FUNCTIONAL STATE OF THE VESTIBULAR SYSTEM OF MAN KEPT IN A HERMETICALLY SEALED SPACE FOR 120 DAYS

(UDC 613.693:612.886)

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Presented by Academician A. V. Lebedinskii
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 60, No. 11, pp. 3-6, November, 1965
Original article submitted January 18, 1965

The ability to assess the state of the vestibular system in individuals confined within a hermetically sealed chamber of limited size for considerable periods, which is an essential feature of life in cosmic vessels, is of very great practical importance. The various physical factors operative in the course of trials (atmosphere developing in the chamber as a result of man's vital activity, ionizing radiation in small doses, periodic increase of temperature, noise etc.) cannot be classed as adequate physiological stimuli for the vestibular system. Yet numerous investigations have shown that the functional state of this system may be materially affected by inadequate stimuli [2, 3, 4, 5, 7, and others]. At the same time, the type of reaction observed in the present experiments would not appear to have been reported.

METHOD

The investigation was directed mainly to the functioning of the semicircular canals. The examinations were carried out on an electric rotatary apparatus (type BU-2).* The subject's head was fixed at an angle of 30° to the rotational axis of the chair. The functional assessment of the vestibular system was based on determination of threshhold sensitivity for an adequate stimulus and the quantitative relationship prevailing between strength of stimulus and magnitude of response reaction. The adequate stimulus was the negative angular acceleration which developed when the chair, which had been rotating at a prescribed constant angular speed, was stopped. Movement was arrested only after the reaction to the commencement of rotation (sensation of movement and rotatory nystagmus), which was seen during the period of acceleration and for a certain time after a steady rotational speed had been established, had disappeared. The strength of the stimulus was expressed in terms of units of angular speed immediately prior to arrest. Threshold sensitivity was assessed from sensory (feeling of rotation in the opposite direction) and somatic (nystagmus) reactions. The quantitative relationship between strength of stimulus (30 and 60°/sec), and value of vestibular reaction was derived from somatic (nystagmus) and autonomic (blood pressure, pulse and respiration rates, mean rate of spread of pulse wave in arteries of the arm) components. Assessment of nystagmus was based on its duration and the electronystagmograph, recorded with bitemporal electrodes. Graphs were constructed from the results (Egmond method [6]).

The subjects were examined before the experiment, after 2, 3, and 4 months in the hermetically sealed chamber, and 3, 8, 18 and 33 days after leaving. The observations were made on 5 subjects between the ages of 19 and 32 years, who were thoroughly examined clinically and physiologically beforehand, and were pronounced suitable for the experiment.

RESULTS

Nystagmus thresholds indicated that all the subjects had normal degrees of vestibular sensitivity. I_4 and M_5 had very high sensory reaction thresholds (Table 1). The steepness of the reaction curves [8] indicated that I_4 had a vestibular system which reacted slowly, whereas reactivity was high in M_5 and G_{r_3} (Table 3).

* This investigation was one of a series, the results of which were reported to the 15th International Astronautical Congress by A. V. Lebedinskii, Yu. G. Nefedov and S. V. Levinskii.

TABLE 1. Threshold Sensitivities of Vestibular System in Terms of Sense of Counter-Rotation (CR) and Nystagmus (°/sec) (Nyst)

Subject	Test	Initial values	Month of expt. 2nd	3rd	4th before emerging	Days after experiment 1st	3rd	8th	18th	33rd
B_1	CR	2	3	3	2	2	2	—	3	4
	Nyst	5	4	6	4,5	4,5	4,5	—	6	4
G_2	CR	7	7	5	8	—	15	20	15	10
	Nyst	7	6	5	8	—	9	8	9	6
Gr_2	CR	5	10	5	5	—	15	30	15	10
	Nyst	8	7	6	6	—	7	6	8	6
I_4	CR	30	30	30	30	—	60	60	60	30
	Nyst	5	5	4	—	—	6	7	7	6
M_5	CR	30	60	—	—	—	—	—	—	—
	Nyst	9	10	9	7	6	9	10	12	—

TABLE 2. Quantitative Relationship between Duration of Nystagmus and Strength of Adequate Stimulation

