Bernstein Network Computational Neuroscience

Recent Publications
- Short-term memory
- Spatial memory
- Imaging techniques
- Decision making
- Perceptual learning
- Fear model
- Data processing
- Basis of hearing

News and Events
- Personalia
- Bernstein members elected into NWG council
- DAAD funding for BCCN Tübingen
- New D-J funding opportunity in CNS
- Visit of Minister Wanka in Göttingen
How bees learn which odors to follow

How successful busy bees are in their search for food depends largely on how well they can, based on their odors, detect nectar-rich flowers from a distance and distinguish them from less promising plants. How do bees memorize the connection between the odor of a flower and whether or not it bears nectar? Can one find this association in the brain of the bee? Researchers around Randolf Menzel at the Bernstein Center Berlin have traced down odor memory to a certain area of the bee brain.

The researchers caught nectar-collecting bees when they were about to swarm out from their hive, and “sent them to school” in their lab. The curriculum contained five different artificial fragrances. First, the bees were introduced to all five odors. Then, in a learning phase, one of the odors was always followed by presentation of a drop of sugar solution, while another odor went unrewarded. This form of classical Pavlovian conditioning is based on the proboscis extension reflex, which is elicited when the bees’ antennas get into contact with sweet liquids. The bees quickly learned to extend their probosces and collect the sugar solution whenever the rewarded odor was presented. This response was faithfully maintained for 3 hours after learning.

To investigate the neuronal basis of this memory process, the biologist Martin Strube-Bloss measured electrical reactions of certain nerve cells, namely the output neurons in the mushroom bodies of the bee brain, which had already been raised as candidates for learning. The result was surprising. During the learning phase, the activities in the neurons did not change at all. But 3 hours after learning, there was a change: more neurons responded to the rewarded stimulus, and the responses to the rewarded stimulus were stronger. So the researchers had actually found a memory trace. Because of its time delay, they could even conclude that it was not due to the learning process itself or to short-term memory, but that they had rather identified the seat of long-term odor memory!

Mathematical analysis by Martin Nawrot showed that the memory trace in the mushroom body is extremely reliable. Already 150 ms after presentation of an odor the researchers could tell, just on the basis of the output neurons of the mushroom body, whether it was the rewarded odor or not. So it seems that the bee could safely rely on this group of neurons in order to tell whether an odor is promising, or - in the wild - which odor it is worthwhile to follow in order to find a nectar-bearing flower.

On the basis of their results, the researchers are now developing a computer model of the bee brain that can associate virtual odors with rewards and is able to take decisions on the basis of what it has learned. In the near future, such artificial brains are then to be applied in biomimetic robots.

Place cells lie in wait

Memories, places and actions are stored in our brain. But what determines for a certain task the contribution of specific nerve cells out of billions of cells? For a long time scientists debated whether the cell’s activation in a specific brain region during a particular case is random or not. Jérôme Epsztein, Michael Brecht, and Albert K. Lee of the Bernstein Center Berlin and the Humboldt University of Berlin now proved that, in the example of spatial memory in rats, later active cells differ early from their quiet neighbors. Their findings push the understanding of memory formation a major step forward.

If we move in an unknown environment, a neuronal map is created in our brain. Memory function is particularly well known in rats. Cells of the rat’s hippocampus ensure that the animal always knows its location. Each of these so-called “place cells” is particularly active when the rat is in a certain area, the cell “fires”. Thus, each site is coded by specific cells. However, in the corresponding region of the brain are also cells that do not fire, they are “silent”. This activity pattern and the selection of active cells is very specific for a particular environment.

Using a sophisticated method, Jérôme Epsztein, Michael Brecht, and Albert K. Lee succeeded for the first time in measuring the electrical properties within individual cells of the hippocampus, while the animals were freely moving. They studied the electrical baseline and the current level from which individual cells responded with a stimulus-response, the so-called threshold. The scientists measured cell activity before, during and after exploration. Therefore, they could compare the behavior of silent cells and place cells before the first site-specific activity. They found that place cells showed from the outset a lower threshold and different discharge patterns.

The scientists assume cell-intrinsic properties to be responsible for these differences. This triggers a series of new questions: What factors account for the differences? How are these cell properties set? Are these properties changed if other cells are active in a different environment? In humans, the hippocampus is central for the transformation of the content of short-term into long-term memory. Dysfunctions in this brain region result in anterograde amnesia. In such cases, previous memories remain, but new information cannot be permanently stored. With their results, the scientists contribute to a better understanding of our memory.

