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INTERDISCIPLINARY INSIGHTS

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ALL NEUROSCIENCES UNDER ONE ROOF

In 2006, LMU Munich has established a forum for neuroscientific research: the Munich Center for Neurosciences (MCN). Here, biologists convene with neurologists and psychologists, and mathematicians discuss with physicists and philosophers. Their different approaches to the same topics combine to produce new – and often surprising – insights into the functioning of the brain.

"If the brain was simple enough to be understood, we would be too simple to understand it". This *bon mot* is a favorite of neurophilosophers, who deem human capabilities and consciousness unfathomable by their very nature – a much disputed topic in the neurosciences. However, there is one thing no one disputes: If we want to understand the functioning of the brain, we have a lot of different questions to answer. That is why the field of neurosciences spans an entire series of branches and methods: Biologists, for example, study the function of individual nerve cells or the signal paths in nerve bundles. Psychologists tackle the question of how awareness, emotions and memory are anchored in the brain. And neurologists look for the causes of nervous diseases in order to develop new approaches to treating them. Even mathematicians, physicists, and philosophers are entrusted to answer important questions in the scope of neuroscience.

Many of these scientific branches have been taught and studied at LMU Munich for quite some time. For most of this time, however, there has been no platform to unify all neuroscientifically oriented institutions in Munich under a common roof. This changed in 2006, the year the Munich Center for Neurosciences (MCN) was established. "The MCN intends to link all of Munich's neuroscience research groups," says Professor Oliver Behrend, Managing Director of MCN. "The aim is to facilitate cooperation in research and teaching, stimulate interdisciplinary discussion, close gaps existing in neuroscientific research, and thereby reinforce Munich's reputation as a top location for neuroscience." The center's cooperation partners are the Bernstein Center for Computational Neuroscience (BCCN), Helmholtz-Zentrum München – German Research Center for Environmental Health, the

Max Planck Institute (MPI) of Neurobiology, and many institutes of the Technische Universität München. “We also intend to cooperate with leading neuroscientific institutions in Germany and abroad,” says Oliver Behrend.

MCN is also a statement of the enormous importance of research: Three new professorships have been established in order to expand research into the strategically important areas of neurophilosophy, functional imaging of brain activity and computational neuroscience. “Computational neuroscience is about imaging neuronal processes using computerized models,” explains Professor Benedikt Grothe, head of the neurobiology division at LMU Munich and MCN spokesman. “We have already filled two high-standing positions with physicists Professor Andreas Herz and Professor Christian Leibold.” With their involvement, an interdisciplinary research initiative is currently in the works. “We are just submitting a proposal for a large-scale collaborative research center to the German Research Foundation, in which information processing in neuronal circuits will be systematically investigated, using both experimental and theoretical approaches,” reports Oliver Behrend.

The MCN board members’ fields range from philosophy, logic and the theory of science to neurobiology. Yet, “interdisciplinarity” already runs deep in the individual areas as it is. Professor Thomas Brandt, for example, successfully combines insights from pure neurological research with mathematical modeling. The core research topics of this neurologist, who has held the first senior research professorship of the Hertie Foundation since 2008, and maintains cooperation with the Clinic of Nuclear Medicine and the Institute of Neuroradiology, are disorders of the visual system and of balance. In a recently published study, Thomas Brandt’s group at the Institute of Clinical Neurosciences dealt with the topic of neglect – a neurological disorder in which patients no longer perceive one side of their body and environment despite an intact optic pathway. “Neglect is an awareness disorder usually caused by damage to the right half of the brain,” he explains. “It leads to the patient no longer responding to stimuli in the left half of their field of vision – it’s as if that side no longer exists for them.”

