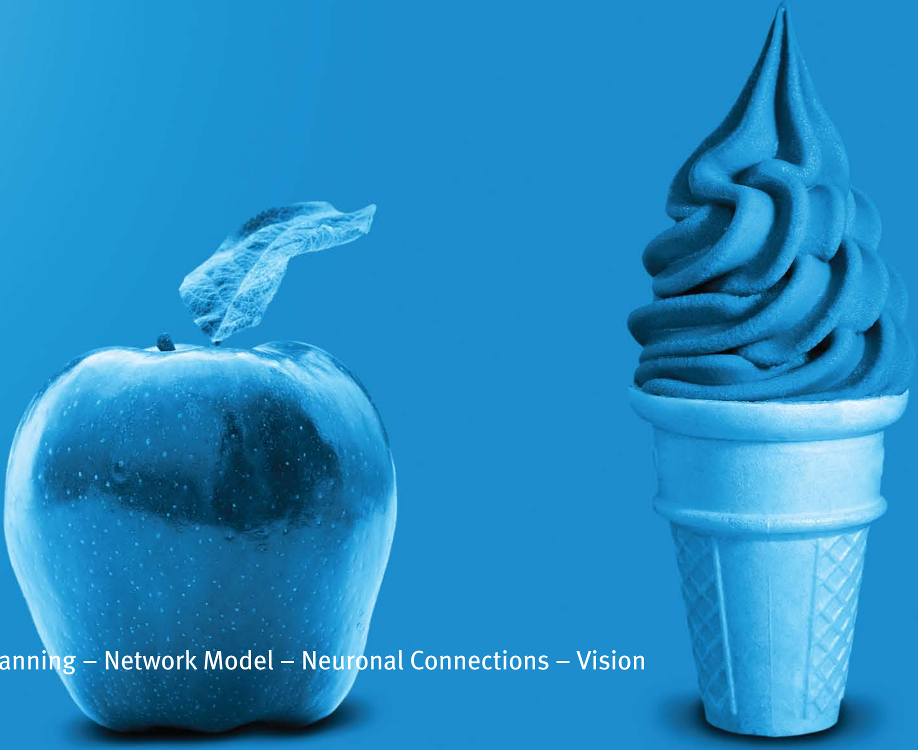
Bernstein Network for Computational Neuroscience

Bernstein Newsletter



Recent Publications
Learning – Movement Planning – Network Model – Neuronal Connections – Vision

Meet the Scientist
Jan Gläscher

News and Events
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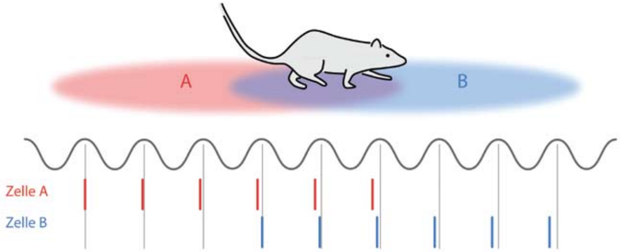
Freiburg – Research Training Group Berlin – Courses and Events

12/2009

Single-trial learning

Walking from the kitchen down the hall and into the living room may take a few seconds. The reason that we can remember having done so is not entirely obvious from a neuroscience point of view. To memorize a sequence of events, they have to be replayed in the brain within a few milliseconds. Previous studies have suggested that the brain could achieve this through a mechanism called phase precession. The phenomenon of phase precession has now been studied by a group of researchers around Richard Kempter, Humboldt Universität zu Berlin and Bernstein Center Berlin, together with scientists at the Rutgers University in Newark, New Jersey, USA. They have analyzed brain activity of rats running back and forth between two water sources. In contrast to previous studies in which data from different trials were pooled, the scientists have now analyzed each trial separately. “The brain should be able to process and store information also during a single trial. With our approach we could show that phase precession can explain the temporal compression of sequences of events within the brain also in single trials and that phase precession actually works far more precisely than previously assumed,” Kempter explains.

