Parallel imaging at 7T facilitates high-resolution whole-brain BOLD fMRI in humans.

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INTRODUCTION

BOLD fMRI at 7T profits from the high magnetic field strength not only because the increased image SNR translates into better spatial resolution but also because of an increased functional BOLD contrast (Yacoub et al. 2005). In order to realize these benefits in practice, a number of problems specific to ultra-high-field MRI need to be counterbalanced: Foremost inhomogeneities in the static magnetic field B_0 as well as B_1 the RF transmission field impair image quality particularly for GE EPI sequences with high EPI factors as are common for functional brain mapping experiments. Parallel imaging (PI) techniques effectively alleviate the detrimental effects of a long EPI readout in the presence of magnetic field inhomogeneities (Moeller et al. 2006). Also, it has been suggested that the experimental sensitivity to the BOLD signal contrast can be assessed by measuring the global BOLD response to a hypercapnic challenge easily induced by a short breath hold (Thomason et al. 2006, Cohen et al. 2004). We use this method to assess and demonstrate the feasibility of high-resolution whole-brain fMRI at 7T using parallel imaging.

METHODS

fMRI experiments were performed on a 7T Philips Achieva whole body scanner equipt with a volume head coil for RF transmission and a prototype 16-channel head coil array for detection (Philips Medical Systems, Cleveland, USA). Three healthy volunteers performed a classic finger-tapping task in a 20sec on/off bloc paradigm. Instead of tapping a second control experiment required subjects to hold their breath repeatedly for 20sec in the same 3 minute paradigm. A time series of functional T2* weighted image volumes were acuired by single-shot multi-slice gradient-echo EPI (TR/TE= 2000/25ms, flip angle= 70 deg, FOV= $(220\text{mm})^2$, matrix= 184^2, slice/gap= 3.5mm/0.5mm and PI (SENSE) reduction factor R= 4 or 5). The data were analyzed with the BrainVoyager QX software (Brain Innovation B.V., Maastricht, NL).

RESULTS & DISCUSSION

Fig.1a shows a single axial slice from one typical experiment (voxel size 1.2x1.2x3.5mm). The overlaid activation map shows all t-scores above 3. The average signal time course (**Fig.1b**) from the boxed activation region in the primary motor cortex (precentral gyrus, see corresponding T1-weighted anatomy in **Fig.2a**) shows a good 10% signal change as does a typical voxel time course shown in **Fig.2b**. The t-score map from the breath-hold experiment (**Fig.3**) also thresholded at t>3 demonstrate little geometrical distortions relative to the underlying anatomical images, but the BOLD sensitivity is seen to vary substantially on a local scale. In conclusion it can be said that whole-brain BOLD fMRI with minimal geometrical distortions and high spatial resolution (~1mm) is feasible at 7T using GE EPI and parallel imaging techniques, BUT a spatially variable BOLD sensitivity must be taken into account when interpreting such data. Hypercapnic challenge (breath hold) experiments are useful for assessing the local BOLD sensitivity. A more homogeneous BOLD sensitivity can only be obtained by solving the problem of magnetic field inhomogeneities inherent to high-field MRI.

REFERENCES

1) Cohen et al. 2004. NeuroImage 23:613-624
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Fig. 1a Mean functional image + t-score map (t>3)

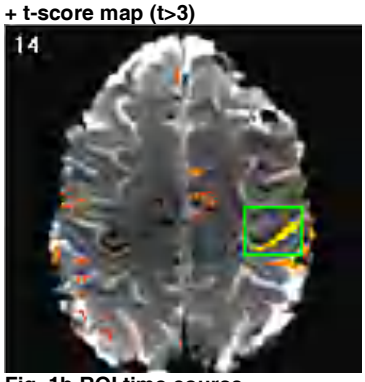

Fig. 1b ROI time course

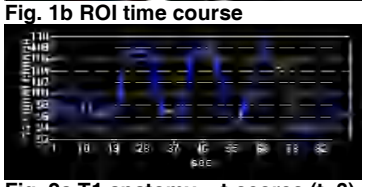

Fig. 2a T1 anatomy + t-scores (t>3)

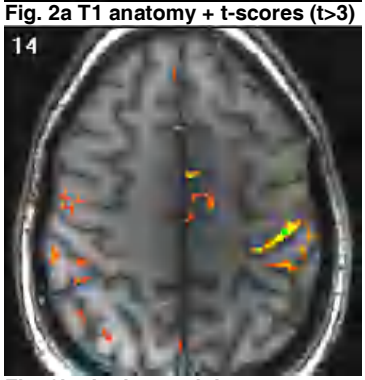

Fig. 2b single voxel time course

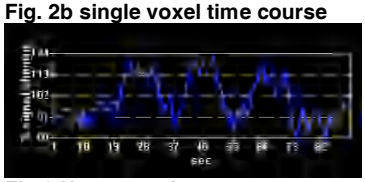

Fig 3 Hypercapnia: Two anatomical slices + t-map (t>3)