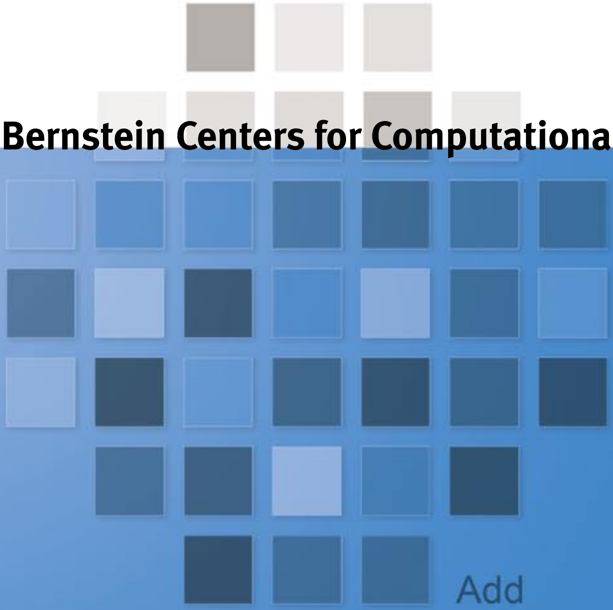
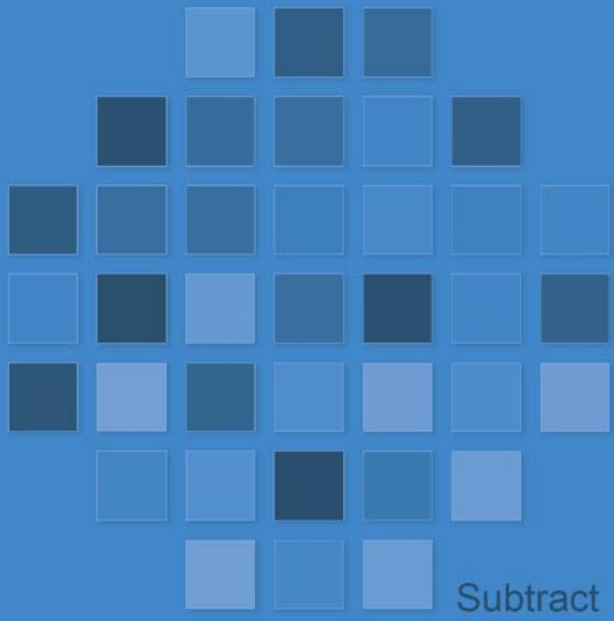
# BCCN Newsletter

**Bernstein Centers for Computational Neuroscience**

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03/2007

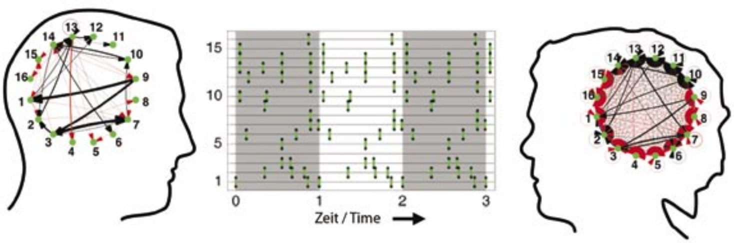
# Two brains – one thought

**Inferring structure from the dynamics of neuronal networks**

When the brain receives sensory input, calculates or remembers, it processes information encoded in a series of neuronal impulses in different nerve cells. The exact timing and dynamics of the spatial pattern of neuronal activity is crucial for information coding. To a certain extent, the dynamics a neuronal network of the brain can produce, i.e. the “thoughts” it can think, is determined by its structure. Nonetheless, two different networks, for instance networks in the brains of two people can still generate the same dynamics and produce the same “thought”. Thus, different structures can display the same functionality. This idea also applies for networks far simpler than that of the human brain. Raoul-Martin Memmesheimer and Marc Timme, researchers at the BCCN Göttingen, have developed a mathematical method to describe the set of all networks that exhibit a given dynamics.

This procedure resembles juggling with many unknowns. Already in a network of 1000 neurons, there are a million possible contacts between any two neurons, each of which can differ in its strength and reaction time. The unimaginably large number of possible networks of a given dynamics resembles a complex figure in a multidimensional space. Here, every point on the surface specifies the data required to determine a network with the desired dynamics. Memmesheimer and Timme have now worked out a mathematical description for this figure. With this, they provide a tool to investigate relations between structure and function of neuronal networks.

