Activation of the sensorimotor cortex by vibrotactile stimulation of the foot: An fMRI study

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PURPOSE: The aim of the study was the development of a paradigm for functional magnetic resonance imaging (fMRI) for the investigation of brain activity within the sensorimotor cortical region of the foot sole. Therefore, a proper vibrotactile stimulus was developed and the elicited brain activation pattern was analyzed with regard to the applicability for functional diagnosis for the cortical area for the foot and the long afferent tracts for the foot.

METHODES: 10 healthy male subjects (25–45yrs) were stimulated with a vibrotactile stimulus above the basic joint of digit I of the foot. The stimulus was delivered through a fully automated moving magnet actuator with frequency (0-100Hz) and amplitude (0-4mm) control. To avoid adaptation phenomena a stimulus wave form was formed as the product of a fixed vibration carrier signal and a modulation term which varied sinusoidally. The carrier frequency was held constant at 100 Hz at a fixed modulation frequency of 25Hz and a fixed stimulus intensity of 0.05N throughout the fMRI run.
Experiments were performed on a 1.5Tesla MR-scanner. For fMRI, we employed T2*-weighted single shot echoplanar sequences (TR/TE/α=0,96ms/66ms/90°,matrix=64x64, acquisition time: 2sec, voxel dimension=4x4x4mm). Twenty-four slices parallel to the bicommissural plane were simultaneously acquired. Five stacks of images during vibration off (condition R) were alternated with five stacks of images during vibration on (condition A) up to a total volume of 85 stacks of images. The scan repetition time for the stimulus on/off conditions was 3s. Post-processing was performed offline with SPM99. A statistical parametric activation map was calculated for each of the 10 subjects and for the group of subjects with an uncorrected $p<0.001$ on a cluster level of $k>8$.

RESULTS: FMRI group data of the 10 subjects shows brain activity: 1. bilaterally within the secondary somatosensory cortex located in the inferior parietal lobule, 2. contralaterally to the stimulated side within the primary sensorimotor cortex located in the pre- and postcentral gyrus, 3. bilaterally within the supplementary motor cortex medially lying in the superior frontal gyrus and 4. on the right hemisphere within the anterior cingulate gyrus.

CONCLUSION: In the present study, an fMRI paradigm for vibrotactile stimulation of the foot sole could be developed. The stimulus can be well defined, frequency and amplitude can be controlled. The stimulus with a modulation frequency of 25Hz induces brain activation within the sensorimotor cortex for the right foot within a group of ten healthy volunteers. However, for the application in clinical functional diagnosis, the parameters of the stimulus still need to be optimized to yield a robust activation pattern. The results hold promise for the applicability of the presented vibrotactile stimulus in functional diagnosis of the cortical area for foot and the long afferent tracts. Functional diagnosis of the sensorimotor system in fMRI using the presented vibrotactile stimulus can further help for the understanding of pathological conditions of the sensorimotor system due to microgravity or simulated weightlessness as well as for the development of therapeutic strategies especially for bedrest syndrome or space motion sickness.

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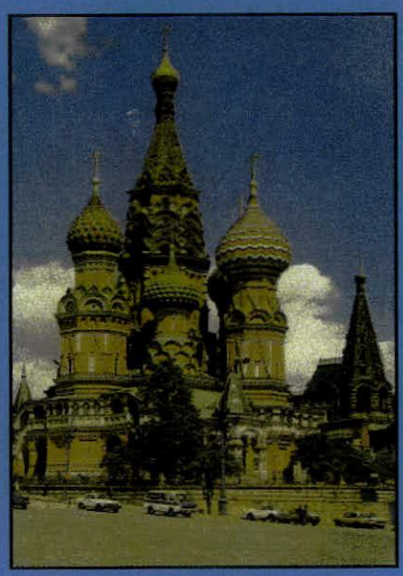
and
Abstracts



THURSDAY, JUNE 10TH

EFFECTS OF GRAVITY ON INTERACTION OF SENSORY SYSTEMS (Chairs, V.R. Edgerton & I. Kozlovskaya)

09:00 Support Afferentation in the Organization of Postural Muscle System
I. Kozlovskaya

09:20 Role of Loading in the Spinal Control of Posture and Locomotion
R. Edgerton

09:40 Gravity Related Organization of the Neural Control of Walking in Human an Nonhuman Primates
G. Courtine

10:00 The Influence of Microgravity on Memorized Arm Movements
F. Gerstenbrand

10:20 Load-Dependent Regulation of Neuromuscular System
Y. Ohira

10:40 Destabilization of Balance Control by Head Movements in Astronaut Testing
W.H. Paloski, N.J. Newby, and E.Y. Hwang

