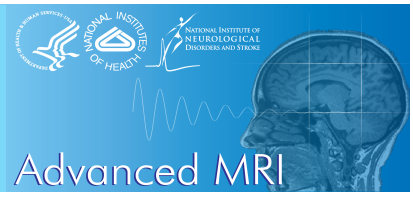
Neuroelectric Decomposition of Resting State fMRI

Zhongming Liu, Jacco de Zwart, Catie Chang, Qi Duan, Peter van Gelderen, Jeff Duyn

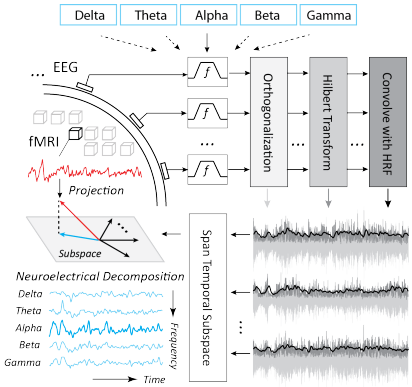
Advanced MRI Section, LFMI, NINDS, National Institutes of Health, Bethesda, Maryland



Introduction

Here we aim to identify, characterize and separate distinct neuronal contributions to resting state fMRI and its correlation structure. We present a novel subspace analysis method[1], based on concurrent fMRI and EEG[2], to decompose the fMRI signal at each voxel into multiple component time-series signals that are temporally correlated with distinct EEG spectral components. By using this method, resting state fMRI signals can be analyzed in an EEG-frequency-specific manner, yielding spectral signatures in the EEG correlates of spontaneous fMRI signals at individual brain regions and the temporal synchronization among widely distributed regions. These spectral signatures can offer important clues for disentangling the involvement of individual regions in network activity.

Methods and Materials

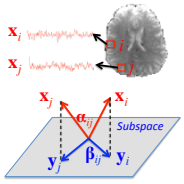


Simultaneous EEG and fMRI

10-min Eyes-Closed Resting State

15 Healthy Volunteers

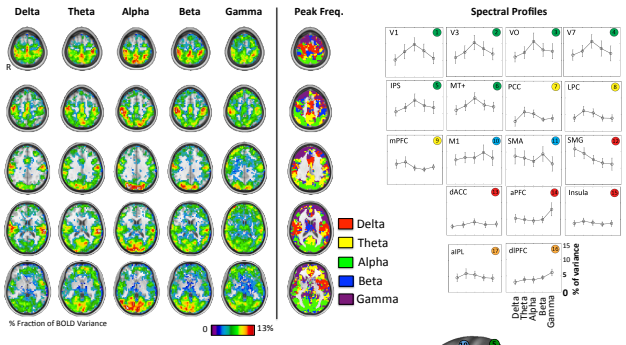
Functional Connectivity



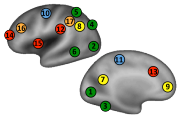
4-D fMRI

5-D fMRI (3D Space + 1D Time + 1D Frequency)

Neuronal Spectral Signature of Regional fMRI Activity



Regional BOLD signal variance explained by distinct EEG frequency bands. The first through fifth columns show the significant fractional variance explained by each EEG frequency band. The sixth column shows the color-coded map of the peak frequency band that accounted for the most variance for each voxel.

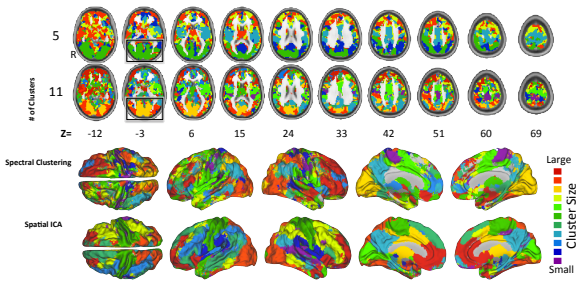


References

1. Liu, Z, de Zwart JA, Chang C, Duan Q, van Gelderen P, Duyn JH (2013) Neuroelectrical Decomposition of Spontaneous Brain Activity Measured with Functional Magnetic Resonance Imaging. Cerebral Cortex, in press.
2. Liu Z, de Zwart JA, van Gelderen P, Kuo L-W, Duyn JH (2012) Statistical Feature Extraction for Artifact Removal from Concurrent fMRI-EEG Recordings. NeuroImage, 59:2073-2087.

