Resolution of Connectivity in Time and Frequency

Organizer: Stephen E. Robinson

Room: # 105

Date and Time: Thursday, October6 / 08:30-10:30

Beyond fMRI: What MEG Reveals about Functional Connectivity in the Time Domain
Brain activity is highly dynamic and is non-stationary. This fact should be obvious by observation of behavior. Functional imaging methods such as fMRI have emphasized the correlations of sub-Hertz activity. Electrophysiological methods such as MEG provide resolution of fast events in both the time and frequency domain. In this symposium we will explore how application of linear and non-linear techniques to MEG reveal the rapidly changing brain dynamics.

Speakers:

- **Mark Woolrich** (Univ. of Oxford, UK)
  "Fast transient spectrally-distinct networks"

  The importance of distributed networks in cognition is well established. In order to be able to respond to fast changing environments, the brain must be capable of coordinating networks on sub-second time-scales. While there has been some success in identifying networks using resting MEG, this has been somewhat limited to static descriptions (e.g. averaged over several seconds), and to using envelope (or power) correlations. Important questions remain unanswered: what specific mechanisms of interaction underpin these envelope correlations, and what are the dynamics of these interactions at very fast time-scales?
  In this talk, I will present an approach that can identify transient periods of distinct network dynamics, even if they persist for very short (<100ms) time-periods. Importantly, distinct networks dynamics are described using their cross-spectra, allowing for the possibility of interactions through phase locking. The approach is able to identify short-lived dynamics by recognizing when they repeat at different times, and thereby pool over them to provide good estimation of the cross-spectral patterns. Finally, I will show how the approach is providing novel insights in both task and rest data (e.g. in local field potential recordings and MEG), and in the clinical domain in psychiatric disorders.

- **Allison Nugent** (NIMH/NIH, USA)
  "Major Depressive Disorder: Disruption across the frequency spectrum"

  Major depressive disorder (MDD) is highly prevalent, frequently disabling, and sometimes fatal. Despite the severity of the public health problem, relatively little is known about the cause of MDD, and treatment is frequently inadequate. A wide array of neuroimaging techniques have been used to study MDD, including EEG and MEG. Frequently, electrophysiological studies of MDD investigate either a single frequency band of interest, or combine large groups of sensors. In our studies, we have begun to use data driven techniques to examine spatial spectral patterns of dysfunction in MDD, revealing that the abnormalities in regions known to be involved in depression, such as the amygdala, possess a complex electrophysiology. We have additionally examined cross-frequency interactions in depression, in hopes that a more comprehensive view of dysfunction in MDD may further our knowledge of this disorder and inform better treatments.

- **Michael Wibral** (Goethe Univ., Germany)
  "Tracking information transfer through cortex with (almost) single sample resolution"

  While anatomical connectivity is largely static on timescale of an experimental epoch in an MEG experiment, the information processing evolving on this fabric is highly dynamic. We have recently introduced two methods to localize information transfer in the brain in time with high resolution. First, we suggested a method based on ensembles of experimental repetitions to properly capture the time-dependent probability distributions in the data and to analyze information transfer for short time windows. Second, within such windows Lizier's method of local information dynamics that reaches all the way back to Fano's local mutual information can be used to give an informational value to every single sample of a recording, bringing the full time resolution of MEG to bear. We will demonstrate the application of these techniques to recordings from a Go/NoGO paradigm and in the investigation of information transfer through visual cortex in a closure task.

- **Matthew Brookes** (Univ. of Nottingham, UK)
  "Connectivity: It's About Time…"

  In the past decade, a vast number of neuroimaging studies have sought to elucidate networks of functional connectivity; specifically, the existence of multiple brain regions which appear to share temporal dynamics. This field has been dominated by functional magnetic resonance imaging (fMRI), however a number of recent studies have looked to MEG to elucidate the electrophysiological effects which underpin the apparent networks observed in the blood oxygenation level dependent (BOLD) haemodynamic signal. In this talk, I will summarise some of our own investigations in this area. I will begin by reviewing the relationship between networks of connectivity observed using fMRI and MEG; I will show that the two modalities are related and, most importantly, I will describe recent evidence which suggests that haemodynamic networks are not simply reflective of electrophysiological networks in isolated frequency bands, but rather are predicted by a non-linear combination of pan spectral and cross frequency electrophysiological interactions. Following this, I will move to the topic of dynamic connectivity. I will review evidence showing that connectivity is non-stationary, and I will show conclusively that, to gain a complete picture of network dynamics, one must assess connectivity on rapid timescales that are inaccessible to haemodynamic imaging.

- **Stephen E. Robinson** (NIMH/NIH, USA)
  "Frequency dependencies of information transfer"

  Transfer entropy (TE) is a non-linear measure of directional information transfer of how well knowledge of past signals from a pair of regions X and Y can predict future values of either X or Y. We have previously shown that the temporal evolution of TE can be observed using "leaky integrator" or sliding window techniques. Although it might seem that information transfer should be studied across the MEG's full range of frequencies, using data from n-back tests we have found that information transfer is not distributed uniformly across the frequency spectrum. We observe that TE is lowest and signal-to-noise is greatest at frequencies below about 50 Hz, where synchronous and rhythmic activity dominate. However, despite the poorer signal-to-noise, the magnitude of TE is generally greatest where asynchronous activity dominates above 150 Hz. These observations are general but depend upon the pair of brain regions that are selected. The frequency dependence of informational measures may provide additional markers for psychiatric disorders.