Assessment of ocular dominance plasticity with functional MRI at 3 Tesla

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Introduction

Monocular deprivation early in life induces changes in central visual pathways that favor the non-deprived eye (1), a phenomenon known as ocular dominance plasticity. The mechanisms by which these changes occur are thought to play important roles during normal development and may underlie basic forms of learning and memory.

Microelectrode recordings and optical imaging of the brain surface are typically used to assess the neurophysiological effects of ocular dominance plasticity. However, the invasive nature and limited spatial coverage of these techniques often limit experimental designs. For example, the time course of plasticity is typically assessed by comparing acute measurements from multiple animals of different ages (2-3). In some cases, longitudinal (rather than cross-sectional) studies are preferable, but these studies are rarely performed because of the difficulty in obtaining stable measurements from chronically implanted immature animals.

The non-invasive nature and excellent spatial coverage of functional MRI (fMRI) make it well suited for longitudinal studies. Our long-term goal is to use functional MRI as a complimentary tool for longitudinal studies of ocular dominance plasticity. Here, we investigate whether fMRI at 3 Tesla has sufficient sensitivity to detect the physiological effects of ocular dominance plasticity in kittens.

Methods

Animals and rearing: A total of 4 kittens (age 4-12 weeks) from two litters were used. Two kittens were monocularly deprived with a removable eye patch secured over the right eye with a lycra hood that fit snuggly around the snout and ears. All experimental procedures have been approved by the Institutional Animal Care and Use Committee at the Boston University School of Medicine and are part of a currently approved animal protocol. **Preparation for imaging:** Kittens were anesthetized with isoflurane gas, placed into a non-invasive head holder (bite bar, and padded head rest), and allowed to breath freely through a gas mask (%50 O_2 / %50 N_2O, 0.7 – 1.2% isoflurane). Drops of atropine sulfate (1%), phenylephrine (2.5%), and proparacaine HCl (0.5%) were administered to the eyes and +2D contact lenses were inserted. The animal's core body temperature, end-title CO_2 and respiration rate were monitored throughout the procedure with MR compatible instruments. Temperature was maintained at 38ºC with a hot water heating pad. **Imaging:** Functional MRI was performed with a 3 Tesla Philips Intera scanner (gradients 2.3 G/cm for single axis, bore size 65cm) and a two element surface coil (7cm), in combination with SENSE parallel imaging. Coronal images were acquired with a T2* weighted gradient-echo echo-planar imaging pulse sequence (TR = 1300ms, TE = 35ms, 2-shots, 15 slices, 1.5 x 1.5 x 2 mm). **Visual stimuli:** Visual stimuli were full field, high-contrast, drifting square wave gratings (4s duration, 25s inter-stimulus interval, 0.2 cycles/deg, 2Hz), presented independently to right and left eyes through a binocular kaleidoscope constructed from acrylic mirrors (**Fig. 1**). The binocular kaleidoscope expands the visual field of the stimulus, allowing equal and independent full field stimulation of each eye.

Results

Repeated MRI scans, with recovery times as short as 24 hours, were well tolerated by all animals based on normal weight gain and active play between imaging sessions. Consistent BOLD activation was detected in the visual cortex and lateral geniculate nucleus (LGN). **Figure 2** shows example coronal images from a normally reared kitten scanned at 6, 9 and 11 weeks of age. Visual cortical activation was observed in the superior portion of posterior slices (**Fig. 2 top row**) corresponding to area 17 of primary visual cortex. Focal, bi-lateral LGN activation was observed anterior and inferior to cortical activation (**Fig. 2, bottom row**). Monocular deprivation during the critical period depressed cortical BOLD responses elicited through the deprived eye (**Fig. 3**). Deprived eye LGN responses were also depressed but to a lesser extent than cortical responses (**Fig. 3**). These results suggest fMRI at 3 Tesla has sufficient sensitivity to detect the neurophysiological effects of ocular dominance plasticity.

References

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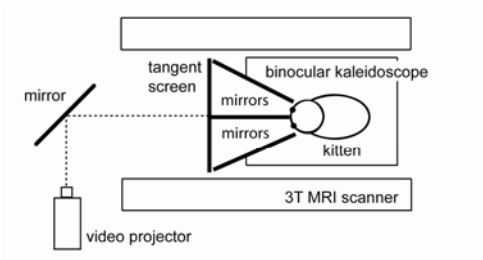

Figure 1

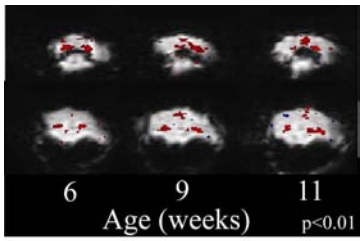

Figure 2

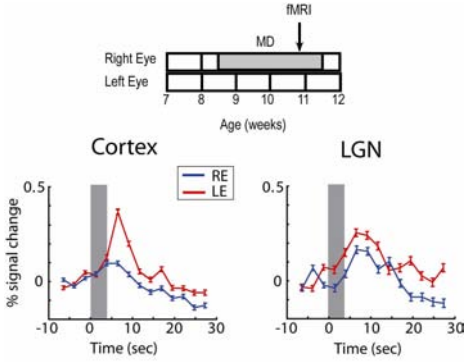

Figure 3