Comparison of Volume-Selective z-Shim and EPI with an fMRI Memory Task

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Introduction

Single-shot gradient refocused echo planar imaging (EPI) is the primary tool used for functional MRI. This conventional method of imaging often suffers from signal drop near the air-tissue interface, such as the amygdala and the orbitofrontal cortex. An effective way of correcting for such artifacts is the method of z-shimming [1]. However, the scanning efficiency is significantly lowered. A new technique called volume-selective z-shim was proposed recently to apply z-shim to only those slices with large susceptibility[2]. Currently, there is still a lack of direct comparison between volume selective z-shimming and normal EPI based on the same scanning time. In this work, an fMRI study using a memory task involving faces is performed while applying both volume selective z-shimming and normal EPI techniques. The results show that despite fewer volumes collected during volume-selective z-shimming, the newly proposed technique is superior to EPI especially in the targeted areas of susceptibility, while little difference is observed in other areas.

Methods

Pulse sequence: volume selective z-shimming pulse sequence was implemented according to methods used in Ref. 2. For practical consideration, a z-shimmed slice acquired two images in every TR using different z-shimming levels, which is defined as the ratio of desired rephrasing gradient moment to its default value. The slice acquisition is designed as follows: for N slices and M z-shimmed slices, a total number of (N+M) slices are selected (Fig. 1). The sequence then goes back to the z-shimmed slices as the slice number is beyond N. In this manner, the effective TR for the two acquired images of the z-shimmed slice is not equal, thus having different weights in the composite image. This is slightly different from the method of Ref. 2, whereby TR is equal.

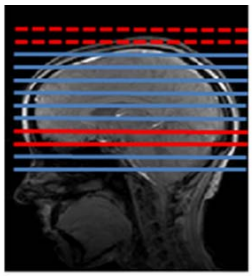

Fig. 1. schematic drawing of the volume selective z-shimming slices. Solid lines: actual slices for imaging; solid red lines: slices to apply z-shim; dashed red lines: virtual slices during slice positioning, the actual slice position is at the red lines.

Data acquisition: 6 subjects were scanned on a 3T Siemens Trio scanner. First, a high resolution anatomical scan was taken using MP-RAGE sequence. The functional scan consists of 6 runs: three runs each were applied to either z-shimming or normal EPI parameters. EPI runs and z-shimming runs were counterbalanced. A block design paradigm was used by presenting 10 seconds of neutral faces (2 seconds per face) alternatively with 10 seconds of fixation. Each run has 8 blocks. For z-shimming EPI, TR/TE = 2500/28 ms; 33 axial slices slice were acquired at 4 mm slice thickness; slices 2 – 11 were z-shimmed, with one z-shimming level set to 1 and the other between 1.10 – 1.15; flip angle = 81° for non-z-shimmed slices but 67° for z-shimmed slices. The same slices were taken for normal EPI, TR/TE = 2000/28 ms, flip angle = 77°. The flip angles were chosen to be the Ernest angle. The subjects were verbally instructed to memorize the faces, upon which at the conclusion of the task they would complete a memory test. The z-shimmed slices were chosen a priori to cover the hippocampus/amygdala and fusiform gyrus areas that would most likely activate during the task. The scanning time was same for all the runs.

Data processing: Z-shimmed images were combined using the sum of squares approach. Data analysis was done in SPM5. Data from z-shimming and normal EPI were processed separately. Realignment (motion correction) was first applied to the functional images. High resolution anatomical images were coregistered and resliced to the mean realigned functional image, followed by normalization that warps the resliced anatomical images to MNI standard T1 template, and then to all functional images. After smoothing, GLM analysis was performed to obtain the contrast of face vs. baseline for each subject. Group analysis was done afterwards.

Results

Fig. 2 shows the activation of the same brain areas across all subjects when using both z-shimming method and normal EPI. The fusiform gyrus is activated with both methods, as expected from the face stimuli. Strong activation near the hippocampus is observed in the z-shimming method, as a result of the memory task. However, for the same p-value, little activation is detected with normal EPI. Fig. 3 is the contrast between z-shimming and EPI, clearly showing that z-shimming recovers more signal in the hippocampus area, without any significant signal loss in other areas.

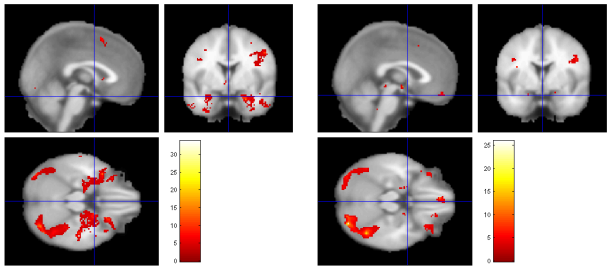

Fig. 2. Activation map from 6 subjects using z-shimming (left) and normal EPI (right). P < 0.01 uncorrected.

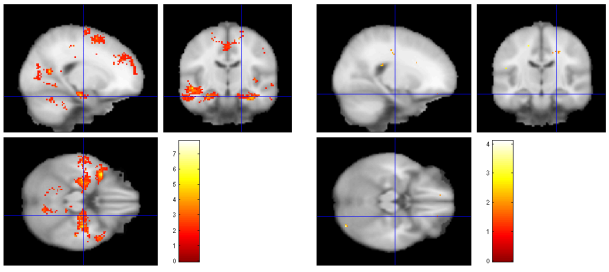

Fig3. Two sample t-test between z-shimming and EPI, left: z-shimming > epi; right: epi > z-shimming. P < 0.05 uncorrected.

Discussion

Our results demonstrate a substantial advantage of using volume-selective z-shimming EPI over normal EPI in the hippocampus area during a memory task. In the well z-shimmed areas such as the fusiform gyrus, although fewer volumes were collected, there is no significant loss of statistical power. This direct comparison suggests that volume-selective z-shimming is a promising solution for reducing susceptibility-related artifacts in fMRI.

References

1. Constable RT, J MRI 5:746-752 (1995). 2. Du Y.P. et al., MRM 57:397-404, (2007).