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AVIATION AND SPACE MEDICINE

V. V. Parin, Editor in Chief

Akademiya Meditsinskikh Nauk, SSSR,
Moscow, 1963

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V. V. Parin, Editor in Chief

Translation of "Aviatsionnaya i kosmicheskaya meditsina"

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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CONTENTS

Page

Results of Physiological Investigations on the Spaceships Vostok 3 and Vostok 4 — 3
I. T. Akulinichev, R. M. Bayevskiy, V. Ye. Belay, P. V. Vasil'yev, O. G. Gazenko, L. I. Kakurin, A. R. Kotovskaya, D. G. Maksimov, B. P. Mikhaylovskiy and V. I. Yazdovskiy

Changes in Some Indices of Respiratory Biomechanics in Sick and Healthy Persons under the Conditions of Hypoxia — 5
V. N. Alifanov

Changes in Bioelectric Activity of the Myocardium in Man after Exposure to Hypoxic Hypoxia According to the Data of Vector Analysis — 9
V. N. Alifanov and L. M. Zemesheva

Biotelemetry on Manned Space Flights — 12
G. V. Altukhov

Some Problems in the Psychology of Flight Activities — 14
B. S. Alyakrinskiy

Some Problems in Ensuring the Radiation Safety of Space Flights — 18
V. V. Antipov, V. G. Vysotskiy, B. I. Davydov, N. N. Dobrov, V. S. Morozov, G. F. Murin, M. D. Nikitin and P. P. Saksonov

Effect of Different Partial Pressure of Oxygen and Environmental Temperature on Regulation of Temperature Relations in the Organism — 20
I. I. Antonov

Medical Service for the Civil Air Fleet of the USSR — 24
A. S. Asribekov

Labor Hygiene in the Spraying of Chemicals from Civilian Airplanes — 26
T. A. Asribekova

Pharmacological Prophylaxis and Therapy of Airsickness — 28
Z. A. Astakhova, Ye. P. Belogortseva, M. D. Kruglik and P. I. Syabro

Page

The Dog Spleen Response to Lateral Acceleration 32
Yu. I. Afanas'yev

Modern Aviation and Problems in Ensuring the Medical Safety of Flights 36
A. N. Babiychuk

The Efficiency of Man Exposed to Radial Acceleration and Breathing of Oxygen at an Excess Pressure 36
V. I. Babushkin and V. V. Usachev

Physiological Reactions to Radial Acceleration 38
V. I. Babushkin, P. K. Isakov, V. B. Malkin and V. V. Usachev

Transmission of Medical Information over Limited-Capacity Telemetry Channels 41
R. M. Bayevskiy

Dynamics of the Elimination of Corticosteroids after Various Actions 44
I. S. Balakhovskiy and I. G. Dlusskaya

Effect of Accelerations on the Growth of Living Beings 46
V. I. Baranov, A. A. Gyurdzhian, M. A. Lomova, L. A. Radkevich, L. T. Tutochkina, T. A. Fedorova, L. P. Furayeva, S. S. Khnychev and N. S. Artem'yeva

Leading Trends in Aviation and Space Ophthalmology 49
V. V. Baranovskiy

Threshold Contrasts and Brightness to Ensure Visibility of Objects at Night and during the Day 51
V. V. Baranovskiy, L. N. Meyer and V. V. Preobrazhenskiy

A New Method of Studying the Tendency to Illusions of Spatial Orientation 53
V. V. Baranovskiy and I. D. Semikopnyy

Increasing Resistance as a Means of Providing Biological Protection against Various Environmental Factors during Flight 56
Z. I. Barashova

Respiration and Gas Exchange in an Acute Hypoxic Test 59
A. V. Beregovkin, P. V. Buyanov and V. B. Malkin

Page

Effect of Change in the Gas Medium on "Primary Potentials" of the Auditory Area of the Cerebral Cortex in Animals and on Some Functions of the Acoustic Analyzer in Man 62
E. V. Bondarev

The Possibility of Biological Objects Growing and Living a Long Time in a Helium-Oxygen Atmosphere 64
V. V. Boriskin, P. A. Gul'tyayev and B. M. Savin

Some Aspects of Medical Examination of Flight Personnel 67
K. F. Borodin

Obesity in Fliers 70
I. M. Buznik

Functional Evaluation of Blood Circulation from Change in Circulation Effectiveness. Value of the Method in Selecting and Training Flying Personnel 73
P. V. Buyanov

Functional Changes in the Cardiovascular System after Exposure to Hypodynamia 76
Yu. V. Vanyushina

Effect of Some Drugs on Tolerance of Accelerations 79
P. V. Vasil'yev and V. Ye. Belay

Structural and Cytochemical Investigations of the Utricle under the Conditions of Relative Rest and after Exposure to Accelerations 85
Ya. A. Vinnikov, O. G. Gazenko, L. K. Titova, A. A. Bronshteyn and V. I. Govardovskiy

Oxygen Supply of the Heart during Respiration at Excess Pressure 87
V. G. Voloshin

Ensuring Radiation Safety on the Flights of Astronauts
Yu. A. Gagarin, G. S. Titov, A. G. Nikolayev and P. R. Popovich 90
Yu. M. Volynkin, V. V. Antipov, N. N. Dobrov, M. D. Nikitin and P. P. Saksonov

Changes in Cardiac Activity during Prolonged Lateral Accelerations 94
A. D. Voskresenskiy

Page

Interrelation of Hemodynamic Changes and Respiration during Accelerations 97
P. F. Vokhmyanin

Involvement of the Vestibular Apparatus in Regulating the Blood Sugar Level 100
R. Kh. Gambarova

Changes in the Bioelectric Activity of Different Parts of the Brain during Exposure to Prolonged Accelerations 102
O. G. Gazenko, B. B. Yegorov, G. V. Izosimov, Yu. P. Limanskiy, A. N. Rasumeyev and P. M. Suvorov

Anticipating Reactions in Flight Activity 105
S. G. Gellershteyn

Data on the Behavior and Some Functions of Persons Kept under the Conditions of Limited Mobility 107
M. A. Gerd

The Physiological-Sanitary Justification for Substituting a Luminous Substance of Intermittent Action for the Phosphor Now Used on Airplane Instrument Dials 111
V. Ya. Gilinskiy and A. Ya. Loshak

The Effect of Low Concentrations of Carbon Monoxide on Man in Pressurized Cabins of Passenger Planes 113
V. A. Gilinskiy, A. V. Chapek, A. G. Kozlova, N. M. Kulikova and A. Ya. Loshak

Morphological Changes in the Nervous System of Animals Subjected to Lateral Accelerations 115
B. S. Glushkov

Some Functional Changes in Man after Prolonged Isolation 116
F. D. Gorbov, V. I. Myasnikov and V. I. Razdovskiy

The Main Problems in Investigating Shock Overloads Arising in Flights on Airplanes 119
S. A. Gozulov and G. P. Mirolyubov

Increasing Resistance to Oxygen Deficiency by Means of Drugs 121
G. I. Gurvich and K. S. Shadurskiy

Page

White Rat Respiration after Prolonged Exposure to Radial Accelerations 123
V. I. Danileyko, A. I. Nazarenko and O. S. Savchenko

Impairment of the Mechanism of Mitosis in Microspores after Flight on Vostok 3 and Vostok 4 126
N. L. Delone, P. R. Popovich, V. V. Antipov and V. G. Vysotskiy

Qualitative (Stage) Evaluation of Flight Fatigue 130
Ye. A. Derevyanko

Psychophysiological Characteristics of Instrument Flying 134
Ye. A. Derevyanko and N. D. Zavalova

Selection of Individuals for Flight Training 136
T. T. Dzhamgarov

The Possibility of Substituting Helium for Nitrogen in the Cabins of Spacecraft 138
A. G. Dianov and A. G. Kuznetsov

Excretion of 17-Oxycorticosteroids in an Investigation of the Efficiency of Airplane Crews on Long Night Flights 140
I. G. Dlusskaya, F. L. Kosmolinskiy and N. A. Fedorov

Vestibular Influences on the Smooth Muscles of the Small Intestine and Blood Vessels after Transection of the Spinal Cord and Vagus, Cervical Sympathetic, and Splanchnic Nerves 143
A. S. Dmitriyev and Ye. V. Burko

Some Data on an Investigation of Chain Conditioned Motor Reflexes in Animals after Long Exposure to an Altered Gas Medium 147
G. P. Doronin

Changes in the Capacity of the Central Nervous System While Learning to Pilot a Training Plane 150
V. A. Yegorov

Change in Back Pressure on the Body and Tolerance of Respiration at Excess Pressure 152
A. V. Yeremin and V. N. Alifanov

Page

Effect on Man of Prolonged Exposure to Atmosphere with a High CO_2 Content 155
S. G. Zharov, Ye. A. Il'in, Ye. A. Kovalenko, I. R. Kalinichenko, L. I. Karpova, N. S. Mikerova, M. M. Osipova and Ye. Ye. Simonov

Evaluating the Biological Effectiveness of Space Flight Factors by Means of the Lysogenic Bacteria E. Coli K-12 (λ) 158
N. N. Zhukov-Verezhnikov, I. N. Mayskiy, V. I. Yazdovskiy, A. P. Pekhov, N. I. Rybakov, G. P. Tribulev, P. P. Saksonov, N. N. Dobrov, V. V. Antipov, V. A. Kozlov, V. G. Vysotskiy, B. A. Mishchenko, K. D. Rybakova, G. P. Parfenov, V. V. Pantyukhova, Ye. V. Yudin and Ye. D. Aniskin

Modern Genetics and Problems in Space Biology 161
N. N. Zhukov-Verezhnikov, M. N. Volkov, V. I. Yazdovskiy, I. N. Mayskiy, P. P. Saksonov, P. A. Konstantinov, A. P. Pekhov, G. P. Tribulev, N. I. Rybakov, V. Ya. Kop'yev, I. I. Podoplelov, N. N. Dobrov, V. A. Kozlov, V. G. Vysotskiy, N. S. Artem'yeva, V. V. Antipov, B. A. Mishchenko, Ye. D. Aniskin, Ye. V. Yudin, K. D. Rybakova and R. I. Shupik

Impairment of Protective Mechanisms Following Exposure to an Altered Gas Medium 164
V. N. Zagryadskiy and Z. K. Sulimo-Samuyllo

An Investigation of Higher Nervous Activity and Some Motor Reactions in Man under Conditions of Brief Weightlessness 167
A. T. Zverev and L. A. Kitayev-Smyk

Some Aspects of Hemodynamics in Breathing Oxygen with High Pressure in the Lungs 169
D. I. Ivanov

Changes in Man's Principal Physiological Functions after Prolonged Exposure to Low Barometric Pressure in a Small Space 172
D. I. Ivanov, V. B. Malkin, I. N. Chernyakov, V. L. Popkov and Ye. O. Popova

Hypoxia and Chemical Thermoregulation 175
K. P. Ivanov

The Time Reserve in Steadily Decreasing Altitude 177
L. S. Isaakyan

Page

Evaluation of the Degree of Tension in Pilots Executing Landings in Various Types of Modern Airplanes under Ordinary Conditions 179
L. S. Isaakyan

Some Results of a Clinical and Physiological Study of Senior Pilots of the Civil Air Fleet 184
L. S. Isaakyan, D. S. Kuleshov, A. V. Chapek, V. M. Kozin, A. N. Ustinova, N. M. Kulikova, Ye. I. Kuznetsova and A. A. Shishova

A Theory Concerning Gravitational Influences on the Organism 188
P. K. Isakov

Effect of Hypokinesia on Certain Indexes of Efficiency and Respiratory Function in Man 192
L. A. Kakurin, B. S. Katkovskiy, A. N. Kozlov and N. M. Mukharlyamov

Obtaining Visual Information during Instrument Flying 194
I. A. Kamyshev

Reactions of Astronauts to Brief Periods of Weightlessness 198
I. M. Kas'yan

Pathomorphological Visceral Changes in Animals after Accelerations 201
M. I. Kas'yanov and G. P. Mirolyubov

Quantitative Evaluation of Operator in a "Man-Machine" System 204
Yu. V. Kiselev

Trace Phenomena in the Central Nervous System after Prolonged Optokinetic Stimulation 205
V. A. Kislyakov and V. P. Neverov

Changes in Electric Activity of the Cerebral Cortex and Subcortical Formations in Animals Exposed to Brief Periods of Weightlessness and Acceleration 206
A. M. Klochkov

Some Sensory Disturbances in Persons Exposed to Weightlessness 209
L. A. Kitayev-Smyk

Page

The Body Position (Postural Reactions) of Animals in Weightlessness 211
L. A. Kitayev-Smyk

Effect of Centrifugal Accelerations on the Venous Outflow in the Cerebral Blood Vessels of Animals 213
V. Ya. Klimovitskiy

Pathogenesis of Hemodynamic Disorders after Exposure to a Supersonic Air Stream 214
A. F. Kovalenko, Ye. Ya. Kaplan, V. P. Boyarkin and A. M. Klochkov

Effect of Hypothermia on Oxygen Deficiency at High Altitudes 217
Ye. A. Kovalenko, V. I. Korol'kov and Ye. A. Il'in

Effect on Brain Oxygenation of Breathing Oxygen during Accelerations 220
Ye. A. Kovalenko, V. L. Popkov and I. N. Chernyakov

Morphological Labyrinthine Changes in Dogs Exposed to Radial Accelerations 223
R. Ye. Kogan and S. S. Makaryan

Speech Audiometry as a Method of Functional Diagnosis in Fitness Examinations of Flight Personnel 227
V. M. Kozin

Effect of Flight Factors on the Adjusting Reflexes 230
G. L. Komendantov

Some Results of a Study of the Cardiovascular System in Fliers on Different Flights 233
S. Ye. Komshalyuk

Histomorphological Changes in Dog Pancreas after Exposure to Lateral Accelerations 235
Yu. N. Kopayev

The Latent Form of Motion Sickness 238
V. I. Kopanev

Training Man for Space Flight 240
A. A. Koreshkov

Page

Weightlessness from the Standpoint of Terrestrial Physiology 242
P. A. Korzhuyev

Development and Preservation of a High Level of Motor Function as a Problem in the Preparation and Execution of Extended Space Flights 245
A. V. Korobkov

Effect of Lateral Accelerations on Dog Lung Histology 247
Yu. N. Korolev

Effect of Lateral Accelerations on Dog Kidney Histology 249
V. V. Korolev

Psychological and Physiological Characteristics of the Work of Airplane Crews in Connection with In-Flight Refueling 252
F. P. Kosmolinskiy

Effect of Prolonged Lateral Accelerations on Monkeys 254
A. R. Kotovskaya, P. V. Vasil'yev, B. A. Lapin, S. F. Simpura, I. S. Grishina and V. I. Kulinskiy

Effect of Accelerations on Liver Structure 257
Ye. F. Kotovskiy

The Use of Hyperventilation in Selecting Candidates for Flying School 260
A. K. Kochetov

Principles Governing the Objective Evaluation of the Thermal State of the Body 262
V. I. Krichagin

Changes in Some Physiological Functions Resulting from Explosive Decompression 267
A. G. Kuznetsov, A. S. Tsivilashvili and A. R. Mansurov

Changes in Respiratory and Cardiovascular Functions after Prolonged Exposure to Low Barometric Pressure 270
A. G. Kuznetsov, N. A. Agadzhanyan, Yu. P. Bizin, N. I. Yezepchuk, I. R. Kalinichenko, L. I. Karpova, I. P. Neumyvakin and M. M. Osipova

Changes in the Vectorcardiogram of Flight Personnel in Early Stages of Hypertension 272
Ye. I. Kuznetsova

Page

EKG Changes in Flight Personnel after Prolonged Nonstop Flights 274
N. M. Kulikova

Participation of L. A. Orbeli in the Development of the Problem of Cosmic Physiology 277
A. V. Lebedinskiy

Some Physiological Aspects of the System of Astronaut Selection and Training 284
A. V. Lebedinskiy, N. I. Arlashchenko, B. B. Bokhov, Yu. G. Grigor'yev, L. N. Kvasnikova and Yu. V. Farber

The Prolonged Effect of Slow Coriolis Accelerations on the Human Organism 289
A. V. Lebedinskiy, N. I. Arlashchenko, V. Ye. Busygin, R. A. Vartbaronov, A. S. Veselov, N. A. Volokhova, Yu. G. Grigor'yev, M. D. Yemel'yanov, T. V. Kalyayeva, Yu. V. Krylov, B. I. Polyakov and Yu. V. Farber

Labor Hygiene and Occupational Pathology Involved in the Work with Centimeter Wave Generators in the Civil Air Fleet 292
A. Ya. Loshak

The Vibration and Radiation Effect on the Acidifying Processes in the Brain Tissues of Rats 296
L. D. Luk'yanova

An Electroencephalogram of an Acute Hypoxic (sic) Hypoxia 297
V. B. Malkin

The Characteristic Features of the Clinical Course and the Expert's Opinion of Flight Personnel Afflicted with Stomach and Duodenal Diseases 301
Ye. T. Malyshkin and B. L. Gel'man

On the Diagnosis and Expert Medical Opinion of Flight Personnel Afflicted with Atherosclerosis 303
Ye. T. Malyshkin, N. A. Gol'din and V. M. Tolstov

Vestibular Reactions under the Effect of Various Angular Accelerations 305
S. S. Markaryan

Page

Reactive Changes in the Inguinal Lymph Nodes under the Effect of Various Overloads on the Organism of Dogs — 309
Yu. V. Mashkovtsev

The Dynamics of the Morphological Changes in the Cerebral Cortex of Dogs Following the Effect of a Transverse Acceleration — 312
D. I. Medvedev

The Effect of a Prolonged Hypokinesia on the Human Blood Circulation — 316
A. L. Myasnikov, R. M. Akhrem-Akhremovich, L. I. Kakurin, Yu. T. Pushkar', N. M. Mukharlyamov, V. S. Georgiyevskiy, Yu. N. Tokarev, Yu. A. Senkevich, B. S. Katkovskiy, A. N. Kalinina, M. A. Cherepakhin, V. A. Chichkin, V. K. Filosofov and P. G. Shamrov

Some Problems of Professional Selection — 318
V. D. Nebylitsyn and B. M. Teplov

The Sanitary Aspect of the Working Conditions Around Ultrahigh Frequency Generators — 321
M. I. Netreba

The Role of the Sinocarotid Reflexogenic Zone in the Reaction of the Blood System to Reduced Barometric Pressure — 324
Yu. V. Nikolayenkov

Evaluating Some of the Organism's Reflex Reactions to Breathing under Increased Intrapulmonary Pressure — 328
P. V. Oblapenko

Studying the Nyctohemeral Rhythm of Functions in Conditions of Limited Mobility — 330
N. Ye. Panferova

The Achievements and Goals of Space Medicine — 333
V. V. Parin

Some Structural Principles of Flight Control and Navigation Systems — 333
Yu. A. Petrov

Page

Pathomorphological Changes Induced in Animals by Rotating Them Around Axes Running Through the Pelvic-Cardiac-Cephalic Region 336
V. G. Petrukhin

The Pathomorphology of Transverse Overloads 339
V. G. Petrukhin and M. M. Sokolova

Some Problems of the Human Personality in Aeronautics, Aviation and Astronautics 342
K. K. Platonov

Evaluating the Effectiveness of the Experimental Methods Used in the Psychological Selection of Aviation Cadets 347
B. L. Pokrovskiy, T. I. Zhukova and V. P. Zukhar'

Some Reasons for Errors Made by the Pilots in Instrument Flying 349
V. A. Ponomarenko and A. G. Shishov

Some Methods of Improving the Perception of Parameters Controlled by a Human Operator 352
V. A. Popov, A. M. Pikovskiy, Yu. V. Kiselev and Yu. V. Krylov

The Reaction of the Organism to the Informational Characteristic of a Stimulus 355
V. A. Popov and A. S. Khachatur'yants

Electrocardiograms in Dogs during Exposure to Certain Altitude Factors 358
V. L. Popkov and I. N. Chernyakov

Effect of Oxygen Starvation on Motion Sickness 362
N. A. Razsolov

The Importance of the Study of Types of Higher Nervous Activity in Man in Selecting and Training Flight Personnel 366
A. A. Rogov, T. T. Gorlanova, M. M. Kantorovich and N. T. Kovaleva

Some Regular Patterns in the Effect of Acceleration on the Organism 368
D. Ye. Rozenblyum

Page

The Nervous System's Role in the Organism's Reactions to Accelerations 370
B. M. Savin

Electroencephalographic Examination of Flight Personnel During Long Flights 372
L. V. Sadovnikova

Functional State of the Vestibular Analyzer during the First Few Hours Following Irradiation with Different Doses 373
A. V. Sevan'kayev

Histochemical Examination of the Changes in the Distribution of the Effect of Dehydrogenase Succinate, Carboanhydrase, Alkaline and Acid Phosphomonoesterase, Adenosine Triphosphatase and Sulfhydryl Groups of Proteins in Inner Organs in Acute State of Oxygen Starvation 376
S. N. Sergeyev

Contemporary Problems in Aviation Physiology 379
N. P. Sergeyev, V. A. Sergeyev and F. P. Kosmolinskiy

The Role of Reduced Reactivity of the Organism in Resistance to Extreme Influences (Acceleration, Radiation) 384
N. N. Sirotinin

Some New Indexes of Hemodynamics, Obtained by Means of the Mechanocardiographic Method 386
M. N. Syviritkin

Metabolic Changes under the Effect of Parachute Jumping 387
Yu. K. Syzrantsev, Yu. F. Udalov and N. A. Chelnokova

Vitamins in the Diet of Aviators and Astronauts 390
Yu. F. Udalov

Changes in Excitability and Lability of the Visual Analyzer under Conditions of Prolonged Nonstop Flights in Multipassenger Turboprop Planes 393
A. I. Ustinova

Some Metabolic Indexes in the Astronauts Yu. A. Gagarin, G. S. Titov, A. G. Nikolayev and P. R. Popovich 395
T. A. Fedorova, L. T. Tutochkina, M. S. Uspenskaya
M. M. Skurikhina and Ye. A. Fedorov

Page

Effect of Angular Rotation Velocities on the State of Several Visual Functions 398
A. B. Flekkel'

Reactivity of the Organism and Methods of Increasing Its Resistance to Certain Flight Factors 401
I. M. Khazen

Histophysiological Changes in Animals Exposed to Accelerations 406
I. M. Khazen, E. M. Kogan and A. S. Barer

Some Results of Manned Space Flight and Problems in Space Biology and Medicine 409
V. I. Yazdovskiy

The Effect of Adequate Stimulations of the Vestibular Apparatus on the Electrical Potential of the Stomach 410
V. T. Khlebas and N. P. Kozhukhar'

The Status of Anticoagulating Mechanisms under Conditions of Prolonged Hypokineses 414
Ye. I. Chazov and V. G. Ananchenko

The Efficacy of the Pharmacological Preparation NII in Combating Motion Sickness of Air Transport Passengers 416
A. V. Chapek

The Influence of Age-Associated Changes in Older Pilots during Re-Learning in the New Aviation Technology and during Performance 419
A. V. Chapek, V. P. Yerokhin and I. P. Poleshchuk

Some Microorganisms as Indicators of Solar Activity and Precursors of Solar Flares 422
A. L. Chizhevskiy

Significance of Parasympathetic Nervous System Tone in Increasing Resistance to Flight Factors 424
M. D. Chirkin

Effect of Brief Physical Training on the Survival of White Rats Kept under Conditions of Prolonged Hypodynamia and Isolation 427
V. A. Shkurdoda

Page

Effect of Parachute Jumps on the Adaptive Reactions in Persons of Different Age Groups 429
S. N. Shurgin and A. N. Mazin

Physiological Reactions in Weightlessness 431
Ye. M. Yuganov

Effect of Airplane Noise on Man and Noise Control Measures 434
Ye. M. Yuganov, I. Ya. Borshchevskiy, Yu. V. Krylov and V. S. Kuznetsov

Effectiveness of Certain Methods of Selecting Personnel by Vestibular Tests 437
Ye. M. Yuganov, S. S. Markaryan, I. I. Bryanov, I. A. Sidel'nikov and R. A. Vartbaronov

Sensorimotor Coordination in Extended Weightlessness in Actual Space Flight 439
V. I. Yazdovskiy, I. I. Bryanov, L. I. Kakurin, Yu. V. Krylov and M. A. Cherepakhin

Radiation Reactions and Chemical Protection of Animals Exposed to High-Energy Protons 442
S. P. Yarmonenko, E. B. Kurlyandskaya, G. A. Avrunina, Ye. S. Gaydova, R. D. Govorun, R. L. Orlyanskaya, G. F. Palyga, V. L. Ponomareva, V. I. Fedorova and N. L. Shmakova

FOREWORD

The conference on aviation and space medicine, the proceedings of which are published in this collection, was held at a time of remarkable achievements by our people in their striving for the peaceful conquest of outer space. The realization of the first space flights of man testifies to the magnificent accomplishments of Soviet science and engineering.

Soviet medicine has made a significant contribution to the preparation for and successful achievement of space flights. We are referring here to space medicine, a new branch of knowledge that has evolved in recent years from aviation medicine.

The last 30 years were marked by the blossoming of Soviet aviation medicine. As long ago as 1934--at an All-Union Conference on the Stratosphere, called at the initiative of the USSR Academy of Sciences--the leading scientists of our country were focusing on the medical aspects of man's mastery of the stratosphere.

A conference on aviation medicine held in 1939 in Leningrad summed up the results of the research done at that time and outlined future research. It is now clear that the scientists of that era obtained factual data and advanced theories which significantly affected the safety of flights beyond the earth's atmosphere.

During the 25 years that have elapsed since the Leningrad conference our scientists have done a tremendous amount of work to ensure the safety of flights by civilian and military aircraft and made outstanding progress in space medicine.

During the arduous years of World War II, Soviet aviation medicine not only coped with current practical problems, but was able to ensure the safety of the first flight of man in a rocket-propelled vehicle. This was made possible by the extensive investigations conducted by many teams in academic and other institutions on the effect on the human organism of the environmental factors characteristic of flight. These investigations were conducted as part of comprehensive high-altitude expeditions, on special testing equipment simulating various flight factors, and during flights themselves.

We remember the now deceased leaders of these scientific teams--the remarkable scientists L. A. Orbeli, V. V. Strel'tsov, I. P. Razenkov, G. Ye. Vladimirov, L. N. Fedorov, A. P. Apollonov, V. G. Mirolyubov and

I. M. Dobrotvorskiy, whose efforts made possible the successful development of aviation medicine and, later, space medicine in our country.

Whereas the subject matter of the 1939 conference dealt mainly with the problems involved in ensuring the safety of high-altitude and prolonged flights, a distinguishing feature of this past conference was the broad range of problems pertaining to man's survival on various vehicles traveling in the earth's atmosphere and beyond--in outer space.

This conference was called because the matters discussed at the meetings and conferences systematically organized by the Division of Biological Sciences, USSR Academy of Sciences, showed that the time had come for a detailed discussion of the accumulated data, if we were to attract even more scientists into the fields of aviation and space medicine.

This conference heard reports on increasing resistance to various flight factors, with emphasis on those factors specific to space flight. It examined the effect of gravity, which includes matters relating to man's exposure to weightlessness and the influence of accelerations of different intensities and directions. It dealt with the problem of living under the conditions of extended flights on spacecraft. The conference paid considerable attention to various medical aspects of space flight, especially the main problems of flight physiology and psychology.

The papers fell into the following groups:

(a) Those dealing with the effect on the organism of various environmental factors (high barometric pressure, low partial pressure of oxygen in inhaled air, high and low temperature, different kinds of radiation, etc.).

(b) Those dealing with the effect on the organism of dynamic flight factors (acceleration, weightlessness, noise, and vibration).

(c) Those dealing with physiology and psychology, hygiene of flight activity, and problems involved in medical examination.

Acquainting large groups of physicians, biologists, and specialists in other disciplines with the proceedings of the conference will contribute to the further progress of aviation and space medicine in our country.

V. V. Parin

RESULTS OF PHYSIOLOGICAL INVESTIGATIONS ON THE SPACESHIPS VOSTOK 3 AND VOSTOK 4

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One of the important objectives of the first tandem space flight of the Vostoks was to investigate the effect on the human organism of prolonged weightlessness. Thanks to the use of several new techniques and improved older ones employed during the preceding flights, it was possible to obtain a large amount of physiological information. Evaluation of this information required that it be compared with the data derived from ground tests simulating some of the conditions obtaining during space flight and with the results of some laboratory investigations.

Extensive material (obtained by telemetry, from radio conversations, logs kept on board, postflight reports and talks) was used to judge the functional state of the astronaut's central nervous system during the flight. Analysis of the material showed that prolonged weightlessness had no appreciable effect on the functional capabilities of the central nervous system of either astronaut. Their efficiency remained at a high level; they performed a variety of tasks during the flight, some involving flight duties, others for research purposes. The astronauts said they did all kinds of work easily and without fatigue during the three and four days of flight. This was objectively confirmed by psychological tests administered during flight. According to EEG data, during the first few hours of exposure to weightlessness there was a predominance of rhythms with a frequency of 5-7 oscillations per second and a comparatively high amplitude. Similar EEG changes have been noted in athletes after intense physical exertion (L. I. Il'ina and S. V. Kukolevskaya, 1962). Later there was a gradual shift toward high-frequency oscillations (β rhythm) with a decrease in the average amplitude of the EEG biopotentials.

Worth noting are the dynamics of electric resistance of the skin, which decreased during the first hours of flight and before landing, indicating marked emotional stress on the part of the astronauts. The daily periodicity of electric resistance of the skin--increase at night and decrease during the day--remained unimpaired throughout the flight. This fact tends to reflect the functional stability of the higher autonomic centers.

Electro-oculograms (EOG) were recorded during flight to evaluate the condition of the vestibular apparatus. Vestibular tests, sometimes with simultaneous recording of an EOG, were included in the program to determine any impairment of vestibular function. According to EOG data, asymmetry of oculomotor reactions, which might indicate impairment of the vestibular centers, and nystagmus were not detected in either astronaut. Analysis of the vestibular tests not accompanying the EOG recording likewise failed to reveal any significant impairment of vestibular function.

EOG investigations, besides the light they throw on the state of the vestibular centers, are of definite value in appraising the level of oculomotor activity, which to some extent may reflect the general activity and motor activity of the astronaut throughout the flight. The changes in oculomotor activity in both astronauts were phasic in character. At the beginning of the flight it was high in A. G. Nikolayev, less so in P. R. Popovich--4-6 eye movements per second.

Eye movements were sweeping and frequently uncoordinated. Motor activity diminished during the 6th and 7th orbits and now solitary, now group oscillations were recorded on the EOG. Subsequently, the EOG revealed a periodic increase or decrease in oculomotor activity. At the end of the flight, both astronauts had secondary, persistent intensified oculomotor reactions, but this activity was much less than at the beginning of the flight.

Cardiac activity was investigated by recording EKGs in the thoracic lead. There was a slight pulse acceleration just before the launching (Nikolayev--from 98 beats/min to 112 beats/min; Popovich--from 94 beats/min to 136 beats/min), with a corresponding shortening of the PQ and QT intervals). EKG changes during the active part of the flight were similar to the data obtained in the course of investigations in the centrifuge. The maximum pulse rate in the first minute of flight was 136 beats/min and 132 beats/min in Nikolayev and Popovich, respectively. After going into orbit, the pulse rate dropped to the level observed 4 hours before the launching during the 6th-7th orbits in Nikolayev and during the 3rd-4th orbits in Popovich. It will be noted that in the course of training in the centrifuge, the pulse rate returned to normal in 5-10 minutes. No EKG changes were noted that might indicate impairment of automatism, excitability, or conductivity. However, 3 single extrasystoles were recorded in Popovich during flight; these also occurred in the course of various tests and training. The nature of the daily periodicity of cardiac activity did not change during flight.

According to pneumographic data, there were no respiratory abnormalities. During the active part of the flight there was some acceleration of respiration, which matched the data obtained during tests in the centrifuge.

Thus, no pathological changes were noted in the physiological functions of either astronaut throughout the flight.

In the active part of the flight there were functional changes that matched the data obtained during tests in the centrifuge. The first few hours of orbital flight were marked by some changes in the functional state of various systems, as shown by a slow return to normal of the pulse, nature of the EEG changes, and electric resistance of the skin.

The nature of the EEG changed in the course of prolonged (3-4 days) exposure to weightlessness, as shown by changes in the relationship between the processes of excitation and inhibition in the higher divisions of the CNS. At the same time, the mental activity and neuroregulatory capabilities of the astronauts remained on a high level.

CHANGES IN SOME INDICES OF RESPIRATORY BIOMECHANICS IN SICK AND HEALTHY PERSONS UNDER THE CONDITIONS OF HYPOXIA

V. N. Alifanov

Respiratory biomechanics is a new branch of the physiology of respiration. It is pertinent to the clinical physiology (functional diagnosis) of respiration (B. Ye. Votchal et al., 1949-1959; J. Comroe et al., 1950, 1951; Brille and Hatsfeld, 1961; others). Respiratory biomechanics has not been studied, so far as we know, under the conditions of rarefied atmosphere and hypoxia.

This report presents data on changes in maximum pulmonary ventilation (MPV) and respiratory reserve, volumetric flow rate of air upon forced inhalation and exhalation (pneumotachometry), forced vital capacity of the lungs (FVCL), and forced vital capacity during the first second of exhalation (Tiffno's index) while the subjects were in a pressure chamber at an "altitude" of 5000 m and while breathing mixtures of gases containing 11 percent oxygen under the conditions of normal atmospheric pressure. All data were obtained by means of a spirograph and spirometabolograph. The subjects were 30-40 year old pilots, both healthy men and those with incipient signs of cardiovascular disease (usually the initial symptoms of hypertension and cardiosclerosis) or with residual symptoms of respiratory diseases (pulmonary tuberculosis, lesions of the air passages, pneumothorax). We examined a total of 75 healthy persons, 30 persons with cardiovascular disease, and 30 persons with respiratory disease. Changes possessing a reliability of at least 95 percent are considered regular.

MPV--an index both of respiratory function and of systemic condition--is distinctly reduced by several pathological conditions (N. A. Troitskiy, 1949; M. M. Tushinskaya, 1949; A. G. Dembo, 1957; others). It is evident from the table that at an "altitude" of 5000 m all the subjects exhibited a significant increase in the MPV averaging 20-28 percent. No significant changes in the MPV were noted on breathing a hypoxic mixture. In the healthy persons, the increase in the MPV in rarefied atmosphere was at the expense of a deepening of respiration, but in those with impaired health this increase was related mainly to an acceleration of respiration, indicating that these persons had a less perfect mechanism of adaptation reactions. It is interesting to note that an increase in the MPV occurred at an "altitude" of 5000 m even when oxygen was breathed. Aerodynamic calculations show that in rarefied air, resistance of the respiratory passages drops in proportion to the density of inhaled air. We believe that the increase in the MPV in rarefied air is due mainly to a lowering of resistance to breathing.

The so-called respiratory reserve, to which some authors attached considerable significance (M. M. Tushinskaya, 1949), is closely related to the MPV. However, the respiratory reserve changed in uncharacteristic fashion in our investigations.

In recent years many authors have been concentrating on the determination of the forced vital capacity of the lungs (FVCL), especially by seconds (Tiffno et al., 1949; Comroe et al., 1954; G. O. Badalyan, 1961; others). The table shows that the FVCL did not change significantly in our investigations. Tiffno's index in rarefied air had a distinct tendency to be low in the healthy persons and in those with residual symptoms of lung pathology. Changes on breathing the hypoxic mixture were not characteristic, showing that with good tolerance of moderate hypoxia there is no pronounced impairment of respiratory biomechanics. The tendency for Tiffno's index to drop at an "altitude" of 5000 m is to be attributed to the aerodynamic properties of less dense air rather than to physiological mechanisms.

Pneumotachometry (B. Ye. Votchal's method) is of value in judging respiratory function. It is evident from the table that the space velocity of forced inhalation and exhalation on breathing the hypoxic mixture did not change significantly in our subjects, although it was somewhat low in all cases. At an "altitude" of 5000 m the space velocity of inhalation and exhalation regularly increased in all the subjects (the values are presented in the table with an allowance made for the difference in barometric pressure). We believe that a moderate decrease in the space velocity of forced inhalation and exhalation is typical of hypoxic conditions and that an increase in this velocity in rarefied air is probably due to a lowering of resistance to respiration.

The findings described above not only broaden our knowledge of the effects of rarefied atmosphere on respiration, but have important functional

Groups of subjects	Functional indices	Examination conditions	Mean value ± error of mean or difference		Reliability in %	
			5000 m	Hypoxic mixture	5000 m	Mixture
Healthy	MPV (in liters)	Initial hypoxia	79.0 ± 3.2 97.0 ± 4.8	57.7 66.7 ± 14.4	More than 95	Less than 50
	FVCL (in liters)	Initial hypoxia	3.0 3.0 ± 0.13	2.5 2.7 ± 0.07		95
	Tiffno's index (in liters)	Initial hypoxia	2.5 2.1 ± 0.16	2.3 2.2 ± 0.19	95	Less than 90
	Forced inhalation (in liters/sec)	Initial hypoxia	5.7 ± 0.17 6.5 ± 0.16	5.3 5.2 ± 0.17	More than 95	40
	Forced exhalation (in liters/sec)	Initial hypoxia	5.2 ± 0.16 6.1 ± 0.19	5.4 5.1 ± 0.17	More than 98	80
With cardiovascular disease	MPV (in liters)	Initial hypoxia	60.5 ± 5.2 81.5 ± 6.2	64.2 76.8 ± 5.9	More than 95	90
	FVCL (in liters)	Initial hypoxia	2.4 2.3 ± 0.2	3.1 3.3 ± 0.2	50	50
	Tiffno's index (in liters)	Initial hypoxia	2.1 2.1 ± 0.06	2.3 2.7 ± 0.3	-	80
	Forced inhalation (in liters/sec)	Initial hypoxia	5.1 ± 0.2 5.7 ± 0.2	5.1 5.0 ± 0.2	More than 99	20
	Forced exhalation (in liters/sec)	Initial hypoxia	4.9 ± 0.24 5.3 ± 0.2	4.7 4.1 ± 0.7	More than 95	More than 95

Groups of subjects	Functional indices	Examination conditions	Mean value ± error of mean or difference		Reliability in %	
			5000 m	Hypoxic mixture	5000 m	Mixture
With respiratory disease	MPV (in liters)	Initial hypoxia	58.0 ± 0.6 78.8 ± 11.4	57.0 57.2 ± 1.9	More than 95	20
	FVCL (in liters)	Initial hypoxia	2.5 2.1 ± 0.24	2.7 2.9 ± 0.14	Less than 90	80
	Tiffno's index (in liters)	Initial hypoxia	2.2 1.7 ± 0.06	2.1 2.3 ± 0.3	More than 99	50
	Forced inhalation (in liters/sec)	Initial hypoxia	5.6 ± 0.3 6.5 ± 0.15	4.7 4.5 ± 0.2	99	60
	Forced exhalation (in liters/sec)	Initial hypoxia	5.3 ± 0.3 5.9 ± 0.2	4.7 4.25 ± 0.7	98	Less than 90

diagnostic value. Medical investigation of respiratory mechanics in persons subjected to the commonest functional load in aviation, i.e., pressure-chamber "elevations" to 5000 m, is undesirable because it is useless in detecting incipient impairment of this form of respiration and it may even confuse the physician. We therefore make the highly important and, to our way of thinking, practical conclusion that respiratory biomechanics should be investigated under the conditions of a hypoxic load only when the inhaled air (gas) possesses ordinary density.

CHANGES IN BIOELECTRIC ACTIVITY OF THE MYOCARDIUM IN MAN AFTER EXPOSURE TO HYPOXIC HYPOXIA ACCORDING TO THE DATA OF VECTOR ANALYSIS

V. N. Alifanov and L. M. Zemesheva

There are few references in the literature to vector analysis of EKGs recorded under the conditions of hypoxia (Tittle, 1940, Gurtler et al., 1954; V. N. Alifanov, 1960 and 1961). These reports contain data on frontal vector measurement. We are unaware of anything dealing with sagittal vector measurement under similar conditions.

Our investigations were conducted in a pressure chamber where the subjects remained for 30 minutes at an "altitude" of 5000 m. EKGs--taken before the "climb" and after 20 minutes at the "altitude"--were recorded in standard, amplified, and unipolar thoracic leads, which made frontal vector measurement possible, and in Aricci's leads, which, according to Zuckerman (1961), permit vector analysis of the EKG to be made in a sagittal plane. Pilots 35-45 years of age with good tolerance of hypoxia were the subjects. This report presents the results of examinations of 15 healthy persons and 15 persons with incipient atherosclerotic cardiosclerosis. All the data were statistically processed for reliability. The results with a reliability of at least 95 percent are considered regular. The figures are presented in the table below.

It is evident from the table that in the healthy persons the most characteristic changes occurred in connection with frontal vector measurement. With hypoxia there was a regular turn of the ventricular vector of AQRS depolarization to the left (averaging 30°), some tendency for the AQRS to decrease (averaging 4.5 μvs), regular increase in the spatial divergence of the AQRS and AT vectors (R/T ratio), and a tendency for the divergence of the vectors of ventricular and atrial excitation (the R/p ratio proposed by V. N. Alifanov, 1960) to increase. The other ratios of frontal vector measurement changed less reliably in the healthy persons.

