ACCOMPANYING EVENT-RELATED DECREASE OF ALPHA BAND EEG AND SUSTAINED NEGATIVE BOLD RESPONSE AT IPSILATERAL PRIMARY SENSORIMOTOR AREA

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Introduction: Blood-oxygenation-level-dependent (BOLD) fMRI is widely used in exploring brain activity. It is of great interest to study the relationship between BOLD signals and electroencephalographic (EEG) Alpha activity (8 – 13 Hz), which would enhance our understanding of the biophysical mechanism of BOLD on one hand and Alpha rhythm on the other hand. While several studies reported spontaneous BOLD and block-wise increase of BOLD are inversely correlated with Alpha [1-2], there is no evidence as to whether or how sustained negative BOLD response (NBR) would be coupled to Alpha changes. Here we combined EEG and BOLD fMRI to investigate the relationship between task-related Alpha and BOLD responses in a unimanual motor paradigm eliciting NBR.

Methods: Ten right-handed healthy subjects participated in the study. The motor paradigm comprised visually cued clenching of left and right hands at 3 Hz paced by metronome. A mixed block and event-related design was developed to accommodate the EEG and fMRI recordings. The task blocks (20 s) were interleaved with rest blocks (20 s) and each run included two repetitions of tasks. Within a task block, there were six events during which subjects performed the appropriate task for 2 s interleaved with inter-trial intervals of varying durations from 1s to 2 s. The same tasks were performed within a block and the sequence of block types were randomized and balanced across runs and subjects. Four runs of EEG (BrainAmp, BrainProducts, Germany) and three runs of fMRI images (3T, Siemens Trio, Germany) were collected in separate sessions with identical stimulus sequence. 64-channel EEG signals were recorded at sampling frequency of 1000 Hz. Electromyogram (EMG) activity was also acquired in the EEG sessions to monitor muscle movement. The anatomical landmarks and electrode positions were digitized using a Polhemus Fastrak digitizer and coregistered with corresponding locations identified from T1-weighted images. Whole-brain functional images with BOLD contrast were acquired using gradient echo planar imaging sequence (32 transverse 3-mm thick interleaved slices with 0.3-mm gap; TR/TE = 2000 ms/30 ms; flip angle = 90°; matrix size: 64*64, FOV: 192*192 mm^2).

Data Analysis: The source strength in the frequency band of interest was obtained using Minimum Norm Estimate in Frequency Domain (MNEFD) [3]. Single-trial source distribution during movement (from 0.5 s to 2 s after the cue) was calculated and compared to the baseline period (from -1 s to -0.1 s relative to the cue). The task-related response was defined as the percentage change of source power relative to the baseline. All dipoles from each individual were then projected onto a reference brain by aligning each subject's sulcal-gyral patterns. The spectral changes were used to make a random-effect statistical map of the differential neural activity on the cortical surface. MRI data were analyzed using BrainVoyager (Brain Innovation, Maastricht). EPI images were coregistered with T1 anatomy and then transformed into Talairach space. After standard preprocessing, general linear model was applied and the resulting set of voxel values constituted the map of beta weight of each task and the associated statistical significance.

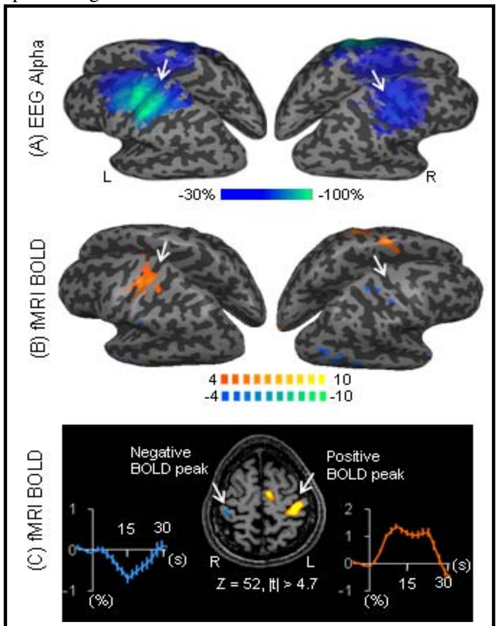

Figure 1: Group results of (A) Alpha decrease (p<0.005) and (B) BOLD changes (p<0.005) during right hand movement displayed on an inflated cortical surface with white arrow indicating the central sulcus. (C) shows the locations of peak BOLD changes and time course of BOLD percentage change derived from these two regions (baseline is from -4 s to 0 s).

