Bernstein Network for Computational Neuroscience

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The human factor in driving

When driving your car, your brain takes care of complicated action sequences, while you may, at the same time, listen to the radio or have a relaxed conversation with your fellow passengers. Neuroscientists are interested in what this example teaches us about how the brain controls behavior in general. “It surprises us again and again how many abstract rules our movements obey, although, subjectively, we have the impression that our movements are not constrained at all,” said Gregor Schöner from the Institute of Neuroinformatics at Ruhr University and the Bernstein Group Bochum. In driving, for example, it has been found that the typical driver initiates a braking or passing maneuver as soon as the estimated time to contact with the vehicle in front falls below a certain value.

The scientists capture such rules in mathematical formulas and incorporate them into theoretical models that describe a specific behavioral context. In this way, Schöner and coworkers develop quantitative driver models that faithfully mimic the typical behavior of a human driver and are capable of learning.

In order to create an empirical basis for this, the Bochum researchers have groups of volunteers take trips through simulated environments in driving simulators, in which they see each other as traffic. The whole thing looks like a video game, but is not nearly as exciting. “In our case, the drivers’ instructions are most of the time quite boring, like ‘maintain speed’, ’stay on track’ or ‘don’t collide’. Only occasionally, they are allowed to overtake,” explained Schöner. In the simulator, researchers can optimally investigate the relationships between the driving situation and drivers’ behavior, since both are recorded simultaneously. In this way, they find rules that are common to all drivers, and others in which different types of drivers vary.

The software components that couple the drivers’ behavior to the simulation environment are provided by the company NISYS (a spin-off from their institute), with which they collaborate in the project “Learning Behavioral Models” of the Bernstein Focus Learning. NISYS’s customers usually are car manufacturers or their suppliers. They use the intelligent software solutions that NISYS provides for simulations that test the interaction of newly developed electronic control and assistance systems with the car’s hardware before they are incorporated into real cars. In this way, malfunctions can be detected and corrected at an early stage, saving cost and development time. This “hardware in the loop” approach nowadays is not only used for highly-bred Formula 1 racing cars, but also forms a standard in regular automobile manufacturing.

A human driver is hardly ever included in these simulations, although humans often control a vehicle quite differently from a computer. Human mistakes constitute the by far most common cause of accidents and pose major challenges even to advanced assistance systems. Right now, the researchers are still busy trying to closely capture the peculiarities of the human driving behavior in order to develop naturalistic driver model. If it were possible to incorporate such models into the simulation of assistance systems, that would enable more realistic simulation of accidents and the validation of assistance systems and accident avoidance strategies.

Networking with NEST

Why should a scientist take up such a Herculean task as to simulate the brain, with all its billions of nerve cells and trillions of connections, which, above all, keep changing all the time? And why should a company like Honda, who usually builds cars, take part in such a project?

For brain researchers like Markus Diesmann (Bernstein Center Freiburg, Bernstein Facility Simulation & Database Technology and Research Center Jülich) and Stefan Rotter (Bernstein Center Freiburg), simulations are a valuable tool for finding out how the brain may work. Only in simulations, features of the brain can be investigated individually, by varying each of them in a systematic way and examining the consequences on the system as a whole.

The technology experts Mark-Oliver Gewaltig and Edgar Körner from Honda Research Institute Europe, industry partner of the Bernstein Center Freiburg, had a different, rather technical motivation. They wanted to use knowledge about the information processing principles of the brain in order to develop intelligent systems that could robustly and flexibly move in complex and changing environments, e.g. autonomous cars or robots.

Thus, both teams, albeit with different motivations, needed to achieve the same goal: To build a simulation system that was able to simulate large networks of nerve cells in a precise and reliable manner.

Already early on, the researchers realized that its parallel architecture is the decisive feature of the brain. Therefore, when constructing the simulator, they made sure that, from the start, processes in the computer simulation were also parallelized. At the same time, they made use of the joint creative potential of the scientific community, by making their system immediately available to interested colleagues.

The long years of the researchers' joint work have now born a wealth of fruit. With the simulation system NEST that they developed, it is now possible to simulate networks of several hundreds of thousands of neurons in a reliable way, and independent from the kind and number of computers used (be it a network of ordinary PCs or a supercomputer). In the meantime, NEST is widely used all over the world and has catalyzed considerable scientific insights into, for instance, how the specific network structure of the visual cortex facilitates fast changes in visual attention.

In the framework of the Bernstein Focus Neurotechnology, the researchers now want to expand their simulation environment by the toolbox NetCAD, that allows to generate, analyze and simulate networks with very complex network structures (topologies). This tool will make it easier to investigate how the topology of a given network is related to its function.