Subject	Stop stimulus (°/sec)	Duration of nystagmus (sec): Initial value	during expt. 2nd month	3rd month	4th month before emerg.	days after experiment 1st	3rd	8th	18th	33rd
B_1	30	31	28	33	23	22	18	—	29	27
	60	40	38	41	33	34	29	—	41	38
G_2	30	18	20	16	14	—	12	17	16	17
	60	27	27	24	20	—	18	27	25	27
Gr_3	30	29	24	27	23	—	27	17	27	25
	60	41	38	37	34	—	40	26	42	40
I_4	30	14	15	10	—	—	5	15	9	11
	60	20	19	15	—	—	9	20	15	18
M_5	30	25	20	19	21	18	19	22	16	—
	60	37	31	29	30	28	28	30	26	—

The examinations made in the course of the experiment produced no evidence, in terms of either sensory or somatic reactions, of change in the threshold sensitivity of the vestibular system (see Table 1). The relationship between strength of stimulus and nystagmus reaction remained normal during this period in all subjects. There were, however, some changes in duration of reaction and the slopes of the curves. These were first noted in the second month of confinement in subjects B_1, Gr_3 and M_5 and in the third month in G_2 and I_4. Towards the end of the experiment the duration of nystagmus was reduced, with parallel reduction in the steepness of the curve, in all the subjects (see Tables 2 and 3).

After the experiment G_2, Gr_3 and I_4 experienced increased sensations of counterrotation. No such sensation was produced by rotation speeds exceeding 60°/sec in M_5, and his nystagmus threshold was also higher. These changes were seen on the third day after the experiment and persisted throughout the period of observation (see Table 1). While the nystagmus threshold remained practically unchanged (except in M_5), its duration and the angle of inclination of the curves were obviously different during this period from the initial duration and slope in all the subjects although stimulus/reaction relationships were normal (see Tables 2 and 3). Both duration and slope were reduced. There was no evidence of any connection between the degree of change in these parameters and the initial reactivity of the vestibular system. Individual differences became evident later. Reactivity tended to fluctuate above and below its original level in subjects B_1, Gr_3 and I_4, remained persistently low in M_5, and returned gradually to its original level in G_2. In the other subjects duration of nystagmus and slope of curve were found to be normal again on the 33rd day. Autonomic vestibular reactions remained virtually unchanged throughout the period of observation (B. I. Polyakov).

TABLE 3. Changes in Tangent of Angle of Inclination of Nystagmus Curve (in absolute values)

Subject	Stop stimulus °/sec	During expt.			Days after expt.				
		2nd month	3rd month	4th month before emerging	1st	3rd	8th	18th	33rd
B_1	16	14	18	13	13	12	—	17	15
G_2	12	11,5	10	9	—	9	13	12,5	13
Gr_3	20	17	16	15	—	18	11	21	20
I_4	9	8	6	—	—	4	10	6	8
M	20	17	16	14	14	15	17	16	—

There was, therefore, evidence of certain vestibular changes in these subjects. There were definite changes in the slope of the nystagmus curves and in the duration of nystagmus while the subjects were in the hermetically sealed chamber and for 120 days afterwards. The changes were most marked in subjects with the steepest curves initially, but it was impossible to demonstrate any definite relationship between slope of nystagmus curve and threshold value. The fact that the changes in the nystagmogram seen towards the end of the experiment were similar in all the subjects suggests that the conditions affecting the subjects while in the chamber had a definite influence on the functional state of the vestibular system, resulting in change in the slope of the nystagmogram and in the duration of nystagmus. As the conditions of this experiment did not in fact provide any adequate form of vestibular stimulation (apart from a limited amount of motor activity), it is extremely unlikely that these changes in nystagmus could have been the result of changes produced in the receptor apparatus. This is confirmed to some extent by the absence of change in the threshold for somatic reaction. The changes in inclination of nystagmus curves and in the duration of nystagmus would appear to have been determined mainly by functional changes in the cerebral cortex.

The raising of thresholds for the sensory component and the fluctuations in duration of nystagmus and angle of inclination of the vestibulogram, observed after the period in the chamber, were probably connected with some process of re-adaptation, determined by the altered mode of life and operation of different physical factors. The important point is that these changes in vestibular function had no obvious effect on the subject's normal activities.

SUMMARY

Estimation was made of the threshold sensitivity and reactivity (cupulometry) of the vestibular analyzer in persons who had stayed in a hermetically sealed chamber during 120 days. It was found that under these conditions functional changes occurred in the main in the central part of the analyzer and were manifested by a decrease in its reactivity.

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