Abstracts

Friday, 5 December – Session I
Chair: Arno Villringer

Different aspects of cortical activity measured by MEG and EEG: Insights from studies on sleep spindles.

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MEG and EEG each provide different perspectives on neural activity. Particularly detailed information on neuronal action can be obtained through invasive recordings using both macro and microelectrodes. We have applied these multi-scalar techniques to investigate a ubiquitous normal oscillation – the sleep spindle. Sleep spindles are bursts of rhythmic 7-15 Hz activity, lasting ~1-3s, that occur during normal stage 2 sleep. In intact animals, spindles appear synchronous across the cortex and thalamus; it is assumed that this is true also in humans based on scalp EEG. We recorded 306 MEG channels simultaneously with 62 EEG channels during naturally-occurring spindles of stage 2 sleep in 7 healthy subjects. EEG recordings were highly coherent across the scalp, at the same time as MEG were clearly not. Often, spindles were apparent in MEG but not in EEG. These discrepancies were true for both monopolar EEG compared to magnetometers, and bipolar EEG to gradiometers. The location and timing of cortical sources inferred from EEG had a low correlation with those inferred from MEG. Intracranial recordings from 9 subjects with depth and/or grid electrodes demonstrated local generation of spindles in frontal, temporal and parietal cortices. Directly-recorded cortical generators are variable in phase, frequency and amplitude across regions, paralleling MEG and contrasting with EEG. Furthermore, depth spindles could occur without appearing in simultaneous EEG. Microelectrode array data suggests that the shifting patterns of local vs. diffuse spindle generation may reflect an alternation between thalamocortical core and matrix systems. Taken together, these findings suggest that spindles are, in fact, not a single coherent entity but are generated by multiple poorly correlated cortical domains. Furthermore, MEG may better represent distributed asynchronous cortical activity during spindles due to its more focal lead fields. More generally, it is combination of different techniques which allows us to more fully probe and understand neuronal function.

Functional connectivity studied by cross-frequency interactions in MEG data

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Traditionally coherence and phase-synchronization have been used as tools to study functional connectivity in human EEG and MEG data. Given the limited success of this approach applied to human data, the time is right for exploring other measures of functional connectivity. I will here give examples of cross-frequency analysis applied to both animal and human data. This includes phase-to-power and power-to-power couplings between signals in different frequency bands. The human examples include 1) task modulated trial-by-trial correlations between frontal theta and posterior alpha activity following errors in a Go-noGo paradigm and 2) trial-by-trial correlations between motor cortical beta activity and posterior gamma activity in a mental rotation task of limbs. The animal data focuses on theta phase to gamma power coupling between medial temporal lobe subregions in the behaving rat. These examples will support the case that functional connectivity can be studied from electro-physiological data by means of cross-frequency analysis.

Friday, 5 December – Session II
Chair: Thomas Jacobsen

MEG As A Tool For Cognitive Neuroscience

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The talk reviews main strengths of MEG as a tool in cognitive neuroscience. 1. Its temporal precision and resultant capability to localise brain processes indicating cognitive operations in time in the millisecond range make it possible to find out WHEN exactly cognitive brain operations take place. This is illustrated addressing the question when we understand signs and symbols, and when information bound to words are being recognized and accessed at different levels. 2. Using state-of-the-art distributed source localisation, it becomes possible to estimate the cortical areas activated during a cognitive process, a procedure best validated using fMRI. In addition to spatial localisation, MEG can determine the order of activation of areas, the spatio-temporal patterns of activation and we can link these activation patterns to specific cognitive processes, for example the perception of noise or speech. 3. More rigorous testing of cognitive theories is made possible by the comparison of theory-driven neural modelling and brain imaging with MEG and other imaging modalities. Neuronal network simulations that mimic the action of different cortical areas and other brain parts can be used to predict spatiotemporal activation patterns. The comparison of activations predicted by theory-driven network models and the factually observed activation spreading in the MEG brain response provides a stringent test of cognitive brain theories, a feature recently exemplified in the domain of attention and language.

Non-invasive investigation of neural communication in the human brain with MEG: Achievements, limitations and future directions

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Interactions between functionally specialised brain regions are crucial for normal brain function. Magnetoencephalography (MEG) is a technique suited to capture these interactions because it provides whole head measurements of brain activity in the millisecond range. However, volume conduction severely limits the use of connectivity measures computed directly between sensor recordings. Therefore, neuronal interactions should be studied on the level of the reconstructed sources. In the presentation I will review several methods which have been applied to investigate interactions between brain regions in source space. I will mainly focus on the different measures used to quantify connectivity, and on the different strategies adopted to identify regions of interest. Despite various successful accounts of MEG source connectivity, caution with respect to the interpretation of the results is still warranted. This is due to the fact that effects of volume conduction can never be completely abolished in source space. However, the ever increasing interest in non-invasive functional connectivity analysis with MEG and the rate of recent developments justify a fair degree of optimism regarding the future of this exciting area of research. MEG/EEG source connectivity analysis maximally exploits the unique capabilities of state-of-the-art electromagnetic measurement systems and will undoubtedly lead to new fascinating insights into the complex relation between the highly dynamic interactions of brain areas and human behaviour.

