Stability of Resting-State Brain Activity Fluctuations Across Time: Evidence from fMRI and MEG

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Target Audience: Researchers in fMRI-EEG/MEG functional connectivity, neurophysiology and characterizations of resting state brain activity.

Purpose

Functional magnetic resonance imaging (fMRI) has been employed to derive measures for brain function from a subject in "resting state", particularly for calculating functional connectivity. There is an increasing use of resting-state functional connectivity to characterize normal brain function as well as neurological disorders such as dementia, autism, and multiple sclerosis[1], but a physiological interpretation of the measurements has been elusive, as the source of the underlying resting-state brain signal fluctuations is still unknown. Magnetoencephalography (MEG) can provide a spatially-resolved measure of brain activity that complements fMRI, and is potentially valuable in clarifying the physiological mechanisms of resting-state fMRI-based functional connectivity. However, MEG and fMRI experiments cannot be performed simultaneously on the same subject. For this reason, establishing a link between the MEG and fMRI modalities requires time-independent analysis of data acquired over different sessions. In this work, we present results from our novel time-independent analysis technique in characterizing resting-state neuronal activity fluctuations. Spectral analysis of fMRI and MEG time-series data is established as the basis of cross-modal fusion.

Method

Acquisition: A CTF MEG system was used to record MEG data, sampled at 625 Hz and recorded on 150 channels. Resting-state MEG data was collected on a single subject (age = 21 years) over 4 sessions —two sessions conducted on the same day 3 hours apart; the third session conducted 3 days later; the last session conducted a week later. Within each session, a total of 4 resting state scans of 8 minutes duration each were obtained for 'eyes-open' and 'eyes-closed' resting state. Four resting-state fMRI scans were obtained on the same subject as for MEG, acquired on a 3T Trio scanner (Siemens, Erlangen, Germany). This was complemented by resting-state fMRI data from 18 previously studied healthy subjects (age = 24.7±3.3 years) to assess reproducibility, using a gradient-echo BOLD at a TR of 2 s, TE=30 ms, matrix size=64x64, slice thickness=5 mm and voxel size=3.4x3.4 mm. For both modalities, the "eyes-open" condition required the subject to fixate on a small cross.

Analysis: Adaptive beamforming[2] was performed on the MEG data in order to resolve the MEG signals from each sensor into a voxel-wise time series that is spatially registered to the subject's MPRAGE image obtained from the fMRI scan. This was facilitated by landmark capsules placed on the subject's head during both the fMRI and MEG sessions. Subsequently, low pass filter of 80 Hz is applied to the MEG data. The fMRI data was preprocessed using the CONN toolbox[3], and we used the signal within white-matter and cerebrospinal fluid masks as nuisance regressors in a multi-variate linear model to remove physiological noise. A Band-pass filter from [0.001, 0.1] Hz was applied to the filtered fMRI data. Finally, the power spectral densities (PSD) of fMRI and MEG time series were computed using Welch's method, and we examined spectral features that are independent of total signal power: median frequency, and the contribution of multiple frequency bands (alpha, beta and theta) to the total signal power.

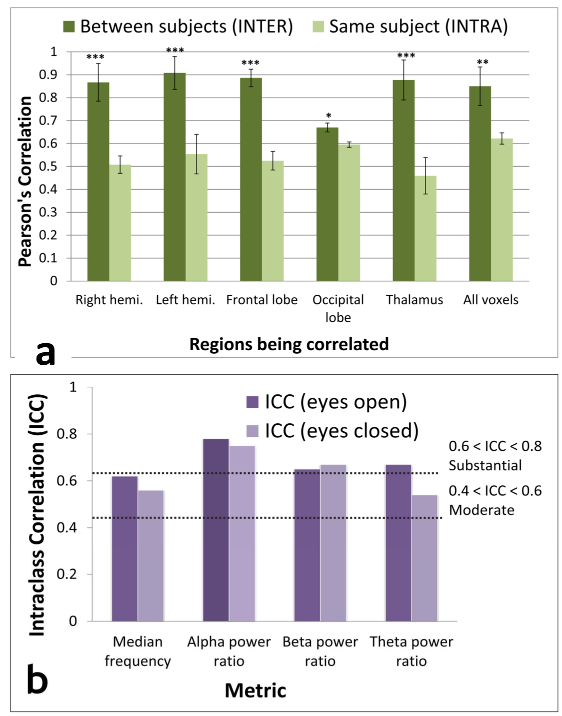

Figure 1. a) Pearson's correlation of median frequency derived from fMRI time course. * 95%, ** 99%, *** 99.5%. High inter-session correlations were observed (eyes closed in this case). b) ICC derived for the various spectral features of the MEG scans, indicating similar brain activity within and between sessions.

Results and Discussion

For resting-state fMRI, the global mean of Pearson's correlations of the median frequency showed a within-subject correlations were > 0.7 across the group, statistically higher compared to between subject correlations. The correlations are spatially variable (see Fig. 1a), suggesting a more detailed study distinguishing among prominent resting-state networks such as the default-mode network. For MEG, the spatial distribution of medial frequency and fractional alpha, beta and theta powers show high correlation between scans. There was no significant difference between intra-session reproducibility and inter-session reproducibility (p=0.5-0.7). High intra-class correlation (ICC) values (>0.5) show that the inter-session variance in MEG measurements of resting-state brain activity is on the same order as the within session variance. Finally, for both fMRI and MEG, the signal power across time was more consistent for "eyes-open" than "eyes-closed" resting state.

Our results provide evidence for a certain stability of intrinsic brain activity across time. This stability is higher in certain brain regions and during "eyes-open" resting state. These findings will enhance our ability to capitalize on the spatially resolved neuro-electric information from MEG to inform resting-state fMRI interpretations of brain activity. Future work will address the link between these spectral features and connectivity.

References

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