Bernstein Conference 2011
Computational Neuroscience / Neurotechnology
and Neurex Annual Meeting
October 4 - 6, 2011

PhD Symposium
“Perspectives – PhD and beyond”
October 7, 2011

Program and Abstracts

Freiburg, Germany
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Welcome to the Bernstein Conference 2011 in Freiburg!

It is my pleasure to welcome you to the Bernstein Conference 2011 in Freiburg, Germany. The Bernstein Conference is the central scientific meeting of the National Bernstein Network Computational Neuroscience (NNCN). This year, it takes place in Freiburg on October 4-6, 2011 and is combined with the annual Meeting of the tri-national Network in Neuroscience Neurex. Since its first edition, this conference has been growing continuously in size, scope, quality and, as a result, international visibility. This year the number of registered participants exceeds 400 and we will have more than 200 poster presentations. In fact, this year for the first time, space for the poster exhibits became a limiting factor. The success of this conference series is further documented by the impressive list of distinguished speakers.

Currently, the Bernstein Network comprises more than 200 research groups at more than 20 locations in Germany, covering all areas of modern neuroscience. Started in 2004, the NNCN is a major research initiative of the German Federal Ministry for Education and Research (BMBF), and constitutes a unique research network in computational neuroscience and neurotechnology. The Bernstein Conference 2011 is jointly organized by the Bernstein Center Freiburg and Neurex. Neurex is the largest European network in the field of neuroscience, covering basic, clinical and applied aspects of neuroscience. Created in 1999, it federates over 1000 researchers in more than 100 laboratories in the tri-national Upper Rhine Valley.

Because of the relevance of neuroscience and neurotechnology also for society, the organizers decided to use this occasion to reach out to the general public. To this end, our program features several dedicated events: the Bernstein Bazar for the professional media, the Neuro Vision film contest, and an art installation, the latter two designed to translate neuroscience in an imaginative form.

I hope you will enjoy the presentations and discussions, the exchange with your colleagues, and the various other events during the Conference.

Finally, I wish to express my sincere thanks to the supporting organizations and sponsors (listed on p. 10) and all who contributed their time and ideas to the success of this Conference.

For the Organizing Committee,

Ulrich Egert, General Chair
ORGANIZATION

General Chair
Ulrich Egert

Organizing Committee
Ad Aertsen
Simone Cardoso de Oliveira
Florence Dancoisne
Andreas Friedrich
Gunnar Grah
Gundel Jaeger
Bernd Wiebelt

PhD Symposium Chair
Janina Kirsch

Program Committee
Ad Aertsen
Ulrich Egert
Florence Dancoisne

Award Committee - Brains for Brains Awards
Jan Benda, Bernstein Award 2007 and BCCN Munich
Simone Cardoso de Oliveira, BCOS
Philipp Hövel, BCCN Berlin
Robert Martin, BCCN Berlin
Constantin Rothkopf, BFNT Frankfurt

Award Committee – NeuroVision Film Contest
Walter Sucher, SWR (chair)
Ursula Biermann, radio/tv free lanced journalist
Paul Pévet, Neurex
Wulf Rüskamp, Badische Zeitung
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NMI
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PROGRAM

TUESDAY, OCTOBER 4, 2011

Welcome, Opening and Bernstein Award 2011 Presentation
Chair: Ulrich Egert (Freiburg)

1:30 – 3:30 pm
- Hans-Jochen Schiewer, Rector of the University of Freiburg
- Andreas Herz, Spokesman of the Bernstein Project Committee
- Paul Pèvet, President of NEUREX
- Ulrich Egert, General Chair BC11
- Presentation of Bernstein Award 2011 (by Dr. Christiane Buchholz, on behalf of the German Federal Ministry of Education and Research)
- Lecture by Bernstein Award winner

3:30 – 4:00 pm Coffee Break

Session 1 - Neural Dynamics in Cortical Networks
Chair: Ad Aertsen (Freiburg)

4:00 – 5:30 pm
- Matthew Larkum (Bern/Berlin)
- Carl Van Vreeswijk (Paris)
- Stefano Cardanobile (Freiburg)

In parallel for the press (from 4 pm):
“Bernstein Bazar” with neuroscientific experts (including the Bernstein Award winner 2011), Theology Library, 3rd floor

5:30 – 6:30 pm Art Exhibit Opening

6:30 – 8:30 pm Fingerfood Buffet

7:00 – 9:00 pm Poster Session

In parallel and upon special invitation only:
Meeting of the Bernstein Project Committee, followed by: General Meeting of the Bernstein Association for Computational Neuroscience, Room HS 1139, 1st floor
WEDNESDAY, OCTOBER 5, 2011

Session 2 - Plasticity and Learning
Chair: Onur Güntürkün (Bochum)

9:00 – 11:00 am  - Andreas Lüthi (Basel)
- Abigail Morrison (Freiburg)
- Mark van Rossum (Edinburgh)
- Robert Gütig (Jerusalem)

11:00 – 11:30 am Coffee Break

Session 3 - Neuronal Mechanisms in Sensory Systems
Chair: Matthias Bethge (Tübingen)

11:30 am – 1:00 pm  - Mathew Diamond (Trieste)
- Jan Benda (Munich)
- Jens Kremkow (New York)

1:00 – 2:30 pm Lunch

Session 4 - Structure, Dynamics and Function of Networks
Chair: Stefan Rotter (Freiburg)

2:30 – 4:00 pm  - Peter Latham (London)
- Petra Ritter (Berlin)
- Markus Diesmann (Jülich)

4:00 – 4:30 pm Coffee Break

Session 5 - Structure, Dynamics and Function of Brains
Chair: Nikos Logothetis (Tübingen)

4:30 – 6:00 pm  - Gustavo Deco (Barcelona)
- Karl Friston (London)
- Cornelius Weiller (Freiburg)

6:30 – 8:30 pm Fingerfood Buffet

7:00 – 9:00 pm Poster Session
THURSDAY, OCTOBER 6, 2011

Session 6 - Dysfunctional Networks: Epilepsy
*Chair: Uwe Heinemann (Berlin)*

9:00 – 10:30 am    - Fernando Lopes da Silva (Amsterdam/Lisbon)
                   - Ivan Soltesz (Irvine)
                   - Delphine Cosandier-Rimélé (Freiburg)

10:30 – 11:00 am Coffee Break

Session 7 - Motor Decoding and Brain-Machine Interfaces
*Chair: Simone Cardoso de Oliveira (Freiburg)*

11:00 am –12.30 pm  - Andrew Schwartz (Pittsburgh)
                     - Ilka Diester (Stanford)
                     - Carsten Mehring (London)

12:30 – 2:00 pm Lunch

Session 8 - Basal Ganglia and Deep-Brain Stimulation
*Chair: Marcos Tatagiba (Tübingen)*

2:00 – 4:00 pm      - Hagai Bergman (Jerusalem)
                     - Arvind Kumar (Freiburg)
                     - Didier Pinault (Strasbourg)
                     - Alim-Louis Benabid (Grenoble)

4:00 – 4:30 pm Coffee Break

Awards Session, *Chair: Simone Cardoso de Oliveira (Freiburg)*

4:30 – 5:30 pm      - Brains for Brains Award Ceremony (*Chair: Simone Cardoso*)
                     - Conferral of Poster Prizes
                     - Presentation of NeuroVision Film Contest (*Chair: Walter Sucher, Südwstrundfunk*)

Evening Lecture
*Chair: Ad Aertsen (Freiburg)*

6:00 – 7:00 pm     Peter Dayan (London)

7:30 – 11:00 pm Conference Dinner
ORGANIZATION AND SUPPORT

The conference is mainly funded by the German Federal Ministry for Education and Research (BMBF) via the Bernstein Focus Neurotechnology Freiburg*Tübingen, which is part of the National Bernstein Network Computational Neuroscience.

Organizers
Bernstein Focus Neurotechnology (BFNT) Freiburg*Tübingen, funded by the German Federal Ministry of Education and Research (BMBF 01GQ0830)
Bernstein Center for Computational Neuroscience (BCCN) Freiburg, funded by the German Federal Ministry of Education and Research (BMBF 01GQ0420)
Bernstein Coordination Site (BCOS), funded by the German Federal Ministry of Education and Research (BMBF 01GQ0706)
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NeurAG (Neurowissenschaftliche Arbeitsgemeinschaft Freiburg / Freiburg Neuroscience Federation)

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Spemann Graduate School of Biology and Medicine, University of Freiburg, funded by the German Research Foundation (DFG)
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CONFERENCE INFORMATION

VENUE

All sessions and events organized within the framework of the Bernstein Conference 2011 (besides the Conference Dinner) take place in the “Kollegiengebäude I”, Platz der Universität 3, one of the major historic buildings belonging to the University of Freiburg in downtown Freiburg.

Within this building, the individual program components will be taking place in the following locations:

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<td>1st floor, room 1108</td>
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<td>All talks within thematic sessions</td>
<td>Aula, 1st floor</td>
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<td>Poster sessions</td>
<td>Entrance hall and adjacent hallway, ground floor</td>
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<td>Meetings of the Project Committee and Bernstein Association for Computational Neuroscience (upon special invitation only)</td>
<td>1st floor, room 1139</td>
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<td>Art Installation (opening hours: 12 am to 8 pm)</td>
<td>2nd floor, room 1228</td>
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<td>Showroom for Neurovision Film Contest candidate films (9 am to 8 pm)</td>
<td>Ground floor, room 1098</td>
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<td>Meeting of the NeuroVision Committee</td>
<td>1st floor, room 1139</td>
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<td>Bernstein Bazar for Stories from the Neurosciences (for the press)</td>
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<td>Speaker’s Preparation</td>
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<td>Storage Room</td>
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<td>Coffee Breaks, Finger Food</td>
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<td>Lunch</td>
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<td>Conference Dinner</td>
<td>Restaurant “le Buffet” in “Karstadt” Department Store, Kaiser-Joseph-Str.165</td>
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INTERNET

A password for the wireless conference network BC11 can be obtained at the registration desk.

In order to use the conference network, you have to agree to the following terms:

• NO copyright or trademark violations
• NO file sharing or large file transfers
• NO video or audio streaming

Please note that all participants share the same network. We recommend having the latest security fixes and (if applicable) a virus scanner for your system installed.

INSTRUCTIONS FOR PRESENTERS

Oral Sessions
The conference has single-track oral sessions. Talks are 20 – 30 minutes (please refer to your individual instructions from the organizers for the exact length of your own time slot), including questions. The main meeting room is fitted with audio-visual equipment, such as projector and microphones. A notebook with standard software (Windows, PowerPoint, OpenOffice, Acrobat Reader) will be provided to upload your talks ahead of time via USB. If you prefer to use your personal notebook, please make sure it can be connected by VGA.

Please get in touch with the session chair at the very beginning of the break preceding your session in order to prepare the technical aspects in advance.

Poster Sessions
Poster Sessions will be held on Tuesday and Wednesday from 7:00 pm to 9:00 pm. Poster boards are numbered according to the abstract numbers as they appear in this program book (labeled as T# for poster session on Tuesday and W# for poster session on Wednesday). On
your presentation day, please set up your poster from 10:30 am on Tuesday, and 9:00 am on Wednesday. Within your poster session, you should present your poster from 7:00 to 8:00 pm if your poster has an odd number and from 8:00 to 9:00 pm if your poster has an even number. Please take down the poster Tuesday and Wednesday by 21:30 pm.

Posters will be displayed in the entrance hall and in the adjacent hallway at the top of the stairs. Pins/adhesive tape will be available upon registration. We apologize that, for technical reasons, figures and formulas could not be printed in these proceedings.

FOOD & DRINK

Coffee and finger food (during poster breaks) are provided free of charge to all registered conference attendees and will be served in the hall in front of the Aula (“Prometheus Hall”).

Lunch will be served in the food court of the cafeteria Mensa I (just opposite the main entrance of the conference building, at Rempartstrasse 18). Your conference material includes lunch vouchers. Each voucher covers the following courses: 1 starter (soup or salad), 1 main dish with 2 sides, 1 dessert from the offer of the day, 1 soft drink. Alternatively to the menu of the day, there’s the “Schnitzel & Fries” option at Mensa I. Additional courses as well as food/drinks from places other than Mensa I are to be paid at your own cost.

CONFERENCE DINNER

The conference dinner will start at 7:30 pm at the top floor of the Karstadt department store Kaiser-Joseph-Str. 165 (at the northern end of Kaiser-Joseph-Strasse, see map above). Please allow about 10 minutes walking time from the conference venue to the Karstadt building. Alternatively, you may use tram no. 2 from “Holzmarkt” (direction “Reutebachgasse” or “Zähringen”). Exit at “Siegesdenkmal” and walk back a few steps until you reach Karstadt.

Your badge (indicating whether you booked the conference dinner upon registration) serves as entrance voucher to the Conference Dinner, so do not forget to bring it along with you.
SPECIAL EVENTS

Bernstein Award for Computational Neuroscience

Since 2006, the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) annually confers the Bernstein Award for Computational Neuroscience to excellent junior researchers with outstanding ideas for new research projects. The award is endowed with up to 1.25 million € over the course of five years and is one of the most highly remunerated research awards for young scientists in Germany. With this funding, the awardees can establish their own, independent research group at a research institution in Germany.

The Bernstein Award 2011 will be presented by Dr. Christiane Buchholz (BMBF) within the opening session of the Bernstein Conference 2011 on October 4, 2011. The Bernstein Awardee 2011 will give a talk immediately following the award ceremony about his/her current and planned research.

Event for the press: “Bernstein Bazar”

The "Bernstein Bazar" offers to journalists the opportunity to get an overview over selected topics of the neurosciences by talking to selected neuroscientific experts, including the Bernstein Awardee.

The bazar works in analogy to speed-dating. At five tables, the following topics are briefly presented by the respective experts:

- Learning and memory (Abigail Morrison, Onur Güntürkün)
- Vision - how we explore the world (Felix Wichmann, Matthias Bethge, Christoph von der Malsburg)
- Brain-computer interfaces (Niels Birbaumer, Ulrich Egert, Tonio Ball)
- How does the brain encode information? (Susanne Schreiber, Martin Stemmler, Jan Benda)
- When the brain does not work the way it should (Martin Weygandt, Oliver Müller, Thomas Hahn)

After 10 minutes, journalists move on to the next table. Following this overview, there is time for individual conversations with the scientific experts.

Brains for Brains Awards

The Brains for Brains Awards are an initiative of the Bernstein Association for Computational Neuroscience, supported by external donors. This year’s awards were kindly provided by Brain Products GmbH, Gilching and Multi Channel Systems MCS GmbH, Reutlingen. The Brains for Brains Award honors outstanding young international scientists who have achieved a peer-reviewed scientific publication before starting their doctoral thesis. It consists of a 500 € cash prize and a travel fellowship of up to 1500 € covering their trip to Germany, participation in the Bernstein Conference and two individually planned visits to selected Computational Neuroscience labs in Germany. During the award ceremony, the awardees give a short presentation of their work.
Poster Prizes

Outstanding poster presentations will be awarded with poster prizes. A jury will judge all posters and name the winners in the award session on Thursday. The prizes are donated by conference co-organizer NeurAG and the Bernstein Center Freiburg.

Art Installation “Sensory Neuronal Network”

“The intention of this project is to offer a perspective on neuronal interactions that is accessible in the strictest sense of the word, establishing a connection with the neurobiological ‘inner world’ through computer simulations that are based on the insights of neuroscientific research. For now, our installation is only able to stimulate such a perspective, but not to found a scientific method.”

(Rainer Dunkel)

Reducing complex questions to their basics is the essence of scientific and artistic work alike. One characteristic difference between these disciplines lies in the criteria that are being applied to identify the aforementioned ‘basics’. Whereas the natural sciences strive to establish maximally transparent and objective quality criteria, e.g. through the peer-review process, the contemporary artistic exploration aims mainly at the subjective experience of the recipient. Considering these fundamental differences, it is not astonishing that these two disciplines hardly benefit from each other nowadays, irrespective of their comparable goals.

With their installation sensory neuronal network, Berlin-based artist Rainer Dunkel and the Bernstein Center Freiburg, particularly Benjamin Staude as well as Stefan Rotter, Arvind Kumar, and Gunnar Grah, endeavor to initiate a discourse that is productive for both disciplines. At the core of their work lies a neuronal, conductance-based integrate-and-fire network. On the one hand, this network controls the acoustic-visual presence of the installation: The tonal translations of firing neurons within the network create an acoustic representation of the neuronal dynamics. On the other hand, sensory elements at the installation allow to directly influence the controlling network. Thus, the immense complexity of neuronal dynamics becomes immediately accessible to the recipient, allowing to directly experience some perpetual questions of neuroscience: How can a system be so reliable in its performance if it reacts in such different ways to apparently identical stimuli? What are the similarities in its responses to identical, as opposed to differing stimuli…?

Approaching a topic of research from an aesthetic perspective furthermore allows a scientist to pose a novel set of questions, for instance: Which aspects of neuronal dynamics are lost through their description in an objectifying, statistic description? How are acoustically perceptible melodies reflected statistically within a network’s activity? Are such aesthetic components biologically relevant – and if they are, could these effects be measured?

The juxtaposition of scientifically-abstract thought and physically-sensual experience in an artistic form offers the chance to confront the scientists themselves in new ways with aspects of their own work. Consequently, the space of the installation becomes “neutral ground” on which scientists and members of the public face the function of their brains as equals. Fostered by the unusual form and an experience that is new for both groups, the installation enables them to enter a dialog.

The installation sensory neuronal network will be presented to the public for the first time at this Bernstein Conference. The opening takes place on October 4, 5:30 pm, in Room 1228 of the University’s “Kollegiengebäude 1”, which also hosts the conference’s main event.
Neurovision Film Contest
International Short Film Competition

“Can you show us the invisible…?”

… we asked both neuroscientists and film students, and we did so for a reason: The insights from brain research and the advances in neurotechnology are of great importance, nevertheless it is often quite hard to communicate them to the general public; to make our work accessible. Neurons are microscopically small, their activity invisible to the eye. Descriptions of brain function and the technological possibilities to interact with it are often quite abstract and not intuitively understandable.

Film, on the other hand, has the ability to illustrate complex ideas, using a single, striking image where many words would otherwise be necessary. For this reason, the Bernstein Conference is featuring for the first time a competition for neuroscientific films.

The entries we received from several countries couldn’t be more diverse in respect of their topics and their filmic approaches. There are, of course, the classic forms of reporting about current scientific findings; and new forms of visualization for brain data which actually make the invisible visible to us. But there’s also noir, parody, and a rather “retro” look at the promises of neuro-technology…

The conditions for entering the contest were rather straightforward: A film had to be shorter than 5 minutes, its language had to be English, and the film’s creators should not have completed an education as a media professional. On the one hand, these requirements should entice scientists to think about ways to research to lay audiences. Communication with colleagues from the same field is part of the daily routine in science, but having to present one’s own work in a generally understandable way tends to be the exception. On the other hand, the conditions were formulated in order to invite film students to approach our complex, but thrilling field of research.

Cast your vote for the audience award!

During the contest, two prizes will be awarded. A jury, consisting of experienced journalists and scientists, will choose their favorite production, and the other prize will be an audience award: Every conference participant will have the chance to see the films and to cast a vote. During the conference, the films that entered the competition will be shown in rotation in room 1098. In your conference bag, you will find a ballot with the films’ titles and their creators. Mark your favorite film (you have one vote) and put your ballot into the box provided at registration. During the award session on the final day of the conference, the winners of the NeuroVision Film Contest will be announced. The award comes with prize money of 500 €.
NNCN PhD Symposium "Perspectives – PhD and Beyond"

Venue: Aula of the historic central University in downtown Freiburg
Time: October 7, 2011; 10 am - 2 pm (small lunch is provided)

In this year's NNCN PhD Symposium we will address the career perspectives of Bernstein PhD students after completion of their thesis work.

To approach this question, we invited four speakers, two from within academia and two from outside, all with an education in neuroscience. Each will report on their personal career, its ups and downs, situations in which they had to decide on how to continue, and what circumstances made them choose the way they went.

The two speakers who continued an academic career will focus on how to select a proper postdoc position, how to define your own field of research by emancipating from your supervisors, and how they managed to become an established scientist in the community.

The two other speakers will cover such aspects as why they decided to leave academic research, how they reached the position they are working in now, how these positions differ from their earlier work, and which aspects of their education were required for their current job.

Our aim is to provide you, the NNCN PhD students, with first-hand insights into the various career perspectives after the PhD. Our goal is to enable you to base future decisions on which direction to take on a more solid basis, including an awareness of your own abilities and the various possibilities open to you.

nuSPIC is an online application which poses the challenge to discover functions implemented (hard-wired) in spiking neural networks (SNNs) by stimulating and recording activity of neurons. In addition, we are inviting users to implement predefined mathematical/logical functions using SNNs. Both these challenges are designed to test the tacit assumptions in neuroscience that functions performed by a specific brain structure can be identified only when sufficient information concerning neural activity and connectivity were available, and any mathematical/logical function can be implemented using SNNs. [detailed abstract on page 36, more information: nuspic.g-node.org]
TALKS
[S1] Contribution of active dendrites to the neural dynamics of cortical circuits
Matthew Larkum
larkum@pyl.unibe.ch
Department of Physiology, University of Bern, Switzerland

The architecture of neural networks is commonly encapsulated in terms of the connectivity between elements and the weights for these connections. The function of the neurons themselves is mostly reduced to simple integrative units. However, this view of the neuron ignores the tremendous complexity of real neurons, particularly neocortical neurons which have a rich array of active conductances that shape and even dominate the input/output function. Most of our knowledge about dendritic properties comes from careful, multi-site recordings in vitro. More recently, techniques have been developed that allow us to study the behaviour of dendrites in vivo which has opened up the possibility of exploring the influence of active dendrites on the neural dynamics of cortical circuits.

In addition to the highly complex intracellular interactions, it has become clear that compartmentalized inhibition (inhibition impinging on different subdomains of the dendritic tree) can powerfully regulate active dendritic processes. The integrative process is therefore highly dependent on the spatiotemporal pattern of inhibitory input which can sometimes drastically change the output firing mode of the neuron. Furthermore, the output of the any given neuron tends to feeds back on to inhibitory circuits and further complexity to the resultant network activity. In this talk, I will summarize the recent advances in this field with an emphasis on the layer 5 pyramidal neuron. I will present data showing how the active properties of this highly complex neuron both shape and are influenced by the network in which it is embedded.

[S1] Orientation selectivity without orientation map
Carl van Vreeswijk
cornelis.van-vreeswijk@univ-paris5.fr
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Most neurons in primary visual cortex (V1) have an orientation selective response. This is true for animals such as cats and primates, in which V1 has an orientation map, as well as for animals without such a map, e.g. rodents. The mechanism for orientation selectivity remains a matter of debate. Whether selectivity is primarily due to feedforward connectivity or to recurrent interactions has not been settled. If the mechanism is primarily feedforward, the presence or absence of an orientation map hardly matters, but if recurrent interactions are important the spatial organization of preferred orientations could affect the mechanism. Theoretical studies of orientation selectivity have, up to now, focused on models of V1 with orientation map. The proposed recurrent mechanisms rely on the fact that, with a map, neurons mostly receive recurrent connections from cells with similar preferred orientations. The connectivity in V1 without map is hotly debated. Unclear is whether connections depend on the difference in stimulus feature preferences. With such a preference, the distributions of orientations of cells projecting to a neuron would be similar to that in cortices with a map and the same mechanism could operate. In contrast, when connectivity is independent of difference in preferred orientation, this distribution is flat. How can orientation tuning arise in this case? Here we argue that orientation selectivity arises naturally in V1 without feature dependent connectivity if it operates in the balanced regime. To this end, we consider a network consisting of an excita-
tory and an inhibitory population of randomly connected neurons with, on average, $K$ recurrent inputs from each population. The strengths of the recurrent connections are of order $1/\sqrt{K}$. Neurons also receive a feedforward input, with an untuned part of order $\sqrt{K}$ and a random orientation dependent part of order 1. Feedforward input, total excitatory and total inhibitory feedback are all much larger than the rheobase. Nevertheless neurons fire at a reasonable rate because the net feedback approximately cancels the feedforward input. Because of the connectivity, the total excitatory and inhibitory feedback are almost untuned. As a result, the untuned part of the feedforward input is approximately canceled by the feedback, but its much smaller tuned part is not. This results in an output of the cells with significant orientation tuning. The heterogeneity in tuning curves is large. Our study predicts that the average voltage of the neurons, relative to rest, shows clear orientation tuning, but the size of the voltage fluctuations are orientation independent.

[S1] Stochastic models of recurrent neural networks
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Stochastic models of neural activity have a long standing tradition in the neuroscientific research, especially with regards to analysis of neural data. Analysis of recurrent neural networks models, in contrast, has been proven difficult. The main tools in the analysis are Fokker-Planck equations. Fokker-Planck theory have made possible to study stability properties and, at least partially, correlations in recurrent neural networks of leaky integrate-and-fire neurons.

Here we report on recent progresses regarding rate based, non Gaussian models of spiking neural networks. We address two different types of models: linear and nonlinear. The prototype for linear models of recurrent spiking networks are the Hawkes networks. In Hawkes networks, input spikes produce a linear transient in the rate of the post-synaptic neuron. Transients caused by different spikes superimpose linearly. A complete theory for pairwise correlations in Hawkes networks exist and can be exploited to study the links between structural properties and dynamical properties of networks.

Nonlinear models exist in several different forms and variants. We describe here multiplicatively interacting point processes and their connection to Lotka-Volterra equations, a type of equations that have been extensively used in the neuroscientific literature, based on phenomenological considerations. In recurrent networks of multiplicatively interacting processes, input spikes have a multiplicative effect on the rate of the post-synaptic neuron. They are linear in the logarithm of the rate and correspond to non leaky integrate-and-fire neurons with exponential escape noise. Recurrent networks of such neurons naturally display complex properties like multistability and chaos and can be used to construct networks with contrast invariant input-output tuning.

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Session 2 - Plasticity and Learning

[S2] Defining the neuronal circuitry of fear
Andreas Lüthi
We use an interdisciplinary approach to address the question how amygdala microcircuits mediate the acquisition and extinction of conditioned fear responses. In my talk, I will describe how switches in the activity between distinct types of amygdala neurons mediate context-dependent expression and extinction of fear memories. Moreover, I will present recent data demonstrating that functionally distinct types of amygdala neurons are specifically embedded and precisely connected both within the local circuitry and within larger-scale neuronal networks. Thus, in contrast to previous models suggesting that amygdala neurons are active during states of high fear and inactive during states of low fear, our findings indicate that activity in specific neuronal circuits within the amygdala cause opposite behavioral outcomes and provide a new framework for understanding context-dependent expression and extinction of fear behavior.

[S2] Syntax, synfire, and synaptic plasticity: Modeling the generation of structure in birdsong and neuronal networks

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Adult Bengalese finches generate a variable song that obeys a distinct and individual syntax. The syntax is gradually lost over a period of days after deafening and is recovered when hearing is restored. In the first part of this talk I will present a spiking neuronal network model of the song syntax generation and its loss, based on the assumption that the syntax is stored in reafferent connections from the auditory to the motor control area. Propagating synfire activity in the HVC (high vocal center) codes for individual syllables of the song and priming signals from the auditory network reduce the competition between syllables to allow only those transitions that are permitted by the syntax. Both imprinting of song syntax within HVC and the interaction of the reafferent signal with an efference copy of the motor command are sufficient to explain the gradual loss of syntax in the absence of auditory feedback.

In the second part of this talk I will consider how the synfire chains assumed in the first part could develop. It has long been thought that spike-timing dependent plasticity (STDP) provides an answer to the question of how the brain can develop functional structure in response to repeated stimuli. However, convincing demonstrations of this capacity in large, initially random networks have not been forthcoming; such demonstrations as there are typically rely on constraining the problem artificially. I will present a theoretical analysis based on a mean field approach of the development of feed-forward structure in random networks. An unstable fixed point in the recruitment dynamics prevents the stable propagation of structure in recurrent networks with weight-dependent STDP. The key theoretical predictions can be confirmed in large-scale simulations. The theory provides insight into the reasons why such development does not take place in unconstrained systems and enables the identification of candidate biologically motivated adaptations to the balanced random network model that might resolve the issue.

[S2] Representational capacity of neural codes in the cortex

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The coding of sensory stimuli in the neural response is a fundamental property of neural systems that impacts many of its properties. The coding scheme also determines how many different stimuli a population of neurons can represent. Although the coding of single stimuli has been studied extensively, coding of multiple stimuli has been studied far less. Here we study the representational capacity in the visual system when stimulus pairs are represented simultaneously. We assume that the response to the individual stimuli is given, and that the neurons interacts non-linearly to form the response to the pair. Using a Bayesian read-out we find that using a linear sum leads to a smaller capacity, than a maximum-like interaction. Thus non-linear interaction improve coding capacity. The results provide a novel interpretation for the non-linear interaction observed experimentally.

[S2] Spike-timing based neuronal information processing: applications to vision and speech

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The timing of action potentials of sensory neurons contains substantial information about the eliciting stimuli. Although computational advantages of spike-timing-based neuronal codes have long been recognized, it is unclear whether and how neurons can learn to read out such representations. We propose a novel biologically plausible supervised synaptic learning rule, the tempotron, enabling neurons to efficiently learn a broad range of decision rules, even when information is embedded in the spatio-temporal structure of spike patterns and not in mean firing rates. We demonstrate the enhanced performance of the tempotron over the rate-based perceptron in reading out spike patterns from retinal ganglion cell populations.

Extending the tempotron to conductance-based voltage kinetics, we show that this model can subserve time-warp invariant processing of afferent spike patterns. Furthermore, we show that the conductance-based tempotron can learn to balance excitation and inhibition to match its integration time constant to the temporal scale of a given processing task. These mechanisms enable already small populations of model neurons to match the performance of state-of-the-art speech recognition systems on isolated word recognition tasks.

Session 3 - Neuronal Mechanisms in Sensory Systems

[S3] Stages of processing for building tactile perception in the rat whisker system

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Our sensory systems gather stimuli as elemental physical features yet we perceive a world made up of familiar objects, not wavelengths or vibrations. Perception occurs when the neuronal representation of physical parameters is transformed into the neuronal representation of meaningful objects. How does this occur? Understanding the general principles for the con-
struction of perception will help explain why we experience the world as we do. An ideal platform for the inquiry is the rat whisker sensory system: it produces fast and accurate judgments of complex stimuli, yet can be broken down into accessible neuronal mechanisms. Understanding start-to-finish tactile perception in rats is a long term project and we are far from reaching its conclusion. Here I will present some pieces of the puzzle that we have so far collected, focusing on what happens in the whiskers and in the brain when a rat senses and classifies a texture.

[S3] **Stochastic adaptation currents as a colored noise source in a sensory neuron**

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Channel noise is the dominant intrinsic noise source of neurons causing variability in the timing of action potentials and interspike intervals (ISI) and thus affects neural information processing. Slow adaptation currents are observed in many cells and strongly shape response properties of neurons. We study the effect of channel noise of adaptation currents on the ISI statistics of an integrate-and-fire model neuron by means of analytical techniques and extensive numerical simulations. We contrast this stochastic adaptation with the commonly studied case of a fast fluctuating current noise and a deterministic adaptation current. For the latter case the ISI density is well approximated by an inverse Gaussian (IG) as expected for white-noise driving and the ISI correlations are negative. In marked contrast, stochastic adaptation generates colored-noise with correlation time given by the adaptation time constant. The resulting ISI density is more peaked and has a heavier tail than an IG density and the serial correlations are positive.

Based on these theoretical findings we investigate potential sources of spike-response variability in auditory receptor neurons of locusts. At low spike frequencies, our recordings show negative ISI correlations and ISI distributions that match the IG, in accordance with a white noise source interacting with an adaptation current. At higher spike frequencies, more peaked distributions and positive ISI correlations appear, as expected for a colored-noise source. Simulations of a minimal conductance-based model of the auditory receptor neuron with stochastic ion channels suggest channel noise from an adaptation current and the receptor or sodium current as the main sources for the colored and white noise, respectively. We also discuss how the different noise sources shape the spike-count statistics. In particular, how the positive correlations caused by the colored noise create an optimal integration time with minimal spike-count variability.

[S3] **Adaptive sampling of visual stimuli in thalamic and cortical neurons**

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Neurons in the visual system have been characterized for decades using predefined sequences of stimuli that sample a limited portion of sensory space. Ideally, it should be possible to adaptively modify the stimuli for each individual neuron to explore larger portions of stimulus space in a ‘closed-loop’ manner (i.e. the stimuli are modified based on the response of the
neuron →, the response of the neuron increases as more effective stimuli are found → the new stimuli are again modified to increase the neuronal response even further.

We have tested different approaches of adaptive stimulus sampling to characterize the response properties of thalamic (lateral geniculate nucleus “LGN”) and cortical (area V1) neurons in the cat. A simple algorithm based on neuronal spike count was remarkably effective at optimizing binary white noise stimuli for LGN neurons. The optimization process was started by presenting a binary noise stimulus. In each iteration of the optimization, we calculated the response maps for black and white pixels. Thresholding these maps provided the main cluster of pixels that were driving the neuron. Once the main pixel cluster was obtained, the stimuli for the following iterations were generated by surrounding the main cluster with a ring of random pixels. Interestingly, we had to introduce spatial correlations among the ring pixels to make the stimulus optimization more effective. The resulting optimal stimulus ensemble revealed more effectively the structure of the receptive field surround than classical reverse correlation methods.

The optimization of white noise stimuli for cortical neurons was more challenging and we are still working on different approaches to make the optimization efficient. At this time, one of the most successful approaches is based on a Particle Swarm Optimization (PSO) algorithm that optimizes sequences of spatiotemporal noise pixels based on isolated single neuron responses. The PSO is a population based technique in which particles move around in a search-space to locate the optimum. Social interactions among particles (and the history of individual particles) are then used to update the particles positions. In our case, a particle represented one sequence of spatiotemporal pixels and the search-space was the entity of the luminance values of all pixels. The PSO algorithm was able to optimize stimulus sequences to drive strong and reliable responses in both linear and nonlinear cortical neurons. Preliminary results suggest that the optimization is remarkably restricted in cortical space (i.e. neighboring V1 neurons that were just a few hundred microns away from the optimized neuron did not show robust increases in firing rate during the optimization process).

Taken together, adaptive sampling provides a powerful approach to optimize white noise stimuli for single LGN and V1 neurons with linear and nonlinear receptive fields. Our preliminary data suggests that this optimization can be remarkably restricted in cortical space, providing new insights into the amount of redundancy in the visual cortex.

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Session 4 – Structure, Dynamics and Function of Networks

[S4] How to throw away information optimally

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A wide range of computations performed by the nervous system involve throwing away information, a particular type of probabilistic inference known as marginalization. This is certainly true of sensory processing; for example, to recognize a person based on the activity of neurons in our retina, we have to throw away information about the person's pose, motion, clothes, background, light level, etc. It is also true in other computations, ones as diverse as causal reasoning, odor recognition, motor control, visual tracking, coordinate transformations, visual search, decision making, and object recognition, to name just a few. The question we address here is: how could neural circuits implement such marginalizations?
We show that when the statistics of spike trains follow a distribution which we call "Poisson-like" - a distribution that is close to what has been reported in vivo - some of the more common marginalizations can be achieved with networks that implement a quadratic nonlinearity and divisive normalization, the latter being a type of nonlinear lateral inhibition that has been widely reported in neural circuits. We illustrate this with three common examples: sensorimotor transformations, visual tracking, and olfaction.

[S4] Brain states - revealing meanings and mechanisms by combining measures and models

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Neuronal dynamics are thought to constitute the foundations of perception, cognition and behavior. Yet, the exact functional roles and underlying generative mechanisms of those ongoing dynamics are largely unknown. I show how we use multimodal imaging and computational approaches to address these issues. First, I will demonstrate that spontaneous large-scale brain oscillations exhibit complex and nonlinear features and how these features emerge in simulated data generated by a thalamocortical neural field model. State-dependent and time-delayed corticothalamic feedback turned out to be a key mechanism. Next, I will present how modes of ongoing electrical oscillations influence information processing in the brain. They not only account for measurable variability in evoked electroencephalography and functional magnetic resonance imaging responses -- but also influence human behavior. Finally, I will demonstrate that brain plasticity related to perceptual learning modifies the ongoing brain dynamics during the resting state. These changes are tightly related to the learning success. Taken together, I will point out how experimental and theoretical studies complement each other in understanding generative mechanisms of brain states and their functional meanings.

[S4] Excitability and robustness of a multi-layered local cortical network model

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In the past decade, the cell-type specific connectivity and the activity of local cortical networks have been characterized experimentally to some detail. In parallel, modeling has been established as a tool to relate network structure to activity dynamics. While the available connectivity maps have been used in various computational studies, prominent features of the simulated activity such as the spontaneous firing rates do not match the experimental findings. Here, we show that the inconsistency arises from the incompleteness of the connectivity maps. Our comparison of the most comprehensive maps reveals their main discrepancies: the lateral sampling range and their account of a specific selection of target cells. Considering both restrictions we compile an integrated connectivity map and analyze the unified map by simulations of a full scale model of the local layered cortical network. The simulated spontaneous activity is asynchronous irregular and the cell-type specific spontaneous firing rates are in agreement with in vivo recordings in awake animals, including the low rate of layer 2/3 excitatory cells. Similarly, the activation patterns evoked by transient thalamic inputs reproduce recent in vivo measurements. The correspondence of simulation results and experiments rests...
on the consideration of specific target type selection and thereby on the integration of a large body of the available connectivity data. The cell-type specific hierarchical input structure and the combination of feed-forward and feedback connections reveal how the interplay of excitation and inhibition shapes the spontaneous and evoked activity of the local cortical network.

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Session 5 – Structure, Dynamics and Function of Brains

[S5] Ongoing cortical activity at rest: The global attractor structure of the brain

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The ongoing activity of the brain at rest, i.e. under no stimulation and in absence of any task, is astonishingly highly structured into spatio-temporal patterns. These spatio-temporal patterns, called resting state networks, display low-frequency characteristics (<0.1 Hz) observed typically in the blood-oxygenation level-dependent (BOLD) fMRI signal of human subjects. We aim here to understand the origins of resting state activity through modelling via a global spiking attractor network of the brain.

This approach offers a realistic mechanistic model at the level of each single brain area based on spiking neurons and realistic AMPA, NMDA and GABA synapses, which represent a degree of physiological detail missing in former models. Integrating the biologically realistic DTI/DSI based neuroanatomical connectivity into the brain model; the resultant emerging resting state functional connectivity of the brain network fits quantitatively best the experimentally observed functional connectivity in humans when the brain network operates at the edge of instability. Under these conditions, the slow fluctuating (< 0.1 Hz) resting state networks emerge as structured noise fluctuations around a stable low firing activity equilibrium state in the presence of latent “ghost” multi-stable attractors. The multistable attractor landscape defines a functionally meaningful dynamic repertoire of the brain network that is inherently present in the neuroanatomical connectivity.

[S5] Active Inference and Action Observation

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This presentation will look at action, perception and cognition as emergent phenomena under one unifying perspective. This Helmholtzian perspective regards the brain as a (generative) model of its environment. The imperative for any brain is then to maximize the (Bayesian) evidence for its model of the world. We will see that this is not just mandated for the brain but for any self-organizing system that resists a natural tendency to disorder in a changing environment. More specifically, maximizing Bayesian evidence leads in a fairly straightforward way to an understanding of action as active inference, and perception in terms of predictive
coding (cf., the Bayesian brain). I hope to illustrate these points using simulations of action observation.

[S5] How can patient data be related to the dual loop model
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Since about thirty years, it was proposed that visual information arriving in the occipital lobe is processed along two ways, a dorsal pathway for the „where“ of the information, and a ventral pathway for the „what“ of the information. However, this dual pathway is not only found in the visual system. It has been suggested for the attentional system, for the motor system and for acoustic analysis. These findings suggest a general pattern of function for the dorsal and ventral stream. In analogy to the acoustic system it is proposed that the dorsal stream subserves the analysis of linearly arranged sequential elements. It uses forward and feed-back models (predictors and controllers) to compare the sensory percept with internal models or emulators. This subserves (automated) correction and the so-called working memory. The ventral stream would serve the structural analysis of perceived elements to given rules and relies on episodical memory to extract meaning and convey thought.

How can we interpret symptoms in aphasia patients under the premises of a dual loop system? Across a series of 100 consecutive acute aphasics, comprehension problems (following verbal commands, word and sentence comprehension and results in the token test) map using the Brunner- Munzel test onto the extreme capsule, illustrating the role of temporo-frontal interaction for comprehension. Repetition problems (automated sequences as numbers, weekdays, syllable, nomina, sentences) map onto the arcuate fascicle.

Does this mean that comprehension is coded for or represented in the extreme capsule? Not at all, the extreme capsule may represent the common denominator of all infarcts from the anterior and posterior MCA territory in patients with (initial) comprehension deficits and the network subserving comprehension. The extreme capsule is needed for integration of semantic and syntactic information from temporal and inferior frontal regions, along with contributions of working memory and episodic memory and rule recall. The findings may underline the functional significance of the dual loop system; however, only looking at comprehension problems is an “unnatural” setting. In most cases single symptoms should be seen isolated. There are few patients with solely a comprehension problem.

Symptoms of patients with aphasia cluster in syndromes. These can be defined and reliably classified. This is due to the irrigation territories of the middle cerebral artery and due to the organization of language in the brain. When classifying the same 100 patients into Wernicke’s type aphasia according to the AAT or AABT, the lesion of the selected 16 patients map onto the posterior STG, i.e. Wernicke’s area, posterior insula and the inferior part of postcentral gyrus. Comprehension problems are a hallmark of Wernicke’s aphasia and indeed most people would agree that the temporal lobe does play a role in semantics. But Wernicke aphasia is characterized by more features, e.g. fluent speech with prominent semantic or phonematic paraphasias, thus also a “defect” in speech production. Wernicke’s area is not the site for correct speech but it participates in the ventral as well as the dorsal stream. While semantic jargon may be due to comprehension problems, phonematic jargon may be related to an affection of the dorsal stream. Area SPT participates in sound-to-articulation mapping in the dorsal stream (Hickok 2000).

As Wernicke himself put it: the sound images do not take appropriate control over the motor images, thus the self-monitoring function of the dorsal stream is affected. Thus, Wernicke
aphasia represents a new phenotype, through lesioning of the temporal lobe and thereby affecting the ventral and the dorsal streams.

**Session 6 – Dysfunctional Networks: Epilepsy**

[S6] **Dynamic models of neuronal systems displaying abnormal oscillations**
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Epilepsy is a dynamic disease of neuronal networks. To understand how epileptic seizures occur, it is necessary to take into account that the brain of epileptic subjects is able to function in two very distinct modes: a normal state and a state characterized by abnormal oscillations, i.e. epileptic seizures. A main question is how the transition (i.e. a bifurcation) from the normal to the epileptic state may take place. Such transitions do not occur easily in the normal brain due to the set of parameters that maintains the stability of neuronal networks (homeostatic factors). In the brain of epileptic subjects, however, these parameters are disturbed so that the threshold for transitions is low and these may occur spontaneously. Here we consider first, the main aspects of how the stability of neuronal networks may be maintained and disturbed in epilepsy. Thereafter we discuss how transitions between normal and epileptic behavior may occur in two important systems with respect to epilepsy: networks of the thalamocortical and of the hippocampal systems. Finally the question of how neuronal networks involved in epileptic behavior may be identified in patients and how seizure sensitivity may be modulated is analyzed.

[S6] **Functional network connectivity of the epileptic hippocampus**
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With the rapid rise in our knowledge about the structural and functional properties of hippocampal microcircuits, it has become possible to closely integrate experimental findings with large-scale, anatomically and biophysically realistic computational simulations of control and epileptic neuronal networks with unprecedented precision and predictive power. We are developing full-scale realistic network models of the control and injured temporal lobe in order to investigate fundamental questions related to normal hippocampal microcircuit function and the mechanistic bases of epilepsy. I review the conceptual framework and biological basis of model development and show specific applications, including new computational and experimental results concerning the roles of aberrant hyper-connected hub-like neurons in seizures. The talk will highlight the unprecedented predictive and analytic power of increasingly user-friendly, freely shared, highly realistic, large-scale computational models in understanding normal circuit function and temporal lobe epilepsy.

[S6] **Computational modeling and interpretation of epileptic activities**
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Electrophysiological recordings play a crucial role in epilepsy treatment and research. To capture the neural mechanisms involved in the generation and propagation of epileptic activities, many recording techniques have been developed, allowing for the observation of neural activity at multiple spatial scales: microscopic (single neurons), mesoscopic (local networks), and macroscopic (global networks). The interpretation of these multiple observations is a key but complex issue. It requires the characterization of the relationships between recorded signals and the underlying neural activity, as well as the inter-relation of the different types of signals. Computational modeling may provide useful tools for addressing these issues. In particular, over recent years, new modeling approaches have been developed which allow for the simulation of electrophysiological signals from ensemble neuronal activity. They combine quantitative descriptions of neuronal activity in neural network models with biophysically inspired modeling of the field potentials recorded by electrodes from such network models (forward modeling). The approach allows for studying, on the one hand, the relationship between recorded signals and the underlying spatio-temporal organization of neuronal sources and, on the other hand, the relations between different types of recordings (LFP, ECoG, EEG, etc.). Two example studies using this modeling approach are shown.

In the first study, at a macroscopic level, the model is used to examine the impact of source-related parameters (source area, location, and synchrony) on the properties of epileptiform activities (interictal spikes) in depth-EEG and scalp-EEG signals, and to relate scalp activities to the underlying intracerebral field potentials. In the second study, at a microscopic level, the model is used to investigate the relationship between correlations in individual neurons’ spiking activities and properties (amplitude spectrum, amplitude distribution) of resulting LFP signals, and to relate the different network activity states to the LFP profiles recorded in these network states.

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Session 7 – Motor Decoding and Brain Machine Interface

[S7] Progress toward a high-performance brain-controlled interface

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A better understanding neural population function would be an important advance in systems neuroscience. The change in emphasis from the single neuron to the neural ensemble has made it possible to extract high-fidelity information about movements that will occur in the near future. This ability is due to the distributed nature of information processing in the brain. Neurons encode many parameters simultaneously, but the fidelity of encoding at the level of individual neurons is weak. However, because encoding is redundant and consistent across the population, extraction methods based on multiple neurons are capable of generating a faithful representation of intended movement. The realization that useful information is embedded in the population has spawned the current success of brain-controlled interfaces. Since multiple movement parameters are encoded simultaneously in the same population of
neurons, we have been gradually increasing the degrees of freedom (DOF) that a subject can control through the interface. Our early work showed that 3-dimensions could be controlled in a virtual reality task. We then demonstrated control of an anthropomorphic physical device with 4 DOF in a self-feeding task. Currently, monkeys in our laboratory are using this interface to control a 7-DOF arm, wrist and hand to grasp objects in different locations and orientations. Our recent data show that we can extract 10-DOF to add hand shape and dexterity to our control set.

[S7] Challenges and Opportunities for Next-Generation Intracortically Based Neural Prostheses
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Neural prosthetic systems aim to restore limb control in patients with motor disorders. When natural motor pathways are destroyed, neural prostheses bypass the faulty circuits by translating neural signals directly from the brain into control signals for guiding computer cursors, prosthetic arms, and other assistive devices. Intracortical electrode arrays are the read out device measuring action potentials and local field potentials from individual neurons, or small populations of neurons, in the motor cortices and can provide considerable information for controlling prostheses. Despite several compelling proof-of-concept laboratory animal experiments and an initial human clinical trial, at least three key challenges remain which, if left unaddressed, may hamper the translation of the systems into widespread clinical use: achieving levels of performance across tasks and across environments comparable to a natural motor control, achieving robustness across multiple decades, and restoring a naturalistic proprioception and somatosensation. Recent algorithm, model, and hardware developments might help meeting the read out challenges (high performance with increased longevity). On the write in side, optogenetics which enables light to control neural activity in specific sets of neurons may allow restoring a naturalistic perception of touch. These new developments may achieve true clinical viability of neural prostheses.

[S7] Brain-computer interfaces using field potentials
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A brain-computer interface (BCI) translates neuronal signals reflecting a subject’s movement intentions into commands driving a machine (e.g. a prosthesis or a computer). In this talk I will present recent findings from our research on the development of BCIs that use non-spiking neuronal signals, e.g. signals measured directly from the surface of the human brain (Electrocorticogram, ECoG) or signals measured non-invasively (EEG / MEG). I will show that different parameters of natural hand/arm movements (e.g. movement direction, velocity and grasp) can be predicted from these signals and used for online control of external actuators. While this demonstrates the principle feasibility of the approach, current BCI control is of limited complexity and performance. To advance ECoG/EEG/MEG based BCIs a better understanding of movement encoding in these signals is essential and I will discuss our recent progress in this direction.
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Session 8 – Basal Ganglia and Deep-Brain Stimulation

[S8] Exploiting basal ganglia tricks to cure its disorders
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Reinforcement learning models postulate that the basal ganglia networks are built as Actor/Critic network and employ bootstrap temporal difference algorithms to achieve optimal behavioural policy through interactions with stochastic environment and despite delayed and incomplete (scalar) feedback.

Continuous high-frequency Deep Brain Stimulation (DBS) is a popular therapy for management of advanced Parkinson's disease – the most common disorder of the basal ganglia. However, since in present DBS systems stimulation parameters are only intermittently adjusted, DBS methods are poorly suited to cope with the fast neuronal and clinical dynamics of Parkinson's disease.

We tested the effects of closed-loop stimulation in the MPTP primate model of Parkinson's disease. Closed-loop stimulation has a significantly greater effect on akinesia and on cortical and pallidal discharge patterns than standard open-loop DBS and matched control stimulation paradigms.

Thus, closed-loop DBS paradigms have potential not only for the treatment of Parkinson's disease, but perhaps of other neurological/psychiatric disorders in which a clear pathological pattern of brain activity is recognized.

[S8] Mechanisms of generation and suppression of oscillations in the basal ganglia
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Movement disorders in Parkinson's disease (PD) are commonly associated with slow oscillations and increased synchrony of neuronal activity in the basal ganglia. The neural mechanisms underlying this dynamic network dysfunction, however, are only poorly understood.

Here, we show that the strength of inhibitory inputs from striatum to globus pallidus external (GPe) is a key parameter controlling oscillations in the basal ganglia. Specifically, the increase in striatal activity observed in PD is sufficient to unleash the oscillations in the basal ganglia.

This finding allows us to propose a unified explanation for different phenomena: absence of oscillation in the healthy state of the basal ganglia, oscillations in dopamine-depleted state and quenching of oscillations under deep brain stimulation (DBS). These novel insights help us to
better understand and optimize the function of DBS protocols. Furthermore, studying the model behavior under transient increase of activity of the striatal neurons projecting to the indirect pathway, we are able to account for both motor impairment in PD patients and for reduced response inhibition in DBS implanted patients.

Acknowledgements
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[S8] Deep brain electrical stimulation: knowns and unknowns
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Brain-machine interfaces, including electrical, magnetic and light stimulations are great challenges with appealing perspectives for engineering, ethics, neuroscience, neurology, and neuropsychiatry. Functional neuroimaging studies have highlighted the neuroanatomical perspective in brain and mental disorders, more specifically with therapeutical focal stimulation of neural networks. Many different brain stimulation techniques have successfully been developed to relieve pharmaco-resistant patients suffering of severe neurological (e.g, Parkinson’s disease and neurogenic pain) and psychiatric disorders (e.g, obsessive-compulsive disorders, Gilles de la Tourette syndrome and schizophrenia). However, there are many knowns and unknowns when it comes to understand the mechanisms underlying the therapeutic actions and side effects of these stimulation procedures. For instance, high-frequency electrical stimulation of the subthalamic nucleus impacts all nearby and remote structures having anatomical and/or functional links with it. Subthalamic stimulation alleviates the motor disorders of patients with advanced Parkinson’s disease and can also, in some of them, modulate some facets of their behavior and personality.