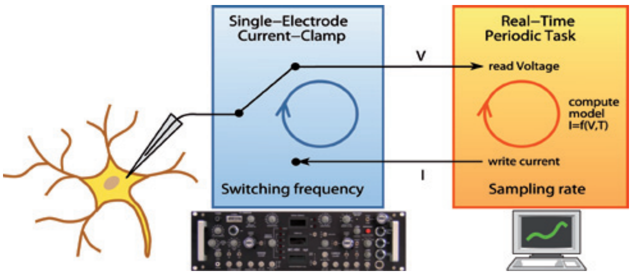
And Marc-Oliver Gewaltig will, in the meantime at EPFL in Lausanne and within the framework of the Blue Brain Project, continue to follow the original vision of one day controlling a robot with NEST-simulated neuronal networks.

www.nest-initiative.org

New amplifier technology makes neurons dance

Nerve cells are like batteries. The non-conductive cell membrane separates the two poles of the battery: the negatively charged cytoplasm from the positively charged space between the cells. The charge of the neural battery provides the driving force for the neurons' "language": Currents of electrically charged particles (ions). These currents are mediated by channels in the membrane that are permeable only for certain types of ions and that open or close, depending on the momentary voltage of the cell membrane. A specific opening sequence of sodium and potassium channels produces the action potential, the basic communication unit in the brain. Besides these quite well-studied channels, there is a whole "zoo" of others–each of them with its own properties. What is the biological "sense" to this diversity, and what functions do the various ion channels have?

To answer these questions, brain researchers have teamed up with engineers to invent a technical trick. A fine glass tube breaks through the cell membrane and, through a highly sensitive amplifier, the membrane voltage is measured. If one keeps the membrane voltage constant (voltage clamp), one can measure the currents flowing through the ion channels. The dynamic clamp method, developed in the 1990ies, goes a step further: To investigate how a certain ion channel will affect the behavior of the cell, one simulates its action by injecting a current through the glass tube into the cell that corresponds to the properties of this channel. But under certain conditions, the technique reaches its limits, since it requires amplifiers with an extremely high sampling rate and a matching software that instantaneously calculates the current to be injected, based on the measured voltage.



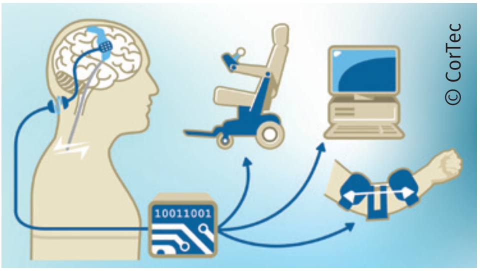
With Jan Benda (Bernstein Awardee 2007, University of Tuebingen and Bernstein Centers Munich and Tübingen), Werner Hemmert (Technische Universität München and Bernstein Center Munich) and Hans Reiner Polder (npi electronic and Bernstein Center Munich), a team with unique expertise has now joined forces to solve these problems. The engineer Polder has decades of experience in the development of special amplifiers. Jan Benda developed a comprehensive software system that can handle complex experimental control online (RELACS, www.relacs.net). And Werner Hemmert contributes an ideal study object: the outer hair cell. It has the curious property to quickly contract or stretch in response to currents flowing into it. Thus, with their dynamic currents, the researchers can make the cell dance.

Science can look forward to three major advances that will result from this collaboration. New amplifiers will allow better experiments. The developed software will be generally available to the scientific community as an open source system. And new experiments will provide exciting insights into previously mysterious sensory abilities of humans and animals. Werner Hemmert's experiments will shed light on how fast the outer hair cells in our ears can "dance", and how they improve our ability to hear. Jan Benda will investigate how slow potassium channels help weakly electric fish to communicate and to localize their prey.

The dynamic clamp technique: Through an electrode and an amplifier (blue), the membrane voltage of a neuron is measured. Based on the voltage and a theoretical model, a software system (yellow) calculates the current through a hypothetical ion channel, which is then injected into the cell through the amplifier.

Many-voiced brain whisperers

Information processing in the brain is based on the exchange of electrophysiological signals between nerve cells. Long ago, brain researchers have realized that one can take advantage of the electrophysiological properties of the brain for medical purposes. EEG measurements of brain activity provide neurologists with valuable diagnostic information on possible diseases. Influencing brain activity by means of electrical stimulation, e.g. by deep brain stimulation in Parkinson's patients, has already yielded remarkable therapeutic successes. No doubt about it, the medical opportunities that electronic interfaces with the nervous system offer are enormous.



