Use of magnetoencephalography (MEG) for the functional motor cortex localization: extraction and localization of the motor component in movement preparation processes by Independent Component Analysis*

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The problem of non-invasive preoperative localization of motor areas in human cortex has not been solved yet.

In clinical practice, localization of the hand representation in the primary motor cortex often becomes one of the main goals of the pre-surgical evaluation. In healthy subjects the area of the motor hand representation usually corresponds to certain standard anatomical landmarks (hand knob in the precentral gyrus), which can be easily found in sMRI images. Unfortunately, in patients with various brain lesions these landmarks may be absent or not corresponding to the area of the motor cortex. In such cases, location of irreplacable areas must be determined according to their functional and/or temporal dynamical characteristics.

Experimental studies of voluntary movements in primates have shown that many cortical areas (primary motor cortex, supplementary motor cortex, premotor cortex, primary sensory cortex, etc.) become activated simultaneously long before movement onset (i.e. in movement preparation phase) (Riehle, 2005). Thus, attempts to map the motor cortex using movement-locked EEG/MEG response with the use of single-dipole modeling are often prone to errors (Chayanov et al., 2012), while mapping brain activity using fMRI highlights only the whole complex of cortical areas involved in preparation and execution of the movement.

It might become a promising method of localizing primary motor area by way of taking into account the characteristic properties of the primary motor cortex temporal dynamics during movement preparation. It is well known that the late component of the motor readiness potential can be recorded in the primary motor, premotor and motor cortices during 300-400 ms before movement onset (Shibasaki, Hallett, 2006). Importantly, of these areas only the primary motor cortex exhibits a sharp, exponential activation roughly 100 ms before movement onset, as has been shown by way of direct epicortical recording (Ikeda et al., 1992; Ohara et al., 2000).

In this study, we recorded MEG data during repeated index finger movements in 18 subjects. Then we attempted to separate the sensorimotor activation complex into several components using the Independent Component Analysis (ICA) and to single out the primary motor cortex activation be way of comparing the components' temporal dynamics with the expected primary motor cortex temporal dynamics.

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Subjects were instructed to raise their index finger at a comfortable pace. We recorded MEG, myogram and accelerometer signal simultaneously. For all subjects, sMRI slices were obtained. Co-registration of MEG and MRI data was performed using program suites “Freesurfer” and “NeuroMag”.

MEG data for all 18 subjects were concatenated into a singe data sequence, and ICA was performed on this sequence. Resulting components were averaged relative to movement onset (which was determined from accelerometer signal), and mapped onto averaged brain surface using distributed source modeling algorithm (cortically-constrained L2 minimum-norm current estimates).

Using similarity to the expected pre-movement activation pattern as the criterion, we selected two out of 50 resulting independent components - one, whose temporal dynamics presumably corresponded to the motor cortex activation, and the second one, whose temporal dynamics presumably corresponded to the sensorimotor cortex activation. If our assumptions are correct, then cortical sources of “sensorimotor” component are expected to localize in post-central gyrus (where the somatosensory cortex is normally found in healthy humans), and cortical sources of “motor” component - in precentral gyrus, where the primary motor cortex usually resides.

Mapping selected components on the brain surface (fig.1) confirmed that the “sensorimotor” component was localized caudally from central gyrus - in postcentral gyrus, and partially in precentral gyrus. The “motor” component was mapped to precentral gyrus, a bit higher then the area of the sensorimotor activation. This result stays in agreement with the localization of index finger motor representation in several studies, which have shown that the motor representation resides 10-20 mm higher than the corresponding somatosensory representation (Schieber, 2001; Onishi et al., 2011; Hadousha et al., 2011).

These results show that, despite high correlation of input data and proximity of sources being separated, it is possible to separate them into two non-overlapping areas of activation, using the approach based on specifics of temporal dynamics of activation in primary motor cortex during movement preparation. Thus, we hope that this method may potentially become useful for preoperative localization of primary motor cortex in clinical practice.

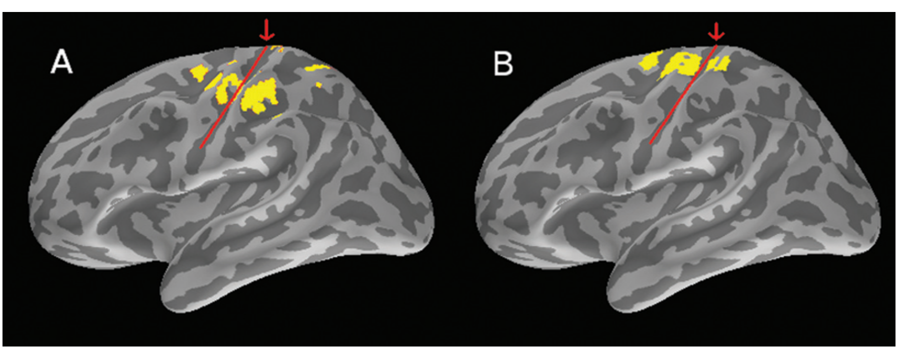

Fig.1 Mapping of “sensorimotor” component (A) and “motor” component (B), using cortically-constrained L2 minimum-norm current estimates. The central sulcus is indicated by the red line.