In parallel, in order to understand the brain functioning under physiological and pathological conditions, various cell-to-network electrophysiological techniques have been designed for the anatomofunctional exploration of brain circuits. Nerve cells are individually endowed with extraordinary underestimated performances, leading them with the power to control brain states and behavior. Indeed, juxtacellular or intracellular nano-stimulation of a single neuron significantly disrupts its functional integrity, can change the state of the related network, modify global brain state and even modulate behavior. The excitatory and inhibitory effects of single-cell nano-stimulation depend on multiple neuronal factors (architectural, cellular synaptic/intrinsic properties and brain state) and on the anatomical target and settings of the electrical stimulation.

So, is it necessary to stimulate a large number of nerve elements to obtain therapeutic effects? Translational basic-clinic studies are required to address this question.

At the Bernstein Conference 2011 we provide an overview of cell-to-network techniques. They are nowadays not applicable in human but help us to understand how small amount of exogenous current can modulate highly-distributed neural networks and subsequently the behavior.

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Since 1987, deep brain stimulation (DBS) has been increasingly used in functional neurosurgery. This reintroduction of the method known from the 50s is due to the discovery of the dual effect of the frequency, the use of frequencies higher than 100 Hz producing an effect similar to what is obtained after the classical electrolytic lesions formerly used.

**Does it work?** For most of the validated indications (Parkinson's disease, dystonia, obsessive-compulsive disorder), clinical reports provided by a large number of teams around the world agree on the efficiency of DBS at high frequency (DBS-HF). The effect is immediate and immediately reversible, it is related to the amplitude of the current delivered, which makes the method adjustable, the adverse effects, depending on the accuracy of the electrode placement, are usually mild and controllable by parameter adjustments, the effects are stable along time. On the other hand, the effect is purely symptomatic and any influence on the evolution of the disease has not been shown so far. The symptomatic profile of the patients changes only because of the evolution of the degenerative process, which creates new symptoms and involves other systems than the dopaminergic system. There are still some debates on the respective merits of some targets (mostly STN versus GPi), and about the profile of improvement induced by the stimulation of the pedunculopontine nucleus) and on the responsibility of STN in mental changes (apathy, mood changes, depression and suicide).

**For what?** DBS-HF works: this means also that it can be used for therapeutic purposes in several targets for several indications, such as in the thalamus (VIM) mostly for tremor, in the pallidum (GPi) for dyskinesias and dystonias, in the subthalamic nucleus (STN) for Parkinson's disease but also for obsessive-compulsive disorders (OCD), for some forms of epilepsy, and more recently in the subgenual cortex CG 25 for depression, in the nucleus accumbens for anorexia mentosa, addiction and OCD, in the internal capsule for OCD and, in experimental animals, in the anterior hypothalamic area for food disorders, as well as in the posterior hypothalamic area for cluster headaches. The pedunculopontine nucleus is a recent target which has raised an important enthusiasm, particularly as a potential solution of the freezing of gait. This is presently revised and it needs a more rigorous approach before making a definite statement, taking into account that the target is extremely difficult to reach with a functional precision, meaning that the variability between the teams might impact seriously the results, and particularly in case of multicenter studies.

**How?** The question of the mechanism of DBS-HF is still a hot topic, 25 years after the introduction of the method. The only established fact is the frequency dependence: the threshold of therapeutic efficacy is about 100Hz. The initial observation of the almost systematic similarity of effects between lesions in various targets and DBS-HF in these same targets had initially led to the quick hypothesis that HF stimulation induced a reversible inhibition, particularly of the neuronal firing. This has been confirmed in some situation, both clinical and experimental, but all the observations have suggested that additional mechanisms could be involved, such as excitation of fibers passing by, or jamming of the electrical activity leading to the inability of the structure to process correctly the information (functional inhibition or informational lesion). The difficulty at the experimental level comes from the electrical artifacts making it difficult to observe the neuronal activity during the stimulation, from the ambiguous interpretations of the observed effects using PET scan. The main problem to interpret the data coming from clinical observations is related to the imprecision of the knowledge of the exact anatomical localization of the active contact and of the extent of the diffusion of the current, which might be involving other structures than those stimulated. Nevertheless, solving this problem, which is more than probably multifactorial, would help improving the method (role of the waveform and of the pattern of stimulation) and the hardware. There is no doubt that in the near future, due to the large number of teams tackling this problem and the progress in technology, we would have an interesting answer. In the mean time, even if we do not know how DBS-HF works, it works.
Evening Lecture

Model-based and model-free reinforcement learning: the experiments

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A recent direction in neural reinforcement learning is to consider multiple mechanisms involved in control. Two of the three that have been identified are model-based and model-free instrumental systems, and their individual characteristics and interactions are now the focus of various theoretically-directed experiments. I will discuss some of our recent attempts, which offer both support and complication for the original suggestions. I will also describe a further experiment that reminds us that we ignore Pavlovian influences at our peril.

Parts are joint work with: Ray Dolan, Nathaniel Daw, Neir Eshel, Jan Glascher, Quentin Huys, John O'Doherty, Jon Roiser, Klaus Wunderlich
nuSPIC: Neural Systems Prediction and Identification Challenge

Our approaches to understanding brain function can be divided in two broad categories:
(1) Observation and analysis of neural activity while animals are performing a sensory, motor or cognitive task. (2) Building models of brain function based on this observed activity using methods from mathematics, physics, engineering and computer science.

The first approach assumes that recording activity – and more neurons under a variety of conditions will suffice to reveal the brain’s working principles. The second approach aims at integrating experimental findings in order to identify basic computational principles that the brain might be using.

Unfortunately, despite efforts standing of brain processes re-makes one wonder if these approaches are indeed suitable to understand brain function. Previously, Hopfield and Tank\(^1\) argued that it is not sufficient to know all details of neurons and their connectivity to extract the function of a neural network. With growing computer power and advancement of experimental methods that allow for increasing high-density sampling of neural activity, it seems that Hopfield and Tank’s message has been lost.

Here, we invite neuroscientists and other like-minded curious people to test the viability of the two basic approaches in neuroscience. To this end, we provide a web interface to our neural network simulator NEST, which can be used to

- perform a wide variety of experiments on small neural networks with spiking neurons, in which we have implemented a particular function. To help the user, we provide full information about neural properties and the connectivity matrix
- implement a given function – logical, mathematical, etc. – using a finite number of neurons and synapses

Those who will successfully extract the built-in function of the network or design a network to implement a specified function will be certified and receive a monetary reward.

This challenge has three broad goals:

To determine if it is possible to extract a function from a small neural network given full knowledge of neural activity and connectivity. Which classes of networks can be easily extracted and which are rather difficult or even impossible, in principle, to handle?

- To determine the specific strategies that users apply to extract the function of a network and to use the successful strategies for better experimental designs.

- To determine the technical and theoretical constraints in implementation of mathematical function using a neural network of spiking neurons?

Moreover, nuSPIC is a powerful educational tool, which can be used for introducing young students from various disciplines to the basic workings of neural networks.

POSTER SESSIONS
ERP decomposition techniques to infer functional modules in the human brain: a neurotechnology lesson from cognitive responses and vigilance studies

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Background and objectives
With modern neurotechnology and related approaches aimed to target specific molecular substrates in the brain in a clinical perspective, one can take advantage to use these as selective tools for laboratory experimentation.

There is a vast body of literature on pharmacological effects and evoked activity or neuronal responses in cell-populations. Numerous drugs available on the market ultimately control excitability in connected cell-assemblies via fluxes of Na+, K+- and Cl¯ ions. This allows also to detect magnetic activation patterns in the working brain (Boeijinga 2002), which back-translates to interpret with large precision gross neuro-electrical manifestations of information processing (cf. Fig 2&3 in http://www.dialogues-cns.org/brochures/15/htm/15_70.asp). We performed a comparative analysis in a data-mining perspective to explain the effect of broad-spectrum modulators of cell-cell interactions, and ligand-gated mechanistic effects in more confined CNS-pathways on drug-resistant cognitive responses in the visual and auditory modality.

Methods
A 28-lead EEG recording system was used for mapping Event-Related Potentials (ERPs) elicited by active auditory and visual cognitive tasks in 48 young healthy male volunteers. Various paradigms in which participants are asked to interactively respond to stimuli presented on a screen for a series of standardized, validated psychometric tests. After correction for eye-movements, evoked potentials for all the correct responses are sorted according to congruous and incongruous stimuli and averaged separately. Data were examined by extracted features from the cascade of components reflecting various steps of information processing in grand mean curves, differences and topographic distribution with special attention on left-right differences in frontal scalp domains. (Neuroscan, EEGLAB). Maps of cognitive responses were subjected to inferential and/or descriptive statistical comparisons.

Evaluations were performed before oral administration and then at regular time points between 1h and 24h post administration of various experimental selective drugs to either attenuate sodium (Na+-dependent spiking, to boost Cl¯-channels, glutamatergic block or, conversely, activation of neuronal nicotinic receptors, knowing to boost Na+-transmission. Blockade of muscarinic acetylcholine pathways, known to change K+-conductances of neuronal membranes, has been used as control.

Results
Nearly all paradigms were associated with late components between 250 and 600 ms predominant over centro-parietal scalp regions, named P300. Drugs which attenuate Na+-transmission did not influence early sensory vigilance, but delayed late components by 20 ms, interestingly for both auditory P300 and visual ERP significant at 6 hours. Na+-boosting, tested in another cohort, improved speed of vigilance but did not change auditory P300 when tested in normal conditions (Dunbar et al. 2007); nevertheless this component improved in the right hemisphere when subjects were under conditions of cerebral deficiency. Pre-attentional components in the auditory paradigm recovered by >20 ms.

During recognition of non-verbal material, Cl¯-channels were shown to play a role in P300 amplitude and peak-latency, again in the right hemisphere. Early component (till about 150 ms) were unaffected, and comparison with brain signals during performance of a dedicated vigilance task with eyes-open confirmed a lack of drug effect in lower mental functions. The substance has recently be proposed as a tool by our group to validate discriminant contrasts in
theta/alpha EEG frequencies compared to other background EEG changes and can be interpreted as marker of hypovigilance in eyes-closed condition (Ferber et al. 2011). Finally we studied the effect of scopolamine, principally to see the effect of changes in K+-conductances; pre-attentional components as well as the post-stimulus latency associated with changes in P300.

Discussion
ERPs are known to reflect the allocation of attentional resources and are a marker of cognitive capacities. Generally speaking, their characteristics are correlated to accuracy or reaction times depending on the task. Blockade of sodium spikes slow down processing by the brain, despite a lack of deterioration in psychometric testing (Aldenkamp and Alpherts 2006). The dissociation of effects of chloride-channel enhancers on early and late ERP components will be discussed in the light of pre-attentional window associated with sensory processing (encoding) and e.g. the postulate of conscious perception starting >200 ms post-stimulus according to e.g. Tallon-Baudry and co-workers (1997). The results of the present observations will be discussed in the light of the role of main neurotransmitter systems in local and possibly inter-hemispheric connections of neuronal networks responsible for these aspects. A direct spin-off when using recognition-tasks of tones or non-verbal material that efficacy of a putative cognition enhancer can be put in evidence by inducing a significant enhancement in brain potentials compared to placebo. In order to avoid a ceiling effect of healthy subjects performing too well, a model of cerebral deficiency can be proposed. Scopolamine results were in-line with the picture above of sensory/pre-attentional/cognitive steps as above and indeed display gradually more effect for components with larger post-stimulus latency. Subsequently a reversal of deteriorated P300 peak-latency can be shown like for the non-selective cognition enhancer (changing Na+- and K+-transmission, Parks et al. 2010). Studies to demonstrate topographic patterns of changes in P300 in patients suffering from Alzheimer’s Disease support the cellular changes in defined pathways. Finally Functional MRI is also being considered for a number of more applicable uses outside of the clinic. It is worthwhile to compare the present asymmetries in ERP with BOLD-imaging results, in order to unify or reappraise the working concept of functionality in the healthy and diseased brain.

References
Boeijinga (2002) Objective markers of drug effects on brain function by way of scalp potential recordings in healthy volunteers. Dialogues Clin Neurosci 4 (n°4); 388-394
The relationship of motor cortex excitability and lesion location in chronic stroke patients

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Cortical lesions following stroke in the primary motor cortex (M1) result in changes of intra- and inter-hemispheric inhibition. Lately it was shown that changes of brain excitability in remote brain areas e.g. the non-affected M1 comprise e.g. a decrease of intra-cortical inhibition (ICI) and down-regulation of inhibitory GABAA receptors that might affect cortical processing within the motor domain.

So far, these adaptive changes of brain excitability were not described in patients with sub-cortical stroke, but are of particular interest to understand homeostasis of inhibition and excitation in such patients and to develop novel therapeutic approaches targeting brain areas remote from the primary brain lesion, including use of brain-machine interface (BMI) technology in neurorehabilitation.

Here we tested the hypothesis that sub-cortical stroke leading to severe motor impairment results in wider recruitment curves and lower cortical excitability as measured by resting motor threshold (rMT) associated with smaller motor map sizes than cortical strokes.

Methods: Severely affected stroke patients (n=20) with no active finger movements were categorized according to their lesion site (cortical/sub-cortical) and underwent evaluation of rMT, recruitment curves and cortical mapping of the non-affected hemisphere using single pulse transcranial magnetic stimulation (TMS).

Results: Preliminary analysis indicates that stroke patients with cortical lesions show a positive correlation of contra-lesional rMT and cortical map size indicating reduced intra- and inter-hemispheric inhibition, while these parameters showed a negative correlation in patients with sub-cortical stroke.

Conclusion: Changes of motor cortex excitability on the non-affected hemisphere depend on lesion location, a finding with important implications for the design of therapeutic approaches that aim at modulation of brain excitability, e.g. using non-invasive brain stimulation, such as repetitive TMS (rTMS) or transcranial direct current stimulation (tDCS).

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Morphological and molecular characterization of focal cortical dysplasias

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Focal cortical dysplasias (FCD) are malformations of the human neocortex which are highly associated with intractable epilepsy, especially in young children. The neuropathological characteristics of FCD extend from mild laminar disorganization and hypertrophic neurons (FCD type I) to severely developed laminar disorders with the appearance of dysmorphic neurons and cytomegalic cells (FCD type II) (Palmini et al. 2004). It is assumed that FCD arise due to local disturbances during prenatal development. To date very little is known about structural and molecular composition of these cortical malformations and to which extent they differ from normally developed neocortex. To address this question we used a combined morphological and molecular approach to analyze human resected FCD (type I and II) specimens from different cortical areas, obtained from patients with pharmaco-resistant epilepsy. In each FCD sample the degree of dyslamination was visualized by immunolabeling for NeuN and non-phosphorylated neurofilament H (SMI32), a marker for pyramidal cell layers 3 and 5, and, in parallel, the expression of genes encoding markers of laminar fate (e.g. reelin, Er81, Rorß, TLE4), interneurons and cell maturity (e.g. doublecortin) was analyzed by real time RT-PCR. In addition we performed expression microarray analysis from FCD IB type temporal lobe neocortex. We found that in all specimens lamination was basically preserved, but there were strong differences with respect to lamina width, in some cases layers were even blurred. In addition, RT-PCR analysis revealed that laminar fate and interneuron markers were basically expressed, but with high variability mirroring the morphological observations. Our expression array results show low effect sizes concerning expression level differences in FCD specimens in comparison to control tumor access tissue due to the heterogeneous FCD tissue type. Furthermore we also could confirm our PCR and morphological results regarding to various expression levels for single gene/markers even among the FCD and especially the control group. Taken together, our data indicate that FCD show not a homogenous disease pattern but a much more complex one than initially assumed.

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References

[T 4] Inverted theta-gamma coupling in a model of temporal lobe epilepsy
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We recently found that local field potential activity is phase shifted between the dentate gyrus (DG) and the entorhinal cortex (EC) in the kainate mouse model of temporal lobe epilepsy (TLE) (Froriep et al. 2010). In this model, features of human TLE, including recurrent epileptiform activity (EA) and major anatomical changes are reproduced by focal injection of kainic acid into the DG. Interestingly, the phase shift occurred in episodes without any visible signs of EA in theta and alpha frequencies (4-12 Hz) but disappeared in higher frequency bands. This is likely to be the case as theta activity is considered a global rhythm, like a neural pacemaker, whereas higher frequencies reflect more local activity and synchronize under certain conditions only. However, as the coupling of gamma band activity to a specific phase of the underlying theta cycle is a prominent feature of the hippocampal activity and the theta activity is shifted between DG and EC, local gamma activity could occur at a different phase of theta in epileptic animals as well. We tested this hypothesis by analysing the average power of gamma activity with respect to the theta wave in the DG in activity between epileptic events. We chose the DG because its anatomical structure has changed whereas the EC is preserved in the kainate mouse model. We show that high gamma activity (70-140 Hz) is in fact altered under epileptic conditions. In particular, the highest gamma power in healthy control animals occurs at the trough of a theta cycle in the DG whereas in comparable activity from epileptic animals, it occurs at the peak. As gamma activity has been associated with fast inhibition, our finding suggests wrong timing of inhibition in the dentate gyrus of epileptic animals, which could lead to EA.

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References

In-vivo mouse brain DT-MRI: Assessment of gender specific response to the thyroid hormone remyelinating treatment

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Multiple Sclerosis (MS) is one of the most common neurological disorders, characterized by extensive loss of myelin, axonal damage and inflammation of the central nervous system axonal tracts. It affects twice more women than men and its progression is gender dependent; the male patients having a faster and more severe outcome. Therefore, the response to different therapeutic strategies might be gender specific. Various features of the MS are mimicked in animal models. Long-term 0.2% cuprizone feeding in mice produces severe brain demyelination, accompanied by gliosis, astrocytic hypertrophy and axonal injury (1), with a stronger demyelination outcome in male animals (2). Noninvasive in vivo diffusion tensor magnetic resonance imaging (DT-MRI) was used here to comparatively quantify, in a longitudinal study, the demyelination extent and the efficacy of a thyroid hormone (T3, tri-idothyronine) based therapy for inducing recovery in demyelinated...
male and female mouse brains. The mice were imaged using a 9.4T small bore animal Scanner (Biospec 94/20, Bruker) and a 4-shots DTI-EPI sequence. The brain pathologic alterations induced by cuprizone caused changes of DT-MRI derived parameter values, including loss of white matter anisotropy and increase of water diffusion values perpendicular to the fiber tracts (D_radial). These pathological features were maintained in both male and females animals which were not subjected to hormonal therapy. The mice receiving thyroid hormone for 3 weeks showed progressive recovery towards normal radial diffusivity values during the 12 weeks of observation. Both males and female mice positively responded to the remyelinating therapy. A certain trend of faster and more consistent recovery was observed in the female mice, which shown decrease of the radial diffusivity immediately after T3 treatment. Similar features of faster remyelination and oligodendrogenesis were observed in the histopathological investigation. This might suggest greater myelinating potential of the newly formed female oligodendrocytes or greater sensitivity to the T3 actions.

The results are valuable for understanding the role of gender in the physiopathology and the remyelination of the white matter. In the view of future translation of the preclinical assays in the clinical environment, DT-MRI investigation is of high value, allowing the quantitative survey of the same individual’s overtime.

Acknowledgements
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References
Matsushima and Morell 2001, 2: Harsan et al., ISMRM 2010

[16] Septotemporal position in the hippocampal formation determines epileptic activity in temporal lobe epilepsy
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Temporal Lobe Epilepsy (TLE) is associated with severe changes in cellular architecture of the hippocampus: cell loss in CA3, CA1 and the hilus, granule cell dispersion, mossy fiber sprouting, altered neurogenesis and gliosis. It is, however, still unclear how these changes contribute to the occurrence of epileptic seizures, in particular since some are supposed to have an anti-epileptic effect while others increase the excitability. In our approach, we characterize the strength and extent of epileptiform activity and then reconstruct the histological pattern at the respective positions along the septotemporal axis of the hippocampus to characterize potential interrelation.

To this end, we used the intrahippocampal kainate mouse epilepsy model, which recapitulates the main characteristics of TLE in humans: recurrent focal seizures, granule cell dispersion and selective cell death in the hippocampus. Following the focal injection of kainate into the hippocampus, we performed multi-site in vivo local field potential recordings along the septotemporal axis of the kainate-injected and in the contralateral hippocampus and quantified the strength of status epilepticus (SE) and recurrent epileptiform activity (EA). In addition, we
used bromodeoxyuridine injections to monitor proliferative activity, immunohistochemistry and in situ hybridization to determine cell fate and interneuron loss and Nissl staining to measure granule cell dispersion and quantified all parameters.

We show that following kainate injection into the septal hippocampus, SE extended along the septotemporal axis of the hippocampus with stronger intensity at intermediate and temporal sites. Comparably, the intensity of recurrent EA was strongest in the intermediate hippocampus. The histological changes also showed septotemporal gradients: (1) Granule cell dispersion was strong in the septal hippocampus and ceased in the intermediate and temporal hippocampus. (2) Neurogenesis was completely lost in the septal hippocampus, but was strongly increased in the intermediate and temporal hippocampus. (3) Inhibitory interneurons were mostly lost in the septal hippocampus, still reduced in the intermediate hippocampus and back to normal numbers temporally. Notably, the site with strongest EA appeared to be the transition zone where neurogenesis reappeared but interneuron numbers were still reduced. Therefore, we assume that the occurrence of strong EA requires increased excitation through the addition of hyperexcitable young granule cells and, in addition, decreased inhibition through the loss of inhibitory interneurons. In contrast, each change on its own has only minor effects.

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[T 7] Simultaneous multisite LFP and SUA recordings across the hippocampal formation in a mouse model of epilepsy

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In temporal lobe epilepsy (TLE), physiological activity within the hippocampal-entorhinal loop is severely altered, visible as recurring epileptiform activity (EA). In many cases, this is accompanied by pathological restructuring of the anatomical substrate, including widespread cell death and aberrant connectivity. These changes, known as hippocampal sclerosis, are thought to underlie EA. However, hippocampal sclerosis is apparent at any time, not only during EA, so it must also have an impact on activity during EA-free periods between epileptic events.

An animal model which reproduces a severe case of focal hippocampal sclerosis, accompanied by recurrent EA, is the intrahippocampal kainate mouse model of TLE. Using this model, we previously showed that the relation of activity in the dentate gyrus (DG) and the entorhinal cortex (EC) is changed during such EA-free periods. In particular, the theta band activity (4-8 Hz) of the DG precedes that in the EC by ~ 25 ms in epileptic mice, whereas both are synchronized under healthy conditions (Froriep et al. 2010).

To investigate the mechanism underlying this delay, a higher spatial resolution of the recordings within the hippocampal formation and the analysis of phase relationships in the local field potential (LFP) between all recording sites are required. In addition, increased temporal
resolution by recording the associated single unit activity (SUA) could reveal changes in spike timing with respect to the underlying LFP. A shift in spike timing relative to the local LFP might reflect pathological plasticity whereas spike timings shifted between hippocampal structures would point to altered network properties.

Here, we addressed these questions using newly developed, custom-made silicon multisite electrode probes (Herwik et al. 2009) that facilitate simultaneous acquisition of LFP and SUA on 16 channels throughout the hippocampal formation. Chronic implantation of these probes enabled us to record both from freely behaving epileptic and control mice.

We show that these probes allow for simultaneous LFP and SUA acquisition in the DG, the hippocampus proper and parahippocampal structures and analyzed the relationship of LFP rhythms between all these sites in EA-free periods. Furthermore, we investigate the spike time relation relative to the underlying theta cycle across these locations.

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References

[8] Declarative and procedural memory dependent behavioural function in a transgenic rat model of Huntington’s Disease: A novel paradigm
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Huntington’s Disease (HD) is a debilitating disease impacting on the individual’s motor, affective and cognitive function and there are no cures or effective therapies today. The predominant pathological signature of the Huntington’s disease is the early and progressive loss of GABAergic medium spiny projection neurones from within the striatum. However, anatomical and metabolic changes in other regions have been described in asymptomatic, preclinical stages of the disease. Deficits in the fronto-striatal loop result in impairment in new learning and cognitive rigidity. These detriments can be offset by compensatory increases in hippocampal based memory systems. We chose to use a transgenic rat model of HD to examine memory capacity and whether this higher order function declines in any way comparable to the changes in declarative and procedural memory observed in HD patients.
40 transgenic rats (tgHD) obtained from three pooled litters, comprised of all genotypes, were used in this study. Behavioural tests were conducted at 6-8 months and again at 12-14 months of age. Each behavioural battery of tests consisted of motoric (rotorod, grip strength) and cognitive (elevated plus maze, Morris water maze, double-H maze) elements. Additionally, 13 of the tgHD rats were examined by PET at 7 and 14 months of age. A dopamine D2-receptor radioligand was employed to examine anatomical and functional data.

Overall, transgenic animals demonstrated poorer performance in motoric behavioural tests, as compared to wildtype litter mates. Little or no differences were observed during the first testing session, whereas slight to modest deficiencies were found when the animals were tested at 12-14 months, consistent with reported observations. In contrast, transgenic animals displayed inferior results in cognitive tests already at 6-8 months, which were more pronounced in the second testing session. Transgenic animals were able to learn the tasks, yet showed poor retention over time. They were able to relearn the tasks, albeit at a slower rate than wildtypes. This was most exacerbated in homozygote females. This population also spent larger amounts of time outside of the closed arms in the elevated plus maze, displaying a disturbed sense of anxiety. This likely contributed to the learning / memory deficits observed. PET examination revealed minimal changes (~2-3 %) groups homozygotes

and wildtype animals at both time points tested. However, one individual showed marked receptor loss (~50 %) at 14 months. Finally, immunohistochemical analysis is underway, which will be used to correlate cellular pathology with the behavioural findings. The significance of these results in relation to disease progression will be discussed.
**NeurOnline: A software to perform online analysis and control of electrophysiological recordings**

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**Project Summary**

It is now standard to record the activity from large numbers of neurons simultaneously, both in behaving animals using acute or chronically implanted electrode arrays, and in brain slices or tissue cultures using substrate-integrated multi-electrode arrays. To enable control and intervention in an ongoing experiment, it is important to monitor certain critical parameters of the recorded activity in real-time. NeurOnline is a software that enables the researcher to perform online analysis of their electrophysiological recordings and to suitably interact with their experimental setups based on these analysis results. Specifically, our software supports optimizing the yield of experiments by providing new algorithms for online analysis that give comprehensive feedback about the status of the experiment in real-time. In addition, we hope to stimulate the development of novel experiments based e.g. on the possibility of fast adaptation of applied stimuli depending on the behavior of the system studied. The software is made publicly available under GPL.

**Technical details**

The software architecture chosen for this project consists in Python scripts that call C++ extensions provided by SIP. The C++ language allows high-performance computations that are crucial for time-critical “online” analyses and an easy use of multiple threads. The Python scripting language, on the other hand, enables experts and semi-skilled programmers at the same time to easily use and extend the envisaged software toolbox. The QT library is used to implement a signal/slot mechanism. A graphical user interface permits to control the analysis and displays the results of all computations performed on the recorded data.

Based on a set of open source drivers (“comedi”), NeurOnline can currently interact with 400 different data acquisition boards (e.g. National Instruments) that are commonly employed in electrophysiological setups. A TCP/IP client has been implemented to allow the communication with high-density multi-electrode arrays (HD-MEAs) currently developed at ETH Zurich/Basel. These devices currently allow sampling from 128 channels (selected from a set of 11,000) at a sampling frequency of 20 kHz per channel. Acquisition from Multichannel Systems multi-electrode arrays is also supported.

A butterworth IIR online filter has been developed to select the appropriate frequency bands of the recorded signals. Online spike sorting is performed on the detected spike waveforms by applying a dynamic template matching algorithm. The Python interface allows NeurOnline to send signals that depend on the result of online signal analysis to other processes, e.g. to update in real-time the visual stimulus displayed by some dedicated software (e.g. “VisionEgg”). NeurOnline is currently used in two laboratories: At the Biomicrotechnology laboratory (IMTEK, University of Freiburg) the dynamics of dissociated cell cultures grown on HD-MEAs are studied. Those arrays have 11,000 recording sites, 128 of which can be recorded at the same time. NeurOnline is currently used to record the data from subsets of electrodes, to detect the spikes in the recorded signals and to organize the scan of the full set of electrodes depending on the recorded activity. At the Neurobiology and Biophysics laboratory (Faculty of Biology, University of Freiburg), extra- and intra-cellular recordings in the neocortex of anesthetized rats are performed. Visual stimuli that preferentially activate neurons in the thalamus (LGN) and in the primary visual cortex (V1) are selected by a method known as adaptive sampling. NeurOnline used in this laboratory for multi-channel signal recording, spike detection, spike sorting and visual stimulus updating.
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[T 10] Inferring intrinsic saliency from free-viewing data
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A central debate in the literature on the deployment of attention in natural images is whether the observed fixation patterns reflect the work of basic low-level saliency mechanisms or, on the contrary, higher-level, object-based behaviour (Nuthmann & Henderson, 2010). The most common approach is to have subjects explore freely natural images ("free-viewing"), and collect fixation locations. Locations which are fixated by the subjects are said to be salient. Therefore, when analyzing such data, the goal is often to correlate local image features with fixations, to see if the former can predict the latter (Kienzle et al. 2009).

However, one important problem is the assumption that all fixations reflect the same underlying level of intrinsic saliency: this is unreasonable because subjects show patterns in their fixated locations irrespective of image content. For example, a well-documented bias is simply to fixate around the center, regardless of what the image is (Torralba et al., 2006). Therefore, a fixation around the center is not necessarily motivated by high intrinsic saliency, because subjects tend to fixate around the center anyway. However, they need good reasons to go look at locations far away from the center, and off-center fixations should receive greater weight.

The raw data used to fit and test image-based models of visual saliency is therefore difficult to work with, because it confuses image-dependent factors and image-independent ones. To untangle these factors, we have developed a statistical model based on a log-additive decomposition of the fixation probability density. Taking inspiration in functional data analysis (Ramsay & Silverman, 2005) and the analysis of spatial data using log-Gaussian Cox processes (Møller et al., 1998), we show that it is possible to approximate the intrinsic saliency in an image by analysing large datasets from free-viewing tasks.

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References
A doubly stochastic model for the quantification and classification of burstiness and regularity in single spike trains

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Bursts and oscillations are distinct neuronal firing patterns which are considered important for information processing in the brain. In experimental practice the classification of these firing patterns is usually based on the autocorrelation histogram (ACH; Perkel et al., 1967) and its visual inspection (Wilson et al., 1977; Paladini et al., 2003). Our aim was to simultaneously quantify the overall burstiness and regularity of spike trains under different experimental conditions. We propose a single model framework which provides an objective classification procedure.

We present a doubly stochastic model that describes firing patterns in two steps: First, a background rhythm with independent normally distributed increments was constructed to represent the oscillatory activity of the process. In a second step, single or clusters of events were placed around their background beats with a Gaussian firing intensity. The model was termed “Gaussian Locking to a free Oscillator” – GLO (Bingmer et al., in press). Using five easily interpretable parameters, the GLO classifies a spike train as bursty or single spike and into an irregular or regularly oscillating firing pattern. The resulting objective classification is based on the theoretical autocorrelation function, which can be derived easily in the described model. The GLO thus provides an objective approach that is directly comparable with visual inspection criteria based on the ACH. We propose to use a marked point process bootstrap procedure (Braun and Kulperger, 1998) for construction of confidence intervals in order to illustrate the uncertainty of parameter estimation and classification precision.

We applied the model to a sample data set obtained from single dopaminergic substantia nigra neurons (n=43) of mice recorded extracellularly in vivo (Schiemann et al., in revision). The classification results of the GLO agreed closely with visual inspection, and a high variety of discharge patterns were reproduced. The GLO thus helps to describe and quantify neuronal firing patterns with respect to burstiness and regularity. Furthermore, the GLO allows the quantitative investigation of parameter changes and complements subjective classification methods in an objective way.

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References


[T 12] The maximal causes of binary data
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Neural activity encodes multiple-cause stimuli with discrete events. Neurons either spike or remain inactive. Many modeling approaches therefore rely on binary units for encoding. Prominent examples are, for instance, restricted Boltzmann machines [Hinton2002] and, more recently, deep belief networks [HintonEtAl2006]. In this work we study a probabilistic generative model with binary units. We investigate the component extraction capabilities of a model with hidden and observed layer both encoding binary data through Bernoulli distributions. In this setting basis functions can not be combined using summation as in sparse coding models [OlshausenEtAl1996] but require non-linear combination rules. One possibility is to use post-summation non-linearities as for RBMs and DBMs. In this work we explore the combination of binary variables using a maximum combination, which was used for continuous variables before [LückeSahani2008,PuertasEtAl2010]. An important difference to RBMs and DBMs is, that the weights in the basis functions can only be positive, thus only increase the activation probability of the observed units. We train our model based on a variational Bayesian approach (Expectation Truncation; [LückeEggert2010]) which uses truncated posterior approximations as proposal distributions. This approach combines a fast preselection of relevant data components with a subsequent recurrent processing phase (compare [SupèrEtAl2001]), and has recently been linked to neural processing. Variational training in the model infers the weights of the connections between the hidden and the observed units as well as the prior activation probabilities of the hidden units. In numerical experiments on artificial data and more realistic data, we show that components of mixtures in binary data can successfully be recovered and that such experiments can be scaled to high dimensional observed and hidden spaces.

References
Online data analysis for a Knee-Ankle-Foot-Orthosis with neuro-control

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A Knee-Ankle-Foot-Orthosis (KAFO) is a modular lower-extremity orthosis prescribed to people with gait disability which might be, e.g., caused by diseases or injury to brain or spinal-cord. The KAFO should support, correct and assist the movement of the corresponding affected joints. Traditional KAFOs are restricted by a gait depending switch of the joints based on (electro-)mechanic non-adaptive switches. Common disturbances (floor unevenness, obstacles, ramps) cannot be mastered in a satisfactory way. Novel approaches include active elements into the orthosis, which do not directly act on the movement. Instead they adjust the compliance leading to new challenges for the controller of such actuators, which are difficult to handle with traditional approaches.

Thus new technologies have to be developed to improve control and to overcome the shortcomings of traditional non-adaptive approaches, thus solving the problem of efficient actuator control. Development of advanced orthotic devices is held back by the vast number of possible indications as well as by the wide range of neuromuscular variability within a specific patient group (Yakimovich et al., 2009). The development of advanced devices is therefore imposing the need for individual (online) adaptation of gait parameters to allow adaptation (1) to changing environments like slopes, stairs etc. as well as to gait parameters like stride length/frequency and (2) to the individual patients with respect to physiological conditions. To do so, we have employed a reflexive neuro-controller as inspired by RunBot (Manoonpong et al., 2007), embedded to a KAFO based on a controllable hydraulic damper, derived from OttoBock’s C-Leg©.

In this study we extend the neural controller with additional neural modules for prediction of expected sensory inputs and observing typical gait parameters (like joint angles). This allows the complete neural controller to adapt gait parameters to master environmental changes like slopes of different steepness and to select different modes of locomotion to accomplish compliance for completely different environments, e.g., stair climbing.

Traditional control approaches are often using a set of optimized thresholds to account for all possible situations and patients at the same time, which proves to be very difficult, considering the variability in patient’s abilities. Therefore the use of these controllers is limited to only a subset of the possible patient groups.

To overcome the shortcomings of these one size fits all approaches, our neural controller needs to satisfy short reaction times, as adaptation should optimally happen within the first step after entering different environments. As a result the neural controller is gaining an ability to adapt the orthosis’ compliance to deal with different situations, matched for individual patients.

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Altered prefrontal-hippocampal (PFC-HC) coupling has been described for patients with schizophrenia as well as subjects carrying psychiatric risk polymorphisms (Meyer-Lindenberg et al., 2005). We have recently implemented a virtual reality version of the radial arm maze task for use in humans; this spatial working memory and decision making task has been intensely studied in rodents for assessing prefrontal function and PFC-HC interactions (Lapish et al., 2008). While fMRI blood oxygenation level dependent (BOLD) data is acquired, subjects move through a virtual park surrounded by various landmarks, and aim to find invisible gold coins hidden at the end of twelve arms. During the training phase, six arms are blocked and subjects are instructed to collect the accessible gold coins and memorize the location of the blocked arms. After a 30-second delay period, the test phase starts – here all the arms are accessible and subjects have to find the remaining gold coins in the previously blocked arms. This phase is followed by a short visuomotor control task, where subjects collect six visible gold coins in an otherwise unchanged environment. A spatial allocentric (landmark-based) strategy is required to solve this task.

First exploratory analyses of the BOLD data recorded from a group of healthy adults (using a blocked design) showed an involvement of the expected “navigational network”, including the dorsolateral prefrontal cortex (DLPFC), midline structures such as anterior cingulate (ACC) and parietal cortices, the hippocampus and caudate nucleus. fMRI data were also analyzed using an event-related design. Regressors were constructed for the following task stages: encoding, decision, reward expectation, reward consumption and delay phase. In addition, task-stage specific seed-voxel connectivity was computed using the beta-series correlation method proposed by Rissman et al. (2004). Furthermore, multivariate statistical/machine learning methods were employed on this dataset. These techniques aim to extract task-processing information contained in the patterns of voxel activation that form the multivariate BOLD time series. The time series were first deconvolved in order to compensate for the filtering effect of the hemodynamic response function, hence achieving a signal that is closer to the underlying neuronal activity. Multivariate test statistics (union-intersection test, Wilk's lambda and generalized Hotelling's T2) were then computed separately for several regions of interest (ROIs) as a measure of the overall discriminability of different task stages within the BOLD signal pattern. Mahalanobis distances were also calculated to identify pairwise differences across different cognitively defined task epochs. The significance of all classification results was tested non-parametrically against time series (block-permutation) bootstraps. Preliminary results demonstrate that those anatomical regions postulated to be involved in task execution, such as the DLPFC and ACC, contain significant information on the task stages which distinguishes them from non-task re-
lated (control) areas. Moreover, pairwise distances reveal interesting differences with regards to the task-related information encoded by these ROIs.

Future work will investigate how the results obtained by different methods relate to each other, and aim to investigate how these network patterns are altered in schizophrenia as well as in healthy subjects carrying different genetic polymorphisms.

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References
Lapish et al. Successful choice behavior is associated with distinct and coherent network states in anterior cingulate cortex. PNAS 2008, 105(33):11963-68.

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Kernel smoothing is a powerful methodology to gain insight into data. It has wide applications in many different fields, ranging from Economics to Neurosciences. The most important basic application of kernel smoothing in Neuroscience is estimation of time-dependent firing rates from neuronal spike trains. Traditionally, this is achieved by the PSTH (Peri-Stimulus Time Histogram) or, alternatively, smoothing with a fixed kernel. The PSTH relies on the availability of multiple trials for averaging out trial-to-trial fluctuations. However, one can obtain a plausible estimate from a single trial as well, using kernel smoothing methods, where the bandwidth of the kernel is a parameter to be selected in analogy to the bin size of the histogram. The form of the kernel is rather unimportant, provided it is smooth, unimodal and normalized. Its bandwidth, in contrast, defines how smooth the resultant rate would be (Nawrot et al., 1999). A suboptimal kernel may result in over-smoothing or under-smoothing, where the optimal kernel is defined by a minimal deviation from the true rate profile. There may be no globally optimal kernel for strongly changing Poisson rates, though. As a cure to this problem one can optimize the estimate by locally adaptive bandwidth selection. To this end, Shimazaki and Shinomoto (2009) suggested a combinatorial way of optimizing MISE (mean square integrated error) as a method of local bandwidth estimation. This method, although effective, is computationally very costly and biased. Instead, we suggest an application of a new method by Botev et al. (2010), namely Kernel Density Estimation via Diffusion. The diffusion method offers a fast completely data driven algorithm for local bandwidth selection, avoiding the boundary bias and the assumption of Gaussianity. An implementation of the new method as a PYTHON package is made available.
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References

Separate Bayesian inference reveals model properties shared between multiple experimental conditions
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Statistical modeling produces compressed and often more meaningful descriptions of experimental data. Many experimental manipulations target selected parameters of a model, and to interpret these parameters other model components need to remain constant. For example, perceptual psychologists are interested in the perception of luminance patterns depending on their contrast. The model describing this data has two critical parameters: the contrast that elicits a predefined performance, the threshold, and the rate of performance change with increases in contrast, the slope. Typical experiments target threshold differences, assuming constant slope across conditions. This situation requires a balance between model complexity to perform joint inference of all conditions and the simplicity of isolated fits in order to apply robust standard procedures.

We show how separate analysis of experimental conditions can be performed such that all conditions are implicitly taken into account. The procedure is mathematically equivalent to a single Gibbs sampling step in the joint model embracing all conditions. We present a very natural way to check whether separate treatment of each condition or a joint model is more appropriate.

The method is illustrated for the specific case of psychometric functions; however the procedure applies to all models that encompass multiple experimental conditions. Furthermore, it is straightforward to extend the method to models that consist of multiple modules.

Discrete symmetric priors for sparse coding
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A standard model to explain the receptive fields of simple cells in the primary visual cortex is Sparse Coding (SC) [1]. However, the update equations used to train this model are not derivable in closed form. As a consequence, most state-of-the-art sparse coding versions use the MAP estimate for inference and training. Furthermore, it is not known if continuous hidden variables represent the best choice, e.g., for sparse coding as model for V1 processing. By using binary hidden variables, for instance, Binary Sparse Coding (BSC) [2], or [3], alternative priors with discrete hidden variables have been investigated in the past. The binary hidden space allows for analytically derivable update rules in closed-form and thus does not require a MAP estimation. However, in contrast, e.g., to Laplace priors, the Bernoulli distribution is not symmetric and its mean is not zero. To study the implications of discrete hidden variables independent of differences in prior symmetries, we, in this work, investigate a generative model with symmetrical and discrete prior distribution. Furthermore, a generative model with such a prior directly connects to recent sparse coding versions with hard-sparseness constraint (compare, e.g., [4]). As model for a discrete and symmetric prior, we use a multinomial distribution for hidden variables that can take on the values -1,0 and 1. In numerical experiments, we train the model using Expectation Truncation (ET) [5], a variational EM method which uses a pre-selection of hidden variables to increase learning efficiency.

To show the effectiveness of the algorithm, we adjusted the linear bars test described in the BSC paper to fit our model. In the linear bars test the model was able to learn both the basis functions and the data noise. The linear bars test also provides considerable evidence that training the parameters using ET reduces the number of local optima. In experiments on more realistic data, we applied the algorithm to 50,000 large scale image patches (26x26 pixels) taken from the van Hateren image data base [6] and pre-processed with pseudo-whitening, using massive parallel computing. In this experiment, we obtained Gabor-like basis functions with similar properties as reported for receptive fields of V1 simple cells. We analyze the obtained Gabors and discuss differences and similarities to different sparse coding versions in the literature.

References

[T 18] Efficient modeling of neural activity using coupled renewal processes
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Generalized Linear Models (GLMs) are stochastic models that have been successfully used to model neural activity of single cells and populations. Typically, this requires the spike train to be binned into a binary time series that is modeled as a Bernoulli-type GLM. Unless a loss in
temporal precision is acceptable, the bin size has to be chosen on the order of milliseconds. This renders an application to long-term recordings infeasible for computational reasons. We propose a new, binning-free application of the GLM framework to model neural activity by noting that spike trains can equally be characterized by the sequence of continuous-valued inter-spike intervals (ISIs). It was shown that single-neuron spike trains can often be sufficiently modeled as a non-stationary renewal process. Here, we focus on the Gamma distribution for the inter-spike intervals as it allows the accommodation of a relative refractory period and includes the inhomogeneous Poisson process as a special case. We generalize the idea of a modulated Gamma process to the population level by including cross-couplings between the neurons in case of recordings from multiple neurons in parallel.

In a Gamma-GLM, each observed inter-spike interval is modeled as a sample from a Gamma distribution whose mean can vary with time, e.g. through modulation by an external stimulus. Traditionally, ISIs are assumed to be independent. However, this renewal assumption can be relaxed by conditioning on the durations of previous intervals. An inter-neuron coupling is introduced by additionally conditioning on the times of spikes of the other neurons. The Gamma distribution and other canonical distributions for inter-spike intervals are part of the exponential family so that efficient maximum likelihood solutions for all model parameters can be obtained using the framework of Generalized Linear Models. Considering the ratio between bin sizes for time-discrete models and the typical length of cortical inter-spike intervals, the computational demand can be reduced by several orders of magnitude. Goodness-of-fit is assessed by adapting standard tests for point process models and evaluating spike prediction performance based on cross-validation.

We demonstrate the versatility of the coupled Gamma model for estimating functional connectivity from multi-electrode recordings. With a data set obtained from multi-electrode recordings of the visual system of the awake monkey, we show that the test power of the Gamma-GLM for detecting functional connectivity links is comparable to the performance of a classical discrete-time GLM albeit requiring much less computational time and memory resources. Using the two models on the same data set, we are able to estimate the unknown, underlying connection density of the network. Finally, we discuss general limitations of coupled Gamma-GLMs on the type of interactions that can be faithfully represented.

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[T19] Unsupervised neural coding of nightingale songs using deep autoencoders
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In this work we tested different deep autoencoder networks for the unsupervised feature extraction of nightingale song spectra. Nightingales are versatile singers. Some individuals can sing up to 600 different songs. Biologists analyzing nightingale communication have to classify audio recordings by comparing hundreds of unknown songs to a database. This work is done mostly manually by matching spectrograms visually. An automatic or semi-automatic method for song classification would speed up this tedious process. We have utilized a recently published learning method to train multi-layered (‘deep’) artificial neural networks to
reduce the dimensionality of – and find correlations within the spectrogram data in an unsupervised manner. We propose several preprocessing steps and network topologies to find low dimensional representations of nightingale songs. First, the audio data is filtered with a band pass to reduce low-frequency noise, e.g. of nearby cars. Then, we normalize the volume and down-scale the spectrograms to 256 x 400 points. This matrix is used as the input layer to the network. The next layer extracts visual features like edges and corner points. Each neuron in that layer serves as a feature detector and shares its incoming weights with different ‘receptive fields’ in the input layer and thus establishes repetition- and shift invariance. The output of this layer will be fed to the next three layers that serve for the dimensionality reduction and are trained as proposed by Hinton (2006). The weights of the network are tuned by comparing the input of the network to its reconstruction: By feeding an input song to the network, a specific code can be read from the last, 16-dimensional, code layer. By projecting back the activity of this layer to the receptive field, using the same weights, it is possible to reconstruct its original excitation; a procedure we use also to measure the quality of the code. Once the training is complete it is possible to classify unknown songs using the low dimensional code with an additional classification layer or other standard classification methods.
Inclusion of NMDA receptor like interactions into the contribution dynamics of synaptic plasticity captures adaptation phenomena in spike timing dependent plasticity

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Spike Timing Dependent Plasticity (STDP) refers to the finding that presynaptic before postsynaptic spiking leads to an increase of the strength of the transmitting synapse, whereas the reversed temporal order decreases the synaptic weight. Also, the magnitude of weight change was found to exponentially drop off with increasing time difference. This particular form of STDP is widely used in modeling studies as a linear kernel to compute synaptic weight changes in response to given spike trains. However, the (bi-)linear approach fails for more complex spike patterns: The induction of long term potentiation (LTP) in response to single pre- and postsynaptic spike depends on spike pair frequency, postsynaptic membrane depolarisation, and the number of presynaptic inputs activated simultaneously (Sjöström et al., 2001). Curiously, long term depression (LTD) is hardly affected by these manipulations. Also, there are nonlinear interactions between spikes at the same synaptic site which cannot be captured by the simple approach.

Here we extend our previous model of synaptic plasticity (Schmiedt et al., 2010). It describes the dynamics of relevant pre- and post-synaptic factors, e.g. presynaptic short term depression, which in combination contribute to a long term synaptic weight change. While it reproduces some experimental data on nonlinear interaction between spikes (Wang et al., 2005, Froemke et al., 2006), it did not recreate the LTP-selective influences including the disappearance of LTP for low frequency pairings. To account for that, we introduced boosting of LTP that depends on the coincident occurrence of recent presynaptic activity and postsynaptic spiking.

Correspondingly, the LTP-part of our new model consists of 4 factors: 1. a trace of the presynaptic activity with a short time constant, 2. a variable that depends on coincident pre- and postsynaptic activity, related to NMDA receptor activation, 3. a factor related to postsynaptic firing rate adaptation and 4. the postsynaptic spike. The long term depression (LTD) part is modeled by only two factors: 1. an exponential trace of the postsynaptic activity with time constant longer than the one for the presynaptic trace which 2. constitutes the other factor.

We find that this slightly extended model captures a much wider range of experimental data while retaining its simple formulation in terms of differential equations which is both biophysically realistic as well as analytically tractable. With appropriate parameters the experimental data of Froemke et al., 2002, Froemke et al., 2006, Nevian and Sakmann, 2006 and Sjöström et al., 2001 are quantitatively reproduced in unprecedented detail. Furthermore, for poisson firing with constant rates the model exhibits BCM-like properties, and for poisson activity with time dependent firing rates we find resonant behavior where the strongest synaptic changes are in the theta range, i.e. we retain the filter properties of synaptic plasticity first predicted in Schmiedt et al., 2010.

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References


[T 21] Hippocampus and prefrontal cortex support contextual fear conditioning in different ways: Insights from a novel cue-array paradigm
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In contextual fear conditioning, a type of associative learning, an initially neutral context-stimulus (CS) is paired with an aversive unconditioned stimulus (US) which evokes fear or anxiety responses. Repeated pairings of the CS with the US result in an association of both stimuli that causes the occurrence of the CS alone to elicit an emotional response. It has been suggested that neocortical systems are able to represent the single features of the context, whereas the implementation of features into a unitary conjunctive representation necessitates the binding capacity of the hippocampus. Human functional magnetic resonance imaging (fMRI) studies have mainly focused on fear conditioning of discrete cues and the few contextual fear conditioning fMRI studies might be confounded by methodological issues. By using two cue-array contexts with identical physical properties, only differing in the arrangement of context components, we aimed to force subjects to uncontaminated contextual processing in order to determine the role of both the hippocampus and neocortical areas during the acquisition of contextual anxiety in humans in more detail. T-contrasts revealed sustained BOLD activity of the electrical-shock-associated context relative to the non-shocked context (CS+unpaired > CS-) in right rostrolateral prefrontal cortex what could be explained by its role in the acquisition of stimulus-shock contingency awareness. Moreover, activation of bilateral insula was found possibly reflecting an anticipation of electric shocks. Transient activity for the same contrast, after the respective stimulus-regressors have been multiplied with a linear decaying function, could be found in regions of the right hippocampus and the right amygdala. Hippocampal activation is thought to represent a binding operation that links the single features into a coherent context representation while amygdala is responsible for fear learning. A psycho-physiological interaction (PPI) analysis revealed connectivity of the right hippocampus to the amygdala and the primary somatosensory cortex (Brodman areas 3a and 3b) as a result of its interaction with the electrical-shock-associated context. These findings depict an information flow from hippocampus to the amygdala which is necessary for contextual fear learning and from hippocampus to the somatosensory cortex which possibly reflects the anticipation of an electrical shock to the right hand.
In future work measures of effective connectivity (DCM) will be employed to investigate the influences that different brain regions exert over another. By means of graph theoretical analysis we want to explore the trial-by-trial evolution of brain network characteristics as association learning progresses.

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[T 22] Modelling memory consolidation with STDP

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Since the famous case of patient H.M. it is known that the acquisition of episodic and semantic memory relies on the hippocampus. After months, or even years, memories become hippocampus-independent and are stored in the neocortex. This process of information transfer is called memory consolidation. However, the detailed biological mechanisms underlying consolidation remain unknown.

As a basis for a mechanistic model of consolidation, we propose a canonical consolidation circuit. In this circuit, the inputs to a network are transformed to outputs via two possible pathways: an indirect pathway, that maps via an intermediate stage of processing, and a direct pathway, that maps directly to the output. In a hippocampal setting, the input stage could correspond to entorhinal cortex, the output to CA1, and the intermediate stage to the dentate gyrus together with CA3. CA3 is generally believed to be the place where new episodic memories are encoded. Hence, during consolidation, information stored in CA3 should, in a first step, get consolidated to the next level, i.e. the direct pathway. We call the circuit canonical because the direct-indirect pathway pattern seems to be ubiquitous in the brain.

