

Comparing BOLD Resonances of TMS, Median Nerve Stimulation and Voluntary Finger Movements

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Introduction

Transcranial magnetic stimulation (TMS) has developed into a widely used tool in neuroscience to study cortical excitability. However, its underlying mechanisms are still poorly understood. The combination of TMS with functional magnetic resonance imaging (fMRI) provides the possibility to directly visualize the TMS induced changes in brain activity at a high spatial and temporal resolution [1, 2]. The hand area of the primary motor cortex (M1) is known to be an ideal target for TMS because effective stimulation results in hand muscle twitches which can be easily observed or measured. Using interleaved TMS/fMRI we wanted to address the following questions:

- Are the activations shown after stimulation with TMS similar to the ones seen after voluntary finger movement and/or peripheral median nerve stimulation?
- Does TMS directly stimulate underlying cortical areas?

Methods

BOLD fMRI was performed at 3 Tesla (Siemens Trio) using EPI (TR 2000ms, TE 36ms, 20 slices, 2x2x4mm³) on 10 right-handed healthy volunteers who were placed in the scanner with the TMS coil over the hand area of M1. Biphasic TMS pulses were applied by a non ferromagnetic figure-of-eight coil connected via an eight meter cable to a Magstim Stimulator outside the magnet room [3]. The individual motor threshold was determined prior to the scanning session.

Each study consisted of 5 successive experimental conditions which were randomised between subjects:

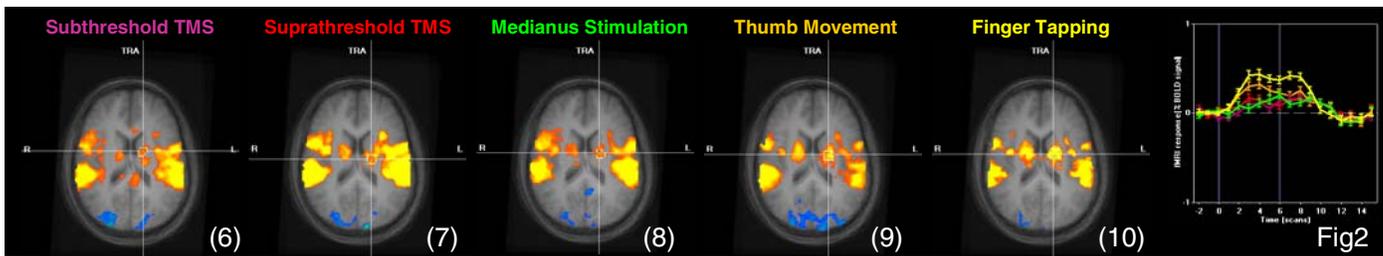
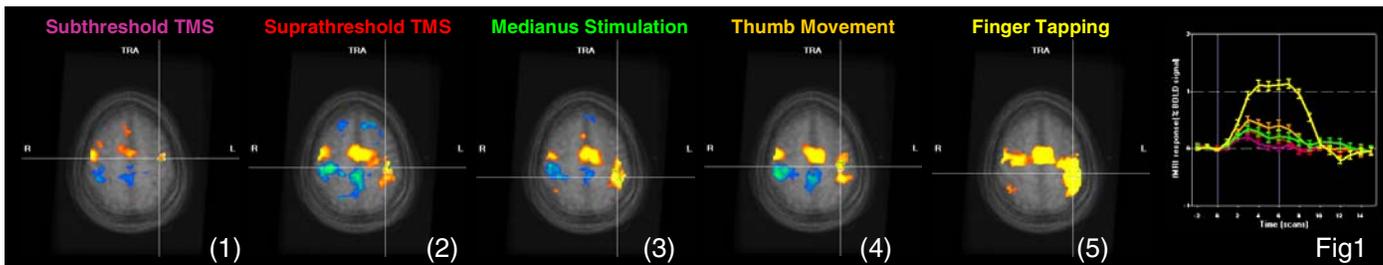
- (1) Subthreshold TMS: TMS at 1 Hz and 90% of the individual motor threshold
- (2) Suprathreshold TMS: TMS at 1 Hz and 110% of the individual motor threshold
- (3) Electrical Median Nerve Stimulation
- (4) Thumb Movement
- (5) Finger Tapping

The conditions (4) and (5) were triggered acoustically by discharging the TMS coil at a low intensity and at the same frequency as during stimulation. The experiment was implemented designed as a block design with epochs of stimulation lasting 12 s and epochs of rest lasting 18 s which were repeated ten times after an initial equilibration period of 18 s. The TMS pulses were applied in the 100 ms gaps between slice acquisitions in order to avoid image disturbances.

Results

During the tasks in which movement was either voluntarily made or induced by stimulation, activation was found in left M1, left primary somatosensory cortex (S1), premotor cortex (PMC), supplementary motor area (SMA), secondary somatosensory cortex (S2), nucleus caudatus, putamen, and thalamus. Deactivation was found in S1 of the contralateral side and the centroparietal cortex during median nerve stimulation, suprathreshold TMS and thumb movement. Finger tapping produced significantly more activation in M / S1 and a greater BOLD response than any other condition (Fig.1 and Fig.2). Suprathreshold TMS, median nerve stimulation and Thumb Movement showed very similar activation patterns (see pictures 2-4, 7-9) and BOLD responses in M1 (see Fig.1). Subthreshold TMS showed no activation in M1 and respectively hardly any BOLD response while eliciting activation in remote motor areas as seen during the other tasks.

During all tasks we found activation of the basal ganglia and S2 (see pictures 6-10). Analog to M1 Finger Tapping resulted in the greatest BOLD response followed by Thumb Movement and then all other tasks (see Fig. 2).



Discussion

Both Supra- and Subthreshold TMS of M1 and Median Nerve Stimulation resulted in the activation of cortical and subcortical structures involved in the motor network that are similar to the ones seen during Thumb Movement. Finger Tapping which is more complex and demands the movement of all five fingers showed more activation than the other tasks and the greatest BOLD responses in all motor areas. The absence of activation in M1 during Subthreshold TMS Stimulation (without finger movement) may be explained by the fact that the local hemodynamic changes in M1 do not exceed the background noise although it is sufficient to elicit activation in remote motor areas. It is therefore likely that the positive BOLD response in M1 during Suprathreshold TMS and Median Nerve Stimulation is the result of reafferent feedback from evoked movements.

References

- [1] Bohning et al.: Central Echoplanar BOLD fMRI of brain activation induced by concurrent transcranial magnetic stimulation. Invest Radiol, 1998.
- [2] Baudewig et al.: Regional modulation of BOLD MRI responses to human sensorimotor activation by transcranial direct current stimulation. Neuroreport, 2001.
- [3] Bestmann et al.: On the synchronization of transcranial magnetic stimulation and functional echo-planar imaging, JMRI, 2003.