IAF/IAA-94-G.1.127

688

JERUSALEM ISRAEL
1994

RESULTS OF SENSORIMOTOR STUDIES PERFORMED ON BOARD OF "MIR" STATION.

I.Kozlovskaya*, F.Gerstenbrand** , M.Berger, B.Babayev, M.Borisov, N. Burlachkova, A.Sokolov.
Institute of Biomedical Problems, Moscow, Russia.
Clinic of Neurology, University of Innsbruck, Innsbruck, Austria.

Abstract.

Temporal, kinematic and accuracy characteristics of voluntary movements, that differed by the effector performing the tasks - eye, head and arm, by sensory guidance - acoustic, visual and proprioceptive ones as well as by their organization - pointing or tracking the line (or the triangle) have been studied in the 3 cosmonauts before, during and after short (7 days) and long term (132 and 175 days) space flights. Results of studies revealed in weightlessness the following alterations of motor control characteritsics: i) a diminished efficiency of programming mechanisms, showed up by a significant decrease of lvelocities and a significant increase of latencies and durations of all pointing movements under study along with the increase of numbers and amplitudts of errors; ii) a decreased abilities to reproduce precisely dimensions and spatial orientation of memorized patterns, demonstrated by the persistent increase of values of size errors and spatial shift of the memorized figure's vector; iii) an increased dependence of spatial orientation of movements on positions of the head revealed by shift in the orientation of the memorized line when the head was bent to the shoulder. All these changes were especially prominent and stable when before the "reproducing" the movements were trained without visual guidance. The results of studies defining the characterictics features of disorders of motor control in microgravity allow to link them to proprioceptive deficiency that develops in its turn, as a result of withdrawal of the weightbearing afferentation.

1. Introduction.

It is well known that exposures to real or simulated weightlessness even of short durations result in development of pronounced sensorimotor disturbances (1, 2, 3). Decline in equilibrium control (4, 5, 6), changes in kinematic and biomechanical structure of locomotion (7), decrease in voluntary movements accuracy (8,9) have been recorded after short- and longterm space flights and analysed in part in simulations studies. Altering deeply activities of basic proprioceptive systems, in the first place vestibular and weight-bearing ones, weightlessness evokes a broad scope of changes in motor control mechanisms (MC) such as reorientation of MC systems to the other more reliable sensori inputs (vision), alterations in tactics and coordination structures of voluntary movements and postural synergies.

These changes being adaptive in their nature cause the development of secondary symptoms which taken together form the "hypogravitational ataxia" syndrome that can affect deeply the motor abilities of cosmonauts during and even more after the short and longterm space flights.

It is obvious that results of pre- and post-flight investigations as well as simulation studies though adding considerable to our understanding of microgravity effects don't reproduce them to a full extent. Changes that are noted during post-flight observation can reflect not only the residual traces of weightlessness effects byt also nonadequate responses of mechanisms under study to gravitational load. At the same time in simulation studies not all of the microgravity factors are usually reproduced. This brings a special importance to providing in addition the onboard studies results of which though being restricted to a small number of observations allow to validate all the data obtained in onground conditions.

Having all said above in mind the experiment "Monimir" was developed aimed in particular to study quatitatively in short and long duration space flights characteristics of preprogrammed and tracking voluntary movements performed by different effectors (eye, head and arm) and triggered by stimuli of different modalities (visual, acoustic, proprioceptive).

Table 1.
Time-table of "Monimir" performance in short - and long-term space flights.

cosmonaut N	flight duration (days)	exper. performance before	flight	after
1. F.V.	7	-21, -15, -7	2 & 5 days	+1, +4
2. A.A.V.	175	-19, -10	26. 57, 73, 87, 95, 122, 137, 144, 154 days	+2, +4
3. A.S.V.	132	-18, -12	27, 60, 72, 105 days	+1, +4

2. Material and methods.

The experiment "Monimir" has been performed on board of space station "MIR" by 3 cosmonauts. in short - 7 days and long - 175 and 132 days term flights. The schedule of the experiments is presented in the Table 1.