Average Data of the Direction and Magnitude of Cardiac Biopotential Vectors in the Frontal and Sagittal Planes

Subjects	Plane of VKG	Conditions	Direction of vectors in degrees				Magnitude of vectors in μvs				Ratio in degrees	
			AP	AQRS	AT	G	AP	AQRS	AT	G	R/p	R/T
Healthy	Frontal	Initial	50	51	37	35	7.9	29.8	23.6	49.7	21	29
		Hypoxia	55	21	33	33	7.1	25.3	23.8	49.5	38	40
		Reliability of difference in percentage	-	98	-	-	-	90	-	-	90	99
	Sagittal	Initial	50	28	65	44	9.7	21.9	24.5	36.6	28	48
		Hypoxia	55	28	66	43	11	22.8	23.9	40.9	36	56
		Reliability of difference in percentage	90	-	-	-	-	-	-	-	90	98
Cardiosclerosis	Frontal	Initial	51	11	29	18	7.6	28.7	25.7	48.9	40	36
		Hypoxia	53	4	27	18	6	23.2	22.0	38.8	46	35
		Reliability of difference in percentage	-	98	-	-	98	95	90	95	90	-
	Sagittal	Initial	52	-4	57	28	8.3	21.8	18.7	31.2	55	72
		Hypoxia	46	3	51	27	9	22.1	16	32.6	50	67
		Reliability of difference in percentage	90	-	-	-	-	-	-	-	-	90

Note: No mention is made of reliability less than 90 percent; the positive direction of the vectors is indicated without a + sign in front of the degrees of direction.

The following points must be emphasized. In healthy persons exposed to hypoxia, changes in the spatial direction of the frontal vectors were dominant. At an "altitude" of 5000 m the direction of the vector of repolarization of the AT and so-called "ventricular gradient" G changed little in conformity with the AQRS. The atrial AP vector deviated frequently, but moderately, to the right. Changes in the ratios of sagittal vector measurement at an "altitude" of 5000 m were less pronounced in the healthy subjects.

It is evident from the table that neither the direction nor the magnitude of the sagittal vectors changed reliably under the conditions of hypoxia. There was a distinct tendency for the AP vector to assume a more vertical position with a slight increase in length. The R/T and R/p ratios changed in the sagittal plane just as in the frontal plane.

As for the physiological mechanisms underlying these changes, analysis of all the EKG leads and some hemodynamic characteristics (arterial pressure, systolic volume of the blood, etc.) reveals that, in hypoxia the deviation to the left of the main vector of excitation of the ventricular musculature of AQRS was caused chiefly by intensification of the functional load on the "left heart" and, in part, by the shifting of the heart to the left when the diaphragm stood somewhat higher at the "altitude" of 5000 m.

V. N. Alifanov (1960) noted that pronounced hypoxia gives rise to symptoms of reflex overloading of the "right heart" owing to increased pressure in the pulmonary artery system. This overloading was initially manifested in a deviation to the right and increase in the AP vector. A reflex load on the "right heart" probably occurs to some extent in all cases of hypoxia, this was reflected in our investigations in the verticality of AP, especially marked in the sagittal plane.

Similar investigations in persons with incipient cardiosclerosis are of great interest because this disease is common and because there are few references in the literature to the effect of hypoxia on persons with various physical disorders.

It is evident from the table that frontal vector measurement in persons with cardiosclerosis has its own peculiarities. At an "altitude" of 5000 m the direction of the vectors was, in general, the same as in healthy persons, except for a regular decrease in the value of all the vectors. The decrease in magnitude of the myocardial biopotentials in these subjects after exposure to hypoxia was so pronounced that it masked the value of the spatial displacements of the vectors. Moreover, the nature of the changes in the sagittal vectors in these subjects differed somewhat from that in the healthy persons. There was a slight tendency for the AP vector to deviate forward and to a more vertical projection of the AQRS.

It is reasonable to assume that persons with incipient cardiosclerosis who are fairly tolerant of hypoxia generally have the same physiological mechanism of changes in heart potentials as that described for healthy persons, but with indications of some oxygen deficit of the myocardium, reflected in a regular decrease in the magnitude of the frontal vectors. This may appear on the EKG in the form of some general decrease in the voltage of the P, R, and T waves. But this decrease is so moderate that it is not detected, as a rule, in the course of an ordinary analysis of the EKG. Only a quantitative vector analysis of the EKG can reveal this phenomenon, which is important for functional diagnosis.

BIOTELEMETRY ON MANNED SPACE FLIGHTS

G. V. Altukhov

Medical monitoring of manned space flights differs from ground observation methods in a number of respects: lack of personal contact between the physician and astronaut, limited amount of medical information transmitted from the spaceship, and impossibility of rendering effective aid in case a serious health problem should arise.

Various radiotelemetry systems are currently used to transmit medical and biological information from a spaceship. Unlike laboratory equipment, the instruments on a spaceship must be very small and light, and operate efficiently and reliably when exposed to overloads and other flight factors. Such apparatus was used for the first time on the November 3, 1957 flight of the sputnik carrying the dog Layka and it recorded several physiological functions of the animal. The experience gained in the flights with animals enabled Soviet scientists to design special radiotelemetry, radiotelephonic, and television devices to provide medical monitoring of the astronauts Yu. A. Gagarin and G. S. Titov on the Vostok and Vostok 2.

Furthermore, the flights of animals resulted in the gathering of experience on interpretation, mathematical processing, and analysis of information received by ground radiotelemetry stations in the form of oscillographic curves.

On Gagarin's flight, the program for telemetry of physiological functions included recording of an electrocardiogram in two leads, a pneumogram, and pulse rate. On Titov's flight, the program was broadened to include recording of a kinetocardiogram, which characterizes myocardial contractility. The physiological methods used on these flights deal mainly with the autonomic body functions.

On the tandem flight of A. G. Nikolayev and P. R. Popovich, the physiological investigations were supplemented by recording of an electroencephalogram, electrooculogram, and cutaneogalvanic reaction, which reflects the state of the central nervous system and vestibular apparatus.

Higher nervous activity and efficiency during various stages of the flight were evaluated from the information obtained during radio conversations, television, objective physical examination, and the astronauts' oral report. Also, radiotelemetric recording of the principal hygienic characteristics was carried out on all four flights: barometric pressure, oxygen and CO_2 content, humidity, and air temperature in the cabin of the spacecraft. During descent, the physiological functions of the astronaut were recorded by an independent system.

Operational medical supervision was effected at ground receiving stations by specially trained medical personnel who at each stage of the flight analyzed the data obtained from radiotelemetry, radio conversations, and television and drew conclusions on the condition and efficiency of the astronauts.

All medical and biological information was subjected to a thorough scientific analysis after the flights.

Interpretation of telemetric curves differs in several respects from the interpretation of oscillograms obtained in laboratory experiments. The difficulties in interpreting the curves arise from all kinds of interference which frequently masks useful information. The recording of physiological parameters in the form of discrete curves likewise greatly complicates the analysis. As a result, it was necessary to work out special methods of interpretation. In-depth scientific analysis of information obtained during flight also included mathematical processing techniques, which serve to produce a maximum of useful information on the physiological state of the organism during flight. This is of great value owing to the uniqueness of these experiments. Accordingly, after they were interpreted, all the data were grouped by flight stages (prelaunching period, the craft's going into orbit, orbital flight, entry into the dense layers of the atmosphere, descent, and landing).

One of the purposes of mathematical processing of the information was to obtain generalized quantitative characteristics of the pertinent physiological indices during different flight stages and to determine the direction of changes in these indices by finding an analytical relationship between their averaged values and the time of the flight as well as the interrelation between the dynamic series of the physiological indices during different stages. The medical and biological information was processed mathematically with the help of semiautomatic calculating machines and electronic computers.

Flight experiment data cannot, of course, be analyzed scientifically without comparing them with the results of the preflight training and laboratory tests of the astronauts. This approach makes it possible to use information theory for predicting the state of physiological functions during space flight.

The volume of information will grow as the flights become longer. This makes it urgently necessary to utilize the achievements of radioelectronics and computer technology to automate maximally the process of interpreting recordings of physiological parameters and entering them into computers for subsequent analysis based on statistical probability methods.

As the flights increase in duration and distance, the scope of physiological investigations will broaden, resulting in an increase in the

total amount of information transmitted by radiotelemetry channels. Even now it is necessary to use computers for automated medical supervision directly on the flights, and they make it possible to transmit the maximum amount of information over telemetry channels of limited capacity. Such systems ought to carry out prolonged and continuous medical monitoring in accordance with a specific program, and generalized physiological and hygienic information right on board the craft, thus permitting the telemetry channels to become unloaded and the medical monitoring system more noiseproof. Solution of the medical problem must take cognizance of the fact that all the values of the physiological and hygienic parameters to be recorded are of three kinds: one reflects the normal values for each individual; the other two characterize the values that are above and below normal.

Owing to the relative simplicity of the logical operations that determine the algorithm for the medical monitoring problem, the latter can be solved by miniature logical circuits of simple design executed on semiconductor elements. There are now available experimental laboratory models of a monitoring device that make it possible to analyze and generalize the information of three physiological parameters--pulse, respiration rate, and body temperature--on the spaceship itself. The device is of value in recording the condition of the astronaut in relation to a combination of input parameters and in accordance with the algorithm controlling its operation.

The introduction of automatic medical monitoring systems functioning on the principle of combining deviations in the parameters to be monitored is making it necessary to devise a scientifically sound coding program and to choose the physiological parameters correctly.

SOME PROBLEMS IN THE PSYCHOLOGY OF FLIGHT ACTIVITIES

B. S. Alyakrinskiy

The task of a modern airplane pilot is very complex, particularly with respect to the perception of the numerous stimuli that serve as signals for various actions on his part. The process of perception is usually considered from the standpoint of organizing the pilot's attention. Experienced instructors have done much in developing a program for focusing and shifting the pilot's attention during different portions of a flight. In essence, the pilot is taught "where and how to look, what to see, what to listen for, how to hold the control stick, what to feel with the hands, legs, and body, and the best position to assume"

(A. F. Katayev). Pilots are taught the art of navigation on the basis of the vast practical experience of their instructors. Yet many problems are still unsolved and numerous accidents are due to shortcomings in the training of young fliers. But this is not the fault of the practical men. The reason is rather the inadequate theoretical foundation of flight activities, specifically the psychology of reading the aviation instruments that are now to be found in virtually every kind of airplane.

Instrument navigation is the most difficult part of flying. The pilot must read many instruments that tell of flight conditions and functioning of the engine (although he has more work than this); he must interpret the readings to form an opinion as to the prevailing situation, make a decision, and then act on it. Performance of all these operations is greatly hampered by the lack of time; a complex flight situation does not permit enough time to receive and digest the instrument information and to make a correct decision. This results in tension and a threat to the flight's conclusion. If the pilot had enough time, he could analyze the situation carefully, having studied his instruments (along with, say, radio information), prepare an optimum plan of action, and carry it out in full control. In reality, however, the pilot does not have these opportunities. Since aviation is becoming increasingly swift, the realistic approach to optimization of flight activities lies in the direction not of increasing the time available to the pilot for flying the airplane, but of accelerating the operations involved through better organization. The pilot's work must be so organized that all his actions are as quick and efficient as possible.

In devising a plan for piloting an airplane based on this principle, let us imagine that it is to be accomplished by some "ideal control device", the nature of which is of no concern to us. Let us view each instrument as an independent channel of information and a single collection of information from any channel as a unit of information, assuming that each glance at the instrument constitutes such a unit. The "idealness" of the control device lies in the fact that it can receive all the information needed, interpret it, develop an appropriate plan of action, and carry out this plan to satisfy the requirements of a changing situation. In other words, the "ideal control device" never suffers from insufficient time, for it can operate at any rate of speed. With such a device we could guarantee the safety and efficiency of flight on any airplane if we were able to prepare for it the best plan of action in any conceivable situation.

Let us imagine the movement of an airplane controlled by our "ideal" pilot at some portion of the flight route marked by a rapidly developing situation. Let the plane travel through this portion in a minute. Let us break down this time into segments of any duration (say 5-second intervals), and take these intervals for units of time and plot them on the abscissa of a rectangular system of coordinates (on the time axis).

Within each unit of time let us determine the modality (category) of the information and the number of units of each modality in accordance with our plan of optimizing the pilot's tasks at given stages of the flight.

In other words, let us answer the questions of how many times and what instruments the pilot is to glance at during each succeeding unit of time (taking into consideration the fact that information is received and processed at the same time). These data are plotted on the ordinate (information axis). If we now join in an unbroken line the apexes of the segments reflecting the number of units of instrument information of different modality, we will obtain a curve characterizing the optimum operating conditions of an "ideal" pilot during a given portion of the flight, although, to be sure, only with respect to the load on its visual analyzer and only as far as the receiving of instrument information is concerned. The resulting curve can be called an "objective informogram" or informogram characterizing the optimum cross section of pilot activity during a given portion of a flight. Such an objective informogram can be calculated by experienced pilots, navigators, and engineers together. We must emphasize once again that an objective informogram reflects only the process of collecting instrument information in such a volume and in such a sequence as to ensure safety and efficiency at a particular stage of a flight. Moreover, this process is not restricted in any way, i.e., it can take place at any speed and with whatever accuracy may be required.

This hypothetical, unrestricted rate of collecting instrument information is simply a method of determining the actual, objectively existing demands made on the "device" that controls an airplane in some specific way (the operation of the optic apparatus of this device in receiving instrument information). In constructing an objective informogram, one must realize that it might be impossible even for the best of pilots to follow it. Nevertheless, the informogram shows what is required of a person who pilots an airplane from instruments in order to optimize his activity. This is true, however, only when we know the actual capabilities of very able pilots. In other words, an objective informogram will be genuinely valuable only when it is supplemented by an informogram that reflects actual human capabilities in receiving and processing information under specific flight conditions on a specific airplane. Since psychologists know the maximum speeds at which instruments can be read intelligently, it should be possible to construct an informogram in accordance with the above-described principle that will be generally accessible to human beings. Such an informogram may be called "subjective". It will be accessible to some abstract pilot who possesses all the positive mental qualities that are known to science and are essential for receiving and processing instrument information. The construction of a subjective informogram can be considerably facilitated by relevant experiments. The use of practical experience is obligatory.

To construct a subjective informogram is to solve one particular problem involved in working out the algorithm of an airplane pilot. The

problem of constructing a subjective informogram has been largely solved in practice, at least as far as the qualitative aspects are concerned. There are available compulsory schemes for apportioning the time of the pilot and directing his attention to the instrument panel. However, the time characteristics of this process are barely indicated. It is the primary purpose of both the objectively prescribed and the subjectively accessible informograms to outline the specific tasks of the pilot with respect to the time they have to be performed.

A comparison of the objective and subjective informograms will make it possible to analyze in detail specific flight conditions (of course, only in the aspect under consideration) and judge the relationship between the demands made on man by flight activities, particularly the functioning of his visual analyzer. In making such a comparison, our attention will be first drawn to those portions of the flight within which the informogram curves will diverge the most. This will enable us to detect the weak points in the pilot's sensory activity and thus properly choose from the requisite number of information units prescribed objectively the number of units that are subjectively accessible to reception on the basis of their relative importance. Subjective and objective informograms will help designers of aviation instruments to create instruments that reflect man's true capabilities.

In devising individual training programs, it is also possible to have a "characteristically individual informogram," which, when compared with the subjective informogram, would enable one to predict the difficulties involved in relearning and, in part, learning the science of aerial navigation. Construction of the aforementioned informograms should lead to the construction of corresponding actograms reflecting the qualitative and quantitative (primarily on the time axis) aspects of the motor activity of a modern airplane pilot. All this work constitutes, on the whole, a practical method of analyzing flight activities in depth, thus greatly facilitating the task of gaining insight into their intimate mechanisms. There is scarcely any need to mention the close connection between the views set forth in this report and the problem of flying capabilities.

Investigation of the psychology of flight activities should be combined with an elucidation and detailed description of the links in the "pilot-airplane" system, links which should rightly be called "vitally necessary" in contrast to the "resultantly necessary" links that are very commonly encountered in the "man-machine" system.

SOME PROBLEMS IN ENSURING THE RADIATION SAFETY OF SPACE FLIGHTS

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Biological experiments on various spacecraft, astrophysical investigations, and, finally, the flights of Soviet and American astronauts have convincingly shown that brief orbital flights below the earth's radiation belts and in the absence of intense solar activity are safe as far as radiation is concerned. The radiation doses received by the astronauts as a result of primary cosmic radiation and radiation of the outer radiation belt were low and noninjurious to the human organism. However, on longer flights involving the crossing of radiation belts and especially if there are chromospheric bursts on the sun, ionizing radiation would definitely be a threat to the health and lives of human beings. With longer flights and orbital flights passing through the radiation belts, cosmic radiation will obviously be the principal obstacle to man's conquering of space.

Protons are the commonest form of penetrating radiation in outer space. About 85 percent of them are in primary cosmic radiation. Large quantities are generated during chromospheric bursts on the sun and they form part of the earth's inner radiation belt. Yet there are no experimental data on the characteristics of the biological effect of protons, their RBE, as compared with X-rays and γ-rays.

From some references in the literature (E. B. Kurlyandskaya et al., A. V. Lebedinskiy et al., and others) and the investigations of members of our laboratory (V. S. Shashkov, B. L. Razgovorov, T. Ye. Burkovskaya, and others) it is reasonable to assume that the RBE of protons with an energy above 100 Mev constitutes a quantity somewhat less than 1 with respect to the LD_{50} for rodents. However, these data were obtained by using a variety of accelerators characterized by very high dose rates and pulse radiation. This should be kept in mind when evaluating the RBE of the protons of primary cosmic radiation, inner radiation belt, and solar bursts.

It is believed that the RBE factor for α particles and nuclei of the heavier high-energy elements ranges from 2-10. However, this assumption is based only on theoretical calculations, since it is still impossible to perform experiments on animals under laboratory conditions owing to the lack of sufficiently powerful accelerators.

Another important problem, in which there are virtually no experimental data available, is the combined effect of radiation and other flight factors (vibration, acceleration, weightlessness, change in

composition of gases, etc.). Yet it is essential to know the specific role played by cosmic radiation in the overall effect of the various flight factors on the human organism and the influence of the nonradiation flight factors on the qualitative and quantitative aspects of the biological effect of radiation. Without this information it is impossible to formulate scientific recommendations on the pharmacotherapy and prevention of radiation injuries.

Our research (B. I. Davydov, V. G. Vysotskiy, T. S. L'vova, N. I. Suprunenko, and others) indicates that acceleration and vibration will variously affect the development of radiation lesions depending on when and in what order these factors are applied. For example, 5-6 days after being irradiated, animals tolerate the effects of vibration and acceleration more poorly than do nonirradiated animals. In addition, these two factors aggravate the course of radiation sickness. On the other hand, if vibration or acceleration is used prior to irradiation, they not only do not aggravate the radiation effect, they even tend to weaken it.

The absence of suitable experimental data on the RBE and combined effect of flight factors plus radiation makes it impossible to make scientifically sound recommendations on maximally permissible radiation levels for astronauts.

Our recommended maximally permissible dose of cosmic radiation of 25 ber per flight is based on theoretical calculations and the known experimental and clinical facts on the injurious effect of ionizing radiation under terrestrial conditions. Such unconditional extrapolation of the data to cosmic radiation is inadmissible. Therefore, the recommended maximally permissible dose of 25 ber is to be regarded as provisional. The dose will be changed in either direction as more experimental data become available on the biological effect of the individual components of cosmic radiation and on the effectiveness of protective measures.

It is obvious that the ideal protection is physical, mechanical protection, i.e., shielding of the cabins of the spacecraft with a thick layer of lead or other material. However, calculations have shown that this is impossible, at least for the present.

Chemical substances which are now available increase resistance to radiation, but most of them for one reason or another cannot be used under the conditions of space flight, as we shall show in more detail in another report. The search for effective pharmacochemical and biological means of providing protection against cosmic radiation is essential to ensure the safety of space flights. Many biological objects--higher and lower plants, microorganisms, and other representatives of the animal and plant worlds--will accompany the astronauts in long flights

and provide food and oxygen, utilize carbon dioxide and other harmful impurities.

The question naturally arises whether certain doses of cosmic radiation can induce hereditary changes in these plants and animals that might severely disrupt the balance existing in the closed ecological system of a spaceship. From the scientific point of view, this possibility cannot be ruled out. That is why it is essential for us to know the effect of cosmic radiation and other flight factors and, if such disruption can occur, find ways and means of preventing the radiation from harming the crew and the various biological objects on board.

A solution of the problems outlined above will make it possible to devise scientifically sound measures to ensure the radiation safety of space flights. The main elements in such a system are:

(a) Reliable monitoring of the radiation level in the cabin of the spacecraft by individual and biological dosimeters mounted in the cabin.

(b) Scientifically sound forecasting of the radiation situation in space, especially chromospheric bursts on the sun.

(c) Effective antiradiation pharmacochemicals and biologicals.

There are of course, many unresolved problems, since space radiobiology is still in its infancy. However, there is reason to hope that radiation safety of space flights will be achieved through the combined efforts of specialists in different fields.

EFFECT OF DIFFERENT PARTIAL PRESSURE OF OXYGEN AND ENVIRONMENTAL TEMPERATURE ON REGULATION OF TEMPERATURE RELATIONS IN THE ORGANISM

I. I. Antonov

A major problem in the study of bodily functions under the conditions of an altered gas medium is the effect of different partial pressures of oxygen and environmental temperature. A number of important theoretical questions are still unanswered. Although of little practical significance, perhaps, they nevertheless are highly interesting from the broad general biological point of view. These include change in heat exchange in various organs and tissues and the mechanisms by which hypo- and hyperoxemia influence the thermoregulatory function of the central

nervous system (CNS). A problem of considerable practical as well as theoretical significance is the extent to which environmental temperature affects the balancing of heat exchange between the environment and organism exposed to different partial pressures of oxygen. These two matters are discussed in the present report.

The investigators of heat exchange fall into two main groups. One group considers the principal reason why the experimental animals died is that their bodies were chilled at low temperatures and that their nervous systems (Kartshevskiy, 1908; Veselkin, 1948; Antonov, 1954; others) and metabolic processes (Smith, 1898; Hill and McCloud, 1903; Shick, 1948; others) became exhausted. The second group maintains the opposite opinion (Gellhorn, 1937; Campbell, 1938; Hirsch and Wagner, 1945; Gubler, 1952; others).

Our data, obtained from two series of experiments (total of 200) on animals, showed that the temperature change in some viscera and peripheral tissues at an environmental temperature of 20° C and partial pressure of O_2 are far from being the same. The change in brain temperature is particularly noteworthy. In hypoxemia there was invariably a complete distortion of the normal temperature relations between the surface and deep layers of the brain after a general lowering of brain temperature. With the development of oxygen deficiency, the ordinary temperature difference between the surface and deep layers leveled out or became temporarily reversed. We observed a similar distortion of brain temperature relations following the toxic action of high pressures of O_2, especially in hyperoxemic convulsions.

In analyzing the data obtained from brain thermometry, we expected to find an elevation in the deep layer as a result of excitation of the motor and autonomic elements of the nervous system during convulsions. However, the sharp drop in the subcortical region and rise in the cortical led us to assume on the basis of Gramenitskiy's data (1950) (the temperature of the deep layers is higher than that of the inflowing blood and, conversely, the temperature of the surface layers is lower than that of the inflowing blood, resulting in the emission of heat by the brain) that in both hypo- and hyperoxemia heat is emitted in these regions chiefly through the blood. We also took into account the fact that hypoxemia is accompanied by reflex dilatation of the cerebral blood vessels and intensification of the blood flow (Marshak, 1940). Consequently, the blood gives off its heat to the surface layer and obtains it from the deep layer. Our assumption was confirmed by experiments with constriction of the common carotid arteries.

The mechanism of action of high pressure of oxygen is somewhat different. The investigations of Benke, Forbes, and Motly (1936), Sorokin (1949), and Lambertson (1953) showed that at first there is

constriction of the cerebral blood vessels and a slowing of the blood flow and that it is only after oxygen poisoning that the vessels become dilated. This phenomenon was clarified by the research of M. P. Brestkin and his school who showed that O_2 under pressure blocks the enzyme systems, i.e., neuroreflex regulation is impaired just as in hypoxemia.

This similarity in mechanism of action of two such inherently different external influences as hypo- and hyperoxemia made it possible to study simultaneously the impairment of temperature relations in the organism and to determine the common elements in their mechanism of action on thermoregulation.

The study of other temperature data revealed a substantial and regular drop in rectal temperature starting at the moment of exposure and progressing during the convulsions. It is caused by a lowering of the level of metabolic processes in the organism and closely reflects the true temperature of the blood under these conditions.

Considering the significant fluctuations in temperature of the skin, subcutaneous tissues, and muscles after a general drop and the fact that the organism regulates its heat balance with the environment chiefly through the skin, it would seem that such fluctuations are caused by a reflex adaptation response to these external stimuli. The fluctuations in temperature of the muscles are of unusual interest. It rose during the first convulsions probably as a result of increased heat production in the "working" muscles but remained unchanged during the later convulsions owing to constriction of the peripheral blood vessels and a slowing of the blood flow. However, the temperature of the liver and kidneys was less variable either because of the considerable heat production of these organs or because of the constancy of their blood supply.

The combination of different partial pressures of O_2 and low (-10°) and high (40°) temperatures clearly has an unfavorable effect both on the general condition of animals and on distortion of the temperature relations, leading in the first instance to pronounced hypothermia and premature death and, in the second, to hyperthermia and death. Of interest is the fact, observed on varying the external temperature, that a temperature of 30° favorably affects both the general condition and the maintenance of temperature relations on the correct level. Temperature fluctuations in the organs investigated were slight and many functions of the organism were not markedly depressed.

Thus, on the basis of Ye. A. Kartashevskiy's calorimetry investigations (1908) and our own findings, it is fair to say that general hypothermia and impaired normal temperature relations between the organs and

tissues in hypo- and hyperoxemia result chiefly from impairment of the thermoregulatory function of CNS, which affects not only the metabolic processes in the individual organs as well as in the organism as a whole, but also the blood supply.

The importance of the CNS in impairment of thermodynamics was confirmed by our second series of experiments on decorticated and decerebrated animals exposed to oxygen deficiency and poisoning. This problem, unfortunately, has not been properly elucidated in medical and biological journals, except for some isolated data on impairment of the thermoregulatory function of the CNS in hypoxemia (Arkhangel'skaya, 1949; Avtonomov and Krelin, 1955). Our observations showed that the drop in rectal temperature in decerebrated and decorticated rabbits was gradual and slight as compared with the rapid and sharp drop in intact animals. The experimental data indicate that extirpation seems to disrupt the adaptation functions of the organism.

Progressive hypothermia caused by the different partial pressures of O_2 seems to us to be an active process related to signals reaching the cerebral cortex along the nervous pathways from the chemo- and pressoreceptors through the hypothalamic region. However, this active drop in temperature under the influence of oxygen deficiency and poisoning is lost or, at any rate, is sharply limited by removal of the superincumbent centers.

It follows from the experimental data that removal of the cerebral cortex causes a loss of adaptation changes in metabolism and a loss of influences on sensitivity to insufficient or excess O_2, which in turn results in increased tolerance of hypoxemia and hyperoxemia. This agrees with the data obtained some time ago by V. V. Strel'tsov and A. G. Zhironkin.

Progressive hypothermia in hypoxemia and hyperoxemia can be understood only in the light of I. P. Pavlov's theory of a constant interaction between the cerebral cortex and tissue processes in the viscera. Presumably the heavy flow of impulses from the interoceptors to the cerebral cortex in hypoxemia and hyperoxemia, in response to which the sensitivity of the cortex changes and some secondary reactions to control oxygen deficiency and poisoning appear, has a different significance in an operated animal. Two kinds of phenomena may be significant here: (1) the portion of the CNS most sensitive to a change in the partial pressure of oxygen (cortex) is missing; and (2) there is complete disintegration of functions, resulting in each tissue system adapting independently of one another to the insufficiency or excess of oxygen.

The following conclusions can be drawn from the data presented above:

(a) A change in the partial pressure of O_2 in the atmosphere significantly influences the thermoregulatory function of the body. Progressive hypothermia arises and impairs the normal temperature relations between the various organs and tissues.

(b) The environmental temperature is an important factor in maintaining thermoregulation at a suitable level in hypoxemia and hyperoxemia.

(c) The external temperature has a favorable effect both on thermoregulation and on a number of other functions by increasing resistance to the different partial pressure of O_2.

(d) Adaptation of the animal organism in general and thermoregulation in particular to the different partial pressure of O_2 is effected by the highest division of the CNS--the cerebral cortex.

(e) The mechanisms responsible for the development and course of temperature impairment in organisms experiencing an insufficiency or the toxic effects of oxygen are alike.

MEDICAL SERVICE FOR THE CIVIL AIR FLEET OF THE USSR

A. S. Asribekov

The organization of health services and the clinic system for flight personnel of the civil air fleet (CAF) dates back to 1930. The growing network of medical installations in various CAF subdivisions revealed the need to organize and direct such installations on air transport. This was done in 1938. The various subdivisions are now served by air health departments and medical services of the larger branches, medical units of flight sections, health stations, dispensaries, polyclinics, hospitals, preventive clinics, medical examination commissions, and department of aviation medicine.

The commercial activity of the CAF and its prospects shape and specialize the network of medical installations operated by the CAF. They have led to the organization of aviation medicine laboratories and, in 1956, of pressure laboratories, centers for functional diagnosis, etc.

The development of aviation technology and introduction of multiplace turbojet and turboprop passenger planes (TU-104, TU-114, TU-135, IL-18, AN-10, AN-24, etc.) and a series of helicopters (MI-1, MI-4, MI-6,

K-15, K-18, V-2, etc.) have made it necessary to solve problems concerning working conditions and the effects of some flight factors to ensure the comfort of passengers and crew.

The extensive work done to create the conditions whereby people of different ages and states of health could fly in comfort enabled the CAF to inaugurate large-scale passenger jet flights, this was the first airline in the world to do so. The experience has been that most passengers, regardless of age or state of health, feel well on these flights.

An important safeguard is the proper training of the crew. The medical service wants flight personnel to function normally, have rest, good food, and adequate sleep before flying.

In view of the great practical difficulties in determining whether a pilot is functioning normally just before a departure and is capable of doing his work efficiently, we must steadily increase the quality of medical examinations by expert commissions, doctors in flight units, airport health stations, and preventive clinics.

Large-scale passenger travel, which has brought about numerous arrivals and departures of planes in most airports and the presence of many planes in the air on scheduled flights, requires an efficient medical service if the CAF is to succeed. This has made it necessary to provide specialized training for CAF doctors at a department of aviation medicine. However, the successful performance of CAF's tasks--the introduction of high-speed multiplace turbojets and turboprops flying at high altitudes over the USSR and between continents, the wide use of airplanes to spray poisons for agricultural purposes, and the need to protect flight and ground personnel while doing so--all these are confronting the medical service with problems and subjects for research:

(a) Preparation of physiological-hygienic standards and requirements for new kinds of air-passenger procedures.

(b) Physiological-hygienic evaluation of passenger planes while they are being tested.

(c) Devising of hygienic and preventive measures to ensure the safety of all CAF planes in any climatic zones regardless of weather conditions.

(d) Analysis of the causes of, and predisposing factors in, air accidents and development of preventive measures.

(e) Clinical-physiological study of flying and engineering personnel under various conditions in order to set up physiologically sound standards to govern working conditions, rest, and eating for efficient and sustained performance of their duties.

(f) Working conditions of personnel engaged in using agricultural poisons in order to devise hygienic measures to improve the conditions and prevent poisoning.

(g) Problems in the theory and practice of medical examination of students and flight personnel with a view to prolonging the period of flying efficiency and protecting their health.

(h) Problems concerned with flight hygiene and airport service to ensure flight safety.

(i) Air travel of passengers of different ages and states of health to work out prophylactic measures.

(j) Devising of methods of saving crewmen and passengers under different flight conditions.

(k) Preparation of a methods manual for aviation medicine laboratories of the CAF.

(l) Coordination of research in the field of civil aviation medicine in the USSR and in the democratic countries.

(m) Working up of hygienic requirements and standards for projected airports, repair shops, and training installations of the CAF.

(n) Problems whose solution is required by the operations of various CAF units.

The CAF recently celebrated its 40th anniversary: The plans for its expansion in the next few years are well known. The medical service of the CAF will have to grow accordingly. Improvement of the service is keeping pace with the progress of aviation technology.

LABOR HYGIENE IN THE SPRAYING OF CHEMICALS FROM CIVILIAN AIRPLANES

T. A. Asribekova

1. The spraying of chemicals from airplanes to control agricultural pests and diseases is becoming increasingly important. The civil air fleet has been doing this since 1925, when it was first utilized to control locusts. In 1928 I. R. Fomenko and in 1929 V. I. Brumshteyn and O. G. Dukel'skaya were the first to study the working conditions prevailing on such projects. Their reports laid the foundation for research on

labor hygiene in connection with the use of insectofungicides from airplanes. M. V. Zakharova and S. I. Slonevskiy (1937) described the aerial dusting of bodies of water with arsenic salts to combat malaria. The authors presented data on the amount of arsenic present in the air of the working areas, on clothing, and on skin of the hands. They recommended appropriate prophylactic measures.

2. During the first few years after World War II, investigations in this field continued. At this time reports were published by aviation physicians P. G. Levsh (1948), N. V. Natanzon (1948), and A. S. Asribekov (1948, 1949), who analyzed the working conditions of special-purpose airplanes and described changes in the health of the pilots and technicians.

3. In 1949, following generalization of the research on labor hygiene, A. I. Belousov, Ya. F. Samter, and M. S. Shtromberg prepared instructions for practicing physicians concerned with the use of chemicals from airplanes.

4. The use of new insecticides like DDT and Lindane made it necessary to study the working conditions of fliers and technicians, devices for individual protection from the poison, and means of preventing poisoning by these chemicals (A. I. Belousov, 1952, 1953).

5. On the basis of their research on the working conditions of pilots and technicians, D. S. Kuleshov, I. M. Geller, A. V. Chapek, A. I. Belousov, A. V. Kaminskaya, and R. S. Slavenchinskaya (1952) made recommendations on organization of their work, rest, and living conditions and prepared instructions for medical supervision of such persons.

6. After the development of highly toxic organophosphorus insecticides (thiophos, mercaptophos, methylmercaptophos, etc.) and herbicides of the 2,4-D group (butyl ester and amine salt) and the need to apply them from airplanes, extensive research was undertaken on the hygienic, toxicological, and physiological aspects of these compounds and the necessary prophylactic measures formulated (Yu. S. Kagan, 1957-1958; Yu. I. Kundiyev, 1957-1958; T. A. Asribekova, 1957-1958; V. A. Kryuchkova, 1957-1958; T. S. Asribekova, 1959; I. T. Brakhnova, 1959; N. K. Statsek, 1961; T. A. Asribekova, 1962; A. G. Vinel', 1962; P. V. Izbavitelev, 1962; Kh. Z. Lyubetskiy, B. E. Gurevich, et al. (1962); A. Yakubov, 1962; T. A. Asribekova, 1963).

7. The investigations of T. A. Asribekova showed that the use of organophosphorus insecticides from airplanes produces changes in the nervous system, predominantly in the parasympathetic division of the autonomic nervous system, a decrease in cardiovascular tone, and changes in the peripheral blood, mainly enzymic in nature, and in some morphological and physicochemical properties. As a result of these investigations, prophylactic and therapeutic measures were proposed, the technical

requirements and experimental models of a respirator were developed, and proposals were made for design changes in the sprayer of the AN-2 and YaK-12 airplanes and in the ventilation system of the V-2 helicopter.

8. The working conditions of those handling pest control chemicals (ground and aerial methods) were also studied by I. T. Brakhnova, G. A. Voytenko, O. N. Kurkatskaya Yu. S. Kagan, V. I. Osetrov, Ye. I. Spynu, N. K. Statsek, and others (the compounds investigated included metaphos, polychlorpinene, hexachlorcyclohexane, mercaptophos, heptachlor, thiophos, and methylmercaptophos).

9. Despite the increased amount of research on the hygiene and toxicology of the insectofungicides applied aerially, much more is needed to satisfy practical needs. In 1962, some 30 insecticides were used this way, but the number rose to 60 in 1963. The total amount of chemicals has also been increasing. Whereas collective and state farms received about 50,000 tons of the chemicals in 1950, they received 596,000 tons in 1962. In view of the effectiveness of the aerial method and possibility of treating large areas in a short period of time, it is expected that the technique will gain in popularity with every passing year.

10. Concentrations of the highly toxic organophosphorus compounds exceed permissible limits in the cockpit of the AN-2 and YaK-12 airplanes and MI-1 and KA-15 helicopters. The pilot is forced to use a respirator, which hampers him in performing operations requiring considerable attention and effort.

11. The bright prospects for aerial spraying and for the continued synthesis of new toxic insecticides require better devices for supplying the cockpit with purified air through special filters plus mechanization and hermetic sealing of the processes involved in opening and sealing the packages containing the chemicals, and in preparing and priming working solutions in airplanes and helicopters, in order to create safe working conditions for the flight and ground personnel.

PHARMACOLOGICAL PROPHYLAXIS AND THERAPY OF AIRSICKNESS

Z. A. Astakhova, Ye. P. Belogortseva, M. D. Kruglik and P. I. Syabro

Studies were made on passengers flying from Dnepropetrovsk to Kharkov, Zaporozh'ye, Rostov, Mineral'nyye Vody, Krivoy Rog, Aller,

Kiev, Moscow, etc. and on through passengers. Drugs were prescribed both to prevent and to treat airsickness. Combinations of preparations proposed by the Pharmacology Department, Dnepropetrovsk Institute, were used:

(a) "Platybrin", consisting of a double tartrate of platyphylline - 5 mg, caffeine with sodium benzoate and sodium bromide - 15 g each.

(b) "Platybrin" No. 2, in which the caffeine and sodium benzoate was replaced with 0.1 g of pure caffeine, and sodium bromide was replaced with potassium bromide in the same dosage of 0.15 g each.

(c) The mixture "PPKB", in which 0.3 g of papaverine hydrochloride was added to the ingredients of "Platybrin" No. 2.

(d) "FPPKB", in which 5 mg of amphetamine was added to the mixture "PPKB".

(e) The mixture "Platkof", consisting of 5 mg of platyphylline bitartrate and 150 mg of caffeine and sodium benzoate. This drug was given to persons known to be allergic to bromides.

All the drugs were prescribed in prophylactically tablet form, 30-45 minutes before departure, both on an empty stomach and after eating. They were prescribed for therapeutic purposes in the airport health unit after symptoms of airsickness developed. The observations were begun in 1960.

Three hundred and six persons known to have suffered previously from airsickness were under observation. In 144 cases the drugs were prescribed for the same passengers both for prophylactic and for therapeutic purposes. The age composition and sex of the individuals are shown in Table 1.

Table 1. Age Characteristics of the Persons Under Observation

Sex	Purpose of drugs	Age						Total
		Up to 10 years	11-20 years	21-30 years	31-40 years	41-50 years	51-60 years	
Males	Prophylactic	2	2	29	37	18	6	94
	Therapeutic	1	3	27	29	14	3	77
Females	Prophylactic	3	5	47	58	19	4	146
	Therapeutic	2	4	47	53	19	8	133

We used the following as criteria of effectiveness of the drugs: the individual's impression of his own condition and manifestation of autonomic disorders--nystagmus, nausea, and vomiting. Sometimes the pulse, blood pressure, and number of respirations were measured. When passengers did not return to the airport, evaluations were made from records of the flight stewards and letters from the persons themselves.

FPPKB, which includes amphetamine, was not prescribed for elderly persons or for those with symptoms of hypertension. Results of the observations in which the drugs were prescribed to prevent airsickness are summarized in Table 2.

Table 2. Effectiveness of Prophylactic Administration of the Drugs

No.	Drug	No. of persons		No. of observations	Effectiveness in %				Side effects
		Males	Females		Excellent	Good	Satisfactory	Lacking	
1	Platybrin	35	45	150	25	45	23	7	None observed
2	Platybrin No. 2	22	28	50	26	47	20	7	The same
3	PPKB	12	38	50	30	51	14	5	"
4	FPPKB	13	17	30	30	57	10	3	"
5	Platkof	12	18	30	22	38	25	15	"

It is evident from Table 2 that the prophylactic use of "Platybrin" and "Platybrin 2" had an excellent or good effect in 70-73 percent of the persons observed. These figures almost coincide with those for "Platybrin" (Syabro's mixture) prescribed to prevent seasickness (R. A. Okunev, Klinicheskaya meditsina (Clinical Medicine), 1958, No. 9, p. 72).

If the bromide was left out of "Platybrin", it was less effective. For example, "Platkof" had a protective effect in 85 percent of the cases, an excellent or good effect in only 60 percent.

The combined drugs PPKB and FPPKB were more effective in preventing airsickness. PPKB and FPPKB had an excellent or good effect in 81 or 87 percent of the cases, respectively. It is also worth noting that these combined drugs had no side effects.

When drugs were ineffective, it was apparently because they were taken late or after eating. Additional observations will be necessary to supplement the small number of cases studied.

The next series of observations concerned the effectiveness of the drugs in the treatment of those passengers already suffering from airsickness. The data are summarized in Table 3.

Table 3. Therapeutic Effectiveness of the Drugs

No.	Drug	No. of persons		No. of observations	Effectiveness in %				Side effects
		Males	Females		Excellent	Good	Satisfactory	Lacking	
1	Platybrin	39	54	93	18	42	36	4	None observed
2	Platybrin No. 2	18	33	51	20	43	34	3	The same
3	PPKB	9	22	31	23	57	19	1	"
4	FPPKB	11	24	35	28	57	19	-	"

The effectiveness of the drugs was evaluated 1-1/2 hours after administration. The effect was considered (1) excellent when all the symptoms of airsickness disappeared and the passenger again felt cheerful, with normal pulse and respiration, (2) good when all the symptoms

disappeared and the pulse and respiration were within normal limits, but a sensation of slight fatigue persisted, (3) satisfactory when autonomic phenomena completely disappeared but a sensation of fatigue or sluggishness remained, and (4) negative when the passenger was suffering from some other disease (cardiovascular insufficiency, gastrointestinal disease).