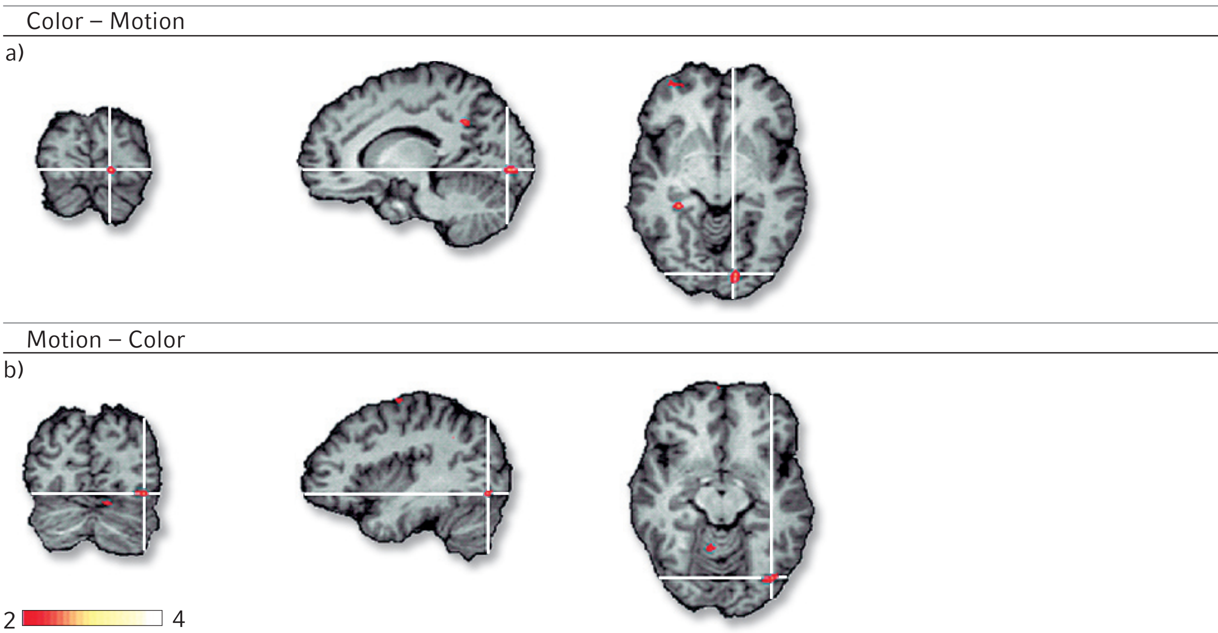
Together with engineer Stefan Glasauer of BCCN, Thomas Brandt has now developed a model that schematically represents the brain regions and nerve tracts involved in neglect. It assumes there is a dominant awareness center located in the right temporal lobe of the brain. This center receives input from different sensory systems, and is connected by excitory and inhibitory nerve tracts to the visual centers of both hemispheres, and to a less dominant awareness center in the left temporal lobe. “Using mathematical algorithms, we have managed to model the strength of the excitory and inhibitory connections,” Thomas Brandt reports. “This has allowed us to make a series of predictions, which we have already compared with existing clinical and experimental data.”

The model assumes in particular that the abolition of inhibitory connections from the right to the left awareness center leads to increased activity in the left visual center – which in turn has an inhibitory action on the right visual center. “The model can thus explain experimental findings of other groups that have not been easy to interpret so far," explains the LMU researcher. "The visual sensitivity of healthy subjects was increased in one half of the visual center by inhibiting the temporal lobes on the same side by magnetic stimulation."

UNDERSTANDING THE CORE OF HEARING

Also benefiting from interdisciplinary approaches in their studies are the neurobiologists working with Benedikt Grothe. Since many years, they have been exploring the neuronal bases of hearing and the temporal resolution and spatial location of sounds. By combining neurobiological methods, mathematical modeling and a psychophysical experiment in a current study, the scientists succeeded in considerably expanding our understanding of the principles of hearing. The researchers dealt with the effect of so-called echo-suppression. "Normally, the brain perceives even minute volume differences between both ears, by which it can spatially locate noises," explains Benedikt Grothe. "The brain suppresses some spatial information, however, for example if there is resonance or echoes. This is an important requirement for locating the real source of the sound."

The researchers had already known from earlier studies that the dorsal nucleus of the lateral lemniscus, or DNLL, plays an important part in spatial location. This brain nucleus responds to sound signals from the opposite ear, and is inhibited by sounds from the ear on the same side – by which it can identify differences in intensity between both ears. With single-unit recordings in the brain of the gerbil, Benedikt Grothe and his team have now shown that a left-side sound signal persistently inhibits the DNLL on the right half of the brain – on average 17 milliseconds after the sound. This means that the directional information of subsequent sounds is suppressed during this time window.



▲ Different brain regions become active depending on the properties of the stimulus the attention is allocated to in a visuell task: Hermann Müller´s investigations revealed an enhanced activation of visual area V4 (in fusiform gyrus) if color is the critical stimulus feature that singles out the search-for target object (fig. a). By contrast, if movement is the critical feature, visual area MT+ (in the occipital lobe) shows enhanced activation (fig. b).