Researchers around Jörn Rickert of the University and the Bernstein Center Freiburg have for years explored the possibility of using such interfaces for motor neuroprostheses that could provide paralyzed people with some movement capacities. "Our studies show that the information about planned movements that could be used for controlling such prostheses, however, is distributed over many neurons in an extensive network," said Rickert. The same is true for encoding of sensory information. Many diseases are also associated with widely distributed changes in brain activity. Electronic interfaces to the brain that take this spatio-temporally distributed nature of brain function into account must therefore contain as many electrodes as possible, in order to be able to simultaneously measure and influence brain activity in as many places as possible.

Developing such multi-channel implants imposes a whole range of technical challenges. To be suitable for everyday use, the systems must be fully implantable, which means that data transmission and energy supply must happen wirelessly. They must be biocompatible, i.e. they can only contain safe materials and must not be degraded by the body milieu–which can be surprisingly aggressive to technical systems. The large amount of electrode channels requires transferring substantial amounts of data. And, of course, the whole system should be as small as possible. "A technical nightmare," admits Karl-Heinz Boven, Managing Director of Multi Channel Systems (MCS) GmbH, Reutlingen.

Within the framework of a collaborative project in the Bernstein Focus Neurotechnology Freiburg-Tübingen, MCS and Rickert now want to tackle this challenge. In cooperation with Thomas Stieglitz from the Department of Microsystems Engineering at the University of Freiburg, a world expert on thin-film electrodes, Rickert already succeeded in developing novel flexible electrodes that combine excellent spatial resolution with optimal tissue compatibility. The collaboration with MCS now also allows to tackle the combination with the necessary electronics and to encapsulate the system. "This will bring us one giant step ahead towards an actual patient-compatible system," said Rickert.

Initial biocompatibility tests are already planned. In further projects, the implant system will be complemented by additional components. The researchers are so confident to arrive at a clinically usable product within the foreseeable future that they dared to found CorTec as a spin-off. The new company will finish the development of the implant system and commercialize it–an impressive example of how ideas from basic research can find their way into real economy.

Transcranial stimulation: A new access route to the brain

Besides the exchange of transmitter substances, information processing in the brain is mainly based on currents of charged molecules (ions). When many nerve cells are active simultaneously, the currents add up and lead to electric fields that can be measured on the scalp.

For a long time, communication with the brain has been largely restricted to “listening” to it in this way. For several decades, however, techniques are now being developed that allow to “talk” to the brain in a noninvasive way (transcranially) by applying electrical or magnetic pulses–with amazing effects.

In transcranial magnetic stimulation (TMS), brief magnetic field pulses induce electric fields in the brain that trigger action potentials in nerve cells. Single pulses activate narrowly defined areas of the brain. By stimulating, for instance, the motor cortex, it is possible to induce contractions of individual muscles.

DC stimulator for transcranial brain stimulation with direct, alternating or random currents.

Multiple pulses at short intervals induce more complex effects that depend on the precise temporal pattern of stimulation. In this way, one can also induce inhibition of certain brain areas.

Brain activity can also be directly affected with small electrical currents. Direct currents (tDCS) influence the membrane voltage at dendrites (the nerve cell processes that collect the input signals), and this alters resting activity. Alternating currents (tACS) also have effects on activity oscillations in the cerebral cortex and on connections between brain areas. Recent research results show that transcranial stimulation can support learning processes that last for hours or even days.

Partly within the Bernstein Collaboration “Transcranial Stimulation”, the Ilmenau-based company neuroConn builds devices that are necessary for future clinic applications of transcranial stimulation. Based on work by Walter Paulus of the University Medical Center and the Bernstein Center Göttingen, new stimulators were developed that can also be used during nuclear magnetic resonance imaging. The stimulation spread within the brain can be better modeled and predicted by new procedures that were developed with Gunter Knoll from the University of Kassel and Helmut Buchner from Knappschaftskrankenhaus Recklinghausen. NeuroConn has also devised a new setup that can simultaneously record EEG during transcranial stimulation, allowing to investigate the effects of the stimulation methods in a more detailed way.

The new repertoire of methods and devices opens up exciting new access routes to the brain that allow to interact with the brain in a more direct and possibly more efficient way than with conventional methods or training. This may lead to new therapeutic options for a large variety of neurological and psychiatric diseases and disorders.

Innovative technology for our most sensitive organ

Medical technological devices are indispensable tools of modern neurology. They must flawlessly meet highest standards concerning their safety, precision and efficiency. After all, the nervous system is our body's most sensitive organ. The Emmendingen company inomed Medizintechnik GmbH has over 20 years experience in the development of devices and systems for neurosurgery, intraoperative neuromonitoring, neurological diagnosis and treatment of pain. In collaboration with the Bernstein Focus Neurotechnology Freiburg-Tübingen, the company is now assessing two problems in the field of epilepsy diagnosis that may offer interesting perspectives for research and new therapies.

