



Bernstein Centers for Computational Neuroscience

BCCN Newsletter



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Meet the Scientist

Felix Wichmann



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06/2007



RECENT PUBLICATIONS

Perception of Time influences Spatial Orientation

Scientists from Munich examined the role that perception of time plays in estimating distances.

There is no doubt that visual stimuli play an important role in spatial orientation: We find our way in a city, because we recognise houses and roads. But what is the role of the perception of time? Do we memorise distances based on the time we need to cover them? From everyday life we are familiar with the phenomenon that we think we must have passed an exit “ages ago”. Recently, scientists in the group of Stefan Glasauer from the Munich Bernstein Center for Computational Neuroscience and the University Hospital Munich Grosshadern, together with colleagues from Rome, have been able to demonstrate that our perception of time indeed influences spatial estimates.

When we talk to each other or concentrate on doing something, time seems to pass faster than when we wait at a bus stop. The fact that our own activity influences the perception of time is not only a daily experience, but also scientifically proven. When subjects solve mathematical problems while trying to keep track of the passage of time, the act of calculating disturbs their sense of time. When they subsequently are asked to reproduce the time which has passed without calculating, the reproduced duration is too short. Scientists in Glasauer’s group exploited this phenomenon to examine the role of subjective time in the reproduction of movement.

To begin with, Glasauer and his colleagues tested the ability of subjects to reproduce different movements. They were given three different tasks: to reproduce as accurately as possible 1) a previously walked distance while being blindfolded, 2) a passive



turn on a swivel chair, or 3) an active locomotor movement on a treadmill. They managed this very well in most cases.

The situation was quite different, when the subjects’ perception of time was disturbed because they were simultaneously solving a mathematical task. They were asked to count aloud backwards in sevens, either while experiencing the movements or while trying to reproduce them. In all tests, it was shown that not only the perceived time, but also the perceived space became distorted, when the subjects calculated while performing the tasks. If the subjects calculated while learning the task, the reproduced movement was too short both in duration and distance. In contrast, if they only calculated while repeating the task, subjects walked or turned longer and further than they should.

In the different experiments the subjects used different cues to evaluate their movements. During rotation on the swivel chair, their sense of balance and visual stimuli played a role; while they walked on the treadmill or on ground with eyes closed, the knowledge and perception of self-generated movement was important. Since the perception of space changed in the same way in all the experiments, the scientists concluded that a general timing mechanism underlies their findings. Not only does time pass subjectively more quickly when we are busy, but the altered perception of time also affects our orientation in space.

Source: Glasauer, S., Schneider, E., Grasso, R. & Ivanenko, Y.P. (2007). Space-time relativity in self-motion reproduction. *J Neurophysiol.* 97:451-61.

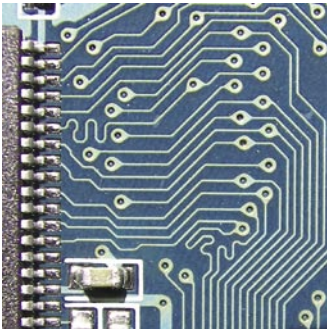


Learning in silico

Researchers investigate learning processes by simulating a cubic millimeter of the brain

The ability of the brain to learn lies in the special properties of the nerve cells and in particular of their connections, the synapses. All brain activity is mediated by information in the form of short electric impulses that are passed from one “firing” cell to the next. In so doing, the cells cultivate their capability to propagate signals. If cell A emits a pulse that evokes a response in cell B, this strengthens the contact between cells A and B. If there is no such causal relationship, or if cell B fires before cell A, the connection is weakened. As a result of this phenomenon, known as “spike-timing dependent plasticity” (STDP), frequent pairings cause strong neural pathways to develop. Conversely, connections which are infrequently used decline.

This “plasticity” of the brain, its ability to adapt physiologically and structurally, is considered to be the foundation of learning. On the basis of a complex computer simulation of 100,000 neurons with 10,000 contacts each – corresponding to about one cubic millimeter of cortex – Abigail Morrison, Ad Aertsen and Markus Diesmann from the BCCN Freiburg have discovered that STDP may be insufficient to explain the learning processes of nerve cells.