How clear is our view of brain activity?

Imaging techniques have become an integral part of the neurosciences. Methods that enable us to look through the human skull and right into the active brain have become an important tool for research and medical diagnosis alike. However, the underlying data have to be processed in elaborate ways before a colourful image informs us about brain activity. Scientists from Freiburg and colleagues were now able to demonstrate how the use of different filters may influence the resulting images and lead to contradicting conclusions.

In the journal Human Brain Mapping, Tonio Ball of the Bernstein Center Freiburg and colleagues from the universities of Oldenburg, Basel and Magdeburg demonstrate how variable the results of imaging techniques like functional Magnetic Resonance Imaging (fMRI) can be – depending on the way how the original data are filtered. The use of filtering algorithms is necessary in order to separate meaningful information from inherent noise that is part of every data set. These filters have different “mesh sizes” or widths, and are indispensable in the first place to reveal activity patterns that span different scale sizes. In most cases, only a filter of one specific width, which differs from study to study, is employed.

Tonio Ball and colleagues systematically investigated the influence of the mesh size of these filters on the resulting imagery of brain activity. They conducted an experiment during which test persons had to rate music by pressing a button while lying in an fMRI scanner. During this task, brain regions responsible for hearing, vision, and arm movements were active. The scientists treated the gained data with filters of different widths and found surprising results: The filters had a marked influence on the outcome of the brain scan analyses, showing increased brain activity in one region in one case, and in a different region in the other case. Even smallest changes in filter width led to areas of the brain appearing to be either active or inactive. This effect can ultimately lead to widely disparate interpretations of such a scan. Tonio Ball and colleagues therefore stress the importance of taking into account the effect of filtering in future interpretations of fMRI studies. This way, scientists won’t run the risk of inadvertently skewing our view of the brain.

Text and translation: Gunnar Grah, Bernstein Center Freiburg

Right, left or straightforward?

Penalty kick: The striker is facing the opponent goalkeeper. He has to decide where to shoot: straight to where the keeper stands, assuming that he will jump into one of the corners, or aiming at the empty space next to the keeper? Both options require fundamentally different planning of the movement. Aiming for the keeper means aiming directly for a physical and visual target. Aiming for the empty corner means aiming for a rule-based goal, which has to be inferred from the position of the physical target (the keeper) and therefore is an indirect aim. Scientists at the German Primate Center (DPZ) and the Bernstein Center for Computational Neuroscience in Göttingen have now uncovered basic neuronal principles according to which monkeys, and putatively also humans, choose between multiple rule-based motor goals.

“Until recently, it was unknown how decisions about rule-based goals are made in an uncertain choice situation,” says Christian Klaes, first author of the study. The researchers were specifically interested in the question of whether we decide on an abstract level, meaning between direct (goalkeeper) versus indirect (empty space), or whether we plan different actions completely before we decide between the two alternative movement plans. The scientists assumptions: If decisions are made on an abstract level, only those cells in movement planning areas of the brain should be active that prepare the action being executed shortly afterwards. If, on the other hand, alternative actions are planned in parallel before a decision is made, all neurons should be involved preparing either of the two actions.

The researchers trained rhesus monkeys on a decision task and measured neural activity in cortical sensorimotor areas, to test which neurons are involved in the different stages of the decision. During the experiment, the monkeys received a short visual spatial cue. After a memory phase, the animals were instructed to either touch a direct goal, the memorized cue position, or an indirect goal, the position on the opposite side of the monitor. Often however, the monkeys only received the spatial cue without further instruction. They then had to decide by themselves, which side to choose.

Remarkably, it was found that both the neurons for the direct and indirect spatial goals were active. “Our results show that the brain plans the alternative movement (...) in parallel before it decides,” explains Klaes. If the decision process is distributed across multiple levels of processing, a more comprehensive cost-benefit analysis could become possible. As Gail concludes: “For our striker it is not enough to know that the keeper on most previous occasions jumped to the left corner, if, at the same time, he knows that he himself is very poor at kicking towards the other corner. Both factors should determine the striker's decision in the end.”

