Neural Correlates of Auditory Distance Perception with Congruent and Incongruent Cues

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Background

Perceiving the sound source distance is of key value in many everyday activities. The psychoacoustics of distance perception and its neuronal correlates are poorly understood. Previous studies identified planum temporale (PT) and superior temporal gyrus (STG) as auditory cortical areas important for intensity-independent auditory distance processing based on the direct-to-reverberant energy ratio (DRR) and the interaural level difference (ILD) cues. However, it is not clear whether the area represents the distance percept per se or one of the intensity independent acoustic cues ILD and/or DRR. To examine this, we conducted behavioral and neuroimaging experiments in a virtual reverberant environment combined with advanced computational analyses.

Methods

The auditory distance stimuli were simulated using a single set of non-individualized binaural room impulse responses (BRIR) measured on a listener that did not participate in this study. The auditory stimuli were broadband noise bursts varying in distance (15–100 cm) on the left-hand side along the interaural axis while the ILD/DRR cue availability was manipulated such that the cues varied with distance either congruently or incongruently. The behavioral experiment involved a distance discrimination task for various stimulus pairs. The discrimination performance was used to confirm that distance perception with congruent cues is better than with incongruent cues. The imaging experiment was a sparse-sampling adaptation fMRI in which the stimuli were random sequences of noise bursts presented from various distances either with congruent or with

incongruent cues. Both univariate and split-half correlation multivariate pattern analysis (MVPA) were performed on the previously identified ROIs.

Results and conclusions

Behavioral results showed that subjects performed better when cues varied with distance congruently, suggesting that the distance percepts are based on both cues. There were no significant effects in fMRI univariate contrast between congruent vs incongruent stimuli. However, the MVPA analysis suggested that the population activation pattern in the auditory cortex ROI encompassing the right PT and STG depended on cue congruency. Given that the sounds were simulated from the left-hand side and the patterns were found in the right hemisphere, the representation appears to be contralateral. Overall, these results are consistent with the hypothesis that the PT and STG represent the distance percept as well as the underlying cues, likely in a distributed interconnected network.

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