It is seen that in every case at least two experimental sessions preceeded and followed studies performed on board the station. The member of the last differed in every flight but the stages of the flight in the long term missions when the experiments performed were similar namely, by the end of the 1st, 2nd and the 3d months. Before the control studies the cosmonauts were familized with the set up and methods used in the experiment in 5-6 additional training sessions. During every experimental sessions the cosmonauts performed a battery of motor tasks that included: i) pointing (preprogrammed) and tracking movements of the eye, arm and head toward acoustic and visual targets that were located at the horizontal and vertical axises at 4 and 16 angular degrees up and down, to the right and to the left of the center of vision. Examples of pointing movements executed in this tasks are demonstrated in Fig.1.

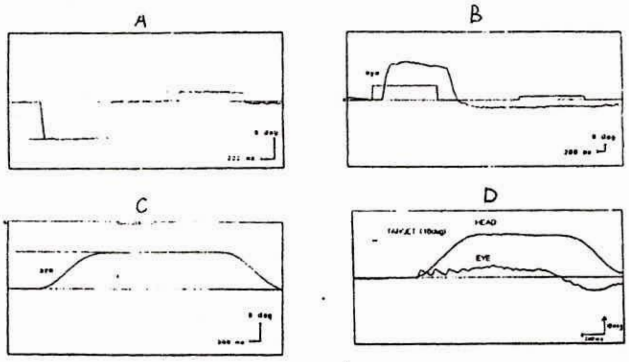


Figure 1. Examples of eye, head and arm movements executed by cosmonauts during "Monimir" performance on board of "MIR" station.
A- eye saccade toward visual target;
B- eye saccade toward acoustic target;
C- arm movement toward visual target;
D- head movement toward acoustic target.

ii) movements of the arm and head reproducing the triangle patterns or line that were memorized during 5 preliminary made active (voluntary) or passive (led by experimentator) movements. iii) the knee tendon reflexes , elicited by tapping the knee tendon with the 3 different forces, namely, the minimal, medial and maximal ones. Acoustic stimuli - clicks of 100 ms duration were presented through earphones of the AKG system. To introduce the visual targets LED matrix system was developed. The eye movements were recorded by the conventional EOG method, the movements of the arm and the hear were registered by two infrared matrix videocameras that were located frontally and sagitally of the subject and thus allowed to reconstruct movements in all three dimensions. All the analogous signals that were recorded along with marking stimuli were stored by IBM computer. Kinematic (amplitudes, velocities) , temporal (latencies, duration) and accuracy (number, direction and size of errors) were analysed using software "BSANALYS", developed for this purpose at the Clinic of Neurology of the Innsbruck University.

3. Results.

Exposition to weightlessness did not affect the performance of visually tracking movement: all their characteristics - kinematic and temporal as well as accuracy did not differ considerable from those recorded before the flight.
At the same time execution of preprogrammed pointing movements underwent significant changes. As it is demonstrated in Fig. 2 on the 3d day of space flight amplitudes and velocities of all movements triggered by acoustic stimuli declined and their durations and variability increased.