Friday, 5 December – Session III
Chair: Angela D. Friederici

MEG analysis in SPM

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I will review recent methodological developments for MEG/EEG analysis within the SPM software package (http://www.fil.ion.ucl.ac.uk/spm). For source reconstruction, the distributed minimum (L2) norm approach is framed within a Parametric Empirical Bayesian framework, which allows 1) use of multiple spatial priors (e.g, several hundred "sparse priors" on the sources), corresponding to covariance components whose relative weighting (degree of regularisation) is estimated automatically from the data using Expectation-Maximisation, 2) use of the Bayesian concept of "model evidence", in order to compare different models, 3) the localisation of total (induced+evoked) power, 4) use of spatial priors informed by averaging over a group of subjects, and 5) the use of inverse-normalised templates meshes for the neocortex, which provide a one-to-one mapping between individual and Talairach space, facilitating group analyses and the use of fMRI spatial priors. For statistics, developments include localisation in space, time and/or frequency using mass univariate statistics and Random Field Theory to correct for multiple comparisons. For connectivity analysis, developments revolve around Dynamic Causal Modelling of 1) evoked transients, and 2) nonlinear coupling between power induced in different frequency bands. Again, model evidence can be used to distinguish between models that consist of different sets of regions and/or different patterns of inter-regional connectivity.

Saturday, 6 December – Session IV
Chair: Burkhard Maess

Face-selective neural responses measured with MEG and fMRI

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Attentional modulation of face and house perception strongly modulates category-related neural responses that can be measured with functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG). MEG detects an early, transient face-selective response, the M170, as well as a weaker and earlier house-selective response. Directing attention to houses in ''double-exposure'' pictures of superimposed faces and houses strongly suppresses the characteristic, face-selective fMRI response in the lateral fusiform gyrus, whereas directing attention to faces strongly suppresses the house-selective response in the medial fusiform gyrus. By contrast, attention has no effect on the magnitude or latency of the M170 or the earlier house-selective response. Late (>190 ms) category-related MEG responses elicited by faces and houses, however, are strongly modulated by attention. These findings indicate that hemodynamic and electrophysiological measures of face-selective cortical processing complement each other. The hemodynamic signals reflect primarily late responses that can be modulated by feedback connections. By contrast, the early, face-specific M170 that is not modulated by attention likely reflects a rapid, feed-forward phase of face-selective processing. fMRI is relatively insensitive to this rapid and transient early stage of processing. Study of the temporal dynamics of face- and object-selective processing, therefore, requires high temporal resolution imaging methods, such as MEG.

Dynamic causal modelling of evoked brain activity: What does it offer to study MEG silent sources?

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The principal aim of Dynamic Causal Modelling (DCM) is to explain evoked brain responses as deterministic responses to some perturbations, i.e. stimuli, in terms of context-dependent coupling, which allows for differences in the shape of responses. These perturbations elicit changes in unobserved neuronal activity simulated in neural networks, which is transformed into observed macroscopic neuroimaging data using a modality-specific (MEG/EEG/fMRI) forward model. DCM for MEG/EEG (David et al., 2006) relies on a neuronal model of interactions between different neuronal populations that has been developed as a generic tool to analyse evoked potentials obtained at the scalp level for any kind of neuropsychological or cognitive experiment. The generative model of DCM for MEG/EEG (David et al., 2005) is based on the Jansen model (Jansen and Rit, 1995). It is combined with rules of cortical-cortical connectivity derived from the analysis of connections between the different cortical layers in the visual cortex of the monkey (Crick and Koch, 1998). The resulting model (David et al., 2005) including intrinsic and extrinsic cortical-cortical connections, is a set of differential equations describing interactions between different inhibitory and excitatory neuronal populations. It can be specified easily (using GUI of SPM software) to embed any hierarchical cortical-cortical network using forward, backward and lateral connections. The crucial point here is that the main purpose of the neuronal model, in the context of DCM, is to constrain cortical dynamics estimated from scalp data in a neuronally plausible way (time constants, propagation delay, directionality of the information transfer, etc.). In this talk, I will illustrate this specific point by showing, using an MEG dataset from Leipzig, how DCM can be used to study subcortical-cortical loops which are commonly assumed to be a priori out of reach of MEG.

Saturday, 6 December – Session IV
Chair: Thomas Knösche

How Can MEG Help Us Understand Narrative?

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We communicate on a daily basis using narrative: We gossip around the water cooler, we describe important events to our loved ones, and we use narrative skills to write a talk. Non-aphasic patients with frontotemporal dementia (FTD) have poorly focused, meandering speech that is poorly organized and frequently tangential. I present some recent work investigating the cognitive and neural basis for the narrative disorder in FTD. The content of FTD speech is semantically coherent and grammatically well-formed, but paragraph-length narrative appears to be impoverished in its structural organization. Our findings suggest that these FTD patients are insensitive to the hierarchical organization of events within a narrative. I also present recent fMRI investigations consistent with the hierarchical organization of narrative. Both structural atrophy in FTD patients and fMRI activation in healthy adults demonstrate a critical role for prefrontal cortex in the organization of narrative. The implementation of the organizational resources underlying narrative structure appears to depend on fine-grained temporal coordination, but the temporal resolution of fMRI techniques is less than optimal. EEG has good temporal resolution, but may not have the spatial resolution needed to distinguish between multiple frontal loci implicated in narrative. MEG would be an ideal technique to help develop insights into large-scale multi-component neural networks like sentence processing.