Neurofeedback audio-visual stimulation (AVS) impact onto the brain networks interaction: fMRI study

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Aims and objectives

To date the therapeutic Audio Visual Stimulation (AVS) is used as a part of neurofeedback treatment for a variety of neuropsychiatric disorders [1]. AVS concerns repetitive presentation of light and sound to the patient. Treatment of anxiety, dysphoria, agitation, depression is the main target for neuropsychiatric disorders and addiction therapy. But usually it can't replace specificity of emotions which could be obtained under the stimulant consumption [2]. Tranquilizers, antipsychotics, sedatives can quickly help to cope with the negative behavioral disorders that accompany drug usage, but reduced psycho-physical and bio-social activity are common side effects of their use. Timoleptics and antidepressants, soft psychostimulants start to have an impact over a longer period [3]. Thus development of the new replacement therapy methods for stimulant addiction is urgent task for today's medicine. Concerning the use of audio-visual stimulation (AVS) as a component of neurofeedback therapy for neuropsychiatric disorders we propose to evaluate its effect onto the brain networks interaction.
Methods and materials

Cohort included 15 volunteers (8M, 7F, 20-32y.o.). AVS was done with NovaPro-100 (Photosonix, USA) using protocol: 12Hz-8Hz-6Hz-3Hz-8Hz. We performed fMRI before and after the AVS using 1.5T Signa Excite (GE, USA). Resting state (RS) and finger tapping task were used for the acquisition of fMRI data with EPI pulse sequence: TR/TE=3000/71ms, FA=90, voxel=4x4x6 mm. Activation and deactivation were modelled with GLM as an opposite contrasts. ICA was done. Analysis was made with FSL software (Oxford GB).
Results

From the GLM analysis of task-based fMRI data, received before the application of neurofeedback audiovisual stimulation, we have found out that during simple unilateral finger tapping task expected activation occurred in such regions: contralateral, to the hand movement, primary sensory-motor area (M1/S1\textsubscript{con}), supplementary motor area (SMA), ipsilateral hemisphere of cerebellum (C\textsubscript{bell}\textsubscript{ips}). Activation occurred in the region of inferior part of precentral gyrus, bordering upon the pars opercularis of the inferior frontal gyrus (Broca's area, BA44), and near posterior section of the superior temporal gyrus (Wernicke’s area, BA22), also activation occurred at the ipsilateral inferior part of precentral gyrus, ipsilateral angular gyrus and contralateral hemisphere of cerebellum. The activation was accompanied by the deactivation of the region ipsilateral primary sensory-motor area (M1/S1\textsubscript{ips}) and the regions of precuneus, posterior cingulated cortex, inferior medial prefrontal cortex, parts of so-called default-mode network (DMN) Fig. 1 on page 6 Fig. 2 on page 6. fMRI data, received after the application of neurofeedback audiovisual stimulation, showed that during simple unilateral finger tapping task activation occurred at the previously described regions but also at the bilateral striatum, lateral prefrontal cortex and left parietal cortex. Analysis of the volume of activation/deactivation showed the before the application of the audiovisual stimulation its ratio was close to the 0.93 (72/77.3 cm\textsuperscript{3}), but after the stimulation ratio value changed to 36 (162/4.5 cm\textsuperscript{3}) Fig. 3 on page 7.

In our study ICA analysis of the resting state fMRI data defined 15 ICA components (as revealed by maps thresholded at Z=2.3), which reflected real functional connectivity (DMN, visual, fronto-temporal), and artificial components (breathing, heart rate). Anatomical revision of independent component map constituents revealed functional connectivity of the regions of inferior medial pre-frontal cortex, posterior cingulate cortex, precuneus and lateral parietal cortex which are widely accepted to form DMN. Also we have found functional connectivity in the region of occipital lobe, which is widely accepted to form resting state visual network. We selected defined IC components for future analysis of its normalized signal timecourse and frequency spectrum. Analysis of the BOLD signal oscillations spectrum from the DMN regions revealed low frequency amplitude prevalence in the range of 0.0067-0.03 Hz with primary peaks at f=0.0167Hz (Power=1392) and f=0.0262 (Power=1435). Visual network timecourse analysis revealed prevalence frequency of f=0.0167Hz (Power=2076) and oscillation became most periodical after the 2 minutes of rest. ICA analysis of the resting state fMRI data recorded after the neurofeedback therapy failed to reveal functional connectivity in the region of visual cortex. Spectrum analysis of the BOLD timecourse in the region of DMN revealed primary frequency of f=0.0357Hz (Power=1051) with much more subpeaks presence. Analysis of the frequencies which were prevailing before the neurofeedback therapy revealed considerable power reduction: f=0.0167Hz (Power=1.2), f=0.0262 (Power=380) Fig. 4 on page 8.
fMRI data acquired at the resting state with closed eyes clearly shows functioning of the DMN and visual networks. But measurement made after the stimulation failed to shows functioning of the resting state visual network which may be possible evidence of partly prolonged effect (which lasted after the cessation of stimulation) of neurofeedback audiovisual stimulation onto the visual cortex. Spectral analysis of the BOLD oscillation at the regions of DMN showed that after the stimulation prevailing frequency changed to the higher values (0.0167Hz and 0.0262Hz to 0.0357Hz) which could be the biomarker for internal brain processes stimulation effect.
Images for this section:

**Fig. 1:** Anatomical representation of the activation and deactivation, measured by fMRI, Z#3.09. Red - regions of activation before the stimulation. Blue - regions of deactivation before the stimulation. Yellow - regions of activation after the stimulation. Green - regions of deactivation after the stimulation.

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**Fig. 2:** Regions of activation and deactivation before and after the neurofeedback AVS, as measured by fMRI, threshold Z#3.09.

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Fig. 3: Total activation and deactivation volumes before and after the neurofeedback audiovisual stimulation, as measured by fMRI, threshold Z#3.09.

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Fig. 4: Frequency spectrum of the BOLD signal fluctuation in the regions of the DMN before and after the AVS.

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Conclusion

fMRI confirmed the prolonged effect of AVS onto the brain by considerable increase of the volume of activation, extinction of deactivation and changes in RS networks interaction.
References