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Space Physiology

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In this highly dynamic era, the five-years' lapse since the society's last conference at Minsk is a considerable period of time. Throughout the world, great changes have taken place in our lives and in the sciences to which we devote our energies. During the same period many new and challenging ideas were born in physiology which, we hope, will retain their importance for the future.

Thanks to electronics, research methodology has advanced strongly, and important results have been achieved in most of Physiology's branches. Some areas of this applied science--in particular space physiology--have been defined and formulated.

The goal of space physiology is to study the character and peculiarities of space flight stresses brought to bear on the organism of animals and man. The emphasis is on basic investigation--to seek out rational ways of increasing man's tolerance to space flight and to determine the basic, physiologic demands of a given organism on a spacecraft's environment and equipment complex. It is in this light that conditions amenable to optimal crew performance must be sought.

Toward this end it is necessary to study the influence on the body of basic groups of factors:

1. those associated with the dynamics of space flight (acceleration, weightlessness, vibration, etc.);

2. those associated with long missions in the artificial environment of a space capsule (microclimate, isolation, hypodynamia, etc.);

3. those which characterize outer space as a unique environment of habitation (radiation, temperature or thermal conditions, etc.).

At the last conference, we presented physiologic data obtained with high-altitude geophysical rockets, as well as with the second artificial earth satellite carrying the dog Layka. This paper reviews the findings of experimental research conducted on artificial satellites [Sputnik] two through five and spacecraft "Vostok" one through six.

I would like to begin this paper with the reminder that problems of formulation and choice of research methodology in space physiology are, to a large extent, determined by the applicability of this science, the advances of space technology, and the feasibility of planning and carrying out basic in-flight research.

The nature of related experiments is typified by the recent "Special Report to the U. S. Congress Concerning the Flight of Ranger-7", whereby lunar photographs were received. The report states that "...the success of the flight was due to the services of a large, associative body. Almost 50,000 people, representatives of government organizations, industry, universities, and the scientific world, took part in the planning and preparation of the spacecraft and the mission. The project cost is evaluated at 260 million dollars, and the construction and launching of Ranger-7, including booster rocket, at 28 million dollars." As we know, almost five years were spent in the implementation and fulfillment of this project. Processing of information gathered during this project, according to the specialists, will require about three years.

Clearly, the performance of biologic research in space, especially during manned space flight, presents a much more complex undertaking.

The study of factors alien to earth conditions brings to light new questions of a theoretical nature stimulating the search for adequate means of their solution. At the same time, the tempo of space research urgently demands working out concepts for control of biological factors and of factors imperiling cosmonaut safety.

Difficulties arising in this field are further intensified for the answers to many important questions cannot be found through direct experimentation. Among these problems, the effect on the body of prolonged missions in a varying gravitational field, the impact of space exploration in our daily lives, as well as other factors must be set in their proper perspective.

However, many space flight factors can be successfully reproduced under laboratory conditions. This is rendered feasible by such technological means as: pressure chambers, vibro-benches, anechoic chambers, centrifuges, and other research equipment facilitating simulation of single and multiple factors anticipated during space flight.

Because of such facilities, scientific research centers and laboratories have compiled a vast body of experimental data in the last few years since the establishment of space physiology as an independent discipline.

Naturally, however, research findings during actual space flight are of particular interest; this report is devoted to a review of such findings.

Please recall that many biologic experiments on the geophysical rockets (1957-59) permitted study of animals' [physiologic] responses during suborbital flight. Dogs display changes in cardiovascular and respiratory functions associated mainly with acceleration encountered during powered flight (lift-off and re-entry). The degree of abnormality, as a rule, is directly proportional to the magnitude of the acceleration.

In experimentation with intact animals (in contrast to test animals under narcosis), development of active or passive defense responses was typical at time of ignition. The autonomic components of this reaction were particularly distinct during the first 20 to 40 seconds after lift-off.