As a mechanism for the transfer of information from the indirect to the direct pathway, we propose spike-timing-dependent plasticity (STDP). STDP is known to adapt synaptic strengths to the earliest input spikes that correlate with a neuron's output. As the indirect pathway has an additional stage of processing, signals take longer to arrive at the output neurons as compared with the direct pathway. The indirect pathway shares its inputs with the direct pathway, and therefore spikes caused by the indirect pathway necessarily have correlations with input along the direct pathway. These correlations drive STDP to transfer information from the indirect pathway to the direct pathway.

We analyzed the information transfer in a linear rate-based model and confirmed the results by using a numerical implementation of the model. Because information transfer is bidirectional, memory transfer may oscillate with time. To increase the performance in our model, this oscillation can be prevented by decreasing the learning rates on the indirect pathway during consolidation, which is a testable prediction of the model. Finally, we implemented the model with integrate-and-fire neurons and confirmed the results of the linear model prediction.
Structural dynamics of the nucleus: Basis for morphology modulation of nuclear calcium signaling and gene transcription

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Neuronal morphology plays an essential role in signal processing in the brain. Individual neurons can undergo use-dependent changes in their shape and connectivity, which affects how intracellular processes are regulated and how signals are transferred from one cell to another in a neuronal network. Calcium is one of the most important intracellular second messengers regulating cellular morphologies and functions. In neurons, intracellular calcium levels are controlled by ion channels in the plasma membrane such as NMDA receptors (NMDARs), voltage-gated calcium channels (VGCCs) and certain α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptors (AMPARs) as well as by calcium exchange pathways between the cytosol and internal calcium stores including the endoplasmic reticulum and mitochondria. Synaptic activity and the subsequent opening of ligand and/or voltage-gated calcium channels can initiate cytosolic calcium transients which propagate towards the cell soma and enter the nucleus via its nuclear pore complexes (NPCs) embedded in the nuclear envelope. With the help of detailed three-dimensional calcium models and in vivo experiments we recently described the discovery that in hippocampal neurons the morphology of the nucleus affects the calcium dynamics within the nucleus. Here we purpose that nuclear infoldings determine whether a nucleus functions as an integrator or detector of oscillating calcium signals. We outline possible ties between nuclear morphology and transcriptional activity and discuss the importance of extending the approach to whole cell calcium signal modeling in order to understand synapse-to-nucleus communication in healthy and dysfunctional neurons.

References


Queisser, G., Wiegert S., and Bading, H. (2011) Structural dynamics of the nucleus: Basis for Morphology Modulation of Nuclear Calcium Signaling and Gene Transcription. Nucleus. DOI: 10.4161/nucl.2.2.15116


Learning-induced changes at the single neuron level predict behavioral performance in the honeybee

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Associative learning in honeybees is a fast and robust process and provides a favorable approach to study the neural substrate of learning and memory in insects [Hammer and Menzel, 1995]. A well-established paradigm to study classical conditioning in honeybees is using the proboscis extension response (PER) where an odor (conditioned stimulus, CS) is paired with sucrose reward (unconditioned stimulus, US) [Bitterman et al., 1983].

It has been previously demonstrated that extrinsic neurons (ENs), which provide the output of the mushroom body, change their odor response profile as a result of PER conditioning [Okada et al., 2007, Strube-Bloss et al., 2011]. In this study we investigated whether learning-induced changes in firing activity of single ENs were related to the expression of the learned behavior. We found a significant correlation between the degree of plastic change at the single neuron level and the degree to which the learned behavior was expressed. Animals that showed higher learning-related changes in ENs activity during repeated test trials also expressed a higher probability to extend their proboscis during repeated testing with the conditioned odor.

Moreover, we found a considerable temporal delay of more than 300 ms between the onset of the conditioned neuronal response and the onset of muscle activation. This delay suggests that ENs do not trigger motor responses directly, but rather provide a reward-related signal to downstream structures (e.g. the lateral horn network) that would control behavior.

Finally, we propose a minimal model of a downstream neuron that integrates EN output via short-term facilitating synapses. This neuron integrates evidence for the presence of a reward-predicting stimulus and provides a decision boundary for the initiation of motor commands and expression of the conditioned response.

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References

[25] Inheritance of place fields in the hippocampus through Hebbian learning
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The hippocampus plays a key role in the acquisition, consolidation, and retrieval of episodic and semantic memory [Andersen, 2007]. Particularly, the hippocampus has been found to be fundamental for spatial memory in rodents since the discovery of place cells, i.e., cells that selectively fire in a specific region of the environment (the place field of the cell) [O’Keefe and Dostrovsky, 1971, Moser et al., 2008]. The hippocampus has been anatomically differentiated into several interconnected regions, all of them showing place-selective firing [O’Keefe and Nadel, 1978]. Motivated by the connectivity within the hippocampus, we hypothesize that a place field in a downstream region such as CA1 is inherited from an upstream region such as CA3 through Hebbian learning.

We examine this possibility by modelling a population of CA3 place cells that projects to a single CA1 cell with synaptic weights that are initially homogeneously distributed. Assuming an agent running at constant speed on a circular track, we use spike-timing dependent plasticity (STDP) [Markram et al., 1997, Kempter et al., 1999, Song et al., 2000, Dan and Poo, 2004] to simulate the evolution of the CA3-CA1 synaptic connections. The STDP rule leads to symmetry breaking of the synaptic weights and, as a result, place fields emerge in CA1. Finally we show that a random initialization of the synaptic connections, which may be regarded as random synaptic wiring at the CA3-CA1 projection, is sufficient to explain the spatial distribution of the place fields in CA1.

References
latory simulations should lead to 3D experience of the bee. Furthermore we have developed a method for extracellular long-time recordings from central neurons in the walking bee for a period of up to one week. We are recording from single mushroom body extrinsic neurons including the PE1. So far we have collected data from animals that steer towards the edges of bar-like structures, and find an increase in neural activity for a certain running behaviour, which is characterized by the orientation of the bee to contrast differences in the virtual scene.

**[T 27]** Cooperative structural plasticity based on pre- and postsynaptic spike timing
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The structure of networks of mammalian neocortical neurons is subject to continuous remodeling. Synapse formation and pruning, however, do not occur randomly [1]. Rather, the relative abundance of multiple-synaptic connections between neurons indicates some cooperation [2]. It is yet unclear by which mechanism this cooperation is achieved. By extending current models of spine plasticity [1,3] we investigate whether spike timing dependent structural plasticity can explain the experimentally obtained distributions of synapse multiplicity [2]. Indeed, although assuming only generic mechanisms which might plausibly be realized locally in the dendritic spine, the model's spike timing dependence can explain cooperative formation and pruning of synapses. Furthermore, the study provides new insights into the possible functional role of silent synapses for structural plasticity, as well as an explanation for the existence of both transient and persistent dendritic spines.

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**References**

**[T 28]** Neural fields and cortical plasticity
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Cortical plasticity and reorganization in adult mammalian brain cortex has been first reported some three decades ago and has been since the center of intensive studies in order to understand the synaptic and structural mechanisms underlying this property. More precisely, these
studies shown that sensory cortical representations are able to reorganize themselves in face of a lesion or sensory deprivation and this would be true for (almost) the whole lifetime; well beyond the so-called critical period. This hypothesis is today strongly supported by several neurophysiological evidence even if the underlying mechanisms have not yet been identified. In this context, we’ve been studied both the self-organization of the somatosensory cortex and its reorganization when a lesion or a sensory deprivation takes place. Based on recent neurophysiological studies and anatomical evidence, we hypothesize that the main site of cortical plasticity may be located in the thalamo-cortical afferent connections while lateral cortico-cortical connections could be used to establish a competition between cortical neurons such that after the competition stage, only a small group of neurons is able to tune itself onto the presented stimulus. The computational model is based on the neural field theory that promotes a mesoscopic approach of the cortex. It is based on a unique integro-differential equation that describes the evolution of cortical activity at any location. Thus a such neural field approach is quite consistent with the common view of the cortex as being a homogeneous structure made of the replication of a canonical element. We show that this model is able to self-organize itself in order to map sensory input and that it is able to recover from a lesion by reorganizing its representations consistently. Finally, in case of sensory deprivation, we show how neuron representations can migrate from inert sensory territories to active ones.

References

[T 29] Information processing in the cerebellum granular layer and changes in plasticity revealing single neuron effects in neural ensembles

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In the current work, an estimate of information flow in terms of spikes in the cerebellum granular layer is discussed. Information transmission at the Mossy Fiber (MF) - Granule cell (GrC) synaptic relay is crucial to understand mechanisms of signal coding in the cerebellum [Albus,1971] [Marr, 1969]. To quantify the information transfer of a whole neuron, we used a computational model of a cerebellar granule cell [Diwakar, 2009], where the excitatory input space could be explored extensively. MFs convey afferent signals to GrCs following sensory stimulation. Plasticity was simulated in the granule cell model by changing the intrinsic excitability and release probability of the cells. Information coding in neurons or brain cells occur as excitatory post-synaptic potentials (EPSPs) and as spikes. The role of both EPSPs and spikes as information content relating the neuron’s response to given input stimuli was ex-
plored. LTP favored generation of spikes whereas LTD favored EPSPs as expected, although the percentage of spikes was higher at low release probabilities than the percentage of EPSPs at higher release probabilities. The role of selective inhibition by Golgi cells for coincidence detection is presented.

The cerebellum input stage has been known to perform combinatorial operations on input signals. A detailed network model [Medini, 2010] was developed to study information transmission and signal recoding in the cerebellar granular layer and to test observations like center-surround organization and time-window hypothesis. It was noted that simple neuron models may be used to abstract timing phenomenon in large networks, however detailed models were needed to study changes in synaptic plasticity. Plasticity and its effect in generation and modulation of spikes in the granular layer network have been analyzed. Our results also indicated that spatio-temporal information transfer through the granular network is controlled by synaptic inhibition. Spike amplitude and number of spikes were modulated by LTP and LTD. The granular network operates a robust population code for a wide range of intervals, modulated by the Golgi cell inhibition and was regulated by the post-synaptic excitability. Understanding population activities of underlying neurons reveal emergent behaviour as patterns of information flow in neural circuits. Local field potentials (LFPs) arise from complex interactions of spatial distribution of current sources, time dynamics, and spatial distribution of dipoles apart underlying conductive properties of the extracellular medium. Hence we reconstructed LFP to test and parameterize the molecular mechanisms of cellular function with network properties. The sensitivity of LFP to local excitatory and inhibitory connections was tested using two novel but simpler approaches [Parasuram, 2010]. Both modelling approaches generated LFP in vitro [Mapelli, 2007] and in vivo [Roggeri, 2008] waveforms as reported in experiments. A third and newer technique called ReConv was designed. ReConv uses repetitive convolutions of jittered post-synaptic potentials to generate LFP as seen in granular layer. Changes to single cell properties during LTP and LTD were reflected in the LFP wave suggesting the sparse recoding function of granule neurons as spatial pattern generators.

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References
The ability for growing axons to locate appropriate spatial targets is an essential part in the formation of correct circuits during neural development. Molecules called guidance cues guide the growth cone of a growing axon. The response of a growth cone to a guidance cue is determined by a complex network of intracellular events. For most guidance cues, two important second messengers within the growth cone are cAMP and calcium. Raising calcium on one side of the growth cone can lead to either attraction or repulsion, though small increases in calcium have different effects to that of large increases. Additionally the baseline calcium level in the growth cone can affect the turning response to a guidance cue. Combined, these elements make it difficult to make predictions about the turning behaviour of a growth cone in response to varied conditions. Additionally cAMP also has a role in determining the direction of growth cone turning, further adding to the complexity of the system.

Currently there are very few theoretical models of signal transduction in axon guidance. In particular, until now there has been no complete and rigorous model of the underlying mechanisms that cause the response of the growth cone to calcium and cAMP. Thus it has been impossible to make predictions of the turning behaviour of a growth cone under previously untested conditions. Making predictions about growth cone behaviour is critical for understanding the changes that occur during development and the role that cAMP levels play in recovery from injury.

We have devised and implemented the first mathematical model of the mechanisms underlying calcium and cAMP dependent growth cone turning. The model exposes a simple but elegant signal transduction network that underlies many seemingly contradictory experimental results. The model is able to account for current experimentally observed behaviours. The signal transduction network is similar to one that has been previously used to model the switch between LTP and LTD, providing an intriguing connection between growth cone guidance and synaptic plasticity.

The model also generates new experimental predictions, which we have tested and confirmed. This strengthens the validity of the model and provides the surprising prediction that decreasing cAMP can cause attraction under certain conditions, which had never previously been reported. This is of great importance in understanding the role of cAMP in development and neural regeneration.
Learning and brain plasticity are most strongly required when the brain suffers from a sudden lesion such as a stroke: brain circuits need to be rearranged and compensatory mechanisms have to be established. It is therefore highly desirable to support and optimize this brain plasticity. We have recently shown that a photothrombotic (PT) lesion in the somatosensory cortex (S1) abolished both ocular dominance (OD) plasticity after monocular deprivation (MD) in mouse primary visual cortex (V1) and visual acuity improvement through the open eye (Greifzu et al., 2011). To obtain insights into the underlying processes of this learning impairment, we analyzed in detail the effects of the stroke-lesion on V1-plasticity in the hemispheres ipsi- and contralateral to the lesion using optical imaging of intrinsic signals. Cortical plasticity mechanisms were challenged by MD of either the contra- or the ipsilateral eye.

In control mice, the binocular zone of V1 is dominated by input from the contralateral eye; MD of this eye lead to a significant OD-shift towards the non-deprived (ipsilateral) eye and cortical activation changed from being significantly stronger after contralateral eye stimulation to a more balanced activation. In contrast, in mice with a PT-lesion in S1, MD of the dominant contralateral eye did not cause an OD-shift towards the non-deprived eye in the lesioned hemisphere and cortical activation remained stronger after stimulation of the contralateral eye. In contrast, in the non-lesioned hemisphere, we observed a significant OD-shift both after depriving the contra- and ipsilateral eye. Thus, OD-plasticity was present in the non-lesioned hemisphere indicating that the reduction of OD-plasticity of the lesioned hemisphere must be a rather specific process and cannot be caused by a general decline of plasticity mechanisms in the entire brain. In fact, the disturbance was more specific than previously thought since MD of the weak, ipsilateral eye could induce a significant change in the OD-index even in the lesioned hemisphere, which became even more strongly dominated by the contralateral eye.

Taken together, the PT-lesion in S1 selectively disturbed OD-plasticity in V1 of the lesioned hemisphere after MD of the dominant, contralateral eye, i.e. a change from a cortex dominated by one eye to a cortex about equally strongly activated by visual stimulation of both eyes. This change is supposed to be primarily mediated by an increase of cortical activation after stimulation of the initially weaker eye. In contrast, the PT-lesion did not disturb OD-plasticity after MD of the weaker, ipsilateral eye (in the lesioned hemisphere), and thus a change from a cortex already dominated by one eye to one even more strongly dominated by this eye. Our results thus further indicate that these two processes depend on different mechanisms.

Reference
The way we learn and act is characterized by a wide-ranging flexibility in adapting to both endogenous as well as exogenous manipulations due to changes in our motivational states and/or environmental factors. A key determinant in this behavioral flexibility is temporal context. It provides a heuristic strategy in situations where the relevance of environmental cues may change and previously irrelevant cues may suddenly become vitally important.

To study whether, and to which extent, changes in the temporal statistics of an operating environment affect the learning of arbitrary visuomotor associations we designed a reversal paradigm on the basis of our previous work in Hamid et al. (2010). In the current study, human observers were required to unlearn stimulus-response associations on the basis of modified temporal contingencies of the presented stimuli. Specifically, observers viewed sequences of highly distinguishable fractal objects (one per trial) and learned by trial and error to associate with each object the one motor response (out of four) that was rewarded. However, at some “undetermined” point, part of the visual objects was replaced by novel objects: some asking for the same motor responses as their ancestors (remained responses) and others requiring different ones (changed responses). The new objects provided either fully informative temporal context or completely an uninformative one (Hamid et al., 2010).

Contrary to the predictions of simple models of reinforcement learning, performance of human observers fell to chance level after any type of reversal. The learning rate depended critically on the impact of reversal on temporal contingencies: learning of novel objects with remained responses was consistently and significantly faster when their predecessor objects also had their motor responses unchanged. Despite the uncertainty might be evoked by the reversals, temporal order effects were observable after each modification of temporal contingencies as they were before it.

These findings suggest that temporal context represents a robust, heuristic strategy that is suitable for natural learning scenarios, in which environmental cues change over the course of time.

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References

Imaging with diffusion tractography the living mouse brain “connectome” in wild type and reeler mutant animals
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A non-invasive detailed insight into the brain’s axonal connectivity in vivo has only become possible since the development of diffusion tensor magnetic resonance imaging (DT-MRI) and fiber tracking (FT). We explore here the use of in vivo mouse brain tractography to demonstrate the impact of the reelin gene mutation in the development of the whole mouse brain connectional anatomy. Using a new global FT algorithm we provide the first in vivo insight...
into the whole living mouse brain “connectome”, comparatively in wild type and reeler mutant animals. One particular connectivity profile is closely examined within the ensemble of reeler and wild-type brain fiber pathways: the lemniscal thalamocortical (TC) connectivity, and more precisely the connectivity between the ventrobasal thalamic nucleus (VB) and the somatosensory cortex. We demonstrate that changes in patterning of the cortical sheet, such as disorganized cortical lamination of the reeler, lead to parallel alterations of TC pathways. Due to the impaired neuronal positioning, the TC projections reconstructed in reeler brain are distorted and thinner than normal. Poorly compacted axonal projections penetrate the cortical plate and run up diagonally in the outer regions of the cortex. From these areas they descend to the deeper cortical planes where the target neurons wrongly end up their migration. Comparatively, the wild-type thalamic fibers are crossing the internal capsule; they run tangentially at the interface of the cortex with the subcortical white matter and ascend to the target fields into the neuronal layer IV of the cortex. The accuracy of the connectional information revealed with our imaging approach is also assessed. We quantitatively validate the TC connectivity profiles generated using in vivo tractography, with correlative histological axonal tracing. Probabilistic maps of the TC projections are co-registered and quantitatively correlated with axonal density maps, generated after analyzing the fibers labeled by Micro Ruby (MiR) tracer injection in the VB of the same animal. The results show high correlation between the TC patterns depicted with the two methodologies. Comparing the in vivo tractography results with the “ground-truth” offered by the axonal tracing data, we not only demonstrate the validity of our imaging approach but we also draw attention to the spectacular capacity of the reeler brain for altering and remodeling its TC circuits through active plasticity mechanisms.

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Markov models for sequences of microsaccades
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While fixating our eyes perform small, erratic eye movements. These so called fixational eye movements (FEM) are classified in tremor, drift, and microsaccades. However, this classification seems incomplete if we account for the possible different shapes and sequences of microsaccades observed during fixation. Over the last decades, the term saccadic intrusion (SI) has been introduced as a fourth type of FEM (Abadi et al. (2000), Vision Research, 40:2813-2829; Abadi & Gowen (2004), Vision Research, 44:2675-2690). The most prominent SI is a monophasic square wave intrusion that is also often referred to as square-wave jerk. This type of SI is a sequence of two saccades separated by a short time interval. Projected on the horizontal direction of movement, the first saccade drives the eye away from the initial position and the second corrective movement returns the eyes back. Whether SIs represent an independent new component of FEM is an ongoing discussion.

In this work, we use a novel method to investigate the statistical dependence of sequences of microsaccades. Our method exploits a recently developed wavelet-based microsaccade detection algorithm and a symbolic dynamics approach (Bettenbühl et al. (2010), Journal of Eye Movement Research, 3(5):1, 1-14). In contrast to previous studies, we neglect temporal proximity of saccadic events during fixation. Consequently, we describe the sequences of microsaccade directions as realizations of a stationary discrete Markov process. Using Bayesian inference, we estimate the order of the Markov chain (i.e., the length of the memory in the sequence of microsaccade directions) with an exact measure, the Bayes factor. Monte Carlo simulations confirmed that our method reliably estimates the order of a Markov process from its realizations.

Our investigation suggests that the observed sequences of microsaccade directions are best described by a first-order Markov process. This finding indicates that at each position in the sequence a microsaccade direction depends only on the previous one. Consistent with such a dynamical model, the most common type of SIs, the square-wave jerk, and single microsaccades appear to be events generated by the same process. Our rigorous statistical treatment lends support to the earlier interpretation “that fixational saccades and SIs are generated by the same neural circuit”

Reference

Legged locomotion: Combining control strategies to increase performance
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Walking animals achieve efficient locomotion in rough terrains and complex environments. To date, most walking robots employ preprogrammed reactive control leading to a limitation of adaptivity. As a consequence, they might have difficulty to locomote over unknown rough
terrain. We are interested in the effect of changing control strategies for some degrees of freedom (DOFs) on locomotion of a hexapod robot in rough terrain. This is investigated by replacing the central pattern generator driven control by less regular strategies.

Three different control strategies are evaluated: a simple neural central pattern generator (PureCPG) [1], a combination of the PureCPG with random walk (RWC) and a combination of the PureCPG with homeokinesis [2] (HKC). In the first case all DOFs are controlled by PureCPG. In the second and third cases the coxa-trochanteral (CTr) joints for elevation and depression of the front legs are controlled by RWC and HKC respectively. Performance is measured in terms of distance travelled in body lengths.

The platform used is a simulation of the real hexapod robot AMOSII. In the experiments we place the robot into rough terrain containing plateaus of three higher altitudes. The maximum altitude being roughly 1.4 times the maximum ground clearance of the legs. Note that the maximum ground clearance of all controllers is equal due to identically chosen joint limits. With these joint limits the PureCPG controller generates an exaggerated stalking gait, already adapted to the rough terrain.

Our results show a clearly higher performance of HKC and RWC compared to the PureCPG. The PureCPG performs a periodic pattern that, once stuck for one cycle, barely has a chance to gain any more ground. The other controllers can vary the position of the front CTr joints relative to the other DOFs. Therefore they have a greater behavioral repertoire to traverse the terrain.

Furthermore, we observe that the RWC and the HKC do not perform significantly different (however, the HKC looks slightly better). So random behavior seems like quite a good strategy in rough terrain. Nonetheless there are advantages to the use of feedback from the sensors which are exploited by the HKC without performance loss. An example is reduced strain on the material as shown by [3].

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References

Independent component analysis of flight maneuvers in tethered Drosophila melanogaster
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The fruit fly Drosophila melanogaster is a key model organism for the study of animal behavior and its underlying neuromotor control. We developed a statistical method based on independent component analysis to classify the wing motion patterns of the fruit fly during tethered flight. The method identifies components of the wing motion that are maximally mutually independent; such components may be viewed as the basic control modes of the flight neuromotor system.

Flies were tethered with a steel rod glued to their thorax and were stimulated to initiate wing flapping. Wing motion was recorded using a high speed computer vision system (TrackFast, SciTrackS.com) and its temporal variations were interpreted as attempted flight maneuvers. The angular positions of the left and right wing during dorsal and ventral reversals in each wing stroke were used as the four mixed signals for independent component analysis (ICA). To preserve and explore the non-stationarity of these signals, they were analyzed in segments of 2000 to 4000 wing strokes. Thus, the non-stationarity of the signal was transformed into the dissimilarity of the separating matrices from distinct segments. This dissimilarity was used to hierarchically cluster the corresponding independent components. The optimal number of clusters was determined by maximizing the silhouette cluster quality index value. In this clustering process, independent components obtained from similar linear combinations of the reversal angles but occurring during separate segments are grouped together.

The most prominent cluster consists of independent components that are obtained predominantly from the difference of ventral reversal angles for the left and right wings. These components have sharp features at the time scale of 40 to 70 wingbeat cycles, and correspond to the well known fast turning maneuvers of flies, called body saccades. Another major group of components contains slower features (time scale of 200 to 500 wingbeat cycles) which are strongly correlated with wingbeat frequency. These two types of features are occasionally simultaneous and in the ICA resolve as two distinct components. Thus these features are controlled independently, which suggests the involvement of distinct synergies of the flight control muscles.

Spatial synchronization structure of field potentials and spikes in a delayed grip task

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Modulations of the local field potential (LFP) are commonly attributed to the synchronization of inputs received by neurons in the vicinity of the recording electrode. Moreover, the LFP is shown to relate to firing rates and the degree of correlation exhibited by nearby neurons [1], establishing the LFP as an excellent monitor of the coordinated neuronal population activity. In primary motor (MI) and premotor (PM) cortical areas, during an instructed delay LFPs typically show oscillatory activity mostly restricted to the beta-range (15–30Hz). However, although it is demonstrated that beta activity exhibits in general a wave-like propagation across the motor cortical surface [2], little is known about how such spatially structured synchronization observed on the population level relates to the organization of task-related spike synchronization on the millisecond time scale [3]. We aim to compare these two levels of correlated activity, extending our previous results relating population dynamics to spike synchrony [4].
In short, two monkeys were trained to press a switch with one hand, and then to pull an object using either a Side Grip or a Precision Grip. The object is either heavy or light. To allow the monkey to prepare the upcoming movement, the grip type was revealed to the monkey preceding a delay period of 1s before the GO signal. Massively parallel LFP and spiking activity was recorded using a 100 electrode array implanted at the MI/PMd border.

Here, we analyze beta oscillations during the preparatory phase with respect to the two grip types and cortical location. Based on the spectral coherency and the degree of phase synchrony across electrodes, we show the spatial inhomogeneity of LFP wave propagation direction and speed. In parallel, we compute the pair-wise significant spike correlations \[3\] between single unit activities as a function of spatial and directional parameters. Lastly, these results are complemented with the map of features extracted from the movement-related potentials observed upon movement execution.

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References

Naturalistic 3D arm movements can be decomposed into motion primitives
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How does the brain generate temporally and spatially coordinated, fluent arm movements? How are they affected by the presence of obstacles? And is it possible to identify elementary movements, called primitives, which can be combined to complex movements?

To approach these questions we investigated naturalistic 3D human arm movements during obstacle avoidance tasks. Experiments show that movement paths are largely planar and that the plane is chosen before movement onset. Additional investigations of different obstacle locations and heights reveal that the choice of movement plane reflects obstacle properties. Obstacles affect the movement path right from the beginning and do not act only locally in a small zone of influence. This implies that movement execution and control are always preceded by perception and initial planning.

As direct consequence of planarity, we decompose the trajectory into the transport and the lift/descend primitives. While the first describes a straight movement from the initial position to the target position, the latter represents up- and downward movements within the chosen plane. The two react independently to changing obstacle properties: shifting the obstacle between start and target does not change the lift primitive (being constantly bell-shaped), while the transport primitive is delayed depending on proximity of the obstacle. Further, the lift/descend primitive scales with obstacle height, while the transport primitive varies only sparsely. This autonomy of each primitive may imply their independent planning and execution by the CNS.
With this decomposition into movement primitives we can also explain observed phenomena like the formation and modulation of a double peak velocity structure during obstacle avoidance movements. Furthermore, it allows deeper insights into Flash and Hogan’s principle of local isochrony, even enabling a natural extension. Altogether, our investigations show that naturalistic 3D obstacle avoidance movements are surprisingly regular. Their kinematic structure can be understood in terms of independent and invariant movement primitives: lift/descent and transport.
Attracting states in anterior cingulate cortex populations associated with decision making: Altered dynamics when targeting dopamine system with d-Amphetamine

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A frequent hypothesis in theoretical neuroscience is that cognitive entities are represented and processed by attracting states of the underlying neural system (Balaguer et al., 2011; Durstewitz et al., 2000). For instance, different attractor-like states may represent different spatial locations or cognitive entities, and transitions between these attracting sets could be associated with the recall of a memory sequence or the execution of a motor plan. Attractor states underlying cognition were previously proposed in the context of working memory (Balaguer et al., 2011; Durstewitz et al., 2000) and decision making tasks. However, although theoretically suggested, experimental evidence is still sparse for the hypothesis that higher cognitive processes proceed by moving between attracting states in higher cortical areas.

Using state space reconstruction theorems (Sauer et al., 1991) and statistical learning techniques (Schölkopf et al., 1998; Mika et al., 2000; Durstewitz and Balaguer, 2010; Braun et al., 2008), we were able to reveal dynamical properties, not easily accessible in previous studies, of anterior cingulate cortex (ACC) multiple single-unit activity (MSUA) during a cognitive task (Balaguer et al., 2011). The approach worked by constructing high-dimensional state spaces from delays of the original single-unit instantaneous firing-rates and all possible products (multinomials) among them up to some specific order. The dynamics within these sparse and high-dimensional spaces of neural activity interactions were then statistically accessed using optimally regularized kernel methods (Schölkopf et al., 1998; Mika et al., 2000; Durstewitz and Balaguer, 2010; Braun et al., 2008).

Results showed cognitive-epoch-specific neural ensemble states (dependent on behavioral performance (Lapish and Durstewitz et al., 2008)) in ACC while the rats performed an ecologically valid eight-arm radial arm-maze task. More interestingly, these cognitively defined ensemble states showed some hallmarks of attracting behavior which became apparent in high-dimensional expansions of the MSU spaces due to a proper unfolding of the neural activity flow.

Nevertheless, those network states where not observed in the original space of MSU recording; it turned out that optimal unfolding of neural trajectories was achieved in an embedding space characterized by a specific maximum order of neural interactions, common across different animals (Balaguer et al., 2011). From these analyses the intrinsic dimensionality which is relevant to the animal’s arm choices could be computed (Braun et al., 2008). Analyses revealed that cognitively relevant network states were embedded in a lower-dimensional nonlinear manifold within the high-dimensional space.

Once established the optimal embedding space, attracting dynamics was also analyzed for animals treated with low- and high-doses of amphetamine. Consistently with our previous study (Balaguer et al., 2011) neural trajectories from animals treated with saline, 1 mg/Kg and 3 mg/Kg of amphetamine where indistinguishable the original MSUA space; while trajectories where properly unfolded for the optimally expanded state space.

However, and in sharp contrast, attracting dynamics was severely compromised for high-doses of amphetamine even in optimal state spaces containing high-orders of neural interactions. This result is consistent with predictions of working memory models, which proposed...
that high concentrations of dopamine should disrupt attractor dynamics in Frontal Cortex
(Durstewitz and Seamans, 2008).
To summarize, results indicate that ACC networks may process different subcomponents of
higher cognitive tasks by transitioning between different attracting states. Moreover attracting
dynamics breaks down for high-doses of amphetamine, in agreement with theories of pre-
frontal cortex function.

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References
dynamics of frontal cortex ensembles during memory-guided decision-making. PLoS Com-
Feature Spaces. J. of M.L. Res. 9, 1875-1908.
Neuro-Cognitive Ensemble Dynamics from High-Dimensional Neural Recordings. Neuro-
forum 4, 266-276.
function with relevance to COMT genotypes and schizophrenia. Biol. Psy. 64, 739-49.
Durstewitz, D., Seamans, J.K., and Sejnowski, T.J. (2000). Neurocomputational models of
behavior is associated with distinct and coherent network states in anterior cingulate cortex.
Neural Comp. 10, 1299-1316.

[T 40] Neurons with unselective rapid responses as reference for relative temporal cod-
ing in primate auditory cortex
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Vocalizations or speech constitute dynamic inputs that are represented in auditory cortices by
precise time-varying activity patterns. Such response patterns are typically analyzed by align-
ing spikes and sensory events using the experimenter’s clock, a laboratory-based reference not
available to the brain. In contrast, neural systems must interpret time-varying responses using
only intrinsic reference frames, a particularly challenging task for stimuli appearing suddenly
or unpredictably. One solution could be provided by encoding information in the relative tim-
ing of neural responses, thereby exploiting intrinsic temporal reference frames. But it remains
unclear whether and how sensory cortices implement a neural reference suitable for relative
coding schemes. We investigate the viability of such a relative coding scheme in primate auditory cortex using a paradigm where naturalistic sounds were presented at random (unexpected) times. Recording neural responses in macaque auditory cortex we found that neurons clustered in two subsets with different properties. A set of stereotypical neurons responded rapidly and unselectively to individual stimuli with minimally varying latency, while another set of stimulus-selective neurons responded slowly and selectively with high latency variability. We then tested the hypothesis that the latency of the stereotypical neurons can provide a reliable and intrinsic reference frame for relative coding schemes. Specifically, we calculated the stimulus information carried by the selective neurons in different neural codes based on the relative timing of their neural responses to either a stereotypical neuron or another selective neuron. Two codes were considered: the relative onset latency between neurons and the full spike train of the selective neuron aligned to the response onset of a reference neuron. Information in latency relative to stereotypical neurons reached 91% of the information in latency with respect to the stimulus onset. The spike trains of the selective neurons relative to the stereotypical neurons contains 84% of the information in spike trains aligned to the stimulus onset, but only 41% relative to another selective neuron. At the population level, an estimate of the latency based on 20 stereotypical neurons allows preserving 95% of the information as measured with the experimenter's clock. We thus demonstrate that information in response latencies and sustained time-varying responses may be decoded by measuring these relative to another neuron’s or a population response. Stereotypical neurons responding unselectively and rapidly to various complex stimuli may serve as an early saliency signal that provides a reliable temporal reference frame that can be used to extract information in the responses of more selective neurons.

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References

**The spiking irregularity of MSTd neurons depends on visual and oculomotor variables**

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Neuronal activity in macaque cortical area MSTd is driven by retinal stimuli, as almost all neurons respond to moving large-field patterns. At the same time, the spiking activity in MSTd is modulated by an internally generated signal related to the monkey’s eye movements. This combination of both visual motion and eye movement related activity makes MSTd an ideal system for analyzing neuronal activity in dependence on different stimulus dimensions. In this work we analyzed the inter- and intra-trial variability of spiking activity by measuring Fano factor (FF), squared coefficient of variation (CV²) and local variation (LV). Two different paradigms were used: fixation with visual stimulation and optokinetic response to a moving large-field stimulus. For the first condition our results complied with a recent neurophysiological study reporting stimulus-related decline in neuronal variability. The second condition, however, revealed opposing behavior. We found that both stimulus variables, retinal image velocity and eye velocity, differentially affected neuronal variability. Spiking irregularity decreased when image velocity increased and eye velocity was kept low, but increased with increasing eye velocity and low image velocity. This finding might reflect a specificity of the local network structure or could be related to the variability characteristics of the input signals. Nevertheless, the observed behavior may also have functional importance reflecting additional timing-based coding independent of the neuron’s mean firing rate.

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**Depth as a latent variable**

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Estimation of binocular disparity in the brain is widely assumed to be based on the comparison of local phase information from binocular receptive fields. The classic binocular energy model shows that this requires the presence of receptive fields in the form of local quadrature pairs within the eye and with phase- or position-shifts across the eyes. While numerous computational accounts of stereopsis have been based on these observations, there has been little work on how energy-models can emerge through learning from the statistics of image pairs. We describe a way to cast binocular disparity estimation as a probabilistic model, and we show how learning on data-bases of multi-camera views of a scene leads to position-shifted Gabor filters. The model agrees with the classical binocular energy and cross-correlation models in that it learns shifted quadrature pairs, while also allowing for more flexible connectivity that yields richer dependencies between the learned filters. Learning on binocular data with known ground-truth disparities furthermore makes it possible to train a network to perform depth estimation entirely based on training data.

In contrast to standard (monocular) feature learning, acquiring training data for binocular feature learning is more challenging as it requires the generation of image pairs in accordance with a given camera setup. We use a methodology for generating image pairs and corresponding ground truth disparities based on recent evidence that due to fixations and vergence, biological receptive fields are confronted mainly with locally smooth surfaces. To generate the training data, we first generate depth maps as slanted planes in 3D. We then generate texture maps using patches cropped from natural images of the same size as the depth maps. Finally, we project the 3D scene onto a set of cameras defined by their camera matrices. We demonstrate how the presence of ground truth disparities makes it possible to learn depth estimation, by adding a pooling-layer that is trained to predict the ground-truth disparities from the inferred binocular encoding. We demonstrate this purely learning-based depth estimation scheme on random-dot stereograms.

Conditional rules of the form "If X then Y" are of vital importance in our everyday life. Recently, researchers have started to uncover the neural substrate underlying cognitive control and conditional rule processing (Reverberi, 2011; Bunge, 2008). Here, we present results from two studies that investigated two critical, so far largely neglected, aspects of rule processing:

1. Which vs When: Do different regions encode rule identity and rule order? What are the brain regions encoding rule order?
2. Where vs What: Does the brain encode rules differently for different types of responses?

To investigate this, we recorded fMRI while participants performed a cued task-switching paradigm, in which participants had to retrieve, maintain, and apply two rules in a fixed order, such as "Check first: If there is an X, do Y. Check second: If there is a V, do W". Using multivariate searchlight decoding (Kriegeskorte, 2006; Haynes, 2007), we found neural double dissociations for both questions:
(1) Regions representing which rule to use (i.e. rule A vs. rule B) differed from regions representing when to use which rule (i.e. rule A before rule B), and

(2) Regions encoding rules that used (spatial) where responses (e.g. “If X, press left”) differed from rules using (symbolic) what responses (e.g. “If X, press where an ‘A’ appears”).

More specifically, rules requiring where/what-responses were encoded in lateral parietal/lateral temporal areas, respectively, reminiscent of the classical dichotomy between the dorsal “where” and ventral “what” pathway. Only right dorso-lateral PFC encoded rule identity in both conditions. Still different regions were found to encode when (i.e. in which order) rules should be applied, including both cortical (e.g. premotor areas) and subcortical structures (e.g. Putamen and Hippocampus).

Our finding that what-response rules are not represented in parietal cortex challenges the current view that rule processing in general depends on a fronto-parietal network. Rather, it suggests that the frequently observed parietal involvement may be due to the need of spatial processing.

In conclusion, we were able to extend previous research on rule representation by (a) identifying the neural code underlying the order with which rules are to be applied; (b) finding a double dissociation that suggests that the brain handles two important features of tasks sets, namely rule identity and rule order, differently; and (c) showing that neural representations of rules differ depending on the required response type. More generally, this work demonstrates that neural representations of multiple features of task sets can be decoded from patterns of human brain activity.

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References


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[T44] Frequency tuning properties across the isofrequency laminae of the inferior colliculus in guinea pigs: Implications for a new auditory midbrain implant (AMI)

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The auditory midbrain implant (AMI) is a new neural prosthesis designed for stimulation along the tonotopic gradient of the central nucleus of the inferior colliculus (ICC) with a single shank array (20 sites) and for those who cannot benefit from cochlear implants. The re-
Results in the initial patients have been encouraging in that they receive lip-reading enhancement and improved environmental awareness. However, they still do not achieve open-set speech perception typical of cochlear implant patients. Since speech perception performance with auditory implants has shown to correlate with a greater number of independent frequency channels of stimulation, we investigated if there were regions along the isofrequency laminae of the ICC with more narrow frequency tuning bandwidths (BWs) that could enable more localized frequency-specific activation. Previous studies in mice have shown narrower BWs in more central ICC regions (Hage & Ehret, 2003). We investigated if this type of BW organization was consistent in other species, particularly in the guinea pig, which is the animal model we currently use for our AMI translational studies.

We performed experiments in 13 ketamine-anesthetized guinea pigs. Normal hearing was confirmed with auditory brainstem responses. We then opened the skull above the visual cortex and inserted a two shank array (16 sites/shank, 100 µm site spacing) through the visual cortex into the ICC. We inserted the shanks into different locations and mapped out the BWs across the isofrequency laminae of the ICC. For each placement and site, we recorded multi-unit spike activity to pure tones to obtain a tuning curve (0 – 70 dB SPL, 500 Hz – 50 kHz, 6 steps/octave). The BW value for each site corresponded to the tuning bandwidth 10 dB, 20 dB, or 30 dB above threshold divided by the best frequency (i.e., Q10, Q20, or Q30, respectively). We plotted these BW values as function of location along an ICC lamina. The shanks were stained with Di-I (1,1’-dioctadecyl-3,3,3’,3’-tetramethylindocarbocyanine perchlorate, Invitrogen) before brain insertion to enable histological identification and reconstruction of all the sites.

Based on our results, BWs appear to be narrower (i.e., higher Q values) in more caudal regions of an ICC lamina that then increase for more rostral and outer regions. These results were consistent across different levels above threshold. We did not observe a concentric organization of BWs as observed in the previous mice study. However, it is possible that we may not have sufficiently sampled the most caudal regions of the ICC to observe broader BWs that would have created a concentric pattern. Nevertheless, these results suggest that location of AMI implantation and stimulation may affect the extent of activation spread across the frequency dimension, and needs to be considered for future studies and patients.

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A multi-scale analysis to set the default mode network in noisy fMRI data

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The Default Mode Network (DMN) is presently defined by those brain zones involved in maintaining a baseline brain activation. This network is usually revealed using Independent Component Analysis upon the fMRI data. However, a number of factors can easily perturb the acquired data, in particular a large head motion. Yet this problem has been partially overcome by registering the acquired brain volume; registration is still very limited in case of large head movements, a frequent scenario in patients with disorders of consciousness.

This article presents a multiscale analysis of the fMRI data which improves the robustness with which the DMN is detected in subjects that move the head during the acquisition process. Initially, the method obtains multiple scales by filtering the original volumes out with a sequence of Gaussian filters. Each fMRI scale is preprocessed by registering, normalizing, smoothing and coregistering, as described elsewhere, using the SPM software. These preprocessed data are then decomposed into the spatial-temporal components with the FastICA algorithm. The DMN is then selected with the Goodness of Fit approach (GoF), for each of the different scales. Finally, the components of the DMN at different scales are summed up, ruling out the original volume.

The approach was validated by perturbing the acquired sequence of five healthy subjects with the six rigid-body movement series obtained from 15 subjects (5 Control, 3 Minimally Conscious State, 2 Locked in Syndrome and 5 Vegetative State), with head motion from 1mm up to 15 mm.

In summary, the proposed method was applied to 18 disturbed data that lost the DMN, from which 11 fMRI data recovered the DMN. The mean of the Goodness of fit of the DMN component increased from 0.1 to 0.4. This multiscale analysis improves the robustness of the DMN detection in case of large head movements.

A neural-dynamic model of counterchange motion detection in one dimension

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Although models based on motion energy provide the standard approach to understanding how motion is detected, recent experimental work on generalized apparent motion is in conflict with this class of models [1]. The counterchange model was developed to account for this new data [2]. It postulates that the instantaneous detection of a luminance or contrast change toward the background at one location and a change away from the background at another location signals motion. The model has been formulated and tested only for apparent motion between two discrete spatial locations. We extend the model to account for real motion along one spatial dimension. This requires us to specify the spatio-temporal filters, on which coun-
terchange motion detection is based. The model takes the spatio-temporal stimuli as input and generates an activation pattern representing motion at any location along the spatial dimension into one of two motion directions. We focus on edge-based motion by defining an appropriate spatial filter. Transient detectors are formulated as pairs of excitatory and inhibitory neurons. Generalizing the model to continuous motion also requires us to address the "sampling" problem, that is, to specify the distances over which transients are combined to a motion signal. We hypothesize that a single such sampling for one distance is sufficient to detect continuous motion over a range of speeds. The motion signal is computed as a product of the two half-way rectified transient signals and fed into two neural fields, one for each motion direction, defined over the single spatial dimension.

We demonstrate that continuous motion at a range of speeds can indeed be detected. We explore how the speed of the stimulus is reflected in the total amount of motion detector activation. Finally, we demonstrate that the results of the original model for apparent motion can be reproduced in the generalized model. We also consider stimuli of varying spatial characteristics.

References

Neural implementation of chaos control improves both speed and reliability
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Chaos control has applications in many fields [1], for example, it has been demonstrated in neural circuits [2] and we have recently used it in order to control robot behavior [3]. One way to achieve chaos control, i.e., rendering unstable fixed points stable, is by adding control perturbations [4, 5].

In a neural implementation of chaos control the application of the control perturbations are restrained by the underlying neural substrate. Hence, the neural implementation itself poses challenges. At the same time, the chaos control method itself is subject to a serious limitation. Convergence speed of such a mechanism becomes very slow when stabilizing more and more periodic points. This has immediate consequences. Take for example an organism, natural or artificial, with a neurally implemented chaos control mechanism where a specific movement is linked to the period of some periodic orbit. For the organism to react to changing environments, new periodic orbits with different periods have to be stabilized as fast as possible resulting in corresponding reactive movements. Hence, reaction time is linked to the convergence time of the stabilization mechanism.

We show that a delay, inevitable due to the neural implementation, improves not only convergence characteristics like speed and reliability but, interestingly, also extends the accessibility
of periodic orbits in terms of stabilization. Chaos control methods usually are parameter-dependent and the parameter influences the speed of convergence. A priori, however, the optimal parameter value is unknown. We systematically study the performance of different adaptation schemes [6], including heuristical [3] methods, that can be used to find the optimal parameter values dynamically. The result is an adaptive, neurally implemented chaos control algorithm that may have wide applications in the dynamics of neural systems.

References

[T 48] Representation of spatiotemporal sequences in hippocampus: A dynamic Bayesian model

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Place cells in the hippocampus of rodents fire preferentially when the animal is in a specific location of its environment. Sequential firing of place cells has been observed not only during movement through a sequence of locations but also during rest periods [1]. This means that place cells learnt to represent experienced sequences of places, i.e. paths. Although several models have been proposed for how individual place cells come to represent specific locations, there are relatively few models for learning and recognition of paths by hippocampal neurons or populations. Here, we present a probabilistic model of population coding in hippocampus based on Lotka-Volterra dynamics [2], which replicates a number of experimental key findings. The model provides for a simple mechanism of how paths can be learnt and encoded as sequential activation of place cells. In the present approach we assume that dynamic templates are encoded by recurrently connected populations of neurons where learning maps these templates to the actually experienced spatiotemporal input [3], i.e. the sensory dynamics induced by moving along a path. After learning, the model implements a predictive coding scheme based on Bayesian inference for nonlinear dynamical systems [4] to recognize paths based on ongoing sensory input. In other words, the model recognizes and predicts the current path by anticipating the sequential activation of place cells. In simulations we show that this recognition and prediction scheme is robust against minor deviations from the learnt path, noise in place cells activity and the speed with which the animal moves along a path. Furthermore, once a path is learnt, the model can also recognize and predict the reverse path, which mirrors another experimental key finding [1]. In summary, we present a probabilistic model of sequential activations of place cells which qualitatively explains a wide range of experimental findings and may be the basis for further research into the role of sequential firing in hippocampus.
References

Cortical up and down states: switching in a conductance-based model

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The role of slow wave oscillations during mammalian sleep recently raised considerable attention from the observation that slow waves can be electrically stimulated [1-2], and that after such a stimulation, a significant increase in memory consolidation can be observed [1]. Cortical slow-waves are comprised of collective depolarization (Up) and polarization (Down) phases. Up phases show an increased firing rate reminiscent of wakefulness [3]. Down states are characterized by comparatively silent levels of neural activity. An interesting experiment showing Up- and Down state switching under electrical stimulation was presented by Shu, Hasenstaub and McCormick [4] in ferret brain slices. In this experiment, Up state could be triggered (switched on) electrically, Counterintuitively, termination of the Up state was possible by stimulation during the Up state by an impulse of same polarity. The dependence of the Up state duration depending on the impulse amplitude and the time difference between the two impulses was studied quantitatively [4]. In a previous study, we have proposed a minimal model mimicking the interplay between recurrent excitation and inhibition controlled by slow adaptive currents [5]. By this quite generic model the experimental time-dependence already can be explained. While the model needs only few parameters, it does not explicitly model neural spiking and it is desired to computationally confirm the approach also from a conductance-based model. To study stimulation at this level of description, we follow the established conductance-based cortex model by Compte et al. [6] which incorporates a two-compartment (soma and dendrite) membrane potential within a Hodgkin-Huxley type formalism. We use a one-dimensional distance-dependent randomly connected network of 256 regular spiking (RS) and 64 fast-spiking (FS) interneurons, an increase of the size did not significantly affect the qualitative behavior. We observe self-generated Up-Down states in the absence of stimulation in accordance with the detailed study of [6]. If we apply low stimulus intensities, the Up state duration is trivially affected marginally, as in the experiment, and for high stimulus intensities a termination of Up states is enforced, giving two delimiting lines as in [4]. For intermediate stimulus intensities the termination of the Up state depends on the stimulus intensity such that the experiment is confirmed within the measurement precision in [4]. We provide also a quantitative comparison with the previous model [5].
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References
1. Marshall L, Helgadottir H, Mölle M, Born J: Boosting slow oscillations during sleep poten-
2. Massimini M, Ferrarelli F, Esser SK, Riedner BA, Huber R, Murphy M, Peterson MJ, To-
noni G: Triggering sleep slow waves by transcranial magnetic stimulation. PNAS (2007)
104:8496-8501.
3. Destexhe A, Hughes SW, Rudolph M, Crunelli V: Are corticothalamic ‘up’ states frag-
4. Shu Y, Hasenstaub A, McCormick DA: Turning on and off recurrent balanced cortical ac-
6. Compte A, Sanchez-Vives MV, McCormick DA, Wang X.: Celluar and network mecha-
nisms of slow oscillatory activity (<1Hz) and wave propagation in a cortical network model.

Small world topology of dynamic reservoir for effective solution of memory
guided tasks
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A large number of biological, technological and social networks, such as the neural network
of C.elegans, power-grid networks, citation networks and numerous cellular networks, exhibit
a small-world topology. Inspired by this we propose a highly clustered neural topology with a
short characteristic path length, for the dynamic reservoir of a standard Echo state network.
The purpose is to generate a stable short term memory for delayed response tasks such as
maze navigation. Characteristic to delayed response tasks, like the road sign problem and na-
vigation through generic T-shaped maze, is the requirement of a temporal memory such that
the system is capable of learning slowly and access previously learned pattern over varying
time delays. For this purpose we use continuous time leaky integrator neurons with an ex-
perimentally determined leak decay rate coupled with the small world architecture. This
mechanism controls the time scale of the internal dynamics of the ESN network.
Restricting our neural pool to 100 neurons we tested our setup initially with the task of learn-
ing a Mackey-Glass system with mild to wild chaotic behavior and finally with the task of
off-line learning of navigation through a maze. For the maze task at each step the state-action
pair (sensor-motor value) serves as the input to the network, while the output gives the re-
quired action which the agent needs to take for a required state. After initial training on a sim-
ple maze, we test the learning of the network by generalizing to a larger arena with varying
starting and ending points. Results of the simulations on the time series data of the Mackey-
glass dynamic system show higher prediction ability than standard ESN networks. The small-
world model along with the ability to control the internal time scale of the dynamic reservoir

[50] Small world topology of dynamic reservoir for effective solution of memory
guided tasks
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A large number of biological, technological and social networks, such as the neural network
of C.elegans, power-grid networks, citation networks and numerous cellular networks, exhibit
a small-world topology. Inspired by this we propose a highly clustered neural topology with a
short characteristic path length, for the dynamic reservoir of a standard Echo state network.
The purpose is to generate a stable short term memory for delayed response tasks such as
maze navigation. Characteristic to delayed response tasks, like the road sign problem and na-
vigation through generic T-shaped maze, is the requirement of a temporal memory such that
the system is capable of learning slowly and access previously learned pattern over varying
time delays. For this purpose we use continuous time leaky integrator neurons with an ex-
perimentally determined leak decay rate coupled with the small world architecture. This
mechanism controls the time scale of the internal dynamics of the ESN network.
Restricting our neural pool to 100 neurons we tested our setup initially with the task of learn-
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ple maze, we test the learning of the network by generalizing to a larger arena with varying
starting and ending points. Results of the simulations on the time series data of the Mackey-
glass dynamic system show higher prediction ability than standard ESN networks. The small-
world model along with the ability to control the internal time scale of the dynamic reservoir
in our setup, results in a stable temporal memory capable of handling varying delays to solve the navigation task with efficient generalization capability to more complex maze.

