GRASE functional MRI with asymmetric spin-echo

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Introduction : Gradient-echo EPI (GE-EPI) sequence is commonly used for blood oxygen level dependent (BOLD) fMRI. However, GE-EPI is vulnerable to susceptibility artifacts. Moreover, the sequential acquisition of 2D slices limits the temporal resolution of GE-EPI to 2-3 seconds per brain volume, and the slice timing has to be corrected during post-processing. Alternative methods have been proposed for fMRI, such as spin-echo EPI, Z-shimming[1], and Haste [2]etc., yet few rival GE-EPI in terms of sensitivity, imaging speed and coverage. GRASE [3] is a hybrid of gradient and spin-echo sequences that provides 3D whole brain coverage with a single excitation. GRASE is also more resistant to susceptibility artifacts than GE-EPI. In the present study, asymmetric spin-echo (ASE) was implemented in GRASE to enhance the sensitivity to BOLD effects. The goal was to develop a novel fMRI method with high temporal resolution, adequate sensitivity, and whole brain coverage with resistance to susceptibility artifact.

Method : Six healthy volunteers (25±4 yrs) participated in this study which was performed on a Siemens 3T MRI scanner. GRASE consisted of GE-EPI readouts interleaved with spin-echo pulse train, and ASE was realized by shifting the central k-space line (or TE) in each EPI readout by adjusting the pre- and rewinding gradients. The ASE factor was defined by the relative position of the central k-space line scaled from 0 to 2 (1 for spin-echo). Four sequences were performed for comparison: 2D EPI, 3D GRASE, and 3D GRASE with ASE factors of 1.2 and 1.4. The image parameters were closely matched in all sequences. The common parameters were: FOV=220mm, Matrix=64×64, rate-2 GRAPPA, 26 slices with 4mm thickness. For EPI, TR=2s, TE=25ms, flip angle=80°; for GRASE, TR=1s, TE=22.6/26.4/30.4ms for GRASE/ GRASE_ASE1.2/GRASE_ASE1.4, flip angle=60°. Inferior saturation was applied during GRASE scans to minimize inflow effects. For each sequence, participants performed two tasks: 1) viewing an 8 Hz flashing circular checkerboard stimulus, and 2) performing a go/no-go response inhibition task. Both tasks employed a block design, with alternating 30s periods of task and rest. Each scan was 4 minutes in length. Each go/no-go block began with a cue indicating which letter participants should stop for in that block. Participants were instructed to press a button for all other letters. The order of sequences within performance of each task was counterbalanced across participants. All fMRI data were preprocessed and analyzed in SPM5, using a standard preprocessing stream. First-level models modeled both task and resting blocks using a boxcar function convolved with a canonical hemodynamic response function. Images for the contrasts task minus rest and rest minus task were computed for both the visual and go/no-go tasks. These images were then taken the second-level and the group-level activation was thresholded at p<0.01 with a cluster size of at least of 10 pixels.

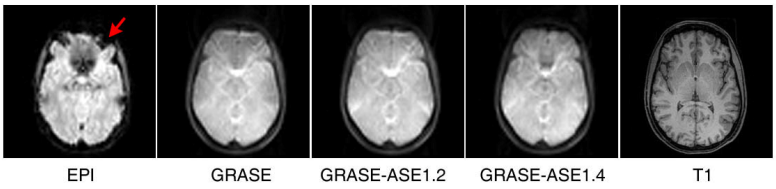

Figure1. Raw images of EPI, GRASE, and GRASE with ASE factors of 1.2 and 1.4 at the same position, along with T1 image

Results : Fig.1 shows the raw images of EPI, GRASE and GRASE with ASE at the same slice position. The EPI image shows considerable signal loss in the orbitofrontal and temporal cortex which are refocused in GRASE images. As expected, GRASE_ASE1.4 shows a small degree of signal dephasing in the orbitofrontal cortex. During visual stimulation, all EPI and GRASE scans showed significant activation in the visual cortex (Fig 2). As listed in Table1, GRASE with ASE factors of 1.2 and 1.4 almost doubled the activated pixel number and peak T-values compared to EPI and standard GRASE. For the go/no-go task, GRASE with ASE factors of 1.2 and 1.4 detected significant task-induced activation in the right ventrolateral prefrontal cortex (RVLPFC), as well as significant deactivation of the "default network", including the medial prefrontal cortex (MPFC) and posterior cingulate cortex. In contrast, EPI and standard GRASE failed to detect significant activation of RVLPFC or deactivation of MPFC.

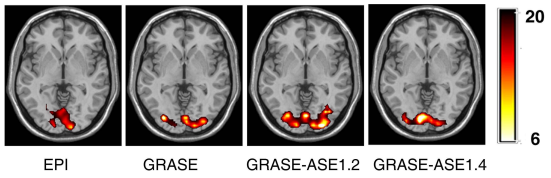

Figure2. Group-level visual activation of EPI, GRASE, and GRASE with ASE factors of 1.2 and 1.4

Table1. The number of activated pixel and peak T-valuesforgroup visual activation

Sequence	EPI	GRASE	GRASE1.2	GRASE1.4
Pixel no.	1110	904	2582	1620
T-peak	24.72	25.72	55.66	56.15

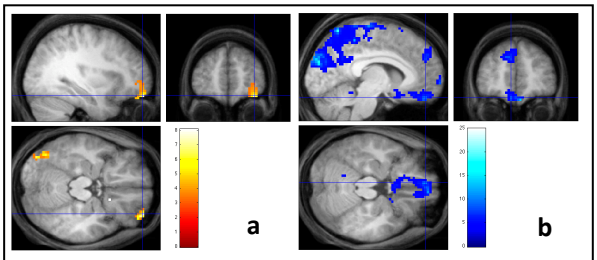

Figure3. Group-level activation (a) and deactivation (b) for the go/no-go task

Table2. The number of activated pixel and peak T-values of MPFC deactivation for the go/no-task.

Sequence	EPI	GRASE	GRASE1.2	GRASE1.4
Pixel no.	24	62	140(p<0.005)	133(p<0.005)
T-peak	8.19	10.61	10.34	13.14

A threshold of p<0.01 was used, except p<0.005 was used for GRASE with ASE

Discussion : The improved sensitivity of 3D GRASE with ASE may be attributed to high temporal resolution (1s per brain volume), reduced susceptibility artifact, and increased sensitivity to BOLD effects using ASE. The GRASE imaging speed may be further improved by parallel acquisition with higher acceleration especially along 2 directions. This may be particularly useful for event-related fMRI and resting state fMRI to filter out physiological noise.

Reference : [1] Heberlein KA and Hu X., MRM 2004; [2]Ye Y et al, NeuroImage 2010; [3]Günther M et al, MRM 2005.