The spectral power of brain oscillations predicts the functions of brain networks

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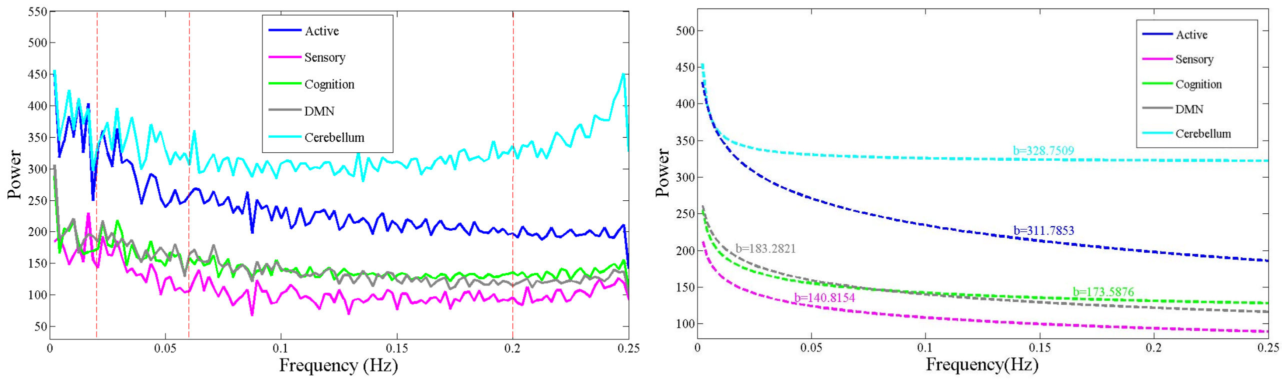
Introductions Up to 10 functional networks contributed by low frequency fluctuations (LFFs) have been reliably identified to consistently exist in human resting brains [1, 2]. These networks consist of regions which are known to be involved in function of motor, vision, execution, auditory, pain perception, language, cerebellum, and the so called default-mode network (DMN). Based on the concept proposed by Weisskoff et al. that the baseline of LFF power spectrums followed a 1/f curve [4], we analyzed resting-state fMRI data of 11 healthy participants with 1/f model, to further investigate the spectral characteristics of brain oscillations across different networks. The parameter "b" in 1/f model was discovered to predict the functions of these networks, which illustrated the spectral power of brain oscillations differed across networks which served different functions such as sensory, active, cognition, and default-mode. The result was supported by the discovery of the prior literature that the spectral characteristics of brain oscillations linked with neural processes which were modulated by the functions of brain networks [3].

Methods Eleven healthy right-handed volunteers (5 M, 6 F), ranging from 20- to 32-years-old, were recruited, trained, and imaged. Scanning was performed on a Bruker Medspec 3.0 Tesla whole body scanner. During the acquisition of resting-state fMRI data, the volunteers were asked to remain as still as possible, resting with their eyes open. 200 24-slice whole-brain volumes were acquired using a T2*-weighted gradient-echo, echo-planar-imaging sequence (TR / TE = 2000 / 30 ms; flip angle = 84°; slice thickness / gap = 5 / 0 mm; 64 × 64 image matrix, FOV 256 × 256 mm^2). After preprocessing of fMRI data (slice timing, rigid body motion correction, spatial normalization, Gaussian spatial smoothing (6 mm FWHM), linear trend removal, and correction of physiological noises), group ICA (Independent Component Analysis) was performed to obtain functional networks of a resting brain (the number of independent components = 20). We sorted these networks into several classes by function such as sensory, active, cognition, cerebellum, and default mode. The average time courses of these classes were first Fourier transformed to obtain power spectrums. Subsequently 1/f model, $I(f) = a(1/f)+b$, was applied to find the baseline of these spectrums to investigate the spectral characteristics of brain oscillations across different functional networks. "f" and "I(f)" represented frequency and amplitude at the frequency respectively. In addition, "a" and "b" were parameters which were determined by least square estimation.



(a) (b)

Results and Discussions Fig. (a) showed the square roots of average spectrums in different classes of functional networks. Fig. (b) represented the baselines of these square roots of spectrums which were obtained by 1/f model. The parameter "b" of various classes of networks was labeled in Fig. (b). It was found that "b" of active, sensory, default mode, cognition, and cerebellum network was 328.7509, 311.7853, 183.2821, 173.5876, and 140.8154 respectively, which illustrated the spectral power of brain oscillations differed across networks which served different functions. Briefly, the parameter "b" in 1/f model could be used to predict the function of these networks. The result corresponded to the prior discovery that the characteristics of brain oscillations within specific classes linked with neural processes which were modulated by the functions of brain networks [3].

References [1] Damoiseaux JS, Proc Natl Acad Sci USA, 2006. [2] Smith SM, Proc Natl Acad Sci USA, 2009. [3] Knyazev GG, Neurosci. Biobehav., 2007. [4] Weisskoff et al., ISMRM, 1996.