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PAPERS ON THE PSYCHOPHYSIOLOGY OF LABOR OF ASTRONAUTS
(COLLECTION OF ARTICLES)

FOREIGN TECHNOLOGY DIVISION

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OCHERKI PSIKHOFIZIOLOGII TRUDA KOSMONAVTOV

Pod redaktsiye N. N. Gurovskigo

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ABSTRACT

A rational regime of work and rest should be constructed on the basis of a consideration of the functional indices. There should also be considered the specific character of the work and the factors affecting the state of the organism of the astronaut (emotional stress isolation from the external work, scantiness of sensory sensations (sensory deprivation) little motor activity, increase attention concentration, the unusual-null-gravity state and others).

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47-SUBJECT AREA 22, 06		

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ABSTRACT

This paper covers isolation and sensory deprivation (SD), the general characteristics of the experiments, the effect of SD on the human organism, the psychophysiological mechanisms of shifts during SD, and the prophylaxis of the influence of SD on the human organism. The conclusion of the monograph is that the problem of the influence of isolation and sensory deprivation on the human organism is very serious. In prolonged space flight the negative sides of the study of man or a group of people in a closed space with small volume can appear to a certain degree and further study of the problem and the development of a whole system of measures and procedures, which prevent the development of undesirable shifts in the organism, are necessory.

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TOPIC TAGS	astronaut, muscle physiology, isolation, sensory deprivation, space flight, visual activity
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47-SUBJECT AREA	06, 22
42-AUTHOR/CO-AUTHORS	KOSMOLINSKIY, F. P.
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ABSTRACT

The problem of man's adaptation to the conditions of prolonged space flight includes questions of the interrelations of the afferent systems of the organism with the modified and customary environment in which he is living.

The adaptation of the organism to the changing conditions of life includes not only energy equilibrium, but also equilibrium between incoming and outgoing information. Hence the conclusion is drawn that any essential disturbance of the regime of incoming information can lead to serious functional disturbances in the organism.

Further study is necessary of the changes of the functional state of the organism under the influence of information overload and sensory deprivation, and also during their alternate effect. Also necessary is the search for new methodical procedures in the investigation, the creation of models of states of sensory overloads, and also the alternation of influences or the organism of loads of different signs is under natural conditions as well as under conditions of simulation of prolonged space flights.

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TT8501720		blood pressure, central nervous system, illumination optics, life support system, pulse rate

TITLE PRINCIPLES AND METHODS OF INVESTIGATING OF THE PROBLEM OF THE SPATIAL DAY

SUBJECT AREA 06, 22

AUTHOR/CO-AUTHORS	DATE OF INFO
ALYAKRINSKIY, B. S.	-----67

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ABSTRACT The problem of the spatial day and the development of means of the artificial stimulation of the process of man's adaptation to unusual (for him) conditions of work and rest should anticipate the following:

1. Study of the effectiveness of pharacological agents strengthening both the inhibitory and stimulating processes in the highest sections of the central nervous system and thereby facilitating man's coping with a new diurnal rhythms.
2. Investigation of the influence of impoverished and modified afferentation on the speed of man's becoming involved in a new diurnal rhythm.
3. Study of the influence of artificial muscular weakening and the voluntary turning off of psychic activity on the speed of normalization of sleep.
4. Development of methodical procedures and their use for studying the individual peculiarities of man's adaptation to artificial diurnal rhythms.

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42-AUTHOR/CO-AUTHORS	10-DATE OF INFO
GUROVSKIY, N. N.	-----67

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ABSTRACT

All possible conditions and situations of prolonged space flight must be analyzed beforehand. They must be provided for in a regime of work and rest to be used during the actual prolonged space flight.

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- **09-TITLE:** THE PHYSIOLOGICAL BASIS OF HUMAN ADAPTATION TO SPECIFIC CONDITIONS OF ACTIVITY
- **47-SUBJECT AREA:** 22, 06
- **42-AUTHOR[illegible]:** KOSILOV, S. A.; 16-DUSHKOV, B. A.
- **10-DATE OF INFO:** -----67
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ABSTRACT

In developing a regime of work and training for the astronaut preparing him for prolonged flights, it is necessary to consider that the regular transitions of various states of efficiency, the beneficial influence of rest and the resumption of work of former intensity are connected with a stable, reliable system of reflexes - the working dynamic stereotype and its most important component - the integral form of work action.

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09-TITLE INFLUENCE OF VARIOUS CONDITIONS OF WORK AND REST ON THE FUNCTIONAL STATE OF MAN DURING A PROLONGED STAY IN A PRESSURIZED CHAMBER

39-TOPIC TAGS bodily fatigue, cabin pressurization, human sense, human memory, life support system, physical fitness, sleep research, space psychologic stress

47-SUBJECT AREA 22, 06

42-AUTHOR/CO-AUTHORS VESELOVA, A. A.; 16-GUROVSKIY, N. N.; 16-DUSHKOV, B. A.; 16-ZHURAVLEV, V. V.; 16-ZALOGUYEV, S.H.

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ABSTRACT

The influence of different regimes of work and rest was investigated with respect to the following functional states of man during a prolonged stay in a hermetic chamber: 1. Investigation of Mental Efficiency and Psychic Functions. 2. Body temperature. 3. Body weight, diurnal energy expenditures and water balance. 4. Muscular efficiency. 5. Investigation of the state of the cardiovascular system. 6. Functional state of external respiration. 7. Investigation of peripheral blood. 8. Investigation of the urine. 9. The microflora of covering tissues and the state of certain indices of Natural immunity.

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39-TOPIC TAGS
astronaut, diurnal variation, human memory, human sense, isolation test, sleep research, space medicine

09-TITLE INFLUENCE OF THE CHANGE OF THE REGIME OF DIURNAL ACTIVITY ON THE HUMAN ORGANISM UNDER CONDITIONS OF ISOLATION

47-SUBJECT AREA
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42-AUTHOR/CO-AUTHORS
MYASNIKOV, V. I.

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ABSTRACT
The possibility of creating an artificial regime of diurnal activity rests on the necessity of controlling the depth and duration of sleep. Up to the present this question has not been completely solved. However, independently of method (the application of pharmacological preparations of directional effect or with the help of electricity and radio) controlled sleep will make it possible to ensure rapid mobilization of the organism for carrying out tasks specified by the flight program (awakening at an assigned period, rapid entrance into the working activity), and possibly rapid relaxation and falling asleep in periods not connected with controlling the spaceship or executing of special investigations, specified by the flight program.

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09-TITLE EFFICIENCY AND THE STATE OF HIGHER NERVOUS ACTIVITY DURING DIFFERENT REGIMES OF HUMAN LIFE		
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42-AUTHOR/CO-AUTHORS GERD, M. A.	10-DATE OF INFO -----67
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ABSTRACT

The change of efficiency with a significant change of the regime of life of the participants in the experiment was mainly expressed in the deceleration of reactions. It was most considerably expressed at the beginning of the experiment (in the sharp transition to the life under the experimental conditions); subsequently the speed of the reactions increased; at the end of the experiment there was observed a certain deceleration in the reactions connected, apparently, with the prolonged stay of the subjects under conditions of the experiment.

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42-AUTHOR/[redacted]	10-DATE OF INFO
KRUTOVA, YE. M.	-----67

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ABSTRACT

The conditions with partial sensory isolation and hypodynamia have the greatest negative effect on the cognitive processes of the subject, the productivity of the mental activity and the attention concentration.

The cognitive process under the conditions of the experiment decelerates in time, deteriorates qualitatively.

Under the conditions of the hermetic chamber with increased temperature and humidity there was observed a more expressed deterioration of the mental efficiency, of the concentration of attention and memory and a deceleration of the cognitive processes. Thus, the mental efficiency quantitatively decreases on the average by 2 times. The attention concentration worsens on the average by 5-10 times as compared to the initial data of the same subjects and the data of the control group.

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09-TITLE THE SIGNIFICANCE OF MUSCULAR ACTIVITY IN PRESERVING THE STABILITY OF THE MOTOR FUNCTION OF THE ASTRONAUT		
47-SUBJECT AREA 06, 22		

42-AUTHOR/CO-AUTHORS KOROBKOV, A. V.; 16-DUSHKOV, B. A.	10-DATE OF INFO -----67
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ABSTRACT

A comprehensive regime of motor activity with correct and regular distribution of the groups of physical exercises made it possible to maintain the stable form of the force and endurance of the basic groups of muscles of the subjects during their stay under conditions of limited motor activity in a chamber with small volume. Included in the overall regime of work and rest were combinations of different forms of physical exercises directed towards improving of the motor activity of the person; these exercises rendered had an effect on the efficiency and the reduction of fatigue of the subjects, and also promoted the preservation of their general motor activity under the conditions of the chamber.

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42-AUTHOR[redacted] DEVISHVILI, V. M.; 16-DUSHKOV, B. A.; 16-KOROBKOV, A. V.; 16-MIRSKIY, M. M.; 16-RATISHVILI, G.G.

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ABSTRACT

At the same time othe regime of work and rest with a different alternation of sleep and activity did not lead upon completion of the experiment to a significant change in the strength and endurance of the basic groups of muscles, with the exception of certain individual muscle groups which, apparently, indicates the correct organization of the motor activity of the subjects. The adaptation of the organism to such an alternation of the periods of work and activity, in which the diurnal rhythm (according to the index of accuracy and stability of the time-strength reactions) is sharply reconstructed, occurs slowly (on the 10-13th day). Moreover, a normal periodicity of change of the physiological indices is established.

TABLE OF CONTENTS

ANNOTATION

This book contains data on the state of the organism and the work-performance of people situated in pressurized chambers, under various conditions of labor and rest and limited sensory information. The book reflects the problems of the psychophysiology of labor of astronauts, but goes beyond the bounds of special questions and is of great importance for such divisions of physiology as the physiology of labor and the physiology of sports.

These papers are timely, because astronautics is confronted by immense problems on the organization of prolonged space flights; therefore the regulation of the life of a crew under such conditions is a very important matter.

The book is intended for a broad circle of physicians, biologists, physiologists and psychologists, and will also be of interest to all readers concerned with the contemporary problems of space medicine.

PREFACE

We draw to the attention of the readers that these papers do not pretend to complete coverage of all questions on the psychophysiology of labor of astronauts. This is explained first of all by the incompleteness of factual material, which in time will be accumulated in prolonged space flights and in the landing of people on other planets.

In these papers are presented the results of an investigation of the influence of different conditions of labor and rest on the work-performance of man. This investigation was carried out for the purpose of determining the best variant of duration and rhythm of diurnal activity in space flight and to establish principles for adapting man to diurnal cycles which may be imposed on him by the conditions of future flights and life on other planets.

In experiments in the study of the conditions of labor and rest certain peculiarities of space flight were reproduced, namely: sensory deprivation and hypodynamia, which hamper the process of man's adaptation to new diurnal rhythms, causing various disturbances of the physiological and psychic functions of his organism. In the works of several authors these disturbances have become independent objects of investigation.

The selection of the materials of these papers responds to the practical demands of space medicine in the area which is concerned with the organization of the vital activity of crew members of ships making prolonged orbital and interplanetary flights. It is exactly for this reason that great attention in these papers is allotted to the problem of the conditions of work and rest of astronauts. A number of conditions of prolonged space flight excludes the possibility of setting up diurnal cycles for the participants on the basis of the 24-hour terrestrial scheme. Among these conditions the greatest significance belongs to the peculiarities of the professional activity of the astronauts, which will be basically the activity of an operator, and also the character, intensity and rhythm of illuminance on board the spacecraft and on other planets of the solar system. The requirement of continuous watch on board the spaceship and its not more than 3-4 hour productive duration determines the necessity of reducing the diurnal cycle to 12-18 hours. As experimental investigations show, the adjustment to a new diurnal regime sometimes takes a very considerable period of time and is accompanied by a lowering of the physical and psychic work-performance. This is why the experimental investigations of the process of adopting a new diurnal rhythm have very timely significance, and the recommendations emanating from the materials of these investigations facilitate the organization and realization of prolonged space flights.

No less important is the problem of sensory deprivation under space conditions. Weightlessness, the monotony of professional activity, and the static character of the visually perceptible environment at many stages of space flight cause a certain underloading of man's system of analyzers, and thereby a lowering of the working tonus of the highest sections of his central nervous system. Such underloading (sensory deprivation) is accompanied by a lowering of overall psychic efficiency and for certain people, by the disturbance of the clarity of consciousness and by hallucinations. Recommendations on the prophylaxis of sensory deprivation contemplate a thorough investigation of all peculiarities of this state.

On the whole the papers are of great interest for specialists in the area of the organization of labor of various members of spacecraft crews.

CERTAIN PECULIARITIES OF THE WORK ACTIVITY
OF ASTRONAUTS DURING PROLONGED
SPACE FLIGHT

In setting up space flights work is an extraordinarily important factor, determining the mode of life. A characteristic peculiarity of the investigations of the working conditions of different professions consists, as is known, in the fact that the objects of study are the already existing forms of human work activity. At first a process of labor develops, specific social and psychological interrelations of people arise in the process of production, and only after a certain period of time is a study begun on the peculiarities of this form of labor and the influence of the conditions of the work activity on the worker's organism is explained.

In prolonged space flights the life of astronauts must be examined as a work process, which must be precisely regulated. A new and very complex problem of space medicine is to make recommendations on the rational structuring of the labor of astronauts during a prolonged space flight at a time when there have been no such flights and, naturally, also when a labor process as a whole does not exist.

In developing recommendations for the work regime of astronauts in flight it is necessary to proceed from the experience accumulated by scientists during the study of labor of different professional groups, from the knowledge of the general principles of the course of psychic and physiological processes of man with careful analysis of the peculiarities and conditions of flight, and also from the data of the study of the reactions of the organism during simulation of the activity of astronauts in laboratory experimentation.

We will not dwell on an exposition of the general principles and characteristics of human psychology nor on the public and social side of labor; we shall endeavor only to carry out a specific analysis of those peculiarities which are characteristic of this labor in prolonged space flight.

The life of a man on board a spaceship differs essentially from the usual working conditions in a number of ways. The most important of these can be formulated in the following manner.

1. A prolonged sojourn under the conditions of the cramped quarters of a spacecraft leads to an absence of the rapid succession of external impressions which are characteristic of life on earth. This condition permits us to speak about the impoverishment of external afferentation and the monotony of stimuli.

2. Changes in the habitual rhythm of the organism's activity are caused by lack of mobility, weightlessness, and the absence of the natural alternation of day and night.

3. The impossibility of broad and various contacts with different people is due to the enclosed state and the constancy of the association with only the members of the ship's crew.

4. The uniqueness of the microclimate, nutrition, and the health-hygienic conditions, etc.

5. The uniqueness of the psychological state caused by the sense of isolation from earth, by the unusualness of the situation, by the possibility of serious emergency situations, etc.

It is necessary to emphasize that for certain of the given peculiarities of the conditions of life of the astronauts it is possible to find some analogy in research of the physiology and psychology of labor. However, there is no experience in carrying out labor operations in a null-gravity state during a prolonged flight, and this state can very significantly change the execution of even the usual labor operations and will require the creation of new objects of work. However, it is doubtful whether the formation of working dynamic stereotypes, and consequently the principles of instruction, will proceed according to any new laws. Therefore, it is not necessary to contrast the labor activity of astronauts with known labor processes.

The labor activity of astronauts in prolonged flight can be schematically divided into the following forms.

1. Activity while on duty at a control panel. This is the most responsible form of an astronaut's work, which consists in monitoring the operation of the automatic systems and also in observing the different indicators, instruments, and signals.

This type of activity can be categorized under the "monitoring," since its essence consists in the function of monitoring the indications of instruments; there is practically no necessity to carry out any kind of movement.

2. Activity of servicing the life-support systems. It will include observation of equipment ensuring the necessary gas composition of the air in the cabins and its humidity and temperature, the conditions of illumination in the cabin and in other premises, the water supply system, etc., and also the work of servicing these systems.

Thus, these forms of labor by their basic characteristics, obviously, will in many respects coincide with the functions of monitoring equipment; clearly, many instruments will be located on a central control panel. However, in the activity of servicing the life-support systems there will also be included the work of cultivating higher and lower plant forms, the repair work in equipment breakdown, i.e., actions requiring specific and rather diverse motor activity of man. Moreover such actions will have the nature of permanent work during the whole flight (work with plants); consequently, it is possible to regulate them. Also there will take place periodical and unanticipated works, which are difficult to take into account (repairs).

3. Activity directed towards personal care. This category includes work in preparing food, carrying out hygienic procedures, sanitary treatment of the premises, etc. This activity also provides for and determines the motor activity of the astronauts; it will be carried out constantly and will play a rather large role among the other operations and work.

4. The activity of astronauts connected with carrying out scientific observations in flight by its nature will be very diverse; however, it is doubtful whether it will require much motor activity from the astronauts during the whole flight, with the exception of certain tasks and especially extravehicular excursions into space and onto other planets. At the present time it is difficult to give a sufficiently complete and detailed analysis and the complete characteristics of the enumerated forms of work activity of the astronaut. During space flights on ships of the "Vostok" type the astronauts carried out observations of the operation of automatic systems; they executed manual operations in controlling the orientation system of the ship; they monitored the life-support systems.

It is possible, obviously, to distinguish two forms of astronaut monitoring activity. The first form is the observation of instruments; it is carried out under normal operating conditions of the automatic systems, where the intensity of the work is not great. The second form of activity is carried out under conditions requiring especially active forms of monitoring with a large number of signals coming at a rapid tempo (during orientation, the docking of ships, landing, emergency situations, etc.). There takes place here a combination of pure observation of instruments and signalling apparatuses plus motor operations for controlling the ship or its systems.

The peculiarities of the first form of activity are determined by the necessity to monitor the instruments, the scanning of which is accomplished by a developed system of alternate and simultaneous observations of different forms of signals. Moreover, the ample activity of perception and the strain of attention combine with the absence of intense muscular actions, which distinguishes this activity as work operations proceeding with little external effort. However, at the same time, the astronaut should be at constant working readiness to perceive unforeseen changes in the conditions of the signals in case of the appearance of emergency situations.

Such a combination of standard, efficient scanning of the customary instruments along with the necessity to be at constant readiness for unforeseen changes determines the stress of the stimulating and inhibiting processes on the cerebral cortex and thereby the rather high demands on the nervous system of the astronauts. Still greater requirements are presented by the period of activity of the second form, when intense forms of monitoring combine with the deciphering of the incoming signals, with decision-making, and with the manual control of certain operations. The rapid tempo of such activity frequently demands from the astronaut the mobilization of all his resources; in the cerebral cortex there can arise situations of the simultaneous existence of intense processes of excitation and inhibition, which, as is known, can lead to conflicting interrelations.

It is necessary to point out that the peculiarities of monitoring activity of an astronaut while working at a control panel will be determined by the specific automatic equipment of the given vehicle. However, this form of activity in its overall structure will most closely recall the labor of an operator of highly automated systems. Moreover the most intense forms of this labor will take place very rarely (in switching on some special signals, in the breakdown of automatic equipment, in maneuvering on the flight course, and others). In other words, the astronaut must constantly be at a state of readiness for special action. Such a form of labor does not require muscular exertions; it is characterized by slight mobility, by high activity of the visual and other analyzers, by the strain of attention. There is used a limited circle of connections produced with the help of the signal system and there does not occur a development of new and complex reflexes and differentiations constituting a physiological expression of a creative function of the brain. This form of work activity is mainly connected with the processes of perception and the processing of information on the basis of ready, earlier developed stereotypes.

Once again it is necessary to emphasize that what has been said pertains to the peculiarities of monitoring activity of an astronaut at work at a control panel, when all instruments and systems are working under normal conditions. On the whole it is difficult to overestimate the significance of man's creative activity during space flight while carrying out observations, comprehending all phenomena, making decisions, carrying out a series of operations, etc.

The physiology and psychology of a monitoring activity of this type are less developed than for physical labor. As applied to space flight the characteristic peculiarities of such activity are:

— monitoring instruments, when under a condition of great activity of perception and strain of attention it is not necessary to carry out any muscular actions;

— the presence of overall stress connected with the possibility of the appearance of emergency situations.

However, calculations of the probability of the appearance of serious emergency situations show the insignificant possibility of such accidents during space flight. Consequently, the activity of astronauts while on duty at a control panel will be connected basically with the functions of monitoring in its pure form.

An exception, as was already noted, is the work of astronauts under special conditions, when the docking of two ships occurs, during landing, or while maneuvering the ship on the flight course.

However, these stages take up a very insignificant period in the overall time of a protracted space flight, and the peculiarities of work during this period have a sufficient number of analogs in aviation practice. Moreover the activity of an astronaut is accompanied by muscular exertions and sensory correction. At the basis of the monitoring activity of an astronaut lies the actual well-known problem of examining all indications of the instruments and signalling apparatuses located on the control panel, and the ability to carry out monitoring actions systematically and with maximum completeness.

The high responsibility and the tension connected with this stimulate an increase of cortex tonus. However, inasmuch as it is difficult to maintain such a stressed state at a constant level, fatigue develops rather rapidly and as a result of this there is a lowering of vigilance.

Thus, the peculiarities of the activity of an astronaut while of duty are basically connected with the process of perception with strained attention and the absence of any external actions.

So, during space flight while monitoring the indications of instruments (signalling apparatuses) activity is limited to only observation and the absence of action in the form of movement. This is like an activity with an inhibited end (certain functions of such an "end" take on themselves signals, which appear in a second signal system in the form of conclusions of the type "all is normal"). In a physiological sense this implies that the work process of an astronaut at a control panel is a process only slightly corrected by feedback or sensory correction, although it certainly is, since observation of instruments and the processes of perception and comprehension of the signals are reflex processes. The weak reinforcement by feedback hampers their course.

The absence (in the course of a monitoring function) of results of the preceding operations makes the work of an astronaut difficult, taking place without reinforcement by the obtained effects. It follows from this that in the development of recommendations for setting up duties for astronauts at control panels it is necessary to plan the work in such a way that it is made up of individual stages which have completeness in the form of definite results.

The monitoring activity in a duty period, apparently, will be made up of uniform components. The absence of variety and of change to other forms of labor promotes, as is known, a relatively rapid development of fatigue; it produces a decrease of perception accuracy and increases the possibility of errors.

All these peculiarities of the work of the astronaut in monitoring automatic systems can be especially clear in cases when the automation of processes reaches levels at which the information becomes relatively insignificant and the activity of the operators takes place under conditions of underloading with stimuli.

This question of underloading is now rather widely reflected in literature. Thus, for example, there appear worthwhile data about the fact that the reduction of the number and variety of signals affects a person more negatively than their abundance (certainly, within known limits), because the working rhythm is lost, an inhibiting process arises and spreads and a feeling of boredom appears. This leads to the thought that the maximum automation of all systems, pursuing the noble purpose of relieving the astronaut and safeguarding the safety of the flight, can at the same time play a negative role. In this regard investigations are still necessary as far as the actual systems of spacecraft are concerned.

Thus, the work of astronauts while on duty at a control panel is a unique form of work requiring the carrying out of investigations directed towards decreasing its negative peculiarities. In this sense questions of the development of optimum conditions and other measures for the organization of given job acquire a paramount role.

Let us speak briefly about other forms of work of the astronaut during space flight of long duration (personal care, repairs, routine maintenance work, etc.), i.e., those forms which include as an obligatory element a specific motor activity. Their uniqueness will be determined by the specific character of free movements under the conditions of weightlessness and the limited volume of the cabin of the spaceship.

Questions of the peculiarities of the coordination of man's action here must be put forward as a special problem, anticipating an analysis of the working movements under conditions of unusual forms of support. The study of the processes of the organism's adaptation to the conditions of weightlessness is very important.

Thus, in the standardization of labor of the astronaut great attention must be given to the study of the influences on this labor of the conditions of space flight. It is possible to assume its negative influence on the overall condition of the astronaut's organism and, in particular, on the state of his higher nervous activity.

According to the data of some researchers, the cramped quarters and the lack of sensory stimuli cause psychic tension and fatigue; according to the data of others, they lead to the development of profound forms of protective inhibition. Therefore, it is necessary to study in detail the influence of such factors, as the immutability and the monotony of the situation on man's labor processes.

The works of a number of scientists have shown the great role of the alternation of impressions on the life and work of man. I. I. Pavlov showed that monotony promotes the development of various forms of inhibition in the cerebral cortex. There are a large number of investigations showing the injurious effect of monotonous forms of labor on man.

The organization of work activity of man on earth anticipates the possibility of his switching to other forms of work and of the change of that stereotypic situation which accompanies the working activity.

Under the conditions of prolonged space flight it is difficult to alter the stereotypic monotonous situation of labor and life. For example, during a flight to Mars, with a duration of about 3 years, a limited number of people — members of the crew of the spaceship — will be forced to exist under conditions of the cramped quarters of the cabin of the spaceship with limited possibilities of movement in a monotonous work situation. Therefore, it is especially important to propose forms of the organization of their labor and rest which would compensate for this deficiency.

As a characteristic of the work activity of the astronauts in the course of posing the question it would be desirable also to point to features connected with a certain variation of the motivation of labor.

In the life of people on earth some of the powerful stimuli of the work activity are social stimuli and incentives, which in various forms (wages, approval, the sense of a job well done, its purposefulness, high quality) reward the labor of man. Astronauts carrying out flights on ships of the "Vostok" type, fulfilling the special instructions of their motherland, knew their high mission, and the recognition of their great services upon their return could be a powerful stimulus for their work activities. How will the motivation of labor be structured during prolonged flights, lasting years, when the public recognition of this labor will be postponed for a very long period of time?

From the most general considerations of the conditions of the life of astronauts in prolonged space flight which have been given, there follows the conclusion about the special importance of the development of recommendations on the rational organization of their labor and rest (in the broad sense of this word). This will be conducive to successful work and life in the cramped quarters of the cabin of the spaceship during flight. In developing such recommendations it is necessary to consider the importance of a well-selected social structure, the correct structuring of rest (reasonable ways of relaxing), rational conditions of work (normal load) and others.

All these considerations have to be at the center of any forthcoming investigations. It is very important right now to determine the objective of a given round of work and to develop adequate methods of investigation.

THE PHYSIOLOGICAL BASIS OF HUMAN ADAPTATION TO SPECIFIC CONDITIONS OF ACTIVITY

In the transition to the fulfillment of work under the conditions of space flight the human organism experiences a considerable reorganization of its functions. The astronaut can endure effects of such factors as acceleration, vibration, weightlessness and others, with appropriate training, directed towards the development of the organism's resistance and tolerance to all these unfavorable factors. But the organism of the astronaut should also be well adapted to the specific order of activity and to the alternation of periods of work and rest.

An inadequately based regime of labor and rest can cause and accelerate the development of fatigue, which is a considerable threat to the health of astronauts and lowers their efficiency.

In the reports of the astronauts A. G. Nikolayev and P. R. Popovich it was noted that all forms of work during flight were easily fulfilled by them and their state of health was excellent. However, certain physiological indices of vital activity and efficiency at the end of the flight testified to the presence of fatigue. Thus, 6 hours after landing the astronauts experienced an increase of pulmonary ventilation; oxygen intake increased by 24% and the discharge of carbon dioxide increased by 30%. Corresponding changes, indicating the development of fatigue in the astronauts, were also distinguished in the alteration of the neurodynamic character of the reactions of the bioelectric activity of the cerebral cortex, which manifested themselves in the exaltation of the alpha-rhythm in central-occipital readings. Furthermore, there was observed a slight drop in the number of erythrocytes in the peripheral blood and an increase of general protein and serum mucoid in the blood. There was also noted a considerable amount of a desoxycytidine-like fraction in a twenty-four hour sampling of the urine, and an increase of the amount of 17-21-hydroxy-20-ketocorticosteroids and creatine. Changes on the part of various functional systems (phase of the cardiac cycle, external respiration and gas exchange, EEG and others) detected in the astronauts V. V. Tereshkova and V. F. Bykovskiy during the second group space flight and lasting for a period of 1-16 days after the completion of flight, corresponded on the whole to the pattern of marked general fatigue. Significant individual peculiarities were detected (N. I. Sisakyan, 1964, 1965) both in the degree of manifestation of the individual symptoms of fatigue and in the nature of the physiological reactions.

Generalizing the results of the flights of American astronauts, experiments in aircraft, in soundproof chambers and the observation of special contingents of persons subjected to a prolonged sojourn in a chamber of small size, a number of authors (David, 1961; Violette, 1964, and others) consider that the adaptation of man to space or to conditions of simulated space flight occurs according to specific regularities. The reaction of man to the prolonged effect of a complex of factors (weightlessness, overload, acceleration, insulation, etc.) is unfavorable, although neither the flights carried out up to the present time nor the ground experiments can serve as the basis for final conclusions. In the opinion of these researchers, the optimum conditions, which can be created in the cabin of a spaceship for supporting normal efficiency (of work) and psychophysiological status of the astronauts, must be determined in the course of further flights of longer duration.

All these data testify to the development in astronauts of definite fatigue, and, thus, the question of a scientifically valid prophylaxis of this condition is timely. One of the effective means of this prophylaxis is a rational regime of work and rest.

In the approach to the development of a regime of work and rest for astronauts it would have been possible to propose the use of one of the proven regimes developed for ground conditions, for example, the regime of activity of workers at a control panel. But life and practice reject such an apparently very practical approach to the solution of this question. We will point out the basic reasons for its unsoundness. First of all in the organization of work on earth we have great possibilities to vary the conditions of the work processes, adapting them to the peculiarities of the human organism. Moreover, frequently a regime close to optimum is found experimentally, i.e., by comparing things put forward by life itself and by producing different versions of them. For example, it is possible to arbitrarily change the beginning and end of work shifts, the time of the dinner break and of additional regulated breaks, etc.

Under the conditions of space flight the alternation of work, periods of sleep, and forms of rest, apparently, to a considerable degree will be subordinated to the peculiarities of the technical devices and a special program (communication with earth, with other astronauts, automatic and manual control, regulation of the conditions of the environment and so forth), which do not have a close analogy in ground work activity. Furthermore, the astronauts are subject round-the-clock to influences of specific factors of the environment, of which weightlessness has a special importance. It is also necessary to consider the extraordinarily high intensity and responsibility of the work of astronauts.

Therefore, it is doubtful whether it is possible to use in their prepared form any of the actual regimes of work and rest developed under ground conditions.

However, it is possible to affirm with all confidence that the general physiological principles of the organism's adaptation to work activity, which are the bases of the dynamics of efficiency and which determine the entry into the work and fatigue, uniquely appear in all forms of labor, including the labor of the astronaut.

In investigating these questions two directions can be followed: first is sequential testing of a number of experimental regimes with a comprehensive characteristic of the productive effectiveness of the people being tested and variations of the physiological processes; the other is the investigation of the principles determining the optimum adaptation of a person to a given type of work, the clarification of dynamics of efficiency variations and of the actual physiological mechanisms of occupational fatigue of astronauts. Investigations in the first direction can lead to determination of a work and rest regime more or less approaching the optimum only after testing a large number of possible variants, selected randomly without any kind of physiologically based system. Investigations in the second direction lead by the shortest possible way to the designated goal — to the formation of an optimum regime of work and rest, in which the alternation of work and rest periods is based on physiological principles. In developing an optimum regime of work for astronauts it is necessary to creatively use all the general principles of the dynamics of efficiency discovered in the physiology of labor and the whole experience of the physiologically based formation of the regime of work and rest of workers in different specialties. Depending upon the technical conditions (machine-tool, control panel, conveyer, etc.), on the basis of the characteristics of productive processes and processes occurring in the organism during work, at the present time specialists in the physiology of labor have the possibility to find and they are finding in practice by the shortest possible route the optimum regime, for given actual conditions, of work and rest for those working in various sections of production and for persons occupied with different forms of labor (S. A. Kosilov, B. A. Dushkov, 1964). The experience in developing physiologically based optimum regimes of work and rest must be used also for structuring the regimes of work for astronauts, taking into account the technical conditions of the work and the physiological principles of the adaptation of the organism to the specific characters of the work activity. The useful general principles, which it is necessary to consider in developing a regime of work for astronauts, are in the first place the general principles of the dynamics of change of man's efficiency. A correct regime of work and rest is characterized by rapid entry into the work and prolonged maintenance of a high and stable level of efficiency or mild fatigue. In developing measures to prevent fatigue it is necessary to turn one's attention not only to the last stage in the dynamics of efficiency, but also to all three periods. Therefore it is necessary to consider the general physiological principles of exercise and the capacity to acclimate oneself to work, which have to be considered in setting up a regime of training and work for an astronaut.

For the physiological basis of an optimum regime of work and rest of astronauts it is necessary to use certain materials about the physiological mechanisms of exercise, adaptation to work, and fatigue. In this respect the principles of the concentration of muscular exertions and of the nervous processes and the formation of dynamic working stereotypes by exercise have definite significance (S. A. Kosilov, 1938, 1941, 1954, 1955, 1963).

In 50 years the physiologists of labor have developed, on the basis of the physiological study of the working dynamic stereotype, of the change of the functional state of the nervous system in the process of work (the concentration of muscular force and of nervous processes, summation of traces of excitation), a method of physiologically based structuring of the optimum regime of work activity. It has been established by S. A. Kosilov that as a result of exercise there occurs a decrease in the time intervals in which the basic work of individual motor acts is accomplished (the development of maxima of speed and acceleration); it has also been shown that according to the amount of exercise a method of work gradually forms during which in the previous stages of movement there are formed favorable conditions for the most effective fulfillment of the subsequent stages of this movement, which testifies to the gradual unification of movement into a complete act, accomplished according to a specific program. This coordination of elements of movement which were previously disconnected into one whole must be examined from the physiological point of view as a unique manifestation of the system of higher nervous activity and of the principle of dynamic stereotype, which is caused by the specific character of the work activity. Inasmuch as this phenomenon cannot be completely identified with the dynamic stereotype of animals or with the motor dynamic stereotype in the interpretation of A. N. Krestovnikov (1954) and M. I. Vinogradov (1958), it was expedient to call it a working dynamic stereotype.

