Crossmodal interaction with the auditory modality affects the BOLD response to visual stimuli

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•**Introduction**: Flickering light leads to synchronized EEG responses named as steady-state visual evoked potentials (SSVEPs), which mainly comprise same frequency of flickering stimulus and its harmonics. SSVEPs have a frequency dependent amplitude characteristics with a selective increases around 10 Hz.

•The blood oxygenation level-dependent (BOLD)-based fMRI has been used to measure neuronal metabolic activity changes. Although there are multiple physiological parameters affecting BOLD signal, positive BOLD (pBOLD) is shown to have a frequency dependent response to the flickering stimulus and a pBOLD peak has been reported to be in accordance with SSVEP observations [1].

•Studies investigating the multi-sensory integration have indicated that the activation of modality-specific areas can be modulated by cross-modal signals. It has been shown that the visual cortex is affected by tactile and auditory stimulation [2]. But there is little knowledge about steady state BOLD responses under multimodal stimulation conditions.

•**Method and Procedures:** The experiment with fMRI was performed on a Philips 1.5T MR system using an 8 channel head coil (Sense Head 8, Philips Medical Systems, Eindhoven, Netherlands) at the Neuropsychiatry Hospital Istanbul. A fiber optic light transmission system connected to a black opaque sunglasses is constructed to deliver visual stimuli whereas standard MRI headphone system is used to deliver auditory stimuli to the subjects during fMRI scans. 10 Hz flash stimuli and 10 Hz modulated white noise signals were given to 4 subjects (2 female) in two separate block designed fMRI sessions. In the first part of the experiment, 10Hz multimodal stimulation (both visual and auditory stimulation -VA) was applied after 10 Hz flash stimuli (Pure visual -V) (Figure 1). In the second part, 10Hz VA stimulation was applied after 10 Hz white noise stimulus (Pure auditory -A). Image processing, data analysis and group analysis were performed using the FMRIB software library package FSL (Analysis group, FMRIB, Oxford, UK) [3, 4].

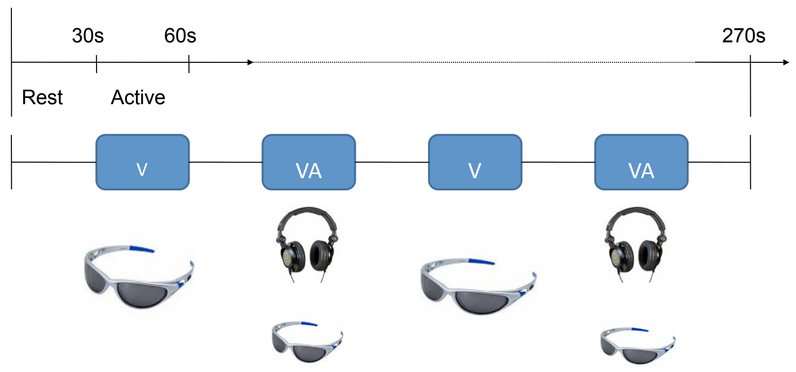

Figure 1. Experimental design

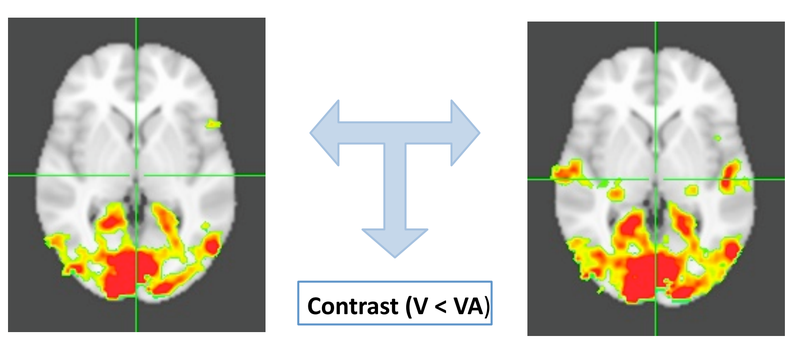

Figure 2. Brain activations for contrast VA>V.

