A Voxel Based Morphometric Analysis of the Effect of Visual Experience on the Structural Organization of the Human Brain

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Introduction:
Neuroimaging studies have demonstrated that the visual cortex of both the totally blind and the partially blind subjects exhibit significant functional plasticity. However, fewer studies have dealt with structural plasticity associated with blindness. In this study we attempted to detect sub-cortical gray and white matter changes with the extent of sightedness a person has, through optimised Voxel Based Morphometry (VBM) technique applied in totally blind subjects, partially blind subjects and controls.

Materials & Methods:
Fifteen controls, thirteen totally blind subjects and seven partially blind subjects (20-30 years) were recruited for the study. The subjects chosen for the study were age, sex and education matched. The reported onset time of blindness for both total and partial blinds ranged from at birth to 6 years of age. In ophthalmologic examinations performed before imaging, five of the total blinds were found to be sensitive only to strong sunlight. None of the subjects chosen for the study had any clinical evidences of stroke, head injury, cardiovascular diseases, history of drug dependence, neurological or psychiatric disorder nor did they have any cortical infarctions on the T2-weighted MR images. The MRI scans were acquired using 1.5 Tesla whole-body MRI system (Siemens Magnetom Vision, Erlangen, Germany) with a circularly polarized head coil and 25 mT/m actively shielded gradient system. T₁-weighted MR images. The MRI scans were acquired using 1.5 Tesla whole-body MRI system (Siemens Magnetom Vision, Erlangen, Germany) with a circularly polarized head coil and 25 mT/m actively shielded gradient system. T₁-weighted 3D-MPRAGE sequence with 160 thin slices was performed in the sagittal plane, FOV = 256x256 mm². Pre-processing and post-processing was performed using SPM2 software in MATLAB environment. Talairach-Daemon Client was used for estimation of Brodmann Areas.

Results & Discussion:
MRI screening revealed ocular atrophy in five out of seven partial blinds and eleven out of thirteen total blinds. The normalized, segmented, smoothed and modulated data sets were assessed using the ‘ANOVA’ showing regions of (a) reduced GM volume in total blinds as compared to controls (b) reduced GM volume in partial blinds as compared to controls (c) reduced WM volume in total blinds as compared to controls (d) reduced WM volume in partial blinds as compared to controls (e) reduced GM volume in total blinds as compared to partial blinds.

Analysis of white matter (WM) showed significant atrophy in the regions of occipital lobe; Pons; Anterior Cingulate and Corpus Callosum of the total blinds as compared to the controls. In the partial blinds, WM reduction was obtained in Pons, Corpus Callosum, Parahippocampal Gyrus and Inferior Frontal Gyrus as compared to controls. A white matter atrophy in Pons and Corpus Callosum suggests a deficit in the effective communiqué between the hemispheres and sensory information processing ability in the blind subjects.

The changes observed in the GM and WM volume of the partially blind subjects were less severe as compared to those of totally blind subjects (Figure 1). Further, no significant change in WM volume was observed between the partially blind and totally blind subjects. However, GM loss was observed in the Cerebellar Tonsil in the posterior lobe of the cerebellum, Superior Frontal Gyrus and the Superior Parietal Lobule in the totally blind subjects when compared to the partially blinds. This may be due to the fact that partial blinds are able to better assess visuo-spatial orientation as compared to totally blind individuals because of greater extent of visual experience.

Figure 1: ‘ANOVA’ showing regions of (a) reduced GM volume in total blinds as compared to controls (b) reduced GM volume in partial blinds as compared to controls (c) reduced WM volume in total blinds as compared to controls (d) reduced WM volume in partial blinds as compared to controls (e) reduced GM volume in total blinds as compared to partial blinds.

Conclusion:
Loss of vision at an early age can induce significant morphological changes due to disuse-related mechanism originating on account of loss of peripheral visual input. These plastic changes are most pronounced in early onset of total blindness as compared to partial blindness.

References: