Neural Activity in Human Auditory and Sensorimotor Cortices Modulated by Passively Varied Divided Attention – an fMRI Study

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Introduction There is much interest in human fMRI studies in understanding the impact of baseline brain activity on the activation observed. To study this, baseline is often altered with an anesthetic agent which leads to additional confounds such as pure vascular effects and attention effects that must be accounted for in order to examine the direct impact on neuronal activity. Using auditory and tactile stimulation alone and simultaneously we demonstrate that the simultaneous multi-sensory stimulation does alter the primary sensory activation indicating the equivalent of a passive attention manipulation.

Materials and Methods Twenty healthy consenting volunteers 20 to 42 years-old were recruited in this study. MRI was performed on a 3T whole-body scanner Trio (Siemens Medical Systems, Erlangen, Germany) with a circularly polarized head coil. The auditory stimulus consisted of randomly presented pure tones presented through MR compatible headphones. The tones were played out in randomized order at 5 different frequencies - 400, 800, 1000, 1500, and 2000 Hz. Four rates were used in this experiment (duration/ISI): A1=250/1250 ms, A2=250/750 ms, A3=250/500 ms, and A4=250/250 ms. Finger-brushing was delivered via a hand-held device with a rotating brush inside stimulating the fingertips at rotating rates S1=0.98, S2=1.46, S3=2.44, and S4=3.91 revolutions/s. For each subject, there were five functional runs when BOLD EPI images were collected (Fig. 1). BOLD image were collected with the following parameters: FOV = 220 × 220 mm^2; matrix = 64 × 64; bandwidth = 2442 Hz/pixel; slice thickness = 3.5 mm; inter-slice spacing = 0.175 mm. Thirty-three AC-PC aligned slices were acquired in an interleaved manner to cover most of the cortex. TR = 2000 ms; TE = 30 ms; the flip angle was 80 degrees. GLM was employed to analyze the data collected for each individual subject. In GLM the regressors were AiSj, for all auditory and sensorimotor combinations except for the case when i = 0 and j = 0 in the same time. The GLM was applied on a per-voxel basis over all 5 runs. The time course for a voxel was normalized by rescaling its temporal mean to 100 and then input into GLM. All 24 β maps were calculated as such using GLM on the normalized time courses of voxels, and we call them normalized β maps. A standard whole brain template (MNI-1mm) was used for subject spatial normalization of individual data. In order to define auditory ROIs, the condition that any auditory stimulus was present regardless of the rate of occurrence was the only regressor in the model. For definition of sensorimotor ROIs, the condition that any tactile stimulus was present regardless of the brushing rate was the only regressor. After multiple-subject integration in the common template space, the mean, standard deviation, and t-statistic were estimated for the β maps on the pool data across subjects. ROIs were defined by thresholding the t-maps, for the secondary ROIs, $p<0.05$, for the primary ROIs, $p<0.001$, both corrected (Fig. 2).

Results and Discussion The normalized β values (percent BOLD changes) within the primary auditory ROI were estimated for auditory and sensorimotor rates and pooled across subjects. When the tactile stimulus of different brushing rate was presented simultaneously, the percent changes in BOLD were affected. Wilcoxon Signed Ranks Test was performed to show how significant the effect of the tactile stimulus was on percent BOLD changes stimulated at all 4 tone rates in the primary auditory ROI, and the results are given in Table 1a. Similar plots were shown in Figures 3b-d for the secondary, primary sensorimotor, and secondary sensorimotor ROIs, and the results of Wilcoxon Signed Ranks Test for these ROIs were given in Tables 1b-d, respectively. In summary, our results show:

(1) Task-induced signal changes primary auditory or sensorimotor cortex decreased as the rate of the other stimulus increased when both were presented simultaneously;

(2) Task-induced signals in the auditory cortex were altered to a greater extent by the tactile stimulus; task-induced signals in the hand-sensory region were more robust to the auditory stimulus;

(3) Task-induced signals in the cortex immediately adjacent to the primary auditory region were affected to a greater extent by the tactile stimulus than those in the primary auditory region (Table 1a & b).

(4) The effect of the auditory stimulus on the task-induced changes in both primary and secondary sensorimotor regions was virtually the same (Table 1c & d).

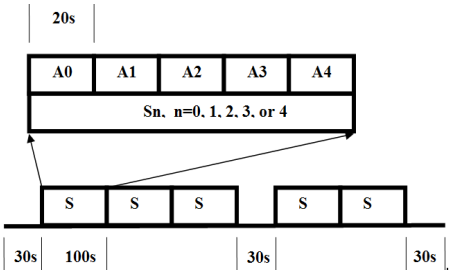

Fig 1 Blocks of auditory and tactile stimulation. During A0, auditory stimulation is absent; during S0, tactile stimulation is absent.

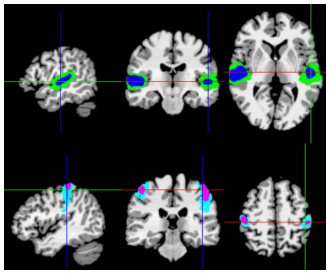

Fig 2 ROIs defined for the auditory and sensormotor cortices.

This passive manipulation of attention will allow attention effects to be dissociated from the direct effects of anesthetic in BOLD fMRI experiments investigating the influence of baseline activity on the BOLD increment.

References [1] Naatanen R. et al., 2001. Trends in Neurosciences 24:283-8; [2] Kayser C. et. al., 2005. Neuron 48:273-84; [3] Kayser C. et. al., 2007. Brain Struct Funct 212:121–32.

	S0	S1	S2	S3
S1	-			
S2	-	**		
S3	**	**	-	
S4	**	**	-	**

(a) primary auditory

	S0	S1	S2	S3
S1	-			
S2	*	**		
S3	**	**	-	
S4	**	**	*	**

(b) secondary auditory

	A0	A1	A2	A3
A1	**			
A2	**	-		
A3	*	-	-	
A4	*	-	-	-

(c) primary sensorimotor

	A0	A1	A2	A3
A1	**			
A2	**	-		
A3	*	-	-	
A4	*	-	-	-

(d) secondary sensorimotor

* p<0.1, decrease; ** p<0.05, decrease; - not significant

Table 1 The tactile stimulus of different levels affects BOLD induced by the auditory stimulus (a & b). The auditory stimulus has similar effects on BOLD induced by the tactile stimulus.

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