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**References**

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**[T 51]** **A biophysical network model for action selection**

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The role of basal ganglia in action selection is well-known [1] and there are various neuro-computational models of action selection [2-4] where their interaction with thalamus and cortex is considered as pointed out in [5]. While these models are biologically plausible models, they are more focused on behavioral aspects of action selection and they deal with neural substrates at systems level rather than neuron level. Though they are effective, the biophysical models of thalama-cortical circuits are more informative in explaining the biological aspects of ongoing processes especially in Parkinson’s disease [6, 7]. In this work, a biophysical model for striato-thalama-cortical circuit is investigated for action selection. The activation at each neural substrate in the model is obtained and discussed. It is observed that the model is capable of generating bursting behavior and the disinhibition of thalamus by globus pallidus pars internus when an action is selected. The model is composed using both Hodgkin-Huxley and Izhikevich neuron models, in order to figure out the efficiency of these neuron models. Since the model is a nonlinear dynamical system, the analyses are carried out with XPPAUT and the effect of excitatory input is explained with bifurcation diagrams. Thus activation at striato-thalama-cortical circuit is explored using mathematical tools developed for nonlinear dynamical systems.

**References**
Optogenetic induction of network level plasticity
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Channelrhodopsin-2 transfected hippocampal neuronal cultures grown on multielectrode arrays allow simultaneous optical stimulation and electrical recording from neuronal networks. As has been previously reported, after maturation these networks develop an electrical activity that is characterized by synchronized bursts. In this work we study the influence of whole field blue light illumination on bursting dynamics of hippocampal cultures. During light stimulation, the mean firing rate is significantly larger than before and after. After turning off the stimulus a silent period follows, then the network gradually switches back to bursting activity with increased firing rate, burst rate and intra-burst firing rate. Using synaptic blockers we found that both excitatory & inhibitory neuronal interactions were involved in mediating changes in the burst structure. We concluded that optogenetic stimulation can be used to persistently change bursting dynamics in biological neuronal networks.

Inference in generative models learned on natural images explains contextual effects in visual cortex
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Dynamic natural scenes are rapidly and efficiently processed by the mammalian brain. As a first approximation, simple neural responses to stimuli presented inside the 'classical receptive field' (cRF) of a cell can be described by linear models. Realistic stimuli, however, extend beyond the cRF and such 'stimulus context' can influence responses in a strongly nonlinear way.
Although these modulatory effects are observed in many sensory systems and highly relevant for understanding brain function, a unifying explanation is still missing. Here we introduce a novel framework to understand contextual modulations of neural responses. We assume that neurons perform inference in a generative model of natural scenes, estimating the probability of presence of specific patterns ('causal fields', CFs) in their sensory input. We show that these causal fields can be learned from patches of natural images and that the resulting model accounts for diverse contextual effects observed for standard stimulus protocols.

First, reverse correlation reveals cRFs with spatio-temporal properties matching experimental findings: (i) RF size shrinks with reverse correlation delay tau and quickly becomes smaller than CF size. (ii) Using dense noise stimuli leads to bi-phasic, Mexican-hat like spatial responses profiles in contrast to Gaussian shapes for sparse noise stimuli. Most importantly, we find that non-classical receptive fields (ncRFs) emerge naturally from competitive interactions between neurons to explain common parts of their sensory input ('explaining away'). Because of this competition, the receptive fields of neurons can be very different from the pattern they actually detect. Second, the responses of our inference model closely match experimental findings from various physiological and psychophysical studies: (i) neuronal responses to stimuli inside their cRFs by stimuli presented in their surround are enhanced for low center stimulus intensities, and suppressed for high center intensities, (ii) cRF size shrinks for higher stimulus contrasts, (iii) ncRF properties vary considerably for neurons with almost identical cRFs. We derive necessary conditions for various center-surround interactions from a minimalistic model.

Taken together, this model establishes a unifying framework to reproduce and interpret various experimentally observed phenomena. Its formulation in terms of probabilistic inference clarifies the computational benefits of facilitating and suppressive center-surround interaction. Finally, our approach provides a principled understanding of sensory neural processing of extended and complex stimuli.

Acknowledgements
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[54] A novel approach to the analysis of the state of coupled networks of spiking neurons in the presence of noise
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The standard approach to the analysis of the stability of networks of integrate-and-fire like neurons is to apply Fokker-Planck equation for the voltage distribution in the network with boundary conditions and re-injection. In this approach the asynchronous state is obtained by determining the equilibrium distribution and its stability by considering perturbations of this state by linearizing the perturbed system yields the eigenvalue-equation. This approach is highly successful for networks with one-variable model neurons and static synapses; however, it has proven to be difficult to extend to networks of model neurons with more than one state.
variable, e.g. networks with short-term plasticity in noisy conditions. To overcome these problems we present a different approach: instead of studying the evolution of the voltage distribution we analyze the system by studying how the inter-spike interval distribution evolves. This determines evolution of the firing rate, which determines the feedback input. Thus, self-consistency gives rate in the asynchronous state and also allows us to determine the eigenvalue-equation in the perturbed system. We will first show that for networks with static synapses this yields the same eigenvalue equation as the classical Fokker-Planck approach. Finally, we will show how the analysis can easily be extended to networks more state variables, for example networks of integrate and fire neurons with short-term plasticity and some results from this case.

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**[T 55] Dynamics of neural networks with different motif distributions**

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Recently, several research fields underwent considerable advances thanks to the study of the networks underlying specific process or phenomena. Some of these studies report that 3-node motifs (small sub-networks contained within larger networks) could be linked with the function of specific biological networks (Milo, 2002).

The network model with structured nodes (SN model) has been recently introduced (Frisco, 2011) as an algorithm able to generate networks with specific features including the 3-node motif distribution (3NMD): the abundance of each 3-node motif in a network. We used the SN model to generate two networks, network 1 and network 2, each with 250 nodes and with different 3NMDs.

These two networks were then used to create two random recurrent neural networks (Dauce, 1998).

We observe the dynamics after applying a stimulus to the network. We used three different functions to apply the stimuli: all: each neuron has an influence; least x connected: the x neurons with the least outgoing connections have an influence; most x connected: the x neurons with the most outgoing connections have an influence. We run tests for x=20, x=50 and x=100.

Our analysis focused on the differences in the dynamics of the two networks depending on the stimuli functions. We observed whether or not a network has regular dynamics after a stimulus has been applied. Before any stimulus is applied the dynamics of network 1 are regular in a few cases, while network 2 never has regular dynamics.

In general, network 1 is more likely than network 2 to have a regular dynamics after any type of stimulus is applied.

When all nodes in the networks receive a stimulus, then in 88% of the tests network 1 has a regular dynamics while network 2 only 53%.

Network 1 has a regular dynamics independently from influencing the least or most connected nodes and the percentages of tests leading to regular dynamics are very close to each other when these functions are applied. We had expected the influence on the most connected nodes to lead to regular dynamics more frequently than the influence on the least connected nodes (this is indeed the case for network 2).
We also noticed that the increase in the number of influenced nodes (least or most connected) is not followed by a proportional increase in the number of networks having a regular dynamics.
The percentage of tests having a regular dynamics deriving from network 1 is always much higher than the ones deriving from network 2.
All this let us to conclude that 3NMD has a strong effect on dynamics.

References

Synchrony between monkey areas V1 and V4 depends on stimulus relevance
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One fundamental question in neuroscience concerns, how neurons are able to switch between different subsets of their synaptic input to selectively process relevant and ignore irrelevant signals. The need for switching arises because of the strong anatomical convergence of a large number of inputs on individual neurons. This general problem becomes particularly apparent in the visual pathways, where the convergent anatomical wiring results in neurons with increasingly larger receptive fields (RFs) in downstream areas. In such larger RFs typically multiple objects will be present at the same time. In this situation, next to signals representing the attended object, a potentially much larger number of signals representing behaviorally irrelevant objects provide input to a neuron. Here, we hypothesize that attention serves dynamical routing of relevant information by selectively modulating the synchrony between neuronal populations along visual pathways.

We therefore investigated if behavioral relevance can dynamically change synchrony between neurons in area V4 and different subsets of their afferent inputs from V1. Single unit, multi unit and local field potential (LFP) signals were recorded from macaque monkeys’ areas V1 and V4 simultaneously. While maintaining their gaze on a fixation spot, the monkeys had to attend to one of two continuously morphing shapes and to respond to reoccurrence of the initial shape in the attended stream. Size and position of the two shapes were adjusted such that both fitted into a single V4 RF while covering two separate, non-overlapping V1 RFs.

We found strong phase coherence of gamma-band LFP between the recorded V4 population and the V1 population representing the behavioral relevant stimulus. At the same time, phase coherence between the same V4 population and the V1 population representing the non-relevant stimulus was only weak.

Moreover, we found that the spike timing of V4 neurons is correlated with the phase of the gamma-band LFP of V1. Interestingly, also this spike field coherence was modulated by behavioral relevance. Neither changes in gamma-band power in V1 nor changes of gamma power or spike rates in V4 could explain these attention dependent synchronization patterns.
The results show that interareal gamma-band synchrony selectively depends on behavioral relevance of the stimulus. This supports the hypothesis, that oscillatory synchrony subserves dynamically selective routing of relevant information through the neuronal processing stream.

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References
Networks of neurons enable creatures to behave in amazing ways. Assemblies of neurons pick up signals from sensory inputs or other groups of cells and these signals must penetrate the downstream networks in order to process or compute what is needed. We use a crustacean, motor-neuron-containing ganglion to investigate signal propagation in small neural networks. The stomatogastric ganglion (STG) of crabs is a small neural network containing about 26 neurons. Most of these are motor neurons and are connected by electrical and inhibitory chemical synapses. The STG contains a central pattern generator that controls the stomach movements of the crab. Within the STG are two subnetworks that control the gastric and the pyloric rhythms. Some STG cells belong exclusively to one of these groups while other STG cells can participate in both rhythms either simultaneously or intermittently. Many years of work have established a connectivity diagram for the STG. Nonetheless, the manner in which signals propagate through this network cannot be simply derived from the static connectivity diagram. The Inferior Cardiac (IC) neuron switches its activity and fires in time both with the fast pyloric rhythm and the slower gastric mill rhythm. It makes connections with a diverse set of STG cells. To understand how signals propagate through the STG, we injected various signals into the IC neuron and simultaneously recorded from many of the other STG neurons. Stimuli included sine waves (0.3, 0.7, and 1Hz), long DC pulses, pink noise, and white noise. We calculated the coherence between either the injected signal or IC neuron activity and other neuron’s firing activity in the network. We are interested in determining whether the different types of synapses have a gating effect on certain types of stimuli. Therefore, we conducted these experiments in the isolated network in control saline as well as in low Ca++/high Mg++ saline to quiet chemical synapses. Sine waves injected into IC propagated into a variable set of STG neurons, including some neurons that are not directly connected to IC.

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Granule cells very effectively sparsen excitatory input from the entorhinal cortex to the hippocampus. This filtering is important for the function of the hippocampus, and likely relates to the intrinsic properties of granule cells. However, the mechanisms underlying granule cell function are unclear. During temporal lobe epilepsy (TLE), granule cell properties change, partly due to an upregulation of inward rectifier K+ (Kir) channels [Stegen et al., 2009; Young et al., 2009]. Also, the expression of hyperpolarization-activated cyclic nucleotide-gated cation (HCN) channels alters during TLE; predominantly resulting in hyperexcitability.
of the respective cell types [Dyhrfjeld-Johnsen et al., 2009]. The functional role of HCN channels in granule cells and the consequence of HCN changes in the dentate gyrus are unknown [Bender et al., 2003].

To investigate the functional consequences of ion channel changes in granule cells during TLE we constructed detailed conductance-based models from recordings and morphologies of human dentate granule cells. As conductances were elevated in sections with severe hippocampal sclerosis (sHS) versus those only mildly affected (mHS), two representative models were build. HCN currents depolarized granule cells, but due to the shunting influence, increases in this current reduced the excitability and shifted the input-output transfer function of granule cells. Our computational investigations show that the simultaneous upregulation of HCN and KIR conductances observed in TLE is well suited to decrease input resistivity while balancing the resting potential. The model also indicates that a low ratio of HCN to KIR prevents theta frequency resonance oscillations in granule cells. Thus, co-regulation of HCN and Kir conductances might be a mechanism of intrinsic plasticity by which granule cells homeostatically scale their output; a property important for the filter function of granule cells, and likely for their survival in epilepsy.

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References
maze. In order to obtain food efficiently, the animals had to keep a memory of the arms they visited before, and maintain it across a delay that separated two task phases.

Here, we present a neural network model which provides a possible neural basis for the memory performance in this task. The network consists of eight pools of neurons, which are connected in a circular fashion, such that activity continuously circulates between states corresponding to each of the eight arms. To encode whether a given arm was visited before or not without interrupting the flow of activity, each pool is subdivided into mutually inhibiting populations of neurons, one of which is associated with a “new” arm, while the other one correspondingly encodes a previously visited, “old” arm. Sensory stimulation is simulated by activating the “new” populations at the beginning of a trial, and the “old” population of a given arm at the time it is entered.

In order to perform the necessary computation, each pool must exhibit and maintain the appropriate bias between the two subpopulations, i.e. either the new or the old population must be persistently active while the other is silent. This bias is initially induced by the sensory stimulation. After the stimulus is gone, the memory is maintained by the reverberating activity itself: Activity decays with a time constant such that there is still some fraction of the peak firing rate left by the time the activity wave returns to that pool. Thus, the population which is more active at this time will be enhanced faster and stronger by the wave, and the bias is fortified because of the mutual inhibition.

In terms of dynamics, the present network will give rise to a persistent memory about the visited arms if the interplay between slowly decaying activity in each pool (which carries the selective bias), and reverberating activity forms a stable limit cycle in the phase space of firing rates. To confirm this quantitatively, we reduce the model further to a system of two pools and conduct a formal stability analysis on the resulting dynamics. In this way, we derived stability conditions on the parameters such that both selectivity between the new and old pools, and continuously reverberating activity is maintained. These conditions generalize to an arbitrary number of pools, and can thus be used to constrain an optimization process to fit the model to the trajectories in the neuronal data.

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References

[61] Single-and multi-unit recordings in humans at the Neurozentrum of the University of Freiburg
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Between April 2007 and May 2011 we implanted 25 patients (6 male and 19 female) with hybrid Macro- and Microelektrodes, so-called Behnke-Fried (BF) electrodes, at the Neurozentrum in Freiburg. While recordings of field potentials with intracerebral depth electrode was indicated in these patients in order to localise their primary seizure focus, we could record activity from either Multi-units (MUA) or from Single-Units (SUA) in 22 out of 25 patients. The average recording time was 10,12 days (5 to 23 days). In 3 patients, each implanted only with a single BF electrode, failure of the microwire bundle lead to the complete absence of MUA or SUA. In contrast, the average failure rate was 19.5% (17 out of 87 BF electrodes) regarding all implanted patients. While none of the patients suffered from any complication of neurological significance, 3 of the patients revealed minor bleedings at a single site, presumably due to the implantation of the macroelektrode. Failure to reach the brain area, targeted during presurgical planning occurred during implantation of 2 Behnke-Fried electrodes in 2 distinct patients.

In 18 out of 25 implanted patients we counted the number of putative single-as well as multi-units mainly during a single recording session. This count revealed a total number of 550 units (both SU and MUs) for 52 functional bundles, each composed of 8 recording wires. Hence the average unit yield was 0.756 units per recording channel in these 18 patients. Furthermore the average discharge frequency was 0.917 Hz for SUA, but only 0.835 for MUA.

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**Model-invariant features of correlations in recurrent networks**
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Depending on the scientific question to be investigated, different models of neural dynamics are commonly in use.

Many studies employ the leaky integrate-and-fire model [1], because it is able to predict spike sequences of real neurons to good accuracy [2], but the analysis of this model is complicated by the very nature of the non-linear threshold process involved. Some studies therefore resort to simplified neural dynamics, like linear stochastic point process models [3], in order to render the problem at hand tractable. An example is the interplay of spiking neural dynamics and synaptic plasticity in recurrent networks, where stochastic point process models have successfully been employed [4]. However, it often remains unclear how the different neuronal models relate to each other and if results from one model carry over to another.

In this work we aim to unify different approaches to recurrent neural networks with excitation and inhibition. We focus on the correlation structure of such networks in the irregular regime [5] and study four different models of neural activity: Linearly coupled rate units [6], linear stochastic point process models [3,4], binary stochastic neuron models with non-linear gain functions [7], and leaky integrate-and-fire models [1,5].

Recent advances in the theory of correlations in recurrent networks [8,9,6] showed that in the regime of asynchronous irregular activity, these models qualitatively yield similar results. Here we show that all four models map to the same self-consistency equation describing cor-
relations in networks with irregular activity. Solving this equation once allows to obtain a self-consistent solution for the correlation structure in the presence of excitation, inhibition and conduction delays. This unification allows to convey results obtained from one model to the others. We exemplify this on the asymmetry of cross correlations [7] and the emergence of fast global oscillations [5].

Acknowledgements

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References

5 Brunel N (2000), Journal of Computational Neuroscience 8, 183–208

[T 63] An analytical approximation to the AdEx neuron allows fast fitting to physiological data

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Fitting spiking neuron models to physiological data sets is often a demanding and time-consuming task. For large-scale network simulations with many different neuron types, it is therefore important to have mathematically tractable, yet in a defined sense still physiologically realistic neuron models that allow for a fast fitting process. Recent extensions of the basic LIF model [1,2,3] enable to reproduce voltage traces and spiking dynamics of real neurons to a reasonable degree. Most of these previous studies used voltage traces to fit the model which are obtained by injecting a fluctuating current into neurons recorded from acute brain slices. Some of the models [1,3] also perform quite well on 'test' sections of these recordings that were not explicitly used for training the model. However, since both training and test data consist of voltage traces generated by input currents with the same statistical distribution, it could be that the model performs well only within the limited input regime used for fitting and would not generalize well to different input regimes.

Here, rather than fitting model parameters to fluctuating voltage traces, we use standard f/I (firing rate over current) curves from cortical pyramidal cells recorded in vitro. These curves cover the whole range of spike rates up to the point of the depolarization block. For this purpose we derive an approximation to the adaptive exponential Integrate-and-Fire model.
(AdEx) [4] which yields a closed-form expression for the f/I curves. This approach is based on a separation of time scales [5], assuming that the time constant of the adaptive current is much slower than the membrane time constant. The model is fitted to almost perfectly match the training set consisting of initial and steady state f/I curves. It is then, however, tested on recordings of voltage traces upon fluctuating input currents as in previous approaches [1,3]. The approximated model allows a fitting process that is about one order of magnitude faster than fits via numerical integration, and it still produces a remarkably low prediction error on the qualitatively different test set. We used established performance measures to assess the prediction capabilities of the model and to compare the results with previously published work [3]. Thus, we have created a neuron model which can be adjusted to physiological f/I curves very quickly, which is physiologically realistic in the sense that it generalizes to independent test sets, and is also mathematically tractable.

Acknowledgements
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References

Transient activation of MT neurons to stimulus velocity changes: experiments and modelling
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Area MT neurons of primate visual cortex are strongly tuned to motion direction and speed. However, electrophysiological investigation of MT response properties most often relies on stimulation with objects of constant features, disregarding that MT neurons display large transients for stimuli in response to features changes. In this contribution, we investigate the response properties of MT cells for de- and accelerating moving stimuli, and analyze putative neural mechanisms behind the observed phenomena. Single electrode recordings were obtained from 106 neurons of area MT of two macaque monkeys engaged in a dimming task at fixation. Stimulation was achieved by a single moving Gabor grating presented inside the RF of the recorded neuron. Each neuron was first charac-
terized for its response preferences according to direction, speed, and spatial frequency. Subsequently it was stimulated with gratings moving in the preferred direction of the neuron with one of two initial speeds, which accelerated or decelerated during the trial by varying factors ranging from 33.3% to 300% of the initial speed. Sustained response profiles show the expected features of a strong directional tuning with almost no response to the anti-preferred motion direction and a spatial frequency-dependent speed tuning of approximately Gaussian shape on a log-velocity scale. However, transient responses to stimulus on- and offsets, and to velocity changes, reveal additional dynamical phenomena: (i) at stimulus on- and offset, neurons also respond strongly to the anti-preferred direction of motion, (ii) at stimulus onset, speed tuning is almost linear, with increasing firing rates for faster movements, and (iii) during speed changes, peak firing rates depend on both, absolute stimulus velocity and relative speed change (acceleration). Thus, there is a clear discrepancy between transient and sustained responses, challenging existing models of direction selectivity in MT. The transient activation and sustained suppression of responses to the anti-preferred direction of movement might be explained by two alternative mechanisms: (i) A weak directional bias in the input to a MT cell, becoming enhanced by recurrent interactions between MT neurons with different preferred directions (‘ring model’), hereby suppressing the responses of cells to the anti-preferred direction (ii) Activation of an MT cell by two feedforward channels, of which the second channel is delayed with respect to the other (Reichardt detector), thus canceling the response to the initiation of a movement into the anti-preferred direction only after the respective delay. In addition, all other transients require a strongly adaptive mechanism, as e.g. dynamic synapses whose transmitter resources become depleted through sustained activation. Models with different combinations of these mechanisms were tested in simulations and fitted to the experimental data. The feedforward model provided the best explanation for the data, reproducing both transient and sustained on- and off-responses. Behavior of the models to speed changes is currently under investigation.

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[T65] Direct numerical simulation of vesicular mobility in the presynaptic terminal
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The activity at chemical synapses is more than a 0-1-coding within the information processing of the central nervous system. Moreover, the synaptic activity itself undergoes short- and long-term changes, resulting in a highly adaptive homeostatic plasticity. Synaptic transmission, directly or indirectly, involves vesicles, which undergo a trafficking cycle in the nerve terminal. This includes the loading with neurotransmitter, docking to the active zone, exo- and endocytosis and finally the supply of recycled vesicles to the active zone. However, the underlying mechanisms are largely unknown. The center of our attention lies on the mobility of the vesicles before exocytosis and after endocytosis. We address the concept of vesicle pools and focus on the question how vesicles...
move within the different pools and as a whole dynamical system. Do they diffuse or follow certain gradients to move to the active zone? Do they attach to the actin filaments? How fast vesicles can move? For most neuronal cells three major synaptic vesicle pools have been proposed: a readily releasable pool, a recycling pool and a reserve pool (Rizzoli and Betz, 2005). Concerning the mobility of the vesicles many observations argue that the recycling vesicles are highly mobile whereas the reserve vesicles are „fixed“. Shtrahman et al. (2005) proposed a stick-and-diffuse-model, which predicts the exponential refilling of the readily releasable pool.

Our approach aims in simulating the collective behaviour of the synaptic vesicles by describing them as particles being solved in the viscous cytosol. In order to solve for the hydrodynamic interactions between the vesicles we use direct numerical simulation methods. Therein the viscous flow of the cytosol is described by the Stokes equation and the movement of the vesicles can be described via explicit boundary conditions. Applying detailed, 3-dimensional simulations, which on the one hand account for the different mobility states of vesicles belonging to different pools and on the other hand include the behaviour of the cytosol, we hope to better understand the dynamics and time scales of vesicle trafficking and recruitment.

References

Biologically plausible connectivity features for the initiation and propagation of bursting in neuronal networks
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Neuronal cultures grown on microelectrode arrays (MEA) from dissociated tissue have been established as a useful biological model in the analysis of network dynamics. Present in their dynamics are periods of strongly synchronized spiking by the network, termed 'bursting', which have been demonstrated to contain different motifs and structure, refuting the possibility that they are merely chaotic activity. Of particular interest are the conditions required for bursting to be initiated and propagated throughout the entire network. Within cultures, burst initiation sites can be well characterized in their location and propagation waves display fairly regular patterns of neuron recruitment within the network burst. Several proposed models of neuronal networks have displayed bursting and depend on the inclusion of a scale-free connectivity. However, the biological basis for this choice of connectivity is not clearly justified for cortical cultures, with evidence from physiological recordings and axonal tracings only providing limited support for such assumptions. Furthermore, scale-free connectivities cannot adequately be reconciled against the emergence of specific areas at the edge of cultures as burst initiation sites. Thus, while it is clear that bursting can be initiated and propagated within biological networks, exactly which features present in their connectivity are responsible for these traits is still undefined.
Thus, we investigate biologically plausible network features that can account for experimentally observed burst initiation and propagation patterns. Specifically, we examine the contribution of long-range connections by assuming a large-scale network of point neurons with a spatially anisotropic connectivity distribution, representing a mature dissociated cortical culture. Using this model and including a simple implementation of synaptic rescaling, we chart how the introduction long-range connections shifts the degree distribution and increases the amount of recurrent activity. Importantly, our model explains the emergence of burst initiation sites and the velocity of burst propagation observed experimentally when evoked by stimulation, when driven with low levels of background activity.

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[T 67] Developmental changes of activity in simple biological neuronal networks
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Correlated patterns of neuronal activity mark an early stage of cortical network development [1]. Accompanied by the formation of first functional circuits and neuron assemblies, this process establishes initial computational properties of a network. One open question is how this process is functionally and structurally reflected by individual neurons. We approached this question by investigating the embedding of single neurons into the spontaneous bursting activity of dissociated networks. Obtained from cortical tissue of newborn rats and seeded on polyethylene iminine-coated microelectrode arrays (MEA), isolated neurons form haphazard networks within days and provide an established model for studying structure-function relations in simple networks [2]. Within the 1st week in vitro, these networks spontaneously generate network-wide bursts with characteristic spatiotemporal propagation patterns that can be recorded extracellularly at defined electrode positions [3]. In addition to sampling population activity with MEAs, we simultaneously recorded individual neuron activity with one or two intracellular patch-clamp electrodes. Network differentiation caused pruning to a neuron density of max. 2,000 cells/mm2 in matured networks at 4 weeks in vitro. With dual patch-clamp recordings, we determined a local connection probability of 0.5 at pairwise distances of max. 450µm. 40% of these connections were bidirectional, revealing a high and recurrent connectivity of the networks. We found that pairwise correlation of spiking within network bursts (NB) increased with network age and across distance, suggesting an increase of overall connectivity. Within the 4th week in vitro, we found a homogenization of correlation degree reflected by a decrease at shorter and a further increase at longer distances. Pairwise correlation between intra- and extracellularly recorded NB activity was highly dependent on the synchrony of spiking at NB onset and the number of spikes/NB, and only to a minor degree on the spatial distance to NB onset location, suggesting that NB propagation involves inhomogeneities in the underlying network connectivity (e.g. functional clusters, long-range connections) and is not purely based on local propagation. In individual neurons, we detected average EPSP frequencies of 5Hz across all network ages. EPSP amplitude distributions, however, systematically decreased with age to average values of 1mV, indicating that synaptic weights scale with increased connectivity and degree of correlation in the matured networks.
In conclusion, our results suggest that fundamental developmental processes are widely preserved in generic neuronal networks in vitro. The homogenization of correlation together with the scaling of synaptic weights and the overall high connectivity imply that differentiation of a network in lack of functional input as observed in perinatal networks in vivo [4] provides a state in which prospective input can be processed reliably.

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References

[T 68] When less is more: Non-monotonic spike sequence processing in neurons
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The computational capabilities of neural circuits centrally rely on the input-output relations of single neurons. It is commonly accepted that neurons respond to inputs monotonically such that increasing the input implies increasing the output. Yet, most theoretical and experimental input-output studies have so far focused on continuous-time inputs, whereas most neurons communicate via exchanging electrical pulses (spikes) at discrete times. Here we show that the stationary response to regular spike sequences is typically non-monotonic such that increasing the input frequency to a neuron may decrease its output frequency. The underlying mechanism relies solely on a combination of the discrete nature of the communication by spikes and generically limited resources required for input sequence processing. As a consequence, this phenomenon universally emerges across a variety of spiking neural systems. It may support stabilizing the generation of spike sequences in neural circuits.

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**Fast acquisition and analysis of cortical neuronal network activity in vivo**

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The registration of neuronal network activity is pivotal for understanding complex information processing in the mammalian brain. We have established an adapted three-dimensional spiral line-scan technique [1] to simultaneously image large assemblies of cortical layer 2/3 neurons of mice in vivo. After bolus loading of the calcium indicator OGB-1, we measured spontaneous as well as induced neuronal network activity. Using regular galvanometric x-y scanners, sampling rates of more than 100 Hz for two-dimensional and up to 10 Hz for three-dimensional spiral scanning patterns were accomplished. Analyzing large data sets manually is very time consuming, therefore several approaches have been developed to automatize this process. Using in vitro data, we quantified the reliability of three different methods: A threshold algorithm, a variable amplitude template algorithm [2] and a linear support vector machine [3]. By varying algorithm parameters we evaluated the strengths and weaknesses of each algorithm under different conditions and preprocessing steps. The demonstrated techniques will enable further studies to broaden the knowledge about cortical information processing by neuronal networks.

**References**


**Efficient spike tests for linear integrate-and-fire neuron models in time-driven simulations**

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The characteristics of time-driven simulation are a fixed-size simulation step and a fixed-size communication interval [1]. The former defines update-and-check points, which are the discrete points in time when all neurons update their state variables and check for a super-threshold membrane potential. The latter defines the discrete points in time when all neurons communicate their spikes. The communication interval is a multiple of the simulation step.
size and limited only by the minimum synaptic transmission delay in the network. Traditionally, spikes are incorporated, detected and emitted only at the pre-defined update-and-check points. However, the time-driven environment of the simulator NEST [2] provides an 'off-grid' framework that enables spikes to be be incorporated and emitted at any point in time [3,4]. For each neuron the arrival times of incoming spikes introduce additional update-and-check points.

As the detection of a threshold crossing can only take place at the next check point, time-driven simulation still bears the risk of missing a threshold crossing: a very brief excursion of the membrane potential above threshold may not be detected. This problem is more pronounced in networks with low connectivity and strong coupling as well as in the case of low firing rates.

Here, we investigate spike tests of increasing complexity and specificity that can supplement the standard test for a super-threshold membrane potential at each check point and that guarantee the detection of all threshold crossings. Firstly, we determine the specificities of simple sifting methods for a range of input scenarios. Secondly, we compare the performances of complex spike tests which faithfully indicate the existence of a threshold crossing between the last and the current check point. This stepwise analysis enables us to identify a cascade of tests which locates all threshold crossings at a low computational cost.

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**References**


[T 71] Lotka-Volterra equations capture large-scale population activity in balanced random networks

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We study the rate dynamics of a sparsely connected recurrent network comprising excitatory and inhibitory neurons [1,3]. We describe its population dynamics by a system of Lotka-Volterra equations, which represent the mean-field equations for interacting populations of perfect integrators with exponential escape noise [2]. Here, we investigate how well this system of coupled nonlinear differential equations, and variants that can account for the mem-
brane leak, reflects the large-scale dynamics of the network. Specifically, we attempt to identify the parameters of such a system from simulated activity in recurrent networks of leaky integrate-and-fire neurons, assess the goodness-of-fit, and compare the fitted parameters with the values obtained in an analytical approximation.

Previous work on such networks demonstrated that, depending on its parameters, several different activity states are displayed: synchronous regular (SR), asynchronous regular (AR), and asynchronous irregular (AI) activity [1]. The analysis was based on a diffusion approximation of input integration in single-neurons and a self-consistent mean-field description using a PDE-based Fokker-Planck formalism. We found that a bifurcation analysis based on coupled nonlinear ODEs leads to compatible results. In particular, we considered the relative strength of recurrent inhibition as a bifurcation parameter, which changes the excitation-inhibition balance. Another bifurcation parameter is the strength of external input, which is effective to induce AR states if synaptic delays are short.

Our analysis represents a first step toward analyzing the dynamics of more complex “networks of networks” that are implicated in various cognitive abilities of the brain.

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References

Switching between network states in hippocampal area CA3
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The hippocampal circuit can exhibit network oscillations in different frequency ranges (“gamma” - 30-80 Hz; “theta” - 4-12 Hz; as well as “theta/gamma” or a bursting regime) both in vivo and in vitro and switch between them [1]. These different oscillatory modes facilitate memory storage in the hippocampus and memory consolidation [2]. The hippocampal neuronal network consists of various types of connected cells that differ in morphology and functional properties, which allows them to provide oscillations with different periods, amplitudes, and phase shifts [1].

Our goal is to investigate how coupling strength and delayed propagation influence synchronization and switching between different oscillatory states in minimal neuronal networks. To this end, we constructed a simple model of neurons comprising two fast-spiking and two slow-spiking cells, respectively. Cells are synaptically connected in an all-to-all manner, with exception of the two slow-spiking cells. The network is described by coupled FitzHugh-Nagumo equations that well reproduce the dynamical behavior of different cells types: their periods, amplitudes, and phase shifts.
The model allows us to analyze the influence of synaptic strengths on the network synchronization and switching between theta, gamma, and bursting regimes. Mechanisms of switching between different rhythms are discussed.

References

[T 73] The spike initiation in neurons with low input resistance
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Spike initiation is generally assumed to occur in the axon's initial segment (AIS). In neurons with very low input resistance, however, this may no longer hold true, because the soma constitutes a huge current sink. As an example, we consider the principal cells of the medial superior olive (MSO). These neurons are very fast coincidence detectors in the auditory brainstem that encode low frequency azimuthal sound localization by interaural time differences. Their enormously low time constant of only a few hundred microseconds yields from a very low input resistance of about 5MΩ at rest [1], which arises from the expression of low-voltage-activated potassium channels and hyperpolarization-activated unspecific cation channels. Since these cells receive a huge amount of slowly-decaying inhibition [1], it is likely that their input resistance in vivo is even much smaller than at rest. Hence the question arises: how are these cells able to elicit action potentials (AP) at all?
By using a multi-compartmental model of an MSO cell, we found that the spike initiation segment (SIS) in the model is still the AIS. The reason for this is the electrotonic independence of the AIS from the leaky soma. The input resistance of the axonal segments is considerably higher than that of the soma and hence an input current is able to evoke an AP in the AIS, while an AP in the soma is hardly distinguishable from a subthreshold response. We conclude that the excitability of the axon enables the cell to convey information downstream, although the soma itself is not excitable. Thus, neurons with low input resistance cannot be realistically modeled using only a single compartment.

References
Couchman K, Grothe B, Felmy F: Medial Superior Olivary Neurons Receive Surprisingly Few Excitatory and Inhibitory Inputs with Balanced Strength and Short-Term Dynamics, J Neurosci 30: 17111-17121

[T 74] Large-scale modeling for simulating multi-electrode array neurochip recordings
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Very few models to date have been developed to examine inhibitory and excitatory effects as observed in in-vitro neuronal networks. In in-vitro experiments about 10,000 neurons of frontal cortex tissue stemming from embryonic mice are cultivated on a multielectrode array (MEA) neurochip (Johnstone 2010). The object was to simulate experimental data and to compare the results with MEA data using statistical methods.

We developed a spiking neuronal model following the Glauber dynamics (Glauber 1963, Hertz 2011). Our model INEX (inhibitory-excitatory) is a cellular automaton whose cells represent neurons with two possible states: ON or OFF. The binary model should show several characteristics: 1) neurons are active without external input or stimulus as observed in experiments; 2) noise is observed; 3) synapses can be either excitatory or inhibitory; 4) bursting occurs. In order to simulate these properties we assume that the spikes obey an inhomogenous Poisson distribution. The inhomogeneity of the neuronal activity is realized by inhibitory or excitatory synapses of varying strength. The corresponding parameters are called weights. Spike time history is added, i.e. the probability of spike occurring increases following a spike in the previous time slice. We used a fully connected network.

For the simulation a network with 10,000 neurons ran for 10 minutes with time slice $\Delta t = 5$ milliseconds. This choice of $\Delta t$ ensures that the refractory period of real neurons is reflected in the model. Two thousand inhibitory neurons (all synapses of the neuron are inhibitory) with weights between -0.2 and 0 and 8,000 excitatory neurons with weights between 0 and 0.7 were generated. From the generated 10,000 spike trains 52 were chosen randomly and compared to a MEA neurochip recording. For the comparison spike and burst rate (mean and standard deviation) were calculated (Schroeder 2008). Additionally the spike rate histogram was plotted.

The results of the simulation show, that spike and burst rate of the model and of MEA experiments correspond what is also demonstrated in the spike histogram. Therefore, the INEX model shows potential to simulate data as observed in experiments with MEA neurochips.

References

[T 75] A neurocomputational model of nicotine addiction based on reinforcement learning
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In modeling nicotine addiction, we consider that addiction develops due to malfunctioning of reinforcement learning processes driven by metabolical modifications in the brain. We base our approach on the fact that addiction develops as a result of damaged reward mechanism.
Excessive fondness for a substance causes compulsive seeking of that substance and opponent process theory is used in explaining the development of addiction. Nicotine blood level triggers the secretion of dopamine (DA) from the ventral tegmental area (VTA) due to a race with the naturally secreted acetylcholine (Ach) neurotransmitter. In return, glutamate secretion in learning processes is affected and it modifies behavioral choices. Chronic nicotine exposure stamps in the behavioral patterns modified by DA secretion and causes addiction development.

The proposed computational model is developed using MATLAB in-house codes and realizes DA secretion from the VTA to the cortico-striato-thalamic (CST) loop using reinforcement learning. DA secretion, action selection, action evaluation, and value assignment subsystems are modeled as nonlinear dynamical systems. The dynamic behavior of these systems is investigated by bifurcation analysis using XPP in order to give an explanation of processes going on from dynamical system point of view. The action selection system uses competitive learning which is modified with VTA DA signaling affected by nicotine. Arithmetically increasing reward value affects the system in favor of selecting the smoking action. Error in expectation symbolizes the modifying effects of the neurotransmitters and changes the output of dorsal striatum, amplifies the emotional input, and updates the stimulus value. Past actions contribute to the evaluation process as the input from the previous action so the cumulative effects of the previous actions trigger the present action selection. During model execution, addictive, non-addictive, and indecisive behaviors are observed in simulation results. Addiction developed in 20/50 trials with an average of 346/1000 steps and standard deviation of 265.76.

To improve the proposed model, reward should be computed as a dynamically changing function of model parameters. Also, the approach should be expanded to include the molecular basis of DA secretion mechanism from the VTA to the CST loop involving the relevant neurotransmitters to be able to give a more realistic model.

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References

Towards realistic receptive field properties in a biologically inspired spiking network model of the mammalian primary visual cortex
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The mammalian primary visual cortex is one of the most studied brain regions and we have a good understanding of the basic principles of information processing in the visual system. Since the operation principles in cortical regions are similar, and dysfunction of some of these principle networks is thought to underlie several neurological and psychiatric diseases, it ap-
pears particularly fruitful to explore candidate mechanisms in the comparatively well-known visual cortex. Building computational models is a crucial step in exploring how the visual system computes and in understanding how neuropsychiatric diseases affect these computations. Our approach tries to incorporate anatomical and physiological data in order to build a model capable of showing a diversity of different, well-understood features. Therefore, we have built a detailed biologically plausible model that unifies as many aspects of early visual processing as possible, with a focus on receptive field properties of single neurons. We used multi-compartment neurons of Hodgkin-Huxley type with a total of 11 active conductances that allowed us to tune single neurons to different firing properties according to experimental data [1,2] and more complex models [3]. Afterwards, we assembled the network with biologically plausible connections and synaptic mechanisms. In contrast to the model of Oliveira et al. [4] our model is based on more detailed single neuron models and was designed to include a broader variety of receptive field properties. We present the detailed network specifications and show simulations testing a variety of receptive field properties (e.g. orientation and direction selectivity, spatial and temporal tuning) of the neurons in our model. An extensive comparison with receptive field properties of real neurons [5,6] is also given.

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References

Modeling the modulation of the theta and gamma oscillations in a small septo-hippocampal network
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Theta (3 - 12 Hz) and gamma (30 - 70 Hz) oscillations in rodent’s hippocampal and septal areas have been thoroughly studied in vivo as well as in vitro. They occur during distinct cognitive states like e.g. free movement or selective perception. Studies revealed that both rhythms exist in isolated CA3 slices [1] whereas in the septum only theta oscillation has been found. In fact, it has been attained [2-4] that the GABAergic connection between both regions contributes to modulate theta and gamma oscillations in the limbic system. This modulation is
thought to be achieved by inhibitory input from the septum to inhibitory CA3 interneurons and thus disinhibiting CA3 pyramidal neurons. The focus of this work is to study the influence of the connection between the septum and the hippocampus CA3 area. On the basis of experimental data and earlier developed models [5,6], we use the Hodgkin-Huxley equations to construct a minimal septo-hippocampal circuit. In our model, we use three hippocampal (CA3) neurons (pyramidal, basket, oriens lacunosum-moleculare) synaptically connected in an all-to-all topology and one septal GABAergic neuron linked with the CA3 basket cell. By changing the synaptic conductances, we extract the range of the coupling strengths at which different patterns emerge and conclude the key parameters for regulating rhythms in our network, in particular theta and gamma. Furthermore, the model is to examine the mechanism of disinhibition and its contribution to the modulation of these oscillation patterns.

References
A model and numerical tool to simulate the neuronal extracellular space
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Modeling the neuronal extracellular space is important for medical applications and research. Extracellular electrical stimulation (EES) in the form of transcranial magnetic stimulation (TMS) is a potential treatment for depression and a possible replacement for electroconvulsive therapy [1]. Deep brain stimulation for movement disorders, and closed loop stimulating devices for the treatment of epilepsy have demonstrated the benefits of EES [2,3]. EES treatments are considered more tolerable than pharmacotherapy as parameters can be tuned easier, have less side effects and no drug interactions. As a research tool, TMS has been used in humans to induce localized “virtual lesions” [4], and transcranial direct current stimulation has been used to induce excitability changes in motor cortex [5]. Extracellular recording of the local field potential (LFP) has been used empirically for decades in electro-physiology. Despite its successful and longstanding clinical application, the theoretical treatment of the extracellular space is still rather simplistic. Two independent approaches are currently used: the "activating function" and the "line source approximation". In the first, the electric potential in the extracellular space is calculated for the a stimulation source and this potential is then used to alter the potential of 1D neurites [6,7]. In the second approach, the neuron is treated as an array of point sources and these are used to calculate the LFP [8,9]. In both cases the feedback of the neuronal currents in the extracellular potential is neglected. For the study of EES and a more complete understanding of the sources of the LFP and its spectral properties it would be essential to consider the reciprocal interaction of neural activity and extracellular potential in complex geometries [8].

We present a model and a numerical tool that simulate the local potentials in extracellular and intracellular space, and alternatively the effect of electric or magnetic stimulation. The model can represent 2D and 3D membranes of arbitrary geometry and has been solved numerically for both cases. To model the electric field, a common particularization of the Maxwell's equations for biological tissues is used [10]. The membrane is treated as a special boundary where current flow is governed by the potential difference and ionic dynamics. To validate the model and the numerical tool, results are compared to well know 1D, 2D and 3D solutions of the cable and Poisson's equations.

References
Stationary linear discriminant analysis - Classifying non-stationary features in brain-computer interfacing

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Introduction
In Brain-Computer Interfacing (BCI), non-stationarity may be imposed by artifacts and learning related adaptation. This can lead to a changing feature distribution and can negatively affect classification performance. In this report we propose a method called stationary Linear Discriminant Analysis (sLDA) which penalizes non-stationary directions in feature space and analyse the effects in simulations and with real BCI data \cite{1}.

Method
The goal of sLDA is to find a direction in feature space which is both discriminative and stationary. To this end we optimize a trade off loss function based on the Fisher ratio used by LDA but catering for non-stationarity \cite{2}.

The objective function can be seen in Figure 1.

\[ \Phi_{\text{ns}} \] is the Kullback-Leibler divergence of the average empirical Gaussian on classes and i-th epoch and \( \alpha \) is the trade-off parameter. The empirical mean and covariance of the j-th class is denoted as \( \mu_j \) and \( \Sigma_j \). The optimization is conducted using gradient descent.

Results
The simulated data consists of 6 sources: we orthogonally mix one non-stationary and five stationary sources. Besides evaluating performance in terms of the angle between the normal vectors to the decision hyperplanes and stationary directions, we also consider classification performance.

sLDA finds the correct subspace (10° - 20° accuracy), whereas LDA often chooses the wrong one. However, the overall performance highly depends on the level of non-stationarity present in the data. Furthermore if the stationary but discriminative directions are not significantly more separable than the non-stationary but discriminative direction, then improvement (in terms of classification accuracy) is not possible. On the other hand if there are a number of stationary directions which are discriminative and there is one non-stationary but moderately discriminative direction, then improvement is possible using sLDA over LDA.

We also evaluate the performance of sLDA on a BCI data set \cite{1}. The mean (median) error rates of LDA and sLDA are 0.295 (0.310) and 0.277 (0.265), respectively. The performance gain of sLDA is significant with \( p=1.96 \times 10^{-7} \) according to the Wilcoxon signed-rank test. One explanation for the improvement, not attributable to the quality of the sLDA solution, is there are BCI specific non-stationarities between the training and test data, which correlate with LDA. According to this, slight deviation from the direction chosen using LDA results in an increase in performance. The improvement of sLDA with \( \alpha=1 \) also suggests that LDA does not choose the optimal classification directions, i.e. it may overfit.

Acknowledgements
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References

[T 80] Local rigidity and soft release for improved ECoG arrays
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The electrocorticogram (ECoG) recorded at the surface of the brain is considered a promising source of signals for neuroprosthetics and related medical applications. Here we present a novel design and fabrication process for an ECoG-recording array, and the first measurements in a macaque monkey. The array consists of three regions: a flexible recording area, a 4-cm-long flexible cable, and a polyimide-over-silicon (PI/SiO2/Si) area on top of which four 32-pin NPD Omnetics connectors were bonded with conductive glue. The flexible components are meant to adapt to the irregular surface of the brain. Furthermore, the entire structure is a free-standing membrane, attached by removable polyimide straps to its carrier substrate. The recording area of the device is a regular hexagon with a side length of 7.2 mm. It consists of two 5-µm-thick PI films enclosing 124 gold electrode sites, each 300-nm thick. The electrode sites have three different diameters (0.1—0.5 mm) and the inter-electrode spacing throughout the array varies between three specific pitch values (0.8—2.2 mm). The purpose of this unique design is to compare signal quality across electrode sizes and distances with a single array and relatively close cortical locations in a single animal. A large area of sputtered Au enclosed by a strip of PI separate from the main working area acts as the reference electrode, which is then bent and fixed to the backside of the array, with the gold side facing towards the skull. The gold layer is partially perforated for increased flexibility and a means to control the propagation of stress-induced cracks in the metal.

The novel design and fabrication process offers three significant advantages: (1) handling of the device is made safer and easier by relying on the rigid substrate; (2) standard soldering techniques can be utilized more comfortably thanks to the Si layer underneath the connector area; and (3) direct manipulation of the array is not necessary for soldering and testing, which reduces the risk of damage and contamination before implantation. The device was implanted epidurally on the primary visual cortex (V1) of a Rhesus macaque (Macaca mulatta) and it has been used successfully to record local field potentials. The data obtained from this array will be used to decide on the most suitable electrode size and inter-electrode distance for a “second-generation” array, which is intended to become part of a fully wireless chronic neural recording microelectronic system.

[T 81] The neural correlates of BCI performance variations in ALS: a pilot study
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Brain-Computer Interfaces (BCIs) hold the promise of enabling completely locked-in subjects, e.g., those in late stages of amyotrophic lateral sclerosis (ALS), to communicate by pure thought. To date, this promise has not been fulfilled. While healthy subjects and subjects in early to middle stages of ALS can learn how to operate a non-invasive BCI (Grosse-Wentrup et al., IEEE Transactions on Biomedical Engineering 56(4), 2009; Kübler et al., Neurology (64), 2005), no successful communication with a completely locked-in patient has been reported in literature.

We believe that in order to enable completely locked-in patients to operate a BCI, we first need to understand the neuro-physiological causes of good and bad BCI performance. These insights might then be used to induce a state-of-mind that is beneficial for operating a BCI, e.g., by neuro-feedback or electrical stimulation.

In a series of recent studies, we have investigated the neuro-physiological causes of performance variations in healthy subjects operating a binary motor-imagery BCI. We found that gamma-range oscillations (between 55-85 Hz) modulate the sensorimotor-rhythm (Grosse-Wentrup et al., NeuroImage 56(2), 2011), resulting in group-average decoding differences of up to 22.2% depending on the state of fronto-parietal gamma-power (Grosse-Wentrup, 5th IEEE/EMBS International Conference on Neural Engineering, 2011).

Here, we report results of a pilot study that reproduces this effect in one ALS patient. We recorded a 128-channel EEG in an ALS patient performing motor-imagery of the left or right hand. The patient was artificially ventilated, with residual control of the right wrist. We trained a support vector machine in classifying left- vs. right hand motor imagery, based on bandpower features over sensorimotor-areas. This resulted in a cross-validated accuracy of 59.2%, which is sufficient to reject the null-hypothesis of chance-level performance with $p = 0.0178$ ($N=120$). To identify brain areas related to BCI-performance, we first performed an Independent Component Analysis, manually rejected independent components (ICs) representing artifactual muscle activity, and then correlated gamma-power of the remaining ICs with a trial-wise measure of motor-imagery performance (cf. Grosse-Wentrup et al. (2011) for a description of this performance measure). In this way, we identified two ICs whose gamma-power exhibited a strong negative correlation with BCI-performance ($\rho = -0.3161/-0.2888$, $p = 0.0180/0.0258$ (corrected for multiple comparisons), $N = 120$). A subsequent source localization procedure identified the origin of these gamma-range oscillations in the right superior parietal lobule, consistent with our findings in healthy subjects.

While it remains to be seen how consistently this effect can be reproduced in ALS, its investigation over the course of ALS progression may provide novel insights into the current failure of completely locked-in patients to communicate by means of a BCI.

**Model generalization in prediction of continuous arm movements from the ECoG**

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Brain-machine interfaces (BMIs) are techniques for the control of external devices using brain signals. A promising approach is the direct decoding of neuronal activity underlying a real or intended movement to control the movements of a corresponding effector. One of the key questions in this effort is, to what extent the decoding models generalize with respect to varia-
tions in individual patterns of movement execution and how stable they are over time. Here, we have addressed these issues based on the electrocorticogram (ECoG) of a patient suffering from pharmaco-resistant epilepsy, who was subdurally implanted with an 8 x 8 electrode grid for diagnostic purposes. The subject played several sessions of a computer game, driving a car on a continuous, random road with the help of a stirring wheel. The subject completed 22 sessions, each 5 minutes long, over three different days of recording. We used ridge multiple linear regression, where the predictor was the low-pass-filtered component of the ECoG signal, and arm position was the predicted response. For each time lag between the predictor and the response, ten-fold cross-validation was used to build the model, predict the trajectory and assess model performance as the mean of correlation coefficients (CCs) between the predicted and the real trajectory. All CCs started to be significantly larger than zero ($p<0.05$) for lags in the interval $[0.0, 1.0]$ s. To address the issue, to what extend the performance is influenced by the precise mode of movement execution, we asked the subject to switch between one-hand control (1HC) and two-hand control (2HC) of the stirring wheel in alternating game sessions. There was no significant difference in the prediction performance (CCs) of both conditions ($p>0.2$). Further, models trained on 2HC were able to generalize on the dataset obtained from 1HC (CC significantly larger than zero), whereas the models built on 1HC were not able to yield significant predictions when applied onto the dataset from 2HC ($p>0.05$). Another important question in BMI applications is the stationarity of informative signal features over longer time periods. In this study, two different conditions were explored: short term stability (STS) within one day and long term stability (LTS) over multiple days. The STS condition was realized by splitting one day of recording into two equally sized, mutually interleaved sessions, while the LTS had the same number of game sessions from two different days. Models of the STS condition were able to generalize to the other dataset from the same day. In the LTS condition, models from day 2 were able to generalize to dataset obtained on day 1 (CC significantly larger than zero), but not vice versa. Our findings suggest the existence of differential generalization patterns both between modes of movement execution and over time. Further exploration of these effects and the understanding of their neural basis will be important topics for applied BMI research.