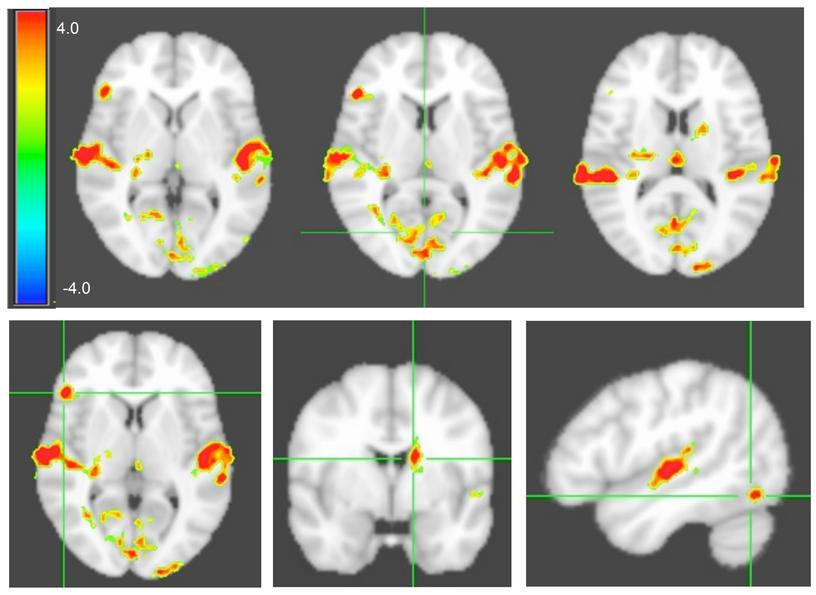

Figure 3. Bimodal stimulation revealed more activation in primary visual cortex (BA 17), visual unimodal association areas (BA 18-19-37) and also in heteromodal areas right inferior frontal gyrus (BA 45) and left caudate nucleus.

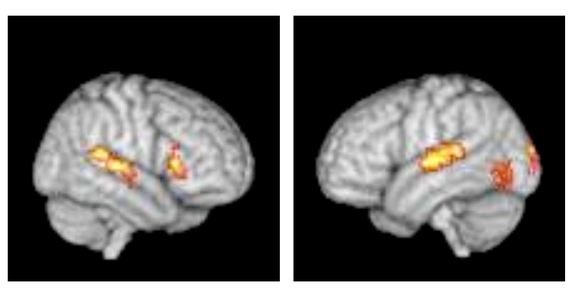

Table 1. Results of cluster analysis

Cluster Index	Voxels	*p*	-log10(P)	Z-MAX	Brain Region
8	1083	1.07e-12	12	6.84	Left BA 42 41
7	1023	3.68e-12	11.4	6.78	Right BA 22
6	788	6e-10	9.22	4.23	Right BA 17 18
5	207	0.00438	2.36	4.71	Left BA 19 37
4	194	0.00697	2.16	5.24	Left BA 19
3	174	0.0145	1.84	5.37	Right BA 45
2	170	0.0168	1.77	4.28	Right thalamus
1	149	0.0375	1.43	5.13	Left Caudate

•**Results**: Across both experiments, visual stimulation in the absence of auditory stimulation and auditory stimulation in the absence of visual stimulation produced predictable bilateral activation of primary visual and primary auditory cortices respectively. When the audiovisual brain activations were contrasted with response to pure visual stimulation, an area in bilateral primary auditory cortices were identified as expected (BA 41,42), but also areas in primary visual cortex (BA 17), upstream and downstream visual association cortices (BA 18,19 and BA 37), right inferior frontal region (Right BA 45) and left caudate nucleus were activated. The area observed in primary visual cortex was located in the posterior part of the calcarine cortex, which represents more peripheral parts of the visual field.

Conclusion: These findings suggest the involvement of the more peripheral visual field by bimodal stimulation in contrast to pure visual stimulation. On the other hand there were no significant changes in primary auditory cortices in bimodal stimulation compared to pure auditory stimulation. Increased pBOLD in unimodal upstream & downstream association areas in bimodal stimulation may represent the increase in perception of visual stimulus as shown by Shams et al. [5]. Left caudate and right inferior frontal area may be involved in multimodal processing as they belong to heteromodal association areas.

These results verify the direct effect of simultaneous auditory stimulation on visual processing and detail them in terms of the detection of specific activation areas that modulate the visual sensory processing through auditory input.

References:

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