Conclusions

1. The drugs can be arranged in ascending order of effectiveness in preventing and treating airsickness as follows: platybrin and platybrin 2, PPKB (platyphyllin-papaverine-caffeine and sodium bromide), and FPPKB (amphetamine-platyphyllin-papaverine-caffeine and sodium bromide).

2. The combined drugs--platybrin and the mixtures PPKB and FPPKB--are recommended for prevention and treatment of airsickness.

THE DOG SPLEEN RESPONSE TO LATERAL ACCELERATION

Yu. I. Afanas'yev

Numerous experimental investigations of animals in vibration testing units and centrifuges and of animals on spacecraft showed that the blood system reacts quickly to acceleration (A. M. Galkin and co-authors, 1958; B. G. Bugrov and co-authors, 1958; I. I. Kas'yan and co-authors, 1962; others). The changes noted are not merely the result of redistribution of blood, they also reflect impairment of hematopoiesis (M. A. Arsen'yeva and co-authors, 1962; N. A. Yurina and N. I. Suprunenko, 1963; others). The most drastic changes in the organs are caused mainly by mechanical factors. The investigations directed by Prof. V. G. Yeliseyev showed (V. G. Yeliseyev, Ye. F. Kotovskiy, and Yu. N. Kopayev, 1963) that the extent of injury is related to the size of the organ and amount of blood flowing in it (liver, lungs, etc.).

According to Gerrat (1957), the dog spleen is an organ whose main function is the deposition of blood. It is fair to assume, therefore, that the accumulation of a large amount of blood in the spleen during acceleration may bring about changes similar to those in other organs. However, in view of the spleen's capacity for rapid and powerful contraction, we can make no a priori claims about the nature of these changes, especially since the organ has hematopoietic, metabolic, and other functions besides deposition of blood. For this reason we undertook

to investigate reactive changes in the spleen of dogs subjected to accelerations.

Method

Experiments were performed on 28 stock-bred dogs. All the animals were subjected to single lateral (chest-back) accelerations of different intensity and duration. There were two series of experiments. In the first, the action lasted 3 minutes with an acceleration of 8 g. In the second series, the animals experienced an acceleration of 12 g for 1 minute. Each series included 14 animals, all of which were immunized against plague 2 weeks before the experiment.

The animals were killed with ether fumes at different times during the experiment--1 hour, 1, 3, 7, 15, 30, and 60 days after the overload. A razor was used to excise fragments from the ventral and dorsal ends of the spleen. These were fixed in Zenker's formalin and Carnoy's fluid. The material was embedded in paraffin and celloidin. Sections were stained with azure-II-eosin, methyl green pyronin by Brachet's method, for connective tissue by Mallory's method, and for ionic iron by Tirmann's method.

Results

Owing to the varied functions and complex structure of the spleen, the results of the experiments were evaluated from the condition of three constituents of this organ: (1) sustentacular-contractile apparatus (capsule and trabeculae), (2) vascular bed, (3) lymphoid tissue.

Analysis of the experimental material showed that the changes in the spleen following accelerations of 8 g for 3 minutes and of 12 g for 1 minute were more or less the same, but the duration of the action seems to be the determining factor. All the changes in the histological structure of the spleen were usually more pronounced and persistent in the first series of experiments than in the second.

Gross inspection of the spleen soon after the animals were sacrificed (30-40 minutes later, when the abdominal cavity was dissected) revealed that the capsule had contracted. Here and there (where the large trabeculae branched out) the capsule was retracted like a funnel, another indication that the smooth-muscle cells of the trabeculae had contracted.

Microscopic examination revealed that the smooth-muscle cells of the capsule and trabeculae were contracted in wavelike fashion so that the trabeculae were alternately enlarged and contracted throughout.

Besides contracted muscle elements, there were degenerative changes in individual smooth-muscle cells, especially in the animals used in the second series of experiments. The protoplasm of these cells was vacuolated, their nuclei wrinkled and crowded to the periphery. These processes were most marked after 3 days.

The red pulp on the first day after the overload was hyperemic in all the dogs. Blood filled all the sinuses and diffusely permeated the reticular stroma of the organ, making it almost impossible at times to discern the boundary of the vascular bed.

The endothelium of the blood vessels (trabecular, central arterial) after 3 and 7 days revealed vacuoles in the cytoplasm, pycnotic nuclei with sloughing off of the endothelial layer, and some ruptured blood vessels. These changes were particularly marked in the animals used in the second series of experiments. Thrombi appear later in the blood vessels, generally in the trabecular veins. Destroyed smooth-muscular cells were noted in the arteries.

Changes in the ionic iron content of the pulp were unstable throughout the experiment, but the first day (after 1 and 24 hours) the amount of hemosiderin was usually higher. The pigment was found both in macrophages and reticular cells and between the cells, generally around the lymph nodes and trabeculae. It is very difficult, however, to speak more definitely about the dynamics of the iron-containing pigment in the spleen because the animals were of different ages.

The lymph nodes of the animals in the first series shrank and released small lymphocytes an hour after the experiment started. The emptying of the nodes was a persistent phenomenon and even after 30 days they contained very few small lymphocytes. Mitotic figures were very rarely seen in the lymphoblasts.

In the second series of experiments, the lymph nodes scarcely changed. In the red pulp, however, the number of lymphocytes increased during the first and second weeks.

By the end of the first month after the start of the experiment, the lymph nodes, mainly in the animals of the first series, contained "hyperchromic cells" (M. A. Arsen'yeva and co-authors, 1962), which stained intensely with azure-II.

After 2 months the microscopic structure of the spleen returned to normal.

Discussion

The results of the experiments show that lateral accelerations in a chest-back direction differing in intensity and duration cause definite changes in the histological structure of the spleen. However, in analyzing the data it is important to differentiate between the effect of the experimental accelerations and that of the ether fumes when the animals were sacrificed.

The spleen, known as a blood depot, ejects it into the peripheral blood channel under the conditions of intense gas exchange or, contrariwise, when insufficient oxygen enters the organism. Consequently, when the animals were killed with ether and conditions of an oxygen deficiency were created, it was to be expected that the erythrocytes present in the red pulp would be ejected into the peripheral blood channel. This compensatory reaction to the oxygen deficiency explains, in our opinion, the fact that the smooth-muscle cells of the trabeculae and capsule were contracted in more or less wavelike fashion regardless of the time the animals were sacrificed. Yet there were also degenerative changes in the smooth-muscle cells of the trabeculae, especially in the second series of experiments. These were apparently due to the accelerations.

Impairment of the structure of the endothelium in the early part of the experiment (3rd and 7th days) and subsequent thrombogenesis were undoubtedly caused by the accelerations. Otherwise, similar changes would have been found at other times in the course of the experiment.

Conclusions

1. Accelerations (8 g - 3 minutes, 12 g - 1 minute) produce degenerative changes in the endothelium of the blood vessels of dogs, smooth-muscle cells of the trabeculae and capsule of the spleen, rupture vascular walls, and cause thrombogenesis therein.

2. Lymph nodes are emptied the first day after acceleration and proliferation of lymphoblasts is inhibited. Mitotic activity is restored slowly in lymphoid tissue.

3. Accelerations (as in the first series of experiments) exert a more potent influence on lymphopoietic tissue, whereas brief but more intense accelerations (as in the second series) result mostly in degenerative changes in the smooth-muscle cells of the capsule, trabeculae, and wall of the blood vessels.

4. The histological structure of the spleen returns to normal 2 months after exposure to accelerations.

MODERN AVIATION AND PROBLEMS IN ENSURING THE MEDICAL SAFETY OF FLIGHTS

A. N. Babiychuk

(The text of the report is not available)

THE EFFICIENCY OF MAN EXPOSED TO RADIAL ACCELERATION AND BREATHING OF OXYGEN AT AN EXCESS PRESSURE

V. I. Babushkin and V. V. Usachev

Depressurization at altitudes above 12,000 m and resultant lowering of barometric pressure in the cabin of an airplane automatically switch the oxygen apparatus to supplying oxygen for breathing at an excess pressure and actuate the altitude-compensating suit. Under such conditions flying may be associated with the appearance of accelerations so that the pilot will experience the total effect of the aforementioned factors, the physiological influence of which has not been elucidated in the literature to which we had access. In this connection we undertook to study the effect of radial acceleration on the human organism breathing oxygen under pressure.

The investigations were conducted both in a centrifuge and under flight conditions. In the former, the rate of cardiac contractions and respiration were recorded and a study was made of various movements simulating some of the pilot's work in controlling his plane and his actions in an emergency situation. On actual flights, recordings were made of the rate of cardiac contractions and respiration, altitude and speed, and intensity of acceleration.

We found that an altitude-compensating suit (ACS) increases tolerance of accelerations by 0.5-1 g. At the same time the increase in the cardiac rate was less than after accelerations of the same intensity but without the use of an ACS. A study of pilot movements showed that an ACS without pressure in its tension system has no appreciable effect on the coordination of movements. With acceleration and breathing of oxygen, the cardiac rate increased by 26-60 beats per minute over the initial values. Switching to breathing of oxygen under pressure (350 mm H_2O) reduced the cardiac rate by 16-42 beats per minute. Use of a G-suit under these conditions caused an even smaller increase in this index--8-30 beats per minute.

With breathing at this pressure but without acceleration, exhalation lasted 2.2-4 seconds, inhalation--1.2-1.9 seconds. During an acceleration of 4 g, exhalation varied in duration from 1.6-3.2 seconds inhalation--1-1.8 seconds, i.e., approximately equal to the original indices.

Analysis of the data obtained after an acceleration of 4 g and breathing of oxygen at a pressure ranging from 400 to 1000 mm H_2O with the use of back pressure (ACS) revealed that the physiological effect resulting from the use of a functioning ACS with acceleration scarcely differed from the above-noted phenomenon of smaller functional changes when a G-suit was worn. For example, the increase in cardiac rate during an acceleration of 4 g with breathing at a pressure of 400 mm H_2O and wearing of an ACS ranged from 10-32 beats per minute.

Under the same conditions, but with wearing of a G-suit, the increase in cardiac rate was 8-30 beats per minute. It is interesting to note that the compensating effect of the ACS during accelerations increased as pressure rose in its tension system. The oral reports of the subjects indicate that during accelerations, even at high excess pressures (800-1000 mm H_2O), it became easier to breathe than when there was no acceleration. The use of a G-suit helped breathing even more by facilitation of exhalation.

The results of our investigations of movements under the conditions of acceleration and breathing at an excess pressure with the use of an ACS showed that the subjects experienced considerable difficulty in doing their routine work, as manifested in the longer time required for performance of the individual components of a motor act. These changes in movements were reflected in various ways in our investigation of movements of the control stick and foot levers involved in controlling an airplane. Interpretation of the coordinograms revealed that when the ACS was functioning, the performance of tasks was approximately 1-1/2 times less precise. With exposure to an acceleration of 4 g, movement coordination changed even more. However, movements by the "eye sector" scarcely changed.

The results of our centrifuge investigations of the efficiency of human beings exposed to accelerations and breathing of oxygen at an excess pressure were paralleled by those obtained under flight conditions. In discussing the data, we must begin by stressing the fact that in breathing oxygen under pressure, with the wearing of a G-suit and exposure to prolonged accelerations, there are less pronounced changes in respiratory and cardiovascular function than when oxygen is breathed under normal pressure. A comparison of these findings with flight reports indicating that breathing under these flight conditions is easier suggests that prolonged acceleration activates additional compensatory

mechanisms that facilitate breathing, exhalation in particular. Besides fewer changes in respiratory function, the increase in number of cardiac contractions is less pronounced. It seems to us that the increase in tone of the skeletal musculature, specifically, the respiratory muscles and the muscles used in the prelum abdominale, is the principal mechanism underlying the relatively small changes in the cardiovascular and respiratory systems.

This adaptation reaction is quite similar to the special "M-1" technique (Lambert, Wood, et al., 1945-1946; Landis, 1948; others) whereby intraabdominal pressure is considerably increased, resulting eventually in less marked functional changes and strengthening the tolerance of accelerations. A summary effect, so to speak, takes place when a G-suit is worn, causing intraabdominal pressure to increase even more. This, in turn, leads both to easier exhalation and to decreased stasis in the abdominal blood vessels. In time the G-suit also performs, in part, the role of an ACS. This idea agrees with references in the literature (N. O. Tsybul'skiy, 1879; Garso, 1919; Youngblade and Noyes, 1933; others) to the fact that there are fewer changes in cardiac activity in case back pressure is used with acceleration.

Thus, our investigations throw some light on the efficiency of fliers exposed to acceleration while breathing oxygen under pressure and help to elucidate the mechanisms of compensation of physiological functions under these conditions.

PHYSIOLOGICAL REACTIONS TO RADIAL ACCELERATION

V. I. Babushkin, P. K. Isakov, V. B. Malkin
V. V. Usachev

The physiological bases for the ideas on the effect of accelerations on the human organism were established in the works of K. E. Tsiolkovskiy (1878), N. O. Tsybul'skiy (1878), V. V. Pashutin (1881), V. I. Voyachek (1908), A. P. Popov (1936), D. Ye. Rozenblyum (1939), V. V. Strel'tsov (1945), and others. The most noted foreign investigators of the physiology of accelerations include Armstrong (1935), Diringshofen (1936), Gauer (1938), Malmejaques (1945), Britton (1950), Lambert (1952), and Duane (1954).

Flight experience has dictated the need for further study of the physiological mechanisms of action of accelerations, a more detailed investigation of the physical fitness of fliers in curvilinear flight,

and the formulation of scientifically grounded recommendations for the creation of effective protection against this unfavorable factor. These problems led to the performance of a series of experiments (1950-1962), which are partly summarized in this report.

The investigations involved centrifuge tests and actual flight, as well as a variety of methods to study the physiological functions and fitness of fliers.

To determine the reasons for individual resistance to accelerations, we compared the data showing functional changes in the cardiovascular and respiratory systems. Analysis showed that highly resistant persons (acceleration of 6-7 g) had a marked elevation of blood pressure in the brachial artery and increased cardiac and respiratory rates. With lower resistance, the rise in arterial pressure was less and the increase in pulse and respiratory rates varied from individual to individual.

The data on conditioned motor reflexes indicated primary impairment of function of the visual analyzer. After exposure to accelerations of "threshold" intensity, changes in these reflexes were biphasic. During the first phase in which the time corresponded to the start of "take-off", there was a marked increase in the latent period of the motor reflexes to light, with a slight increase in the latent period of the motor reflexes to sound. During the second phase, which corresponded in time to the appearance of visual disturbances, the motor reflex to light disappeared although the conditioned reflexes to sound were preserved. Soon afterward (10-15 minutes later), the magnitude of the vasomotor conditioned reflexes decreased considerably. Sometimes there were paradoxical reactions.

To obtain a better understanding of the role of the conditioned-reflex component in the mechanism of development of compensatory reactions, special experiments were run in which the conditions of an ordinary experiment were reproduced, but the acceleration was no more than 1.5 g. The subjects were not informed of the intensity of the preceding action; it was included in the series of rotations during which the subjects were exposed to greater accelerations. The results of these investigations showed that arterial pressure rose insignificantly during accelerations of 1.5 g (about 10 mm Hg) while there was a more pronounced increase in the pulse rate (from 4 to 22 per minute). Consequently, in trained persons compensatory changes in blood circulation take place even before the effect of accelerations is manifested, resulting in rapid development of these reactions.

Some investigators (V. V. Strel'tsov, 1938; M. D. Chirkin, 1937; G. Shubert, 1937; others) have pointed out that increased tone of the skeletal musculature is significant in the adaptation to accelerations. This view is based on observations showing that involuntary contraction

of the abdominal muscles increases resistance to accelerations. However, no special experiments were performed to study the functional state of the skeletal musculature during accelerations. We studied the bioelectrical activity of the muscles of the chest, abdomen, and lower extremities in response to accelerations of different intensities. We found that the amplitude of the biocurrents of muscles in the lower extremities and abdomen distinctly increased during accelerations of 1-2.5 g. However, the biocurrents of the chest (intercostal) muscles became activated usually by more intense accelerations (3 g). The most pronounced increase in amplitude of the muscle biocurrents occurred during accelerations of 2 to 5 g. A further increase in acceleration generally failed to increase the amplitude of the biocurrents and often reduced it.

A series of experiments was performed on subjects wearing a G-suit. The creation of pressure in the suit during accelerations caused a sharp decrease in the amplitude of the biocurrents of the abdominal and femoral muscles, and in some experiments they disappeared entirely.

This pattern of changes in muscle biocurrents in response to accelerations is similar to the changes in bioelectric activity of muscles observed by V. S. Gurfinkel' et al. (1955) in static work. It is interesting to note that, just as in the case of accelerations, so too in static work, after the load reaches a maximum, the amplitude of the biocurrents soon decreases. This similarity suggests that both cases involve common mechanisms of reflex reorganization of skeletal muscle activity.

This view was confirmed by investigations of gas exchange during accelerations. Analysis of the experimental data showed that lung ventilation increases (up to a certain point) as acceleration is intensified. With accelerations of 5 g, lung ventilation is more than double the original value. The use of a G-suit caused less marked changes in respiration. Lung ventilation meanwhile grew less than in the experiments in which a G-suit was not worn.

With accelerations of 5-6 g, the subjects used much more oxygen--almost twice the original amount. The percentage of oxygen utilization by blood flowing to the lungs decreased during accelerations, but the total consumption of oxygen grew steadily. At the same time there was a considerable increase in the amount of carbon dioxide released so that the respiratory quotient rose to unity and frequently slightly above.

The results of the investigation of gas exchange also showed that during the first 5 minutes after exposure to accelerations oxygen consumption remains high while the respiratory quotient remains close to unity. These findings indicate that accelerations cause a marked increase in the metabolic rate. The use of a G-suit significantly reduces

oxygen consumption during accelerations. Consequently, energy expenditure with accelerations of equal intensity was less when a G-suit was worn than when it was not.

The development of compensatory reactions--increased skeletal muscle tone, growth of functional activity of the cardiovascular and respiratory systems--during accelerations results in greater expenditure of energy. The use of a G-suit apparently removes part of the "load" from these functional systems and thereby enlarges the physiological capabilities of fliers.

TRANSMISSION OF MEDICAL INFORMATION OVER LIMITED-CAPACITY TELEMETRY CHANNELS

R. M. Bayevskiy

Man's conquest of space is enlarging the scope of research problems and making it necessary to increase the reliability of medical monitoring because the amount of information to be transmitted from spacecraft to the earth is growing. At the same time the greater duration and distance of space flights is sharply restricting the possibilities of transmitting information. Thus, it is essential for us to be able to transmit the maximum amount of information over limited-capacity telemetry channels.

Information theory may provide the key to solving the problem. Actual messages usually contain a number of repetitions or information already known. If only the essential information is extracted from a message, it could be transmitted over telemetry channels with one-tenth or one-hundredth the capacity of the channels required to transmit the communication as a whole. The presence of useless along with useful information in a message is called redundancy in information theory. Efficient coding of medical information can be based on the elimination of redundancy.

Let us take, for example, the transmission of an electrocardiogram over a radiotelemetry channel, assuming continuous recording for 20 minutes. To restore the original shape of the curve requires that it be transmitted at a speed of at least 100 dots per second with 5 percent accuracy of quantization.

According to our calculations, an EKG contains about 400 binary units per second. Therefore, about one-half a million such units of information will be transmitted in 20 minutes.

In processing (interpreting) the resultant data, the waves and intervals on the EKG are measured and about 10 different indices are determined (PQ, QRS, QT, Sp, etc.). These measurements occur at an average frequency of once a minute. Thus, 200 figures are obtained in a 20-minute recording. If a suitable automatic device is used and figures are transmitted instead of the EKG curve, a message of 200 four-digit numbers will contain about 5000 binary symbols, i.e., 100 fewer than the EKG. What is important here, besides the gain in capacity of the telemetry channel, is the fact that the information does not require special processing and can be analyzed while the flight is proceeding.

A further reduction in the number of messages to be transmitted from the spacecraft may be achieved with a more rational code. One variation in coding is to transmit only deviations from previously transmitted values. The transmission of statistically generalized indices such as M. σ. S. could be quite effective. Coding could be even more economical if symbols indicative of a normal or pathological state of the given index were entered into the communication channel rather than the actual numerical indices.

Finally, we must mention the possibility of consecutive transmission of medical information instead of the parallel recording now used. Even a simple temporary commutation of measurements would provide a definite gain with respect to the amount of information to be transmitted. If the measurements were automated, there would be primary accumulation of data for a given period of time and then transmission of these data. The indices measured simultaneously would be transmitted consecutively.

The principle of producing a symbolic code through identification of pertinent information and elimination of all the data that have no practical use was utilized to design several kinds of special medical research apparatus. For example, models were made of a 4-channel electromyograph and 4-channel electroencephalograph designed to transmit information over a single limited-capacity channel. The encoder of the electromyograph made a count of impulses every second in each lead and determined the integral value of the biocurrents, with the formation of 8 pulses reflecting the frequency-amplitude composition of the biocurrents in the 4 leads of the electromyogram. A telemetry channel with a capacity of about 150 bits per second is needed to transmit 8 pulses per second with 5 percent accuracy of quantization. The transmission of 4 electromyograms without coding requires 4 telemetering channels with a capacity of 2000-3000 bits per second each.

The principle of coding an electroencephalogram is based on identification of the alpha, beta, gamma, and delta constituents and determination of the integral values of the biocurrents at the output of each filter for a period of 2 seconds and the general integral values of the biopotenials

in each lead. Thus, 20 pulses reach the channel input per second. This likewise produces an almost one-hundred-fold gain in the capacity of the telemetry channels.

The possibility of producing a code that reflects very specific information brings up the question of preparing special codes for medical monitoring on flights. The first such attempt was made in connection with the designing of a translation-summation instrument for simple translation of pulse, respiration, and motor activity signals with the recording of every 25th or 50th pulse. In case of coincidence, the pulses were discriminated by suitable selection of their amplitude or width.

To solve the problems involved in medical monitoring of space flights, V. V. Bogdanov, L. A. Kazar'yan, A. M. Zhdanov, and the author devised an automatic system with direct input of information that produces a code by combining the features that characterize deviations from various physiological parameters. The same coding principle was utilized in a model of an indicator on diode matrices that V. Ya. Kostikova, A. P. Kalinovskiy, and B. A. Soshin built at our suggestion. The transmission of a symbolic code makes it possible, first, to reduce the required capacity of the telemetry channels; secondly, to increase transmission reliability and freedom from interference; thirdly, to increase the efficiency of medical monitoring.

However, this method of constructing a symbolic code is very elementary and is useful only at the first stages of the work. More effective coding requires the use of statistical methods, specifically, probability and correlation principles. The probability of different signals appearing at the input of a telemetry channel is not the same. If simpler signals are used to transmit the most probable signals than to transmit the least probable, a major gain can be achieved in channel capacity. Moreover, the very distribution of probabilities between codes is of definite diagnostic interest to physicians. Coding with prediction is also of interest, since it is not the messages themselves that are transmitted but the signals correcting the values of the signals predicted beforehand.

There are as yet no mathematical principles for statistical coding of medical information. However, the future undoubtedly lies with these methods and the use of electronic computers as coding devices will be helpful in working out new coding techniques.

DYNAMICS OF THE ELIMINATION OF CORTICOSTEROIDS AFTER VARIOUS ACTIONS

I. S. Balakhovskiy and I. G. Dlusskaya

The efficient standardization of flying activities, like the determination of permissible intensities of other actions characteristic of flying on modern airplanes, is considerably hampered by the lack of sensitive indices for evaluating the changes brought about in the body by an action of a given intensity.

A number of practical problems can be solved by using specific indices that reflect changes characteristic of a particular kind of action, such as the change in oxygen content of the blood in hypoxia, body temperature upon cooling or overheating, impairment of blood circulation due to accelerations, or breathing at an excess pressure. However, if the mechanism by which the factor causes injury is unknown, specific sensitive indices are usually also lacking. In this case it is justifiable to try to find nonspecific indices which, even though not characteristic of a concrete type of action, would nevertheless indicate that some abnormality is present. If such an index were available, it could be used to solve a host of problems, even those for which no reliable scientific approaches exist.

All this is particularly applicable to flight fatigue, emotional stress, and prolonged isolation since the pathophysiological mechanisms of the disorders that arise in these circumstances are almost completely unknown.

The ideas of the Canadian scientist, H. Selye, on "stress", which have gained wide circulation in the West these past 10 years, seem to offer some hope for the development of such indices because Selye was able to show that functional activity of the adrenal cortex increases in response to a great variety of actions (Selye, 1946; Selye and Hauser, 1956).

The investigations of N. A. Vorob'yev (1960), I. V. Fedorov and G. G. Sturua (1961), Vance and Marchbanks (1958, 1960), and Bruner and Klein (1961) showed that flying on a modern airplane seems to stimulate the excretion with urine of double to triple the normal amount of adrenocortical hormones and related metabolites, the so-called corticosteroids. Therefore, without deciding beforehand the question of whether the adrenal cortex actually performs the adaptation functions ascribed to it by Selye, we decided to try to find out whether the function of the gland is increased by a variety of actions.

Of the many methods of evaluating adrenal function, we chose the following three: determination of corticosteroids and ketosteroids

excreted with human urine and determination of corticosteroids in rat blood. These indices enabled us to study the dynamics of the endocrine reactions of rats to sound stimulation and physical exertion (swimming) as well as the functional state of the adrenal cortex in fliers and other subjects under conditions characteristic of modern flying.

We found increased adrenocortical activity in all cases. In the rat experiments, mere handling or very careful immobilizing of an animal caused a sharp (more than 100-110 percent) increase in the corticosterone content of the blood, the maximum being noted during the first half hour after the action with a return to the original level after 1-1 1/2 hours. The hormonal reaction to sound or physical exertion (swimming) was likewise pronounced (more than 150 percent); it continued throughout the action (15-30 minutes) and for about 1-1/2 hours after it was halted. The duration of the reaction increased if the actions were repeated on the same day, although the maximum remained virtually the same. After daily experiments on the same animals for a month, the quantitative and time characteristics of the response to swimming and sound changed slightly.

Analysis of the data obtained in pressure-chamber tests showed that the subjects were in a "pre-start" state characterized by increased excretion of adrenocortical hormones with urine before the test. The amounts were considerably (by 100-150 percent) in excess of those noted in the same persons on the days when there were no experiments. In some instances maximum excretion of hormones occurred after rather than during the action.

Examination of flying personnel completing short or long flights under different conditions showed that during flights marked by unusual difficulties more corticosteroids were excreted than during ordinary flights (increases of 300-400 percent and 40-80 percent, respectively, over the original level). Sometimes maximum excretion occurred after the flights, just as in the pressure-chamber tests.

Examination of parachutists showed that more hormones were excreted during jumps than on control days or days of cancelled flights. The most significant fact here was the increased excretion of corticosteroids at night after jumps.

Our findings indicate that a nonspecific hormonal reaction of the adrenal cortex actually takes place after a great variety of actions. It is highly complex in nature and is activated by a very sensitive neural mechanism. The reaction lasts for a day or less, and its intensity does not exceed normal limits.

EFFECT OF ACCELERATIONS ON THE GROWTH OF LIVING BEINGS

V. I. Baranov, A. A. Gyurdzhian, M. A. Lomova, L. A. Radkevich,
L. T. Tutochkina, T. A. Fedorova, L. P. Furayeva,
S. S. Khnychev and N. S. Artem'yeva

The part played by gravitational forces in the growth and activity of living beings is a subject of major general biological interest.

A special rotating device was designed and assembled for the purpose of raising animals under conditions involving prolonged exposure to acceleration. The intensity of centripetal acceleration could be increased from 0.4 to 5.0 g by changing the rotation rate and distance of the container with animals from the center of rotation (maximum distance 135 cm). The rats were rotated in containers made of plexiglas, and their behavior was recorded by a movie camera fastened to the axis of the stand.

Using a control board, we were able to select the desired rotation rate, provide suitable light for the moving pictures, and record 5 physiological functions in specially trained animals. Simultaneous rotation of the stand and containers around the axis created the conditions for Cariolis acceleration to develop. The latter was also in effect while the animals were running. Running could be stimulated from the control board by putting food into the feed boxes and turning on bulbs (conditioned food signal) found on one of the containers.

The experiments were performed on white laboratory rats exposed from birth to 4-6 hours of rotation daily, except Sundays. The intensity of centripetal acceleration was 1.5-3 g. The litter was divided into two groups--experimental and control--and put under the two females that had given birth to the rats at approximately the same time. The following biological and biochemical methods were used to investigate the animals:

(a) General clinical observation of their condition, behavior, skin, and growth.

(b) Regular weighing (every 3 days).

(c) Hematological investigation (N. I. Suprunenko).

(d) Comparison of the behavior and coordination of movements of the animals during rotation.

(e) Biochemical analysis of blood--amount of nonesterified fatty acids, total protein, protein fractions, and serum mucoids in the plasma (M. A. Lomova and L. T. Tutochkina).

(f) Biochemical analysis of urine--Dische-positive substances, total nitrogen, and creatine-creatinine (T. A. Fedorova, L. P. Furayeva, and S. S. Khnychev).

(g) Periods of sexual maturity, course of the estrus cycle in females, regenerative processes (N. S. Artem'yeva).

(h) Some indices of the reaction of the vestibular apparatus to adequate and inadequate stimuli (N. N. Livshits and Z. I. Apanasenko).

Some 200 experimental and control rats were used. In addition, several hundred intact animals were investigated for changes in selected biochemical indices in response to acceleration.

At the end of the experiments, a comparison was made between the reaction of the experimental and control rats to a single exposure to brief intense accelerations of 5, 10, and 20 g, with observations on the survival rate, biochemical, and hematological indices of the blood and urine.

The general condition of the experimental rats did not differ from that of the control. While being rotated the animals were able to move around and take food. Under similar rotation conditions the control animals sat, bunched together, and looked helpless. No differences were noted between the two sets of animals in tolerance of lethal accelerations.

The experimental rats lagged considerably in weight, achieving only 60-80 percent of the weight of the control between the 20th and 50th days (the weight difference eventually decreased); they showed signs of anemia: erythrocyte count, leukocyte count, and hemoglobin concentration were 89.6, 93.4, and 99.1 percent of the level recorded for the control. The albumin content of the blood was somewhat low, while the globulin and serum mucoid content was high, resembling changes of degenerative character.

The rats exposed to acceleration daily, excreted appreciably less Dische-positive substances (48 percent), total nitrogen (62 percent), creatine (31 percent), and creatinine (66 percent) than did the control.

Finally, the experimental females exhibited marked impairment of the estrus cycle, as shown by lengthening of the resting phases and by shortening and indistinctness of the estrus phase. However, there were cases of normal gravidities and births in both groups of animals. Regeneration of the ovaries after they were resected was likewise the same in the control and experimental rats.

The reaction of the experimental rats to single intense acceleration was highly interesting. In several series of experiments, a single

exposure to an acceleration of 5, 10, or 20 g produced biochemical changes of the stress type in the control rats:

(a) Marked increase in concentration of nonesterified fatty acids.

(b) Changes in the protein fractions and serum mucoids--reduction in content of the latter and increase in the albumin-globulin ratio after moderate acceleration (5 g); increase in serum mucoids and decrease in the albumin-globulin ratio after high acceleration (20 g).

(c) On the second day after acceleration the daily urine exhibited increased excretion of Dische-positive substances, total nitrogen, and creatine-creatinine.

(d) Changes in the estrus cycle in the females, as shown by a lengthening of the resting phase after moderate acceleration (5 g) and lengthening of estrus after high acceleration (20 g).

A single exposure to intense acceleration produced some effects that differed from those in the control:

(a) The increase in concentration of nonesterified fatty acids set in later and lasted proportionately longer.

(b) The biochemical changes were less pronounced.

(c) The increased content of Dische-positive substances, total nitrogen, and creatine-creatinine in the urine were also less pronounced than in the control animals.

Thus, our investigations show that gravitational conditions exert a complex and multisided effect on various physiological processes (growth, development, metabolism, estrus cycle, etc.). Functional tests (single exposure to intense acceleration) revealed several differences in metabolism between the experimental and control animals.

The idea that under conditions of increased gravitation small animals develop as a result of practical adaptation processes while large animals are produced by reduced weightlessness must be considered an oversimplification. One of the probable factors is that animals find it difficult to obtain and digest food under conditions of increased gravitation. In some of the last experiments, both the experimental and the control animals were completely deprived of food during the hours of rotation. The differences between the two groups of animals in weight, blood proteins, and some other indices were much less pronounced in these series of experiments.

We are still far from complete understanding of the mechanism of action of gravitation on vital processes. It is a problem that urgently calls for further study.

LEADING TRENDS IN AVIATION AND SPACE OPHTHALMOLOGY

V. V. Baranovskiy

The value of keen eyesight to airplane pilots and astronauts can scarcely be exaggerated. We need only note that some 90 percent of all the information from the external environment reaches man through his visual analyzer.

The rapidly increasing sophistication of airplanes has given rise to new flying conditions and complicated the task of fliers. Yet the functional capabilities of the human eye have scarcely changed. It is probably worthwhile, therefore, to outline some of the directions in which aviation and space ophthalmology should proceed.

There are several such directions and they are usually intertwined when it comes to dealing with practical problems. One of them is to determine the maximum functional capabilities of the eye in connection with the physical and dynamic factors involved in flying. There is obviously need to determine not only the permissible intensities of the individual factors but the possibilities for training visual functions. Experimentation along these lines has revealed what maximum permissible accelerations should be: the absence of pronounced effects from weightlessness, the main laws governing the action of vibration, etc. But much still remains to be done on prolonged exposure to rarefied atmosphere, on breathing at an excess pressure, and on the effects of acceleration and weightlessness.

Owing to the complicated aviation technology and systems of controlling aircraft, it is important to determine not only the conditions that ensure the tolerance of a given factor, but the conditions that are essential for successful piloting of an airplane over a longer or shorter period of time. A knowledge of the extent to which environmental factors influence visual functions should make it possible correctly to formulate the basic physiological and hygienic requirements for devices to reduce the dependence of visual functions on external influences and ambient factors. These requirements will ultimately determine the necessary compromises between the capabilities of technology and the demands of physiology.

The second direction relates to the creation of comfortable seeing conditions in the plane cabin for the crew. The problems involved in lighting the cabins of airplanes and spacecraft are unusually complex. However, the outlook is promising for the development of cabin equipment that will not make unduly severe demands on the light sensitivity of the eye. It seems that there will be more comfortable conditions for visual work in the cabin than have prevailed hitherto.

The need for more diffuse light in cabins on high-altitude flights led an investigator (Whiteside) to recommend the use of paint with a high reflection factor during the daytime and the installation of additional white floodlight screens to illuminate the instrument panel during night flights.

Comfortable seeing conditions in the cabin of a spaceship are important because natural light changes sharply during a flight. Moreover, the change occurs periodically and is repeated at relatively short intervals. A human being, therefore, has to readapt periodically to this situation, which may impair his visual efficiency. The problem is to determine the permissible drop in brightness that reduces to a minimum the effect of readaptation during drops in illumination in so-called "nighttime" operating conditions.

Human beings quite frequently suffer impairment of spatial perception and autonomic disorders while flying on modern planes. To study the mechanisms of these phenomena and devise scientific methods of preventing them, it is useful to investigate the interdependence of the space analyzers, which enable man to orient himself correctly. Such an investigation should include a determination of the basic laws of visual orientation.

An important objective of research is to obtain scientific criteria for selecting flight personnel. Efforts here have been focused on defining the functional state of the visual analyzer in keeping with the requirements of flight activity. More precise information is now available on the requirements for color and spatial vision and a new method has been devised to test it.

Owing to the extremely heavy load placed on the eyes of the pilot and the high speeds at which modern airplanes fly, the present methods of studying isolated visual functions under static conditions, as is usually done for ease of investigation, are unsatisfactory. Visual functions must be studied dynamically, with the time factor a major criterion. This approach will soon become basic in the development of scientifically sound medical examinations. It will entail research on the capacity of the visual analyzer, the maximum amount of information that can be processed in a unit of time, the degree of change in the volume of information that can be processed while other analyzers are functioning,

etc. It will require the joint efforts of physiologists, biophysicists, and mathematicians and it will help to solve a number of problems in aviation and space medicine relating to simplification of vehicle control systems and orientation during flight.

At the dawn of the aviation era the limits of human activity were determined by the influence of the physical or dynamic factor of flight and the ability to withstand it. Now, however, technology has developed to such a point that the limits of human efficiency will depend mainly on the physical capabilities of man, especially on the capacity of his analyzers, the study of which should occupy an important place in aviation and space medicine.

We should like to emphasize, in conclusion, that while there are several major directions in which the science of aviation and space medicine should proceed, the specific subjects of investigation should be connected with the practical problems raised by the development of aircraft and space vehicles.

THRESHOLD CONTRASTS AND BRIGHTNESS TO ENSURE VISIBILITY OF OBJECTS AT NIGHT AND DURING THE DAY

V. V. Baranovskiy, L. N. Meyer and V. V. Preobrazhenskiy

One of the characteristics of the visual analyzer which determine the visibility of objects is contrast sensitivity. The threshold of contrast sensitivity, i.e., the capacity of the eye to perceive minimum differences in the brightness of objects and the background, depends on a number of factors--brightness, angular dimensions and shape of objects, brightness of surrounding background, and time of presentation of the objects.

Published data on determining threshold contrasts cannot be fully utilized for practical calculations because they were based on a small number of observers and did not take into account the time the objects under study were presented. We therefore undertook laboratory and field investigations of threshold contrasts and brightness in relation to the time of presentation of objects under nighttime and daytime conditions.

The investigations under daytime conditions with illumination of 10,000 lux were started with measurements of the visibility (V) of black and white disks (from 2 to 25 angular minutes in size) 50 m away from the observer. The unknown contrast (E) was defined as the ratio

of the actual contrast (K) to the visibility (V): $E = \frac{K}{V}$. The contrast K for dark objects observed on a background of sky against the sun was taken as 1, but for light objects it was calculated from measurements of the brightness of the object (B_0) and sky (B_s): $K = \frac{B_0 - B_s}{B_0}$.

Seventy observers with a visual acuity of at least 1 took part in the investigations. Each observer, after a short training period, determined the visibility of objects as they appeared and disappeared in the visual field.

Threshold values for the conditions under which the objects became visible or invisible were derived by statistical processing of the experimental data. The threshold contrast during the appearance of an object more than 20 angular minutes in size was 0.06 with a probability of 100 percent. Reduction of the objects to 10, 6, and 2 angular minutes resulted in an increase in the threshold contrasts to 0.14, 0.24, and 0.44, respectively. The threshold values decreased 1-1/2 times for conditions involving the loss of visibility as compared with the appearance of the objects.

The data can be used for rectangular as well as round objects. According to the literature, a rectangle with the sides in a ratio of 1:8 cannot be distinguished from an equidimensional disk.

On starry nights, 10 observers in the laboratory determined the threshold values of the brilliance required for discrimination of silhouettes of objects with side ratios of 1:2 and 1:6 during limited and unlimited periods of time.

The brightness of the background changed from 0.9 to 10^{-3} nt. The size of the background was 1.3 angular degrees; the size of the objects - 6, 10, and 20 angular minutes. The distance between the object and the observer was 5 m.

The experimental data obtained can be helpful in determining the maximum brightness beyond which any increase would not hasten discrimination. Table 1 summarizes the maximum values that ensure almost instantaneous (about 0.04 second) discrimination, with a probability of 100 percent of objects of different angular dimensions with a side ratio of 1:2 as they appeared against backgrounds of variable brightness.

Analysis of the experimental data shows that the threshold brightness required to discriminate the silhouette of an object grows with increasing brightness of the background. The smaller the angular dimension of the object, the greater the brightness that is required to

Table 1. Threshold Brightness Ensuring the Discrimination of Objects in 0.04 Second Against Backgrounds of Variable Brightness and Angular Dimensions of Objects with a Side Ratio of 1:2

Angular dimension of object (minutes)	Brightness of background (nt)			
	0.93	0.14	0.016	0.01
20	1.6	0.48	0.10	0.063
10	2.4	0.80	0.35	0.25
6	4.3	1.4	0.54	0.40

discriminate it. If the time is increased from 0.04 to 2-5 seconds, the threshold brightness decreases twofold or more. The intensity of the threshold brightness derived for objects with a side ratio of 1:2 must be increased 1-1/2 times to permit the discrimination of objects with a side ratio of 1:6 but with equal width. Moreover, the threshold brightness for the appearance of an object is 1-1/2 to 2 times higher than the threshold brightness when it becomes invisible.

Conclusions

1. The threshold values of contrasts for objects more than 20 angular minutes in size observed against the sky during the daytime are 0.04-0.06 for the appearance or disappearance of an object, respectively.

2. Virtually instantaneous discrimination of objects at night can be achieved by doubling the threshold brightness established in the case of unlimited time of observation.

A NEW METHOD OF STUDYING THE TENDENCY TO ILLUSIONS OF SPATIAL ORIENTATION

V. V. Baranovskiy and I. D. Semikopnyy

Man orients himself in space as a result of the interaction of several analyzers, the visual and vestibular in particular. Thus, the appearance of illusory sensations of spatial orientation reflects a change

in this interaction. The reasons for the change may stem from the nature of visual orientation during flight. Systematic tracking movements of the eye during flights over clouds, in cloudiness of variable density, when it is raining or snowing, etc., may well be significant. It is known from the literature (Grable, 1952) that eye movements of fliers beyond the cabin increase considerably when weather conditions are unfavorable.

The role of the kinesthetic component in the interaction of the analyzers has not been adequately studied. Optokinetic nystagmus, which frequently arises as a reflex of tracking, is a simple and widespread form of visual-kinesthetic association.

In order to assess more objectively the effect of visual-kinesthetic stimuli on the excitability of the vestibular apparatus, specifically, on the functional asymmetry of the labyrinth, we determined the degree to which subjects would turn when walking on a spot with eyes closed before and after observing moving objects.

The experiments included the following procedures:

(a) Walking on a spot with eyes closed (and wearing opaque eyeglasses) for 2 minutes.

