National Bernstein Network Computational Neuroscience

Nationales Bernstein Netzwerk Computational Neuroscience

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Summary The National Bernstein Network Computational Neuroscience is a funding initiative of the German Federal Ministry of Education and Research (BMBF). It aims at understanding the brain's function through the interdisciplinary approach of Computational Neuroscience. In a joint collaborative effort, biologists, physicians, psychologists, physicists, mathematicians, and computer scientists translate experimental results into mathematical models that can be tested in computer simulations. Their insights into normal and pathologically altered brain functions open new perspectives for innovative treatments as well as technological applications. ►►► **Zusammenfassung** Das Nationale Bernstein Netzwerk Computational Neuroscience ist eine Förderinitiative des deutschen Bundesministeriums für Bildung und Forschung (BMBF). Sein Ziel ist es, die Funktionsweise des Gehirns mit Hilfe des interdisziplinären Forschungsansatzes der Computational Neuroscience zu verstehen. Biologen, Mediziner, Psychologen, Physiker, Mathematiker und Informatiker kooperieren dabei, um experimentelle Ergebnisse in mathematische Modelle zu übersetzen und diese in Computersimulationen zu testen. Die gewonnenen Erkenntnisse über normale und krankhaft veränderte Hirnfunktionen eröffnen neue Perspektiven für innovative Behandlungsmethoden und technologische Anwendungen.

Keywords J.3 [Computer Applications: Life and Medical Sciences]; I.6 [Computing Methodologies: Simulation and Modeling]; J.2 [Computer Applications: Physical Sciences and Engineering]; H.1 [Information Systems: Models and Principles]; I.2 [Computing Methodologies: Artificial Intelligence]; I.4 [Computing Methodologies: Image Processing and Computer Vision]; I.5 [Computing Methodologies: Pattern Recognition] ►►► **Schlagwörter** Neurowissenschaften, Neuroinformatik

1 Structure of the Funding Measure

Understanding the function of the human brain still remains a major scientific challenge. Computational Neuroscience tackles this problem by a strictly interdisciplinary approach. By combining experiments, data analysis, mathematical models and computer simulations, it allows to systematically test hypotheses about brain function in a quantitative manner. Using this approach offers an enormous innovation potential for medicine as well as for information and communication technology and – albeit with a certain time delay – for the sector of education.

In order to use this potential, the Federal Ministry of Education and Research (BMBF) supports German research in this discipline with the funding measure "National Bernstein Network Computational Neuroscience".

The network was named after the German physiologist Julius Bernstein (1839–1917). With his "membrane theory", Bernstein provided the first quantitative biophysical explanation for information transmission in neurons.

Currently, the Bernstein Network Computational Neuroscience consists of more than 200 research groups in more than 20 German cities/regions.

1.1 Bernstein Centers

The *Bernstein Centers* are the Bernstein Network's core structural elements. Established in 2004/2005 and located

Figure 1 The current status of the Bernstein Network.

Figure 2 Dedicated Bernstein Center buildings in Freiburg (left) and Berlin (right).

at Berlin, Göttingen, Freiburg, and Munich, the Bernstein Centers are regional nuclei that gather a critical mass of experimentalists and theoreticians from different disciplines cooperating in joint projects. In order to ensure sustainability beyond BMBF funding, the local host institutions contribute additional, long-term support, e. g., by funding of scientific staff or provision of premises. In this way, considerable new capacities have been created, including the establishment of seven new tenured professorships. The centers are also substantially engaged in academic training in computational neuroscience. BMBF support for the four initial Bernstein Centers amounts to approximately 40 million Euros. The Bernstein Centers' research topics are fundamental questions of neuronal information processing, including the role of neural variability, dynamics and adaptivity, and of space and time.

In 2008, the BMBF announced a second call for Bernstein centers – Bernstein Centers II – that are planned to start in the coming years.

