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.T_1 weighted 3D-MPRAGE sequence with 160 thin slices was performed in the sagittal plane, FOV = 256x256 mm^2. 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 '**AN**alysis **O**f **VA**riance (ANOVA)', thresholded at $p \leq 0.001$ uncorrected, to find the alterations in the brain tissue composition of the blind subjects relative to the control group.

Significant gray matter (GM) volume loss was observed in regions of neo-cerebellum; parietal lobe; Insula; Parahippocampal Gyrus; limbic lobe; Frontal Gyrus and pre-frontal lobe in the total blinds relative to thecontrols. In partial blinds, GM volume loss was detected in the regions of occipital lobe; limbic lobe and Caudate relative to the controls. GM atrophy in the above regions suggests a deficit in fine motor coordination, spatial judgment, visual memory retaning capacity, regulation of emotional behaviour and control of voluntary movement.

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.

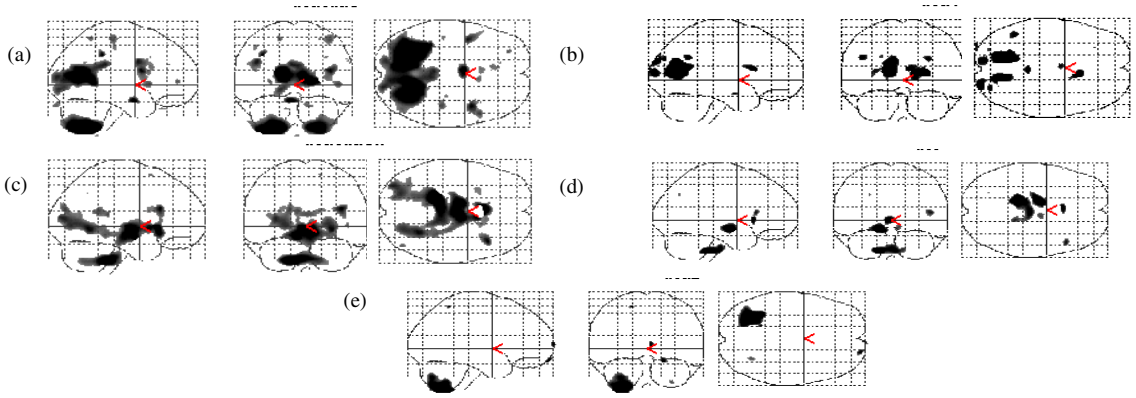

Figure 1: 'ANOVA' showing regions of (a) reduced **GM volume** in total blinds as compared to controls (b) reduced **GM volume** in partial blinds as compared to controls (c) reduced **WM volume** in total blinds as compared to controls (d) reduced **WM volume** in partial blinds as compared to controls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