EVENT-RELATED FUNCTIONAL MRI AT HIGH SPATIAL AND TEMPORAL RESOLUTION USING UNFOLD

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Introduction

High temporal resolution is important to detect transient BOLD signal modulations in event-related functional MRI (fMRI) [1]. If spatial coverage is required, a major challenge for high resolution fMRI is limited temporal resolution. The UNFOLD method [2] to increase image acquisition speed has recently been applied to high resolution fMRI using a 3D-spiral sequence [3]. The presented combination of UNFOLD with a simple Cartesian imaging sequence can be easily implemented and does not require regridding of k-space data. In this study, a modified multi-echo FLASH sequence [4] was accelerated by UNFOLD by a factor of eight to obtain high resolution 3D images covering half of the brain within 3 seconds. This multi-echo 3D-UNFOLD-FLASH was applied to an event-related finger tapping experiment. The goal was to validate feasibility of this technique for fMRI requiring both, high temporal and spatial resolution.

Methods

Measurements were performed on a 3 T Magneton Trio system (Siemens, Erlangen, Germany) using a 16 channel head coil. The multi-echo 3D-UNFOLD-FLASH was used with the following parameters: TE/TR = 35 ms / 93.6 ms, FOV = 180 x 180 x 48 mm^3, flip angle = 22°, bandwidth = 520 Hz/Px, 3D encoding direction: head-foot, phase encoding direction: anterior-posterior. A fat-saturation pulse of 5 ms was applied before RF-excitation of a 3D slab. The matrix size was 256 x 256 x 16 leading to an in-plane resolution of 0.7 x 0.7 mm^2 and a slice-thickness of 3.0 mm. Each 3D-timeframe was two and fourfold undersampled along the slice and phase encoding direction, respectively. Thus, imaging speed of a single time frame was accelerated by a factor of eight resulting in a temporal resolution of 3.05 s per volume. Voxel-wise, spectral components arising from aliasing were set to zero to remove spatial overlaps [2].
Three healthy subjects participated in this event-related fMRI study. They received an auditory stimulus presented at a rate of 1/15 Hz. At each stimulus, finger tapping was performed for three seconds. In a total scan time of 13 min, 256 image volumes were acquired and reconstructed using UNFOLD. Functional results were processed and analyzed with the statistical parametric mapping software SPM8. Images were realigned to the average image (see Fig. 1) and coregistered to a T_2-weighted structural image before they were normalized to MNI coordinates. Subsequently, they were smoothed with a 1.4 x 1.4 x 3.0 mm Gaussian kernel. A one-sided t-test with $\alpha < 0.005$ was used to detect BOLD activation. Minimal cluster size was k = 50 pixels. The free software tool MARINA was used to identify activated brain areas.

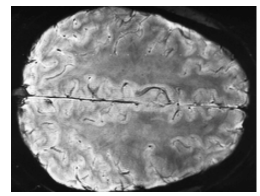

__Figure 1.__ Average image of 256 Multi-Echo 3D-FLASH images acquired at TE of 35 ms and a total scan time of 13 min during fMRI.

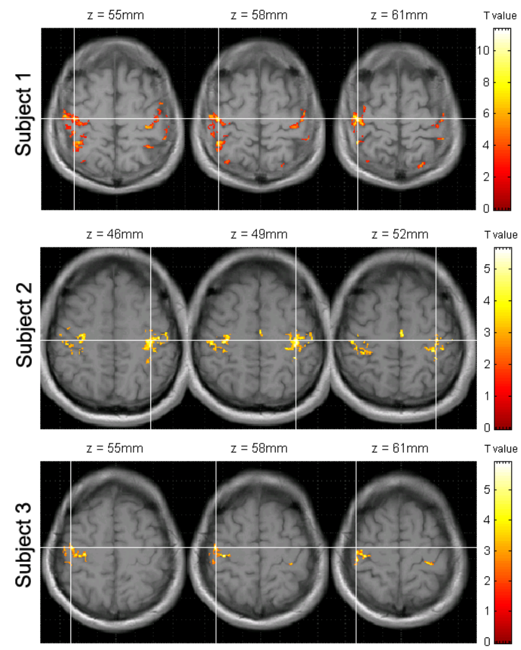

__Figure 2.__ FMRI results from three different subjects overlaid on an individual T1-weighted image presented in MNI space. Strong bilateral activation can be seen in two of three subjects. The z-coordinates are depicted for each slice. The left hemisphere is displayed on the right. The crosshair points at the peak voxel.

Subject	T^{max}	N^{active}	MNI: x y z	Area
1	11.33	4510	43 -18 61	Primary Motor Cortex-R
2	7.77	5401	-37 -20 49	Primary Motor Cortex-L
3	8.88	1794	38 -22 46	Primary Motor Cortex-R

__Table 1.__ Maximal t-value T^{max}, number of activated voxels N^{active}, MNI-coordinates of the peak voxel and the associated brain area are given for three subjects, who underwent a bilateral finger tapping experiment.

Results

The average of 256 images acquired during the fMRI experiment is free of noticeable artifacts at an in-plane resolution of 0.7 x 0.7 mm^2 (see Figure 1). Normalized activation maps show sensomotoric activation in all subjects (see Figure 2). No clear false positive activation can bee seen. The peak voxel in each subject was located in the Primary Motor Cortex (see Table 1).

Discussion

The results suggest that a Cartesian T_2*-weighted acquisition sequence in combination with UNFOLD is feasible for event-related functional experiments at high spatial and temporal resolution. We showed that artifact free high resolution morphological images can be acquired with UNFOLD. Further, it was demonstrated that activation can be reliably detected in the Primary Motor Cortex associated with finger tapping even though event-related paradigms have smaller signal than conventional block design fMRI [5]. In this study, periodic stimuli were used. Therefore, spectral components of an activated voxel can be easily separated from aliasing components allowing high undersampling factors using UNFOLD [2]. In future work, this technique will be applied to more complex cognitive paradigms without a fixed stimulus frequency, which might require more sophisticated temporal filtering strategies to detect BOLD activation.

References

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