EEG/LFP workshop: Understanding neural excitation/inhibition
1st September 2015, Sheffield, UK
Abstracts

Michael Okun: Coupling of individual cortical neurons to LFP - intracellular and extracellular views

Cortical LFP is among the most commonly observed and studied electrophysiological signals, yet some of its basic properties remain disputed. Thus, the introductory part of the talk will briefly describe the current state of the debate on the origins of LFP and its spatial spread.

The main part of the talk will be devoted to the relationship between the activity of individual cortical neurons and the nearby LFP. First, I will describe our and related works that studied the correlation of LFP to membrane potential and the excitatory and inhibitory synaptic inputs of single cells, and our finding that the spike-triggered LFP average (stLFP) faithfully reflects the correlation between the membrane potential of the neuron and the LFP. I will then tell about our recent effort to understand the heterogeneity of stLFP among neighbouring cortical neurons, and the possible mechanisms responsible for it.

Li I Zhang: Laminar processing and excitation/inhibition balance in the auditory cortex

Research in my laboratory has been centered on understanding how auditory information is progressively transformed and encoded by neural circuits along the ascending central auditory pathway for generating perception and behaviors. Taking this opportunity, I will share with you our progress in understanding the synaptic circuit basis for the specific and sequential laminar processing in each layer of the primary auditory cortex. I will describe how differential excitatory/inhibitory balance and interplay in terms of spectral, temporal and amplitopic relationships, which are inherited from variations of local circuits all recruiting a feedforward inhibitory circuit module, lead to differential laminar processing. In particular, I will discuss the circuit basis for the modulation of the cortical excitation/inhibition balance in different brain states.

Rune W. Berg: What can the spinal cord teach us about balanced networks, gain modulation and distributed population coding?

Motor patterns such as chewing, breathing, walking and scratching are primarily produced by neuronal circuits within the brainstem or spinal cord. These activities are produced by concerted neuronal activity, but little is known about their connectivity and the degree of participation of the individual neurons. To unravel the network dynamics we here use multi-channel (256 channels) in combination with intracellular single-neuron recordings in turtles performing scratch motor

patterns. We find 1) the synaptic input to individual neurons are often intense causing high-conductance states, which likely consist of balanced E/I. 2) The gain of motorneurons is changed in time on sub-second timescale, and this gain modulation is performed in a way that optimizes the muscular control, 3) the spike rate distribution across the neuronal population is "log-normally" shaped, i.e. normally shaped on logarithmic frequency-axis. Similar features are seen in other parts of the central nervous system, which suggest that we can address questions about balanced networks in the spinal cord that are otherwise difficult to address.

Ying Zheng: How synaptic excitation and inhibition may shape the dynamics of somatosensory evoked potentials

In this talk, a dynamic model of the local field potential (LFP) based on the co-tuning property of synaptic excitatory and inhibitory conductances of pyramidal neurons will be presented. The model will be used to estimate the excitatory and inhibitory components of LFP in the supragranular and granular layers of the neocortex of rodents. The validity of the model will be demonstrated on multi-channel micro-electrode data obtained during pharmacological manipulation of the balance between neural excitation and inhibition, by the micro-infusion of bicuculline in the barrel cortex of rodents. It will be shown that the positive deflection in the supragranular layer of the LFP is dependent solely on the excitatory synaptic activity of the local pyramidal neural population. Finally we present concurrent EEG/LFP recordings in the barrel cortex of rodents in response to whisker stimulation, and discuss the implications of our model on the interpretation of somatosensory evoked potentials.

Judith M. Ford: Predictive coding failures in psychosis

Psychosis is characterized by deficits in predictive coding: A basic inability to make valid predictions about the source and content of current sensations might produce misperceptions (e.g., hallucinations) and misinterpretations (e.g., delusions). That is, if predictive mechanisms are dysfunctional, sensations that should have been predicted, but were not, might take on inappropriate salience.