So called “place cells” in the brain of humans and animals are thought to be essential for us to be able to navigate in space. When one walks through a defined area in a room, the corresponding place cells are activated. If a rat, for example, crosses the overlapping place fields A and B, first the place cell A, then the cells A and B and finally the place cell B will be activated (see figure). This sequence of events will take place in a time frame of seconds. For neurons, though, several seconds almost seem like eternity. Only if cell A sends out an impulse – one says it “fires” – a few milliseconds before cell B, the connections between two cells are strengthened and the brain may be able to memorize the sequence “AB”. Such a compression of the sequence of events is coded in the brain through phase precession. Place cells follow a given rhythm in the brain; they fire in a defined beat. But they don’t precisely stick to this beat – while the rat crosses the place field A, the timing of place cell A will gradually precede the general rhythm. As a result, when the rat runs from A via AB to B, the A-cell will always fire just before the B-cell within each cycle. Thereby, the event “AB” can be memorized.



While the rat strives through its territory, the timing of place cells will gradually precede the general rhythm.

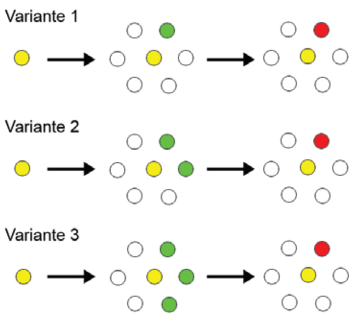
In the group of Richard Kempter, Robert Schmidt has now investigated this phase precession by analyzing single trials, i.e. by analyzing each run between two water sources separately. The scientists showed that, within a single run, phase precession very precisely indicates where in the place field the rat resides. The phase precession varies considerably, though, from run to run. Thus, when several runs are pooled before the analysis, phase precession appears less accurate. Through the approach of analyzing the data of each run separately, the scientists therefore showed that the phase-precession code works much better than previously assumed. In addition, they observed that phase precession often is only in the range of half a cycle. This observation explains why the order of events is kept when the temporal sequence is compressed in the brain. If phase precession would cover a whole cycle, the events of two subsequent cycles would be confounded.

Source: Schmidt, R., Diba, K., Leibold, C., Schmitz, D., György Buzsáki, G., & Kempter, R. (2009). Single-Trial Phase Precession in the Hippocampus. Journal of Neuroscience, 29:13232-13241.

The brain plans in advance – if it can

How much effort our brain can put into preparing a movement greatly depends on the concrete circumstances. If you reach for an object standing in front of you on the table, the movement can easily be prepared. If you reach for it while it is suddenly dropping you have to react quickly, without having time to plan in advance. Scientists around Jörn Rickert, Bernstein Center and University Freiburg, together with colleagues from Berlin and Marseille (France), have now discovered that identical movements can be based on different neural activities in the motor cortex of the brain – depending on how well the movement is planned. Their results play an important role, for example, in developing brain-controlled prostheses for severely paralyzed patients.

In order to examine how the brain controls movements that are differently well planned, the scientists analyzed brain activity of rhesus monkeys that was recorded at the Centre National de la Recherche Scientifique in Marseille. The animals were sitting in front of a screen with six push buttons arranged in a circle out of which they were supposed to touch a specific one in each trial. In one version of the experiment, it was explicitly indicated to the monkey a second before the onset of the reach-out movement which push button was to be pressed – this button lit up green. Then, a color change to red was the signal for the animal to reach out for the button. In other versions of the experiment, at first, only the rough direction of the movement was indicated – two or three adjacent push buttons lit up green. After a second, however, only one of the push buttons went red; the monkey then had to reach out for this button. With this procedure – for a second – the animal was kept in a state of relative uncertainty about what to do exactly.



After the monkey has touched the middle push button (left), a different number of buttons light up in green (middle row). After a change to red, the monkey touches the remaining button (right).