During weightlessness, pulse rate, respiratory rate, and blood pressure briefly assumed elevated readings, recovering gradually thereafter to approximately baseline levels. Studying the animals' response to weightlessness during this experimentation was impeded by the masking affect of the G-forces during the powered phases of the flight. Occasionally, normalization was slow following the transition from high acceleration to weightlessness, as clearly evidenced in the space flight of the dog Layka.

Unrestrained, small laboratory animals (mice, rats) were found (up to ten minutes) to gyrate continuously during periods of weightlessness, as if "swimming" in the air. With time, they acquired a certain amount of adaptation, and their movements became less chaotic and ineffectual; they were able to secure a foothold with greater frequency. Apparently, a measure of assistance could enable them to secure a hold on the walls of their container.

In weightlessness experiments on airplanes, I. I. Kas'yan and E. M. Yuganov proved that imparting to the animals' container spin sufficient to develope an angular momentum of 0.28 G enables them to orient their bodies and direct their movements. Further research in this direction is of great importance; long-range, spacecraft design hinges thereon.

Rocket experiments have shown the response of animals to space flight to be other than pathologic. In the post-flight period, no permanent, adverse changes or anomalies were noted. Animals can, therefore, satisfactorily tolerate rocket travel. Moreover, this proved the reliability and effectiveness of life support systems used in these experimental flights.

Experiments on the satellite-spacecraft [Sputnik] series (1960-61) were outstanding. Not only was study of the effects of orbital flight accomplished utilizing on-board telemetry to record physiologic functions but additional valuable information was gathered after return of the biological specimens to earth. Regarding organization, tactics, and partly methodology, this experimentation served as a series of unique trial runs before the upcoming space missions involving man--the cosmonauts.

Animals, plants, microorganism cultures, and biochemical substrata were employed as biological specimens. In the craft, life support systems were designed to maintain their biological functions within normal levels. In line with the program, selected physiological and hygienic parameters were radiotelemetrically recorded.

The use of radiotelemetry for the control of spacecraft systems and for scientific measurements opened new avenues for space physiology research. Development of radiotelemetry rendered obvious the nature of systems to be used for this space effort.

Noteworthy differences between the so-called classical method of research problem solution in the laboratory and the spacecraft will be pointed out.

Physiological research performed on spacecraft yielded results in harmony with conclusions drawn earlier during the suborbital flights of animals, although differences in duration and characteristic of the incident G-forces were at play.

In the majority of animals, cardiovascular and respiratory responses were uniform and rather strong, in spite of selection of the healthiest animals and their pre-flight training. The nature of the responses was an indication of the state of stress on the given system. As was shown in specially conducted experimentation (Kiselev, 1962; Voskresenskiy, 1963), transverse acceleration most directly affects lung ventilation and vascular blood supply*, including the pulmonary blood supply. Changes observed in circulatory regulation are of great interest (Shul'zhenko, 1964).

Assuming that these phenomena are dictated by defense mechanisms and occur during considerable muscular stress, then during lift-off and re-entry hypoxia can be anticipated. Therefore, the study of hemodynamics and of blood supply during transverse acceleration assumes great significance, as does the search for methods of increasing the tolerance thereto.

In a state of weightlessness continued up to one full day (in contrast to suborbital flights), recordable indices recovered to pre-launch levels. However here, too, was noted the lag phenomenon in baseline level restoration.

Moreover, a cardiac arrhythmia was frequently observed in the ECG (P-R interval, T amplitude). There was a relative decrement of the systole. This seemed to suggest some peculiarities in autonomic, functional regulation during weightlessness.

Therefore, further study of the principal autonomic functions during the most stressing phases of the flight is indicated, as

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*Translator's note: literally "redistribution".

much for the understanding of corresponding physiological mechanisms as for a more profound insight into the phenomena under investigation.

