Functional MRI in stroke patients following brain-computer interface-assisted motor imagery rehabilitation

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Purpose: Robot-assisted motor imagery and brain-computer interface (MI-BCI) is a promising rehabilitation technique for stroke patients who suffer from motor disabilities [1]. Transcranial direct current stimulation (tDCS), a technique of noninvasive brain stimulation, is able to modulate the cortical excitability, and hence holds the potential to improve motor function recovery [2,3]. The primary aim of this study was to investigate the structural and functional changes of the brain after rehabilitation training of MI-BCI combined with or without tDCS in stroke patients.

Methods: We conducted a randomized, double-blind study of combined tDCS and MI-BCI vs sham-tDCS and MI-BCI in chronic stroke subjects. X healthy controls (age…) and 19 patients (53.5 ±11.8 years old, 9 males and 4 females) who had their first ever subcortical stroke more than 9 months leading to unilateral and moderate to severe impairment in the upper extremity were recruited with written consent. Patients were randomly assigned to 2 groups, training over 2 weeks with either 20 min of tDCS or 1 min of tDCS (ramping up and down, the sham-tDCS group) preceding training. Each therapy session consisted of 20 min of brain stimulation with electrodes placed on the bilateral cortical M1, followed by 40 min of MI-BCI where the subject performed a reaching task while being presented with the clock game interface of the MIT-Manus robotic system. Motor function was evaluation by Fugl-Meyer assessment (FMA), transcranial magnetic stimulation, and MRI performed before and after the training.

MRI data were collected using a 3T scanner (Siemens Trio, Germany). In the scanner, the subject performed a dynamic hand grip cued by a visual stimulus of a moving red circle. Four functional scans were performed in a randomized order: Acive left (AL), Active right (AR), Passive left (PL) and Passive right (PR),where the passive movements were performed by a trained operator with the subject relaxed. A target grip strength for the active and passive paradigms was 30% MVC of the respective an non-affected hand respectively. fMRI data were acquired with a single-shot gradient echo EPI sequence with TR=3000 ms, TE=30ms, voxel size =3.4mm isotropic, and number of measurements = 89. The functional and structural data were analysed using FSL [4] and in house MATLAB (MathWorks, USA) codes. Functional MRI data with large motion was discarded.

Results: Fig.1a represents group activation maps of controls versus patients before and after rehabilitation. While controls showed activation in the insula and thalamus, a significant loss in activity in these areas was seen in the patients and was regained after rehabilitation. The BOLD signal change negatively correlated with the FMA and positively correlated with the cortical excitability measured by TMS.

Discussion: We show that the patients showed decreased activations in areas like the insula and thalamus and is correlated with cortical excitability. The increase in activation in the insula and thalamic regions in the stoke-affected hand movement was consistent with cortical excitability. These findings present evidence of training-induced cortical plasticity, sustained at two weeks post-treatment that underscore the therapeutic potential of MI-BCI. Complementary structural and functional connectivity data collected will further elucidate the mechanisms involved.

References: [1] Sharma N et al. Stroke 2006 37(7) :1941-52 ; [2] Page SJ et al. 2009 23(4) :382-8 ; [3] Jang SH et al. Neurosc Lett 2009 460 :117-20.
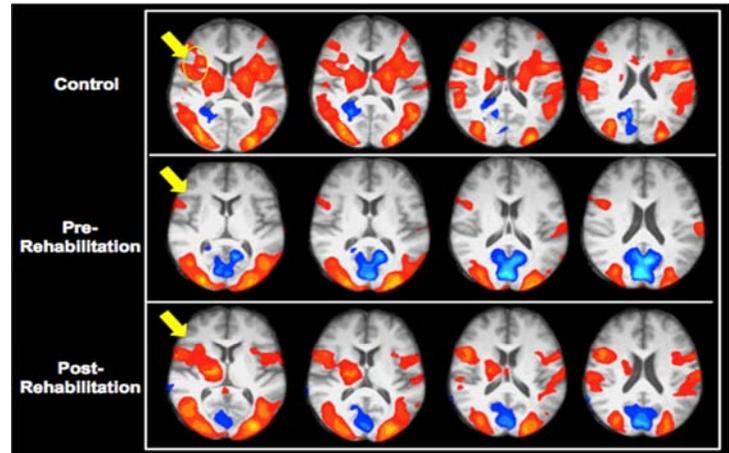
Fig. 1. Activation maps of LA task in controls (top), patient pre-treatment (middle) and post-treatment (bottom). Yellow arrow refer to the ROI of most significant change.
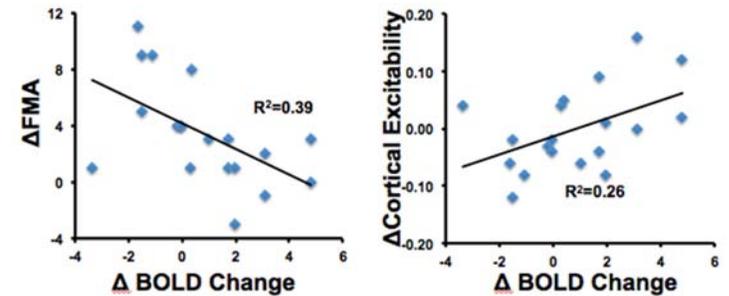

Fig.2 Correlation between the ΔFMA (left) and Δcortical excitability (right) with ΔBOLD change after vs before rehabilitation in patients.