Using quantitative statistical methods, the scientists examined how well the movement direction can be determined from the recorded activity of the nerve cells in different phases of the experiment. They discovered that the neural coding of movement strongly depends on the quantity of information available. If the movement goal is exactly known, the movement is precisely prepared by the brain. In this case, the movement direction can be determined from the activity of the neurons even prior to the beginning of the movement – i.e. during the planning phase. If the goal is not exactly known the movement can of course not be planned equally well. The neurons in this case, however, work all the more accurately during the execution of the movement.

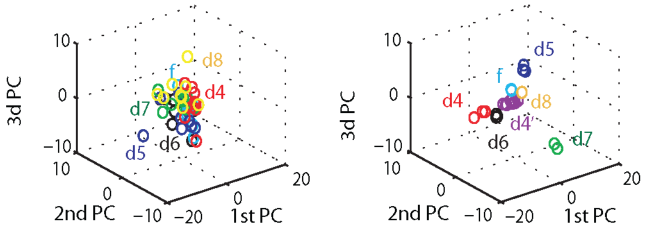
The results achieved by the scientists are used, for example, to develop “Brain Computer Interfaces” (BCIs). Using BCIs, movement information shall be read from the brain so that severely paralyzed patients will be able to control prostheses by means of their thoughts. “Our – just like other – results show, however, that there is no one-to-one relationship between neural activity and movement,” Rickert explains. Movement coding can be strongly influenced not only by planning certainty, but also by attention or motivation. “Such factors must also be considered when decoding a movement from the brain and in applications to Brain Computer Interfaces,” says Rickert.

Source: Rickert, J., Riehle, A., Aertsen, A., Rotter, S. & Nawrot, M.P. (2009). Dynamic encoding of movement direction in motor cortical neurons. J Neurosci;29(44):13870-82.

SORN knows what's next

We mostly obtain information in the form of sequences of events. We hear speech as a chain of words, music as a sequence of sounds and we perceive our visual surroundings as a series of images. Our brain is specialized in processing such sequences. How does it proceed? How does it regard every instant in the context of preceding information? These questions have now been addressed by Andreea Lazar, Gordon Pipa and Jochen Triesch, scientists at the Bernstein Focus Neurotechnology Frankfurt und Frankfurt Institute for Advanced Studies. They have developed a computer model of a neuronal network that is based on biological properties of neurons and that can store sequences of events better than previous models. The scientists called their network "SORN", which stands for "Self-Organizing Recurrent Network". They have also taken a closer look at the storing mechanism of SORN. "This can help us understand how the brain could in principle store sequences of information", says Triesch.

When cell A sends out an impulse that triggers a response in cell B, the contact from cell A to cell B is strengthened. If the impulse from cell A is sent after B was activated, the connection is weakened. This principle is called "spike-timing dependent plasticity" (STDP) and forms the cellular basis of learning and memory. Also SORN builds on STDP. But the model also considers further properties of nerve cells: For one, a neuron adjusts its contacts to upstream cells depending on its own activity. For another, it also adapts the threshold level at which it produces a neuronal impulse itself. Taken together, these mechanisms ensure that each cell in the network is neither too active nor too passive. "The fact that our network takes these mechanisms into account distinguishes it from most other networks. And they are crucial for SORN's function", says Triesch.



Representation of the last six letters in the sequence 'eddddddddf' in a non-learning network (left) and SORN (right). The axes of the plot correspond to aspects of neuronal activity in which the variability is largest. The plot demonstrates that single letters in SORN are more clearly distinguishable.

To test the network, the scientists made it learn chains of letters or numbers. The network was then able to complete fragments of letter or number chains. This ability of the network to finish incomplete sequences reflects a crucial function of the brain: we can understand a sentence even if we did not catch all of it acoustically. The brain completes a perception quickly by using previous knowledge.

