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Symposium 1: Phase (Basic MEG)

S1-1: Mechanisms for evoked responses
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Although brain responses evoked by sensory stimuli are virtually always the result of action potentials arriving at a source area, the details of the sequence of events at the target site may vary. This has caused controversy as to what are the most important mechanisms that result in an observable evoked response. According to several authors, phase resetting of the ongoing rhythmic neuronal activity is a major determinant of evoked potentials and fields. However, several other authors claim otherwise. In this paper, we will analyze the properties of the two possible basic evoked-response mechanisms: 1) Additive type: MEG/EEG responses result from neuronal activity that is (linearly) added to any background activity. 2) Phase-resetting type: The phase of ongoing rhythmic activity is reset by stimuli. In addition, we will describe how the suppression of ongoing activity by stimulation may give rise to an evoked response and how ongoing activity may affect the responsivity of neuronal networks to external stimuli. We conclude that although some of the most widely-publicized arguments in favor of the phase-resetting theory appear weak, the analysis of phase can play an important role in the interpretation of spontaneous and evoked MEG and EEG data.

S1-2: Neuromagnetic evaluation of binaural unmasking
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Binaural listening improves signal detection in the presence of background noise. This effect is known as binaural unmasking, and is related to the ability of the auditory system to extract interaural differences in auditory stimuli. The most common paradigm to assess binaural unmasking has been the measurement of the masking level difference (MLD), the masked threshold difference between the antiphase conditions, in which the signals are pi radians out of phase and the noise is in phase (SpiN0), and the homophasic conditions, in which the signals and noise are both in phase (S0N0). Under the optimum conditions, the magnitude of binaural unmasking assessed by the MLD exceeds 15 dB. In the present study, binaural unmasking was evaluated using auditory evoked magnetoencephalography (MEG) in eight healthy right-handed volunteers. Peak latency and amplitude of the N1m response to tone bursts of 250 Hz, 1000 Hz, and 4000 Hz were measured under S0N0 and SpiN0 conditions. N1m responses to stimuli at or above the psychophysical threshold were found bilaterally in all subjects except one who had only right hemispheric N1m. N1m response for the SpiN0 stimulus had larger amplitude and shorter latency than that for the S0N0 stimulus in each hemisphere and at each sound level. Neuromagnetic binaural unmasking was greatest around the threshold level, corresponding to psychophysical binaural unmasking; became smaller with greater stimuli, indicating the suprathreshold unmasking effect; and disappeared at around 15-20 dB above the threshold. Psychophysical binaural unmasking can be quantitatively evaluated by MEG in the auditory cortex level of the bilateral hemispheres.

S1-3: Somatosensory dynamic gamma-band synchrony: a neural code of sensorimotor dexterity
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Through a novel cerebral source extraction method from magnetoencephalographic signals, the Functional Source Separation (FSS), primary cortical codes of sensorimotor dexterity were investigated: in the somatosensory counterpart, through representation assessment of two fingers with different levels of functional skill. In the motor counterpart, through assessment of cortical features related to better and worst performances. During an isometric contraction, we found that synchronous activity of primary sensory and motor areas in the high gamma band was dependent on the performance level and with low variability in the healthy population, suggesting to be a sensorimotor feedback efficiency index, quantitatively estimating the continuous functional balance between primary sensory and motor areas devoted to hand control. In the sensorimotor cortex, each finger cortical representation was studied by separately
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providing a passive simple sensory stimulation. In the two hemispheres, neural oscillatory activity synchronization was analysed in the characteristic frequency bands by two dynamic measures, one isolating the phase locking between neural network components, the other reflecting the total number of synchronous recruited neurons. In the dominant hemisphere, the phase locking selectively in the gamma band was higher for the thumb than for the little finger and it correlated with the contra-lateral finger dexterity, scored by the Fingertip writing test. The gamma band amplitude showed similar tendency to the phase-locking, without reaching statistical significance. These findings suggest the dynamic gamma band phase locking as a code for finger dexterity in the primary sensory cortex, in addition to the magnification of somatotopic maps. This local index of intra-cortical connectivity was altered in mildly disabled relapsing-remitting multiple sclerosis patients, also in absence of any impairment of central sensory conduction. It is suggested that the diffuse damage influencing the multi-nodal network subtending complex cerebral functions in multiple sclerosis also affects intrinsic cortical connectivity in primary sensory areas.

S1-4: Long-range multi-frequency synchronization reveals large-scale sensorimotor networks in MEG source space

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Increasing evidence from human and non-human primate studies suggests that long-range cerebro-cerebral synchronization might be a signature of the ongoing communication between distant neural populations essential for integrative behaviour. In the present study, we investigate the modulation of inter-areal coupling in different frequency bands during a sustained visuomotor task recorded both with Magnetoencephalography (MEG) and intracortical EEG recordings in humans. Right-handed subjects were instructed to manipulate a track-ball continuously counteracting the unpredictable rotations of a cube displayed on a screen. MEG source activation time series were computed via minimum-norm estimation in single-trial mode and transformed to cerebral maps of task-related power and coherence modulations. Furthermore, the MEG source data were compared to the results of the spectral analysis of the depth recordings from implanted epilepsy patients performing the same task. Our results show modulations of oscillatory power in specific frequency bands in multiple areas including an increase in high gamma power (60-90 Hz) in motor and premotor areas during visuomotor control. Coherence analysis provides evidence for task-specific increases in low-frequency (2-5 Hz) coherence between the primary motor cortex (M1) and multiple cortical and subcortical brain areas forming large-scale functional networks including the fronto-parietal circuit and the cerebello-thalamo-cortical pathway. Furthermore, our study revealed further task-related long-distance coherence increases in high-gamma and alpha (8-12Hz) ranges in various structures. Finally, comparing intracerebral data with the MEG findings provides valuable insight both into the observed phenomena and the utility of each of the two techniques for the study of large-scale brain-dynamics.

S1-5: Relevance of pathological oscillatory synchronization revealed by MEG

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Oscillatory synchronization is a key mechanism in neuronal communication and functional integration and MEG offers the possibility to study this cortical synchronization non-invasively. In the past few years an emerging number of studies revealed that a variety of neuropsychiatric diseases are associated with an abnormal synchronization. Two good examples for this will be highlighted in this talk: Parkinson's Disease and Hepatic Encephalopathy. It could be shown that Parkinsonian resting tremor is associated with an oscillatory network comprising multiple cortical and subcortical brain areas, which interact in defined frequency ranges. Moreover, recent studies showed that couplings within this network are modulated by levodopa, the commonly used medication in Parkinson's Disease. So, it became possible to study neurophysiological effects of therapy. For Hepatic Encephalopathy (HE) an explicit relation between severity of disease and oscillatory synchronization phenomena could be shown: Frequency of coherences between brain and muscle activity and between cortical and subcortical areas decrease with worsening HE. The same applies to spontaneous resting state activity. Moreover, this is paralleled by a slowing of processing of visual stimuli: The so called critical flicker frequency decreases with deterioration of HE and can be used as a reliable measure of HE. Taken together, studying pathological oscillatory synchronization as revealed by MEG allows further insight into pathophysiological mechanisms and disease treatment and offers new perspectives for disease monitoring.