1.2 Bernstein Groups

In order to establish further sustainable local Computational Neuroscience cores within Germany, and to broaden the scope of research areas represented in the network, five *Bernstein Groups* were established at Bochum, Bremen, Heidelberg, Jena, and Magdeburg in 2007. Bernstein Groups are smaller than Bernstein Centers and work on more concisely defined research topics,

Figure 3 Left: Bernstein Award Winners 2006–2008: Dr. Matthias Bethge, Dr. Jan Benda, Dr. Susanne Schreiber. Right: Parliamentary Secretary of State Thomas Rachel confers the Bernstein Award 2009 to Dr. Jan Gläscher.

such as the visual cortex, dynamic field models, detailed single-neuron modeling, the neuromatrix of pain, and individual neural components of cognition. The funding of Bernstein Groups amounts to 5 million Euros.

1.3 Bernstein Collaborations

In order to interlink the research at Bernstein Centers with additional expertise at other locations, *Bernstein Collaborations* were established in 2007. Eleven Bernstein Collaborations between partners at Bernstein Centers and at one or two other locations are funded by a total amount of 7.5 million Euros. Subjects of Bernstein Collaborations are complementary to the subjects of the Bernstein Centers and comprise topics such as neurovascular coupling, temporal precision of neural coding, imaging methods, memory, neuronal synchronization mechanisms, transcranial magnetic stimulation and neural network simulations.

1.4 Bernstein Award

For any new area of research, it is of fundamental importance to attract highly talented young scientists. To that end, the *Bernstein Award* was established in 2006. It enables young research scientists of any nationality to establish their own independent research group at a German university or research institute. The award is conferred annually and is equipped with funding of up to 1.25 million Euros over five years. Topics of previous Bernstein Award winners include neural coding in early vision, noise in sensory signal processing, computational properties of intrinsic neuronal properties and human decision making.

1.5 Bernstein Foci

In order to bridge the gap between basic and applied research and to accelerate the development of concrete applications, two funding measures termed "Bernstein Foci" were implemented in 2008 and 2009.

As a first focus topic, the *Bernstein Focus: Neurotechnology* aims at exploiting neuroscientific findings in technological applications. Four consortia located at Berlin, Frankfurt am Main, Freiburg/Tübingen and Göttingen are supported by 34 million Euros. Research within these consortia focuses especially on brain machine interfaces for prosthetics and technology, and on artificial vision and robotics. With the BMBF support, eight new professorships were created in this area.

The *Bernstein Focus: Neuronal Basis of Learning*, in contrast, deals with the mechanisms of learning and memory and their possible applications in technical systems and in medicine. Eight smaller consortia, each located at two to four German cities, are funded within this scheme with a total of 16 million Euros. Their research topics comprise short- and long-term memory, visual learning after stroke, sequence learning, state dependence of learning, decision making, and application of learning mechanisms in service robots.

1.6 German INCF Node (G-Node)

The "*International Neuroinformatics Coordination Facility*" (INCF) was set up in 2005 under the umbrella of the "Organisation for Economic Co-operation and Development" (OECD), with Germany as one of its founding members. INCF acts as a catalyst for the global flow of information and for the scientific interaction towards the development of programs, standards guidelines and infrastructures in Computational Neuroscience and Neuroinformatics. In addition to the international headquarters of the INCF secretariat in Stockholm, Sweden, the individual member states maintain so-called national nodes of the INCF network. The German National Node

G-Node German Neuroinformatics Node

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Figure 4 The G-Node is the German National Node of the International Neuroinformatics Coordinating Facility (INCF).

Figure 5 Industry Partners of the Bernstein Network.

(**G-Node**) is an integral component of the Bernstein Network, thus interlinking the National Network to the international community. The G-Node is located at Munich and develops and enhances tools to accelerate the exchange of scientific data and methods. It is supported by the BMBF with 2 million Euros.

1.7 Industry Partners

Documenting the relevance of Computational Neuroscience for technological applications with a significant economic potential, the Bernstein Network also includes 22 *industry partners*. The companies involved range from IT hardware manufacturers over medical and research instrument suppliers to telecommunication companies and manufacturers of identification systems, electronic equipment and cars.

The Bernstein Network's industry partners comprise: Biomed NMR, Brain Products, certon, Cochlear, Daimler, Honda Research Institute Europe,.Infineon, inomed, Leica Microsystems, L-1 Identity Solutions, Magnicon, MED-EL, Multi Channel Systems, neuroConn, nisys, NIRx, NMI, Otto Bock Health Care Bosch, Schunk, Thomas Recording, T-Labs, VITRONIC.