To investigate the abilities of SORN, the scientists first of all focussed on networks that consisted of up to 800 neurons. A distinguished feature of SORN is its ability to robustly detect long sequences of reoccurring elements, like in the string "abbbbbbbbbc". It effectively counts the letters. The reason for this, as the scientists showed, lies in the way in which the letters are represented by neuronal activity of the network. SORN stores the fifth "b" in a sequence in a neuronal activity pattern that is quite different from the one representing the sixth "b". Letters are thus coded in the context of the whole sequence. Other networks that are not quite as good at learning sequences of letters represent the fifth and the sixth "b" in a sequence by rather similar activity patterns. The next major challenge will be to test what properties the network would have if it consisted of significantly more neurons.

Lazar, A., Pipa, G. & Triesch, J. (2009). SORN: a Self-organizing Recurrent Neural Network. Front. Comput. Neurosci. 3:23

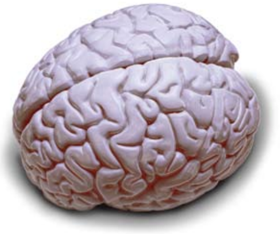
Why the left brain hemisphere matches the right

Right after birth, humans cannot yet see perfectly well. Perceptual capabilities are acquired as the respective neuronal connections in the brain develop. The activity of nerve cells contributes to the structuring of the brain so that information processing eventually is also learned by practice. For a long time, scientists assumed that such an activity-dependent structure formation has only local effects, while the gross architecture of the brain already exists at the time of birth. This idea is now challenged by scientists from Göttingen and Jena. They show that long-range connections between neurons help to coordinate the development of different brain regions and even of the two brain hemispheres. This process continues for many weeks after the onset of vision.

Fred Wolf of the Max Planck Institute for Dynamics and Self-Organization and the Bernstein Center for Computational Neuroscience in Göttingen and Siegrid Löwel of the University of Jena have investigated areas of the visual cortex in cats – areas that process information from the eyes: the primary visual cortex (V1), which is specialized in processing fine contours and the secondary visual cortex (V2), which better responds to larger and faster moving stimuli. During visual development, so called columns form in the visual cortex – groups of neighboring nerve cells that respond to similar aspects of a visual stimulus. While primary and secondary visual cortex are concerned with different aspects of image processing, they nevertheless work closely together and are connected by long-range neuronal connections: Regions of V1 and V2 that analyze the same part of the visual field have particularly strong connections.

Using complex image analysis methods, Fred Wolf and his colleagues have now discovered that these long-range connections influence the size of the columns and thus the structure of the brain regions. „Column sizes vary strongly – both within the visual cortex and between individuals,“ explains Siegrid Löwel, who has carried out the experiments. Nevertheless, certain rules could be identified: For example, if in one animal certain V1 regions had particularly large columns, then the corresponding V2 regions that process the same part of the visual field also had columns that were particularly large. This means that exactly those regions, which are linked by far-reaching neuronal connections, were similar in size. Moreover, the scientists observed symmetries in column sizes between the visual cortex in the left and in the right brain hemisphere – but again only in those regions that were strongly interconnected.

These correlations do not exist from birth, but develop during the first weeks after eye opening. “This first phase of learning how to see takes us humans six months and cats approximately 18 weeks. For a long time it has remained unclear why these development processes take so long,” Fred Wolf says. Apparently, the architecture of completely different brain areas is coordinated during this learning phase, so that in the end the left brain hemisphere matches the right one. “Just as in a globalized world, which is characterized by local and far-reaching contacts, also the exchange of information during brain development is based on an interplay of short and a far-reaching neuronal connections,” Wolf says.

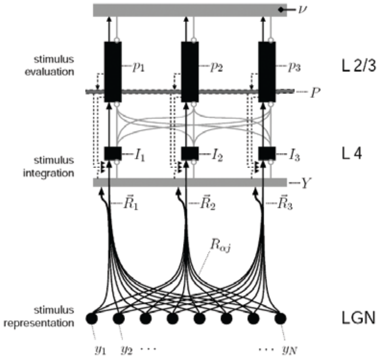


Kaschube, M., Schnabel, M., Wolf, F. & Löwel, S. (2009). Interareal coordination of columnar architectures during visual cortical development. PNAS, 106(40):17205-10.