Source: Morrison, A., Aertsen, A. & Diesmann, M. (2007). Spike-timing dependent plasticity in balanced random networks. *Neural Computation*, 19 (6) 1437-146

From earlier studies the researchers knew that their computer simulation reproduced many dynamical properties of living cortical tissue. The virtual neurons fire with about the same frequency as in the brain, and the activity neither escalates nor decays – the system exists in a “dynamic equilibrium”. Now they have extended their model to take the plasticity of neuronal connections into account. To this end, Morrison developed a mathematical formulation of the STDP learning rule that fitted the available experimental data significantly better. This development allows the model to become considerably more realistic.

To investigate whether the computer model can simulate learning processes, the researchers repeatedly stimulated a specific group of neurons. Their initial observations were in agreement with the predictions of the learning model: as the stimulated neurons transmitted the stimuli to their downstream neurons, these contacts were strengthened. However, this occurred at the expense of the contacts from their upstream neurons in the network. As the stimulated group responded to the external stimulus, their other inputs became redundant and decayed. After a while, the researchers determined that the entire stimulated group had decoupled itself from the rest of the network.

STDP is therefore not sufficient to explain learning in large neuronal networks, additional requirements must be satisfied to enable the system to learn. There are already strong indications as to what these requirements might be. With the simulation of large networks, Morrison and colleagues have a powerful tool to appraise a variety of different models and uncover the secret of neuronal learning.



How can we locate sounds in closed rooms?

The mechanisms of echo suppression.

In every natural environment there are echoes – sounds reach the ears not only directly but are also reflected by objects and then reach the hearer from all sides with a short time delay. The fact that we can locate the source of a sound is due to “echo suppression.” Information about the direction of the echo is suppressed by the processing of acoustic information in the brain. Scientists from Benedict Grothe’s group from the Ludwig-Maximilians-Universität Munich and the Bernstein Center for Computational Neuroscience have found out which neuronal circuitry is the basis for these mechanisms in mammals.

We are perfectly able to locate the echo which is produced by shouting in the mountains, which only echoes back after a longer time. In closed rooms however, where the echo is only deferred up to 20 milliseconds the brain suppresses the information about the direction from which the echo comes. Scientists from Grothe’s group examined neurons in the “Dorsal Nucleus of the Lateral Lemniscus” (DNLL), an area of the brain, which we know is involved in locating sounds. Sounds which come from the right side are louder in the right ear than in the left one. In the DNLL of the left side of the brain, there are neurons which are stimulated by signals from the right ear and inhibited by signals from the left ear. They only react when sounds come from the right side; therefore we can say that they are “sensitive to direction”.

Now scientists could show that these inhibitions by sounds from the left ear continue for up to 20 milliseconds longer than the sounds exists. This is extremely long; normally the duration

of the inhibition of a neuron corresponds exactly to the duration of the signal which provoked it. In further experiments scientists could show that this long-term inhibition suppresses the reaction of the cells which are sensitive to direction – they become “deaf” for 20 milliseconds. The source of this long-term inhibition is located in the opposite DNLL. The signal from the left ear makes a detour over the right side of the brain in order to suppress the echo again in the left DNLL. Naturally this process also applies inversely for the neurons, which are sensitive to directions in the right DNLL.

That cells, which are sensitive to direction are deaf to the echo, only partly explains the phenomenon of echo suppression. After all we notice the echo, only the information about the direction is missing. Grothe and his colleagues have shown in a computer model which included further acoustic brain regions, that the echo provokes a neuronal reaction in higher brain regions and that the long-term inhibition in the DNLL only reduces the information about the direction of this perception. In psychophysical experiments with human subjects the scientists could confirm the predictions of their model.

These results will be used amongst others in robotics. For a robot to be able to react to commands like, for example “Come here!” it also has to be able to locate sounds in closed rooms.

Source: Pecka et al. (2007).

Inhibiting the inhibition:
a neural network for
sound localization in
reverberant environ-
ments. *J Neurosci*, 27
(7): 1782-90





Neural cells in cross fire

Controversy evokes over fundamental question in neuroscience

In 1952, Alan Lloyd Hodgkin and Andrew Fielding Huxley proposed a quantitative description of the emergence of electrical impulses in neurons, for which they received the Nobel Prize. In April 2006, scientists working with Fred Wolf, BCCN Göttingen and MPI for Dynamics and Self-Organization, showed for the first time evidence that not all cells conform to the Hodgkin-Huxley model. The publication of their results in the journal “Nature” has meanwhile evoked a controversy in the scientific community.

