Closing the eyes in blind-folded subjects induces deactivation in early visual cortex

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Introduction

Recent observations from EEG [1,2] and PET [3] have indicated a difference in brain states with the eyes open compared with the eyes closed. What is unclear from these studies is if closing the eyes changes the brain state only by reducing the photons reaching the retina or if the effect is independent of the visual input. To adress this, we designed an experiment to compare 'eyes-open' and 'eyes-closed' states using fMRI that is independent of the light entering the eye. We observed a decrease in blood oxygenation level dependent (BOLD) signal and cerebral blood flow (CBF) with eyes closed in the early visual cortex indicating that the activity of the early visual cortex can also be modulated with no change in the visual stimulation. Some implications of this finding are discussed.

Methods

We measured BOLD signal and CBF on 12 healthy subjects (21-40 year old, 10 male, 2 female). The subjects were imaged with a 4T whole body imaging systems (Varian NMR systems) using either a 34cm volume coil or a surface receive coil (Nova Medical), which was placed closed to occipital cortex. Four oblique slices parallel to the calcarine sulcus were acquired with a voxel size of 3.75mm x 3.75mm x 4mm. We used an arteial spin labeling sequence (PICORE-QUIPSS II with TR = 2s, TE = 26 ms, TI1 / TI2 = 700ms / 1400ms, flip angle = 90 degrees), which enabled us to measure BOLD signal and CBF simultaneously [4]. The BOLD signal is constructed as the running average of the control and tagged images and the CBF as the running difference [4]. All data were coregistered to avoid a movement bias. In addition to darkening the room completely, the subjects' eyes were covered with a blindfold to avoid any ambient light reaching the eyes. Four cycles of 40 seconds 'eyes open' followed by 40 seconds 'eyes closed' were preformed. A verbal cue was used to prompt the subject to open or close his eyes. The BOLD signal time series for each voxel was correlated with a reference function constructed assuming a gamma-variate hemodynamic response and the correlation coefficient threshold was varied until about 50 voxels in the visual cortex were activated for each subject. The average time courses were built from these selected voxels.

Results

Eight of 12 subjects showed significant decrease in BOLD signal in the visual vortex during 'eyes-closed' compared with 'eyes-open'. Two subjects were excluded from the analysis due to movement artifacts and for two other subjects no significant change in BOLD signal in the visual cortex was observed. No subject reported a change in illumination during 'eyes open' periods compared with 'eyes closed' periods. A representative subject is shown in Figure 1. All voxels which have a correlation coefficient above the threshold are color-coded on top of the underlying is the average CBF image. It can easily be seen that almost all significant voxels are located in the grey matter of the visual cortex. The corresponding BOLD signal time course is presented in Figure 2. The 'eyes closed' periods are indicated in grey. The modulation of the BOLD signal due to closing and opening the eyes can be seen in every cycle. The decrease in BOLD signal compared with eyes open is approximately 4%. The corresponding decrease in CBF was approximately 15%.

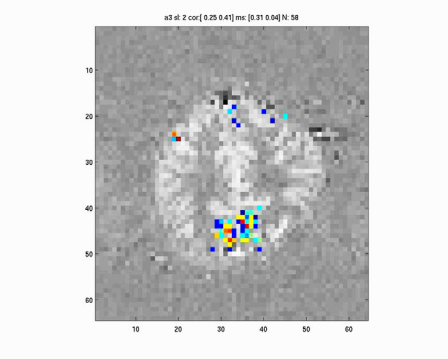

Figure 1

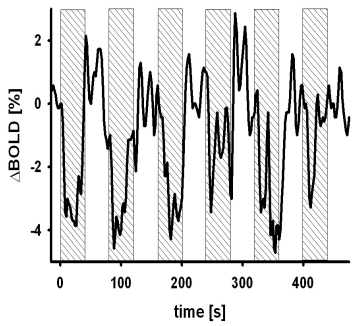

Figure 2

Discussion

A decrease in BOLD signal -- and presumabely in neuronal activity -- in the early visual cortex was found due to closing the eyes, with no visual stimulation in either state. With this experiment we were able to demonstrate that the activity of the early visual cortex can be modulated independent of photic stimulation and top-down processes like goal-directed attention. Further studies are needed to evaluate the neuronal pathways and mechanisms, which are causing this effect. Closing the eyes may be a cue to initiate a general shift in brain states and the relationship between this effect and the reported increases in EEG alpha-power require further investigation [1]. This work demonstrates that fMRI provides a sensitive tool for probing brain states independently of specific stimulation.

References: [1] RI Goldman et al Neuroreport 2487-92 (2001) [2] Moosmann et al Neuroimage 20: 145-58 (2003)[3] ME Raichle et al PNAS 98: 676-82 (2001) [4] EC Wong et al NMR Biomed 10:237-49 (1997).