately constituted. In spite of advances that have been made in the characterisation of different neural connections or the improvement in the description of their interaction (e.g. in certain perceptive processes), there is still a long way to go before it is actually understood how neurons bring about consciousness. Besides an understanding of the co-operation between neurons in neural networks, the central questions of current brain research are concerned with brain plasticity, that is, the change in brain structure over time (typical in learning processes, for instance), and interindividual variance in brain structure.

MIND AND BRAIN

In addition to advances made in scientific perception as well as existing and potential future possibilities for intervention in the human brain, it is above all the far-reaching epistemological and philosophical theses of leading neuroscientists on the possibilities of a natural-scientific explanation of mental processes which have attracted public attention in the past. According to these theses, the insights of modern neuroscience should lead to a radical change in human’s self-conception, i.e. our perceptions of subjectivity and personal identity, of self-awareness, will and action control.

The round undertaken through the discussion between neuroscience, philosophy and cultural science in the present report however, shows that the far-reaching theses on the determination of mental processes by neural occurrences in the brain, and on the illusionary nature of freedom of will, have not until now been sufficiently supported empirically. Both neuroscientists and representatives of the humanities and cultural science are faced with the problem of the translation of the mental into neural or the neural into mental. The reproach of the humanities by several neuroscience protagonists is that their concepts on the relationship of mind and brain ultimately lead – contrary to their own intentions – to the natural-scientifically untenable assumption of the existence of an independent mental essence besides the material, because they are unable to explain how mental processes are brought about on the basis of neural activity. The allegation of an »explanation gap« however also applies to neuroscience, as long as it is unable to solve the problem of the establishment of meaning through a »neural code« however this may be constituted. The meaningful content of consciousness is constituted socially and objectified through language and writing or other symbolic systems. How this is realised on the neural level has yet to be understood.

The question of the possible social consequences of neuroscientific insights or theses on the relationship between mind and brain can – following one of the current positions in the philosophical discussion – be answered with a (provisional) »So what?«, until the neural based »algorithms« of mental states and processes are decoded to such an extent that feeling, thinking, behaviour and decisions are predictable on the basis of processes observed in the brain. Regarding the often referred to possible consequences of neuroscientific advances in criminal law, this would mean that the condition of the brain which existed immediately before a criminal act was committed could be reconstructed, and the decision to commit the act would be perceivable as clearly determined by this brain condition. As research seems still to be a long way from this, there are temporarily no grounds given for a fundamental revision of our everyday understanding of liability and responsibility, free will and the criminal concept of guilt.

KNOWLEDGE AND LEARNING

The interest both of the general public as well as educational research in the methods and findings of brain research is substantiated in the hope that this could contribute to improved learning. However it appears that an unambiguous interpretation of the current results of neurophysiological research in the context of learning is extremely rare. Indeed there is a better understanding today of which mechanisms of information processing have to be assumed to explain (different levels of) learning success, why people learn different things with varying degrees of success in particular phases of their lives, how for example certain learning processes are physically or chemically realised in the brain and how learning processes find expression in the brain's architecture. Yet exactly which processes are running in the brain so that a corresponding learning success can be achieved is still one of the unresolved issues. If neural preconditions are missing, then tried and tested learning environments remain ineffective. If no learning opportunities are available, people with efficient brains remain incompetent. The causes of the majority of learning difficulties lie between these two extremes and can be explained by previous learning experience. A look at brain neurophysiology alone does not help here. In order to give a new chance to people with a failed learning career, the knowledge that they are lacking needs to be described as accurately as possible, and learning environments have to be created which will allow for the acquisition of this missing knowledge.

Against this background, the present report discusses what brain research and educational research can expect from each other, the implications which arise from neurophysiological studies of the human brain for cognitive scientific and learning psychological as well as pedagogic theories in the context of learning or teaching/learning research. It is also shown that insights from brain research may indeed describe the basic conditions under which successful learning can take place, but that the contributions of neuroscience are as yet too indefinite to be able to provide concrete guidance in designing learning opportunities. Nevertheless brain research has been able to confirm many of the results of long years of teaching and learning research: It is better understood today, for a series of cognitive scientific results, psychological insights and pedagogic practices, why some things function or conversely why they do not.

NEUROELECTRIC INTERFACES AND NEUROPROSTHETICS

All of the cognitive and emotional processes in the brain are accompanied by electrical activity, which represents a basis for signal transmission between individual neural elements in the central nervous system. The possibility thus arises of connecting technical systems to nerves using neuroelectric interfaces.

Three illness clusters can currently be identified, which have already been treated using neuroelectric interfaces. The first cluster includes illnesses and injuries in the area of the sensory systems. The neuroelectric interfaces inserted here are auditory and visual implants as well as implants to restore the sense of balance. The second cluster relates to illnesses and injuries of the motor system. These include among other things movement disorders, caused by involuntary motor function, such as for example Parkinson's disease or dystonia, but also dysfunctions in voluntary motor control caused principally by paraplegia and strokes. The systems so far deployed are the so-called brain-machine interfaces as well as deep brain stimulation. A third cluster of dysfunctions relates to the internal environment of the human body. This takes in chronic pain conditions, obsessive-compulsive disorders, depressions and epilepsy. The interfaces used (vagus nerve, deep brain, motor cortex and spinal cord stimulation, among others) do not have any direct interaction with the environment. The level of development of the various systems differs greatly and ranges from general clinical use – e.g. the cochlea implant to restore hearing in more than 100,000 cases worldwide or spinal cord stimulation for the treatment of pain conditions in more than 50,000 patients – right up to basic research in the laboratory or on individual test persons (e.g. with retina implants).

