Multimodal integration of high-density EEG and fMRI during controlled tasks and spontaneous epileptic activity

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Abstract:
Although fMRI has been proven to be a powerful technique to study brain activity with high spatial resolution and with almost homogeneous whole brain sensitivity, it has limited temporal resolution and infers brain activity indirectly through hemodynamic changes. Electroencephalography (EEG) provides high temporal resolution but lacks the spatial resolution of fMRI and it has an inhomogeneous sensitivity profile – being less sensitive to deeper brain regions. These distinct properties make simultaneous EEG/fMRI a perfect candidate for multimodal integration. However, simultaneous acquisition of EEG and fMRI is not trivial due to high magnetic fields, and leads to many artifacts especially on the EEG signals (e.g., ballistocardiogram, gradient, cyrocooler artifact). These artifacts, so far, limited the use of EEG mainly to define regressors for fMRI analysis.

One such application is detecting interictal epileptic discharges from simultaneously measured EEG and then performing fMRI analysis to determine hemodynamic correlates. This is a powerful way of multimodal integration but it still does not fully benefit from the rich information brought by EEG. The advancements in signal processing techniques and hardware now make it possible to acquire decent quality high-density EEG (hdEEG, 256 channels) simultaneously with fMRI.

In this talk the focus will be on integrating simultaneously measured hdEEG/fMRI and how to better exploit the EEG information for this purpose. Unlike most of the previous studies we performed this integration not only at the sensor level but also at the source (cortex level) by performing EEG source analysis. The differences and similarities will be stressed by investigating results obtained from hdEEG measured both inside and outside the MR scanner. We used wavelet-based Maximum Entropy on the Mean (wMEM) method, which provides a unified framework to handle source localization of oscillatory patterns in the time-frequency domain by combining discrete wavelet representation for temporal modeling. The wMEM allows focusing on a few time-scale components (or frequency bands) that correspond to specific oscillations and correctly estimating the spatial extent of their generators along the cortex. Moreover, this method benefits from efficient filtering properties of discrete wavelet decomposition to cope with additional artifacts and noisier conditions inside the MR scanner. After providing our findings on well controlled tasks such as median nerve stimulation and finger tapping, the outcomes of this multimodal integration in studying epileptic activity will be presented.