REGION AND FREQUENCY DEPENDENT COUPLING BETWEEN RESTING-STATE POWER AND TASK INDUCED ACTIVITY

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Purpose: The coupling relationship between resting and task state is important for understanding the neural mechanism and individual variability in function MRI studies. It has been reported that low frequency signal of resting-state can predict task-induced BOLD activity at subject level[1,2]. The low frequency signal in resting state typically refers to BOLD fluctuation under a frequency of 0.08-0.10Hz. Furthermore, this frequency is divided into several sub-bands in some studies, and these bands were found significantly characterize specific brain functional systems. These evidences raise the question that whether the rest-task coupling could also be frequency dependent. To answer the question, we computed the correlation between resting-state signal power and task-induced activity amplitude across subjects, as a function of frequency. The correlation relationship is investigated over full frequency-band and several sub-frequency bands[3] as well. Our preliminary result shows that the coupling is both non-stationary over frequency and region-dependent.

Method: Sixty-five healthy subjects were recruited (39 males) in this study. All subjects first underwent an 8-min resting-state scan with eye-closed, and then an 8-min hand-move task scan. The latter one consists of two 42s resting blocks in the beginning and the end, and seven 36s task blocks interleaved by six 24s resting blocks. Subjects had their eyes fixed on a crossing mark during the resting blocks, and a flicking (1Hz) hand picture in the task blocks. Functional images were collected on a GE 3T MR750 scanner using GRE-EPI sequence in axial plane, with 43 interleaved slices (TR/TE=2000/30ms, FA=90°, matrix=64×64, NEX=1, FOV=220mm, thickness=3.2mm, no gap). A 3D anatomical scan was also acquired.

Images were preprocessed using SPM8 on MATLAB (R2009b). The first 5 volumes were discarded, and the remaining images were realigned, normalized, and then spatially smoothed. The resting-state images were first slice timing corrected before above-mentioned pre-process. Group activation was detected through a two-level statistical modeling. Seven regions of interests (ROIs) were defined, including left and right premotor cortex (lmot/rmot), left and right visual cortex (lvis/rvis), left and right thalamus (ltha/rtha), and supplementary motor area (sma). For resting-state data, multi-taper power spectral density was estimated at each voxel after the removal of major nuisance terms including head-motion and linear trend. The frequency bands were separated into several sub-bands (i.e. Band_1: 0.038-0.054Hz, Band_2: 0.054-0.074Hz, Band_3: 0.074-0.082Hz, Band_4: 0.082-0.102Hz, and Band_5: 0.102-0.122Hz), and the total power in each band was calculated. In comparison, power in the typical full slow bands (Full: 0.01-0.08Hz) was also obtained. The correlation between task activity amplitudes and resting-state powers of multiple frequency bands across subjects were further investigated.

Results: The correlation between task-activity and resting-state power across subjects was measured as a function of frequency. These correlations were found to be not stable, but fluctuate dramatically over the entire frequency band. Fig. 1 gives example cases of three defined ROIs of lmot (blue), lvis (red) and ltha (green). The two reference lines in magenta correspond to a significant level of $P=0.05$. Moreover, the correlation values can vary from negative to positive, which indicates the possibility of a very weak correlation when the power is simply averaged over a long-rang frequency band, such as 0.01-0.08Hz. Additional comparison based on power sums over above-defined frequency bands further proves this observation. The bar-plot (Fig. 2) shows frequency preference related with rest-task correlation of each ROI. Interestingly, the rest-task correlation is found significant ($P<0.05$, above/below two magenta lines) in Band_1/5 for motor, Band_4 for visual and Band_2 for thalamus system respectively. Resting-state power over the full slow band is not significantly correlated with task activation.

The resting-state low-frequency power has been used as an index of individual variability of task activity. As an important application, we conducted a similar comparison. Fig. 3 shows the group activation map with inclusions of individual's full slow band power (Full-band, middle), 5 sub-band powers (Multi-band, left) and nothing (Raw, right) as covariates in one-sample t-test respectively. The representative slice map clearly shows enhanced t-score and sensitivity with 'Multi-band' covariates, and more clusters in the occipital lobe survived above a P value of 10^{-12}.

In addition, the usage of sub-band resting-state power as an index of individual variability shows good performance in group-level statistics (Fig 3). This metric should be adopted and tested with more task-based datasets.

Discussion: Fig. 1 and 2 reveal that the coupling relationship between resting-state power and task activity is not stationary either over the full frequency band (<0.25Hz) or over the typical low-frequency band (0.01-0.08Hz). This coupling relationship is also region-dependent. From the ROIs in this study, we found each system has its own preferred frequency-bands within which the rest-task correlation reaches significance. Moreover, the direction of correlation can be either negative or positive depending on the frequency band. This observation suggests that a simple sum over a long frequency range could eliminate the rest-task correlation[4], in which case sub-band frequency analysis could be more accurate and promising.

Another important finding is that the rest-task coupling is also detected in high frequency band (>0.1Hz). BOLD signal in Band_5 (0.102-0.122Hz) is usually considered as physiological noise related with cardiac and respiratory noise. Previous studies on individual variability of task activation have suggested neuronal, vascular and other physiological sources. Therefore, the strong correlation at Band_5 shown in Fig. 2 may indicate the variability of activation in the left motor cortex across subjects is also affected by physiological signals. On the contrary, the correlations in Band_1/2/4 may indicate the neuronal and vascular sources of individual task variations[2,5].

Conclusion: In sum, the current preliminary study reveals a non-stationary, frequency and region dependent coupling relationship between resting-state power and task activity amplitude across subjects. The results suggest the rest-task link is not simply linear correlated, but has a complicated unknown, and meaningful story underlying. The mechanism is worth a further investigation in future.

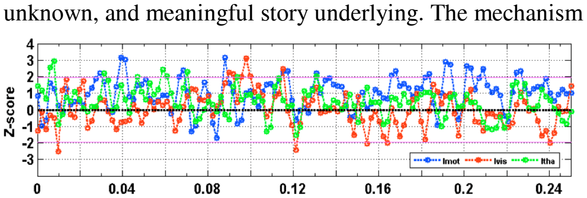

Fig. 1

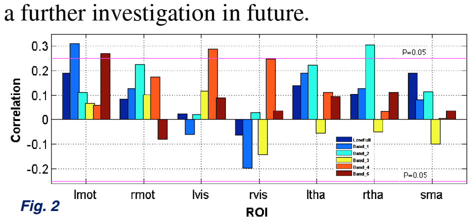

Fig. 2

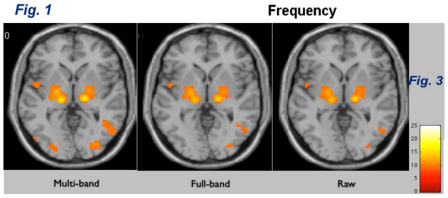

Fig. 3

Fig. 1, Rest-task correlation is not stationary and varies dramatically across frequencies.
Fig. 2, Resting-state power is most correlated with task-activity at specific sub-frequency band for each brain regions.
Fig. 3, Comparison of activation map obtained from three processing metric in group-level statistics.

References: **[1]**. Mennes, M. et al., 2010. NeuroImage 50, 1690–1701; **[2]**. Mennes, M. et al., 2011. NeuroImage 54, 2950–2959; **[3].** Wee C.Y. et al., 2012. PLoS ONE 7(5): e37828; **[4].** Di X. et al., 2012. Cereb. Cortex; **[5]** Kannurpatti S.S. et al., 2010. Magn Reson Imaging 28, 466–476.