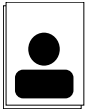
Neurons communicate by passing electrical impulses. When a neuron receives a signal, the voltage across its membrane changes. As soon as a certain threshold is reached, voltage-gated sodium channels in the membrane open up and sodium ions can pass into the cell. This in turn leads to a further increase of the membrane potential and a so-called „action potential“ arises – the neuron now sends out a signal itself. According to the Hodgkin-Huxley model, the voltage across the membrane is the only trigger needed for voltage gated sodium channels to open. However, Wolf and his colleagues found that the Hodgkin-Huxley model cannot account for the emergence of action potentials in neurons of the cortex. The threshold value in these cells is very variable; at the same time, action potentials arise extremely rapidly. As they demonstrated, this can be easily modeled if one postulates that the sodium channels exert an influence on each other to open cooperatively.

It should not come as a surprise, that questioning the universal validity of this fundamental equation was met with disbelief by some scientists. In the January issue of Nature, David McCormick, Yale University School of Medicine, and his colleagues published their doubts about Wolf’s model. Action potentials in some

neurons arise in a cellular process, the axon, at about 30 μm distance from the cell body. As the axon is however too thin to apply a pipette without destroying the structure, the membrane potential is generally measured at the cell body. McCormick points out that this could lead to artifacts. In a mathematical model he suggests how the rapid emergence of action potentials measured in the cell body may potentially be explained by the Hodgkin-Huxley model if such artifacts are substantial. In addition, he attempts to measure the membrane potential at the site of its emergence by cutting off the axon and applying the pipette to a “bleb”, which is formed by the nerve cell where its axon is cut. Data obtained in this way show a significantly slower emergence of action potentials than data published by Wolf et al.

In their reply published in the same issue of Nature, Wolf and colleagues can convincingly dispel both of McCormick’s critiques. First, they point out that the removal of the axon results in a radical reorganization of the molecular structure, so that data obtained from measurements at the axon blob are not reliable. In addition, also McCormick’s mathematical model cannot convince Wolf and his colleagues. While the model predicts the emergence of an action potential at a fixed threshold of -55V, measurements show that such a fixed threshold potential does not exist in real neurons. Thus, Wolf and his colleagues regard McCormick’s model as yet another indication that the Hodgkin-Huxley model does not suffice to explain the emergence of action potentials in cells of the cortex. For the time being, Wolf’s model appears to remain the most plausible hypothesis.

Source: „Hodgkin and Huxley model – still standing?“ McCormick, D.A., Shu, Y. & Yu, Y. / Naundorf, B. & Wolf, F. and Volgushev, M. Nature Vol 445, 2007



MEET THE SCIENTISTS

Felix Wichmann

Between machines and psychology

Our visual capability is quite an astonishing phenomenon. Not only can our brain process lines, contours, and colors in vast quantities instantaneously but it is also capable of interpreting this information correctly. Once a two dimensional image reaches the retina, the brain reconstructs its corresponding three dimensional surroundings. The brain can pick out objects from the run of contours and the distribution of areas and colors. Furthermore, the brain has the ability to classify objects by recognizing them as a “tree” or “human.” Felix Wichmann is interested in different aspects of this multifaceted process. Wichmann is professor for “Modeling of Cognitive Processes” at the Bernstein Center for Computational Neuroscience in Berlin and at the Technical University Berlin. “How are things perceived – and how are they represented in a psychological space”, Wichmann defines the focus of his research activities.

In an early step of visual processing, the brain determines the three dimensional structure of what we see. To achieve this, it uses different criteria, such as the run of contours, the distribution of shadows, and the relative size of objects. “The question is how the brain combines and evaluates these different pieces of information. This is a very interesting field from a mathematical point of view,” Wichmann says. “How does the brain bring together different evidences? Does it take the quality of information into account?” Wichmann investigates this topic in close collaboration with Matthias Bethge, the first winner of the Bernstein Prize of the Federal Ministry of Education and Research.

