Functional Magnetic Resonance Imaging of the sensorimotor cortex of the lower limbs by means of a force controllable actuator

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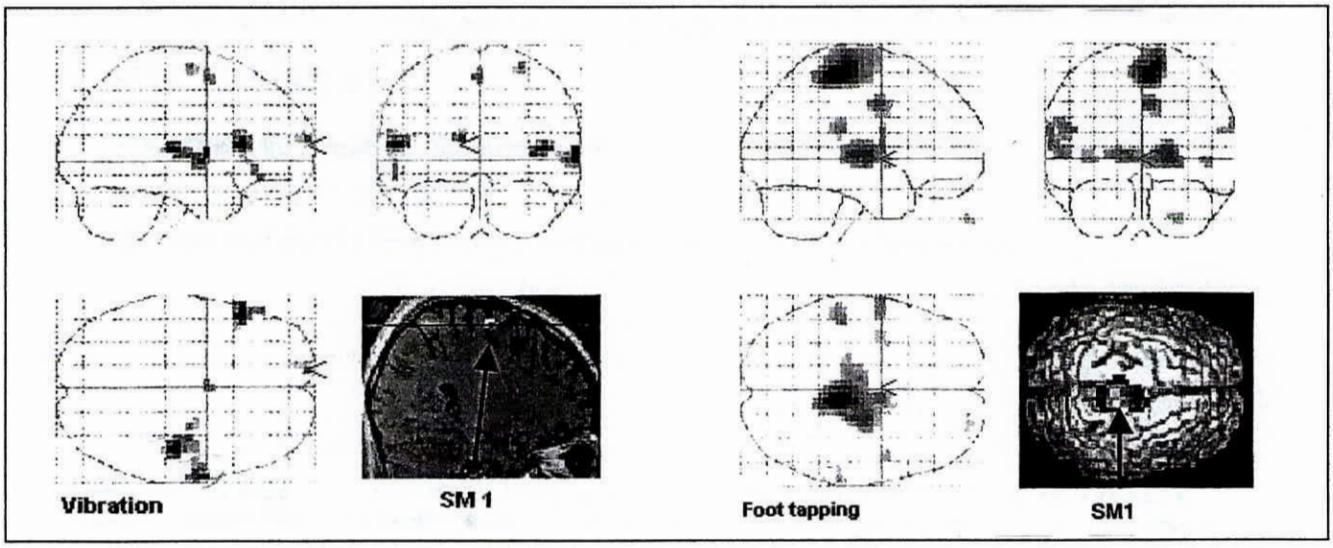
PURPOSE: Functional diagnosis of the sensorimotor cortex is of increasing importance for the planning of neurosurgical intervention in patients with brain tumor or for the planning or monitoring of post stroke rehabilitation. In these patients, active motor paradigms such as finger-to-thumb tapping or foot tapping are often difficult to perform because of severe motor deficits. Therefore, paradigms, which do not need the collaboration of the patient under investigation, are needed. The aim of the study was the implementation of a vibrotactile stimulation paradigm within the MR environment and to compare the results with the foot-tapping paradigm.

METHODS: 10 healthy, male volunteers performed a foot-tapping paradigm with the right foot. In a second experimental run, the subject's sole was vibrated with a controllable electromagnetic actuator. To synthesize sinus vibrations during time varying preloads, we used a force controllable actuator with embedded encoder with a linear stroke range 20-40 mm, a force output of +/-30 N and a frequency response of 0 - 100 Hz (1mm amplitude).

Prior to the second measurement, we performed a test vibration procedure with a 50 Hz vibrotactile stimulus and elicited a tonic vibratory reflex (TVR) in the flexor hallucis and flexor digitorum longus, which was recorded by EMG. The vibration stimulus was applied onto the sole of the right foot above the basic joints of the toes I–V.

All experiments were performed on a 1.5 Tesla MR-Siemens-Scanner with an echo-planar capable gradient system (rise time 300μsec, 25mT/ms) and a circular polarized head coil (FoV=240mm). We employed T2* weighted single shot echo-planar (EPI) sequences (TR/TE/α=0,96ms/66ms/90°, matrix =64x64, acquisition time: 2 sec, voxel dimension=4x4x4mm). We acquired 24 slices parallel to the bicommissural plane. Post-processing was done with software SPM99. A statistical parametric activation map (SPM99) was calculated for the whole subject group with an uncorrected p value of $p < 0.001$ and a cluster size of 4.

RESULTS: Group analysis over 10 subjects showed:
1. For the foot tapping paradigm of the left foot cortical brain activation of the contralateral hemisphere could be elicited within the precentral gyrus (BA 4) he postcentral gyrus (BA 3a,b) - which can be summarized as primary sensorimotor area SM1 - and the anterior cingular gyrus (BA 32). Ipsilateral brain activation could be detected within the medial portion of GPrC and GPoC. Bilateral brain activation was lined out within the inferior parietal lobule (BA 40), the superior temporal gyrus (BA 22) and the medial portion of the GFs (BA 6).
2. For the vibrotactile stimulation of the sole of the left foot cortical brain activation could be elicited contralaterally within SM1, LPi and GTs, ipsilaterally within the inferior frontal gyrus (BA 46) and the anterior portion of the superior frontal gyrus (BA 9) and bilaterally within the SMA.



CONCLUSION: Our results hold promise for the application of the vibrotactile stimulus for the functional diagnosis of the sensorimotor cortex in patients with brain tumor for the planning of neurosurgical intervention or in patients with motor deficits in stroke or spinal cord injury for monitoring of neurorehabilitation and prognosis. In our study, we implement an MR compatible moving coil actuator, which can easily be controlled and which can be applied for detailed functional maps of the sensorimotor cortex for the lower extremities especially for patients with spinal cord injury and damage of the long tracts.

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会議録

Neuroimage : HBM 2002 Sendai Japan : HBM 8th international conference on functional mapping of the human brain : June 2–6, 2002 Sendai, Japan : program. : Neuroimage specisl issue : 8th annual meeting of the Organization for Human Brain Mapping : Jun 2002, Sendai, Japan

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Size & Duration : lxviii : 28 cm. + With a CD-ROM

Description : Program

ISSN : 10538119

Golaszewski, SM; Siedentopf, CM; Gallasch, E; Ropele, S; Mottaghy, FM; Koppelstaetter, F; Felber, SR; Fazekas, F
Functional Magnetic Resonance Imaging of the sensorimotor cortex of the lower limbs by means of a force controllable actuator.
8th International Conference on Functional Mapping of the Brain (HBM 2002) ; JUNE 2-6, 2002; Sendai, JAPAN. 2002.
[Oral Communication]