Two PhD thesis defenses

Resting-State Functional magnetic Resonance Imaging---Based on BOLD and ASL Techniques

By Qihong Zou, Supervisors Profs Yufeng Zang and Yihong Yang

The thesis investigated resting-state human brain activity based on BOLD and ASL fMRI techniques. There are totally 5 studies: 3 by BOLD fMRI, 1 by ASL fMRI, and 1 of combination of BOLD and ASL fMRI. In **Study 1,** a new approach fractional amplitude of low-frequency fluctuations (fALFF) was proposed to reveal regional brain activity. In s**tudy 2,** we showed that both strength of regional activity (ALFF and fALFF) and resting-state functional connectivity (rsFC) can predict N-back working memory task induced activity. Further, we find that the rest-task relationship in these frontal and parietal regions was stronger at higher task loads. In **Study 3,** we applied rsFC to investigate the relationship between the thalamus and visual cortex using BOLD fMRI and whether the correlations would be modulated by different physiological conditions, i.e. eyes closed (EC) and eyes open (EO). In **Study 4,** we investigated both the static (mean CBF calculated with conventional method) and dynamic characteristics (e.g. ALFF) of resting-state CBF using ASL fMRI and showed high static and dynamic activities in the default mode network including MPFC and PCC. In **Study 5,** we combined resting-state BOLD and ASL fMRI and found that resting-state CBF correlated with the strength of BOLD dynamics (fALFF and ALFF) at large part of areas within gray matter. The two techniques are complimentary to detect the difference of spontaneous activities between EO and EC resting states.

Publications during PhD

Cao, Q., Zang, Y., Sun, L., Sui, M., Long, X., ***Zou, Q.***, Wang, Y., 2006. Abnormal neural activity in children with attention deficit hyperactivity disorder: a resting-state functional magnetic resonance imaging study. Neuroreport 17, 1033-1036.

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Shin, W., Geng, X., Gu, H., Zhan, W., ***Zou, Q.***, Yang, Y., 2010. Automated brain tissue segmentation based on fractional signal mapping from inversion recovery Look-Locker acquisition. Neuroimage 52, 1347-1354.

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Zou, Q., Long, X., Zuo, X., Yan, C., Zhu, C., Yang, Y., Liu, D., He, Y., Zang, Y., 2009a. Functional connectivity between the thalamus and visual cortex under eyes closed and eyes open conditions: a resting-state fMRI study. Hum Brain Mapp 30, 3066-3078.

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The spontaneous brain activity: resting-state fMRI network studies

By Chaogan Yan, Supervisor Prof Yufeng Zang

This dissertation focused on the spontaneous brain activity with undirected network analysis as well as directed network analysis. Firstly, we performed undirected network analysis with single-seed-region functional connectivity to investigate how the functional connectivity within the DMN correlated with different resting-state conditions. We found significantly higher functional connectivity as well as local activity with a measure of amplitude of low frequency fluctuation (ALFF) in both eyes-open conditions as compared to the eyes-closed condition. Secondly, we performed directed network analysis at region-wise level to investigate the driving and driven architectures of small-world directed functional network. The directed brain network followed a 'small-world' topology with significant modular structures. Importantly, several driving hubs predominantly located in the components of the attentional network and several driven hubs predominantly located in the components of the DMN were identified. Thirdly, we performed directed network analysis at voxel-wise level to identify the inhibitory driving, excitatory driving, inhibitory driven, and excitatory driven patterns of the human brain. The DMN showed high inhibitory driving density while the attentional network showed high excitatory driving density. Both of these two networks showed high inhibitory driven density. The memory-related network showed high excitatory driven density. Fourthly, to further understand the structural basis of the functional networks, we explored the topological properties of the fiber bundle anatomical network and its relation with individual differences (sex and brain size). The females showed greater local efficiencies than males. Smaller brains showed higher local efficiency in females but not in males, suggesting an interaction between sex and brain size. Finally, we developed a MATLAB toolbox called DPARSF for "pipeline" data analysis of resting-state fMRI to provide an indispensable tool-support for the aforementioned studies. DPARSF can help us for conveniently preprocessing (slice timing, realign, normalize, smooth) data and calculating resting-state fMRI measures (functional connectivity, ALFF, regional homogeneity etc.) and contribute to intraoperative data processing.

Publications during PhD Study

1. **Yan CG**, Gong GL, Wang JH, Wang DY, Liu DQ, Zhu CZ, Chen ZJ, Evans A, Zang YF, He Y (2011) Sex- and brain size-related small-world structural cortical networks in young adults: a DTI tractography study. ***Cerebral Cortex***. 21: 449-458.
2. Wang ZQ[**], **Yan CG**[**], Zhao C, Qi ZG, Zhou WD, Lu J, He Y, Li KC (2011) Spatial patterns of intrinsic brain activity in mild cognitive impairment and Alzheimer's disease: A resting-state functional MRI study. ***Human Brain Mapping***. In Press.
3. Kang J, Wang L, **Yan CG**, Wang JH, Liang X, He Y (2011) Characterizing dynamic functional connectivity in the resting brain using variable parameter regression and Kalman filtering approaches. ***Neuroimage***. In Press.
4. Tian LX, Wang JH, **Yan CG,** He Y (2011) Hemisphere- and gender-related differences in small-world brain networks: a resting-state functional MRI Study. ***Neuroimage***. 54: 191-202.
5. Zhang TJ, Wang JH, Yang YC, Wu QZ, Li B, Chen L, Yue Q, Tang HH, **Yan CG,** Lui S, Huang XQ, Chan RCK, Zang YF, He Y, Gong QY (2011) Abnormal small-world architecture of top-down control networks in obsessive-compulsive disorder. ***Journal of Psychiatry and Neuroscience***. 36: 23-31.
6. **Yan CG**[*] and Zang YF[*] (2010) DPARSF: a MATLAB toolbox for "pipeline" data analysis of resting-state fMRI. ***Frontiers in Systems Neuroscience***. 4(13).
7. Liu DQ, **Yan CG,** Ren JJ, Yao L, Kiviniemi VJ and Zang YF (2010) Using coherence to measure regional homogeneity of resting-state fMRI signal. ***Frontiers in Systems Neuroscience***. 4(24).
8. **Yan CG,** Liu DQ, He Y, Zou QH, Zhu CZ, Zuo XN, Long XY, Zang YF (2009) Spontaneous brain activity in the default mode network is sensitive to different resting-state conditions with limited cognitive load. ***PLoS ONE***. 4(5): e5743.
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11. Zhu CZ, Zang YF, Cao QJ, **Yan CG,** He Y, Jiang TZ, Sui MQ, Wang YF (2008). Fisher discriminative analysis of resting-state brain function for attention-deficit/hyperactivity disorder. ***Neuroimage***. 40:110-20.

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