A study of exercise during simple and complicated movements and of work with a variation of the duration of the micropause under conditions of various activity showed that the concentration of the nervous processes during exercise was connected not only with the effect of the conditional reinforcement of achieving the result, but also with the change of the functional state of the nervous system due to the summation of traces of excitation, which remained after the termination of each routine movement. The indicated principles were true both for physical work, as well as for actions requiring mainly intensity of attention, and for solving mental problems. Thus, a study of the traces of excitation which remain after carrying out a simple visual-motor reaction showed that they can be recorded for 8-10 seconds after the termination of the motor reaction, i.e., during a time interval, in which a new work function or work movement is able to arise and develop (B. S. Volkov, S. A. Kosilov, 1965). During fatigue due to mental work this time increases, and after rest it decreases.

This peculiarity in disturbance of the working dynamic stereotype is also observed in the course of preparation for flights and in persons who have spent a prolonged time under conditions similar to space flight. From the point of view of physiological theory of the working dynamic stereotype one of the characteristic features of the specific character of the work of the astronaut is the limitation of stimuli signalling the results of actions and the limitation of the possibility of accumulation (summation) of traces of excitation. On the basis of these peculiarities it is possible to assume that in astronaut fatigue the state of nervous system must change due to the lowering of the concentration of the nervous processes in the "ruling seat of excitation," which in turn can be a cause of the deceleration of work actions and of the development of subjective sensations of difficulty in carrying out motor actions. In checking with the help of a method developed by us (B. A. Dushkov, 1965) on the basis of the theory of the working dynamic stereotype and of shifts of the state of the nervous system, objective data were obtained characterizing the specific nature of this fatigue. Thus, after a five-day stay of two test subjects (O-v and Ch-n) under conditions simulating certain features of space flight (pose, nutrition, conditions of life and so forth), there were noticeable changes in the data characterizing the accuracy and stability of temporal-strength reactions. There was a decrease of muscular strength in both of the test subjects. For test subject Ch-n the ability to continuously maintain half of the exertion of maximum force decreased from 38 to 31 seconds, and for O-v — from 53 to 42 seconds. The muscular force hardly changed at all. After the experiment the test subjects made greater errors in reproducing small and large measured exertions. Changes were observed in reproducing given time intervals (Table 1). As shown by the data presented in Table 1 about variations of the magnitude of reaction after the 5-day experiment, there occurred in the test subjects a deterioration of differentiation in appraising time and exertions, which is proof of the deconcentration of the nervous processes which occurred.

For example, towards the end of the test after the experiment in test subject Ch-n there occurred a decrease of accuracy in determining 10-second time intervals, in the direction of reducing them by 30-40%. Moreover, the error in reproducing small exertions in a time interval of 10 seconds increased up to 35 arbitrary units. Analyzing the difference in the results of the experiments by individual indices of temporal-strength reactions before and after the experiment, it is possible to conclude that in a given case great distinctions are revealed in motor coordination, static strength, and the estimation of time intervals. The reliability of the neuromuscular apparatus in carrying out assigned physical work decreased and the functional capabilities for carrying out programmed mental activity at a specified volume in a required time period decreased.

Table 1. Variation of temporal and strength indices before and after the 5-day experiment.

Number	Index	Subject Ch-n: before the experiment	difference	after the experiment	difference	Subject O-v: before the experiment	difference	after the experiment	difference
1	Muscular strength (kg)..	48,15	—	45,15	— 3	42,1	—	42,1	— 0
2	Strength endurance (s)..	38	—	31	— 7	53	—	42	—11
3	Pause of 10 s...........	8	—2	13	+ 3	9	— 1	4,0	— 6
4	Small force.............	15	—5	30	+10	25	+ 5	30	+10
5	Pause of 10 s...........	8	—2	13	+ 3	9	— 1	8,6	—1,4
6	Large force.............	95	+5	110	+20	100	+10	120	+30
7	Pause of 10 s...........	10	0	12	+ 2	9	— 1	6,0	— 4
8	Small force 3 s.........	30/2,5	+10/—0,5	35/2	+15/— 1	30/2,7	÷10/—0,3	30/4,4	÷30/÷1,4
9	Pause of 10 s...........	12	+2	8	— 2	9,5	—0,5	9	— 1
10	Large force 3 s.........	80/2,5	—10/—0,5	110/2	+20/— 1	95/3	+ 5/0	80/3	—10/0
11	Pause of 10 s...........	8	—2	8	— 2	10	0	8	— 2
12	Small force 10 s........	18/9	—2/—1	55/8	+35/— 2	24/9,5	+ 4/—0,5	15/10	5/0
13	Pause of 10 s...........	10	0	7	— 3	10	0	10	0
14	Large force 10 s........	80/11	—10/+ 1	110/6	+20/— 4	100/10	+10/0	80/10	—10/0

Notes: 1. Indices in Nos. 8, 10, 12, 14 are given in the form of fractions: the numerator – measured force in arbitrary units; in the denominator – the duration of the time intervals.

2. Subject was given the task of producing a small force – 20 arbitrary units – and a large force – 90 arbitrary units.

The deconcentration of the nervous processes in connection with a 5-day stay in a chamber of small volume was also revealed by the method of determining exertions and time by mental arithmetic. In this method the test subject was ordered to compress a dynamometer systematically and with maximum speed according to a given program and to add up in his mind the number of kilograms of force produced. After the stay under experimental conditions the number of allowed errors was increased in the development of the forces; the number of intervals between the consecutive compressions of the dynamometer increased. These indices vary nonuniformly in different altitudes after the experiment. Most of all errors in forces were registered for test subjects in positions of standing and lying on the stomach. In fulfilling the test (mental arithmetic) in certain postures (sitting, lying on the back) the count time is reduced, which apparently indicates a certain training of the subject to such activity.

By observation and interrogation it was revealed that the subjects' attention was first drawn to their own fatigue on the third day of their stay in the chamber. Pains in the knee joints and decline of the general health (debility) were noted.

After we had diagnosed the presence of special fatigue in the test subjects and explained its physiological mechanism, it becomes possible to outline a course of prophylaxis of fatigue by optimizing the work regime. It is essentially, that on the basis of the experimental data certain criteria were obtained for determining the dynamics of the change of the nervous system of the test subjects, by which it is possible to determine the early stages of disturbance of the working dynamic stereotype. The ascertainment of the early stages of specific fatigue is a decisive condition for the successful prophylaxis and optimization of the work and rest regime under extreme conditions.

A study of the actual processes of exercise of innovators of production (S. A. Kosilov, 1959) and of students (Z. N. Briks, S. A. Kosilov, 1963) made it possible to note the great significance in mastering complex work operations of the planning of work actions and of the constant collation of executed work actions with a presentation of the correct manipulations. Simultaneously with a check of the actions in accordance with the available concept there occurs an improvement and a more precise definition of the integral form of the work actions due to the enrichment of the motor experiment.[1] The data available in literature indicate that for work connected with remote control operations by technology the formation and reproduction "of an operational form" is characteristic (D. A. Oshanin, 1966). Apparently, this factor has great significance in work and in the regime of the vital activity of the astronaut. A physiological analysis of the integral form of work actions showed the most important conditions of its reliability. For improving and maintaining the integral form of work actions there is necessary the recording in the cerebral cortex of traces of excitations from correctly carried out, most effective variants of work operations. These traces, being summarized during repetition or during entry into work, attain that level of intensity, at which ideas of the best variants of fulfilling a given work action, which are recognized by man appear. Part of the traces of excitation can remain below the threshold of consciousness and nevertheless render influence on the control and the more precise definition of the work movements. The unification in a single system of the ideas about the correct method of fulfilling the work operation (obtained from instructions) with the nonrealized traces of excitation of the motor analyzer is a unique unification in the work process and an interaction of functions of the first and second signal systems. As a summation will occur in the work regime, and the reliability of the integral form of the work actions, apparently, will depend on that.

For successful mastery of the skills and the rapid entry into the work it is important before beginning the work to propose to reproduce the verbal instructions simultaneously with the carrying out of the exercises. The formation in man of a clear integral form of work actions significantly facilitates correct work procedure, which can promote the programming of man's behavior under specific conditions.

Under the influence of different factors acting on the astronaut's organism, the integral form of work actions experiences changes, which are expressed in the nonuniform weakening of its different components, in particular, components connected with traces of excitation in the second and first signal systems. It is known, that a test subject located in a pressure chamber under conditions of lowered pressure registers a recording of good health in the presence of sharp disturbances in his handwriting. A. V. Yeremin, I. I. Kas'yan, I. A. Kolosiv, V. I. Kopayev, V. I. Lebedev (1965) indicate that, according to their observations, in astronauts who are experiencing prolonged flight, disturbances develop in the sensory and motor functions. These disturbances are connected with a sense of fatigue.

The conclusion follows from this, that in an astronaut work regime it is necessary to provide exercises directed at supporting and strengthening the integral form of work actions, in particular, exercises, in which there are simultaneously included motor actions and mental problem-solving (which are coordinated with each other), that is the simultaneous carrying out of reactions to a complex stimulation, including direct stimulations and stimulations addressed chiefly to the second signalling system. With respect to the investigated pupils a positive influence was rendered by the simultaneous reproduction of verbal instructions and the corresponding work movements. Analogous to this in our investigations (B. A. Dushkov, F. P. Kosmolinskiy, 1966) a favorable effect was established on the efficiency of those who experienced special exercises, which provided activity for the first and second signalling systems, and simultaneous carrying out of motor actions and verbal accounts.

The final period in the dynamics of efficiency is characterized by the development of fatigue. The study and development of fatigue makes it possible to draw the conclusion, that fatigue (under specific conditions of work) is intimately connected with a regular change in the functional state of the nervous system due to the prolonged summation of traces of excitation.

Moreover, after achieving a high level of efficiency the further continuation of work and the summation of traces does not lead to the increase of excitability and functional mobility of the system of the working dynamic stereotype, but to their reduction according to Vvedenskiy's [Wedensky's] law of parabiosis. The actual manifestations of these regularities of work processes under ground conditions were observed in a study of the dynamics of efficiency for workers according to shift hours. Thus, for example, for workers at a control panel there was observed an increase of functional mobility of the visual analyzer (determined by the critical frequency of the disappearance flashings of the phosphene) and excitability (determined by the value of the threshold of electrical stimulation of the optic nerve) during the first two hours of work and a reverse change of these indices at the end of the working day (A. I. Kikolov, 1955). In the given example there was observed a change of functional mobility in the visual analyzer; in other works analogous dynamics were established for the state of the motor analyzer (T. N. Pavlova, 1954).

The lowering of the excitability and functional mobility (lability) causes a disturbance of the concentration of the nervous processes and as a result a disturbance of the working dynamic stereotype. Thus, on the basis of the data obtained in the study of the physiological processes (examined above) for workers under various conditions, it is possible to reveal the physiological essence of fatigue as a disturbance of the working dynamic stereotype due to a change of the functional state of the nervous system (the lowering of the excitability and functional mobility of the nervous system and the development parabiotic inhibition). Along with this it is necessary to consider that the basic process constituting the essence of fatigue is different depending upon the peculiarities of the actual form of work. Moreover, it is especially important to consider two circumstances. In the first place, a disturbance of the concentration of the nervous processes and a disturbance of the working dynamic stereotype do not equally affect the functions of different analyzers, organs and systems. Usually changes are primarily noted in those functions, which most of all take part in the work process. Thus, for example, in difficult physical labor the changes of the physiological functions will differ from the data obtained during the study of fatigue in stereoscopists. In the first case the changes will be observed in functions of the muscular system, and in the second – sight. Secondly, disturbances in neurodynamics, connected with industrial fatigue, do not immediately lead to deceleration or cessation of the actual work. For the most part a man with fatigue for a certain time continues his work, seeking various ways of adapting to his changing state of efficiency.

Let us dwell on certain principles of physiological processes, which are characteristic of workers doing mental tasks. During intense mental work requiring special concentration of attention and the rapid execution of a great number of mental actions, efficiency drops rather rapidly, which is expressed in a decrease of the hourly productivity of labor, starting with the 4th and 5th hour of work (T. N. Pavlova, 1957; V. P. Solov'yeva, 1957). In the execution of such work the accumulation of traces of excitation continues considerably longer, which leads to development of more profound stages of the parabiotic process in the cortical sections of the motor analyzer and to the appearance of such a radical countermeasure of fatigue, as protective inhibition, which protects the nerve cells from excessive exhaustion.

The period of productive work activity constitutes a comparatively small (by time) part of the diurnal period of a man's life. In developing a diurnal regime of work and rest it is necessary to consider that after executing work for production man switches to other activities determined by other dominants of behavior, which are different from the work dominant.

In setting up diurnal regimes of work and rest it is necessary to consider the dynamics of the diurnal variations of physiological functions. Moreover, it is necessary to consider that the diurnal rhythm of physiological functions is attached to heredity, and also to the personal experience of each person in the form of complex systems of conditioned reflexes (intake of food, rest, sleep, etc.). This order of actions forms the so-called diurnal dynamic stereotype, which is characterized by the increase of excitability of the vegetative systems and the motor apparatus during the daytime hours and by the lowering of their excitability at nighttime.

Various deviations from typical diurnal periodicity can take place with a different regime of work and rest depending on the peculiarities of the actual form of work and also on various, sometimes constant disturbances of the habitual tempo and rhythm of the work.

The question of adaptation to a new regime of work and rest, to modified diurnal dynamics of physiological functions was the object of investigation of a number of authors.

Thus, for example, in the work of Raboutet and others (1960) it was noted that the adaptation to a new regime of work and rest for pilots flying great distances was very difficult. Lewis, Lobban (1954) observed the physiological state of 8 test subjects, who lived a 22-hour day (on Spitzbergen). For one of them a reorganization of rhythm occurred, for the other seven the 24-hour rhythm turned out to be stable.

An interesting investigation of the change of efficiency of test subjects, who were located in a special chamber, was conducted by Haute (1960). The following regime was proposed for the test subjects: 4 hours of work, 4 hours of rest and again 4 hours of work, etc. The work consisted of operations with complex control systems. The average value of productivity was considered, which for each operator was estimated at 8-hour intervals. The author notes that the adaptation in various people was different. For certain functions of the operator (for example, taking instrument readings) the diurnal rhythm was very distinctly expressed, whereas for the same functions for certain other operators if it were expressed, then it was much weaker. The degree of adaptation of one and the same operator was different for different types of activity (for example, taking readings, discrimination, work at a radar screen). For one of the operators, whose diurnal component was especially distinctly expressed, adaptation to the 8-hour day turned out to be the most difficult. Apparently, the degree of adaptation to artificial external regimes depends on the reconstruction of our diurnal rhythm with respect to various changes of the conditions of vital activity.

In the study of diurnal rhythmicity of vegetative functions in space flight (G. V. Altukhov, P. V. Vasil'yev, 1965, and others) it was revealed that during the prolonged stay of a person under conditions of weightlessness a number of changes of the vegetative functions occurs (pulse rate, breathing rate, temperature of the body) in the diurnal rhythmicity, the mechanism of which, in the opinion of the authors, probably, is connected both with the specific influence of weightlessness, as well as with emotional tension.

For organizing the diurnal regime of work and rest of the astronaut an important conclusion from a number of works dedicated to the study of the diurnal periodicity of physiological functions (S. O. Ruttenburg and N. I. Nasledova, 1963; G. M. Gambashidze, 1965, and others), was the possibility of adjustment (adaptation) of the organism to a variable diurnal regime. As an index of such adaptation there can serve the range of the diurnal oscillations of certain physiological functions (body temperature, pulse rate, efficiency, etc.). The most susceptible with respect to the influences of the diurnal regime are functions of the muscular and nervous systems, the more inert processes of thermoregulation and the functions of blood circulation. Alternating under control of this index the diurnal and shift regime, it is possible to purposefully change the diurnal dynamics of physiological functions. In individual cases work can promote an alteration of the diurnal rhythm. Thus, in the investigations of V. P. Solov'yeva, G. M. Gambashidze (1960) it was shown that the diurnal rhythm of physiological functions in personnel working on the night shift was preserved without changes, also M. A. Gritsevskiy and Ye. A. Fat'yanova (1964) note that the intra-shift rhythmicity of physiological functions turned out to be modified in comparison with the usual diurnal periodicity of workers of the chemical industry, working on the night shift.

There have been conducted experiments, establishing the possibility of changing the diurnal periodicity of vital functions in animals. According to G. I. Shirokova (1949), for apes (Macaque Lapunder) there was observed a definite diurnal rhythm of conditioned reflex activity, indicating that apes completely cease responding to complex conditioned signals at nighttime. However, to simpler, well reinforced stimuli it is possible to obtain full-valued answers (Ye. M. Cherkovich, 1961). As the investigations of Den Su I and K. P. Ivanov (1961) showed a change (inversion) of the light regime (illumination at night and black-out by day) even on the 4th day leads to a corresponding reconstruction of the rhythm of motor activity in animals (Loris tardigradus). Corresponding shifts in gas exchange, respiratory rate and body temperature attain complete expression considerably later, on the 11-12 day.

In the investigations of O. P. Shcherbakova (1938, 1959) it was established for apes that in the creation of such a rhythm of life, in which the animals at night were located in artificial illumination and obtained food, and during the day were in the dark and did not obtain food, a complete reconstruction of the usual dynamics of the vital functions was observed in them.

Under the influence of such conditions there was noted a change of the diurnal rhythm: moreover for the animal an increase of vital functions occurred during the night hours, and a lowering — in the daytime hours.

With reference to solving the problem of the physiological basis of the diurnal regime of vital activity of the astronaut decisive significance belongs to the clarification of the fundamental possibility of "reconstructing" the diurnal periodicity of the functions in the sense that an increase of the excitability of the vegetative functions and the motor apparatus would develop in the hours of wakefulness during nighttime work. If one were to agree with the opinion of E. I. Brandt and O. I. Margolina (1954) about the impossibility of such a reconstruction, then it is necessary to construct the order of work and life of the astronaut strictly sticking the terrestrial rhythmicity.

The authors affirm that the distorting of the diurnal rhythm of man in an experimental setup does not succeed in practice.

Interesting observations were made by I. S. Kandror (1954). He showed that under specific conditions, as, for example, in travelling by train from Moscow to Vladivostok, the diurnal rhythm was reorganized during the 8 days of the trip. For the passengers on the train even after 3 days of travel reconstruction of the diurnal stereotype is occurring. As is known, between Moscow and Vladivostok the difference in time is 7 hours. During each day of travel the whole system of life of the passengers is shifted by 1 hour. And their behavior changed accordingly: the passengers began to rise, to go to sleep, to take food, to go out at the stations not according to Moscow, but according to local time. Simultaneously with this the times changed, when the indices of physiological functions (temperature of the body) reached the greatest or least value.

In another investigation by this same author it was noted that for people in the extreme north in the periods of the polar day and the polar night different disturbances of an adaptive character and ranges of the diurnal temperature curve were observed. In the period of the polar day most frequently there is noted a lengthening of the daytime phase, and in the period of the polar night — a lengthening of the night phase. The author was inclined to examine these data as an index of the modified balance of the stimulating and inhibiting processes in the cerebral cortex depending upon the intensity of the natural illumination.

A comparison of the data, mentioned above, shows that shifts in the diurnal stereotype of the functions of man occur easily, if the whole vital structure changes simultaneously.

Investigations in chambers showed that adaptation to the usual 24-hour cycle (sleep did not correspond to night) for test subjects occurred more rapidly (on the 8th day), then to the 18-hour cycle. Apparently, here great significance is possessed by the reconstruction of the periodicity of sleep and wakefulness, which did not coincide with the external rhythms. Apparently, adaptation to new diurnal rhythms will occur gradually, surmounting the former temporary relationships of the periods of sleep, work and rest.

In connection with the examined materials great significance was connected with the question of special measures, promoting adaptation to diurnal rhythms. In reference to astronauts and test subjects located in chambers of small volume, it would be interesting along with the physiologically based motor regime to experience the effect of hypnotization (for example, by a flashing light) and electronarcoses, and also others, for example, certain pharmacological means of regulating the processes of inhibition and excitation.

In developing a regime of work and training for the astronaut preparing him for prolonged flights, it is necessary to consider the circumstance that the regular transitions of various states of efficiency, the beneficial influence of rest and the resumption of work of former intensity are connected with a stable reliable system of reflexes — the working dynamic stereotype and its most important component — the integral form of work action.

The multilateral activity of man in society is a source of necessary stimulations for the formation and maintenance of the integral form of work actions — the idea of the purpose of labor, "which as a law determines the method and character of his actions and to which he must subordinate his will."[2] Proceeding from these considerations, it is necessary in the process of preparing for the specific conditions of the activity of astronauts not only to carry out training for surmounting difficulties of an exogenous character, in order to withstand the extreme influences of external factors, but also to develop a reliable program of working behavior, ensuring a high level of purposeful intellectual and physical activity.

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Footnotes

[1]There was developed by S. A. Kosilov (1965) a concept of work actions, which corresponds to a physiological mechanism of collation; they occur at a given moment of the work actions with those planned and recorded in the previous experiment. It has been experimentally established that the indicated comparison is based on a summation of the traces of excitation of irritations coming from perceived instructions, and from direct influences on the nerve endings of analyzers, including the motor analyzer.

[2]K. Marx. "Capital." Volume I. Moscow, 1949, p. 185.

CONCERNING A RATIONAL CONSTRUCTION OF THE WORK REGIME FOR ASTRONAUTS

At the present there still cannot be compiled a professiogram of astronaut work. In literature there is almost no information on this question. Published reports have examined the efficiency of test subjects under ground laboratory conditions simulating certain factors of space flight (F. D. Gorbov and others, 1963; N. N. Gurovskiy and others, 1966).

A correct regime of work and rest sustains and prolongs a high level of efficiency in man and helps prevent fatigue and overfatigue. The increase of pulse rate and arterial pressure, the increase of the rate of respiratory movements and lung ventilation, the increase (and in other cases the lowering) of emotional excitability, etc., in performing work have to be examined as symptoms of excessive stress in the astronaut and of the burden (enervation) of work. A more profound degree of fatigue manifests itself by prolonged impairment of the physiological indices and by their sharp oscillations during the course of the work period.

It is necessary to note that there is no strict proportionality between the magnitude of these functional changes and the degree of the work burden. The level, at which ore or another function establishes itself in a prolonged period of time can be a consequence of the adaptability of the organism to the work being done and is not a symptom of fatigue.

A rational regime of work and rest of astronauts should be constructed on the basis of a consideration of these functional indices. There should be also considered the specific character of the work and factors affecting the state of the organism of the astronaut (emotional tension, isolation from the external world, scantiness of sensory sensations or sensory deprivation, little motor activity, raised concentration of attention, the unusual null-gravity state and others).

I. M. Sechenov emphasized that for work without fatigue a definite relationship is necessary between the factors of work (frequency and force of movements and also the magnitude of the surmounted obstacles) and the duration of the rest periods.

It is generally known that man's efficiency during the working day varies in a regular manner.

At the beginning of the work day for 1-2 hours the entry into the work occurs. It is characterized by a gradual increase of efficiency and work productivity (the period getting into the work). There is an increase in such a productive index as hourly output, caused by the speed of the cognitive processes, the work movements (the development of motor conditioned reflexes, functional mobility, concentration of the nervous processes, etc.).

Then comes the period of efficiency characterized by the rather prolonged stability of the efficiency level. In the third period there is observed a lowering of the indices of efficiency and work productivity, indicating the arrival of fatigue. Before the end of the working day it is frequently possible to detect one more period — "a final burst," when for a short period of time efficiency is improved.

Measures on work hygiene should help support high efficiency and prevent fatigue. With the appearance of initial symptoms of fatigue short-term breaks for rest are recommended; they can be passive or active (filled with specially selected physical exercises).

The question of the duration of each break is decided depending upon the level of stress and the character of the work.

In physical labor this break covers the time necessary for restoring the rate of cardiac contractions, pulmonary ventilation, oxygen intake, etc.; in most cases it will be 5-10 minutes.

Of greatest significance in restoring of the efficiency of the organism are the first 3-5 minutes of rest. Therefore, in organizing the regime of work and rest for the astronaut one should try to replace prolonged breaks with frequent short breaks. An advantage of short breaks consists in the fact that during a short rest the work set is preserved.

During short breaks the rest of astronauts can be passive or active. Active rest with physical exercises is more effective. Complexes of physical exercises should be selected with consideration that the astronaut is subjected to unique factors of the environment (for example, weightlessness), and also of the peculiarities of his work.

Experimental investigations show that persons occupied with mental work should have short breaks after every hour of work. Thus, in a study of the regime of work and rest of people working at a control panel in a television studio it was established (A. I. Kikolov, 1960) that the indices of the physiological functions reflect positive adaptation to the work during first 3-4 hours, after which there occurs a progressive lowering of efficiency. Therefore, the duration of work at a control panel during a working day was limited to 4 hours and 30 minutes. The remaining time (2 1/2 hours) the control panel workers used for other work. Also recommended was the alternation of work at the panel with other work processes. During the 4 hours and 30 minutes of work at the control panel, after every hour of work breaks of 10 minutes each for rest were organized (three breaks at the expense of the work time). Such a regime considerably improved the efficiency of the operators. In particular, the pulse and arterial pressure were stabilized, and during the program transmission they increased insignificantly (maximum arterial pressure increased by 12 mm mercury without a change in the minimum).

Stereotypic alternating of work and rest were justly called by A. D. Slonim (1962) vital stereotype, including in this idea not only muscular activity, but also periods of rest, taking of food, sleep, etc. E. I. Brandt and O. I. Margolina (1954) showed that the disturbance of a given stereotype leads to a decrease of the amount of work fulfilled, to a lowering of motor activity. The cited authors established that a regime of sleep and wakefulness, deprived of the rhythmical alternation of periods of work and rest, but preserving the normal relationship of work time and rest, does not lead to the disturbance of the normal diurnal rhythym of body temperature changes and is connected with the appearance of a new reflex to the setup: the ability to fall asleep at any time of the day, regardless of the previous period of sleep or wakefulness. Actograms recorded during sleep indicate equally profound sleep in the day and night hours. During complete disturbance of the rhythym of work and rest (with the loss of rest in a home setup) in the test subjects there were observed disturbances of the diurnal curve: increase of body temperature, pulse rate and arterial pressure during sleep (especially in the nighttime hours) which indicated serious disturbances in the interrelation of cortical and subcortical regulation. The diurnal stereotype reflecting basically the dynamics of distribution of the stimulating and inhibitory processes can vary with the disturbance of the conditions of rest, causing the appearance of fatigue. With serious overfatigue the dynamics of nighttime sleep deviates from the norm; the actogram shows agitated sleep, body temperature increases, which serves as manifestation of functional disturbances in the diencepholic region and partly in the reticular formation.

In organizing diurnal regimes of work and rest it is necessary to take into account the given initial conditions: a) the beginning and end of work time, b) duration of sleep during the day, c) the arrangement for taking of food, d) the change of the level of efficiency of the organism during hours of the day, considering that the astronauts will have "their own" during the course of the day.

The initial point for designing a regime of work and rest for astronauts is the characteristic of the active cycles of vital activity (work, sleep, active rest).

Great importance belongs to the time-study data of the variation of the work operations. From the curves of the duration of the work operation and the microintervals between consecutive work operations it is possible to form a preliminary opinion on the ordering of work and rest. Breaks for rest should be taken at times, which are most suitable for the work, including in them the processes of personal care.

Besides it is necessary to consider the changes according to hours of the day of a number of physiological indices (variation of body temperature, amount of sugar in the blood, excretion with the urine of hormones, ascorbic acid, etc.).

In regulating the nonworking time it is necessary to consider the individual interests of each participant of the flight in order to spend the time in carrying out favorite occupations.

Switching to a new activity in time free from work can be considered a variety of rest. It should not be a continuation of the work, fulfilled during the day.

In distributing the work load during the day it is necessary to start with a change of functional mobility of the nervous processes toward the end of the working day.

According to the Institute of Labor Hygiene and Occupational Diseases (IGTPZ) of the AMN of the USSR (S. A. Kosilov, 1957), in carrying out boring, monotonous work the functional mobility at the end of the working day decreases more, the more boring the work being performed, which manifests itself by increasing the duration of the work operations. Moreover, it appears that the change of functional mobility takes place mainly in that analyzer, which is taking the basic part in the work. For example, during work on a conveyer the change of functional mobility is observed in the motor analyzer, in proofreading work – in the visual analyzer.

In the experimental work of V. B. Liberman and T. A. Trubitsyna (1954) it was established that the difficulty of work for man is determined by the influence of the totality of signals from within and from the environment, which are connected with the amount of work produced, including verbal stimuli. At the same time the formation of a working stereotype does not simultaneously embrace all physiological functions.

In constructing regimes of work and rest it is necessary to give attention to the questions of eliminating sensory deprivation during prolonged space flight and to the organization of psychic stimuli (interest in the labor process). It is necessary to vary the form of the work as much as possible for automating of certain work operations.

An effective way to compensate for the sensory deprivation is by activating the intellectual processes and by employment of the astronauts' ability to organize their thoughts and ideas. Moreover, it is impossible to forget Ewrard's opinion (1959), which in the work "The Conditions of Man's Sojourn in a Spaceship" emphasized that usually the mechanisms of man's adaptation to the conditions of isolation and sojourn in a limited space were examined from a purely psychological point of view. In reality they are more complex and are based on neurological and endocrine substrata. Prolonged or repeated stress can lead to the exhaustion of the adaptational possibilities of certain physiological systems.

Henry (1958) indicates the importance of motivation and moral qualities as factors providing the best indices of activity. The personality of the astronaut affects his motivation, individual reaction and his interaction with other members of the crew. The importance of motivation and the purposefulness of the work was also noted by Jmus (1961).

Experiments with isolation showed that the organs of sight must be in continuous action (replacement of illuminance and color gamma), otherwise the ability to perceive a stable image is lost. Also attention is turned to the safeguarding under conditions of insulation of a sufficient level of attention (vigilence). During work with equipment, especially with oscillographic indicators, visual fatigue sets in after short time (30 minutes). For the purpose of preventing fatigue and increasing vigilance the use of pharmacological means (benzedrine) is suggested.

Edward and Eddowes (1961) came to the conclusion that the construction of a space cabin responding to the physiological requirements of man reduces the influence of isolation.

Gerathewohl (1959) considers that a prolonged stay in an isolation cabin leads to disturbances of the physiological functions of the organism, causing a sharp lowering of appetite, insomnia, profuse perspiration, irritableness and loss of weight. The productivity of mental work (addition and subtraction of single-digit numbers) worsens, not in a quantitative, but in a qualitative respect.

The monotony of the work and the setup, which characterizes the conditions of the stay in a spaceship during prolonged flight, caused diffused inhibition in the cerebral cortex as a result of monotonous and weak stimulations.

It is characteristic that foreign authors until recently did not pose the question about the possible compensation of the insufficient exteroceptive stimulations by proprioceptive ones, in particular by physical exercises, for the purpose of maintaining the tonus of the cerebral cortex at a proper level.[1] Meanwhile the

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[1]Only in the flight of the Gemini-II were physical exercises (3 times per day, 10 minutes each) included in the order of life of the astronauts.

necessity of including a strict motor regime in the order of the day for astronauts has been repeatedly emphasized by researchers in our country (A. V. Korobkov, 1962; T. T. Dzhamgarov, 1962, and others).

This point has definite significance in the theory of the interaction of analyzers developed by Soviet scientists (A. V. Lebedinskiy, 1963; Yu. G. Grigor'yev, M. D. Yemel'yanov, 1962, and others).

Thus, an astronaut regime will depend on the number of personnel in the crew, on the problems confronting each member of the crew, on the character and duration of the space flight.

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SENSORY DEPRIVATION IN SPACE FLIGHT

Prolonged space flights have put in the foreground a number of new medico-biological problems connected with the influence on astronauts of new and unusual conditions of existence. One of such problems is the study of the efficiency and he behavior of man during a prolonged stay in an isolated space of small volume.

As a result of the absence of contact with the external world (the space is closed) and the little motor activity (the space is limited in volume) sensory environment in space flight reduces to a series of simple, monotonous and constantly repetitive stimulations.

To the study of the consequences of the effect of sensory limitation there have been dedicated a considerable number of research works. Especially important are the investigations dedicated to the study of the effect on the organism of the limitation of external sensory information under conditions of isolation.

The effect of isolation has been studied from very diverse points of view; in the social and demographic sense (prison isolation, the life of hermits); in a psychological aspect, during the formation of small collectives living and working in autonomous colonies (during prolonged sailing in small vessels and submarines, in polar expeditions); there have also been studied casuistic cases of isolation (people who have experienced shipwreck, speleologists); investigations have been conducted for clinical purposes (study of the behavior of mental patients) and, finally, in the experimental sense, for the clarification of certain theoretical questions of physiology and psychology, for example for clarifying the mechanisms of the interaction of analyzers, and others.

It is necessary to note that the problem of sensory deprivation was posed in our country back in the 20's. The initiation of the study of the problem of the effect of sensory starvation on the organism was I. P. Pavlov. In 1923 he conducted an analysis of the state of a patient with affected visual and auditory analyzers, on the basis of which was drawn the conclusion that for normal activity of the cerebral cortex it is necessary to have a definite influx of stimulations. The weakening or the elimination of afferent impulses leads to the appearance of a deep, so-called passive, inhibition. These fundamental considerations lay at the basis of the works of V. S. Galkin (1932), who showed that the experimental shutting down of sight, hearing, olfaction in dogs leads to the appearance and propagation of diffused sleepy inhibition (passive sleep).

The systematic study of the effect of sensory deprivatory in the interests of special physiology began abroad in the 50's. In experiments there were created various conditions of isolation and sensory limitation from the most drastic (placing in a plaster cast, shutting down the analyzers, etc.) to the relatively simple (sojourn in a soundproof chamber). Moreover, abroad there have been employed more drastic forms of isolation in contrast to those of our domestic researchers, who have tried to simulate the situation of isolation with respect to actual space flights. As a methodical prerequisite of works connected with the problem of sensory deprivation there can be considered the idea formulated by Miller (1958) and concluding that in the life of living beings there have to be distinguished specific information processes and phenomena, which are of an energetic nature. At the basis of this concept lies the initial position to examine the whole variety of processes and phenomena of organic life as information, the nature of which is determined by the level of complexity of the organisms or "living systems."