In this talk I will describe our efforts to study these prediction mechanisms, using both context-based and action-based paradigms. Context-based paradigms are the industry standard, but rely on appreciation, learning and remembering the context. Action-based paradigms, in which animals respond to sensations resulting from their own movements, are more ecologically valid and reproduce the innate experience of all species. In moving and navigating through the environment, animals need to both inhibit their responses to these self-generated sensations to prevent end-organ fatigue, and they need to herald the experiences so they can identify them as coming from self. I will discuss EEG and fMRI reflections of these signaling mechanisms and how they tend to be abnormal in psychosis.

Jorge Riera: Revisiting electrophysiological phenomena in the brain using a multi-scale approach

In this talk, I will revisit some concepts related to the multi-scale origin and the interpretation of electrophysiological phenomena in the brain. I will first examine how electrical events emerge from single neuron (i.e. micro-scale) to a neuronal mass (i.e. meso-scale), with emphasis on the differentiated proportions by means of which synapses and single spikes contribute to the local field potential (LFP). To that end, I use a methodology developed in our lab to analyze volumetric electrical activity of neuronal masses in the somatosensory barrel field and the auditory cortex of Wistar rats. The key elements of this methodology are a three-dimensional microelectrode array and a novel inverse method for the current source density analysis. I will discuss the interplay between excitatory and inhibitory populations in auditory signal codification, as well as notable geometrical aspects in neurons which determine the LFP visibility. In the second part of this talk, I will discuss emergent events from the meso-scale as multipolar source contributions (i.e. macro-scale) to the EEG and MEG. The general consensus for more than thirty years about the existence of common dipolar sources for the EEG and MEG is challenged using experimental data. To that end, we propose an analytical series expansion to represent the volumetric current density inside cortical columns, and used it to obtain closed expressions for the respective current multipolar components.

Elizabeth Milne: Unbalanced excitation and inhibition in autism spectrum conditions?

Autism spectrum conditions (ASC) are characterised by difficulties in social / communicative function, restricted interests and repetitive behaviours. The aetiology underlying ASC has not yet been identified, however one influential theory states that neural excitation and inhibition is unbalanced in ASC (Rubenstein & Merzenich, 2003). In this talk I will review existing evidence for this theory and consider how EEG can be used to investigate excitation / inhibition in clinical conditions including ASC. I will also highlight the fact that autism is highly heterogeneous and discuss the possibility that a single profile of unbalanced excitation / inhibition may not occur universally in ASC.

Scott Makeig: High-resolution imaging of effective sources of human scalp EEG data

Much research using human scalp electroencephalography (EEG) has explicitly or tacitly treated EEG potentials either as indexing diffuse electrical activity from everywhere in the head, with little or no regard for its exact brain origins, or as imagined currents proceeding directly upwards from each cortical area to a supervening recording electrode. This has led to EEG being viewed as at best a very fuzzy brain imaging modality, one far exceeded in resolution by fMRI and MEG imaging approaches. However, EEG has several unique advantages over these other non-invasive brain imaging modalities – it has high temporal resolution, is lightweight, portable and even wearable, and is much lower cost. In addition, the presumption that 'the EEG inverse problem' of determining the cortical sites contributing to scalp channel EEG recordings, and their individual cortical signals, is far more precisely solvable than previously imagined. One breakthrough occurred 20 years ago with the development of Independent Component Analysis (ICA). A second breakthrough, I believe, is the

recent development by my colleague Zeynep Akalin Acar of an approach for minimizing the major source of EEG localization error, the conductivity value of the skull. This value varies widely across subjects, ages, and genders, yet no established method for accurate measurement or estimation yet exists. Together, these advances mean that 10-20 or more distinct cortical source signals that contribute strongly to a given high-density scalp EEG recording can now be separated from the scalp data and moreover, the cortical locations and distributions of the supporting source patches can be imaged with at least cm-scale accuracy. This allows and invites a new era in human electrophysiological imaging for clinical and basic research purposes, in which high-density EEG recordings, combined with stable subject electrical head model for each subject derived from an MRI head image, will achieve the long dreamt-of goal of using EEG as a high-resolution cortical imaging modality. I will discuss possible applications and further research opportunities.