Adaptation of the visual cortex in response to cataract surgery

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Introduction

A plethora of studies have documented the plasticity of the brain during development [1]. However, only few studies have investigated the adaptability of the aging visual cortex. No previous studies have investigated how the normal aging brain responds to full and immediate restoration of input after chronic impairment [2]. We here examine the effect on excitability of the visual cortex as measured by the Blood Oxygenation Level Dependent (BOLD) signal in cataract patients before and after cataract surgery.

Material and Method

We examined 15 patients without brain disease before cataract surgery, 2 days after surgery and 6 to 8 week after surgery. The patients were in age range 35-84 year median age 70 year, 5 female and 10 male. Thirteen subjects had binocular cataract, two had monocular cataract. We assessed the effects on the activation pattern in primary areas by using a region of interest (ROI) approach.

Functional MRI

The scanning was performed on a 3.0 T Siemens Magnetom Trio Scanner (Siemens, Erlangen, Germany). The functional volumes were acquired using the standard single channel birdcage headcoil (Siemens, Erlangen, Germany). T_2*-weighted echo planar imaging (EPI), with 40 slice of 3mm positioned to the anterior and posterior commissures (AC-PC line), were acquired with the following parameters: TR=2.37s, TE= 30 ms, flip-angle 90 degree, FOV= 192mm and in-plane resolution 3 x 3 mm^2. For each eye (while the other eye covered by an eye-pad) 121 volumes were acquired. During the functional MRI acquisition the cardiac cycle and the respiratory rate were recorded with an infrared pulse oximeter on the patient's index-finger and a pneumatic thoracic belt, respectively. In addition to the functional scan a Magnetization Prepared RApid Gradient Echo (MPRAGE) volume was also acquired for anatomical localization and normalization purposes.

Visual stimulation: was done using a LCD projector, placed in an adjacent room, projecting through a zoom lens on a screen behind the patient's head. The screen could be seen by the patient through a mirror, covering 12 degrees x 18 degrees of the visual field. The stimulus consisted of a full-field black and white annular checkerboard reversing at 8 Hz with checker sizes reflecting the cortical magnification factor [3]. Each eye was stimulated separately; the non-stimulated eye was covered by an eye-pad. The stimuli were organized in blocks of 10s periods of flickering checkerboard, 10s interval of pause. The total scan time for each eye was 5 min 6 s. The patient remained in the head coil while the eye-pad was moved to the other eye. The stimulation sequence of the two eyes was balanced.

Analysis

The anatomical scans were normalized using the SPM5 software package. We identified Brodmann Area (BA) 17 from the MPRAGE scan using the SPM5 anatomy toolbox [4]. Functional scan were realigned, normalized and smoothed (8 mm full width at half maximum isotropic Gaussian kernel) prior to the analysis. The analysis for each individual scan was performed using a general linear model (GLM) as implemented in SPM5. In order to reduce residual autocorrelation additional nuisance regressors were added in the GLM to account for signal induced be movement, cardiac and respiratory effects [5].

Results and discussion

One-way analysis of variance revealed no significant (p=0.15) change in the mean activation (difference between operated and non-operated eye) over the three examinations in the primary visual cortex. However, we observe a tendency that activation slowly decreases postoperatively significant at the $p \leq 0.05$ level when testing for a linear effect in the difference between operated and non-operated eye as a function of examination as illustrated in figure 1. We conjecture that this effect may be caused by additional processing in the visual cortex required when the eye is affected by cataract or (slowly) recovering after cataract surgery. Note that even though visual acuity is almost completely restored immediately after surgery we fail to see a clear effect in the neural activity as measured by BOLD fMRI. Preliminarily these data show interesting results, however, further studies are needed in order to clarify the effect that quick recovery of vision (such as cataract surgery) has on the cortical activation.

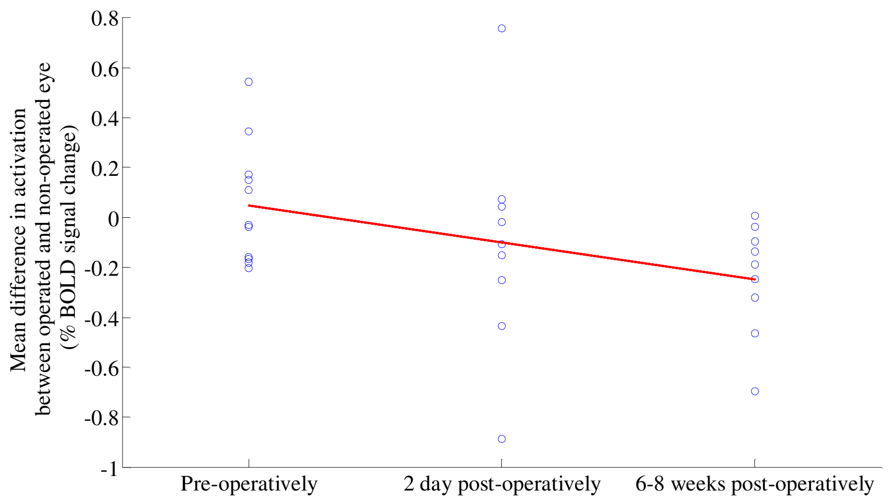

Figure 1. Difference in BOLD signal change between the two eyes (y-axis). Preoperatively (1), 2 days after operation and patch (2), and 6-8 weeks later during restitution without patch (3), (x-axis).

The figure shows averages over the BA17 ROI as the individual observations (subtractions of activity in affected and unaffected eye) as blue dots and a linear fit over the 3 examinations by a red line (slope significant at $p \leq 0.05$).

References: [1] Barret *et al.*, Neuroscientist 2004. [2] Karmakar *et al*, Neuron 2006. [3] Slotnick *et al.*, Clin. Neurophysiol 2001. [4] Eickhoff *et al.*, Neuroimage 2005. [5] Lund *et al.*, Neuroimage 2006.