S16 - Symposium Session 16

Wednesday, September 28, 15:30 - 17:30
Sala Magna

PROBING CORTICAL OSCILLATIONS WITH TRANSCRANIAL STIMULATION

Chair: Dr. Bradley R Postle (U. Wisconsin-Madison)

Speakers: Massimini Marcello, Peter Brown, Gregor Thut, Bradley R. Postle

The past decade has witnessed an explosion of interest in cortical oscillations as a fundamental property of brain function. Oscillatory dynamics have been implicated in, for example, perception, binding information across anatomically distributed networks, navigation, memory, motor control, and conscious awareness. But although the role of neuronal oscillations in some physiological states, such as sleep, is universally accepted, the importance of oscillations for many classes of behavior remains unclear. Are the behaviorally correlated oscillations that are present in every type of physiological measurement, from intracranial electrophysiology to functional magnetic resonance imaging (fMRI), essential of the functions under study, or mere epiphenomena? Correlational techniques, no matter how technologically or analytically sophisticated, can never decisively answer this question. The recently developed procedures featured in this symposium, in contrast, offer a novel way to investigate the role of cortical oscillations in brain function. They do so by simultaneously stimulating the brain and measuring the consequences of this stimulation on brain activity. They not only bring to bear the principle that perturbation supports stronger inference about brain-behavior causality than does correlation, they also allow for nuanced investigation of oscillatory dynamics by, for example, controlling population-level oscillations via entrainment to an exogenous source, or observing individual variation in response to the selective biasing of oscillations within specific frequency bands. This symposium will illustrate the power of these approaches within four research domains: neural correlates of consciousness, visual perception and attention, working memory, and motor control.

ABSTRACTS

OSCILLATIONS AND EFFECTIVE CONNECTIVITY IN HUMAN CORTICOTHALAMIC NETWORKS

Authors: **Massimini Marcello**[1] , Mario Rosanova[1]
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Complex cognitive events, from sensory perception to dreams, are sustained by fast causal interactions -- effective connectivity -- among specialized cortical regions that are reflected in electroencephalogram (EEG) oscillations. We will demonstrate how combing EEG recordings with navigated transcranial magnetic stimulation (TMS/EEG) allows one to simultaneously measure evoked EEG rhythms and state-dependent cortical effective connectivity. This approach has revealed that each cortical region generates oscillations at a distinctive characteristic frequency (natural frequency), either when stimulated directly or when activated indirectly via TMS to another area. These high-frequency sustained TMS-evoked oscillations, together with long-range corticocortical interactions, are predictive of an individual's level of awareness: they are systematically reduced during loss of consciousness in deep sleep, anesthesia, and coma. Further, they are recovered during REM sleep, when subjects experience dreams, and in acute brain injured patients before they can reestablish a reliable communication with the environment. They are also sensitive to psychiatric diagnosis: a decrease in TMS-evoked potentials in the gamma band (30-50 Hz) and a reduced spreading of activation is observed selectively in schizophrenia patients. In this way, TMS/EEG measurements suggest the existence of a causal link between TMS-evoked oscillations and corticocortical connectivity. Thus, whereas observations of the spontaneous EEG are limited to inferences based on temporal correlations (cortical functional connectivity), applying controlled TMS perturbations to different cortical areas affords causal investigation of the functions of cortical effective connectivity.

FORCED SYNCHRONISATION OF NEURONES TO 20 HZ SLOWS VOLUNTARY MOVEMENT IN BOTH HEALTHY SUBJECTS AND PATIENTS WITH PARKINSON'S DISEASE