Text and translation: DPZ press office, Alexander Gail (modified)

**Reading the fine print of perception**

Wine connoisseurs recognize the vintage at the first sip, artists see subtle color variations and the blind distinguish the finest surface structures. Why are they considered superior to laymen in their field? Researchers at Charité – Universitätsmedizin Berlin, the Bernstein Center Berlin, the NeuroCure Cluster of Excellence and the Otto-von-Guericke University of Magdeburg have determined which areas of the brain are particularly active when perceptual skills are trained. In the journal Neuron, they show how one becomes an expert: not by visual processing of more details one becomes an expert. Instead, we learn by improving our ability to distinguish subtle details better.

Scientists from the research group of John-Dylan Haynes, professor at the Bernstein Center Berlin and Director of the Berlin Center for Advanced Neuroimaging at the Charité, have examined, together with colleagues from Magdeburg, how brain activity changes across the course of a learning process. For this, they measured changes in nerve cell activity in the brain with the help of functional Magnetic Resonance Imaging (fMRI). Their reasoning was: if the learning effect is primarily based on an increasingly detailed representation of the stimuli, then the visual center should be involved in learning. However, if the progress is due to an improved interpretation of the stimuli in the brain, then learning should involve brain areas for decision making.

“The fMRI measurements clearly showed that the activity in the visual center remained the same during the entire learning process,” says Haynes. “However, a region in the prefrontal cortex, which plays an important role in the interpretation of stimuli, was becoming more and more involved”. Hence, the researchers concluded that the learning process takes place at the level of decision making. “If our perception sharpens during learning, then this is not so much due to the fact that more information reaches the brain,” concludes Haynes. “Instead, we learn more and more to correctly interpret the given information. We see details in pictures that we were not aware of at the beginning.”

The researchers investigated the learning processes using simple geometric images. In the experiment, the twenty subjects for a short time looked at a small stripe pattern on a screen. They had to decide in which direction the stripes pointed. Over time, they could recognize details better and better. “Now it would be possible to use our approach to investigate whether similar effects also hold true, say, for wine connoisseurs or top chefs,” explains Haynes.

Thorsten Kahn, PhD student at the Bernstein Center for Computational Neuroscience developed a mathematical model for this study that very precisely predicts the learning processes in the brain. “Such models are very important to systematically analyse the data,” says the young researcher. “The collaboration between modeling and data collection works particularly well in the Bernstein Center, where psychologists, physicians, physicists and mathematicians work together.”

Translation: Press office, Charité Berlin

---

Masked fears

Fear is a natural part of our emotional life and acts as a necessary protection mechanism. However, fears sometimes grow beyond proportions and become difficult to shed. Scientists from Freiburg, Basel and Bordeaux have used computer simulations to understand the processes within the brain during the formation and extinction of fears. In the scientific journal PLoS Computational Biology, Ioannis Vlachos from the Bernstein Center Freiburg and colleagues propose for the first time an explanation for how fears that were seemingly overcome are actually only hidden.

The reason for the persistency of fears is that, literally, their roots run deep: Far below the cerebral cortex lies the “amygdala”, which plays a crucial role in fear processes. Fear is commonly investigated in mice by exposing them simultaneously to a neutral stimulus – a certain sound, for example – and an unpleasant one. This leads to the animals being frightened of the sound as well. Context plays an important role in this case: If the scaring sound is played repeatedly in a new context without anything bad happening, the mice shed their fear again. It returns immediately, however, if the sound is presented in the original, or even a completely novel context. Had the mice not unlearned to be frightened after all? The fact that fears can be “masked” has been known for some time. Recently, two co-authors of the present study discovered that two groups of nerve cells within the amygdala are involved in this process.

By creating a model of the amygdala’s neuronal network, Ioannis Vlachos and colleagues were now able to find an explanation for how such a masking of fears is implemented in the brain: One group of cells is responsible for the fear response, the second for its suppression. Activity of the latter inhibits the former and, thus, prevents fear signals to be transmitted to other parts of the brain. Nevertheless, the change in their connections that resulted in an increased activity in the fear-coding neurons in the first place is still present. As soon as the masking by the fear-suppressing neurons disappears, for example by changing the context, these connections come into action again – the fear returns. According to the scientists, these insights can be transferred to us humans, helping to treat fears more successfully in the future.