When medication fails in patients with severe epilepsy, surgical removal of the epileptic focus is the last therapeutic option. Such an operation is a tricky matter. Surgeons have to know the exact position of the focus, have to be able to access it in a precise way and must make sure not to destroy any important healthy brain tissue, e.g., the language areas. Therefore, extensive diagnostics is performed in preparation of such surgeries. Electrodes with which the physicians can record brain activity and locate the source of pathological brain activity are implanted into the patient's brain. In addition, the patients' responses to electrical stimulation of the electrodes can provide hints on the function of the stimulated areas.

Model of a new hybrid electrode developed by inomed that combines field electrodes (rings) with micro wires for measuring single neurons.

New electrode systems that reach into the depth of the brain and not only measure the summed activity of many neurons, but also the contributions of individual nerve cells, have proven very useful for this task. In a cooperation between inomed and Stefan Hefft, Dominik von Elverfeld, Irina Mader and Andreas Schulze-Bonhage from the Epilepsy Center of the University Hospital of Freiburg, critical points in these systems could already be decisively improved. New instruments have improved surgical procedures, and an appropriate fixation system was developed. The electrode connectors were modified for use in the MRI scanner, allowing much better control on their position. In the near future, the researchers will investigate whether alternative electrode designs can improve attributing the electrical signals to individual nerve cells and allow adjusting electrode positions depending on neuronal activity. This would not only allow diagnosis to become more efficient and accurate, but would also facilitate functional exploration of deep brain areas.

A second project with Andreas Schulze-Bonhage and with Thomas Stieglitz from the Department of Microsystems Engineering at the University of Freiburg deals with a new approach for the treatment of epilepsy that tries to suppress epileptic activity by electrical stimulation. In Parkinson therapy, deep brain stimulation is being used successfully for many years. Previously used multi-electrode systems, however, only allow stimulating individual electrodes (or pairs). But in order to efficiently and precisely affect spreading epileptic brain activity, it is most likely that one has to adopt to the distributed activity of the brain and use spatiotemporal stimulation patterns at multiple electrodes. A multiplexer, developed by inomed within the project, offers exactly this opportunity. In animal experiments, it will now be tested whether stimulation can confine or suppress epileptic activity–a fascinating possibility that would open a new option to counteract epileptic seizures.

Close to the neuron, and yet, it moves

An old dream of the neuroscientist: witnessing in real time how individual nerve cells contribute to solving a behavioral task, coordinating natural movements or orientation in space.

Modern electrophysiology has a wide repertoire of methods to record the electrical activity of the brain. But when trying to get down to the level of individual nerve cells, things get complicated. Current recording systems typically require to take the animal to an electrophysiology lab, to attach a sensitive recording device and to connect it to a number of technical devices that finally track down the activity of individual neurons within the electric noise in the brain and record it. Since the electrodes are positioned each day anew, researchers can record from individual cells for only a few hours. And the types of tasks that the animals can deal with in the lab–most commonly, simple computer "games" controlled by a joystick or touch screen–are quite restricted. Although this classical approach has achieved significant progress in understanding the basic functions of nerve cells, the conclusions to be drawn about natural and long-term behavioral contexts remain limited.

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Recent years have seen the development of implantable systems that can permanently remain in the brain. They have allowed following individual neurons over weeks or months, in some cases even years. But because, with time, scar tissue forms around the electrodes, the recorded signals typically get worse and worse. And also these systems, like conventional methods, require a wired connection to the recording devices.

Alexander Gail from the German Primate Center and the company Thomas RECORDING now want to tackle this problem in a collaboration within the Bernstein Focus Neurotechnology Göttingen. Their idea is to build an implantable system in which the electrodes can still be freely moved in both directions after implantation. In this way, their positions could be readjusted in order to optimize the recorded neural signals.

The researchers' goal is to build a system with 64 electrodes, such that a large number of neurons can be recorded. For the system to be small enough to be attached to the head, new electrodes and micromechanical components need to be developed. A miniaturized robot that can accurately move in three dimensions will take care of moving the electrodes. In a next step, the system can also be adapted to a wireless mode of operation.