However, there is still a long way to go from understanding these primary steps of visual perception to exploring the

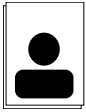
processes underlying the recognition of objects in a natural surrounding. When observing a bird in a tree, thousands of contours and shadows need to

be analyzed – nonetheless, we recognize it immediately. “We detect animals at an extraordinary rate, within 250 milliseconds,” Wichmann says, “it has been estimated that there are only about ten serial processing steps from sensation to reaction.” Thus the brain obviously does something quite clever to simplify the process. “To find this ‘something’ is our motivation,” says Wichmann. Through statistical analysis of images of animals, he hopes to find out what is special about them. A bird in a tree, for example, shows a very compact shape with defined contours – notably different to its branched surrounding. This could be a key as to how the eye detects animals.

Detecting a compact shape in a branchy environment, however, is only one aspect of vision. In order to recognize the object as a “bird,” we need to classify it; that is, we need to assess its resemblance to other objects known to us. This process is so essential yet so much a part of daily life that we are hardly aware of its significance.

One of Wichmann’s approaches to the question as to how we classify objects is to investigate our ability to differentiate human gender. What criteria do we use to classify someone as male or female? The distinctive feature about Wichmann’s approach is that he uses models of machine learning and thereby expands the methodological repertoire of cognitive research. He has the highest credentials in this field of research. Wichmann is





MEET THE SCIENTIST

a psychologist by training but has turned his attention towards the field of machine learning particularly during his past years at the Max Planck Institute for Biological Cybernetics in Tübingen. He is now working on an interesting interface between these topics.

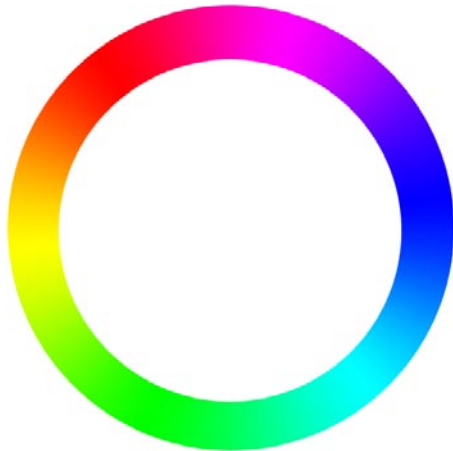
“Some machines are very good at classifying. Machines can learn, for example, to decipher handwritten postal codes,” Wichmann says. Machines also are quite adept at determining the gender of human faces. “So-called support vector machines can be trained to even make the same mistakes as humans. The advantage of using a machine is that I can subsequently take it apart and have a look inside,” Wichmann says. From here, he can infer how humans classify faces. Whether humans really proceed in a way similar to the machine still needs to be tested. Support vector machines reflect “psychological reality,” as Wichmann calls it, to an astonishing degree. Just like humans, these machines predominantly consider the eyes and the mouth region to

classify faces according to their gender. The nose or other facial features are considerably less relevant.

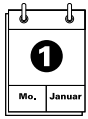
How we classify objects or how we judge their resemblance to each other is not necessarily connected to their physical features. If monochromatic colors, also known as prismatic colors, are sorted according to their wave length, the picture is quite different to the one obtained when arranged by psychological similarity. The former will be a linear layout, the latter a circular one. “Psychological and physical space are two different things,” Wichmann says, “and this is a principle that does not only apply to colors.”

Frank Jäkel, a PhD student in Wichmann’s lab, scanned thousands of tree leaves and then asked subjects which ones were most similar. In this case, resemblance could be arranged in a “psychological space” so that the distance becomes a measure of likeness even though “geometry is more complex in this case. It is non-Euclidean and therefore less intuitive but it is calculable,” Wichmann explains.

The goal of Wichmann’s work is to find rules according to which the physical world is represented in our brain. “If we knew how people classify objects, the applicability would be enormous,” Wichmann says. Even if machines today are already very good at identifying postal codes or grouping faces according to sex, there is no machine that is as efficient as the human brain.



What we perceive as similar does not necessarily have similar physical properties as well. Monochromatic colors are sorted according to similarity in the top panel and according to wave length in the bottom one. Purple and red look similar, nonetheless they are of very different wave length.



Bernstein Partners

The Bernstein Centers are core components of the “National Network Computational Neuroscience” which is funded by the Federal Ministry of Education and Research. This network is now expanding to include the Bernstein Partners. Five “Bernstein Groups” and eleven “Bernstein Collaborations” will be included in the funding measures. The Bernstein Collaborations link working groups both inside and outside the current Bernstein Centers. They are designed to combine theoretical and experimental approaches. Bernstein Groups are more complex and comprehensive; they are being established as local structural centers in regions where there is no Bernstein Center. They will be initially supported by funding of the first three years; the money can also be spent to finance positions for young researchers.

