Simultaneous recordings of MEG and intracranial EEG

Organizer: Christian-G. Bénar and Sarang Dalal

Room: # 103

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Simultaneous Recordings of Invasive and Non-Invasive Electrophysiological Data: Novel Insights into Brain Dynamics

Magnetoencephalography and electroencephalography are formidable tools that provide non-invasive access to the complex spatio-temporal dynamics of brain networks at an exquisite temporal resolution. Yet this strength comes at a high cost : Before it reaches the surface, neuronal activity needs to be summed over neuronal ensembles and propagates through large areas of hierarchically organized and connected cerebral structures. Thus, it is not clear to which extent the activity of deep sources such as amygdala, hippocampus, thalamus, basal ganglia can be reliably extracted from surface signals. The only way to elucidate the relationships between remote surface signals and actual brain activity is to simultaneously record MEG or EEG with electrodes implanted within the brain. Moreover, such recordings open a unique opportunity to perform a combined analysis at the two levels of recordings, by analyzing networks between deep structures (seen in depth recordings) and the whole cortex (seen by MEG/EEG). Combining insights from invasive and non-invasive methods is an emerging trend that will undoubtedly enhance basic neuroscience as well as clinical research. The invited experts will share past and most recent findings on this topic and will provide an overview of where the field is heading in the near future.

Speakers:

- **Jean-Michel Badier** (Aix Marseille Université. INSERM. France)
  "Simultaneous MEG and Intracerebral recordings: Technical aspects and Virtual SEEG"

  MEG and invasive Stereotaxic EEG (SEEG) record the activity from the same origin but present different sensitivity. An important question is sensitivity of MEG to deep sources as well as the capacity of signal processing techniques to infer the origin of the signal. The best strategy to answer these questions is to record simultaneously MEG with SEEG.
  We will present how we solved various technical problems linked to the constraints of simultaneous MEG and invasive recordings. Compatibility of the materials, and physical limitations of surgical equipment have been solved by appropriate electrodes and fixation techniques. Electromagnetic perturbations have been solved by the use of totally electrically insulated EEG amplifiers.

  We will then show examples of recordings where activities present in the invasive recording can or cannot be seen with MEG. Finally reconstructions of source time courses with Independent Component Analysis and Beamforming reconstructions will be compared to the invasive recordings. More studies are required for investigating influence of noise and source location. Nevertheless, we will show that it is possible, even in the absence of apparent activity on MEG signal, to reconstruct cortical activations that are comparable with the invasive recordings.

- **Stefan Rampp** (Univ. Hospital Erlangen, Germany)
  "Invasive EEG and MEG – Clinical value"

  Invasive EEG (iEEG) recordings are considered the gold standard for localization of the epileptogenic zone. However, due to the limited spatial coverage and the "tunnel view" of individual electrodes, iEEG has to focus on specific regions where it offers excellent signal to noise ratios (SNR). MEG on the other hand provides a comprehensive view on the whole cortex. While the temporal resolution is excellent, SNR is much lower in comparison to iEEG. The combination of both in either separate or simultaneous recordings offers the best of both worlds. MEG focus localization provides non-redundant evidence. Using this information for planning of iEEG optimizes coverage and chances to adequately record the seizure onset. Simultaneous recordings allow evaluation of complex propagation patterns beyond the coverage of iEEG electrodes. It also enables the evaluation of MEG sensitivity for deep sources, e.g. in mesial temporal areas and in cases of depth-of-sulcus focal cortical dysplasia. Finally, the combination of iEEG and MEG can be utilized to detect, localize and validate subtle epileptic activity, such as high frequency oscillations. The presentation reviews such advantages, opportunities and challenges of combining iEEG and MEG in a clinical context.

- **Maité Crespo García** (Univ. of Konstanz, Germany)
  "Application of a MEG-iEEG simultaneous recording helps to validate slow-theta power decreases during the encoding of item-place associations"

  Numerous MEG/EEG studies have concluded that increased hippocampal theta power is associated with better subsequent episodic memory and spatial performance. However, recent invasive studies have shown that successful encoding of items and associations are mainly characterized by broad decreases in theta activity (3-8 Hz). To investigate this issue further, we focused on theta activity time-locked to the encoding of item-place associations during virtual spatial navigation. For this purpose, we used the rare opportunity to simultaneously record MEG and iEEG from an epilepsy surgery patient who was implanted in the left parietal and temporal cortex. We found that late 2-3 Hz slow-theta power and spatial accuracy were negatively correlated in sources of hippocampal-entorhinal complex (p-cluster <0.05). Functional connectivity analyses provided crucial insights: during power decreases, slow-theta in right anterior hippocampus and left inferior frontal gyrus phase-led the left lateral temporal cortex and predicted spatial accuracy. Our study allowed us to validate our MEG results obtained in a sample of healthy participants by showing similar phase-synchronization patterns referenced to either beamforming sources or intracranial signals. Taken together, our findings suggest that decreased slow-theta activity may reflect a neural mechanism underlying the encoding of detailed spatial information and item-context associations.

- **Karim Jerbi** (Univ. of Montreal, Canada)
  "Sailing the surface or diving into the deep ? Insights from simultaneous invasive and non-invasive brain recordings"

  Understanding the organization and functional role of large-scale brain networks requires not only access to brain signals with high temporal, spectral and spatial resolution, but also adequate sampling of the involved brain circuits. While invasive electrophysiological approaches such as stereotactic-EEG (SEEG), electrocorticography (EcoG) and deep brain stimulation (DBS) recordings all provide signals with high spatio-temporal resolution, they often lack spatial coverage and the recording sites are entirely determined by clinical requirements. By contrast, non-invasive methods including MEG and EEG provide full-head coverage which allows for source-level investigations of brain network dynamics. However their resolution is inherently limited by the inverse problem and by field spread or volume conduction effects. This talk will review ongoing work that explores data acquired simultaneously with invasive and non-invasive methods in order to bridge the link between these levels of observation. In particular, joint surface and depth recordings will be reported in patients with epilepsy and in patients suffering from bipolar disorders. Our findings advance our understanding of the relationship between surface and depth measurements of oscillatory brain dynamics, and provide potentially novel insights into the alteration of the latter in epilepsy and bipolar disorders.

- **Vladimir Litvak** (UCL Inst. of Neurology)
  "Oscillatory Cortico-Subcortical Networks: An Insight from Combined MEG, Intracranial Recordings and Deep Brain Stimulation"

  Deep Brain Stimulation (DBS) surgery affords a unique opportunity to record local field potentials (LFP) from sub-cortical structures in awake humans. Combining such recordings with MEG makes it possible to characterise the oscillatory connectivity of DBS targets with the rest of the brain and look at modulation of oscillatory activity and connectivity by tasks and treatment. Our analysis of combined LFP-MEG recordings in several different subcortical targets and several different disorders showed that oscillatory coherent cortico-subcortical networks are a ubiquitous feature in these data, suggesting that they are likely to also be present in the healthy brain. More recently we have been working on elucidating the possible computational role of these networks by combining MEG-LFP recordings with cognitive tasks tailored for each DBS target. I hope to present the first results from these projects as well as from our highly technically challenging project where we recorded LFP and MEG during clinically effective DBS in Parkinson’s Disease patients.