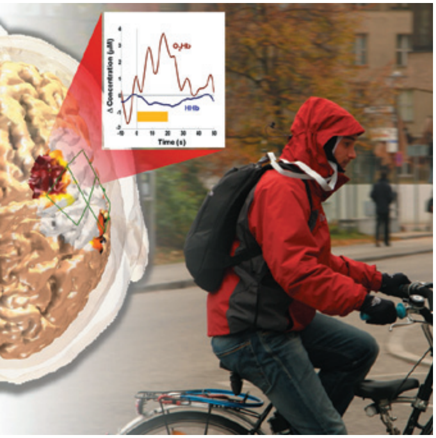
By integrating these new approaches, it will become possible to record neuronal activity in the natural environment of animals like rhesus monkeys–a technical breakthrough that will offer great perspectives for brain research. At the same time, the possibility to move freely will strongly improve the experimental conditions for laboratory animals. And also for medical use in human patients, the new technology will be of interest, since implantable and wireless recordings systems are a basic requirement for modern neural prostheses. "Basic research, animal welfare and medical applications," said Gail, "this is the three-fold motivation that drives us in our efforts." Three goals that truly seem worthwhile.

mini-NIRS: New glimpse into the brain

Modern imaging technologies that allow glimpses into the brain's activity require bulky nuclear magnetic resonance scanners, thus restricting their use to the laboratory. A promising alternative is the new method of near infrared spectroscopy (NIRS). As in EEG, it assesses the brain from the skull's surface. But while EEG directly measures voltage changes caused by neuronal activity, NIRS provides clues about the metabolism of the brain.

A near infrared source shines light into the brain. A few centimeters apart, a detector measures how much of the light has passed the tissue. Since the tissue's light transmission depends on the amount and the oxygen level of the blood, and since brain activity increases flow of oxygenated blood into the activated area, the amount of transmitted light can be related to neuronal activity.

Functional magnetic resonance imaging is also based on measurements of blood oxygenation. But NIRS technology is orders of magnitude smaller and cheaper. What's more, electromagnetic fields or muscle contractions do not interfere with the measurements. This makes NIRS an ideal candidate for mobile approaches that investigate brain activity not in the lab, but in real life situations.



In der Berliner Innenstadt mit mini-NIRS gemessene Aktivierung der motorischen Hirnrinde.

Activation of motor cortex measured with mini-NIRS in downtown Berlin.

In the Bernstein Focus Neurotechnology Berlin, scientists around Jens Steinbrink from the Charité and Klaus-Robert Müller from Technische Universität Berlin, together with the Berlin-based company NIRx, are working on the technical implementation of that idea. They have integrated 20 miniaturized light emitters and detectors into a wearable cap. The light is produced and measured directly on the skull, making bulky fiber optics dispensable. The electronics for data registration, consisting of an interface the size of a thick paperback and a laptop, fit into a backpack that is connected to the cap through a few thin wires.

In first tests, the researchers have already shown that their new mini-NIRS system is suitable for real world situations. They made volunteers pass a bike course at the banks of Berlin's river Spree while pressing levers upon acoustic cues. Even under these tough conditions, they could reliably extract motor control signals for the hand movement from the brain's contralateral motor center.

"In some subjects, we could even relate individual hand movements to the NIRS signals", explains Christoph Schmitz, CEO of NIRx and head of the study – an important prerequisite for future uses of the new technology. Indeed, the researchers nourish ambitions not only towards basic research but also towards concrete technological and medical applications.

Brain-computer interfaces, with which for instance paralyzed patients control technical devices, could be rendered more usable and more robust by using NIRS. Also healthy people could profit from the new technology. With NIRS, e.g., brain states like attentiveness could be monitored in safety-sensitive situations, allowing timely interventions.

Better prostheses for more quality of life

How profoundly healthy arms and legs contribute to our quality of life is often only noticed when they fail to work - for example, when we have to wear a cast after a fracture. Many people have to live permanently with motor disabilities, caused, for instance, by paralysis or amputation. Even the most modern prostheses are still far from the perfection of natural limbs, especially as far as functionality and ease of use are concerned.

The Duderstadt company Ottobock is world leader in orthopedic technology. In collaboration with scientists of the Bernstein Focus Neurotechnology Göttingen, it has now set itself the goal of applying latest neuroscientific findings to the development of intelligent and flexible assistive devices. To this end, the company also contributes to financing the new professorship of Dario Farina at the Bernstein Focus Neurotechnology and the University Medical Center Göttingen.

To compensate for partial paralyses that often remain after a stroke, orthoses are used that support the leg. Up to now, these devices are usually rigid, so that walking is possible, but very tiring and cumbersome. Recently, Ottobock developed first orthoses with flexible knee joints. Their function is inspired by biology and has already been used successfully in leg prostheses: When

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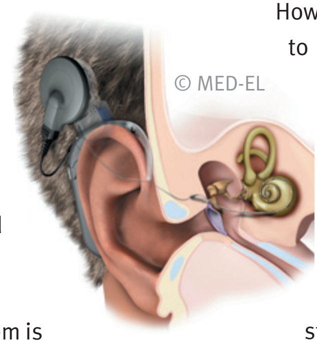
loaded by body weight, the knee is locked, such that the leg can not buckle. When unloaded, the knee is unlocked, allowing the leg to bend and swing down. As of yet, however, the system is not able to adapt to changing conditions such as slopes, uneven ground or performance fluctuations over the day. To achieve this kind of adaptivity is the goal of a collaboration with Florentin Wörgötter, who already has successfully applied biologically inspired mechanisms to make walking robots learn.