The influence of weightlessness on myocardial contraction is of significant interest. In fact, during space flights animals' phonocardiograms and seismocardiograms have been recorded (R. M. Bayevskiy); for peripheral blood circulation studies, sphygmography was utilized. The evaluation of ECG data revealed interesting information concerning changes in contraction, automation and neural regulation of the heart.

In the spacecraft satellite series, studies were made to determine the nature of canine motor activity during weightlessness. The animals were allowed, with certain restrictions to move about within their capsules. Television and telemetric data (Zhuravlev, 1962) brought to light a definite tendency toward automation of frequently repeated movements; e.g., movements directed toward fixing the body in space.

A study of animals' efforts in a state of weightlessness showed, that after several hundred repetitions of a maneuver, an animal is capable of a given performance with minimum energy expenditure. In guinea pigs, during the first ten days after their return to earth, intensified potentials were recorded in electromyograms of the posterior extremities (M. N. Lifshits). On the other hand, control animals displayed mild changes in muscular bioelectrical activity and only during the first 24 hours after return to the laboratory.

Higher nervous activity was studied in two laboratory mice after a flight in an artificial earth satellite [Sputnik]. Their motor-digestive processes displayed no changes in reflex time or intensity (Luk'yanova, et al., 1962). These findings led Lifshits to believe that central nervous system changes were, apparently, confined to the motor centers. No evident changes were observed in the post-flight behavior or in the conditioned reflex activity of test dogs.

Of importance, too, is that extended observation of the test animals revealed no physiological or biochemical damage or change. Only in animals which had completed a 24-hour orbital flight were biochemical changes noted from two to six days after their return to earth. These were apparently produced due to an earlier reaction to stress (Gyurdzhian, Domin, et al., 1962). Nor were any changes noted in the blood profile, if a brief and moderate leukocytosis is ignored. Thus, the enumerated tests failed to show a clear cut deviation from the norm.

Histological and, in particular, karyologic research gave somewhat different results. In test animals (after one day flight), the incidence of chromosome damage was from two to three times greater than in the control group (Arsen'eva, Antipov, et al., 1962). Morphological analysis revealed intensified myelopoiesis and somewhat suppressed erythropoiesis. Genetic studies also proved to be very interesting (Dubinin, et al., 1962; Zhukov-Berezhnikov, et al., 1962). Space flight can elicit genetic changes in different organisms, often influencing their development and reproduction (insects, Actinomycetes, seeds and shoots of several plants).

As yet, no parallel has been drawn between the effects observed and any definite factor of space flight such as cosmic radiation. Similar results can be achieved by exposing test subjects to massive acceleration or to vibration (Parfenov, 1962).

In this connection, we are faced with a vastly important and intriging problem; namely, how does space flight bring its effect to bear.

Here, realization is essential that each factor, whether independent or combined with other factors, may differ in the specific nature of its effect. Along with a general evaluation of the effect of space flight factors, a more detailed research into the basic physiological functions needs to be established.

Certain phenomena are observed with ever greater frequency; for example, physiological changes in animals often fail to manifest after exposure to G-forces because of exceptional compensatory and adaptation mechanisms.

In particular, data gathered during acceleration studies emphasize the importance of reflexes. During acceleration, reticular formation inhibition develops which apparently protects the cerebral cortex against an excessive flow of impulses (D. D. Parin, A. N. Razumeyev, et al., 1963). However, even under these conditions, considerable functional and even morphological changes were observed in the tissues of various organs (Vinnikov, et al., 1963; Petrukhin, 1962; Eliseyev, et al., 1964).

More research work is necessary to better understand the nature of these phenomena taking into account both direct and indirect effect of space flight factors on cell masses as well as the neuro-humoral regulatory and adaptation mechanisms and tropic processes at the cellular level (A. V. Lebedinskiy, V. N. Mastryukova).

However, the analysis of data gathered from rocket and earth satellite launchings show that space flight renders no unfavorable biological effect on animals or man. This conclusion, however, is assured only for known experimental factors as duration, altitude and other orbital flight parameters.