In cooperation with neurobiologist Michael Pecka and computer scientist Thomas Zahn, the researchers simulated the observed effects in a computer model containing the excitory and inhibitory tracks between the auditory regions of the brain. Next, in a sound location experiment, they recorded sounds directly at the ear of subjects and fed these into their model in the form of audio files. With an astonishing result: “The model quite precisely predicted the behavior of human hearings,” reports Benedikt Grothe. “In particular, it simulated the fact that the brain still perceives subsequent echoes even with very short time intervals, but can no longer locate their direction.” The ten participants were unable to locate echoes within a time window of 16 milliseconds, but already recognized that they had heard two different sounds in a time window of just 7.5 milliseconds.

Rather than sight and hearing, Professor Herrmann Müller’s research focuses on another psychological function: selective attention. “We want to understand how, out of the abundance of stimuli in the environment, we select those that determine our behavior,” says the Chair of General Psychology and MCN board member. At the moment, LMU psychologists concentrate on the role memory plays in attention processes. To help understand this, they use a combination of neuroscientific methods. They are also working with, among others, the Neurological Clinic of LMU Munich and the MPI for Human Cognitive and Brain Sciences in Leipzig.

By means of psychological experiments, Herrmann Müller and his team have already shown that the brain unconsciously remembers those properties of a stimulus that contribute to the successful fulfillment of a visual search task – its shape or color, for example. Neuropsychological methods such as recording electrical brain activity (EEG) and functional brain imaging using magnetic resonance tomography (fMRT) shed light on which areas of the brain are involved in this process. Herrmann Müller and his team discovered, for example, that regions in the frontal lobe compare the current stimuli in the visual field with those stored in memory. Certain areas of the visual brain are placed into a heightened state of readiness depending on which stimulus attribute is being searched for. “If, for example, color is the decisive stimulus attribute, then the color area V4 will be activated in the posterior brain, while activity simultaneously drops in other visual areas, such as the motion area MT+,” Herrmann Müller explains. In an investigation with neurological patients, the researchers also discovered that damage to certain areas in the frontal lobe makes it considerably more difficult to switch attention from one stimulus property to another. “We intend to use the results of this research to optimize task situations in man-machine systems. This could facilitate the participation of handicapped people in certain work processes.” The psychologists are currently working within the cluster of excellence Cognition for Technical Systems (CoTeSys), coordinated by TU München, on an “intelligent” module for humanoid robots to improve their interaction with humans. The aim is to optimize joint work processes so that as few changes in attention and memory processes are required as possible.

RESEARCH AND TEACHING ON EQUAL FOOTING

Teaching stands equal to research at MCN. The Center has been instrumental in the success of the Graduate School of Systemic Neurosciences (GSN) in the Federal and State Excellence Initiative. MCN also coordinates teaching in the master's programs Neurocognitive Psychology (NCP) and Neurosciences, which have arisen from the Elite Network of Bavaria. "Both programs are internationally aligned, and combine curricular content from the fields of neurobiology, psychology, neurophilosophy and mathematical modeling," says Hermann Müller. "Thus a practically oriented, interdisciplinary transfer of knowledge is the primary objective of postgraduate studies at the graduate school." Furthermore, MCN is involved in the international exchange programs Amgen Scholars and LMU Harvard Young Scientists Forum (YSF), which are to promote interdisciplinary exchange and the education of highly qualified students, doctorates and postdoctorates. Yet another forum for interdisciplinary cooperation for all researchers is the Lecture Series. Alongside regularly published lectures, this provides a platform for scientific discussion. "That is the advantage of MCN," says Thomas Brandt: "that people get together, discuss their research, and thereby generate new ideas."

Prof. Dr. Dr. h. c. Thomas Brandt has been head of the Institute of Clinical Neurosciences in the scope of a senior research professorship of the Hertie Foundation since 2008. He is a member of the MCN board of directors, of the Graduate School of Systemic Neurosciences, and spokesman for the integrated Research and Treatment Center for Vertigo, Balance and Oculomotor Disorders.
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Prof. Dr. Benedikt Grothe has headed the Chair of Neurobiology since 2003. He has been Director of the Department of Biology II since 2004 and spokesman for the "Munich Center for Neurosciences – Brain and Mind" (MCN-LMU) and coordinator of the "Graduate School of Systemic Neurosciences" (GSN-LMU) since 2006.
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Prof. Dr. Oliver Behrend is the Managing Director of MCN. His research focuses on the field of systemic neurobiology. He is involved in teaching at the Biocenter of LMU Munich and heads the Aquatic Bioacoustics Laboratory of Humboldt University, Berlin.
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Prof. Dr. Hermann Müller has held the Chair of General and Experimental Psychology at LMU Munich since 2000. Since 2004, he has headed the master's program Neurocognitive Psychology. He is a member of the MCN board of directors.
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