In the different projects, the neuronal basis of cognitive processes is being investigated at different levels of complexity – from the single cell to small networks on to higher brain function. When neurons transmit signals, they “fire.” Every cognitive

process is based on neurons “firing” in a defined spatio-temporal pattern. But how is the scent of a flower a sound or a memory encoded in this dynamic pattern of activity? How does the neuronal code control movements? A branch of the Bernstein projects is concerned with these questions. Others focus on investigating which neural circuits can bring about the spatio-temporal activity patterns observed.

The improvement of clinical and technological applications is also approached by the research plan of the Bernstein Partners. For example, the development of neuroprosthetics is addressed. Other projects attend to the improvement of methods in the field of transcranial stimulation or imaging technology. These approaches will contribute to basic research as well as to clinical diagnosis.

Further Information:

<http://www.gesundheitsforschung-bmbf.de/de/1363.php>

<http://www.gesundheitsforschung-bmbf.de/en/1363.php>

Bernstein Groups

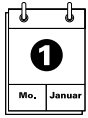
- Neuronal Signal Processing: Gabriel Wittum (University of Heidelberg)
- Cognitive Networks: Jochen Braun (University of Magdeburg)
- Processing of Pain: Herbert Witte (University of Jena)
- Dynamic Fields: Gregor Schöner (University of Bochum)
- Visual Adaption: Klaus Pawelzik (University of Bremen)

Bernstein Cooperations

- Neurovascular Coupling: Gregor Rainer (Max Planck Institute for Biological Cybernetics, Tübingen), Klaus-Robert Müller (TU Berlin)
- Information Coding: Martin Göpfert (University of Köln), Andreas Herz (HU Berlin)
- Physiology and Imaging: Andreas Hess (University of Erlangen), Michael Sibila (TU Berlin), Frank W. Ohl (Leibniz Institute for Neurobiology, Magdeburg)
- Memory Network: Uwe Thomas (Thomas Recording GmbH), Matthias

H. J. Munk (Max Planck Institute for Brain Research, Frankfurt), Klaus Obermayer (TU Berlin)

- Neuronal Synchronization: Rüdiger Köhling (University of Rostock), Stefan Heftt (University of Freiburg)
- Movement Associated Activation: Christoph Braun (University of Tübingen), Carsten Mehring (University of Freiburg)
- Olfactory Coding: Giovanni Galizia (University of Konstanz), Randolf Menzel (FU Berlin)
- Transcranial Stimulation: Gunter Knoll (University of Kassel), Walter Paulus (University of Göttingen), Klaus Schellhorn (NeuroConn GmbH)
- Network Simulation: Peter Bastian (University of Stuttgart), Alexander Borst (Max Planck Institute for Neurobiology, Martinsried)
- Temporal Precision: Hermann Wagner (RWTH Aachen), Richard Kempter (HU Berlin)
- Action Potential Coding: Siegrid Löwel (University of Jena), Maxim Volgushev (University of Bochum), Fred Wolf (Max Planck Institute for Dynamics and Self-Organization, Göttingen)



Tendering

The Federal Ministry of Education and Research (BMBF) intend to fund measures for the establishment of local “**Bernstein Centers for Neurotechnology.**” The centers will add an explicitly application-oriented component to the National Network for Computational Neuroscience.

This is to help create the new structure required for linking neuroscientific research results with technological application at an early stage and for firmly establishing the internationally emerging discipline of neurotechnology in Germany. The inclusion of industrial partners and users and the transfer of technology through staff exchanges between academia and industry will be an integral part of the Centers for Neurotechnology. The funding procedure is two-tiered. In a first step, project outlines must be submitted by June 15, 2007 at the latest.

Source / further information:

<http://www.gesundheitsforschung-bmbf.de/en/1579.php>

Bernstein scientists at high profile

From March 29 to April 1, the seventh meeting of the German Neuroscience Society took place. Two of the nine plenary lectures were given by scientists from the Bernstein Centers. Furthermore, Bernstein researchers were involved in seven of the 24 symposia at the meeting. The numbers show a growing interest in the field of computational neuroscience and a strong position of the Bernstein Centers within the field.