11:00 – 11:15 MORNING BREAK

11:15 The Critical Role of Gravity in Determining Adaptation of the Gain of the Ya and Pitch Angular Vestibulo-Ocular Reflex
S.B. Yakushin, Y. Xiang, T. Raphan, and B. Cohen

11:35 Motor Control and Segmental Stiffness in the Lumbo-Pelvic Region: Ensurin Joint Protection Against Antigravity Forces
C.A. Richardson, J. Hides, and C.J. Snijders

11:55 Velocity of Head Movements and Sensory Motor Adaptations during and afte Short Spaceflight
F. Hlavacka and L.N. Kornilova

FREE PAPERS: NEURO-SENSORY SYSTEMS

12:15 Effects of Vestibular and Support Afferentation Upon Characteristics of Visu Pursuit during Exposure to Microgravity
L.N. Kornilova, Ch. Mueller, V. Temnikova, M. Alekhina, and I. Kozlovskaya

12:25 Sensory Motor Reflex Development in Hypergravity
R. Wubbels, V. Bouet, A. Gramsbergen

12:35 Microgravity Reveals Invariant Temporal Relationships Between Focal and Equilibrium Components of Whole Body Reaching
J. Patron, P.J. Stapley, and T. Pozzo

12:45 Postponed Potentiation as a Facilitation Mechanism of Rat Adaptation to Repeated Hypergravity and Microgravity Effects
I.B. Krasnov

12:55 – 14:30 LUNCH

14:30 A Mathematical Model of the Response of Semicircular Canal and Otolith to Head Rotation under Gravity
V.V. Alexandrov, T.B. Alexandrova, T.G. Astakhova, N.V. Kulikovskaya, V.I. Kurilov, S.S. Migunov, and N.E. Shulenina

14:40 Locomotor System Development in Hypergravity
V. Bouet, J. Ijkema-Paassen, R. Wubbels, and A. Gramsbergen

14:50 GABA and Glutamate Exocytotic Release and Uptake by Rat Brain Synaptosomes under Extremal Conditions
T. Borisova N. Pozdnyakova, N. Krisanova, and N. Himmelreich

15:00 Sensitivity and Growth of Fish Otoliths
A.V. Kondrachuk

15:10 Activation of the Sensorimotor Cortex by Vibrotactile Stimulation of the Foot: An fMRI Study
S.M. Golaszewski, C.M. Siedentopf, F. Koppelstaetter, E. Gallasch, M. Verius, S.R. Felber, D. Zur Nedden, I. Koslovskaya, F. Gerstenbrand

15:20 Can Be Organized an Acoustical Vertical?
J.A. Altman, M.Yu. Agaeva, and I.Yu. Kirillova

15:30 The Mechanisms of Spatial Orientation in Conditions of G Stress
I.V. Bukhtiarov, O.A. Vorobjov, M.N. Khomenko, and I.B. Ushakov

15:40 – 15:55 AFTERNOON BREAK

15:55 Structurally-Functional Shifts in the Ventrolateral Nucleus of the Thalamus of Rats at the Prolonged Hypokinesia, as a Model of Gravitational Pathology
B.A. Nashbullin, A.I. Gozhenko, and S.I. Dolomatov

16:05 Learning with Simulation Only - Artificial Skills
B. Johannes, V.P. Salnitski, K.M. Goeters, P. Maschke, D. Stelling

16:15 Physiological Reactions of Primates to 9-D Immersion and Head-Down Immobilization
V.I. Korolkov, V.P. Krotov, Y.V. gordeev, A.O. OLazarev, V.I. Lobachik, T.E. Burkovskaya, M.A. Dotsenko, G.N. Durnova, A.D. Kaplansky, I.N. Chistyakov, and O.N. Vasilieva

16:25 The Robot and the Satellite for Tele-Operating Echographic Examination
Ph. Arbeille, J. Ayoub, P. Vieyres, M. Porcher, J.L. Boulay, V. Moreau, and G. Poisson

16:35 Contemporary Conception of Anti G Protection of Cosmonauts in Flights Aboard "SOYUZ" Space Vehicles
A.R. Kotovskaya, I.F. Vil Viliams, Y.Yu. Lukjanuk

16:45 Impact of Magnetic Storms and Other Helio-Geophysical Factors on Human's Health, Safety and Reliability of Functioning in Aeronautics and Other Systems of Extreme Risk
A.I. Mikhailov, G.V. Shilov, P.M. Shalimov, Y.I. Gurfinkel, and V.L. Voeikov