LABORATORY 9

Laboratory of Neurobiology of Motor Control

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DIRECTIONS OF ACTIVITY

Laboratory of neurobiology of motor control investigates the mechanisms of control of posture and movements for more then 30 years. At present time the efforts are focused at study of system of internal representation and its role in motor control and at the investigations of reference systems used by brain for organization of motor behavior. During last years it was shown that in situations with discrepancy between real and perceived position of body segments many motor reactions such as vestibulo-motor and neck influences on leg muscles or oculomotor reactions are determined not by real body configuration but by its description in the system of the internal representation.

In the activity of laboratory the studies of neural mechanisms of locomotion in cat traditionally took an important place. Now we begin to study stepping automatisms in humans. These studies continuing the works of this scientific school successfully advance.

Manned spacefights open a possibility for studying how the human central nervous system adapts to the microgravity, to what extent the gravitation is essential for processing of proprioceptive information and for motor control. A series of joint research projects with France, ESA and NASA was accomplished in this direction during 1982-2003 under conditions of real spaceflights.

MAIN RESULTS

During 2003 we continued the studies of the role of human motor cortex in the control of posture and movements using the method of transcranial magnetic stimulation. In these studies we compared the EMG-responses of leg muscles on stimulation of motor cortex during usual standing and during standing on unstable support – rocking platform in form of sea-saw. It was shown that the instability of support, making the task of equilibrium maintenance more complex, enhances the muscular responses on transcranial magnetic stimulation. At the same time the measurements of

H-reflex demonstrated that instability of support does not provoke the increase of excitability of spinal motoneurons. This observation permits to make a conclusion about the increase of the role of motor cortex in more complex equilibrium tasks requiring the change in control strategy. In other kind of experiments we studied the role of motor cortex in anticipatory postural reaction in bimanual motor task. In this task the subject maintained the load by one arm, then the arm was unloaded by subject himself or by experimenter. The comparison of EMG-responses of arm muscles under conditions of active and passive unloading has shown that the realization of anticipatory postural reactions (anticipatory postural adjustment) probably did not demand the additional mobilization of cortical structures.

Analyzing the interrelations of perception constancy and the system of internal representation we studied the intrinsic rules used by central nervous system in elaboration of reference system for collection and interpretation of incoming information from visual and proprioceptive sources. In these experiments we recorded the horizontal eye movements and torque of trunk muscles during torsions around the vertical axis in different spine segments. It was shown that muscular torques did markedly increase with the decrease of rotation frequency, whereas the torques of passive elastic and viscous forces should increase with the enhancement of angular speed. The enhancement of tonus of axial muscles at low speeds is related with the increase of subjective estimations of amplitude of rotation and, accordingly of amplitude of eye movement at decreasing rotation velocities. Thus, the responses of trunk muscles on spine torsion are determined by the changes of internal representation of body configuration, and not by direct proprioceptive inputs. These experiments clearly demonstrate the connection between higher and lower levels of motor control system. It is confirmed that the anticipatory eye movements in response to axial torsion of a spine are also determined by changes in internal representation of body configuration. Such anticipatory orientational movements probably help in elaboration of stable reference system necessary for programming and realization of motions.

Physiological mechanisms of visual stabilization of vertical posture were investigated by means of evaluation of parameters of quite standing and postural reaction on vibratory stimulation of muscular proprioceptors under different condition of visual control: with eyes open and eyes closed and in prismatic glasses. Experiments permitted to make a conclusion about double function of vision in postural regulation – as a basis for elaboration of spatial reference system and as an afferent source for information about the movement of own body relative to this system.

We performed the studies of role of different sources of sensory information in elaboration of the representation of vertical. For this purpose we compared the perception, memorizing and reproduction of orientational visual information in ground conditions while introducing the discordance between the information about the head and trunk position and gravitation (on tilting chair) and under conditions of prolonged orbital spaceflight. Experiments were conducted on 6 cosmonauts in weightlessness in fixed position and during free floating and on 13 subjects on Earth. It was shown that under ground conditions CNS uses multimodal reference system based both on the proprioceptive and gravitational information. During prolong staying in weightlessness CNS elaborates reference system that takes into account the absence of gravity.

The motion in space requires from human the capacity to form mental representation of environment. This internal representation about passed trajectory appears on the basis of integration of visual, vestibular and proprioceptive information. It is known that in ground conditions left and right turns are perceived similarly, whereas

pronounced asymmetry exists in perception of upward and downward turns – downward turns are perceived as being larger. For elucidation of the role of gravitation in this asymmetry we analyzed data of experimental studies perform at International Space Station under conditions of weightlessness. Was studied the passing by subject of 3-D virtual labyrinth and reproduction of passed trajectory by memory. Preliminary data demonstrate the decrease of the asymmetry of perception in weightlessness. So it could be concluded that at the Earth gravitation plays an important role in the elaboration of multimodal reference systems, however in the weightlessness the visual system prevails and if the vision is excluded CNS uses reference system anchored tj the natural axes of the human body. Spaceflight also gives rise to the changes of the EEG pattern of the cortical activity while performing such tasks.

Were continued the investigations of the neurophysiological mechanisms of evoking of locomotion and of locomotory control; we studied the nature of stepping automatism in healthy humans and peripheral influences on stepping movements under conditions of voluntary and evoked walking. The main problem is connected with the search for methods of activation and control of stepping by means of some peripheral and central influences.

We began studies of dynamic characteristics of movements in patients with endoprosthesis of hip joint using podometry, EMG and stabilography. The method of evaluation of the state of human motor system by parameters of changes of support reactions during simple movement – standing-up from the chair – was developed. Method is used for the evaluation of the effectiveness of rehabilitation in patients with motor disorders.

Within the framework of cooperation with laboratory of motor systems of neurological of clinic of the Bern university and laboratory of neurophysiology of hearing and motor control of Institute of physiology of Frieburg university was studied the coordination of two hands in monkey in motor task which required the coordination of essentially differing movements of right and left hand. It was shown the aim of control system consists in providing of synchronization of reaching the movement targets for both hands.

With the purpose of finding-out, how the accuracy of internal representation of lengths of body parts varies during maturing of motor system, we measured the accuracy of the indication of characteristic points of a forelimb (elbow, wrist and end of middle finger) without the visual control in adults and children (4-11 years). We recorded the initial error of indication and dynamics of its increase with time. The considerable differences of accuracy of internal model of the forelimb with age were revealed. In children the apparent shortening of a limb occurs, and both the hand and forearm are shortened. In adults underestimation of forearm length is much less pronounced that in children. It was shown that the effectiveness of utilization of visual information for correction of internal representation of arm position in children before 6-7 years of age is much less that in senior children and in adults.

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