Stronger brain functional connectivity revealed by Multi-band acquisition of fMRI

Zhan Xu[1], Guang-Yu Chen[1], Andrew Nencka[1], and Shi-Jiang Li[1]
[1]*department of biophysics, medical college of wisconsin, milwaukee, wi, United States*

Introduction: Multiband (MB) acquisition is a newly developed imaging acceleration technique, which excites and reads out multiple slices simultaneously by implementing multiband radiofrequency pulses [1]. In its application to fMRI, whole-brain scans can be finished within TR less than 1s, while the standard EPI (single-band [SB]) scan requires at least 2s. It is unknown whether the temporal contrast-to-noise ratio (CNR) and the underlying neuronal signals from MB are better. We did simulation in Matlab and implemented real human brain data to compare whole brain functional connectivity (FC) of the posterior cingulate cortex (PCC) on the MB and SB data sets. The results demonstrated that there was stronger FC from the MB data set, which has shorter TR. Higher sample frequency (fs) does provide better CNR after sampled signal are filtered.

Data: Open source resting-state whole-brain fMRI (R-fMRI) data sets of 10 normal human subjects were downloaded from the University of Minnesota NKI-RS Dataset; both MB and SB results are available for each subject. Important image parameters are: 0.645s TR, 900 time points (tps), 10 min duration for MB; 2.5s TR, 120 tps, 5 min duration for SB; 3-mm isotropic voxel size for MB and SB.
Simulation: For TR=0.645s, fs=1.6Hz; for TR=2.5s, fs=0.4Hz; therefore, fs/fo ranges from 4(0.4/0.1) to 100(1.6/0.015). In resting-state fMRI, the signal fo (highest original signal frequency) that is of importance is 0.015Hz-0.1Hz, here we generated sinusoid signal at 0.05Hz for 1000s, sampled noisy signal then filtered with bandpass filter at 0.015Hz-0.1Hz.

Method: We did three sets of comparison on both real and simulated data set. In Comparison No. 1, we truncated MB data (sampled signal at higher fs) to have same duration as SB data (sampled signal at lowest fs), but more tps. In Comparison No. 2, we truncated MB data (sampled signal at higher fs) to have the same tps as SB data (sampled signal at lowest fs) but a shorter duration. In Comparison No. 3, we down sampled MB data (sampled signal at higher fs) to have the same time interval as SB (sampled signal at lowest fs), so they have same tps and duration. In real data, PCC FC is calculated in the native space of each subject. Then, paired *t*-tests (p=0.05) were implemented after the FC image was warped into tlrc N27 space. Results of real data are shown in Fig1, Monte Carlo 5000 times' simulation are shown in Fig2

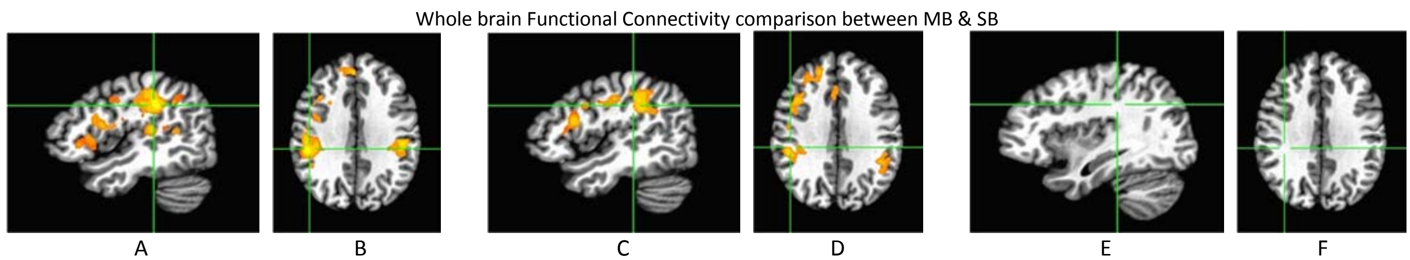

Fig1: Whole-brain paired *t*-test FC by using PCC as seed; yellow regions are where the MB FC is stronger than the SB FC. A, B) Results of comparison No. 1 when truncated MB data has same scan duration as SB but more time points. C, D) Results of comparison No. 2 when truncated MB has the same time points as SB but less scan duration. E, F) Results of comparison No. 3, when down sampled MB has the same time series interval and the same duration. In this case, MB has almost identical TR as SB data, their FC have no significant difference.

