Improved Estimation of Human Cortical Activity and Connectivity with the Multimodal Integration of High Resolution EEG Recordings and Hemodynamic Data

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Abstract: Nowadays, several types of brain imaging device are available to provide images of the functional activity of the cerebral cortex based on hemodynamic, metabolic, or electromagnetic measurements. However, static images of brain regions activated during particular tasks do not convey the information of how these regions communicate with each other. In this study, advanced methods for the estimation of cortical connectivity from combined high-resolution electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) data are presented. These methods include a subject's multicompartment head model (scalp, skull, dura mater, cortex) constructed from individual magnetic resonance images, multidipole source model, and regularized linear inverse source estimates of cortical current density. Determination of the priors in the resolution of the linear inverse problem was performed with the use of information from the hemodynamic responses of the cortical areas as revealed by block-designed (strength of activated voxels) fMRI. We estimate functional cortical connectivity by computing the directed transfer function (DTF) on the estimated cortical current density waveforms in regions of interest (ROIs) on the modeled cortical mantle. The proposed method was able to unveil the direction of the information flow between the cortical regions of interest, as it is directional in nature. Furthermore, this method allowsto detect changes in the time course of information flow between cortical regions in different frequency bands. The reliability of these techniques was further demonstrated by elaboration of high-resolution EEG and fMRI signals collected during visually triggered finger movements in four healthy subjects. Connectivity patterns estimated for this task reveal an involvement of right parietal and bilateral premotor and prefrontal cortical areas. This cortical region involvement resembles that revealed in previous studies where visually triggered finger movements were analyzed with the use of separate EEG or fMRI measurements