BP 12: Neuroscience

Time: Tuesday 10:30–12:15 Location: H44

Invited Talk BP 12.1 Tue 10:30 H44

The first micro seconds in the life of a nerve impulse — •Fred Wolf — MPI for Dynamics and Self-Organization, 37073 Goettingen, Germany

The first micro seconds in the life of a nerve impulse

Neurons process and encode information by generating sequences of action potentials(APs). In the living brain, neurons operate under an intense synaptic bombardment causing strong and seemingly random fluctuations of their membrane potentials. Recent theoretical studies have revealed that under such conditions apparently minor modifications of the initiation dynamics of APs can dramatically change the nature of AP encoding (1-4). These studies have triggered a re-evaluation of the dynamics of AP generation in real nerve cells (3-5). Intriguingly, these studies indicate that (i) the actual dynamics of neuronal APs qualitatively deviates from the predictions of the canonical and widely accepted physiological model of AP generation, the Hodgkin and Huxley model, and that (ii) the AP dynamics appears to be optimized for the processing of fast varying signals (3,4). Here, I will discuss theoretical analyses of neuronal encoding, biophysical models, and in vitro experiments supporting the hypothesis that a direct cooperativity between sodium channel molecules within the neuronal membrane forms the origin of this unanticipated phenomenon.

(1) Fourcaud-Trocme et al. J.N. 23:11628 (2003) (2) Naundorf, Geisel, Wolf J.C.N. 18:297 (2005) (3) Naundorf, Wolf, Volgushev Nature 440:1060 (2006) (4) Naundorf, Wolf, Volgushev Nature, 445:E2 (2007) (5) MacCormick, Shu, Yu Nature 445:E1 (2007)

BP 12.2 Tue 11:00 H44

On the stationary state of a network of inhibitory spiking neurons — •Wolfgang Kinzel — Theoretische Physik, Universität Würzburg

The background activity of a cortical neural network is modeled by a homogeneous integrate-and-fire network with unreliable inhibitory synapses. Numerical and analytical calculations show that the network relaxes into a stationary state of high attention. The majority of the neurons has a membrane potential just below the threshold; as a consequence the network can react immediately - on the time scale of synaptic transmission- on external pulses. The neurons fire with a low rate and with a broad distribution of interspike intervals. Firing events of the total network are correlated over short time periods. The firing rate increases linearly with external stimuli. In the limit of infinitely large networks, the synaptic noise decreases to zero. Nevertheless, the distribution of interspike intervals remains broad.

BP 12.3 Tue 11:15 H44

Stimulation mechanisms of neurons in dissociated networks on wide planar electrodes — •A. Reiher[1], H. Witte[1], A. Krtschil[1], A. de Lima[2], A. Nörenberg[2], T. Voigt[2], and A. Krost[1] — [1]Inst. of Exp. Physics, Uni Magdeburg, PO Box 4120, 39016 Magdeburg — [2]Inst. of Physiology, Uni Magdeburg, Leipziger Str. 44, 39120 Magdeburg

Dissociated nerve cells from embryonic rat cerebral cortex form electrophysiologically active networks. If these networks are cultured on planar interdigitated gold electrodes, the stimulation conditions and the response of the cells can be analyzed. A blockade of synaptic activity in networks with antagonists to neurotransmitters glutamate and $GABA_A$ receptors offers the possibility to investigate the stimulation mechanism of isolated neurons. A significant parameter for stimulation is the lateral distribution of the field strength along the interface. Measurements and simulations of the field strength exhibited a geometry induced enhanced field strength along the electrode edges. Position dependent analysis of stimulated somata in synaptically blocked networks revealed a sporadic correlation between the number of excited neurons and the local electrical field strength. We varied the density of cell extensions along the electrode edges in specially designed networks to investigate whether the stimulation is realized via somata or dendrites and axons. After blocking the synaptic transmission, the stimulation is more efficient via dendrites and axons. We explain the excitation mechanism taking into account the geometrical distribution of cell extensions crossing electrode areas of high electric field strengths.