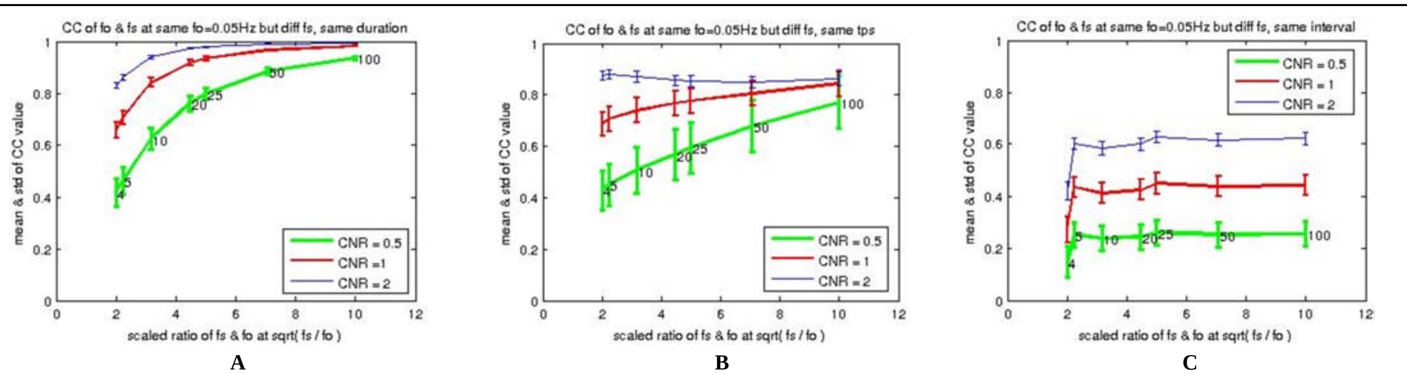

Fig. 2: CC of original signal and filtered noisy signal at different fs. Value at each data point on green curve indicates the ratio of fs/fo. Different colors indicate different CNR. A is result of Comparison No.1, B is result of Comparison No.2, C is result of Comparison No.3. Under same CNR, CC value is bigger at higher fs in Comparison No.1 & 2. Under same fs, CC value bigger at higher CNR in Comparison 1,2 &3. Under same fs & CNR, CC value is biggest in Comparison No.1, secondly in Comparison No.2, smallest in Comparison No.3

Analysis: Figures 1A and B indicate that the MB data set has stronger FC than SB data set. This can be explained by better temporal CNR due to more tps in the same duration. In our data set, the TR of MB data set is nearly four times shorter than SB data set. The fs of MB is almost four times larger than that of SB. Within the same scan time, MB yields more samples than SB. Assuming that the noise level remains constant in both modalities, the MB will have a higher temporal CNR due to signal averaging effect. Fig 2A described the same rationale.

However, in images 1C and D, the FC remains stronger when using the MB technique, even if the latter requires the same number of tps that the SB technique does. This result is quite interesting. It indicates that the MB technique produces better quality in a smaller time frame. Fig 2B described the same rationale. To avoid dynamic variation, we truncated the same tps from MB data set at a different period. The paired t-test result of different period with SB data set showed similar significant difference.

Furthermore, as evidenced in Figures 1 E and F, when the down sampled MB had the same time interval and tps as SB, the paired t-test gives no significant difference. Fig 2C described the same rationale.

Conclusion: By analyzing the FCC, as well as simulation of data quality in terms of fs, we proved that MB acquisition is able to provide better temporal CNR with shorter scan duration than the SB technique. This advantage allows for greater freedom in working with fMRI data acquisition parameters. We can compensate scan time to obtain finer resolution, while not sacrificing temporal CNR.