Investigation of the neural basis of the Default Mode Network using parallel Independent Component Analysis of simultaneous EEG/fMRI data

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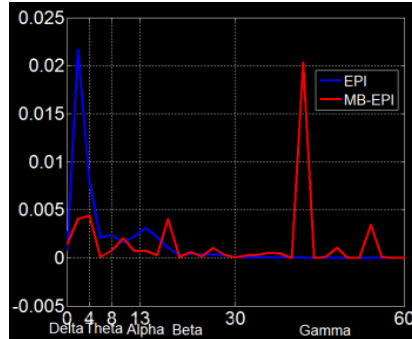
Introduction: Electroencephalography (EEG) has high temporal and low spatial resolution, but the opposite is true for fMRI. Therefore, combining EEG and fMRI data provides complementary measures of neural electrical activity at high temporal resolution and hemodynamics at high spatial resolution. Previous work using simultaneous EEG/fMRI has shown that the slow temporal dynamics of resting state networks (RSNs) obtained from fMRI are correlated with smoothed and down sampled versions of various EEG features such as microstates and band-limited power [1,2]. On the other hand, EEG microstates have been shown to be scale-free, and there is speculation that corresponding resting state fluctuations may exist not only in the low frequency, but also high frequency, which would make resting fluctuations obtained from fMRI more meaningful to typically occurring fast neuronal processes. In this study, we test this critical hypothesis using an integrated framework involving simultaneous EEG/fMRI acquisition, fast fMRI sampling (TR=600ms) using multiband EPI (MB-EPI) [3], and EEG/fMRI fusion using parallel independent component analysis (pICA) which does not require the downsampling of EEG to fMRI temporal resolution.

Methods: Resting state fMRI data (one run each, of eyes open and eyes closed) were collected on a 3T Siemens Verio scanner using a 12-channel matrix head coil using (1) single-shot gradient-recalled EPI sequence with 29ms TE,1000ms TR, 90° flip angle ,64 x 64 x 16 acquisition matrix for six healthy subjects (4 male and 2 female) and (2) MB-EPI sequence [3] with 30ms TE, 600ms TR, 55° flip angle, 64 x 64 x 16 acquisition matrix for six healthy subjects (3 male and 3 female). MR-compatible 64 channel EEG amplifiers (Brain Products, Germany) and a MR-compatible EEG cap with 63, 10-20 system distributed scalp electrodes and an ECG electrode were used for simultaneous EEG acquisition. The EEG data acquisition clock was synchronized with the MRI scanner clock using Brain Product's Sync Box, resulting in exactly 10,000 data points per TR interval. EEG data were digitized with a sampling frequency of 5 kHz and 0.5 μV resolution, within a DC-250Hz frequency range and with reference to FCz. Impedance at all recording electrodes was less than 20 kΩ. The recorded EEG data were subjected to standard preprocessing by Brain Vision Analyzer 2.0 software (Brain Products), including gradient and cardio ballistic artifact removal. First level group temporal ICA analysis of EEG data was done using EEGIFT toolbox [4]. Standard resting state pre-processing of fMRI data was carried out using DPARSF toolbox [5]. First level group spatial ICA analysis of fMRI data was performed using GIFT toolbox [6]. First level temporal EEG components and spatial fMRI components obtained from EEGIFT and GIFT, respectively, were fused using pICA in a second level analysis using Fusion ICA toolbox [7].
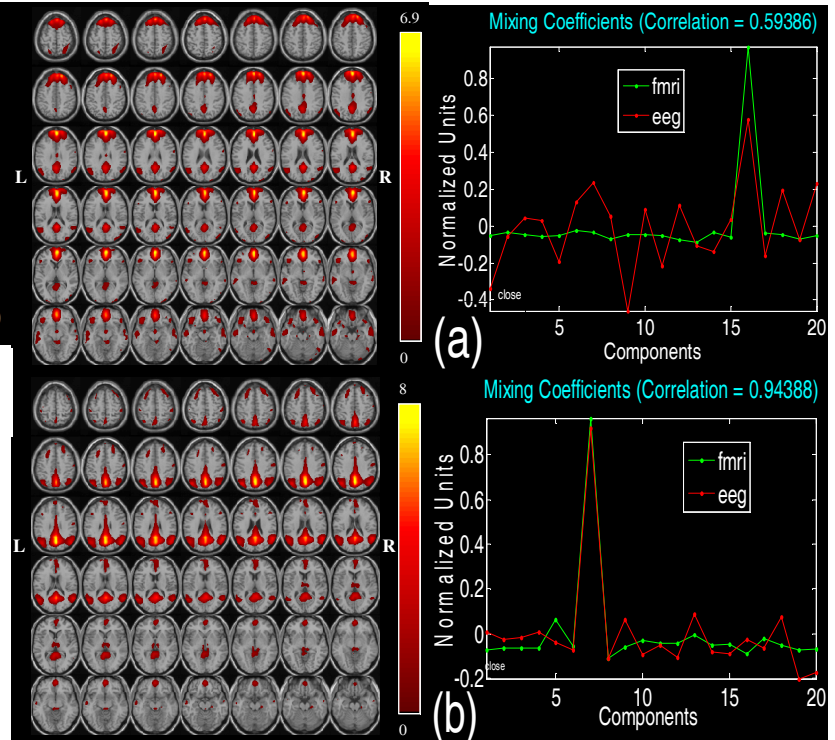
Results and Discussion: As shown in Fig.1, a pICA fMRI component showed the default mode network (DMN) for both EPI and MB-EPI. However, the between-modality correlation coefficient for MB-EPI was higher. As shown in Fig.2, the power of the corresponding EEG

Fig 2 Power of different frequency bands of EEG pICA component of DMN for EPI and MB-EPI acquisition

pICA component was greater in lower frequency bands for EPI and in high frequency bands for MB-EPI. Identical results were found for Eyes open condition (not shown here). These results demonstrate that: (i) electrical correlates of DMN consist of both low and high frequency fluctuations, (ii) faster fMRI sampling is required to reveal DMN's high frequency electrical correlates, (iii) faster sampling also improves the correspondence between EEG and fMRI, (iv) resting state fluctuations reveal scale-free fractal properties and (v) the association of DMN with fast electrical dynamics proves that its neural origin is relevant to typically occurring fast mental processes.

Fig 1 fMRI pICA component corresponding to DMN for (a) EPI and for (b) MB-EPI acquisition. Also shown is the correlation between EEG and fMRI mixing coefficients

References: 1) Yuan et al, *NeuroImage*, 60(4):2062-72, 2012 **2)** Goldman et al, *Neuroreport*, 13(18): 2487-2492, 2002. **3)** Feinberg et al, *PLoSOne*,5(12),2010 **4)** www.mialab.mrn.org/software/eegift/ **5)** www.restfmri.net/forum/DPARSF **6)** http://mialab.mrn.org/software/gift/ **7)** http://mialab.mrn.org/software/fit/