BP 12.4 Tue 11:30 H44

Modeling Neural Correlates of Selective Attention — •Hecke Schrobsdorff[1,2], Matthias Ihrke[1,3], Jörg Behrendt[1,3], Björn Kabisch[1], Marcus Hasselhorn[1,3], and Michael Herrmann[1,2] — [1]Bernstein Center for Computational Neuroscience Göttingen — [2]Institute for Nonlinear Dynamics — [3]Georg-Elias-Müller Institute, Göttingen University

In order to reveal cognitive mechanisms of selective attention, we study the paradigm of negative priming. In negative priming experiments, subjects have to discriminate a target from a distractor stimulus. While identical targets in two subsequent displays, the positive priming condition, leads to a speedup in reaction time, the opposite effect, a slowdown, is achieved if the former distractor becomes target in the actual display, called negative priming.

We model the process of discrimination by a dynamical systems approach with an adaptive threshold suppressing irrelevant stimuli. Our model perfectly explains phenomenological data, furthermore it makes predictions about behavior in rare stimulus configurations. Semantic representations of different stimuli are modeled by an activation level of cell assemblies. Therefore the model provides an interpretation of systematic variations of event related potentials from EEG recordings during negative priming trials.

BP 12.5 Tue 11:45 H44

Sequential Desynchronization of Clusters in Neural Networks with Partial Post-Spike Response — •Christoph Kirst[1,2] and Marc Timme[2,3,4] — [1]Faculty of Mathematics, University of Cambridge, CB3 0WA, United Kindom — [2]Network Dynamics Group, Max Planck Insitute for Dynamics and Selforganisation and — [3]Bernstein Center for Computational Neuroscience Göttingen, Bunsenstr. 10, 37073 Göttingen, Germany — [4]Center for Applied Mathematics, Theoretical and Applied Mechanics, Kimball Hall, Cornell University, Ithaca, NY 14853, USA

The response of a biological neuron to incoming signals strongly depends on whether or not it has just emitted a spike. Here we propose an analytically tractable network model of spiking neurons with partial post-spike response, that bridges between total charge conservation and total charge loss of supra-threshold inputs considered in previous models. For a rise of the membrane potential towards the firing threshold with a convex shape we find a sequence of desynchronization transitions between sets of admissable cluster states that is controlled by the strength of the post-spike response. We explain the mechanism underlying this transition and reveal similar phenomena in biophysically detailed models.

BP 12.6 Tue 12:00 H44

Non-invasive detection of human brain function using diffusing-wave spectroscopy — J. Li[1], F. Jaillon[1], G. Dietsche[1], T. Elbert[2], B. Rockstroh[2], G. Maret[1], and •T. Gisler[1] — [1]Universität Konstanz, Fachbereich Physik, 78457 Konstanz — [2]Universität Konstanz, Fachbereich Psychologie, 78457 Konstanz

Near-infrared light which is multiply scattered by biological tissue contains rich information on microscopic motions of scatterers deep within the tissue. The analysis of the speckle pattern fluctuations in terms of microscopic particle displacements is the basis of diffusing-wave spectroscopy (DWS), the extension of quasi-elastic light scattering to the regime of strong multiple scattering.

DWS was recently used to detect the activation of the human motor cortex upon somatosensory stimulation through the intact scalp and skull [1, 2]. Analyzing the measured autocorrelation functions of the scattered electric field a significant, hemispherically asymmetric acceleration of the cortical dynamics upon stimulation was found.

The origin of this accelerated dynamics has not entirely been clarified. In this contribution we present DWS measurements with a multispeckle detection setup which allows to follow non-stationary scatterer dynamics upon different stimulation protocols (motor, visual, and memory) with a temporal resolution of 26ms and to discriminate scatterer dynamics related to pulsation from other mechanisms.

[1] T. Durduran et al., Opt. Lett. 29, 1766-1768 (2004). [2] J. Li et al., J. Biomed. Opt. 10, 044002-1-12 (2005).