

Multimodal Approaches to Functional Neuroimaging: Towards Physiology-Empowered Brain Imaging

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While fMRI has become a cornerstone of modern cognitive neuroscience, it nevertheless suffers from important limitations. One of the most important limitations of fMRI is due to the fact that it measures brain activity only indirectly via activity-coupled changes in haemoglobin oxygenation. From these blood oxygenation level dependent (BOLD) signals it is not possible to recover all aspects of the underlying neuronal activity ('inverse problem' of fMRI). Important aspects of neuronal activity, e.g., the level of background activity, timing of action potentials, types of synaptic activity such as excitation versus inhibition cannot be recovered from fMRI signals alone. In animal studies this shortcoming has been addressed by simultaneously integrating invasive electrophysiological recordings (Logothetis et al. 2001). The aim of studies summarized in this talk is to provide a non-invasive multimodal approach applicable in human studies allowing to obtain some of the neurophysiological information which cannot be recovered from fMRI alone.

Subsequently, some three examples of fMRI limitations regarding the identification of underlying neurophysiology are given together with approaches to overcome them:

A) Background Activity: fMRI typically assumes an arbitrarily defined 'baseline' and thus does not allow to address the important level of background activity. The latter, however, is important particularly in the light of research findings indicating an interaction between background activity and evoked activity. Our approach to address this issue is based on simultaneous EEG-fMRI recordings. This allows for an identification of background rhythms in the EEG and to relate them to fMRI derived patterns of activation/deactivation.

B) Synaptic Inhibition and fMRI signals: fMRI correlates of inhibitory processes have been discussed controversially. We addressed this issue in several models of inhibition employing subliminal stimulation and transcallosal inhibition induced by transcranial magnetic stimulation together with recordings of haemoglobin oxygenation. Our studies indicate that the effect of inhibition on haemoglobin oxygenation is context-sensitive, in particular it seems to depend on the level of background activity.

C) Measurement of Action Potentials (AP). Action potentials occur on a time scale of milliseconds while the fMRI signal is measured at a temporal resolution on the order of seconds. Thus, it is not possible to draw conclusions about the occurrence and timing of AP based on the fMRI signal alone. Our approach to investigate APs in humans is based on the simultaneous recording of High-Frequency EEG-Bursts (HFB) occurring at a frequency of 600 Hz and fMRI. It has been shown that HFBs which occur after median nerve stimulation reflect evoked action potentials in thalamus and primary somatosensory cortex. We demonstrate that these measures of action potentials can be cross-correlated with the fMRI signal and typically be related to generation structures along the thalamocortical pathway of somatosensory processing.