Influence of Gradient Acoustic Noise on fMRI Response in Human Visual Cortex: A Neuronal Interaction Perspective

N. Zhang[1], W. Chen[1]

[1]Center for Magnetic Resonance Research, Department of Radiology, University of Minnesota Medical School, Minneapolis, MN, United States

Introduction Recent studies on the cross-modal interaction between the visual and auditory sensory show that sound can slightly modify the perceived temporal characteristic of visual stimulus such as duration and frequency, or can even radically alter the quality of the visual percept. At the same time, a large portion of blood oxygenation level dependent (BOLD) based functional magnetic resonance imaging (fMRI) studies are accompanied with the MRI scanner acoustic noise resulted from the mechanic oscillation of the gradient coils placed in a magnetic field. The visual-audio interaction phenomenon and the existence of acoustic noise during MRI acquisition will potentially generate two questions in fMRI studies involving visual activation: (i) does the acoustic noise during MRI acquisition influence the neural behavior regarding visual processing? (ii) if it does, how serious would this influence be? In this study, dynamic fMRI combined with paired-stimuli paradigm[1] was utilized to study the effect of the acoustic noise on visual cortex BOLD response from the perspective of cross-modal neuronal interaction between the auditory and visual cortex.

Methods A red LED checkerboard (12.8 cm × 5.9 cm) was used to generate short (17 ms) visual flash stimulation. The inter-stimulus interval (ISI) between the gradient sound and the flashing was varied. Six ISIs of 50 ms, 100 ms, 200 ms, 300 ms, 500 ms and 700 ms were used in every fMRI study in a pseudo-randomized order. All fMRI studies were performed on a 4T/90 cm bore magnet (Siemens, Erlangen, Germany) system with the Varian INOVA console (Varian Inc., Palo Alto, CA). For the fMRI measurements: gradient echo planar images (GE EPIs) (FOV = 20×20 cm^2; 64×64 image matrix size; TE = 22 ms; TR = 1.35 s, 7 coronal slices, 5 mm slice thickness) covered the most of the calcarine fissure in the human primary visual cortex (V1) were acquired. Each fMRI run was composed of seven control periods (40 image sets each) interleaved with six task periods (10 image sets each) with a different ISI for each task. Six runs were acquired for each study.

Two parameters, BOLD intensity and the number of activated pixels (or activation size), were examined to estimate the effect of the acoustic noise on the visual cortex BOLD response. For BOLD intensity, common activated region of interest (ROI) in V1 was generated from the pixels that passed statistical significance for all the six tasks for each fMRI run, using the period cross correlation method. The time course for each corresponding task was then averaged across the six runs. For each subject, the quantification of BOLD intensity was based on the averaged time course, using the integral of the BOLD signal with the baseline subtracted from the time course. The integral data for each task were expressed as normalization to the average for all the six tasks. For the number of activated pixels, all the corresponding image volumes from the same task were at first averaged in k-space, and then the activation maps for each task were generated using the cross correlation method. The number of activated pixels was then calculated based on the activated maps generated for each task using the same cross correlation coefficient. ROI was determined based on the anatomical images acquired before the fMRI experiments to make sure it mainly covers the primary visual cortex. The data were also normalized to the average of the number of activated pixels for the six tasks.

Results Figure 1 illustrates the dependence of the BOLD intensity (normalized to the average of the BOLD intensity for the six tasks) on the relative delay between the MRI scanner noise and the flashing light (ISI) from the average of nine experiments. Figure 2 summarizes the dependence of the number of activated pixels on the delay between the acoustic noise and the flashing light from nine experiments. Student t-tests show that both the BOLD intensity ($p = 0.03$, $n = 9$) and the number of activated pixels ($p = 0.038$, $n = 9$) at ISI = 300 ms are significantly smaller than the average of all the six tasks.

Discussion Neuronal activation in the human primary visual cortex was significantly suppressed by the acoustic noise 300ms preceding the flashing light visual stimulus. This suppression is likely caused by the cross-modal neuronal interaction between visual cortex and auditory cortex based on two facts: (1) Acoustic sound stimulation alone does not have any significant effect on visual activation. This conclusion has already been demonstrated by Bandettini et al[2]. The suppression of visual activation induced by acoustic noise is time (or ISI) dependent. Statistically significant suppression of visual activation happens when ISI = 300 ms and this suppression gradually disappears when ISI increases. The result regarding the modulation of visual activation as a function of ISI can eliminate the possibility that the deactivation of visual activation caused by the acoustic noise is actually due to attention, because if subject starts to lose attention from ISI = 300 ms on, visual activation at longer ISI should be suppressed also, which is in contradiction with our experimental observation. This study provides evidence regarding the cross-modal neuronal interaction between the visual cortex and the auditory cortex. This observation should have impact on fMRI applications.

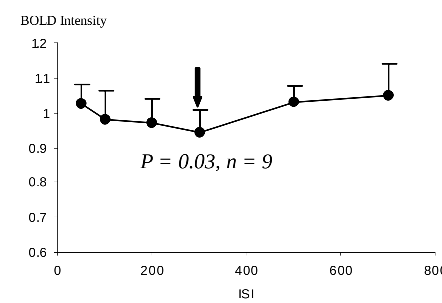

Fig. 1 Dependence of BOLD intensity on ISI

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Reference [1] Ogawa S et al, PNAS 2000; 97:11026-11031. [2] Bandettini P et al, MRM 39:410-416 (1998)

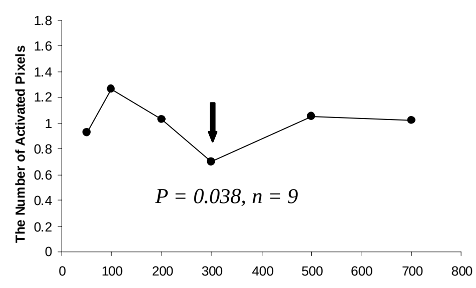

Fig. 2 Dependence activation size on

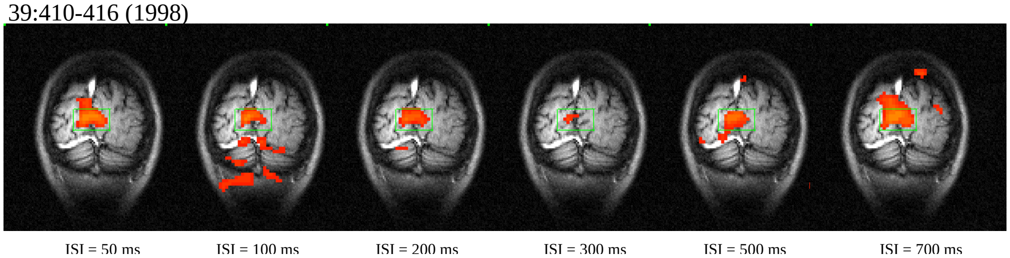

Fig. 3 BOLD activation maps with different ISI.