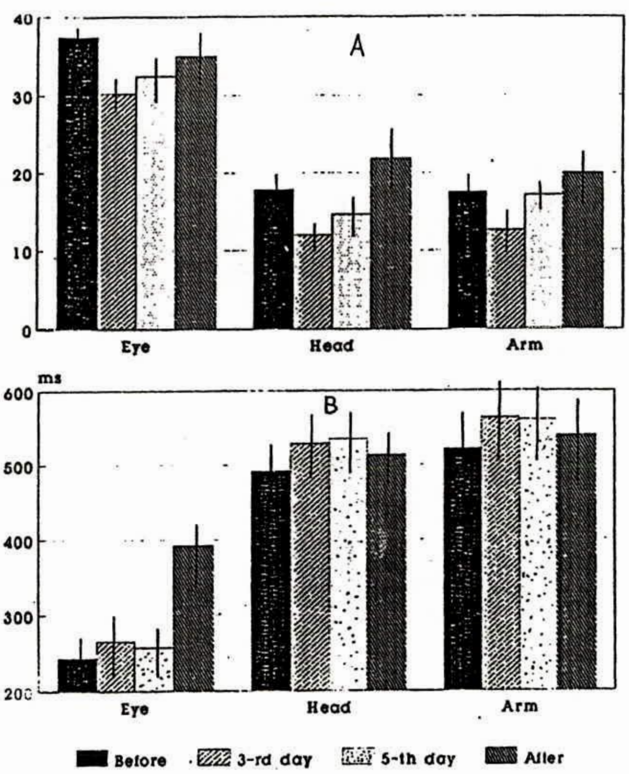


Figure 2. Characteristics of eye, head and arm movements during short-term space flight (7 days). Cosmonaut F.V.
The tendency of slowing down evident in all movements under study including quite slow (cautions!) movements of the arm toward acoustic and visual target (see Fig.3a) and even eye saccade triggered by visual targets (Fig.4) did not show any signs of corrections throughout the 132 and 175 days in weightlessness and disappeared very quickly (almost immediatelly) after return to 1-g (Fig.3 and 4).

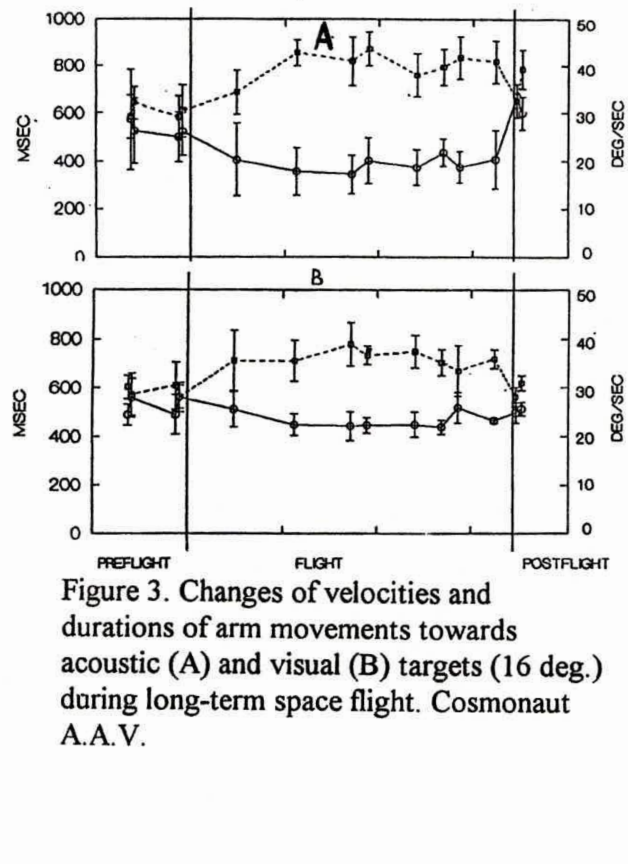


Figure 3. Changes of velocities and durations of arm movements towards acoustic (A) and visual (B) targets (16 deg.) during long-term space flight. Cosmonaut A.A.V.

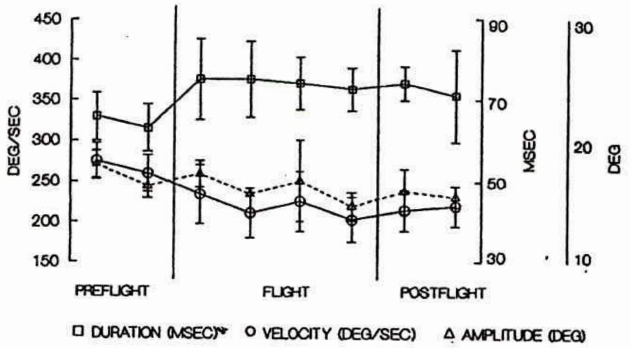


Figure 4. Changes of velocities, durations and amplitudes of saccades toward visual target (16 deg.) during long-term space flight. Cosmonaut A.S.V.

