# Do fMRI Resting State Networks have True High Frequency Electrical Correlates of Neural Dynamics?

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**Purpose:** Previous studies have showed that the envelope of EEG gamma band power, when convolved with the hemodynamic response function and downsampled to fMRI temporal resolution, is correlated with slow fMRI fluctuations in resting state networks (RSNs) [1][2]. However, this is not a high frequency electrical correlate of fMRI RSNs because: (i) the envelope of EEG gamma band is used, which itself is a low frequency signal, (ii) the envelope is smoothed and downsampled, eliminating all high frequency information. Therefore, simultaneous EEG/fMRI studies have not been able to assess whether fMRI RSNs have a true neural basis in millisecond-scale fast neuronal dynamics. In order to address this issue, we propose a framework where simultaneous EEG/fMRI data is acquired with multiband EPI with TR (for fMRI)=1000 and 200 ms. Further, parallel independent component analysis (pICA) is used to fuse the two modalities such that the native spatio-temporal resolution of either modality is not compromised. We apply this framework to the visual cortical RSN obtained from healthy individuals, with the hypothesis that, faster fMRI sampling of 200 ms allows one to recover truly high frequency electrical correlates of visual cortical fMRI RSNs.

**Methods:** Resting state fMRI data from six healthy subjects 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 and (2) Multiband (MB) EPI sequence with 30ms TE, 200ms TR, 55˚ flip angle, 64 x 64 x 16 acquisition matrix and a multiband factor of 8 [3] (henceforth, MB8). MR-compatible 64 channel EEG amplifiers (Brain Products, Germany) and an MR-compatible EEG cap with 63, 10-20 system distributed scalp electrodes (with an ECG electrode) were used for EEG acquisition simultaneously with fMRI. Both EEG and fMRI data underwent standard pre-processing. Using temporal ICA [4] and spatial ICA [5], 20 temporal and 20 spatial components were obtained from EEG and fMRI, respectively, and input to a second level analysis wherein 20 parallel independent components (pICs) were derived using pICA[6]. The EEG pIC corresponding to the fMRI pIC representing the visual cortical RSN was obtained by maximizing the cross correlation coefficient between their mixing matrices.

**Results and Discussion:** The visual cortical fMRI pIC map obtained from EPI and MB8 data are shown in Fig.1, confirming the spatial signature of the visual cortex. Next, we show that the EEG pIC component indeed corresponds to this visual network. First, the correlation coefficient between the visual cortical EEG and fMRI pICs' mixing matrices was 0.69 for regular EPI, 0.72 for MB- EPI (both $p<0.05$ corrected). Next, the cross power spectral density between mean fMRI time series from the visual cortex and a HRF-convolved and down-sampled version of the EEG pIC time series is shown in Fig.2A. This indicates predominant low frequency (range of [0.008, 0.1] Hz) cross-spectral power. Hence, we obtained the correlation coefficient between them in this frequency range which was 0.12 ($p=0.0001$) for EPI and 0.16 ($p=3.7 \times 10^{-18}$) for MB8. These results indicate that the EEG pIC time series did indeed correspond to the visual cortical fMRI pIC, albeit with higher frequency information in it which we could exploit. Therefore, we calculated percentage cumulative power for the visual cortical EEG pIC in all frequency bands for both EPI and MB8 data as shown in Fig.2B. This shows that the EEG pIC for both EPI and MB8 had predominantly low frequency power in the Delta band while only MB8 had additional power in higher frequency bands such as Alpha, Beta and Gamma. These results demonstrate that: (i) electrical correlates of fMRI visual RSN consist of both low and truly high frequency fluctuations; (ii) faster sampling is required to reveal high frequency electrical correlates of RSNs; (iii) faster sampling rate improves the correspondence between EEG and fMRI; (iv) the association of fMRI visual RSN with fast electrical dynamics shows that its neuronal origin is relevant to typically occurring fast mental processes.

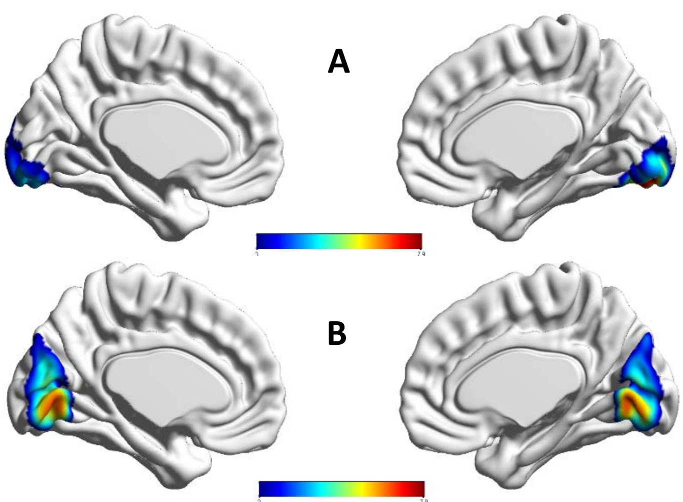


**Figure 1** The visual cortical fMRI pIC map for (A) EPI and (B) MB8

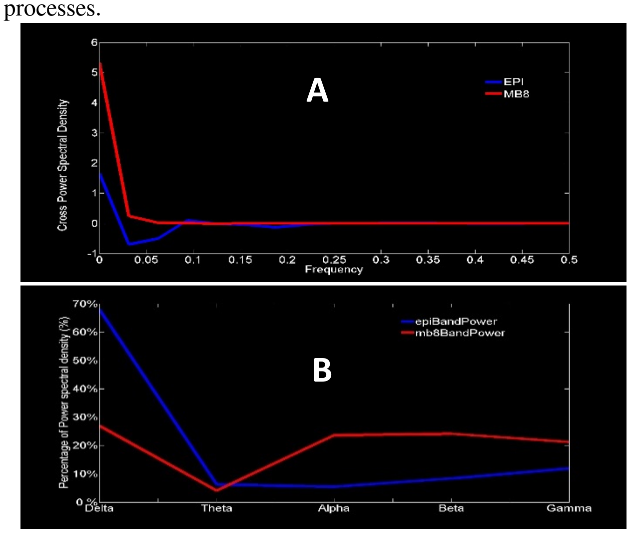


**Figure 2** (A) power percentage at different frequency bands (Blue is for EPI, and Red is for MB8). (B) Cross Power Spectral Density for EPI and MB8 (EPI is blue, MB8 is red)

**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)** http://mialab.mrn.org/software/gift/ **(6)** http://mialab.mrn.org/software/fit/