By spring, 1961, all preparations for the space flight of the first cosmonaut, Yu. A. Gagarin, on the spacecraft "Vostok" were in order. Animal experimentation had demonstrated the safety of such a flight having served as a dry run to test the effectiveness and reliability of life support and landing systems. Medical monitoring methods had also been tested. Systems for the localization and retrieval of the spacecraft and cosmonaut after landing were perfected. Still, the first manned space flight was, to a large extent, a step into the unknown.

It was impossible to accurately predict the influence of prolonged weightlessness on the cosmonaut's spatial orientation, coordination, overall condition, and proficiency.

Yu. A. Gagarin was the first to be exposed to the entire complex of space flight factors--to see and to feel that for which subsequent cosmonauts would have to be trained. This flight proved that man can tolerate all phases of short-duration space flight without prejudicing performance and functional activity. In fact, the functional changes were all within the frame of compensatory processes.

Post-flight examination of the cosmonaut failed to reveal any negative findings. The spacecraft's main systems performed normally. It was now possible to begin implementation for our next phase; namely, longer flights.

The sixth and seventh of August, 1961, a full-day's orbital flight was successfully completed by Titov. Pulse and respiratory rate changes recorded before lift-off were clearly parallel for Titov and Gagarin. After completion of all pre-mission preparations, in the execution of which the cosmonaut played an active part, lift-off was successful.

G-forces in the powered phase developed as previously computed. Noise and vibration accompanying the firing of the rockets created no discomfort. Cabin barometric pressure was equal to that on earth[a]; temperature, humidity and percentage composition of the atmosphere were the same as recorded at pre-launch time. Increased pulse and respiratory rate, already noted in the pre-flight period, mounted during the first minute of flight; the pulse was 130 beats and the respiratory movements were 20 per minute. Respiratory amplitude increased two and one-half times. Changes in temporal indices of the ECG were in step with the increased heart contractions.

In spite of mounting acceleration, the heart rate, after the first minutes of powered flight, decreased considerably, and by the time the spacecraft was injected into orbit, it stood at 110 beats per minute. Subjectively speaking, the cosmonaut tolerated powered flight well. During the transition to weightlessness, Titov experienced an illusion of "body inversion"; his instrument panel appeared to be above him, and he piloted the craft as if he were upside-down in relation thereto. This sensation continued for nearly one minute. Thereafter, his sense of spatial orientation was restored to normal.

During weightlessness, his heart rate continued to gradually decrease, so that after six hours it was slightly greater than normal. However, well defined, periodic increases in heart beats (from 70 to 105/min) were recorded. The electrocardiogram revealed no change. Changes were, however, observed in the kinetocardiogram which characterizes the contractile function of the heart's musculature. However, there is no information which would preclude

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[a] Tr. note: This is a literal rendition of original Russian.

the adversity of such changes. The respiratory rate did not show any important changes.

Attention should be focused on certain sensations of discomfort which arose during orbital flight and which the cosmonaut ascribed to motion sickness. These sensations were expressed by a slight dizziness and nausea noticeable during sudden movement of the head and when observing quickly moving objects undergoing rapid angular displacement. These phenomena created slight discomfort, but did not impair proficiency. From entries made in the spacecraft logbook during weightlessness, Titov's handwriting in space does not essentially differ from that on earth. After sleeping, the cosmonaut felt somewhat better, and during the re-entry, dizziness and nausea completely disappeared. After completion of the 17th orbit, the retrorocket was ignited, and the spacecraft began its descent. During retrofire, considerable G-forces were generated giving rise to a brief "grey-out"--a phenomenon also observed on the centrifuge.

Subjectively, the cosmonaut tolerated retrofire well and the physiological parameters showed no important deviations from baseline data.

