Navigated 3D fMRI vs. 2D fMRI

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Introduction: In functional MR imaging, methods which can achieve higher Signal to Fluctuation Noise Ratio (SFNR) are always desirable. Such methods can increase the temporal resolution or enhance our capability to detect even subtle BOLD signal changes. In principle 3D stack of spirals methods can achieve higher SNR than the 2D spiral method [1]. However, incoherence across the k_z direction causes increased fluctuation noise in 3D method. Here we examine the use of navigation [2] to increase SFNR in 3D method.

Methods: The 3D spiral acquisition method excites the whole FOV in the slab select direction, adds phase encoding in the same direction and then performs 2D spiral acquisition for each phase encoding step to acquire the 3D k-space data. Experiments were performed on a normal subject using a 1.5 Tesla whole-body scanner (Signa, GE Medical Systems, Milwaukee, WI) with normal head coil. Imaging parameters are TR/TE/FA/MAT/NSLC = 100ms/40ms/27/64*64/16. Additional data collected before the phase encoding gradient was applied were used to perform the phase correction along the slab select direction. Functional activation data was obtained with an auditory task in which subject heard tones at 3Hz during a 20-s "on" block and no tones during a 20-s "off" block. Six complete cycles were used for a total scan time of 4 minutes. Activation maps were overlaid on the T_2 images for visual inspection. SFNR is given by the ratio of average signal to the signal standard deviation across the time frames for a given pixel. The region of interest for the noise analysis is an 8*8 matrix located in a region near auditory cortex but avoiding susceptibility-dephasing and CSF.

Results: Representative results are shown below. Fig. 1 gives the comparison of auditory activations between 2D, 3D and navigated 3D acquisition methods. For thinner slices (4mm), the navigated 3D fMRI demonstrates greater volume and intensity of activations. For 6mm slices, the navigated 3D fMRI is not clearly an advantage over 3D or 2D fMRI. Detailed SFNR and fluctuation noise analyses for different slice thicknesses are given in Fig. 2. Patterns of percent of fluctuation are nearly independent of slice thickness. However, the advantage of 3D acquisition methods in SFNR vanishes gradually as the slice thickness increases. Fig. 2 also shows that the navigation correction is more important for thicker slices.

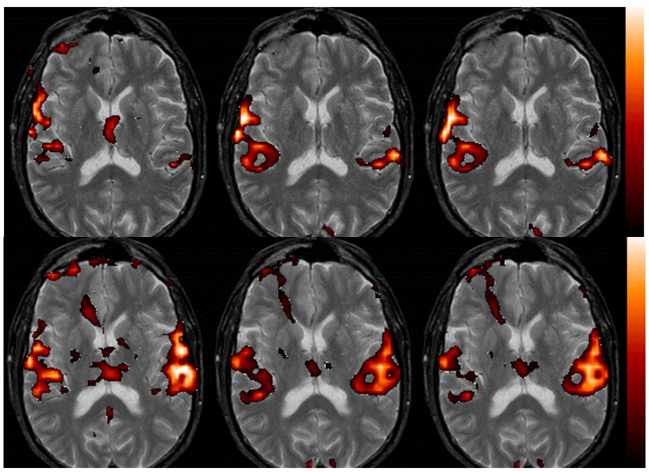

Figure 1. Comparison of auditory activations between 2D (first column), 3D (second column) and navigated 3D (third column) acquisition methods. The slice thickness is 4mm for first row and 6mm for second row.

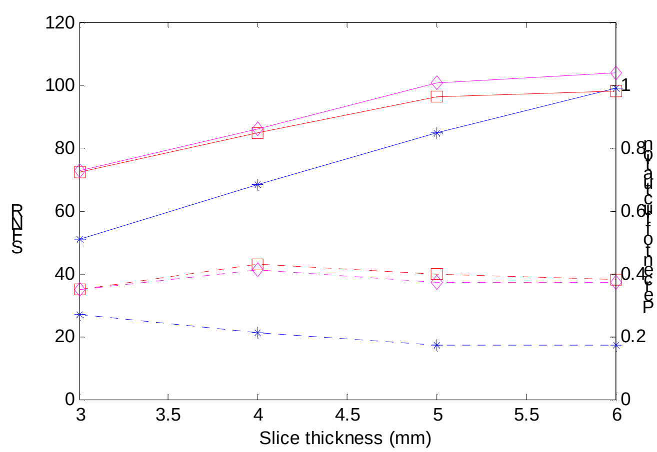

Figure 2. Comparison of SFNR (solid lines) and percent of fluctuation (dotted lines) between different slice thicknesses. Stars, squares and diamonds correspond to 2D, 3D and navigated 3D acquisition methods respectively.

Discussion: Results show that navigation correction can reduce fluctuation noise and increase SFNR in 3D acquisitions especially with thicker slices. However, for thicker slices, 3D acquisition methods lose SFNR advantage over 2D. Since the percent of fluctuation doesn't change, the results indicate that 3D acquisition methods suffer more signal loss than 2D as the slice thickness increases. This may be caused by intravoxel dephasing across the slab select direction because the signal in 3D methods is more sensitive to susceptibility-induced gradients. Future work will further elucidate reasons for the signal loss for thicker slices in 3D methods, thereby allowing 3D methods to achieve their theoretical superiority over 2D. Nevertheless, navigation can increase SFNR and BOLD signals in 3D fMRI and make 3D methods a superior alternative to 2D techniques.

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Reference:

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