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**[T 83]** EMG-based simultaneous and proportional estimation of wrist kinematics and its application in intuitive myoelectric control for unilateral transradial amputees

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We propose a method for estimating wrist kinematics during dynamic wrist contractions from multi-channel surface electromyography (EMG). Surface EMG were recorded simultaneously with joint kinematics of the wrists during mirrored bilateral dynamic movements of the wrist/hand complex. The protocol was designed with the aim of proportional and simultaneous control of multiple degrees of freedom (DoF) of active prostheses by unilateral transradial amputees. Therefore, the proposed approach was tested in both amputees with such condition
(N=3), and in intact-limbed control subjects (N=5). The algorithm extracted 4 time domain (TD) [1] features and 6 autoregressive features (AR) [2] from multi-channel surface EMG, recorded at the amputated side (amputee subjects) or non-dominant side (control subjects). The extracted features from all channels were used to train 6 dedicated multi-layer perceptron networks, each of which estimated the one joint angle of the 3 DoFs of the wrists of both sides. The results showed that, during the mirrored bilateral tasks, the joint angles at the 3 DoFs of amputees at the intact side can be accurately estimated from surface EMG recordings at the amputated side. The contra-lateral estimation accuracies for amputee subjects were 62.5±8.50% across all 3 DoFs, and the ipsi-lateral estimation accuracies of this subject group were 79.3±10.4%. In comparison, the contra-lateral and ipsi-lateral estimation accuracies of the intact-limbed control subjects were 72.0±8.29% and 73.6±8.59%, which is comparable with previous reports [3], [4]. Although there was a statistically significant difference between the contra-lateral estimation accuracies of the two subjects groups, the contra-lateral accuracies of the amputee subjects are remarkably high, since these subjects have not been able to use the remaining muscles at the amputated side for such complex motor tasks following the amputations. Interestingly, the ipsi-lateral accuracies of the amputee subjects were higher than that of the controls, presumably because the amputees use their remaining hand more often than the controls. The results of this study demonstrated the feasibility of the proposed myoelectric control approach to provide an intuitive myoelectric control strategy and specific training paradigm for unilateral transradial amputees, superior to the current state-of-the-art in myoelectric control methods based on pattern recognition.

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References
Rats’ invariant object recognition relies on tracking salient visual features across object views

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Understanding the neuronal basis of invariant object recognition is a formidable challenge that will ultimately require methodological approaches as diverse as integrative neurophysiology and molecular/genetic manipulations. In this perspective, some investigators have started exploring rodents as possible models for the study of object vision. However, it remains controversial whether rodents possess visual processing machinery that can support invariant objects’ representations.

The two behavioral studies that explicitly addressed this issue reached opposite conclusions. Minini and Jeffery (2006) concluded that rats lack invariant recognition abilities and rely, instead, on low-level image cues to discriminate objects. By contrast, Zoccolan et al (2009) showed that rats can recognize objects despite considerable variation in their appearance (e.g., size and viewpoint changes). However, this finding does not exclude the possibility that rats’ invariant recognition relies on detection of some low-level image cue that is somewhat preserved across most appearances of the test objects.

In this study, to rule out such a low-level strategy and better understand what mechanisms underlie rat object vision, we trained 6 rats to discriminate the same two target objects and tolerate the same size/viewpoint transformations as in Zoccolan et al (2009). Then, we applied to a subset of such transformations an image masking technique (Gosselin and Schyns, 2001) that allowed identifying the “salient” image patches used by the rats to successfully recognize each object view. This approach revealed that the salient image patches for recognition of a given object “tracked” the object’s transformations, i.e., changed in position, size, and orientation, as the object translated, shrunk and rotated in the animals’ visual field. Moreover, we investigated to what extent rats are able to optimally use the visual information that distinguishes the two target objects by performing an ideal observer analysis (assuming pixel independence).

These results indicate that rats’ recognition of visual objects does not trivially rely on some transformation-preserved low-level cues, but, rather, depends on neuronal representations of object features that are truly and largely tolerant to a wide range of image variations.

References


Path Integral Modeling of Stochastic Neuronal Dynamics

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We present investigations on stochastic dynamics of neuronal behavior in response to changes in ionic currents through the neuronal membrane. We work with the relative potential defined as the difference between the membrane potential and threshold firing potential of a neuron. Using a path integral representation, we obtain the conditional probability density of relative potential fluctuations as the fundamental solution of an appropriate Fokker-Planck equation. We do this for several forms of time-dependent current modulation coefficients which are defined in analogy to drift coefficients in the configuration space diffusion equation. In particular, we determine the conditional probability density for sinusoidal, exponential and polynomial time dependence of current modulation coefficients. To accommodate wider classes of behavior, we also obtain solutions for oscillatory but non-periodic time-dependence of current fluctuations modeled with special functions such as Bessel and Neumann functions. For interpretation of results, we show various plots of the conditional probability density as a function of relative membrane potential and time for the different types of ionic current modulation. Remarks are also made on possible connections with biophysical neuronal systems.

A nested attractor framework for binocular rivalry

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A general framework for the study of bistable perception is presented, based on competing stochastic integrations. Specifically, we investigate how a globally bistable dynamics can emerge between two ensembles of individually meta-stable components ("nested attractor"). This framework was introduced recently by Gigante et al. (PLoS Comp.~Biol.~2009) and is the first to account for both first-order (dominance times) and second-order properties (variability of dominance times).

Here, we present our progress towards an analytic treatment of discrete stochastic integration, as a contribution to a general theory for nested attractors beyond the context of binocular rivalry. Specifically, we derive a continuous Fokker-Planck equation for the integration process in the limit of many elements, obtaining exact equilibrium distributions and closed-form expressions for first and second order statistics. To attain the global relaxation-oscillator dynamics that is characteristic for bistable perception, we implement and discuss additional mechanisms, such as feedback from global to local states, or short-term plasticity in competitive interactions.

Our preliminary results suggest that this framework accounts in a natural and straightforward manner for:

*Dominance times in dependence on absolute and relative stimulus strength ("Levelt's Second Proposition").
*Variability of dominance times in dependence on absolute and relative stimulus strength.
*Generalized symmetry of dependence on stimulus strength (Brascamp et al., Journal of Vision 2006).
In summary, the dynamics of stochastic integration suggests that bistable perception may be best understood in terms of distributed ensembles of individually meta-stable populations.

Acknowledgements
Guido Gigante, Paolo Del Giudice

References

[187] Single trial coupling of EEG and fMRI reveals the haemodynamic correlate of the N400
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The N400, a negative event-related potential (ERP) peaking around 400 ms after stimulus onset, has been shown to vary systematically with the processing of semantic information. It is considered to represent neural activity associated with the access of conceptual information. While scalp recordings have contributed to the analysis of the psychological processes represented by the N400, they have not been equally successful in identifying its neural substrate. However, intracranial ERP recordings show that at least parts of the N400 generating network reside in the anterior medial temporal lobe (AMTL). Also functional magnetic resonance imaging (fMRI) has revealed a critical role of the AMTL in accessing semantic information. These data suggest that the N400 is at least in part a volume conducted representation of activity in the AMTL structures. However, so far ERP and fMRI data have not been recorded simultaneously during a semantic priming task. In order to investigate the association between the N400 effect and the semantic priming effect in the blood oxygenation level dependent (BOLD) signal we employed ERP and event-related fMRI in 16 subjects. They were presented related and unrelated word-pairs and had to indicate their fit by button-press. Independent component analysis supported ERP determination revealed a N400 effect at centro-parietal electrodes. In the fMRI results the loci of the global maxima were found bilaterally in the AMTL. For purposes of data fusion, we performed an EEG-informed fMRI analysis. This approach accounts for dynamical changes within the N400-generating brain network by considering additional variance stemming from the trial-by-trial fluctuation of the EEG signal and including this information into the explanatory fMRI model. Results show that the amplitude of the N400 covaries with activity modulations in the left AMTL.

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Computational modeling of intracellular chloride accumulation and diffusion

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It is well established that spatiotemporal dynamics of intracellular chloride affect GABAergic synaptic transmission and its reversal potential (EGABA). Our simulations of chloride diffusion within dendrites suggest that EGABA changes induced by activation of GABAergic dendritic synapses propagate beyond the site of chloride influx and affect neighbouring synapses.

References


Novel tools and techniques for interacting with neurophysiological data

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Structured, efficient, and secure storage of experimental data and associated meta-information constitutes one of the most pressing challenges in modern neuroscience, and does so particularly in electrophysiology. The German INCF node aims to provide a full-stack solution for this specific domain, consisting of two layers. First, we offer server-side infrastructure that holds gathered data in an object model tailored to field-relevant demands and exposes these entities through a convenient HTTP-based, RESTful interface. Second, we make a collection of client-side tools available which facilitate data consumption and allow native integration into various popular analysis environments. Existing work flow and code are leveraged wherever possible: By transparently managing the transition from G-Node object format to native data structures and vice versa, our client libraries enable scientists to benefit from a powerful, semantic storage system without having to alter established processes drastically.

Given the variety of analysis environments in use, we acknowledge that a sensible storage solution needs to integrate with existing tool chains, and must do so seamlessly. To this end, G-Node puts forward a set of client libraries for Python, JVM languages (e.g., Java), MATLAB, and R that hide virtually all intermediate operations (e.g., HTTP transfer, JSON parsing, and caching) and thereby render stored recordings readily accessible. Key aim is natural user experience that adheres to each language's idiosyncrasies by converting G-Node objects into idiomatic and computationally efficient local representations.

Our MATLAB toolbox, for instance, exploits the runtime's heavily optimised array and matrix handling when rendering objects. Specific entities are transferred into the workspace by means of a single command, and behave like standard structures. This allows painless interfacing with existing tools for plotting and analysis while retaining critical information about experimental logic. Moreover, scientists with extensive experience in MATLAB become productive right away. Bindings to R, on the other hand, present requested data as suitably laid
out data frames, again emphasising clean integration into standard patterns of the respective language. Such transformations are bidirectional: the client libraries simplify tagging and storing of existing recordings, and support effortless re-upload of modified objects. Recordings and their structure are therefore easily shared between analysis tools and laboratories. In addition, we are currently developing browser-based visualisation tools aiding scientists during exploratory data analysis.

Crucially, the extent to which advanced features of the object model are used is determined by the individual scientist. Thus, by providing unobtrusive yet fully-featured access, our client utilities bring advantages of the G-Node data management system closer to the neurophysiologist's workbench.

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References
Parvalbumin deficiency affects burst discharges but not network properties of the RTN.

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The Reticular Thalamic Nucleus (RTN) represents a unique gateway in filtering and sorting sensory information that pass through the thalamocortical and corticothalamic circuit. Anatomically it's a thin neuronal capsule topographically located between the cortex and dorsal thalamus, which is characterized by GABAergic neurons rich in Parvalbumin (Pv). In our previous work we observed that, in the PvKO mouse, the firing properties of cortical neurons were affected and epileptogenic activity induced by PTZ was increased (Schwaller, 2004). The post-inhibitory rebound bursting mediated by the RTN and the recurrent TC excitation are likely to play a key-role in spike wave discharges associated to epilepsy. In this study we asked whether the absence of the "Ca2+ buffer" Pv affects the functional interconnectivity and the firing properties of the RTN. The single electrode recordings were carried out in anesthetized mice in the rostro-medial portion of the RTN spanning the region from dorsal to ventral. In the RTN of wildtype and PvKO mice we distinguish 4 types of cells characterized on the basis of their firing pattern: tonically firing, irregular firing, medium bursting and long bursting. In the PvKOs, the medium bursting type was significantly increased at the expenses of the long bursting and irregular firing types when compared to the wildtype mice. On the other hand the amount of tonically firing neurons was comparable between genotypes suggesting that this population is not affected by the lack of the “slow Ca2+ buffer” (Figure 1). In general the average firing rate of the cellular types was unchanged. Interestingly in all bursting types there was a significant increase in the burst duration with about the same number of spikes, thus leading to a reduction in intraburst frequency. This suggests that the dynamics of burst discharges is affected in absence of Pv. Cross-correlation analysis of simultaneously recorded neurons from the same electrode tip showed that most cell pairs displayed either no interaction or negligible synchronicity (64% wt and 60% PvKO). Strong synchronous activity was observed in less than one third of the population both in wildtype and PvKO mice and other interactions accounted for less than 5% in both genotypes. This suggests that the functional connectivity of the RTN, driven by the relay nuclei and the cortex, is independent of Pv activity. On the whole, our study suggests that Pv ablation does not change the structure of the thalamo-cortical circuit but affects the dynamics of burst discharges in the RTN.

Acknowledgements
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References
When dissimilar images are presented to the two eyes, perception starts alternating spontaneously between each monocular view, a phenomenon called binocular rivalry (Leopold and Logothetis, 1999). Several imaging studies in humans have shown the involvement of a frontoparietal network of cortical areas in perceptual transitions during binocular rivalry (Lumer et al., 1998). Here we investigate the possible role of parietal visual areas in perceptual alternations during rivalry in the rhesus macaque. Neural activity in the lateral intraparietal area (LIP) was recorded extracellularly while the subject was presented dichoptically and asynchronously with two rivalrous patterns, resulting in flash suppression (Keliris et al., 2010). The paradigm ensures excellent control over the subject’s perceptual state. Preliminary results confirm the transient change of brain activity around perceptual reversals at the single cell level. The recorded cells typically showed an initial burst of activity after the onset of a stimulus as well as at stimulus/perceptual changes, followed by a sustained response (Bisley, 2004). The transient response of recorded neurons has a short latency, lasts a few hundred milliseconds and is always positive while the sustained response is suppressive in some cells and excitatory in others. We speculate that these responses may reflect two separate underlying processes. The short latency response may reflect a fast sensory signal conveying the information in a bottom-up manner, while the sustained activity may represent top-down influences originating from higher areas in the prefrontal cortex. The functional magnetic resonance imaging (fMRI) studies performed previously could not dissociate these two tightly overlapping signals because of the poor temporal resolution of the technique. Analysis of the firing rates of single and multi-units indicate that the transient part of the response predicts well the change in perception while the sustained activity does not show a significant correlation with perceptual state. This might be explained by the little selectivity of the sustained response of parietal neurons towards particular stimuli (Lehky and Sereno, 2007). It is believed that LIP neurons provide a representational map of saliency, integrating bottom-up and top-down information to guide the allocation of spatial attention (Bisley et al., 2011). We argue that the transient response of LIP neurons after perceptual switches is an indication for a role of this region in providing a change signal to higher areas. It is possible, that the intraparietal activation observed in humans around perceptual transitions may simply reflect the elevation of neural activity as a result of a novel percept rather than a causal role of the region in driving the switches. We are therefore planning to extend the binocular flash suppression paradigm to normal binocular rivalry and monitor the activity around spontaneous perceptual alternations in order to delineate what happens without any concomitant physical change in the stimulus. Furthermore, local field potentials, temporal dynamics of single unit activity and synchronization between neurons might provide a better understanding of the top-down influences of prefrontal cortex especially during the sustained response. This analysis is currently in progress.

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References

|T 92| Did I do that?: Causal inference of agency in goal-directed actions

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The perception of own actions is affected by visual information and internal predictions [1]. Integration of these cues depends on their accuracies [2], including the association of visual signals with one’s own action or with unrelated external changes [3]. This attribution should thus depend on the consistency between predicted and actual visual consequences. The goal of this work is to develop quantitative theories for the influence of the sense of agency on the fusion of perceptual signals and predictions derived from internal forward models. Our work exploits graphical models as central theoretical framework.

**Methods**

We used a virtual-reality setup to manipulate the consistency between pointing movements and their visual consequences and investigated its influence on self-action perception. Participants were seated in front of a horizontal board on which their right hand was placed with the index finger on a haptic marker, representing the starting point for each trial. Participants were instructed to execute straight, fast (quasi-ballistic) pointing movements of fixed amplitude (9 deg visual angle), but without any explicit visual target. The hand was obstructed from the participant’s view and terminal visual feedback was provided veridical or manipulated. Participants were then asked two questions:
1) What direction did you point to? And 2) Did you cause the direction of the visual feedback?

We then asked whether a causal inference model accounts for the empirical data, assuming a latent agency-variable: if the visual stimulus was attributed to one’s own action, visual and internal information should fuse in a Bayesian optimal manner and not if attributed to external influences.

**Results and Conclusion**

The model correctly predicts the data, showing attribution of visual signals to one’s own action for small and stronger reliance on internal information for large deviations. We discuss the causal inference model’s performance compared to alternative models, applying methods for Bayesian model comparison.
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References

Characterization of single unit synchronization patterns in the primate fronto-parietal reach network
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The fronto-parietal reach network in primates comprises the dorsal premotor cortex (PMd) and the parietal reach region (PRR). These two areas interact with each other in a dynamic fashion during reach-planning. We trained 3 monkeys in 2 variations of a sensorimotor transformation task. 2 of the monkeys did a center-out reach task where a color cue indicated to them whether they had to make a reach towards (PRO) a spatial cue or in the opposite direction to it (ANTI). A third monkey did center-out reaches either with or without a reversing prism. In both conditions, the position of the spatial cue had to be integrated with the context of the task (PRO or ANTI, PRISM or NO-PRISM) in order to compute the final motor goal from the spatial cue. The exact mechanism how such integration is achieved is unknown. The properties of single neurons within each area have been extensively studied, but not much is known about the functional connectivity within each area. We tested the hypothesis that synchronization of different neural ensembles could play a role (1) by characterizing the spike-spike correlation between these ensembles in the two areas.

We used cross correlograms (CCG’s), to characterize the pattern of correlated single unit discharges within each of these two areas (2). To disregard slow temporal co-fluctuations in spike rate which affect CCG’s (3), spike-jittered CCG’s were subtracted from the raw CCG’s (4). The standard deviation of the jittered CCG’s was used to construct confidence intervals to assess statistical significance of correlated discharges.

Our results indicate very different correlation patterns within each of these two different areas. We found robust correlated discharges in PRR of all three monkeys. These were characterized by high correlation coefficients in a large percentage of the neuron pairs during steady states within the trial, such as the fixation period. Transitions between these states such as cue presentations momentarily destroyed this correlation pattern which soon recovered. This may reflect a transient re-organization of the PRR neural ensembles. Although both areas are very similar in terms of tuning properties of neurons and encoding of movement plans (5, 6, 7), we found an absence of correlated discharges in PMd. These results indicate that synchronization of neural ensembles might be a feature used by PRR but not PMd in encoding additional information above and beyond rate coding.
Acknowledgements
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References

Complex interactions between stimulus components in the auditory network of the cricket – consequences for coding and mechanism
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Sensory systems are usually confronted with a complex mixture of different stimulus components. How does a neural network with broadly-tuned filters cope with such a situation? We addressed this question using the auditory system of crickets as a model. The cricket’s auditory environment is divided into a low-frequency channel associated with mating signals and a high-frequency channel linked to predator signals. This clear behavioral partition is reflected in the simple layout of the auditory system: in the prothoracic ganglion exist two ascending neurons (AN1 and AN2) that are excited at different carrier frequencies and receive inhibition from a broadly-tuned local neuron (ON1). We recorded responses from all three neurons in the network while presenting amplitude-modulated stimuli with either single carrier frequencies or with a mixture of different, independently modulated carriers. We quantified temporal and spectral tuning by estimating linear-nonlinear models consisting of a linear filter and a static nonlinearity.

Carrier-frequency specific tuning for temporal features of a sound changed markedly when comparing responses to single and to mixed carriers for both ascending neurons, but not for ON1. Additionally, the presence of multiple carriers in a sound had a down-scaling effect on the nonlinearities for each individual carrier, indicating a suppression of responses. The observed changes have the potential to maximize information about temporal patterns in the stimulus by minimizing interference between carrier frequencies: selective suppression can isolate individual carrier frequencies; changes in the filter shape can preserve specific frequency bands in the spike train spectrum for the encoding of the temporal pattern at individual carrier frequencies. In our system suppression seemed to be most important in shaping information transfer.

A rate-based model of the network reproduced the changes in temporal selectivity. The changes in the filter shape of both ascending neurons then arose by an increase of effective inhibition mediated by ON1. This effect seemed to depend mostly on the temporal pattern of inhibition from ON1, not on the average strength of the inhibition. Thus, even the small early auditory network of the cricket can exhibit adaptive, nonlinear interactions between different components of a stimulus.
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[T 95] Coincidence detection and information processing in drosophila olfactory system
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One question in computational neuroscience is how sensory information is transformed from initial detection, through neural processing to eventual generation of a perception that drives specific behavior. A simple and thus for this purpose often used system is the olfactory system of the fruit fly Drosophila [Masse and Turner, Curr Biol, 2009]. In Drosophila, sensory signals elicited by odors are transmitted from the antenna to inner parts of the brain including Antenna Lobes (ALs), Mushroom Body (MB) and Lobe Neurons. The MB consists of about 2500 Kenyon Cells (KCs) and is believed to play an important role in associative learning [Newquist, Neurosci Biobehav Rev, 2011] and coincidence detection in olfactory information processing [Busto et al., Physiology, 2010]. The functionality of this specific neural architecture as well as the coincidence detection property of KCs to detect different odor concentrations has not been studied in every detail. In this study, we use information theory to analyze information processing in the olfactory system of Drosophila [Mikula and Niebur, Neural Comp, 2003].

More specific, we are addressing the following question: How does information content at the output level (KCs) depend on threshold size, firing probability and the number of simultaneously activated neurons at the input layer (AL) of which the latter two correspond to odor concentration? First, we abstract the MB structure so that we are able to asses information theoretical measures in a fully analytical way. Second, we perform simulations on a more realistic model of the system with a lower level of abstraction to extend these information theoretical findings. This more realistic model is a network that is formed of two layers which are connected in feed-forward manner where AL neurons (input layer) project to KCs (output layer) and one KC neuron receives several connections from the AL layer [Smith et al., Biol Cybern, 2008]. We then generate different input patterns and calculate the output firing probability of KCs systematically varying the coincidence detection threshold of KCs. The information content of KC output was measured using the binary entropy function. It is then used to quantify maximum system's efficiency for the detection of different odor concentrations since behavioral studies show that flies are indeed able to detect different concentrations of any odor [Xia and Tully, PLoS Biol, 2007].

Our results suggest a mechanism that uses different coincidence detection thresholds - and not only a single fixed value - to obtain maximum information content of KCs, enabling the system to reliably detect different odor concentrations, and hints for more experimental studies in order to prove or disapprove this hypothesis.

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Sequential dependencies in perceptual decisions

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In most psychological experiments, observers respond to multiple trials that are presented in a sequence. In perceptual psychology, it is common to assume that these responses are independent of responses on previous trials, as well as of stimuli presented on previous trials. There are, however, multiple reasons to question the ubiquitous assumption of “independent trials” - for example, responses in cognitive experiments depend on previous stimuli and responses, and it is unclear why perceptual tasks should be unaffected by such serial dependencies. This observation raises two central questions: First, how strong are trial by trial dependencies in psychophysical experiments? Second, what are statistical methods that would allow us to detect these dependencies, and to deal with them appropriately?

Here, we present a model that allows for quantification of such trial by trial dependencies and apply it to psychophysical data-sets from perceptual decision tasks. Using multiple data-sets from one auditory and two visual experiments as well as simulated data, we show that our model successfully detects trial by trial dependencies if they are present and allows for a statistical assessment of the significance of these dependencies. Although the strength and direction of trial by trial dependencies varied considerably between observers, significant trial by trial dependencies were observed in 6 out of 7 observers. For those observers, model fits improved considerably if trial by trial history was incorporated into the model. The trial by trial dependencies we observed could be well captured by linear superposition of effects from multiple previous responses and stimuli. We conclude that previous trials and responses influence responses in perceptual tasks, too.

A model of human dichromat color vision that may help to explain the evolution of trichromacy

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References

In humans, the basis of color vision is established by the cone photoreceptor system, which consists of three spectrally different cone photoreceptor types termed short (S), middle (M), and long (L) wavelength sensitive, respectively. In established models of color vision, signals from these cones are encoded in two opponent systems. One system compares messages from L and M photoreceptors, and signals in this system are assumed to result in color percepts of red and green. Another system compares signals from S cones with a combination of L and M cones and is thought to support percepts of blue and yellow. In so-called red-green blind humans, either the M or the L cone type is missing and they are unable to discriminate certain colors that appear red and green to the color normal observer. Nevertheless these dichromats use the terms “red” and “green” in a consistent and meaningful way to describe their color percepts - a surprising finding considering that it is commonly assumed that the basis for their red-green color vision is an opponent combination of M and L cone signals.

We present a model for color vision that is consistent with the neurobiological processing of cone signals and accounts for the mapping of receptor excitation towards color percepts both in human dichromats and trichromats.

In the early primate visual system, cone signals are processed by neurons with ON- and OFF center-surround receptive fields. Following this pattern, our dichromat model combines the outputs of either M-cones (protanope case) or L-cones (deuteranope case) with their surround via horizontal cells, with subsequent rectifying into parallel ON- and OFF-midget pathways (Martin, 1998). Additionally, we consider luminance dependent input from a receptor sensitive in the shorter wavelength range, such as the rods (Lee et al., 1997).

Our model postulates, that in protanopes MON signals towards “green”, and MOFF towards “red”; likewise in deuteranopes, LON signals towards “green”, and LOFF towards “red”.

In a second stage of the model, two types of cortical cells receive and subtract signals from several adjacent M/LON– and M/LOFF-neuron. Again the summed OFF responses signal towards red the summed on responses towards green.

The blue-yellow mechanism in our model also assumes center-surround formation through horizontal cells, rectification into ON and OFF channels and a contribution of the rods with center like sign. Thereby a S dominated signal in the center is opponently connected with a mixed LM surround. Additionally, and in line with experimental findings, we propose a luminance dependent non-linearity that increases L+M-signals at higher luminance.

The model is able to predict color naming as measured with the hue scaling method in both human dichromats and trichromats. It also explains intensity dependent hue changes such as the well established Bezold-Brücke effect.

Assuming a processing similar to our dichromat scheme also for our dichromatic ancestors, provides an explanation for how the addition of a third cone opsin could lead to trichromacy and direct use of the additional spectral information.

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References
A model of retinal ganglion cell processing under natural viewing conditions

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The retina is an important first stage of visual processing and is intensively studied. Little is known, however, about the retinal responses under natural viewing conditions. In particular, it is interesting to consider whether standard receptive field (RF) models can capture important features of the retinal response to complex non-stationary stimuli. We present a conceptually simple model of the peripheral visual system and investigate its behaviour under simulated eye movements. Specifically, we identify possible retinal mechanisms for rapid post-saccadic signalling as observed in several experimental studies.

We model the retina as a simple photoreceptor grid which feeds forward to a retinal ganglion cell (RGC) layer consisting of numerous distinct RGC populations. We model four such populations: linear midget cells, both On-type and Off-type, and non-linear parasol cells, On-type and Off-type. Spatial receptive fields are given by a difference-of-Gaussians model. Temporal integration profiles for each population are described by the difference of two bi-phasic temporal filters which are combined with the spatial receptive field to form a rank-2 spatio-temporal filter. For midget RGCs, this filter is linearly convolved with the stimulus and rectified to generate a membrane potential. Neuronal spiking is simulated by a threshold function with non-linear feedback. Parasol cells implement a non-linear spatial integration, in which the receptive field is divided into sub-fields. Contributions from each sub-field are temporally integrated and rectified, before being summed to provide an estimate of the parasol cell membrane potential. The standard centre-surround RF can be recovered by combining sub-field RFs.

The model reproduces several salient features in the reported behaviour of mammalian retina, including spatial and temporal modulation transfer functions. In addition, numerous studies have reported rapid post-saccadic bursting in retinal sub-populations. This behaviour is reproduced in our model, which displays strong transient responses to simulated saccades on a 10-ms timescale. These responses are observed primarily within our Off-type parasol population, and are less pronounced in On-type parasol cells. Midget RGCs do not display post-saccadic bursts. These differences in populations arise as a result of differing spatial and temporal integration profiles and the parasol integration non-linearity. Such dynamics are also implicated in the generation of latency codes for rapid post-saccadic processing. Our model thus captures prominent features relevant for understanding retinal processing during natural vision.

Coding of electrical signals in different subsystems of the electrosensory system of the weakly electric fish

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The role of noise in neural information processing is still a controversial topic. The notion that intrinsic noise inevitably degrades information transmission still dominates the debate. However, in a population of spiking neurons noise can reduce redundancy and/or control the level
of synchrony in response to certain stimulus features. Target neurons may selectively read out synchronous spikes only (coincidence detector) or unspecifically integrate over all input spikes, thus extract different aspects of the signal that stimulated the population of input neurons. In this view the amount of noise in a neural system might be optimally tuned to achieve the required signal processing properties.

Weakly electric fish are an ideal model system for tackling this question experimentally. They have two parallel electrosensory systems that share a similar architecture and process similar stimuli but exhibit different response characteristics/variability: the active electrosensory system receiving input from tuberous receptors and the passive one receiving input from ampullary receptors. Interestingly, the baseline discharge of P-units, the majority of the tuberous receptors, show a much larger variability of their interspike intervals than the one of the ampullary receptors. Thus, the target neurons of the respective systems receive input from populations of receptor neurons that discharge more (ampullary receptors) or less (tuberous receptors) regular.

Furthermore, we observe that both receptor populations show different degrees of heterogeneity. The receptors of the active electrosensory system vary considerably stronger with respect to their baseline-firing rate and response variability.

The two subsystems of the electrosensory organ are thus very well suited to allow for a comparative study on the role of noise and population heterogeneity. We here present, as a first step, recordings from the receptor neurons of the wave-type fish Apterodonotus leptorhynchus and simulations of both systems. We compare basic response properties of both receptors and address by random amplitude modulations the tuning of both receptor types to dynamical stimuli and the influence of noise and heterogeneity on coding performance.

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[T 100] An information theoretic approach to an entropy-adaptive neurobiologically inspired object recognition model

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Over the last few decades neuroscientists and psychologists have made some tremendous progress in understanding some of the processes in the visual cortex, providing a starting point from which it has been possible to create computational models of object recognition in the human brain.

We propose an adaptive information theoretic approach to a biological-based object recognition system. Our approach is based on the investigations of the role of entropy in the human brain. Here, we extend these findings for their applicability to the enhancement of an object recognition system. Our recognition system is based on HMAX, initially proposed by Serre, Wolf and Poggio, which models the ventral pathway in the areas of the visual cortex V1, V2 and V4 and its hierarchical feedforward structure.

Supported by recent neurobiological research, we argue that information entropy is fundamental in neural processing and show that its integration into the model does benefit the object recognition process. We examined our entropy-enhanced model on the Caltech-101 image database and achieved better performance compared to the standard model.
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References

JD Fitzgerald, LC Sincich, and TO Sharpee. Minimal models of multidimensional computations. PLoS Computational Biology 7 (3), e1001111, 2011
P Reina&el and RC Reid. Temporal coding of visual information in the thalamus. The Journal of Neuroscience 20(14) 5392–400, 2000
A stimulus-driven model for the activity-dependent development of salt & pepper arrangements of orientation selectivity in rodent visual cortex

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Response characteristics of orientation-tuned neurons in the primary visual cortex appear to be similar even in mammalian lineages widely separated in evolution. The spatial arrangements of tuning properties across the cortex, however, show fundamental differences. While in primates and carnivores the orientation preference of neurons varies smoothly and progressively (orientation map), in rodents and lagomorphs it appears to be randomly distributed (salt & pepper). Recently, it has been shown that orientation maps in different species realize a common design that can be explained by a general class of activity-dependent self-organization models. However, it is currently unknown whether the salt & pepper arrangement can be explained by similar activity-dependent mechanisms and whether there are common layout rules for its design? Here we present a stimulus-driven model for the activity-dependent development of salt & pepper layouts in rodent visual cortex. In the model, visual stimuli are represented by their position and orientation in visual field coordinates. Activity patterns in the cortical layer are designed to ensure soft-competition within the cortical layer as well as a tendency of co-activation of neighboring units. The selectivities of activated units are modified by a Hebbian learning rule to better match the parameters of the stimuli. By a symmetry argument, the model has two stationary solutions: (i) the unselective homogeneous state and (ii) the pinwheel free orientation stripe state. Linear stability analysis shows that by a non Turing-type instability, the nonselective state can become unstable, leading to the spontaneous emergence of orientation selectivity in the model.

By extensive simulations, we show that despite the co-activation of neighboring units during the learning process, the emerging states exhibit a salt & pepper arrangement of orientation selectivities. Furthermore, any ordered arrangement of orientation preferences dynamically decays into a salt & pepper arrangement. The spatial layout of numerically stationary states of the model can be characterized by a local negative correlation of preferred orientations, a high stimulus coverage, and a low discrepancy. Both, high coverage and low discrepancy are more pronounced when compared to a Gaussian random field with negative correlations alone. Our results indicate that the seemingly random arrangement of orientation selectivity in rodents might be the result of a dynamical activity-dependent learning process. They furthermore suggest the existence of general principles for the design of salt & pepper arrangements.
Disruption of the thalamocortical signal-to-noise ratio in the pathogenesis of psychoses

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Sensory and cognitive deficits are common in many neurobiological disorders. Mental illnesses, which worsen with senescence, are thought to result from dysfunctional cortex- and thalamus-related networks. So, understanding their pathogenesis and dysfunction with a reliable neurophysiological hallmark would certainly provide a new breath for the discovery of innovative therapies.

In schizophrenia, sensory deficits are thought to originate from a reduced signal-to-noise ratio within sensory information processing circuits and to be due to NMDA receptors (NMDAr) hypofunction. The NMDAr antagonist ketamine is a psychotomimetic substance that induces sensory deficits and increases the amount of spontaneous gamma (30-80 Hz) brain network oscillations, suggesting that such deficits can be due to the increase of gamma noise. Here we show for the first time a reduction of the NMDAr-related sensory signal-to-gamma noise ratio during the pathogenesis of psychosis. We found that, in the rodent somatosensory system, ketamine (or MK-801) reduces both the sensory evoked thalamocortical response, including sensory-evoked gamma oscillations, and the signal-to-gamma noise ratio, and it weakens the long-term potentiation of the thalamocortical synapses. Ketamine or MK-801 increases gamma noise coherence only between interconnected structures, supporting the hypothesis of the existence of multiple independent cortical and subcortical generators of gamma oscillations during the resting state. Local cortical application of ketamine or MK-801 creates a focus of gamma hyperactivity, proving that such generators can be modulated independently. Furthermore, we found that thalamic deep brain stimulation increases the signal-to-noise ratio within thalamocortical somatosensory circuits. Therefore, we predict that any therapeutic-goal procedure enhancing the signal-to-noise ratio may have important implications for treating perceptual and cognitive abnormalities in mental illnesses.

D-amphetamine induces an increased dopamine release in the core part of the nucleus accumbens of adult rats following a neonatal functional blockade of the prefrontal cortex.

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Schizophrenia (SZ) is a complex neuropsychiatric disorder which is thought to result from a defective connectivity between several integrative regions stemming from developmental failures (Weinberger & Lipska, 1995; Lew is & Levitt, 2002). Various anomalies reminiscent of early brain development disturbances have been observed in the patients' left prefrontal
cortex (PFC) (Akbarian et al., 1993; Kalus et al., 2000). Data obtained over the past three decades support the hypothesis of a dopaminergic (DA) dysfunctioning in SZ (Harrison, 1999; Carlsson et al., 2001). Psychostimulants were found to induce SZ symptoms in healthy humans (Zahn et al., 1981), but they can also exacerbate symptoms already present in SZ patients (Sato et al., 1992; Lahti et al., 1995; 2001). Additionally, recent cerebral imaging studies show ed that D-amphetamine produces a more important increase of the striatal DA release in SZ patients (Laruelle et al., 1996; Abi-Dargham et al., 1998). Thus, the present study aimed at investigating the effects of D-amphetamine on DA responses in a subregion of the ventral striatum of adult rats, following a neonatal inactivation of the left PFC (infralimbic/prelimbic region). Reversible functional blockade of the left PFC was carried out by local TTX microinjection in 8-day-old rats, i.e a critical time of the neurodevelopmental period (Clancy et al., 2001). DA variations were recorded in the left core part of the nucleus accumbens using in vivo voltammetry in freely moving adult rats (11 weeks). Control animals received an i.p injection of NaCl (0.9%); D-amphetamine was injected i.p at 0.75mg/kg or 1.5mg/kg doses. The results were the following: 1) A clear dose effect was observed for the two conditions (PBS and TTX microinjection at PND8); 2) Following the injection in adult animals of the highest -amphetamine dose (1.5mg/kg), DA increase in the core was more elevated in TTX microinjected animals than in PBS microinjected animals. These data suggest that rats microinjected with TTX in the left PFC at PND8 display a more important reactivity to D-amphetamine than controls. Taken together, our findings may contribute to a better understanding of the pathophysiology of SZ.

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[W 3] Dopaminergic reactivity to D-amphetamine is increased in adult rats following a postnatal functional inactivation of the anteromedian prefrontal cortex
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Schizophrenia is a complex neuropsychiatric disorder thought to result from a defective connectivity between several integrative regions stemming from developmental failures (Weinberger & Lipska, 1995; Lewis & Levitt, 2002). Various anomalies reminiscent of early brain development disturbances have been observed in the patients’ left prefrontal cortex (Akbarian et al., 1993; Kalus et al., 2000). Data obtained over the last 30 years support the hypothesis of a dopaminergic dysfunctioning in schizophrenia (Swerdlov & Koob, 1987; Harrison, 1999; Carlsson et al., 2001). Psychostimulants, such as D-amphetamine, can exacerbate symptoms in patients with schizophrenia. Recent cerebral imaging studies showed that D-amphetamine produces a more important increase of the striatal dopamine release in patients with schizophrenia (Laruelle et al., 1996; Abi-Dargham et al., 1998). In the context of animal modeling of the pathophysiology of schizophrenia, the present study was designed to investigate the effects of D-amphetamine on dopaminergic responses in the nucleus accumbens in adult rats, following a neonatal inactivation of the left prefrontal cortex (infralimbic/prelimbic region). Transient functional blockade of the left prefrontal cortex was carried out by local TTX microinjection in 8-day-old rats, i.e a critical time of the neurodevelopmental period (Clancy et
Dopaminergic variations were recorded in the left core part of the nucleus accumbens using in vivo voltammetry in freely moving adult rats (11 weeks). Control animals received an i.p. injection of NaCl (0.9%); D-amphetamine was injected i.p. at 0.75mg/kg or 1.5mg/kg doses. The results were the following: 1) A clear dose-effect was observed for the two conditions (PBS and TTX microinjection at postnatal day 8; 2) With the highest D-amphetamine dose (1.5mg/kg), dopamine increase in the core was more elevated in TTX microinjected animals than in PBS microinjected animals. These data suggest that rats microinjected with TTX in the left prefrontal cortex at at postnatal day 8 display a more important reactivity to D-amphetamine than controls. Taken together, our findings may contribute to a better understanding of the pathophysiology of schizophrenia.

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**[W 4] Neurochemical mechanisms of perceptual deficits in schizophrenic patients – A spiking neural network approach**

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Schizophrenia is a mental disorder which is characterized by positive symptoms (psychosis, hallucinations and paranoia) and negative symptoms (flattened affect, anhedonia) as well as cognitive and perceptual deficits [1]. Dakin et al. [2] report that schizophrenic patients are less vulnerable to 'contrast-contrast' illusions ('surround suppression', i.e. the mutual inhibition of a focal visual stimulus and its surrounding). This weaker contextual suppression can be interpreted in terms of reduced GABAergic inhibition [3]. Recently, research in schizophrenia has focused on GABAergic inhibitory neural circuits [4]. However, the exact neural basis and perceptual consequences of a compromised GABAergic system remain unclear.

We modeled the effects of manipulating particular aspects of GABAergic neurotransmission (altered decay times at GABAergic synapses, reduced availability of GABA and decreased density of GABAergic interneurons [4]) on surround suppression strength. Therefore, we built a model of primary visual cortex based on anatomical and physiological data, using the neuron model from Izhikevich [5].

The model exhibits surround suppression, i.e. shows reduced activity to stimuli mimicking a high-contrast surrounding than compared to stimuli mimicking a uniform surrounding. Furthermore, increased decay times at GABAergic synapses lead to a reduction in surround suppression in our network model. This suggests one possible factor of altered perception in schizophrenia and is in agreement with previous modeling studies, e.g. in the auditory system [6].

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References

Molecular and cellular characterization of the APO-SUS/APO-UNSUS rat model displaying schizophrenia-related features

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Schizophrenia is a complex and disabling neuropsychiatric disorder thought to result from a combination of multiple genetic, environmental and epigenetic factors that provide vulnerability to early- and later-life stressors. To address this issue, two rat lines have been pharmaco-genetically selected and bred from an outbred Wistar population based on their stereotypical gnawing responses to the dopamine agonist apomorphine. The apomorphine-susceptible (APO-SUS) rats represent a well-characterized animal model displaying schizophrenia-relevant features (high dopaminergic drug sensitivity, decreased prepulse-inhibition, increased exploratory behaviour); apomorphine-unsusceptible (APO-UNSUS) rats are the phenotypic counterparts of the APO-SUS rats. To identify the molecular-(epi) genetic background of the model, we identified single-nucleotide polymorphism (SNP) and mRNA expression differences between the two lines. Using a genome-wide 800K SNP microarray analysis of genomic DNAs from intercrossed APO-SUS/APO-UNSUS rats, we recently discovered that a single genetic variation is linked to the high dopaminergic responsiveness of the APO-SUS rats. To investigate how the interaction of this genetic variation with environmental factors affects gene expression patterns, we performed mRNA expression profiling of the dorsal striatum and prefrontal cortex of APO-SUS and APO-UNSUS rats four hours after an environmental challenge (open field; OF) or a pharmacological challenge (1.5 mg/kg apomorphine injection; APO). A number of gene transcripts differentially expressed in basal and challenged APO-SUS and APO-UNSUS rats were identified, including the immediate early gene transcript fosB, and its alternatively spliced form ΔfosB. We found a higher number of FosB/ΔFosB-positive cells in the APO-SUS OF/APO rats compared to that in the APO-SUS control/saline-injected, and also compared to the APO-UNSUS OF, APO and control/saline-injected animals. In addition, we found that the OF and APO challenges caused an overstimulation of only a small subpopulation of specific neuronal cells in the APO-SUS rat brain, and these cells were identified as GABAergic interneurons. It will be of great interest to characterize the functional properties of these cells. Through our studies we hope to contribute to a bet-
The extracellular matrix protein Reelin, synthesized and secreted by Cajal-Retzius cells and GABAergic interneurons, is an important regulator for the formation of cortical layers during development and maintains this lamination in the adult hippocampus. In temporal lobe epilepsy (TLE) patients and in a TLE mouse model, Reelin levels are decreased which causes a migration defect of adult granule cells (Haas et al., 2002, Heinrich et al. 2006). However, not only absolute Reelin levels, but also proper proteolytic processing, giving rise to several Reelin isoforms, is important for its biological function. So far, it is unclear whether pathological processing of Reelin contributes to the malpositioning of dentate granule cells under epileptic conditions. To address this question, we used rat organotypic hippocampal slice cultures to investigate the effects of kainate (KA)-induced epileptiform activity on Reelin processing and the impact of Reelin cleavage on dentate granule cell layering.

As a prerequisite we showed that Reelin processing is decreased under epileptic conditions. Treatment of organotypic hippocampal slice cultures with KA resulted in an increase of high molecular weight Reelin isoforms in tissue and a significant decrease of the secreted 180 kDa Reelin fragment. This KA effect could be mimicked by incubation with protease inhibitors. Following epileptiform activity, we found a decrease of MMP-2 and MMP-9 (gelatinases) activity exclusively in the molecular layer and the granule cell layer of the dentate gyrus and elevated levels of the endogenous tissue inhibitor of MMPs-1 (TIMP-1). Both, epileptic conditions and impaired proteolytic cleavage of Reelin by inhibition of MMPs caused a significant widening of the granule cell layer and an extracellular accumulation of unprocessed Reelin. In summary, these experiments indicate that epileptic conditions impair the proteolytic processing of Reelin by an unbalance of MMPs and their inhibitor TIMP-1. As a consequence, Reelin accumulates extracellularly as a biological inactive form and contributes to granule cell dispersion.

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References
How degrading networks can increase select cognitive functions

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It has recently been shown that despite the severe cell atrophy associated with manifest Huntington’s Disease (HD), increased proficiency can be demonstrated in select behavioural tasks (Beste et al., 2008). Using computational models of the striatal micro-circuit we show possible mechanisms underlying the phenomena as a result of the excitotoxicity (Fan and Raymond 2007) and the competitive and selective dynamics of signal selection in the striatum.

The increase in sensitivity to endogenous glutamate associated with HD could increase the performance of NMDA dependant tasks such as those involving auditory sensory memory (Kujala et al. 2007), in spite of the severe neural deterioration. Using Mismatch Negativity (MMN), studies by Beste et al. (2008) show that patients with symptomatic HD out perform pre-symptomatic HD (pHD) and a healthy control group, exhibiting lower reaction times and error rates for standard and deviant stimuli.

We propose that this phenomenon is a feature of the network structure of striatal neurons when combined with the excitotoxicity hypothesis, occurring due to the connectivity of the striatum. Using the biologically inspired model of the striatal microcircuit taken from Humphries et al. (2010), we show competitive dynamics within the network, demonstrating an inherent competitive selective signal behaviour.

By modelling two separate cortical inputs, representing two distinct actions, to sub-populations in the striatal model, we show that the network displays preferential selectivity to a strong input signal, suppressing the activity of the weaker signal at the onset of the stronger. The network displays a further reactive selectivity: the removal of the stronger signal subsequently boosts the population response to the weaker signal, possibly encouraging behavioural switching back to the ongoing signal. Defining these two elements of selectivity allows us to investigate how this selectivity evolves as the network degrades as in manifest HD.

Mimicking the excitotoxicity, we up-regulate the NMDA conductivity versus the AMPA, progressively eliminating over-excitatory neurons from the network. Using a new measure for signal selectivity, our model show that excitotoxic cell atrophy, combined with increased excitability of the surviving cells, can encourage signal selectivity. Suggesting that a pathogenic increase in a transmitter sensitivity, while encouraging cell atrophy, can mediate network level behaviour, affecting the competitive signal selection dynamics due to increased activity.

Thus, our results suggest that the paradoxical cognitive enhancement of the manifest HD patient is due to their selectively enhanced signal selection in the striatum.

We suggest that the striatal model can be a useful tool to shed light onto the ramifications of hypotheses such as excitotoxicity, and by examining changes in network dynamics, may provide the basis for a select few counter-intuitively improved cognitive functions in HD patients.

References


Resolution limit of neurochip data

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Spike sorting of extracellular recordings aims to approximate the intracellular 'ground truth' as close as possible. It is desirable to quantify the quality of the resulting spike trains assigned to putative neurons in order to make subsequent analysis conclusions reliable.

To analyse retinal ganglion cell activity recorded with a planar high resolution multi-transistor array ('Neurochip') comprising 16384 sensors (pitch = 7.4 µm), we use an algorithm that allocates action potentials to corresponding units by evaluating the pairwise similarity of their spatiotemporal waveforms (Lambacher et al., 2011).

This and most other sorting algorithms are based on the assumption that each neuron is identifiable by its unique extracellular action potential waveform. However, different processes might alter the waveform to be recorded: intracellular action potential variation, noise and finite sampling. Only if the difference of the extracellular field signatures originating from different neurons exceed the above processes, spike trains may be properly sorted. Here, we aim to investigate the 'resolution limit' of Neurochip data.

By constructing synthetic data sets we imitate the intracellular 'ground truth' and are able to control the uniqueness of the extracellular waveforms via the choice of different templates, the signal to noise ratio and the sampling conditions.

We set up artificial neurons, from which we generate synthetic spike trains. Using a subset of sensors, that cover the spatial extension of somatic activity (\(\sim 60 - 80 \mu m\)) only, we are able to resolve its temporal time course with high resolution (sampling rate \(\sim 80 \text{kHz}\)). We then construct spatiotemporal templates by averaging over several hundred raw threshold crossings aligned in time. The smooth spatiotemporal average is subsequently downsampled to the sampling rate of the synthetic data set (e.g. 12 kHz). Drawing different downsampled subsets leads to events of variable shape and thus mimics the sampling jitter. Neural signals are superimposed to the noise with a defined signal to noise ratio. Noise is either Gaussian, using parameters from real recordings or directly taken from real recordings.

By controlling the spatial separation of two synthetic neurons we determined the minimum distance needed to separate neurons that exhibit the same extracellular waveshape. The separation was accepted if more than 95% of the spikes were properly allocated to the corresponding neurons. For signal to noise ratios comparable to those identified by human observers in real recordings, the minimum distance was found to be 15.8 µm. This is comparable to the dimensions of typical neuron somata. The preliminary tests suggest that high-resolution extracellular sensor arrays are needed for efficient spike sorting.

Acknowledgements
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Reference
A step-filter test for change point detection in nonstationary poisson processes

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Stochastic point processes on the line are widely used to model empirically observed spike trains. However, such spike train analysis often requires the observed point process to be stationary, in particular with respect to the firing rate (e.g. [1]). This stationarity assumption is typically inappropriate in empirical data sets, which may lead to erroneous conclusions in the performed statistical analyses (e.g. [2,3]). We therefore propose a statistical test for rate nonstationarity of Poisson processes. In contrast to previous methods (e.g. [4]), we particularly intend to identify the time intervals of constant rate in a process with piecewise constant rate function. The proposed stationarity test is therefore associated with a method that reliably locates rate changes in different time scales in Poisson processes having a piecewise constant rate function.

The proposed Step Filter Test (SFT) tests the null hypothesis of rate homogeneity against the alternative of piecewise constant rate by comparing the number of spikes $N_1=N_1(t,h)$ and $N_2=N_2(t,h)$ in adjacent intervals $(t-h,t]$ and $(t,t+h]$. For fixed time $t$ and window size $h$, the function $D(h,t)=(N_2-N_1)/\sqrt{N_2+N_1}$ has an asymptotic normal distribution under the null hypothesis. This function is extended in a multivariate way, first by running through a suitable set of time points $t$ in a moving window analysis and thus checking every time point for rate changes. Secondly, we apply different window sizes $h$ in order to take into account rate changes in different time scales, in contrast to methods that chose one fixed kernel size (e.g. [5]). We show that the resulting multivariate extension of $D(h,t)$ has an asymptotic normal distribution. Interestingly, the covariance matrix has a simple structure which depends only on the time lag between two analysis windows and is independent of the underlying firing rate.

In order to correct for multiple testing, we propose to use $M$, the maximum of $|D(h,t)|$ over all $t$ and $h$, as a test statistic of the SFT. Due to the asymptotic normality and the known covariance structure of $D$, the threshold quantile $Q$ of $M$ at level alpha can be derived computationally.

After rejection of the null hypothesis, we propose a change point detection algorithm which uses the values of $D(h,t)$ in order to locate the change points as closely as possible. The procedure integrates information from different window sizes and thus makes use of the fact that larger windows show a higher test power, while smaller windows provide the ability to detect fast rate changes. We applied the SFT to simulated data and to a data set of spontaneous activity in single units recorded from the dopaminergic substantia nigra of anesthetized mice. By detecting multiple change points in the empirical data set, the objective results of the SFT are in high agreement with subjective criteria such as visual inspection.

Acknowledgements
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References
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Here we investigate neurons of two morphological classes, which reside in the Antennal Lobe (Al) of the honey bee: local neurons (LN) and projection neurons (PN). We ask, whether it is possible to conclude the neurons’ morphological class from the neurons’ electrophysiological properties. If this is the case, which combination of features of electrophysiological activity will most effectively describe the difference between LN and PN?

We analyzed data from 80 intracellularly recorded AL neurons, 33 of which were unambiguously identified as either LN or PN. For each and every neuron we estimated a number of electro-physiological measures. We then explored clustering of neurons based on the principle components of every possible combination of these measures. Using hierarchical clustering with wards-linkage (REF) we determined which combination of measures performed best in separating identified PN and LN.