(b) Observation of moving vertical white-and-black strips 10 cm wide in a cylinder 80 cm in diameter revolving at the rate of 20 rpm (angular velocity - 120 deg/sec or 2.1/rad/sec).

(c) Walking again on a spot with eyes closed for 2 minutes.

While walking the subject took about 100 steps a minute, bending the legs at the knees and swinging the arms in the usual way. The subject observed the movement of the white-and-black strips while sitting inside the cylinder. Meanwhile, we used a mirror to watch the development of optokinetic nystagmus in the subject as the cylinder was revolving.

The second test of walking on a spot, after observation of the moving strips, was conducted the same way as at the start of the experiment. Divisions were placed at every 30° on the floor to record the degree to which the trunk turned while the subject was walking.

We thus obtained an objective method of investigating the effect of visual-kinesthetic stimulation on excitability of the vestibular apparatus, which was reflected in a tendency for illusions to develop and influence the correctness of spatial orientation.

We also performed a series of experiments involving the observation of moving objects for 2 to 25 minutes and, in two cases, for 55 and 60 minutes.

Before visual-kinesthetic stimulation, 90 percent of the subjects turned their trunk about 360° while 1 person did so more than 720°. At the end of the experiment 72 percent made a turn of about 360°, while 10 percent of the persons turned more than 720°.

Analysis of the data revealed an interesting relationship between the direction of the turning and revolving of the cylinder clockwise and counterclockwise. For example, in most of the persons (85 out of 108), the turn after observation of moving objects was in the direction opposite to that of the movement. Consequently, this turn can be regarded as the result of an illusion of spatial orientation due to visual tracking of moving objects. No direct connection was noted between the extent of the turn at the start of the experiment, before observation of the moving objects, and that at the end of the experiment.

All this shows the value of using visual-kinesthetic stimulation in the form of observation of moving objects when investigating the tendency for an incorrect idea of spatial orientation to arise.

With repeated investigations and a simultaneous increase in the time of observation of moving objects, the results differed from day to day, ranging from 30 to 105°.

Of greatest interest, however, are the data obtained after different periods of observing moving objects. They show that there is no direct connection between the time of observation and magnitude of the turn of the trunk, even in the case of complaints of not feeling well by the subjects who observed moving objects for 55-60 minutes. They tended to develop a misconception of their spatial orientation after visual-kinesthetic stimulation. It arose during the first two minutes and did not increase even after longer stimulation.

Analysis of the material revealed that the frequency of cases with a marked reaction of optokinetic nystagmus was virtually the same among flight personnel and enlisted men.

Study of the data on the flying activities of the pilots who reacted sharply to optokinetic stimulation (with a more than 720° turn) showed that all 6 men were capable of performing their regular flying duties in accordance with the existing combat training program.

Thus, our method makes it possible to evaluate objectively individual idiosyncrasies in impairment of spatial orientation, a subject that calls for psychophysiological investigation.

Conclusions

1. We have developed an objective method of quantitatively determining individual tendencies toward illusions of spatial orientation accompanying observation of moving objects.

2. The new method makes it possible to detect about 96 percent of the persons who develop functional asymmetry of the labyrinth, which results in a misconception of spatial orientation. This is manifested in a more than 720° turn of the trunk during 2 minutes of walking on a spot with closed eyes after optokinetic stimulation.

3. The method can be used in psychophysiological examinations to select flying personnel for flights in SMU when determining the degree of fatigue, degree of flight strain, and effect of alcohol intake.

INCREASING RESISTANCE AS A MEANS OF PROVIDING BIOLOGICAL PROTECTION AGAINST VARIOUS ENVIRONMENTAL FACTORS DURING FLIGHT

Z. I. Barashova

It is a well-known fact that the means of providing physical protection for human beings on high-altitude flights and in space travel are limited. Such factors as vibration, weightlessness, acceleration, and other overloads can under certain conditions cause pathological changes in the body. Hence, measures to achieve a high level of general human or animal resistance remain on the agenda of the day.

By a high level of resistance we mean the capacity of the organism to function normally under extreme circumstances. If extreme factors are for short periods of time so strong that the body temporarily is unable to maintain self-control, then we define as a high level of resistance the capacity of the body to resume normal functioning quickly and completely, with no impairment of health, as soon as the stressor ceases to act.

Resistance can be increased in two ways. The single action of some factor can significantly reduce sensitivity to the effect of the next adverse factor. For example, moderately severe hypoxia during exposure to ionizing radiation or the preliminary ingestion of some chemical or pharmacological substances that prevent peroxides from being stored in tissues decreases the primary effect of radiation. Similarly, resistance

to severe overloads and acute hypoxia can be increased by first injecting the organism with narcotics or other substances that inhibit the central nervous system and substantially reduce nerve cell sensitivity to the above-mentioned factors. However, such biological protection can only be temporary. It is useless in situations that require man to continue to function normally while exposed to a stressor.

Of more significance is the increase in resistance that would permit the normal functioning of all systems, primarily the CNS. This can be done by specific training (conditioning to the effect of the most injurious agent) and by nonspecific training (increasing the nonspecific resistance of the body in all possible ways). Nonspecific resistance is increased by heightening the reactivity of all the homeostatic systems, especially by changing cell chemistry, which makes the body less vulnerable to many adverse external and internal environmental factors.

What means can be used to increase general nonspecific resistance, what are the limits of this nonspecificity, is it possible to change nonspecific resistance in all living organisms--these are the main problems that confront us. There is now a mass of information which indicates that directed change in resistance is possible for any organism from man to paramecium, even for the plant cell. It is interesting to note that the means of changing resistance in all kinds of animals are the same in principle. Such means include the repeated action of agents, which are addressed ultimately to cell metabolism and which cause adaptive changes in cell chemistry. Hypoxia, muscular exertion, change in ambient temperature, and some drugs can serve as agents. A single exposure by itself can also be a factor in increasing resistance because it brings about changes both during the action of the agent and after cessation of the action. For example, a one-time exposure to fairly acute hypoxia or intense muscular exertion (mostly involving high speed) causes impairment of the oxidation metabolism of cells along with increased utilization of energy substances (in the case of intense muscular exertion), adaptive increase in activity of the oxidation-reduction enzymes, intensification of anaerobic release of energy and, as a result, accumulation of incompletely oxidized metabolic products and growth of the oxygen debt. There is an excessive accumulation of energy sources (glycogen, phosphocreatine), proteins-enzymes, and various biologically active substances (myoglobin, glutathione, ascorbic acid, creatine, etc.) in the restoration period. Similar processes take place in a great variety of tissues.

These trace reactions are gradually extinguished if the same stressors do not continue to act. When repeated, they again bring about the whole set of biochemical changes in the cells followed by a restoration phase. The adaptation processes improve and become more economical; they are summed up and become consolidated, i.e., they persist for longer periods of time. The resultant adaptation weakens, so to speak, the

initial force of the agent because the cells "learn" to react more economically and "resourcefully". In other words, the cell structures become more resistant. The changes in cell chemistry are not limited to changes in the nature and rate of the metabolic processes. There are other processes with still unknown mechanism that increase the resistance of cell structures to a great variety of agents that are addressed to the metabolic processes and at the same time directly influence the native structure of the cell. For example, rat muscle tissue and cerebrocortical tissue adapted to hypoxia become more resistant to ethyl alcohol or high concentrations of caffeine. The sorption properties of reticuloendothelial tissue decrease with respect to vital dyes while the osmotic resistance of erythrocytes grows. The structural reorganization of muscle tissue can also be judged from changes in electroconductivity and dielectric permeability of muscles in vivo. In some way or other the properties of the structural and contracting proteins of the skeletal musculature change. The rate of restoration of the actomyosin complex, after dissociation of this complex by ATP, was found to be higher in rats adapted to hypoxia than in the control.

Although these fragmentary data do not completely account for the origin of changes at the cell level in animals adapted to hypoxia, they undoubtedly do indicate that there are significant changes in the physicochemical properties of cells in animals conditioned to hypoxia.

Since repetition of the action of different stressors (hypoxia, muscular exertion, changes in ambient temperature, some drugs or other chemical compounds) reveals the existence of similar changes in cell chemistry, it is easy to understand why conditioning to hypoxia, for example, increases resistance to chilling or to the performance of high-speed muscular work, acceleration or radiation, and why muscle conditioning increases resistance to hypoxia, acceleration, chilling, etc.

Cell chemistry changes at all levels following exposure to extreme factors. Nonspecific resistance increases wherever adaptation to repeated exposure to stressors occurs. Consequently, it is fair to say that adaptive changes at the cell level are the basis of nonspecific resistance in the organism.

Nevertheless, the concept of nonspecificity is not an absolute one because each adaptation may include not only common or similar processes but also specific adaptive reactions which need not have general significance. Resemblance in cell adaptation is by no means identity. Moreover, the complex organisms of the higher animals include in their mechanisms of adaptation not only changes at the cell level but adaptive changes in the functioning of different systems, the significance of which may vary from situation to situation.

It is worth noting, too, that not every kind of conditioning will lead to a change in nonspecific resistance. It is essential to take into

account the nature and force of the agent, the frequency and duration of its use. The facts show that only a rational and many-sided conditioning of the human or animal organism ends in increased nonspecific resistance.

RESPIRATION AND GAS EXCHANGE IN AN ACUTE HYPOXIC TEST

A. V. Beregovkin, P. V. Buyanov and V. B. Malkin

Hypoxic hypoxia is now widely used as a functional test of nervous reserves, respiration, and blood circulation in essentially healthy persons and as a means of detecting various latent forms of disease. There is a definite correlation between resistance to oxygen deficiency and resistance to other unfavorable environmental factors (high and low temperature, hypocapnia, radiation, etc.).

The use of hypoxic hypoxia as a functional test is a promising method of selecting flight personnel and of keeping under dynamic observation persons exposed to a variety of flight factors. Accordingly, we undertook an investigation of respiratory function and gas exchange in hypoxic hypoxia. The purpose of our work was both to determine the general principles underlying changes in respiration and to detect individual respiratory reactions to hypoxia. We also endeavored to evaluate the individual reactions from the diagnostic standpoint.

Acute hypoxic hypoxia was caused by inhalation of gaseous mixtures of nitrogen with oxygen. There was a total of 64 investigations involving 48 essentially healthy males ranging in age from 20 to 23 years. In the first series of investigations, we used a mixture with an oxygen content of 9.3-10.9 percent; in the second series, the oxygen content was 8-8.5 percent.

The investigations were conducted under the conditions of basal metabolism (immediately after a night's sleep, on an empty stomach, lying down). The frequency, depth, and rhythm of respiratory movements and the maximum lung capacity were recorded with a spirograph. Pulmonary ventilation was determined with a gas meter. The Douglas-Haldane method was used to investigate gas exchange.

The principal indices of respiration and gas exchange were determined at rest, during breathing of the gaseous mixture, and after changing to breathing of atmospheric air.

Analysis of the results show that pulmonary ventilation, depth of respiration, maximum lung capacity, and oxygen consumption were definitely related to the degree to which the partial pressure of oxygen was reduced in the inhaled mixture.

Pulmonary ventilation increased in 54 cases (by 3-125 percent), remained unchanged in 3, and decreased in 6 (3-30 percent).

In the first series of investigations, pulmonary ventilation increased on the average by 24 percent, in the second series, by 47 percent.

The respiration rate scarcely changed. Average figures for the change in respiration rate remained within the limits of errors in the method.

The depth of respiratory movements increased in 58 cases (by 8-176 percent), remained unchanged in 4, and decreased in 2 (by 8-21 percent).

In the first series of investigations, the vital capacity increased on the average by 28 percent, in the second series, by 51 percent. Pulmonary ventilation increased mostly through an increase in the depth of respiration.

The maximum capacity of the lungs decreased in 49 investigations (by 4-65 percent), remained unchange in 2, increased by 6 percent in 1.

In the first series of investigations, the maximum lung capacity decreased on the average by 16 percent, in the second series, by 28 percent.

Similar changes in external respiration were noted under the conditions of rarefied atmosphere with elevations in the pressure chamber to "altitudes" of 5000-7000 m.

Oxygen consumption in the first series of investigations decreased after 15 minutes by an average of 11 percent and then gradually increased until the end of the test (50th minute) when it was 98 percent of the original level, i.e., this index returned to normal.

The amount of oxygen consumed in the second series dropped by 71 percent (4-6 minutes) and by the end of the investigation was only 79 percent (15 minutes).

During the first few minutes (4-6) after breathing atmospheric air, oxygen consumption was higher than the original figures (by 40 percent in the second series).

The diagnostic significance of the degree of increase in pulmonary ventilation is of considerable value in determining the individual resistance of healthy persons to hypoxia. There are two schools of thought on this matter. Most authors associate a high level of ventilation with good resistance to oxygen deficiency (A. P. Apollonov, V. G. Mirolyubov, P. K. Isakov, L. L. Shik, and others). Others attach considerable significance to hypocapnia as a factor that largely determines individual resistance to hypoxic hypoxia (V. V. Strel'tsov, Antony, and others).

In our investigations, a decrease in pulmonary ventilation, like an extreme increase (more than 100 percent above the original level) was generally associated with poor tolerance of hypoxia.

Evidently both of the aforementioned points of view are rather one-sided. A low level of ventilation results in severe hypoxic disorders, whereas a marked increase (over 100 percent) lowers resistance to oxygen deficiency due to the development of hypocapnia. Thus, there seems to be an optimum area of increase in pulmonary ventilation which varies with the extent to which the partial pressure of oxygen in inhaled air is reduced and with the individual characteristics of the person examined (specifically, his sensitivity to hypocapnia). For most persons this area with gaseous mixtures containing 10.5 percent oxygen ranges from 20 to 75 percent, 8 percent oxygen - from 30 to 90 percent.

There is no consensus in the literature on the nature of the reflex reorganization of respiration. Several investigators state that an accelerated respiration rate in hypoxic hypoxia is the most typical feature of external respiration, whereas changes in the depth of respiratory movements are more variable (Haldane and Priestley, 1937; A. G. Ginitsinskiy and A. V. Lebedinskiy, 1947). P. I. Yegorov (1932) noted, however, that with the development of acute oxygen deficiency essentially healthy persons have slightly more numerous respiratory movements (an increase of 10 percent), but respiration becomes quite deep.

In our observations, the increase in pulmonary ventilation was occasioned mainly by increased vital capacity. Unchanged vital capacity or a decrease therein testified to low resistance to hypoxia.

Thus, increased depth of respiration is the most typical form of human adaptation reaction to insufficient oxygen in inhaled air. (A reduction in maximum lung capacity in hypoxic hypoxia is mentioned by Paul Behr.)

We found no references in the literature to the diagnostic value of this index in hypoxia. The reduction in maximum capacity noted in most of our observations was evidently due to hypervolemia of the pulmonary circulation and thus the result of a compensatory reaction to the

extensive aeration of blood in the lungs. However, a marked decrease in vital capacity (by 40 percent or more) generally coincided with poor performance in the hypoxic test. This last was probably caused by severe impairment of the hemodynamics of the pulmonary circulation. This assumption is based on the results of investigations in which the development of hypoxic hypoxia was associated with a substantial increase in pressure in the right ventricle of the heart and pulmonary artery (V. V. Parin and F. Z. Meyerson, others).

The changes that we noted in oxygen consumption in acute oxygen deficiency confirm the results of studies by L. L. Shik, Ye. Opitts, and others, who observed during the first minutes of the onset of hypoxia a decrease in oxygen consumption followed by an increase and then a return close to the original level. A pronounced decrease in oxygen consumption during the first minutes of an investigation and its slow restoration are an index of low resistance to oxygen deficiency.

Thus, the diagnostic criteria of low resistance to oxygen deficiency were the absence of an appreciable change in the volume of pulmonary ventilation or a sharp increase therein (over 100 percent), a decrease in the depth of respiration, a marked decrease in vital capacity (40 percent or more), and a marked reduction of gas exchange early in the test followed by a slow return to normal.

EFFECT OF CHANGE IN THE GAS MEDIUM ON "PRIMARY POTENTIALS" OF THE AUDITORY AREA OF THE CEREBRAL CORTEX IN ANIMALS AND ON SOME FUNCTIONS OF THE ACOUSTIC ANALYZER IN MAN

E. V. Bondarev

The present stage in aviation technology requires a deeper and more comprehensive investigation of the adverse factors encountered in flight (acceleration, hypoxia, noise, etc.). Of equal importance is a problem in space research pertaining to living quarters on space vehicles, namely, the composition of the artificial gas medium in a hermetically sealed capsule.

Interest in the acoustic analyzer of fliers on jet aircraft is growing because of its heavy load. The possibility of substituting sound signals for some of the visual information is now under discussion.

We studied the effect of flight factors on the acoustic analyzer in two respects: (a) the influence of hypoxia and substitution of helium

for nitrogen in the ambient atmosphere on the "primary potentials" of the auditory area of the cerebral cortex in response to sound; (b) the influence of moderate hypoxia (corresponding to an altitude of 5000 m) on some functions of the human acoustic analyzer.

Changes in the "primary potentials" were investigated in a chronic experiment using 7 cats with electrodes implanted in the auditory region of the cortex. During the investigation the animal was kept in a hermetically sealed chamber secured to a special bench in such a way as to enable it to maintain its normal posture. The "primary potentials" were evoked by brief (80 m/sec) sounding of pure tones at frequencies of 500, 1000, 3000, 6000, and 10,000 cps from an audio oscillator with a constant intensity of 60 db at the level of the animal's ear. The tones were supplied at the rate of 5-7 per minute through a high-fidelity loud speaker.

We began by recording the "primary responses" of the auditory area of the cortex to the sounds with the animals breathing the surrounding air (control). Some of the animals were then elevated in the pressure chamber to "altitudes" of 5000 and 8000 m (from the platform in 30 minutes). In other cases the chamber was successively filled with gaseous mixtures containing 11.2, 7.2, and 6.8 percent oxygen, corresponding to altitudes of 5000, 8000, and 9000 m (from the platform in 30 minutes). In still other cases the atmospheric nitrogen was almost completely replaced with helium at a normal barometric pressure; the animals were kept in this mixture for 12 hours.

The following served as indices of the "primary response": latent period of the reaction calculated from the time the stimulus was applied, the intensity and duration of the positive and succeeding negative phases of the induced potentials, and the amplitude ratio in both phases.

The second part of the investigation was carried out on 20 subjects, 18-28 years of age, in a pressure chamber at an "altitude" of 5000 m. The following indexes of the condition of the acoustic analyzer were investigated: intelligibility of the words presented to the subjects with different degrees of intensity; operating efficiency according to the data of a sampling reaction, and interval of discreteness of separate perception of two sound stimuli.

The intelligibility of words was determined from articulation tables prepared on the basis of recent research on the physical and phonetic constants of Russian speech. The differences in intensity levels of the tests made it possible to obtain a speech audiogram.

The operating efficiency of the acoustic analyzer was determined in a sampling reaction from Shannon's formula, taking into account the number of correct responses, errors, and reaction time. The interval of

discreteness was determined from the differentiation of single and double clicks.

After statistically processing the results of the investigations, we found that:

(a) Changes in the "primary potentials" of the auditory area of the cat cortex began to appear at an "altitude" of 5000 m and became more pronounced at 8000-9000 m.

(b) With hypoxia there was a lengthening of the latent period of the "primary potentials", a progressive decrease in the amplitude of the negative phase, and, starting at 8000 m, increase in and shortening of the positive phase; the responses to the higher frequency sounds (above 6000 cps) were more affected.

(c) Twelve hours of exposure to a helium-oxygen mixture had no significant effect on the "primary potentials" of the auditory area of the cat cortex.

(d) Moderate hypoxia at an "altitude" of 5000 m raised the threshold of perception of sound in the healthy subjects but somewhat reduced the intelligibility of words at low sound intensities; when the subjects were conditioned to "altitude", the above-mentioned changes were less pronounced.

(e) The operating efficiency and interval of discreteness of the acoustic analyzer showed no significant changes at an "altitude" of 5000 m.

THE POSSIBILITY OF BIOLOGICAL OBJECTS GROWING AND LIVING A LONG TIME IN A HELIUM-OXYGEN ATMOSPHERE

V. V. Boriskin, P. A. Gul'tyayev and B. M. Savin

One of the most important problems relating to living quarters on spacecraft designed for distant travel is the creation and maintenance of the most suitable gas medium. It requires the creation of highly favorable conditions for biological objects to grow normally and survive on long flights, and the ability to provide the necessary equipment.

The great interest displayed in recent years in studying the effect of substituting helium for nitrogen in the ambient atmosphere on animals and human beings is due to the fact that helium, as an inert gas, is superior in several respects to nitrogen as a diluent of oxygen in the cabins of interplanetary spaceships.

The possibility of living things growing and living for a long period in a helium-oxygen atmosphere is also highly interesting from the standpoint of general biology because it may help to determine the biological significance of atmospheric nitrogen for the higher animals and man. The literature on the subject is meager and contradictory.

These problems were studied in 1960-1961 in a series of experiments involving a variety of biological objects in different stages of ontogenetic and philogenetic development, and kept for many days in a helium-oxygen atmosphere. We investigated the possibility of (a) chick embryos and frog egg cells developing in a helium-oxygen atmosphere, and (b) of chicks, white mice, and dogs living in this atmosphere for 10-15 days. For the purpose of comparison, parallel experiments were performed with the same biological objects in a nitrogen-oxygen atmosphere.

The oxygen content of both gas media ranged from 19-23 percent, the CO_2 content, from 0.2-1.2 percent. The amount of nitrogen present did not exceed 1-1.5 percent.

Results

Development of chick embryos. Inspection and weighing of the eggs and examination of the embryos extracted from them at different stages of development failed to reveal any significant differences--either in time or in nature of embryogenesis--between the egg cells incubated for 21 days in the helium-oxygen and nitrogen-oxygen media. It was noted, however, that shrinkage of the eggs during incubation was 3-5 percent greater and the weight of the hatched chicks was 2 g lighter in the helium-oxygen atmosphere than in the nitrogen-oxygen. It was impossible to determine whether this was due to the higher temperature at which the helium-oxygen medium was maintained or to the physicochemical properties of the helium.

With maintenance of the incubation temperature conditions, approximately the same number of chicks was hatched in both gas media. Continued observation of their growth and development until maturity under ordinary conditions failed to reveal any significant difference between them.

Development of frog egg cells. Observation of the development of frog eggs in the gas media under study was particularly interesting because it took place in water, which possesses higher thermal conductivity than helium. This leveled out the difference between nitrogen and helium with respect to their influence on heat loss. Frog development is attended by several complex phases of reorganization and transformation during which the exclusion of atmospheric nitrogen apparently cannot help but have an effect if its presence is actually necessary for normal development. However, 20 days of observation of the embryonal and larval periods of development in the medium in which atmospheric nitrogen was replaced by helium failed to reveal anything unusual either in the time they occurred or in their nature. Nor were any differences noted between the experimental and control groups when the tadpoles were shifted from the helium-oxygen medium to ordinary atmospheric conditions and observed for 2 months as they passed through all the stages of metamorphosis and formation of the frog organism.

Chicks and White Mice Kept in a Helium-Oxygen Medium

Two groups of chicks incubated in nitrogen-oxygen and helium-oxygen media were placed in a chamber with a helium-oxygen atmosphere as soon as they were hatched. Ten days' observation of their growth, weight, general behavior, and reaction to food and various external stimuli showed that with an outside temperature of about 30°C, which is essential to maintain the thermal balance and normal behavior of chicks in an ordinary atmosphere, the chicks in the helium-oxygen medium "froze", bunched together, moved about, and ate very little. Raising the temperature of the helium-oxygen medium to 34-36° resulted in normalization of motor and feeding activity, and the subsequent development and behavior of the chicks were the same as in an ordinary atmosphere. After they were transferred to ordinary living conditions, they reached maturity without exhibiting any adverse effects from the 10 days they were kept in the helium-oxygen medium.

The results were the same in the experiments with the mice, which were kept for 15 days in a helium-oxygen medium. The mice showed no signs of temperature discomfort in the nitrogen-oxygen medium when the ambient temperature was 21-22° or in the helium-oxygen medium when the temperature was 24-25°. With these temperature regimes there were no perceptible differences in the condition and behavior of the animals in the two gas media. Nor were any adverse effects observed after they were transferred to ordinary living conditions.

Dogs Kept in a Helium-Oxygen Medium

Dogs were kept in a helium-oxygen medium for 14 days, during which we observed their behavior, external respiration, gas exchange, energy

consumption, electrocardiogram, conditioned reflexes, skin, subcutaneous, muscular, and rectal temperatures. We found that with an external temperature of 23-26° muscular and subcutaneous temperatures dropped by 0.7-0.9°, energy consumption increased by 80 m/kal per minute, and the cardiac rate accelerated by 10 beats per minute. There was a diminution of motor and feeding activity, and some inhibition of conditioned reflexes. Raising the external temperature to 27-28° brought the temperature of body tissues and physiological functions to their original level and under these conditions these indices did not differ from those of the animals kept in the nitrogen-oxygen atmosphere at an ambient temperature of 19.5-22.5°. The animals' motor activity was also restored. Subsequent observation of the animals under ordinary conditions disclosed no adverse effects from the many days they spent in the helium-oxygen medium.

Thus, our experiments show that substituting helium for oxygen in the ambient atmosphere had no appreciable effect on embryonal development. When a higher ambient temperature was maintained in order to preserve the thermal balance, long exposure to the helium-oxygen atmosphere did not impair the vitality of animals representing different stages of phylogenetic development. The need to maintain a higher temperature (by 4-6°) in the helium-oxygen atmosphere was occasioned by the fact that helium has greater thermal conductivity than nitrogen and thus causes the organism to emit more heat.

SOME ASPECTS OF MEDICAL EXAMINATION OF FLIGHT PERSONNEL

K. F. Borodin

1. Medical examination of flight personnel (MEFP) in Russia has come a long way since the War Department issued its first order defining the medical requirements in selecting personnel for balloon and air units. This important branch of medicine has developed chiefly in the direction of matching the health requirements of personnel with flying conditions on different kinds of aircraft and perfecting appropriate examination methods.

Instead of a priori requirements for visual acuity, color perception, condition of the labyrinth, and physical development--to which the orders of prerevolutionary Russia were largely restricted--we now have a document that deals both with matters concerning the organization of examinations and with scientifically valid, differentiated health requirements for members of crews on different kinds of planes. We have also a special handbook for medical commissions describing the procedures used in MEFP.

2. The theory of flight fitness examinations rests on a scientific and materialistic understanding of the unity and interdependence of somatic and mental processes, of social and biological factors, of the human organism and the environment.

The main principles of MEFP include:

(a) Comprehensive study of the individual, including a general physical examination, special physiological, psychological, and other functional investigations resembling flight conditions and study of the individual under actual flying conditions.

(b) Continuous evaluation of the health of flight personnel through periodical medical examinations, preflight medical check-ups, and keeping of records.

(c) A scientifically grounded and MEFP-approved individualized method of evaluating the results of investigations from the biological as well as social standpoints. The fitness for flying of individuals with health abnormalities is determined on the basis of formal symptoms of disease and with due regard for the functional capabilities of the individual, stage of disease, prognosis of occupational activity, attitude, value to the service, experience, etc.

3. Despite the success of MEFP, some matters call for further study. One need is to improve and secure wider use of functional methods of investigation that reflect more accurately activities on various kinds of aircraft in order to determine the fitness of examinees. This is necessary because the possibility of continuing flight activities is not always determined by morphological changes, that is to say, the functional state of the organism very often establishes the framework of the occupational activity of flight personnel. The problem should be dealt with in practice chiefly by:

(a) Making wider use of certain excellent clinical methods of functional investigation on an outpatient and, especially, inpatient basis.

(b) Administering a specially prepared program of tests in flight so as to determine the effect of existing health conditions on efficiency.

(c) Undertaking scientific research to find and check new functional tests.

The various approved methods of investigation and evaluation of the results are fully described in official handbooks. We need only emphasize that the recommended number of investigations should be made in every single case.

Tests during flights should assume increasing importance. Specifically, they should be considered mandatory for vestibular disorders, marked decrease in auditory acuity, persistent impairment of the barofunction of the ears and appendages of the paranasal sinuses. The tests should be given with due regard for flight safety and, of course, in the absence of contraindications.

4. There are two trends in the research aimed at finding new methods of investigation that are more in line with flying conditions. One is to determine the functional capabilities of the individual with respect to concrete flying conditions. The other is to detect incipient forms of diseases and latent functional impairments.

Included in the first trend are:

(a) Establishment of criteria for evaluating the functional capacity of the cardiovascular and respiratory systems for tolerance of respiration at an excess pressure.

(b) Establishment of criteria for expert evaluation of the results of tests on a flight trainer.

(c) Refinement of speech audiometry data to deal with the problem of audibility of radio signals during flight.

(d) Development of better methods of determining the physical condition of flight personnel in order to judge their ability to withstand unfavorable flight factors.

(e) Dynamic investigation of visual analyzer function in order to determine the rate of visual perception under flight conditions.

This trend is concerned with investigating the functional capabilities both of individual analyzers and systems and of the body as a whole for tolerating the specific conditions of flight activities.

The second trend of research assumes that the onset of diseases that limit or make impossible flight activities is usually preceded by functional, often reversible, changes in the body, although these changes cannot be readily detected in the ordinary physical examination, they must be known before it is decided whether the examinees should be permitted to continue flying and whether corrective measures are feasible.

Of greatest practical importance is determining the initial manifestations of atherosclerosis of the coronary blood vessels. The methods now used (EKG investigation with inhalation of an oxygen-poor gas mixture, after injection of glucose; pressure-chamber tests; determination of the rate of blood flow, etc.) are sometimes helpful in turning

up latent forms of the disease, but we are not completely satisfied with the data they yield.

It is equally important to find ways of detecting the initial manifestations of sclerosis of the cerebral arteries. The clinical data obtained in the course of the usual neurological investigation are usually indicative of an advanced stage of the disease and they are rarely encountered by medical commissions. The psychological tests used for this purpose likewise do not provide a complete answer. It is important that physiological and psychological tests be designed which would permit early diagnosis of incipient sclerosis of the cerebral arteries, when there are only slight abnormalities in CNS function.

5. Research efforts must be directed toward achieving maximum objectivization of examination results. It is wrong, however, to try to set up precise criteria, as some investigators do, for determining the degree of fitness for flying from the results of a given investigation. Each investigation should be considered simply as one part of the clinical examination which is designed to help in making an accurate diagnosis or to evaluate certain specific functional capabilities. One investigation is a completely inadequate basis for an expert decision; this is reached only in the course of a collective discussion of all examination results and evaluation of a host of other factors, particularly, compensation of an existing health defect, nature of future flight assignment, and many others. Therefore, the results of various investigations should make possible a more objective evaluation of the functioning of a given organ (system) or tolerance of individual flight factors or certain adverse environmental conditions, but not a determination of the degree of fitness for flying.

OBESITY IN FLIERS

I. M. Buznik

Obesity is not uncommon among fliers. It usually develops in older, generally highly competent, persons. Obesity reduces resistance to overloads, increases sensitivity to decompression disorders (Armstrong, 1954), and decreases physical endurance. All this naturally has an adverse effect on the fitness and combat efficiency of the individual, and also impairs flight safety. We concluded from an analysis of the results of weighing fliers that the number of those for whom obesity preventive and therapeutic measures should be taken is very substantial.

It is widely believed that obesity is caused by overeating. But this is scarcely enough to explain the pathogenesis of obesity or to provide the basis of preventive and therapeutic measures. After all, any obesity results from overeating, i.e., from the consumption of more food than the body needs.

Obesity in fliers is often said to be due to the high caloric content of their food ration. Reduce the ration, then, and you will prevent obesity. But if this were so, how does it happen that all fliers do not get fat? Why is the weight of some fliers abnormally low? The reason is evidently not to be sought solely in excess caloric intake.

In studying the problem, we analyzed the weight of fliers over a period of years, tracing the pattern of weight gain in those suffering from obesity.[1] Weight is put on slowly and it becomes pronounced only after a few years. The average increase is 1-2 kg a year, rarely 3-4 kg. It may be due to a very slight excess in the caloric content of the food eaten over the amount of energy expended, which can easily be demonstrated by appropriate calculations. For example, if the weight gain for a year is 3.65 kg, it will average about 10 g per day. This is equal to a daily excess of 7-8 g of food fat or 70-80 calories of other nutrients. Consequently, the excess of calories in food over the amount of energy expended need be very slight for obesity to develop.

In the light of the foregoing, it is doubtful that obesity can be successfully controlled by reducing the caloric content of the fliers' ration, say, to 4000 kcal because on some days they would exceed the energy expended. For example, in expending about 3000 kcal or energy, the excess will come to 1000 kcal. To reduce the caloric content even more is hardly feasible because the energy expenditure of fliers varies within fairly broad limits from day to day and it may amount to 4000 kcal (O. P. Molchanova, A. F. Legun). On such days a ration with a small caloric content would clearly be inadequate.

It is difficult to say whether excessive calories in the diet is the cause or only a precondition of obesity. It is a generally known fact, confirmed by special investigations, that in healthy young people the energy balance is regulated by quite accurately determined physiological mechanisms. Such persons do not become corpulent regardless of the amount of food they eat (I. M. Buznik, 1951). Hence, obesity develops not because of the food eaten but because for some reason regulation of its utilization has been impaired. The reason is to be found in metabolic impairment which makes overeating possible. If this is so, reducing the caloric content of the ration will not by itself overcome obesity unless, of course, the ration is clearly inadequate.

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[1]For greater clarity and exposure of the dynamics, the results of weighing will be represented graphically.

The connection between metabolic impairment and obesity is sometimes obvious, as in endocrine disorders. The more frequent development of obesity in older persons can also be linked to a change in metabolism. Age increases the activity of the diencephalic-hypophyseal system, which is involved in regulating lipid metabolism, endocrine and liver function, etc. Neuroses, obesity, and other metabolic disorders arise as a result.

Obesity is often attributed to inadequate physical activity. The relationship between the latter and amount of energy expended is beyond doubt. The greater the physical exertion, the more energy is expended and the less opportunity for excess depositon of fat. However, even here is it more difficult to prove a causal relationship than appears at first sight. It is not quite clear why, for example, slight physical activity contributes to the development of obesity in some persons, whereas it has no effect on the weight of others.

The psychological factor, including the attitude to food, although usually underestimated, is of considerable importance. Unnecessary stimulation of the appetite with alcoholic drinks and spicy food and poor family habits with respect to overeating also promote obesity. Hereditary predisposition may be another factor.

Thus, the main reason for obesity is impaired regulation of metabolism. An excess food intake and slight physical activity are factors in the development of obesity but not the causes. Autonomic-endocrine disorders, hereditary predisposition, and the psychological factor may also play a role in the process. The extent to which metabolic disorders may be caused by flying is not clear.

It is extremely difficult to cure obesity. What are required are easily applied methods and instructions that will not be left on the paper on which they are written. It is sometimes recommended that a special menu be prepared for fat people, noting the amount of food consumed and the chemical composition. But this would require special personnel and it would not be of much value because calculations of the caloric content of a diet will mean very little unless the amount of energy expended is known. Only a rough guess can be made as to the energy likely to be expended in a given physical activity. For this reason we think it is fundamentally impossible artificially to regulate the energy balance. The fact is we can only reduce the caloric content of a diet and bring it to a point where it will cause partial starvation and a lowering of efficiency.

Most methods of weight reduction are unfortunately linked to sharp limitations on food intake (M. N. Yegorov and L. M. Prostyakov, 1957; Tanhauser, 1934; Norden, 1930; Banting and Epstein, 1887; others). Such methods are impracticable in a flying unit because a marked limitation of caloric content might result in weakness, ready fatigability, and sharp impairment of efficiency.

Experience has also shown that the results of such treatment are not permanent, for the weight lost is regained fairly quickly. The reason for this, we believe, is the crudeness of the methods based on dietary restrictions. Sharp limitations on food intake cause powerful, adequate stimulation of the receptors that regulate the energy balance. The result is appetite stimulation and a change in attitude toward food and treatment.

Study of the pathogenesis of obesity suggests another approach. Obesity should be eliminated as slowly and as imperceptibly as it develops. This requires rather minor dietary restrictions. A slight reduction in the portion to be eaten will sometimes be effective. By regulating the intake of food and observing his weight, every obese person can stabilize and then reduce it. It must be borne in mind that without the active cooperation of the individual, nothing will succeed. Even if his food intake is restricted, the weight may remain unaltered because a fat person can decrease the expenditure of energy by reducing his physical activity.

Increased physical exertion could well play an important part in the prevention and treatment of obesity. Physical exercise, sports, hiking, tourism, and hunting are other useful ways of normalizing the energy balance. They confer the additional benefit of increasing the functional capacity of the body, especially that of the cardiovascular system.

FUNCTIONAL EVALUATION OF BLOOD CIRCULATION FROM CHANGE IN CIRCULATION EFFECTIVENESS. VALUE OF THE METHOD IN SELECTING AND TRAINING FLYING PERSONNEL

P. V. Buyanov

Methods of functional evaluation of blood circulation are essential for the selection, preparation, and training of flying personnel. They are useful in studying the compensatory-adaptive capabilities of the body in response to flight factors. Supervision of the course of training and prevention of damage to the adaptive mechanisms are particularly important.

The method of recording tacho-oscillograms and oscillograms makes it possible to judge the functional adequacy of blood circulation from the condition of the main indices of hemodynamics, each of which throws light on a particular phase of hemodynamics. Only the minute volume of circulating blood can characterize cardiovascular function. However,

the absolute values of the minute volume have no independent meaning considered apart from gas exchange because cardiac activity is directed wholly at providing the body with the nutrients it requires, chiefly oxygen, in adequate quantities and at the right time. The relationship between the metabolic processes and cardiac output has long been known (Linhard, 1915; Lundsgaad, 1915; Ewig, 1931; Bauman and Grolman, 1931; N. N. Savitskiy, 1935; others). Thus, the minute volume can give us an idea of the functional sufficiency of blood circulation only when correlated with the metabolic processes. Savitskiy was quite justified in introducing the concept of an obligate (proper) minute volume needed for normal oxidation under the conditions of basal metabolism. Later studies demonstrated the practical value of the concept of "obligate minute volume" in functional diagnosis of the blood circulation in various pathological processes (S. O. Vul'fovich, 1935; B. A. Ivanovskiy, 1935; V. P. Nikitin, 1950; P. V. Buyanov, 1958; others).

The method of evaluating the obligate volume has two main shortcomings. First, the volume is calculated from tables of the proper basal metabolism; the actual gas exchange characteristic of a given subject under certain conditions is not taken into account. Second, it does not permit a comparison to be made of the cardiovascular system after measured loads. In aviation, space, and sports medicine practice, the functional adequacy of the cardiovascular system is determined chiefly from its reaction to load tests and tolerance of occupational factors.

In 1958-1963 we conducted investigations in which we simultaneously studied oxygen utilization and cardiac output both under the conditions of complete physical rest and after various actions (measured physical exercise, breathing at a high pressure, oxygen deficiency, influence of hypodynamia). Thirty deep squats a minute served as the test involving measured physical exercise. Breathing at a high pressure (300 mm H_2O) continued for 10 minutes. Gas mixtures with an oxygen content of 8.0-8.5 percent (duration of respiration 10-15 minutes) and 9.3-10.5 percent (duration 30-60 minutes) were used in the oxygen deficiency test.

The hemodynamic indices were determined from tacho-oscillograms and oscillograms recorded on a mechanocardiograph designed by N. N. Savitskiy. The cardiac output was found graphically by Bremzer and Tanke's method as modified by Liliestrand and N. N. Savitskiy, oxygen utilization - by Haldane's method (245 observations) and Belau's method (101 observations).

Since the cardiac output is a function of gas exchange and the functional adequacy of the cardiovascular system is proportional to the economy with which the volume of circulating blood is used with an equal amount of utilized oxygen, we introduced an index of blood circulation effectiveness. This index is determined from the volume of blood used

per 100 m^3 of oxygen utilized by the body. The less blood used per unit of oxygen utilized, the more effective blood circulation is.

A total of 346 investigations were conducted under the conditions of complete physical rest. The index of circulation effectiveness averaged 2.04 liters (between 1.60 and 2.48). In most cases, the values of the index were similar in repeated investigations of the same person.

In our opinion, the index indicates the degree of efficiency of cardiovascular regulation with respect to gas exchange. Despite systematic exposure of the men to different aviation factors within the limits of their endurance, the index of circulation effectiveness either did not change or it even dropped appreciably. The latter was apparently caused by the development of compensatory-adaptive reactions and indicates that the men were well trained to cope with these factors. In some of the subjects, systematic exposure to high pressure, high temperatures, and prolonged restriction of movements substantially increased the volume of circulating blood needed for the body to use the given amount of oxygen. The latter indicates that the influence of the above-mentioned factors was beyond the compensatory capabilities of the body. Cessation of the actions and establishment of a suitable regime generally caused a return of the index of blood circulation effectiveness to normal.

Blood circulation effectiveness was low in some of the subjects. As a rule, they had a large volume of blood in relation to the oxygen utilized. These persons had little endurance and ability to adapt to various aviation factors. Some of them eventually suffered impairment of the cardiac rhythm and had hypertensive reactions.

The effectiveness of the blood flow increased after measured physical exercise. The index of blood circulation effectiveness in the healthy persons ranged from 0.78 to 1.22 liters (1.00 on the average). Five minutes after the exercise it rose in most instances to the original level or near it. Persons with poor adaptability to environmental changes, including some with hypertension and neurocirculatory dystonia, responded to the physical exertion with a much smaller decrease in the effectiveness index. More economical blood circulation during physical exercise is, in our opinion, an extremely important adaptive mechanism which ensures a large increase in the energy requirements of the body with minimum exertion of the cardiovascular system. In our observations, after measured physical exercise, the cardiac output rose by 65 percent on the average while the utilization of oxygen increased 3.23 times.