Seeing and learning to see

When we see and perceive, image information that reaches the retina of the eye in form of light is transformed into neuronal signals that can be processed by the brain. The brain represents different images as different patterns of neuronal activity – for each image specific groups of neurons are activated in a specific way. But how exactly are these activity patterns generated and how does the brain learn which pattern corresponds to which image? At the Frankfurt Institute for Advanced Studies and the Bernstein Focus Neurotechnology Frankfurt, Jörg Lücke has developed a computer model that sheds more light on these questions. The model imitates neuronal circuits of the cerebral cortex and can learn to recognize image segments, even if these are very noisy. In this ability, the model reflects a core property of the human brain: also we recognize and learn to recognize images that are subjected to noise which is caused by the scattering of light and by imprecisions in neural processing.

The part of the cerebral cortex that processes visual information – the visual cortex – is organized in so called columns. Columns are groups of neurons that jointly analyze a defined area of the visual field and extract relevant information, as for example the course of edges. To better understand how a column extracts image information, Lücke has simulated its function in a computer model while taking current results about the neural circuits within a column into account.



Neuronal circuit underlying the column model

Recent findings show that there are groups of cells within a column that mutually activate each other. In such groups, a self enhancing process can occur once a threshold level is reached, and the whole cell group will become active. In addition, these cell groups are interlinked by inhibitory connections. This ensures that only some of the groups show full activity at any given time. All visual information is thus represented by active and passive cell groups.

The cell groups receive visual information from upstream neuronal connections. The model column learns by itself which neuronal activity corresponds to which visual input. If groups of cells are activated by a certain input, the connections to their corresponding upstream cells will be reinforced. A defined visual stimulus will thus always elicit a similar pattern of neuronal activity. Lücke's model does not simulate the activity of single neurons, but rather puts these principles of the neuronal circuits into mathematical formulas that can be processed by a computer.

To test his model, Lücke investigated how well it can learn to represent visual stimuli – or, in terms of biology, how well it can learn to recognize and represent image segments. He confronted the system with images of lines that contained different amounts of noise and with contours that typically occur in natural images. The results of these experiments demonstrate the advantages of the circuit system that was simulated by the model: Through the activation of whole cell groups, it is very robust against errors. Noise in the input pattern and malfunctioning of single cells are compensated. The robustness of the system and the close connection it establishes between image recognition, learning, and neuronal circuits are the major innovations of this work.

Lücke. J. (2009). Receptive field self-organization in a model of the fine structure in V1 cortical columns. Neural Comput. 21(10):2805-45.

MEET THE SCIENTIST

Jan Gläscher

Bernstein Award winner 2009

The Bernstein Award of the Federal Ministry of Education and Research (BMBF), valued at up to 1.25 Million Euro, was issued this year for the fourth time. Jan Gläscher (California Institute of Technology, Pasadena) was selected by the jury for his outstanding scientific contributions and his innovative research program. The award was presented by Parlamentary State Sectretary Thomas Rachel on September 30th at the Bernstein Conference Computational Neuroscience in Frankfurt. The prize is internationally announced and awarded annually to distinguished young researchers in the field of computational neuroscience.

How do we make decisions? Progress in the field of neuroscience has revealed basic concepts about how and where in the brain alternative possibilities are compared and weighed against each other. There are, however, many factors that influence decision making, which have not been sufficiently considered in previous models – not everybody decides in the same way and our social environment often influences us in our decisions. Gläscher investigates these factors. “My research approach, a combination of functional Magnetic Resonance and computational methods, perfectly integrates into the research of the Bernstein Network”, says Gläscher. Gläscher studied psychology at the universities of Gießen and Mannheim. Subsequently he carried out his PhD thesis in the field of cognitive neurosciences with Christian Büchel and Bernd Dahme at the University of Hamburg. Since 2006, he is at the California Institute of Technology. With the award money, he will return to Germany and start his own research group at the University Hospital Hamburg-Eppendorf.