Text and translation: Gunnar Grah, Bernstein Center Freiburg

Faster by teamwork

Groups of neurons in the cerebral cortex can process and transmit signals significantly faster than previously thought. Scientists at the Max Planck Institute for Dynamics and Self-Organization, the Bernstein Center Göttingen and the University of Göttingen have shown in theoretical calculations that the communication speed of a group of neurons is only limited by the speed with which individual neurons fire a signal. In this way, groups of neurons can handle several hundred stimuli per second.

Each neuron in the cerebral cortex is under “constant fire”: it incessantly receives electrical impulses, called spikes, from about 10,000 other nerve cells. However, it itself emits only about ten spikes per second. After each spike, a neuron requires a short recovery time. If further spikes hit the cell in direct succession, it is not ready to fire and cannot process the new information. The neuron remains silent. Scientists have traditionally assumed that the brain can only handle signals with frequencies of up to 20 hertz. But recent experiments have shown that groups of neurons can respond much faster than previously thought. Neuronal networks can transmit signals of up to 200 hertz. So far, this behavior could not be explained.

“A theoretical model of this behavior must take the detailed dynamics of electrical currents in the cell membrane into account,” Fred Wolf explains the approach of his study. The large number of incoming stimuli constantly causes voltage fluctuations on the cell membrane. But only if they exceed a certain value the neuron generates an own impulse. This process of firing takes only a few fractions of a millisecond.

The scientists have now succeeded for the first time to include this complicated process in a model, such that the response of a neuronal group could be computed directly from the incoming signal. “If the neuronal group does not produce an output anymore, this indicates that the input signal was too fast and has overburdened the neurons,” Wei Wei, first author of the study, illustrates the basic idea of the model. The researchers’ calculations show that the upper limit for the processing speed depends only on the time that it takes the neuron to induce an impulse. Teams of neurons can thus easily receive and transmit high-frequency signals of several hundred hertz.

The new results could also be of great significance for developmental neurobiology. Researchers have known for a long time that in infants and young animals, visual experiences only from a certain age onwards generate new connections of nerve cells in the cerebral cortex. These new results could now explain this phenomenon. Siegrid Löwel, developmental neurobiologist and member of the Bernstein Center Göttingen explains: “Generating new connections only works reliably if the neurons can respond quickly and accurately to incoming sensory information.” If experiments would prove that the neurons of young animals are not able to process signals as fast as adult animals, this would confirm that explanation.

Text: Birgit Krummheuer (shortened)

How flies hear you whisper

In the inner ear, sensory cells transform incoming sound waves into electrical signals. Scientists now found out that a specific ion channel in the auditory system of the fruit fly Drosophila is apparently responsible for signal transduction in the most sensitive type of sensory cells. It regulates the fly’s ability to perceive the faintest sounds. Furthermore, the scientists showed for the first time that not one but several types of ion channels act as sound transforming units in the ear. The study, published in Current Biology, was conducted by Martin Goepfert in the Collaborative Research Centre “Cellular mechanisms of sensory signal processing”, at the Department of Cellular Neurobiology at the University of Göttingen and at the Bernstein Center Göttingen.

For years, scientists have been searching for ion channels whose loss causes complete deafness – without these sound transducers, ears cannot produce neuronal signals. But despite numerous studies on the auditory systems of fruit flies, mice, rats and humans, none of these ion channels could be identified yet. In their experiments, the Göttingen scientists removed the known ion channel “NompC” from the fly’s ears. It turned out that the flies could hear even without the ion channel, but that their hearing sensitivity was greatly reduced. Only when the insects were exposed to very loud sounds, nerve signals were transmitted from the ears to the brain. The scientists could trace the flies’ ability to hear weak sounds to a certain group of particularly sensitive sensory cells in the ear. It turned out that exactly this group of cells requires the NompC channel for sound conversion.

The channel also exists in the surrounding, less sensitive, sensory cells. But sound conversion in these cells must be based on a different ion channel, since loss of the NompC channel does not impair sound conversion in these cells. Because of their discovery, the researchers will have to change their scientific approach. “If we continued to restrict our search to those ion channels whose loss causes complete deafness, we probably would never find the sound transducers in the ear,” says Thomas Effertz, first author of the study.