Our analyses show that it is indeed possible to separate [class, with high certainty] LN and PN on the grounds of electrophysiological features only. We achieved the by far best clustering results (81% separation) based on only two PCs from a combination of six selected features, namely the CV2 (a measure of spiking irregularity), the Fano-Factor (a measure of across-trial spike count variability), the rate change (from spontaneous to stimulus response), the average response latency, the latency variation (across different stimuli), and the baseline power of the membrane potential. Many other feature combinations perform less well but still satisfactorily (70%-76% classification success). Amongst these good combinations, measures of spiking activity were more frequently represented than measures of sub-threshold activity. Neurons in the LN and PN cluster differed significantly for those features which we identified as most potent. Hence, the separation which we achieved in the principle component space can be described statistically on the level of the original features.

We conclude that LN and PN in the honey bee AL are characterized by different electrophysiological properties, which are represented by measurable features. Still, none of these measures alone is a potent tool to predict a neuron’s morphology. The combination of several classical measures however offers a foundation to tell apart LN from PN with a certain probability in cases where morphological data is not at hand.

Acknowledgements

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The mammalian prefrontal cortex (PFC) is centrally involved in higher cognitive functions such as working memory, decision making, or cognitive flexibility. Malfunctioning of this system or the neuromodulatory inputs into it have been associated with the severe cognitive symptoms experienced in schizophrenia, attention-deficit hyperactivity disorder, and other psychiatric conditions. To prepare the construction of a physiologically valid network model of the PFC, we have carried out a detailed statistical analysis of neural activity from a set of in-vivo recordings from the PFC of behaving rats. Our analyses are based on multiple single-unit recordings obtained with multi-electrode arrays or tetrodes in various behavioral settings. In particular, the distributions of inter-spike intervals (ISI), statistics that capture local variations in spike trains (Lv) [1, 2], and neural interaction statistics, like Pearson-type cross-correlations [3,4], were examined. These analyses were performed both on selected time segments adhering to statistical criteria for weak stationarity (ST), and on the data sets as a whole without enforcing any stationarity conditions (non-ST). Since the examined data sets come from behavioral tasks with a lot of stimulus-, movement-, or cognition-related activity, the spike trains could be expected to strongly violate stationarity assumptions. Performing the analyses under both ST and non-ST conditions thus allowed to estimate the impact non-stationarities would have on the estimated quantities and distributions. Here we also introduce a method for assessing stationarity empirically.

We found that many of the obtained distributional properties were robust with regards to violation of weak stationarity, at least with the amount of data available in the present study. Two of those properties are of particular interest, namely a power law relationship for the distribution of mean ISIs with a slope of approximately -1.5, and a clearly bimodal Lv-distribution suggesting the presence of at least two profoundly different spiking patterns in PFC.

In contrast, cross-correlograms appeared quite sensitive to violation of stationarity conditions as reported previously [5]. The distribution of cross-correlations also appeared to have long tails, but did not seem to exhibit power-law behavior.

The analyzed statistical characteristics should provide a number of important constraints for fitting connectivity and synaptic properties of PFC network models.

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References
Big research efforts nowadays focus on modeling human drivers in order to improve safety and achieve smooth traffic flows. While dynamic models exist for driving tasks at the control level, models for lane keeping, car following and lane change, at the tactical level, the sequencing of these tasks is commonly performed as static finite state machines [Song et al, 2000]. Our aim is to bring light to the sequencing dynamics of the tactical level of human driving. This is a challenging task that requires accurate models of the control level tasks as performed by humans. This poster presents the tools and methods we will use to obtain complete models of human driving behavior. While most of the models are obtained from data where the human driver interacts with simulated drivers, we propose a multi-driver configuration to obtain more realistic driver interaction. We set up a multi-driver laboratory with ten independent cabins and implemented a realistic multi-driver simulator where all the drivers interact while driving on the same simulated road.

All vehicle and environment state data relevant to model a driver behavior can be stored, the global status of the simulated cars can be monitored on-line through the local network and instructions can be delivered to individual drivers. Therefore, our simulator allows us to establish or force specific traffic situations that could be impermissible in real life, while still having human drivers involved to gather relevant control and sequencing data sets. Based on these data sets and using state of the art control level models we plan to develop a methodology to build human-like driver models that can be used for testing and validating Advanced Driving Assistance Systems (ADAS). Once the control level is fully identified we will design and carry out experiments to model the sequence and decision dynamics in normal driving situations [Pellecchia et al, 2005]. Early experiments on car following control have been already performed and we are experimenting with a driver model for steering control that includes sensoriomotor aspects of human driving [Sentouh et al, 2009].

References
[W 13] Inferring higher-order correlations from filtered spike activity

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Nonlinear response properties turn neurons into highly sensitive detectors for higher-order features of their input (see e.g. [1]). Whether or not higher-order correlations are important for cortical information processing, however, can only be decided by the analysis of experimental data.

Common data analysis methods (e.g. [2]) to investigate the potential role of higher-order correlations (HOCs) are devised for the application to spike recordings from multiple single neurons. A recent particularly promising approach is the cumulant based inference of higher-order correlations (CuBIC, [3]). CuBIC allows to infer a lower bound on the maximal order of correlations by employing the cumulants of the population spike count, i.e. the population spike activity “filtered” with a rectangular kernel. Compared to other methods, this approach can detect even weak HOCs in the activity of large neuronal populations based on realistic sample sizes.

However, describing HOCs in a neuronal population does not reveal its influence on the activity of a neuron at the next processing stage. In this respect, estimating cooperative dynamics in the presynaptic spike activity from an intracellular recording of a single neuron would be advantageous (cf. [4] for an approach based on pairwise correlations). To approach this issue, we represent the subthreshold activity as presynaptic activity filtered with a fixed kernel and adapt CuBIC accordingly. Studies on surrogate data revealed that the new method can reliably infer HOCs even from short stretches of membrane potentials.

Acknowledgements
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References
1. Kuhn et al., Neural Comput 2003

[W 14] A novel approach to network motif detection applied to the analysis of pain processing networks

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Connectivity analysis gains in importance for understanding cortical information processing. We used connectivity analysis to investigate EEG recorded processing of painful intracutaneous stimuli and directed interactions within the pain matrix in patients with major depression and healthy controls, by means of frequency selective generalized partial directed coherence (gPDC) [1]. The networks that originate from this analysis model pain processing in both groups and therefore represent important information for improving the currently inadequate understanding of the relationship between pain and depression. These pain processing networks (PPNs) cannot be readily interpreted because they exhibit dense and intricate patterns of directed interactions. To describe the local topology of PPN’s of both groups we present a novel approach to network motif detection that extends the original approach of Milo et al. [2] to the case of sets of networks. Motifs are small, non-random subnetworks that are thought to act as functional meaningful building blocks of their network. A further novel aspect of our approach is taking into account the identifiers of employed EEG electrodes as vertex labels. In this way our approach preserves the anatomical and functional important positional information of motifs in the network. As a consequence, labeled motifs can be interpreted as patterns of characteristic directed interactions. We demonstrate that our motif detection approach is suitable to reveal different as well as identical patterns of characteristic directed interactions in the PPNs of patients with major depression and healthy controls while omitting unspecific interactions.

References

[W 15] Ten thousand times faster: Classifying multidimensional data on a spiking neuromorphic hardware system.
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Discrimination of sensory inputs is a computational task that biological neuronal systems perform very efficiently. Assessing the principles in those systems is a promising approach to develop technical solutions for many problems, such as data classification. A particular problem here is to train a classifier in a supervised fashion to discriminate classes in multidimensional data. We implemented a network of spiking neurons that solves this task using a neuromorphic hardware system, that is, analog neuronal circuits on a silicon substrate. This system enables us to do high-performance computation in a biologically inspired way, with spiking neurons as computational units. In this contribution, we illustrate solutions to technical challenges that occur when implementing a classifier on neuromorphic hardware.
The network topology of the insect olfactory system provides a well suited template for a neuronal architecture processing multidimensional data. In our classifier network, the value of each dimension of a data vector determines the rate of a stochastically generated spike train. The spike trains are fed into non-overlapping populations of neurons. Those populations project onto an association layer with winner-take-all properties representing the output of the classifier. During classifier training, the weights in this projection are adjusted according to a firing-rate based learning rule.

The values in multidimensional data sets are typically real numbers, but neuronal firing rates are restricted to values between zero and some maximal value. Hence, the data must be transformed into a positive, bounded representation. We achieved this by representing each data point as a vector of distances to a number of points in data space (“virtual receptors” [1]). The representation by virtual receptors inevitably introduces correlation between input dimensions. We reduced this correlation using lateral inhibition in the first neuronal layer, leading to a significant increase in classifier performance. We found that decorrelation was most efficient when we scaled the inhibitory weights according to the correlation between the connected populations.

We ran our classifier network on a neuromorphic hardware system that runs at ten thousand times the speed of biological neurons, thus suited for high performance computing [2]. However, the considerable variance of rate-response sensitivity across hardware neurons decreased classification performance. We therefore developed a calibration routine to counteract the neuronal variance.

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References

Introduction

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Introduction
As a classical paradigm in auditory psychophysics, Tone-in-Noise (TiN) detection still presents a challenge as regards the question which auditory cues human observers use to detect the signal tone (Fletcher, 1938). For narrow band noise, no conclusive answer has been given as to which stimulus features explain observer behavior on a trial-by-trial level (Davidson, 2009). In the present study a large behavioral data set for TiN detection was analyzed with a modern machine learning algorithm, L1-regularized logistic regression (Tibshirani, 1996). Enforcing sparse solutions, this method serves as a feature selection technique allowing the identification of the set of features that is critical to explain observer behavior (Schönfelder and Wichmann, 2011).

**Methods**

An extensive data set (>20,000 trials/observer) was collected with six naïve observers performing TiN detection in a yes/no paradigm. Stimuli were short (200 ms) sound burst consisting of a narrow band gaussian noise masker (100 Hz) centred around a signal tone (500 Hz). Data was collected in blocks with fixed signal-to-noise ratios (SNRs) at four levels along the slope of the psychometric function. Data on response consistency was also collected, estimated from responses to pairs of similar stimuli and serving as a measure of reproducibility of single trial decisions. Subsequently, linear observer models were fit to the data with an L1-regularized logistic regression, for each observer and each SNR separately. The set of features used during data fitting consisted of three components: energy, sound spectrum and envelope spectrum, with each component comprising one (energy) or multiple (spectra) scalar entries characterizing the presented sound.

**Results**

In terms of the psychometric function, observers could hardly be distinguished, only one – a trained musician – had a significantly lower threshold than the rest. Nevertheless, the analysis of perceptual features resulted in two groups of subjects using different combinations of auditory cues, as already observed by Richards (1993). Energy alone, as suggested by Green and Swets (1966), was not sufficient to explain responses, nor was the shape of the envelope spectrum, as proposed by Dau (1996). Instead, most observers relied dominantly on a mixture of sound energy and asymmetric spectral filters, with a peak frequency centered above the signal tone and a negative lobe below. These filters may correspond to off-frequency listening effects or result from the asymmetry of the auditory filters. The results suggest that observers relied on multiple detectors instead of one single feature in this task. Differences in detection strategy across different SNR were not observed. In general, observers showed poor consistency in their responses, in particular for low SNR. Nevertheless, single-trial predictions from the extracted observer models were reliable within the boundaries dictated by response consistency (Neri, 2006).

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**References**


[W 17] Extraction of functional domains in optical imaging data using regularized non-negative matrix factorization
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Functional optical imaging is widely used to measure neuronal activity in the living brain. In many cases, the neuronal activity exhibits spatial structure which reflects a distinct physiological organization of the tissue. However, exact data on that organization is often not available in functional imaging. This poses the challenge of automatically estimating distinct spatial domains and their corresponding stimulus response based on functional data alone.

The decomposition of observations into their generating sources is an instance of the Blind Source Separation problem. Previous approaches to this problem were based on Principal and Independent Component Analysis. However, both methods reach their limits if the number of sources lies within the range of the number of images, or even exceeds them. In this contribution, we introduce a regularized non-negative matrix factorization algorithm to overcome this problem. Using a toy dataset, we compare its performance to established approaches. In addition, we demonstrate its applicability in two natural datasets where the non-negativity condition is met: to discover (a) glomeruli, the functional domains of the olfactory bulb in mice, in intrinsic optical images and (b) inhibitory olfactory projection neurons in calcium imaging data of the lateral horn of Drosophila.

To cope with the low observation to source ratio, we restricted the generative model in the introduced algorithm in several ways. The non-negative matrix factorization itself imposed the constraint of only positive contributions of the sources. Moreover, a sparseness constraint enforced localized sources. Additionally, we introduced a new modification in the Hierarchical Alternating Least Squares (HALS) algorithm to promote spatially decorrelated sources.

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Neuron versus time clustering in the identification of cell assemblies
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A major challenge in the analysis of neural activity data when considering spikes as the main information carrying unit is the detection of sets of neurons which act as functional groups. Such neuronal cell assemblies can be identified by clustering the spectrum of zero-lag cross-correlation between all pairs of neurons in a network or by dimensionality reduction of the similarity matrix of the spike trains.

Here we investigate how the identification of cell assemblies is dependent on the methodology chosen. We construct a self-similar network of inhibitory adaptive exponential integrate-and-fire neurons that is stimulated with Poissonian excitatory input. For such a network one would expect that groups of neurons show a similar activity as the network as a whole. However, we observe that there is a difference between the evolution of network activity and sets of neurons clustered according to their correlation. When analyzing medium spiny neuron calcium imaging data, we again find that the results of the two methods are not in line.

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References

The matched Gabor transform - A tool for adaptive phase extraction
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A core aspect of time-frequency analysis is always the question of time-frequency resolution. The latter is determined by the analysis method and has a crucial influence on the appearance of the result. Most methods, like Gabor transform or continuous wavelet transform, have parameters which have to be adapted to the data in order to obtain meaningful results. As the methods enforce a certain time-frequency resolution, the danger of interpreting effects of the methods instead of interpreting effects in the data is omnipresent [1].

The Matching Pursuit algorithm introduced by Mallet and Zhang in 1993 [2] decomposes a signal into dictionary atoms and builds up a pseudo Wigner-Ville distribution to provide a data-adaptive time-frequency resolution. The pseudo Wigner-Ville distribution is a pure power distribution and provides no phase information.

This drawback is addressed by the Matched Gabor Transform (MGT), recently published in [3]. It combines the decomposition into atoms of the Matching Pursuit algorithm with thereon adapted Gabor transforms. Accumulating the time-frequency planes yields the final result. By that, an data-adaptive phase extraction becomes possible.

We demonstrate the usage of the MGT on real-life EEG and MEG data of a photic driving experiment. Periodic optical stimuli lead to an entrainment of the alpha oscillation which can be seen by an amplitude increase as well as a phase locking after the stimulus onset. Considering possible effects in the gamma frequency range, the method has a big advantage. As this area in the time-frequency plane can be contaminated by broad-band short-time saccadic artifacts [4], it is important to retain the natural characteristics of any observed activity to be able to distinguish oscillatory neuronal activity from saccadic interferences. Therefore, the MGT might be the future key tool for phase analysis in EEG and MEG analysis.

References
Probabilistic modeling of novelty-based exploration and operand conditioning

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One of the basic adaptation mechanisms of living being is the exploration of novel, yet unknown environments. Exploration of a novel option may even be advantageous from an evolutionary point of view, since the new option may reveal to be more rewarding than the options exploited so far. It is thus not surprising that novel stimuli tend to be associated with a stronger explorative behavior in the context of a reward-based learning paradigm in humans (1). Stimulus novelty enhances these exploratory choices through engagement of neural reward systems, such as the ventral striatum (VS) and the ventral tegmental area (VTA), which have been shown to be activated both by novelty and reward (2). VS and VTA are mesolimbic dopaminergic structures, involved in operand conditioning and are closely linked to reward-related learning (3). From a computational perspective it has been postulated that novel, unexpected stimuli are intrinsically rewarding, equivalent to a “novelty bonus” (4).

The present study investigated the link between novelty-based explorative behavior and its influence on operand conditioning in a reward-motivated decision-making task. The paradigm consisted of a first phase, where subjects were familiarised with different categories, followed by the actual testing phase, where subjects had to choose between two categories. One of the categories was more rewarding than the other and subjects had to learn which of both categories was “best”. Depending on the condition, novel stimuli pertaining to the corresponding category were either presented in the best rewarding or in the worst rewarding category, having the effect of accelerating or decelerating learning, as compared to the control condition. Additional fRMI analysis further revealed a prediction error activation in the VS and VTA, which were stronger in novel rewarded trials as compared to standard rewarded trials. In order to investigate subject's behavior quantitatively, we developed a probabilistic hidden markov model and introduced a parameter to allow for explorative behavior towards novel stimuli. This exploration novelty bias was accounted for by biasing the probability of an action towards the category presented with the novel stimulus. Individual variation in novelty response were characterized by finding the best-fitting values of metaparameters for each subject.

Altogether, we have not only shown that novelty enhances neural responses underlying reward anticipation in decision-making, but also that novel stimuli have a direct influence on operand conditioning. These results as well as individual differences could be reproduced by a probabilistic computational model.

References
1. Wittman et. al. (2008) Neuron 58,967-973
How metabolic constraints shape neuronal adaptation: A unifying objective function for synaptic plasticity

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The brain is always facing limited metabolic resources and thus it should adapt itself to function in an energy-efficient manner. The consideration of an energy-efficient coding leads to the requirement of a sparse output firing distribution. This idea resulted in the formulation of sparse coding, which has shown how such a constraint can shape the neuronal circuit and its representations.

But not only the action potentials them self are metabolically expensive, but also their transmission and postsynaptic effects. A presynaptic spike will increase the postsynaptic potential (EPSP) and reestablishing the resting potential consumes energy. Thus, if the EPSP does not contribute on average to the firing of the postsynaptic cell, this synapse wastes energy and should be weakened. If it otherwise does repeatedly help to fire the cell it should be strengthened.

So, basically Hebb's postulate can be seen as a consequence of energy efficient signaling. Putting it in statistical terms, we want the membrane potential to be either near the resting level or above threshold, but spent less time in the subthreshold regime. Therefore, we require a sparse distribution of the membrane potential.

In this work, we formulate a differential-Hebbian learning rule by applying a gradient descent on a sparseness measure of the membrane potential. We conduct compartmental simulations in NEURON and compare the results to experimental data. Our learning rule reproduces many different protocols and experimental setups for long-term synaptic plasticity. These not only include timing-dependent plasticity (STDP) for pairing and frequency protocols and their location dependence along the dendritic tree, but also rate-based metaplasticity similar to the BCM rule. Therefore, we show that one can construct a unifying objective function for synaptic long-term plasticity and that energy efficiency is a major part of it. Thus, we cover two of Marr's three levels of analysis: the computational level in terms of energy efficiency and the algorithmic level based on a biophysical differential-Hebbian learning rule from which one could establish the link to the actual biological implementation.

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Peripheral electrical stimulation triggered by movement related cortical potentials enhances cortical excitability

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We propose a new paradigm for artificially inducing cortical plasticity based on detection of movement related cortical potentials (MRCPs) and peripheral nerve stimulation. For this purpose we have developed a self-paced asynchronous brain-computer interfacing (BCI) system that 1) detects MRCPs produced during motor imagination of ankle dorsiflexion; 2) upon the detections of MRCPs, it triggers peripheral electrical stimulations timed with the negative peak of the MRCPs. In this way, a causal connection between motor intention and the peripheral afferent volley is established. Five healthy subjects participated in the experiments. Each experimental session consisted of three phases. In the first phase, the cortical excitability of the subject was assessed by measuring motor evoked potential (MEP) at the tibialis anterior muscle induced by transcranial magnetic stimulation (TMS) (baseline). The second phase was the BCI intervention phase, which was performed in two separate runs (a run refers to a continuous EEG recording). In the first run, an MRCP template was extracted from multi-channel EEG recordings during a series of self-paced executed dorsiflexions. Once the template was extracted, a run of self-paced motor imagination of dorsiflexion was performed. The motor imaginary MRCP was detected online based on the MRCP template extracted in the first run with a matched filtering approach. When online detection occurred, a peripheral electric stimulation was delivered to the common peroneal nerve, timed at the peak negativity of the MRCP. After the BCI intervention phase, the cortical excitability was assessed again with the same procedure as in the first phase (through MEP magnitude induced by TMS). Stretch reflexes were also measured from 2 of the 5 subjects to assess alterations in spinal excitability. Over the 5 subjects, the average magnitude of the MEP increased significantly after the BCI intervention by 23±31%, with no changes in the M1 component of the stretch reflex. These results demonstrate for the first time that it is possible to alter the cortical projections to the tibialis anterior muscle by using a self-paced BCI system based on online motor imagination that triggers peripheral stimulation. This type of repetitive proprioceptive feedback training based on the decoding of self-generated brain signals may be a requirement for purposeful skill acquisition in healthy humans and in the rehabilitation of individuals with brain damage such as stroke.

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The term associative strength describes the extent to which the conditioned stimulus (CS) predicts the reward (unconditioned stimulus, US). It is generally accepted that the associative strength is mirrored in the conditioned response (CR) during acquisition (Rescorla & Wagner, 1972). A recent study in honeybees (Apis mellifera) demonstrates a correlation between the US duration during classical conditioning and the susceptibility of a long-term extinction memory for protein synthesis-inhibition (Stollhoff & Eisenhardt, 2009, J. Neurosc.). This study suggests that the associative strength depends on the duration of the US. However, a correlation between the CR and the US duration during acquisition was not observed. This might be due to the fact, that only the occurrence of a CR was recorded (proboscis extension: yes or no) resulting in dichotomous data. Here, we asked whether quantifying the CR by elec-
trophysiological recordings of a muscle responsible for proboscis extension, uncovers the effect of the reward duration on the associative strength during acquisition and memory retention.

References

[W 24] Experience-based learning mechanism with a concept of vigilance
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Cognitive Neuroscience studies have identified an early warning system in the human brain that can avoid making past mistakes again. They have shown how the brain remembers details about past dangers [1]. An activity was found in the Anterior Cingulate Cortex (ACC) after making mistakes [2]. This cortex area works as an early warning system that adjusts its behaviour to avoid dangerous situations. It responds not only to the sources of errors (external error feedback), but also to the earliest sources of error information available (internal error detection) [3]. It becomes active in proportion to the occurrence likelihood of an error [4]. Therefore, it can learn to identify situations where humans may make mistakes, and then help avoid such situations to occur [2]. It learns to predict error likelihood even for situations where no error occurs previously. Through the observation of particular areas located in cerebral cortex that has been shown to be responsible for cognitive control. Neuropsychological studies demonstrated a switching in human learning strategies around the age of twelve years. This switching, goes from learning with positive feedback to learning with negative feedback -- probably comes from the combination of brain maturing and experience [5]. We have produced an early warning mechanism that can help avoid repeating past errors in the generation of bipedal motion patterns for a humanoid robot to achieve robust walking. The objective of this learning mechanism is to adapt parameters of a low-level controller. In detecting its domain of viability, which increases adaptation to external perturbations [6][7].

We specified by the state space “V” of those intrinsic parameters. The mechanism must be able to learn from negative feedback (failure) and positive feedback (success). Therefore, it must have experience with success and other with failure within the state space “V”. As each vector “v” from “V” leads to either success or failure, the mechanism will evaluate whether this vector belongs to the success domain or to the failure domain. The decision mechanism (“go”, “nogo”) works as an early warning system similar to that in ACC [2]. Psychological studies suggest that some people are more tolerant to risk than others who are more cautious, [8]. The vigilance is related to human learning approaches and decision making. In the standard psychological assessment of risk taking, people are classed as risk seeking or risk averse [9].
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In our study the vigilance is represented by a threshold that is used to adjust the early warning signal in the decision mechanism. This threshold describes the tolerance of risk. According to vigilance threshold, we can distinguish between two different behaviors for the system, risk taking and risk averse. Thanks to the two behaviors the system can gain experience in walking, and in case of risky behavior the system learns better with more failed trials. Changing vigilance in learning phases between trials will change the behavior of the system to risks.

References

Reverse engineering in Drosophila larvae - Modeling neural control of learned versus innate behavior
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A series of recent behavioral studies have described learned and innate behavior in Drosophila larvae under a variety of experimental conditions (reviewed in Gerber & Stocker, 2007). In order to conceptualize these findings, a qualitative circuit-level model for the regulation of
this behavior has been proposed (Schleyer et al., In Press). Here we follow and extend this approach by simulating the processing of olfactory and reinforcing stimuli in a simple sensory-to-motor circuit during olfactory conditioning and during testing of naive behavior. The proposed circuitry is constrained by neuroanatomy, in particular we introduced plastic synapses between mushroom body Kenyon cells and their output neurons, receiving reinforcement signals from the subesophageal ganglion. The expression of behavior is regulated as follows in the circuitry: (i) Innate preference is driven by the net sum of innate appetitive or aversive values of sensory stimuli. (ii) Learned preferences, in contrast, are behaviorally expressed only if this yields a positive gain compared to the acute testing situation. As expected we find that our circuit-model can well reproduce the majority of behavioral observations. In addition the proposed model constitutes a possible control-architecture for a biased random walk of an artificial agent searching for food in a circular arena. We further aim at a more detailed understanding of the extracted behavioral control principles by analyzing trajectories of individual animals recorded under different experimental conditions.

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References
completely aware of the spontaneously arising sensory percepts in their right index finger for two hours per day; while keeping their normal meditative practice for the rest of the day (6 hours). Due to the rigid meditation posture in Zazen, where meditators are completely motionless, physical stimulation of the finger tips can be ruled out. After the 3 day meditation, subjects’ tactile performance was measured again. As markers of tactile performance we measured touch thresholds, spatial 2-point discrimination thresholds, and localization performance on the tip of digit 2 and 3 of the right hand, and digit 2 of the left hand. A group of 10 age-matched controls (age: 51.7 ± 4.2, 5 female) kept their normal meditative practice for the whole 3 days without focussing on somatosensory percepts. After meditation touch thresholds in the right index finger of the sensory focussing group were lowered by a factor of 3.13 ± 0.15 in average (controls: 0.95 ± 0.27). Individual reduction of thresholds ranged from 1.75 up to 11.49 fold. 2-point discrimination thresholds in the right index finger were lowered by a factor of 1.2 ± 0.13 (controls: 1.01 ± 0.07). Localization performance remained on average unaltered in both groups. For touch thresholds, pre-post comparison revealed significant changes (t-test) for all fingers tested, while for 2-point discrimination thresholds significant effects were found for r2 and r3, but not for l2.

Our data show that focussing on a particular body part, here the right index finger, drastically improves tactile abilities indicating that merely being aware without external stimulation or training improves tactile abilities. Typically, neuroplasticity describes how the external world shapes brain organization. Our findings indicate that this framework has to be extended to incorporate the observation that intrinsic brain activity created without external events can similarly alter perception and behavior.

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**References**


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**How outcome expectations organize learned behaviour in larval Drosophila**

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Drosophila larvae combine a numerically simple brain, a correspondingly moderate behavioural complexity and the availability of a rich toolbox for transgenic manipulation. This makes them attractive as a study case when trying to achieve a circuit-level understanding of behaviour organization. From a series of behavioural experiments, we here suggest a circuitry of chemosensory processing, odour-tastant memory trace formation and the ‘decision’ process to behaviourally express these memory traces— or not. The model incorporates statements about the neuronal organization of innate versus conditioned chemosensory behaviour, and the kinds of interaction between olfactory and gustatory pathways during the establishment and behavioural expression of odour-tastant memory traces. It in particular suggests that innate olfactory behaviour is responsive in nature, whereas conditioned olfactory behaviour is captured better when seen as an action in pursuit of its outcome. It incorporates the available neuroanatomical and behavioural data and thus should be useful as scaffold for the ongoing investigations of the chemo-behavioural system in larval Drosophila.

References

**Principled homeostatic mechanisms from mutual information maximization**

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Recurrent neural networks can exhibit complex dynamic behavior and form a rich class of models with which to perform computation. In biological neural networks there are several homeostatic mechanisms that ensure the network remains in a useful regime. Here we present a computational view which unifies several homeostatic mechanisms. Using a simple neural model we show that maximizing the mutual information between presynaptic input and the postsynaptic spike leads to homeostatic mechanisms which closely resemble intrinsic plasticity and spike-timing-dependent plasticity. Most computational models also require some form of synaptic normalization to prevent runaway synaptic strengthening, however maximizing mutual information naturally leads to decreased plasticity once a stable representation has been found.

The close links between information theory and probability allow us to create a principled decoding mechanism for prediction. We show preliminary work that maximizing mutual information forces the network to predict the next state of a structured input signal. This work could provide clues for the organizational principles in relatively unstructured neural networks such as the antennal lobe of the insect olfactory system. To accurately identify an odor...
the antennal lobe needs to accumulate information over several time periods, and use the information to create a distributed representation. This representation needs to convey the certainty (or uncertainty) of the odor identity over all known odors and is an ideal fit to our proposed neural model.

Synaptic scaling generically stabilizes circuit connectivity

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Neural systems regulate synaptic plasticity avoiding overly strong growth or shrinkage of the connections, thereby keeping the circuit architecture operational. Accordingly, several experimental studies have shown that synaptic weights increase only in direct relation to their current value, resulting in reduced growth for stronger synapses [1]. It is, however, difficult to extract from these studies unequivocal evidence about the underlying biophysical mechanisms that control weight growth.

The theoretical neurosciences have addressed this problem by exploring mechanisms for synaptic weight change that contain limiting factors to regulate growth [2]. The effectiveness of these mechanisms is difficult to justify from a biophysical perspective, in particular those that require knowledge of global network status (e.g. knowledge of the ‘sum of all weights’) for normalization. Also spike-timing-dependent plasticity [3] cannot guaranty stability because various types of plasticity exist across different neurons and even at the same neuron, depending on the location of the synapses [1].

Therefore, it remains an open question how neural circuits simultaneously stabilize their many synapses and ensure diversity in the presence of a variety of distinct plasticity mechanisms.

In 1998, a series of studies initiated by Turrigiano augmented this discussion by demonstrating that network activity is homeostatically regulated, suggesting that weights \( \omega \) are regulated by an activity-dependent difference term [4,5]. Accordingly, synaptic scaling compares output activity \( v \) against a desired target activity \( v_T \) of each individual neuron [5]. Most straightforwardly, such a local weight change is defined by \( \frac{d \omega}{dt} = \gamma (v_T - v) \) [6], where the long characteristic time scale (hours up to days) of synaptic scaling is determined by a small factor \( \gamma \).

Synaptic scaling operates in parallel to conventional plasticity and acts simultaneously on different synapses. Here we suggest that synaptic scaling is combined with different types of plasticity mechanisms in the same circuit or even at the same neuron and regulates synaptic diversity across the circuit.

We demonstrate that it robustly yields stable and diverse weight distributions which moreover are independent of the individual plasticity mechanism. As scaling co-acts with plasticity, such a combined mechanism is mathematically characterized by a weight change \( \frac{d \omega}{dt} = \mu G + \gamma H \). Here \( \mu \) defines the rate of change of conventional synaptic plasticity, \( \gamma \mu \geq 1 \), and \( G \) and \( H \) describe the specific types of plasticity and scaling, respectively [7]. For example, \( G \) is different for plain Hebbian plasticity than for STDP. As we show, combining any type of conventional plasticity \( G \) with nonlinear weight-dependent scaling \( H \) naturally yields global synaptic stabilization across the circuit regardless of the specific form of the plasticity \( G \) and also largely independent of the intrinsic neuron dynamics. Our study demonstrates that synapses are stabilized strictly in an input-determined way thereby capturing characteristic features of the inputs to the network. As an important result, we show that such systems are capable of representing a given input pattern via stably changed weights along several stages of
signal propagation. This holds even in circuits containing a substantial number of random recurrent connections but no particular additional architecture.

References
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[W 30] Do synaptic dynamics and STDP govern connectivity motifs?
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Recent evidences in rodent prefrontal cortex (Wang et al, 2006) and olfactory bulb (Pignatelli, Markram, and Carleton, unpublished data) suggest that synaptic short-term facilitation and depression may be correlated to specific connectivity motifs. In particular, it was observed that two excitatory neurons with facilitating synapses form predominantly reciprocal connections, while two excitatory neurons with depressing synapses form unidirectional connections. However, the causes for these structural differences are unknown.

We propose that connectivity motifs could emerge by the interaction of short-term synaptic dynamics (STD) and long-term spike-timing dependent plasticity (STDP). While the influence of STDP on STP was shown experimentally in vitro (Buonomano 1999), how STP and STDP mutually interact, in active recurrent networks, is largely unexplored. Our approach combines the Tsodyks-Markram (1997) STD phenomenological model with the STDP “triplet” model (Pfister et al 2006, Clopath et al, 2010), which captures dependencies on both time and frequency of long-term plasticity. As “proof of concept”, we implement the STD-STDP on networks with random initial topology, composed by adaptive exponential integrate and fire model neurons (Brette & Gerstner, 2005). Synaptic connections in the networks are either all facilitating or all depressing. Upon identical external stimulation patterns, we find that all networks with depressing synapses evolve non-symmetric connectivity motifs, while networks with facilitating synapses evolve reciprocal connectivity motifs, for the largest part of the simulations (~95%).

Our model highlights appropriate biophysical conditions under which STP-STDP could explain the correlation between facilitation and reciprocal connectivity motifs as well as be-
between depression and unidirectional connectivity motifs. These specific conditions may lead to the design of experiments for the validation of the proposed mechanism.

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References


Modeling the effect of Dopamine through changing causality in STDP
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The inclusion of reinforcement into learning rules with spike timing dependent plasticity is often simulated as a third factor in weight adjustment. This is used as a way to simulate delayed reward but ignores instant changes to firing behavior that are correlated to changing levels of phasic dopamine. In particular, the discovery of novel actions may be influenced by existing levels of dopamine while new input patterns arrive.

We present an alternative way of looking at how a novelty signal may be influencing the behaviour of synapses to modulate the causal reaction to input spike patterns. By modulating the causal relationship between input spikes and output spikes of a trained two-layer network, we also gain effects on network learning that can in turn be used for reinforcement learning. The suggested method is not in conflict with existing methods of dopamine simulation, and the two methods may be combined if wanted.

References


[W 32] Unifying procedural memory consolidation and structure learning in a recurrent network model of motor control

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Humans can improve their performance in movement sequence tasks through practice, but such motor learning has shown a wide variety of puzzling and partly contradictory effects. Blocked training of multiple sequences has been shown to lead to reduced retention compared to interleaved training and a wide variety of proactive and retroactive facilitation and interference effects have been observed [1]. Furthermore, recent studies have shown that transfer of learning between different tasks is based on structural task similarities [2]. Here we address the question of how these phenomena can be understood in terms of the shaping of neuronal representations through different plasticity mechanisms in a recurrent network model.

We use a sparsely connected recurrent network whose connectivity is shaped by STDP, intrinsic plasticity, and synaptic scaling, similar to [3]. Additionally, this network is connected to a layer of motor neurons mediating the movement sequence. We apply this network to a series of experiments about movement sequence learning [2, 4-6] and use a single set of parameters in all simulations. The network learns to carry out the correct movement sequences over trials and shows striking similarity to the human behavior in a variety of training schedules over different sequence similarities.

We show how psychophysical performance measures are reflective of the underlying neuronal representations in the recurrent network. These results are interpreted in terms of the changes in the neuronal sequence representations and testable predictions for further experiments are derived. Specifically, we show how sequence similarity and training schedule interact to produce a rich set of interference and facilitation effects thereby unifying structure learning and procedural consolidation.

Acknowledgements

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References
1: Robertson, Pascual-Leone, Miall (2004), NRNN
2: Braun, Waldert, Aertsen, Wolpert, Mehring (2010), PLOS
4: Koedijker, Oudejans, Beek (2010) JMB
5: Shea, Panzer, Wilde (2006), JMB
Feedback loops allow controllers to work in an effective manner, especially in dynamic environments, where the systems under control may be influenced in one way or the other. Usually the behavioral control unit changes the motor command according to the available sensory information. Here, a neuronal closed loop system is presented which acts completely on the local motor control level and can inject sensory feedback, thereby generating sensitive actuators which are characterized by a reduction of unnecessary motor stress.

The proposed system is based on homeokinetic control [Der, 2001], a paradigm for self-organized control of autonomous robots. Due to the homeokinetic principle motor command generation is based on proprioceptive sensory feedback. The system's input, called reference signal here, is the desired motor primitive generated by the behavioral control unit. Its output, the motor command, directly drives the actuator. Hence the system is placed between controller and actuator. If the actuator can follow the reference signal, e.g. a motor can achieve the desired angle, the system will not intervene. However, if the actuator cannot follow the reference signal, e.g. a motor is blocked and can not achieve the desired angle, the system will downsize the motor command. As a consequence, in abnormal conditions motor commands are decreased if they cannot be properly realized. This way the closed loop circuit guides motor command execution.

The proposed system is applied to a physically realistic simulated legged robot where we use an oscillation generated by a central pattern generator (CPG) as a reference signal. In normal conditions the desired walking behavior can be realized following the original CPG signal. When colliding with an obstacle and motors get blocked the corresponding motor command is drastically reduced due to the proposed neuronal closed loop system and thereby unnecessary motor stress is decreased. Note, the reference signal generated by the behavioral control unit does not change. If the robot passed the obstacle and the motors can move freely again, the reference signal is executed as before the collision.

This result exemplifies, how a small neuronal circuit can inject sensory feedback into local motor control and thereby generate sensitive actuators. Furthermore the presented approach for blockade detection in legged robot locomotion relies only on one sensor quality, while usually more information, e.g. torque, joint angle velocity, foot contact and/or distance sensor information, is required [von Twickel et al., 2011, Cruse et al., 2007].

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References
A pattern recognition system for low-latency prosthesis control

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Pattern recognition in myoelectric data for prosthetic control faces a trade-off between classification accuracy and controller latency[1]. We propose a preprocessing that removes uninformative data parts in order to improve classification accuracy for short signal integration times. We study the selection of data features and electrodes in the problem of classification of hand postures from which control signals can be derived. Measured signals contain a superposition of signals that arrive from the central nervous system, transductions of these signals and intrinsic muscular activity, where that latter part are here assumed to be independent of the type of contraction performed.

Methods

In order to control a transradial hand prostheses 126 monopolar sEMG signals were recorded. The data were obtained from able bodied subjects performing repeatedly eight different static contractions (hand open and close, wrist flexion, extension, abduction, adduction, pronation and supination). We use a locally linear multivariate regression model to represent the intrinsic muscle activity and to determine the contribution from the extrinsic input. This input to the muscle is assumed to carry the classification-relevant information while simultaneous removal of activity from the intrinsic dynamics results in a noise reduction. The regression coefficients are computed for the complete data set to capture the intrinsic activity independent of the specific contraction. Next we compute the relative root mean square (rRMS) of the external signals pursuing the aim of reducing the size of the time window. As classification algorithm a linear discriminant analysis (LDA) is employed.

Results

Using rRMS of the electromyographic raw signals as features, gives a good classification result (accuracy of 99.9% with a standard deviation of 0.5%) for time windows of 100 ms when the ten best electrodes are chosen by sequential forward floating selection. If the time window is reduced, the classification accuracy decreases steadily and reaches 84.3% (standard deviation of 0.8%) for 10 ms. For this time window length, we are able to improve the classification result by 4% computing the rRMS of the extracted external signal instead of the filtered raw data. This improved classification accuracy gradually converges to the accuracy of raw data rRMS as 100ms time window length is approached. Acceptable performance 99.9% can be reached already for time windows of 40ms which implies a very short latency in control while the larger time windows are providing a safety margin for realistic applications.

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System identification recently enabled several laboratories to model human stance control. These models use sensory feedback control for coping with unforeseen external disturbances (support surface tilt, push against body, etc.), this despite biological ‘complications’ such as noise, inaccurate sensor signals, considerable time delays, etc. There still exist considerable differences between the models. Our laboratory, for example, focused on on-line inter-sensory interactions, by which humans extract estimates of external disturbances and use these in a direct disturbance rejection (DEC model, disturbance estimation and compensation; overview, Mergner 2010). Using model simulations, we found that it describes and predicts human balancing behavior across a broad range of experimental situations. We then went one step further and re-embodied the model into a biped robot (1 DOF, ankle joints) for hardware-in-the-loop simulations in the human laboratory, considering this a more realistic testing with respect to internal noise, inaccuracies such as leaky instead of ideal integrators, etc. Most recently, we developed a 2 DOF robot (ankle and hip joints; PostuRob II). In this we successfully tested the DEC model (see Hettich et al. 2011 on www.posturob.uniklini-freiburg.de). We then offered PostuRob II to other laboratories for testing their models in comparison to human data. Posturob II was constructed with human-like anthropometric parameters (see above, Hettich et al. 2011). The robot’s trunk, leg and feet segments consist of aluminum frames interconnected by hip and ankle joints. Signals from human-inspired mechatronic vestibular, joint angle, and joint torque sensor components are input to, and signals for the actuator control (commanding pneumatic ‘muscles’; Festo, Germany) are output from a real time PC. There, the control model is executed as a compiled Simulink model (Real-Time Windows Target; The MathWorks Inc., USA). The robot is freely standing on a motion platform and the same experimental procedures are applied as in the human subjects.

In a cooperation with A.V. Alexandrov and A.A. Frolov (Moscow) we implemented another stance control method based on a controller of ankle and hip eigen-movements (or ‘natural synergies’; see Alexandrov and Frolov 2011) in a Simulink model and downloaded it on PostuRob II. After some model adjustments, PostuRob II was able to balance. Responses to transient, steady state sinusoidal and pseudorandom tilts and translations of the support surface were recorded in terms of trunk-space (TS) and leg-space (LS) angular excursions as well as center of pressure (COP) shifts. These data are currently compared to human data. Furthermore, they are compared to those obtained with the DEC model. Thus, PostuRob II represents a valuable tool in this field of research in that it allows such comparisons within the same testbed. Further laboratories are invited to also make use of PostuRob II.
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References

[D] The motor neuron recruitment strategy and muscle anatomical properties determine the influence of synaptic noise on the variability of motor output
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During muscle contraction, alpha motor neurons receive synaptic input from tens of thousands of neural connections, causing continuous fluctuations of the membrane voltage (synaptic noise) and resulting in variability in the times of occurrence of action potentials (Berg et al., 2007). This inherent variability may determine unstable motor output. We hypothesized that in human muscles the influence of synaptic noise on the stability of motor output would be limited by the mechanisms of transduction into force (spatial and temporal summation of force twitches) so that the synaptic noise at motor neurons would be a limiting factor in motor output stability only for a small range of generated forces. To verify this hypothesis we described force generation analytically and we simulated it by a computational model of motor unit population and realistic descending motor commands (Dideriksen et al., 2010). The simulations varied the contraction force, the level of synaptic noise, the motor neuron population size (100-500), the recruitment range (40-70% of the maximal force, MVC), and the motor unit twitch contraction times (slowest fiber: 45-180 ms; fastest fiber: 15-60 ms).

The simulations indicated that once the generated force exceeded a certain threshold, primarily the low-frequency components of the descending drive were reflected in the force variability, whereas synaptic noise was almost completely filtered out. This was reflected in a gradual decrease in the correlation between the discharge time variability and the force variability as contraction force increased, whereas the correlation between the variability of the descending drive and force variability was not influenced by the generated force. These simulation results were explained by the analytical derivation as the combination of the low-pass filtering effects related to the convolution with the motor unit twitches (temporal summation) and the averaging filter performed by the summation of single motor unit forces (spatial summation). The force value above which synaptic noise did not influence the stability of force varied with recruitment range and muscle properties, however for typical values for these parameters it was smaller than 10% MVC.

In conclusion, the motor neuron recruitment strategy and muscle properties in typical muscles are tuned so that the influence of synaptic noise on motor output stability is limited to relatively low forces only. For greater forces, the synaptic noise is not anymore a limiting factor and force variability is determined by the low-frequency oscillations in motor neuron discharge rate which are due to the ability of the central nervous system to generate a stable neural drive to muscles when integrated with afferent input.
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References
A distributed code for color in natural scenes derived from center-surround filtered cone signals

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In humans and other trichromats, information about the color of the environment is encoded in the retina by three different types of cone photoreceptors that are sensitive to different parts of the spectrum. The signals from the cones are transmitted to the lateral geniculate nucleus (LGN) and visual cortex via two parallel pathways. Chromatic signals are encoded in a cone-opponent fashion, where one pathway encodes the difference between medium and long-wavelength sensitive cones, while the other pathway encodes the difference between these two and the short-wavelength sensitive cone. Consequently, the selectivities of the neurons in the LGN form two separate clusters, corresponding to the two classes of cone opponency. In the visual cortex, however, these clusters are not observed, and the chromatic selectivities are more distributed (Lennie et al. 1990; Komatsu 1998), which is in accordance with a population code for color (Wachtler et al. 2003). Previous studies of cone signals in natural images typically found cone-opponent codes with chromatic selectivities corresponding to two directions in color space (Wachtler et al. 2001; Caywood et al. 2001). Here we investigate the role of spatio-chromatic filtering in the retina for the encoding of color signals. Cone signals estimated from natural color images were pre-processed by center-surround filtering and rectification, leading to parallel On- and Off- channels. Independent Component Analysis on the resulting signals yielded basis functions that showed spatio-chromatic selectivities specific for On- and Off- signals, respectively. Most basis functions were color selective. In contrast to previous analyses of linear transformations of cone signals, the selectivities were not restricted to two main chromatic axes, but were more continuously distributed in color space. The distributions were not uniform but showed several clusters, resembling the population code of color in the cortex (Wachtler et al. 2003). Our results indicate that a population code with distributed selectivities for color may arise from efficient encoding of center-surround filtered cone signals in On- and Off- retinal pathways.

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References
Neurons in the cortex appear to participate in coding and computational processes that span local populations. Large-scale multielectrode recordings make it possible to access these processes empirically by fitting statistical models to unaveraged data. In neocortex, neural firing exhibits extensive temporal and spatial correlations, and a typical sample of neurons still reflects only a very small fraction of the local population. What kind of statistical model best describes the concurrent spiking of cells measured with cortical multielectrode recordings?

We argue that the most appropriate model captures shared variability in firing by a low-dimensional latent process evolving with smooth dynamics, rather than by models of direct coupling. We test this claim by comparing a dynamical system model with realistic spiking observations to coupled generalized linear spike-response models (GLMs) using cortical recordings. We find that the dynamical system approach outperforms the GLM in terms of goodness-of-fit, and reproduces the temporal correlations in the data more accurately. In addition, we find that a dynamical system model with non-Gaussian count probabilities provides very realistic population spike counts, i.e. that it can account for the observed synchrony across the population.

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**Mapping the functional architecture of working memory in Macaque pre-frontal cortex using movable electrode arrays**

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Prefrontal cortex (PFC) is the hub of a distributed system that coordinates the selection, planning and execution of motor behaviors. Working memory links these operations in PFC by providing temporal continuity between prior experience and present action. Although patterns of intra- and inter-layer synaptic connectivity have been identified in PFC, the laminar organization of sensory, motor and memory-related activity within this network remains unknown. To address this problem, we used a chronically implanted microdrive with independently movable electrodes to map the depth dependence of spatially tuned local field potentials (LFP) in PFC of Rhesus macaques (Macaca mulatta) as they performed memory-guided eye
movements. We show that the persistent representation of a remembered target location is limited to superficial layers of PFC. By contrast, the representation of target position during cue and saccade epochs is distributed across superficial and deep cortical layers. This indicates that superficial PFC may be specialized for the maintenance of spatial working memory.

[W 40] The effect of the input correlation structure on pyramidal layer V neurons
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Each cortical neuron is constantly receiving synaptic inputs from thousands of presynaptic neurons. Already the most simple spiking neuron models show that the output of a neuron is not only determined by its input rates of the presynaptic neurons, but also by the correlation of the input trains. Using simulations of pyramidal layer V neurons we investigated how the output is modulated by the higher order correlations in the excitatory and inhibitory inputs. We demonstrate how the higher order correlations affect the output firing of the stimulated neuron by exposing it to Poisson input trains with the same spiking rates and second order correlations but different higher order correlation profiles. The results show that higher order correlations can significantly alter the statistics of the single neuron firing. Thus in order to understand neural processing experimental characterization and theoretical analysis of the higher order correlations is needed.

[W 41] Input synchrony strengthens correlation transmission via noise suppression
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Whether precise spike timing [1] conveys information in cortical networks or whether the firing rate alone is sufficient is still matter of controversial debates. While it is often argued that synchrony is an epiphenomenon caused by shared afferents among densely interconnected neurons [2], several studies have reported task related modulation of spike synchrony, lately in primary visual cortex [3] and motor cortex [4]. Recently, cortical networks were found to exhibit very weak correlations [5], thus suggesting either population-rate codes or potentially providing a suitable substrate on top of which spike synchrony can represent information. In this work we theoretically investigate the efficacy of common synaptic afferents on the one hand and synchronized inputs on the other hand to contribute to closely time-locked spiking activity of pairs of neurons [6]. We employ direct simulation and extend earlier analytical methods based on the diffusion approximation [7] to pulse-coupling, thus allowing us to describe correlations on the level of synchronized presynaptic sources.
We investigate the transmission of correlated synaptic input currents by pairs of integrate-and-fire model neurons. We therefore generate input currents exhibiting zero to full correlation and realize each correlation value by different proportions of common afferents and spiking synchrony. The comparison of the count correlation of the output spike trains of neurons driven by these currents allows us to address the question how much synchrony is caused by presynaptic synchronous activity and how much is due to the high convergence and divergence the cortex’ connectivity.

We find that, at a fixed working point, the transmission of a particular input correlation is boosted when it contains synchronous events compared to when induced by common input alone, giving rise to a higher output correlation and sharpening the correlation function. In the regime of high input correlation this boosting is even more striking, resulting in an output correlation higher than the total correlation in the input. Making use of recent theoretical insights [8] into the non-linear response properties of neurons, we provide a quantitative understanding of how the threshold acts as a noise suppression mechanism, explaining the correlation transmission gain > 1.

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References

Tracking learning of enharmonic pitch-change in american popular music using single-trial EEG decoding
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We present results for a detectable signal in electroencephalography (EEG) measurements in response to enharmonic changes of pitch. In particular, when the pitch-change occurs at a constant location in the same song, we find that subjects exhibit discrimination that is different from when the pitch-change is not at a constant location. Upon further investigation, we found through the neural data that each subject habituates to the pitch-change at different times in the course of the experiment. The stimulus domain is composed of four pitch-change profiles and one control superimposed on the American popular song “Eye of the Tiger.” With $N = 6$ subjects, two versions of the experiment were performed. Both versions entailed 7 runs of 5 trials, where each trial consisted of a 91-second excerpt of the song. However, one version contained completely unrelated pitch-change profiles across all trials of all runs (i.e., the random version), whereas the other did not (i.e., the non-random version). In particular, the non-random version contained pitch-changes at the same location in the song, although they could be of different directions (e.g., pitch-up or pitch-down). With these two versions of the experiment, we were able to gauge whether a learning effect could be developed in the subjects for the non-random version, as opposed to the random one. We collected EEG data with a 64-channel passive-electrode BioSemi cap.

For the analysis of data from these experiments, we extended previous work from our lab on perceptual discrimination by using logistic regression analysis. In particular, we performed a leave-one out (LOO) classification of pitch-shift (pitch-up, pitch-down, and generic pitch-change) vs. control conditions, using the area under the receiver characteristic curve (ROC) as a measure of classification accuracy. For each subject, there were multiple statistically significant (99%) post-stimulus components of pitch-shift discrimination for the random version of the experiment. This result is insensitive both to the place in the song as well as the absolute pitches of the preceding and succeeding versions of the song. Furthermore, when averaging classification results across subjects, several poststimulus components between 200-600ms were seen, indicating a common response across subjects. Finally, the lack of clear discrimination between pitch-change and control conditions in the nonrandom experiment indicates a learning effect in the subjects. Upon further investigation, it was found using a subset of epochs from the non-random version that an optimum and significant pre-stimulus discrimination window exists before the pitch-change. This implies two things: 1) that subjects are learning the pattern as the experiment progresses and 2) that the pre-stimulus discrimination becomes attenuated after the pattern is discovered (later trials) and before it is noticed (earlier trials).

