

Investigating the whole brain with 1.5mm isotropic resolution and 1.5s TRs using highly accelerated high-field fMRI

C. A. Olman^{1,2}, S. Moeller², J. F. Schumacher³, S. K. Thompson³, E. J. Auerbach², K. Ugurbil², and E. Yacoub²

¹Psychology, University of Minnesota, Minneapolis, MN, United States, ²Radiology, University of Minnesota, Minneapolis, MN, United States, ³Neuroscience, University of Minnesota, Minneapolis, MN, United States

Introduction

As very high-field scanners become more readily available, neuroscientists are increasingly interested in taking advantage of the increased signal-to-noise ratio for high-resolution fMRI applications. The drawback to high-resolution scans with corresponding thin slices is the limited coverage in the through-slice dimension, unless temporal resolution is sacrificed to increase the number of slices. We have previously described a GE EPI pulse sequence with multi-band slice excitation [1], allowing multiple slices to be acquired in parallel. We demonstrate here the application of this pulse sequence to an object recognition task. For tasks such as this, which study a distributed neural code and the effects of feedback in cortical networks, both full-brain coverage and high (spatial and temporal) resolutions are necessary.

Methods

Four subjects were scanned on a 7 T magnet (MagneX Scientific, UK) equipped with a Siemens console (Erlangen, Germany) and an Avanto body gradient set capable of 45 mT/m and a maximum slew rate of 200 T/m/s, and a custom-made 16-channel head coil. Scanning sessions consisted of six functional runs (6 min. each), plus acquisition of a T_1 -weighted reference anatomy (1 mm isotropic resolution) and a field map. Anatomical reference scans were acquired with a pulse sequence which interleaves a proton density acquisition with the T_1 -weighted acquisition to allow divisive intensity normalization during post-processing [2], which enables automated cortical surface reconstruction (using SurfRelax in this experiment). Visual stimuli subtended 6 degrees of visual angle and were projected on a screen behind the subject's head. For the first three experiments, functional data were acquired with a 160 x 160 mm field of view and a matrix size of 128 x 128 (reduction factor of 4) for a nominal in-plane resolution of 1.3 x 1.3 mm. Using multi-band excitation 32 sets of 4 coronal slices were acquired with a 2 sec TR, to cover the whole brain (192 mm in the A/P direction) with a 1.3 mm slice thickness. For subsequent experiments data were acquired with 1.5 mm isotropic resolution (30 sets of 4 coronal slices) and a 1.5 s TR. Functional data were analyzed with custom Matlab software after being corrected for B_0 inhomogeneity-induced distortion using the FUGUE tool distributed with the FSL toolbox.

Results

The distributed patterns of activity measured during an object recognition task (intact vs. scrambled, Fig. 1A) were consistent with known organization of the visual system. In addition, contextual modulation of BOLD responses in primary visual cortex (V1) was observed in all subjects. This modulation was stronger for difficult (cluttered background) than for easy (clean background) object recognition tasks (Fig. 1B). This pattern would not have been detected by a low-resolution analysis that calculates only an average response in a given cortical area because some voxels in V1 responded more strongly to intact objects, and others responded more strongly to unorganized images.

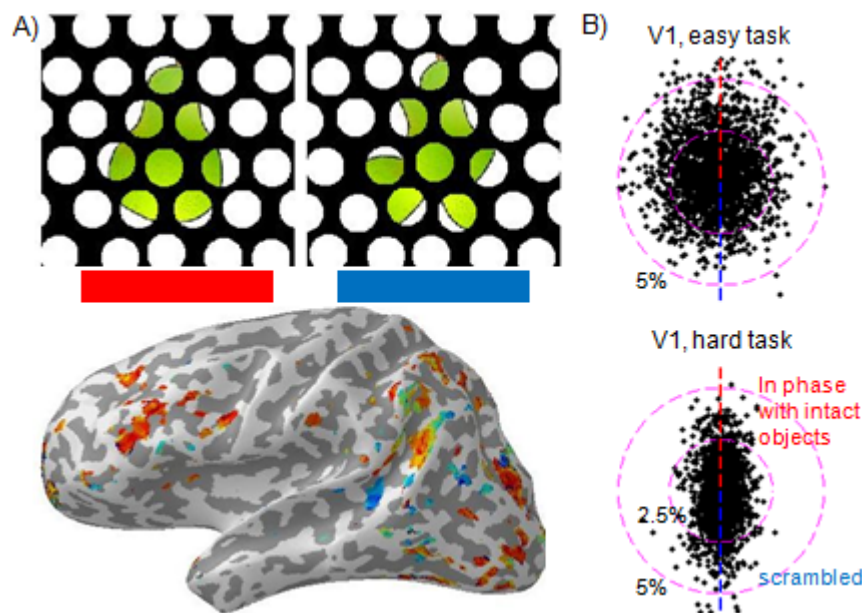


Figure 1. Distributed BOLD activity patterns within and between cortical areas reveal new information about visual object processing. A) Intact (recognizable) and scrambled (unrecognizable) objects were presented in a block design. Subjects covertly named objects throughout each scan, succeeding for 100% of the intact objects and <20% of the scrambled objects. Global patterns of activity are visualized on a cortical surface defined from the T_1 -weighted anatomy acquired during the same scanning session. Red colors indicate clusters of voxels with a larger BOLD response during blocks in which objects were recognized, blue indicates regions where BOLD response was higher when objects were not recognized. B) The responses for each voxel from V1 of one representative subject (1.3 mm resolution) are plotted on a polar coordinate system in which radius indicates strength of modulation and polar angle represents response phase (timing of peak BOLD response during block alternation cycle). In the easy task (top plot), objects were presented without background clutter, as in (A). In the hard task (bottom), objects were presented with background clutter.

References: 1. Moeller et al. ISMRM 2008, #2366, 2. Van de Moortele et al., ISMRM 2008. **Acknowledgments:** This work was supported by NIH MH70800, R01 EB000331, P41 RR008079, P30 NS057091, as well as the Keck Foundation and the MIND institute.