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Preparation, actuation, and goals of future space missions emphasize the significance of research into human responses, particularly of the auditory analysor, to prolonged exposure to an altered gas environment.

Various authors cite the high threshold of the auditory analysor to acute hypoxia and to a CO_2 rich atmosphere (C. G. Kulikovskiy, 1939; A. P. Popov, 1938; I. Ya. Borshchevskiy, 1958). Popov in 1938 found that auditory acuity is little altered during a brief exposure to an 8-10% O_2 atmosphere; only a slight tendency to decline is observed. Nor was a decrement in auditory acuity observed in subjects breathing for several minutes a gas mixture with low O_2 concentrations (to 12%), though in a number of experiments an elevation in threshold sensitivity to high frequencies was observed.

During acute hypoxia, loss of auditory acuity occurs only at the onset of unconsciousness, a fact which is of practical significance to aviators and cosmonauts. The data presented indicate that during acute hypoxia, the central and cortical portions of the auditory analysor play an important role in the mechanism that may lead to hearing impairment. These central and cortical portions are most sensitive to O_2 deficiency.

The ever increasing duration of space missions has presented researchers with the task of studying a given organism's ability to adapt to continuous, prolonged (several days) exposure to a group of factors including artificial, cabin atmospheres. Some authors consider changing the percent concentration of cabin atmosphere for prolonged missions to present several advantages. Replacing the atmospheric nitrogen with helium can eliminate the harmful effects of incident radiation, decrease the lift-off payload

*Translator's note: According to Pavlov.

of the spacecraft, etc. (A. G. Dianov, A. G. Kuznetsov, 1963). The opinion has been expressed that surplus CO_2 in a cabin atmosphere could be used for regeneration of oxygen through photosynthesis, to prevent hypocapnia, and to minimize cosmic radiation injury (S. G. Zharov, et al., 1963).

In spite of its practical importance, the question of the impact on man's hearing by factors associated with the artificial atmosphere in the space capsule has been little studied, thus necessitating special experimentation.

Studies of the auditory function were performed with 25 to 30 days permanence in an artificial atmosphere. Three series of experiments were conducted in all. In each experiment, the auditory thresholds were determined relative to atmospheric conductivity at frequencies of 125, 250, 500, 1000, 3000, 4000, 6000, and 8000 cps as well as reverse adaptation times to 1000 cps after three-minute presentation of white noise at 90 decibels.

All necessary measures were taken in simulating the conditions for a prolonged stay within a small, closed ecologic system.

In the first series of experiments involving several days' exposure to reduced barometric pressure (380 mm Hg) and normal pO_2 (150 to 160 mm Hg), auditory acuity was characterized by a certain instability (A. G. Kuznetsov, N. A. Agadzhanyan, 1963). The highest values for the auditory threshold were recorded during the first half of the experiment. Thereafter, with a constant, somewhat scattered distribution of auditory threshold sensitivities, a tendency toward relative increase thereof was observed in all test subjects. In evaluating the findings by employing the method of least squares (Ye. S. Venttsel', 1950), the general tendency in the alteration of hearing graphically approximates a straight line gradually approaching the abscissa. The adaptation time recorded on various days of the experiment fluctuated between 45 and 70 to 110 and 150 seconds. This test is extremely labile; no specific tendencies have been established. In silence, the auditory threshold at the end of prolonged exposure does not differ significantly from the initial threshold. Consequently, prolonged exposure under reduced barometric pressure with normal PO_2 does not significantly effect auditory function.

In the second series of experiments, the test subjects were placed for 30 days in an atmosphere containing from one to 2% CO_2 (S. G. Zharov, et al., 1963). No pronounced changes were noted in the auditory threshold nor in the time of reverse adaptation. However, there was a tendency for the auditory threshold to become considerably elevated in the first six days of this experiment. Thus, on the first day of the experiment, the auditory threshold was 15-17 decibels higher than on the 21-22nd days of the experiment. No auditory fatigue was evidenced in the test subjects at the end of the experiment. Thus, 30 days exposure to an atmosphere containing one to 2% CO_2 did not affect the auditory analysor.