To examine the applicability of their model, the researchers calculated all possible networks that generate a given dynamics and simultaneously are structured as simple as possible, e.g. with the minimal number of connections and the minimal strengths of the synapses. “Applied to a real network, one could for instance analyze which structural optimization principles function in evolution”, says Timme. The dynamics of a number of very simple networks that generate repetitive patterns – like insect walking patterns – are already well-understood. Has evolutionary pressure kept the structural complexity of such networks to a minimum, or could there have been other networks with an even simpler structure, yet possessing the same dynamics? Is it possible that many more networks fulfilling the same functional and structural conditions could have evolved? With the help of the new methods developed by Memmesheimer and Timme, we have come a step closer towards understanding these puzzles.




*Different neuronal networks can bear the same pattern of activity - as shown in this example of a network of 16 neurons. Similarly, the exact neuronal structures of the circuits in a human brain can differ from person to person, yet they can display a comparable dynamics and the same functions.*

Sources: Memmesheimer, R.-M. & Timme, M. (2006). Designing the Dynamics of Spiking Neural Networks. Physical Review Letters 97 (18), 188101

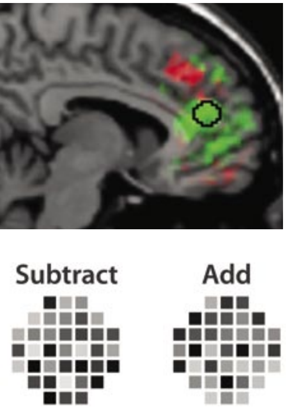
Memmesheimer, R.-M. & Timme, M. (2006). Designing complex networks. Physica D: Nonlinear Phenomena 224 (1-2), 182-201.

# Revealing Secret Intentions

**Scientists decode concealed intentions from brain activity**

Every day we plan numerous actions, such as to return a book to a friend or to make an appointment. How and where the brain stores these intentions has been revealed by scientists arround John-Dylan Haynes from the BCCN Berlin, at that time at the Max Planck Institute for Human Cognitive and Brain Sciences. For the first time they were able to “read” participants’ intentions out of their brain activity. This was made possible by a new combination of functional magnetic resonance imaging and sophisticated computer algorithms.

The researchers let subjects freely and covertly choose between two possible tasks - to either add or subtract two numbers. Even before the participants had seen the numbers and had started to perform the calculation, the researchers were able to recognize the subjects intentions with 70% accuracy based alone on their brain activity. This experimental setup ensured that the intention itself was being read out, rather than brain activity related to performing the calculation or pressing the buttons to indicate the response. “It has been previously assumed that freely selected plans might be stored in the middle regions of the prefrontal cortex, whereas plans following external instructions could be stored on the surface of the brain. We were able to confirm this theory in our experiments”, Haynes explained.




*Regions marked in green: covert intentions before they were carried out. Regions marked in red: intentions that were already being acted upon.*
*The fine-grained activity patterns differ depending on intention.*

The work of Haynes and his colleagues goes far beyond simply confirming previous theories. To reveal the previously invisible, the researchers used a new method called “multivariate pattern recognition”. An important technical innovation of this method lies in combining information across extended regions of the brain to strongly increase sensitivity. The success of the method has a good reason. “The experiments show that intentions are not encoded in single neurons but in a whole spatial pattern of brain activity”, says Haynes. They furthermore reveal that different regions of the prefrontal cortex perform different operations. Regions towards the front of the brain store the intention until it is executed, whereas regions further back take over when subjects become active and start doing the calculation. “Intentions for future actions that are encoded in one part of the brain need to be copied to a different region to be executed”, says Haynes.

These findings also raise hope for improvement of clinical and technical applications. Already today the first steps are being made in easing the lives of paralyzed patients with computer-assisted prosthetic devices and so-called brain computer interfaces. These devices focus on reading out the movement the patient intends to – but is unable to – perform. Previous research has shown that patients can move artificial limbs or computer cursors purely by the power of their mind. The current research by Haynes and colleagues now opens the perspective to read even abstract thoughts and intentions out of patients’ brains. One day even the intention to “open the blue folder” or “reply to the email” could be picked up by brain scanners and turned into the appropriate action.

