Wide screen visual stimulation: fMRI combined with fast GABA detection

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Introduction

Blood-oxygenation-level-dependent (BOLD) fMRI is the most-widely used technique to measure brain function, for both neuroscience and in the clinic. The interpretability of the signals measured, relies on the relationship between BOLD signals and the underlying neuronal activation patterns. It has been demonstrated that BOLD signals correlate well with high-frequency spectral power changes (>40Hz) measured with electrophysiology [1-2], however their relationship to neuronal metabolism is still not completely understood. The combination of functional MRI and functional GABA (γ-aminobutyric acid, a major neurotransmitter involved in brain function) measurements at high field is a promising avenue to relate BOLD signals to neuronal metabolism because both BOLD sensitivity, and spectral resolution and signal-to-noise are enhanced. The visual cortex is an attractive target region for this investigation, because its function is well characterized and it can be stimulated in a well-controlled manner. A key limitation, however, is the limited visual field of view attainable; the elongated scanner bore together with closed transmit coil configurations compromise the maximum projection size for visual stimulation. Often multiple mirrors and prisms have to be used. A large visual field of view is of particular importance, as it can allow a large voxel that encompasses tissue that is uniformly active (thus minimizing partial volume effects with in-active tissue that can mask signals arising from active tissue). Here, we examine the effectiveness of using a half volume transmit coil with a large screen for visual stimulation, in terms of extent of activation in primary visual cortex and in terms of achievable voxel size for relatively fast GABA measurements in the same region.

Method

Half volume coil set-up. This set-up consists of an open half-cylinder multi-transmit head coil with 8 channels (Fig. 1 up right) and two high-density 16-channel surface coils for receive (MR Coils B.V., Drunen, Netherlands). The transmit channels are connected to 8x1kW amplifiers and controlled in amplitude and phase for RF shimming. The projection screen is located at the back of the coil. The size of the projection is ~17x24 cm^2 visible though a 17x20 cm mirror (angulated at 45 degrees) positioned ~10 cm from eyes (>60 degrees of visual angle).

Standard MRI set-up (for reference). A volume transmit coil with a 32-channel receive head coil (Nova Medical, MA, USA). The screen is located at the front of the transmit coil and visible through prism glasses and a mirror (Fig. 1 up left). The projection size is ~9 x 15 cm^2 at ~30 cm from eyes (about 11 degrees of visual angle). In both cases the B_0 shimming was performed locally on the visual cortex. When using the half volume set-up an extra preparation phase was done to shim the B_1 field on the visual cortex.

For both set-ups an fMRI scan and a GABA scan was made with the following properties: fMRI (single-shot EPI, TE/TR= 27/1800 ms, 1.5x1.5x1.5 mm3 voxel, 16x17x5.3 cm^3 FOV, acquisition time= 3.5 min). 35 slices were prescribed orthogonal to the primary visual cortex (V1). We performed GABA spectroscopy with the following sequence: MEGA-sLASER [3] (single voxel, TE/TR= 78 /4000 ms, a voxel size of 25x25x20 mm^3 for the standard head coil (Fig.1 bottom left corner) and a voxel size of 40x40x20 mm^3 for the half volume coil (Fig.1 bottom right corner), spectral bandwidth: 4000 Hz, total acquisition time= 2:16 min).

The visual task for the fMRI scan consisted of a reversing checkerboard at 8Hz, in a 16s ON/OFF Block design, and run duration 3.5 min. fMRI data were analyzed using AFNI (motion correction, regression of stimulus time-course; the resulting activation maps were thresholded at $p<0.05$ Bonferroni corrected).

Results

The half volume coil set-up shows a large fMRI activation of the visual cortex encompassing about the entire extent of V1 (Fig. 1, middle right). In contrast, the limited visual field of view with the standard setup (Fig 1. middle left) resulted in substantially smaller spatial extent of activation, and mainly in the lower part of visual cortex due to the reduced screen height. The increased spatial extent of activity allowed for a larger spectroscopy voxel size comprising of tissue that would be uniformly active (Fig. 1 bottom row). The benefits of the increased voxel size can be seen in the MRS spectra by an increase in SNR . The GABA peak is clearly visible in the larger voxel, obtained in only 2:15 min.

Discussion & Conclusion

With the half volume set-up we increased the area of visual stimulation, allowing activation of the entire V1. This has shown a more than 2-fold SNR gain in GABA detection of predominantly active tissue as compared to conventional 7T setup, thereby bringing functional GABA detections at temporal resolutions that match closer to activation paradigms.

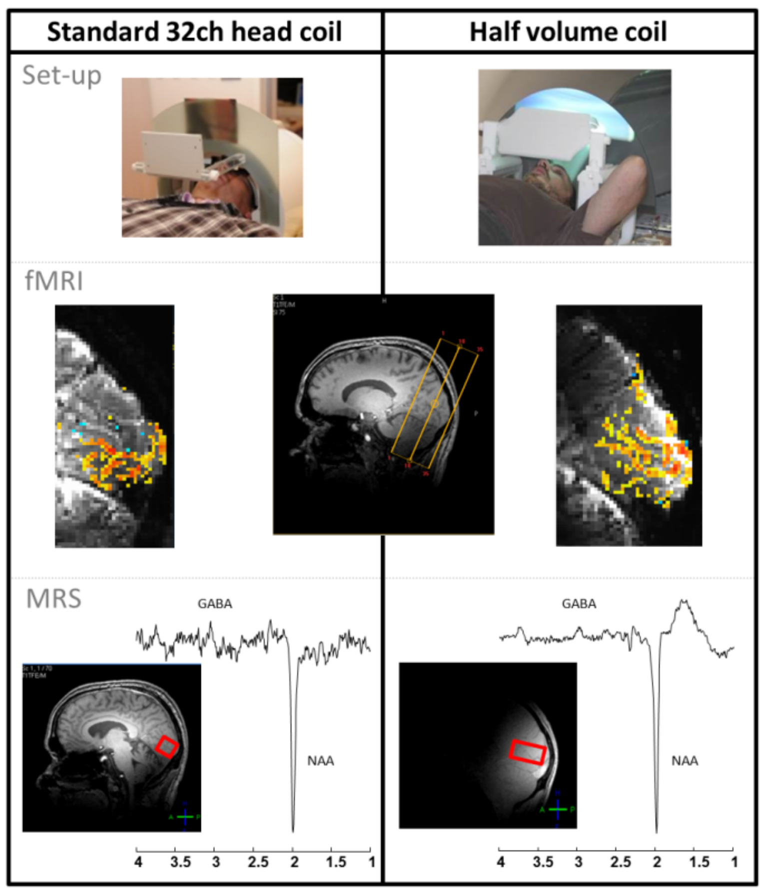

Figure 1: Results for the screen setups used with the standard head-coil (left column) and the half-volume tx coil (right column). Upper row: illustration of setup. Middle row: fMRI results for a sagittal slice encompassing the medial potion of V1 (p<0.05 corrected). The voxel position is shown on the anatomical images (right panels) Lower row: GABA edited spectrum for the voxel locations/sizes illustrated above.

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[3] A. Andreychenko et al. 2012 Magn Reson Med; 68:1018–1025