© Uwe Dettmar, Universität Frankfurt

Thomas Rachel, Parlamentary State Secretary in the BMBF (left), presents Jan Gläscher with the Bernstein Award (right)

Gläscher conducts behavioral experiments in combination with functional Magnetic Resonance Imaging (fMRI) in order to investigate decision making. In a typical experiment, subjects are asked to decide between different symbols. Each symbol is associated with monetary gain or loss, but the probability of a positive or negative outcome is unknown to the subjects. It is only with time that they learn which decisions most often lead to profitable gains. “This prototypical decision situation is a good tool for analyzing evaluation processes in the brain,” says Gläscher.

But what if the situation becomes more complex and several different factors influence decision making? Gläscher will investigate this by various modifications of the experiment. In one project, for example, the subjects are not confronted with neutral symbols, but with pictures of more or less attractive persons. How are, in this case, attractiveness and expected monetary gain integrated in the brain? Also the impact of unconscious evaluation processes or prejudices on decision making are investigated in this project. How is the decision of male subjects, for example, influenced by the image of women in leadership positions?

In a second project, Gläscher addresses how long it takes people to relearn after the relation between symbol and monetary value has changed. Neurotransmitters – biochemical messengers in the brain – play an important role in relearning processes. Genetic predisposition as well as nutrition can have an impact on the production of such neurotransmitters. Gläscher investigates how these factors affect the ability to relearn and if genetic determinants that impair decision making can be compensated for by diet or by medication.

In a last project, Gläscher addresses the question of how much we are influenced by the decisions of others. How does a subject react if he/she would really opt for one alternative but everyone else goes for the other one? Would he/she give in to peer pressure? And to what extent do such influences depend on how likable the other persons are?

In all experiments, brain processes are measured using fMRI. “We compare the fMRI data with predictions from certain models for learning and decision making. With this method, we can very precisely determine specific variables, e.g. the expectation value attributed to a certain decision,” Gläscher explains. In the long run, a better understanding of decision making will contribute to improved therapies for psychiatric diseases. Decision behavior is impaired in diseases like depression or obsessive-compulsive disorders. “If we know more precisely how to influence evaluation processes, more specific therapies may be developed,” says Gläscher.

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Options of a daily decision situation: Apple or ice cream? Our decision is based on internal motives – whether we prefer something refreshing or something healthy.

Call for Proposals: Bernstein Award 2010

Also for the year 2010, the Federal Ministry of Education and Research (BMBF) has announced the “Bernstein Award for Computational Neuroscience”. The award is endowed with up to 1.25 Mio Euros, is announced internationally and allows young scientists to establish an independent research group at a German university or research institution. Deadline for application is May 25, 2010.

http://www.gesundheitsforschung-bmbf.de/en/1834.php

1. Bernstein R&D Workshop

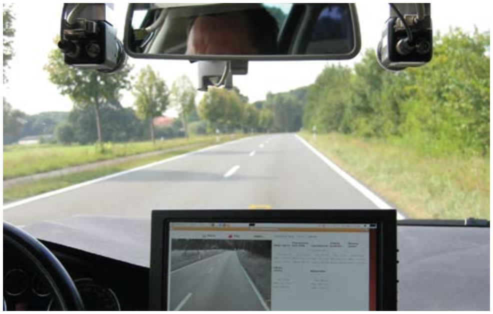
The first Bernstein R&D Workshop took place on November 11, 2009, at the Bernstein Center Freiburg. The workshop was entitled “Electrophysiological methods for recording and stimulation”. In this workshop, scientific and industrial experts met in order to critically evaluate the existing methods, to identify potential problems and to evaluate the demand, potential and prospects of new technological developments.

http://www.nncn.de/nachrichten-en/rdworkshop2009/

EU-Project „DRIVSCO“

Foresight is the key to safe driving. But this is particularly difficult when it is dark and visibility is poor. Within the framework of the project “DRIVSCO”, funded by the EU with 2.8 Million Euro, scientists have developed a driver assistance system that can solve this problem. DRIVSCO learns from the driver during daytime and applies this knowledge at night, when its infrared system can see farther than the human eye. The project was coordinated by Florentin Woergoetter, scientist at the Bernstein Center for Computational Neuroscience and the University of Goettingen in Germany. Another eight partners from six different European countries were involved in the research project. A first prototype of the driver assistance system has been implemented in a test vehicle by the company Hella Hueck (Lippstadt, Germany).

