Texture and depth processing in Early, late Blind and sighted controls by haptic stimulus: An fMRI study

Ankeeta Sharma[1], Senthil Kumaran[1], and Rohit Saxena[2]

[1]*Department of NMR, All India Institute of Medical Sciences, New Delhi, Delhi, India,* [2]*Dr. Rajendra Prasad Centre For Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, Delhi, India*

Background and Purpose: Using fMRI to map object-related brain regions, robust and consistent somatosensory activation in the occipito–temporal cortex was observed. This study will possibly help us in understand the neural correlates of activation pattern for perception of texture and depth and sizes of objects that are used in routine life also how early and late blind subjects differ in their perception skills with normal sighted individual.

Methods: Twenty five early blind (mean age + SD = 13.21 ± 2.81 years) and twenty five late blind subjects (mean age + SD = 13 ± 2.61 years) were recruited and ten healthy controls (mean age + SD = 20.33 + 6.25 years) all right handed from the clinics of our institute who had acceptable motion parameters (<1.5mm translation, <1° rotation) were considered for analysis. Standard diagnostic and exclusion criteria were followed. Functional MRI scans were conducted on standard clinical 3T whole body MR scanner (Achieva 3.0T TX, Philips, Netherlands) with the subject in supine position. For texture and depth processing: Patients were presented with plastic and wooden shapes in the scanner, with the help of E-prime and MRI compatible headphone. Single-shot echo planar imaging (EPI) sequence was used for the functional MRI studies to study the Blood oxygen level dependent (BOLD) effects in the whole brain. (Number of slices: 30, slice thickness 4.5 mm; TR: 2000 ms, TE: 30 ms, FOV: 231.7 mm, flip angle: 90° Number of Dynamics: 160,resolution: 64 x 64) was used for the BOLD sessions. Pre- and post-processing was carried out using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). The BOLD clusters were converted from MNI template to the Talairach and Tornoux coordinates, for estimation of anatomical areas. One sample t-test (p<0.001, cluster threshold 10) was usedfor group analysis.

Results: When subjects selectively attended to certain features of the stimulus (shape or object), brain activation increases were found in the primary and secondary visual cortices compared to a baseline condition In the late blind group (Figure 1. object:c,d and shapes: I, j) activation was predominantly observed in both the hemispheres with left dominance. Bilateral activation in Fusiform Gyrus, Medial Frontal Gyrus, Middle Frontal Gyrus and Precentral Gyrus was observed. Specifically During the object recognition task early blind showed activation in Superior Frontal Gyrus (L; 387), Cingulate Gyrus (R; 3840, Fusiform Gyrus (L; 215), Middle Frontal Gyrus (L; 134), Inferior Parietal Lobule (L; 98), Precentral Gyrus (L: 74; R:52), Superior Temporal Gyrus (R; 59) and in late blind bold response was observed in Cuneus (R; 30), Insula (L; 27)and Lingual Gyrus (L; 21), Claustrum (L; 19). We also noticed some less prominent area in Inferior Frontal Gyrus and right Caudate, Post-central Gyrus.In control group for the object texture and depth recognition task bilateral activations was observed in Medial Frontal Gyrus, Parahippocampal Gyrus, and Superior Temporal Gyrus, also left hemispheric areas: Cerebellum, Inferior Parietal Lobule (135), Post- central Gyrus (148) and right hemispheric areas Fusiform Gyrus (12), Inferior Frontal Gyrus (76), Lentiform Nucleus (12). During Shape texture and depth perception task there was left dominance with higher activity in Precuneus (L; 276), Cuneus (R; 25), Cingulate Gyrus (R; 15) and Middle Temporal Gyrus (R; 12) also in left Claustrum, Inferior Parietal Lobule, Middle Temporal Gyrus, Posterior Cingulate, Precuneus,Superior Temporal Gyrus and right Insula recognized in blind group. In control group for the same task BOLD response was higher in Inferior Parietal Lobule (R; 314), Precentral Gyrus (L:; 115), Medial Frontal Gyrus (R: 107) with lefthemispheric Cerebellum, Inferior Frontal Gyrus, Inferior Parietal Lobule, Precentral Gyrus, Sub-lobar, Superior Temporal Gyrus and right hemispheric Inferior Parietal Lobule, Medial Frontal Gyrus, Middle Occipital Gyrus, Middle Temporal Gyrus, Precentral Gyrus, Sub-lobar, Superior Frontal Gyrus.

Discussion: The BOLD response results support the existence of a large-scale neural system for tactile object recognition. A central stage in object recognition pathway is an occipito–temporal region termed the lateral occipital complex (LOC), which is preferentially activated by visual objects compared to scrambled images or textures[1]. Most somatosensory object-selective voxels overlapped a part of the visual object-related region (LOC). Neuronal populations in the occipito–temporal cortex may constitute a multimodal object-related network based on the extraction of basic features (such as contours) and their spatial arrangement, which together define an object[3].High activation in inferior parietal lobule in control subjects suggests a more active role of this centre in object recognition. Additional activation in superior parietal lobule is in line with its role in tactile object recognition. In the late blind subjects in comparison with control subjects most activation foci were found in the parieto-occipital area encompassing the precuneus and superior and inferior parietal areas this could be due to the production of mental images relying on haptic sensitivity[2]. This interpretation is further supported by the fact that activation in the somatosensory areas (was retrieved in blind subjects only. Activation in the visual associative area BA 19, well represented in our study, in relaying haptic information in blind people.

Conclusion: The late blind predominantly recruit precuneus shown earlier to be involved in mental imagery task suggesting that precuneus is taken up as an additional alternative / support to occipital area and in early blind subjects primarily recruit cingulate (BA 24) and temporal areas for object recognition suggesting an alternate pathway of perception invoking memory as prime component for perception.

Table 1. Subject details

	Mean Age	STDEV	Blindness onset
Sighted	20.33	6.25	Normal
Early blind	13.21	2.81	>6 months
Late blind	13	2.61	<2years

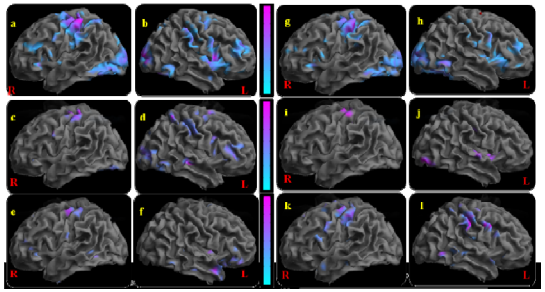

Fig 1. *Significant BOLD pattern in early blind (Object: a, b and Shapes: g, h), late blind (Object : c, d) and Shapes: I, j) and sighted controls (Object: e, f and Shapes: k, i) during texture and depth recognition task*

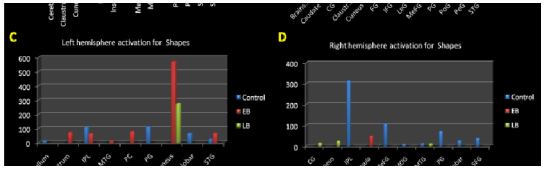

Fig 2. *Graphical representation of BOLD pattern in early blind, late blind and sighted controls for texture and depth perception task*

References:

Amedi A, Malach R, Hendler T et alVisuo-haptic object-related activation in the ventral visual pathway. Nat Neurosci. 2001 Mar;4(3):324-330.

Cavanna AE, Trimble MR.The precuneus: a review of its functional anatomy and behavioural correlates.Brain. 2006 Mar;129(Pt 3):564-83. Epub 2006 Jan 6.