BOLD fMRI using T2* weighted selective parity single shot 3D GRASE imaging

B. A. Poser[1,2], M. Günther[3,4], and D. G. Norris[1,2]

[1]FC Donders Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, Netherlands, [2]Erwin L Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, Germany, [3]Neurological Clinic, University Hospital Mannheim, University Heidelberg, Germany, [4]mediri GmbH, Heidelberg, Germany

Introduction and Theory

Blood oxygenation level dependent (BOLD) functional MRI (fMRI) finds widespread application in studying brain function. Here, three factors play an important role. First, high temporal resolution of typically < 3s per whole-brain acquisition, second, good signal to noise ratios (SNR) at acceptable spatial resolution to keep experimental durations short, and third, low artifact levels to ensure faithful image-to-anatomy mapping.

Currently 2D gradient echo EPI (echo planar imaging) is the most widely used compromise due to its favorable functional sensitivity and acquisition speed, but at the price of image distortion and dropout artefacts.

3D acquisitions have the advantage of generally higher SNR as compared to the 2D counterparts at same resolution. They can also help alleviate the dropout artifact by using slab excitation followed by e.g. Cartesian (EVI) (1) or spiral (2) readout; however, the rapid T_2* decay typically sets practical limits to acquisition volume per excitation.

An attractive alternative for the rapid acquisition of 3D data is the 3D GRASE (gradient and spin echo) sequence (3,4) which following excitation features multiple refocusing pulses in-between which a number gradient echoes are acquired around the central spin echo. Here, the available readout time is much increased as the signal decay is ruled by T_2 (rather than T_2*). In its original form, GRASE would have extremely limited BOLD sensitivity, and the requirement to meet the CMPG condition prohibits the introduction of additional T_2* weighting.

Based on the principles of the recently presented method for selective parity RARE imaging (5) we here demonstrate a modification of the GRASE sequence for fMRI which removes the CPMG constraint, and furthermore reduces the energy deposition by the introduction of a variable flip angle scheme (5,6).

Methods

In the selective parity approach (5), displacing read gradients are used as in standard displaced RARE (7), but with the important difference that both 'odd' and 'even' echoes within an echo train are selected, by placing the displacing gradient after or before a given echo, respectively. To minimize energy deposition, the refocusing angles are chosen using a recursive algorithm, such that the signal amplitude satisfies a predetermined modulation function. At each echo the parity that gives the desired signal amplitude for the minimum refocusing angle is selected. Even echoes are acquired with inverted gradients on the 3D-PE axis which is accounted for by appropriate time reversal and complex conjugation during image reconstruction.

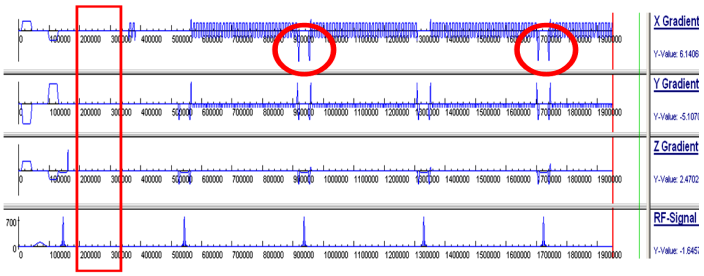

Fig 1: Sequence diagram of the selective parity GRASE sequence

We apply this scheme to an extreme of the GRASE sequence in which an entire 2D plane in k-space is acquired between each refocusing pulse (3,4). Schematics of the modified sequence are shown in Fig 1, where the red box and circles, respectively mark the additional T_2* weighting and read displacers (here for *odd-even-odd-even-…*echo acquisition). *In vivo* experiments on a 3T Siemens TIM Trio scanner (Siemens, Germany) with 12 blocks of 20s/30s on/off reversing checkerboard stimulation were performed on three volunteers with matrix 64x64x16 at 3x3x3mm^3 resolution, T_2*-weighting 30ms, BW=2000Hz/px, TE=40ms, TR=2s, readout train=600ms, fat saturation. 'Centre-out' acquisition was used in the slice direction. Even parity echo data were conjugated and time reversed before entering the product image reconstruction. Functional data were processed (motion correction, drift removal) and analyzed using t-tests at $p < 0.005$ in Brainvoyager 2000 (Maastricht, NL).

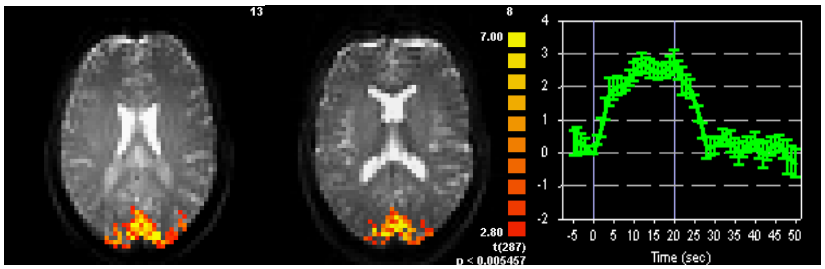

Fig 2: activation from one subject overlaid on GRASE images

Fig 3: stimulus response

Results and Discussion

Fig 2 shows selective parity activation from one subject, overlaid on the corresponding GRASE images. The average stimulus response is shown in Fig 3. The initial experiments show that activation can faithfully be detected using the proposed sequence. Combined with parallel imaging, fast single shot whole brain coverage will be feasible. Obvious advantages of the technique include potentially high SNR thanks to 3D excitation, and very short volume acquisition times. The sequence can be expected offer an attractive alternative to other fMRI acquisition schemes.

References

1. Mansfield P, Coxon R, Hykin J. JCAT 1995;19(6):847-852.
2. Hu Y, Glover GH. MRM 2007;58(5):947-951.
3. Gunther M, Oshio K, Feinberg DA. MRM 2005;54(2):491-498.
4. Song AW, Wong EC, Hyde JS. MRM 1994;32(5):668-671.
5. Norris DG. MRM 2007;58(4):643-649.
6. Le Roux P, Hinks RS. MRM 1993;30(2):183-190.
7. Norris DG, Bornert P, Reese T, Leibfritz D. MRM 1992;27(1):142-164