Another focus of the cooperation is the improvement of control mechanisms for hand prostheses. Modern prosthetic hands already allow simple grasping movements. The patient controls them by activating muscles in the stump, which is measured by electrodes in the prosthesis. But the number of control signals that can be derived like that is small, and the control itself remains simplistic and little intuitive. Furthermore, usually only one of the degrees of freedom (e.g. closing or rotating the hand) can be controlled at a time, and the patient must switch between these modes. Simultaneous use of several movement options will require new control mechanisms. To allow for more complex and more natural movements, optimized signal processing and pattern recognition algorithms are employed in the collaboration with Dario Farina and Michael Herrmann.

In addition, the scientists now want to measure muscle activity with not only two (as is common today), but with many electrodes. The expected outcome would be not only more control signals, but also a better robustness to electrode displacements or failures. Another promising extension of prosthetic hands would be the use of sensory feedback. Only if the user can feel how much power his artificial hand exerts on an egg that he is grasping, for example, he can adjust the force optimally to make sure the egg does not break.

Towards better cochlear implants

To hear what goes on around us – impossible for profoundly hearing-impaired or deaf people. Modern cochlear implants (CIs) are able to restore hearing in such patients. A microphone and an audio processor, worn behind the ear like a hearing aid, record the sound and compute the stimulation data. These data are then wirelessly sent to the implant that electrically stimulates the remaining auditory nerve fibers in the cochlea. As with normal hearing, depending on pitch, different sections of the cochlea are stimulated. The activity of the nerve fibers is then transmitted to the brain, which interprets them as auditory events.



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But although these implants are tremendously helpful, certain situations still present a challenge. When many people are talking at the same time, it is difficult to filter out a specific speaker. Music perception is limited, and problems also occur with sound localization.

The reasons for this are complex. One problem is that it is unclear which spatial and temporal stimulus patterns optimally encode speech. To answer this question, Werner Hemmert from the Bernstein Center Munich and the Technical University, in collaboration with the CI manufacturer MED-EL, applies a typical strategy of Computational Neuroscience: “Virtual experiments” in theoretical models. First, the scientsts in Hemmerts research group created a model that reflects the electrical activation of nerve cells in normal hearing. A second model mimics the activation induced by a CI. In this model, the researchers can systematically vary the algorithms of the CI model’s audio processor, which translates sound into electrical stimuli, until the evoked neuronal activations most closely resemble the natural ones. The new algorithms could decisively improve CI technology.

Another problem is that electrical stimulation spreads within the tissue into all directions. Thus, when stimulating one cochlear turn, also the one above or below can be activated. As a result, hearing will be blurred. The new technique of optogenetics inspired Tobias Moser of the Bernstein Center, the Bernstein Focus Neurotechnology and the University Medical Center Göttingen, to replace electrical stimulation by light. Because light can be focused, it can have much more local effects.

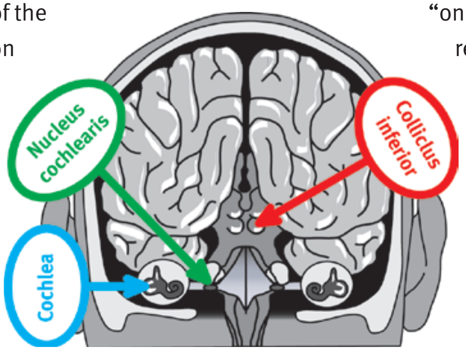
However, the nerve cells in our ears normally do not respond to light. Here is where optogenetics comes into play. It uses molecules that change their properties upon illumination, and thus can trigger a certain reaction. There are, for example, ion channels that open upon illumination and thus can activate a neuron electrically. If one could get these molecules into the cells of the inner ear, the recipient could literally be made to hear optical stimuli, instead of the electrical stimuli used in CIs today. In initial studies, Moser and coworkers have already successfully applied optogenetic methods to render the cochlear neurons of experimental animals light-sensitive and to activate the auditory nerve by light.

