fMRI Studies in Alert, Behaving Primates at 4.7T

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Introduction

Although significant progress has been made in high-field fMRI studies of primates (1), the use of anesthetics, paralytics and contrast agents in fMRI studies has introduced difficulties in data interpretation. fMRI studies in alert, behaving primates are essential due to the detrimental effect of anesthetics on the BOLD signal (2), as well as the ability to match human study protocols for comparison purposes. This work describes fMRI studies in alert, trained primates in which visual stimuli designed to activate regions of visual cortex were presented. The animals used in this study completed a six month successive approximation training process in which they became accustomed to the MRI environment and learned to fixate on a small cross presented in the visual field.

Method

Data were acquired on a Varian/Magnex 4.7T 60cm vertical bore scanner equipped with a chair/elevator mechanism for positioning the animals. Rhesus macaques were imaged in an upright sitting position. Binocular visual stimuli were delivered using an Avotec visual display system capable of eye tracking for verification of stimulus viewing and fixation accuracy. Inversion recovery (T_1) anatomic reference images were acquired with FOV=128mm, matrix=256^2, slice thickness=2mm, TR=2000ms, TI=650ms, while an echo planar sequence with FOV=128mm, TR=2000ms, TE=27ms, matrix=64^2 was used to acquire functional images. A quadrature birdcage volume resonator was used for transmit and receive for both reference and functional images. Visual stimuli were delivered in a block design with interleaved 30s periods of cross-fixation alternating with cross-fixation plus one of three flickering (5Hz) patterns: a disk 22º wide at the center of the field, or 15º wedges originating from the center of the field. Acquisition runs were 4-6 minutes in duration. Images were analyzed following application of motion correction, a Gaussian smoothing kernel with FWHM=5mm, and high-pass temporal filtering. Time series statistical analysis was used to provide Z-statistic maps with a cluster significance threshold of $p = 0.01$ (3-5).

Results

Figure 1 shows the BOLD activation maps for the various stimuli overlaid on anatomical images acquired while the animal was alert. The top panel shows a flashing disk stimulus in which striate and extrastriate areas of both hemispheres of the visual cortex are activated. The next two panels show use of the flashing wedge presented to either hemifield. As expected, presentation of hemifield-specific stimuli resulted in activation of visual cortex in one hemisphere only. Z-scores, from single 4 or 6 minute runs were on the order of 3-6.5 for the flashing wedge stimulus, while the large flashing disk yielded scores ranging from 7-9.8.

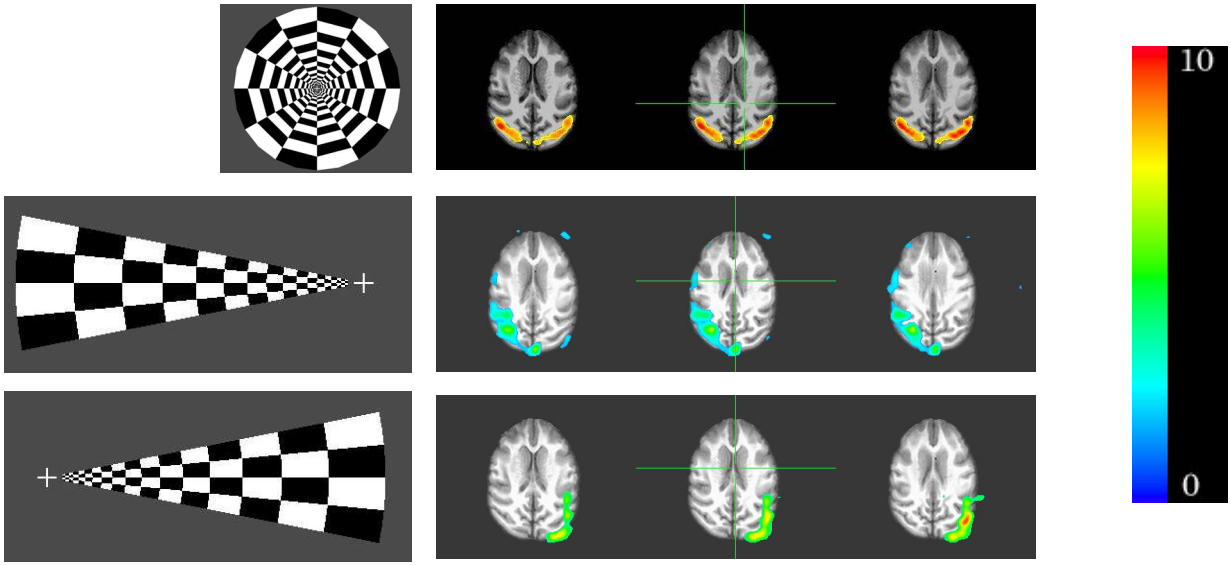

Figure 1: Stimuli and thresholded BOLD activation maps (color scale represents Z-statistic)

Discussion

These results demonstrate the feasibility of performing fMRI studies in alert primates when an appropriate training process is applied and ergonomic factors (e.g. upright seating, temperature control, etc.) are taken into account. The use of the hemifield stimuli with subsequent single hemisphere activation indicates that a general motion artifact was not being observed.

References

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