On the contrary to usual interrelations, decrease of movements' velocities was accompanied in 0-g by obvious decrease in their accuracy. As Fig.5 shows, the number of correct movements of the head toward visual target felt down on the 2d day of flight almost to 0 and even with the visual feedback the large part of correction movements (up to 60 %) still were noneffective.
Weightlessness affects greatly also execution of memorized patterns movements especially those learned passively (see Methods). As it is shown in Fig.6 the circumference of the triangles toward 73d day of flight dropped down almost by 30% and stayed low untill cosmonaut returned to 1G. The absent of significant changes in the movement durations when thee length of the decreased pointed out to significant decrease of movements' velocity.

Along with changes in metrics and velocities weightlessness affects greatly abilities of subject to keep constant orientation of figures.

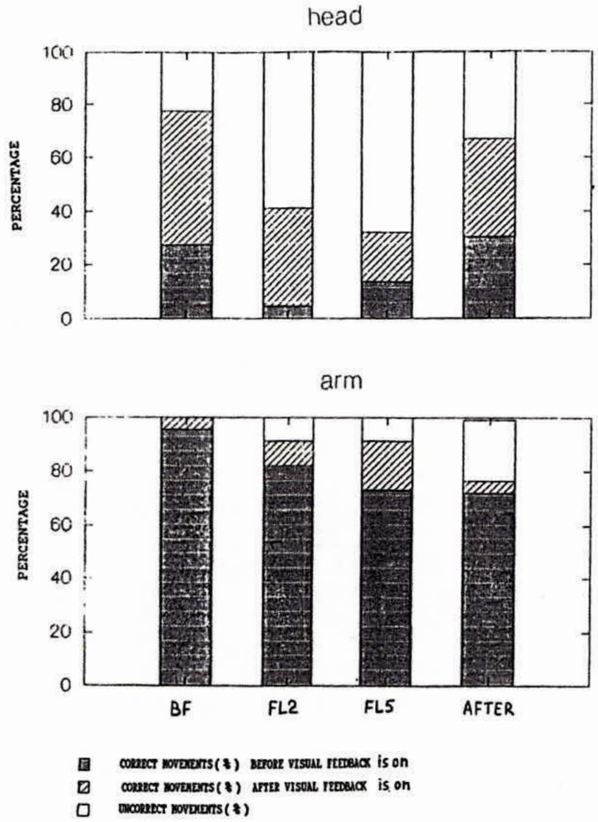


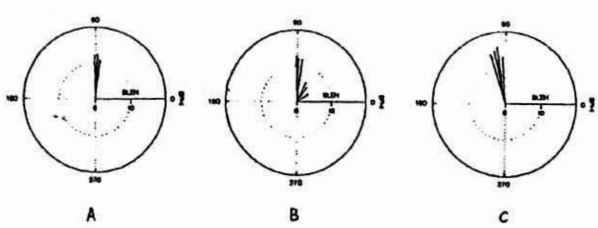
Figure 5. Changes of precision characteristics of head and arm movements toward visual target during short-term space flight. Cosmonaut F.V.

Figure 6. Changes of direction of the patterns vector (triangle) during short-term space flight. Cosmonaut F.V.

A- before

B- in-flight

C- after.