The third series of experiments consisted of the study of auditory function during a 25 day exposure to a helium and oxygen atmosphere. Extreme elevation of the auditory threshold was in continuous evidence during transition from normal atmosphere to the helium and oxygen mixture. Auditory threshold fluctuation on various days during the experiment did not exceed the physiologic norm. Adaptation time was altered falling between 40-180 seconds. At the experiment's end the auditory threshold in silence was practically equal to the baseline threshold. Thus, exposure to a helium-oxygen mixture may be assumed to exert no specific influence on the auditory analysor.

Elevation of the auditory threshold during the first days of prolonged experimentation may be viewed as a primary compensatory response of the auditory analysor to new stimuli. The abrupt transition from a normal to a helium-oxygen atmosphere is accompanied by transformation of a great deal of earlier conditioning. Such conditions confront the organism and especially the higher echelons of the CNS and analysors with new demands eliciting corresponding compensatory responses which are often nonspecific in nature. Thus, the most diverse atmospheric factors in our experiments (reduced barometric pressure, increased CO_2 content, supplanting atmospheric nitrogen with helium) elicited a typified response from the auditory analysor. The stabilization of the auditory threshold observed in all the experiments performed in the second and third week indicates to us a successful adaptation to new conditions.

Notably, however, this stabilization of the auditory function was observed only when stimuli which elicited no significant deleterious effect were at play. Relative sensitization of the hearing observed during the second half of the prolonged experimentation is of extreme interest. The mechanism of such phenomena observed through dynamic audiometry of subjects remaining for prolonged periods in the confines of a small, sealed cabin can only be postulated. It is hardly conceivable that the elevated excitability of the central portions of the auditory system, which lie at the basis of the observed sensitization, is the result of intensified stimulatory processes in the cerebral cortex. S. G. Zharov and V. A. Il'in showed in 1963, that during prolonged exposure to hypobaric pressure and increased CO_2, the EEG alpha rhythm is inhibited, undergoing a decrement in amplitude; diffuse slow waves appear. These symptoms are linked to intensified manifestations of inhibition within the cerebral cortex.

Cortical inhibition triggers stimulation [release of inhibition] of the subcortical centers. The increased auditory sensitivity in the second half of the prolonged experiments may be assumed to be linked to adaptational, trophic influence on the auditory centers. However, these questions require special elaboration. Many authors (G. V. Gershuni, 1959; A. V. Antropov, 1959; A. I. Vozhzhova, I. A. Sapov, 1961; L. S. Khachatur'yants, 1963 et al.) consider that changes in the time required for reverse adaptation hinge largely on the central portion of the auditory analysor. Therefore, intensification of cortical inhibition in the second half of the experiments apparently elicits prolongation of the time required for reverse adaptation.

Several hours exposure to an atmosphere containing 3-4% CO_2 produces auditory threshold elevation by 20-25 decibels throughout the range of frequencies employed in the experimentation.

Our experimentation showed that a comparative evaluation of the auditory analysor response during prolonged exposure to the described spaceflight factors facilitates derivation of a range of auditory threshold fluctuation. This bears witness to an adaptation response or to the accumulative compounding of harmful stimuli. Thus, with auditory threshold fluctuation of less than 10-15 decibels, adaptation to new conditions is possible. Elevating auditory threshold sensitivity by more than 20 to 25 decibels reflects fatigue of the adaptational mechanisms as well as of the auditory analysor. As a rule changes within the auditory system are reflected in data involving physiological and autonomic indices.

The findings speak highly of the auditory system's tolerance of changes in gas environment, and they may be used to derive variations in the hygiene parameters of space cabin habitation.

Summary

Studies have been made of man's response to reduced barometric pressure (308 mm Hg) with normal pO_2, to 2% CO_2 air, and to a helium and oxygen atmosphere. Dynamic audiometry and studies of the time required for reverse auditory adaptation revealed no tendencies for deviation beyond the physiologic norm. Notably, the auditory analysor displays great tolerance to space cabin atmospheres.