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An analytical study of population coding of dynamic stimuli

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Many aspects of human perception can be understood as arising from probabilistic inference. Particularly when integrating cues from different sources with different reliability humans have been observed to integrate these cues optimally in a Bayesian sense [1, 2]. Claims of optimality of the observed behavior abound, although little theoretical work has been done to establish this. Here we propose an analytical model of stimulus reconstruction from noisy spike trains, in which we are able to solve for the mean squared error of an ideal Bayesian observer. Furthermore, this is done in a time-dependent fashion which allows us to study the evolution of the error.
We present analytical results for a simplified labeled-line population coding model of Poisson spiking neurons with Gaussian-shaped tuning functions. By drawing the stimuli from a Gaussian process distribution and under the assumption of strongly overlapping tuning functions, we are able to derive a time-dependent filtering scheme for the reconstruction of the stimulus. From that we find a differential equation for the mean squared error of an ideal Bayesian observer. This has been studied via direct simulation of the spike trains and a mean-field approximation. We observe the existence of a finite optimal tuning width for both cases. This has been reported before for the case of static stimuli [3]. Our findings are also consistent with findings of tuning function adaptation in primates [4].

The present work seeks to provide a comprehensive and solid approach towards neural coding in a dynamic framework. We believe a thorough analysis of neural coding could shed light on phenomena as tuning function adaptation and shapes of tuning functions in the context of Bayes optimality. The approach is also very flexible so that a number of systems could be investigated with it. There are some natural extensions to the present work, namely the inclusion of more complex spike generation mechanisms and the analysis of high-dimensional cases. This work provides a first step towards a mathematical and ecological theory of sensory processing.

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References
It was recently shown that cortical networks are highly sensitive to single spike perturbations [1]. In these experiments was demonstrated that triggering a single additional spike can cause a cascade of additional spikes which rapidly decorrelate the networks' microstate. This high sensitivity of cortical networks is theoretically not well understood.

In a minimal model of cortical networks, namely randomly coupled inhibitory networks of integrate-and-fire neurons in the balanced state, we show that a high sensitivity to single spike and even single synapse perturbations coexists with dynamic stability to infinitesimal perturbations. On the one hand, the Lyapunov spectra, quantifying the dynamics with respect to infinitesimal perturbations, is negative definite and invariant to the network size. Thus, the stable dynamics is extensive and preserved in the thermodynamic limit. On the other hand, the pseudo Lyapunov exponent, characterizing the rate of state separation after single spike failures, is positive and shows no sign of saturation in the high connectivity limit. Thus, such perturbations induce exponential and basically instantaneous state separation.

By examining the transition from stable to unstable dynamics for arbitrary perturbation sizes, we derive a unifying picture of tangled flux tubes composing the networks' phase space. These flux tubes enclose unique stable trajectories but adjacent flux tubes separate exponentially fast. An estimate of the flux tube length from the observed flux tube radius suggests that the entropy of distinct network states grows faster than in the extensive case as $N \log(KN)$. Surprisingly, the flux tubes become vanishingly thin in the thermodynamic limit, suggesting unstable dynamics even for infinitesimal perturbations. This contradicts the prediction from the Lyapunov analysis and reveals that characterizing the dynamics of such networks as stable or chaotic depends on the order in which the thermodynamic limit and weak perturbation limit are taken. This appears to be the origin of the outstanding controversy about the dynamical nature of the balanced state [2-5].

Summarizing, we analyzed a minimal model of cortical networks and found a surprising coexistence of stable and unstable dynamics. This draws a picture of dynamics flux tubes which enclose unique stable trajectories yet separate exponentially fast. The scaling of the flux tube radius was used to estimate the entropy of distinct network states and revealed the origin of the controversy about the dynamical nature of the balanced state in such networks.

References

Continuous dynamic photostimulation - inducing defined, in-vivo-like fluctuating stimuli with channelrhodopsins

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Central neurons typically operate in a noise driven regime: thousands excitatory and inhibitory synapses give rise to a constantly fluctuating conductance. Its statistic is similar to low-pass filtered white noise conductance that can be parameterized by its average, standard deviation and correlation time. An understanding of action potential generation and encoding in the noise driven regime requires the detection of action potential times during stimulation with defined time dependent conductance.

Channelrhodopsin variants, expressed in neurons have been almost exclusively used to drive action potentials by illumination with very brief, intense light flashes; effectively imprinting action potential patterns, that are largely independent of the neurons intrinsic response properties.

Using the only known weakly inactivating channelrhodopsin variant ChIEF under continuously fluctuating illumination by an LED, we achieve a defined, reproducible conductance modulation that mimicks the naturally occurring synaptic inputs. Cultured hippocampal neurons subjected to this continuous dynamic photostimulation (CoDyPs) generate seemingly random, but reproducible patterns of action potentials, even in experiments lasting several hours. Within the range of illumination intensities used (up to 0.3 mW/µm²) the induced conductance change can be predicted, up to a factor describing the number of expressed ChIEF-Molecules, by convolution of the light signal with the light-conductance transfer function of ChIEF. This Transfer function was determined from light-induced currents, recorded in voltage clamped cultured cells (HEK-293), transiently expressing ChIEF. It resembles the transfer function of a simple single pole low-pass filter with a corner frequency of 20-25 Hz.

Together with non-invasive action potential detection by extracellular electrodes, CoDyPs lays the foundation for very long-lasting studies of action potential generation in a fluctuation driven regime. This promises to allow the measurement of dynamical response properties and the respective cut-off frequencies from individual neurons. It might also prove a useful addition to conventional flash-evoked imprinting of action potential patterns for in-vivo experiments.

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Small fluctuations of the Nernst membrane potentials caused by astrocytic spatial buffering in the rodent hippocampus

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Introduction
Removal of potassium by glial cells implies the net uptake of potassium at sites of elevated potassium, i.e. where neurons are firing action potentials, and release of potassium at sites where no or little neuronal activity is going on, resulting in a redistribution of extracellular potassium (Figure 1). While there is evidence that glial uptake of potassium is partly mediated by Na+/K+ ATPase, many studies indicate that influx of potassium through inward rectifier ion channels plays a predominant role (Kofuji and Newman, 2009). It is firmly established that glial cells remove excess potassium from the extracellular space by mechanisms like spatial buffering as proposed for astrocytes, or potassium siphoning, proposed in the retina (Kofuji and Newman, 2009; Newman and Reichenbach, 1996). The resting membrane potentials of both neurons and glial cells are largely defined by a high plasma membrane conductance for potassium ions, and thus attain negative values close to the Nernstian equilibrium potential for potassium ions (Hodgkin and Katz, 1949; Somjen, 2002). Accordingly, small variations of the potassium concentration in extracellular space [K+]ex lead to changes in the membrane potential of neurons and to alterations in neuronal firing thresholds and neurotransmitter release (Newman, 1985; Somjen, 2002). Impaired extracellular potassium buffering has also been proposed as a significant mechanism underlying various neurological deficits related to abnormal neuronal depolarization, hyperexcitability, and seizures (Somjen, 2002). Despite the worthwhile computational studies on the influence of glial dynamics on the neuronal membrane potentials (Clay, 2005; Cressman et al., 2009; David et al., 2009; Park and Durand, 2006; Somjen et al., 2008; Ullah et al., 2009), there exists a need for fundamental investigation of glial influences on synaptic systems at equilibrium states. Potassium and other ionic resting potentials, which are obtained by Nernst equation, are substantial parameters of major electrophysiological equations such as the Hodgkin-Huxley equations.

Materials and Methods
In order to investigate the effects of glial spatial buffering on the Nernst potentials, we modified the Poisson-Nernst-Planck equation by adding a functional of potassium concentration $F(c)(x,t)$, which depends on the gradient of the extracellular potassium concentration as well as on the glial ionic exchange rate with the extracellular space. The Nernst equation is then derived as a phase space relationship of the steady state solutions of the modified Nernst-Planck equation. The restriction of the modified equation into one-dimension is a valid first approximation to the higher dimensions, which even provides analytic solutions. Thus, we will focus only on the one-dimensional equation. The analytic solution of the modified Nernst-Planck equation suggests that the modifications by the spatial buffering functional induce an additive correction term for the Nernst equation.

Results
By estimating the equation parameters from the experimental data, we can identify the magnitude of the correction term. It appears that the range of the glial impact on the neuronal Nernst potential is approximately between -0.9 and 2.9mV. This means an average glial influence of about +1mV resp. a current of 100pA. Although, there are no experimental studies validating these estimations, the calculated electrophysiological values appears to be plausible in the framework of glial research. While these fluctuations of about 5% of the potassium Nernst potential are comparatively small (as expected), they provide parameter corrections for especially the Hodgkin-Huxley equations, which are of interest for further computational investigations of neuron-glia interactions.

Discussion
Although the achieved results are feasible from the experimental point of view, the present mathematical model leaves place for improvements. For instance, potassium uptake by glial cells is not only done through channels. There is also evidence that glial cells take up potassium by Na+/K+ ATPase or other transporters such as Na+/K+/2Cl- co-transport. Because these processes are mainly governed by the gradient of ion concentrations, the subsequent
modifications of the Nernst-Planck equation by these processes appear to be of the same form as the introduced functional $F(c)$. Therefore, it is expected that the extension of our model with further gradient-dependent uptake mechanisms reveal a similar analytical behavior with a potentially different range for the values of the glial impact. Nevertheless, the consideration of different types of ions in the modeling of glial homeostatic processes will increase the complexity of the mathematical analysis and requires further investigations.

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**References**

[W 47] Network inhomogeneity promotes spontaneous bursting in vitro
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Spontaneously initiated synchronous bursting events (SBE) are widely observed in neuronal systems and are considered important in shaping fundamental neuronal circuitry in early cortical development (1,2). Likewise, SBE dynamics represent the predominant type of activity in developing networks of cultured neurons in vitro. Interestingly, theoretical models have shown that hierarchical network structures embedding clusters of strongly inter-connected neurons are optimal for initiating and sustaining spontaneous activity (3). We hypothesize that activity-dependent wiring supports the formation of clustered network structures supportive to SBE initiation. To test this we chronically manipulated activity-dependent structural plasticity in developing networks of cortical neurons in vitro by chronic inhibition of protein kinase C (PKC). Previous studies showed that PKC inhibition in developing cerebellum promotes dendritic outgrowth and arborization of Purkinje cells (4), and impairs pruning of climbing fibers (5), linking this protein closely to structural plasticity. We consistently found that developmental inhibition of PKC in cortical cell cultures increased dendritic outgrowth, impaired neurite fasciculation and clustering, and abolished network pruning. This resulted in more homogeneous and potentially better connected networks. In consequence, propagation of activity within SBE was faster and occurred in highly regular wave fronts. SBE were, however, triggered from fewer sites and at much lower rates suggesting that the homogeneous networks forming under blockade of activity-dependent wiring processes embed fewer SBE initiation zones. To further confirm that SBE frequencies in homogeneous networks were limited by reduced spontaneous network activation, we provided additional input by electrical stimulation. Interestingly, homogeneous networks formed under PKC inhibition achieved even higher activity levels when electrically stimulated than inhomogeneous control networks. Our data suggests that activity-dependent structural plasticity promotes network inhomogeneity which increases spontaneous activity levels during development. Based on recent evidence for a reciprocal scaling between synaptic strength and number of neuronal partners in vitro (6), we propose that locally more confined synaptic targeting within neuronal clusters promotes stronger and more recurrent coupling of neurons. The resulting connectivity patterns would more easily amplify spontaneous excitation beyond a critical threshold and thus serve as SBE initiation zones.

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References
In the last ten years, several models of basal ganglia dynamics have been proposed in order to explain the abnormal neural oscillations that appear in Parkinson's disease. Recently, Nevado Holgado et al. [1] have shown that a two-dimensional nonlinear model of the subthalamopallidal feedback loop, which interconnects the subthalamic nucleus (STN) and the external part of the globus pallidus (GPe), exhibits oscillations in the beta band when the parameters of the model are those of the pathological state. They proposed, moreover, a simplified model for which the condition for oscillations can be computed analytically. In our work, we consider a slightly more general model of the subthalamopallidal feedback loop, that includes a self-excitation loop of the STN onto itself and allows more general activation functions. It coincides with the model of Wilson and Cowan [2], with the difference that interconnection delays are included and that the refractory period is neglected.

Our approach [3] to obtain existence conditions for neural oscillations can be separated in two steps. In a first step, the existence of equilibrium points is studied. In the absence of delays, our method gives a necessary and sufficient condition for the existence of a unique stable equilibrium, independently of the level of external inhibition applied to the system (this condition excludes the possibility of having multiple equilibria [2]). In this case, the system can be linearized around its equilibrium. In a second step, Nyquist's stability criterion is applied to the feedback loop. This criterion gives directly the maximal admissible delay in the loop. When the internal delays of the STN and of the GPe are neglected, our stability condition can be computed analytically. Otherwise, a transcendental equation must be either solved numerically or approximated. In any case, existence conditions for oscillations are obtained, without the need of integrating numerically the differential equations associated to the model. Comparing our method to that proposed by Nevado Holgado et al., we have found that when the internal delays are small our zero self-delay approximation gives an improved analytical condition for the existence of oscillations. If the value of the internal delays is close to that of the external ones, the method of [1] gives more precise results. More surprisingly, it appears that when the gain that describes the excitation level from the STN to the GPe is small the method of [1] gives very good results, even in the absence of internal delays. Another observation that comes out from our study is the influence of the STN's self-excitation gain on stability. This gain was not considered in [1]. It appears, however, that it has an impact on the existence of multiple equilibria (a point that was already observed in [2]) and on the delay margin of the system.

References
Stable but sensitive: multi-stable perception arbitrates to the exploitation-exploration dilemma

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The dynamics of visual inference can be studied in the phenomenon of multi-stable visual perception: when a multi-stable visual display is viewed continuously, its phenomenal appearance reverses spontaneously at irregular intervals. Presumably, a multi-stable display stimulates recurrent neural networks with several distinct steady-states of neural activity (attractor states), which are continually destabilized by neural adaptation and by neural noise.

We set out to characterize the dynamical balance of stabilizing and destabilizing factors in the multi-stable perception. Despite high diversity of reversal statistics – differing by one or two orders of magnitude between observers and displays – we found a hidden consistency: almost all observers (21 of 24, viewing 3 displays) operated in a narrow dynamical regime near the brink of an oscillatory instability, or, equivalently in a marginally bistable regime.

This regime is functionally unique in that it combines relative stability of perceptual outcome and high sensitivity to input modulations. This combination can be understood as follows. Both dominance and response times are short at the bifurcation, but grow longer as the system enters more deeply into the bistable regime. A compromise is reached at some distance to the bifurcation. When the input changes from being balanced ($I_1=I_2$) to being biased ($I_1<I_2$), the bifurcation border moves towards the bistable region. Accordingly, a system previously situated near the border may find now itself at the border and able to respond with a rapid reversal. In short, being near the bifurcation affords both stability when the input is constant and sensitivity when the input changes.

Our results may generalize to visual inference, where a goal conflict between stability and stability seems unavoidable. In terms of attractor dynamics, a stable appearance of a visual scene, resulting in reciprocal excitation between visual and memory activity, would be expected to stabilize a particular pattern of activity. The downside would be reduced sensitivity to incremental changes in the visual input, for attractor dynamics would tend to counteract any change. If the system is to remain sensitive, associative stabilization by memory traces must not go too far. A combination of neural noise and adaptation would seem to offer an appropriate strategy for balancing stability and sensitivity, ensuring that alternative interpretations are exhaustively explored.

In conclusion, we surmise that a marginally stable dynamics arbitrates the exploitation-exploration dilemma of a perceptual system that acquires its store of prior experience through reinforcement learning.

Relation between spike correlations and network structure

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Correlations between neural spike trains are a widely studied phenomenon, due to their ubiquity and their influence on neural network dynamics and function. A state of relatively weak correlations and irregular spike trains is often assumed to be a good model for normal activity in cortical networks. 'Balanced' networks of leaky integrate-and-fire neurons display low average correlations and irregular spike trains. There, the interplay between excitatory and inhibitory populations has been proposed as a key mechanism of correlation reduction. However, the variance of the correlations is typically still large.

We describe pairwise correlations in networks of integrate-and-fire neurons in the framework of point processes [1] considering only linear responses of all neurons. This approximation is applicable under a wide range of conditions, provided that spike activity is sufficiently irregular, and that reset effects are taken into account. The approach yields a simple analytical expression for correlations in the network and the connectivity matrix that encodes the synaptic topology of the network. Differences in correlations can be fully attributed to differences in the connectivity structure between neurons.

As correlations result from multiple direct and indirect synaptic connections [2], the inverse problem -- inference of network structure from correlations -- has no unique solution in general. We find that this fundamental ambiguity can be considerably alleviated, if a priori knowledge about specific features of the network structure, as for example sparse connectivity, is taken into account.

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References

Identification of electrophysiological endpoints in stem cell-based systems for developmental neurotoxicity testing
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The toxicity of chemicals on brain development is of major concern. A predictive in vitro test for potential developmental neurotoxicity (DNT) needs to be an inexpensive, quick, standardized and predictive alternative to present in vivo methods. Here, we combine endpoints based on attachment, proliferation, differentiation and electrophysiological analyses, comparing four neuronal systems (murine embryonic stem cells, human neural progenitor cells and human teratocarcinoma cells) grown on microelectrode arrays (MEAs). Electrophysiological recordings show a spontaneous electrical activity of the networks derived from murine embry-
oncic stem cells and human teratocarcinoma cells neuronal networks only. Comparison of their properties at different developmental stages shows activity increasing from 1st to 3rd week. Supplementary to the MEAs data we provided measurements of Ca+2 transient curves, which support existence of active neuronal networks in case of murine embryonic stem cells and human teratocarcinoma cells.

Moreover, we optimized the differentiation of human teratocarcinoma cells, which now yields up to 2 times more neurons in a 3 to 5 days shorter time. In summary, we analyzed functional endpoints for electrical activity and network properties of 3 cell lines during the period of neuronal maturation.

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[W 52] **Reliable and adaptive numerical methods for realistic neurons**

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In the numerical solution of spatially extended neurons with detailed morphological representation and non-linear Hodgkin-Huxley-like models, current widely used and therefore de-facto standard methods are Finite Difference schemes in combination with time stepping by Backward Euler or Crank-Nicolson methods. In this poster, we show a bunch of novel methods such as Finite Element and Finite Volume schemes as well as linear implicit time stepping schemes of Rosenbrock type. Special attential is paid on their applicability under various conditions regarding stability and accuracy. Further we show adaptive variants of the schemes which adapt spatial and temporal resolution according to distinct measures of neuronal activity, and discuss reliability and efficiency of the methods.

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[W 53] **Hypothetical grid cell activity from the synchrony of coupled Kuramoto oscillators**

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We present here various hypothetical grid cell activity derived from a formulation of the OIM (Burgess & O’Keefe 2007) using a system of weakly-coupled Kuramoto oscillators (Kuramoto 2003) which has implications in predicting grid cell development, directionally projected grid cell activity and spatial frequency variation.

We firstly demonstrate a novel approach to the OIM by showing that it can be modelled in terms of the collective synchrony of several Kuramoto VCOs, whose natural frequency is set
according the speed, running angle and preferred direction of the virtual rat and some baseline oscillators with fixed natural frequency. We simulate two separate systems of oscillators. The first is composed of 8 oscillators, 4 having a baseline natural frequency, the other 4 VOCs each with a natural frequency corresponding to a particular preferred direction, running direction and speed as defined by the OIM. The second set is composed of 4 VOCs only without the baseline oscillators. In each of our two systems of oscillators we try two different arrangements of coupling connectivity, all to all and linear bi-directional connectivity varying coupling strength within ranges where we see visible bifurcation in grid cell activity over the spatial extent.

In the all-to-all connectivity for both the 8 and 4 oscillator case we see a gradual increase in the activity across the entire spatial extent with increasing coupling strength. This could be representing a disruption of grid cell activity via coupling or alternatively a grid cell early in neonatal development where synaptic pruning is beginning to take place, however this is at odds with current results of grid cell development (Langston et al 2010).

Significantly in the 8 oscillator model with a linear bi-directional coupling topology, we see projections of grid cell activities along particular preferred directions and also critically a clear decrease in spatial frequency over the ranges of coupling strengths. These results suggest firstly that a coupling mechanism between a few theta band oscillators could be sufficient for encoding place along particular directions through summation or hebbian selected directionally projected grid activity. Secondly and crucially that spatial frequency variation found in grid cells from the ventral to dorsal MEC (Hafting et al 2010) could arise from coupling between VOCs and baseline oscillators in a linear bi-directional topology.

Acknowledgements
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References

Variability dynamics in motor cortex differentiate global network state from task related activity
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It has previously been shown that variability in cortical spike trains is modulated during experimental tasks (eg Churchland et al. 2006, Nawrot 2003). In this study, the idea of ascribing neuronal response-variance to neuron-intrinsic and network-state dependent sources (eg. Churchland et al. 2011, Nawrot 2010) is elaborated on. Previously published single unit spike data (Rickert et al. 2009) from monkey motor cortex during a reaching task is analysed with
respect to count and interval variability of the spike trains. Time resolved Fano Factors (FF) and squared Coefficients of Variation (CV^2) were computed using previously described methods (Nawrot et al. 2008). These analyses yielded that the FF is high during spontaneous activity (FF>2), strongly modulated within trials and differs significantly across experimental conditions, while the CV^2 remains largely constant at low values around 0.5. The conclusion is drawn that the interval-variability (CV^2) reflects the neuron's intrinsic variability under stationary input conditions while the trial to trial variability (FF) depends on the ongoing activity in the surrounding network. It is proposed that the ratio CV^2/FF can be used as an indicator for the task-specific recruitment of single neurons in a network.

Acknowledgements
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References

Routing of information flow by selective visual attention in LFPs of monkey area V4

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The processes that govern information routing in the highly interconnected networks of the brain are still not known. A particularly well studied case of routing is visual attention, which enables selective processing of behaviourally relevant visual in visual cortex. For characterization and identification of the neuronal mechanisms underlying the attention dependent gating of information flows, we developed a new method allowing a direct and simultaneous estimate of the contributions of target and distracter objects to the neuronal activity pattern. Our method determines bounds on the spectral filter properties of attentional gating, thereby providing constraints for possible underlying mechanisms. A simple model using membrane potential oscillations for gating reproduces our results for area V4 in macaque monkeys. Macaque monkeys were trained to perform a shape-tracking task (Taylor et al. 2005), in which the animal had to direct attention to one of two sequences of morphing shapes on a
CRT screen. Both shapes were placed within a typical V4 RF. The luminances of the filled shapes were modulated independently and randomly for each 10 ms frame. Recordings of V1 local field potentials (LFPs) were performed with an array of chronically implanted micro-electrodes. Simultaneously, we recorded LFPs with up to three microelectrodes in a retinotopically matching part of V4.

The LFPs were split into their frequency components by a wavelet transform. As a measure for the effective contribution of each stimulus to the LFP signal, we computed the spectral coherence between their luminance modulation and the LFPs. Coherence of the flickering pattern of the stimuli with the LFP activity in V1 differed strongly for the two stimuli. For a stimulus within the V1 RF, we found significant coherence values in a range from 0.1 to 0.25 with the maximum below 10 Hz and a second peak around 20 Hz. For the stimulus outside the V1 RF, coherence was strongly reduced in the frequency range below 10 Hz and vanished entirely above 10 Hz. There was no clear effect of attention.

In contrast, for recording sites in V4 where both stimuli were inside the RF, we found a strong effect of attention. For the attended stimulus the coherence between the stimulus and the LFP was several times higher than for the non-attended stimulus. Switching attention was accompanied by a corresponding reversal of the coherence pattern. Significant coherence was typically limited to frequencies up to 15 Hz with a maximum around 5 Hz and values between 0.07 and 0.14.

Our findings were qualitatively reproduced by a linear threshold unit whose input was modeled as a superposition of a noise signal with a frequency of 100 Hz and a subthreshold oscillation in the gamma frequency range. Attentional gating was realized by increasing the amplitude of the carrier gamma oscillation until the noise signal could cross the threshold. Coherence spectra were found to have a similar shape as in the experiment, with cut-off frequency at about half the frequency of the carrier.

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[W 56] Neural dynamics of sequence generation and behavioral organization
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Recently, we have introduced a neural-dynamic model for sequence generation within the framework of Dynamic Field Theory (DFT). In this model, the sequence consists of stable states of the dynamics of neural fields, defined over one [1] or several [2] characteristic, behaviorally relevant dimensions. The sequential transitions are triggered by a neural-dynamic representation of the condition of satisfaction, which detects a match between the expected perceptual state at the end of a sequential action and the actual perceptual input. We have shown that this neural-dynamic model for sequence generation is robust against noise in neural representations and sensory inputs as well as against variable duration of actions in a behavioral sequence.

Here, we demonstrate how the DFT framework for sequence generation may be extended to accommodate task-dependent constraints on the order of actions within a sequence. In particular, we develop a model for behavioral organization of neural-dynamic modules, or elemen-
tary behaviors, which guide the behavior of an agent. Earlier attempts to use dynamical systems to solve the problem of behavioral organization [3] revealed its complexity and inherent instability. Formulating the whole model -- both the sensory-motor systems and the task-driven constraints -- in the same framework of dynamic neural fields demonstrates that the rules of behavioral organization [4] may be embedded in continuous neuronal dynamics. As the controlled instabilities lead to sequential switches between the stable dynamical states, the rule-based sequencing emerges on-the-fly during the behavior from the interplay of the neuronal activation dynamics with the perceptual inputs. We implemented the model on a robot to demonstrate how it may be embodied in an acting agent.

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References

Functional network analysis reveals differences in the semantic priming task
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The recent years have seen the emergence of graph theoretical analysis of complex, functional brain networks estimated from neurophysiological measurements. The research has mainly focused on the graph characterization of the resting-state/default network, and its potential for clinical application. Functional resting-state networks usually display the characteristics of small-world networks and their statistical properties have been observed to change due to pathological conditions or aging.

In the present paper we move forward in the application of graph theoretical tools in functional connectivity by investigating high-level cognitive processing in healthy adults, in a manner similar to that used in psychological research in the framework of event-related potentials (ERPs). More specifically we aim at investigating how graph theoretical approaches can help to discover systematic and task-dependent differences in high-level cognitive processes.
such as language perception. We will show that such an approach is feasible and that the results coincide well with the findings from neuroimaging studies.

Dynamic interactions between visual working memory and saccade planning
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In a recent line of psychophysical experiments, we found that working memory for a surface feature interacts dynamically with saccadic motor planning, even if this feature is task irrelevant [1]. We used a reactive saccade task in which subjects were required to quickly fixate colored targets that appeared in a certain region on the screen and ignore distractors appearing in other regions, while simultaneously keeping a color in memory for a subsequent test display. A match between the remembered color and the color of either the designated target or a distractor had significant effects on saccade target selection, metrics of averaging saccades, and saccade latency.

To explain these effects, we present a neurodynamic model of the perceptual, memory and motor planning processes involved in this task. We build on previous accounts of saccade planning [2] and feature working memory [3] based on the framework of Dynamic Field Theory. The model consists of multiple interconnected neural field representations with lateral interactions. In an architecture that is consistent with visual processing pathways in the primate visual cortex, the neural fields are organized in three modules: A low-level representation of the visual stimuli, capturing both color and location; a spatial pathway, dealing with spatial attention, saccade target selection and saccade initiation; and a surface feature pathway, including a working memory representation that can retain color information in the form of sustained activity. While this memory activity does not evoke any overt effects in the other parts of the model, it influences the evolution of activity in response to a visual stimulus. By modulating activity patterns in the shared low-level representation, it can exert a biasing effect on the formation of a motor plan. With this model, we simulated the complete experimental time course, including formation of working memory from a visual cue, planning and execution of saccades under different stimulus conditions, and subsequent test of the memory performance. We were able to replicate the key experimental observations regarding saccade target selection, metrics and latency. Our work shows how neural processes supporting perception, memory and motor planning can interact even if they are localized in largely separate representational structures.

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References
In order to elucidate the role of local, cortical networks in information processing in the brain, many studies both experimental and theoretical have been conducted over the past decades, spanning all levels and scales of investigation. Although the properties of local and inter-laminar synaptic connections have been investigated in great detail, the question remains if this is sufficient to describe more generic properties of cortical networks. Concomitantly, several neuroanatomical studies (Hellwig 2000; Binzegger et al., 2004; Stepanyants et al., 2009; Voges et al. 2010) have consistently suggested that an estimated 50-75% of the connections a neuron receives originate outside the local volume (radius: ~250µm). These connections have not been investigated in detail yet, which is mainly due to methodological constraints, but potentially have a strong impact on the local processing of information. Hence, they have received more and more interest over the past few years in order to complement the already well-established picture of local and laminar connectivity in terms of physiological properties and specificity. Their high number alone (up to 75%) together with potentially different connectivity patterns and synaptic properties might change the view of how cortical networks process information considerably. Here, we used photostimulation to map long-range horizontal projections to layer 5B pyramidal neurons in acute cortical slices. For lateral distances of 200-1500µm, we found intact projections and characterized their physiological properties as well as their layer of origin. The average amplitude of EPSCs slightly dropped with distance, while strong connections were still present over long distances. Short and long range connections showed an equally high synaptic reliability of close to 100% in most tested synapses, the same level of amplitude variability, and an equally high temporal precision of <1ms. Indications for layer- and distance dependent differences in synaptic physiology are reported on especially for L5 and L6 projections. In summary, our data provide an initial parameterization of long-range connections, which could be used to refine structured models of cortical networks. We conclude that long-distance horizontal connections could represent a substantial fraction of inputs to the local, cortical network (Boucsein et al, 2011). Secondly, although they showed a slight drop in amplitude with increasing distance, they contribute with reliable and precise inputs to the single neurons in layer 5, thus impacting the local computation considerably.

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Synaptic regulation of spike firing in interneurons of the striatum in vivo

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The striatum, the major input nucleus of the basal ganglia, is numerically dominated by a single class of principal neurons, the GABAergic spiny projection neuron (SPN) that has been extensively studied both in vitro and in vivo. Much less is known about the sparsely distributed interneurons, principally the cholinergic interneuron (CIN) and the GABAergic fast-spiking interneuron (FSI). Here, we summarize results from two recent studies on these interneurons where we used in vivo intracellular recording techniques in urethane-anaesthetized rats (Schulz et al., J Neurosci 31[31], 2011; J Physiol, in press). Interneurons were identified by their characteristic responses to intracellular current steps and spike waveforms. Spontaneous spiking contained a high proportion (~45%) of short inter-spike intervals (ISI) of <30 ms in FSIs, but virtually none in CINs. Spiking patterns in CINs covered a broad spectrum ranging from regular tonic spiking to phasic activity despite very similar unimodal membrane potential distributions across neurons. In general, phasic spiking activity occurred in phase with the slow ECoG waves, whereas CINs exhibiting tonic regular spiking were little affected by afferent network activity. In contrast, FSIs exhibited transitions between Down and Up states very similar to SPNs. Compared to SPNs, the FSI Up state membrane potential was noisier and power spectra exhibited significantly larger power at frequencies in the gamma range (55-95 Hz). Cortical-evoked inputs had faster dynamics in FSIs than SPNs and the membrane potential preceding spontaneous spike discharge exhibited short and steep trajectories, suggesting that fast input components controlled spike output in FSIs. Intrinsic resonance mechanisms may have further enhanced the sensitivity of FSIs to fast oscillatory inputs. Induction of an activated ECoG state by local ejection of bicuculline into the superior colliculus, resulted in increased spike frequency in both interneuron classes without changing the overall distribution of ISIs. This manipulation also made CINs responsive to a light flashed into the contralateral eye. Typically, the response consisted of an excitation at short latency followed by a pause in spike firing, via an underlying depolarization-hyperpolarization membrane sequence. These results highlight the differential sensitivity of striatal interneurons to afferent synaptic signals and support a model where CINs modulate the striatal network in response to salient sensory bottom-up signals, while FSIs serve gating of top-down signals from the cortex during action selection and reward-related learning.
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References

[W 61] Self-organizing small-world networks are most robust against local disturbances
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Small-world networks display enhanced signal-propagation speed, computational power, and synchronizability. Neuronal networks in the brain share properties of small-world networks and, in addition, dynamically rewire their connectivity by forming and deleting synapses. It is unclear whether small world networks are best in repairing damages caused by loss of connections and input. Neuronal networks show a reciprocal interaction between topology and the flow of neuronal (electrical) activity they generate. Topology determines the activity flow through the network, whereas on a longer timescale, the flow of activity requires new connections to be formed or existing ones to be removed. Importantly, neurons try to maintain their electrical activity at a certain setpoint (homeostasis of electrical activity). That is if neurons loose synaptic input due to a lesion, they respond with a local change in connectivity to obtain more activity from different sources. Here we investigate by a computational modelling study based on a model for activity-dependent structural plasticity [1,2], first, how local changes in synaptic connectivity alter global network topology after a circumscribed loss of input; and second, which topologies best support network repair re-establishing homeostasis in electrical activity of all neurons. We found that reorganizing networks become more random as they form more long-range connections after a loss of input and those neurons loosing their input increase their centrality inbetweenness. Interestingly, an increased randomness and centrality inbetweenness has been recently found in functional connectivity of ipsilateral cortical and contralateral cerebellar networks following subcortical stroke [3]. As a second important result we found that small-world networks recover fastest compared to regular and random networks from a loss of input in terms that all neurons return to homeostasis in electrical activity. The small-worldness of brain networks may therefore have an evolutionary advantage since those networks are more robust against lesions than regular (and random) networks.

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References

[W 62] Rapid odor classification by divergent networking along the olfactory path
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Using the insect brain (honey bee) as a model we here concentrated on the influence of divergent connections between two subsequent neuropiles along the olfactory path. Divergency along a neuronal path is thought to be necessary to increase the degree of separation between incoming stimuli. In the present study we show that it is rather the speed of separation which is increased due to divergent connections than the separation itself.

In the honey bee, several hundred Projection Neuron (PN) axons from the primary olfactory processing center, the Antennal Lobe (AL), diverge onto a few hundred thousand intrinsic Kenyon Cells (KCs) in the next layer of processing in the Mushroom Bodies (MB). After being processed into the MB the Information is converged to a few hundred Extrinsic Neurons (ENs). We recorded responses of PNs (N=111) and ENs (N=75) to two odors and their mixture. Inter alia we analyzed the response latencies of single units as well as the related population response latencies by calculating the Euclidean Distances between the different odor representations. Odor stimuli were equally well classified by each ensemble. Surprisingly, the EN ensemble started separating approximately 20 milliseconds earlier than the PN ensemble and reached maximum separation 60-120 ms earlier. Simultaneous recordings showed that a few PNs respond 10 to 70 ms before the ENs, and they probably initiate the EN ensemble response. We suggest that a function of projection of fewer (PN) dimensions onto higher (KC) dimensions in the MB is to facilitate rapid odor classification rather than the classification itself. Further processing by the AL network at a longer timescale may provide more detailed information necessary for implementing other qualities of odors or plasticity.

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[W 63] Inhibition enhances capacity of sequence replay: a mean field model
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Sequences of neuronal activity patterns can be stored in networks of binary neurons with binary synapses. Patterns are bound into associations via the clipped Hebb rule proposed by Willshaw et al. in 1969 [1]. Such a memory representation is distributed and resilient against local damage.

Inspired by hippocampal replay of behavioral sequences [2] we study the capacity limit of a sparsely connected network. Reactivation of pyramidal neurons has been demonstrated to coincide with Sharp-Wave Ripple events (SWR). Recent evidence[4] suggests that each ripple is the framework of expression of a principal cell assembly, and that inhibition follows excitation in time.

In order to address the effect of inhibition, we extend on the mean-field model of a CA3-like recurrent excitatory network by Leibold and Kempter [4]. There, it was shown that successful replay requires a minimum sparseness in the code and that the network capacity increases with it. However, stability of replay is lost eventually.

Here, we found that the introduction of global inhibition feedback makes sequence replay possible with a sparser code, thereby increasing the memory capacity of the network. At the same time, the range of firing thresholds compatible with replay became broader, suggesting a more robust behavior with noisy, biological neurons.

Phase-space analysis with static linear inhibition implemented as a threshold shift showed that inhibition works by adaptively stabilizing unstable replay regimes.

The effect of a capacity increase visible under static inhibition was replicated when adding a third, inhibitory population to our mean-field model. The regions of stable replay calculated from both 2D and 3D models were verified in cellular simulations.

We conclude that any form of inhibition that offsets the activity background from non-memory-participating neurons, whether instantaneous or delayed provides a capacity increase.

References


[W 64] The role of fast inhibition in AMPA and NMDA receptor mediated network burst dynamics in cortical cultures

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Synchronous patterns of activity are considered to play an essential role in the development of neuronal networks within a wide range of brain structures (Shatz, 1990). Similarly, in net-
works of dissociated cortical neurons spontaneous activity appears in form of network-wide bursts (NB) that are thought to be generated by recurrent excitatory pathways (Robinson et al. 1993; Jimbo et al. 2000). Inhibitory pathways, which suppress excitation, are however also considered important in shaping NB dynamics. As in native cortical tissue, glutamatergic fast AMPA receptors (AMPA-R) and slow NMDA receptors (NMDA-R) are the main mediators of excitatory synaptic transmission among neurons in vitro and fast inhibition is mediated via GABA_A receptors (GABA_A-R) (Legrand et al. 2004). Despite of a solid characterization of AMPA-R, NMDA-R, and GABA_A-R at the monosynaptic level, their respective contributions to particular phases during the NBs are still not well understood.

In this work we studied the role of both, fast and slow recurrent excitatory pathways, in initiating and maintaining NBs by blocking AMPA-Rs or NMDA-Rs in cortical cultures in vitro. Additionally, we investigated the influence of fast inhibition on shaping mainly AMPA-R or NMDA-R mediated NBs by additional GABA_A-R blockage. Network-wide activity was recorded with 59 planar extracellular electrodes under different pharmacological conditions. We analyzed the changes of overall network activity, NB rate and NB structures between the baselines and either AMPA-R or NMDA-R blocked activity and further between the latter states and GABA_A-R blocked activity.

Our results show that overall firing rates decrease after blockage of each of the excitatory receptors and in turn increase after block of fast inhibition as expected. Moreover, under all pharmacological conditions spontaneous activity was organized in NBs. Investigating the role of AMPA-Rs and NMDA-Rs on NB dynamics revealed that overall firing rates decrease three times more by NMDA-R blockage than by AMPA-R blockage. In contrast, burst rates decrease 10 times more by AMPA-R blockage than by NMDA-R blockage. This indicates that AMPA-Rs are in greater charge of initiating NBs than NMDA-Rs which mainly contribute in maintaining already initiated activity.

Our results further show that NMDA-R blocked bursts become shorter containing fewer spikes than control bursts and conversely, AMPA-R blocked bursts become longer containing more spikes. We suggested that this involves differences in time course and strength of feedback inhibition during NBs between both conditions. We therefore identified the influence of fast inhibition on recurrent glutamatergic network activity by blocking GABA_A-Rs, finding that overall firing rates are nearly ten times higher when NMDA-Rs were blocked compared to network state where AMPA-Rs were blocked. Moreover, disinhibition of NMDA-R blocked networks enhanced the early and late phases of bursts, while disinhibition of AMPA-R blocked networks shortened the late phase of bursts. This indicates that GABA_A-Rs effectively shut down AMPA-R mediated spiking and on the other hand further dampens the NMDA-R mediated network activity.

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References

The antagonism between cognitive flexibility and stability: behavior, neural bases and interindividual differences
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In the present study, individual differences in cognitive flexibility and stability and their neural bases were examined using functional magnetic resonance imaging (fMRI). Starting from computational models of working memory by Durstewitz and Seamans (2008), a new behavioral paradigm was developed, allowing us to assess cognitive flexibility in terms of task switching costs as well as cognitive stability in terms of distracter suppression. Individual differences were additionally captured by the relative number of switches in an ambiguous condition. The behavioral data showed reliable switching and distracter costs as well as an increased difficulty in the ambiguous condition, both in reaction times and error costs. Task performance relied on a distributed system of lateral and medial frontal, parietal and occipital regions. Cognitive flexibility additionally induced increased activation in the middle frontal gyrus/inferior frontal sulcus, while distracter suppression elicited increased activation in right dorsolateral prefrontal cortex (DLPFC). Individual differences in cognitive flexibility modulated prefrontal processes, such that less flexible persons showed increased activity in the right inferior frontal junction area (IFJ) and bilateral DLPFC during task switching. The results of this study support a dichotomy of cognitive flexibility and stability and give first hints to the neural bases of interindividual differences in cognitive stability and flexibility.

References

A representation of projective and topological spatial terms within a neurodynamical framework for spatial language behaviors
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We have in previous work presented a neurodynamic model of spatial language behaviors based on the framework of dynamic neural fields. This model can produce relational spatial descriptions from a scene or use such a description to locate and identify a specific object, and it solves these tasks in a single biologically plausible architecture. It was used both in robotic applications [1] and in simulations of psychophysical experiments [2], where it quantitatively accounted for signatures of relational spatial term use and reference object selection in hu-
mans. The model receives real-world camera input and forms a simple representation of the visual scene. It uses object color as simple identifying feature and implements an attentional process to link object identities to locations. The system puts two objects selected from the visual scene in a spatial relation: a reference object on which the relation is anchored, and a target object whose position is described. A neural coordinate transformation process links object locations in the scene to a metric representation of relative positions. This relative position information, in turn, is connected to discrete representations of spatial terms through weight patterns that reflect spatial semantics.

Here, we show that this framework can be extended to a wider set of spatial relations and tasks. Previous implementations only supported the projective (i.e., direction sensitive) spatial terms "left", "right", "above", and "below", which have taken an eminent role in psychophysical literature. We add the topological (distance sensitive) spatial relations "near" and "far" as well as "between", and show that these can be treated by the same mechanisms. The term "between" takes a special role because it is a binary relation between three objects, that combines properties of both projective and topological relations. To accommodate for spatial descriptions using "between" and to generally increase the behavioral repertoire of the model, we now allow for multiple target and reference objects in a single relation. The dynamics of the neural field representations for target and reference object location were adjusted to support multi-item working memory. The application of the spatial semantics takes place in parallel for multiple locations, but additional control mechanisms were added to allow for sequential input and output of object identities. These extensions demonstrate the flexibility and adaptability of our neural framework for spatial language behaviors.

References

Variations of horizontal cortical network structures and their corresponding state space dynamics
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Neuronal wiring in the cortex exhibits a complex spatial pattern composed of local and long-range patchy connections [1,2]. Most studies on cortical networks dynamics, however, are either based on purely random wiring or neighbourhood couplings [3,4,5]. Assuming an enlarged spatial scale we analyzed the effect of different horizontal connectivities on the 'idle' dynamics of cortical networks. We considered purely random or purely local couplings, i.e. distance dependent connectivities, as well as mixed network architectures that also include spatially clustered projections. Our networks consisted of ~50.000 conductance based integrate-and-fire neurons, spatially embedded in a 2D sheet of cortex with a side length of five millimetres. Network dynamics were simulated with NEST/PyNN [6]. Focusing on the regularity and synchrony in neuronal spiking, we compared the spatio-temporal activity patterns and the phases
spaces of such network architectures. Different dynamical states (e.g. synchronous regular or asynchronous irregular firing) occurred, in dependence of the input rate and the relation between exc. and inh. synaptic strengths [3,4,5]. Assuming distance-dependent synaptic delays led to a first set of changes in the phase space of random networks [4]. In addition, we found that networks including local coupling exhibited higher firing rates, sharper transitions, as well as various types of complex network activities. In contrast to random networks, models with distance dependent connectivity architectures exhibited wave propagations. In order to capture such activity patterns we computed a delay-dependent correlation coefficient. The effect of including patchy projections, however, was not detectable from our analysis. Furthermore, to account for stability, we applied spatially restricted activity injections. Depending on the network architecture, the dynamics changed from a low activity state to high firing rates, and then switched back or not.

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References

|W 68| fMRI based Granger causality as a measure of effective connectivity in macaque visual cortex

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Granger causality (GC) analysis of fMRI blood oxygen level dependent (BOLD) time series has been proposed as a statistical tool to analyse directional influences between remote brain regions. Ongoing BOLD activity is treated as a set of stochastic time series (STS) generated by stochastic processes whose properties can be captured by autoregressive models. GC quantifies the improvement in predicting one brain region STS by inclusion of that from another region. Here, we show how GC can be tested using the ensemble of single-voxel time series in a region of interest (ROI). Granger causality was tested on F statistics derived from linear regression models using BOLD time series. Ongoing BOLD activity was extracted from four ROIs: three in V1 and one in MT/V5 area of the macaque visual cortex. fMRI scans were made under three stimulus conditions, whereby (1) a single ('centre') grating was presented, (2) the single grating was flanked by 2 additional gratings, and (3) only the flanking gratings were shown. ROIs were not spatially homogenous in their influence on each other; we found a variable number of voxel pairs with significant F statistics. GC analysis showed that the V1 ROI which represented the ‘centre’ grating was influenced by the MT/V5 ROI when centre-flanker stimuli were shown, but not by the V1 ROIs representing the flanking gratings. It thus
appears that centre-flanker interactions (at distances >3 deg of visual angle) arise mainly through feedback, not through lateral intra-areal connections.

Quantitative models for stimulus-response relations in neuronal networks in vitro

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Electrical stimulation of nervous tissue is increasingly used in the treatment of CNS disorders, in neurotechnological devices or in examining the physiological properties of single cells and the function of networks of neurons. Interactions between ongoing and evoked neuronal activity render the stimulus’ response sensitive to the network state and the history of previous activity. Here, we were interested in the interactions that arise between spontaneous and evoked network activity and how they shape and modulate stimulus-response relations. Our goal was to obtain analytical models for a user-defined interaction with neuronal activity.

We recorded and electrically stimulated rat cortical cell cultures on microelectrode arrays. Spontaneous network activity consisted of recurring periods of globally synchronized firing, so-called network bursts. The duration of intervals that preceded network bursts best predicted the length of the following network burst. Variable responses to electrical stimulation depended on the timing of stimulation relative to preceding network bursts. Response lengths increased exponentially and saturated with longer duration of pre-stimulus inactivity with $y(t) = A(1-e^{-\alpha t})$. Response delays, in turn, decreased exponentially and saturated at a low level with $y(t) = Be^{-\beta t} + C$. User-defined timing of stimulation relative to spontaneous activity significantly reduced trial-by-trial variability and thus facilitated further examinations on state-dependent stimulus-response relations.

Disinhibition by blockage of GABAA-receptors yielded \(\sim 183\%\) more spikes per network burst with \(\sim 88\%\) longer intervals and unchanged overall firing rates. The modulation of response delays by the duration of pre-stimulus inactivity persisted under disinhibition. The correlation between distance to stimulation site and response delay was enhanced and the speed of propagation clearly depended on stimulus-timing.

Facilitation of synaptic transmission by overexpressing DOC2B, a synaptic protein mainly involved in vesicle priming and docking, yielded \(\sim 39\%\) more spikes per network burst and \(\sim 72\%\) longer intervals. The rate parameter $\beta$ that describes the relation between recovery from pre-stimulus, burst-induced depression and response delay decreased in young networks (< 20 DIV) whereas it increased in old networks (\(\geq 20\) DIV) with DOC2B. This suggested slower and faster recovery, mediated by e.g. vesicle replenishment, depending on the network’s maturation state.

In summary, we identified explicit rules for the modulation of evoked responses by spontaneous activity in generic neuronal networks in vitro. Our data support a process of network depression due to depletion of readily releasable vesicles during network bursts followed by subsequent recovery.

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Asymmetric generalization of target jump adaptation suggests tuning changes at the level of motor goals -- a neuronal network simulation

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We previously presented a behavioral target jump paradigm (Westendorff et al., 2010), in which reach movements reliably adapted to target error alone, without prediction error caused by perturbed feedback about the hand position. The target jump task induced adaptation with an asymmetric generalization, i.e. reach corrections for the adapted target were transferred more strongly towards unperturbed probe targets which lay in the direction of the target jump, compared to probe targets in the opposite direction.

We here present a three-layer recurrent neuronal network with which we can simulate the reach adaptation behavior of the target jump paradigm. The presented model was previously used for simulating context-specific sensorimotor transformations (Brozovic, 2007) and needed only minor modifications for simulating the target jump task. After learning a 1-to-1 standard mapping from spatially local sensory input to a congruent motor output across the whole workspace, the model was re-trained at a single spatial position to perform a 15º rotation of the motor output relative to the local sensory input. In this adapted state the generalization of adaptation effects to unperturbed probe target locations was measured equivalently to human psychophysics. We analyzed the changes in the neuronal tuning properties at the different levels of the model in response to the induced target jump adaptation. The model reproduces the asymmetry in generalization observed in the experimental data. The strength of the asymmetry is dependent on the tuning width of neurons in the output layer, but can be robustly found over a wide range of parameters. The asymmetry of generalization is contingent upon changes of tuning properties in the hidden layer. If tuning changes in the hidden layer were prevented, than the model still adapted to the local target jump but showed symmetric generalization, which does not match the psychophysical results.

This implies that adaptation in the learning model is achieved by changes in the mapping from the input to the hidden layer, rather than changes in the mapping from the hidden to the output layer. Our results suggest that adaptation in our target jump task likely affects motor goal representations at early visuospatial stages of reach planning, rather than changes at the motor execution level. The simulations predict specific changes of tuning properties in areas like the posterior parietal cortex during target jump adaptation.

References
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Impact of intrinsic neuronal heterogeneity on firing rates and spike train correlations

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We studied the impact of neuronal heterogeneity on the spiking activities in a population of leaky integrate-and-fire neurons. In the high input regime, the sum of synaptic inputs to a neuron can be approximated by a fluctuating input noise, characterized by its mean and variance (Brunel & Hakim, 1999; Kuhn et al., 2004). Based on data from in vitro recordings (Padmanabhan and Urban, 2010) and new insights from mathematical analyses, we conclude that common input into heterogeneous neurons is better realized by an identical noise with different values of mean and variance than by the usual practice of adding independent noises to individual neurons. We identified the distinct roles of the mean and the variance for the spiking activity of a population of heterogeneous neurons. We found that the output firing rate of a neuron is largely shaped by the mean level of the noise, whereas the distributed values of the variance give rise to different degrees of imprecise spiking. To conclude, when receiving common input, heterogeneous neurons may differ considerably in their output firing rates, and their spikes may be jittered by several milliseconds, a phenomenon some researchers have termed “decorrelation” (Padmanabhan and Urban, 2010).

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References

Recurrent inhibitory coupling improves discrimination of temporal spike patterns
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Inhibitory neurons are considered to play a central role as rhythm generator and in shaping feed-forward receptive fields. While much attention has been paid to such effects on excitatory neurons, little is done to study these inhibitory neurons' ability to directly process information. Here we present a linear classification model that investigates the inner workings of a recurrent inhibitory neural network. Our work focuses on quantifying the performance of a recurrent network of inhibitory integrate-and-fire neurons in canonical classification tasks. The model begins with parallel independent excitatory Poisson inputs connected to the recurrent network. Then, the network output is feed-forwardly directed to a read-out linear classifier. The analysis is then conducted as a function of variables such as inhibitory weight, read-out delay, etc. to shed light on the principles behind the network’s computational capacity. It is found that there is an optimum weight amongst the inhibitory neurons that yields the best performance, and this improvement could be as much as 30%. The optimum weight is where
the sum of the network’s mutual information (MI) and binary MI is the highest, and it occurs when the network’s response to a stimulus is about 40%-50% silent. This illustrates how a recurrent neural network may optimize its topological parameters to obtain more computational capacity than a simple feed-forward network [1,2].

