Frequency Correspondence between fMRI and EEG signals before and after Sleep

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Target audience

Sleep neuroimaging researcher or investigator who has interests on the signal correspondence of EEG-fMRI.

Purpose

Functional magnetic resonance imaging (fMRI) is a powerful tool to investigate the brain due to its high spatial resolution, but the spectral domain of blood oxygen-level dependent (BOLD) signal was yet fully understood, especially in the resting-state fMRI (rs-fMRI) [1]. To dig out the intrinsic frequency implications in the spontaneous BOLD signal, we simultaneously recorded the rs-fMRI and electroencephalogram (EEG) signal, because EEG signal has long been used to observe variety of frequency bands, indicating physiological meanings [2]. Therefore, to disclose the underlying meaning of rs-fMRI frequency distributions, we observed the variability and correspondence of frequency bands in both EEG and rs-fMRI under two different physiological conditions (before and after sleep).

Methods

Six healthy volunteers participated (age range: 21-23 y/o, all right-handed) were scanned in a 3T Tim Trio scanner (Erlangen, Germany). Around midnight, participants were requested for a 3-hr sleep inside the scanner and, before and after the midnight sleep, they underwent one 6-min rs-fMRI scan in each condition. The rs-fMRI signal was acquired using the GE-EPI (TR = 2.75 s, TE = 35 ms, 35 slices with thickness of 3.4 mm, MTX = 64x64, FA = 85°). Data were simultaneously recorded with a 32-channel MR compatible EEG system (Brain Products, Gilching, Germany). We used Analyzer 2.0 (Brain products) for artifact-removal. The rs-fMRI analysis was carried out using AFNI for signal processing. Both the rs-fMRI and EEG signals were decomposed from the visual area (BA17 in fMRI, O2 channel in EEG). In addition, to observe the dynamic frequency distribution, we used the Hilbert-Huang transform (HHT) [3] to study the spectral correspondence between the rs-fMRI and EEG signals. After HHT, the resulting signals were transformed into the time-frequency maps. Matching the temporal resolution, the T-F maps of EEG and rs-fMRI were multiplied as the covariance maps, indicating the spectral correspondence between EEG and fMRI.

Results

Figure 1 shows T-F maps of rs-fMRI and EEG in both pre- and post-sleep conditions. We could find the subtle variations of high frequency power after sleep in EEG [decreased power: α (8-13Hz), θ (4-8Hz) and δ (0.1-4Hz); increased power; β (12-30Hz) and γ (25-100Hz) after sleep (Fig 1c)]. Fig. 2a and 2b demonstrate the EEG-fMRI spectral covariance before and after sleep, respectively. Before sleep, Fig. 2a presents that the higher covariance between EEG-fMRI and the spectral correspondence demonstrates an opposite relation. However, the correspondence became sparse after sleep.

Discussion

To understand the frequency relationship between EEG and rs-fMRI, we conducted HHT in EEG-fMRI analyses for the first time, and the covariance analysis between the T-F maps of EEG and rs-fMRI on pre-sleep and post-sleep data, respectively. The decreased low frequency (α, θ and δ) and increased high frequency (β) implied that the level of consciousness after sleep was higher than that of pre-sleep. On the other hand, the negative correspondence between rs-fMRI and EEG agreed with previous study by Scheeringa et al. [4]. We demonstrated that under the resting states, the opposite spectral relation remains in EEG-fMRI, but the correspondence exists variability dependent on physiological states.

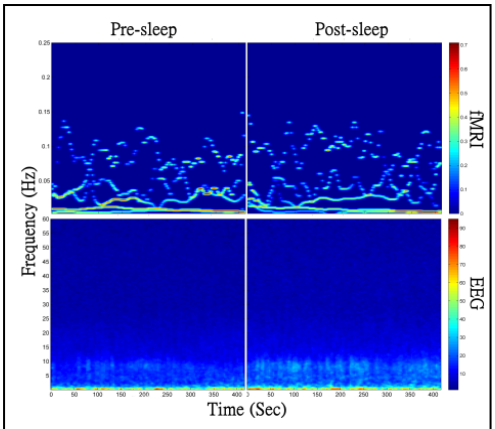

Figure1. Time-frequency results of HHT before and after sleep.

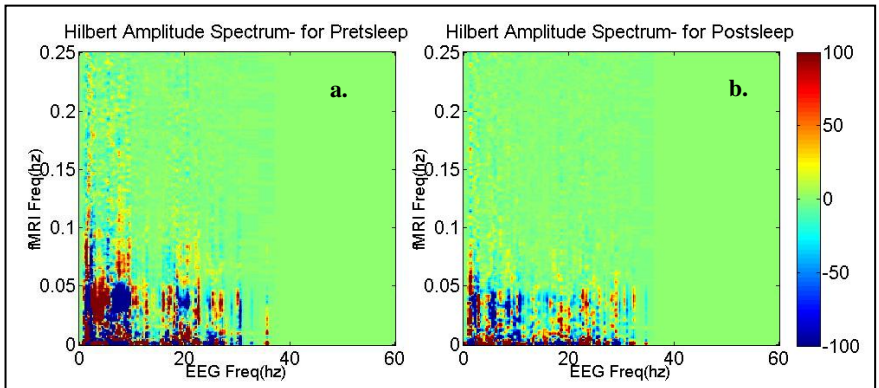

Figure 2. Spectral covariance between fMRI and EEG before and after sleep.

Conclusion

The purpose of this study was to investigate the relationship of frequency on the rs-fMRI and EEG under the resting state. Applying the HHT, we found the opposite frequency correspondence between EEG and fMRI in the resting state. Furthermore, such correspondence may change according to the physiological conditions.

Reference

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