Functional MR imaging of the awake monkey in a novel vertical large-bore 7 Tesla setup

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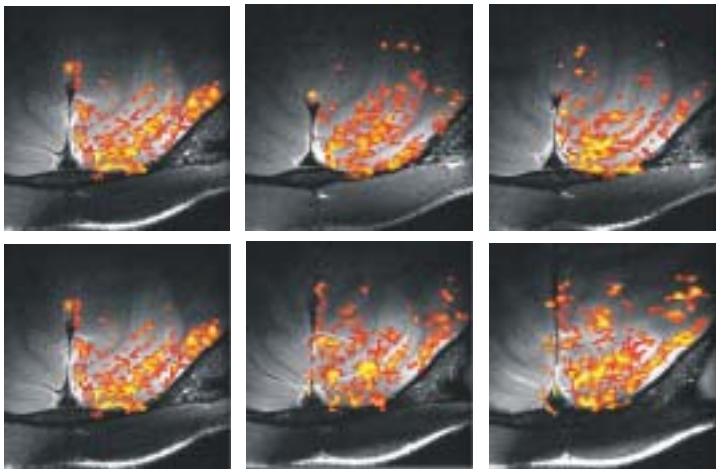
First fMRI results in the awake trained monkey (*Macaca mulatta*) using a novel vertical 7T/60cm MR system are reported. The setup was custom-designed for MR imaging of monkeys in upright position and simultaneous electrophysiological recording. Using fast gradients and optimized RF coils, the benefits of high magnetic field with increased signal and contrast-to-noise ratio are demonstrated in high-resolution anatomical and functional images.

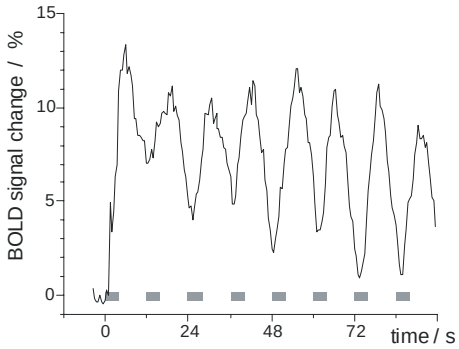
Introduction

Functional MR imaging in monkeys promises to build a bridge between brain research in humans and the large body of systems neuroscience work in animals [1]. Simultaneous fMRI and electrophysiology was recently used in the anesthetized monkey to elucidate the neural activity underlying the fMRI BOLD signal [2,3]. Here we present the first results from a novel high field (7T), large-bore (60cm) *vertical* MR system, in which MR imaging and electrophysiology is performed in the awake trained monkey. Upright positioning of the animal was chosen for fMRI to minimize discomfort, expedite their training process, and ensure longer cooperation during the demanding psychophysical testing.



MR System and Setup

The 7 Tesla magnet has a 60 cm bore, an overall height of 6.40 m, and an empty weight of 80 tons. The system, extending over three floors, is quality shielded for low and high-frequencies to ensure noise-free electrophysiological recording of both local field and action potentials inside or outside the magnet bore. It is controlled by a four-channel BRUKER BioSpec console. The 38-cm gradient insert achieves 80 mT/m in 130 μs. A variety of surface coils, quadrature surface coils, saddle coils, actively-decoupled combination coils, and surface coil assemblies for hetero-nuclear studies were custom-built similar to designs reported previously [4-6]. A prototype of primate chair was custom-designed and built to accommodate for the positioning of the electrophysiology assortments, the reward of the animal, the stimulus presentation, and the control of unwanted movement. The chair is driven into the magnet with a vertical transport system. All cables connecting the proximal end of the recording and monitoring devices to the main equipment were fed through a filter panel at the lower end of the chair. A similar chair was built for the experiments on anaesthetized animals. Full-field visual stimulation was done with a rotating checkerboard using 4s stim-on, 8s stim-off in 8 epochs. For fMRI experiments in the awake monkey, severe challenges like motion and dynamic off-resonance due to breathing, chewing, or body movement needed to be tackled.



Results

Initial MR imaging experiments were performed with gradient echo, spin echo, and inversion-recovery sequences to determine T1, T2, and T2* values for tissue. As expected, T2 of gray matter was decreased to 50 ms at 7 T compared to about 70 ms at 4.7T [1]. Functional imaging on the *awake* monkey was performed using single-shot GE-EPI with 0.75x0.75 mm^2 resolution (1 mm slice thickness, TE 25 ms, TR 0.5 s for 7 slices). Results from a *single* fMRI series are shown in Fig. 1 and 2 demonstrating robust activation with high *cc* values >0.5 and BOLD percent changes >5%.

The quality of the first anatomical and functional images acquired with this system promises the ultra-high resolution required to examine the local electrophysiological signal measured with microelectrodes in the context of the activation of small networks assessed in functional MR imaging.

References

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