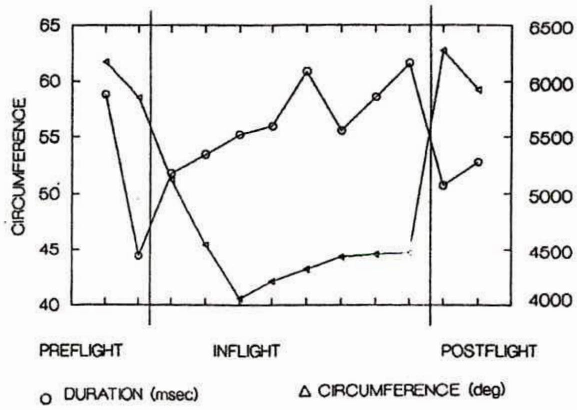


Figure 7. Change of metric of pattern (triangle) during long-term spacee flight. Cosmonaut A.A.V. As Fig.7 shows in weightlessness the vector of triangle - constant before flight slipped in subsequent movementsalmost to a horizontal plane. After return to 1G this shift was immediatelly corrected with slight overshooting. Decrease ability retain movements orientation in space and their bigger dependance on the other that usual is demonstrated by the Fig.8 that summaryzes the results of head inclination on movements orientation. As it is seen, if before the flight changes of head orientation did not have any effects on the direction of horizontal movements, in flight it followed by aligning of movement acts with the "neck-head" axis.

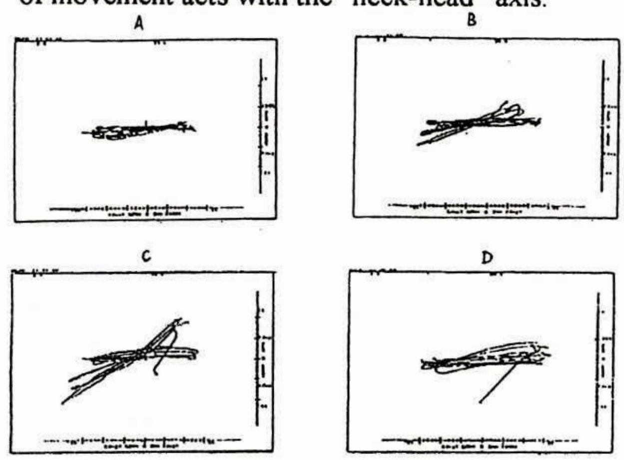


Figure 8. Orientation of horizontal line during "head to shoulder" test.

Cosmonaut F.V.

A- before flight;

B- 2d day of flight;

C- 5th day of flight;

D- after flight.

4. Discussion.

Thus the results of studies of kinematic, temporal and accuracy characteristics of fast and slow tracking movements in short and longterm space flights along with movements patterned and spatially oriented revealed at least 3 groups of alterations in activity of motor control mechanisms that develop consistantly under conditions of microgravity. The first one, namely, the slowing down velocities of presumably preprogrammed pointing movements accompanied by an increase in their latencies and durations along with an enlargement of numbers of noncorrect mostly undershooting movements points out to inability or increase in difficulties of programming movements under microgravity conditions. The absense of specificity of these changes, similarities of the time course of their development in movements performed by any effector (eye, head, arm) triggered by any stimulus modality allow to suggest that they reflect changes in activity of programming mechanisms of MC, an incrreasing difficulties for them to program correctly movements characteristics and as a result rejection of the programming tactics of control in favor of slow but safe approximating tactics. This conclusion is full consistent with the results of "statokinetics" studies performed also on board of "MIR" station that revealed of impossibility in space to perform accurately simple, preprogrammed movements when the visual feedback can not be used (eyes closed). An increase in difficulties of work of preprogramming mechanisms can be in its turn a result of the reduction of proprioceptive inflow caused by a great decline of extensor muscles tone and suppresion of activity of support and otolith afferent input.

Results of studies performed earlier point out to development under all the "supportless"" conditions (space flights, immersion) deep atonia of extensor muscles, that cause in its turn a significant decrease of the activity of the proprioceptive input and appearance subsequently signs of partual deafferentation of motor control system. In particular disturbances of the second and third types, revealed by a decreased ability to reproduce precisely dimension and spatial orientation of memorized movements patterns and an increased dependance of spatial orientation of movements on positions of the head can be considered as a result of this deafferentation both vestibular and proprioceptive that makes orientation system less stable and more to stimuli usually ignored and not participating in defining movements orientation.