References

[W 73] From worms to humans: common principles of large-scale organization in the nervous system
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Despite the significant differences in the number of neurons and structures observed in the brains across the animal kingdom, the nervous systems of all animals suffer of similar limitations to acquire reliable information from the environment and serve the same functional purposes. These limitations and goals are the main driving forces shaping the large-scale architecture of the neuronal connectivity. Here, we review knowledge gained in the recent years by means of complex network analysis on the organization of both anatomical and functional connectivity of few species. They share a few fundamental architectural features: (i) neural systems possess short but abundant alternative processing paths, (ii) neurons and cortical regions form clusters of densely interconnected elements, and (iii) neural systems contain few network hubs. This architecture supports the idea that brain function is to be understood as emerging from the collective working of its constituents without a single coordinating center. The modular organization is a consequence of the specialization of different parts, and the highly interconnected hubs help in the integration and/or coordination of multisensory information.

[W 74] Dendritic versus somatic resonance
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Membrane-potential resonance characterizes the ability of a neuron to selectively respond to stimuli in a preferred frequency band. It has been associated with the occurrence of sub-threshold membrane-potential oscillations (MPOs) and has been shown to be of functional
relevance, as exemplified by the correlation of resonance frequencies with the spacing of grid fields in the entorhinal cortex [1] and the dependence of this spacing on the resonating H current [2].

Resonance arises from the interaction of passive and active membrane properties, usually requiring the presence of slowly-activating conductances that act as high-pass filters and are able to effectively oppose slow changes of the membrane potential. The distribution of slow conductances responsible for resonance (like H or M), however, can differ between the compartments within a neuron. In CA1 neurons, for example, it is known that the density of H channels increases by more than 60-fold from soma to dendrites and is largest in the distal parts of the dendritic tree [3]. Accordingly, resonance can also depend on the spatial localization within a cell. Still, cells are usually classified as either resonant or nonresonant on the basis of somatic injection of ZAP currents (sine-wave functions with a linear increase in frequency).

Here, we investigate to what extent and under which circumstances cells with dendritic resonance may be misclassified as nonresonant by somatic measurement of resonance properties. We use simple conductance-based multicompartmental models to analyze the effect of dendritic resonance on somatic input (and hence resonance estimates based on somatic recordings). We find that indeed, even a strong dendritic resonance may not be detectable with somatic ZAP protocols. The extent to which dendritic resonance is masked depends on neuronal morphology as well as the distribution of active conductances within the cell. In addition, we show that although dendritic resonance may not show up somatically, indirect consequences of dendritic resonance can affect the soma. In particular, MPOs of dendritic resonance-induced origin may propagate to the soma, leading to a situation where such cells when measured somatically do exhibit subthreshold MPOs in the apparent "absence" of resonance. A local dendritic resonance filters dendritic inputs - even if it should not show up somatically - and is hence crucial for the flow of information in neuronal networks. It is therefore important to identify the circumstances under which dendritic resonance could be missed in somatic assessment of resonance properties.

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References

[W 75] Compartment-specific projection patterns onto pyramidal cells in rat neocortex

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Pyramidal neurons in layer V of the neocortex constitute a major output population of the cortical network. Due to their good accessibility and their intricate morphology, showing a prominent apical dendrite spanning all cortical layers and terminating in an expanded tuft, these
cells have been utilized to characterize general principles of cellular physiology of cortical pyramidal cells. In particular, it has been shown that the apical dendrite and the soma undergo functional decoupling during maturation, resulting in a strong attenuation of EPSP’s arising from synapses located on the distal apical dendrite on their way to the soma. Furthermore, it was shown that apical dendrites of large layer V neurons are capable of active potential generation, such as Calcium- and NMDA-spikes. While connectivity of the somata was, up to now, extensively examined with anatomical, paired recording and photo stimulation methods, little is known about which populations of neurons project to the distal dendrite and are, thus, mainly involved in the generation of active potentials in the distal dendrite.

Here we used an experimental approach employing simultaneous distal dendritic and somatic patch-clamp recordings in vitro together with presynaptic glutamate uncaging to examine the properties and layer-dependent projection patterns onto the two compartments of layer V pyramidal neurons within the rat somatosensory cortex.

With this new combination of methods we were able to detect inputs from presynaptic neurons with a lateral distance of more than 1mm in acute brain slices and to compare the functional input maps from soma and apical dendrite. As reported previously, a substantial fraction of connections gave rise to EPSP’s which underwent a strong attenuation along the apical dendrite and were hardly detectable at the soma. Surprisingly, however, the functional maps derived from dendritic vs. somatic recordings showed considerable differences in the layer in which the somata of the presynaptic neurons were located. While we could confirm the established projection patterns onto the soma, originating from cells in layers II/III, V and VI, the presynaptic neurons projecting onto the distal dendrite predominantly originate from supra-granular layers. These compartment-specific projection patterns onto layer V pyramidal neurons point to a distributed integration of inputs coming from different cortical layers. These findings may help to further understand the role of dendritic integration in large layer V pyramidal cells, in particular the nonlinear mechanisms in the distal dendrite and the presynaptic populations involved in their generation.

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High-gamma coupling between and within human pre- and primary motor cortex during movements

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In this study, we investigated neuronal interactions between pre- and primary cortical motor areas and their information about movements by analyzing partial directed coherence (PDC) and phase locking values (PLV) of high-gamma (80-200Hz) electrocorticographic (ECoG) signals recordings in humans during visually cued and self-paced motor tasks.

Five types of motor tasks were performed (each by 2-6 subjects): (1) cued individual finger flexion; (2) cued 8-directional center-out joystick movement; (3) cued brain-controlled 1D cursor movement based on motor imagery; (4) cued brain-controlled 1D cursor movement based on motor movements; (5) self-paced left/right joystick movements.

We computed the PDC to analyze the directional interactions of high-gamma activities between pre-motor cortex (PM) and primary motor cortex (M1). The PDC from PM to M1 increased briefly before and during the movements, consistently across all five motor tasks. Additionally, the involvement of different parts of dorsal and ventral PM depended on whether the task was cued or self-paced: for cued movements (1-4), we observed an increase in the PDC from dorsal pre-motor to primary motor cortex, while for self-paced movements (5), the most prominent observation was an increase in the PDC from ventral pre-motor cortex to primary motor cortex.

For movement tasks (1) and (5) we investigated the dependence of PM-M1 interaction on the movement type. To this end, we computed the PLV separately for index and little finger movements and separately for left/right joystick movements, and decoded the movement type from single-trial PLVs. On average, we found that the movement type could be inferred correctly from the PLVs in about 80% of the trials.

Our results indicate that the directed coherence patterns reflect information flow from pre- to primary motor cortex during different types of motor tasks, and the involvement of different parts of pre-motor cortex, depending on whether movements are externally cued or self-paced. Moreover, the high-gamma phase coupling between PM and M1 depends on the type of movement performed and could, therefore, potentially be used as a neuronal control signal for brain-machine interfaces.

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An online brain-machine interface using decoding of movement direction from the human electrocorticogram

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A brain-machine interface (BMI) allows subjects to control an external actuator directly via their brain activity, without participation of the spinal cord or the peripheral motor system. BMIs can be characterized by the approach used to translate brain signals into effector movements. Here we use a “direct motor” BMI approach where movements of an artificial effector (e.g. movement of an arm prosthesis to the right) are controlled by motor cortical signals controlling the equivalent movements of the corresponding body limb (e.g. arm movement to the right). This approach has been successfully applied in monkeys and humans by accurately extracting parameters of movements from the spiking activity of multiple single-units. These spiking activities can only be recorded with electrodes implanted into the brain. Here we show that the same approach can be realized using brain activity measured directly at the surface of the human cortex (electrocorticogram, ECoG). Five subjects suffering from intractable pharmaco-resistant epilepsy voluntarily participated in the study after having given their informed consent (study approved by the Freiburg University Hospital's Ethics Committee). As part of pre-surgical diagnosis, all subjects had an 8x8 ECoG grid implanted subdurally over the hand/arm motor cortex. Subjects interacted with an experimental paradigm shown on a computer screen. Each trial consisted of a pause phase (1-2 sec) followed by a preparatory informative cue (1-2 sec) informing the subject to prepare for executing a hand/arm movement to the left or to the right (arm contralateral to the implantation site). After a delay of 2-3 sec, a go cue was presented and subjects executed the movement within the next three seconds. Subsequently, a cursor on the screen was moved according to the movement direction decoded from the subjects’ ECoG signals. Closed-loop BMI control of movement direction was realized using low-pass filtered ECoG signals during movement execution. Significant BMI control was achieved for 4 out of 5 subjects with correct directional decoding in 69%-86% of the trials (75% on average across all sessions). In one of the sessions BMI control was achieved using ECoG signals from only two neighbouring electrodes, indicating the feasibility of using smaller ECoG implants with smaller and/or denser electrode grids for direct motor BMI applications. Our results demonstrate the feasibility, in principle, of an online direct motor BMI using neuronal signals from the brain surface. Thus, for a direct motor BMI, ECoG might be used in conjunction with or an alternative to neuronal signals measured within the brain, with possible advantages due to reduced invasiveness.

Acknowledgements

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Incidence of a first stroke in Europe is about 1.1 million and prevalence about 6 million per year. Currently, about 75% of people affected by a stroke survive one year or more and this proportion will increase in the coming years due to enhanced quality in hyper-acute, follow-up acute and sub-acute care, and life-long treatment of these conditions. From all the stroke survivors showing no active upper limb motion at hospital admission, 14% showed complete recovery, while 30% showed partial recovery and 56% showed no recovery (Hendrick et al. 2002). Stroke survivors with chronic hand plegia and very low score in the Fugl-Meyer scale show limited residual muscle activity in the upper arm extensor muscles and normally no residual finger extension. Currently, there is no accepted and efficient rehabilitation strategy available that aims at reducing focal impairments in patients with chronic stroke and complete hand paralysis. In tight collaboration, the University of Tübingen (Germany) and the National Institutes of Health (NIH) demonstrated for the first time that stroke patients with complete hand paralysis can learn to control a magnetoencephalography (MEG) based Brain-Computer Interface (BCI) to drive a hand robotic orthosis (Buch et al. 2008). The BCI was used to move a cursor on a screen and depending on correct or incorrect response the hand orthotic device would or would not move the hand respectively. The results could not be translated out of the lab and patients needed the orthosis to move their hands. In a later study, we demonstrated that the combination of BCI and daily life-oriented physiotherapy can elicit functional recovery improving hand and arm movements as well as gait (Broetz et al. 2009). Furthermore, using a multimodal neuroimaging approach based on fMRI and diffusion tensor imaging (DTI) we investigated brain plasticity in the motor system along with longitudinal clinical assessments. We found a convergent association between functional and structural data in the ipsilesional premotor areas (Caria et al. 2010). Parallel to these findings we studied the effect of haptic feedback during the use of a sensorimotor rhythm (SMR) BCI. Here, an online EEG-based proprioceptive BCI was used for stroke rehabilitation (Ramos-Murguialday et al. 2009 & 2010) controlling a robotic exoskeleton online (250msec delay) using brain signals. In our study 36 chronic stroke patients with minimal residual hand extension underwent a 6-week daily online haptic-BCI rehabilitation therapy combined with goal-oriented physiotherapy. Several multimodal pre- and post-measurements were used to assess physiological and functional rehabilitation. The pre-measurements were conducted twice, two months before and immediately before the 6-week daily training. These two measurements allowed us to have a baseline of neurophysiological and psychophysiological data to check for stability and reliability of our measurements. The post-measurements were divided in two phases as well having one on the day after the last day of training and the second one six months later as a follow-up measurement. Magnetoencephalography (MEG) was used to measure sensory inputs using pneumatic vibrotactile actuators fixed to the index and pinky fingers and the lip. The ability to imagine and perform movement was assessed through a three-class protocol using MEG and functional magnetic resonance (fMRI). The MRI-scanner was also used to acquire important information related to anatomy and anatomical connectivity. To explore the corticospinal tract integrity, neuronavigated TMS was applied to the patients acquiring MEPs from lower and upper arm muscles and thus allowing us to have a more precise cortical map of
flexors and extensors. TMS was applied following several protocols to elicit more stable and greater MEPs using pre contraction or imagination of movement. Several movements included in the Fugl-Meyer scale were used to generate a protocol to register muscle activity from the healthy and paretic side for further comparisons. EEG screenings were performed in order to identify most relevant oscillatory brain frequencies and electrode positions during hand opening and closing. This information was used to set up the online proprioceptive BCI classifier. Other psychological and physiotherapeutical tests (e.g. Wolf Motor Function Test, Fugl-Meyer Score, Ashworth Scale, SEIQL) were performed to correlate functional scales with neurophysiological data. Patients were assigned into one of three different feedback contingency groups (positive, negative and non-contingent feedback). Pilot results of this clinical study will be presented and discussed.

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References

In vitro method for a stable activation of a single neuron by synaptic envelope stimulation
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Focal extracellular electrical stimulation of cultured cortical networks (CCNs) growing on micro-electrode-arrays (MEAs) gives rise to two different types of early (<15 ms) neuronal responses: (i) Extremely reliable spikes with high temporal precision (jitter <0.1 ms) that were described previously to be generated by direct stimulation of the neuronal machinery of mem-
brane excitability ("directly evoked spikes"), and (ii) fairly reliable yet temporally imprecise (jitter ca. 1 ms) responses, the "synaptically evoked spikes". Here we show that these latter spikes are synaptically mediated responses. Unlike direct responses, early synaptically activated spikes are modified by application of synaptic blockers. Response latency and jitter increases with blocker concentration, leading to gradually decreasing response probability and, eventually, complete abolishment of responses. Hence, changes in the synaptic population input are expressed in the response latency as well as the response probability of these neurons. The response characteristics to different stimulation amplitudes and frequencies provide further insight into synaptic population dynamics. Unlike directly evoked spikes, the response latency of synaptically mediated spikes decreases with increasing stimulation amplitude, probably due to stronger activation of the synaptic population. This offers a way to distinguish between direct and synaptically evoked responses without pharmacological intervention. With the objective to demonstrate the potential of this experimental approach for describing interactions between multi-synaptic input and the responding neuron, we employed a standard short-term plasticity protocol. Paired-pulse stimulation with amplitudes below threshold revealed up to threefold magnification of the response probability, comparing first and second responses. Furthermore, we successfully applied the Neuronal Response Clamp, a closed loop method that maintains stable various response features; we used that method to expose fluctuations in synaptic envelop threshold over extended timescales. The methods described offer a tool to monitor long-term response fluctuations and plasticity of a complete (lumped) elementary functional unit that includes the synapses activating a given neuron, its dendritic arborization and its somatic integration.

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Paralysis and brain-computer interface: Classical semantic conditioning for communication?
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The development of brain-computer interfaces (BCIs) over the last three decades has focused on providing a muscle-independent channel for communication. While locked-in patients can control BCIs with high accuracy, until now patients in the completely locked-in state (CLIS) have not be able to use BCI systems for communication. Based on Miller & Dworkin’s studies showing the impossibility of operant conditioning in curarized rats (Dworkin & Miller, 1986), we hypothesized that (i) the ability for operant learning gets lost in complete paralysis (ii)and classical conditioning may represent a more suitable learning paradigm for CLIS patients.
In this study we propose a differential semantic classical conditioning paradigm to enable basic YES/NO communication.
Four patients in the locked-in state (one female, ages 54, 44, 61, 37), diagnosed with Amyotrophic Lateral Sclerosis (ALS) participated in an EEG study. Each patient completed 12 sessions. All patients had very limited available communication and relied on head/eye tracking and blinking for expression of their thoughts and needs. To condition YES/NO responses in the EEG, patients listened to true and false statements (conditioned stimuli, CS1 and CS2) which were paired with two different loud tones (unconditioned stimuli, US1 and US2). The patients were instructed to think YES or NO after each true or false (respectively) statement. After pairing CS and US in the first 100 acquisition trials, conditioning trials (CS+ US) were mixed with trials in which the statements were no longer paired with the US. In this phase the EEG patterns after the unpaired statements were used for offline classification of the conditioned response (YES/NO thinking in the EEG). Stepwise linear discriminant analysis (SWLDA) was employed for this classification.

Preliminary classification results indicate the feasibility of the proposed paradigm for basic communication in severely impaired patients which have very limited means of communication. Ongoing measurements with CLIS patients will test the usefulness of this paradigm for enabling communication in patients with no alternative communication channel.

Acknowledgements
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References

[2009] Transcranial DC stimulation (tDCS) improves voluntary modulation of mu-rhythm used for brain-machine interface (BMI) control
Surjo R. Soekadar, Matthias Witkowski, Anusha Venkatakrishnan, Ander Ramos Murguialday, Leonardo G. Cohen and Niels Birbaumer

The development of non-invasive and invasive BMI systems that translate electric or metabolic brain signals into control commands of external devices has experienced an impressive growth over the last years. They usually rely on the subjects' ability to control neural activity. The more rapid and accurate the control of such activity, the more effective BMI systems are. However, learning to control such activity often requires extensive training and, thus, it would be desirable to find strategies to facilitate learning.

In the motor domain, learning can be improved through designing practice protocols and/or by combining practice with stimulation of the central nervous system in the form of transcranial magnetic (TMS) or direct current stimulation (tDCS) that can facilitate learning effects. It was shown that these stimulation techniques can influence brain rhythms. Some of these rhythms, as for example the mu-rhythm (8-13Hz), were successfully utilized to control BMI systems. Here, we pose the hypothesis that application of non-invasive cortical stimulation
over relevant brain regions facilitates control of neural activity in the mu-rhythm range used for online BMI control. If so, this could translate into better and more effective training protocols used in the context of assistive/biomimetic and restorative/biofeedback BMI systems. Preliminary data support this hypothesis. We found that 20 minutes of anodal tDCS delivered immediately before BMI training improved reliable production of event-related desynchronization (ERD) of mu-rhythms. Analysis of neurophysiologic correlates of this improvement indicated that tDCS improves consistency of ERD production and optimal timing of mu-rhythm modulation.

We propose that brain stimulation might improve efficiency of BMI systems and help elucidating mechanisms underlying voluntary control of neural activity.

Acknowledgements
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Intrinsic connectivity of the inferior colliculus using glutamate uncaging

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The inferior colliculus (IC) is an important information processing center in the auditory system. It acts as a hub in both the ascending and the descending auditory pathway. Previous studies suggested that the IC has anatomical fibrodendritic laminae and is tonotopically organized [1,2]. The intrinsic connectivity of the IC, which likely is crucial to auditory processing as well, is, however, only little investigated.

We study the intrinsic connectivity of the IC with photostimulation using caged MNI-glutamate in vitro in Mongolian gerbils. With our stimulus protocol action potentials can be evoked within in a 100 µm radius around the soma independent of cell type. Our data shows that IC cells receive both inhibitory and excitatory inputs from within the IC.

References
2. MM. Merzenich, MD Reid: Representation of the cochlea within the inferior colliculus of the cat. Brain Res. 1974 Sep 13; 77(3):397-415.

Human like trajectories for humanoid robots

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The neuronal basis of movement preparation, during which movement parameters such as movement direction are assigned values, is fairly well understood (Georgopoulos, 2000). Motor and premotor cortex as well as portions of the parietal cortex represent movement parameters through the activity of neuronal populations (Bastian et al., 2003; Cisek & Kalaska, 2005).

The parameter representation is of dynamic nature, updated in the course of movement. It adapts to boundary conditions of the motion plan or to environmental changes. Schwartz (2004) was able to decode motor cortical activity in the motor cortex and utilized this knowledge to drive a virtual or robotic end-effector. Thus he proved that the motor cortex is involved in the generation of movement planning. At this level of abstraction we assume that the movement of an end-effector, as well as human walking movement, is represented appropriately by its direction and satisfies other constraints, such as obstacle avoidance or movement coordination.

A neuronal dynamic of movement generates goal-directed movements and satisfies other constraints, such as obstacle avoidance. Movement is generated by choosing low-dimensional, behaviorally relevant state variables. Behavioral goals are represented as attractors of dynamical systems over such behavioral variables (Schöner et al., 1995). The robots trajectory emerges as a solution of these dynamical systems, in which the behavioral variables are stabilized at attractors corresponding to behavioral goals. Constraints are included in a similar manner as repellers. Recently we applied this approach to generate reaching movements for
manipulators under obstacle avoidance and orientation con- straints (Iossifidis & Schöner, 2009; Reimann et al., 2010a,b).

We aim to develop an approach to robotic action based on dynamical systems that is quantitatively modeled on human behavior. By varying the intrinsic parameters obtained for different individuals we will be able to implement different personal styles of movement. In this contribution we implement the neuronal dynamics of movement on a humanoid robotic system which generates goal-directed walking movements while avoiding obstacles.

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References

[W 84] A digital receptor neuron connecting remote sensor hardware to spiking neural networks
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Networks of spiking neurons (SNNs) and modulated connections between them are the core substrate for information processing in the nervous system. However, so far only few technical attempts to control artificial systems with the help of SNNs have been made. Here, we
present our early-stage work on the way to processing real world stimuli within an artificial neural network in order to reverse-engineer principles of neural systems in insects. We make use of iqr [Bernadet et al., 2010], a simulation environment designed “for the Construction of Multi-level Simulations of Brain and Behaviour”, and adapted this software to serve our needs. Specifically, (1) we created a digital receptor neuron (DRN) module that receives network input from sensors via UDP, (2) we extended the existing models of neurons and synapses to capture more aspects of biological neurons (conduction-based inputs, spike frequency adaptation), (3) we introduced simulation time as a state variable in the neuronal models to enable real-time synchronization, and (4) we contributed a raster plot as a means of visualizing spiking activity in small networks on the fly. In ongoing work models of chemoreception and olfactory processing [Krofczik et al., 2009; see also companion abstract by Meyer et al.], the neuronal representation of associative memories [Strube-Bloss et al., 2011; see also companion abstract by D’Albis et al.], and behavioral performances during classical conditioning [see companion abstract by Pamir et al.] are analyzed on the physiological and behavioral level. In order to deepen our understanding of the underlying principles we plan to use our tool to implement and test neuromorphic models in a robotic system.

Acknowledgements

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References


[W 85] Benefits of ego motion feedback for interactive experiments in virtual reality scenarios

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The investigation of neuronal accounts of cognition is closely linked to collaboration between behavioral experiments, theory and application and supports the process of moving from pure behaviorist correlation analysis to gaining a real understanding of the underlying mechanisms. Cognition builds upon the individual behavioral history, and the understanding of cognition is based on neuronal principles.

The study of human behavior incorporates in particular interactive, dynamically changing scenarios with multiple human individuals. Both the acquisition of behavioral data of human subjects, the modeling of behavior, as well as the evaluation in interactive scenarios, makes it necessary to generate simulated images of reality. Simulations allow the investigator to precisely control the structure of the environment the subject interacts with. Furthermore, situa-
tions that would be too dangerous in the real world (e.g. near-crash driving situations) can be investigated using virtual reality.

By nature, simulated reality frameworks are designed to simulate naturalistic environments. Within these environments, ecologically relevant stimuli embedded in a meaningful and controlled context can be presented. The quality of experimental data acquired within the simulated environment depends not to the last on the degree of immersion of the human subject. Driving experiments usually attempt to relate observable driver behavior to cognitive inputs. The precise visual (retinal) input of a driver in a driving simulator depends also on the exact position of his head with respect to the screen (Noth et al., 2010). The major meaning of ego motion feedback can be considered as a continuous calibration here.

In a virtual cooperation scenario, consistency matters - if an operator perceives an object at 1 m distance, moving 20 cm towards it should decrease the perceived distance to 80 cm, moving to the side of an object which occludes another one should reveal the latter (Pretto et al., 2009).

The ego-motion feedback mitigates the cues that remind operators of the fact that they are in a virtual and not in the real world. The way the appearance of a virtual object changes due to a lateral head movement is identical to its real counterpart, which means that even relations between real and virtual objects remain (Creem-Regehr et al., 2005; Cutting, 1997).

In this contribution we introduce a head tracking system which is utilized to incorporate human ego motion in simulated environments improving immersion in the context of a human-robot collaborative task and in an interactive driving simulator.

For both cases, we explain how the ego motion feedback leads to a more precise comprehension of the virtual scene and how the aspect of immersion influences the feeling of being “really” inside of the virtual scene and the weakening of the awareness of the border between the real and the virtual world.

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References
Collaborative efforts in neuroscience require efficient ways to organize neuroscience data for further analysis and computational modeling, as well as for sharing data between collaborators. A major obstacle to fully exploit the scientific potential of experimental data is the effort it takes to access both data and metadata for application of specific analysis methods, for exchange with collaborators, or for further analysis some time after the initial study was completed. At the German INCF Node, we provide tools together with a dataspace to reduce the time scientists usually spend on data management, import/export, conversion, keeping recorded data safe and properly archived. We support collaborations by providing an infrastructure to manage projects, experiments, permissions, upload data just through the web, using the G-Node Data Management Platform (www.g-node.org/data/). We address the problem of accessing data stored in different formats existing in Neuroscience, and provide a service for automatic data conversion. Basis for the development of data management infrastructure and tools are data models that reflect the conventions in neurophysiology and at the same time keep the balance between high flexibility, which is required to account for the diversity and complexity of current neurophysiology approaches, and standardization, which is necessary for reproducibility and efficient exchange of data.

To facilitate data annotation and metadata management, we support and utilize the Open metaData Markup Language (odML) approach. odML is an open, flexible and easy-to-use format to specify metadata for sharing it within the lab and between applications. This format specifies a hierarchical structure for storing arbitrary meta information as extended key-value pairs, which can be logically grouped into sections and subsections. The odML (http://www.gnode.org/projects/odml) defines the communication format, but does not restrict the content or its structure, so that it is inherently extensible and can be adapted flexibly to the specific requirements of any laboratory.

For organization and management of physiological recordings, we adopt the object model developed in the NEO project (http://packages.python.org/neo/). This approach provides common names and concepts to deal with electrophysiological data in an easy and well-structured way. It accounts for the trade-off between minimizing the data validation routine and at the same time keeping sufficient consistency. The NEO data model concept is already used in several neuroscientific projects (OpenElectrophy, NeuroTools) and thus provides a promising opportunity to cooperate with other initiatives while not increasing the number of existing standards. On top of this data model we develop a set of core services (Data API) and applications (Client API libraries), focusing on MatLab, Java and Python as the most popular languages and tools used in Neuroscience. This will enable scientists to integrate access, management, import, export, and exchange of their data with their common tools and workflows in the laboratory.

**Acknowledgements**
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**References**
Wachtl T, Nawrot MP, Benda J, Grewe J, Zito T, Schiegel W, Herz AVM (2009) Development of tools for data analysis and data sharing at the German Neuroinformatics node. 2nd INCF Congress of Neuroinformatics Pilsen, Czech Republic, September 6-8
Brain activity patterns and performance of children with Attention Deficit Hyperactivity Disorder (ADHD) compared to healthy controls during a working memory task - a functional near-infrared spectroscopy (fNIRS) study

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Objective
The aim of the study is to investigate differences in brain activity patterns (measured with fNIRS) and performance of children with attention deficit hyperactivity disorder (ADHD) and healthy control children during a working memory task. A previous fNIRS study conducted with adults showed significantly reduced prefrontal activation and poorer performance during a working memory task in the ADHD group compared to a healthy control group (Ehlis et al., 2008). It is assumed that these differences are observable as early as childhood.

Methods
To measure brain activity during the working memory task, a functional near-infrared spectroscopy (fNIRS) system is used (Hitachi ETG 4000). This system measures changes in oxygenated and deoxygenated haemoglobin on the cortical surface using light in the near-infrared spectrum (Obrig et al. 2000).

As performance data for the working memory task mean reaction times, standard deviation of reaction time, omission errors, commission errors and correct reactions are recorded.

Participants are children aged 7 to 10 years. So far, 9 children with ADHD (MW = 105.0 months, SD = 12.5; 7 male) and 7 healthy control children (MW = 103.3 months, SD = 14.9; 2 male) participated. The children with ADHD are pre-diagnosed by child psychiatrists or clinical psychologists and the diagnosis is confirmed with questionnaires according to the DSM-IV diagnostic criteria for the combined type of ADHD. For the healthy control group (CG), psychiatric and neurological diagnoses are exclusion criteria.

The computer-based working memory task consists of a picture-n-back-task with three conditions (0-back, 1-back, 2-back). Each condition is presented four times (total of 12 blocks). In each block, 15 pictures are presented, each block takes 30 seconds and is followed by a 20 seconds resting phase. The pictures are presented in a pseudo-randomized order to ensure that a constant number of target stimuli is presented (4 per block) and the difficulty of the blocks is equal. The blocks are presented in a randomized order, not beginning with a 2-back-block and without presenting the same condition consecutively.

Preliminary results: For the statistical analysis of the performance data Mann-Whitney-U tests for independent samples (ADHS vs control) were conducted for each condition (0-back, 1-back, 2-back) and for the whole working memory task. In addition effect sizes were calculated. Children with ADHD made more commission errors overall (ADHD commission errors Mdn = 4.00, CG commission errors Mdn = 1.00, U = 11.50, p < .05, r = -.54) and showed a less stable reaction time overall than healthy controls (ADHD standard deviation of reaction time Mdn = 228,26, CG standard deviation of reaction time Mdn = 168,11, U = 15,00, p < .05, r = -.44). There were no other significant performance differences between the groups. The effect sizes for the non-significant performance differences were small to medium (r = -.01 to -.41). The missing significances are possibly due to a lack of statistical power.

Perspective: fNIRS data will be analyzed and the focus will lie on enlarging the sample size with gender-matched participants.
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References
Multisensory integration via density estimation

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Multisensory integration is the task of combining redundant (i.e., statistically dependent) environmental cues into a single estimate for a common underlying stimulus; for example, the redundant - but presumably noisy - information about hand position provided by vision and proprioception. Statistically optimal combination of these signals weights them by their precisions (inverse variances) and yields a minimally varying estimator of the stimulus. Human perceptual and sensorimotor behavior have been shown to approach such statistical optimality in a variety of contexts, even when the redundant sensory signals are represented quite differently across modalities. For example, when planning and executing a reaching movement, we appear to approximate maximum-likelihood integration of visual and proprioceptive signals of the arm, despite their disparate encoding and the nonlinear relationship between the spaces of the two signals. Given the complexity of this and similar mappings, it seems likely that the neural mechanisms that implement sensory integration also learn it from experience; and indeed, learning of inter-sensory maps has been shown experimentally, in e.g. the auditory-visual maps of the barn owl. Here we ask how more complex multidimensional maps can be learned de novo by a relatively simple network from the joint statistical properties of the inputs.

Our approach is to learn to integrate by extracting the underlying causes from the data, via density estimation in a restricted Boltzmann machine (RBM). We show that the model can: learn to integrate nearly optimally; learn prior distributions over stimuli; integrate additional cues in hierarchical stages; learn to combine two independent cues with a third (as with gaze angle, retinal position, and proprioception); and generate missing data, e.g., to make predictions about one modality based on another, or to plan motor actions based on their hypothesized relationship.

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References
Evaluating the importance of different temporal features of calling songs in cricket phonotaxis

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Acoustic signals are used by Gryllus bimaculatus to communicate and they play a key role in mate choice. Males produce calling songs to attract females, females in turn use these songs to discriminate conspecific songs from the signals of other species. If they are willing to pair females approach the singing male - a behavior referred to as phonotaxis. So far, extensive behavioral experiments in which phonotactic responses of female crickets were tested by varying song features, revealed that song patterns are processed in the time rather than in the spectral domain [1]. Here, we explored the relevant cues for song pattern discrimination on several time scales.

We present feed-forward artificial neural networks (ANNs) that quantitatively predict the phonotactic value for untested calling songs that are described by temporal features such as duration, pause, period and duty cycle for both pulses and chirps. We employ ANNs with the following architecture: Input neurons representing temporal song features project to nonlinear neurons in the hidden layer which project to the output neuron that relates the phonotactic value. For training and testing the networks we used 218 artificial songs for which the phonotactic values had already been determined in experiments. Our complete ANNs that use eight temporal song features show a mean squared error (MSE) of MSE = 0.034. By a greedy backward elimination of features, we came up with minimal ANNs using just pulse period, chirp duration and chirp duty cycle as features. The dimensionality reduction of the feature space also improved the performance: The mean squared error for minimal networks is MSE = 0.019.

Thus, our findings suggest that among all tested temporal features, pulse period on the short time scale and chirp duration and chirp duty cycle on the long time scale are the most relevant ones for the evaluation of conspecific signals. Further, the minimal ANNs show high predictive power and can be used to complement experimental testing of female phonotaxis in the laboratory.

Acknowledgements
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References
Humans use for their spatially oriented behavior often a combination of vestibular and visual sensory cues to overcome problems inherent to each set of these cues (vestibular: noise, frequency transfer characteristics; vision: relative motion, saturation at high velocities). Having modeled human non-vision stance control and implemented the model into a robot with an artificial vestibular system and proprioceptors (Mergner 2010), we now aim to provide the robot with a human-inspired visual sensor and visual-vestibular fusion mechanisms. We start with corresponding human experiments. We evoke postural reactions through support surface tilts and analyze the response variations under defined visual conditions in order to identify the effects of the following 3 visual cues: body-relative-to-scene (1) angular velocity and (2) linear velocity, and (3) body angular position with respect to the visual vertical. We assume that these visual cues are complementary to vestibular signals and are fused with them. Here we present first results on stroboscopic illumination that allows to eliminate visual velocity information.

Six healthy subjects were presented with a pseudorandom tilt sequence of the support surface in the sagittal plane (spectrum, 0.016-2.2 Hz). Angular motion of trunk in space (TS; through hip control) and of leg in space (LS) were measured opto-electronically (Optotrak® 3020). Motion of center of whole-body mass (COM; through ankle control) was calculated thereof. The spectral characteristics of stimuli (tilts) and responses (LS, TS, and COM) were analyzed in terms of Bode histograms. Subjects were tested twice in each of the following three conditions: “eyes open”, “eyes closed”, and “eyes open with stroboscopic illumination” (strob. rate: 4, 6, 8, and 10 Hz; expos. time: 25 ms).

A. Providing full visual information with “eyes open” (position plus velocity information) compared to “eyes closed” improved stance stability in that (a) LS and COM excursion gain values were smaller (mid-frequency range, factor \(\approx 1.5\)), and (b) TS showed a similar reduction in excursion gain, but in addition a phase reversal.

B. Reduced visual information with “eyes open with stroboscopic illumination” (visual position information; reduced or no velocity information) compared to “eyes closed” yielded (a) no effects on LS and COM responses, and (b) reduced TS excursion gain (\(\approx\)half of that in A,b), but yielded no phase reversal.

These findings extend previous knowledge on the stroboscopic illumination effects in that specific effects of tilt frequency on hip and ankle control are identified. We now use these effects to explore which changes in vestibular parameters of our stance control model would allow to mimic the human findings.

References

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Neural correlates of auditory stimulus selectivity encoded by the precise temporal structure of EEG oscillations

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Oscillations prevail in encephalographic (EEG, MEG) signals and supposedly reflect cognitive processes such as sensory representations or the routing of sensory information [1]. Typical MEG/EEG studies focus on the relation between oscillation amplitude (power) and the
sensory-cognitive variables, making power an important marker for studying the brain [2].

However, recent studies have begun to also consider the dynamic signature of EEG/MEG signals, such as characterized by the phase of slow oscillations [3]. Several studies have shown that the precise temporal structure (phase) of slow encephalographic oscillations can be informative about sensory stimuli or details of the cognitive task. Noteworthy, in some studies the phase proved to be more informative about the presented stimuli than the same signal’s power [4,5,6].

However, the neural correlates underlying the information carrying capacity of the phase of slow oscillations remain unclear. We here directly tested whether the stimulus selectivity of low frequency EEG phase patterns indeed reflects the selectivity of neuronal firing in the underlying cortical areas. We employed the same naturalistic acoustic stimuli in two experiments, one recording scalp EEG in human subjects and another recording intracortical field potentials and single neurons in macaque auditory cortex (see e.g. [7]). Using stimulus decoding techniques we found that stimulus selective patterns of neural firing imprint on the phase of slow (theta band) oscillations rather than on their amplitudes. We found that sets of stimuli (sampled from the long acoustic stimulation sequence) that can be discriminated by the oscillatory phase pattern slow oscillations can also be discriminated by neural firing rates and vice versa. Importantly, no such relation was found between oscillatory power and firing rates. Our results demonstrate a level of interrelation between scalp EEGs and neuronal firing that pertains to stimulus selectivity (preference) and which goes beyond known correlations between the strength of neural firing and EEG oscillatory amplitude. Thereby our findings enhance the link between the activity of sensory cortical neurons and non-invasively measured field potentials, and improve the interpretation of EEG-based studies and their implications towards understanding the neural dynamics of sensory perception.

References
Spatial correlations in natural images have been considered repeatedly and are commonly characterized through their power spectrum, which has empirically been shown to fall approximately according to $1/f^2$, where $f$ is the spatial frequency. This has led several studies to propose explaining the properties of retinal ganglion cells and the psychophysically measured contrast sensitivity function in terms of these regularities. Similarly, psychophysical performance in a variety of contour perception tasks has been related to the distribution of edge elements in natural scenes.

But usually the power spectrum and the distribution of edge elements are treated as invariant across the visual field. Additionally the spectrum is reduced to a one-dimensional function of spatial frequency by rotationally averaging the two-dimensional spectrum assuming rotational invariance. Furthermore, the power spectra underlying such analysis are commonly obtained as averages over large sets of images. To reduce the redundancy, for instance, under the assumption of additive white noise, it can be shown that the optimal filter is the product of a whitening filter and a lowpass filter. This Wiener filter has been applied to natural images, the resulting filters have been shown to be closely related to retinal Ganglion cells’ receptive fields.

However, this method does not explain the variability of ganglion receptive fields across the visual field. We abandon the three assumptions above and show that taking into account the power spectrum variability, in terms of the orientation, position across the field of view leads to a rich set of filters, which can be succinctly captured parametrically. From the power spectra analysis, we generate a population of whitening filters. We verify that the emerged filters keep the center-surround shape, however, they do not have the usual circular concentric shape. Moreover, by explicitly modeling the geometric transforms imposed by the imaging process of the eye we furthermore estimate the distribution of edges across the visual field. This provides testable predictions of the properties of ganglion cells across the visual field.

We conclude that to understand properties of sensory neurons it is important not only to consider the regularities in the natural environment but also the regularities imposed by the imaging process.

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[W 93] Sensory selectivity in random cortical circuits
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How does selectivity to stimulus features arise in the sensory cortex? Experiment suggests that local connectivity in certain sensory cortical areas is not biased towards functional similarity but anatomical proximity, regardless of the existence of feature maps. On the other hand, computational models use structured connectivity and/or plasticity to achieve sensory selectivity. We use analytical and computational methods to show that recurrent networks in the balanced regime, where the network is driven by strong fluctuations as a result of strong excitation and inhibition, can generate selectivity to levels observed in biology with unbiased (both in the mean number of connections and connection weights) random connectivity in functional space. We use this idea to model rodent V1 layer 2/3 circuitry with input from an orientation selective pool of neurons, mimicking layer 4 cells. What causes selectivity in such a network? Irregularity due to random sampling causes neurons to receive non-uniform input
across changes in stimulus orientation. Connection probability conditioned on difference in preferred orientation is modulated with a small bias towards similar orientation preference. Furthermore, selectivity achieved in these networks is robust to contrast changes, a central feature observed in visual cortex, and to average number of input connections to a neuron. We compare the balanced network to a network characterized by weak synapses and hence driven by the mean signal. Although it is possible to achieve a high selectivity in this scenario, robustness to contrast and average number of input connections is lost. Finally we consider an application of the balanced network to rodent olfactory cortex and study odor representation in olfactory cortex with random projections from olfactory bulb.

[W 94] Exploring assembly dynamics in mouse V1 during natural visual stimulation
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The analysis of spatiotemporal activity patterns in the visual system is fundamental to understanding how visual scenes are encoded in cortex. Here we leverage state-of-the-art 3D Ca-imaging techniques (Gobel et al 2007) to record in vivo from primary visual cortex (V1) layer 2/3 of the mouse visual cortex during artificial and natural movie presentation. This technique allows simultaneous recording from large ensembles of neurons while retaining single cell resolution. The concurrent monitoring of many neurons within a functional column together with the use of dynamic stimuli allows for analysis of the size of local functional ensembles and inter-neuron correlations as well as the time-varying composition of the encoding ensemble. The analysis of such high dimensional data however remains technically challenging. One proposed method for detecting synchronous activity within cell assemblies is gravitational clustering (Baker & Gerstein 2000, Gerstein et al. 1985). The method proposes a transformation that maps the firing activity of neurons into motion of particles in a force field. These forces result in an aggregation of particles associated to neurons with correlated firing rates while separating particles representing neurons that fire independently. We combined gravitational clustering with principle component decomposition and conventional clustering methods to further reduce dimensionality, allowing us to better visualize the evolution of correlations between cells.

To calibrate our method we simulated noise processes that exhibit a dynamic spatio-temporal correlation structure which is then used to drive neuronal spiking. Gravitational clustering was able to correctly identify correlated neuronal assemblies and to describe the epochs during which they formed. In application to the high-dimensional imaging data we focus on the identification of cooperative groups of neurons within a single cortical column and visualize changes in neural synchrony over time and between stimuli.

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References

[W 95] Contrast invariance in recurrent networks of multiplicatively interacting neurons
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Contrast invariance has been reported as an important property of orientation selective neurons in primary visual cortex. Here we show that in random recurrent networks of multiplicatively interacting neurons, this phenomenon occurs in a natural way. There is no need to impose rectification by a transfer function, as it is the case in networks using the classical Wilson-Cowan model, since rectification arises as a consequence of the mean-field description of the network in form of coupled Lotka-Volterra rate equations. We show that the shapes of the output tuning curves obtained by network stimulation are invariant upon input scaling (contrast invariance). We also show that sharp orientation tuning can be obtained in an inhibition dominant operating regime of the network. Finally, we compare this behavior with simulated neuronal responses in a more realistic network of spiking leaky integrate-and-fire neurons. Summarizing we argue that the multiplicative model provides a mathematically convenient and biologically realistic description for the networks in visual cortex.

[W 96] A robotics-based approach to modelling choice reaching tasks
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The work presented here aims to develop a robotics-based model for choice reaching experiments (see [1]; for a review). In these experiments participants are asked to make rapid reach movements towards a target. Here we focus on modelling choice reaching experiments which gave some insight as to how visual attention operates by using an odd-colour search task, i.e. reaching for a green square among red squares and vice versa (e.g.[1]). In these studies Song and Nakayama showed that the attentional selection of the movement target operates in parallel with the execution of movements and that it is possible for the selection process to correct movements during their execution. Their conclusion is based on the finding that in a high number of trials movements were initially directed towards a distractor and only later were adjusted towards the target. These “curved” trajectories occurred particularly frequently when the target in the directly preceding trial had a different colour (priming effect). To mimic these visually-guided movements we embedded our current modelling approach to visual attention (e.g. [2]) in a closed-loop control of a robot arm (see [3] for examples of similar robotics-based research). The robot arm was built with LEGO Mindstorms NXT. The model input is provided by a camera filming the arm from a birds-eye view. Our modelling framework of
visual attention assumes that target selection is implemented through parallel interactions between competitive and cooperative processes in the brain. In order to link this model with the control of the robot arm it was extended with the aid of the dynamic neural field theory (DNFT) by [4]. Like our attentional model DNFT also postulates that dynamic processes are crucial for understanding human behaviour. Furthermore DNFT assumes that movement parameters are topologically represented in the brain. In the resulting model the attentional stage determines the location of the odd-colour target and, parallel to this, the dynamic neural fields calculate the movement parameters. The resulting model is able to mimic the results of the odd-colour search task including the priming effect. Interestingly the model also generates human-like trajectories with a bell-shaped velocity profile as a direct consequence of the way the dynamic neural fields generate movement parameters. In the future we plan to extend our model to be able to simulate a broader range of choice reaching experiments, e.g. the Simon effect [5].

References

Honeybee neurons use millisecond time-differences in stimulus coherence for odor-object segregation

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Segregating objects from background, and determining which of many concurrent stimuli belong to the same object, remains one of the most challenging unsolved problems both in neuroscience and in technical applications. While this phenomenon has been investigated in depth in visual and acoustic domains (Gestalt theory, cocktail party effect) it has never been addressed in the olfactory domain. Natural olfactory stimuli fluctuate at fast timescales, which in principle contain information about their constitution. However, it is not known whether and, if so, how animals use this temporal information to segregate concurrent odor-objects from independent odor sources. Thus, the study of odor processing needs a reassessment to take this fast timescale into account. We addressed this issue by combining physiological and behavioral experiments in honeybees. We searched for a neural mechanism of odor-object segregation and asked whether projection neurons in the antennal lobe (the insect homolog of the olfactory bulb) are influenced by short time delays in the onsets of individual components in odor mixtures. Using in vivo calcium imaging we found that the processing of temporally incoherent mixtures with 5 to 600 ms odor-onset delays between the components involved more inhibitory interactions than the processing of coherent mixtures. This inhibition appears to be mediated by a global rather than a glomerulus-specific circuit. Currently we are testing possible functional consequences of these inhibitory interactions, including computational models.
and behavioral experiments, to investigate whether honeybees could and actually do use millisecond temporal difference in stimulus coherence for odor-object perception.

Acknowledgements
We thank Nadine Treiber and Sophie Kroenlein for help with the behavioural experiments and the entire Galizia group for fruitful discussions.

[W 98] Induced Roelofs effect in reaching
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Goal-directed reaching requires accurate localization of the target object. But the localization of visual objects is prone to illusions induced by the visual context. In the induced Roelofs effect (IRE), the position of a task irrelevant visual object induces a shift in the localization of the visual target object. This is true when subjects have to indicate the position of the target object relative to an array of reference positions, e.g. by response keys or by pointing to it with delay. In contrast, when subjects in the same task indicate the position of the target object by pointing to it without instructed delay or by directly reaching towards it with or without delay, no IRE is induced [1]. This discrepancy was taken as evidence for separate visuospatial representations for direct sensorimotor processing compared to spatial cognitive processing [2]. Here we test if an IRE can also be induced for reaching movement towards the target stimulus, which would argue against such strictly separate processing.

We asked human subjects to perform reaches towards visual target stimuli in the frontoparallel plane. Each trial started with a brief appearance of a reference array (RA) of five horizontally arranged boxes which indicated the potential target positions. Then the target and a surrounding task-irrelevant visual frame were flashed, followed by a decision array (DA) immediately after the cue/frame offset. The DA was identical to the RA, but could be placed at different positions on the screen. While keeping ocular fixation, subjects had to reach towards the DA box which corresponded to the RA box in which they had seen the flashed target. The results showed a reliable IRE for reaching. In our task the reach goal needed to be defined relative to a task-relevant object, i.e. in an object-based reference frame, while in previous experiments the reach goal was directly defined by the target objects. The results suggest that during object-based encoding of motor goal locations, the information of additional task-irrelevant objects can induce systematic mis-localizations of the reach goal. This finding argues against strictly separate visuospatial representations for direct sensorimotor processing compared to spatial cognitive processing.

References
Top-down attentional bias for perception of tactile stimulus attributes

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The selective nature of human perception implies functional interactions between sensory processing and attentional control. Here, we used functional magnetic resonance imaging (fMRI) to investigate the cortical network involved in tactile change detection of multiple tactile features. Tactile stimuli of two different spatial patterns that could be presented at one or other temporal frequencies were presented via a fingertip-sized multi-pin stimulation device to the left index finger. The task was to attend to either the spatial pattern or the temporal frequency, in order to detect any occasional change in that respective stimulus attribute. Assessing task-dependent effects revealed a distributed network of somatosensory as well as prefrontal and parietal activations. Frontoparietal components of this network including the inferior frontal gyrus (IFG), the prefrontal cortex, and the intraparietal sulcus selectively responded to the detection of change in the task-relevant stimulus attribute. An additional analysis of effective connectivity assessed in terms of psychophysiological interactions (PPI; Friston et al. 1997) provided evidence that the primary somatosensory cortex, the secondary somatosensory cortex, and the IFG composed a network related to the functional integration of task-relevant sensory information into tactile processing circuits. Modeling context-dependent causal influences within this functional network using dynamic causal modeling (DCM; Friston et al. 2003) further revealed that the IFG was intimately involved in the coordination of top-down attentional control for specific stimulus features and the processing of bottom-up sensory information.

References

Responses to complex novel stimuli can be predicted by a simple neuron model of spike generation

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Sensory neurons have to encode stimuli that are drawn from distributions that considerably vary in their mean, standard deviation, spectral content, etc. depending on, for example, task or time of day. This potentially implies that a receptor neuron is driven in different dynamical regimes and that the neuron adapts on longer time scales to accommodate itself to such changes in the input statistics. Therefore, stimuli from all relevant statistics should be used when characterizing a neuron's responses. Alternatively, one can select a smaller set of stimulus classes for a characterization in form of, for example, a computational model and then
probe different dynamical regimes of the neuron to challenge this characterization. We exemplify the latter approach on the example of electroreceptive neurons of weakly electric fish. Weakly electric fish use their electric organ discharge (EOD) for electrolocation as well as for communication. Amplitude modulations (AM) of the fish's EOD are encoded in electroreceptors (p-units). Behaviorally relevant AMs result in communication contexts from the interaction with other fish, or in hunting tasks from prey. The receptor cells respond phase-locked and probabilistically to each EOD cycle and show prominent negative serial correlations between successive interspike intervals. We built a simple leaky integrate-and-fire model with adaptation current (LIFAC) and constrained its operating point and intrinsic noise strength by the baseline statistics of measured p-units, while we set its sensitivity and adaptation properties to match responses to step stimuli. This model then not only reproduces the baseline ISI distributions and serial correlations, but also successfully predicts the spike responses to AMs from communication contexts. Interactions of two fish produce sinusoidal beats of a given frequency that are transiently modulated by communication signals. Therefore, the stimuli we used to probe our model, contain more complex dynamics than those the model is adjusted for.

The generalizing properties of such a single cell model are based on the use of canonical models for the spike-generation and adaptation dynamics. By using established measurements to determine the parameters of the different processes, the model then captures the dynamics of the measured neuron for a large range of different stimulus classes. Therefore, we have shown that a simple model of spike generation can reproduce the behavior of a receptor cell to statistically different stimuli even when only constrained to its baseline statistics and step responses.

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**[W 101] Pharmacological analysis of the spatiotemporal activity pattern in the chicken optic tectum**

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The midbrain is an important processing area for sensory information in vertebrates. The optic tectum (TeO) and its mammalian counterpart, the superior colliculus, receive multimodal, topographic information and contain a sensory map which plays a role in spatial attention and in orientation movements. In avian, the TeO consists of 15 layers including separated input and output areas making it an ideal model system to study multimodal integration. Previous studies have mostly focused on characterization of particular cell types or cytochemistry. Only few studies have investigated network activation throughout the depth of the tectum.

Our aim is to analyze the architecture and function of tectal local neuronal circuitry as well as the interplay between the TeO and modulatory midbrain areas e.g. the nuclei isthmi. To understand those complex interactions, we need to explore the spatiotemporal activity patterns with respect to the general cytoarchitecture of the TeO.

We use an optical imaging approach with voltage sensitive dyes (RH795) to investigate population responses at a high temporal and spatial resolution in a chicken midbrain slice preparation. Thus, we can match activity patterns to the general layout of the TeO based on histological data. Based on histological data we can roughly link our findings with the general layout of the avian TeO.

Here, we show inter- and intralaminar neuronal activities under different pharmacological regimes. The TeO section was activated by electrical stimulation of afferent layers, which mimicked the input from retinal ganglion cells. This evoked a two-component neuronal response.
consisting of a short (~10 ms) and a long-lasting component (up to several hundred ms) extending (i) in layer 5, where horizontally aligned neurons are located, and (ii) into deeper layers along radial oriented neurons. Ca2+-free solution and AMPA receptor restricted activity to the site of stimulation, indicating that most of the signal was postsynaptic and glutamatergic. Disinhibition enhanced signal amplitudes and spatial extent of the excitation. Interestingly, cholinergic transmitters were important in retention of the inhibition in the slice preparation indicating complex local networks. We will propose a simple model for the circuitry in the TeO.
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