Sensory perception and spatial judgement imagery patterns in healthy and visually handicapped subjects - an fMRI study

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Introduction: Mental imagery seems to involve functional properties close to visual perception and could share the same internal representation, since they exert an influence on each other [1]. Visually handicapped (VH) subjects are able to perform mental imagery tasks with the same efficiency as sighted subjects in spite of a close relationship between imagery and visual perception [2]. Functional MRI studies have been carried out to measure cerebral activation related to a set of manual sensorimotor tasks performed in the absence of visual guidance.

Material & Methods: Six healthy subjects and two congenitally blind subjects were recruited in the age group 20-40years. The BOLD experiments were carried out using Head coil (circularly polarized) in a 1.5T whole body MR system (Magnetom Vision, Siemens, Germany). 33 slices parallel to the bi-commissural plane with the uppermost slice aligned 2 mm below the vertex, covering the whole brain were acquired using gradient echo EPI with TR = 1.68 ms, echo time TE = 64 ms, field of view = 230 x 230 mm^2, voxel volume = 3.59x1.8x3mm^3, flip angle= 90°, matrix size = 128 x 64. Block paradigm (BABABABA….) with alternating phases of activation (A) and baseline (B) was chosen. A total of 78 sequential image volumes (belonging to six cycles + one initial baseline for eliminating T1 saturation effects and acclimatization to the gradient noise) with an optimized inter-scan interval (7.053s) were taken. The experiments were divided into two sessions. In the first session (task 1), subjects were exploring a three-dimensional object fixed at a particular location during active phase (16 objects during entire cycle) so as to infer its shape (sensory perceptive condition, exploring). In the second session (task 2), the task was exploring the spatial three-dimensional distance from one object to another (spatial judgement, orientation, exploring). The subjects did not feel or see the objects prior to the study. The fMRI data were pre- and post-processed using SPM99. One-sample 't' test and one way ANOVA for group analysis within task and across tasks (uncorrected $p \leq 0.001$, extent threshold 'k' = 5 voxels) were used. All images were realigned to the first volume, corrected for motion artefacts, normalized (4 mm^3) to standard stereotaxic space (template provided by the Montreal Neurological Institute), smoothed using 6 mm FWHM Gaussian kernel. Talairach-Daemon Client (ver. 1) by University of Texas Health Science Centre, San Antonio was used for estimation of Brodmann areas.

Results and Discussion: In the visuoperception task (first task), significant activations ($p \leq 0.001$) were observed in the middle frontal gyrus, cingulate gyrus, middle occipital gyrus, superior temporal gyrus of right cerebrum and superior and inferior parietal lobule, postcentral gyrus in the left hemisphere for healthy subjects. For the same task the blind subjects recruited inferior frontal gyrus, precuneus (parietal lobe) and cuneus (occipital lobe) in addition to the above mentioned areas.

Activation in superior and inferior parietal lobules can be attributed to spatial orientation processing and spatial encoding. Activation in peristriate region of the occipital lobe may be associated with visuospatial processing and also with visual perception. Cuneus and precuneus activation may be due to the retrieval of visual images or due to anticipation, as they play an important role in recall and judgment. Frontal gyri including the middle, inferior and superior frontal gyrus are related to attention shifting, decision making. Middle occipital gyrus is part of the visual association cortex and is involved in higher order processing of visual information. Visually handicapped subjects involve visuospatial cognition in addition to perception, as compared to controls.

The second task involved visuospatial judgment. Significant activations ($p \leq 0.001$) were found in the precentral, superior frontal, medial frontal, cingulate, superior temporal gyri, precuneus, middle occipital gyrus, cuneus, middle frontal gyrus, inferior frontal gyrus, fusiform gyrus, superior and inferior parietal lobule, middle temporal gyrus, sub-gyral both in the case of blind subjects and healthy volunteers. Similar representation in both healthy and VH subjects suggest that mental imagery tasks related to visuospatial material has been executed with the same efficiency in both the groups. Figure 1 and figure 2 display the activation pattern in healthy and VH subjects for task 1 and task 2 respectively.

Conclusion: VH subjects recruit neural areas responsible for visuospatial judgement for parametric identification. Visuospatial location and the judgement recruit similar areas of the brain in visually handicapped subjects as in controls, even though they did not have any visual experience and accessed their environment using nonvisual modalities.

References:

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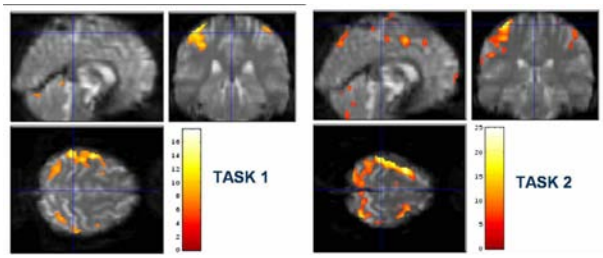

Figure 1. BOLD activation pattern for perception and visuospatial judgement in Healthy Subjects

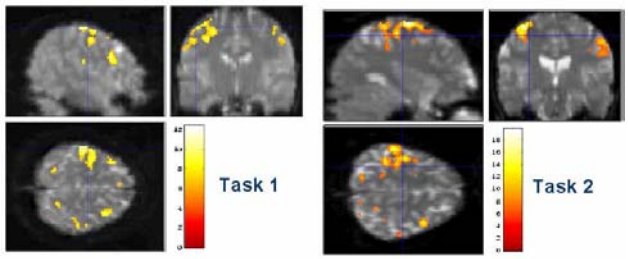

Figure 2. BOLD activation pattern for perception and visuospatial judgement in visually handicapped Subjects