Confocal microscope image: receptors in the fly’s ear (green), superimposed: receptor responses to sound (red to yellow).
**News and Events**

**Personalia**

**Onur Güntürkün** (BFNL Sequence learning, Ruhr-Universität Bochum) received the Medal of Merit of North Rhine-Westphalia for his merits for the academic, personal and social exchange between Germany and his country of birth Turkey.  
www.idw-online.de/de/news417517 (in German)

**Gregor Schöner** (BGCN Bochum, BFNL Learning from behavioral models, Ruhr University Bochum) coordinates the new EU project “Neural Dynamics”. The project aims at developing robots that can, like humans, orient in their environment. © Gregor Schöner

**Philipp Hövel** is leader of the new junior research group “Nonlinear Dynamics and Control in Neuroscience” at the Bernstein Center Berlin. The position was established in the center’s second funding period at the Technische Universität Berlin.  
www.idw-online.de/de/news410951 (in German)

**Hermann Wagner** (BCOL Temporal Precision, RWTH Aachen) was elected member to the German National Academy of Sciences Leopoldina, and, for the term 2011/2012, President of the German Zoological Society.  
www.nncn.de/nachrichten-en/leopoldinawagner

**Bernhard Schölkopf** (BCCN Tübingen, BFNT Freiburg-Tübingen, Max Planck Institute for Intelligent Systems, Stuttgart and Tübingen) receives the Max Planck Research Award 2011, endowed with 750.000 euros. Each year, the award is conferred to two scientists – one in Germany and one working abroad – who are internationally renowned and from whom further top scientific achievements in the framework of international collaborations can be expected.  
www.idw-online.de/de/news413142 (in German)

**Felix Wichmann** was appointed new W3 Bernstein Professor for Neural Information Processing at the BCCN Tübingen and the Wilhelm Schickhard Institute for Computer Sciences at the Eberhard Karls University Tübingen.  
New D-J funding opportunity in CNS

On May 20, 2011, BMBF, DFG and JST published guidelines for the new funding scheme entitled “Germany-Japanese Collaboration in Computational Neuroscience”. The new funding measure has the objective to establish transnational research projects and aims at deepening already existing collaborations between researchers of these two countries and raise them to a new level. Deadline for applications: August 8, 2011.

www.nncn.de/nachrichten-en/djcall/

Minister Wanka visited Bernstein Center Göttingen

In February 2011, Prof. Dr. Johanna Wanka, Science Minister of the state of Lower Saxony, visited the Bernstein Center Göttingen to get informed about the development and perspectives of the Center and the Bernstein Focus Neurotechnology Göttingen. She was particularly impressed by the Bernstein Center’s interdisciplinary approach. She was convinced by the fact that students receive simultaneous high-level training in two very different scientific disciplines: neurobiology and theoretical physics.

www.ds.mpg.de/Aktuell/pr/20110225/index.html (in German)

DAAD funding for doctoral program at BCCN Tübingen

Within the framework of the DAAD funding program “International doctorate in Germany” (International promovieren in Deutschland), the Bernstein Center Tübingen receives a three year funding for its doctoral program “Neural Information Processing”. The program further strengthens the internationalization of postgraduate training at the Bernstein Center Tübingen.

Five Bernstein members elected into NWG council

In the beginning of 2011, the members of the German Neuroscience Society (NWG) have elected the society’s new Executive Committee for the 2011-2013 term. The following Bernstein members were elected council members:

President:
- Herta Flor (BCCN Heidelberg-Mannheim)

Treasurer:
- Andreas Draguhn (BCCN Heidelberg-Mannheim, BGCN Heidelberg)

Section spokesmen:
- Computational Neuroscience:
  Fred Wolf (BCCN and BFNT Göttingen, BFNL Visual Learning, BCOL Action Potential Encoding)
- Developmental Neurobiology/Neurogenetics:
  Michael Frotscher (BCF Freiburg)
- Systems Neurobiology:
  Stefan Treue (BCCN and BFNT Göttingen)