Quelle / Source: Haynes, J.-D., Sakai, K., Rees, G., Gilbert, S., Frith, C. & Passingham, D. (2007). Reading hidden intentions in the human brain. Current Biology 17, 323–328.

# The role of sleep in predicting epileptic seizures

**The state of vigilance is a crucial factor in the prediction of epileptic seizures.**

Epilepsy is one of the most common neurological diseases. Patients suffer from unpredictable seizures, triggered by a simultaneous discharge of a large number of neuronal cells. Every seizure hits them like a bolt from the blue – they have no way of knowing when a storm of neuronal activity is brewing. There are attempts to identify characteristic changes of neuronal activity that precede a seizure via mathematical analysis of electroencephalograms (EEG). Nonetheless, these approaches are not yet ready for clinical applications. A good prediction model should be very sensitive, i.e. it should ideally detect every approaching seizure so that the patient can rely on the system. High sensitivity, though, also entails a high number of false positives – predicted seizures that never take place. Andreas Schulze-Bonhage, scientist at the Neurocenter of the University Medical Center Freiburg, together with Björn Schelter, Jens Timmer, and other scientists at the Freiburg Center for Data Analysis and Modeling, have found that the number of false predictions can be drastically reduced when the prediction algorithm takes the sleep-wake cycle of the patient into account.

Shortly before a seizure, the brain activity of patients changes with respect to certain criteria. A procedure for predicting epileptic seizures, the so called "Dynamic Similarity Index," compares the brain activity of a patient in a given time window with the respective data from a reference interval that was not followed by a seizure. Using the EEG data of a group of patients, Schulze-Bonhage, Timmer and their colleagues investigated how well epileptic seizures could be predicted with this procedure.

The scientists noted that false predictions mainly occurred at night, when the patients were asleep. They could show that this irregular distribution over a period of 24 hours was caused by the choice of reference interval. Conventionally, the Dynamic Similarity Index uses a period as a reference interval, during which time the patient was awake. If the scientists changed this reference interval to also include a sleep phase, the number of false predictions could be reduced by up to 50%. This involved only a slight attenuation of the sensitivity of the procedure. With the new reference interval, the number of correctly predicted seizures was reduced by 16-26%.

The data of Schulze-Bonhage, Timmer, and their colleagues showed that the sleep-wake rhythm is a crucial factor in the prediction of epileptic seizures. Taking into account that the brain activity differs depending on the state of vigilance can therefore contribute significantly to improving prediction algorithms, eventually making them applicable in clinical settings.

Source: Schelter, B., Winterhalder, M., Maiwald, T., Brandt, A., Schad, A., Timmer, J. & Schulze-Bonhage, A. (2006). Do false predictions of seizures depend on the state of vigilance? A report from two seizure-prediction methods and proposed remedies. Epilepsia 47(12):2058-70.

# Christian Leibold

**From synapses to memory**


Christian Leibold is remaining faithful to the Bernstein Centers for Computational Neuroscience, he is moving from Berlin to Munich, where he is taking up a professorship in the Neurobiology Department of the Ludwig-Maximilians University, of which Benedikt Grothe is the director. The move to Munich is a return to familiar territory for Leibold, who studied here and did his doctorate under the supervision of Leo van Hemmen

Leibold‘s research is varied. However, his different projects have a common denominator: he studies the role of cellular changes in individual neuronal connections in the context of the brain as a whole. During brain activity, information is passed on from cell to cell in the form of short electric impulses, – we say that the neurons “fire”. This flow of information between the neurons may alter the connections between them, called synapses. When cell A stimulates postsynaptic cell B, i.e. A fires shortly before B, the synapse between A and B is strengthened. It is assumed that this process, known as synaptic plasticity, is the cellular basis of learning. In this way information is stored in the synapses. But how can this knowledge about cellular processes be extrapolated to the learning processes in the brain? What effect does synaptic plasticity have on the overall function of the brain?