Analysis of objective telemetric data, as opposed to subjective data, bears witness to the capability of the cosmonauts to work effectively and to tolerate space flight. The daily physiological rhythm, including exercise, rest, sleep, food intake, and elimination of waste, is not noticeably changed during space flight.

The orbiting of two spacecraft, involving A. Nikolaev and P. Popovich, was qualitatively a new step in man's conquest of space.

These missions were designed to shed light on the impact on man's overall condition, his performance, and his vital physiological and psychological functions by prolonged exposure to the complex of space flight factors. Equally important was the evaluation of pre-mission training of cosmonauts designed to increase tolerance to acceleration, weightlessness and psychological stress. Here, too, determining which elements of this training should be maintained and which required correction or supplementation was of importance.

Finally, evaluation of criteria for food rations, oxygen, and sanitation* were also in order.

Special interest was attached to better understanding the effect of prolonged weightlessness on the vital physiological functions, sensory organs, and cardiovascular system. Neither the single-orbit mission of Yu. Gagarin nor the one-day flight of G. Titov gave sufficient data for such evaluation.

Emotional stress, which is unavoidable at lift-off and re-entry, greatly masked the direct influence of flight dynamics and, thereby, weightlessness. In addition, the relatively short stay in orbit was insufficient for the development of the processes connected with hypothetical cardiovascular system adaptation during weightlessness (absence of the hydrostatic factor).

Assessment of the degree to which the prolonged exposure to weightlessness might tell on sensory organ function thus affecting cosmonaut proficiency was of paramount interest. Finally, it was necessary to clarify if the discomfort experienced by G. Titov was an unavoidable symptom of space flight.

Solution of the above questions was greatly significant to planning and training for future space flights having at the same time an obvious bearing on spacecraft design.

In comparison with earlier flights, the extended scope of research methodology and the resulting harvest of scientific data were noteworthy. The similarity in pulse rate and respiratory changes found in Nikolaev and Popovich during their group flight is striking. A marked increase in pulse rate was noted during the powered phase, especially at first, with a gradual recovery to original values during weightlessness. Furthermore, a definite, daily periodicity in physiological index changes was observed. Finally, it is impossible to ignore the extremely characteristic increase in pulse rate and respiration rate toward the end of the flight which was an apparent manifestation of response to stress--the cosmonaut's anticipation of the crucial re-entry phase.

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*Tr. note: probably referring to waste disposal.

We will focus our attention more in detail now on individual stages of the experiment. In the pre-launch training period, psychological examinations indicated that both cosmonauts maintained a high degree of self-control. Symptoms of oppression, apprehension or depression were absent. Adequate concentration in the performance of tasks under simulated and daily situations was manifested. Together with maintenance of a high level of alertness, behavior and speech were well controlled. Tests revealed a high threshold for irritating stimuli, no changes in physiological indices from baseline data recorded outside the confines of the launch facility* (F. D. Gorbov). Important data was also gathered through the objective control of sleep. Both cosmonauts slept well, and the aktograms** showed no deviation (L. I. Kakurin).

Directly before lift-off, increased nervous tension was in evidence. However, all performance was absolutely adequate and precise. Pulse rates increased.

During powered flight, no peculiarities were in evidence. Physiological indices were as anticipated. In orbit, the pulse rate returned to original levels for Popovich within five to six hours and for Nikolaev within ten to twelve hours. Analysis of electrocardiographic data revealed neither pathologic changes nor any disorders in cardiac stimulation, conductivity or automatism. Periodically, a variation in T wave amplitude was noted. Also observed were decreases in P and R wave deflection amplitude and, in Popovich, a systolic index decrement.

Thus, during the flight, the cosmonauts were in good condition, and the completion of extensive in-flight, programmed tasks bears witness to their satisfactory proficiency.

As is well known, the cosmonauts periodically controlled the craft's attitude manually, took motion pictures, recorded instrument readings, and established frequent voice communication with tracking stations and between themselves. One of the assigned tasks was

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*Tr. note: The Soviets term this a "Spaceport".