DRIVSCO saves images and road data and compares them to the driver’s reactions: How strongly does the driver break if a turn of a certain angle lies ahead? How does he/she steer the car? At night, the system uses infrared headlights in order to detect the course of the road. If the driver’s behavior deviates too strongly from the usual behavior, for example when he/she does not recognize a turn at night, the driver is alerted by the system. “The scientific challenge in the development of the system was the matching between image data and driver reactions”, explains Woergoetter. The system has to learn which image aspects are crucial and which reactions they entail – it thereby also considers the driving style of different drivers.



© A. Rotter, Hella KGaA Hueck & Co

Driver assistence system DRIVSCO: Screen for monitoring the course of the road.

5th Bernstein Conference 2009

The 5th Bernstein Conference took place from September 30 till October 2, 2009 in Frankfurt a. M. The organization was carried out by the BFNT Frankfurt under the direction of Jochen Triesch. 266 scientists, among them 183 Bernstein members, 38 international participants and seven invited students and postdocs from the Sloan-Swartz Centers for Theoretical Neurobiology joined the conference. Abstracts of conference papers were published in the scientific journal Frontiers in Computational Neuroscience.

Bernstein Award for Jan Gläscher. The first conference highlight was the Bernstein Award presentation to Jan Gläscher (California Institute of Technology, Pasadena, Kalifornien) by Thomas Rachel, Parliamentary State Secretary at the Federal Ministry of Education and Research. “The Bernstein Award of the Federal Ministry of Education and Research, endowed with 1,25 million Euros, is a success story. This year, we succeeded with this award to bring Dr. Jan Gläscher, an excellent young researcher with a fascinating research project, back from California to Germany”, Rachel said. (see also page 13)

Awards for Bernstein Conference Contributions. With support of the Deutsche Telekom Laboratories, outstanding conference contributions were awarded with 300 Euro each. Anna Levina‘s talk was chosen as best oral presentation. The awards for the best three posters went to Michael Schmucker, Detlef Wegener and Jan Wiltschut. Jörg Conradt received the award for the best live demonstration.

International PhD Programs at the Bernstein Center Freiburg

The Bernstein Center Freiburg's application for setting up the Erasmus Mundus Joint Doctoral Programme "EuroSPIN" (European Study Programme in Neuroinformatics) was selected for funding by the European Union. Within this program, PhD-students are trained in the interdisciplinary field of neuroinformatics. The program is conducted in cooperation with the Kungliga Tekniska Högskolan (KTH) in Stockholm, Schweden, the University of Edinburgh, UK and the National Centre for Biological Sciences, Tata Institute of Fundamental Research in Bangalore, India, and starts in 2010.

www.bccn-freiburg.de/news/news-events/erasmus_mundus_english

In addition, the Bernstein Center Freiburg has been successful with its application for a Marie Curie Initial Training Network (ITN). The "FACETS-ITN" (Fast Analog Computing with Emergent Transient States-Initial Training Network) connects universities, research centers, companies and commercial scientific institutions from six European countries and investigates the structure and mathematical principles of biological, neural networks by a combination of experiments and theory.

www.bccn-freiburg.de/news/news-events/FACETS-ITN_de

Research Training Group at the BCCN Berlin

The Research Training Group "Sensory Computation in Neural Systems", designed as the core of the BCCN Berlin PhD program, has been accepted for funding by the DFG. The Research Training Group will start in 2010 and can support 20 PhD-students with scholarships. Its main focus is the analysis of neuronal information processing in sensory processes. Coordinator of the program is Prof. Klaus Obermayer of the Technical University Berlin. Furthermore, scientists of the Charité-Universitätsmedizin, the Free University Berlin, and the Humboldt-University zu Berlin contribute to the program.