Miller (1953, 1958) made an attempt to unite this information theory of his with the theory of G. Sel'ye concerning the adaptational syndrome (stress) and with the theory of nervism. According to Miller, there exists between the organism and the environment a definite connection through stimuli causing specific reactions, which he defines with the idea of stress. Information comes to the organism and the organism responds to it with outgoing information (reactions).

In the opinion of Flaherty (1961), it is difficult in space flight to articulate a particular individual stressor and the shifts in the organism caused by it, and therefore a full-value determination of the stresses and changes in the activity of the organism is possible through the united efforts of different specialists. Werdwer (1961), however, does not attach great importance to stress under conditions of astronaut work, since he considers that the astronaut can suppress the state of physiological stress by an effort of his will. Werdwer modified the concept of stress and defined it as a state appearing in the human organism in the process of performing a task and impelling him to cope with it.

Sensory underloading or sensory loss is acceptably denoted by the term "sensory deprivation" (in the following account we will designate this term by the abbreviation SD).

Isolation and Sensory Deprivation

The pioneer of experimental investigations in studying the field of isolation and SD abroad was the great Canadian physician, physiologist and psychologist Hebb, who conducted the first experiments (carried out as early as 1934) with test subjects situated in SD-rooms or soundproof chambers. Numerous experiments on animals (rats, rabbits, apes) for the purpose of studying the influence of SD on behavior and higher nervous activity were performed Lilly (1956), Bexton, Heron, Scott (1954), Heron (1957), Miller (1958) and others. These investigations revealed that in SD there develops a state of apathy, inhibition of motor activity and a general lowering of the tonus of the cortical functions.

Analogous data were noted in observations on people. Thus, a study of the psychic status of healthy persons against a background of SD was conducted by Petric, Collins, Solomon (1958), Petric, Ormaston (1958), Ruff, Levy, Thaler (1959) and others, who noted a general lowering of psychic activity and efficiency, a reduction of emotional stability, the appearance of a disturbed state, sometimes a sense of hostility towards the experimenter and, finally, disorganization of thinking and internal speech.

Simultaneously experiments were conducted studying the influence of SD on the state of people suffering from psychic and nervous diseases (Lilly, 1956, 1960; Cameron, 1963; Svab, Gross 1965, and others). Thus, if mental patients (schizophrenics, senile and hyper-senile psychotics) are placed in a dark room, even with incomplete soundproofing, many of them will experience hallucinations, excitation and other symptoms of their basic illness (Cameron, 1963). Hence the conclusion was drawn that the lowering of the flux of external afferentation, in particular, the depriving of people of visual perceptions, especially people with weakened nervous systems is a unique model for the study of the influence of SD on the functioning of the central nervous system.

Since the middle 50's experiments on SD have attracted even greater attention from the scientific research centers of the army, air force and navy in the United States and Canada. Situations, in which individual persons and groups find themselves during war and peace time, in their effect on the nervous system are very similar to the effect of SD (submarine duty, winterings at polar stations, sojourning at uninhabited desert site).

The results of these investigations were correlated at symposia in Boston (1958) and at Harvard Medical School (1959).

General Characteristics of the Experiments

Numerous experimental works conducted for the purpose of studying the influence of SD on the organism can be classified according to the degree of isolation and sensory information in the following manner: a) relative and more rigid isolation (for fast obtaining of the effect); b) limited communication with the external world in a room and in a small cabin (limitation of quarters); c) individual and group isolation, where individual isolation within the group is also possible; d) relative immobility (limitation of size of the quarters) and rigid immobility (strapping down with belts, putting one in a plaster cast, etc.).

Under conditions of real space flights, abviously, there will take place a combination of various forms of isolation and limitation of sensory extero- and proprioceptive stimuli. Moreover, considering the small load on the motor analyzer under conditions of weightlessness, it is possible to assume that during prolonged stay in the cabin of a spaceship all phenomena of sensory deprivation will obtain still sharper expression.

Jaxon and Helly (1962), who carried out an analysis of certain experimental works on the study of the effect of SD on organism, consider it necessary tc take into account the following peculiarities of the given experiments: the character and force of the stimuli, the significance of the stimulus for the subject, the degree of limitation of movements, the characteristics of social isolation.

The numerous methodical procedures, used by different researchers for decreasing the stream of afferent impulsation, can be reduced to the following:

a) absolute reduction of sensory stimuli (Lilly, 1956; Heron, 1957; Henry, 1958, 1961; Edwin and others, 1959; Ruff, 1959; Ewrard, 1958; Ruff and others, 1961; Jonekcheere and others, 1959, and others);

b) reduction of the informativeness of the stimuli (Miller, 1953);

c) increasing the monotony of the sensory environment without removing the stimuli (The Laboratory of Psychiatric Investigations at Harvard Medical School, 1959; Burns, 1963).

The conditions of experiments were quite varied. Various procedures were employed for limiting the size of the quarters and creating conditions of isolation (a dark room with soundproof walls, a soundproof chamber; a room with partial soundproofing or with normal sound conductivity; an SD-room upholstered with foam plastic, etc.) and different methods of limiting sensory information (special eyeglasses; a mask for the eyes; headphones carrying "white noise"; cardboard handcuffs; special gloves taking away the tactile perception of the hands and feet; a bathtub with water heated to body temperature, etc.). The experiments varied according to duration and strength (rigidity) conditions. In all cases in the investigation a uniform contingent of test subjects was selected and the experimental and control groups were isolated.

The results of the experiments were evaluated on the basis of an analysis of objective physiological indices, recordings in diaries during and after the experiment, conversations with a psychologist and psychiatrist (particular attention was paid to the presence of visual and auditory hallucinations), and the quality with which the different psychological tests were carried out. Also considered were the general condition and behavior of the test subjects.

The Effect of SD on the Human Organism

Analyzing the results of the experimental material, it was possible to classify all changes occurring in the human organism under the influence of limited sensory information, into three basic groups: a) changes of the functions of the cerebral cortex; b) changes of the emotional sphere; c) vegetative shifts.

In the opinion of Heron, Bexton, Hebb (1956), the maintenance of normal controlled (by the mind) behavior requires the continuous reception of sensory information. Prolonged isolation leads to serious changes in the psychic sphere of man, which manifest themselves by disturbing of his mental efficiency. As a result of prolonged rigid isolation Ewrard (1959), Jonekcheere, Henrotte and others (1959), Denenberg, Morton (1962) and others noted in the test subjects the development of pessimism, a disturbed state, depression, and a reduction of the emotional tonus and mental abilities.

The same phenomena were observed in the experimental investigations of Graybiel, Clar (1961) who studied the conditions of piloting of aircraft and noted that about 36% of the pilots during flights at high altitude in a single-place aircraft experienced a sense of isolation from the earth.

During high-altitude flights in balloons, as described by Simons (1958, 1959, 1962), there appeared a feeling of isolation from the earth, accompanied by auditory and visual hallucinations.

According to Henry (1961), Lilly (1963) and others, during SD-experiments in the test subjects there was noted inappropriate behavior and disturbance of the psyche; various hallucinations were observed, which had a fantastic character or corresponded to real forms. Hence conclusions were made about the possibility of the appearance in healthy people under conditions of space flights of psychopathological symptoms.

As a characteristic example in the study of the effect of SD on the organism it is possible to cite the experiments of Heron, Bexton (1956), conducted on students during their insulation in special rooms. The test subjects were in a supine position on comfortable couches. The possibility of visual, auditory and tactile perceptions was artificially excluded: on eyes were placed eyeglasses with light-absorbing filters, on the ears — audiphones, on the hands — special cardboard cases. The intake of food and physiological functioning were carried out as necessary.

The reaction of these test subjects was characterized by appearance of a sense of "hunger" with external impressions, which led them to motor disquietude (several, for example, thrashed their hands against the walls of the room). The absence of any distinct mental representation weighed on the test subjects: they slept or they lay awake. The majority refused to continue the experiment after 24-72 hours. Those remaining in the room for more than 2 days had visual hallucinations.

The hallucinations appeared in cases with rather drastic limitation of sensory information. This phenomenon was observed by Ruff (1961), Henry (1958, 1961) and others.

Chunningham (1960) indicates that under conditions of isolation a person in the beginning behaves in a very extreme manner towards the hallucinations; then the critical attitude towards them vanishes and they acquire an overpowering significance. In the opinion of Ruff (1961), hallucinations induced by drastic conditions of isolation can lead to complete disintegration of the personality.

An important means of testing in the selection of astronauts is the ordeal in a soundproof chamber. For many test subjects a prolonged stay in solitude causes the appearance of hallucinations.

The more realistic the hallucinations are in their content the greater danger they present for the pilot of a spaceship (Bohem, 1962).

Heron (1957) describes the existence in test subjects situated in a soundproof chamber of disorganized thinking, false sensations right up to hallucinations, physical and psychic fatigue, and boredom, which lead to the lowering of motivation.

Sanford, Silverman, and Shmavonian (1962), and Van Wulften-Palthe (1961) refer to very similar phenomena of the lowering of overall physical and psychic tonus and the loss of motivation.

A number of research workers point to the state of stress appearing under conditions of isolation, where some of them consider this phenomenon characteristic for the whole period of stay under these conditions (Hahna, 1962; Heron, 1957; Sanford and others, 1962), and others (F. D. Gorbov, V. I. Myasnikov, V. I. Yazdovskiy, 1963) define the given state as analogous to the prelaunch state. Under conditions of isolation, in the opinion of F. D. Gorbov, V. I. V. I. Myasnikov, and V. I. Yazdovskiy, a state of fatigue develops. The development of fatigue is also indicated by Graybiel and Clark (1961), M. B. Umarov (1962), Sanford and others (1962).

We find a similar picture in the description of experiments of strict isolation, presented by the French researchers Jonekcheere, Ewrard, Henrotte (1959). The test subjects were given instructions to regulate the composition of the atmosphere. In proportion to the duration of the experiment there was observed the appearance of symptoms of fatigue and a disturbed state in the change of the composition of the air (it subjectively seemed to the test subject that the percentage of carbon dioxide was increasing, although objectively its amount remained normal).

Many researchers note considerable changes in the emotional sphere of test subjects in SD-experiments: the appearance of various degrees of apathy, depression, alarm and fear (Heron, 1957; Sanford and others, 1962, and others).

Sometimes apathy and clouded consciousness in the people had such profound forms that one of the most important instincts – the instinct of self-preservation – was destroyed, and the person was close to suicide (Chunningham, 1960).

As noted above the serious disturbances of the psychic life of the test subjects, which were pointed out by foreign authors, obviously, were connected with the excessive loading of the organism of the test subjects by the rigid conditions of the experiment. And the point here was not only the fact that the factors of isolation and sensory deprivation were acting, but also a number of additional factors complicating the situation of the experiment (being strapped down by belts, being situated in a plaster cast, the uncomfortableness of the position, sometimes sensations of pain, etc.). The absence in the test subjects of conscious motivation in carrying out similar kinds of experiments which are not a model of the real conditions of life and work of man, also has indubitable significance.

Being based on experiments of extraordinary rigid isolation, which is not peculiar to real space flights, as a result of which, naturally, many test subjects actually were on the brink of psychic disorders, American psychologists began to attribute excessive importance to the factor of isolation in space flight (Lilly, 1960; Denenberg, Morton, 1962, and others). In their articles it is pointed out that in actual interplanetary flight there will be apprehension and fear of complete estrangement from earth.

In this direction experiments were conducted by the American Lilly (1956), who placed test subjects in a tank with warm water (to simulate weightlessness); for isolation from light and sound the test subjects put on masks. Under such conditions the people rapidly began to experience disturbed psychic activity and visual hallucinations.

The American scientists who described numerous hallucinations during the prolonged isolation of these healthy people, obviously expanded the idea of hallucination, including in it certain forms of sensory deception and eidetic representations. An example of including eidetic representations in hallucination can serve the utterance of one of the American subjects, which spoke of his feelings this way: "I saw a rattlesnake, but, fortunately, understood that it was unreal." However, the researcher (Lilly 1956) nevertheless assessed this state as a hallucination. Such sensory deceptions usually occurred only in those persons, who were not able to be occupied with anything in the hours, not regulated by the program, and they did not appear at all during the carrying out of an assignment.

Experiments with the limiting of stimuli under conditions of isolation, conducted by Soviet scientists, showed that a healthy person with high moral-volitional qualities can be for a prolonged time situated in a soundproof chamber without any kind of psychic changes threatening the state of his health. The various specific sensory deceptions which arise do not bear a morbid character. This form of sensory deception (pseudopsychopathological phenomena) pertains to illusions which are connected with the incorrect perception of stimuli, the informative characteristic of which is insufficient (O. N. Kuznetsov and V. I. Lebedev, 1965). The illusions by themselves are not a symptom of psychic disease and are frequently encountered in healthy people, especially in those cases, when something disturbs the distinct perception of visual and auditory forms, for example bad illumination.

The initial mental condition of people: fatigue, dispersiveness and the state of expectation and fear, has great significance.

O. N. Kuznetsov and V. I. Lebedev (1965), describing the presence in the subjects during investigations in a soundproof chamber of illusions of a type of errors of recognition due to insufficient information, the sense of an outside presence, eidetic representations, ideas of relationship and supervaluable ideas, do not consider these phenomena pathological and propose to call them pseudopsychopathological. According to F. D. Gorbov, V. I. Myasnikov and others (1962) psychopathological phenomena in Soviet astronauts during tests in a soundproof chamber were absent.

Soviet scientists consider that the factor of isolation must be studied in reference to the conditions which can take place in space flights. Most important of all here, obviously, is the fact that the person believed in the necessity of the task carried out by him, and this clearly recognized the points of the given investigations. Each experiment was in the soundproof chamber – that is the moral and volitional test for future astronauts, which prepares them to fulfill the most complex assignments.

In the works of American researchers, in particular Heron (1957), it was noted that SD had a destructive influence on efficiency and purposefulness and frequently led to the refusal to undergo any further stay under conditions of isolation due to the development of boredom. How far boredom was seen as a negative phenomenon is attested by the fact that this mental condition in certain works of foreign authors obtained the name "enemy number one."

Henry (1958, 1961) and Hebb (1959) point to boredom, its destructive influence on efficiency and psychical purposefulness. These same authors note the development of a state of depression and apathy, and also an increase of suggestibility and emotional instability. Frequently there was also noted the appearance in the subjects of a sense of euphoria, indicating the lowering of control on the part of the cerebral cortex over the functions of the subcortex.

The state of euphoria appears before the end of the experiment or immediately after it and is characterized by highly inadequate (to the situation) excitation, when the subjective appraisal does not correspond to the objective impairment of the functional state of the organism (Van Wulften-Palthe, 1961; Sanford, Silverman, 1962, and others).

According to M. B. Umarov (1962), the state of euphoria in the course of the experiments disturbed sleep and inhibited the restorative processes of the nervous system. M. A. Gerd (1963) and N. Ye. Panferova (1964) noted the appearance at the end of experiments of a state of euphoria, despite the fact that during the experiment a state of apathy was predominant.

Gerathewohl (1959), Ewrard, Henrotte, Jonekcheere (1959), N. A. Agadzhanyan and A. G. Kuznetsov (1962) indicate an impairment of the mental abilities during the prolonged stay of subjects in a soundproof chamber. Bexton, Heron, Scotte (1954) describe cases, when the subjects lost the ability to think systematically and efficiently — there arose so-called blank periods.

All these phenomena cannot fail to have an effect on efficiency. Chunningham (1960) notes that first of all the qualitative side of the work activity suffers, and during complication of assignments there is observed a lesser degree of psychological and physiological improvements in view of the appearance of a certain interest toward the assignment being carried out. Ewrard (1958), Ewrard, Henrotte, Jonekcheere (1959) detected an increase of tonus of the vagus nerve because of the development of fatigue, due to disturbance of sleep and the presence of discomfort.

In all experiments with rigid SD considerable vegetative reactions were observed: quickening of the pulse rate, a sharp increase of adrenaline into the blood, perspiration, impairment of appetite, etc.

Many authors speak about a distortion of the sense of time, other false sensations, of the loss of adequate reactions during strict isolation in soundproof chamber tests (Henry, 1961; Ruff, 1961; Chunningham, 1960; B. A. Dushkov and F. P. Kosmolinskiy, 1966).

Despite the stabilized opinion, that in the absence of an influx of new impressions time "stretches infinitely," a group of research workers noticed the reverse phenomenon. In this respect the experiment of the French speleologist Michel Cifre is interesting (1962): he descended under the earth to a depth of 130 m in the Skarsson ice cave and spent there more than 1500 hours (62 days) for the purpose of studying the influence of prolonged solitude and the absence of communication with the external world on the sense of time. Inasmuch as under these conditions it was impossible to observe the alternation of day and night the orientation in time was disturbed very quickly. For Cifre "the continuity of time disintegrated." After 40 days it seemed to him that only 25 days had elapsed. When the experiment was finished, he stated that he had not surmised that the end was so near. The same was noted by the speleologist Josef Lourres (1965) who stayed 3 months in Vinneron cave, and Antoine Sennit (1965) who stayed 125 days in Olivieu cave. Thus, on the 2nd of April when Sennit was notified that the end of his experiment was imminent, he was very surprised, because according to his calculations it was only the 6th of February.

Psychophysiological Mechanisms of Shifts During SD

A number of authors stand on the point of view that at the basis of the mechanism of psychic changes during SD is the appearance of inhibitory processes in the cerebral cortex, which depend both on the sensory underloading of the cortex itself, as well as on the lowering of the flow of afferent impulses going into the cortex from the subcortex and the reticular formation of the brain stem (Henry, 1958; Hebb, 1958; Heron, 1957; Miller, 1958).

I. P. Pavlov considered that the attenuation or the shutting down of afferent impulses leads to the appearance "of passive" inhibition. Analyzing the data of the works of V. S. Galkin (1932) on the shutting down of the functions of a number of analyzers in dogs, I. P. Pavlov indicated that under these conditions there takes place a lowering of tonus, attenuation of the stimulation process, which facilitates the appearance and propagation of inhibition in the cerebral cortex.

The experimental study of the visual analyzer under conditions of lowered illuminance made possible the assumption expressed by A. V. Lebedinskiy (1958), about the fact that in cases of a lowered state of tonus of the cortex the development of the inhibitory process during the stay in darkness will be expressed rather distinctly. A. V. Lebedinskiy in his experiment on animals noted the disturbance of the balance between the motor and vegetative components during the stay in the darkness. The cause of the strengthening of the vegetative reactions sees in the appearance and irradiation of the inhibitory process in the cerebral cortex.

Henry (1958, 1961) explains the appearance of the psychopathological symptoms during isolation by the disturbance of the balance between internal information and information from the sensory organs, recording everything occurring during sleep. Higher nervous integration is disturbed. Internal information becomes predominant, as a result of which hallucinations, disturbed dreams and other phenomena appear.

It is possible that the development of passive inhibition against the background of the lowered excitability of the nerve cells is specific for sensory underloading, since, according to a number of authors, the thresholds of sensitivity during the use of electrophysiological methods turned out to be raised (Heron, 1958).

A number of foreign researchers considers that sensory adaptation is carried out with help of the reticular formation (Miller, 1960; Megun, 1962).

Under conditions of sensory isolation, when the reticular system is deprived of sensory flow, it falls into an unusual situation and adapts to it, as far as this accumulated reserve of information in subcortex permits it (the numerous complaints of the subjects to the unusual influx impressions of the past, with which they "cannot cope").

The attenuation of the customary background of stimulations, and also the removal from the sensory environment of the unusually strong or unusually weak stimuli develop not only the inhibitory process in the central nervous system, but also generate a group of reactions (especially cortical ones) of a stimulation nature, which replenish the deficiency of stimulations. At the same time there exists the possibility to examine SD as a special form of stimulus, inasmuch as the experiments showed that the reactions to SD are fully comparable with the reactions to individual specific stimuli and to sensory overloading (Hahna, 1962).

The sense of alienation, fear, the appearance of illusions of the position of the body in space Hebb (1958) connects with the excitation of the lower and medial surfaces of the temporal lobe of the brain. Hahna (1962) considers that participating in this is not only the temporal lobe, but also the visceral part of brain and the hypothalamus. This same researcher advances an assumption about the overexcitation of the parasympathetic nervous system during fear right up to the stopping of the heart in diastole.

Consequently, isolation and SD cause complex psychophysiological reactions in man's organism, which it is necessary to examine as comprehensively as possible. On this matter, Ewrard (1958) in his report "The Conditions of Man's Sojourn in an Interplanetary Ship" justly wrote that "...usually the mechanisms of man's adaptation to conditions of isolation and sojourning in a limited space have been examined from a purely psychological point of view; in reality they are more complex and rest on a neurological and endocrine substratum." Strong or repeated stress can lead to the exhaustion of adaptation and to the failure of certain physiological systems.

During SD a system of protective reactions acts on different levels of the organism (the entire organism, the nervous system, the organ, the cell), which are examined as a struggle of living beings for information (Miller, 1958). Certain experiments on the adaptation of the organism to SD testify to the biological significance of this factor in the life of the animal. Obviously, the higher the organism stands on the evolutionary ladder, the more difficult it is for it to adapt to SD. In the opinion of Miller, the more complex the "living system," the more information it requires for its "nutrition."

Thus, sensory isolation as a result of the absence of contact with people and the external world and little motor activity causes fatigue, stress, a state of diffused inhibition, which leads to physiological and vegetative shifts in the organism, but this in turn leads to a lowering of efficiency, a loss of vigilance, etc., in other words — to a lowering of the possibility of obtaining information by the organism itself.

Hence the importance of solving the problem of sensory deprivation is understandable, since the struggle with consequences of the influence SD emerges as a struggle to increase the efficiency and the reliability of the work of the whole system.

Prophylaxis of the Influence of SD on the Human Organism

One of the decisive factors in this respect is the organization of internal stimuli: interest in the work process, the variety of forms of work, a sufficient degree of loading, a definite level of complexity of the tasks can be a rejection of complete automation of certain processes (Henry, 1961; Thomas, John, 1960; Yu. K. Dem'yanenko, 1962).

Ruff (1959) proposes to produce the automation of reactions, but under the condition of the presence of various interesting tasks. An effective compensation for sensory deprivation, in his opinion, is the intellect itself, the mental faculties of the subject, his skill to organize his thoughts and ideas. Heron (1957) also points to the importance of this factor.

We encounter this same thought in the work of Chunningham (1960), who considers that the only salvation from the development of disintegration of personality under conditions of isolation is the possibility to occupy oneself with some form of activity that is significant and purposeful. Chunningham cites the case of the seven-year isolation in a deep cave of a doctor Boun, whose psychic equilibrium was maintained thanks to correctly organized and purposeful activity.

Ruff (1961) and Chunningham (1960) also note that the intellectuality and the employment of people with some forms of activity, if they are significant and purposeful, prevent the appearance of hallucinations.

Experimental data indicate that strong-willed, purposeful people are able under conditions of isolation for a rather prolonged time to preserve and even to increase the indices of their mental efficiency (Heron, 1957; Graybiel, Clark, 1961; Ruff, 1959; Henry, 1958, and others).

In special literature there is widely illuminated the role of motivation and the volitional processes in human activity. To the importance of motivation and moral qualities as factors ensuring the best indices of activity point Edward and Eddowes (1957), Henry (1958) and others in their works. Psychic tone and motivation influence the reaction of the individual, his interaction with other members of an isolated group (or crew). The main consequence of boredom is considered by Henry (1961) to be ineffectiveness and negligence of actions. So that the readiness of astronauts for immediate actions in a critical situation is maintained at a high level, it is proposed to vary their work during a prolonged period of flight (Chunningham, 1960; M, B. Umarov, 1962, and others).

We find a good example of tolerance of insulation in the work of Henry (1961) in connection with the analysis of questions of the influence of motivation, and also the organization of interesting and various activity for the personnel of the submarine "Nautilus" during prolonged autonomous sailing.

Experiments of Hebb (1958) on isolation showed that the organs of sight should be in continuous action (the alternation of illuminance and color gamma), otherwise the ability to perceive a stable image is lost. Obviously, this can have meaning under conditions of space flight during work with instruments on a control panel, when the prolonged intense concentration of attention takes place against the background of general sensory limitation and the monotony of the situation, which can lead to a definite mismatch in the functions of the analyzers (overloading of the visual during underloading of the auditory, muscular and others). Markworth (1962) also pays attention to the safeguarding of the normal work of the organs of sight and of a sufficient level of attention (vigilance). In work with equipment, especially with oscillographic indicators, in his opinion, sight fatigue appears after a short time (30 minutes). For the purpose of prophylaxis of fatigue and the increase of vigilance he proposes the use of pharmacological substances (benzedrine).

Sanford and others (1962) for creating a favorable emotional background and increasing the functional abilities of the central nervous system also recommend certain pharmacological agents (stimulants of the benzedrine or ampetamine type).

The emotional color of the activity of the astronaut has important significance. As is known, suppression of emotional tonus leads to a lowering of efficiency (Corkindale, 1961, Hahna, 1962; M. B. Umarov, 1962). An increase of emotional tonus and consequently, an increase of efficiency is attained by the introduction of physical exercises (Ruff, 1961; T. T. Dzhamgarov, 1962; M. B. Umarov, 1962; A. V. Korobkov, 1964, V. L. Marishchuk, 1966). Ruff (1961) considers that the bombardment with proprioceptive impulses during physical exercises maintains the tonus of the cerebral cortex at a proper level, examining this phenomenon as a factor of the compensation of deficient afferent stimuli.

Edward and Eddowes (1961), proceeding from the data obtained by Beeton and Gerathewohl (1959) in studying the operation of isolation, came to the conclusion that the construction of the space cabin, responding to the physiological requirements of man and his individual demands, can reduce the effect of isolation.

In order to combat the disturbance of the psychic functions as a result of the lowering of information level of the brain cortex, the astronaut should have an idea about them, understand the cause of their origin – hence the necessity of preliminary instructions as indicated by Henry (1961).

In solving the problems of future prolonged flights there appears such a serious question, as the recruitment on reasonable terms of crews for multiseat spaceships. There rises the important problem of human psychology under conditions of the prolonged existence of a small organized group. Experiments simulating space flight showed that being situated in a limited space involves raised excitability, which in individual cases changes into hostility. The presence in the cabin of two or more astronauts can negatively reflect on their work capacity, which, obviously, will be directly proportional to their interdependence (Gross, Šv̄ab, 1965).

Hence the necessity of a thorough study of the question of "psychological compatibility" under conditions of sojourning in a limited space with small volume. Abroad (mainly in the United States) considerable attention has been allotted to this question for the purpose of developing requirements for the characteriological peculiarities of individual members of a crew, in whose combination the appearance of serious conflicts is least probable. The importance of the problem of "psychological compatibility" is indicated in the work of F. D. Gorbov and F. P. Kosmolinskiy (1966).

In conclusion it is necessary to note that the problem of the influence of isolation and sensory deprivation on the human organism is very serious. In prolonged space flight negative sides of the sojourning of man or a group of people in a closed space with small volume can appear to a certain degree. This is why further study of this problem and the development of a whole system of measures and procedures, which prevent the development of undesirable shifts in the organism, are necessary.

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INFLUENCE ON THE HUMAN ORGANISM OF MODIFIED AFFERENTATION

The problem of man's adaptation to the conditions of prolonged space flight includes questions of the interrelations of the afferent systems of the organism with the modified and customary environment in which he is living.

Under conditions of space flight it is possible to expect an alternating influence on the organism of modified afferentation – of sensory underloading and sensory overloading (sensory deprivation and sensory bombardment according to the terminology of Miller, 1958).

The change of the "spectrum" of stimulations under conditions of space flight leads to load variations on the analyzers of the nervous system. The load on the visual, auditory, muscular-joint and other analyzers most frequently decreases, which makes it possible to talk about sensory deficiency or underloading (deprivation). In certain cases, during special or complicated conditions of flight, the load on the analyzers systems can be increased and then sensory overloading is indicated.

In the opinion of Miller (1958), the adaptation of the organism to the changing conditions of life includes not only energy equilibrium, but also equilibrium between incoming and outgoing information. Hence the conclusion is drawn that any essential disturbance of the regime of incoming information can lead to serious functional disturbances in the organism.

It is assumed that among the factors affecting the organism during prolonged space flight, great specific weight will belong to the so-called "situational" factors, in particular isolation, constancy and monotony of stimuli and especially sensory deficiency. Leaving aside other "situational" factors having indubitable psychophysiological importance in space flight (the feeling of isolation from earth, change of spatial orientation, the absence of a sense of support, etc.), we focus our attention on sensory deprivation (sensory underloading) as a synthetic factor having great influence on the transformation of the overall functional state of the organism and the structure of the dynamic stereotype of higher nervous activity.

During prolonged space flights man can find himself under the influence of different forms of impoverishment sensory stimulations, which depend on a number of causes, of which it is possible to indicate the following.

1. Insulation of an individual or group of people (social isolation), i.e., the absence of contact with the external world and other people, which is accompanied by the sharp reduction of external (exteroceptive) afferentation.

2. Sojourning in a small (limited in volume) space is conducive to little motor activity (hypokinesia or hypodynamia) and secondly to the reduction of internal (interoceptive), mainly proprioceptive, afferentation.

3. Weightlessness, with which there occurs a change of the character of motor reactions as a result of a sharp decrease of the stream of internal afferent impulsation.

4. General lowering of the stream of external afferentation, i.e., the scantiness of visual, auditory and other stimulations during a prolonged influence on the organism of a monotonous and limited circle of stimuli (monotony of situation).

The problem of sensory deficiency has been illuminated by numerous theoretical and experimental works, in which the researchers pay attention to the considerable shifts in the psychic activity of the subjects situated in a closed space with small volume. Thus, under conditions of prolonged isolation for the subjects experienced decreased general physiological tonus, sleep was disturbed, the functions of attention changed, sensorimotor reactions deteriorated, there appeared a state of nervous tension, sometimes apathy, etc. (Heron, Bexton, Hebb, 1953; Lilly, 1956; Hebb, 1958; Ruff, 1961; Hahna, 1962; Sanford, Silverman, Shmavonian, 1962; F. D. Gorbov, V. I. Myasnikov, V. I. Yazdovskiy, 1963; V. I. Myasnikov, 1964, and other)[1]

However, it is hardly possible to expect, that under the conditions of real space flight in the presence of the clearly expressed motivation in the behavior of astronauts, with the contemporary system of selecting and training them, there can appear such serious pathological states, psychic depression, hallucinations and even disintegration of the personality, which is indicated by certain foreign researchers, based on their own experimental data (Heron, 1957; Hauty, 1960; Horowitz, 1964, and others).

Sensory underloading, or "sensory hunger," can lead to a reduction in efficiency and functional working "of vigilance" ("operational attention"). Even in the 50's under conditions of aerial flights the appearance of diffused carotid inhibition was noted in pilots in cases of flying of aircraft by instruments (F. P. Kosmolinskiy, 1954). The evident influence of situational monotony, uniformity of stimulations and a reduction in the stream of external afferentation was present. The introduction of automation into aerial navigation attracted the attention of specialists (V. A. Popov, A. M. Pikovskiy, Ye. I. Ivan'kov and others) to this question.

In the soundproof chamber investigations with a duration of 10-15 days conducted by F. D. Gorbov, V. I. Myasnikov, V. I. Yazdovskiy (1963), there was noted the development in subjects of complex

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[1]These questions are illuminated in detail in a survey article of F. P. Kosmolinskiy and Z. D. Shcherbina in this collection.

physiological changes depending, in the opinion of the authors, on the limitation of external afferentation. In the first days of the experiments there was noted the intensive excretion with urine of 17-ketosteroids, indicating the development of emotional stress in the subjects. In subsequent days the authors noted oppression of the functions of the suprarenal gland and the development of phenomena of fatigue. The monotony of the surrounding setup, the poverty of external impressions and solitude came into the experiment as factors having an independent significance, as conditons and causes of the development of stress and fatigue.

Simultaneously with the study of questions of the influence on the human organism of the deficiency of external afferentation there were conducted numerous investigations of the influence of the deficiency of internal afferentation depending on the change of the gravitational field (weightlessness) and the limitation of mobility under conditions of sojourning in cramped quarters (hypodynamia). Our astronauts, like the American astronauts during orbital flights of prolonged duration were in a lying position, and the working operations carried out by them did not require great physical loads and active movements. This circumstance led to a reduction in the overall functional tonus of astronauts (I. M. Arzhanov, A. V. Beregovkin and others, 1966; I. M. Arzhanov, I. I. Bryanov, V. A. Baturenko, P. V. Buyanov and others, 1966). However, under the conditions of real space flight the astronauts are under the influence of a complex of extreme stimuli. Therefore, it was natural that the researchers wanted to analyze the isolated influence of the factor of prolonged immobility on the human organism. In this direction, for example, there were carried out the works of Graveline (1962), Yu. V. Vanyushina (1963), L. I. Kakurin and others (1963), Lubek, Wilgosh (1963) and others.

L. I. Kakurin, B. S. Katkovskiy and others (1963) selected as an experimental model a strict bed regime with man staying in a horizontal position for 20 days. As the authors note, two factors of these experiments – hypokinesia and the reduction of the hydrostatic pressure of the blood column – could be the cause of the possible disorders of the function of the motor apparatus, the system of blood circulation and respiration.

Analyzing the numerous literary sources touching on the problem of information biological loads, we arrive at the conclusion that along with the rather thorough treatment of questions of the influence of sensory deprivation the questions of sensory overload (under conditions simulating space flight) remain less illuminated. Meanwhile in certain stages of flight the astronaut undoubtedly encounters this phenomenon, for example, during radio transmissions with earth, the carrying out of repair works, special scientific investigations, during docking of spaceships, and also during various complicated and emergency situations. For example, how great can be the loads on the visual analyzer alone during work at a control panel with numerous indicators is indicated by the investigations of I. A. Kamyshev (1963). The author, in studying the peculiarities of visual information in flying by instruments in trainers determined, that for individual sections of the flight the intensity of eye movement from instrument to instrument reached 150 and even 200 movements per minute, i.e., the pilot on the average monitored 3 instruments during each second. These data indicate the great concentration of attention of the pilot and the indubitable deficit of time for his work. Something similar can also exist for astronauts during propelled sections of a flight.