**Tr. note: An <u>aktograph</u> is a device which is used to record the movements of a caged, but otherwise unrestrained animal.

self-observation and a detailed recording thereof. They performed special psychological and vestibular tests, and studied the peculiarities of existing and performing in a state of "free-floating" after removing their harnesses. In addition, the cosmonauts carried out various research assignments, among them biological experiments.

In arithmetic tests (involving mental solution) the time of execution for both cosmonauts did not deviate from control test times, and only one mistake for each was noted in computations which had been perfectly correct during the training period. Geometric configuration tests were performed without error, and execution time was normal. In the spacecraft's logbook, Nikolaev and Popovich repeatedly made the entry, "Psychological tests accomplished; proficiency unimpaired."

In connection with the sensation of motion sickness experienced by Titov, in the prolonged, group flight a series of tests was designed to determine the efficiency of spatial perception and of the vestibular apparatus in particular.

These tests should have revealed sensory or motor disorder during vestibular stimulation (turning and tilting of the head and trunk). The cosmonauts noted that the prescribed tests were performed precisely and easily. In the state of "free-floating" with the eyes closed, determining the body's spatial orientation proved to be impossible. In addition, Nikolaev noted that a sharp turn of the head in one direction caused his outstretched arm to move in the opposite direction.

Thus, performance of "vestibular in-flight tests", the analysis of the above described physiological indices as well as a comparison of vestibular test results before and after flight revealed no clear cut changes. The cosmonauts emphasized that they tolerated weightlessness subjectively well.

Possibly, special preparatory training played a positive role in the fact that the cosmonauts suffered no coordination disorder. Only at first, in the precision testing consisting of drawing stars and spirals, was it possible to detect a deviation from the manner in which this task had been performed on earth and during subsequent periods of the flight. Careful analysis of handwriting in the on-board logbook also showed some changes.

Nikolaev and Popovich, in the same way as Gagarin and Titov, experienced no difficulty neither in ingesting food or drink nor in performing natural body functions. They slept well and with increasing depth in ensuing days. Neither anorexia nor taste disorder was noted.

After the flight, excitability, lack of power of concentration, and absent-mindedness were all mildly in evidence. A comparatively decreased threshold for irritating stimuli was evidenced by single errors in discrimination tests. Detailed clinical and physiological examination in different post-flight periods brought no anomalies to light. Only slight fatigue was observed. This research yielded a wealth of information, and the succeeding missions of V. F. Bykovskiy and V. V. Tereshkova were better prepared as a result.

These missions took place in June of 1963. Bykovskiy was in orbit for 119 hours, and Tereshkova for 71 hours. Their simultaneous missions facilitated collection of additional information characterizing human response to prolonged weightlessness in a spacecraft's artificial environment. The outstanding feature of this mission was that it represented the first time a woman had journeyed into space. Naturally, this called for additional research to determine the impact of spaceflight on a female.

For in-flight cardiovascular evaluations, seismocardiography was utilized. This system was well aspected from flight experiments involving animals. The seismograms were recorded off the same channel as the electro-oculogram (practicing economy of telemetric means).

Seismocardiography was one of the first methods to have been found applicable for space research and then for clinical use. Due to its simplicity and convenience, seismocardiography can be recommended for extensive application in general medical practice.

In the group flights, special attention was paid to gathering objective data on the central nervous system.

Telemetric recording of the EEG during space flight was first performed on "Vostok-3" and "Vostok-4" with cosmonauts Nikolaev and Popovich. Silver electrodes were used, which were placed on the forehead and on the nape of the neck. The same method of EEG recording was used in the flights of Bykovskiy and Tereshkova. Here, galvanic skin resistance was also recorded.