The adaptive reactions of the blood circulation to the energy requirements of the body are based on the neuroendocrine connections of the cardiovascular system with tissue metabolism that guarantee a prompt and adequate response of the arterioles and capillaries to the requirements of tissue metabolism. Evidence for this also comes from the

direction and phase quality of the changes in the effectiveness index during oxygen deficiency and breathing at a high pressure. There were likewise individual differences in the responses due to qualitative characteristics of the adaptive mechanism.

The following conclusions seem reasonable:

(a) The differences observed in blood circulation in relation to oxygen utilization are connected with the state of the mechanisms of blood circulation regulation.

(b) The value of the index of circulation effectiveness when the body is at rest and undergoing various functional loads is of value in qualitatively characterizing the functional state of blood circulation in satisfying the energy requirements of the body.

(c) An evaluation of blood circulation effectiveness in relation to oxygen utilization makes it possible to control more precisely the systematic actions of various flight factors on the organism and to determine the conditioning needed to be able to withstand them.

FUNCTIONAL CHANGES IN THE CARDIOVASCULAR SYSTEM AFTER EXPOSURE TO HYPODYNAMIA

Yu. V. Vanyushina

In the course of human phylogenesis and ontogenesis, the cardiovascular system acquired, and is constantly training adaptive reflex mechanisms to maintain blood circulation at an appropriate level under the conditions of gravity. Movement, physical exertion, and change in bodily position regularly stimulate the cardiovascular system. Thus, the central nervous system receives a steady stream of impulses from the cardiovascular receptors and activates the reflex mechanisms that regulate blood circulation. Under the conditions of weightlessness this stream of impulses might be expected to diminish considerably in view of the limited muscular activity and complete exclusion of the force of gravity in changing from a horizontal to a vertical position and vice versa. We therefore thought it would be interesting to determine how the cardiovascular reflexes that resist gravity might change in human beings required to remain a long time in circumstances that limit reflex impulses from the muscles and cardiovascular system.

Two series of experiments were performed. The first series involved subjects immobilized for 5.5-10.5 days in a special armchair in a position

of maximum muscular relaxation. The second series was performed with subjects who remained suspended in a tank of water for 5.5-11.5 days. In both series of investigations the subjects were assigned a regime of maximum limitation of movements. The ground series consisted of 6 experiments, the water series, of 3. All the subjects were essentially healthy males, 20-22 years of age.

An orthostatic test was used to evaluate the mechanisms of the cardiovascular system responsible for adaptation to the force of gravity. A change in bodily position from horizontal to vertical causes gravitational forces to act on the blood. Due to hydrostatic pressure the blood rushes down to the blood vessels of the abdominal cavity and extremities. In the development of compensatory mechanisms, the effect of hydrostatic pressure is compensated by an increase in vascular tone. With inadequate compensation the aforementioned hydrostatic phenomena cause the abdominal blood vessesl to dilate and overflow with blood while the other parts of the body, including the brain, become anemic. In the former, the maximum blood pressure either does not change or actually increases owing to hypercompensation; in the second, it drops unless it is secondarily compensated by an increase in the force and frequency of cardia contractions.

Two types of orthostatic tests were used. One involved a table turning along the horizontal axis with passive change of the subject's position from horizontal to vertical. The pulse rate and arterial blood pressure were measured every minute for 10 minutes before rotation and for 5 minutes afterward. The second test involved the subject's actively changing from a sitting to a standing position. The same cardiovascular indices were studied after 10 minutes in a sitting position and 1 minute after changing to a standing position.

In taking the orthostatic test before exposure to hypodynamia, all the subjects felt well with a pulse acceleration of 10-12 beats per minute. The maximum blood pressure reaction ranged from -2 to +8 mm Hg, the minimum, from +15 to +20 mm. According to the literature (A. L. Vilkovyskiy, Martinet, Waldvogel, A. Gitter, and others), this is equivalent to the normal reaction to a change in bodily position from horizontal to vertical.

After prolonged exposure to hypodynamia, the cardiovascular reaction to the orthostatic test changed considerably. Acceleration of the pulse was greater than before the experiment by 20-49 beats per minute. In the experiments with hypodynamia for 5.5 days, we noted a slight impairment of blood pressure regulation. The impairment was greater in the experiments involving a longer exposure, i.e., a marked lowering (by 20 or more mm Hg) of systolic pressure after the orthostatic test.

After long exposure to the water simulation of weightlessness, dysfunction of the reflex mechanisms regulating cardiovascular activity

was even more pronounced, e.g., extreme tachycardia (acceleration of the pulse by 50-74 beats per minute) and a sharp drop in systolic blood pressure (by 26 mm Hg). The minimum blood pressure showed a tendency to rise. A sharp drop in maximum blood pressure with a simultaneous rise in minimum pressure caused a marked decrease in pulse pressure (about 8-12 mm Hg). In some cases the subjects felt dizzy after rotation.

We thought it would be interesting to study the chronotropic activity of the heart (by N. P. Razumov's method) with an unconditioned orthostatic stimulus while administering the above-described tests. Such a stimulus activates the nerves that accelerate the cardiac rhythm. The method is useful in judging the speed with which the regulatory mechanisms of the heart are engaged after a change in position. After hypodynamia we observed an increase in the intensity and, in some cases, a slowing of the rate of development or pathological ability, instability of the orthostatic and clinostatic reflex.

Observations of the change in intensity and rate of development of Aschner's oculocardiac reflex revealed some sluggishness in the cardiovascular reflexes after hypodynamia. After the subjects remained in the armchair or water for a considerable period of time, the oculocardiac reflex decreased while the rate at which it developed slowed.

Thus, in human beings remaining for a long time under the conditions of limited mobility, while lying in an armchair or in water, the adaptive reactions of the cardiovascular system to the force of gravity decrease. The weakening of these mechanisms is manifested, during an orthostatic test, in a sharp acceleration of the pulse, drop in systolic and pulse pressure, and slight cerebral anemia, as shown by vertigo.

One of the reasons for the decrease in the compensatory reaction of the cardiovascular system to postural changes may be dysfunction of the neuroreflex mechanisms that regulate cardiovascular activity, as shown by decreased intensity, sluggishness, and unstable development of the cardiovascular reflexes (in orthostatic and clinostatic tests, Aschner's reflex).

After prolonged exposure to weightlessness and return to gravitational conditions, the preservation and maintenance of cardiovascular reactions to the force of gravity are essential for the successful completion of a flight. Hence, to enable man to remain in a weightless state for a long period of time, it is highly important to devise ways and means of preventing impairment of regulation of the cardiovascular system.

EFFECT OF SOME DRUGS ON TOLERANCE OF ACCELERATIONS

P. V. Vasil'yev and V. Ye. Belay

The problem of increasing bodily resistance to the effect of accelerations that occur at certain portions of flights of airplanes and spacecraft is exceptionally important. Practical use is now made of such methods as having the pilot assume a certain position with respect to the acceleration vector, suitably designed seats, G-suits, physical conditioning, etc. There are references in the Soviet and foreign literature to the possibility of increasing resistance to accelerations by using immersion systems (E. H. Wood et al., 1943; G. P. Mirolyubov, 1961; Blake-Shador, B. Hensley, and R. Simmons, 1961; B. Blake-Sheffer, 1962; Silvan James, 1962; others), hibernation ("anabiosis") on space flights (S. Pernes and A. Smith, 1960; B. Blake-Sheffer et al., 1961), and drugs (V. Ye. Kolla, 1953; K. G. Vasil'yev et al., 1957; R. Amirov, 1961; V. I. Danileyko, 1962; A. Skano and G. Meyneri, 1961; Greyner, 1956). This last approach deserves especial attention and study because a knowledge of the pharmacodynamics of the compounds, the nature of their effect on different organs and systems, and the genesis of disturbances can be used to change the reactivity of the body and increase its resistance to various factors.

This report[1] presents some data obtained in experiments with sympathomimetic amines (epinephrine, norepinephrine, amphetamine, phenatine [condensation product of amphetamine and nicotinic acid], and ephedrine) and anesthetics (chloral hydrate and pentothal sodium). Most of the experiments were performed on white mice, a few on white rats, rabbits, and dogs. The mice were the principal experimental animals because a great many of them could be used. The survival rate was the criterion of effectiveness in the experiments on the white mice and rats, while changes in cardiovascular activity as traced on the EKG (standard leads) and in respiration served this purpose in the experiments on the rabbits and dogs.

Accelerations were produced in centrifuges with a radius of 31 cm for the mice and rats and 3.7 m for the rabbits and dogs. In all the experiments, the accelerations were transverse to the longitudinal axis of the body.

Solutions of the drugs prepared just before use were injected intraperitoneally into the mice and rats and intravenously, subcutaneously, or intramuscularly into the rabbits and dogs. The doses, methods, and

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[1] S. P. Kolchin and Ye. S. Sviridova participated in the research.

times the drugs were injected and the intensities of the accelerations applied in the individual experiments are noted below in the descriptions of the results.

The very first experiments on rabbits subjected to accelerations of 9 units for 6 minutes revealed that intramuscular injection of 0.17 mg/kg of norepinephrine 15-30 minutes before rotation led to a delay in the onset of bradycardia, which, in the opinion of most investigators, indicates a breakdown in the compensatory-adaptive mechanisms of the cardiovascular system.

These findings are in complete agreement with the results of the experiments of A. Skano and G. Meyneri (1961) with positive accelerations. We emphasize that in our experiments not only did cardiac activity in the compensation stage persist longer in response to the accelerations, but, what is just as important, the degree of decomposition, judging from the bradycardia, was much less pronounced.

Some experiments with intravenous injection of 0.025 mg/kg to 0.1 mg/kg of norepinephrine 2-3 minutes before rotation produced contradictory data, which required special experimental analysis. The results of the investigations on the white mice were equally contradictory. In some experiments there was a marked increase in the survival rate, but a decrease in others. It was impossible here to detect any relationship between the dose of the drug (from 0.2 mg/kg to 5 mg/kg) or time it was injected (from 10 to 60 minutes before rotation).

The administration of 0.1-1 mg/kg of epinephrine to white mice had similar results. For example, when determining the effectiveness of epinephrine from the LD_{50} in one experiment, the resistance of the animals to the accelerations increased by 6.5 units, but decreased by 5.2 units in another.

Thus, the results of our investigations do not permit any final judgment on the effect of epinephrine and norepinephrine on the resistance of animals to accelerations. As noted above, besides these two drugs, we also tested amphetamine, phenatine, and ephedrine. The best results were achieved with amphetamine and ephedrine.

Experiments with amphetamine were performed on 792 white mice with a determination made of both the survival rate of the control and experimental animals exposed to a constant intensity (50-55 units) of acceleration and time of action (10 minutes) and the median lethal dose (LD_{50}) of acceleration measured by Berens' method (1929). A substantial number of experiments were run in order to determine the dose and time to inject the drug before rotation.

Table 1. Results of Determining Control and Experimental (Amphetamine) Mouse Tolerance of Lateral Accelerations by Berens' Method (LD_{50}) (Rotation Time - 10 Minutes)

No. of revolutions of centrifuge	No. of mice	Experimental data		Integration			Mortality rate, %	LD_{50}[1]
		Died	Survived	Died	Survived	Total		
340	4	0	4	0	18	18	0	
360	4	1	3	1	14	15	6.6	
380	4	2	2	3	11	14	21.2	
400	4	3	1	6	9	15	40.0	
420	4	1	3	7	8	15	46.7	61.0 Units
440	4	2	2	9	5	14	64.3	
460	4	3	1	12	3	15	80.0	
480	4	2	2	14	2	16	87.3	
500	4	4	0	18	0	18	100.0	
340	4	0	4	0	23	23	0	
360	4	1	3	1	19	20	5.0	
380	4	1	3	2	16	18	11.0	
400	4	1	3	3	13	16	18.7	
420	4	1	3	4	10	14	28.3	69.7 Units
440	4	1	3	5	7	12	41.7	

Table 1 (Continued)

No. of revolutions of centrifuge	No. of mice	Experimental data		Integration			Mortality rate, %	LD_{50}[1]
		Died	Survived	Died	Survived	Total		
460	4	1	3	6	4	10	60.0	
480	4	3	1	9	1	10	90.0	
500	4	4	0	13	0	13	100.0	

[1]The intensity of acceleration was determined from the formula $n = \frac{N^2 \cdot R}{900}$, where n is the intensity of acceleration, N is the number of revolutions, and R is the size of a centrifuge arm in meters.

The results showed that after intraperitoneal injection of 0.8-1 mg/kg of the drug 15-30 minutes before acceleration, the resistance of the mice, as determined from the LD_{50}, rose. For example, resistance in the animals given 0.9 mg/kg of amphetamine was 8.7 units higher than in the control (Table 1).

After a dose of 0.1-3.0 mg/kg, the positive effect of amphetamine decreased, but after a dose of 5.0 mg/kg the effect was negative.

Highly satisfactory results were also obtained with the other sympathomimetic drug - ephedrine (Table 2).

It is evident from the figures in Table 2 that the most potent effect followed intraperitoneal injection of 0.5 mg/kg of ephedrine. Halving the dose reduced to zero its effect on the animals' resistance to accelerations, while increasing the dose decreased the positive effect.

The experiments in which the LD_{50} was determined revealed that injection of 1.0 mg/kg of ephedrine increased the experimental mice's resistance by about 7 units as compared with the control (from 47.5 to

Table 2. Effect of Ephedrine on the Survival Rate of Experimental and Control White Mice Subjected to Lateral Accelerations with an Intensity of 55 Units

Group of animals	No. of mice in the group	Outcome		Survival rate, percent
		Died	Survived	
Control	20	14	6	30
0.25 mg/kg of ephedrine	20	14	6	30
Control	38	30	8	21
0.5 mg/kg of ephedrine	38	24	14	36.9
Control	60	44	16	26.6
1.0 mg/kg of ephedrine	60	40	20	33.4

54 units). Increasing the dose to 10.0 mg/kg reduced the LD_{50} from 47.5 units in the control to 44.6 units in the experimental group.

Experiments are now under way on rabbits. Intramuscular injection of 20.0 mg/kg of ephedrine had a negative effect, but 5.0 mg/kg had a slight positive effect. Experiments with this drug are continuing, mainly to find the optimum effective dose and optimum times of injecting the drug.

Thus, the results of our experiments and the published data (T. Greyner, 1956; A. Skano and Meyneri, 1961; others) indicate that several sympathomimetic amines have a distinctly favorable effect on resistance to accelerations. The mechanism of this action is still unclear. To attribute it solely to the effect on vascular tone, as some authors do, is scarcely possible. The increase in resistance is evidently due to the more complex nature of the action of the drugs on several functional systems (cardiovascular, nervous, endocrine, etc.). Special investigations will be needed to elucidate these mechanisms.

To date little systematic work has been done in studying the effect of anesthetics on tolerance of accelerations. In his dissertation, V. I. Danileyko (1962) merely mentions that in experiments on white rats he observed a 16-40 percent increase in the survival rate as compared with the control after subcutaneous injection of 50 mg/kg of sodium amytal.

On the other hand, according to the incidental observations of B. S. Savin, anesthetized dogs showed a deterioration in the condition of the

compensatory mechanisms responsible for keeping blood pressure in the vascular bed constant. Intact animals withstood circulatory impairment after exposure to accelerations up to an intensity of 5-6 units; anesthetized animals did so only up to an intensity of 2-3 units.

We studied the effect of two anesthetics on tolerance of accelerations: chloral hydrate, which acts chiefly on the cerebral cortex, and pentothal sodium, which acts chiefly on the subcortex. We tested both large doses, which caused deep anesthesia with a loss of reflexes to pain, and small doses, which produced only mild general inhibition, as manifested in decreased motor activity and sleepiness.

Experiments on white mice and rats revealed that the injection of 200 mg/kg of chloral hydrate 15 minutes before the start of rotation increased resistance by 2-10 units, as determined from the LD_{50}, whereas a 400 mg/kg dose reduced it from 65 to 48 units.

A dose of 30 mg/kg of pentothal sodium increased tolerance of acclerations by 4-19 units, but a 100 mg/kg dose reduced it by 14 units.

The variable response to the same doses of anesthetics (all the other conditions were equal) was evidently caused by individual peculiarities both in the reaction to the anesthetic and in the reaction to subsequent exposure to the accelerations. The negative results of the experiments with large doses of chloral hydrate and pentothal sodium were probably due to a lowering of the function of the compensatory-adaptive mechanisms of the organism in response to the unusually strong environmental stimuli. Similar results were obtained in many other investigations (Ye. V. Guber, 1950; T. Ye. Kudritskaya, 1950; I. R. Petrov, 1952; others) dealing with the effect of different forms of oxygen deficiency.

Thus, analysis of our own and published data show that by using drugs to change the functional state of the organism, one can increase its resistance to accelerations.

The aim of future investigations should be to find highly effective and conveniently administered drugs that most satisfy the requirements of specific flights.

STRUCTURAL AND CYTOCHEMICAL INVESTIGATIONS OF THE UTRICLE UNDER THE CONDITIONS OF RELATIVE REST AND AFTER EXPOSURE TO ACCELERATIONS

Ya. A. Vinnikov, O. G. Gazenko, L. K. Titova, A. A. Bronshteyn, and V. I. Govardovskiy

1. Although the significance of the utricle (a membranous sac located in the vestibular part of the labyrinth) in maintaining muscular tone has been adequately studied, the mechanism of function of this organ, which senses the position of the human and animal body in a gravitational field, is still obscure. Studies of its substructural and cytochemical organization both under the conditions of relative rest and after exposure to accelerations or weightlessness are of considerable interest in this respect. They may well provide the key to an understanding of the mechanism and regulation of function of the organ under the aforementioned conditions.

2. An electron microscopic study of the utricle of mammals (guinea pigs and rhesus monkeys) and birds (pigeons) at relative rest revealed the presence of evolutionary gradations reflecting the ecological conditions of locomotion of these animals in a gravitational field. The utricle of these animals contains columnar hair cells supplied with button-like synapses, as well as jug-shaped sensory cells enclosed in cup-shaped synapses. In this cup the guinea pigs have only 1, the monkeys 2, and the birds about 5 hair cells. The substructural organization of the columnar hair cells differs from that of the jug-shaped hair cells with respect to the nucleus, shape, and size of the mitochondria, shape and location of the synaptic vesicles, structure of the synaptic membranes, etc. There are also differences in the distribution and location of the ribosomes, which in the hair cells are generally not underlain by membranes of the endoplasmatic network. In guinea pigs, the ribosomes are found only in the basal part of the sensory cell under the nucleus, whereas in monkeys and pigeons they can also be found in the apical part of the sensory cell. However, the distribution and structure of the hairs (of one kinocilium and cluster of stereocilia), which crown the hair cells and support the otolithic membrane with otoliths, remain unchanged in all the animals investigated.

3. Cytochemical investigations of the distribution and activity of several biologically active substances (DNA, RNA, total protein,

functional protein thiol and carboxyl groups, some mucopolysaccharides, oxidation enzymes, and acetylcholinesterase) in the hair cells of the guinea pig, monkey, and pigeon utricle under conditions of relative rest likewise revealed ecologically related resemblances and differences in cytochemical organization, which can be superimposed on the substructural equivalent and which characterize the basic energy processes of their vital activity. For example, RNA (bound with the ribosomes) in guinea pigs is generally located only in the basal part of the hair cell. In monkeys and pigeons, RNA (bound with the ribosomes) is located both in the basal part of the cell and at its apical pole. The activity of the oxidation enzymes in the mitochondria of the synapses of the utricle hair cells is more intense than in the intracellular mitochondria. Acetylcholinesterase is found in all cases only near the synapses. The content of total protein, functional groups, and mucopolysaccharides may vary in different utricle structures, but it remains unaltered in the hairs of the hair cells and otolithic membrane in all the animals investigated.

4. After accelerations of 10 g lasting 3 minutes and repeated 5 minutes, 1 hour, 2 hours, 3 hours, 8 hours, and 24 hours later, the hair cells of the animals revealed similar specific changes along with some differences related to the substructural and cytochemical organization of the different animals. The passage of nucleolar RNA from the nucleus into the cytoplasm observed in the basal part of the guinea pig hair cell after acceleration was confirmed and interpreted with the electron microscope. After the first rotation and, especially, after multiple ones, there was a polar "filtration" of the ribosomes through the pores of the nuclear membranes into the cytoplasm of virtually all the hair cells, where they induced the formation of a spherical area in the endoplasmatic network, in which intense protein synthesis seemed to take place. In the monkeys and pigeons, however, similar processes occurred mainly in the columnar hair cells with the button-like synapses.

The outer nuclear membrane in all the sensory cells becomes "detached" and forms characteristic folds, apparently due to changes in nuclear processes during intensified functioning caused by acceleration.

The decrease in activity of the oxidation enzymes after acceleration is generally accompanied by some swelling of the mitochondria and change in the electron density of their membranes and cristae.

The decrease in activity of acetylcholinesterase in the synaptic region is accompanied by some changes in the synaptic membranes and synaptic vesicles (containing acetylcholine) and in their relations with the mitochondria.

Finally, hairs of the hair cells (stereocilia) and the otolithic

membrane undergo changes in the location and content of some mucopolysaccharides after acceleration.

5. The changes in structural and cytochemical organization of hair cells in the synapses of the utricle after acceleration are apparently characteristic of them in a state of excitation and transmission of impulses. This state is accompanied by a chain of biochemical processes that take place in a strictly determined substructural location. These processes are related, first, to nucleic acid function (i.e., protein synthesis); second, to oxidation enzyme activity (i.e., tissue respiration); and, third, to acetylcholinesterase activity (i.e., the cholinergic mediator system).

Our findings throw some light on the mechanism of function of the organ of gravitation on the subcellular level of organization. There is reason to believe that it can be regulated under the conditions of space flight. However, the processes of specific stimulation of the utricle and the interlinking of its activity with the other receptor sections of the vestibular apparatus are still obscure. Their elucidation is on the research agenda.

OXYGEN SUPPLY OF THE HEART DURING RESPIRATION AT EXCESS PRESSURE

V. G. Voloshin

Numerous investigations have shown that respiration at excess pressure causes marked functional body changes, notably in the respiratory and cardiovascular systems: the heart assumes a heavy load and is compelled to function under unfavorable conditions. Data suggest that studies on the blood and oxygen supply of the heart under these conditions would undoubtedly be of theoretical and practical interest.

There are no experimental data in the Soviet and foreign literature on the state of the coronary blood flow, myocardial temperature and oxygen tension therein during respiration at excess pressure. The first investigations of this kind were carried out on dogs by a group of scientists under the direction of D. I. Ivanov, who found that excess pressure reduces the rate of blood flow in a phasic manner, extent of reduction varying with amount of excess pressure. After respiration is excluded, the rate of blood flow increases sharply, sometimes above the original level, after which it returns to normal. The use of a compensating suit slows the reduction in the rate of blood flow.

We performed a series of chronic and pressure-chamber experiments on the coronary blood flow of dogs breathing at excess pressure. The volumetric blood flow rate was determined by the thermometric method as modified by M. Ye. Marshak and recorded on an ink-writing instrument of the "Mikrograf" type. We constructed a special attachment that made it possible to record on highly sensitive scales using the entire width of the tape (210 mm). This attachment was later used to record the temperature. We recorded, also, the EKG, EMG, pneumogram, and pressure under a mask.

The operations, performed under sterile conditions, used morphine-urethan anesthesia, with artificial respiration carried out by M. Ye. Marshak and G. N. Aronova's method. The experiments were run after the animal recovered (starting the 7th day).

Blood-flow reactions did not differ significantly in the acute and chronic experiments, nor were any differences noted between the reactions of the intact and anesthetized animals in the chronic experiments.

After exposure to noncompensated excess pressure, there was generally a decrease in the coronary blood flow followed by a slight increase. Later, a slight temporary increase alternated with a decrease. In the acute experiments the blood flow reaction to excess pressure was more uniform and usually took place in three phases: decrease, partial increase, decrease. These differences in the blood-flow reaction of the intact and anesthetized animals may have been due to the fact that the adaptive reactions of the anesthetized animals were less complete. Moreover, there was no situational reaction or emotional factors, and individual characteristics were less pronounced.

The exclusion of excess pressure was accompanied by an increase in the blood flow above the original level followed by a return to normal. Sometimes there was an initial brief increase when the excess pressure was slight. When external compensation was used, there was a decrease in the blood flow after high (over 300 mm H_2O) excess pressure.

Altitude experiments, with oxygen supplied by a serial KKO-3 were carried out in a pressure chamber with a smooth increase in ambient pressure corresponding to altitudes up to 30,000 m followed by the animals remaining at the particular "altitude".

Elevation in the pressure chamber frequently caused an increase in the coronary blood flow--highly pronounced in some animals--and was most likely due to a manifestation of the orienting reflex to unusual stimuli (the situation and noise of the machinery operating the chamber). Apparently these changes became conditioned reflexes.

The turning on of excess pressure caused a more or less appreciable increase in the blood flow. In some animals, as the pressure and "altitude" increased, the blood flow decreased, giving way to an increase at high "altitudes". In other animals, this decrease did not occur and elevation was accompanied by an increase in blood flow. Starting with an "altitude" of 20,000 m (sometimes sooner, sometimes later), marked fluctuations frequently appeared on the blood-flow curve. When they remained at the particular "altitude" (30,000 m or 20,000 m in some animals), first a slow, then a steep, drop in the blood-flow curve down to zero on the instrument took place against a background of fluctuations in the blood flow. After the "descent", the blood flow increased sharply and remained for a long time above the original level.

The decrease in coronary blood flow when breathing at excess pressure suggests that the myocardium was inadequately supplied with oxygen under these conditions (there actually were EKG changes characteristic of myocardial hypoxia).

These findings led us to carry out additional investigations along the same lines. An acute experiment studied oxygen tension in the myocardium of the left ventricle by the polarographic method. When breathing at excess pressure, oxygen tension in the myocardium dropped in proportion to the amount of pressure. After the pressure was turned off, the polarogram slowly returned to the original level.

These results confirm our earlier finding that excess pressure causes myocardial hypoxia, the degree varying with the amount of pressure.

The temperature of the myocardium of the left ventricle was measured under the same conditions. Breathing at excess pressure regularly caused a distinct elevation of myocardial temperature after a decrease in the coronary blood flow. This increase may be sharply intensified in the case of poor tolerance of excess pressure and in some instances amount to 0.65° C even with slight excess pressure. With good tolerance of the pressure, the temperature rises more slowly and is periodically stabilized. However, even in these instances the temperature increase is of the order of 0.3-0.5°.

The use of external compensation significantly decreases these temperature changes. When the pressure is turned off, the temperature at first drops quickly, then slowly, but usually remains above the original level, stabilizing after 2-5 minutes.

An elevation of temperature in a functioning organ may be regarded as an index of the intensity of the metabolic processes and the concomitant heat production. There are indications that disruption of metabolism, e.g., interference with the cycle of oxidizing

phosphorylation, causes an increase in heat production.

Temperature changes appearing in the myocardium after exposure to excess pressure take place much more slowly than do blood flow changes. This is evidence in favor of the metabolic character of these changes. However, one must also take into account the state of the regional blood flow, which can apparently introduce its own corrections into the temperature of an organ. In this connection, it is pertinent to note that myocardial temperature always rises after a decrease in the coronary blood flow.

With reference to the condition of our experiment, it is more plausible to believe that the temperature of the myocardium reflects the relationship between heat production and heat removal from the blood flowing out of the functioning heart. At excess pressure this balance between heat production and heat removal is upset with a decrease in heat removal and, possibly, with an increase in heat productions as well.

ENSURING RADIATION SAFETY ON THE FLIGHTS OF ASTRONAUTS YU. A. GAGARIN, G. S. TITOV, A.G. NIKOLAYEV, AND P.R. POPOVICH

Yu. M. Volynkin, V. V. Antipov, N. N. Dobrov,
M. D. Nikitin, and P. P. Saksonov

Recent advances in science and technology have made it possible to study the physical parameters and biological effects of cosmic radiation, and to ensure the radiation safety of space flights.

In an orbital flight of the Vostok, the astronaut is exposed to primary cosmic radiation (galactic rays) and bremsstrahlung arising from the interaction of electrons in the outer radiation belt with the shell of the vehicle. Nor can one rule out the possibility of slight irradiation by protons of the inner radiation belt, which comes down, e.g., in the region of the Brazilian magnetic anomaly, to altitudes of 230-320 km.

According to the data of S. N. Vernov et al. and V. Ye. Nesterov et al., at altitudes of 180-340 km with a 65° tilt in the orbit, approximately 90 percent of the absorbed dose is due to primary cosmic radiation, 10 percent to radiation of the earth's radiation belts. It will be noted that primary cosmic radiation is composed of strongly ionizing heavy nuclei which may produce nuclear splitting ("stars") in a

biological object. In view of the biophysical characteristics of the action of the heavy component, it is to be expected that the biological effectiveness of this kind of radiation will be substantially higher than the effectiveness of X-rays or γ-rays.

Measurements made on satellites 2-5 and the Vostoks showed that at these heights the integral daily dose of radiation fluctuates between 8 and 15 millirads (mrad). It is obvious that even with allowance made for the high biological effectiveness of the heavy component of primary cosmic radiation, the radiation dose received during short flights at altitudes of 180-250 km is not dangerous.

A real threat to the astronaut's health at these altitudes comes from the protons produced during chromospheric flares on the sun. Solar protons possess an energy of several Mev to 700 Mev, although in some cases they may attain an energy of several Bev.

After major solar flares, the intensity of cosmic radiation at great distances from the earth grows a 1,000-fold and even 10,000-fold outside the magnetic field, causing a vast increase in the doses up to lethally dangerous levels of the order of 500 rad or more. On orbits of the Vostoks, the screening effect of the earth's magnetic field has an effect, the radiation dose decreasing to several dozen rad per burst. Since solar flares do not occur at regular time intervals the probability of striking a flare of varying intensity depends on the average probability of its appearance and the duration of the flight.

Besides the protons of solar flares, astronauts Nikolayev and Popovich were endangered by the ionizing radiation caused by the high-altitude nuclear blast set off by the U.S. over Johnston Island in the Pacific on July 8, 1962.

In light of the foregoing, the radiation protective measures for the Vostok flights called for:

(a) Forecasting the radiation situation in space.

(b) Measurement of the integral dose and dose rate on the spaceship itself.

(c) Biological dosimetry of cosmic radiation.

(d) Use of antiradiation drugs in emergency situations.

A service was organized to forecast radiation activity in space, which observed solar activity both before and during the flight. Astrophysical observatories and heliophysical stations in different parts of the Soviet Union made continuous optic, magnetic, and radio observations

of the sun. In addition, the intensity of radiation in the upper layers of the atmosphere was directly measured by instruments carried on sounding balloons sent up 6-8 times a day from different parts of the USSR, including the polar regions. The information thus obtained was of great value to the flight managers.

Radiation safety was enhanced by (1) structural features that prevented cosmic radiation from penetrating the cabin of the spacecraft and protected it from the effects of the radiation caused by the high-altitude nuclear blast, and (2) antiradiation drugs to be taken in case the radiation situation deteriorated greatly.

Vostok and Vostok 2 were monitored by individual ILK and IFK dosimeters and thermoluminescent glasses. The total dose absorbed by Gagarin and Titov was 0.6 ± 1.5 mrad and 12 mrad, respectively. Due to the greater length of the flights of Vostok 3 and Vostok 4, special dosimeters were installed and the readings were transmitted via telemetry to ground observation stations. Moreover, the set of individual dosimeters was increased. A. F. Nikolayev and P. R. Popovich had a DKP-50, thick photoemulsions, etc. besides the dosimeters available to Gagarin and Titov.

According to the dosimeters on board, the total dose during the flights of Vostok 3 and Vostok 4 was 43 ± 1 mrad and 32 ± 1 mrad, respectively (C. N. Vernov, I. A. Savenko et al.). The readings of the individual DKP-50 dosimeters did not exceed the errors caused by self-discharge. According to the data provided by the individual dosimeters placed on the astronauts, Nikolayev's absorbed dose ranged from 48 to 64 mrad, Popovich's - from 37 to 46 mrad (I. B. Keyrim-Marjus et al.).

The set of detectors of ionizing radiation placed in the living quarters made it possible to evaluate the radiation conditions in which the biological experiments were performed. Judging by the thick photoemulsions and scintillation counters, the integral dose in these areas on Vostok 3 and Vostok 4 was 56 ± 8 mrad and 45 ± 7 mrad, respectively, during the flight. The contribution of the charged particles to the integral dose constituted about 40 percent of the amount, some two-thirds of the contribution consisting of heavy nuclei (Z 1).

According to the data provided by the IFK and ILK dosimeters, the total dose during the flight was about 50-60 mrad (V. N. Lebedev, V. S. Morozov et al.). Thus, the mean dose rate of radiation during the flights of Vostok 3 and Vostok 4 was 13 ± 2 mrad/24 hours, i.e., it was above the dose rate on the Vostok (7.2 mrad/24 hours) or Vostok 2 (8.4 mrad/24 hours). The increase in dose rate may have been due to possible residual radiation arising from the high-altitude nuclear blast of July 8, 1962.

It is evident from the above-mentioned measurements that the integral doses detected by various methods agree with each other within the limits of measurement errors. These doses do not exceed the standards established for persons working with sources of penetrating radiation and they do not endanger human health.

Besides various instruments, the spacecraft carried an assortment of biological specimens (air-dried plant seeds (wheat, pea, onion, pine, cabbage, beet, etc.), microspores of Tradescantia paludosa, a lyosogenic culture of E. coli K-12 (λ), Drosophila melanogaster, human cancer cells, and Ascaris suum eggs) for biological monitoring of cosmic radiation and for investigation of the injurious effects of space flight factors, including ionizing radiation, on hereditary structures and physiological functions of the individual cell and of the organism as a whole.

It will be noted that the results of the radiobiological investigations agree very nicely with the physical measurements. These experiments showed that genetic tests can be used to determine the injurious effect of space factors on the hereditary structures of certain objects. For example, various disruptions of mitosis were discovered in wheat shoots (V. V. Khvostova et al.), tradescantia microspores (N. L. Delone et al.), an inducing effect in lysogenic bacteria, etc. (N. N. Zhukov-Verezhnikov et al.). These changes were probably caused by a number of flight factors, including ionizing radiation. It is also possible that such factors as vibration and accelerations may sensitize certain objects to cosmic radiation and thereby permit ionizing radiation to become effective in much smaller doses. On the other hand, the physiological methods used failed to detect any significant changes in the activity of other objects under the influence of flight factors.

Clinical observations and special laboratory tests made on Gagarin, Titov, Nikolayev, and Popovich at regular intervals since their flight also clearly confirm the fact that cosmic radiation did not impair their health.

It may therefore be stated that results to date testify to the effectiveness of the measures used to ensure radiation safety during manned flights on spacecraft of the Vostok type.

CHANGES IN CARDIAC ACTIVITY DURING PROLONGED LATERAL ACCELERATIONS

A. D. Voskresenskiy

Experiments herein described stem from this fact: intense lateral accelerations may cause myocardial hypoxia and cardiac disorders (Muller, 1961; Barer, 1962; C. Vacca and L. Vacca, 1962). In acute experiments on anesthetized dogs, we investigated the oxygen content of blood specimens obtained before and during accelerations (from an artery and coronary sinus), measured the amount of blood flowing out of the sinus in 1 minute, and recorded EKGs in standard leads. Respiration was maintained with a DP-2 apparatus and constant ventilation. Accelerations of 3, 6, and 9 g lasted 1, 4, and 1 minute, respectively. In 91 experiments, a tray with a dog was secured at a 90° angle to the inertial force (back-chest acceleration; in 14 experiments - at a 45° angle (equal back-chest and pelvis-head components of acceleration).

The oxygen content of arterial blood in the first minute of accelerations of 3 and 6 g remained at about the original level. In the 4th minute of acceleration of 3 g, it decreased moderately in most cases; in the 4th minute of acceleration of 6 g, the decrease was generally very sharp. Acceleration of 9 g significantly reduced the O_2 in the first minute.

The relationship between O_2 content of arterial blood and intensity and duration of acceleration is clearly reflected in the change in mean values (Table 1).

In the blood flowing out of the coronary sinus, the mean O_2 content decreased in the entire series of experiments (Table 2). A comparison of the figures in Tables 1 and 2 shows statistically validated correlation between the degree of decrease in O_2 in arterial and venous coronary blood.

It is also worth pointing out that the amount of oxygen in coronary sinus blood decreased even in the many experiments where the oxygen content of arterial blood rose (the 3 g, 1 minute series).

In the first series of experiments the arteriovenous difference in oxygen increased somewhat on the average; in series 2 and 3, there was virtually no change; in series 4 and 5, it decreased. An unusually large decrease in the arteriovenous difference occurred in the 4th minute of an acceleration of 6 g owing to a sharp reduction of O_2 in arterial blood.

Table 1. O_2 content of arterial blood specimens before and during accelerations

Nature of Action	3 g, 1 minute	3 g, 4 minutes	6 g, 1 minute	6 g, 4 minutes	9 g, 1 minute
No. of experiments	30	14	30	15	16
Before acceleration	16.4±0.57	16.3±0.46	16.3±1.3	16.4±1.7	16.5±1.2
During	16.8±0.71	15.1±0.85*	16.0±1.4	12.0±1.7*	13.3±1.1*

Note. The ± sign is followed by the value of the standard deviation of the mean value; * statistically significant difference in mean values.

Table 2. O_2 content of blood flowing out of the coronary sinus before and during acceleration

Nature of Action	3 g, 1 minute	3 g, 4 minutes	6 g, 1 minute	6 g, 4 minutes	9 g, 1 minute
No. of experiments	30	14	30	15	16
Before acceleration	5.3±0.41	4.8±0.49	4.0±1.99	5.2±1.87	4.9±0.61
During	4.7±0.48	3.4±0.45*	3.5±0.90	3.0±1.0*	3.7±0.52*

Although the rate of blood outflow from the coronary sinus usually rose substantially, it dropped in a relatively small number of experiments, rarely exceeding 25 percent of the initial value.

EKG changes generally corresponded to those described by other authors after lateral accelerations, the degree of change varying considerably from experiment to experiment and showing a distinct connection with the dynamics of outflow from the sinus. In the experiments in which the rate of outflow increased, the EKG changes were comparatively slight and quickly disappeared after the centrifuge was halted. The pulse rate remained constant throughout. Only in rare cases was there sinus arrhythmia and solitary ventricular extrasystoles. In the experiments with decreased outflow, all EKG changes were sharper and persisted longer after termination of accelerations. There was often a progressive decrease in the cardiac rate, marked arrhythmia, extrasystole, and sharp changes in the QRST complex, symptoms indicative of myocardial hypoxia and cardiac disturbances.

When the tray was placed at 45° angle to the accelerations, the minute outflow from the sinus decreased sharply in almost all the experiments. The period of stable pulse and relatively minor EKG changes was only 15-20 seconds in some cases. The EKG changes were much more pronounced than in the experiments with purely lateral acceleration.

Analysis of results clearly shows that lateral accelerations increased the heart's oxygen requirement, as revealed by the regular decrease in O_2 content of the coronary sinus blood with a simultaneous increase in the outflow of sinus blood. Maintenance of a fairly high level of coronary blood flow seems to be a basic factor that compensates for the heart's increased oxygen requirement. With a decrease in the outflow from the sinus, cardiac disturbances arose even when the O_2 content of arterial blood did not decrease during acceleration. Yet, despite marked impairment of blood oxygenation in the 4th minute of acceleration of 6 g, we failed to observe a single instance of arrhythmia or pulse deceleration if the outflow from the sinus remained high.

However, an increase in outflow cannot be regarded as an absolute sign that the oxygen supply to the heart is adequate. In some cases, especially with a sharp decrease in the O_2 content of arterial blood, the blood-flow rate may be maximal and unable to prevent the development of myocardial hypoxia (6 g, 4 minutes).

Impairment of blood oxygenation intensifies the compensatory mechanisms, as is shown by a correlation between the O_2 content of arterial blood and the degree of myocardial uptake of oxygen from the blood.

The experiments in which the tray was tilted at a 45° angle show that the hemodynamic changes arising after exposure to the head-pelvis

component of acceleration impair the blood supply of the myocardium and promote cardiac disturbances.

INTERRELATION OF HEMODYNAMIC CHANGES AND RESPIRATION DURING ACCELERATIONS

P. F. Vokhmyanin

Many investigators have noted that changes in respiration take place during accelerations. Pulmonary ventilation usually decreases in relation to intensity of acceleration because of contraction of the diaphragm, abdominal pressure, and lowering of the ribs. Contraction of the diaphragm results in inspiratory expansion of the lungs. The lengthening of the period of exhalation is caused by laryngeal resistance to exhalation, leading to an increase in intrapulmonary pressure (strain). This complex protective reflex--regularly observed in jumps, collisions, lifting of weights, etc.--is well-known to fliers who use the method of straining during accelerations. Breathing with straining on exhalation, according to J. Fulton (1948), increases fliers' tolerance of accelerations by 2.4 g on the average. However, Valsalva's experiment produced a favorable result with half the accelerations, showing the significance of an optimal level of intrapulmonary pressure and cyclicity in its rises.

Measurements of intratracheal pressure in deeply anesthetized dogs showed a rise after a "head-pelvis" acceleration of 3 g to 9 mm Hg, 5 g to 6 mm Hg with rapid breathing and to 12 mm Hg with slow breathing (200 mm Hg). With shallower anesthesia, intratracheal pressure during acceleration increases even more: acceleration of 3 g to 20-24 mm Hg, 5 g to 15 mm Hg. After repeated accelerations, with cumulation of the effects, the intensity of intratracheal pressure varies with the intensity of acceleration--with 3 g it rises less, but with 5 g it increases to 27 mm Hg.

Experiments with respiration at high pressure have shown that vascular tone and venous pressure increase after such elevations of intrapulmonary pressure.