It should be borne in mind that the execution by astronauts of urgent operations under conditions of a time deficit causing a state of sensory overload, will be, as a rule, superimposed on an already established state of lowered functional tonus as a result of one or another duration action of sensory underloading. For researchers the study of the character of the reactions of man under these conditions of sharp drop of sensory information is of indubitable interest. But to create a model of such a situation – a difficult matter.

However, aviation training presents to us certain possibilities for comprehending such a state. Thus, we (F. P. Kosmolinskiy, S. Ye. Komshalyuk, N. A. Fedorov, I. M. Khazen, 1963; F. P. Kosmolinskiy, 1963, 1964) have inspected crews accomplishing one of the most complex flying assignments – flights with refueling of aircraft in the air. During these flights the time of refueling, which requires great attention and great operator skill, as a rule, occurs during a period, when the pilot, having flown the aircraft during many hours with the help of an automatic pilot, is in a state of lowered physiological tonus. A sharp drop of information loading appears. This circumstance, as it seems to us, transforms the given type of flying assignment into a kind of model of certain situations in a space flight (for example, the docking of spaceships).

Moreover, we have in mind not the reproduction of the actual activity and motor reactions of the astronaut[2], but only the simulation of the complex psychophysiological stress under conditions of excess information. In these investigations attention was focused on the presence of the great peculiarity in the state and behavior of pilots while carrying out the refueling.

The execution of refueling requires from the pilot great accuracy of operation, exceptional motor coordination, concentration and attention. Under these conditons of increased sensory loading great physiological stress is noted subjectively and objectively. The basic physiological functions change sharply. All components of emotional (sthenic) stress are present – psychic excitation, vegetative dysfunction, characteristic changes of posture and mimicry etc. Extreme limits are reached by the rate of cardiac contractions (up to 160-186 per minute) and respiration (up to 40-54 per minute). Perspiration increases sharply (moisture loss reaches 5-7% of the pilot's body weight), heat generation increases (body temperature is increased by 0.7-1.2°). Great biochemical shifts are noted: the excretion of 17-ketocorticosteroids from the organism increases sharply (sometimes exceeding the normal rate by 6-8 times) and the excretion of ascorbic acid increases sharply exceeding the original level by 10-20 times and more, which indicates the state of stress (I. G. Dlusskaya, F. P. Kosmolinskiy, N. A. Fedorov, 1963; F. P. Kosmolinskiy, S. Ye. Komshalyuk and others, 1963).

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[2]Similar investigations were conducted by Simons and Walk (1965), who studied the motor reactions of subjects during the simulation of the process of going from one "spaceship" to another, in a weightlessness tank located in the fuselage of an aircraft of carrying out flights along Kepler's parabola.

The physiological analysis of these data leads to the conclusion that such sharp emotional stress of a pilot fueling an aircraft is due to a number of causes. Among these stress arising in the pilots due to the narrowing of the space field has the most significance: the boundless spaciousness of the air ocean due to the proximity of the refueling aircraft (the tanker) suddenly becomes surprisingly "crowded." Furthermore, the operation of joining the aircraft causes definite psychological difficulty consisting in the unification of two forms of activity: the customary piloting of the aircraft on the basis of already reinforced, firmly developed, automated skills and the required performance of the additional, relatively new and less familiar (to the pilot) task of refueling, which is connected with great loading of the analyzer systems. The considerable predominance of psychic directivity for fulfilling this new and, consequently, nonreinforced (in stereotype) activity turns out to be dominant, which seemingly suppresses the reinforced skills of piloting and thereby causes a difficult nervous-psychic state.

The executed investigations make it possible to outline a number of prophylactic measures directed towards increasing the stability of the organism under conditions of the prolonged effect of sensory overloading or sensory deprivation.

It is in connection with this fact that both sensory underloading, and sensory overloading lead in the end to physiological stress and fatigue, then the problem first of all reduces to the necessity of maintaining a high level of functional possibilities of the organism.

First of all the question is the development of optimum regimes of work and rest with regard to the actual conditions and problems of space flights.

An important prophylactic measure is a special motor regime for maintaining the necessary physiological tonus, efficiency and stability of a number of psychic functions. This regime includes the overall physical load and special physical exercises which are fulfilled several times per day (T. T. Dzhamgarov, I. I. Petrushevskiy, 1961, and others).

A. V. Korobkov (1963) advances as a general principle for increasing the stability of the organism to factors of the environment a regime of motor activity. This regime is especially necessary under conditions of isolation and sensory deprivation. Vigorous motor activity, static efforts and increased muscular tonus generated huge stream of sensory information, which by a reflex mechanism promotes improvement and stability of higher nervous activity, renders an actuating, and also a trophic influence on various tissues, activates the function of glands of internal secretion, positively affects the stability of the vestibular apparatus, etc. A. V. Korobkov examines the regime of motor activity as a means of preserving the terrestrial "spectrum" of information and on this basis of safeguarding the optimum state of the biological environment of the organism, and hence psychic activity and mental efficiency.

One of the methods of maintaining at a sufficient level the external sensory information in the cabin of a spaceship is the organization of the whole situation and character of life on the ship. A complex of questions belongs here, the individual ones of which grow into serious scientific problems and directions: the interaction of the crew members among themselves (questions of group psychology, stimulation of the second signal system of reality), the organization of work on a control panel (questions of the psychophysiology of work, engineering psychology), the creation of a necessary level of visual stimulations (the organization of the interior, its periodic interchangeability), and also of auditory stimulations (a system of musical programs), etc. G. K. Mikushkin (1966) advances the idea of using the mechanism of interaction of analyzers for stimulating some analyzers through the activation of others. Thus, in his opinion, "functional atrophy" of a muscular analyzer under the conditions of weightlessness can to a definite degree be compensated for thanks to an increase of the functions of the visual and auditory analyzers. This can be attained, on the one hand, by training astronauts on earth, and on the other – by simulating in the cabin of the spaceship terrestrial, "habitual" conditions with respect to space and time. In this aspect, in particular, the development of stable forms of reactions in astronauts on the basis of visual, auditory, and vestibular analyzers is necessary. They lie at the basis of perception of space and time and the perception of the spatial attitude of the body.

It is necessary to attach great significance to the possibility of using certain physiological stimulants in prolonged space flights for the purpose of maintaining a sufficient level of efficiency and psychic activity. Thus, for example, the additional administration of pharmacodynamic doses of certain water-soluble vitamins (ascorbic acid – 300 milligrams, vitamin P – up to 150 milligrams, vitamin B_1 – 25 milligrams, paraminobenzoic acid – 50 milligrams, and others) with glucose leads to good results in aviation practice – to the increase of overall physiological tonus and to the lowering of nervous stress in pilots carrying out complex flights (F. P. Kosmolinskiy, I. G. Dlusskaya and others, 1963).

For the purpose of combating the phenomena of stress and increasing emotional stability during the effect of sensory overloading certain authors propose specially directed training. Thus, V. L. Marishchuk proposes to foster the skill of self-control over one's own emotional state with regard to the external manifestations of emotion. For this it is necessary to know how to determine the presence of constraint in the involuntary tension of muscles; to control the rhythm and depth of breathing; to check the pulse under conditions of emotional excitation; to develop special skills towards complete voluntary relaxation of muscles and towards establishing a calm rhythm in breathing. By developing special skills of self-control over the external manifestations of emotions and by surmounting them it is possible to increase emotional stability.

In conclusion one should note the necessity of the further expansion of research works in the field of study of the changes of the functional state of the organism under the influence of information overload and sensory deprivation, and also during their alternate effect. Also important is the further search for new methodical procedures in these investigations, the creation of models of states of sensory overload, and also the alternation of influences on the organism of loads of different sign as under natural conditions, as well as under conditions of simulation of prolonged space flights.

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PRINCIPLES AND METHODS OF INVESTIGATING OF THE PROBLEM OF THE SPATIAL DAY

The problem of the organization of work and rest of astronauts; the regime of their vital activity on board a spaceship, on orbital stations and, in the future, on other celestial bodies, primarily on the moon; is included among the number of urgent problems of space medicines. The organization of the life of man in space in the first place assumes a basis of the most rational vital rhythm: the interchange of periods of wakefulness and rest, which on the earth correspond to periods with different intensity of illuminance, i.e., periods of terrestrial days: days-nights.

Towards the beginning of day the human organism arrives at a state of working readiness; the light period of the day is the time of the greatest productivity of human activity; towards night the organism undergoes functional reorganization ensuring full value rest. The beginning of day and night have become for us unique signal stimuli, and the process of tuning our organism for work and rest has all the features of a complex conditioned reflex. Analyzing the phenomenon of the diurnal periodicity of physiological functions on the basis of the facts obtained in the experiments of O. P. Shcherbakova and K. M. Bykov (1954) leads to the conclusion that the periodic changes in those functions have at their basis temporary nerve connections, conditioned reflexes and combinations formed as a result of the whole situation, in which there has occurred the effect of the impulses determining the diurnal periodicity, with the specific state of the lower vegetative centers effecting the level of a number of physiological functions. The strength of such conditioned reflexes other things being equal, as a rule, is very considerable. The usual interchange of day and night "... has so entered into our habit that our physiological and psychological stability is somewhat dependent on this interchange" (K. M. Bykov, 1954).

This is why the reorganization of the diurnal rhythm, especially the first period of such a reorganization, leads to the lowering of efficiency and to the deterioration of a person's health. Thus, in particular, it is known that even a 12-hour flight on a jet aircraft with a speed 900 km/h leads to a change of the physiological rhythm caused by the interchange of day and night.

The organization of man's diurnal rhythm will demand serious preliminary investigation under the conditions of existence in space. The basis of the conception, from which are examined the basic principles and means of investigating the problem of the spatial day, is the position that our normal, terrestrial, i.e., 24-hour day is the optimum variant of the solution of this problem, in particular, under the condition of man's comparatively short-term existence in space. Such a point of view is shared by a number of researchers. Therefore the first question is question concerning those conditions of existence, which (at least, at the contemporary stage in the conquest of space) exclude the possibility of organizing a terrestrial rhythm of twenty-four hours in space.

The most important of such conditions are the following.

1. Peculiarities of the occupational activity of astronauts. This activity is characterized by expressed monotony, uniformity and the inevitable lowering of working vigilance, and these conditions are all the more expressed the more reliably and dependably all systems of spaceship operate. The function of vigilance especially suffers from cumulative effect of fatigue (Hauty, 1959). The reduction of working vigilance limits the duration of duty (watch) of the astronaut and, consequently, creates an additional limiting condition for organizing the spatial day. Apparently, the duration of continuous tracking under the conditions of space flight cannot be more than 4 hours. The investigation by Mervill Jones (1960) established that

during high-intensity and prolonged flights the normal duration of duty for a radio operator was 3 hours. With greater duration the deterioration of the work standards, stress and irritability progressively increased.

2. The duration of the aftereffect "monitoring" activity. A reduction of the psychic productivity of an operator takes place not only toward the end of duty, but also for a certain time after it. Consideration of this aftereffect regulates the profile of the diurnal rhythm on spaceships.

3. The character and intensity of illumination in the cabin of a spaceship. Illumination and diurnal rhythmicity are connected by a cause and effect relationship. The diurnal periodicity of the vital activity of man and of many representatives of the animal and plant kingdom has at its foundation a periodicity of illumination intensity (primarily solar). In special experiments with apes O. P. Shcherbakov (1949) "converted" day into night, systematically illuminating the cage at night and darkening it during the day and confining the feeding time to the night. It turned out that already by the 7-8th day the maximum of temperature, and of motor activity and the highest values pH of the urine had shifted from daytime to nighttime. Creating from the astronomical day 2 "days" and 2 "nights" (illuminating and feeding the apes from 0900 to 1300 and from 1900 to 0100 hours), O. P. Shcherbakova obtained two periods of motor activity, two temperature maxima and two maxima of respiratory rate.

When O. P. Shcherbakova illuminated the cage at night and darkened it during the day, and fed the apes during the day (in darkness), the curve of the physiological functions reflected almost exclusively the influence of the illumination.

Aschoff (1964) showed that the intensity of illumination plays a special role in determining diurnal periodicity in various organisms.

It is important to emphasize that man's dominating visual analyzer and its receptor were formed under the influence of sunlight. Therefore, the spectral sensitivity of the eye falls within the maximum of the spectral curve of solar energy, which permitted S. I. Vavilov to call the eye solar. Furthermore, solar energy is an important factor, affecting the metabolic process of the organism (hence its use in medicine - heliotherapy).

4. Peculiarities of muscular activity of astronauts. Muscular activity has a direct relationship to the diurnal periodicity of the physiological functions. In the experiments of N. Ye. Panferova (1963, 1964) hypodynamia was accompanied by a levelling off of the physiological activity of the human organism (blood temperature, pulse rate, blood pressure). The same conclusions were drawn on the basis of an analysis of the physiological indices in the soundproof chamber tests of Yu. A. Gagarin (1962).

5. The number of crew members on a spaceship. Depending upon the increase of the number of crew members the order of the day for astronauts can move in the direction of an even greater approximation of a optimum regime.

6. Individual peculiarities of astronauts and their past experience. It is known that some people possess the ability to fall asleep and to wake up at any given time. The past experience of a person (the habit of mono- or polyphase sleep, "dead" hour, etc.) also determines the degree of his adaptation to an unusual diurnal regime.

Analysis of the conditions determining the organization of regimes of work and rest of astronauts for the purpose of making practical recommendations for each real flight, does not mean, however, the exclusion of broader scientific search within the bounds of the problem, which interests us. At the basis of this broader investigation of the problem of the spatial day, from our point of view, should be assumed the completest possible classification of diurnal rhythms, which are not tied to any actual conditions of man's existence. In constructing this classification we proceed from the position, in which our normal terrestrial 24-h rhythm is the optimum duirnal rhythm. Increasing or decreasing the number of hours in this day, we obtain extended (25-, 26-hour, etc.) or shortened (23-, 22-, 21-hour, etc.) days. Any diurnal variant, if it is taken as unique and invariable over a certain period of time, can be called a static variant (static day). Besides this static variant, there is conceived the so-called "migrating," or dynamic, variant, the essence of which reduces to the fact that each alternate period of the day, for example, the period of sleep, each time moves away (or approaches) with respect to time from the end (relative to the end) of the preceding period, for example, of work. In other words, the migrating day is characterized by the inconstancy of its period with respect to the time of the beginning, the termination and the duration, where such inconstancy can be variously directed, i.e., in one case this will be the constant shifting away of a definite period, for example, of sleep, from the preceding period, in other case – the approach, in a third – a periodic alternation shifting away and approach. The same can also take place with respect to the absolute duration of different periods of the day.

The following type of day is a mixed day; the mixed day in contrast to the simple day we call such an order of wakefulness and sleep, when, let us say, after a 12-hour day comes an 18- or 24-hour day or some other kind of day, where each variant of day is used either one time only, or is repeated one or another number of times. Such is the classification, from which must be constructed experiments studying the diverse variants of diurnal rhythms in space. We already noted that the usual terrestrial variant must be considered the optimum variant of diurnal rhythm. However, this statement does not at all signify a negation of man's possibility to master other, different (from terrestrial), rhythms of existence. Moreover, it is possible to consider as proven man's ability to adapt to various diurnal rhythms. Thus, in particular, in the investigation of D. I. Ivanov and others (1963) it was shown that under conditions of unusual diurnal rhythm (sleep from 2030 hours to 0230 hours and from 1200 hours to 1400 hours) the diurnal periodicity of the basic physiological functions not only levelled out, but also was distorted: the pulse rate and respiration rate, and the body temperature during sleep were greater than in the period of wakefulness which did not have place with the usual diurnal rhythm other things of the experiment being equal (D. I. Ivanov and others, 1963). Specialists of the "Lockheed" firm report the positive results of 30-day experiments, in which subjects according to a schedule worked 4 hours and rested 4 hours.

In his notes G. S. Titov (1963), who lived a total of 25 hours under conditions of a rhythm different from the terrestrial rhythm, notes that for him the conceptions "night" and "day" shifted somewhat. The reorganization of diurnal rhythmicity in man – a rather difficult and often very protracted process. Thus, in particular, in the work of V. P. Solov'yev and G. M. Gambashidze (1962) there are given the data of a study of the physiological function of works on the night shifts in the Moscow subway. Even the many-year distortion of the diurnal rhythm for them (work by night, sleep by day) was not accompanied by a reorganization of the rhythm of the physiological functions; the cause of which the authors see in the poor organization of the daytime rest.

T. P. Vol'khina and R. I. Kryuk (1962) investigated the physiological functions of linotype operators under conditons of 3-shift work and they found that in the night shift they always correspond to their level in these hours of the day and that the worst efficiency fell exactly during these hours. Hence the conclusion was drawn that diurnal periodicity affects the state of the organism of linotype operators. According to E. I. Brandt and O. I. Margolina (1962), cooling on the night shift for workers of railroad transport in winter was more marked than on the day shift with an identical work load.

Den Su I (1962) established that the electrical activity of the muscles during complete apparent rest was greater during the daytime hours. The stability of the normal terrestrial rhythm in man follows further from that fact that during complete isolation and while cutoff from all timers there is established in man a spontaneous vital rhythm close to the 24-hour rhythm (Aschoff, 1930, 1937).

It is necessary to emphasize that the acknowledgement of man's possibility to adapt to new vital rhythms does not signify the facility of the actual study of the peculiarities and mechanisms of such adaptation, since the dynamics of the physiological functions in the various diurnal rhythms in the majority works known to us was a total response of the organism to the numerous conditions of the experiment. Thus, most frequently the astronauts or the subjects went over to new regimes of work and rest under new (for them) conditions of total existence in general: in soundproof chambers, in spaceship simulators, in weightlessness tanks, etc.

Therefore, we see ways of studying the "spatial" day in a simplification of the conditions of the experiments to such a degree, which would ensure the possibility of recording the influence on the human organism each time of only one unusual factor of his future existence in space. Thus, for example, in the first stage of the experiment the subject will remain under usual (for him) conditions of life and activity, but their rhythm, i.e., the duration of the periods of wakefulness and sleep, changes according to a set program. The new rhythm is superimposed (applied) on the former form of the person's life. In the second stage there is investigated the influence on the subject of only the new (for him), for example monitoring, activity under normal conditions, then – the influence of this activity under normal conditions, but with another rhythm, then – in a spaceship simulator at first with a 24-hour rhythm and, finally, under conditions simulating as completely as possible the complete situation of life in space.

An important problem within the bounds of the problem of the spatial day, further, is the development and approbation of the means of artificial stimulation of the process of man's adaptation to unusual (for him) conditons of work and rest.

A program of operations in this direction should anticipate the following.

1. Study of the effectiveness of pharmacological agents strengthening both the inhibitory and the stimulating processes in the highest sections of the central nervous system and thereby facilitating man's coping with a new diurnal rhythm.

2. Investigation of the influence on the speed of man's becoming involved in a new diurnal rhythm of impoverished and modified afferentation.

3. Study of the influence on the speed of the normalization of sleep of artificial muscular weakening and the voluntary turning off of psychic activity.

4. Development of methodical procedures and their use for studying the individual peculiarities of man's adaptation to artificial diurnal rhythms.

These are the most important points confronting space medicine and psychology in the field of study of the problem of the spatial day.

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INFLUENCE OF VARIOUS CONDITIONS OF WORK AND REST ON THE FUNCTIONAL STATE OF MAN DURING A PROLONGED STAY IN A PRESSURIZED CHAMBER

In developing regimes of work and rest we proceeded from source material concerning the fact, that with a change of diurnal rhythm the flow of the basic physiological functions of the organism changes, which is expressed by the impairment of the overall state, the change of thermal regulation, the lowering of the indices of the activity of the cardiovascular and muscular systems and the mental and physical efficiency connected with them. These changes are functional, and after a specific time adaptation of the organism to these new conditions can occur. The process of adapting in a given case will be characterized by the stabilization of the functions of the organism at a new level.

These conclusions to an equal degree must also be true for the activity of a crew of a spaceship in prolonged flight. In connection with this different regimes of life, under conditions limited by the number of features characteristic for space flight, were also tested.

The investigations were conducted in a pressurized chamber with a volume of 23 m^3 (free air volume 15 m^3), which was of welded metallic construction.

The chamber was equipped with place for rest (bed), a special seat (bucket seat) for the subject while on duty, dining and work tables, the necessary research equipment and a life-support system (regeneration equipment, air conditioning unit, heaters, etc.).

Three subjects participated in the experiments: I-v, 30 years old; M-v, 27 years old; and S-v, 23 years old.

In the first 15 day experiment the reactions of the organism during a life regime organized around 4 hours of sleep and a 16 hour period of wakefulness for each subject (Fig. 1), were studied.

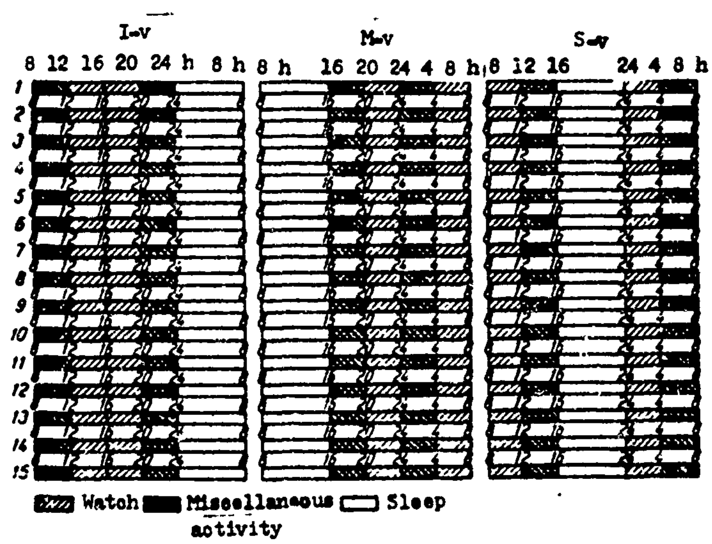

Fig. 1. The distribution of periods of sleep, miscellaneous activity and watches for subjects in the first experiment.

For the first subject the distribution of periods of sleep and wakefulness did not essentially differ from the habitual: he slept from 2400 to 0800 hours, then he spent 4 hours in miscellaneous activity; at 1200 hours he went to work and with the exception of a one-hour break was on watch until 2000, after which he rested and devoted time to miscellaneous activity. For the second subject — sleep time occurred in the period from 0800 to 1600 hours. After sleep there was a period of miscellaneous activity, then watch (from 2000 to 2400 hours), then again 4-hour periods of miscellaneous activity and watches.

For the third subject sleep was from 1600 to 2400 hours; after this came the work period until 0400 hours, and from 0400 to 0800 — the period of rest and miscellaneous activity. Then, from 0800 to 1600, there again followed periods of work, rest, and miscellaneous activity. Thus, the period of wakefulness for him, as well as for the second subject, was not habitual and took in hours of the astronomical night.

The second 15-hour experiment participated in by the same subjects was conducted a month after the first one, i.e., after all traces of the first experiment had vanished. The regime of work and rest here was organized in the following manner: the subjects slept 6 hours each; they were on watch the same number of hours (two watches of 3 hours each) and they spent the same number of hours on rest and miscellaneous activity (Fig. 2). Thus, the duration of 3 astronomical days corresponded to 4 "days" of the experiment, i.e., the whole experiment consisted of 5 equal cycles of 72 hours each.

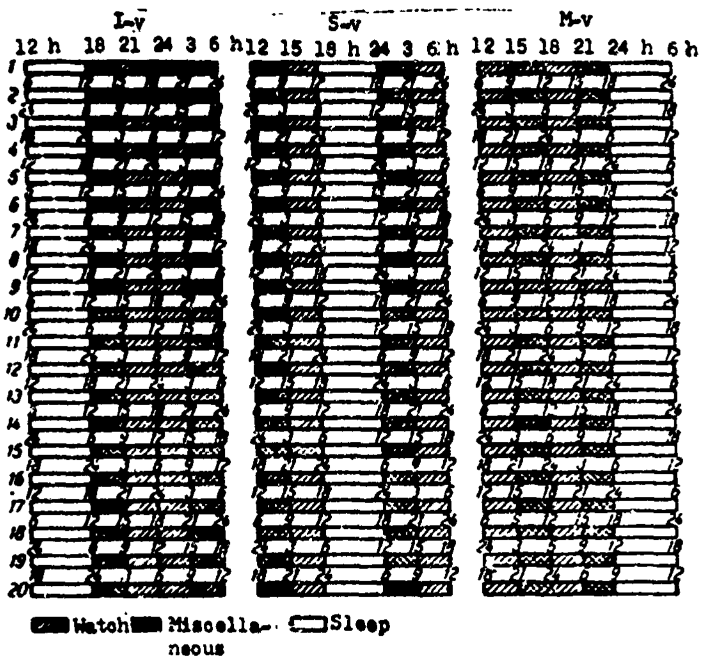

Fig. 2. The distribution of periods of sleep, miscellaneous activity and watches for subjects in the second experiment

The work activity during the watch periods in both the first and second experiment consisted of: monitoring activity (observation of the apparatus - panel - for 2 hours during the time of the watch); work on the generalization of the results of the investigation of the gaseous environment and functional changes of the organism; systematic recording of their observations in the logbook; muscular activity (a series of physical exercises).

The duty was carried out at a panel in a special bucket seat in an altitude corresponding to the altitude of an astronaut. On duty during the period of the so-called monitoring activity the tester worked at a special panel. He had to in the case of a signal arrival on the panel collect with the help of 6 toggle switches a changing program of answer signals. For developing a responsible altitude on the part of the tester during the work at the panel a "penalty system" was established – in the case of nonreception of the signal or of erroneous judgement in the answer a sound with a volume of 105 dB was automatically switched on. The turning off of the siren was possible only with the help of the other two testers, of which one at this instant had to interrupt his sleep, and the other had to tear himself away from the program, which was provided by the schedule.

In the periods of miscellaneous activity and rest the subjects, besides health-hygienic measures and food preparation, occupied themselves with medical investigations, work on a cycle-ergograph, and they also performed a series of physical exercises.

Before the beginning of the experiments the testers underwent a complete medical checkup and were found to be healthy and suitable for participation in the experiment.

Methods of investigation. For appraising the regimes of work and rest complex investigations were employed, including various methods for studying mental and physical efficiency.

The degree of attention of the testers was evaluated with the help of a proofreading test, which consisted of a set of printed characters (1600) on one page in groups of 3 to 5 symbols each and 40 printed characters on each line.

The subject had to delete a specific combination of letters. His attention concentration was judged according to the number of errors (omissions or incorrectly deleted combinations). The time it took to perform the test was also considered, i.e., how rapidly the subject focused his attention.

In a test of memory the subject had to memorize abstract and concrete words (20 words). The nature and amount of material reproduced in a specific interval of time served as the basic index of the state of the memory of the subject for the given time interval.

Mental efficiency and the cognitive process as such were studied with the help of a modified Kraepelin test, and associative experiment, and also a set of forms by which were traced the processes generalization and analysis. In the associative experiment the subject had to answer with a word of opposite meaning for each presented word. Moreover, 3 words were put forth, 2 of which were in a specific semantic dependence. For the third word it was necessary to select a fourth, which would have the same semantic connection, as the first with the second (the method of parallel analogies).

The modified Kaepelin test consisted of 8 pairs of numerical series with 23 numbers in each line. In each pair of lines the numbers were located one under the other, which the subject had to add in succession and subtract this sum from one and the same three-digit odd number. The result of the calculations were recorded under each pair.

The work time on each line was strictly limited. After 30 seconds the subject had to on a signal from the experimenter to pass to the next line.

The speed and accuracy of the calculations (Kraepelin test), the character of the associations, the adequacy and the latent time of the response reaction (association experiment) made it possible to judge the mental efficiency and the thinking process.

In both the experiments on the basis of daily two-time measurements of the axillary temperature the state of thermoregulation was estimated. The subjects were weighted every day.

For the characteristic of the magnitudes of efficiency and the influence of the regime of work and rest on a man's fatigue during his stay in the pressurized chamber these methods were used: ergography, dynamometry, investigation of motor coordination and the determination of muscular tonus.

The recording of the ergographic indices was carried out by a conventional method during work on a digital ergograph with a rhythm of one movement per second and a load weight of 4 kg. The work was performed until fatigue set in. For the characteristic of the restoration processes after 2 minutes of passive rest the work was repeated until fatigue set in. The amount of work in kilogram-meters (carried out until fatigue set in), the length and range of the ergographic curve were subjected to analysis.

The strength of the muscles of the wrist of the right hand was determined before the work on the digital ergograph, immediately after it and after 10 minutes of passive rest. The measurements were conducted three times under constant conditions. Spinal strength was measured before and after work on a cycle-ergograph (with a load of 600 kgm/min during a period of 25 minutes).

A study of motor coordination was made by many researchers with a method characterizing the functional state of the motor center of the cerebral cortex. In our investigations the preciseness of the movements was determined on an instrument, which made it possible to record insignificant deviations of hand movement from the established path pattern. In the analysis the number of errors, the time and the length of the completed path were considered. For obtaining comparable data a calculation of the number of errors per unit of speed was made.

The functional state of the blood circulation apparatus was evaluated according to hemodynamic indices, which were studied under identical conditions for both experiments.

The measurement of arterial pressure and pulse rate, the recording of an electrocardiogram and a polycardiogram were carried out immediately after the subjects' sleep. In the experiment with the 18-hour diurnal cycle the data obtained were analyzed depending upon time the subjects awakened.

Investigations of the function of external respiration were conducted for all the subjects under the strictly standard conditions of basic exchange, soon after sleep and on an empty stomach. An examination was carried out 3 times before, 4-5 times during the experiments and once after they had ended.

In the first experiment the investigations were carried out on the 2, 5, 8, 11, and 14th day, moreover, the time of the investigation, as well as the time of sleep, was fixed.

During the second experiment with the 18-hour cycle the investigations were conducted on the 3, 6, 9, and 12th astronomical day; and although the time of sleep was shifted, the investigations for each subject were fixed and were always conducted at the same time.

Considering that 0600 and 0800 hours were comparable with the generally accepted time of investigating the external respiration, it was proposed to clarify, how the given function would be changed at other times, in particular at 2400; 1600, and 1800 hours (Table 2).

Table 2. Time of the investigation of external respiration (the time of day).

The Subjects	First experiment, time	Second experiment time
I-v.........	08	00
M-v.........	16	18
S-v.........	00	06

The rate and minute volume of respiration were studied; tests were made with respiration delay on inhalation and expiration. The gas exchange was determined with help of a Belou gas analyzer system. Then a number of auxiliary values were calculated: respiratory volume, volume of alveolar ventilation, respiratory equivalent, oxygen utilization factor, respiratory coefficient and basal metabolism.

The nitrogen content in the diurnal amount of urine excretion was investigated (by the Kyeldahl method). The intake of material for the investigation was carried out before the experiment, during the experiment (each day) and after its termination.

Hematological investigations were carried out for each subject after sleep, on an empty stomach. The number of erythrocytes and leucocytes, the amount of hemoglobin, and the time of erythrocyte sedimentation were studied. The size of the erythrocytes were determined; the leucocytic formula was calculated and the number of thrombocytes and reticulocytes was determined.

In the second experiment for the purpose of obtaining additional data about the overall stability of the organism and, in particular, about the resistance of its tissues to the action of various factors the osmotic resistance of the erythrocytes of the peripheral blood (ORE) of the subjects was studied. It was determined before the experiment, on the 8, 11, and 14th day of the experiment and after the subjects had exited from the chamber. Each time 5-7 parallel samples were taken. The ORE was determined according to the modified method of Vasilevskaya, Barasheva and others (L. V. Serova, 1964). Concentrations of sodium chloride from 0.4 to 0.85% were used.

During the tests the microflora of the integumentary tissues were studied and certain indices of the natural immunity of the subjects were investigated. The microflora of the skin of the subjects was investigated by the imprint method proposed by N. N. Klemparskaya and O. G. Alekseyeva (1958).

It was in connection with this that in the experiments there was also studied the influence on the autoflora of human cutaneous coverings of bactericidal clothes, into chemical bond with the material of which there was introduced hexachloraphene; the investigation of the microflora was carried out on exposed (the internal surface of the skin of the left forearm) and constantly clothes-covered (left shoulder blade) sections of the subjects' skin.

For the purpose of more completely studying the human microflora on the internal surface of the skin of the left forearm the subjects were treated with 215 strains of staphylococci in the first and 120 strains in the second experiment. In the treatment cultures there were investigated: the ability to lyse the erythrocytes of human and rabbit blood, the coagulation of citrated rabbit plasma, the presence of the enzyme hyaluronidose, the resistance to the bactericidal dyes bromthymol blue and crystal violet, the assimilation of mannitol and the pigmentformation in lactate agar. The microflora of the pharynx was studied by the washing method proposed by K. I. Truzhetskey and Ye. I. Olen'yeba (1957).

The state of the natural immunity of the subjects was evaluated according to the bactericidal function of the skin determined by the ratio of B. coli-675 (imprint method proposed by N. N. Klemparskaya) to the phagocytotic activity of the neutrophils of the blood and the amount of lysozyme in the saliva.

The investigation of the lysozyme activity of the saliva of the subjects was conducted according to the O. G. Alekseyeva (1965) method. The maximum dilution (titer) of saliva collected on an empty stomach was determined, with which there is observed the lysis of a suspension of a standard strain Micrococcus lysodeicticus.

The investigation of the state of the autoflora of the inteumentary tissues and the indices of natural immunity for obtaining the intial stable values was conducted several times before the experiment.

The obtained results were subjected to statistical treatment by calculating the X^2-criterion.

Thus, the complex investigation by the enumerated methods made it possible to judge the changes of the functions of the different systems of the organism and the efficiency of the subjects in the course of the experiment.

a) Investigation of Mental Efficiency and Psychic Functions

The investigation of attention showed, that the time for carrying out proofreading tests for all 3 subjects during the experiment with the 24-hour cycle of vital activity increased as compared to the initial data.