The development of neuroelectric interfaces has recently speeded up considerably, and the range of new fields of application is expanding noticeably. This trend feeds on advances made in ICT technology, from the miniaturisation of mechanical and electronic systems as well as from the latest findings on the functioning of the brain. Neuroprosthetics is a field in which visions of future potential technological developments play a not to be underestimated role, and repeatedly also attract a great deal of public interest. Although it is sometimes difficult to assess to what extend such visions are realistic, they are nevertheless of great importance not least for the public perception of the field of research. Internationally the development of new neuroprosthetic applications is driven in particular by military research, for which considerable support money is available.

A peculiarity of neuroelectric interfaces in contrast to other implants (e.g. an artificial heart) is that they can directly influence the central nervous system and with it, at least potentially, human behaviour, the human psyche and personality, a fact which raises fundamental ethical questions. Also hypothetical possibilities of improving human mental faculties through neuroelectric interfaces (so-called »neuroenhancement«) play a not insignificant role in this context.

MENTAL AND NEUROLOGICAL DISORDERS

Medically oriented research undoubtedly represents the most important sector within the field of brain research or neuroscience, both in relation to public and private investment or resources, and with regard to the insights and results obtained on the function und dysfunction of the brain or the nervous system. Brain-related illnesses are usually subdivided into psychological (such as anxiety disorders, depression, psychoses) and neurological disorders (such as Alzheimer's disease, epilepsy, migraine, Parkinson's disease), although it is almost impossible to draw a clear line between the two categories. Those referred to as psychological disorders, are those whose origins are predominantly associated with the brain, for which personality changes are characteristic and which – at least thus far – are mainly described on the level of symptoms and not by means of the (physiological) mechanisms, which lead to the disorder. The differentiation and attribution of psychological compared to neurological disorders – which may also affect the peripheral nervous system – are notably characterised by social valuations: Whereas diseases of the nervous system are in the main considered to be »normal« diseases such as diabetes or cardiovascular diseases, those suffering from psychological disorders often meet with specific reservations.

Neurological, and above all neurodegenerative disorders are featuring increasingly in the aging society; at the same time as psychological diseases appear to be on the increase globally. Total numbers (which are difficult to quantify) are estimated to be in the range of 25 to 30% of sufferers within the population of Germany and of Europe, with two thirds of these mentally ill. The European Commission sees an increasing threat to health and the national economy and is working on the »Development of a strategy for the promotion of mental health in the European Union«.

The present report describes the medical and social significance of psychological and neurological diseases using the symptoms of anxiety disorders, ADHD, depression, Parkinson's disease, schizophrenia and the approaches made to their treatment as examples. The extremely broad spectrum of analytical, diagnostic and therapeutic procedures for the research and treatment of neurological and psychological diseases can but be touched upon. The main emphasis in the report is on agent-oriented pharmaceutical procedures and in particular psychotropic drugs with potential non-medical everyday use (including addictive drugs and stimulants). Psychotherapeutic procedures are only mentioned with regard to their often complementary, in part however competitive relationship to biological/medical-based neuroscientific approaches. Also the important natural-scientific research fields of genome and proteome analysis and genetic and cell therapy are only treated in a condensed manner concerning their scientific and medical significance, as they are as yet little oriented towards applications but are primarily research-based in comparison with pharmaceutical procedures.

A (rapidly) increasing use of psychotropic drugs in everyday life has been documented for large, in particular performance-oriented, sections of the population in the USA, and can be increasingly observed in Europe. The consequences for the individual and society as a whole are without doubt difficult to foresee in many respects, yet seem far-reaching in principle. The discussion of social trends and the implications of new medically exploitable findings from neuroscience are thus concentrated on the increasing use of psychotropic drugs, in particular for improvements in performance, for self and external manipulation. The problem indicates a close reference to perhaps the largest health and socio-political challenge of the decades to come, the demographically characterised increase in neurodegenerative disorders. Many of the drugs used for their treatment are also potentially suitable for performance improvements for healthy people.

The central motives and targets of psychopharmacologic interventions are outlined in the current report, such as the stimulation of attention and the ability to concentrate, improvement of learning and memory, the uplifting and stabilising of moods, improvement of communication skills as well as the compensation of age-related mental, psychological and neurological restrictions. Overall there are pressing issues for politics, society and technology assessment. Quite fundamentally it is a question of how to deal with demands for performance under the terms of a competitive society and the consequent effects on social norms and the prevalent image of humanity.

FURTHER TA REQUIREMENTS

The present report provides an overview of the status of neuroscientific research in various fields of application and sketches current and potential future scientific-technical developments as well as the consequences and problems possibly associated with them. In this, it became clear that in-depth TA studies appear useful and important for a number of developments in the medical application of neuroscience, e.g. on the development of neurodegenerative disorders in an aging society and the challenges resulting from this for the healthcare system. Taking up this issue however, would imply an approach which would reach beyond the subject of »neurosciences« and include social as well as health policy questions. Moreover there are aspects or topics, such as for example the debate on the relation of mind and brain or also the neuroscientific understanding of knowledge and learning, which could not perhaps be sufficiently discussed in the available report, for which policy relevant insights are not however currently expected to arise from in-depth examination.

For further TA studies the subject of »pharmacological and technical neurointerventions: benefits and risks in medicine and everyday life« offers itself as brain research-specific in the stricter sense. With this subject the problem currently focussed on in the policy debate- i.e. the potential improvement and increase in human capabilities through the application of neuroscientific insights (»cognitive enhancement«) – would be taken up. Furthermore those scientific-technical developments that, according to the present study, are of utmost social and political importance (psychotropic drugs and neuroelectric interfaces) would be taken account of. The topic of enhancement results in addition in a reference to the current, research policy relevant debate on the convergence of nanotechnology, computer science, life sciences and neurosciences (»Converging Technologies«).

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