In our experiments, blood pressure was measured simultaneously in the carotid and femoral arteries before and after tracheotomy. The degree of change in pressure during accelerations varied with the depth of anesthesia. In deeply anesthetized animals, pressure in the femoral artery before the tracheotomy increased two-fold after an acceleration

of 3 g to 180 mm Hg, 4 g - to 230 mm Hg. Blood pressure in the carotid artery fell to 42 and 17 mm Hg, respectively. After the tracheotomy, pressure in the femoral artery rose only after 10 and 7 minutes of accelerations to 132 and 160 mm Hg. Pressure in the carotid artery fell to 0 before the acceleration reached 3 g.

With weak anesthesia, arterial pressure during acceleration was higher. Intrapulmonary pressure on exhalation and venous pressure were also higher. Whereas the level of venous pressure in the deeply anesthetized animals during acceleration was close to the theoretical calculations of hydrostatic pressure of liquid in proportion to the intensity of acceleration, in the weakly anesthetized animals it was much higher than the theoretical value.

The arteriovenous difference in blood pressure decreased in the paired arteries, although it occasionally leveled out, despite the high arterial pressure. The increase in resistance to the flow of blood in the major blood vessels and aorta under these conditions (along with increased cardiac activity) seems to be a factor in the elevation of arterial pressure in these vessels, and this should have compensatory value for the shifting of blood therein in the direction of action of the acceleration. This mechanism of compensation is impaired by tracheotomy while the reflex mechanisms in the receptor zones of the vascular bed obviously become slowed.

This complex protective reflex with the pressor effect that the organism executes by raising intrapulmonary pressure on exhalation has compensatory value in accelerations owing to its many-sided influence on cardiovascular activity:

First, the elevation of intra-abdominal and intrathoracic pressure may exert pressure on the surface of the major blood vessels in these cavities and narrow their lumen and capacity.

Second, the elevation of intrapulmonary pressure is accompanied by increased vascular tone, a phenomenon known from experiments with breathing at excess pressure in a mask.

Third, the elevation of venous pressure observed under these conditions of respiration increases resistance to the flow of blood in arteries paired with these veins.

It follows from the foregoing that the rate of blood flow during accelerations sometimes slows, despite the elevation of arterial pressure in that part of the body toward which the hemodynamic changes are directed. Although investigators often take elevated arterial pressure as a sign of improved hemodynamics during accelerations, nevertheless, unlike normal blood circulation conditions, stasis may result from

accelerations. Some investigations have revealed an impairment of higher nervous activity in animals during "head-pelvis" accelerations despite a fairly high level of pressure in the carotid artery (Sulimo-Samuyllo et al.). Under such conditions one must take into consideration not only the possibility of the brain becoming anemic, but also the development of hypoxic phenomena of a congestive character if accelerations are continued for any length of time.

The results of the investigations showed that reflex reactions of the neuromuscular apparatus of the larynx to accelerations are of unusual interest. Although they are ordinarily not considered in the complex of protective reflexes to accelerations, they exert a direct regulatory effect on respiration and through it on hemodynamics. The cortical nucleus of these reflexes is believed to be in the region of the second and third frontal gyri. There is good reason to believe that there are subcortical centers and that they are closely connected with the motor analyzer.

Summary

The body's defense reactions to accelerations are complex reflexes that participate in all of its functional systems.

Motor protective reflexes (increase in muscular activity, especially in the abdomen and chest (diaphragm) aimed at mechanical protection of the viscera) are particularly sharp. These reflexes are closely connected with respiration, activity of the diaphragm, and muscles of the larynx and chest during accelerations, and they result in involuntary, sustained expansion of the lungs and cyclical resistance to exhalation.

The aforementioned protective reflexes and related pressor-vascular reactions appear earlier than the vascular reflexes from the receptor zones of the blood vessels, thus aiding the body when exposed to accelerations.

An important aspect of hemodynamics during accelerations may be the slowing of blood circulation, which after prolonged exposure may result in hypoxia.

INVOLVEMENT OF THE VESTIBULAR APPARATUS IN REGULATING THE BLOOD SUGAR LEVEL

R. Kh. Gambarova

Investigations on animals and human beings show that during space flights changes take place not only in various organs and systems, but in the vestibular apparatus as well. The vestibular apparatus which plays a major role in coordinating movements and spatial orientation, is also involved in autonomic functions.

To determine the degree and nature of involvement of the vestibular apparatus in regulating the blood sugar level, we performed the following series of experiments:

Series I - Study of change in blood sugar before and after rotating rabbits in a Barany chair (with the same rate of rotations and different duration of rotation).

(a) Rotation at the rate of 10 rotations in 20 seconds.

(b) Rotation at the rate of 10 rotations in 15 seconds.

(c) Rotation at the rate of 10 rotations in 10 seconds.

(d) Rotation at the rate of 10 rotations in 5 seconds.

Series II - Study of change in blood sugar before and after rotating rabbits in a Barany chair (with a different rate of rotations and identical duration of rotation).

(a) Rotation at the rate of 20 rotations in 20 seconds.

(b) Rotation at the rate of 15 rotations in 20 seconds.

(c) Rotation at the rate of 10 rotations in 20 seconds.

(d) Rotation at the rate of 5 rotations in 20 seconds.

Series III - Study of the significance of the functional state altered by drugs (bromides, caffeine) on the nature of reflex influences from the vestibular apparatus on blood sugar.

Series IV - Study of change in blood sugar after rotating in a Barany chair rabbits with vestibular apparatus destroyed by the method of A. B. Tsypin and Yu. G. Grigor'yev. Blood was taken from the auricular vein twice before rotation, then 5, 15, 30, and 60 minutes

later. The sugar content was determined by Fujita-Iwatake's method.

The following conclusions emerged from the investigations:

(a) Stimulation of the vestibular apparatus with rotations at the same frequency but with different duration of rotation changes the blood sugar content.

(b) Stimulation of the vestibular apparatus with 10 rotations in 20 seconds, 10 rotations in 15 seconds, and 10 rotations in 10 seconds increases the blood sugar content, but 10 rotations in 5 seconds decreases it.

(c) Depending on the number of rotations and the rate, the maximum increase or decrease in blood sugar content occurs at different times.

(d) Stimulation of the vestibular apparatus with rotations at the same frequency and identical duration of rotation likewise changes the blood sugar content.

(e) Stimulation of the vestibular apparatus at the rate of 20 rotations in 20 seconds and 15 rotations in 20 seconds decreases the blood sugar content, but 10 rotations in 20 seconds and 5 rotations in 20 seconds increase it.

(f) Depending on the number of rotations and the rate, the maximum increase in blood sugar content occurs with rotation at the rate of 20 rotations in 20 seconds and 15 rotations in 20 seconds by the 5th minute, but the maximum increase with rotation at the rate of 10 rotations in 20 seconds occurs by the 15th minute and at the rate of 5 rotations in 20 seconds, by the 5th minute.

(g) Interoceptive metabolic reflexes from the vestibular apparatus change under the influence of caffeine and bromides.

(h) After administration of 20 mg/kg of caffeine, stimulation of the vestibular apparatus by rotation on a Barany chair at the rate of 10 rotations in 20 seconds first increases, then sharply decreases the blood sugar content, which returns to the original level by the end of the control time.

(i) After administration of 500 mg/kg of a bromide, stimulation of the vestibular apparatus by rotation on a Barany chair at the rate of 10 rotations in 20 seconds slightly decreases the blood sugar content, which returns to the original level by the end of the control time.

(j) Blood sugar increases after unilateral and bilateral destruction of the vestibular apparatus.

(k) Rotation of animals on a Barany chair with unilateral destruction of the vestibular apparatus at the rate of 10 rotations in 20 seconds decreases the blood sugar content, the maximum being reached after 15 minutes. Under these experimental conditions, the original blood sugar content is not restored after 60 minutes.

(l) Rotation of animals on a Barany chair with bilateral destruction the vestibular apparatus at the rate of 12 rotations in 20 seconds has little effect on the blood sugar content.

(m) In the light of the foregoing, it is fair to assume that the vestibular apparatus exerts an effect on the blood sugar content.

CHANGES IN THE BIOELECTRIC ACTIVITY OF DIFFERENT PARTS OF THE BRAIN DURING EXPOSURE TO PROLONGED ACCELERATIONS

O. G. Gazenko, B. B. Yegorov, G. V. Izosimov, Yu. P. Limanskiy, A. N. Rasumeyev, and P. M. Suvorov

Study of the nervous system's reaction to accelerations has great practical significance for aviation and space medicine. The use of electrophysiological mthods has made it possible to investigate the dynamics of nervous system function both during and after accelerations.

The general nature of the changes in bioelectric activity of the cerebral cortex and some subcortical formations in response to accelerations was described in the works of Jasper et al. (1956), V. I. Babushkina et al. (1955), Sam-Yakobsen (1959), Edie and French (1962), and others. However, the nervous mechanisms of these disturbances have not yet been elucidated.

After analyzing the data on the functional state of the higher divisions of the CNS in man and animals, we tried to uncover the various mechanisms governing the interaction of different parts of the brain in response to accelerations. In investigations of 118 healthy young persons--using an ink-writing EEG, with mono and bipolar leads--we studied the bioelectric activity of the frontal, parietal, and occipital regions of the cerebral cortex. The accelerations were produced in a centrifuge in a head-pelvis direction (intensity 3-7 units) and

back-chest direction (intensity 7-12 units), the duration of action ranging from 30 seconds to 3 minutes.

The changes in bioelectric activity had many features in common regardless of the direction of the accelerations. The only difference was in the time that the EEG reaction set in. With the head-pelvis direction, this reaction appeared sooner and took place much more quickly than with the back-chest direction.

The dynamics of these changes was characterized by a phase development of the process, with β rhythms predominating at the start of acceleration. The α rhythm, in some cases, became less distinct with eyes closed than before the action, while its amplitude and index decreased. We designated this shift toward desynchronization of the cortical biopotentials as the first phase: it usually occurred with axial radiations of 3-4 units and lateral accelerations of 5-8 units. As the action continued, the amplitude and index of the α rhythm with eyes closed increased against a background of rapid oscillations. At this time some of the subjects had distinct oscillations of the α rhythm even with eyes open. This second phase of "exaltation of the α rhythm" followed axial accelerations of 5-7 units and lateral accelerations of 8-10 units. The amplitude of the α rhythm then decreased again, and the β rhythm gradually disappeared. Slow θ and Δ waves began to predominate on the EEG. This phenomenon usually preceded visual disturbances, the appearance of the so-called "gray shroud". Synchronization of the cortical biopotentials characterized the third phase.

A comparison of the changes in the biopotentials with the simultaneously recorded value of arterial pressure (in the pinna) showed them to be definitely related. The development of phase processes in the cortex was accompanied by a gradual fall in arterial pressure.

The original picture of bioelectric activity was gradually restored in the aftereffect period, with the amplitude of the α rhythm with closed eyes decreasing as soon as the rotations ceased. The rapid frequencies predominated at this time, but, after 1-3 minutes of exposure, the α rhythm with eyes closed became more pronounced than under normal conditions, its amplitude likewise increasing. Bioelectric activity usually became normal after 5-7 minutes.

The purpose of the experiments on animals was to find some common patterns underlying the changes in bioelectric activity in different parts of the brain after lateral accelerations. The general nature of the changes in cortical biocurrents in relation to the intensity and time of action was studied in 50 rabbits. The intensity ranged from 2 to 14 units. The rate of increase was constant-- 1 unit every 10 seconds. The cortical biopotentials were recorded in a bipolar lead from the sensorimotor region. The rabbits exhibited phase changes in

cortical biopotentials during accelerations that resembled those observed in humans. The first phase was marked by desynchronization of the cortical biopotentials, decrease in amplitude, and simultaneous shift toward the high frequencies. Later, against this background appeared individual high-amplitude slow waves of 2-3 oscillations a second, which became dominant fairly quickly. Thus, the second phase, unlike the first, was characterized by a shift toward slow synchronous oscillations. Cardiac disturbances (arrhythmia and extrasystole) and marked slowing of the respiration rate developed against this background. We also distinguished a third phase of pronounced autonomic changes in response to acceleration, occurring only after accelerations of more than 6 units. After the accelerations were halted, the original picture of bioelectric activity was gradually restored.

Our later investigations were designed to study the reactions of different brain formations. Accordingly, electrodes were first implanted in the sensorimotor cortex, posterior hypothalamus, and reticular formation of the midbrain, with intensity of acceleration ranging from 3 to 7 units.

The experiments showed that during the first phase, when desynchronization was noted in the cortex, synchronous oscillations of the basic rhythm of 5-6 a second intensified in the reticular formation and hypothalamus. Accelerations of about 7 units produced slow high-amplitude waves in the cortex (second phase). At this time, slow high-amplitude activity was also evident in the hypothalamus but there was a decrease in the amplitude of the basic rhythm of 5-6 oscillations a second in the reticular formation. Then a marked shift toward rapid oscillations was noted in the potentials derived from the hypothalamus. Activity completely disappeared at this time in the reticular formation while slow waves predominated in the cortex. Continuation of the rotations caused activity to disappear both in the cortex and in the hypothalamus.

When rotation was halted, if the animal survived, bioelectric activity was restored in these formations. In all cases there was first restoration in the cortex, then in the hypothalamus and, finally, in the reticular formation. A similar picture was also observed in oxygen starvation by V. B. Malkin, A. N. Razumeyev, and G. V. Izosimov.

Thus, of all the formations that we investigated, the most sensitive (reactive) to accelerations was the reticular formation. The reason for this may be its unusual sensitivity to an inadequate blood supply (Keti, 1956). On the other hand, since the rostral portion of the reticular formation is a collector of afferent impulses en route to the cortex, it can develop into a focus of protective inhibition as a result of an "avalanche" of impulses arising from the mechanical action of accelerations on the various receptors of the body.

To clarify these mechanisms, special microelectrode investigations of cell units of the brainstem reticular formation were carried out on cats anesthetized with chloralose. A total of 100 cell units was recorded.

From the very beginning of the accelerations, there was a significant increase in the frequency of the spike activity of the neurons. With simultaneous recording of 2-3 neurons, one could see that their activity was nonsynchronous. Then, as the action continued, the grouping of spikes was recorded in individual bursts with periods of "silence". The periods of silence gradually lengthened and the bursts became shorter. The activity of the action potentials was synchronous when they were derived from 2-3 neurons simultaneously. These changes coincided in time with the appearance in the reticular formation of ordered rhythms at a frequency of 5-6 oscillations a second. After 80-85 seconds, with accelerations of 5 units, activity of the cell elements ceased entirely. In the restoration period these phenomena occurred in reverse order. At first, bursts of cell activity appeared, after which the rhythm of the neuron regained its original characteristics.

Hence, the fact that the start of changes in the reticular formation coincides with the time when acceleration causes virtually no profound hemodynamic changes (beginning of rotation) suggests that the afferent systems play a part in the mechanism of changes in nervous activity. The stream of impulses flowing along the afferent pathways may give rise to inhibition in the reticular formation. The resultant inhibition presumably protects the cerebral cortex from the injurious effect of the accelerations.

Our findings show that prolonged accelerations cause significant changes in the bioelectric activity of different parts of the brain. These changes are evident from the very beginning of the accelerations.

Research on the functional state of the CNS during accelerations should be broadened to include the practical problems involved in protecting the organism from the injurious effect of space flight factors.

ANTICIPATING REACTIONS IN FLIGHT ACTIVITY

S. G. Gellershteyn

1. Stimulus-and-reaction in the behaviorist interpretation does not accurately reflect the true nature of the sensorimotor activity of

fliers. We find incontrovertible proof of this view in the results of psychological analysis of the processes that characteristically take place in critical situations, when time is short, and under conditions of emotional stress.

2. The weakness of the materials describing flight activity lies not in the lack of facts or analytical judgments apropos of these facts but in the absence of a leading idea, the need of which is felt most keenly when synthesizing the data and when trying to write up the integral characteristics of flying as an occupation and to reveal its psychological nucleus.

3. Like any other complex occupation involving danger and possible contact with acute and difficult situations, flying at certain times requires high concentration of will and readiness and the ability to withstand factors that subject the nervous system to arduous trials and prolonged stress.

4. To understand the processes that take place in these situations, one must contrast the stimulus-and-reaction concept with a psychological concept that would reflect the true relations among the sensory, intellectual, and motor components of flying.

5. It seems that this concept should be based on a dynamic understanding of the sensorimotor complex in the light of which all the influences impinging on the sensory sphere would be regarded not as stimuli following one another but as a stream consisting at each moment of traces of past and precursors of future influences. In any given field of consciousness always there are elements of the past, present, and future fused together by the problem confronting the flier. A stimulus in the strict meaning of the word is an arbitrary term when applied to a genuine flight situation at critical moments. In each unit of time the external influence combines with traces of apparently forgotten processes and, even more important, with the "embryos" of those actions that seem to be stored up for events that have not occurred but which are expected.

6. It is in this connection that we have a right to speak of the role of anticipating processes in flying. Anticipation should be regarded as a means of orientation toward the predictable future. There is a genuine process of anticipation based on knowledge or recognition of the logic of the development of events. Just as a situation developing in flight generally contains the seed of a future situation, so does the seed of a future action mature in the mental activiity of a flier at each moment. "Stimulus and reaction" constitutes a long drawn-out phenomenon that embraces that which was, is, and will be.

7. Anticipation becomes possible owing to the latent reaction of expectation, which is rightly called the adjusting reaction. It attunes the flier to certain actions when there seems to be as yet no reason for them. It apparently prepares and shapes these actions, forming their initial latent phase. If the expected events occur, the flier, thanks to anticipation, is better prepared to cope with them, and his actions are not only sounder but quicker--even under clear-cut conditions of time shortage.

8. It would be inexcusable if, convinced as we are of the enormous significance of anticipating processes in flight activity, we failed to take steps to confirm it experimentally for possible use in dealing with the selection and training of personnel and control of accidents. Our past experiments, though scarcely complete, sometimes enabled us to come close to experimental modeling of the anticipating processes, but, unfortunately, we only came close. Now more than ever it is time for us to return to the problem and seek an adequate experimental solution through a direct attack.

DATA ON THE BEHAVIOR AND SOME FUNCTIONS OF PERSONS KEPT UNDER THE CONDITIONS OF LIMITED MOBILITY

M. A. Gerd

The normal functioning of the human organism as it evolved over a long period of time is dependent on motor activity of various kinds and degrees, periodicity, etc. Human motor activity can be safely restricted up to limits that are still uncertain to us. Restricting mobility beyond these limits is apparently harmful to man.

On space flights human beings will in all likelihood be in situations where their activity will have to be based on some restriction of mobility. The astronauts in the cabin of the Vostoks were lying down (mostly on their back) and their activities did not require much active movement, strength, speed, or static exertions. Moreover, in weightlessness, movements are made without the ordinary resistance that develops when the body is shifted under the influence of gravity and they do not place the load on the organism that they do under terrestrial conditions. Consequently, it will be possible to speak of phenomena of immobility in weightlessness despite the many actual movements.

All this indicates that the effect of limited mobility on the body is a major scientific problem in space research. First things to be considered here are the possible degrees of immobility, permissible duration, and how the phenomenon is perceived by the persons themselves. They have both practical significance in the organization of space flights and theoretical significance in studying movements as a biological necessity. Appropriate investigations were undertaken to throw some light on these questions.

A total of 12 experiments lasting 2, 5, 7, and 10 days were conducted. The subjects--healthy persons 20-22 years of age--were placed in an arm chair that simulated in angular parameters the working place of a astronaut on board a Vostok. To obtain maximum immobility, the subjects were instructed not to move, and a locking device was used to ensure this. They were in a semi-reclining position, head raised, legs partly bent at the hips and knees--a position of maximum muscular relaxation in which muscular fatigue is very slow to develop.

The techniques used to study motor activity and behavior included recording of movements, time study, recording of actograms (by Ye. I. Lavrenchik). During the experiments the Mede device with recordings (as modified by Komotskiy, Gerd, and Ferov) was used to measure the precision and direction of movements, nature of deviations (upward, downward, to the right, to the left), duration of deviations, change in characteristics of static exertions of the arm. The speed of simple motor reactions was recorded by the apparatus. A study was also made of the correlation of the processes of excitation and inhibition in the CNS. There were daily inquiries and observations in accordance with a specially prepared program.

The results show that motor behavior, mental state, and several physical functions changed considerably in 10 out of the 12 subjects.

Analysis revealed that the changes, despite the variety of forms, fell into general patterns with characteristic features and 5 separate periods. Individual features were manifested in, (a) the nature of the phenomena and time they arose, (b) the fact that the periods were long drawn out in some subjects but short in others, (c) the differences in intensity of the motor reactions, and (d) subjective sensations.

First period (1-5 hours) - characterized by the fact that the subjects admitted that the position assumed was maximally comfortable with little desire to move. The time study and actogram indicated the subjects easily conformed to the requirement of the experiment--to lie still.

Second period (it lasted a day in some subjects, up to 6 days in others) - characterized by increasing desire to change position, stretch the legs, stand up, begin to move vigorously. In 9 out of the 10 subjects these desires became clearly pronounced, and the impossibility of satisfying them made 4 persons somewhat irritable and slightly apathetic. Unusual kinds of movements began to appear, without obvious shifting of the extremities and trunk--scarcely perceptible stretching, exertion of various groups of muscles, supination of shoulder and forearm muscles, twitching, feeling of heaviness. Three subjects felt sharp pain when they first tried to tense their arm muscles.

The initial site of the disagreeable sensations throughout this period was followed by irradiation of the pain; some persons developed a general sensation of fatigue. The time study and actogram showed a sharp increase (up to threefold) in the number and intensity of barely perceptible movements. Judging by the arithmetic means, the precision of the movements decreased even more (0.5 to 2-fold), their rate slowed (by 2 to 6 hundredths of a second), and hand tremor increased (1.5 to 2-fold). Seven of the 10 subjects became more apathetic: 3 reacted sluggishly to people and other stimuli, while 4, on the other hand, although depressed, demanded constant attention, became loquacious and quick to take offense.

Fourth period[1] - characterized by increasing pain. Some first became aware of it within 5 hours of the start of the experiment, others - only on the 3rd or 4th day. Pain developed in the lumbar region, gastrocnemius muscles, and muscles of the posterior part of the femur. All had pain in the knee joints.

At first the sensations were transient and mingled with fatigue, followed by sensations of heaviness and itchiness. The pain, as a rule, was in one or two places. However, in most subjects the pain became more pronounced and widespread. In two, it "crawled" all over the body.

The time study data showed that in some subjects the number of movements at this time sharply decreased, but increased in others. However, the desire to move and to stand up became overwhelming.

Emotional changes were marked by a considerable poverty of mental reactions. The subjects lay quietly, answered questions in monosyllables, turned away from people, and scarcely reacted to stimuli

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[1] Tr. Note: The author does not mention the third period.

(3 subjects). Four subjects in a melancholy mood had a strong desire to come in contact with the attendants, to chat, to be in a situation with changing impressions. Almost all had a very poor appetite. Signs of euphoria appeared only when the planned end of the experiment drew near.

Changes in the volitional sphere were manifested in the difficulty with which some subjects performed the assigned tasks. Elements of weak negativism were observed in 3 persons. The methods used to investigate mental alertness (arithmetic problems, etc.) showed some slowing of the intellectual processes, despite complete retention of the higher mental functions.

Based on measurements of the latent period after differentiations and of the time of the "behind" reflex, it is reasonable to conclude that in most of the subjects immobilization gave rise to changes in the direction of a predominance of the processes of inhibition.

Fifth period (observed in 3 subjects at the end of 7 to 10 day experiments) --characterized by progressive weakening of negative sensations. Pain and fatigue disappeared and the urge to move was no longer acute.

Time study data and actograms showed a reduction in the number of movements made during this period. Almost all the subjects had the urge to stand up and to change postion; there was tense expectation of the end of the experiment, producing in most either an improvement in mental state or mild euphoria.

As soon as the experiment ended, and for 1-3 hours thereafter, the subjects felt weak and dizzy and had difficulty in moving. There was a sharp deterioration in motor and static characteristics and a slowing of the speed of movements. Such phenomena as unsteady gait, weakness, and sluggishness persisted for 2-3 days. All this underlines the need of movement as a prime biological requirement.

On the basis of our findings, it would seem that the degree of immobilization used in our experiments is close to the limits of what man can tolerate, although the actual limits are not yet known. Immobilization can continue for more than 10 days without prolonged aftereffects and complete restoration of all functions in 2-4 days.

The theoretical basis of the biological need of movement is as follows. Prolonged immobilization evidently causes changes in normal biochemistry in the trophism of muscular tissue and nature of its proprioceptive impulses, and, as a result, in other unconditoned and conditioned reflex innervation of the muscles. The need of movement apparently enables the body to manage the load essential for its normal

functioning. An indication of this, as shown by our experiments, was the increasing desire of the subjects to move.

The contrast between the need of movement and the possibility of satisfying this need apparently gave rise, on the one hand, to various disagreeable sensations (starting with local fatigue and ending in pain) and, on the other, to persistent movements that did not involve shifting of the extremities or trunk. These reactions could compensate only partially for the lack of a motor load, giving rise to increasingly disagreeable subjective sensations and change in mental state the longer the immobilization lasted.

It is a well-known fact that such phenomena as depression, mild apathy, and poor frame of mind often cause general motor sluggishness. Our findings suggest the possibility that the reverse relationship exists too, i.e., immobilization combined with relatively limited external information may result in depression and inhibition.

THE PHYSIOLOGICAL-SANITARY JUSTIFICATION FOR SUBSTITUTING A LUMINOUS SUBSTANCE OF INTERMITTENT ACTION FOR THE PHOSPHOR NOW USED ON AIRPLANE INSTRUMENT DIALS

V. Ya. Gilinskiy and A. Ya. Loshak

The main criterion of a pilot's fitness for independent flight, especially in foul weather, is his ability to fly by instruments. He must therefore be able to see instantly and evaluate the readings of the individual instruments, determine the position of various switches, etc. The dials are painted with a luminous substance of constant action, a source of gamma radiation. It is intense enough, according to our data, to make an important contribution to the total dose of external radiation received by the personnel, especially on gas-turbine aircraft. We therefore thought it necessary to determine whether the radioactive paint could be replaced by some other substance of intermittent action which, though lacking in radioactivity, would ensure adequate visibility. We also thought it worthwhile to determine the best color for the paint and lighting system of the instrument panel. Accordingly, we made 7 flights on a LI-2 and 14 flights on a TU-104 using experimental instrument panels with a luminous substance of intermittent action and making appropriate physiological-sanitary investigations. The program called for the following:

(a) Determination of the effectiveness of the lighting system of the instrument panel, control panel, etc., involving the use of substances with zinc or cadmium sulfide irradiated by UFO armatures.

(b) Determination of the relationship between the brightness of the instrument dials during flights at twilight and at night and physiological requirements.

(c) Determination of the level of eye adaptation and readaptation in pilots during long flights and near airports.

(d) Determination of the electric sensitivity of the eye.

(e) Determination of the pilot's problem when masking shroud or blue fog appears in the cockpit.

(f) Determination of the possibility of distinguishing warning signs on instruments.

(g) Determination of the amount of radiation emanating from the instrument panel.

(h) Determination of the radiation level in airplane cabins.

(i) Conducting individual monitoring of the crew.

(j) Determination (on the basis of the available data) of the degree of fatigue resulting from flying by instruments painted with the tested luminous substances, followed by a comparison of the data and then checking them against the results obtained by using a substance of constant action.

During the flights, besides obtaining subjective data, we used a variety of methods previously approved for scientific and practical investigations in aviation medicine.

Our investigations were carried out:

(a) With FK-102 orange-colored cadmium and FKP-03K green-colored zinc sulfide.

(b) At different times of the day (in daylight, at twilight, at night) and under different meteorological conditons.

(c) At all stages of the flight and near airports.

(d) With lighting systems for landing turned on in full or in part.

(e) While using an ARUFOSh-45 or ARUFOSh-50 armature with different ways of regulating the bias lighting sector.

(f) Before, during, and after flights.

(g) During night flights over well-illuminated inhabited localities.

The results of the investigations showed that in the passenger compartments the levels of radioactive radiation do not exceed the background characteristic of the altitudes at which the measurements were made. The dose rates of gamma radiation (mr/hour) recorded on the

surface of aviation instruments, in the working places of the first and second pilots, and at different spots in the crew compartment (with use made of a luminous substance of intermittent action, 65 hours a month sanitary rate of deposit, and 10-month work year) were one-half to one-third the maximum permissible level.

The results of an investigation of higher nervous activity, various functions of the visual analyzer, perception and evaluation of readings of aviation instruments, degree of fatigue of flight personnel, etc., revealed that insignificant physiological changes (within the limits of ordinary functional changes) appeared in bodily functions after 4-hour flights with the experimental system of instrument-panel illumination. Similar results were obtained in an investigation of flight personnel when a luminous substance of constant action was used.

It appears that the green color is best, as demonstrated in the processes of eye adaptation and readaptation, electric sensitivity of the eye, shortening of the afterimage and lengthening of the latent period. The degree of change in these indices was 15-25 percent. The use of green paint also improves the conditions for reading the dials of instruments and makes it easier to distinguish between warning signs.

The conclusions of our investigations are as follows:

(a) Instrument panels painted with a luminous substance of constant action should be changed owing to the relatively high radioactivity.

(b) Lighting instrument panels with luminous substances of intermittent action irradiated by UFO armatures is effective.

(c) Of the two types of instrument panel lighting, the more useful is the FKP-03K green-colored zinc sulfide.

THE EFFECT OF LOW CONCENTRATIONS OF CARBON MONOXIDE ON MAN IN PRESSURIZED CABINS OF PASSENGER PLANES

V. A. Gilinskiy, A. V. Chapek, A. G. Kozlova,
N. M. Kulikova and A. Ya. Loshak

The human organism in general and during flight in particular requires careful observance of certain environmental conditons, i.e., the so-called comfort conditons that make it possible for a flier to live and remain fit with minimal fatigue during flight.

Many authors (A. A. Letavet, E. E. Grigor'yev, L. S. Gorsheleva, I. I. Datsenko, and others) have concluded that prolonged exposure to low concentrations of carbon monoxide may adversely affect health by causing chronic carbon monoxide poisoning.

We found no references in the available Soviet or foreign literature to carbon monoxide effect on human beings in pressurized cabins exposed for 3 hours to maximum permissible concentrations and to low concentrations under ground conditions (pressure-chamber experiment) and at altitudes of 8000-10,000 meters.

There is as yet no consensus either in international practice or in the Soviet Union on the maximum permissible concentration of carbon monoxide in pressurized airplane cabins. The specialized literature contains no data that confirm the soundness of applying the maximum permissible CO concentration (0.02 mg/liter) established for ground conditions to the conditions of low partial pressure of oxygen in inhaled air.

We performed pressure-chamber experiments on 82 persons to study the effect of low concentrations of carbon monoxide. We also made 30 flights on IL-18, AN-10, and TU-104 planes during which we examined 185 members of the crew and passengers and studied 347 air samples obtained in the cabins.

The results of the investigations showed that 3 hours' exposure to carbon monoxide (starting with 0.01 mg/liter or more), both under experimental conditions (ground and pressure-chamber at 2400 m) and during actual flight had adverse effects on the functioning of several organs and systems, namely:

(a) Higher nervous activity (manifested in a breakdown of differentiations; deterioration of memory, capacity and concentration of attention; increase in amount of time required for a proof-reading test, etc.).

(b) Functions of the visual and vestibular analyzers (increase in latent period and decrease in duration of the after-image, shortening of the time of illusion of counter-rotation, etc.).

(c) Metabolic processes (change in bodily temperature).

(d) Cardiovascular system (change in arterial pressure, oscillatory index, change in myocardial function, etc.).

(e) Muscular strength (decrease in indices of manual dynamometry).

(f) Tissue respiration (formation of carboxyhemoglobin in the blood).

(g) Leukopoiesis (change in composition and formed elements of the blood).

On the basis of the physiological-sanitary data obtained and the results of laboratory tests, it is suggested that the maximum permissible concentration of carbon monoxide in pressurized passenger airplane cabins be 0.01 mg/liter.

MORPHOLOGICAL CHANGES IN THE NERVOUS SYSTEM OF ANIMALS SUBJECTED TO LATERAL ACCELERATIONS

B. S. Glushkov

Although much material on the subject has been gathered in the past 20 years, continued study of morphological changes arising in the nervous system after exposure to accelerations is of value in clarifying the reasons for impairment of various functions caused by acceleration. Unfortunately, morphological data are meager.

This report presents preliminary findings on morphological changes in various divisions of the nervous system of animals subjected to single lateral accelerations of varying intensity and duration. Experiments were performed on 7 rabbits, with accelerations ranging from 4.9 to 5.9 g produced in a centrifuge with lateral (back-chest) orientation of the animals in the direction of the centrifugal force. The action lasted from 60 to 180 seconds. The animals were kept under observation from 1 to 7 days after the experiment.

The following were used for histological investigation: the entire brain, two fragments from each section of the spinal cord with the intervertebral ganglia, both nodose ganglia of the vagus nerves, both superior cervical sympathetic ganglia, semilunar ganglia, thoracic sympathetic chain, celiac ganglia, and some viscera (heart, lungs, esophagus, stomach, major blood vessels). All material was treated by the methods of Nissl, Van Gieson, Marchi, Mallory, Bielschowsky-Gros, Cajal in Ranson's and Favorskiy's modifications, and with hematoxylin-eosin.

Hemorrhages of varying severity were found in the brains of 4 rabbits - from small extravasates to a large subcortical focus in rabbit No. 2 (5.2 g.- 180 seconds). All animals showed spinal cord

hemorrhages concentrated, for the most part, in the gray substance, chiefly in the thoracic and lumbar segments, in the nature of small perivascular foci.

Perivascular edema was noted in all cases. When stained by Nissl's method, the most distinct but generally reversible changes in nerve cells were found in the cerebral cortex (chiefly in layers 2 and 3) and hippocampus. These changes represented various phases of chromatolysis of Nissl substance, frequent vacuolation of nerve cells and, at times, "severe disease" of the latter.

Changes in the nerve cells of the intervertebral and other sensory and autonomic ganglia were insignificant, consisting mainly in a redistribution of Nissl substance in the cell body - in a coarsening or dispersion of the substance.

The nature of the morphological changes caused by lateral acceleration which seem to be reversible, suggests they are the result of marked disorders of blood circulation in the CNS.

SOME FUNCTIONAL CHANGES IN MAN AFTER PROLONGED ISOLATION

F. D. Gorbov, V. I. Myasnikov, and V. I. Razdovskiy

The increasing pace of automation of industrial processes is making essential the early and discriminating determination of stress and fatigue. The problem assumes greater urgency in cases where the factor of continuous work is combined with spatial shifting of man with the object, e.g., in various types of transport, aviation, and, above all, in spacecraft (V. I. Yazdovskiy, 1962).

In 18 experiments, the subjects spent 10-15 consecutive days in a small, enclosed space in a specially equipped chamber. The main condition of the experiment - isolation - was ensured by solitude, lack of two-way oral communication, and practically complete isolation from outside light, sound, or other stimuli. One-way communication from subject to experimenter was limited by the program and transmission time.

The subjects' functional state was evaluated in various ways: observation of behavior and emotional reactions; the dynamics of bioelectric activity in the cerebral cortex; determination of the speed of motor reactions; and psychological exercises (tests for "noise

immunity" were devised by F. D. Gorbov and L. D. Chaynova) combined with data derived from observation and recording of vocal reactions on magnetic tape.

Analysis of data showed that functional change began before the experiment started, continued throughout the experiment, and lasted for some time after it was over. Each stage had its own peculiarities. During the preparation for the experiment the subjects exhibited some tension, reflected in slight agitation with appropriate change in facial expression, vocal intonation, etc. These phenomena were observed in some subjects after 1 or 2 days of isolation. In cases where signs of stress were very pronounced, the EEG showed an indistinct α rhythm against a "background" of β activity while the index of the α rhythm dropped 8-40 percent below the original level. In recording the motor reaction, we observed a spread in the indices of the latent period and spontaneous fluctuations of the cutaneogalvanic reflex. Investigations of "noise immunity" were accompanied by the appearance of errors at the start and in the middle of the work.

Biochemical findings also testified to the development of emotional stress at this time. For example, there was an increased excretion of urinary 17-ketosteroids, the highest level being noted on the 2nd-3rd day of isolation, i.e., when fatigue could not yet have been fully manifested. It is noteworthy that in the control experiments, when the subjects were in the chamber under the same conditions, including diet, but could communicate freely with the outside world, there was no increase in urinary 17-ketosteroids (Yu. F. Udalov). Emotional stress during the preparation period and first days of the experiment were regarded as analogous to the pre-starting state based on inadequate preliminary adaptation of the subjects to the experimental conditions. The emotional stress was a wholly adequate reaction and was not accompanied by important deviations in accomplishing the experimental psychological tests and tasks. These changes, which imply some modification in the body's functional state, can be regarded to a certain extent as a standard of stress since there was no question of fatigue at this time.

The subjects began to experience fatigue after the 6th-7th (8th) day. They felt also, the need of conversing, of communicating with the experimenter, as shown by the construction of reports in interrogative form and inclusion in the reports of "extra" words and expressions not called for by the instructions or bearing directly on the experiment. At the same time there were 20 to 30-minute periods when the subjects were motionless and outwardly apathetic. Prolonged isolation caused marked changes in the bioelectric activity of the cerebral cortex: EEGs recorded at this time showed a decrease in the amplitude of the biopotentials, appearance of diffuse slow waves on the original EEG curve

(before the presentation of light as a stimulus), and a lowering of cortical reactivity and excitability. Fairly significant changes were noted in the degree and duration of exaltation of the α rhythm following exposure to light. For example, in those persons who from observation and self-evaluation, seemed to be fatigued, exaltation of the α rhythm after exposure to light became longer and longer until by the end of the experiment it was stagnant and incapable of being reversed (V. I. Myasnikov, 1963).

Investigation of the motor response showed a statistically significant lengthening of the latent period of the reaction at the end of the experiment (by an average of 120 milliseconds). This increase was probably caused by fatigue, the first signs of which appeared simultaneously with the development of inhibition in the CNS (according to the EEG data). Study of "noise immunity" showed that the "level of the assigned activity" decreased during the second half of the experiment. Analysis of the results of handling the numerical table showed considerable "disinhibition of differentiations" both in calculation and in correct designation of the answer (a black figure was shown instead of a red one and vice versa). In doing so the subjects exhibited a tense attitude, engaged in mimicry, and made a great many searching movements. The middle stage of the work with the black-and-red table was the most difficult with respect to differentiation because the numerical difference between the figures in the black and red rows decreased to unity even where there was a sharp increase in the number of similar stimuli through repetition of 1, 2, and 3 (F. D. Gorbov, 1960). Investigation of "noise immunity" at the end of the experiment was accompanied by an increase in the total amount of time spent on the numerical table.

Excretion of urinary 17-ketosteroids decreased when subjects showed pronounced signs of fatigue. According to N. N. Sirotinin (1960), a decrease in the excretion of 17-ketosteroids is an unfavorable indication, signifying the organism's low tolerance of adverse conditions. The protracted change and limitation of afferent impulses, in the experiments with isolation, was a new and unusual stimulus that resulted in complex mental and physiological changes followed by the onset of fatigue.

Our investigations showed that a drastic limitation of general afferent impulses had a significant effect on the subject. The changes in psychoneurologic function varied at different stages of the investigations. Simultaneous recording of psychological and physiological indices made it possible to ascertain the qualitative aspects of the changes and to determine and delimit the state of tension and fatigue. The conditions and causes of the development of stress and fatigue were the monotony of the surroundings, poverty of external impressions, and solitude--all factors of independent significance. These states can

and must be prevented by effective stimulation to promote the optimum interaction of the afferent systems.

THE MAIN PROBLEMS IN INVESTIGATING SHOCK OVERLOADS ARISING IN FLIGHTS ON AIRPLANES

S. A. Gozulov and G. P. Mirolyubov

The present stage in the evolution of aircraft and space flights demands better methods of enabling the crews to land safely. Catapulting followed by a parachute landing is often made more difficult by unfavorable conditons (rough, stony ground, strong winds, etc.) or the climatic and geographic characteristics of the area (arctic, desert, sea, etc.).

Many safety problems in landing, after enforced abandonment of the craft, are resolved by the use of a pressurized separable cabin or capsule which the pilot can land. Physiological investigations of animal (dogs, white rats, mice) tolerance of shock overloads in landing have shown that the boundary lines beyond which functional disorders and morphological injuries arise in the organism are separated by a slight overload and that under certain conditions they close together. In the latter case, the functional disorders are accompanied by microscopic injuries to individual tissues and organs, apparently secondary reactions to the action.

Physiological reactions to shock overloads at high landing speeds are characterized by impairment of the rate and depth of respiration up to complete standstill, disruption of the cardiac rate and change in the EKG indices, change in arterial pressure, impairment of muscular excitability, and other phenomena.

Marked changes can be observed in the gross morphological and histological picture when the animals are dissected after the event. Since the degree of injury varies with the consistency and relative position of the organs, the frequency with which a given organ is injured varies from animal to animal. In all animals, the lungs are the most frequently injured, then the liver, spleen, and intestine, in this order. The nature and site of the hemorrhages throw light on some aspects of the mechanism of injury to the viscera. Specifically, lung injury is caused largely by the pressure wave that arises in the abdominal cavity and passes through the diaphragm into the thoracic

cavity. An important factor in the damage is the fact that dense organs (heart and lungs) are near one another.

According to the data of foreign authors, a speed of 3 to 9 m/sec is the optimum for landing from the engineering standpoint. Since this may produce intolerable shock for the organism, it is essential to use shock-absorbing devices. However, in emergency situations or when landing on other planets, the impact of landing may be 10 times greater than under ordinary conditions, and special protective measures are needed if injury is to be prevented. Experiments on animals have shown that immersion in a liquid and other methods may significantly reduce the landing impact. For example, the use of a gypsum bed permits safe landing on hard ground at a speed of 14 m/sec, which results in an impact of 1000 units. Further research in this field is urgently needed.