Thus, for subject I-v the time for carrying out the proofreading test before the experiment was 4 minutes 40 seconds. During the stay in the hermetic chamber it was increased to 11 minutes 31 seconds, i.e., by 2.5 times as compared to the initial data.

For subject S-v the time for performing the proofreading test increased, but insignificantly. If before the experiment it equaled 5 minutes 25 seconds, then during the experiment the same test was carried out in 6 minutes 35 seconds.

For the third subject M-v the time for carrying out the test also increased (4 minute 37 seconds before the experiment and 6 minutes during the experiment).

The number of errors in fufilling the proofreading test increased by 2.5 times only for subject M-v (before the experiment there were 5 errors, during the experiment their number increased to 12). For the remaining subjects (I-v and S-v) the increase in the number of errors in fulfilling the proofreading test was not marked. Thus, the concentration process in the first experiment for all subjects was varied.

More expressed changes of attention concentration were observed for the same subjects in the regime of vital activity with the 18-hour cycle. Moreover, it was revealed that on days, when sleep occurred during the customary night time, the attention concentration varied less and, conversely, in periods, when sleep occurred in the daytime, these indices were considerably worse. Thus, for subject M-v on the 5th day of his stay in the chamber the number of errors in fulfilling the proofreading test increased to 18; on the 11th day it equaled 16 and on the 14th day the number or errors increased to 20.

As compared to the initial data (6 errors) the attention concentration had noticeably deteriorated (Fig. 3).

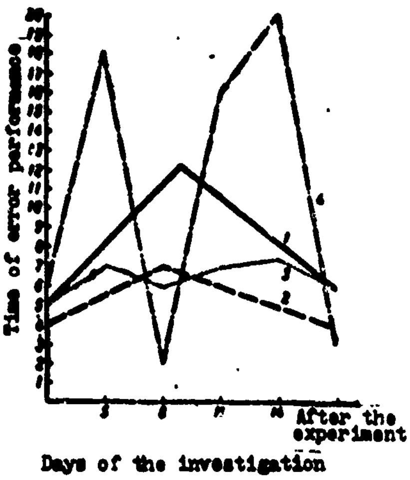

Fig. 3. The change of attention concentration in the first and second experiment for subject M-v. 1 – errors in the first experiment; 2 – performance time in the first experiment; 3 – errors in the second experiment; 4 – performance time in the second experiment.

For subject I-v the number of errors in performing the proof-reading test also increased. If before the experiment he had one error, then on the 5th day – 6 errors, on the 8th – 4 errors, on the 11th day – 4 errors, on the 14th day – 8 errors.

In the memory study it was revealed that the amount of memorized material for the subject S-v in the first experiment decreased as compared to the initial data (Fig. 4). In the second experiment with the 18-hour cycle the irregularity of material memorization was observed during the days.

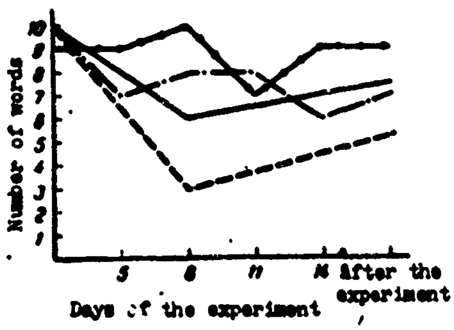

Fig. 4. Memory change for subject S-v in the first and second experiment.

For subject I-v during the period of the first and second experiments the indices hardly changed at all in the amount of material memorized. But the time required to memorize the presented words increased (as compared to the initial data).

Changes were also observed and in the investigation of mental efficiency. In both the first and second experiments for all 3 subjects there was revealed an increase in the latent time of the response reaction on the average by 2 times (associative experiment).

The productivity of mental activity in the first experiment toward the end of the stay of the subject in the pressurized chamber decreased insignificantly for all 3 subjects.

An analysis of the productivity of mental activity in the second experiment for the watches and the overall data of each day testified to its change in the direction of deterioration, especially for subject S-v. The productivity of mental activity decreased for him by almost 2 times in the periods of the second watch.

For subject M-v the mental productivity fluctuated sharply by days, as also in terms of watches. The mental productivity of subject I-v during the period of the first and second experiment remained nonuniform, without noticeable decrease toward the end of the stay in the pressurized chamber.

From the given material it is clear that the greatest changes in the psychic functions and mental efficiency on the whole were observed in the second experiment, in which the regime of vital activity of the subjects was altered considerably both in respect to duration and distribution of hours of work and rest.

b) Body Temperature

Twice daily measurements of the axillary temperature showed that in all cases it was within the limits of normal values. Moreover, it was expedient to carry out statistical analysis of the obtained data to determine the fact of the development of a new diurnal rhythm in accordance with modified regime of life, especially for subjects M-v and S-v, whose sleep time in the first experiment occurred during the daytime.

For subject I-v, whose sleep time was usual, there were no deviations from the normal dynamics of body temperature (diurnal rhythm), as one should have expected. For subject M-v the difference between "morning" (1600 hours) and "evening" (0800 hours) temperature was insignificant (on the average for the period of the experiment they were 36.3 and 36.6° respectively); for subject S-v the difference between "morning" (2400 hours) and "evening" (1600 hours) temperature was also not marked. In the last two cases the absence of differences in the values of body temperature in rising from and in going to sleep is noteworthy. Thus, from all appearances, the development of a new physiological rhythm of thermoregulation for these subjects did not occur.

In the second experiment, when the astronomical time 2400, 0600, 1200 and 1800 hours was by turns for each subject now "in the morning", now "in the evening," the values of the axillary temperature also did not fall outside the limits of the physiological norm; moreover no evidences were noted of the development of a new rhythm of thermoregulation.

c) Body Weight, Diurnal Energy Expenditures and Water Balance

For all subjects in both experiments against a background of a general tendency towards a certain decrease in fluctuations of body weight were observed within the limits of 0.5 kg. The excess of energy expenditure for the 2 subjects (I-v, S-v) above the caloricity of the food consumed, which equalled on the average 2760 kcal (Table 3), was small, in consequence of which the weight loss was also insignificant.

Table 3. Energy expenditures for the subjects in the hermetic chamber.

Subject	Energy expenditures during free time		Energy expenditures during the watch period	Energy expenditures during sleep (in accordance with the source material they were accepted as equal to 70 kcal/h per kg of body weight)	Diurnal energy expenditures
	Energy value of the physical exercises	Energy expenditures during the remaining free time			
I-v	848,2	995,0	714,0	599,2	3156,4
M-v	656,5	775,6	672,0	555,2	2659,3
S-v	607,7	953,6	768,0	664,4	3005,7

The energy expenditures for individual periods and for the day on the whole in the first experiment, presented in Table 3, were calculated on the basis of the data on gas exchange during different types of activity and of the time study of the work operations.

In the experiments an investigation of the water balance in the subjects (Table 4), was carried out.

Table 4. Average value of the water balance from the calculation on one tester in milliliters in both experiments (during an experimental day).

First experiment with a 24-hour cycle		Second experiment with an 18-hour cycle	
water intake	water discharge	water intake	water discharge
1. Water contained in the ration, 836	1. Amount of diuresis 1004	1. Water contained in the ration, 627	1. Amount of diuresis 827
2. Water taken in as drink, 1566	2. Moisture collected in the chamber, 1636	2. Water taken in as drink in the chamber 1499	2. Moisture collected in the chamber, 1607
Total 2402	2640	2126	2434

As follows from Table 4, the moisture discharge in the chamber during the time of the second experiment, in spite of the lower air temperature, was more intense as compared to the first experiment (89.3 and 68.8 mℓ/h).

d) Muscular Efficiency

The efficiency of the subjects – the basic index of the state of neuromuscular activity – underwent in the period of the stay in the pressure chamber a series of changes following one after the other depending on the difficulty in carrying out the test and the degree of training of the participants. The changes in a man's efficiency, who is situated for a prolonged time in a pressurized chamber have their own regularities: thus, on the first day, as a rule, there is observed a considerable decrease in the work carried out before fatigue, which can be connected with the reaction of the organism to the new conditions of living. With the development of adaptive mechanisms the efficiency increases somewhat, however, it does not attain the initial level. At the end of the period of the stay in the pressurized chamber there takes place a constant, independent of the duration of test, decrease of efficiency, which, in all probability, is connected with the adjustment of the organism to the specific period of the test. In this period the subjects subjectively note weakness, increased fatigue.

A similar directivity of changes of efficiency was also observed by us in the present investigations. Moreover, the dependence of the values of efficiency of the subjects is clearly expressed not only on the conditions of the environment in the pressurized chamber, but also on the regime of work and rest (Table 5). Thus, the amount of work carried out before fatigue in the experiment with the 18-hour diurnal regime decreased from the 34.68 kg-m of the initial level to 19.58 kg-m, i.e., by 15.1 kg-m, whereas in the test with the 24-hour regime the decrease of efficiency was a total of 3.2 kg-m.

Table 5. Value of the change of efficiency in percents of the initial.

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
First experiment	100	82,7	85,4	91,3	76,3	114
Second experiment	100	61,0	71,1	65,5	56,0	95,0

It is necessary to note that after termination of the second experiment the restoration of efficiency was not observed even by the 7th day after the subjects had come out of the chamber. An appraisal of the functional state of neuromuscular activity was also carried out with respect to the effectiveness of the restoration of efficiency, the index of which was the percent by quantity of work of the second stage to the first stage carried out after 2 minutes of rest. This index, as is shown by the experience of the preceding tests, reacts rather minutely to the change of living conditions. Thus, the 18-hour regime of existence, which is unusual for man, led in the second experiment ot a gradual increase in fatigue, to a decrease in the effectiveness of the restoration of efficiency (Table 6).

In the first experiment attention is focused on the high indices of efficiency restoration, which testifies, apparently, to the sufficiency of the two-minute rest, especially in the first day of the stay in the hermetic chamber.

Table 6. Effectiveness of the restoration of efficiency in percents.

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
First experiment	64,7	116,3	97,1	70,9	69,0	91,5
Second experiment	60,2	56,0	62,5	61,0	36,4	34,2

An analysis of the ergographic curves showed that the length of the ergogram, this unique index of the functional state of the motor center of the cerebral cortex, was considerably reduced during the period of the subjects' stay in the pressurized chamber. Moreover, a more distinct reduction took place during the 18-hour regime of work and rest. Furthermore a unidirectionality in the changes of the length of the ergogram was observed with changes of the value of efficiency (Table 7). Changes in the range of the ergogram were insignificant and did not exceed ±0.56 m.

Table 7. Length of the ergographic curve in percents.

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
First experiment	100	83	85	91	76	91
Second experiment	100	61	71	66	56	96

The data of the dynamometric investigations made it possible to note that the strength of the muscles of the wrist decreased only toward the end of the prolonged stay in the chamber. The increasing of the difficulty of the conditions of work and rest in the second experiment led to a more noticable decrease in the strength of the muscles, when already by the 3rd day of the stay in the pressurized chamber the strength of the muscles had decreased by 16% (Table 8).

In both experiments the changes in the values of the spinal strength were insignificant and did not exceed 3-6% of the initial level. It is characteristic that in the earlier tests conducted in the pressurized chamber the spinal strength decreased to a greater degree than the strength of the muscles of the wrist which, apparently, was connected with the predominance (in the chamber of limited volume) of additional statistical loads, which cannot fail to affect value of the spinal strength.

Table 8. Strength of the muscles of the wrist of the right hand in kilograms.

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
First experiment	54	58	54	52	54	54
Second experiment	57	48	50	42	52	54

The functional state of the motor center of the cerebral cortex was also evaluated on the basis of an investigation of the precision of the movements. In the second experiment additional data for determining muscular tonus was used for this evaluation.

An analysis of the obtained results made it possible to note a certain increase in the number of errors per unit of speed in the second experiment (Table 9).

Table 9. Changes in the index of the exactness of the movements (arbitrary units).

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
First experiment	4,7	6,4	4,7	3,5	5,6	4,9
Second experiment	4,7	4,2	5,2	5,0	5,9	6,3

The determination of the tonus of the thigh muscles was carried out before and after the work on the cycle-ergograph. The results of the investigations were expressed in the absolute units of a scale of a myotonometer-device. The obtained data (Table 10) testify to a significant decrease in the tonus of the muscles during the period of the stay in the pressurized chamber, which reflects a reduction of the strength of both the stimulating and inhibitory process of the central nervous system. A physical load of average severity, the work on a cycle-ergograph, as a rule, led to a further decrease of the tonus of the thigh muscles.

Table 10. Influence of a physical load on the tonus of the thigh muscle (arbitrary units).

	Before the experiment	Day of the experiment				After the experiment
		3	5	9	13	
Before the work on the cycle-ergograph	23,2	17,6	9,2	7,2	6,8	11,6
After the work on the cycle-ergograph	14,4	12,8	8,0	8,0	4,8	7,4

As follows from Table 10, the negative influence of the physical load on the tonus of the muscles decreases somewhat with the duration of the test, which, however, is relative and depends mainly on the more expressed decrease of muscle tonus before the work on the cycle-ergograph.

Thus, the neuromuscular activity of a man under conditions of a prolonged stay in a pressurized chamber undergoes definite changes leading to the lowering of efficiency and to the development of fatigue in the subjects. Moreover, the degree of the changes depends on the severity of the conditions of the existence, also including in the conditions a correctly organized regime of work and rest.

e) Investigation of the State of the Cardiovascular System

During the stay of a man in a hermetically-sealed chamber of limited volume definite changes are observed in the functional state of the cardiovascular system.

In connection with this great interest is manifested in the study of the cardiovascular system of subjects while they are situated under the various conditions of a regime of life and active work.

The investigation of the pulse rate of the subjects in the first experiment made it possible to note an appreciable decrease.

The change of the arterial pressure in the given experiment was different for different subjects. Thus, in the subject I-v, whose vital activity proceeded in the regime with a constant diurnal periodicity, there was noted a marked reduction in the maximum and minimum arterial pressure during the whole experiment.

In subjects S-v and M-v with the presence of a general tendency towards a reduction of the arterial pressure on individual days of the investigations there was observed an increase of the maximum and minimum pressure, where the level of the maximum pressure in individual cases exceeded the background values.

The pulse pressure in the experiment with the 24-hour diurral cycle changed insignificantly and did not exceed the bounds of 35-55 mm Hg, which, apparently, can testify to the rather good functional state of the circulatory apparatus.

In the second experiment for all 3 subjects there was also observed a reduction in the pulse rate. The dependence of the rate of cardiac contractions on the time of awakening was more expressed in the subjects S-v and M-v: in awakening at 0600 and 2400 hours the pulse rate decreased as compared to the background data to a greater degree than in awakening at 1200 and 1800 hours (Table 11).

Table 11. Pulse rate after sleep by cycles.

Time of day (hours)	I-v						S-v						M-v					
	Before	1	2	3	4	5	Before	1	2	3	4	5	Before	1	2	3	4	5
6	—	60	60	64	60	54	—	52	54	52	48	—	—	48	52	56	54	56
12	84	64	54	60	60	54	66	60	60	60	54	54	72	54	60	62	52	—
18	—	66	54	60	60	52	—	52	56	60	54	54	—	64	36	54	60	60
24	—	60	56	54	60	64	—	52	56	48	54	56	—	66	54	48	54	52

In Table 11 there are presented the data of the pulse rate in the experiment with the 8-hour diurnal cycle depending upon the time of awakening of the subjects.

The maximum pressure in the second experiment decreased for all subjects. Moreover, a dependence of the degree of the reduction of the maximum pressure on the time of awakening was noted.

As can be seen from Table 12, the maximum pressure decreased more noticeably in the case of the awakening of the subjects at 0600 hours. In awakening at 1200, 1800, and 2400 hours high values of maximum pressure were observed.

The changes in the minimum pressure did not have a marked character. Furthermore, it was possible to note a somewhat higher level for subject S-v (70-84 mm Hg).

Table 12. Maximum pressure after sleep by cycles.

Time of day (hours)	I-v						S-v						M-v					
	Before	1	2	3	4	5	Before	1	2	3	4	5	Before	1	2	3	4	5
6	—	96	94	100	100	104	—	104	102	98	102	—	—	92	90	100	100	100
12	115	104	108	104	90	98	114	104	108	110	98	102	114	100	110	110	106	—
18	—	108	110	108	104	98	—	112	94	106	110	108	—	110	110	108	102	106
24	—	100	110	108	114	110	—	104	98	100	104	108	—	100	104	102	100	98

In apprasing the tonus of the vascular system the method of determining the propagation velocity of the pulse wave (PVPW) was employed.

The PVPW in the left heart-carotid artery section in both experiments practically did not change. The transit time of the pulse wave was within the limits 0.03-0.04 of a second.

The PVPW in the left heart-toe of the right leg section changed during the period of the second experiment from 5.3-6.4 m/s (the beginning of the experiment) to 5.6-6.9 m/s toward the end of the experiment.

The PVPW in the left heart-finger of the right hand section (determination was conducted only in the experiment with the 18-hour diurnal cycle) during the period of the stay of the subject in the pressurized chamber was 4.8-5.8 m/s toward the end of the experiment.

Thus, as can be seen from the presented data, the tonus of the main vessels in various sections of the vascular channel increased somewhat.

In analyzing the electrocardiogram in both experiments a certain increase of the PQ interval for subjects I-v and S-v was revealed.

During phase analysis of the cardiac cycle (polycardiography) in both experiments there was noted a statistically reliable increase of the mechanical systole of the left ventricle of heart due to the increase of the expulsion phase (isotonic contraction). The protodiastolic period and the phase of isometric contraction practically did not change here.

The background data of the expulsion phase were within the limits of 0.23-0.27 of a second; toward the end of the experiment the duration of the expulsion phase increased to 0.29-0.32 of a second and upon completion of the experiment gradually reduced to the initial values.

The duration of the mechanical systole of the left ventricle in the experiments also increase (from 0.28-0.3 to 0.32-0.36 of a second).

f) Functional State of External Respiration

No significant changes were ascertained in the studied function by the investigations. It was ascertained that the oxygen intake and, consequently, the basal metabolism did not change as compared with the initial values. It is true, in the second experiment for subjects I-v at 2400 hours and M-v at 1800 hours there was noted in individual periods an increase of the amount of oxygen consumed (up to +30.7% of the proper norms), but on the whole for the period of the experiment the changes were uncertain.

With a constant oxygen intake the utilization factor of oxygen in these days was lowered, and the ventilation equivalent was increased that could testify to a deterioration of the effectiveness of ventilation and to a decrease of the diffusion ability of the lungs.

On the basis of the few observations (27 measurements) conducted, it is also possible to conclude that astronomical time as such, apparently, does not affect the amount of basal metabolism, if all the remaining conditions of its determination are observed.

g) Investigation of the Peripheral Blood

The changes of the peripheral blood did not exceed the limits of the standard physiological norms. On the given figures are presented individual data, concerning each subject, which were obtained during the whole period of observation, and average values depicting the general tendency of the changes of certain hematological indices.

The changes on the part of the red blood were characterized by an increase of the amount of hemoglobin for the two subjects up to 16-17% (the initial level was 14-15%). Simultaneously with this in the 2 subjects during the period of the first experiment and after its termination there was observed a certain decrease in the number of erythrocytes. The indicated changes testify to the presence of a definite hyperchromia and an increase of the number of reticulocytes in 2 subjects in the first experiment and a considerable increase in their number in all subjects in the second experiment (Fig. 5). The data obtained in studying the function of external respiration indicates an insufficient oxygen supply in the organism.

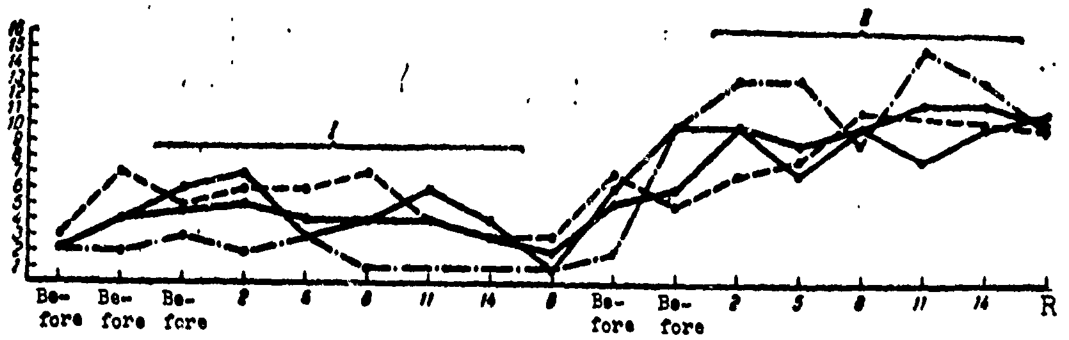

Fig. 5. Change of the number of reticulocytes in the blood of the subjects. I – first experimental period; II – second experimental period; R – restoration.

Definite changes were also observed on the part of the white blood. The number of leucocytes increased somewhat during the period of the first experiment and was especially marked on the 2-8th day of the second experiment (Fig. 6).

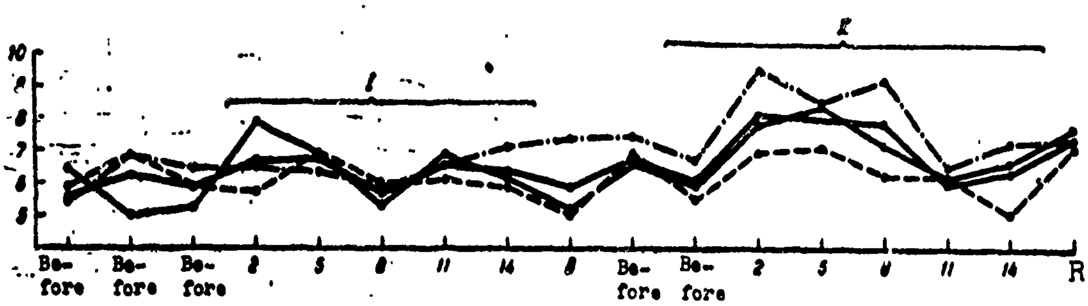

Fig. 6. Change of the number of leucocytes in the blood of the subjects. I - first experimental period; II - second experimental period; R - restoration.

The increase of the number of leucocytes occurred mainly due to the increase of the number of neutrophils and especially of the lymphocytes. The latter, apparently, can be explained by the development of a certain fatigue in the subjects, which is also confirmed by data of other investigations.

The osmotic resistance of the erythrocytes in the blood of the subjects in the second experiment underwent the following changes.

Before the beginning of the experiment maximum values were noted in subject M-v: in a 48 mg % solution of NaCl for him 53% of the erythrocytes were whole, in a 44 mg % solution of NaCl - 25% of the erythrocytes were whole. S-v had less - in a 48 mg % solution he had only 26% of the erythrocytes intact (Table 13). The difference in the indices for the individual subjects is statistically reliable.

Towards the 8th day of the experiment in all 3 subjects there was noted a sharp increase in the stability of the erythrocytes in comparison with the initial data. Thus, in subject M-v before the experiment in a 48 mg % solution of NaCl there were 53% of the erythrocytes intact, and on the 8th day - 82%. In subject I-v these values were respectively 41 and 57%; in S-v - 26 and 55%. Then the resistance of the erythrocytes starts to drop, and towards the 11th day of the experiment in a 48 mg % solution of NaCl M-v has a total

Table 13. Change of the osmotic stability of the erythrocytes of the peripheral blood in the experiment with the 18th hour diurnal cycle.

Subject	Period of observation	No. of observation	% of intact erythrocyte in a 48 mg % solution[1] NaCl
M-v	Before experiment	7	53±2,4
	8th day	7	82±2,6
	11-14th day	12	61±3,0
	After experiment	5	41±1,3
I-v	Before experiment	6	41±5,0
	8th day	6	57±6,5
	11-14th day	11	35±3,4
	After experiment	5	16±4,0
S-v	Before experiment	5	26±5,6
	8th day	5	55±6,2
	11th day	5	14±4,5
	14th day	5	23±4,3
	After experiment	5	13±4,0

[1]A concentration of 48 mg % in this case turned out to be the most characteristic – the "critical" point in the hemolysis curve.

of 61% of the erythrocytes, I-v has – 35%; an expecially sharp drop in the studied index was noted in this period for subject S-v (14%).

Subsequently for the two subjects, M-v and I-v, the values characterizing the osmotic stability of erythrocyte remain at the level attained towards the 11th day; there is actually no difference between the 11th and 14th day. And only for subject S-v does the sharply lowered (towards the 11th day) resistance of the erythrocyte increase towards the 14th day. The difference in the values between these periods is statistically reliable.

In examining the subjects, after they came out of the chamber, a reduction in the stability of the erythrocytes to the norm (for S-v) or lower than the norm (for I-v and M-v) was noted.

Thus, during the 15 days of the experiment consisting of 20 18-hour cycles the osmotic resistance of the erythrocytes in the subjects changed several times and rather regularly: it increased towards the middle of the experiment; it decreased towards the 11th day; it stabilized at this level towards the end of the experiment and again dropped after the subjects came out of the chamber. The only disturbance of this regularity was a certain increase of the studied index for subject S-v on the 14th day (see Table 13).

h) Investigation of the Urine

The results of the investigations of diurnal diuresis show that in reducing the diurnal amount of deaminated protein towards 2400 hours in second experiment there was obtained an average value equal to 114.2 g per day which exceeds its amount in the first experiment by almost 20 g. Consequently, the deamination of the protein and the need for it were greater in the second experiment, which can testify to the more severe conditions of this experiment.

i) The Microflora of Covering Tissues and the State of Certain Indices of Natural Immunity

The stay of a person in a hermetically sealed chamber of limited volume is usually accompanied by an increase of the level of microbe contamination of the skin and the mucous membranes of the oral cavity and pharynx.

In the first experiment the level of microbe contamination of the skin for the different subjects for the whole period was unequal. However, the number of microorganisms inhabiting the integuments considerably exceeded the average level established for a healthy person (Table 14).

Table 14. The total number of microorganisms on the skin of the forearm and the shoulder blade of the subjects in the first experiment.

Subjects	Site of the investigation	No. of colonies before experiment			Day of the experiment			No. of colonies after the experiment
					5	8	14	
I-v	Forearm..........	70	90	40	780	370	1 300	40
	Shoulder blade...	70	150	140	920	460	600	190
M-v	Forearm..........	180	70	340	480	80	350	220
	Shoulder blade...	120	110	50	230	—	50	260
S-v	Forearm..........	160	220	160	110	160	36	80
	Shoulder blade...	70	90	150	170	100	30	40

An especially noticeable increase of the total number of microorganism on the skin was noted for subject I-v. It is necessary to note that both before the experiment, and while it was being carried out the number of microbes on sections of the skin which were exposed and covered by clothing was identical, and the change of the level of microbe insemination was monotypic.

The data about the make-up and the number of microorganisms on different sections of skin agree with our data obtained in a number of previous experiments, in which the identity of changes of the number of bacteria on the skin of the internal surface of the left forearm and left half of stomach during the stay of a person in a hermetic chamber was shown.

The number of hemolytic forms of bacteria during the experiment changed little.

A certain increase of the number of staphylococci forming hyaluronidose and coagulose was observed on the 14th day of the experiment and after its termination.

On the 8th day of the experiment on the skin of the subjects an increase in the amount of staphylococci resistant to biomycin and levomycetin was noted. It was especially expressed for subjects M-v and I-v.

The microbe contamination of the oral cavity and the pharynx of the subjects noticeably increased. This increase was especially expressed on the 5th day of the experiment, when the total number of microbes increased by 400-500 times as compared to the initial level. The basic number of microorganism, revealed in this period was represented by non-hemolytic streptococci.

The investigated indices of natural immunity were within the limits of the initial level.

In the second experiment clothes made from bactericidal fabric were employed.

In connection with this there were noted in the second experiment certain changes in the make-up of the microflora of the skin of the subjects, connected basically with the influence of the bactericidal agent of the clothes on the microorganisms.

The total number of microbes on the exposed and clothes-covered sections of the integuments of the subjects increased. However this increase was less expressed than in the first experiment. Toward the end of the experiment there was observed a lowering of the number of staphylococci, having symptoms of pathogenicity and possessing resistance to biomycin and levomycetin.

The microbe contamination of the oral cavity and the pharynx in the subjects in the second experiment, just as in the first, increased considerably.

As is known, phagocytosis is one of the most characteristic indices of unspecific immunity, which are inseparably connected with the general and immunological reactivity of the organism (I. I. Mechnikov, 1950; V. M. Berman, and Ye. M. Slavskaya, 1959, and others).

Recently phagocytic reaction has been widely used for appraising the influence of different factors of the environment on the human organism (V. K. Navrotskiy, 1957; A. I. Pakhomychev, 1960; A. F. Stoyanovskiy, and T. V. Rasskazov, 1961, and others). An investigation of the phagocytic activity of the neutrophils of the blood showed that with the increase of the duration of stay of the subjects in the chamber a reduction in phagocytotic reaction (Fig. 7) occurred.

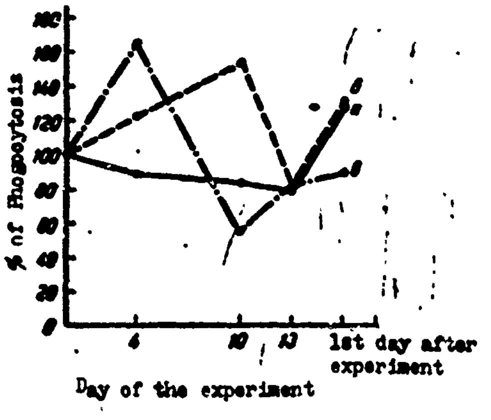

Fig. 7. Phagocytic activity of the neutrophils of blood of the subjects. (a) subject I-v; (b) subject M-v; (c) subject S-v.

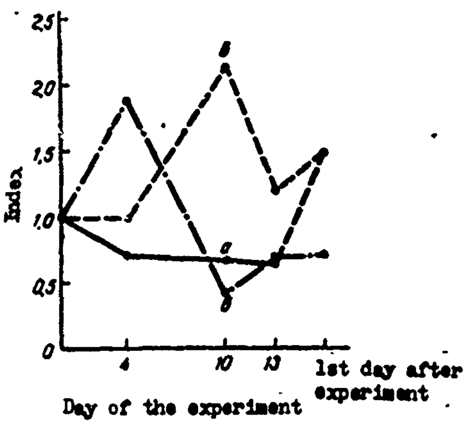

Fig. 8. Intensity of phagocytic reaction. (a) subject I-v; (b) subject M-v; (c) subject S-v.

As can be seen from Fig. 7, on the 13th day of the experiment for all subjects the percent of phagocytosis decreased by 15-18.8% as compared to the initial level. Moreover, in 2 subjects (I-v, S-v) simultaneously with the lowering of the phagocytotic activity of the neutrophils there was also observed a decrease in the intensity of phagocytosis (phagocytic index) (Fig. 8). Thus, for example, before the experiment the phagocytotic index in these subjects was equal to 1.27-1.47, and on the 10th and 13th day of the experiment respectively it was 0.6 and 0.4-0.7, i.e., it decreased by 2-3.6 times as compared to the initial level.

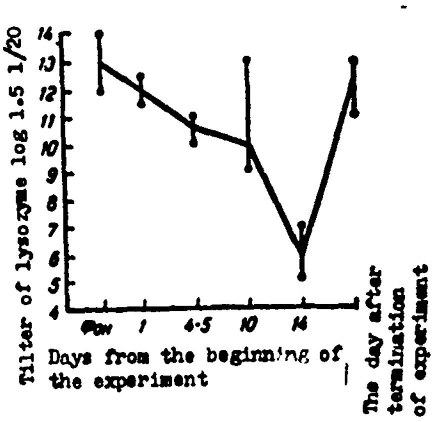

Fig. 9. Dynamics of the activity of lysozyme. The vertical lines signify the individual indices of lysozyme in the saliva.

The lysozyme activity of the saliva in the subjects during the period of the experiment decreased (Fig. 9). Toward the end of the experiment the titer of lysozyme for all subjects descended by approximately 10-20 times. On the day after leaving the chamber a rise was noted in the activity of lysozyme.

Discussion of the Results of the Investigations

The prolonged stay of a man in a hermetically closed chamber with limited volume takes place under living conditions, which in many respects are different from the usual conditions of his existence. The basic peculiarity is that in locating a person in a hermetic cabin contamination of the air medium is observed by different chemical substances and microorganisms, where a definite dependence of the changes of the medium or the processes of the vital activity of the person takes place. A man under these conditions becomes the basic formative cause of these changes in the medium.

A characteristic peculiarity of living in a hermetically closed chamber is also the fact that man is subjected to the simultaneous influence of a complex of unfavorable factors. Furthermore, it is necessary to emphasize that the simultaneous action of many factors, in spite of their slight significance, can cause definite changes in the functional state of the human organism. Thus, according to the data of many investigators (I. I. Sklyanskaya, 1944, and others), high air temperature increases the penetrability and absorptivity carbon monoxide located in the air and increases its effect.

The fact is also well-known that the combined action of several toxic substances causes in a number of cases a greater effect than that, which is caused by the simple sum of the action of each of them individually.

A permanent stay in such an environment cannot occur without affecting the human organism. A result of this can be the appearance of the unique accumulation of physical effects, which was observed in our investigations, when the impairment of the functional state of many systems of the organism increased in proportion to the duration of the experiments.

Established regularities took place and in carrying out the two experiments described above. The influence on the human organism of different conditions of rest and active work was studied in these experiments. Furthermore, the changes observed in the state of the investigated systems and functions of the organisms of the subjects were characteristic of a man's stay in a pressurized chamber and they caused first of all the development of symptoms of general asthenia.

The basic index of the state of the human organism under these conditions of living is the evaluation of the functional state of the central nervous system, making it possible to give the characteristics of the complex processes of adaptation to the unusual conditions of existence and to trace the reorganization of the activity of the cerebral cortex to this new functional level.

As has been established in numerous experiments, changes on the part of higher nervous activity during a man's stay in a hermetically closed chamber of limited volume are characterized mainly by the attenuation of the excitroy as well as the inhibitory process with the predominance of the deterioration internal inhibition. The change of such indices of psychic activity, as the time for performing a proofreading test, the latent time of a response reaction in an association test, apparently, also can testify to the impairment of the mobility of the nervous processes.

