Power density distribution of spontaneous BOLD fluctuations

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Introduction: In resting state MRI studies, the observed BOLD fluctuations are commonly considered to reflect ongoing neural activity [1]. Recent EEG studies suggest intrinsic neural activity varies across cortical regions [2]. However, the corresponding BOLD power distribution across brain regions has rarely been examined The BOLD power density across the cortex might vary due to inhomogeneous neural activity. To test this hypothesis, we compared potential differences in BOLD power density across different regions, including primary and secondary somatosensory cortex (S1 and S2) and subcortical structures (caudate putamen, CP) in a rat model under anesthesia. In unconscious animals, inputs from the environment should be largely disconnected, emphasizing the dominant intrinsic activity of the resting state.

Materials and methods: A group of SD rats (male, *n* = 9) were examined with resting state fMRI under medetomidine anesthesia. Eight minute resting state fMRI scans (GE-EPI; TR 500 ms; TE 15 ms; 2 mm slice thickness; inplane resolution 300 × 300 mm^2) of one coronal slice covering SI/SII were acquired on a 9.4T Bruker scanner with a homemade surface coil. Each EPI data set was preprocessed, including head motion correction, spatial smoothing (500 mm FWHM) and signal normalization (% change to mean) in SPM8 and MatLab. The power spectrum of each voxel of the BOLD time course was computed by Welch power spectral density estimate (window length: 120 sec and 50% overlap). The power map across voxels was calculated by averaging the power of a given frequency range, including 0.01-0.1 Hz, 0.1-0.25 Hz and 0.3-0.4 Hz.

Results: The BOLD power map displays clear power density distribution across significant anatomical structures, such as cortex and CP. The high power density is mostly in frequencies less than 0.3 Hz, with little power in the neighboring control frequency (Fig. 1). Region of interest analysis of the power spectrum from S1, S2 and CP are shown in Figure 2, indicating high powers at low frequency end for both regions, but different ranges between CP and cortex, and significant higher power in S2 than in S1 at around 0.2 Hz.

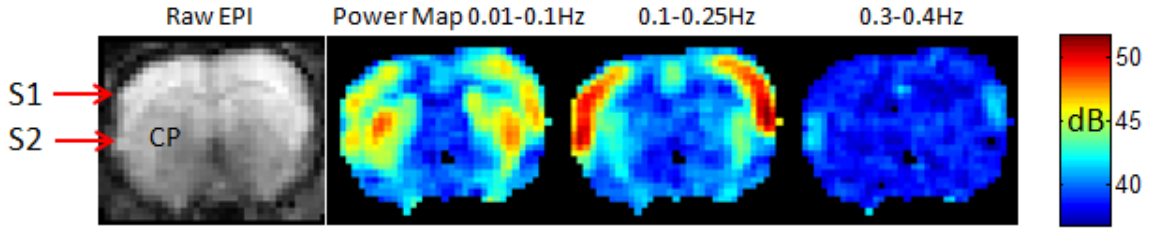

Fig. 1. BOLD power density map. (left panel) Raw EPI. (right panel)The mean power of a given low frequency range of each voxel was calculated, showing the power distribution across brain regions.

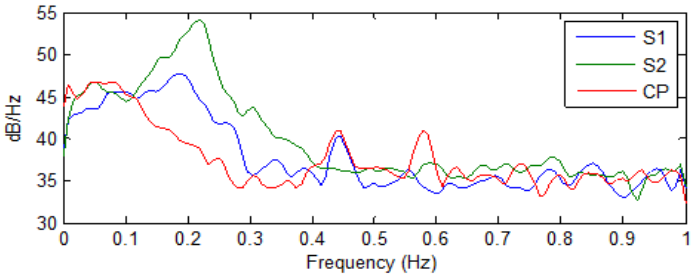

Fig. 2. Average BOLD power spectra. The power peaks are different between CP (~0.1Hz) and cortex (S1/S2, ~0.2 Hz). The peak profiles are pretty similar in cortex of S1 and S2, but higher amplitude in S2 than S1.

Discussions: The present studies demonstrate a significant spatial variation in the BOLD power distribution that may be linked to intrinsic brain activity. Relative to S1, the BOLD signal of S2 has higher power around 0.2 Hz, and stronger interhemispherical connectivity (not shown). The corresponding neural power distribution is to be determined, although the previous electrophysiological findings of higher neural excitability in association areas relative to primary sensory areas in intrinsic activity [3]. The fMRI power density in the rat, as demonstrated by the present study, may provide preliminary insights into ongoing neural excitability. Moreover, the power difference in the frequency ranges and peak between CP and cortex may be due to variations in neurovascular coupling. The vasculature distributions are similar throughout the cortex but much different between cortex and CP, which may be a potentially confounding factor when interpreting functional connectivity across cortex and subcortical structures.

References: [1] Logothetis N. et al., Annu. Rev. Physiol, 2004, 66:735-769 [2] Yuval nir, et al., Neuron, 2011, 70:153-169 [3] Steriade, M., et al., J Neurosci, 1993, 13: 3266-3283