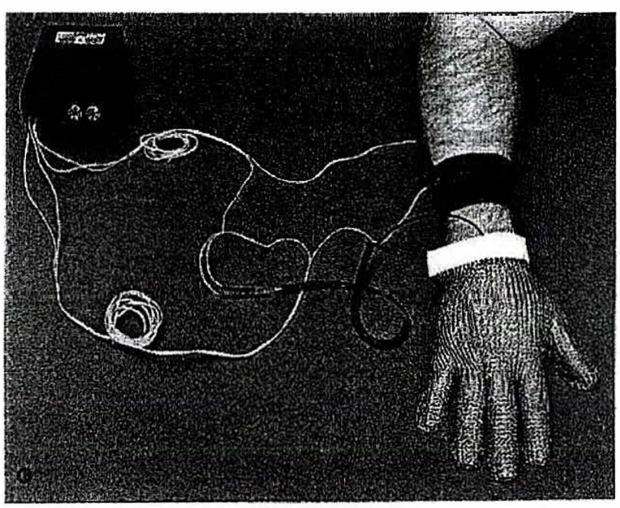
fMRI of the human sensorimotor cortex before and after subsensory whole-hand afferent electrical stimulation

S.M. Golaszewski[1], C.M. Siedentopf[2], F. Koppelstätter[2], F.M. Mottaghy[3], M.R. Dimitrijevic[5], S.R. Felber[2], P. Berlit[1], E. Gerstenbrand[4]

[1] Dept. of Neurology, Alfried Krupp Krankenhaus Essen, Germany
[2] Dept. of Neuroradiology, University Hospital of Innsbruck, Austria
[3] Dept. of Nuclear Medicine, Research Center Jülich, Germany
[4] Ludwig Boltzmann Institute for Restorative Neurology and Neuromodulation, Vienna, Austria
[5] Division of Restorative Neurology and Human Neurobiology, Baylor College of Medicine, Houston, Texas

PURPOSE: Electrical stimulation of the whole-hand using a mesh-glove has been shown to improve volitional movements of the affected hand and arm and to decrease muscle tone after hemispherical stroke in patients who have reached a recovery plateau. The goal of this study was to investigate the effect of stimulation of the nerve afferents of the hand on brain cortical activity elicited by whole-hand subthreshold stimulation for sensation in healthy human subjects.

METHODS: Mesh-Glove: A two-channel stimulator delivers a train of 50 Hz stimuli (pulse with 250 µs, 0.9 mA) to the mesh-glove that has a built-in socket, which connects both anodes of the stimulator. The cathodes of the stimulator are separately connected to a 4 x 3 cm koraya-padded carbon rubber electrodes placed over the dorsal and volar surfaces of the forearm proximal to the wrist. The mesh-glove is made of conductive, flexible wire and is easily slipped over the hand. Before fitting the hand with the mesh-glove a conductive jelly is applied over the whole hand. ❻

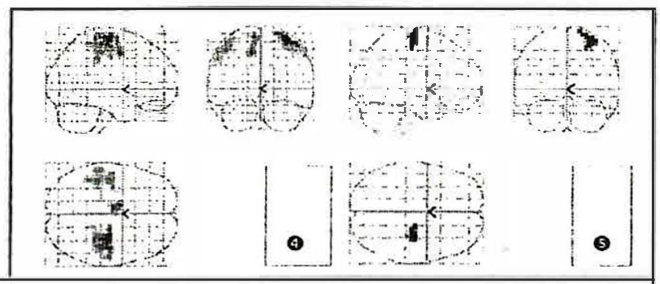


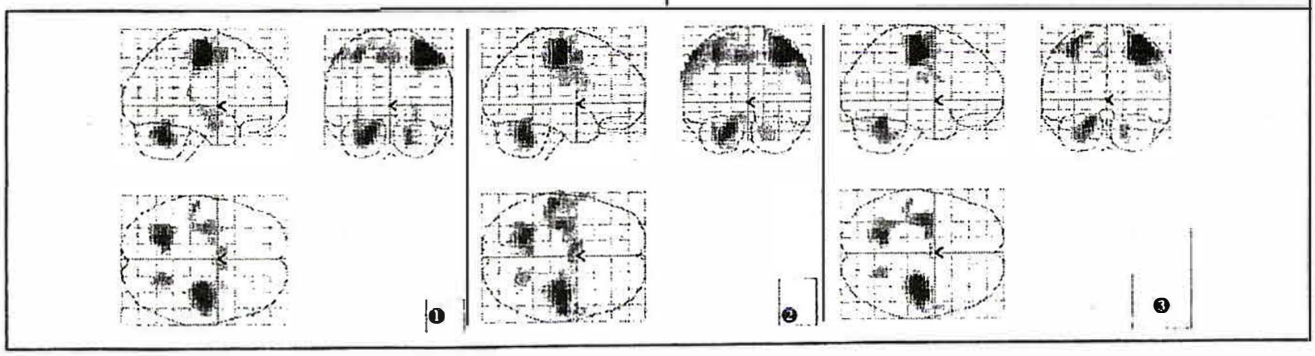
10 healthy subjects were studied using BOLD-fMRI with: 1. a test-motor-task (TMT) with finger-to-thumb-tapping of the left hand, 2. an afferent electrical whole-hand stimulation of the left hand below the sensory level for sensation for 30 minutes , 3. a second fMRI run with the same paradigm as in the test-motor-task immediately after the electrical stimulation (CMT1) and 4. a final identical fMRI run two hours post stimulation to test the cortical changes induced by the electrical stimulation (CMT2). Experiments were performed on a 1.5 T MR-scanner and for fMRI we used echo-planar-sequences. Data analysis was performed with SPM99.

RESULTS: Group-analysis of fMRI-data showed:

Within-group analysis: ❶ statistical significant BOLD-response during TMT contra- and ipsilaterally within SM1, PM and SMA as well as on both cerebellar hemispheres with a dominance of the left hemisphere ipsilateral to the stimulated hand, ❷ statistical significant increase of BOLD-response during CMT1 of the contralateral hemisphere within the M1, S1 and PM and on the ipsilateral hemisphere within M1, S1, PM and SMA, ❸ BOLD-response two hours post stimulation with decrease of brain activation nearly to TMT-level ($p < 0.05$, corrected for multiple comparisons).

Between-group analysis: ❹ CMT1 versus TMT with statistical significant increase of brain activation within contralateral SM1 and PM as well as ipsilateral SM1, PM and SMA, ❺ CMT2 versus TMT with residual BOLD- response two hours post stimulation contralaterally within the M1 ($p < 0.05$, corrected for multiple comparisons).





CONCLUSION: fMRI reflects an increased BOLD-response within the sensorimotor cortex due to subsensory electrical stimulation of the whole hand and thus leading to augmented local-field-potentials as neurophysiological basis of extended motoneuron recruitment. This potential brain modulation effect of intracortical unmasking of motoneuron activity by this special kind of electrical stimulation technique of the hand holds promise for the application of fMRI in the planning of neurorehabilitation strategies in stroke patients.

Contact: Stefan Golaszewski stefan.golaszewski@uibk.ac.at

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