Effect of Amplitude and Amplitude Modulation in vibrotactile stimulation of the foot: a fmri study

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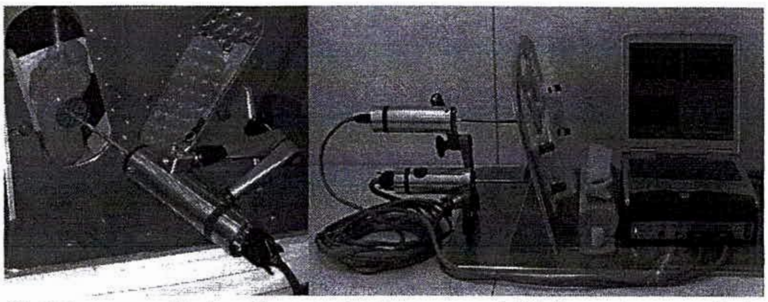
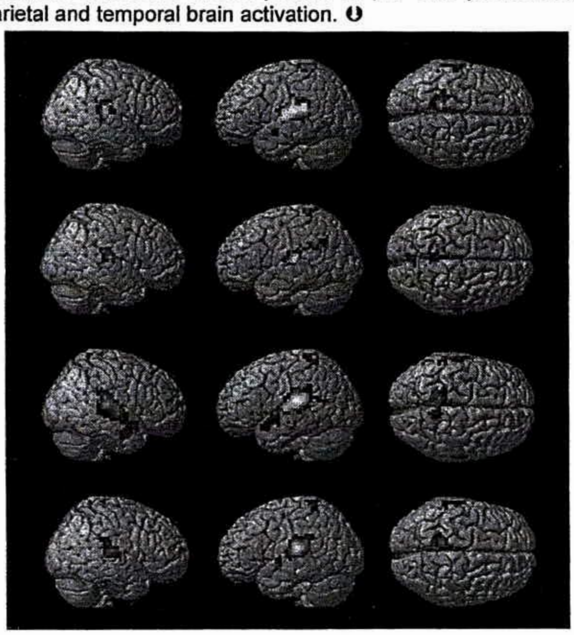
PURPOSE: The aim of the study was to investigate the effect of amplitude and amplitude modulation in vibrotactile stimulation of the foot. Therefore, a proper vibrotactile stimulus was used and the elicited brain activation pattern was analyzed to find best vibration parameters and an optimized experimental protocol for the applicability of the developed paradigm in clinical functional diagnosis of the brain.

METHODS: 16 healthy male subjects (20–45yrs) were stimulated with a vibrotactile stimulus applied onto an area of 20 cm² of the arch of the right foot. The stimulus was delivered through a fully automated moving magnet actuator system. The preload of the stimulus was 0.05 N. To avoid adaptation phenomena we implemented the vibration paradigm in event related design technique, where a series of single event stimuli with stimulus duration of 1 sec within a variable interstimulus interval was applied. One baseline condition (no stimulation) and 4 stimulation conditions were integrated into 2x2 design. The 4 vibration conditions were in detail:

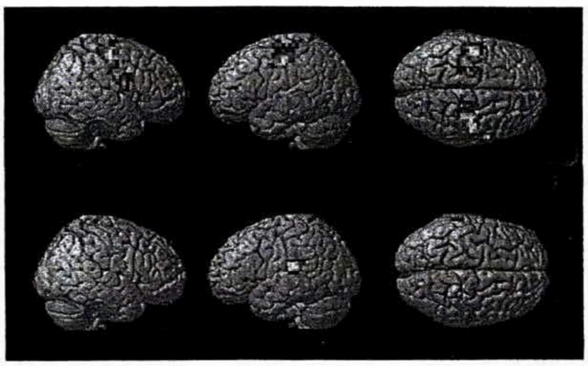


0.4 mm amplitude and a carrier frequency of 50Hz ❶, 0.4 mm amplitude with a carrier frequency of 50 Hz and an amplitude modulation of 25 Hz ❷, 1.6 mm amplitude with a carrier frequency of 50 Hz ❸, 1.6 mm amplitude with a carrier frequency of 50Hz with an amplitude modulation of 25 Hz ❹. The sequence of stimuli was randomized for each subject. Stimulus duration was one second. On average, every seven seconds a stimulus was presented. Experiments were performed on a 1.5 Tesla MR-scanner. For fMRI, we employed T2*-weighted EPI sequences. Post-processing was performed with SPM2. A statistical parametric activation map was calculated for each of the 15 subjects and for the group of subjects (second level analysis) and reported for clusters, which surpassed an initial threshold of $p < 0.005$ uncorrected for multiple comparisons with a corrected p-value of $p < 0.05$ on cluster level.

RESULTS: **Intra-group** results: The results of the four conditions showed a known pattern of pre- and postcentral, parietal and temporal brain activation. ⬇



The **between-group** analysis 0.4 mm versus 1.6 mm amplitude ❺ showed significant differences within or near the pre- and postcentral gyrus bilaterally and the right inferior, medial and middle frontal gyrus. The between group results 1.6 mm versus 0.4 mm amplitude ❻ showed significant differences within or near the inferior parietal lobule, the superior temporal gyrus, the temporal transverse gyrus, the caudate nucleus, the middle cingulate gyrus, the insula and the hippocampus on the left side. The between-group results non-modulation versus modulation and modulation versus non-modulation showed no significant BOLD difference. ⬇



CONCLUSION: In the present study, an fMRI paradigm for vibrotactile stimulation of the foot sole was implemented within the MR environment. Varying stimulation protocols in foot vibration lead to subtle differences within corresponding fMRI maps. We could not confirm an increasing stimulus-response-relationship between vibration amplitude and BOLD response contralateral in SI as reported from Nelson et al. (2004) for thumb vibration. Nevertheless, the increased vibration amplitude from 0.4 mm to 1.6 mm causes BOLD deactivation within sensorimotor areas not involved in foot and gait sensorimotor activity especially bilaterally within the sensorimotor representation of hand and face. Modulation of vibration amplitude with a modulation frequency of 25 Hz did not increase the BOLD response within related sensorimotor areas of the foot. The fMRI results indicate that in neurorehabilitation the vibrotactile stimulus as therapeutic tool should be applied very specifically and targeted, since different vibration parameters elicit different brain responses.

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