Another equally important matter requiring experimental investigation is human resistance to shock overloads lasting longer than the shock of catapulting. The need to save the crew of a spaceship in an emergency situation or to remove the pilot from the zone of fire of a rocket engine accounts for the practical importance of research on the effect of prolonged overloads in these situations. Experiments have made possible the construction of safety devices for the Vostok, and have thrown light on some specific characteristics of prolonged overloads (the evaluation of which requires a new approach), and on some parameters of overloads previously disregarded or unknown.

To investigate the effect of the aforementioned overloads on man, it is essential to develop and use techniques for early diagnosis of disorders which indicate the limit of physiological endurance of impacts. It is equally important to investigate the biodynamic reactions of the body to shock overloads. Theoretical considerations have confirmed the idea derived from experimental investigations that the correlation between the period of the natural frequency of bodily oscillations, duration of overload and rate of increase thereof plays a major role. The duration of an overload and rate of increase were taken into account by investigators as factors (on a level with intensity of the overload) influencing resistance, but the effect of the frequency characteristics of the body were disregarded. This was probably due not so much to neglect as to the practical difficulties involved in measurement and instability of the period of the natural frequency of bodily oscillations. The latter changes with the position of the body, degree to which it may be held fast by straps, muscular tension, etc. Study of the relationship between resistance to shock overloads and correlation of the aforementioned three values gives investigators still another criterion for evaluating a factor of practical importance.

Further study of shock overloads with different parameters and their mechanism of action on the organism and the development of methods of

resistance to such factors will help to ensure the safety of modern aircraft and thus improve their tactical qualities.

INCREASING RESISTANCE TO OXYGEN DEFICIENCY BY MEANS OF DRUGS

G. I. Gurvich and K. S. Shadurskiy

One of the basic problems in aviation and space medicine is to ensure airplane and spaceship crews an adequate supply of oxygen. There are two approaches to the problem: (a) development and perfection of methods to provide individual oxygen supplies; (b) creating pressurized cabins that maintain a certain partial pressure of oxygen. Together, the two methods render flights safe either in the earth's atmosphere or in outer space.

Of practical value, especially on long space flights, undoubtedly will be the ability to decrease sensitivity to oxygen deficiency. In recent decades various drugs have been proposed that are capable of increasing in varying degrees bodily resistance to hypoxia. These are mainly compounds that exert a tonic effect and compounds with an anesthetic, somnifacient action. Prolonged use of the first group, whose effect is transient, results in exhaustion of the physiological reserves; the second group impairs general efficiency. For these and other reasons these drugs have not been used in aviation and space medicine. Therefore, in our own efforts to find drugs capable of increasing resistance to hypoxia, we focused on compounds with no unpleasant side effects (in the dosage used).

Our attention was drawn to the indole derivatives. We began with the following: serotonin (5-hydroxytryptamine), iproniazid, BAS (1-benzyl, 2.5-dimethyl-serotonin), and compounds provisionally called indole I, indole IV, and indole XXIX.

Rappoport, Green, and Page (1949), Erspamer (1961), and others have shown that serotonin is widespread in tissues and organs of animals, and possesses high physiological activity. It is essential for the normal functioning of the CNS and other systems.

The effect of serotonin on resistance to oxygen deficiency was studied in 19 guinea pigs, 20 rats, and 20 mice. All the animals in these and subsequent experiments came from the same animal house and they were of approximately the same age and weight. Ten guinea pigs, 10 rats, and 10 mice served as the control. The experimental animals were

injected intramuscularly with serotonin at the rate of 0.2 mg per kg of body weight an hour before exposure to hypoxia. The control animals were injected with physiological solution, which produced no visible abnormalities in the general behavior of the animals. Hypoxia was caused by elevating the animals in a pressure chamber to an "altitude" of 11,000 m, at which the survival rate was studied.

The time of respiratory standstill (in minutes) at an "altitude" of 11,000 m in the animals that received serotonin and in the control was:

Guinea pigs		White rats		White mice	
Control	Experimental	Control	Experimental	Control	Experimental
8	7	0.2	1.8	3	2
9	12	0.4	2.4	3	5
11	18	0.4	2.7	3	5
11	24	0.5	3.2	4	60[1]
12	28	0.5	3.4	17	60
12	32	0.5	3.7	19	60
13	34	0.6	5.4	21	60
16	38	0.7	8.2	24	60
24	41	0.8	9.0	26	60
24	—	1.2	3.7	28	60
14	26				
/17.3-11.7/	/28.3-23.9/				

[1]After being kept for an hour at the "altitude", the animals were "lowered" and kept under observation for 2 weeks.

It is evident from the table that resistance to acute oxygen starvation was much higher in the experimental animals than in the control.[1]

The amino compounds in the animal organism are known to undergo constant oxidative deamination, and the enzyme monoaminoxidase plays an important part in this process. In 1955 Weller et al. first demonstrated that iproniazid suppresses the activity of monoaminoxidase and promotes the accumulation of serotonin. Our experiments on 150 white mice showed that intraparietal injection of 100 mg/kg of iproniazid considerably increases resistance to hypoxia. It is particularly effective when injected 2, 3, 4, 5, 6, or 7 days before exposure to hypoxia.

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[1]The results were processed statistically in all the experiments in which the experimental animals survived at the "altitude" less than an hour.

Combined injection of iproniazid and serotonin in 120 mice showed that the combination markedly lowers sensitivity to hypoxia, especially when iproniazid is injected 2, 6, or 7 days before exposure.

BAS was administered orally for 5 days at the rate of 5 mg per g of body weight to 40 rats and 100 mice. The experiments showed that the very first day after the injection the life span of the experimental animals at an "altitude" of 11,000 m was far above that of the control, the difference being most pronounced at an "altitude" of 10,000 m. The increased resistance of the experimental animals persisted for 10 days after the injections were terminated.

In experiments on 120 rats, the effect of 5 days of injection of 5 mg/kg of BAS was studied 3, 6, and 9 days later. Resistance to hypoxia was most pronounced on the 6th and 9th days.

The same dose was used on 18 guinea pigs, 10 of which served as the control. The "altitudes" at which excitation was recorded and convulsions developed in the experimental animals were much higher than in the control. This difference was most pronounced on the 5th day after injection.

The next group of experiments involved the use of indole I, indole IV, and indole XXIX on 140 mice. The results showed that under certain experimental conditions (selection of dose and time of injection) resistance to hypoxia can be significantly increased.

Thus, our factual material suggests that it is very worthwhile to look among the derivatives of indole and hydrazine for drugs to increase resistance to oxygen deficiency.

WHITE RAT RESPIRATION AFTER PROLONGED EXPOSURE TO RADIAL ACCELERATIONS

V. I. Danileyko, A. I. Nazarenko and O. S. Savchenko

Acceleration affects the vital activity of the organism in a great variety of ways. A very important index of the functional state--the degree of compensation of the changes that take place in the body--is the intensity of gas exchange or level of its energy expenditure (V. I. Babushkin, P. K. Isakov, et al., 1958; P. K. Isakov, 1958).

The dynamics of these indices in human beings and animals subjected to intense gravitation (the effect of acceleration and that of a gravitational field are, of course, identical) have been studied by many investigators (L. Bjurlen, 1938; G. Armstrong and D. Heim, 1938; others).

Influenced by the thought that functional changes are inevitable in all three components of respiration (external respiration, transport of oxygen by blood in the pulmonary circulation, tissue respiration), we decided to try a somewhat different approach to the study of the energy balance when the organism is subjected to a gravitation factor. Consequently, we performed experiments on 254 white rats weighing from 102 to 160 g exposed to lateral accelerations in centrifuges with an arm length of 65 and 256 cm.

The level of oxygen utilization was determined in 95 experiments performed on 53 animals with the aid of a Krog apparatus. The tube through which oxygen entered the hermetically sealed chamber (on the centrifuge arm) with the animals during rotation was connected to the apparatus by a movable adapter.

Carbon dioxide was absorbed by soda lime or KhPI placed in the chamber with the animals. The respiration rate was investigated with a carbon pickup secured to the animal's chest or with a piezo crystal that transformed the respiratory oscillations of the air in the respiratory system into electrical impulses amplified and fed into the input of an N-700 oscillograph.

Blood circulation in the pulmonary circulation was evaluated by gross inspection and, in a few cases, from microscopic examination of lung specimens.

The intensity of brain tissue respiration was determined in a Warburg apparatus.

The animal's body temperature was measured after the experiment with a mercury thermometer or TEMP-60 electric thermometer.

Some of the animals were sacrificed so that we could measure the temperature of the brain, liver, and kidneys. Liver temperature was measured, in 10 animals, during acceleration.

In the experiments involving a large centrifuge, we found that the rate of oxygen utilization by white rats exposed for many minutes to lateral accelerations ranging from 2 to 30 units was higher than the normal level. This fact fits in with the prevalent ideas on the general biological mechanisms of gas exchange in living things subjected to intense gravitation.

However, it is also well known that with a given level of action varying from species to species, external respiration is suppressed. For man and some animals (monkeys, dogs, etc.)7-10 units constitute such a limit, but the values are higher for animals with a small body mass (in this case white rats). Our experiments showed a significant increase in oxygen utilization even with accelerations of 17 units lasting 5 minutes.

Thus, the idea advanced by G. Galiley, K. E. Tsiolkovskiy, and others that there is a relationship between the biological effect of gravitational action and body mass of the individual has been confirmed experimentally. One may speak of the specifically species characteristics of the changes in gas exchange under these conditions.

We found marked individual fluctuations in oxygen utilization that apparently varied with the reactivity of the organism, etc. With accelerations of 5-17 units lasting for several minutes, the respiration rate slowed only slightly.

The following data obtained in one of the series of experiments are illustrative.

Oxygen utilization and respiration rate in a group of white rats during experiments in a centrifuge (comparative values from 9 animals)

Before rotation	5 units, 5 minutes	10 units, 5 minutes	15 units, 5 minutes	After rotation
Oxygen utilization in 5 minutes				
34.0	80.7	99.9	136.0	35.3
Respiration rate in 1 minute				
123.4	95.6	89.3	94.0	102.4

The body temperature of the animals dropped by 3-8° after the experiments, while the temperature of the viscera dropped by 3-5°.

Respiratory movements were markedly impaired in the animals that died after 15 minutes of accelerations of 22-26 units. With accelerations of 28 units, respiration became impaired in the first 2-3 minutes; with accelerations of 50 units, in the first minute of the experiment.

Oxygen utilization increased even in cases where extensive hemorrhages were found in the lungs of the animals sacrificed after the experiment. After experiments in which white rats were exposed to lateral accelerations of 50 units lasting 1-1/2 minutes, A. I. Nazarenko found a statistically significant increase in oxygen

utilization by brain tissue. This increase is apparently due to compensatory changes directed at liquidating the oxygen debt in brain tissue and to intense afferent impulses from the displaced tissues and organs.

One author found that after prolonged intense gravitation the animal's body temperature dropped sharply by 10 or more degrees with a given value of the action (V. I. Danileyko, 1958, 1959, 1961, 1962). This phenomenon, called postgravitational hypothermia, depended only to an insignificant extent on air cooling because it appeared even after the animal was carefully insulated against heat. (The phenomenon of postgravitational hypothermia in our experiments was accompanied by an increase in oxygen utilization.)

The drop in temperature measured in the rectum and viscera occurred simultaneously except that the temperature of the viscera under these conditions, as in the natural state, was always a little higher than the temperature of the surface tissues and rectum.

It follows from the foregoing data that the respiratory function in an organism exposed to intense gravitation and its energy expenditure change in all the components of respiration.

This work is the first part of an investigation into the nature of these changes and the relations among them since they are fairly complete reflections of changes in the general state of the organism. The organism's tolerance of gravitation would be increased if they were prevented.

IMPAIRMENT OF THE MECHANISM OF MITOSIS IN MICROSPORES AFTER FLIGHT ON VOSTOK 3 AND VOSTOK 4

N. L. Delone, P. R. Popovich, V. V. Antipov,
and V. G. Vysotskiy

The main categories of hereditary changes are: (1) gene (point) mutations; (2) structural rearrangements of chromosomes; (3) mutations of genomes resulting in polyploidy; (4) nonbreakage of chromosomes resulting in the appearance of hyperploids and aneuploids.

Although Tradescantia microspores are of no value in studying the first type of mutations, they are an ideal object for analyzing chromosome rearrangements. They can also be used in analyzing the third and fourth categories of mutations. It is possible to analyze figures with

impaired mitoses (while studying one cycle of cell division during which some action was carried out) and thus trace the first stages in the development of polyploid and other forms. N. P. Dubinin observed primary nonbreakage of chromosomes in Drosophila exposed to space flight factors on sputniks.

Tradescantia paludosa microspores and analysis of the specimens by the acetocarmine method have been described by us elsewhere. Cut Tradescantia stems with inflorescences were placed in special holders on Vostok 3 and Vostok 4. The experiment on Vostok 4 was performed by astronaut P. R. Popovich who fixed the material during the 37th orbit, i.e., 56 hours after the launching. We analyzed the metaphases, anaphases, and telophases (Table 1) as well as binucleate pollen (Table 2).

With a normal course of mitosis in Tradescantia paludosa microspores, the mitotic figures change as follows. In the early interphase, the nucleus of the microspore is in the center of the cell; it then shifts to one of the edges where it remains even in the period of early prophase. During the second half of the prophase, the nucleus moves to the center and remains close to the flat wall of the cell. In the metaphase, the axis of the spindle is so situated that the chromosomal plate is always parallel to the flat wall. We recorded figures reflecting both impairment in the regular movement of the nucleus and impairment in the mechanism of passage of the mitosis itself. We divided these figures into 6 groups.

Group 1. The nucleus in the prophase did not go to the center of the cell. It remained in a corner, but the nuclear cycle did not appear to be impaired, because the chromosomes were in the form of metaphase bodies and even split as in the anaphase and telophase.

Group 2. The chromosomes formed a "rosette". The nucleus in the prophase moved to the center, but in the metaphase the chromosomes were not found in the equatorial plate but were collected in bundles at the flat wall of the cell very tightly squeezed by the centromeres.

Group 3. The direction of the axis of the spindle changed so that the chromosomal plate in the metaphase was on another plane and, as a result, the telophases and nuclei of the binucleate pollen were also located on another plane. It will be noted that the position of the nuclei in binucleate pollen may change even after they are correctly situated, a phenomenon that should be borne in mind when analyzing these cases. We identified this as a separate group 6.

Group 4. Individual nonbroken chromosomes lagged.

Group 5. Three- and four-pole mitoses and, as a result, tri- and quadrinucleate cells.

Table 1. Number of impaired mitotic figures in Tradescantia paludosa microspores exposed to space flight factors (analysis of anaphases and telophases)

Name of spaceship	Mitotic phases exposed to the factors	No. of cells	No. of impairments		Including							
					Group 1		Group 2		Group 3		Group 4	
			Absolute	As percent	Absolute	As percent	Absolute	As percent	Absolute	As percent	Absolute	As percent
Vostok 4 Fixed by Popovich 56 hours after the launching	Late interphase, early, middle, and late prophase, metaphase	712	15	2.11±0.54	3	0.42	6	0.85	4	0.56	2	0.28
Vostok 3 Fixed 18 hours after landing	Middle, late interphase, early prophase	401	4	0.99±0.50	1	0.25	2	0.49	1	0.25	-	-
Vostok 4 Fixed 48 hours after landing	Middle interphase	83	2	2.40±1.68	-	-	-	-	1	1.20	1	1.20
Control		1000	-	-	-	-	-	-	-	-	-	-

Table 2. Number of impaired mitotic figures in Tradescantia paludosa microspores exposed to space flight factors (analysis of binucleate pollen)

Name of spaceship	Mitotic phases exposed to the factors	No. of cells	Group 5		Group 6		Reliability
			Absolute	As percent	Absolute	As percent	
Vostok 4 Fixed by Popovich 56 hours after the launching	Binucleate pollen	500	1	0.2+0.197	11	2.2+0.65	2.39[1]
Vostok 3 Fixed 18 hours after landing	Late interphase, early, middle, late prophase	500	4	0.8+0.39	13	2.6+0.71	2.99
Vostok 4 Fixed 48 hours after landing	Middle, late interphase	500	2	0.4+0.28	7	1.4+0.53	1.66
Control at space center	–	500	–	–	2	0.4±0.28	–
Control in Moscow	–	500	–	–	1	0.2+0.197	–

[1]Compared with the control at the space center

We used Tradescantia microspores as a model in studying the effect of space flight factors on the mechanism of mitosis. Naturally, the method of preparing the specimens has to be perfected in order to eliminate the possibility of artifacts. It will be noted that the figures in groups 1, 2, 4, and 5 cannot appear if the specimens are poorly prepared. However, reorientation of the nuclei in groups 3 and 6 can take place. Thus, one must be especially careful when analyzing these groups of changes.

Ionizing radiation can, of course, impair mitosis, but the dose must be fairly high. For example, a 400 r dose of X rays in our experiments had no effect at all on the microspores. Nor did accelerations of 5000 g impair mitosis. Presumably, the main reason for such changes is weightlessness, but experiments will have to be designed more rigorously to prove this.

One must also bear in mind that the effect of combined factors on the cell is never a simple addition of the number of changes induced, but rather new qualitative changes.

QUALITATIVE (STAGE) EVALUATION OF FLIGHT FATIGUE

Ye. A. Derevyanko

It is generally acknowledged that flight fatigue is essentially nervous and mental in origin. Thus, in studying fatigue, considerable attention is paid to the CNS, whose function is characterized by several indices--instability, relationship between excitation and inhibition, etc.

In the presence of unfavorable factors, these indices, at first, change unequally. Investigations made by the V. Ye. Vvedenskiy-A. A. Ukhtomskiy school revealed that in the initial phase of exposure to a parabiotic agent, excitability and rate of conduction of impulses decreases while the accommodation constant increases, instability grows, and chronaxie and the refractory stage shorten. In the transitional phase, on the other hand, excitability increases and the accommodation constant decreases. It is only in the final phase that all the indices testify to functional deterioration--the development of parabiosis.

Investigators likewise encounter a variety of changes in the indices of CNS function when studying fatigue. As a rule, some methods

regularly show a decrease in fitness, others an increase, still others show no clear-cut changes.

The conflicting results led some investigators to search for methods that would enable them to evaluate the depth of fatigue from a quantitative analysis of the changes, but all efforts proved futile. The fact is that none of the available methods permits a quantitative evaluation of fatigue, apparently because of the phase quality of the changes in the indices.

In investigations conducted jointly with V. P. Zagryadskiy, P. N. Oblapenko, P. Ya. Nurdygin, A. A. Kupriyanov, N. D. Zavalova, T. I. Zhukova, I. P. Korenev, and others, we found that in the onset of flying fatigue, just as in the development of parabiosis, the indices of CNS function change at first in different ways. On the basis of these investigations, we selected a number of methods with varying sensitivity to developing fatigue.

The highly sensitive methods include a determination of the critical rate of coalescence of light flashes and the duration of afterimages. Moderately sensitive methods include a determination of muscular endurance, time of a simple motor reaction to light and sound, time and accuracy of differentiation of sounds of varying intensity. Methods of low sensitivity include a determination of muscular strength and mobility of the motor analyzer (tapping test).

It was impossible with the intensity of the flight load under study to detect any clear-cut changes in the indices of the methods used to measure certain mental processes (memory, attention, speed and accuracy of reading instruments, etc.). On the other hand, V. A. Petrovykh and B. L. Pokrovskiy noted a distinct lowering of the functional level of these processes after a very heavy flight load.

It was found that most of the methods mentioned above, show an improvement in results at the beginning of a load and begin to decline only later. The highly sensitive methods are the earliest to show an improvement in results, but are also the first to reverse. Therefore, at a time when these methods are showing a deterioration in results, weakly sensitive methods show an improvement. As fatigue intensifies, this group too begins to reverse so that the results of the investigations become increasingly alike (Table 1).

Investigations showed that trace excitation has a tremendous effect on efficiency. Right after the plane lands, most indices, owing to the excitation prevailing in the CNS, point to a high level of efficiency. As the excitation is extinguished, symptoms of fatigue become increasingly evident (Table 2). Therefore, the degree of fatigue should be determined after the excitation caused by emotional flight factors has been extinguished in the CNS.

Table 1. Dynamics of change in indices in the development of fatigue caused by flight activity of varying intensity

Intensity of flight load	Nature of change, in percent		
	Highly sensitive methods	Moderately sensitive methods	Weakly sensitive methods
Low	+68/-12(20)	+27/-19(54)	+17/-5(78)
Moderate	+ 7/-36(57)	+22/-20(58)	+36/0(64)
Above moderate	0/-80(20)	+ 7/-42(51)	+20/-13(67)
High	-	+ 6/-70(24)	0/-57(43)

Note. In the numerator - the number of cases of improvement in results; in the denominator - deteriorations; in parentheses - virtually unchanged.

Table 2. Nature of the change in simple conditioned motor reactions in fliers during a day's flying under a heavy load

Indices	Before Flying	After the first flight	After the second flight	After the third flight	15-30 minutes after conclusion of the flights
Reaction time in σ	185	177	150	172	219
As percent of investigations before flying	100	96	86	93	118

Our investigations provide additional confirmation of A. A. Ukhtomskiy's view that a feeling of weariness is a delicate and reliable index of incipient fatigue and that the early stages of fatigue do not impair the "functional harmony of the organism" or decrease efficiency. They also demonstrated that using methods which produce results largely dependent on volition introduces an undesirable variability.

The findings presented above made it possible to develop a stage system of evaluating the depth of fatigue.

The following data are used:

(a) Subjective condition of the flier.

(b) Observations of the flier's behavior.

(c) Nature of the flights.

(d) Dynamics of nervous and mental tension.

(e) Results of investigations using methods of varying sensitivity to developing fatigue.

The characteristics of the three stages of fatigue were described in detail in F. P. Kosmolinskiy and Ye. A. Derebyanko's book Utomleniye letnogo sostava (Fatigue in Flight Personnel) (1962). The proposed approach has several shortcomings that should be corrected:

(a) Little use is made of weakly sensitive methods, the number of which should be increased.

(b) The results of several methods depend to some extent on the level of volition.

(c) It is not quite clear just which aspects of the state of the CNS are characterized by most of the methods selected for use in investigations. For example, there is still no consensus even on the particular aspect of the CNS that is characterized by a "simple" conditioned motor reflex (B. M. Teplov).

PSYCHOPHYSIOLOGICAL CHARACTERISTICS OF INSTRUMENT FLYING

Ye. A. Derevyanko and N. D. Zavalova

Most of a pilot's efforts in instrument flying are directed at retaining and changing the current flight parameters in accordance with his evaluation of the incoming information and the flight plan. Obtaining information on flight conditions to guide his actions, the pilot manipulates the controls to change the plane's position. Flying is a continuous process of sensorimotor coordination in which the pilot, besides visual signals, receives sound, acceleration, and proprioceptive signals. It is the visual information, however, as has been demonstrated by flight experiments, that has the greatest influence in retaining or changing the mode of operation. Attempts to keep a plane flying horizontally with no visual information available resulted in a significant change in the spatial position and flight parameters during the first minute of blind flying and the pilot lost his spatial orientation.

Visual information in instrument flying is different from that in visual flying. First of all, information about the spatial position of the plane has to be processed by the pilot. Secondly, information reaching the pilot from instruments is discrete because there are interruptions in the perception of the readings of each instrument. The information comes in parts, i.e., it is given out by different instruments or by different markings on the same instrument, and the pilot has to synthesize the individual signals into a complete image.

The stream of data reaching the pilot can be arbitrarily divided according to function into control and correcting information. The former applies to the mode of operation, whereas the latter is needed to perform an action designed to maintain or change the current flight parameters. The instruments play different roles from the standpoint of providing control and correcting information. The pilot controls the flight conditions with all the instruments (altimeter, course indicator, variometer, gyro horizon), and a change in the readings of any of the instruments may signal the start of an action. However, the pilot receives correcting information mainly from the variometer and gyro horizon. These, then, are the instruments that a pilot uses in blind flying. According to I. A. Kamyshev, a pilot looks at them 70 percent of the time.

The need of correcting information is dictated by the complexity of motor activity in controlling a plane. This activity cannot be considered a chain of simple motor reflexes (signal movement). It consists of two main elements: (a) perception and evaluation of the readings of the instruments, (b) sensorimotor coordination of movements.

In controlling the mode of operation, the pilot receives and processes incoming information. The processing culminates in a decision to act. As soon as the pilot decides, the purely sensory elements of his activity ends. The performance of an action to retain or change the mode of operation includes the execution of movements based on a continuous flow of correcting information. The performance of motor acts aimed at retaining or changing the current flight parameters takes a good deal of time. The correcting information that arrives during the performance of a motor act does not permit instantaneous measurement of the amplitude and duration of deviation of the control stick. The need of constant correction of movements is due to the fact that the nature and duration of motor acts aimed at the same goal fluctuate considerably. It seems that sensorimotor correction of actions is the central part of the process of controlling an airplane and it requires active attention on the part of the pilot throughout the flight.

The process of receiving and evaluating instrument readings, apart from the performance of movements for control purposes, is not complex. Laboratory investigations have shown that a little training will enable unskilled subjects to determine the spatial position of an airplane from instrument readings just as quickly and as accurately as veteran pilots, with 2-2 1/2 seconds spent on perceiving and evaluating the readings of the principal instruments. In one flight experiment, after opening the instrument panel, the pilot began to make the first movement to bring the plane into a horizontal position within 0.3-0.8 second, i.e., he evaluated the situation very quickly.

Thus, analysis of a pilot's actions in controlling an airplane shows that sensorimotor coordination of movements to control the craft is the most complicated part of his work during an ordinary flight. The perception of instrument readings, reconstruction and maintenance of his impressions on the current mode of operation up to the time that he takes action, is not difficult for an experienced pilot.

The coordination of movements with instrument readings is the "bottleneck" that may cause loss of time and create tension if a complication should develop. Successful control of a plane does not require rapid movements; it depends on accuracy of measurement and smoothness of movements. The existing set of instruments provides little help for the pilot in selecting the most effective movements. The information he uses to correct his movements has to be considerably processed and recoded. It reaches him in discrete form so that it is impossible for him to perform an immediate and precise motor act without correcting movements.

The pilot's task can be eased and extra time provided chiefly by helping him in the performance of motor acts. This can be done by changing the instrument readings. Instruments should yield coded

information in maximally convenient form and decide for the pilot the amount, intensity, and smoothness of movements required for control purposes. That is to say, they should issue clear commands as to how an action should be performed at each particular moment.

SELECTION OF INDIVIDUALS FOR FLIGHT TRAINING

T. T. Dzhamgarov

The selection of individuals for flight training is an urgent problem, whose theoretical and practical aspects have been inadequately considered. The existing methods -- somewhat one-sided we believe -- provide no means of studying motor abilities, some of which are extremely important for successful flight training. They are also rather passive in that they are designed simply to determine the degree of fitness for flying, but fail to indicate ways in which the necessary qualities can be developed.

The purpose of investigations that we conducted with our colleagues (V. L. Marishchuk, N. V. Sysoyev, K. I. Brykov, and L. V. Yakusheva) was to devise and verify experimentally under flight school conditions: (a) methods of predicting the capacity for flight training and (b) physical conditioning techniques to correct individual shortcomings in acquiring flying skills. Four series of experimental investigations were run over a period of 4 years (1959-1963).

The basis of the selection method used in our investigations was a combined study of certain motor abilities and individual psychological traits that are most conducive to successful flight training. The examination program for the candidates took cognizance of the data derived from a preliminary analysis of the reasons for training failures.

Among the motor abilities studied were the speed of reflexes to complex signals and delicate coordination of movements. These abilities were also studied in conjunction with exercises involving the diversion of attention and artificially stimulated emotional stress. Special apparatus was used in the tests.

The main criteria used in evaluating the results were the objectively recorded speed and accuracy with which the control exercises were performed and the degree of change in these indices during the examination (for characteristics of the process of acquiring motor

skills) and also when the conditions for performing the exercises were changed (for characteristics of the ability to shift attention rapidly and emotional stability). At the same time, the behavior and actions of the subjects were systematically observed. In addition, some autonomic changes in performing the exercises were recorded in order to evaluate individual "stress reactions".

A special physical training program was usually conducted during the period of theoretical instruction. Depending on the concrete shortcomings revealed during the selection examination, this training was aimed chiefly at: (a) coordination and precision of movements, (b) speed of movements and actions, ability to divide and switch attention, (c) emotional stability and techniques of mastering tension.

The showing in the initial flight training was the principal basis for evaluating the prognosis of flying capabilities and effectiveness of the special physical training program. The following parameters were used in the evaluation: number of flights before the first solo take-off, the amount of flying time before the first solo take-off, flight progress, opinion of instructors on the desirability of further training, and data on dismissals for unsuitableness.

The effectiveness of our methods was confirmed by: (a) a clear-cut relationship between the candidate's examination ratings and the results of the initial flight training and (b) the high accuracy in forecasting the instances in which flight training was unproductive (75--80 percent) or, conversely, when it was highly successful (95-100 percent).

The usefulness of the special physical training program to eliminate individual shortcomings was revealed by the fact that the trainees in the experimental group were on the average 20-30 percent more successful than the control in carrying out equivalent parts of the program.

Some idea of the accuracy of the predictions and degree of effectiveness of the special physical training program[1] is provided by the figures presented in the table above.

These data and the relative simplicity of the examination testify to the practicality of the proposed method. It will easily identify

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[1]Tr. Note: Not included in the text.

the following groups: (1) candidates with pronounced shortcomings that render their admission to flying school inadvisable, (2) individuals with outstanding flying capabilities who should be specially recommended for admission to flying school, (3) individuals with shortcomings that can be corrected by special physical training during the period of theoretical instruction.

The special physical training designed to supplement the regular exercise program should be regarded as an essential part of the training of future fliers.

THE POSSIBILITY OF SUBSTITUTING HELIUM FOR NITROGEN IN THE CABINS OF SPACECRAFT

A. G. Dianov and A. G. Kuznetsov

The possibility of substituting helium for nitrogen is of considerable interest in connection with research on the microclimate of spacecraft cabins. This substitution seems feasible both from the physiological and from the technical standpoints: because helium is less soluble than nitrogen in liquids and, especially, in fats, an atmosphere consisting of oxygen and helium is not too conducive to the decompression disorders that may arise in human beings in the cabin of a spacecraft when the pressure drops. This assumption is supported by studies on the use of helium to prevent caisson disease in divers (M. I. Yakobson, 1950) and theoretical investigations (Roth, 1959).

The substitution of helium for nitrogen eliminates the possibility of harmful actions to humans by radioactivity. These actions can arise under the influence of cosmic radiation on nitrogen molecules (Bowman and Dingman, 1960). The high thermal conductivity of helium makes it reasonable to assume that human beings in a spacecraft cabin with a helium-oxygen atmosphere will be more tolerant of higher ambient temperatures than in air. If this is confirmed experimentally, helium will play a major role in protecting man from the high temperatures that may develop in a spacecraft. The use of a helium-oxygen atmosphere in a spacecraft will make it possible to reduce the vehicle's weight at launching because helium has one-seventh the density of air. Moreover, helium will be valuable if the spacecraft should lose its airtightness, because helium is the best available leak tester. There is also reason to believe that the substitution of helium for nitrogen will result in a decrease in the amount of energy needed for enforced ventilation in the cabin.

The effect of a helium-oxygen mixture on man and animals has been studied by foreign and Soviet authors (Barach, Benke, Cook, Orbeli, Zal'tsman, Boriskin, Gul'tyayev, Savin, and others). Experiments demonstrated that animals can remain for a long time (up to 3 1/2 months) in a gas medium in which the atmospheric nitrogen has been replaced with helium. In a temperature range of 18-22° C, helium, which is a better heat conductor than nitrogen, increased gas exchange in the animals by intensifying the loss of heat. When the helium-oxygen mixture was heated to 27-29°, however, no significant changes were noted in the animals.

The effect on man of substituting helium for nitrogen was investigated in experiments of no more than a few hours' duration (use of helium in deep-water descents of divers, in treatment of certain diseases of the respiratory organs, etc.) Results showed that for a short time man can breathe a helium oxygen mixture not only at normal but also at high pressure (up to 16 atmospheres). However, it is important to note that in these experiments the helium-oxygen mixture was used only as a breathing mixture, not as a gas medium in which man was to remain for some time. To date there have been no long-term experiments testing this possibility.

The purpose of this investigation was to study the possibility of man's remaining for a long period of time in a pressurized cabin in which helium replaced nitrogen. Two experiments lasting 22 and 30 days were carried out with two groups of subjects who remained in a helium-oxygen mixture 10 and 25 days, respectively. The CNS, respiration, cardiovascular system, gas exchange, heat exchange, speech, hearing, as well as behavior and general well-being, were kept under observation.

Results showed that helium,due to its high thermal conductivity, markedly affected heat exchange. Exposure to the helium-oxygen mixture at temperatures comfortable for air (18-24°) resulted in appreciable cooling of the subjects, as reflected in a sensation of cold and a lowering of skin temperature.

In the helium-oxygen medium, the zone of heat comfort for the subjects when awake during the day ranged from 24.5 to 27.5° and at night while sleeping - from 26 to 29°. These changes were caused by the more pronounced cooling properties of the helium-oxygen medium as compared with air. The experimental data examined below [1] were obtained mainly at the comfortable temperature of a gas medium in a pressurized cabin.

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[1] Tr. Note: Not included in the text.

Investigations of CNS functions made by V. F. Onishchenko, V. V. Boriskin, P. A. Gul'tyayev, A. V. Sergiyenko, and others showed that inhibition gradually developed in the subjects' cerebral cortex in the course of the experiments, as revealed by the appearance of low-frequency oscillations on the EEG and by a slight lengthening of the latent period of the conditioned motor reflexes. Analysis of data indicated these changes were caused not by the substitution of helium for nitrogen, but by the influence of prolonged hypodynamia and relative isolation. The general sense of well-being, behavior, and efficiency of the subjects did not change in the helium-oxygen medium.

The indices of the external respiration, cardiovascular system, gas exchange, and energy expenditure of the subjects under the conditions of basal metabolism or in a state of relative rest likewise did not change significantly. However, the use of a functional test in the form of measured physical exercise showed that minute ventilation, cardiac rate, amount of oxygen utilized and energy expended gradually increased the longer the experiments lasted. These changes too were not attributable to the helium-oxygen medium, but to prolonged hypodynamia and relative isolation. There was a distinct, progressive increase in the deconditioning of the subjects as the experiments continued. Each additional physical exercise required more and more exertion on the part of the respiratory and cardiovascular systems and gas exchange.

The investigations of I. Ya. Borshchevskiy, V. S. Kuznetsov and Yu. V. Krylov showed that breathing a helium-oxygen mixture markedly affects speech, as reflected in a shift of the spectrum toward the high frequencies by a value of the order of 0.7 octave. Clarity of speech tends to deteriorate, although not as far as the level of permissible values of intelligibility. The auditory function does not change appreciably.

The experiments described above have demonstrated that man can remain a long time (up to 25 days) in a pressurized cabin in which helium is substituted for atmospheric nitrogen.

EXCRETION OF 17-OXYCORTICOSTEROIDS IN AN INVESTIGATION OF THE EFFICIENCY OF AIRPLANE CREWS ON LONG NIGHT FLIGHTS

I. G. Dlusskaya, F. L. Kosmolinskiy and N. A. Fedorov

Investigators of flier fitness under the conditions of long, tense flights used more than physiological, psychological, and clinical methods. They devoted considerable effort to determining changes in the homeostasis of the internal fluids, including the hormones.

The question of human efficiency in critical situations has long interested scientists. Body reactions designed to preserve the constancy of the internal environment and to ensure normal functioning of organs and systems have been described in the reports of Soviet physiologists, who assign the nervous system a leading role in the maintenance of homeostasis.

Besides directly influencing the resistance of the organism, the nervous system is also responsible for humoral regulation--the activity of the endocrine glands--as reflected in the research of L. A. Orbeli on the adaptation-trophic influence of the nervous system on the state of the tissues and peripheral neuromuscular apparatus. Speaking of the body's reserves in performing a given task, we might also mention H. Selye"s theory of the adaptation syndrome, the heart of which is the reaction of the pituitary-adrenal system, i.e., in response to various external agents (pharmacological, physical, infectious, neuropsychic, etc.), secretion of the hormones of the anterior lobe of the pituitary (ACTH) increases as does that of the adrenocortical hormones. An important element in this view is the ability of the adrenocortical hormones--the glucocorticoids--to hasten the conversion of proteins into carbohydrates and thereby increase the energy reserves of the organism. It is reasonable to suppose that such a mechanism of "emergency" utilization of protein reserves evolved and became fixed phylogenetically when it was vitally important for animals in danger or in the excitement of hunting to be able to mobilize quickly all their resources, including the utilization of proteins for energy purposes.

The adrenal cortex of man and mammals synthesized three kinds of steroid hormones: (a) the glucocorticoids, of which the main one in man is hydrocortisone, (b) the mineralocorticoids (aldosterone), and (c) the male sex hormones (adrenosterone and testosterone). In response to an increase of ACTH in the blood, the secretion of other hormones, chiefly the glucocorticosteroids, also increases.

To evaluate the secretion of glucocorticosteroids by the adrenal cortex, one may calculate the content of any of these compounds in the blood or their excretion with urine. It is technically more difficult to do so in the blood, for the material is poorly preserved and it is not easy to take blood when required, especially during a flight. It is easier to investigate hormones in urine, and the material is more readily preserved. Moreover, the urine collected during a flight is a unique reflection of the biochemical changes that have taken place. Besides free hormones, the urine contains their metabolites and compounds with glucuronic acid. The determination can be made from the amount of corticoids entering the blood, which can be used as the basis of judging the overall reaction of the pituitary-adrenal system.

We determined the total bound and free 17-oxycorticosteroids after long night flights involving refueling in the air. Similar investigations were carried out in 1958 by Marchbanks, who observed a significant increase (twofold) in the amount of 17-oxycorticosteroids excreted with urine during a 23-hour flight only in the captain, the person mainly responsible for the flight, for landing, and for refueling in the air. The changes in the other members of the crew examined--navigator, radio operator, and second pilot--were insignificant and well within normal limits.

I. V. Fedorov and G. G. Sturua, who reported (1961) on an investigation of fliers taking part in a succession of short (30-40 minute) flights, found that on nonflying days the hourly excretion of steroids during the day was 30-50 percent higher than during the night. On flying days, however, the hourly excretion during the first flight was double the original level and it even increased somewhat during the second flight. Within a few hours after landing the values returned to normal.

The present investigation focused specifically on fliers during long night flights. Urine was collected immediately before the takeoff, immediately after landing, and during the first 6 hours after landing (there was generally a 6-hour rest period). The urine was preserved and later analyzed for its content of 17-OH-KS by the Silber-Porter method as modified by Yudayev. In processing the data, account was taken of the excretion of 17-oxycorticosteroids in γ/hour during three periods: an average of 1 hour before a flight, after 1 hour of flight, and 1 hour after post-flight relaxation.

A noteworthy feature of the dynamics of the hormonal reactions was that during the hours of flight there was a relatively low level of excretion, but a fairly high level during the hours of post-flight relaxation. A significant increase in hormonal excretion during flight occurred in 2 controllers (by 80 and 230 percent) and in 3 captains (by 100, 200, and 500 percent, i.e., 2- to 6-fold).

The flight with assignment not completed was particularly interesting. The captain and controller showed a substantial increase in hormonal excretion during the flight (by 200 percent), and it remained high even during the post-flight hours of relaxation. Yet hormonal excretion in the second pilot did not change during the flight hours, although it increased during the first post-flight hours. A 5-fold increase in excretion of steroid hormones during the flight was observed in the captain, who carried out a complicated assignment. An increase in excretion in the other members of the crew took place only in the hours of relaxation.

The earliest hormonal changes (during the flight) took place in the captains and controllers because they have the main responsibility on this type of airplane. The duties and experiences of the second pilots were simpler and the increase set in only during the post-flight hours.

An interesting fact revealed during the examination of several members of the same crew was that the hormonal reactions in the captains and controllers or in the controllers and second pilots on the same flight were similar and assumed the form of parallel curves on graphs. This was apparently the result of similar flying conditions and emotional stress in these members of the crew.

In summary, the excretion of steroid hormones with urine increased significantly during long night flights mostly in the plane captain and controller, who performed complex tasks. When such flights were relatively uneventful, hormonal secretion in the crew changed very slightly during the flights, usually decreasing. When the flight was over, during the first 6 hours of relaxation, there was a marked increase in excretion (by 50-150 percent) over the pre-flight level in 12 of the 16 persons examined.

This phenomenon can be attributed to the length and tension of the flights and to the fact that they took place at night (from about 2200 to 0600 hours), when the reactivity of the pituitary-adrenal system is different (somewhat lower) from that during the day.

VESTIBULAR INFLUENCES ON THE SMOOTH MUSCLES OF THE SMALL INTESTINE AND BLOOD VESSELS AFTER TRANSECTION OF THE SPINAL CORD AND VAGUS, CERVICAL SYMPATHETIC, AND SPLANCHNIC NERVES

A. S. Dmitriyev and Ye. V. Burko

G. Brown in 1909 pioneered the study of vestibular autonomic reactions with his investigations of respiration in frogs subjected to progressive vertical accelerations. Later, as a result of the rapid development of science and technology; high-speed travel on the earth and, above all, in the air; and need to solve a number of clinical problems, scientists became interested in the physiology of the vestibular apparatus. Many reports were published on the effect of vestibular stimulation on different autonomic and animal functions. Extensive experimental material now exists on the cortical and subcortical mechanisms of vestibular influences on the striated musculature (Ewald,

1892; Voyachek, 1908; Quicks, 1922; Magnus, 1924; Khilov, 1929, 1952; Yarotskiy, 1937; Asratyan, 1940, 1947; Bakhvalova, 1950; Min'kovskiy, 1953; Beleceanu-Stolnich, Faluts, and Laurian, 1954; Dmitriyev, 1953, 1958; others).

