Cross-modal plasticity in congenitally blind subjects

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Introduction

In sighted humans a considerable area of the neocortex is part of the visual system (1,2). What are the functions performed by this considerable part of the human brain in congenitally blind subjects? Auditory processing appears to be one of these functions (3, 4), processing of tactile stimuli another. However, there is a controversy concerning the situation with congenitally blind subjects. Whereas some authors (5, 8, 11) claim V1 activation with Braille stimulation of congenitally blinds, Buchel et al. (7) recently denied V1 activation in this subject group. We wanted to contribute to this issue by using the high spatial resolution of fMRI and improved methodology to investigate a homogeneous group of congenitally blinds never experiencing residual visual perception.

Methods

Four congenitally blind subjects (Table 1), all experienced Braille readers (mean age 35.75 years, male), read a strip with non-contracted non-word Braille letters. The resting index finger was positioned on the platform of a MR-compatible tactile stimulation device with the strip moving at a speed of 2.4 cm/sec at the finger tip. Each subject was measured on three different days and 2 runs per day were carried out resulting in 990 recordings of each slice. During each run the subject performed four different stimulation conditions four times: 1. Reading a Braille sentence consisting of 120 Braille letters. 2. Tactile imagery of Braille reading with the sentence "I am lying in the scanner and reading Braille letters". 3. Counting of the spaces between Braille letters without attention to the letter's meaning. 4. Stimulation with Braille similar characters without meaning: random dots

The order of these 4 conditions was completely randomized and 1 run comprised 16 stimulation phases alternating with rest. Every run consisted of 5 resting and 4 stimulation phases per condition. During each phase 5 images were recorded per slice (990 images per slice per subject) and every phase lasted 30s. The stimulation strip was in motion during each stimulation condition, except during tactile imagery.

The 4 sighted control subjects (mean age 32.0 years, all right-handed) read words consisting of 6 embossed Roman letters (strip moving at a speed of 0.33 cm/sec at the finger tip). The measurements were carried out on a 3 Tesla TRUKER Medspec scanner using a phase-corrected blipped gradient-echo, single shot EPI sequence (TE/TR=60/6000ms, 128*128matrix, 256*256 FOV, 30 axial slices, slice thickness 3mm, no interslice gap, sinc pulse excitation). To avoid artifacts due to head movements individual plaster helmets were applied for optimized head fixation (13). These plaster helmets allow direct comparison of different runs recorded with exactly the same head position.

The scans from each subject were realigned with a 3D-sinc interpolation using the software package AIR v3.0 (Automated Image Registration). Correlation analysis was performed using a correlation threshold of 0.4 and a box-car reference function. Reliability maps were calculated by superimposing data of different runs and colour coding pixels according to the degree of replicability (12).

Results

Results clearly show the primary "visual" cortex (Table 2) consistently activated within the occipital cortex of all four blind subjects for Braille reading (condition 1). We found no activation in this area for tactile imagery (condition 2) and reading of random dots (condition 4), and much less activation for counting of interspaces (condition 3) compared with Braille reading. There was no activation within the occipital cortex of sighted subjects for embossed Roman letters reading.

Fig.1 shows the active pixels superimposed on anatomical slices (MDEFT-sequence). The numbers in the left corners give the distances from the shown slices to the AC-PC-plane in millimeters.

Discussion

The literature pertaining to activation of secondary visual cortex (V2, V3,...) is consistent, however there are inconsistencies concerning activation of primary visual cortex. One possible factor influencing these inconsistencies could be the existence of residual visual perception in congenitally blinds. Therefore, we wanted to investigate this issue by using a group of congenitally blinds who have never experienced any kind visual perception whatsoever. Our FMRI-study shows activation of the primary "visual" cortex in all these subjects. Since our subjects never experienced any kind of visual perception, activity related to residual vision can be excluded as an explanation of our functional results.

References


Table 1: Characteristics of the blind subjects (S=Subject, H=Handedness, P=Preferred side of reading, L=Left, R=Right, A.=Anophthalmos, R.P.=Retinopathia pigment., E.=Enucleation)

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>Age</th>
<th>H</th>
<th>P</th>
<th>Cause of blindness</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td>29</td>
<td>R</td>
<td>R</td>
<td>A.</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>34</td>
<td>R</td>
<td>R</td>
<td>R.P.</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>37</td>
<td>R</td>
<td>R</td>
<td>E.</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>43</td>
<td>L</td>
<td>L</td>
<td>R.P.</td>
</tr>
</tbody>
</table>

Table 2: Activation in the Area striata (occipital cortex) by Braille reading of blind subjects (number of pixels, L=Left/Right)

<table>
<thead>
<tr>
<th></th>
<th>Subj.1</th>
<th>Subj.2</th>
<th>Subj.3</th>
<th>Subj.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/ R</td>
<td>41/2</td>
<td>6/22</td>
<td>80/55</td>
<td>41/32</td>
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