Leibold has been working on this topic since his doctorate. It all started with the question of how animals develop sound localization. In the first days after birth an animal is not yet able to locate sounds. This ability must first be developed through self-organization processes of the nervous system and is based on synaptic plasticity. If a sound comes from the right, it reaches the right ear before the left. The detection of this minimal time difference, in the range of only a few microseconds, is an important mechanism which many animals – and also humans – use to locate sounds. This is arguably one of the most accurate mechanisms that the brain has ever produced. The question of precisely which learning rules underlie the development of sound localization has been one of Leibold’s research interests since his doctorate and is increasingly becoming one of the main focuses of his work. The new research environment plays a big role here, as he explains: “In Benedikt Grothe’s department nearly everyone works on a topic related to spatial hearing”. Most of the scientists there work experimentally, Leibold, as a theoretician, is a valuable addition to the department.

It is still a mystery how neuronal signals are able to detect the tiny time difference, which occurs when a sound coming from one side reaches one ear before the other. In mammals, for example, while we know that inhibitory neuronal connections play an important role here, the temporal resolution of these inhibitory synapses is, however, too slow by several orders of magnitude. “I am currently pursuing the idea that not only the temporal accuracy of the inhibition but also the amplitude of its synaptic current must be precisely regulated so that sound localization can develop”, says Leibold. The next question which he wishes to investigate is how such an adaptation occurs in the course of development, i.e. during ontogeny. ▸

▶ Leibold's interest in the role of the synapse in the context of the brain is, however, not restricted to the development of sound localization. A further focus of his work, which he pursued in Berlin in collaboration with Richard Kempter, is how memories are stored by means of synaptic plasticity. When we learn something, the strength of some synapses is changed at a cellular level. But how is this information, which is stored in the synapses, retrieved?

Information is encoded in the brain within the dynamics of neuronal networks, i.e. neurons fire in a defined spatial-temporal pattern. Each change in a synapse has an effect on the dynamics of the network. Newly acquired information which is stored in the synapses, is read out via such changes in the network dynamics. "Our main interest is understanding the interaction between network dynamics and memory retrieval," says Leibold. How precisely must a network be organized in order for it to be able to learn? How do certain characteristics, like the number or the strength of the connections or the ability of individual synapses to change, alter the storage capacity of the network or the accuracy of the reproduction of information?

Leibold investigates the effect of synaptic plasticity on the network dynamics and thus on the retrieval of information using the example of the sense of orientation in the rat. When the rat runs around in its cage, so-called "place-cells" in its brain indicate where the rat currently is. Each place-cell is assigned to a particular area; as soon as the rat enters this area, the cell becomes active. The brain is able to calculate the exact position of the rat from the combination of different place-cells. However, not only the position is represented by the neuronal activity of the network. In every moment, the precise timing of the brain's neural activity also encodes the time period each neuron has already been active. In this way, the movement of the rat in the last few seconds is stored in compressed form. Leibold, Kempter and their colleagues in Berlin investigated how such a temporal code comes about and what role synaptic change plays here – an area of research which Leibold will continue to pursue in the future. In this way the scientists are bridging the gap between cellular "memory", which is seen in synaptic change, and short-term memory in the context of the brain as a whole.

# Master Program Computational Neuroscience in Berlin

In the fall of 2006 the Master Program Computational Neuroscience started in Berlin. Meanwhile, eight students from Germany, India, Israel, and Pakistan have completed the first of four terms. What was offered to them?

The Master Program is supported by Berlin Technical University (TU), Humboldt-Universität Berlin zu Berlin (HU), and Charité Universitätsmedizin Berlin (Charité) and was set up by Klaus Obermayer (TU) and by Laurenz Wiskott together with other members of the Bernstein-Center Berlin. It is envisaged to comprehensively teach students in the electrifying field between experimental and theoretical Neuroscience. The language of instruction is English. The Program addresses German and international students from science, engineering, computer science, and medicine. In the first year students are brought to a common level of knowledge. The second year focuses on scientific work in the laboratories and working groups of the Bernstein-Center. The Bernstein-Center comprises of TU, HU, and Charité, and also Freie Universität Berlin, Max-Delbrück-Center for Molecular Medicine, and Fraunhofer Institute Computer Architecture and Software Technology, as well as the Wissenschaftskolleg zu Berlin.