In the flight of Nikolaev and Popovich, slow changes were recorded in electrical resistance of the skin. These measurements are made relative to the magnitude of the functional voltage potential output of a circuit with current directed counter to the resistance*. In Bykovskiy and Tereshkova, relatively rapid changes in resistance were recorded during exposure to prolonged stimulation. During these periods, the number of individual responses as well as their duration and amplitude were measured. Since the magnitude of the stimulus was unknown, determination of latency was impossible.

To keep check on the functional condition of the vestibular apparatus, in the first and second group flights, electro-oculography was employed. Recording oculomotor activity was performed with the aid of silver electrodes placed on the skin of the temporal canthus.

Detecting any tendencies for the EEG, GSR, and EOG indices to change was of essence, as was the degree of association of the cosmonauts' well-being with the other indices of their overall condition during flight.

The data accumulated allowed for the separation, into various phases, of some of the general peculiarities in the changes of individual physiological indices depending on the different phases of the mission.

The typical response displayed by the cerebral cortex as far as bioelectrical activity during the first hours and days of the mission was concerned consisted of high-frequency oscillations. Decipherable EEG tracings evidenced either continuous or periodic predominance of the β-rhythm in Nikolaev, Popovich, and Bykovskiy for at least 48 hours. The index of low-frequency oscillations remained small, and, in any event, showed no tendency to increase.

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*Tr. note: The reference here is apparently to use of the <u>impedance method</u> of quantitative electrodermal reaction with direct current. This is as opposed to the <u>potential method</u>.

EEG tracings for Tereshkova in the first day of flight and in the morning hours of the second day revealed the predominance of higher frequencies.

The initial flight period was characteristically distinguished by intensified oculomotor activity and an increase in the number of rapid fluctuations in galvanic skin resistance per unit time.

These responses may be associated with hyperaffectivity and excitement after safe injection into orbit. Such factors as voice communication with tracking stations and between spacecraft, receiving commands and signals and watching for extravehicular objects in solo flights could act as stimuli of the CNS.

The process of gradual adaption to space flight is reflected in the dynamics of the EOG and GSR indices. Significantly, during the second day both oculomotor activity and the average number of rapid fluctuations in the GSR tracing decreased considerably.

On the other hand, the combined effect of all the new (relative to degree and nature) stimuli and of the heavy working schedule can eventually lead to fatigue and inhibition of the CNS.

During isolation experiments (several days in the confines of a small area), the initial forms of fatigue were evidenced by the EEG's as frequency shifts (changes) in the slower rhythms (D. I. Ivanov, et al., 1963). In this regard, great interest is attached to the observation of an increase from the second to the third day in the slow waves in Tereshova's EEG's recorded during daylight hours. Tereshkova maintained her spirits and efficiency, and the changes in the EEG may be viewed as an objective symptom of CNS functional "reformation"*, which on longer missions could manifest itself in the form of pronounced fatigue. However, in evaluating the EEG data, one must keep in mind that synchronous brain potentials, generally viewed as a sign of increased inhibition, can also reflect shifts induced by excitation. The sinking of oculomotor activity below baseline levels is another symptom probably of similar prognostic pertinence. A secondary increase in eye movement during the final orbits can be explained as due

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*Tr. note: adaptation.

to an emotional response in anticipation of re-entry. At this time, the profile of Tereshkova's EEG's also reflected important changes. The definition of the slower waves diminished, and again, as at the beginning of the mission, the β-rhythm rose to predominate.

The eye movement stultification, the nystagmoid phenomena and the sharp intensification of the slow EEG waves in Tereshkova appeared almost simultaneously on the second day of the mission. Although this cosmonaut experienced no subjective motion sickness, the coincidence of nystagmoid movement and changes in the EEG profile are thought to be linked to the specific impact of weightlessness on the vestibular apparatus. This effect, however, did not reach such proportions that it could elicit recordable, autonomic disorders or decreased efficiency. However, the unusual functional conditions of the vestibular analyser during weightlessness corroborate some of the subjective impressions of other cosmonauts. Thus, Popovich indicated that he sensed no vestibular-autonomic disorders, but whenever bending the body suddenly forward, he experienced each time a sensation somewhat reminescent of the sensory response induced by a rotary chair.