The next step is now to create hearing prostheses that emit light signals instead of electrical pulses. With the newly developed micro-LED technology, it has become possible to produce LEDs that are small enough to be introduced into the cochlea. This brings optical CIs within technical reach–a fascinating idea that the researchers are going to explore in collaboration with Ulrich Schwarz from the University of Freiburg and the Fraunhofer Institute for Applied Solid State Physics.

Novel hearing prostheses in the midst of the brain

Cochlear implants (CIs) are currently the most successful neural prostheses that have helped many people re-gain hearing abilities. However, they can only be applied when the auditory nerve is intact. For patients in which this is not the case (e.g., due to certain cancers), or in which a deformed cochlea makes it impossible to insert CI-electrodes, this treatment is not an option.

To help these patients, scientists are trying to devise neuroprostheses that act on other stations of the auditory pathway. The next possible station would be the cochlear nucleus in the brain stem. But so far, the level of hearing quality, in particular of speech comprehension, that has been achieved with brain stem implants mostly remains well behind that provided by cochlear implants.



In the Bernstein Focus Neurotechnology Göttingen, a collaboration between researchers at the Medical University of Hanover around Thomas Lenarz with the company Cochlear and Dominika Lyzwa from the group of Michael Herrmann at the Max Planck Institute for Dynamics and Self-Organization in Göttingen is now investigating the possibility to apply neural prostheses in the inferior colliculus in the midbrain.

Similar to an onion, the colliculus is made of several "shells", each representing a specific frequency range, i.e., a specific sound pitch. Therefore, in principle, the same technology as in cochlear implants can be applied: a microphone behind the ear picks up the sound and a speech processor analyzes it and splits it up into different frequency bands. The signals are then wirelessly transmitted to the implant, which in turn generates stimulation pulses with which the nerve cells in the shells are stimulated.

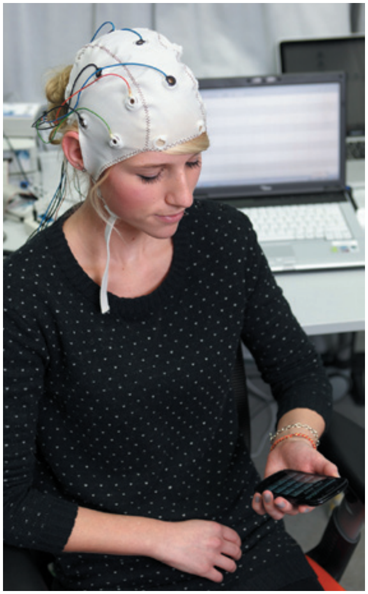
In initial clinical trials, 5 patients indeed regained hearing with this new type of implant. As of yet, however, also their hearing quality does not quite reach that achieved by cochlear implants. In animal experiments, the Hannover researchers have examined possible reasons for this. Firstly, a single straight electrode shaft will only activate a small patch of each "onion shell", so only a fraction of all nerve cells responsible for a frequency will be activated. Secondly, it turned out that the nerve cells in the colliculus tire easily: they are active only for a short time, and then take a break before they can get activated again.

The researchers have now found an approach that addresses both problems: They use not only one, but two adjacent electrode shafts. In this way, they can reach twice as many neurons in each layer. And if they stimulate the two electrodes alternately, the neurons can also take their breaks.

In animal experiments, this approach has already proven successful. Now, the technology has to be optimized for human use. Thomas Lenarz has already been able to adapt the surgical technique for safe implantation of two electrode shafts. Now, the stimulation technique still has to be optimally adapted to the specific characteristics of the colliculus and to the electrode pair. In the foreseeable future, the new technology will be tested clinically. Thus, because of this very successful collaboration, a novel neuroprosthesis is already within reach.

Good connection? Ask the brain!

In modern telecommunication, audiovisual content is omnipresent. A business phone conference in the morning, a quick podcast on the latest news in between, and, in the evening, hanging out in front of a couple of internet videos – many of us take all this for granted. But when corrupted sound or image quality makes it hard to keep track, we realize to what extent good quality is key to digital communication.



But how can one measure the transmitted quality, e.g. of speech? Classically, subjects are asked to answer this question in retrospect by filling in questionnaires and rating scales. But in this way, one can only capture features that the subjects can consciously perceive and can verbalize. Yet, it is known that unconscious factors can also affect perceived quality and can influence user decision in the long run.

Researchers around Sebastian Möller, Jan-Niklas Antons and Robert Schleicher of the Telekom Innovation Laboratories and the Bernstein Focus Neurotechnology at TU Berlin have now adopted a novel approach to this problem. They did not ask the subjects, but rather their brains. The researchers measured the electroencephalogram (EEG) and compared brain activities of subjects listening to optimal quality audio sequences to when they listened to sequences with degraded speech quality, e.g. by lower bit rate encoding or noise.

