Tactile perception and Braille semantic task in late blind subjects using fMRI: understanding Braille dots and objects

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Introduction: Blind people rely on spatial information delivered by the remaining intact senses, such as hearing and touch, as a result of their lack of visual experience [1]. This may implicate visual cortex in a wide range of cognitive tasks in the blind. Absolute sensory thresholds for detecting tactile stimuli and tactile 'two-point thresholds' (the minimal distance between two tactile stimuli required to discriminate Braille dots) are comparable to the sighted controls [2]. We have studied the tactile, spatial perception and language aspects in late blind subjects using BOLD at 3 Tesla.

Materials and Methods: Six right handed early blind female subjects (table 1) were recruited after clinical evaluation in the clinics of our institute. Standard diagnostic and exclusion criteria were followed. After obtaining the Ethical approval for the study, the study was carried out using 3T MR scanner (Achieva 3.0T TX, Philips, Netherlands) and 32 channel head coil. An object holding platform was positioned at arm's length to the subjects after strapping the elbow of the subjects (to avoid shoulder movement). On this perspex platform, a rotating sheet with 12 small object-holders was mounted for tactile perception. For the spatial perception, rotating sheets with object holders at different positions were inserted during the course of the experiment. For Semantic processing, subjects were presented with antonym noun pairs, with four options written on Braille paper mounted on Braille base plate. Auditory cues were presented using E-prime software for changing between baseline and active phases. Single-shot echo planar imaging (EPI) sequence was used for the Blood oxygen level dependent (BOLD) studies with number of slices: 30, slice thickness 4.5 mm; TR: 2000 ms, TE: 30 ms, FOV: 231.7 mm, flip angle: 90^o, Number of Dynamics: 160 (perception task) & 192 (language task), resolution: 64 x 64. Pre and post-processing were 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 way ANOVA ($p<0.001$, cluster threshold 5) was used for group analysis.

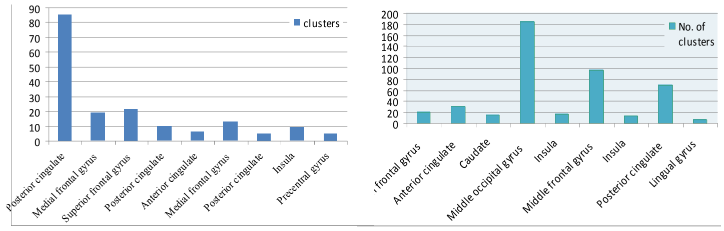

Figure 1. Number of BOLD clusters for (a) Semantic processing with respect to tactile perception task, (b) Spatial perception with respect to semantic task

Results: When subjects selectively attended to certain features of the stimulus (shape or object), BOLD clusters (fig. 1) were found in the primary and secondary visual cortices compared to a baseline condition. In the late blind group (Table 2), activation was predominantly observed in both the hemispheres with left dominance. Bilateral activation was observed in middle frontal gyrus (BA 9). Specifically caudate, lingual gyrus, middle occipital gyrus, Sub-gyral, middle frontal gyrus, cuneus, lingual gyrus and caudate body observed to be more activated for spatial vs language task; precentral gyrus, superior frontal gyrus was seen for tactile vs language task; but areas (medial frontal gyrus, posterior cingulate, anterior cingulate, insula) was found to be activated during both examination. Middle occipital gyrus exhibited an activation of 184 clusters with more activation in right hemisphere. Bilateral activation observed for language vs tactile analysis posterior cingulate gyrus and medial frontal gyrus is greater in right hemisphere than left.

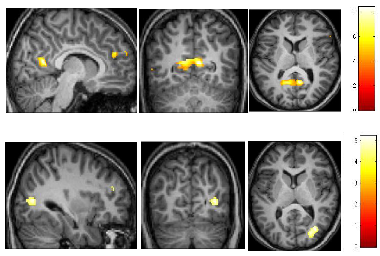

***Figure2.** The brain activation pattern for the blind patients in the Occipital area*

Discussion: The occipito-temporal and parietal cortical networks are involved in the processing and integration of shape/motion cues, ultimately contributing to object recognition [6]. The cerebellum may be involved in processes contributing specifically to spatial learning and memory [3]. Activation in the V1 (primary visual cortex, BA 17) would reflect completion of neural reorganization from the somatosensory areas towards visual areas and the V1, which would also take place in late blind people. This brings us back to the concept of a development stage particularly propitious to brain reorganization as a function of experience, where in the system will adapt and make use of information gathered through the remaining sensory modalities. Activation in the parietal lobes may be due to its role as association cortex, where many related functions such as attention, spatial representation, working memory, eye movements and the guidance of actions come together. Increased activation of the anterior cingulate has been observed during performance of tasks that require subjects to selectively attend to a stimulus or an inhibiting response to a particular stimulus, and to orient attention to an unexpected or novel stimulus [4]. The lingual areas are associated with the semantic tasks during Braille reading, whereas, the association cortex is more involved during perception tasks. The absence of visual input during early development may alter the role of the occipital cortex in late blind subjects.

Table 1. Details of the subjects

Subject	Sex	Age (years)	Aetiology	Age of onset (years)	Residual vision
LB1	F	14	Atrophic bulbi	3	none
LB2	F	12	Corneal ulcer	4	low
LB3	F	13	Nystagmus	3	low
LB4	F	13	Nystagmus	3	low
LB5	F	12	Accident	5	none
LB6	F	16	Pthysisbulbi	3	none
Mean Age ± SD		13.3± 1.5			

Table 2. BOLD activation in early blind subjects for semantic language task with respect to tactile task

Clusters	mni	cerebrum	Areas
21	-22 46 20	Left	Medial Frontal Gyrus
31	-18 32 10	Left	Anterior Cingulate
15	18 -12 16	Right	Caudate
184	42 -80 10	Right	Middle Occipital Gyrus
17	-40 8 6	Left	Insula
97	40 42 30	Right	Middle Frontal Gyrus
13	40 14 10	Right	Insula
22	6 -58 16	Right	Posterior Cingulate
48	-18 -58 14	Left	Posterior Cingulate
7	-22 -56 8	Left	Lingual Gyrus

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