1.8 Bernstein Coordination Site

Established in 2008, the Bernstein Coordination Site supports the scientists of the Bernstein Network in their joint activities and serves as a link between the BMBF, the grant agency (PT-DLR) and the individual network partners. Furthermore, the coordination site engages in press and public relations activities such as the production of print media (brochure, newsletters, flyers), distribution of press releases about the network's research, organization of events for the public and the maintenance of a comprehensive central website (nncn.de). The Bernstein Coordination Site also serves as a central contact point for international contacts and funding organizations, and regularly represents the Bernstein Network at international conferences with exhibitions. The Coordination Site is hosted by the Bernstein Center in Freiburg and is supported with a funding volume of 1.4 million Euros.

2 Teaching & Training Offers

Since the interdisciplinary research approach of Computational Neuroscience poses special demands on the researchers' abilities, a major goal of the Bernstein Network is to enhance academic training in the relevant fields and to incorporate the discipline of Computational Neuroscience into the academic education. Members of the Bernstein Network are engaged in more than twenty pre- and postgraduate teaching programs as well as in advanced courses and summer or winter schools. An up-to-date list of all current Teaching & Training activities of the Bernstein Network can be found under www.nncn.de/Studienprogramme.

2.1 Master's Programs

Currently, Bernstein members teach in Master's programs at 10 locations of the Bernstein Network.

The first and only dedicated "MSc Computational Neuroscience" program in Germany was established by the Bernstein Center Berlin and is hosted by the Technical University Berlin, the Humboldt University Berlin, and the Charité Berlin. The program is taught in English and the Master's degree is conferred by the Technical University and the Humboldt University. The program was recently accredited by the ASIIN agency.

The topics of the other Master's programs range from neuro-cognitive psychology, experimental, cognitive or medical neuroscience over computational science and scientific computing to medical biotechnology.

Two Master Programs at the Ludwig Maximilians University in Munich ("Neuroscience" and "Neuro-Cognitive Psychology") are part of the Elite Network of Bavaria (ENB) that is dedicated to the education of highly talented students.

Three Master's programs are integrated into MSc/PhD graduate programs: the "MSc/PhD program Neurosciences" in Göttingen, the "MSc/PhD program Integrative Neuroscience" in Magdeburg, and the "MSc/PhD Program Neural & Behavioral Sciences" in Tübingen.

The programs "Neuro-Cognitive Psychology" in Munich, the "Neuroscience" master program of the Georg August University in Göttingen and the "International Graduate Program Medical Neurosciences" of the Charité Berlin were awarded with the quality label "TOP 10 International Master's Degree Courses made in Germany".

The "Trinational Joint Master in Neuroscience" offers the unique option to study simultaneously at three different universities (Strasbourg, Freiburg, and Basel) in three different countries (France, Germany, and Switzerland).

2.2 PhD Programs

PhD Programs with Bernstein participation are situated at Berlin, Bochum, Bremen, Freiburg, Göttingen, Heidelberg, Magdeburg, Munich, and Tübingen.

Dedicated Computational Neuroscience PhD programs are established in Berlin, Freiburg, and Göttingen. The topics of the other PhD programs range from Molecular & Cellular Life Sciences, Biology & Medicine, Medical and System's Neuroscience over Mind & Brain to specialized topics like Orientation and Motion in Space or Human Centric Coordination.

Five of the Graduate Programs were selected for funding by the German Excellence Initiative:

- the "Berlin School of Mind and Brain" (Berlin),
- the "Spemann Graduate School of Biology and Medicine" (Freiburg),
- the "Hartmut Hoffmann-Berling International Graduate School of Molecular and Cellular Biology" (Heidelberg),
- the "Graduate School of Systemic Neuroscience" (Munich) and
- the "MSc/PhD Program Neurosciences", the "PhD Program Sensory & Motor Neuroscience", and the "PhD Program Systems Neuroscience" as part of the "Graduate School of Neuroscience and Molecular Biology" (Göttingen).

