Subcortical Auditory Information Processing after Bilateral Auditory Cortex Ablation

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INTRODUCTION Descending projections from cerebral cortex to subcortical nuclei are among the largest pathways in the brain [1], suggesting that they are important for subcortical processing. In the auditory system, the cortical output targets subcortical nuclei such as the inferior colliculus [2, 3]. However, compared with the ascending pathways, the functional roles of these corticofugal projections are poorly understood. Non-invasive fMRI is well suited to investigating this question because it can assess activities in multiple nuclei simultaneously. In this study, bSSFP fMRI was applied to study the effect of bilateral auditory cortex ablation on the responses to sound pressure level (SPL) change in low subcortical target nuclei.

METHODS ***Animal Preparation:*** Male Sprague-Dawley rats (~200g) underwent bilateral auditory cortex ablation (ACA, N=6) surgery and were imaged after about one month. Normal age-matched controls (CTRL, N=6) were also imaged. All animals were mechanically ventilated with isofluorane anesthesia during MRI. ***Acoustic Stimulation:*** Monaural broad band noise (BBN, Fig. 1a) was produced by a high-frequency magnetic speaker (MF1, TDT) and delivered through custom-made tubes into the right ear of animals. Animals were stimulated with a combined block-design (80 s on and 40 s off) and sweeping paradigm (Fig. 1b). To examine the dynamic dependence of BOLD responses on sound pressure level (SPL), the BBN SPL was linearly increased and decreased during the first and second half of each on-period. ***MRI Procedure:*** All fMRI data were acquired on a 7T Bruker scanner using a 2D bSSFP sequence (FOV=32×32mm^2, matrix=64×64, FA=19°, TE/TR=1.88/3.76ms, average=4, temporal resolution=1 s, 890 repetitions, single slice with thickness=1.0 mm). Two fMRI sessions were performed to image two slices (gap=0.2 mm). ***Data Analysis:*** The first 10 images from each session were discarded. The remaining images were realigned using SPM8. Then the correlation coefficient (CC) between each voxel's temporal signal profile and the model function was calculated using custom-written Matlab scripts. Activated regions were identified using threshold of CC>0.087 and cluster size>3. Number of activated voxels and average CC value in activated regions were quantified. Unpaired two-sample *t* tests were performed to examine the differences between two groups.

RESULTS Fig. 2a presents the activation (CC) map of a representative animal from the CTRL group, showing BOLD responses in the inferior colliculus (IC) and lateral lemniscus (LL). Fig. 2b plots the normalized BOLD signal profiles averaged across all activated voxels and 7 blocks in both structures. Fig. 3 shows the averaged CC maps of both groups. The total number of activated voxels in both IC and LL was significantly (p<0.001, Fig. 4a) larger in ACA group. The average CC value in LL is also significantly (p<0.05, Fig. 4b) increased in the ACA group, while in IC it shows an increasing trend but not significant.

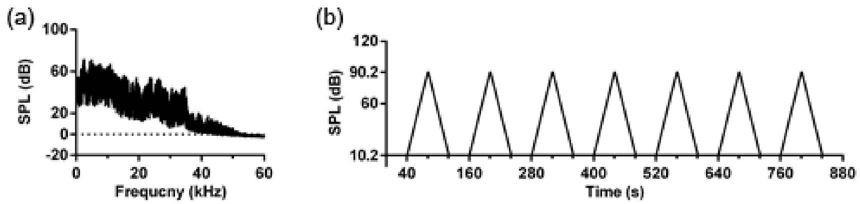

Fig. 1. (a) Frequency spectrum of the broad band noise (BBN) used in this study. (b) Combined block design (80 s on and 40 s off) and sweeping paradigm for acoustic stimulation. The BBN SPL was linearly increased and decreased during the first and second half of each on period.

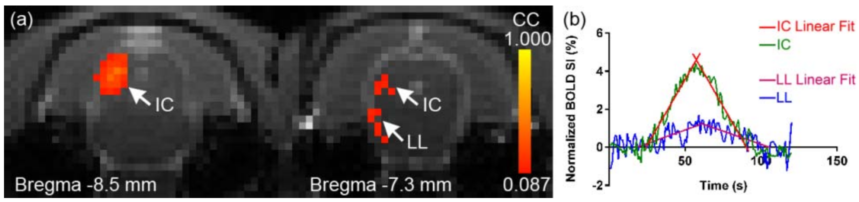

Fig. 2. (a) Activation map of a representative animal from the CTRL group. The inferior colliculus (IC) and lateral lemniscus (LL) were activated upon right ear stimulation. (b) Normalized BOLD signal profiles in IC and LL. BOLD signal change was close to linear following the SPL change.

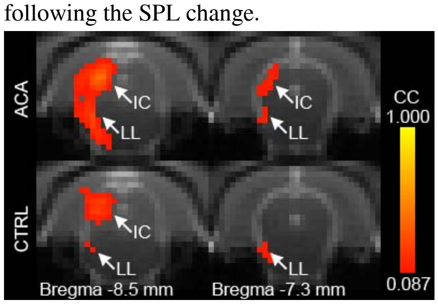

Fig. 3. Averaged activation maps of the ACA and CTRL group.

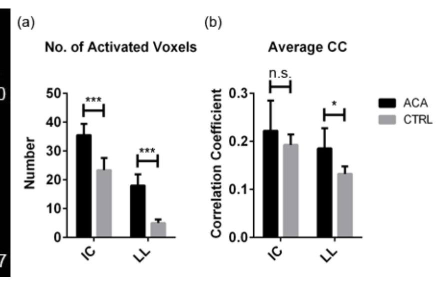

Fig. 4. Comparisons of the activations in IC and LL between the two groups. No. of activated voxels in both IC and LL was significantly (p<0.001) larger in the ACA group. The average CC value in LL was significantly larger in ACA group while in IC it shows an increasing trend but not significant.

DISCUSSION AND CONCLUSION Our fMRI results revealed that the activations in IC and LL increased after bilateral AC ablation, suggesting that the AC normally provides feedback inhibition to these subcortical structures during prolonged stimulation [4]. The increased correlation between the BOLD responses and stimulation indicates increased sensitivities of neurons in these structures to the SPL change after cortical input deprivation [5]. Such findings provide important information for understanding the functional roles of auditory descending projections. Moreover, our results demonstrated that fMRI with a large field of view can be a highly efficient and effective approach for investigating the functions of corticofugal connections. Note that fMRI is non-invasive and suited for longitudinal studies. Future work therefore may look into the corticofugal modulations systematically on both spatial and temporal scale.

References: [1]Winer J.A. Hear Res 2006;212:1-8. [2]Winer J.A., J Comp Neuro 1998;400:147-74. [3]Schofield B.R. Hear Res 2011;279:85-95. [4]Suga N. J Comp Physiol A Neuroethol Sens Neural Behav Physiol 2008;194:169-83. [5]Yan J. and Ehret G. Eur J Neurosci 2002;16:119-28.