The project benefits from scientists like Gabriel Curio and Klaus-Robert Müller, who contribute their long-standing expertise in EEG to the joint project. From basic research, it is known that unexpected or odd inputs trigger specific patterns in the brain, such as the so-called mismatch negativity or the P300 (a positive deflection of the EEG after about 300 milliseconds). These patterns can serve as an indicator that the brain has detected a corruption. "We can even find these patterns when the subject says that it hasn't noticed any difference, which is amazing," said Jan-Niklas Antons. The brain seems to take note of more signal corruptions than its owner realizes. Thus, with the EEG approach, the researchers have an entirely new instrument at hand to determine the quality of audiovisual signals in a quantitative and objective way.

Indeed, the researchers have been able to show that their EEG paradigm can be used to reliably assess speech quality. Another goal of their work is to standardize the method and to develop an easy-to-use setup that non-experts can operate, e.g. in usability labs. In this way, the new brain data on perceived quality would be available for the product optimization process.

The perspectives for applications in the telecommunications industry are obvious–not only for the collaborating partner Deutsche Telekom. Using the new methodology, developers might soon identify new critical features in audio and video encoding that were not taken into account previously because their influence on the perception was unknown. As a result, the consumer will be able to look forward to further improved sound and picture quality in their favorite audiovisual media.

Events

Event	Title	Organizer(s)	URL
Dec. 3-8, 2012, Frankfurt am Main	FIAS Winter School: „Intrinsic Motivations: From Brains to Robots“	J. Triesch (BFNT Frankfurt)	www.im-clever.eu/announcements/events/fias-winter-school
Dec. 9-16, 2012, Obergurgl, Austria	FENS-IBRO-Hertie Winter School: „Brain Dynamics and Dynamics of Brain Disease“	A. Kumar, S. Rotter, A. Aertsen (all BCF Freiburg), A. Saria	http://fenswinterschool.org/
Feb. 18-22, 2013, Berlin	BCCN Berlin Winter School: „Ethics and Neuroscience“	J.-D. Haynes (BCCN and BFNT Berlin), F. Bermpohl, V. Casagrande (BCCN Berlin)	www.bccn-berlin.de/ethics
Feb. 19-21, 2013, Göttingen	NWG course: „Transcranial Magnetic and Electrical Stimulation“	A. Antal, W. Paulus (BCCN and BFNT Göttingen, BCOL Transcranial Stimulation)	www.nncn.de/termine-en/kursgoettingen2013/
Feb. 25 - Mar. 1., 2013, Munich	5. G-Node Winter Course: „Neural Data Analysis“	C. Boucsein (BCF Freiburg), T. Wachtler (G-Node)	www.g-node.org/dataanalysis-course-2013
Mar. 6-10, 2013, Delmenhorst	1st Bernstein Sparks Workshop: „Cortical Neurointerfaces“	K. Pawelzik (BGCN Bremen, BFNL Sequence Learning), A. Kreiter (BGCN Bremen), S. Paul, W. Lang, A. Janssen, S. Cardoso de Oliveira, K. Schwarzwälder (both BCOS), D. Poggel, M. Daniel	www.nncn.de/termine-en/corticalneurointerfaces/
Mar. 13-16, 2013, Göttingen	NWG Annual Meeting 2013 with contributions by Bernstein Network members	German Neuroscience Society	www.nncn.de/termine-en/nwg2013/
Aug. 25-29, 2013, Bremen	European Conference on Visual Perception (ECVP) 2013	U. Ernst (BPCN 2010, BGCN Bremen), C. Grimsen, D. Wegener, A. Janssen	www.ecvp.uni-bremen.de
Sept. 25-27, 2013, Tübingen	Bernstein Conference 2013	M. Bethge (BCCN Tübingen, BPCN 2006), J. Lam (BCCN Tübingen)	www.bernstein-conference.de
Oct. 6-11, 2013, Freiburg	BCF/NWG course: „Analysis and Models in Neurophysiology“	S. Rotter, U. Egert, A. Aertsen, J. Kirsch (all BCF Freiburg), S. Grün (D-J Collaboration, BCCN Berlin)	www.bcf.uni-freiburg.de/events/conferences-workshops/20131006-nwgcourse/

The Bernstein Network

Chairman of the Bernstein Project Comittee: Andreas Herz

The National Bernstein Network Computational Neuroscience (NNCN) is a funding initiative of the Federal Ministry of Education and Research (BMBF). Established in 2004, it has the aim of structurally interconnecting and developing German capacities in the new scientific discipline of computational neuroscience and, to date, consists of more than 200 research groups. The network is named after the German physiologist Julius Bernstein (1835–1917).

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