Results: Group analysis of EEG source showed that an event-related decrease of Alpha source accompanying sustained negative BOLD response (NBR) was found at the ipsilateral primary sensorimotor cortex during right hand movement (peak Talairach coordinates [42, -25, 52] and [49, -19, 49] for BOLD and Alpha respectively). Although a weak negative change at ipsilateral right hemisphere was identified (t = -1.97 and p = 0.08), individual results of fixed effect analysis revealed that seven subjects out of ten showed significant NBRs at the hand region of ipsilateral sensorimotor area during right hand movement (p<0.05). Random effect analysis results of the seven subjects are depicted in Figure 1. Ipsilateral Alpha decrease associated with right hand movement was significant and consistent across ten subjects studied (p = 3e-8 for group of ten subjects and p = 9e-6 for group of seven subjects, one-tail). A stronger contralateral decrease was co-localized with BOLD increase during both left and right hand movements. However, no significant change of BOLD at the ipsilateral motor area for left hand movement was identified (t = 0.986 and p = 0.35). Then we investigated whether individual Alpha and BOLD responses would co-vary at the right sensorimotor area (Positive (PBR) and Negative BOLD response associated with left and right hand movement respectively). To do so, we first normalized the Alpha changes according to their maximum modulation across all tasks and BOLD changes (beta weights) correspondingly. Results showed that no correlation was found between the changes of these two measurements (r = -0.38, p = 0.17). However, a linear correlation of modulation magnitudes was found when we compared the absolute value of BOLD change with Alpha decrease (r = -0.72, p = 0.003), as depicted in Figure 2.

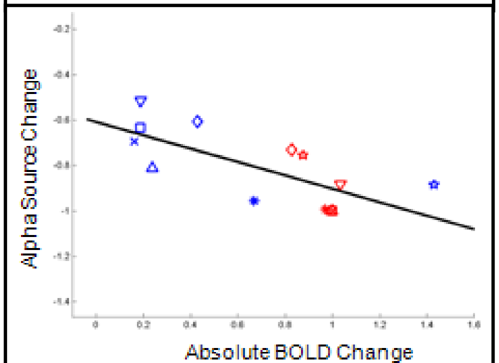

Figure 2: Relationship between normalized Alpha and absolute BOLD changes associated with left (red) and right (blue) hand movements. Different symbols indicate different subjects. Black line is the result of linear fitting.

Discussion and Conclusion: Our results showed an excellent co-localization of event-related decrease of Alpha and sustained NBR at the ipsilateral primary sensorimotor area, which suggests that these processes can be intimately linked. NBR has been shown to be coupled with cerebral blood flow in motor [4] and visual [5] cortex. Inhibition in the ipsilateral motor cortex induced by motor cortex in the other hemisphere has been documented in electrophysiological studies using Transcranial Magnetic Stimulation (TMS) [6], which suggests that the NBR is a marker of neural deactivation. Additional evidence supporting the neural origin of NBR comes from a combined fMRI and electrophysiological study by Shumel et al. [7] which showed that both PBR and NBR were strongly correlated with neuronal activity. Hence, a NBR in the ipsilateral M1 represents a decrease in neural activity. Here we demonstrate again that NBR is correlated with changes of neural activity. Although it is not immediately clear how decreased neural activity can be related to event-related decrease in Alpha, one possible explanation is that the neural deactivation breaks the synchronization of thalamocortical neural populations, which are thought to be essential for the generation of resting Alpha rhythm [8]. Both increased and decreased neural activity might cause the desynchronization of the Alpha-rhythm network, which could be manifested as the decrease of Alpha activity.

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Reference: [1] R.I. Goldman et al., NeuroReport 13(2002) 2487- 2492, [2] B. Feige et al., J.Neurophysiol. 93(2005) 2864-2872, [3] Yuan et al., IEEE TNSRE in press, [4] B. Stefanovic et al., NeuroImage 22(2004) 771-778, [5] A. Shmuel et al., Neuron 36(2002) 1195-1210, [6] A. Ferbert et al., J.Physiol. 453(1992) 525-546, [7] A. Shumel et al., Nat.Neurosci. 9(2006)569-577, [8] G. Pfurtscheller et al., Clin.Neurophysiol. 110(1999)1842-1857.