In Berlin the young neuroscientists benefit from a multitude of teaching offerings; in addition to the well-established Master and PhD Program, "Medical Neuroscience," this year the graduate school "Berlin School of Mind and Brain" will start and the "Berlin Mathematical School" has begun its teachings in parallel to the Master Program. On the teachers' side there is also a spirit of beginning: the newly appointed Bernstein Professors Michael Brecht, John-Dylan Haynes, and Felix Wichmann contribute significantly to the teachings of the Master Program.

Until March 15th, interested students can apply to the master program, to enlarge it by a class of 2007 or to vitalize the newly starting PhD Program.

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Further information: http://www.bccn-berlin.de/teaching
Daniela Pelz, daniela.pelz@bccn-berlin.de

# International Neuroinformatics Coordinating Facility (INCF)

Knowledge in the field of neuroscience is growing at a stunning pace. Tens of thousands of scientists worldwide contribute new data, which is frequently not adequately archived and cross-linked. At the same time, the neurosciences are addressing increasingly complex questions. To understand how the brain functions, how it codes information, stores memories, and generates thoughts, increasingly more intricate algorithms for the analysis of experimental data and elaborate computational models are devised through the "Computational Neurosciences." The goal of the International Neuroinformatics Coordinating Facility (INCF) is on the one hand to bundle existing experimental knowledge and on the other hand to advance approaches in data analysis and modeling and to make either freely accessible to scientists.

The Global Science Forum (GSF) of the OECD has initiated the INCF to further the development of Neuroinformatics ▶

▶ and Computational Neuroscience as a global effort with the support of all ministers of research within OECD. To this end, data is organized and technical know-how is being developed in several national nodes and then linked internationally. A German Neuroinformatics Platform, first established in 2004, serves as the INCF National Node of Germany. The platform is chaired by Andreas Herz, Humboldt University and BCCN Berlin. Coordinator of node operations is Raphael Ritz. A formal transition to a status as INCF National Node will take place in 2007. The pilot project is funded through a grant from the German Ministry for Science and Education (BMBF).

Further information: http://incf.org
http://www.neuroinf.de

# Upcoming events

**Inauguration of the BCCN Göttingen**

The Bernstein Center Göttingen will be inaugurated on March 28th, just before the well-known Göttingen Neurobiology Conference. In the first two years of its existence, present research groups have been supplemented through a new professorship and three junior research groups. The center is now optimally equipped to fundamentally advance the field of computational neuroscience and to realize innovative applications in the field of robotics and neuroprosthetics in the coming years. With a view to the future, this will now be celebrated. The inauguration will be attended by international notables from science and politics. In an invited lecture, Barry J. Richmond from the National Institute of Mental Health will provide an insight into the structure and precision of neuronal responses.

Further information:
Tobias Niemann, contact@bccn-goettingen.de

**Opening of the BCCN building in Berlin and inaugural lectures**

The opening ceremony for the new BCCN building in Berlin will take place on May 7th and 8th. The event will be combined with the inaugural lectures of the BCCN newly appointed Bernstein Professors Michael Brecht, John-Dylan Haynes, and FelixWichmann, as well as the inaugural lecture of Laurenz Wiskott.

Further information:
Margret Franke, margret.franke@bccn-berlin.de

**Berlin Colloquium**

The “Berlin Colloquium” of the Daimler-Benz Foundation will take place on May 9th, following the opening of the BCCN building. The topic of the colloquium is “Mind researchers – what our brain reveals about our thoughts.” The colloquium is being organized by Gabriel Curio and John-Dylan Haynes, scientists at the BCCN Berlin.

Further information: http://www.daimler-benz-stiftung.de/home/events/berlin/de/start.html

# Personalia

**George Gerstein guest at the BCCN Freiburg**

George Gerstein, Professor Emeritus from the University of Pennsylvania (Philadelphia, USA) visited the BCCN Freiburg for a 3-month research stay, supported by the BCCN Freiburg’s visiting scientist program. During the visit, a new measure for detecting synfire chain activity was developed, leading to new avenues for collaborative research with this pioneer of computational neuroscience.

More detailed reports of this and other visits to the BCCN Freiburg can be found under:
http://www.bccn.uni-freiburg.de/news/mobil

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*Cover image: John-Dylan Haynes investigates how the brain stores concealed intentions. The fine-grained activity patterns differ depending on intention.*

# Impress

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