The Göttingen "MSc/PhD Neuroscience" program, the Tübingen "MSc/PhD Neural & Behavioural Sciences" program as well as the Munich "Molecular and Cellular Life Sciences" program are also International Max Planck Research Schools, with the involvement of several local Max-Planck Institutes.

2.3 Advanced Training

In addition to the aforementioned degree programs, members of the Bernstein Network, especially also the G-Node, are engaged in a number of advanced courses, and in national and international summer or winter schools. For instance, the Bernstein Center Freiburg is hosting the renowned European Advanced Course Computational Neuroscience in the years 2008–2010.

Advanced training options within the Bernstein Network also include offers for postdoctoral training and opportunities to set up independent junior research groups.

3 International Meetings Organized by the Bernstein Network

3.1 Bernstein Conference

In order to foster communication and exchange within the Bernstein Network and with the international scientific community, a yearly Bernstein Conference is organized at varying network locations since 2005. Participation of foreign students and postdocs is encouraged by travel fellowships. For instance, since 2008, a mutual exchange program with the Sloan Swartz Centers for Theoretical Neurobiology has allowed 10 selected PhD students and postdocs to participate in the annual Bernstein Conference and the annual Sloan Swartz Summer Meeting, respectively. The exchange is supported by the BMBF and the Swartz Foundation.

The Bernstein Conference is followed by a PhD-student/postdoc symposium that is independently organized by Bernstein students and postdocs. This meeting allows young researchers to gather first experiences in organizing their own conference and provides an ideal platform for informal and intense exchange and discussions with selected invited speakers.

3.2 Binational Workshops

Since 2006, the Bernstein Network has organized a series of binational workshops with other countries that also maintain substantial expertise in the field of Com-

Figure 6 Participants of the Bernstein Conference 2009 in Frankfurt a. M.

putational Neuroscience. The workshops gather leading experts from both countries and representatives of the relevant funding organizations. The series started with Japan (two workshops in 2006 and 2009, respectively) and the United States of America (2009), and is planned to be continued further. The German-American workshop has contributed to a new German-American funding initiative in Computational Neuroscience ("Germany-USA Collaboration in Computational Neuroscience", within the CRCNS funding scheme) that is jointly financed by American (NSF, NIH) and German (BMBF) funding organizations.

4 Research Topics

Although directed at all aspects of brain function, research within the Bernstein Network is committed to the common denominator of the Computational Neuroscience approach. Neurophysiological processes and neuroanatomical characteristics are broken down into elements that can be described in a mathematical language, yielding models that can be implemented in computer algorithms.

Since many aspects of brain function are still only insufficiently understood, this endeavour still requires a substantial amount of basic research. Considering also pathologically altered brain processes, however, immediately offers medical implications of this approach. And since even advanced information technology can still learn a lot from the performance and reliability of the brain, also technical applications can profit from the Bernstein Network's research.

On the basic research side, one of the main questions aims at understanding the code by which sensory impressions, memory and reasoning are translated into neuronal activity. Understanding this code to the level that it can be implemented in technical brain machine interfaces will allow developing technical neuroprostheses that can replace lost brain functions. A prominent example for successful applications of neuroprostheses are cochlear implants that restore hearing in the deaf by transforming sounds into electrical stimulation pulses. Furthermore, different variants of motor brain machine interfaces can already now replace simple motor functions in severely paralyzed patients. Deeper insight into the how neuronal activity is altered in neurological diseases (such as epilepsy, Parkinson's disease and migraine) will allow to use deep brain stimulation techniques to renormalize neuronal activity. And finally, unravelling the mechanisms of learning and memory will in the long run help to improve human learning and maybe even restore memory functions.

As far as technological applications are concerned, knowledge generated by the Bernstein Network is applied in a wide range of information technologies, such as in humanoid robots, artificial vision, telecommunication and learning machines. In driver assistance systems, for example, artificial vision can be used to recognize obstacles on the road, or advanced EEG techniques can be used to detect driver fatigue. Incorporating sensory functions such as vision, touch and hearing into robots and equipping them with humanoid learning abilities will produce more interactive, autonomous and robust robots that can be applied in a wide variety of technical, service or support tasks.

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