Personalia

The development of the brain is the focus of a research proposal involving **Fred Wolf** from the Bernstein Center Göttingen and scientists from Pittsburgh and Tokyo. The research project is funded by the Human Frontier Science Program with an amount of about 1 million Euros. In theoretical models, Wolf has already shown that nonlocal neuronal contacts play a pivotal role in the development of the cortex. The experimental verification of these theories is the goal of the research projects, which involves molecular biologists, neurophysiologists and mathematicians alike.

Job advertisements

All of the Bernstein Centers have positions open for young researchers. The Bernstein Centers offer an interdisciplinary working atmosphere in a promising research field. Further information about job openings can be found on the pages of the Bernstein Centers:

www.bccn-berlin.de

www.bccn-freiburg.de

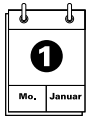
www.bccn-goettingen.de

www.bccn-muenchen.de

On our own account

The BCCN Newsletter depends on the input of the scientists from the Bernstein Centers. We appreciate ideas and proposals. Editorial deadline for the next issue is August 1.

Contact: [Katrin Weigmann, mail@k-weigmann.de](mailto:Katrin.Weigmann@k-weigmann.de)



Upcoming events

The annual **Neurex-BCCN Meeting**, entitled “New approaches to the study of brain function and dysfunction,” will take place from **July 22 to 23**. The meeting will be a part of the festivities celebrating the 550th anniversary of the University of Freiburg. Scientific issues ranging from the molecular to the systemic level will be discussed in five different sessions. A strong emphasis is put on the clinical application of scientific results.

Information and registration:

<http://www.bccn.uni-freiburg.de/news/neurex-bccn-2007/>

The **third Bernstein Symposium** will take place from **September 24 to 27** in Göttingen. During the annual event, scientists of the four Bernstein Centers will have the opportunity to discuss their research in a series of talks and poster presentations. Also this year, a PhD workshop and course on presenting scientific results to the public will take place in the framework of the symposium. For the first time, the symposium will include the Bernstein Partners.

Contact: Tobias Niemann, tobias@nld.ds.mpg.de

The “**Third International Workshop on Seizure Prediction**,” organized by members of the Freiburg Bernstein Center for Computational Neuroscience, will take place from **September 29 to October 2** in Freiburg.

Information and registration:

<https://epilepsy.uni-freiburg.de>

In honor **Leo van Hemmen’s 60th birthday**, a symposium will take place in Herrsching am Ammersee from September 27 to 29. The research of van Hemmen, professor for theoretical physics, focuses on the neuronal basis of sensation in animals and humans. He contributed essentially to the formulation of a learning rule that is based on the exact timing of neuronal activity. He thereby has promoted the field of computational neuroscience considerably.

Contact: Isolde von Bülow, ivb@zi.biologie.uni-muenchen.de



Coordinators of the Bernstein Centers

Prof. Dr. Ad Aertsen
Albert-Ludwigs-University Freiburg
Institute for Biology III
Schänzlestraße 1
D – 79104 Freiburg
Email: aertsen@biologie.uni-freiburg.de
URL: www.bccn-freiburg.de

Prof. Dr. Ulrich Büttner
Ludwig-Maximilians-University Munich
Department of Neurology
Marchionistraße 15
D – 81377 Munich
Email: ubuettner@nefo.med.uni-muenchen.de
URL: www.bccn-muenchen.de

Prof. Dr. Theo Geisel
Max Planck Institute for Dynamics and Self-Organization
Bunsenstraße 10
D – 37073 Göttingen
Email: geisel@ds.mpg.de
URL: www.bccn-goettingen.de

Prof. Dr. Andreas V. M. Herz
Humboldt-University Berlin
Department of Biology
Invalidenstraße 43
D – 10115 Berlin
Email: a.herz@biologie.hu-berlin.de
URL: www.bccn-berlin.de

Cover image: The inside of a computer. To understand complex systems like the human brain, computer models are essential. One example is the investigation of learning processes with the help of computer models (see page 3).

Impressum / Impress

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Editing:
Katrin Weigmann, mail@k-weigmann.de

Translation, English Language Editing: Maj-Catherine Botheroyd,
Eleanor Livesey, Abigail Morrison, Katie Ogston, Katrin Weigmann

Coordination:
Tobias Niemann, Simone Cardoso de Oliveira,
Margret Franke, Isolde von Bülow

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GEFÖRDERT VOM



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für Bildung
und Forschung