http://nwg.glia.mdc-berlin.de/de/news/ (in German)
## Upcoming events

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organizers</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 8-9, Tübingen</td>
<td>Symposium: Retinal Coding in Light of Clinical Applications</td>
<td>Thomas Euler, Matthias Bethge, Judith Lam (BCCN Tübingen)</td>
<td><a href="http://www.bccn-tuebingen.de/events/symposium-a.html">www.bccn-tuebingen.de/events/symposium-a.html</a></td>
</tr>
<tr>
<td>June 14-17, Espoo, Finland</td>
<td>International Conference on Artificial Neural Networks (ICANN) 2011</td>
<td>E. Oja (K.-R. Müller, K. Obermayer, BCCN &amp; BFNT Berlin, area chairs)</td>
<td><a href="http://www.cis.hut.fi/icann2011/">www.cis.hut.fi/icann2011/</a></td>
</tr>
<tr>
<td>Aug. 1-26, Bedleowo, Poland</td>
<td>16th Advanced Course on Computational Neuroscience (with Bernstein members as faculty)</td>
<td>D. Jäger, P. Latham, Y. Prut, C. van Vreeswijk, D. Wojcik, T. Bem</td>
<td><a href="http://www.neuroinf.pl/accn">www.neuroinf.pl/accn</a></td>
</tr>
</tbody>
</table>
## Upcoming events (cont.)

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Organizers</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 4-6, Boston, USA</td>
<td>4th INCF Congress of Neuroinformatics</td>
<td>International Neuroinformatics Coordinating Facility (INCF)</td>
<td><a href="http://www.neuroinformatics2011.org">www.neuroinformatics2011.org</a></td>
</tr>
<tr>
<td>Oct. 4-6, Freiburg</td>
<td>Bernstein Conference 2011</td>
<td>U. Egert, A. Aertsen, F. Dancoisne, G. Grah, G. Jäger, B. Wiebelt (BCF Freiburg), S. Cardoso (BCOS)</td>
<td><a href="http://www.bc11.de">www.bc11.de</a></td>
</tr>
</tbody>
</table>
The Bernstein Network

Chairman of the Bernstein Project Committee: Andreas Herz (Munich)
Deputy Chairman of the Project Committee: Theo Geisel (Göttingen)

Bernstein Centers for Computational Neuroscience (Coordinator)
Berlin (Michael Brecht)
Freiburg (Ad Aertsen, Director: Stefan Rotter)
Göttingen (Theo Geisel)
Heidelberg / Mannheim (Daniel Durstewitz)
Munich (Andreas Herz)
Tübingen (Matthias Bethge)

Bernstein Focus: Neurotechnology (Coordinator)
Berlin (Klaus-Robert Müller)
Frankfurt (Christoph von der Malsburg, Jochen Triesch, Rudolf Mester)
Freiburg – Tübingen (Ulrich Egert)
Göttingen (Florentin Wörgötter)

Bernstein Focus: Neuronal Basis of Learning (Coordinator)
Visual Learning (Siegrid Löwel)
Plasticity of Neural Dynamics (Christian Leibold)
Memory in Decision Making (Dorothea Eisenhardt)
Sequence Learning (Onur Güntürkün)
Ephemeral Memory (Hiromu Tanimoto)
Complex Human Learning (Christian Büchel)
State Dependencies of Learning (Petra Ritter, Richard Kempter)
Learning Behavioral Models (Ioannis Iossifidis)

Bernstein Groups for Computational Neuroscience (Coordinator)
Bochum (Gregor Schöner)
Bremen (Klaus Pawelzik)
Heidelberg (Gabriel Wittum)
Jena (Herbert Witte)
Magdeburg (Jochen Braun)

Bernstein Collaborations for Computational Neuroscience

Bernstein Award for Computational Neuroscience
Matthias Bethge (Tübingen), Jan Benda (Munich), Susanne Schreiber (Berlin), Jan Gläscher (Hamburg), Udo Ernst (Bremen)

German INCF-Node (Coordinator)
G-Node (Andreas Herz, Director: Thomas Wachtler-Kulla)

German–US-American Collaborations (Coordinator)
Berlin–Cambridge (Klaus Obermayer)
Freiburg–Cambridge (Andreas Schulze-Bonhage)
Lübeck–New York (Lisa Marshall)
Mannheim–Los Angeles (Thomas Hahn)
Munich–San Diego (Christian Leibold)

The Bernstein Network for Computational Neuroscience is funded by the Federal Ministry of Education and Research (BMBF).

Imprint

Published by:
Coordination Site of the National Bernstein Network Computational Neuroscience
www.nncn.de, info@bcons.uni-freiburg.de

Text, Layout:
Simone Cardoso de Oliveira, Johannes Faber, Kerstin Schwarzwälder (News and Events)

Editorial support:
Coordination assistants in the Bernstein Network

Design: newmediamen, Berlin

Print: Elch Graphics, Berlin