The application of accelerated functional connectivity magnetic resonance imaging to study the higher frequency band resting state functional connectivity (R-fcMRI) and the improvement for the individual R-fcMRI repeatability

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Introduction:

Resting-state functional connectivity MRI (R-fcMRI) has been used to study brain functional networks. It has potential to assess the risks of diseases, such as Alzheimer's disease (AD) (1). However, the challenge of the R-fcMRI method in clinical application is its large variance. The most recent fMRI study found that acquiring more time points can significantly increase the reproducibility from a single subject measurement (2). Acquiring more time points requires longer acquisition time, increasing the possibility of motion artifacts and patient distress. To overcome this challenge, we hypothesized that fast-image acquisition with a shorter TR than conventional TR values (2s) could increase repeatability. In addition, fast-sampling rate could expand the frequency range to be observed beyond 0.25 Hz. In this study, we investigated the repeatability of resting-state functional connectivity, using both normal TR (2s) and short TR (0.5s). We used conventional low-frequency band (0.01-0.1Hz) to higher frequency band of BOLD signals up to 1.0 Hz. We employed the default mode network (DMN) to test our hypothesis.

Materials and Methods:

Subjects and Imaging acquisition*:** Thirteen young healthy subjects (18–35 years old) were recruited for this study. Visit twice in two weeks. For each visiting, six resting-state functional MRI data sets (run1 to run6). Run1 and run2 were two 6-minute conventional slow (TR=2) scans. Run 3 and run 4 were two 6-minute conventional fast (TR=0.5s) scans with reduced FOV (covered a part of the DMN regions). Run 5 and run 6 were two 6-minute accelerated scans. Imaging was carried out on a 3T GE MR750 whole-body scanner with a body transmit and a MRII 32-channel receiver coil. *Slow nonaccelerated echo-planar imaging (EPI) (TR=2s)*: Two 36 slice resting data sets from run1 and run 2 (axial-resting) were obtained in six minutes each time with a single-shot gradient EPI pulse sequence with TE/TR/flip angle/slice thickness, 25ms/2,000ms/90°/4mm, matrix size=64x64 and FOV=24 cm. *Fast nonaccelerated EPI (TR=0.5s)*: Two 10 slice resting-state data sets for run 3 and run 4 (axial-resting) were obtained with a single-shot gradient EPI pulse sequence with TE/TR/flip angle/slice thickness, 25ms/500ms/90°/4mm, matrix size=64x64 and FOV=24cm. *Fast accelerated EPI (3)(TR=0.5s)*: Two runs (run 5 and run 6), each had 4X9 slices, which covered the whole brain, using the accelerated single-shot gradient EPI pulse sequence with TE/TR/flip angle/slice thickness, 25ms/500ms/17°/4mm, matrix size=64x64 and FOV=24cm. High-resolution SPGR 3D images were for anatomical reference. ***Preprocessing: despiking; detrending; motion correction; cardiac and respiratory signal removal; and white matter, CSF and global signal removing.

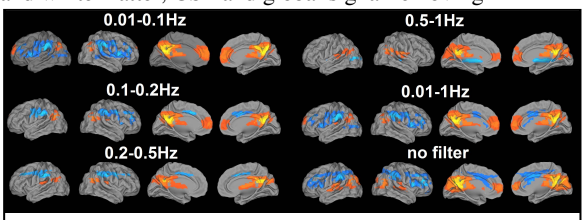

Figure 1: Default mode network pattern (PCC seed) in different frequency bands.

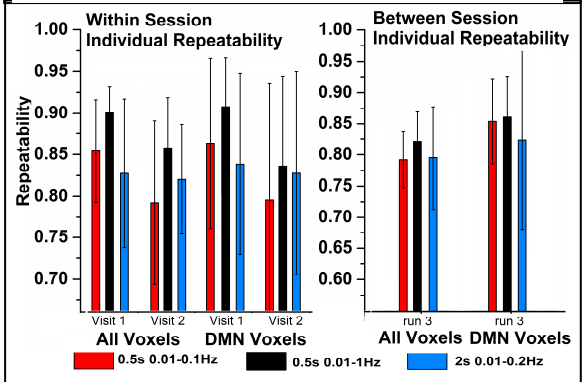

Figure 2: Within and between session (visit) repeatability of different frequency bands from various TR resting-state time series.. The highest repeatability is the time series with TR=0.5s and its frequency band is 0.01-1Hz (black color).

Results:

DMN in higher frequency bands: Recent research (4) shows that the spatial distribution of functional connectivity is frequency dependent. This not only exists in the lower frequency band but also in the higher frequency band beyond 0.1Hz. Therefore, based on our hypothesis, we calculated the DMN, using different frequency band BOLD signals. Figure 1 shows the DMN pattern in different frequency band. It is very obvious that the DMN pattern still exists in higher frequencies, especially 0.1-0.2Hz and 0.5-1Hz. **Voxelwise DMN repeatability**: The functional connectivity of PCC for each subject and each run is calculated by correlating the averaged signal of the PCC area with all voxel time series. In order to examine the repeatability and its relationship with the frequency band, the R-fcMRI was calculated with different frequency bands (figure 2). The 2s TR time series was filtered into four frequency bands: One was 0.01-0.1 Hz, which was the conventional resting-state low-fluctuation band; the second was 0.1-0.2Hz, which was a high-frequency band; the third was 0.01-0.2 Hz. The broad band was combined with the first and the second frequency bands. The fourth was a whole band with no filtering. In order to be comparable with 2s data sets, the 0.5s TR time series were filtered into six frequency bands: 0.01-0.1Hz, 0.1-0.2Hz, 0.2-0.5Hz, 0.5-1Hz, 0.01-1Hz, no band pass filtering. The correlation values between all voxel's PCC functional connectivity values (two runs with the same frequency band) were calculated. The repeatability of two runs within and between sessions also was calculated. Figure 2 shows the repeatability within session and between sessions of different frequency bands (it does not show all frequency bands). The highest repeatability of R-fcMRI between and within sessions is the 0.5s TR data set with a frequency band between 0.01 to 1Hz. All voxels results included all the brain voxels no matter it belongs to the DMN network map or not. DMN voxels only included the voxels that belongs to the DMN network map

Conclusion:

We investigated the R-fcMRI repeatability of two pairs of data sets acquired with different TR (0.5s and 2s) and found that short TR data has higher repeatability than its longer counterpart. The DMN pattern still significantly exists in a higher frequency band beyond 0.1Hz up to the Nyquist frequency of 1Hz. The result suggests that R-fcMRI analysis including data with the highest possible observed frequency increases single subject repeatability.

References: 1.Li SJ*, et al.* (2002). *Radiology*. 2.Chang C & Glover GH (2010) . *Neuroimage*. 3.Anderson JS, et al (2011) *AJNR Am J Neuroradiol* 3. 4.Jesmanowicz A,et al (2011) *Brain connectivity*. 5.Biswal B,et al. (1995). *Magn Reson Med*. 6.Baria AT, et al.(2011) *J Neurosci*.