Authors: **Peter Brown**[1]
Affiliations: [1]Oxford University

Motor processing is accompanied by changes in the degree of oscillatory synchronisation of neurones within motor loops. One of the most prominent changes is a suppression of activity in the beta (~20 Hz) frequency band. Interest in beta activity is heightened by its pathological exaggeration in Parkinson's Disease (PD), where movements are dramatically slowed. However, whether attenuation of beta activity is a prerequisite for successful voluntary movement or just an epiphenomenon remains unclear. We investigated the question of causality by stimulating the motor cortex of healthy subjects using transcranial alternating current as they performed reaction time finger movements. Stimulation at 20 Hz did not affect response time but did reduce finger peak acceleration finger by ~20 %. This was not true of cortical stimulation at the control frequency of 5 Hz. Thus, artificially elevating neuronal synchronisation at 20 Hz impairs movement speed in healthy subjects. Does this mean that the elevated beta synchrony in PD compromises movement? Proving this is more difficult as spontaneous synchronisation may be at ceiling levels. Accordingly, we stimulated a subset of PD with relatively preserved finger tapping performance through existing therapeutic deep brain stimulation electrodes. Stimulating the subthalamic nucleus of such patients at 20 Hz again slowed movement. The results indicate that beta band synchronisation actively slows voluntary movement in both healthy subjects and PD patients, and that this is a property of beta activity at both cortical and subcortical levels. The findings also help explain why beta synchrony is increased in paradigms requiring response suppression and why therapeutic manoeuvres that reduce beta synchrony improve motor performance in PD.

REVEALING THE ROLE OF OSCILLATORY ACTIVITY IN VISUAL CORTEX EXCITABILITY AND VISUAL PERCEPTION USING TMS AND EEG

Authors: **Gregor Thut**[1]
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There is converging evidence from many fields in neuroscience including psychophysics, animal electrophysiology, and human electro-/magnetoencephalography (EEG/MEG) that brain oscillations in lower frequency bands (theta to alpha) play an important role in perception. This talk will cover the contribution of combining transcranial magnetic stimulation (TMS) with EEG to this topic. It will focus on rhythms of the visual brain and how their spectral features (power and phase) relate to TMS-inferred visual cortex excitability, and to visual perception. Although a growing body of EEG/MEG-data shows correlations between oscillatory state and behaviour, only by pairing instantaneous measures of oscillatory and excitability state can we see directly that it is fluctuations in cortical excitability that underlies these phenomena. I will survey recent studies on the relationship between spontaneous variability in ongoing brain oscillations, visual cortex excitability, and visual detection/discrimination. I will also present new data on how these oscillations over visual areas are modulated through non-visual input such as sounds (or direct stimulation through a single TMS pulse). These data reveal that sounds (or TMS) bias ongoing oscillations, such that they become phase-aligned to the non-visual event (occipital phase locking). Notably, the cross-modally evoked brain waves in lower frequency bands (here alpha) are co-varying (cycling) with TMS-inferred visual cortex excitability. This is supportive of phase-alignment playing a crucial role in shaping neuronal sensitivity. This also supports the notion that the sampling of sensory information is cyclic, and in alignment to natural brain rhythms (discrete sampling theory of perception).

SIMULTANEOUS RTMS-EEG REVEALS FUNCTIONAL ROLE OF OSCILLATORY DYNAMICS IN WORKING MEMORY

Authors: **Bradley R. Postle**[1]
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In previous work we have sought to determine the necessity for working memory of various cortical regions by targeting them with rTMS while subjects performed delayed-recognition tasks. Although this approach has yielded effective hypothesis tests, it has sometimes done so in unanticipated ways, such as when rTMS applied to posterior parietal cortex while subjects remembered the locations of stimuli produced an improvement in performance. To explore the factors underlying such “paradoxical” results, we repeated the experiment while simultaneously recording the EEG. The results revealed, with behavior-by-region specificity, two independent effects: (1) Individual differences in the effect of 10 Hz rTMS on power in the upper alpha band (~10-13 Hz) predicted individual differences in the effect of rTMS on performance (a negative relationship); and (2) Individual differences in the effect of rTMS on alpha:gamma phase locking (10:40 Hz) also predicted individual differences in the effect of rTMS on performance, but with a positive relationship. Thus, rTMS influenced the workings of two independent task-related processes. In the domain of verbal working memory, although our past work has reliably produced rTMS-related decrements in performance, EEG recordings also reveal individual differences, such that the magnitude of rTMS-related suppression of delay-period theta-band power predicts the magnitude of the rTMS-related behavioral impairment. The implications of these results are twofold. Methodologically, they demonstrate that the assumption that rTMS produces a “virtual lesion”, perhaps by “injecting noise” into neural circuits, is not always justified. Functionally, they identify causal evidence for the oscillatory mechanisms underlying putative cognitive mechanisms.