G-Node Courses

From February 8 to 12, 2010, the G-Node organizes with and at the University of Warsaw the winter school "Advanced Scientific Programming in Python". Deadline for application: December 6, 2009. Further information at www.g-node.org/python-winterschool/. The "2nd G-Node Winter Course in Neural Data Analysis" will be held from March 1 to 5, 2010. Deadline for applications: December 31, 2009. Further information at www.g-node.org/dataanalysis-course-2010/.

http://www.g-node.org/Teaching

Upcoming Events

Event	Title	Organization	URL
08. - 12. Feb. 2010, Warsaw, Poland	Winter School: Advanced Scientific Programming in Python	P. Durka, J. & Z. Jedrzejewscy-Szmek (University of Warsaw), T. Zito (G-Node)	http://www.g-node.org/python-winterschool/
25. -28. Feb. 2010, Salt Lake City, USA	Bernstein Network booth at Cosyne meeting	General Chair: Maneesh Sahani (University College London, UK)	http://cosyne.org/
01.-05. Mar. 2010, Munich	Winter Course: Neural Data Analysis	G-Node Sonja Grün (RIKEN, BSI, Japan)	http://www.g-node.org/dataanalysis-course-2010/

The Bernstein Network

Bernstein Centers for Computational Neuroscience (BCCN)
Berlin – Coordinators: Prof. Dr. Michael Brecht
Freiburg – Coordinator: Prof. Dr. Ad Aertsen
Göttingen – Coordinator: Prof. Dr. Theo Geisel
Munich – Coordinator: Prof. Dr. Andreas Herz

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

Bernstein Focus: Neuronal Basis of Learning
Visual Learning – Coordinator: Prof. Dr. Siegrid Löwel
Plasticity of Neural Dynamics – Coordinator: Prof. Dr. Christian Leibold
Memory in Decision Making – Coordinator: Prof. Dr. Dorothea Eisenhardt
Sequence Learning – Coordinator: Prof. Dr. Onur Güntürkün
Ephemeral Memory – Coordinator: Dr. Hiromu Tanimoto
Complex Human Learning – Coordinator: Prof. Dr. Christian Büchel
State Dependencies of Learning – Coordinators: Dr. Petra Ritter, Prof. Dr. Richard Kempter
Learning Behavioral Models – Coordinator: Prof. Dr. Gregor Schöner

Bernstein Groups for Computational Neuroscience (BGCN)
Bochum – Coordinator: Prof. Dr. Gregor Schöner
Bremen – Coordinator: Prof. Dr. Klaus Pawelzik
Heidelberg – Coordinator: Prof. Dr. Gabriel Wittum
Jena – Coordinator: Prof. Dr. Herbert Witte
Magdeburg – Coordinator: Prof. Dr. Jochen Braun

Bernstein Collaborations for Computational Neuroscience (BCOL)
Berlin-Tübingen, Berlin-Erlangen-Nürnberg-Magdeburg, Berlin-Gießen-Tübingen, Berlin-Constance, Berlin-Aachen, Freiburg-Rostock, Freiburg-Tübingen, Göttingen-Jena-Bochum, Göttingen-Kassel-Ilmenau, Munich-Göttingen, Munich-Heidelberg

Bernstein Award for Computational Neuroscience (BPCN)
Dr. Matthias Bethge (Tübingen), Dr. Jan Benda (Munich), Dr. Susanne Schreiber (Berlin), Dr. Jan Gläscher (Hamburg)

Project Committee
Vorsitzender des Bernstein Projektkomitees / Chairman of the Bernstein Project Committee: Prof. Dr. Ad Aertsen
Stellvertretender Vorsitzender des Bernstein Projektkomitees / Deputy Chairman of the Project Committee: Prof. Dr. Theo Geisel

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Title image: Apple or ice cream? Options of a daily decision situation.

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GEFÖRDERT VOM

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und Forschung