Feasibility of high resolution 3D fMRI with whole brain coverage

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Introduction: One problem in high resolution fMRI studies is the low SNR of images. Although using a surface coil could increase the SNR, it will limit the studies to a certain area of the brain. However there are cases where high resolution fMRI over the whole brain is desired which will result in a large number of slices. The 3D method (1,2), as an alternative, has the benefit of increased SNR compared to the multi-slice 2D methods especially when the number of slices is large. The temporal resolution is very poor since multi-shot spirals are used to achieve the high in-plane resolution. However, using UNFOLD (3) technique it can be improved to a level which is equivalent to that of a single-shot spiral.

Methods: Experiments were performed on normal volunteers using a 3 Tesla whole-body scanner (Signa, GE Medical Systems, Milwaukee, WI) with a small head coil. A 3D 2-shot stack-of-spirals trajectory was used to cover the k-space. The FOV in the slab select direction was 96mm and the excited slab thickness was 93mm. 64 slices were reconstructed from 3D data with a slice thickness of 1.5mm. Two end slices were discarded to reduce aliasing artifacts. The in-plane trajectory consisted of two interleaved uniform density spirals with an echo time of 30ms, in-plane FOV of 22cm and in-plane matrix size of 128 × 128. Therefore the voxel size is 1.5mm×1.7mm×1.7mm. The TR for each spiral was 80ms and the flip angle was set to be Ernst angle (20°) to maximize the signal. 80 time frames were collected during the functional scan with a block design of 20s-on/20s-off and a task of a contrast-reversing checkerboard visual stimulus and bilateral sequential finger apposition paced by auditory cueing tone at 3Hz supplied through earphones. The total scan time was 819.2s. Two interleaved spirals were alternated during data collection. During the reconstruction process, UNFOLD technique was used to produce a separate time frame for each interleaved spiral. Therefore altogether 160 time frames were produced with an effective temporal resolution of 5.12s. The activation maps were generated by testing the degree to which the measured time series signal matches the sine wave model since the block lengths were short enough to sharply attenuate higher harmonics. For visual inspection, the activation maps were mapped onto T_2-weighted images obtained with a fast spin-echo (FSE) sequence (TE/TR of 68/3000 ms, echo train length of 8) using IDL software.

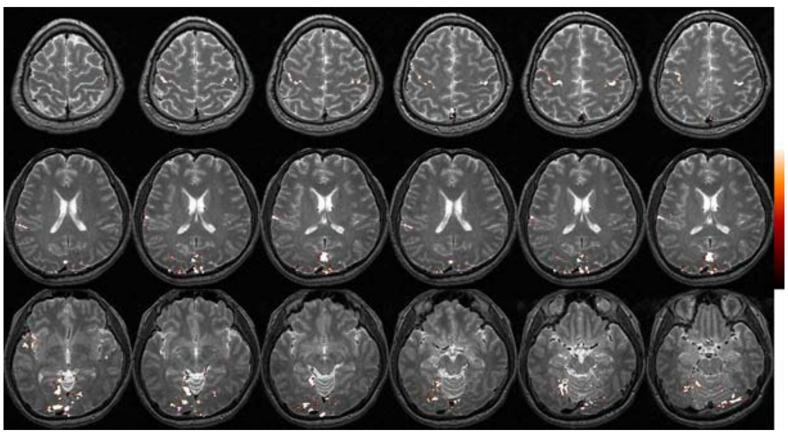

Figure 1. Activation maps from representative slices in motor (1st row), auditory (2nd row) and visual (3rd row) areas.

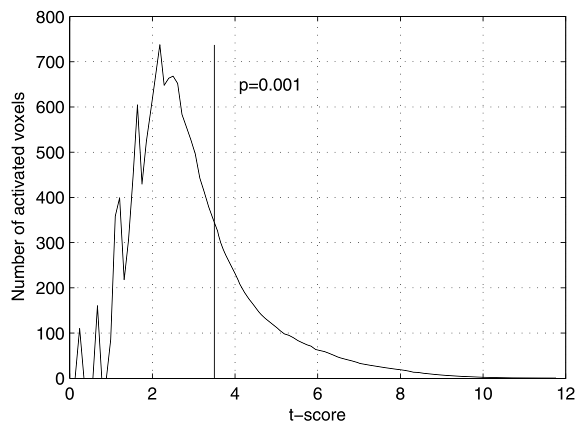

Figure 2. The histogram of activated voxels. Vertical bar depicts the threshold of p=0.001

Results: Functional results from representative slices in motor, auditory and visual areas are shown in Fig. 1. The scale of p-value is from 0.001 to 0.00005 and the corresponding t-score is from 3.50 to 4.35. Fig. 2 shows the histogram of activated voxels. The total number of activated voxels is 4381 and the average t-score is 4.98 when the threshold is set to be p=0.001.

Discussion: Experiments have shown that high resolution fMRI studies over the whole brain could be done within a reasonable amount of scan time. However, the temporal resolution is still somewhat low. To improve the temporal resolution, one way is to use the conjugated spiral-in/out technique (4) which will halve the scan time per time frame by combining the spiral in and out trajectory. However it is not applicable to high field fMRI studies (>3T) since the optimal TE is so short that there is no room for the spiral in trajectory. Another way is to use the partial k-space method which can improve both the SNR efficiency and the temporal resolution due to the existence of physiological noise according to our recent finding. We believe that with all these technique, the high resolution fMRI study over the whole brain with reasonable temporal resolution is feasible, which not only produces activation maps with much more details, but also increases our capability to study those regions suffering from the large signal dropout due to susceptibility gradients.

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Reference:

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