Isotropic Sub-Millimeter fMRI of V5 in Human at 7T

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Introduction:

Recently a combination of a zoomed approach (reduced FOV) with parallel imaging was proposed, to improve the image quality of single-shot EPI acquisitions [1]. For high resolution single-shot EPI at high field strength the use of parallel imaging is mandatory to address the problems of susceptibility induced geometric distortions and blurring due to T2* decay. However, imperfect parallel image reconstruction can result in remaining aliasing artifacts. The combination of parallel imaging with a zoomed approach can eliminate this specific problem, enabling high resolution fMRI acquisitions at ultra-high field strength [2]. Since human cortex is convoluted, the use of isotropic resolution is essential to identify specific areas, as for example V5, within the layer structure. The goal of this study is to demonstrate the feasibility of sub-millimeter isotropic resolution fMRI at ultra-high field strength.

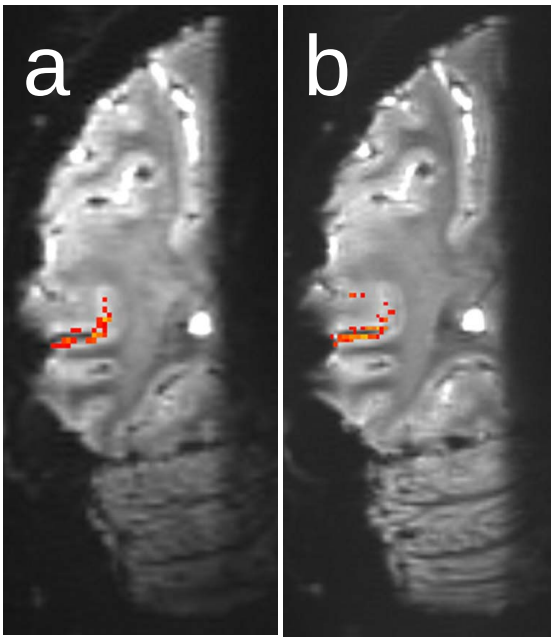

Fig 1: fMRI acquisitions from the same subject within a time frame of one month. The activation is overlaid onto the EPI mean image. a) Single-shot zoomed EPI with 0.8 mm and b) with 0.7 mm isotropic resolution.

Methods:

All experiments were performed on a 7T whole-body MR scanner (MAGNETOM 7T, Siemens Healthcare Sector, Erlangen, Germany). An 8-element phased array head coil (RAPID, Würzburg, Germany) was used. Eight healthy volunteers were included in the study; informed consent was obtained before each study. A functional paradigm with blocks of 40s stimulus-on and stimulus-off was used with 8 epochs for a total acquisition time of 20 min. For stimulus-on an expanding and contracting star field and for stimulus-off a static star field was shown to the subjects to activate the motion sensitive area V5. The experiments were performed with a zoomed EPI sequence (TR=5000ms, TE=27, FOV=43x128mm^2, 15 slices, voxel size=0.7x0.7x0.7mm^3) with OVS using a SKEWED pulse as proposed in [3,4] and a GRAPPA reconstruction with a 2D convolution kernel [5] with 3 source points along the readout direction and four source points along phase encoding direction and an acceleration factor of three.

Results and Discussion:

Fig.1 shows the mean EPI image from two different fMRI acquisitions, acquired within a time frame of one month from the same subject. The activation pattern is overlaid onto the mean EPI images. The zoomed EPI acquisition with an isotropic resolution of 0.8 mm is shown in Fig. 1a, while Fig. 1b shows nearly the same slice with an isotropic resolution of 0.7 mm acquired a month later. Enlarged sections of those images are shown in Fig. 2 with the activation pattern (Fig. 2a and 2b) and without the activation pattern (Fig. 2c and 2d). Normally the activation pattern is overlaid onto an anatomical scan with good gray/white matter contrast. In this study the activation pattern is overlaid onto the mean images from the EPI raw images. Due to this, there is no potential error in the registration as might occur whenever the activation pattern is overlaid onto anatomical images from a separate scan. As can be seen in Fig. 2, the activation is mostly concentrated above and below the vein but not within the vein.

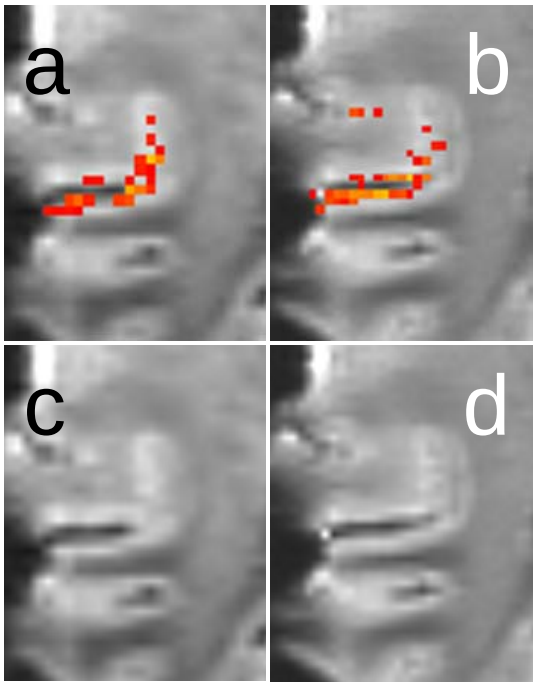

Fig 2: (top row) Enlarged sections showing the activation of V5 with 0.8 mm (c) and 0.7 mm (d) isotropic resolution. (Bottom row) The same EPI images without the activation.

Conclusion:

Sub-millimeter isotropic resolution fMRI is feasible at ultra-high field strength using a combination of parallel imaging and a zoomed approach. The open question, whether gradient echo EPI acquisitions at ultra-high field strength mostly show activations arising from oxygenation changes in larger veins, is not fully answered. However, in this case it is clear that the V5 activation does not come from the big adjacent vein. Further studies should allow studying cortical layer-specific activations.

References:

[1] Heidemann, et al. ISMRM 2008 #1284. [2] Heidemann, et al. HBM 2008 # 314. [3] Hwang, et al. JMR 1999;138:173-77. [4] Pfeuffer, et al. NeuroImage 2002;17:272-86. [5] Griswold, 2nd Workshop on Parallel Imaging 2004; p. 16-18.