The results of investigations of neuromuscular activity showed that a stay under conditions of a hermetically closed chamber causes on the part of the neuromuscular apparatus characteristic deviations: impairment of the indices of efficiency, reduction of muscular strength, decrease of muscle tonus and impairment of motor precision.

The noted shifts, expecially the decrease of efficiency, testify to the decrease of the reserve resources of the organism. The cause of the observed shifts are basically the changes in the central element of the motor analyzer of the cerebral cortex.

The functional state of the cardiovascular system of the subjects in the experiments also changed. In both experiments a reduction in the maximum arterial pressure and a decrease of the pulse rate, an increase of the PQ interval and an increase of the propagation velocity of the pulse wave were observed. The indicated changes of hemodynamics are typical for the stay of a person in a hermetically closed chamber with limited volume.

During the stay of the subjects in the hermetic chamber there was observed an increase in microbe contamination of the skin and mucous membranes. The increase of the total number of microbes on the covering tissues was accompanied by an increase of the number of bacteria having individual symptoms of pathogenicity. The number of microorganisms lysing the erythrocytes of human and rabbit blood, capable of growing on a broth medium and assimilating mannitol, (which forms hyaluronidose) increased.

The cause leading to the quantitative and qualitative changes of the autoflora must be considered the decrease in the immunobiological reactivity of the person.

Thus, as one may see from this data, during the stay of a person in a hermetically closed chamber with limited volume no pathological shifts were observed in the state of his organism. The simultaneity and continuity of the action of the unfavorable factors along with their slight significance create the conditon for the development of a summational effect, which causes the development of a unique reaction of the organism in response to the action of the whole complex of unfavorable factors.

The change of the regime in carrying out the second test, expressed by the introduction of the 18-hour diurnal cycle, caused an intensification in the manifestation of changes in the functional states of various systems of the organisms of the subjects.

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INFLUENCE OF THE CHANGE OF THE REGIME OF DIURNAL ACTIVITY ON THE HUMAN ORGANISM UNDER CONDITIONS OF ISOLATION

The devlopment of principles and methods of a rational organization of the regime of diurnal activity of astronauts occupies one of the leading places in the practice of space medicine. In the opinion of certain authors (B. S. Alyakrinskiy, 1966, and others), a successful solution of this question is impossible without considering such conditions, as the constructional peculiarities of cabins of spaceships and workstations, the peculiarities of the work and the number of crewmembers and so forth. However, in our opinion, the list of conditions will be incomplete, if one does not consider the peculiarities of man's vital activity from the point of view of his diurnal stereotype for time, which was established and secured in the process of evolutionary development. It is known that the human organism has available only limited reserves for the problem of reorganizing the physiological cycle of wakefulness and sleep with respect to both time and also to the preservation of the conditions of homeostasis in the broad sense of this word. It has been ascertained that, first, the reorganization is not accomplished instantly: for this a time of from one to two weeks is necessary (O. P. Shcherbakova, 1949; A. Emme, 1962, and others), secondly, it is connected with definite functional disturbances expressed in a sense of hunger, drowsiness, insomnia, etc. (Strughold, 1965). The last is more expressed in middle-aged persons and also depends on the peculiarities of the new regime of work and rest. Hauty (1960), studying the efficiency of operators at radar installations, ascertained that the reorganization of a normal regime into a fractional one with multiple alternation of periods of wakefulness and sleep in the course of the day caused in the operators a reduction in efficiency and the development of drowsy states during the periods "official" wakefulness. The author does not give any physiological foundation for the noted symptoms, except the reference to the fact of the change of the habitual form of life.

Considering the insufficient treatment of the problem of work and rest in reference to the problems of space flight, research was conducted studying the influence of various regimes of diurnal activity on the functional state of organism under conditions of isolation.

We carried out a series of investigations with a duration of 10-15 days in a specially equipped chamber (a soundproof chamber) with the assistance of some healthy men aged 23-25 years. The chamber was equipped with special apparatus and instruments entering into the system of stimuli presentation and information collection, which transmit data out of the chamber; this data characterizes the functional state of the organism and the operation of the life support system.

The basic condition of the investigation — prolonged isolation of the subjects — was provided by: solitude, the absence of two-way speech communication, the practically complete isolation from external light sources, sound influences and other stimuli. The one-way speech communication from the subject to the experimenter was limited in program and duration of transmission.

The activity of the subjects during the investigation was strictly regulated by the order of the day and included: performing experimental-psychological tests and assignments, recording and appraising the indications of the instruments, operating apparatus, transmitting of current reports, preparing to record physiological functions (attaching electrodes, measuring interelectrode resistance and others), miscellaneous activities as maintaining personal hygiene, preparing food, etc.

In the experiment various regimes of diurnal activity were used (Fig. 10):

– usual (work by day, sleep by night);
– shifted (work by night, sleep by day);
– fractional with multiple alternation of the periods of wakefulness and sleep during the day.

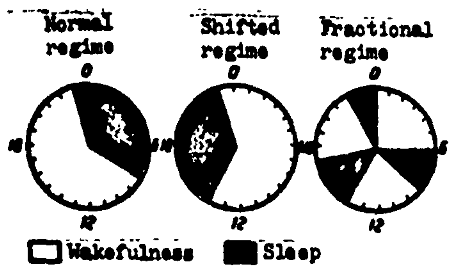

Fig. 10. A diagram of the regimes of diurnal activity of subjects in experiments with isolation.

The duration of sleep in all experiments was 9 hours.

The appraisal of the functional state of the organisms of the subjects was carried out in tote:

1) according to the observation of the behavior and emotional reactions;

2) according to the dynamics of the bioelectric activity of the cerebral cortex;

3) according to the results of the determination of the speed of the response motor reaction;

4) on the basis of the actual performance of experimental-psychological tasks (tests on noise immunity, developed by F. D. Gorbov and L. D. Chaynova, (1959).

The appraisal of the individual peculiarities of behavior was carried out on the basis of visual and teleobservation and the filming of the subjects, in conjunction with the results of all remaining methods of investigation. This made it possible not only to more completely characterize the main points in diurnal rhythmicity, as falling asleep and awakening, but also to judge the adequacy of behavior during prolonged experiments with isolation.

The bioelectric potentials of the brain were recorded from the symmetrical sections of the head with a bipolar (forehead-back of the head) lead. As electrodes there are used silver plates with a diameter of 7-8 mm wrapped in gauze and moistened by a physiological solution with the addition of a special paste. The recording was made on an eight channel inkwriting Al'var electroencephalograph. During the recording the subject sat in a chair in the dark with his eyes closed. A light stimulus (a intermittent light with a frequency of 9-11 bursts per second and with a duration of 5 seconds each) was supplied from a photostimulator located 60-80 cm from the eyes of the subject. At the time of presentation of the light stimulus the subject opened his eyes, with cessation – he closed them.

At the basis of the investigation of the speed of the response motor reaction was a method of determining the latent period of reaction with the simultaneous recording of an electromyogram (EMG) from the muscles of the deep flexor of the fingers of the right hand; the skin galvanic reflex (SGR) according to I. R. Tarkhanov – the potential difference between the palm and the back surface of the left hand; an electroencephalogram (EEG) from the symmetrical sections of the head with a bipolar (forehead-back of the head) lead. As the stimulus a short series of light bursts are used. The investigations were conducted repeatedly with an interval of 20-30 seconds. The response motor reaction was in the form of a hand contraction.

For studying noise immunity work with the selection of figures according to a given program was employed. For this rectangular taoles were used with figures of black (from 1 to 25) and red (from 1 to 24) colors, placed in random combinations and excluding the possibility of memorization. The computing operation, which was the basis of the program, consisted in the compilation of natural series of numbers in increasing and diminishing order. The responses were recorded on a tape recorder, the recording of which was conducted continuously. The data of the actual response of the subject were reflected in the form of graphs, consisting of two columns of figures (in the order of the responses from the top - downwards); for clarity they were separated into an upper and lower part at a distance proportional to the numerical difference between the figures of the corresponding pair in such a way that the numbers of the black and red series with the least difference (12-13) were placed directly next to each other. The time interval between the responses were placed in a standard scale opposite the corresponding figure.

The investigations showed that the "distortion" of the habitual order of life, the transition from one regime of sleep to another against a background of prolonged isolation had a definite effect on the organism, leading in certain cases to symptoms of fatigue.

As it turned out, fatigue during a normal regime of diurnal activity was less than during the fractional and shifted regimes. Furthermore, an impression was created of insufficient rest during the time allotted for sleep, which led to the gradual increase of the symptoms of fatigue. The latter was characterized by the appearance, starting with the 5-7th day of the experiment, of the sensation of lassitude.

The subjects disclosed the need for conversation in beginning communications with the experimenter, which affected the construction of the current reports by giving them an interrogative form, in requests for the transmission of time checks in the inclusion in the current reports of "superfluous" words and expressions not provided for by the instructions and having direct relationship to the experimenter. At this time there were noted periods with a duration of 20-30 minutes, when the subjects sat, not carrying out any actions, with an apathetic appearance. In reading a book it was possible to see, how they, rapidly running their eyes over the text, mechanically turning over the pages, continued reading for a short period, at times not trying to find the place in the book, where they had stopped earlier.

The observations of the behavior of the subjects in the experiments with the fractional and especially with the shifted regime pointed to the development in them of drowsy states during the periods of wakefulness and during breaks free from the execution of physiological and experimental-psychological assignments.

The development of drowsiness in the periods not requiring active attention arose, obviously, due to the "falling off of the mass of stimulations usually entering into the cerebrum" (I. M. Sechenov 1963), and the change of the customary regime diurnal activity promoted the development of these states.

The development of the states of drowsiness in the periods of wakefulness had an effect on the quality of sleep: it became shallow; the subjects could not fall asleep for a long time, and if they fell asleep, then they frequently lost the ability to awaken independently in the assigned period.

The sensation of fatigue was accompanied by a lowering of the quality of execution of the experimental-psychological tests and by a whole complex of changes on the electroencephalograms. The character of these changes was intimately connected with the regime of diurnal activity. For example, the bioelectric activity of the brains of the subjects in the experiments with the usual regime of diurnal activity in 60% of the cases was characterized by a lowering of the amplitude of the alpha rhythm on the initial EEG curve. In the experiments with the shifted regime from the 2-5th day there was noted on the EEG a lowering of the amplitude of the biopotentials and the appearance of slow diffuse waves. The index of the alpha-rhythm in the experiments with the usual regime of diurnal activity changed insignificantly, descending toward the end of the investigation by 2-15% of the initial level; in the experiments with the shifted regime the index of the alpha-rhythm descended more significantly: by 13-33% during the first days, by 61-90% on the 5th and 82-99% on the 10-15th day of the experiment (V. I. Myasnikov, 1964)(Fig. 11). The changes of the bioelectric activity of the brain in the subjects with the fractional regime were 75% analogous to the changes of the biopotentials of the brain in the subjects with the usual regime and they only had a 25% similarity with the dynamics of the bioelectric activity of the brain characteristic for the shifted regime. The index of the alpha-rhythm toward the end of the investigation descended by 17-51%.

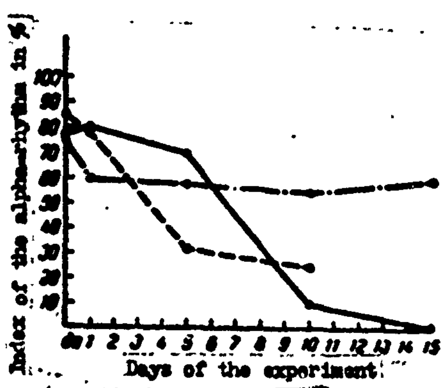

Fig. 11. The change of the index of alpha-rhythm on the EEG of subjects with different regimes of diurnal activity. The dash-dot line — the usual regime, subject L-v; the solid line — is the shifted regime, subject Sh-n; the broken line — the fractional regime, subject G-ko.

A study of trace reaction on the EEG of the subjects showed that in 70% of the cases as an aftereffect of the rhythmic light stimulus an exalted burst of alpha-rhythm was noted. Analysis of the trace reactions from the point of view of duration of flow showed that the duration of exaltation of the alpha-rhythm depended on the regime of diurnal activity employed in the experiment. In particular, in some of the subjects in the experiments with the shifted regime the exaltation of the alpha-rhythm according to the length of the stay under conditions of isolation became more and more prolonged (Fig. 12), acquiring from the 6-70th day a stagnant character, being interrupted only by the effect of the subsequent stimulus (V. I. Myasnikov, 1963). Studying the problems of the electroencephalography of sleep, P. I. Gulyayev (1955) noted a qualitative difference in the course of trace reactions in man during sleep and with symptoms of fatigue. Analyzing the material obtained by us from this point of view, we came to the conclusion that the manifestation and duration of the exaltation of the alpha-rhythm for different subjects were unequal and were connected with the peculiarities of the functional shifts. In subjects with symptoms of fatigue exaltation of the alpha-rhythm had a stagnant character, whereas in people with marked drowsiness trace reactions were noted in the form of short (not more than 10 seconds) bursts of the exalted alpha-rhythm (Fig. 13). The investigations also showed that the changes in the bioelectric activity of the brain after turning off the light stimulus came with a different speed: the exaltation of the alpha-rhythm in subjects with symptoms of fatigue appeared only after repeated presentation of the light stimulation (Fig. 14).

A different manifestation of the duration of the trace reactions is connected, obviously, with the peculiarities of the functional changes in the central nervous system, caused by the drowsy states in some cases and symptoms of fatigue — in others. Not dwelling on the qualitative distinctions of these states, it is necessary to say that the stagnant character of the exaltation against the background of slow diffuse waves and the lowering of the amplitude of the biopotentials, representing a complex reorganization of the cortical functions according to parameters of lability and excitability, was evaluated as a symptom, characteristic of fatigue. Conversely, short bursts of synchronized and exalted alpha-rhythm in subjects with marked drowsiness were more characteristic of diffuse inhibition as a result of the drowsy states. This is also testifi to by the fact that in these subjects the burst of the exaltation of the alpha-rhythm appeared frequently only after repeated presentation of light stimulus, which was a result of the accumulation of the stimulus and indicates a lowering of the functional mobility of the cortical neurons.

The investigations of the speed of the response motor reaction (V. I. Myasnikov, 1964) showed that in subjects in the experiments with fractional and usual regimes of diurnal activity analogous results were obtained — a decrease of the time of the latent period of the reaction toward the end of the experiments respectively from 0.42 to

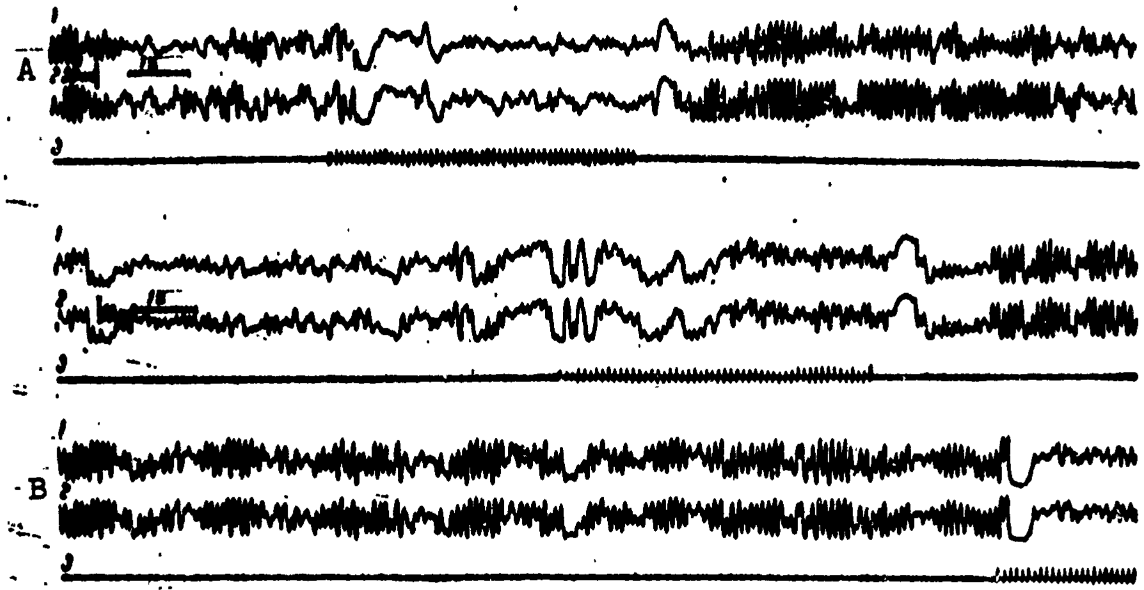

Fig. 12. Dynamics of the duration of trace reactions on the EEG of subject SH-n in isolation during a shifted regime of diurnal activity. 1 — EEG, forehead-back of the head, right; 2 — EEG, forehead-back of the head, left; 3 — mark of the stimulus; A) duration of the exaltation of the alpha-rhythm on the 5th day of the experiment; B) the same on the 12th day; [мкВ = μV].

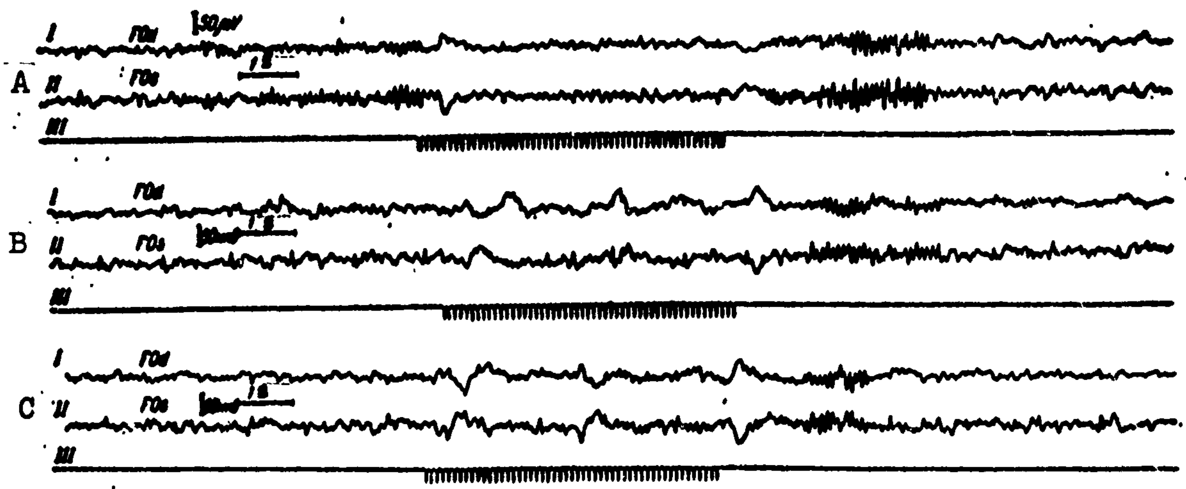

Fig. 13. Dynamics of the duration of trace reactions on the EEG of subject G-n in isolation with a shifted regime of diurnal activity. 1 — EEG, forehead-back of head, right; 2 — EEG, forehead-back of the head, left; 3 — mark of the stimulus; A) duration of the exaltation of the alpha-rhythm on the 4th day of the experiment; B) the same on the 7th day; C) the same on the 10th day; [мкВ = μV].

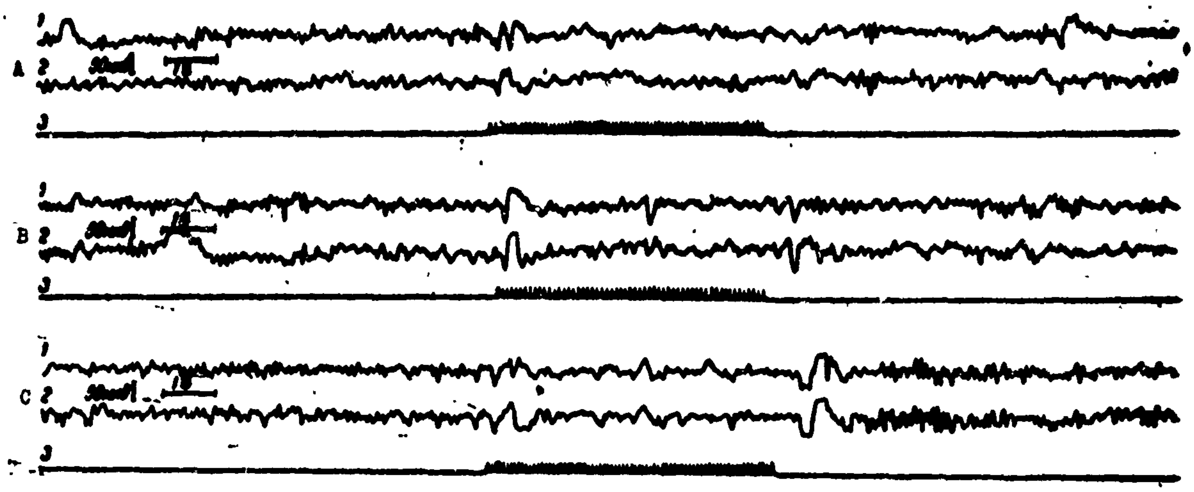

Fig. 14. Effect of the accumulation of the stimulus on the EEG of the subject N-v. 1 — EEG, forehead-back of the head, right; 2 — EEG, forehead-back of the head, left; 3 — mark of the stimulus; A) traced reaction to the first presentation of the light stimulus; B) the same on the second presentation; C) the same on the third presentation; [MKB = μV].

to 0.30 and from 0.56 to 0.38 of a second. The decrease of the latent period of the response reaction toward the end of the investigation indicated the fact of training for the actual test with the subsequent automation of the skill. The value of training in decreasing the time of the response reaction was indicated earlier (A. V. Chapek, 1956; N. N. Gurovskiy, 1957, and others). In the shifted regime of diurnal activity the latent period of the response motor reaction toward the end of the experiment, in contrast, increased from 0.33 to 0.46 of a second (Fig. 15). The increase of the latent period was caused, probably, by the symptoms of fatigue, the first signs of which were detected together with the development in the central nervous system of processes of inhibition (according to electroencephalographic investigations). The fact of the influence of fatigue on the increase of the time of the response motor reaction was noted in the investigations of other authors (A. N. Krestovnikov, 1954; O. G. Gazenko, 1955; Ye. I. Boyko, 1961, and others). The investigations of noise immunity testify to this. The level of noise immunity of subjects in the experiments with the shifted regime of diurnal activity dropped toward the end of the experiment. In analyzing the work with the digital table there was detected a great amount of

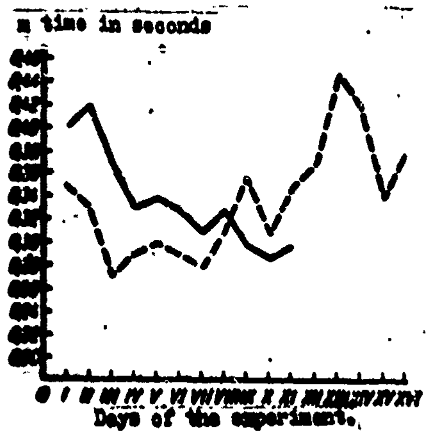

Fig. 15. The curve of the latent period of the response motor reaction in subjects under conditions of isolation with various regimes of diurnal activity. m – the arithmetic mean of the latent period; solid line – changes with the usual regime; dotted line – the same with the shifted regime.

"disinhibition of differentiations" with respect to both calculation and the correct indication of the responses (a black figure was indicated instead of a red one and vice versa). Moreover, in the subjects there was noted the stress of posture and mimicry and a great number of searching motions. The most difficult for differentiation was the middle stage of the work with the black-red table, where the number of similar stimuli increased sharply due to the repetition on ones, twos and threes (F. D. Gorbov, L. D. Chaynova, 1959). The investigation of noise immunity was accompanied by an increase of the total time of work with the digital table and the number of different errors (superfluous responses – demonstrations, divergence and convergence of the series, perseveration of the figures and others) (Fig. 16). In spite of the fact that the obtained data had a certain difference in the quantitative and qualitative expression, nevertheless the level of noise immunity toward the end of experiments with the shifted regime descended. This lowering was connected with the symptoms of fatigue, to which the data of the electroencephalographic investigations and also the increase of the time of the response motor reaction testify. In the experiments with the fractional regime the quality of work with the black-red table toward the end of the investigation also decreased. This was expressed in errors on different sections of work with the digital table (Fig. 17). It is necessary to note that errors for subjects with the fractional regime of diurnal activity were encountered more frequently than with the usual regime, but more rarely than with the shifted regime. As for the character of the errors, they did not differ at all from what was described above and they did not have a tendency to be repeated. Thus,

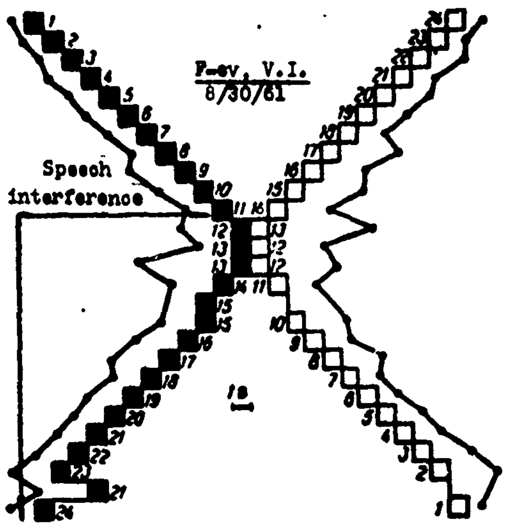

Fig. 16. The results of the work with the black-red table of subject F-v (shifted regime of diurnal activity) on the 10th day of the experiment. The black squares — the black series of figures; light — the red series of figures; the broken line — interresponse intervals of time.

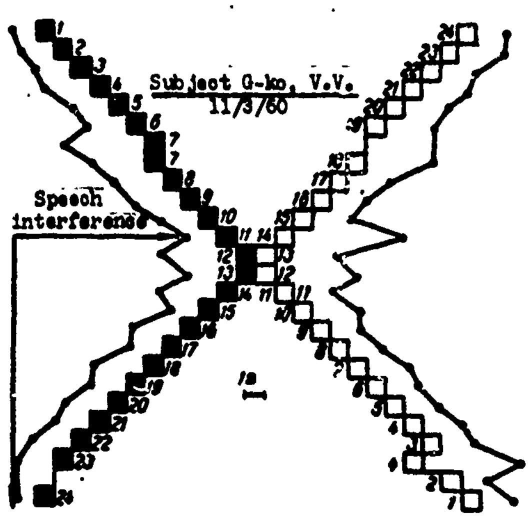

Fig. 17. The results of work with the black-red table of subject G-ko on the 10th day of the experiment (fractional regime of diurnal activity). The designations are the same, as in Fig. 16.

if it is considered that the frequency of the appearance of the errors and their character are an objective expression the level of noise immunity, then the latter in the experiments with the fractional regime was lower than with the usual, but higher than with the shifted regime (Fig 18). The results of the works of K. M. Bykov, A. D. Slonim (1949), E. I. Brandt and O. I. Margolina (1949, 1954) showed that the problem of maintaining efficiency during night work is inseparably connected with the diurnal rhythm of the physiological functions. A. D. Slonim and O. P. Shcherbakova (1935) expressed the assumption that the unfavorable subjective sensations during the night shifts are caused by necessity to perform work against the background of the lowered excitability of the vegetative center. The specially undertaken

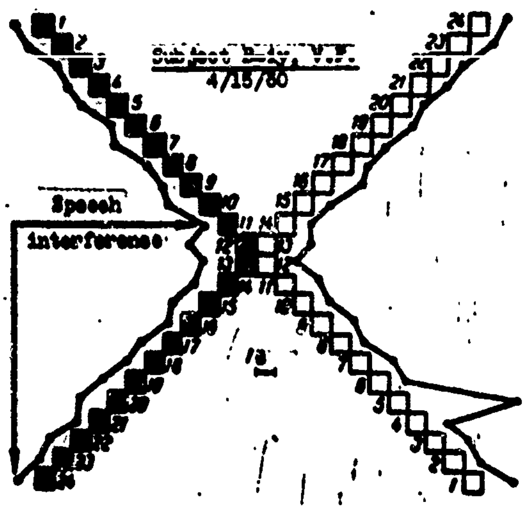

Fig. 18. The results of the work with the black-red table of subject B-iy on the 10th day of the experiment (usual regime). The designations are the same, as in Fig. 16.

electrophysiological investigation of the functional state of the central nervous system by the method of the curves of bioelectric reactivity showed that the prolonged stay of subjects under conditions of isolation with a shifted regime of diurnal activity causes a lowering of the excitability and reactivity of the cerebral cortex: the reorganization of the bioelectric activity to the light stimulation before the experiment was noted by the 5-6th second; at the end of the investigation the reorganization of the biopotentials appeared by the 10-12th second. Sharp reactions were recorded only during the first recording; during the second and third they were weakened or were completely absent (Fig. 19).

The obtained data indicate that in the isolation experiments not only the limiting of external afferentation and also the monotony of the situation affected the subjects' organisms, but the regime of diurnal activity also had a significant effect on the neurophychic sphere.

This circumstance can be allowed for by recommendations for the astronaut's order of the day. In organizing a regime of diurnal activity it is necessary to consider along with the tasks existing before the flight the peculiarities of the situation, the workstation and so forth.

The homogeneity and the monotony of the situation and weightlessness will promote the development of drowsy states. The

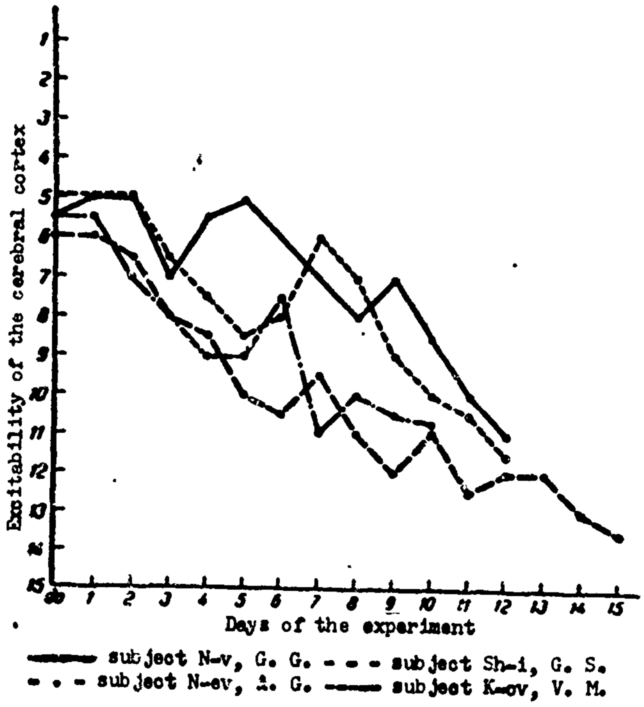

Fig. 19. The change of the excitability of the cerebral cortex in the subjects in experiments with isolation (shifted regime of diurnal activity).

transition from wakefulness to sleep, according to the teachings of I. P. Pavlov, is accomplished through a series of hypnotic phases, which can also be observed in shallow sleep. During the phase states, for example during the so-called paradoxical phase, the sensitivity of the nerve cells to the effect of very weak stimuli — traces from earlier existing impressions — increases. They can be experienced by astronauts as sharp dreams or can have the character of eidetic representations outwardly similar to hallucinations. The characteristic peculiarity of eidetic representations, as was shown by the experiments with isolation, was the fact that, they were accompanied by a great number of associations and emotional reactions expressed in a feeling of joy, annoyance, malice and so forth (V. I. Myasnikov, 1963). As example we will describe the eidetic representations in the isolation experiment of subject D-m.

"So, how do I feel? At times contented, at times — depressed. There is some internal alertness, which manifests itself in the fact that I am listening all the time... moreover, I graphically recall familiar melodies. Sometimes they pop into my ears willy-nilly. I listen to preludes of Rachmaninov, Brahms, Ravel (violin concerto) and, of course, vigorous Beethoven. Such pure Beethoven I haven't heard for a long time, And I lie here in the morning, too lazy to get up, and I hear Beethoven's Ninth Symphony – such inexpressible joy.

Listening to Rachmaninov... I suddenly and distinctly 'see' all the surroundings of the Bol'shoy conversatory hall and I even hear the voices of the mistress of ceremonies. And even better were the vocal pieces, my favorite arias and romances, and boring and flat snatches of mishmash from the dance halls of cities and resorts whirled around in my head like a wild potpourri. They really haunted me. One of them saves me – I start to listen to possible noises in the chamber – every sound of music 'inside me' ceases."

Having at their basis the "inertia of nervous excitation", these complex psychophysiological symptoms, not reflecting any kind of pathology, are more frequently encountered in children and more rarely in adults (Jaensch, 1927; M. M. Kononova, 1929, 1934; L. Vygotskiy, 1930, and others). Being subliminal under normal conditions, they were, under conditions of silence and monotony, spontaneously reproduced, and the emotional stress connected with the duration of the effect of the indicated factors made these impressions distinct and, on the surface, similar to hallucinations.

The development of drowsy states and as a result of this – the development of hypnagogic hallucinations or eidetic representations can lead to a lowering of the psychophysiological resources of the crewmembers from the standpoint of efficient distribution of attention while observing the instruments and equipment of the ship and of speed and accuracy in performing work operations in controlling the ship in outer space.

Ways of preventing the development of drowy states and the consequences resulting from these are:

— the rational construction of the interior of the spaceship cabin. The interior of the cabin, including a customary (terrestrial) setup in stylized and generalized form should exert influence on the psychics of the astronaut and by means of associations should create the necessary emotional background (V. V. Zefel'd, 1964);

— the creation of different sources "of impressions" in the ship's cabin: a cabin interior controlled from earth, tape recorders playing recordings of different musical works, the viewing of motion pictures, and so forth.