5. References.

1. Chkhaidze L.V., 1968. Coordination of voluntary movements of man in spaceflight environment. Nauka, Moscow, p.33.
2. Kakurin L.I., Tcherepahin M.A., Pervushin V.I., 1971. The influence of space flight factors on the muscle tone in man. Kosm. Biol., N2, 63-68. (in Russ.).
3. Kozlovskaya I.B., Aslanova I.F., Grigorieva L.S., Kreidich Yu.V., 1982. Experimental analysis of motor effects of weightlessness. The Physilogist, 25, 49-52.
4. Homick J., Reschke M., Miller E., 1977. The effect of prolonged exposure to weightlessness on postural equilibrium. In: Biomedical Results from Skylab, NASA, SP-377, 104-112.
5. Kozlovskaya I.B., Kreidich Yu.V., Oganov V.S., Kozerenko O.P., 1981. Pathophysiology of motor functions in prolonged manned space flights. Acta astronautica, 8, 1059-1072.
6. Clement J., Gurfinkel V.S., Lestienne F., Lipshits M., Popov K., 1984. Adaptation of

postural control to weightlessness. Exp. Brain Res., 57, 61-72.
7. Chekirda I.F., Yeryomin A.V., 1974. Dynamics of cycle and acycle locomotions in Soyuz-18 crewmembers after 63 day space flight. Kosm. Biol. Med., 4, 9-13 (in Russ.).
8. Kubis J.F., McLaugglin E.L., Jackson J.M., Rusnak R., McBride G., Saxon S., 1977. Task and work performance on Skylab missions 2,3 and 4. In: Biomedical results from Skylab, NASA, SP-377, 136-154.
9. Kozlovskaya I.B., Dmitrieva I.F., Grigorieva L.S., Kirenskaya A.V., 1988. Gravitational mechanisms in the motor system. Studies in real and simulated weightlessness. In: Stance and motion. Eds. Gurfinkel V.S., Massion J., Plenum Press, 38-48.

OCLC WorldCat

Erweiterte Suche | Bibliothekssuche

45th Congress of the International Astronautical Federation Compilation of Papers.

Autor: Congress of the International Astronautical Federation 45, 09-14.10.1994, Jerusalem>; Microgravity Sciences and Processes

Verlag: Jerusalem IAF 1994

Ausgabe/Medienart: Gedrucktes Buch

Details

Dokumenttyp	Buch
Alle Autoren:	Congress of the International Astronautical Federation <45, 1994, Jerusalem>; Microgravity Sciences and Processes
OCLC-Nummer:	1075534581
Beschreibung:	366 S.

https://catalog.hathitrust.org/Record/009446158

45th Congress of the International Astronautical Federation : October 9-14, 1994 Jerusalem, Israel.

Language(s):	English
Published:	Paris, France : International Astronautical Federation, 1994.
Subjects:	Space law > Congresses. Aeronautics > Congresses. Space stations > Congresses. Astronautics > Congresses.
Note:	v. [9] includes ununumbered papers. Includes IAF papers numbered from 94-001 - 94-1100, with omissions in numbering. Title from paper IAF-94-001.
Physical Description:	v. : ill. ; 28 cm.

IAF/IAA-94-G.1.127

JERUSALEM ISRAEL
1994

RESULTS OF SENSORIMOTOR STUDIES PERFORMED ON BOARD OF "MIR" STATION.

Kozlovskaya I.B., Babayev B.M., Borisov M.E., Burlachkova N.I., Sokolov A.I. - Chief and scientific researchers

Gerstenbrand F., Berger M. - Professor and Dozent

45th CONGRESS OF THE INTERNATIONAL ASTRONAUTICAL FEDERATION

October 9-14, 1994 / Jerusalem, Israel