In this fashion, EEG, GSR and EOG data contribute greatly to our conceptions concerning the influence of prolonged space missions on the cosmonauts' general condition. The dynamics of these indices are reflected in man's adaptation to space flight which sets in after about two days. Changes in the EEG and a sharp decrement in oculomotor activity are, apparently, objective, prognostic signs of fatigue. EOG data facilitates more valid evaluation of the influence of weightlessness on the functions of the vestibular analyser*. It is important to emphasize that the changes in the EEG, GSR and EOG observed during space flight did not accompany subjective sensations of mounting fatigue, symptoms of vestibular dysfunction or noticeable degrading of efficiency. To present in a single report the wealth of information gathered through the above described experimentation is impossible. Only studies which seemed of greatest interest and significance are discussed here.

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*Tr. note: analyser is used here in the Pavlovian sense.

The basic outcome of the work performed to date was to plot the course of further research in the area of space physiology. The following elements apply:

1. study of physiological effects associated with the effect of all space flight factors on animals and man;

2. investigation of the influence of prolonged weightlessness on physiological mechanisms and prophylactic measures to counter undesirable manifestations;

3. elucidation of the physiological mechanisms that come into play during the transit from G-loading to weightlessness and vice versa;

4. investigation of the impact of protracted confinement of movements (hypokinesis) as encountered in space cabins and establishment of prophylactic measures;

5. study of physiological changes arising in man during long-term dependence on an artificial environment in a sealed cabin, establishing, thereby, basic physiological and hygenic requirements under these conditions;

6. investigation of the significance of emotional stress and the neuro-humoral mechanisms for regulating compensatory responses to extreme conditions;

7. further refinement of biotelemetric techniques for physiological research during space missions.

The above enumeration of avenues for further research is by no means complete; it is sufficient, however, to indicate the scope and diversity of obstacles which space physiology must overcome. Moreover, it is important to emphasize that successes in the realm of space physiology reach beyond applied astronautics. Hereby emerges the more general importance of achievements in space science. At the present stage of its evolution, space physiology's furtherance not only stems from general physiology and related disciplines, but in turn, through a feedback association with these sciences, it lends to their enrichment. Space physiology with biotelemetry has brought to light new experimental facts and ideas affording profound understanding and an evaluation of physiological processes and phenomena.

Hopefully, recognition of this fact will bring the attention of a large number of physiologists to bear on the problems facing space physiology and will bring them to apply their knowledge in the various specialized areas of physiology.

Parameters of Different Space Missions

Parameters	Artificial Earth Satellite	"Sputnik" Series				"Vostok" Series					
	II	2	3	4	5	1	2	3	4	5	6
Electrocardiogram	+	+	+	+	+	+	+	+	+	+	+
Seismocardiogram	-	-	+	-	-	-	-	-	-	+	+
Phonocardiogram	-	-	+	-	-	-	-	-	-	-	-
Sphygmogram	-	-	-	+	+	-	-	-	-	-	-
Arterial Oscillogram . .	+	+	-	-	-	-	-	-	-	-	-
Kinetocardiogram	-	-	-	-	-	+	-	-	-	-	-
Pneumogram	+	+	+	+	+	+	+	+	+	+	+
Electroencephalogram . .	-	-	-	-	-	-	-	+	+	+	+
Electrooculogram	-	-	-	-	-	-	-	+	+	+	+
Electromyogram	-	-	+	-	-	-	-	-	-	-	-
Aktogram	+	+	+	-	-	-	-	-	-	-	-
Galvanic Skin Resistance	-	-	-	-	-	-	-	+	+	+	+
Body Temperature	-	+	+	-	-	-	-	-	-	-	-