The possibility of the development of an emergency situation in space flight may cause in people, reacting pathologically to a similar situation, agitation, psychic excitation or depression, disturbed notions and as a result of this the disturbance of sleep, in particular insomnia. The duration and manifestation of insomnia depend not only on the causes, but also on the individual eccentricities of the personality. Therefore, insomnia can be caused by a deficiency of sleep in some cases or of its qualitative characteristics (depth of sleep, abundance of dreams, difficulties in falling asleep) — in others. The disturbance of the quality of the sleep in similar cases will lead to symptoms of fatigue with a subsequent lowering of the efficiency of the crewmembers. Pathogenetic therapy should be reduced to the taking of soporific, neuroplegic preparations, tranquilizers and ataractics.

An analysis of the experimental data obtained in isolation with different regimes of diurnal activity, made it possible to compare the results of the investigation among themselves and to draw certain conclusions about the possible functional deviations in the neuropsychic sphere of the astronauts. This, in turn, determines the means of coming to a solution of the problem of prolonged maintenance of high efficiency of crewmembers of a spaceship in flight. In the end the solution of problem reduces to the development of a rational regime of work and rest. In this respect the problem of the reliability of the operator from the standpoint of his efficiency can be solved, for example, by creating an artificial regime of diurnal activity on the ship.

The possibility of applying such a regime of diurnal activity rests, in particular, on the necessity of controlling the depth and duration sleep. Up to the present time this equstion has not been completely solved. However, independently of the method (the application of pharmacological preparations of directional effect or with the help of electricity and radio) controlled sleep will make it possible to ensure rapid mobilization of the organism for carrying out tasks specified by the flight program (awakening at an assigned period, rapid entrance into the working activity), and possibly rapid relaxation and falling asleep in periods not connected with controlling the spaceship or executing of special investigations, specified by the flight program.

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EFFICIENCY AND THE STATE OF HIGHER NERVOUS ACTIVITY DURING DIFFERENT REGIMES OF HUMAN LIFE

In this monograph there are presented the results of a study of the process of the adaptation of the human organism to life under different variants of a regime. The experiment was carried out simulating certain conditions of a spaceship with a crew of 3 men, whose forces organized all the forms of necessary works, in particular round-the-clock duties – watches.

It is possible to assume that the reorganization of an evolutionary constituted diurnal periodicity of sleep and wakefulness depends on a number of causes and to a certain extent on how rapidly in the course of the experiment the sleep of the subjects is normalized and how rapidly the reorganization of their vital activity for productive wakefulness in the night hours occurs.

For the characteristics of sleep and wakefulness a written and oral interrogation was carried out. The mental efficiency during the experiment was estimated by a number of methods. Inspections were carried out on the first and second watch after equal intervals from the time of awakening, in succession, in the night, morning, day, and evening periods of the astronomical day.

The subjects had to carry out written computations on paper multipling three-digit figures by three-digit figures, in oral computation – in their mind the multiplying two-digit numbers by two-digit numbers (examples of identical difficulty were selected). During one examination the subjects solved 10-20 examples, which made it possible to process the obtained data by a method of variational statistics and to present them in the form of arithmetic mean values indicating their average error and standard deviation.

In the associative experiment in the course of 2-3 minutes with intervals of 10-15 seconds 20 words – nouns, designating objects of usual everday use and not having any logical connection with each other – were called out to the subject. The subject had to respond, not pondering, with the first word coming into his head. The reaction speed was calculated and the quality of the oral responses was appraised.

For studying operations requiring the coordination of precise hand movements the subjects had to execute a task involving the fastening of components with screws and nuts. They had to rapidly perform 70 operations, each of which consisted of five elements: they had to take a screw out of a box, place it in the aperture, take a nut, place it on the screw, and tighten it. The time-study observations made it possible to record the execution time of each operation, the errors and their type.

The character of the higher nervous activity of the subjects was determined before the experiment and immediately after the termination of the experiment. The strength of the processes of excitation and inhibition, their dynamism, the predominance of one process over another were investigated by the method of V. D. Nebylitsyna (1961).

The value of a tentative EEG-reflex in response to the five-second action of a sound with a frequency of 200 imp/s was determined. The value of the depression of the alpha rhythm (in seconds) during the first, second, and third presentation of the sound was measured. The speed of the disappearance of the alpha rhythm depression during repetition of the sound (before the primary and complete increasing of frequency) was recorded, i.e., under the condition, when during three times in succession the alpha rhythm depression was absent. A conditioned reflex was produced by a sound with a frequency of 200 imp/s with a simple (light) reinforcement, and also a conditioned reflex by the same sound during activating reinforcement, in the capacity of of which there was used the ten-second exposure of photographs (as the index of the manifestation of the conditioned EEG-reflex there served the value of alpha rhythm depression in seconds during the presentation of the isolated sound). The formation of differentiation was produced. As the differential stimulus there was used an intermittent sound with a frequency of 100 imp/s, presented after 2-5 combinations of sound with a frequency 200 imp/s with an activating reinforcement (as the index of the process of the formation of differentiation there served the number of associations before obtaining the first of the three cases of alpha rhythm disappearance).

A study of emotional stress was carried out immediately after the experiment with the help of a special boom with a width of 4 cm and a length of 2.5 m, located at a height of 4 cm from the floor. The subject had to move along this apparatus to the sounds of a metronome with a speed of 2 steps per second (with a step length of 45-50 cm). The loss of equilibrium (oscillations and jumpings) was recorded; with the help of an electrocardiograph the pusle rate, respiration and total speed of movement along the length of the boom (in seconds) was recorded. The degree of emotional stress was ascertained in raising the boom to a height of 40 and 70 cm from the floor.

It was shown by the preliminary experiments that the considerable quickening of the cardiac contractions appearing here, the respiratory delay, in the change in the walking speed — symptons, which appear in a condition, when the subject fears to go along the boom. The state of emotional intensity negatively affects motor coordination. Its impairment, in turn, increases the sense of stress and fear in moving along the narrow boom at a relatively great height.

Therefore, the state of motor coordination was also used as an index of emotional stress.

The results of these experiments showed the following. For subject L. I., who slept during the night and was awake during the day, sleep was normal: he fell asleep rather rapidly; his sleep was without dreams.

In the wakeful period the subject felt in the first half of the experiment rather well. At the end of the experiment he began to complain about the appearance of fatigue and general languor; the forms of activity being executed began to require volitional efforts, the desire to occupy himself in treating the scientific materials decreased, slight noises and minor malfunction irritated him. The appearance of these symptoms L. I. explained by the prolonged stay in the chamber.

The speed in performing mental operations during the first and second watch during the course of the experiment fluctuated insignificantly. A certain statistically doubtful deceleration was observed only at the very end of the experiment (a significant deceleration of the written calculation was recorded on the 13th day, in the first watch). During the course of the experiment the subject performed individual mental operations with approximately identical speed and only at the end of the experiment did there appear a great irregularity in the speed of the arithmetical operations: some calculations L. I. solved quite rapidly, others – extraordinarily slow. In the statistical treatment of the obtained data this was reflected in the different values of the deviations from the arithmetic mean value.

Immediately after the end of the experiment L. I. worked fast and made here an unusually (for him) large number of errors. In the subject's behavior there was noted unusual talkativeness, his movements were less exact.

An examination conducted 20 minutes after the end of the experiment by the electroencephalogrophic method made it possible to detect an increase (by 2.3 times) of alpha rhythm depression during the first presentation of sound. The process of primary extinction of a tentative reaction was carried out faster (by 1.5 times) than before the experiment. However, complete extinction (up to its absence during 3 times in succession of alpha rhythm depression) was not successfully attained. Conditioned alpha rhythm depression was producted in a greater (by 2.9 times) (than before the experiment) number of associations of sound with light. The value of the conditioned alpha rhythm depression in simple and activating reinforcement after the experiment significantly decreased (respectively by 2.1 and 4.4 times), and starting with the 6th presentation of the stimulus (in simple reinforcement) and with the 8th (in activating reinforcement) alpha rhythm depression vanished. Differentiation was not successfully produced due to the absence of conditioned alpha rhythm depression.

In the movement of the subject along the boom there was recorded a deceleration of the movements (before the experiment 4.8 seconds, after – 5.2), a quickening of the pulse was noted (from 75 to 81), there was a delay in respiration, the number losses in equilibrium increased (Table 15).

Table 15.

Subjects	Before the Experiment				After the Experiment			
	1 time		2 times		1 time		2 times	
	pulse rate	time, in seconds	pulse rate	time, in seconds	pulse rate	time, in seconds	pulse rate	time, in seconds
	Height of 4 cm from floor							
G. M.	79	5,7	—	—	115	5,8	125	4,8
N. S.	78	6,6	71	5,3	89	6,3	81	5,2
	Height of 40 cm from floor							
G. M.	78	5,3	75	5,7	100	6,6	115	6,0
N. S.	78	5,9	91	5,6	97	8,0	107	7,8
	Height of 70 cm from floor							
G. M.	86	5,5	90	5,3	125	8,1	115	8,1
N. S.	93	5,7	99	5,9	115	7,5	105	6,5
	Height of 4 cm from floor							
	Number of oscillations	Number of jumps	Number of oscillations	Number of jumps	Number of oscillations	Number of jumps	Number of oscillations	Number of jumps
G. M.	0	0	0	0	1	0	2	0
N. S.	0	0	1	0	3	1	2	0

Subjects (G. M. and N. S.), who lived according to regimes with wakefulness at night and sleep at the unusual time, on the 1-7th day of the experiment complained abut poor sleep: they had difficulty falling asleep, during the sleep they frequently awoke, after sleep they did not feel cheerful and rested. After 9-10 days for G. M. sleep had improved somewhat and after 10-12 days his sleep had normalized. N. S.'s sleep before the end of the experiment was restless.

During the watches, according to time study data, at the beginning of the experiment the subjects in the night and early morning hours frequently dozed and even slept. On the 10th day these states hardly appeared at all.

The interrogation data, having a relationship to the characteristic of the state of wakefulness, can be reduced to the following: at the beginning of the experiment subjects G. M. and N. S., carrying out assignments during night hours, complained about sleepiness and the inefficiency of the mental operations connected with it. In executing assignments during daytime hours they pointed to the absence of a state of complete cheerfulness – to languor, and sometimes, conversely, to stress that, in their opinion, was the result of insufficiently good sleep. Starting from the second half of the experiment and especially at the end of it the subjects noted that in the nighttime hours it became easier to fulfill work assignments, than during the day, and work was calmer. In subjects G. M. and N. S. with respect to the length of the experiment the overall languor and stress in performing mental operations increased; there appeared the complaint about rapid fatigue; there was also noted on expressed negative relationship to the performances of certain assignments. The subjects explained the overall impairment of their mental condition by the prolonged stay under the conditions of the experiment.

The data obtained during the study of mental efficiency made it possible to come to a conclusion about the high quality of the work operations. In the associative experiment primitive speech responses (interjections, repetitions of word-signals, and the refusals to respond) were hardly recorded at all. The number of errors in computation increased only in one case (for subject N. S. during written computation).

The speed of the mental operations of subjects G. M. and N. S. in the period of the experiment was considerably less than before the experiment. The deceleration of reactions in the course of the experiment was traced in most cases, however, it was not statistically certain.

The dynamics of the change of speed of mental operations made it possible to draw the conclusion that the performance of the assignments in the beginning of the experiment was delayed more than in the subsequent periods of the experiment. In a number of cases such a deceleration was statistically proved. A comparative analysis of the speed in all cases of solving the problems showed that at the beginning of the experiment the subjects in performing one assignment carried out the arithmetical operations at one time relatively fast, at another time very slowly. A similar irregularity in the mental operations was especially distinctly observed in the work of the subjects in the night period.

At the end of the experiment in a number of cases there was recorded an increase in the speed of reaction and the disappearance of cases of the especially prolonged performance of individual assignments (such dynamics of changes was not traced in the change of the computation rate for subject N. S.: obviously, the gradual acceleration for this subject according to the experiment with the given mental operations was connected with the training).

An analysis of the speed in performing the work operations at the beginning of the experiment in the first and second watch showed the following: subject G. M. in the first watch in conjunction with the two relatively contributory factors (the evening hours and after 4-6 hours of sleep) performed the assignment- more rapidly than in the second watch. In the middle of the experiment (the 6-11th day) in a number of cases G. M. in the second watch performed the required operations faster than in the first. At the end of the experiment (the 13th day) the average time of the reactions in first and second watch was approximately identical.

For subject N. S. at the beginning of the experiment (2-3rd day) the speed of reaction in the first watch (at night, but immediately after sleep) was considerably delayed. Furthermore, the subject, fulfilling the assignment, solved individual problems rather slowly. In the second watch, which occurred early in the morning against a background of considerable fatigue (13-14 hours after sleep) the reaction speed was also small. In the middle and at the end of the experiment (6-13th day) the subject sometimes worked faster in the first watch, sometimes in the second watch; in a number of cases the reaction speed was approximately identical.

The performance of the assignment of fastening the strips with screws and nuts at the beginning of the experiment was slow. The subject performed this action especially slow at night. In the middle and at the end of the experiment the work began to be carried out faster, moreover, in the first and second watch the subjects worked with approximately identical speed. The coordination of the fine hand movements for subject G. M. considerably deteriorated, toward the end of the experiment he dropped the nuts and screws, and executed superfluous motions.

Immediately after the termination of the experiment G. M. and N. S. carried out the required actions rapidly, but here an especially large number of errors was recorded for them. A qualitative analysis of these errors made it possible to determine them as essential (the subjects forgot the multiplication table, in performing the associative experiment primitive speech responses appeared).

Moreover, the behavior of G. M. and N. S. during the inspections differed from the usual: the subjects uttered aloud certain sections of their assignments, forgot the results of their own actions, appealed to the experimenter, tried to joke, etc. In the interrogation G. M. and N. S. noted a joyful and excited state; they said they worked easily, without tension, they did not feel fatigue.

An examination of the reaction of the nervous system by the electroencephalographical method was carried out only for N. S. (G. M. belonged to the type of people, who do not manifest an alpha rhythm).

Forty-five minutes after the termination of the experiment in subject N. S. there was not detected any changes in the value of the tentative reaction as compared to similar data obtained before the experiment. However, in the second and third presentation of sound, i.e., 9 and 14 seconds after the first presentation, the value of alpha rhythm depression sharply decreased as compared to its values before the experiment (in the second presentation by 7 times and in the third - by 1.8 times). The process of primary extinction of the tentative reaction was carried out faster (by 2.5 times), however, complete extinction was not attained after 25 presentations of the sound. Conditioned alpha rhythm depression was produced in a greater (by 2.6 times) (than before the experiment), number of associations of sound with light. The value of the conditioned alpha rhythm depression decreased in simple (by 3.6 times) and in activating reinforcement (by 2.3 times). Differentiation was not successfully produced.

The materials (Table 15) obtained in the movement of the subjects along the boom at a different height made it possible to record greater (than before the experiment) oscillations in the walking speed along the boom. The movements became nonuniform: the subjects sometimes ran, then they began to walk very slowly, they stopped, for a long time then they could not take the next step. The pulse became more rapid and increase on the high booms was more considerably expressed. In the words of subject G. M., the movement along the raised boom began to cause greater (than before the experiment) apprehensions.

On the day after the termination of the experiment the reaction speed was approximately the same as before the experiment; the number of errors sharply decreased; the behavior of the subjects did not reveal significant deviations.

The materials obtained in studying the efficiency of the first subject (L. I.), whose regime of life assumed a time of sleep coinciding with the night period, indicated unerring and rapid execution by the subject of the various experimental assignments. A certain deceleration of the reactions at the end of the experiment, obviously, was connected with the fatigue and the state of general languor which developed in the course of the experiment. The absence during the period of the experiment of the deceleration of reactions in the second watch as compared to the first watch testified to the preservation of the normal efficiency of the subject in the period of wakefulness. One of the essential causes determining the high efficiency of L. I. was good sleep.

The materials obtained during the study of the efficiency of G. M. and N. S., who stayed awake at night, in the early morning and late evening hours (under a condition of sleep at an unusual time of the day), testified to a deceleration of almost all reactions. This signified that a significant chnage of the regime of life, not affecting the quality of the work, led to inhibited mental operations.

An especially great deceleration of the reaction speed in the first half of the experiment indicated that the sharp transition from the usual regime of life to the experimental one was considerably reflected in the efficiency of the subjects. The impairment of the sleep and wakefulness processes with such a transition, obviously, can be examined as one of the causes of the decline of efficiency. In all probability, a certain role was also played by the diurnal periodicity, in which the nighttime hours were the least productive for mental operations. The tendency towards the normalization of the reaction speed under the condition of the improvement of sleep and the state of wakefulness testified to the beginning of the process of acclimatization.

It is known that the duration of alpha rhythm depression in a tentative reaction can be treated (V. D. Nebylitsyn, 1966) as an index of the stimulating process. A detected increase of alpha rhythm depression in one of the subjects made it possible to assume a greater (than before the experiment) intensity of the excitation process in the first presentation of the sound. However, a rapid decrease in the value of the tentative reaction after 7-12 seconds (in the first and second presentation of the light) indicated a sharp lowering of its intensity. A faster (than before the experiment) primary extinction of the tentative reaction and, conversely, a deceleration of the extinction before obtaining during 3 times in succession the absence of alpha rhythm depression testified, on the one hand, to the greater intensity of the inhibition process, and on the other – to the low level of its dynamism. It is known that the generation rate of a conditioned reflex is a function of the stimulating process (Ye. N. Sekalov, 1958, and other), and, consequently, if in a person inhibition is less expressed than excitation, reflexes will form rapidly in him, and if inhibition predominates – slowly. The speed of the development process of EEG-reflexes made it possible to draw the conclusion about the considerable postexperimental shifts in the relationship of the processes of excitation and inhibition in the direction of the predominance of excitation. The decrease (as compared to the data obtained before the experiment) of the value of the conditioned reflex and its rapid disappearance testified to the extinguishability of the excitation process. The fact that we did not successfully produce differentiations, whereas before the experiment they were obtained rapidly, indicated a weakening of the inhibitory process; it is known that the formation rate of differentiations, according to N. A. Podkopayev (1952) and N. I. Mayzel' (1956), is an index of the strength of the inhibitory process.

Thus, the state of higher nervous activity immediately after the experiment was characterized by the predominance of the excitation process; moreover, the excitation process possessed less (than before the experiment) strength; it appeared rapidly, but having appeared it was rapidly extinguished. The inhibition process also weakened.

Obviously, such a state of higher nervous activity of the subjects had an effect on their efficiency, as a consequence of which it was possible to assume the appearance of the haste of the actions, an increase in the number of errors, the absence of proper control and a serious attitude to their work on the experimental assignments. The shifts with respect to the processes of excitation and inhibition, the weakening and rapid extinction of excitation, the weakening of the inhibition process can also be explained by certain features of the behavior of the subjects and by their mood. The materials obtained during the study of the indices of the subjects walking along the boom testified to the fact that the participants in the experiment at this period were in a state of emotional stress.

The fact that the given symptoms took place only immediately after the experiment, and then vanished, testified to the connection of the above described state with the postexperimental period.

Summarizing everything that has been said above, it is possible to draw the conclusion that the efficiency in a regime of life with sleep in the nighttime (in the course of the experiment) changed insignificantly and its changes were connected with the prolonged influence of the conditions of the experiment.

The change of efficiency with a significant change of the regime of life of the participants in the experiment was mainly expressed in the deceleration of reactions. It was most considerably expressed at the beginning of the experiment (in the sharp transition to the life under the experimental conditions); subsequently the speed of the reactions increased; at the end of the experiment there was observed a certain deceleration in the reactions connected, apparently, with the prolonged stay of the subjects under conditions of the experiment.

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DYNAMICS OF MENTAL EFFICIENCY UNDER CONDITIONS OF HYPODYNAMIA, ISOLATION AND ELEVATED TEMPERATURE IN A PRESSURIZED CHAMBER

In prolonged space flights man will be subjected to the influence of specific conditions — weightlessness, hypodynamia, deficiency of afferentation, etc. Work activity under these conditions will therefore differ in its structure from activity under usual terrestrial conditions. Thus, for example, the monitoring activity of the astronaut will be characterized by monotony, uniformity, the comparative poverty of external impressions (the almost unchanging picture of the stellar sky, the absence of external sound stimulations, etc.). Therefore, it is necessary, when maximumly approaching the actual conditions of vital activity in flights, in laboratory terrestrial experiments to thoroughly trace the dynamics of mental and physical efficiency under the influence of various unfavorable conditions.

The majority of the foreign and domestic investigations has been dedicated to the study of the influence of conditioned isolation, hypodynamia, decreased and increased barometric pressure in the chamber, hypoxia, etc., on the physical efficiency of man. Thus, Levy and Thaler note that under conditions of strict isolation efficiency decreases, neuromuscular stress and a state of depression appear. This state becomes worse with the increase of the period of the stay in the chamber.

Gerathewohl (1959), Hartman (1962), Ewrard and Henrotte (1959) indicate such a change. Lewis (1959) in his experiment showed, that under conditions of insufficiently strict isolation efficiency also descends.

Analogous data were also obtained by domestic researchers (M. B. Umarov, A. V. Lebedinskiy, S. V. Levinskiy, Yu. G. Nefedov, F. D. Gorbov, V. I. Myasnikov, V. I. Yazdovskiy and others).

In investigations, dedicated to the study of the influence of hypodynamia (Gerathewohl, N. A. Agadzhanyan, A. G. Kuznetsov and others), there is noted along with impairment of physical efficiency a decrease of attention and a deceleration of the cognitive processes.

It is necessary to say, however that up to the present the unstudied question remains, of how in regard to dynamics the mental efficiency and psychic functions change both under conditions of isolation and hypodynamia, as well as under unfavorable temperature changes of the environment in the pressurized chamber.

In domestic and foreign literature the investigations dedicated to this question are not reflected.

The purpose of the present investigation — to study the influence of limited mobility, partial sensory isolation and increased temperature in a pressurized chamber of small volume on the mental efficiency and psychic functions of a subject (thinking, memory, attention).

We conducted three experiments. The purpose of two 15-day experiments was to study the influence of the conditions of partial sensory isolation and hypodynamia on the concentration of attention, memory and mental efficiency of the subject. The investigation was conducted in a pressurized chamber of small volume (5 m^3) at a temperature of 20-23°, an atmospheric humidity of 45%, and a carbon dioxide content of not more than 0.5-0.8%.

In the first experiment a scientific colleague (32 years) was the subject; he had a good education and good physical training and had repeatedly participated in analogous experiments. In the second experiment an engineer of 29 years was the subject; he was participating in the experiment for the first time. The communication with the subjects was accomplished with help of a microphone. The third experiment was dedicated to the study of the influence of increased temperature and humidity in the chamber on the same processes and efficiency: 4 subjects were investigated, who were in a specially equipped chamber. The temperature in the chamber was 38-40°, the humidity was 66-70%. In the chamber each day for 4 hours were placed the 2 subjects. The investigation was carried out for 4 days, so that each pair was in the chamber 4 hours each per day.

The investigations in the first two 15-day experiments was carried out before the experiment, 4 times in the course of the experiment (on 2, 8, 10, and 14th day) and after exiting from the pressurized chamber. In the third experiment the investigation conducted daily before the beginning of the experiment and 2 hour after going into the pressurized chamber.

The regime of vital activity in the two 15-day experiments did not change; the customary regime was in effect. The subjects slept during the customary nighttime and came to work at 9 o'clock a.m. After the morning hygienic procedures and a medical examination they performed mental and physical work according to a specific program, alternating it with active rest.

The control group consisted of 15 subjects, who had passed a thorough medical selection. All the subjects — physicians and engineers of ages up to 30 years — were occupied with analogous activity, but under usual conditions. The material of the investigation of the subjects of the control group made it possible to compare and to estimate those changes of the psychic processes and mental efficiency, which developed under the conditions of limited mobility, isolation, and thermal action.

In the study of mental efficiency the following methods were used.

For studying the productivity of the mental activity and its rate — the complicated and modified Kraepelin test (per line addition and subtraction of numbers during the same time interval). The productivity was judged here according to the number of operations performed and the quality of the performance (the number of erroneous solutions).

The concentration of attention was studied with the help of proofreading tests. The appraisal of the concentration was made according to the presence or absence of errors in carrying out the test. The test performance time, i.e., how rapidly the subject concentrates his attention on the object, was an additional index of the character of attention concentration.

For investigating memory concrete and abstract words were used. The preservation of the new material and the permanence of the memorization were judged by the character of reproduction immediately after the presentation and after a specific time interval.

The thinking of the subjects was studied with the help of an association experiment (variants — to respond with a word of opposite meaning). According to the character of the associations, and the response time there were judged the peculiarities of the cognitive activity of the subject.

In the first 15-day experiment during the stay of subject A in the pressurized chamber with small volume the productivity of his mental activity nonuniformly deteriorated, attaining the greatest loss near the time of exiting from the pressurized chamber. If one were to trace the dynamics of the change of productivity of the mental activity and its rate, then it would be revealed that its greatest loss would fall on the 2, 8, and 10th day of the experiment (Fig. 20). It is exactly on these days that the number of errors noticeably increased in performing the proposed operations. The rate of assignment performance decelerated. The time required for execution of the individual mental actions increased by one and a half times as compared to the initial data.

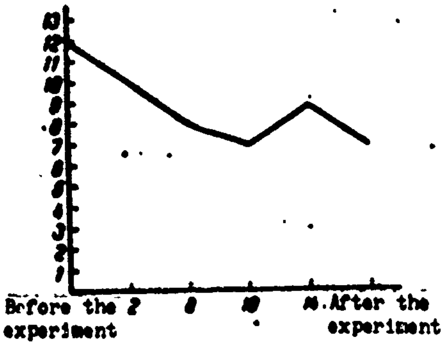

Fig. 20. The change of the productivity of mental activity of subject A. Along the axis of the abscissas — the days of the investigation; along the axis of the ordinates — the number of mental operations carried out.

On the 10th day for subject A the rate of mental activity decelerated still more; productivity dropped.

On the 14th day of the stay in the pressurized chamber there was observed an increase of mental productivity: the number of erroneous solutions decreased; the activity rate became more uniform. In the interrogation it was ascertained that this occurred due to the termination effect and the mobilization of the compensator possibilities of the organism.

"I became accustomed to the conditions of the pressurized chamber — he says, — but I had to have great willpower to perform the assignment. I tried to perform it thoroughly, because I knew that there remained one more day, the last day of my stay in the chamber. This inspired me."

The latent time of the response reaction in the association experiment for subject A on the 2nd and 8th day was increased by almost 2 times as compared to the initial data and the data of the control group.

The dynamics of the change of attention concentration of this subject was almost analogous to the changes of the productivity of the mental activity (Fig. 21). The concentration of attention dropped, starting with the 2nd day of the stay in the pressurized chamber, attaining its greatest loss on the 8th day. On the 14th day an improvement was observed.

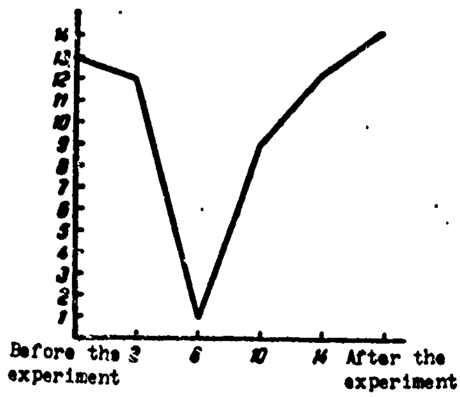

Fig. 21. The change of attention concentration for subject A (the first experiment).

The memory of subject A during the whole experiment hardly changed at all.

An insignificant memory loss was observed only on the 2nd day of the stay in the hermetic chamber. During the remaining days the function of the memory remained unchanged.

The indices of attention concentration and memory after exiting from the hermetic chamber improved insignificantly as compared to the initial data, but the productivity of the mental activity decreased. Towards the end of the execution of the assignment (productivity curve descended) rapid fatigability appeared. It is necessary to say, however, that the investigation after the subject exited from the hermetic chamber was conducted not on the 1st but on the 3rd day. Before the investigation the subject had active diurnal rest.

In the second 15-day experiment (subject B) the dynamics of the change of the psychic functions and the productivity of the mental activity by days was close according to its own indices to the data obtained during the investigation of subject A (the first experiment).

On the 2nd day of the stay in the hermetic chamber with small volume for him, just like for the first subject, the productivity of the mental activity deteriorated as compared to the initial data (Fig. 22). There were observed more erroneous solutions in performing

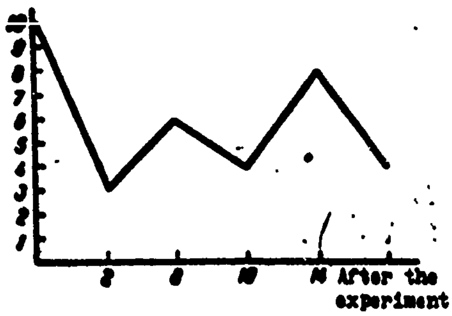

Fig. 22. The change of the productivity of mental activity of subject B.

the mental operations; the overall time for performing the individual actions was extended.

On the 8th day the productivity of the mental activity also dropped, but less than on the 2nd day.

A more marked productivity drop was observed on the 10th day of the stay in the hermetic chamber.

On all the enumerated days the attention concentration for the subject also dropped (Fig. 23). The time for performing the proof-reading tests was extended.

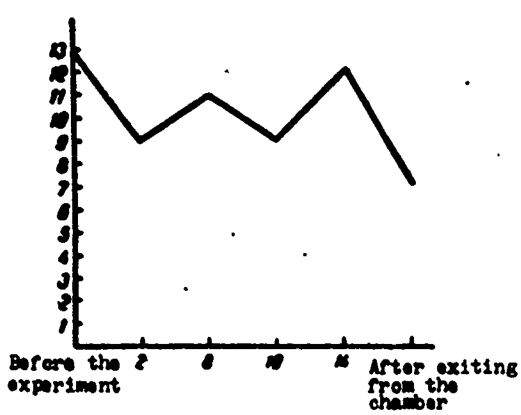

Fig. 23. The change of attention concentration of subject B. (the second experiment).

In the association experiment an increase of the latent time of the response reaction appeared, but the associations were adequate.

The memorization process decelerated in time. The subject

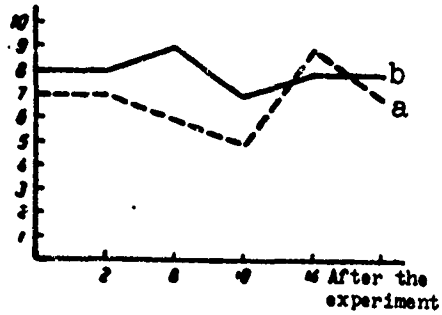

Fig. 24. The dynamics of memory change in subject B. Along the axis of the abscissas — the days of the investigations; along the axis of the ordinates — the number of memorized words. a) abstract words; b) concrete words.

asked for slower presentation of the words for memorization, referring to the difficulty of memorization. If for subject A the memory during the experiment almost did not undergo changes, then for the second subject a noticeable irregularity in the memory loss (Fig. 24) is observed.

It is characteristic that for him, as well as for the first subject, on the 14th day of the stay in the hermetic chamber there was observed improvement both in the productivity of the mental activity, as well as in attention concentration. The mental operations he performed qualitatively better; the number of erroneous solutions was sharply reduced. However, the rate of mental activity descended; the time for performing the individual operations was extended. Subjectively, subject B appraises it this way: "I became accustomed to the conditions of the hermetic chamber. My state of being was good. I perform the assignments only slower and with effort, trying to execute them well."

After exiting from the hermetic chamber (the indices were taken on another day) the productivity of the mental activity was reduced. The rate of performing mental operations sharply decreased and was nonuniform as compared to the background data; the subject became rapidly fatigued. The concentration of attention, the process of concentrating was slowed down. The indices of memorization were analogous to the data obtained from the experiment.

It is necessary to note that in subject B there was also observed a more expressed deceleration of the cognitive process. The latent time of the response reactions was increased. The associations in general were inadequate. The objective data were also confirmed by the results of a self-check. The subject refers to the fact that it was difficult for him to think, he became "wooden," he notes dizziness, difficulties in concentration.

The data of the analysis of the indices of the change of the psychic processes and the productivity of the mental activity of subject B testifies to the more expressed negative influence on him of the conditions of the experiment.

A study of the materials of the investigation obtained in the experiment with the temperature effect shows that the influence of increased temperature and humidity in the chamber on the 4 subjects participating in the experiment was different. This distinction is explained, obviously, as due to the typological peculiarities of the subjects by their training for effects of a similar kind, and also by their attitude to the performance of the assigned work.

In two subjects (C and G) the deviations were not so significant. For two others (E and F) the influence of the conditions of the experiment was sharply expressed.

On the first day of the investigation in subject C the number of errors in performing the proofreading test increased considerably, attention concentration deteriorated as compared to the initial data. The performance time of the test remained unchanged.

On the second day with the same body temperature (38°), chamber temperature (39°), humidity (66%) the time for performing the proofreading test became protracted, but the number of errors decreased. The amount of memorized material on the first day of the stay of the subject in the chamber, the temperature in which was 39°, decreased by 30-40% as compared to the initial data. The mental productivity of subject C on the first day as compared to the background data decreased. The rate became nonuniform. The time required to perform the mental operations increased.

In the association experiment there was revealed a deceleration in the time of the response reactions; the associations were adequate.

On the second day the influence of the increased temperature and humidity was noticeably less.

In subject D, located in the chamber simultaneously with subject C, almost analogous changes were observed.

On the first day there was also revealed a deterioration of attention concentration and an increase of the performance time for the proofreading test. On the second day the effect of the raised temperature and humidity was less. The attention became more concentrated, and focused; the number of errors in executing the proofreading test decreased.

Memory, just like for the first subject, situated simultaneously in chamber, on the first day of the investigation worsened. The amount of material memorized by him dropped by 30% as compared to the initial data and the data of the control group, and on the second day by 20%. In this case, as we see, the data of the investigation of the memory by days for both subject were almost analogous. An analysis of the data of the productivity of the mental activity of subject D testifies to its drop. Furthermore, the rate of the activity became nonuniform with a drop toward the end of the stay in the chamber, which testifies to incipient fatigue. If one were to compare the data of the mental efficiency by days, then the efficiency would have noticeably deteriorated on the first day. The quantitative side did not suffer especially, but the qualitative side did: more errors appeared in performing the tests. The cognitive processes slowed down; the latent time of the response reaction in the association experiment increased as compared to the initial data, but the associations were adequate.