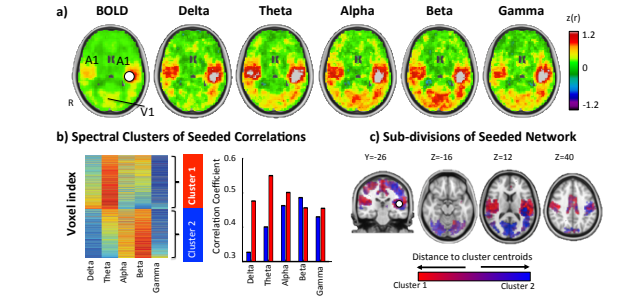
Correspondence to Zhongming Liu at liuz5@mail.nih.gov

Brain Parcellation based on Regional Spectral Signatures

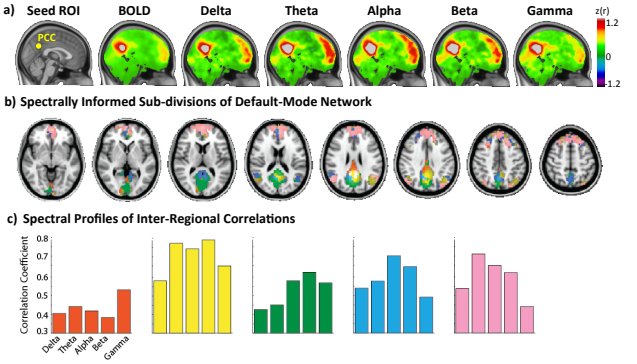


Spectrally informed parcellation of brain regions. a) 5 and 11 spectral clusters are color-coded and shown in axial slices. b) The 11 spectral clusters shown on cortical surface, in comparison with 11 spatial ICA components. The color indicates the cluster size.

Neuronal Spectral Signature of Functional Connectivity



Spectral dependence and subdivision of the auditory cortex seeded functional network. a) The seed-based correlation maps with the seed ROI in left A1, based on either the original BOLD signals or the component BOLD signals associated with distinct frequency bands. b) Two spectral clusters of the seeded correlations. The color matrix shows the relative correlation strength across frequency bands for the voxels resorted by clusters. The bar charts show the mean spectral profile of the absolute correlation coefficients averaged within the first (red) and second (blue) clusters. c) The spatial distribution of the two sub-divisions of the A1-seeded correlation map, color-coded by the distance to the centroid spectral profiles of the two clusters.



Spectral dependence and subdivision of the default mode network. a) Frequency dependence of the PCC-seeded correlation. b) Five sub-divisions of the default-mode network. The sub-divisions are colored coded and the brightness of the color is used to encode the strength of the correlation to the seed ROI at PCC. c) Voxels within each sub-division share a similar spectral profile in their correlations to the seed ROI, as shown by the bar plots color coded in the same way.

Summary and Conclusions

The developed neuroelectric decomposition approach effectively expands four-dimensional (4-D) fMRI data (i.e. 3-D in space and 1-D in time) to 5-D data with the additional dimension representing the frequency of neuroelectric oscillations observed with EEG. Applying it to resting brain, we found spectral signatures indicative of differential contributions of EEG frequency bands to regional fMRI activities and their inter-regional temporal correlations. Such spectral signatures led us to parcel the brain into organized spectral clusters that resemble established functional systems, and offered additional clues as to the spectral distinction of spatially overlapping functional networks.