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Title - 100 character limit·

Processing spatial and pitch attributes of sounds in the absence of visual experience: an fMRI study

Introduction - 1000 character limit·

Several studies have demonstrated that the occipital cortex of early blind individuals becomes massively involved in the processing of auditory information (Collignon et al., 2009). However, it is still unclear whether the recruited occipital cortex processes these colonizing stimuli in a global manner or does so using the functional modularity normally used in treating visual stimuli in sighted subjects. Indeed, the visual and the auditory systems seem to share the same "dual" functional organization principle with a "ventral" stream postulated to be involved in analyzing object properties (referred to as the "What?" stream) and a "dorsal" stream devoted to perception of object position in space (also termed the "Where?" stream) (Ungerleider et Mishkin, 1982; Rauschecker & Tian, 2000). The purpose of this study was to determine whether this ventral/dorsal functional dissociation for auditory stimuli exists in the reorganized occipital cortex of congenitally blind subjects.

Methods - 2000 character limit·

We tested 11 congenitally blind and 11 individually matched blindfolded sighted subjects in a block design fMRI paradigm. In the "spatial" blocks, participants had to determine if the second sound of a pair was left- or right-sided when compared to a probe sound, regardless of the variation in pitch of these sounds. In the "pitch" blocks, participants had to determine if the second sound of a pair was lower or higher-pitched when compared to the probe sound, regardless of the position of these sounds. The physical attributes of the sounds used in the "spatial" or the "pitch" blocks were exactly the same. Also, by using a psychophysical staircase method in the scan, we obtained approximately 90% correct performance in both tasks and in both groups, ensuring that any difference in the observed brain activations could not be attributed to the difficulty of the tasks.

fMRI time series have been acquired using a 3-T TRIO TIM system (Siemens, Erlangen, Germany). Multislice T2-weighted fMRI images were obtained with a gradient echo-planar sequence using transverse slice orientation (35 slices; 3.2 mm slice thickness; 0.8 mm inter-slice gap; voxel size: 3x3x3.2 mm3; matrix size 64x64; time repetition (TR)= 2200 ms; time echo (TE)= 30 ms; field of view= 192; flip angle = 90 deg.). Functional volumes were analyzed using statistical parametric mapping 8 (SPM8—http://www.fil.ion.ucl.ac.uk/spm) implemented in MATLAB. The analysis of fMRI data, based on a mixed effect model, has been conducted in 2 serial steps, accounting respectively for fixed and random effects. For each subject, changes in brain regional responses were estimated by a general linear model including the responses to the pitch and spatial conditions. Individual summary statistic images were used in a random effects analysis. Groups were compared using two-sample t tests. Statistical inferences were made at $p<0.05$, after small volume correction.

Results - 2000 character limit ·

A first analysis realized over all subjects (Blind and Sighted) and testing the main effect of the task revealed expected regions selective to the spatial or pitch processing of sounds (Spatial > Pitch: i.e. inferior and superior parietal lobules; Pitch > Spatial: i.e. extended temporal lobe activations). These first results reveal the suitability of our paradigm to probe the "dual-stream" organization of the auditory system.

A global contrast "Blind-Sighted (Spatial+Pitch)" revealed the massive recruitment of the occipital regions for sound processing in blind subjects (with regions remaining significant after whole brain family-wise corrections). Groups (Blind > Sighted) by conditions (Pitch > Spatial) interactions analysis did not reveal any significant results. This is due to the fact that the "Pitch > Spatial" contrast in the blind group did not yield significant activations. Further analyses revealed that blind subjects automatically processed pitch information in the "spatial" blocks, activating similar structures as in the "pitch" blocks. The major result of the study is that the group (Blind > Sighted) by condition (Spatial > Pitch) interaction analysis revealed that the spatial processing of sounds in blind participants selectively recruited regions well known to be involved in visuo-spatial processing in sighted subjects (Haxby et al, 1991), like the right dorsal extrastriate cuneus (12 -80 22mm, Z=4.27, p_{svc}=0.001) and a region located near the ascending limb of the inferior temporal sulcus corresponding to the right hMT+/V5 (48 -76 6mm, Z=4.18, p_{svc}=0.001) (see Figure 1). When submitting the right dorsal extrastriate cuneus of blind subjects to psychophysiological interactions analyses (PPI), we observed significant functional connectivity between this region and bilateral inferior parietal lobules and the bilateral superior frontal gyri.

Conclusions - 1000 character limit ·

These data suggest that reorganized occipital regions in blind subjects involved in the spatial processing of sounds are part of an extended network known to underlie this ability in sighted subjects (Arnott et al., 2004), further underlying the functional relevance of the crossmodal plasticity observed in this population. We believe that the present study represents a compelling demonstration that the "dorsal occipital stream" is not only crossmodally recruited for the processing of sounds, but also maintains its functional role for spatial processing in the absence of any visual input since birth.

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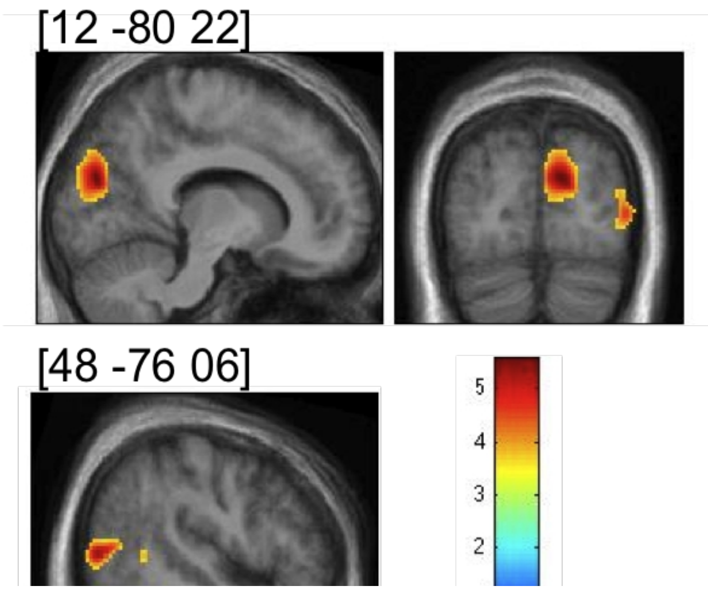

Figure 1: fMRI results of the group (Blind > Sighted) by condition (Spatial > Pitch) interaction analysis (display: p uncorrected < 0.001).