An analysis of the data obtained in the investigation of the psychic functions in the second pair of subjects E and F and the productivity of their mental activity testifies to the more marked effect on these by the conditions of increased temperature and humidity in the chamber. Thus, the productivity of the mental activity of subject E sharply decreased qualitatively on the first day. There was a still greater drop of the quality of the executed cognitive operations on the second day. The number of erroneous solutions increased by 3 times as compared to the initial data and the data of the control group; expressed fatigue appeared (the productivity curve descended toward the end of the execution of the assignment). Attention concentration sharply fell, the number of errors increased by 10 times as compared to the initial data on the first day of the investigation and by 8 times — on the second day. Memory remained stable on both the first and second day of the experiment. The time of the response reaction in the association experiment hardly changed at all.

In subject F paired with subject E the attention concentration also sharply dropped on the first and second day of the experiment. On the first day it decreased by 3 times as compared to the initial data, on the second day — by 2 times.

The productivity of the mental activity of subject F sharply decreased on both the first day of the investigation and also on the second. The rate of the assignment performance decelerated; marked fatigue appeared.

Memory, just as in subject E, did not undergo significant changes.

In the association experiment the latent time of the response reaction doubled; the associations were frequently not reasoned out and they were inadequate. It is characteristic that the vegetative functions in the last 2 subjects (E and F) during the experiment also changed more sharply.

An analysis of the material, thus, shows that under the conditions of a hermetic chamber with small volume with partial sensory isolation and limited mobility, with the temperature in the chamber not higher than 20-22° and with the humidity not more than 45% the productivity of the mental activity for both subjects sharply oscillates with respect to the days, worsening toward the end of the stay in the hermetic chamber. An expressed impairment of the productivity of the mental activity, and also of the attention concentration and thinking for both subjects on the second day of the stay under the conditions of the hermetic chamber and on the 8th (for tested A), on the 10th (for tested B) day of the experiment is noted.

The conditions with partial sensory isolation and hypodynamia have the greatest negative effect on the cognitive processes of the subject, the productivity of the mental activity and the attention concentration.

The cognitive process under the conditions of the experiment decelerates in time, deteriorates qualitatively.

Under the conditions of the hermetic chamber with increased temperature and humidity there was observed a more expressed deterioration of the mental efficiency, of the concentration of attention and memory and a deceleration of the cognitive processes. Thus, the mental efficiency quantitatively decreases on the average by 2 times. The attention concentration worsens on the average by 5-10 times as compared to the initial data of the same subjects and the data of the control group.

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THE SIGNIFICANCE OF MUSCULAR ACTIVITY IN PRESERVING THE STABILITY OF THE MOTOR FUNCTION OF THE ASTRONAUT

The problem of the stability of the motor function has great value for preserving different aspects of the vital activity of the organism and maintaining the high efficiency of the astronaut in flight. The stability of the motor function to a significant extent is connected with the level and the character of the development of a number of psychic, physiological and biochemical processes, and also with the morphological development of various organs and systems, which in turn depends on the character and level of the physical preparedness of the person.

In some cases high physical preparedness ensures the expansion of the possibilities of life under conditions of the change of the gas composition of the air, of temperature, natural radiation and others; in others — broader compensation for the possible negative shifts appearing under the conditions of existence, which are different from the terrestrial conditions (weightlessness and others).

At the basis of the intensification and preservation of the interconnections of the organism with the environment, which is attained as a result of systematic and organized motor activity, lies the improvement of a number of psychic functions, motor control, metabolism, functions of respiration, blood circulation, secretion of the glands of internal secretion and others.

We will not dwell on an analysis of the physiological reactions of a man during the action of all factors of a space flight; we will only point out the change of certain peculiarities of the motor function in connection with the conditions of weightlessness and hypodynamia.

Dietlein (1964) noted that in carrying out physical work (stretching a rubber extensor-exerciser) during Cooper's flight the speed of restoration of the pulse rate after the work to the initial level was considerably delayed during the flight as compared to the preflight speed. This relatively slow pulse restoration testifies to the impairment of the overall state of the astronaut, inasmuch as the speed of restoration of the pulse rate is one of the basic indices of the level of physical training. There was also noted the manifestation of orthostatic hypotension with an increase of the pulse rate from 83 in the horizontal position to 123 in the standing position. The average arterial pressure for Cooper after the flight was considerably lower than before or during the flight. Even 18 hours after the flight symptoms of orthostatic instability were noted. In studying the data of astronaut Schirra's flight, the same author indicates, in the postflight period the pulse rate in the horizontal position was 56, the arterial pressure – 120/84 mm Hg. In the transition to the vertical position the pulse rate increased to 104, the arterial pressure dropped to 94/70. It is notewrothy that these manifestations of orthostatic hypotension were maintained for 18 hours after the flight. Schirra did not note dizziness or other symptoms, which could be attributed to the cardiovascular system, when he assumed the vertical position in the postflight period.

The appearance of orthostatic hypotension, observed after two flights, is, apparently, the result of the influence of unfavorable factors, in particular weightlessness. In the presence of gravitation the big veins of the lower limbs are subjected to the effect of a pressure of about 100 mm Hg due to the weight of the hydrostatic column of blood. During weightlessness, and also during a stay in bed, during immobilization or during a stay in water this hydrostatic pressure is practically absent. The vasomotor reflex mechanisms, which control the tonus of the veins and thanks to which maintain the return of the blood to the heart, do not ensure successful control of the vascular tonus. In returning to normal gravitation these reflexes cannot be rapidly restored without a certain period of readaption to the forces of the gravitational field, and the accumulation of the blood in the veins of the lower limbs.

According to Dietlein (1964) under conditions free from gravitation the load on the skeletomuscular system noticeably decreases. The movement of the body is facilitated, and the need for contraction of the powerful musculature, which supports the normal posture of the body, noticeably decreases. The load and the stress applied to parts of skeleton during muscular contractions simultaneously decreases, the load on the skeleton also decreases, which is connected with the necessity of supporting the weight of the body. It is impossible to forget that a strict bed regime or immobilization leads to the atrophy of muscles and finally to excess excretion of calcium with the urine, which is connected with the beginning of demineralization of the bones of the skeleton. The beginning of the atrophy of the muscles and bone under conditions of weightlessness can be anticipated after approximately 14 days with a progressive increase after that, if one does not use prophylactic measures or medicinal means. Dietlein assumes that the existing program of isometric exercises can either prevent muscular (skeletal) atrophy, or delay its development.

At the present time one of the widespread methods for simulating weightlessness under ground conditions is the immersion of a person in water (Benson and others, 1962).

In studying the effect of a man's stay in water with various duration a significant decrease of the stability of the cardiovascular system of the subjects to the orthostatic tests is noted (David, 1961). Graybiel, Clark and others (1961) in investigating the effect of immersion of various duration noted considerable changes in the reactivity of the cardiovascular system, muscular functions, the disturbance of motor coordination and the ability of the subjects to orientate themselves in space. It was noted that the tolerance of overloads after a stay in water is considerably diminished. In the first 3 days after the beginning of the experiment there were observed a general water loss, polyuria, an increase of the excretion of nitrogen with the urine.

In the work of David (1961) on the appearance of the influence of lowered motor activity on the tolerance of overloads there was noted a lowering of muscular force and ability to fulfill physical work, a disturbance of stability of the motor function. D Ye. Greyvlayn (1962) notes that under the influence of a 7-day stay of the subjects in water for them the amount of performed work on the cycle-ergometer decreased. The work was accompanied by a more marked pulse rate, respiratory rate, and a decrease of the pulse arterial pressure. The orthostatic test during the experiment and after it was accompanied by a more expressed pulse rate, a decrease of the pulse arterial pressure, an increase on the EKG of the P wave, and a merging of the S and T waves. For the purpose of evaluating the functional state during simulated weightlessness there was conducted an investigation on professional divers, who for 18 hours were completely (with a respiratory mask) submerged in a water tank at a temperature of 34.4-35° (Berson and others, 1962). These authors note that after a prolonged stay in the water the motor accuracy decreased and a number of indices of motor coordination deteriorated. In the water the subjects developed much greater force than was required by the instructions.

Being based on a mathematical analysis of hermodynamics and considering the unusual conditions of existence under conditions of lowered gravitation, Moutzithropoulos (1963) points to a number of disturbances appearing under conditions of weightlessness or lowered gravitation, the basic ones of which are muscular weakness and even degeneration of the muscles. The absence of the force of terrestrial gravitation to a considerable degree complicates the work of man on board a spaceship-satellite and can even lead to a great loss of efficiency. Furthermore, the lowering of muscular tonus and disturbance of coordination in the muscular movements can appear. Nevertheless it is possible to assume that man can adapt to and carry out flight assignments without errors. The effect of weightlessness on the cardiovascular system is expressed by a slight lowering of the arterial pressure and the heartbeat rate with a periodic quickening of the pulse. Such functions as respiration, the swallowing of food, defecation and urination, are not disturbed. Thus, the human organism can endure the short-term effect of weightlessness. The question of the effect of prolonged flight still remains open and awaits solution.

The influence of limited mobility on the human organism under different conditions of work and athletic activity was studied by a number of authors (A. V. Korobkov and his coworkers, 1961). They investigated the effect of prolonged (many-day) relative adynamy under the conditions of a naval expedition and relative isolation. They studied the influence of relative adynamy on the state of certain motor functions under conditions of prolonged isolation in this experiment. The authors revealed that under conditions of relative adynamy different (in depth and character) changes appeared both in the motor and vegetative functions. Under the influence of the prolonged effect of hypodynamia there arises a sharp lowering of the functional possibilities of the organism for such indices, as muscular force, endurance, and the ability to coordinate movement. The question of physical training acquires important practical significance under these conditions.

Thus, a state of weightlessness, or close to it, has a very significant effect on a number of physiological reactions connected with the motor function, which can determine the success of the whole space flight. Weightlessness with the increase of the duration of the flight has a great effect on the vital activity and behavior of the astronauts.

At present it is possible to indicate two methods of increasing the resistance of the organism to the effect of unfavorable factors of the environment — specific and unspecific. In the specific method the increase of the resistance of the organism is attained by the action of the stimulus itself, for example in superheating during frequent location under conditions of high temperature, in hypoxia with a deficiency of oxygen in the inhaled air, et. The development of resistance to any factor (for example, overload) during the action of other stimuli (hypoxia) constitutes an example of unspecific increase of resistance.

This phenomenon was noticed very long ago and has been widely used in practice of hydropathy, physical exercises, cold rubdowns, air baths.

Some of the methods of unspecific increase of the resistance of the organism to unfavorable factors are physical exercises which simultaneously solve a number of problems promoting improvement of the motor and vegetative functions in the organism.

Many experimental investigations and observations have revealed that purposeful physical training and toughening increase the resistance of the organism to unfavorable factors of the environment and to diseases (N. V. Lazarev, 1958; A. V. Korobkov, V. A. Shkurdov, N. N. Yakoviev, Ye. S. Yakovleva, 1962, and others).

Physical training increases the resistance to hypoxia (N. N. Yakovlev, 1955; Ya. A. Egolinskiy and M. M. Bogorad, 1959) to the effect of toxic substances (N. V. Lazarev, 1958, and others), to various kinds of diseases (M. A. Shernyakov, 1959, and others), to penetrating radiation. Physical exercises can increase the resistance of the organism to changes of temperature (N. A. Matyushchkina, 1956, and others).

In the process of muscular work there occurs an improvement of the nervous regulation of the motor and vegetative functions. During purposeful physical training in the muscular system the chemism of the metabolic processes is significantly changed, nervous and humoral regulation improves, and the activity of many enzymatic systems is increased. All of this promotes the development of the protective properties of organism and increases its resistance to a number of unfavorable factors.

In connection with the peculiarity of space flights there arises the important question of the character of physical exercises (duration and intensity), which can be recommended for flight, and for their influence on the efficiency and unspecific resistance of the organism.

In a special series of investigations conducted by A. V. Korobkov, D. A. Golovacheva, V. A. Shkurdoda (1960), it has been shown that for each of the so-called unspecific factors of the effect a specific "spectrum" of action to the various functions is peculiar. For different factors these "spectra" can "overlap" and reinforce one another, which not infrequently leads to an undesirable effect. The conditions of the training do not have a lesser significance, which was shown by A. V. Korobkov and others (1960), when training occurred at a high ambient temperature. Furthermore, the motor efficiency increased and the resistance to radiation fell below that in control groups, who did not undergo training.

Serious disturbances in the internal organs (obesity of the kidneys, atrophy of the thymolymphatic tissue, stomach ulcers and ulcers of the pancreatic gland) can appear in the organism during prolonged exhausting training, and also with continuous marked stress. Similar pathological changes in various organs and tissues can occur with shorter-term, but extraordinarily intense physical and emotional stress.

All these factors indicate the necessity of selecting such methods and means of physical and psychological training, which would reflect the specific character of space flights, and would consider the peculiarities of the complex reorganizations and changes of the functions of the sustentaculo-motor apparatus under the influence of the conditions and factors of flight.

It is possible, apparently, to assume that a system of preliminary training, which is developed taking into account the special directivity, which finds a continuation in physical exercises in flight and after the return to earth, makes it possible to preserve high physical and mental efficiency. The system of physical training should prepare man for prolonged space flight and ensure the preservation in flight of the specially important motor skills, the physical and volitional qualities, and also the resistance to the unfavorable specific conditions of flight. For this purpose various means and methods of physical training have to be used. An important factor in preserving the high efficiency and health of the astronaut is a well organized motor regime during the flight itself. Furthermore, complexes of physical exercises which are properly suited to the diurnal periodicity become reference points.

The success of the application of physical exercises in flight depends on how well a number of conditions will be observed. The first requirement is that physical exercises have to correspond to the dynamics of the physiological processes occurring in the human organism, and promote the reorganization of the diurnal rhythm with respect to the conditions of life in the ship.

The regime of motor activity of the astronaut should be suited to the actual peculiarities of the diurnal periodicity and the changes of the physiological functions.

Another important requirement is that the exercises employed in the complexes strictly correspond to the peculiarities of the astronaut's activity and to the changes of the pysiological mechanisms during the flight and that they allow for the basic, typical features of the occupational motor activity of the astronaut (rate and degree of physical effort, attention stress, coordination structure, etc.).

In the physiology of work and sport it has been demonstrated that the adoption of the rhythm and rate of activity occurs better and faster with a selection of exercises, which by rate and rhythm are similar to the work at hand (B. A. Dushkov, 1963). This is also confirmed by the experimental works conducted under conditions close to space flight (isolation, limited mobility, hypokinesia, etc.). Thus, for example, in the investigation of two different regimes (of 10 days each) of motor activity of man under conditions of limited mobility and isolation (A. V. Korobkov, 1961) there was revealed that with a more rational complex of physical exercises the resistance to the inhibitory effect of the complex of factors of isolation increases. The authors also showed that different forms of employed physical exercises promoted a more stable mental efficiency of various times of the day. The exercises are an important factor in raising the emotional-volitional tonus and in safeguarding the greater effectiveness of the restorative processes. The positive influence of a systematic application of physical exercises leads to an increase of mental efficiency and improvement of the state of being of the subjects.

For maintaining the physical conditioning of the astronauts under conditions of prolonged weightlessness and stay in the limited space of the spaceship certain authors, as, for example, Wallace Aunan (1964), have recommended exercises of the isometric type executed by exerting forces pulling or pushing on immovable objects. The method is based on the premise that the development of muscles occurs more rapidly if they create forces not leading to complete fatigue. Muscular contraction lasting 6-8 seconds gives the greatest result. In the opinion of the author, during this period the muscle is under a state of tension, but the reserves of energy are not exhausted. The increased formation of muscular fibers is connected with the fact that the muscle does not pass through a phase of restoration, which is necessary after an exhausting load. Training according to this system should be gradual. During the first 2-3 weeks a half-load is recommended. Without a preparatory period a full load can lead to traumata. It is necessary to observe caution with respect to the duration of the forces. The system is appropriate for the training of weightlifters, soccer players and other categories of athletes. As for space flight, there is still uncertainty, as to how much time the astronaut should allot to exercises of this type. Under usual conditions daily training of 10-15 minutes is considered sufficient. Under conditions of space flight, possibly, training of up to 1 hour per day (10-12 periods of 5 minutes each) will be necessary. Analogous exercises may also be included in the system of preflight training of astronauts. However, Wallace Aunan does not present sufficiently convincing experimental material, confirming his view.

A number of authors have studied the effect of physical training on efficiency under conditions of prolonged hypodynamia (V. V. Bazhanov, V. I. Chudinov, 1964; V. V. Bazhanov, V. A. Sergeyev, V. V. Mitin, 1965). The authors investigated a system of exercises of the inertial and isometric type, executed with a sharp stop at the end of the amplitude. The results of the investigations showed that the application of physical training during prolonged-limited mobility increases the maximum force of the subjects by 3.3%. Furthermore, certain functional indices were improved. For example, the ability to perform cyclical work with submaximum intensity increased by 5-7%, and the force of individual groups of muscles by 5-10%.

In the two 15-day experiments in investigating the influence of different regimes of work and rest on the functional state of the organisms of subjects there was also revealed the positive influence of physical exercises on the preservation of a high level of efficiency and on the reduction of fatigue.

In the first experiment a system for training the subjects was employed. In the groups of tasks were included various physical exercises of the pulling type, movements for strengthening the muscles of the torso, legs, arms, exercises for relaxation and motor coordination, and also exercises with an expander, dumbbells and on an exercycle. All the subjects noted a considerable improvement in their health after the occupations.

As a rule, their efficiency increased, their motor activity improved, and the feeling of fatigue and sleepiness was gone.

Questionnaire data and visual observations show that the rate of the exercises varies depending upon the days of occupations and the health of the subjects. It is as if they became accustomed to a specific (peculiar only for them) rate of performing of motor actions. Such acclimatization and stabilization to a rate can serve as an estimation of the state of the subjects.

In the first days of the stay in the hermetic chamber to the question "At what rate is it best to perform an exercise of a group: slow, average or fast?" the subject mainly named the average rate. However, according to the degree of performance of the groups of physical exercises in the questionnaires there appeared entries about the desirability of interchanging various rates – slow, fast, average and combinations of these. During further performance of the exercises individual differences in the rate of the movements were revealed.

In the period of becoming accustomed to a new regime of work and rest and especially in the first 2 days of the experiment there were frequent disturbances in the order and sequence of the repetition of individual exercises, provided by the program of investigation, in spite of sufficient familiarization with the program before the experiment. The exercises were performed sluggishly and carelessly, with disturbance of the amplitude and the basic characteristics of the movements.

On the 5-6th day the same exercises were performed with great desire and interest. Fewer errors were made, the quality of execution improved, a tendency to increase the time of the occupations due to greater repetition of individual movements appeared. At the end of the experiment a certain reduction in interest toward the physical exercises was noticed due to the acclimatization to the complexes in the 15-day experiment.

It is necessary to point out the positive attitude of the subjects towards performing exercises with the expander, the dumbbell, and on the exercycle.

In the second 15-day experiment a system of physical exercises were organized taking into account the specific character of the chamber conditions: the limitation of space for the occupations, the arrangement of the instruments, etc. In compiling the system there was provided such an order of physical exercises, which specified correct and regular distribution of the individual exercises or their groups in specific connection with which there was created a most favorable reaction of the organism to the exercises being utilized. In the overall regime there were included groups of exercises after sleep, in the period of miscellaneous activity and during watch.

The groups "of morning" hygienic gymnastics consisted of exercises of the pulling type and movements for individual muscular groups. The long stay in the seat (bucket seat) and the static forced position of the body demanded in organizing and applying the complexes of gymnastics during a watch a calculation of the characteristic and typical features of the activity. During the miscellaneous activity there was performed a complex directed towards maintaining the basic motor skills and physical qualities.

Such a comprehensive regime of motor activity with correct and regular distribution of the groups of physical exercises made it possible to maintain the stable form of the force and endurance of the basic groups of muscles of the subjects during their stay under conditions of limited motor activity in a chamber with small volume. Included in the overall regime of work and rest were combinations of different forms of physical exercises directed towards improving of the motor activity of the person; these exercises rendered had an effect on the efficiency and the reduction of fatigue of the subjects, and also promoted the preservation of their general motor activity under the conditions of the chamber.

Thus, applied physical exercises in a motor regime can serve as an important feature both during the course of the preparation for a prolonged space flight and also for the preservation of high efficiency during the flight and in the period of restoration.

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INVESTIGATION OF THE MOTOR FUNCTION OF MAN UNDER CONDITIONS OF A MODIFIED DIURNAL REGIME

In connection with the problem of prolonged space flight the question of the resistance of the motor function of man to specific conditions acquires great significance. A number of authors (Yu. V. Vanyushina and others, 1966; L. I. Kakurin and others, 1966, and others) showed the influence of unfavorable factors (hypodynamia, a modified regime of nutrition and others) on the neuromuscular apparatus. However, there still remains the little studied question about the change of the motor function of man during his prolonged stay in a chamber of small volume under conditions of a modified diurnal rhythm.

We, in investigating the influence of a modified diurnal rhythm[1] (on 18-hour diurnal rhythm) on the functioning of the muscular apparatus, used a complex of methods for determining the accuracy and stability of the indices of simple motor reaction and muscular activity. In the 15-day chamber experiment 3 subjects (M-v, I-v, and S-v) participated.

The measurements of the muscular strength and static endurance were conducted with the help of a manual dynamometer specially

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[1]The conditions and character of the experiment are described in the article by A. A. Veselova, N. A. Gurovskiy and others located in this collection.

designed by V. M. Abalokov (of the Central Scientific Research Institute of Physical Culture). The measurements were carried out before and after the experiment, and also on the 4, 7, 10 and 13th day before the first and second watch, and also after the watches.

The measurements of the strength and endurance of the basic groups of muscles were conducted before and after the experiment on a special test bed, which made it possible to investigate specific groups of muscles during flexor and extensor movements of the forearm, shoulder, torso, thigh and lower leg.

The investigation of the muscular-joint sense and motor coordination for small and large proportioned force was carried out with the help of the dynamometer. By the conditions of the experiment it was necessary to produce with the right hand small (1/10 of the maximum) and large (1/2 of the maximum) proportioned forces. The action had to be carried out without looking at the indicator of the dynamometer.

The skill of proportioning the forces was developed and secured during preliminary experiments. On the same dynamometer a study of the "sense of time" (for 3 and 10 seconds) was conducted. This study was carried out before the experiment. Besides, the subject with his right hand produced an assigned small or large proportioned force, with his left — he started the stopwatch. The error in producing an assigned time during the development of small and large proportioned forces was considered.

For a complete study of the motor function a method of program stabilography developed in the Central Scientific Research Institute of Physical Culture was used. This made it possible to estimate the skill to finely proportion forces in the redistribution of pressure on the fulcrum. The method consists of the following: the subject stands on the stabilographic platform and assumes a standard pose (his usual stance). He must follow the "program" curve plotted beforehand on the moving paper tape of recorder, and, redistributing the pressure on the edges of the stabilographic platform, control the pen of the ink-writing galvanometer, seeking the maximum coincidence of the obtained recording with the line of the "program."

In an analysis the indices of disagreement expressed in arbitrary units and the results of their mathematical-statistical treatment were considered.

For estimating the ability and the switching of the activity of the individual muscles and muscular groups a methodical procedure of electromyographic determination of the periods of voluntary tension and relaxation of the skeletal muscles was used (according to V. L. Fedorov). The indices of the latent time of tension (LTT) and relaxation (LTR), and also their relationship (the index $\frac{LTT}{LTR}$) were treated by conventional methods of mathematical statistics.

According to the data of the investigation of muscular strength and static endurance, the muscular-joint sense and the time of development of small and large proportioned forces, no sharp changes of their attenuation is observed. However, it is possible to note significant oscillations of muscular strength, the muscular endurance of the hand, the muscular-joint sense and the "sense of time" in the diurnal dynamics during the period of the experiment. Especially great changes in these indices are noted for subject M-v. Toward the end of the experiment his muscular strength had decreased by 7 kg, there was deterioration in the results characterizing the muscular-joint sensitivity to a small proportioned force. For the same subject it is also necessary to note the considerable fluctuation of the "sense of time" and the muscular-joint sense according to the data obtained during the first and second watch, and also on the days of the experiment. Such changes in the indices, characterizing the delicate adaptability of the organism to a specific regime of vital activity, can be explained, apparently, by the fact that for him the rhythm of diurnal periodicity was very much out of phase, and acclimatization to the new alternation of sleep, wakefullness, and work had still not occurred. For the 2 other subjects less marked shifts in the muscular strength and in the data characterizing the power reactions and the intervals of time were noted during the experiment. As compared to the measurement before the experiment during the period of the 4, 7, 10th days for subject I-v there is small increase of muscular force. There also did not occur significant changes in the muscular endurance. It was characterized by a stable value of from 25 to 30 seconds during the period of the 4, 7, 10, and 13th day of the experiment.

For subject S-v there was observed a considerable reduction in the muscular endurance, which after the experiment decreased for the right arm from 35 to 17 seconds, and for the left – from 42 to 12 seconds. Moreover, the muscular endurance already by the 4th day of the experiment had decreased as compared to the initial data by 7 seconds for the right hand. The sharp drop in muscular endurance, apparently, indicates the lesser conditioning of this subject to similar kinds of experiments, since he was only for the second time participating in an experiment, whereas the other two subjects – M-v and I-v – were participants of many prolonged experiments in the chamber. The muscular endurance for S-v before the first watch during the period of the whole experiment (on the 4, 7, 10, and 13th day) was higher than after the watch which indicates symptoms of developing fatigue toward the end of the watch. According to the stay of subjects I-v and S-v in the hermetic chamber as compared to the first days the indices of the "sense of time" and the muscular-joint sensitivity to small and large proportioned forces improved for them, which indicates a certain adaptability of the organism to the proposed alternation of different periods of sleep, work and rest. The materials obtained by the method of program stabilography showed that subjects I-v, M-v and S-v in different ways underwent the complex reorganization of the diurnal rhythm. The initial and final values of the indices of disagreement in the stabilograms demonstrate the marked improvement in the execution of the test by subjects I-v and M-v and the absence of noticeable changes for S-v (Table 16).

In Table 16 there is shown the difference of estimators. Thus, for subject S-v the criterion of the authenticity of the distinctions is 0.53, for I-v and M-v – 1.08 and 2.46 respectively. Furthermore,

Table 16. Results of the analysis of the stabilograms of the subjects before and after the experiment.

No. of attempt and estimators	I-v		S-v		M-v	
	before	after	before	after	before	after
1	373,5	398,0	420,0	469,0	754,0	588,0
2	460,0	404,5	486,0	474,5	634,0	494,5
3	435,5	440,0	508,0	409,5	820,0	456,0
4	517,5	395,0	501,5	336,5	518,5	464,0
5	360,5	421,5	375,5	405,5	574,0	419,5
M±m	460,5±52,45	429,8±18,14	458,1±26,98	437,2±29,47	660,1±43,93	478,6±24,39
σ±m	117,3±37,09	40,56±12,82	58,1±18,37	65,9±20,84	98,22±31,06	54,54±17,35
v,%	±24	±9	±13	±15	±16	±11
P,%	±11	±4	± 6	± 7	± 7	± 5
t		1,08	0,53			2,46

for the difference in the reaction of the subjects the indices of variability of the sign point to the action of the factor. The indices are equal for S-v to ±15 and ±7% against ±13 and ±6%; for I-v — ±9 and ±4% against ±24 and ±11%; for M-v — ±11 and ±5% against ±16 and ±7% respectively (see Table 16). It is possible to assume (on the basis of the control experiments) that for subject S-v in contrast to I-v and M-v the natural scientific execution of the test was "blocked" by the complex conditions of the experiment and by the sharp shift of the diurnal rhythm of vital activity.

On the basis of the totality of the results of the analysis it is possible to form an opinion about the fact that ability to control one's stance practically did not suffer, subject M-v was the most resistant to the influence of the factor (according to the test). The results of the electromyographic analysis of the ability to as rapidly as possible shift from tension of the muscle to its relaxation, and conversely, are presented in Tables 17 and 18.

The tendency towards the recution of the indices of latent time (LT) after the experiment is evident.

One of the most probable causes of such levelling off of the changes of the mean values of LT of various muscles is, apparently, the heterodirectivity of these changes for muscles of the anatomical antagonists and the contralateral muscles, noted for subject M-v

Table 17. Latent time of tension and relaxation of subject M-v in the second experiment.

Muscles	LTT_{max} (ms)		LTR_{max} (ms)		$\frac{LTT_{max}}{LTR_{max}}$		LTT_{min} (ms)		LTR_{min} (ms)		$\frac{LTT_{min}}{LTR_{min}}$	
	before	after	before	after	before	after	before	after	before	after	before	after
Dostronemius												
right	420	380	440	210	0,955	1,810	240	100	190	130	1,263	0,769
left	420	420	380	300	1,105	1,400	280	240	210	60	1,333	4,000
Tibial												
right	340	380	410	360	0,829	1,000	220	180	390	200	0,564	0,900
left	500	340	480	420	1,042	0,810	210	180	380	200	0,553	0,900
Femoral rectus												
right	510	240	480	230	1,063	1,043	230	160	460	140	0,500	1,143
left	300	480	440	370	0,682	1,297	160	380	320	180	0,500	2,111
Femoral biceps												
right	480	490	560	240	0,857	2,042	180	220	300	220	0,600	1,000
left	380	520	440	510	0,864	1,020	260	120	220	220	1,[illegible]	0,545
Biceps (arm)												
left	350	330	310	470	1,129	0,681	300	180	260	290	1,071	0,621

Table 18. Results of the statistical treatment of the indices of the latent time of subject M-v before and after the experiment (voluntary tension and relaxation of the muscles).

No.	Index	$M \pm m$		$\sigma \pm m$		V, %		P, %		
		before	after	before	after	before	after	before	after	
1	LTT_{max}	411±25,1	364±31,1	75,4±17,8	93,4±22,0	±18	±24	± 6	± 8	0,42
2	LTR_{max}	438±22,7	346±35,6	68,2±16,1	106,7±25,1	±16	±31	± 5	±10	2,18
3	$\frac{LTT_{max}}{LTR_{max}}$	0,947±0,051	1,234±0,151	0,152±0,036	0,452±0,106	±16	±37	± 5	±12	1,81
4	LTT_{min}	231±15,3	196±26,8	45,8±10,8	80,5±19,0	±20	±41	± 7	±14	1,13
5	LTR_{min}	306±30,0	182±22,1	90,0±21,2	66,4±15,7	±33	±37	±10	±12	3,33
6	$\frac{LTT_{min}}{LTR_{min}}$	0,841±0,120	1,332±0,367	0,360±0,085	1,101±0,259	±43	±83	±14	±28	1,27

after the experiment. This is evident from a comparison of the values of LTT_{max} of the right gastronemius and tibial muscles, the right remoral rectus and biceps muscles, the right and left tibial muscles, the right and left femoral rectus muscles; the LTT_{min} of the femoral rectus muscles, the right and left femoral biceps muscles; the LTR_{max} of the left femoral rectus and femoral biceps muscles, the right and left femoral biceps muscles (Table 17).

It is also necessary to note the primary increase of the index $\frac{LTT}{LTR}$, testifying, according to V. L. Fedorov, to the improvement of the balance between the excitory and inhibitory components. The connected heterodirected shifts of this index for the muscles again testify to cross character of the manifestations of the modified regime $\left(\frac{LTT_{max}}{LTR_{max}}\right.$ of the right and left tibial, of the left gastronemius and tibial muscles, the $\frac{LTT_{min}}{LTR_{min}}$ of the right and left gastronemius, of the right gastronemius and tibial muscles, of the right and left femoral biceps muscles, of the left femoral rectus and biceps muscles$\left.\right)$.

Attention is focussed on the increase of the indices of LTR and on the decrease of the index of $\frac{LTT}{LTR}$ (for both the minimum and maximum values) of the biceps of left arm — the only muscle of the upper limbs, the changes of the time responses of the EMG of which it was possible to record (Table 18).

The greatest oscillations of the indices characterizing the force endurance are observed for subject S-v. Thus, of 8 measurements of the individual muscle groups (flexion and extension of the torso, thigh, forearm, lower leg and flexion of the arm) in 5 cases there occurred a reduction in the endurance, and in 3 cases there were no changes. For the two other subjects in 5 cases from 8 an increase occurred, in 2 — a decrease, and in one — the indices remained unchanged. The decrease of the endurance of the basic muscle groups for subject S-v is explained, apparently, by the fact that he, less than other subjects, was conditioned for such complex experiments. Not less important for the decrease of muscular endurance for subject S-v is the fact that he in contrast to the two other subjects did not always completely perform the complexes of physical exercises and especially those movements, which were calculated to develop this quality.

Thus, the oscillation of muscular strength, the endurance of the muscular-joint sensitivity, the time intervals during the experiment can be explained by the complex reorganization of the diurnal rhythm of the physical functions. The distribution of sleep in the days preceding the investigation had great importance in this reorganization.

A comparison of the characteristics of the fluctuation of the indices of muscular tension and relaxation before and after the experiment makes it possible to note the considerable increase of the variability of all indices under the influence of the unusual situation of the experiment.

Great influence on the change of these indices was caused by the fact that the regime of the vital activity of the subjects was considerably modified both in duration and also in distribution of the hours of work and rest (the 18-hour "diurnal" rhythm).

At the same time the regime of work and rest with a different alternation of sleep and activity did not lead upon completion of the experiment to a significant change in the strength and endurance of the basic groups of muscles, with the exception of certain individual muscle groups which, apparently, indicates the correct organization of the motor activity of the subjects. The adaptation of the organism to such an alternation of the periods of work and activity, in which the diurnal rhythm (according to the index of accuracy and stability of the time-strength reactions) is sharply reconstructed, occurs slowly (on the 10-13th day). Moreover, a normal periodicity of change of the physiological indices is established.

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH

DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}
rot	curl
lg	log