# PAID fMRI at 7T - investigating the benefits of multi-echo EPI at high field

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## Introduction

In fMRI, the use of a single TE generally requires a compromise in functional sensitivity due the variation of T2* across the brain. At lower field strengths the usefulness of ME-EPI schemes such as PAID (parallel acquired inhomogeneity desensitized) fMRI (1) is more obvious as the $T_2$* values are longer, allowing more echoes two be acquired. Substantial benefits could be demonstrated at clinical field strengths (1-4). At higher fields, $T_2$* becomes increasingly short (20-25ms at 7T), and the duration of the EPI readout may preclude suitably short TEs for the second and later echoes, especially for higher spatial resolutions/larger matrix sizes. The purpose of this abstract is to investigate whether using ME-EPI together with accelerated parallel imaging can offer benefits beyond the expected reduction in distortion, and whether gains in functional sensitivity (that is, BOLD CNR) can be achieved.

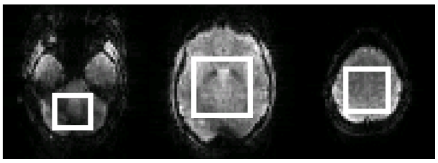

**Fig 1:** ROIs used for calculation of relative CNR of different ME weighting schemes vs. conventional EPI. Results are shown in the table

| ROI | 1 | 2 | 3 |
|---|---|---|---|
| simple sum | 1.10 | 1.10 | 1.03 |
| T2* weighted | 1.07 | 1.14 | 1.06 |
| CNR weighted | 1.17 | 1.19 | 1.08 |

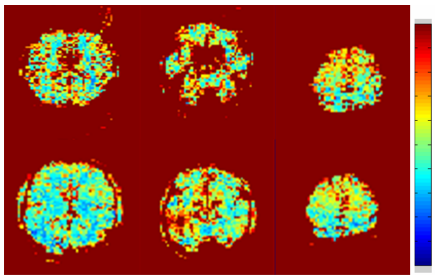

**Fig 3:** temporal noise in corresponding slices from conventional (top) and CNR weighted data. (scale 0-2%). SNR benefits are observed over the entire brain, dropout is reduced.

## Methods

A multi-echo EPI sequence was implemented on a Siemens 7 T whole body scanner (Erlangen, Germany), equipped with a 8-channel head TX/RX coil (Rapid, Wurzburg, Germany).

Two protocols were used on three volunteers: (a) 'standard' EPI scan: TE=24ms i.e. minimum possible at BW=1900 Hz/px, (b) 4 echoes at TE=9, 21, 33, 45ms with BW=2500Hx/px with GRAPPA (af=3) acceleration. Common parameters were Fov 224x224mm$^2$, matrix 64x64, 36 slices of 3mm thickness (20% gap), and TR 2s. No fat saturation and excitation flip angle 60 were used due to SAR limitations. Thorough manual shimming on the VOI was performed before the measurement. The sensitivity performance was analysed in two ways. First, from single and ME resting state data (50 volumes) relative CNR gains for simple and adaptive summation were calculated for various ROIs (see Fig 1) as described in (1), and tSNR of the processed data series was determined. Second, a matching paradigm with emotional faces that is known to elicit amygdala and fusiform face area (FFA) activation, which is particularly problematic due to distortion and dropout artifact. The task consisted of ten 30s blocks of face trials vs. elliptical shapes as control condition. ME data were subjected to (a) simple summation and (b) weighting based on assumed T2*=22 ms, (c) CNR weighting as previously described in the PAID method (1). In short, the relative pixel-wise BOLD CNR is estimated as the product of TE and tSNR (calculated from 50 resting state volumes), and used as weighting filter for the echo combination. Pre-processing and statistical analysis on all data series were done in Brainvoyager2000 (motion correction, linear drift removal, 4mm smoothing, t-test at $p < 0.005$, uncorr.).

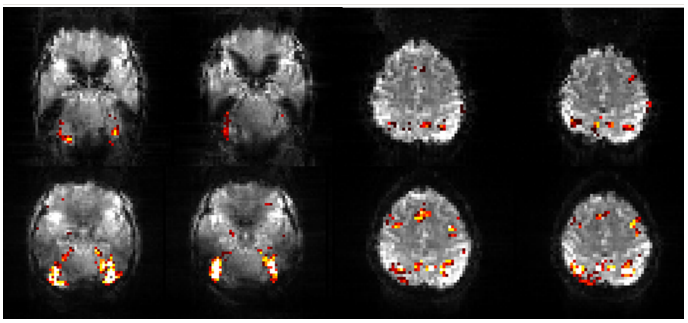

**Fig 2:** conventional EPI (top) and CNR weighted ME images (bottom) of one subject with activation overlays ($p<0.005$) showing activation in fusiform face area and motor cortices. Both dropout and distortion artifact are strongly reduced in the PAID data; activation size and t-scores are considerably higher

## Results and Discussion

Standard and PAID images with activation overlays are shown in Fig 2; distortions and through-plane dephasing artefacts are considerably lower in the PAID data, particularly in the inferior brain. Nyquist N/2 ghost artifact also appears to be lower. The tSNR evaluation (Fig 3) and CNR analysis (table) confirm that sensitivity benefits can be obtained throughout the brain, and the SNR loss induced by parallel undersampling and g-factor noise is outweighed by the advantages of ME acquisition. Functional experiments revealed stronger FFA and motor activation in ME-EPI data than conventional EPI. At $p < 0.005$ amygdala activation was only detected in the ME data, in one subject. The first experiences indicate that accelerated ME-EPI is also advantageous at 7T. With the rapid technological advances in coil design and number of receive channels, very much higher acceleration factors than used here should allow further improvements, resulting in both sensitivity enhancement and simultaneously reduction of distortion artefacts.

**References**

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