However, the physiological mechanisms of the labyrinthine influences on the smooth musculature have not been adequately studied. While a relatively large number of studies have been published on changes in blood pressure caused mainly by decreased tone of the vascular wall after stimulation of the labyrinth (Spiegel and Demitriades, 1922; Perekalin, 1928; Khilov, 1933, 1958; Lozanov, 1938; Klosovskiy and Semenov, 1947; Khechinashvili, 1958), there are only isolated reports describing vestibular influences on the smooth muscles of the gastrintestinal tract (Spiegel and Demitriades, 1922; Perekalin, 1928; Suvorov, 1958; Rassvetayev, 1958; Khazen, 1958; Lopatin, 1960).

The purpose of this investigation was to study the characteristics and mechanisms of the vestibular influences on the smooth muscles of the intestine and blood vessels under the conditions of rotation in a centrifuge at different speeds and with different radii and to determine the post-rotation changes in these indices after transection of various autonomic nerves and the spinal cord. Study of these matters will throw more light on the physiological mechanism of seasickness, which is caused by stimulation of the vestibular receptors, and includes such reactions as nausea, vomiting, urination, defecation, change in blood pressure, etc., — reactions under control of the smooth muscles.

In acute experiments on dogs anesthetized with morphine-ether, electromechanograms on a MPO-2 oscillograph recorded motility of the ileum, tone of the intestinal wall, blood pressure, and respiration. These indices were recorded continuously before, during, and after even rotation of the animal, whose head was in the middle or on the periphery of the centrifuge. Vestibular tests were made after transection of various nerve trunks and the spinal cord and after destruction of both labyrinths. The transections were carried out in different sequences.

The first series was devoted to a study of vestibular influences on ileal motility and blood pressure, taking into account the radius (from 0 to 130 cm), speed (from 10 to 40 rpm), and direction (clockwise and counter-clockwise) of rotation. The second series focused on the effect of vestibular stimulation on the same indices as in the first series, but after successive transection of the vagus, cervical sympathetic, and splanchnic nerves, and of the spinal cord at the level of the 2nd-3rd thoracic vertebrae before and after exclusion of the labyrinths of the internal ear.

The first series of experiments showed that ileal motility was inhibited by rotation in all 44 dogs. The latent period of this reaction ranged from 5 to 75 seconds, while the aftereffect appeared 3 minutes after the centrifuge was halted. Complete inhibition of motility by rotation was noted in 177 tests, intensification of motor activity in 35, temporary intensification and then inhibition in 24, and no changes in motility in 20 vestibular tests.

The animals were divided into three groups according to the principal changes that took place in intestinal motility: (a) animals with inhibition predominating (30); (b) animals with intensification predominating (9); and (c) animals with an indistinct response to stimulation of the labyrinth (5).

It is interesting to note that the reaction of the ileum to acceleration disappeared in almost all cases after bilateral destruction of the labyrinths.

The changes in intestinal motility varied with the intensity of the vestibular load. The greater the speed of rotation, the larger the number of tests that revealed intestinal inhibition, with a proportionate decrease in the number of tests that showed no definite changes in motility. For example, after rotation at the rate of 10 rpm, no changes in motility were found in 11.7 percent of the tests, but after rotation at 30-40 rpm the figure dropped to 4.5 percent. Arterial blood pressure (in the common carotid artery) under the influence of the accelerations fell to 20 mm Hg. More significant changes in blood pressure were noted after caudocranial rotation, i.e., when the dog's head was on the periphery of the centrifuge.

The data obtained in the first series of experiments partly agree with the data obtained in chronic experiments on dogs rotated at a high speed (from 3 to 10 g) (Suvorov, 1958; Khazen, 1958) and after experimental rolling (Rassvetayev, 1958) in connection with a study of the effect of accelerations on gastric motility. However, these authors did not set out to determine the relation of the vestibular apparatus to these reactions because they used accelerations without excluding the active participation of various extralabyrinthine systems in these reactions. Nevertheless, they did show that gastric motility is inhibited by accelerations. Perekalin (1928) observed an intensification of ileal motility in response to inadequate stimulation of the labyrinth, but the data obtained in the present investigation concerning the inhibiting effect of the labyrinth on ileal motility contradict his findings.

The decrease in vascular tone (drop in blood pressure) that we observed under the conditions of rotating in a centrifuge with a long radius (130 cm) was apparently related to the function of the otolithic part of the labyrinth.

The second series of experiments showed that the inhibition of intestinal motility by accelerations persisted after bilateral transection of the vagus and cervical sympathetic nerves, but disappeared after bilateral destruction of the labyrinths.

These findings do not agree with the data of V. Ye. Perekalin (1928), who states that transection of the vagus nerves relieves the motility intensified by calorization of the labyrinth with cold (15°) or hot (45°) water and decreases the tone of the ileal wall.

Transection of the spinal cord, vagus, cervical sympathetic, and splanchnic nerves somewhat altered the nature of ileal motility, but did not suppress the peculiar effect of accelerations. After both labyrinths were excluded, the aforementioned rotation changes in intestinal motility disappeared in almost all the experiments. It is evident that the smooth-muscle reaction to slight accelerations is vestibular in origin and that it is executed by nerve mechanisms located in the brain stem. However, it is still impossible to identify the specific pathways through which vestibular influences reach the smooth muscles of the intestine. It is reasonable to assume that the efferent part of the arc of this reflex includes more than just the fibers passing through the vagus, cervical sympathetic, and splanchnic nerves. These reflexes can also be executed without the participation of the spinal cord. This agrees with the well-known fact (Meshcheryakov, 1959) that after transection of the spinal cord at the level of the 6th-7th cervical vertebrae and extirpation below the transection site, there are no significatnt changes in the motility of the alimentary canal. However, our data do not preclude the possibility that the aforementioned nerve conductors participate in the labyrinthine influences on the smooth muscles.

We have concluded from our preliminary findings that vestibular reactions can be executed by nervous as well as by humoral mechanisms.

SOME DATA ON AN INVESTIGATION OF CHAIN CONDITIONED MOTOR REFLEXES IN ANIMALS AFTER LONG EXPOSURE TO AN ALTERED GAS MEDIUM

G. P. Doronin

Although electrophysiology is now widely used in objective investigations of the CNS, the method of conditioned motor reflexes has not lost its independent value in studying the effect of an altered environment on the formation of complex responses. The published data indicate that the indices of conditioned activity are several times more sensitive than those of other methods for determining the threshold values of toxic products and many other injurious factors (Yu. P. Frolov, 1944; L. I. Kotlyarevskiy and A. G. Bukhtiarov, 1960; others).

The use of chain motor reflexes in investigating the prolonged action on animals of altered gas composition in inhaled air, rarefied atmosphere, and some other factors that may occur in actual space flight is of considerable theoretical and practical interest.

We performed experiments on white rats, using the method of chain conditioned motor reflexes developed in the Department of Higher Nervous Activity, Moscow State University (director, Prof. L. G. Voronin). This method was technically perfected by us jointly with engineer B. A. Miloslavov. Using a relay system with temporary delay circuits, which made it possible to switch on conditioned stimuli in a definite sequence, we prepared an automatic electric device for prolonged (up to 2 months) investigations of chain motor reflexes in the white rats.

It is known that, in chain motor reflexes, a highly specific motor reaction corresponds to each stimulus in the chain. The correct execution of the preceding link is reinforced by activating the next stimulus in the chain and the entire chain of motor reactions becomes an unconditioned stimulus. Numerous investigations (K. I. Kunstman, 1923; L. G. Voronin, 1948, 1952; V. K. Krasuskiy, 1954; N. A. Rokotova, 1954; G. I. Shirkova, 1955; others) have shown that the connection with the unconditioned stimulus of just the last or closing component of a chain determines the force of the individual links in a complex chain stimulus. The first stimulus in the chain becomes the determining or "trigger" component. Later, the sequence of the conditioned stimuli joined into a chain becomes the main signal. The subsequent movement of the animal is largely determined by the nature of the preceding proprioceptive impulses.

The formation of temporary connections between the cortical centers excited by a chain of stimuli, the food center, and corresponding projections of the motor analyzer results in the creation of a "functional combination center" in the cerebral cortex. The use of chain conditioned motor reflexes makes it possible to investigate the delicate process of analysis and synthesis of the complex stimuli that act in a definite sequence on a living organism.

It has been established that the structure of a chain motor reflex is more or less vulnerable to the influence of unfavorable environmental factors. In this regard, we investigated chain reflexes in the experiments of A. G. Kuznetsov, S. G. Zharov, and N. A. Agadzhanyan, who studied the effect of prolonged exposure to minimum levels of barometric pressure and high concentrations of carbon dioxide in inhaled air (pCO_2 14.2-35.6 Hg). A sequence of movements corresponding to the stimuli was formed and stabilized in white rats:

light → movement to platform 1 -- light 2 → movement to platform 2 -- sound of an electromagnet → movement to the feed box.

The stimuli were switched and the food reinforcement was delivered automatically as the animal passed across the contact platforms. Conditioned inhibition was established by the first stimulus in the chain and an additional component, blinking light. Meanwhile a disengaging reaction was formed in the animals - movement to platform 3, reinforced after a little while by activation of the chain of positive stimuli. Execution by the animals of movements of the positive chain against the background of the blinking light was interpreted as a "disruption" of inhibition.

The system of conditioned motor reflexes formed simulated the complex activity of animals in getting food and made the artificially created situation resemble the conditions of a natural experiment.

Chain motor reflexes were studied in 10 experiments lasting from 2 to 60 days. The pattern of the changes therein was traced under the conditions of normal and high CO_2 content in inhaled air at altitudes of up to 10,000 m.

With the pCO_2 about 14 mm Hg (2 percent), there were fluctuations during the first 2-3 days in the time of execution of the individual links in the chain, usually the first or "trigger" link. The structure of the chain reflex remained virtually unafffected. More characteristic was a lengthening of the time of the motor reaction, which disrupted the conditioned inhibition, as well as a complete loss of this movement and appearance of searching activity, prolonged cleansing reactions, etc.

With a pCO_2 of 35.6 mm Hg (5 percent) there was more pronounced impairment of the established system of conditioned reflexes. As a rule, during the first days of exposure the time of reaction to the first stimulus in the chain increased by 0.3-0.5 seconds, and losses of individual links or execution by the animals of a variety of movements unrelated to the signal value of the stimuli were common. There were frequent "disruptions" of inhibition with execution of movements of the positive chain against the background of the blinking light and omission of the reaction releasing the conditioned inhibition. The chain motor reflexes were restored during the second week of exposure to these conditions, although at a somewhat different level. However, the reactions to the conditioned inhibitory stimulus were irregular, testifying to the increasing deficiency of internal inhibition.

The introduction of an additional factor - rarefaction - into the experiments resulted in some peculiar conditioned activity by the animals the first day after they were "elevated". This was evidently due to meteorism and to the transient influence of sound stimuli at the time that the barometric pressure was lowered and the particular gas medium created.

Maintenance of normal pO_2 under the conditions of a rarefied atmosphere ensured preservation of chain conditioned motor reflexes at more or less the original level.

Experiments with brief hypoxia showed that at an altitude of 4000-5000 m the structure of the chain motor reflexes became impaired and phase states appeared. At 6000-6500 m some of the animals developed complete inhibition of the previously formed complex systems of conditioned motor reflexes.

Thus, it has been shown that the method of chain motor reflexes is highly sensitive and useful in studying the effect of some factors specific to aviation and space medicine.

CHANGES IN THE CAPACITY OF THE CENTRAL NERVOUS SYSTEM WHILE LEARNING TO PILOT A TRAINING PLANE

V. A. Yegorov

An important aspect of aviation physiology and psychology is the amount of information a flier perceives and processes. Studies have shown a direct relationship between the amount of information perceived and reaction time (Hick, Hayman). Once the average time per signal is determined, it is possible to calculate the reaction time for a great many signals. In investigating the speed of perception and processing of information, it is necessary to bear in mind that these change in the course of training in relation to changes in the capacity of the trainees while they are acquiring the ability to control the apparatus.

We investigated the problem in connection with a TL-1 trainer, starting with the assumption that the trainee's capacity is a function of the complexity of the task to be performed and the degree of skill acquired. Experiments were performed on 48 healthy persons from 18 to 28 years of age, none of whom had had any previous "flight" experience on the trainer or any flight training. Each subject was required to react to a radio command by moving a certain control lever on the trainer: in the first series - any one lever (a simple movement); in the second series - two levers (a complex movement); in the third series - the subject performed the same movements as in the second series, but while "flying" he had to react to a command quickly and correctly and to do his best to prevent other "flight" parameters (except the one to be changed) from changing.

The movements were selected in accordance with the rules for piloting a trainer and airplane, and the commands were grouped together in such a way that in each succeeding group the information contained in a signal was increased by 1 bit over the preceding group. The use of mechanical and electrical systems made it possible to record (in the form of curves on the tape of a K-12-21 oscillograph) all the movements of the TL 1 control levers, readings of the main piloting and navigation instruments, speech stimulus, pulse and respiration of the subject.

The "landing approach exercise based on the straight line system" was used as the training "flights". The amount of processed information was calculated from Shannon's formula, which treats erroneous answers on conversion to capacity as a loss of information.

We studied changes in capacity in the course of acquiring skills from all three series before the "flights" and after 5, 10, 15, and 20

training "flights". There was a total of 538 experiments, 275 of which were training "flights" and 263 control experiments, with 27,792 measurements of reactions to commands.

We found that capacity is not a constant, that it changes as skill is acquired. For example, the time required to process 1 bit of information in response to various commands decreased by 16-46 percent with simple movements by the 20th "flight", by 60-70 percent with complex movements, and by 47-71 percent with handling the controls "in flight".

As skill increased, there was not only a decrease in the times required to process 1 bit of information, but a linear relationship appeared between the amount of information and processing time. This did not occur in the experiments performed before the start of "flights".

Analysis revealed a relationship between the time required for processing information and the complexity of the movements. For example, the time required by trained individuals to process 1 bit of information with simple movements was 0.096-0.117" (capacity was 8.5-10.4 bits/sec, respectively), but with complex movements the time was 0.180-0.189" (5.2-5.5 bits/sec).

The time required to process 1 bit of information with complex movements was always more than with simple movements. This difference gradually leveled out during training in parallel with the development of skills. For example, the time required to process 1 bit of information before training averaged 0.169" with simple movements and 0.519 with complex movements (an excess of 307 percent), but after 20 training periods - 0.104" and 0.184", respectively (an excess of only 177 percent).

Execution of commands during a "flight" was a more complex motor task, and it also influenced the time required to process information (0.212-0.292" for 1 bit; 3.4-4.5 bits/sec), an increase of 0.057" for each bit as compared with the "non-flight" movements.

A significant correlation (0.94 on the average) was noted between the quality of execution of the flights and the capacity displayed in taking the above-described tests. Capacity in the absence of trainer control skills ("poor" execution of control flights) amounted to 4.9-6.9 bits/sec with simple movements, 2.3-4.1 bits/sec with complex movements, and 0.7-2.2 bits/sec with movements involved in executing "flights").

Capacity with formed skills ("excellent" execution of control flights) with simple movements amounted to 8.3-11.2 bits/sec, 5.3-6.6 bits/sec with complex movements, and 3.3-4.7 bits/sec with movements "in flight".

To prevent the acquisition of skill in the course of repeated control experiments from influencing the results of the investigation, we checked the capacity of two subjects only after the acquisition of skill in controlling the trainer (no control experiments were performed during the training "flights"). The results, as in the main group of subjects after the acquisition of skills, were such as to suggest that the control experiments had no appreciable effect.

Thus, capacity or the inverse value (the time spent on processing 1 bit of information) is a good index of the complexity of the motor component in a task to be performed and the degree of skill acquired in controlling a flight trainer.

CHANGE IN BACK PRESSURE ON THE BODY AND TOLERANCE OF RESPIRATION AT EXCESS PRESSURE

A. V. Yeremin and V. N. Alifanov

The main prerequisite of the proper functioning of an oxygen supply system intended for respiration at excess pressure is that it provide back pressure on all parts of the body equal to intrapulmonary pressure. This depends to a large extent on the correct fitting of the altitude-compensating suit (ACS). Since fitting is generally done "by eye", there is, of course, no guarantee of uniform and adequate back pressure when there is excess pressure in the lungs.

To determine how improper fitting of a ACS affects the tolerance of respiration under pressure, we studied a number of healthy males, 20 to 30 years of age, observing functional changes during the breathing of oxygen at excess pressure on the ground and at an altitude of 20 km (in a pressure chamber) with changes in external back pressure (a) on the entire body, and (b) on individual parts of the body, thus stimulating the defects of the ACS.

In our first series of investigations, we used a special oxygen apparatus designed by V. S. Yakovlenko that enabled us to regulate pressure separately in the hermetic helmet and in the compartments of the ACS. In the second series, we used a suit with separate compartments for the abdomen, chest, thighs, shoulders, forearms, and shins.

Pressure in the compartment of the tightening device of the ACS was regulated in such a way that the pressure created on the body (or individual parts) by the suit was 70, 50, and 30 mm Hg lower or 30 or

50 mm Hg higher than the intrapulmonary pressure, which remained constant.

The sequence of the first series of experiments was as follows. An excess pressure of 55, 104, 126, or 136 mm Hg was created in the helmet and the same pressure in the tightening device of the ACS. Pressure in the compartments was then successively increased or decreased, as mentioned above. The same order was followed in the high-altitude experiments, but pressure in the helmet was always 104 mm Hg.

There were two variations in the second series of experiments. At first an excess pressure of 55 mm Hg was created in the helmet and a corresponding back pressure in turn on the abdomen, chest, thighs, shoulders, forearms, and shins (simultaneously). Then with a pressure of 104 mm Hg in the helmet and a corresponding back pressure on the body, the pressure was reduced (usually to zero) also in turn in the individual sections of the compartments of the tightening device. High-altitude experiments were performed with a pressure of 104 mm Hg. The exposure of each set of pressures usually lasted no more than 5 minutes.

There was a total of 69 experiments: 49 in the first series, 20 in the second. During the investigations we recorded the biolectric activity of the heart (EKG), brain (EEG), some respiratory muscles (EMG), saturation of blood with oxygen (oxymetry), blood pressure, and respiration rate. The thoracic and abdominal cavities were X-rayed and pressure in the helmet and ACS pressure on the body (at 9 points) were measured. Also, account was taken of the subjects' impressions of their own condition and findings of medical observation.

The results of the first series showed that external back pressure consistently influenced the nature of the physiological changes only as long as pressure in the helmet did not exceed 104 mm Hg. A decrease in back pressure caused a proportional deceleration of respiration, increase in the amplitude and duration of the EMG, and an acceleration of the pulse. An increase in back pressure caused the opposite changes, except in the pulse rate, which increased under these conditions too. With pressures in excess of 104 mm Hg (126-136 mm) in the helmet, regardless of the external back pressure, there was an acceleration of the pulse and respiration as well as a continuous and intensified flow of impulses from the respiratory muscles, which signified that the ACS had inadequate compensating characteristics.

At an altitude of 20 km, a change in external back pressure was subjectively tolerated better than on the ground. The amplitude and duration of the EMG were less pronounced. The pulse, on the other hand, became more rapid. The X rays showed that at high altitudes the diaphragm was displaced upwards by the expanding gases of the intestine, assumed a more normal position than in the ground experiments, and more

actively participated in respiration. This was undoubtedly the reason for the sensation of easier breathing at excess pressure at high altitudes.

The saturation of blood with oxygen at high altitudes under all pressure conditions came to 80-90 percent, but the bioelectric activity of the brain scarcely changed. Total exclusion of the pneumatic system of the suit at an altitude of 15 km did not reduce efficiency for 3-5 minutes.

Changes in back pressure on individual parts of the body under both ground and high-altitude conditions produced similar reactions. Changes in the EMG were greatest when pressure on the abdominal area was reduced; breathing under these conditions was subjectively the most labored. A decrease in pressure on the chest had the least effect. Marked difficulty in breathing and very pronounced EKG changes followed a reduction of pressure on the shoulders and, especially, on the thighs. This was apparently due to the fact that the work of the compartments in these areas also affected the adjacent areas (below the abdomen and upper part of the chest) and that venous stasis developed (jar effect), which was subsequently confirmed by I. N. Chernyakov, V. N. Polyakov, and A. V. Yeremin. Exclusion of the compartments in the region of the shin and forearms for up to 5 minutes had no significant effect on the physiological functions or feelings of the subjects. The saturation of blood with oxygen and bioelectric activity of the brain changed very little, as in the first series of experiments.

Findings

1. In breathing at excess pressure under ground conditions and at an altitude of 20 km, a discrepancy of ±50 mm Hg for 5 minutes between pressure of the ACS suit on the body and intrapulmonary pressure had no major effect on basic physiological functions. A discrepancy of more than 50 mm Hg resulted in labored breathing and marked cardiovascular changes, thus significantly impairing the tolerance of respiration at excess pressure.

2. Good compensation of the abdomen and upper part of the thighs was of the greatest importance. Compensation of the chest, shoulders, shins, and forearms played a somewhat lesser role.

3. At an altitude of 20 km, even a relatively slight decrease in back pressure on the body was satisfactorily tolerated for no more than 5 minutes, after which the "jar effect" developed, especially in the region of the extremities.

EFFECT ON MAN OF PROLONGED EXPOSURE TO ATMOSPHERE WITH A HIGH CO_2 CONTENT

S. G. Zharov, Ye. A. Il'in, Ye. A. Kovalenko, I. R. Kalinichenko, L. I. Karpova, N. S. Mikerova, M. M. Osipova and Ye. Ye. Simonov

Most investigators believe that the air in spacecraft and stations should be completely free of the accumulated CO_2 products of metabolic processes. There are some who disagree and recommend that excess CO_2 be used to regenerate oxygen photosynthetically, to prevent the hypocapnia that arises in certain flight situations, and even to offset the injurious effect of cosmic radiation.

These considerations led us to investigate the effect of high CO_2 concentrations on man subjected to a variety of space factors (accelerations, weightlessness, radiation, hypoxia, hypodynamia, isolation, rarefied atmosphere, etc.).

The literature provides few references on this subject. The permissible concentrations of CO_2 established for the air of living quarters, submarines, gasproof shelters, and airplanes cannot be applied to the atmosphere of spacecraft and stations, because living conditions in the latter differ considerably from those that obtain in vehicles operating in a normal gravitational field.

According to Sheffer (1961), the CO_2 concentration of air inhaled during a prolonged stay (about 42 days) in submarines should not exceed 0.5-0.8 percent; an increase to 1.5 percent may cause pathological changes.

Our experiments dealt with the effect on man of prolonged exposure (about 30 days) to atmosphere in a confined space with an average CO_2 content of 1 or 2 percent. They were performed in a 7 m^3 pressure chamber at an air temperature of 20 ± 2° C, relative humidity of 40-60 percent, and CO_2 content in inhaled air of 19-22 percent. The concentration was automatically regulated by a specially devised system accurate to 0.05-0.1 percent CO_2 (G. I. Badikov, B. A. Miloslavov, and G. K. Solov'yev, 1963). The effect of the different CO_2 concentrations was evaluated from the following indexes: total CO_2 content of the blood by Fisher's method; alkaline reserve of the blood by Van Slyke's method; pH and pCO_2

of the blood (on a combination analyzer manufactured by the Gotard Company); partial pressure of CO_2 and O_2 in alveolar air; pH, ammonia, carbonates, and titration acidity of urine; EKG's; and arterial pressure.

Subjects were given physical examinations before and after exposure. Efficiency and functional stability were evaluated from 6-lead investigations of brain biocurrents conditioned motor reflexes, outlining of geometric figures, and problem solving. The curve of cerebrocortical reactivity was studied by M. N. Livanov's method.

There were two experiments with 2 subjects in each. Both were exposed for 30 days: one to atmosphere containing 1 percent CO_2, the other to 2 percent CO_2.

Results of the first experiment show that 30 days' exposure to air containing 1 percent CO_2 had no significant effect on either the sense of well-being, efficiency, or basic physiological functions. Pulse rate, arterial pressure, EKG, tests with respiratory standstill, temperature, and body weight remained essentially unaltered. Increase in pulse excitability and in time required to outline the figures (G. D. Doronin), and intensification of α activity on the EEG (gradual increase in amplitude of the α waves and α index, exaltation of α waves with maximum intensity of light as a stimulus) were approximately the same as in the control experiments of equal duration (A. G. Kuznetsov, 1962).

Observed changes indicated a slight lowering of cerebral cortex and cardiovascular function under the influence of hypodynamia and similar stimuli. Total CO_2 content of the blood (tCO_2) in subject A. rose from 40 to 50 percent by volume and in subject N. from 46 to 53 percent by volume, while the blood pH remained virtually unchanged. Due to the increased CO_2 tension in the blood, urinary ammonia and carbonates increased and pulmonary ventilation rose during the first half of the experiment by an average of 0.5-1 liter/m. During the second half, despite the pCO_2 increase in alveolar air and blood, pulmonary ventilation, by virtue of adaptation to the CO_2 effect, decreased by approximately the same amount.

Thus, results of the first experiment show that prolonged exposure (30 days) to atmosphere with a CO_2 content averaging 1 percent increased the pCO_2 in alveolar air and caused both free and chemically bound CO_2

to accumulate in the blood. In view of this, we may conclude that under such conditions human beings develop compensated gaseous acidosis. This state can be regarded as completely reversible, owing to the insignificant rise in pCO_2 and the relatively slight increase in tCO_2 in blood, which disappeared as soon as the experiment was over.

Subjects in the second experiment were found to have a larger accumulation of both free and chemically bound CO_2 in the blood, thus making the changes in physiological functions more pronounced. For example, in P., pCO_2 in alveolar air and in blood rose from 38-39 mm Hg to 43-46 mm Hg. Essentially the same changes were observed in the other subject. P.'s alkaline reserve rose from 53 to 63-66 percent by volume, whereas in the other subject it scarcely changed. This phenomenon probably occurred because P., unlike U., engaged in 30 minutes of physical exercise (an average load of 3500-4000 kgm) twice a day, causing more rapid accumulation of CO_2 in the body.

In both subjects, during the first 15-20 days, there was a drop in blood pH from 7.41-7.47 to 7.34-7.38 units, respectively, indicating noncompensated gaseous acidosis. Pulmonary ventilation throughout this experiment remained above the original level by an average of 1.6-3.7 liters/min. U.'s blood pressure scarcely changed, while P.'s maximum and minimum pressure was above the original level. P. complained of heaviness in the head and general sluggishness during physical exercise. In the aftereffect period, this subject had a persistent elevation of minimum blood pressure to 95-100 mm Hg and decrease in the pulse difference to 20 mm Hg, indicating functional cardiovascular weakening. This is also attested by a reduction in the time of breath holding on inhalation and exhalation and by an increase in pulse excitability during exercise. Urinary excretion of ammonia and carbonates exceeded that in the first experiment.

Whereas in the first experiment the EEG of both subjects showed an intensification of α activity, which we ascribed to the more synchronous activity of the brain cells under the influence of similar situational stimuli, in the second experiment the α index and amplitude of the α waves decreased while the activity of the high-frequency oscillations became intensified and that of the slow waves with a frequency of 5-7 cps decreased. The EEG changes resembled a desynchronization reaction. We concluded that EEG changes in the second experiment were caused mainly by increased CO_2 tension in the blood.

Our study of the physiological indexes shows that, after a prolonged stay (about 30 days) in the atmosphere of a confined place with a high CO_2 content, man develops signs of acidosis, hypodynamia, and fatigue.

Acidosis intensified as the CO_2 concentration rises from 1 to 2 percent and the time spent in the chamber increases. Efficiency remains fairly high when the CO_2 content averages 1 percent, but an atmosphere with 2 percent CO_2 causes a marked deterioration in ability to perform physical exercises and gives rise to much more functional tension. However, the ensuing changes are wholly reversible.

EVALUATING THE BIOLOGICAL EFFECTIVENESS OF SPACE FLIGHT FACTORS BY MEANS OF THE LYSOGENIC BACTERIA E. COLI K-12 (λ)

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Biological experiments with objects varying in radiation sensitivity are of considerable value in judging the genetic effects of space flight factors. The most interesting of these objects are lysogenic bacteria, which react to comparatively small doses of ionizing radiation with induced phage production. Our experiments showed that roentgen and gamma rays (0.2-0.4 r), protons of various energies, and rapid neutrons cause genetic damage to lysogenic bacteria. The inducing effect is directly related to the irradiation dose and the "dose-effect" curves are exponential in nature. These findings enabled us to use the lysogenic system in all the experiments on Soviet spacecraft.

This report presents the results of a study of phage production by E. coli K-12 (λ) in specimens exposed during the Vostok 3 and Vostok 4 flights and in laboratory investigations on the combined effect of vibration and irradiation.

Method

In the spacecraft experiments, we used suspensions of a 5-hour culture of E. coli K-12 (λ) of a certain concentration prepared in physiological solution with 20 percent meat-peptone broth (total volume 1.5-2 ml) added. The controls were suspensions in ampuls kept at the spaceport (essential control) and under laboratory conditions (technical

control). All objects were stored on ice. After the flights were completed, we determined the number of viable cells and phage-producing bacteria (induced) in the experimental and control samples of the cultures.

Since some free phage particles (spontaneous bacteriolysis) are always present in cultures of lysogenic bacteria, we used an indirect method of determining induced phage production, employing specific antiphage serum to inactivate the phage particles originating spontaneously. Accordingly, specimens were taken from each sample and inoculated onto meat-peptone broth.

The test tubes were placed in a water bath at 37° for 55 minutes (latent period). Antiphage serum was added to the bacterial suspension after conclusion of the latent period to suppress the spontaneous phage particles. After 10 minutes the action of the antiphage serum was halted by diluting the suspensions and adding streptomycin. Inoculations were made by the method of agar layers in the presence of streptomycin bacteria, a stable indicator strain. In addition, the experimental and control batches were analyzed for the presence of free bacteriophage in the medium without preliminary incubation under optimum conditions.

Objects were prepared in similar fashion to study the combined effect of vibration and irradiation under laboratory conditions. Vibrations were produced on a vibration stand at frequencies of 35, 70, and 700 cps, with an amplitude of oscillation ranging from 0.4 to 0.005 mm and an acceleration of 10 g, for 15, 30, and 60 minutes. GUBO Co 60 (dose 100 r, rate 21 r/min) was used as the source of gamma rays. Experiments were performed both with combined and with separate exposure to gamma rays and vibrations. In the case of combined exposure, vibrations were produced 1-1/2 to 2 hours before or after irradiation.

Results

In the flight experiments, induced phage production was investigated 48, 72, 96, and 120 hours after the spacecraft landed.

We evaluated the results of each experiment by means of an index R, which is the value of induced phage production as compared with spontaneous production, and the Fisher-Student index of statistical reliability (P). Analysis of the phage-producing activity of the lysogenic culture E. coli K-12 (λ) exposed on Vostok 3 and Vostok 4 showed that the number of phage particles in the experimental batches exceeded that in the control. In the batches exposed on Vostok 3, the number of cells producing phage particles, observed 48 and 72 hours after the vehicle landed, was 3.5-4.6 times greater than in the batches left on earth.

Thus, the Vostok 3 and Vostok 4 experiments revealed that space flight factors had an inducing effect on the lysogenic bacteria, E. coli K-12 (λ), as reflected in a tangible increase in phage-producing cells. The inducing effect was much more pronounced in the Vostok 3 experiments than in those on Vostok 4, apparently because of a longer exposure to the flight factors on Vostok 3.

As noted above, the inducing effect persisted for 48-72 hours after landing, after which the level of induced phage production fell to that of spontaneous phage production. This agrees with the results of a study of the inducing effect of protons, which also persisted for a few days after the action halted and then declined.

Our method is of value in determining the inducing effect of ionizing radiation within the limits of 0.2-0.4 r. However, it does not follow from this that the induction of lysogenic bacteria observed in the spacecraft experiments was caused by the aforementioned dose of cosmic radiation. The inducing genetic effect may well have been caused by the combined action of various space flight factors (vibration, acceleration, weightlessness, radiation).

Our investigations on the effect of vibrations ranging from 35 to 700 cps suggest that vibration is a major factor in the radiogenetic effect recorded in the lysogenic bacteria.

Thus, the combined action of vibration and gamma irradiation followed by vibration (simulation of flight conditions) intensified the biological effect of the gamma rays almost twofold. However, no inducing effect was observed in the experiments involving vibration alone. In the experimental batches, the number of phage-producing bacteria did not exceed that in the batches not subjected to any agent. This indicates that under flight conditions vibrations probably exert a sensitizing influence, i.e., they increase the sensitivity of lysogenic bacteria to ionizing radiation, thus permitting ionizing radiation to have an inducing effect with doses smaller than 0.2-0.4 r. This hypothetical explanation of the results obtained requires experimental confirmation.

In conclusion, we wish to stress the importance of combined investigations. It is particularly essential to study the effects of the various components of cosmic radiation (protons, electrons, neutrons, heavy particles, γ and roentgen rays) combined with the mechanical factors of space flight.

MODERN GENETICS AND PROBLEMS IN SPACE BIOLOGY

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Some of our data on the genetic aspects of space biology have already appeared in earlier publications. This communication examines three subjects: the current status of space flight genetic danger, genetic basis of the search for drugs to provide antiradiation protection from hereditary anomalies during these flights, and some genetic considerations in exobiological problems.

The first of these subjects can be examined in the light of new information derived from a genetic analysis of the offspring of the various organisms that were carried on Vostoks 1, 2, 3, and 4. To begin with, we must say that the idea of using for this purpose a set of biological objects on all levels of organization has been completely justified. If the planners of the experiments had restricted themselves to a single object, the results would have been one-sided. If, for example, only insects (Drosophila) had been used, the launching data on the first vehicle to return (the second Soviet spacecraft) could not have been correctly interpreted. Ya. L. Glembotskiy, E. A. Abeleva, Yu. A. Lapkin, and G. P. Parfenov at that time reported as follows: "Assuming that the mutagenic effect (0.44 percent induced lethals) noted in mature sperm of the strain in question was caused by ionizing radiation, the dose of this radiation would need to be approximately 140-150 rad... The point nature of the induced mutations (20 affected cytologically) and high rate of mutation of the spermatids as compared with that of the spermatozoa indicate that they may have been caused by cosmic radiation." This applied to recessive lethal mutations. After the flight, a tangible increase in frequency was obtained in regard to dominant lethal mutations, too. If there had not been other biological objects on the same spacecraft, the aforementioned facts would have been a serious obstacle in the way of determining the feasibility of the first manned space flight.

However, this spacecraft, as is known, carried various objects (notably, lysogenic bacteria, which had a distinct genetic reaction to 0.3-1 r) which made possible the introduction of corrections into the data. The lysogenic bacteria showed no increase in the relative number of genetic changes (measured by the number of phage particles produced) as compared with cultures kept at the spaceport and under ordinary laboratory conditions, making it obvious that the sharp increase in mutations in Drosophila was not evidence of the presence (in the orbit) of any

radiations capable of exerting genetic influence. The effect in Drosophila was due to the way they were exposed, to biological characteristics absent in man and highly organized animals, and to the individual cellular and subcellular structures.

It is of interest to reflect that, if only lysogenic bacteria (as the most sensitive objects) had been exposed in order to detect the genetic efficiency of ionizing radiation, it would have been correct to conclude that there were no genetically active doses of radiation in the orbit. However, the significance of the combined genetic effect of various space flight factors would have escaped attention. The result undoubtedly would have been the same as that obtained in investigating Drosophila.

Comparison of the data gathered by various laboratories utilizing the standard set of biological objects to study the aftereffects of space flights suggests that undoubtedly certain factors are lacking in these orbits which, by themselves, could significantly increase the relative number of genetic changes in cells. However, the already identified set of launching and flight factors have the potential for causing genetic changes, the number of which exceeds in level the ground control. Subsequent flights (Titov, Nikolayev, Popovich) revealed that not only Drosophila but also lysogenic bacteria can react to a fairly long flight with an increase (albeit slight) in induced phage production, i.e., with genetic changes.

These new observations are theoretical. The fact is Drosophila, which cannot be secured on spacecraft like astronauts or be oriented to the flight axis in a chest-back direction, might have manifested genetic changes in response to mechanical stimulation of vibrations and accelerations. The experiments with lysogenic bacteria imply that other factors than vibrations and accelerations can induce genetic changes, however slight.

Experiments simulating flight conditions (N. I. Rybakov and V. A. Kozlov) revealed that exposure of these bacteria to a combination of vibrations and γ rays (100 r) followed by vibrations again almost doubled the genetic effect of the γ rays. However, the physical measurements showed that completely effective levels of cosmic radiation were actually lacking in the orbits. Thus, to account for the "effect of the lysogenic bacteria" there is one more possible source of genetic effects that must be carefully examined--weightlessness.

The genetic effect of weightlessness should be studied independently, since attempts to increase genetic changes in lysogenic bacteria by means of vibration devices without irradiation were unsuccessful even when 700 cps were used. Since lysogenic bacteria have been observed to react only to long space flights, these studies require sustained influences, and

one way to achieve these is by the microcentrifuge system, which is still in the planning stage. This system, which would generate accelerations of 1 g, could provide gravity during space flights, the biological objects serving as a control for other objects in a weightless state. Genetic analysis of their offspring would throw light on the effect of weightlessness in, so to speak, a pure form, since all the other flight factors acted on all the objects equally. While setting up the study of the genetic effect of weightlessness as a new item in our program, we should nevertheless not forget the necessity of examining the genetic danger presented by cosmic radiation on new space flight routes. This applies to vibrations and accelerations as well, especially when the launching of a rocket with acceleration is a protracted affair.

Thus, a team of Soviet biologists and physicians, by direct experiments on spacecraft, was able to advance our knowledge of genetic danger in space, thus ensuring the safety of the flights already made. This research must be intensified in order to safeguard future flights, which will be longer and, therefore, pose greater genetic danger. This makes it essential to speed up the search for new preventive drugs, and the second part of this paper will present some data on this area. It will be recalled that chemical antiradiation protection has been based for a long time on the search for drugs capable of preventing radiation sickness or the physiological changes that precede it. The search for drugs to prevent the development of genetic effects in offspring is not being pursued as intensively as it should mainly because of the lack of a biological model that could be used to furnish the primary characteristics of prospective protective chemical substances.

In 1961-1963, N. N. Zhukov-Verezhnikov, M. N. Volkov, I. N. Mayskiy, V. I. Yazdovskiy, A. P. Pekhov, P. P. Saksonov, N. I. Rybakov, V. A. Kozlov, P. A. Konstantinov, and others suggested that lysogenic bacteria be used for systematic selection of "antigenetic" substances that could be given to astronauts. The reports presented by our team at this conference contained detailed material on lysogenic bacteria as one of the most promising models for the primary selection of such substances.

We should like to emphasize that drugs of this kind can be used for other purposes than preventing radiation genetic injuries. Long-term treatment of lysogenic bacteria with such compounds results in a blocking of the pathological information present in the DNA of these bacteria and introduced therein by the so-called moderate bacteriophages. Such treatment, to be sure, merely blocks rather than removes this information because lysogenic bacteria remain immune to superinfection by the corresponding moderate phage.

This opens up a new approach to the prevention of genetic anomalies, especially those resulting from malignant degeneration of cells, which are a transformation or mutation genetic process. We succeeded in

achieving, more or less, the first "immunization" against pathological genetic changes by a unique kind of "weakened genetic vaccine." In fact, the analogy to immunization with live vaccines is striking. Just as a weakened vaccine confers immunity without sickness, so does a fragment of bacteriophage DNA brought into the genotype of the bacterial cell confer immunity without at the same time being able to cause the production of phage, which some investigators regard as a peculiar "malignant disease of bacteria."

To digress, we may recall that our team has called attention to the eventual possibility of providing "immunity" against cancer by such blocked DNA molecules extracted from cancer cells. This is one of the possible effects of nucleinotropic substances, which thus differ in principle from antiblastic substances because they are directed not at killing cancer cells (which also more or less threaten normal cells) but at normalizing the genetic changes underlying the transformation of normal into malignant cells or at preventing the very possibility of such transformation.

In commenting on some medicogenetic problems in this paper, we wish to stress that protection of astronauts from genetic injuries is one of the main problems of modern genetics. It cannot be solved without going into the most fundamental aspects of genetic information and control.

The Decree of the Central Committee of the Communist Party of the USSR and USSR Council of Ministers mentions the necessity of learning to control the processes of heredity and metabolism.

The need of genetic safeguards for space flights has stimulated a number of investigations that have implications for more than space biology. Making use of the most complex and effective modern research techniques, they give promise of enriching other branches of modern biology and medicine.

IMPAIRMENT OF PROTECTIVE MECHANISMS FOLLOWING EXPOSURE TO AN ALTERED GAS MEDIUM

V. N. Zagryadskiy and Z. K. Sulimo-Samuyllo

On space flights man may have to function in an altered gas medium, exposed to a host of unusual factors that will tax the organism's broad capabilities for adapting. It is, therefore, extremely important, theoretically and practically, to study the physiological mechanisms of

compensatory reactions and impairment. Thus far, attention has focused mostly on adaptability to low partial pressure of oxygen in the ambient atmosphere. The capacity of the organism to withstand high concentrations of carbon dioxide, which cause hypercapnia, and the factors that promote the washing out of carbon dioxide from the body (hypocapnia) now deserve serious study, since the disruption of homeostasis by hyper- or hypocapnia cannot but affect reactivity to various space flight factors.

We and our colleagues recently made a comprehensive investigation of the effect on human beings and animals of prolonged exposure to atmosphere containing low concentrations of carbon dioxide (from 1.5-5 percent) with normal and high (about 40 percent) oxygen content. We studied resistance to lateral accelerations, breathing oxygen at excess pressure, physical exercise, and high ambient atmospheric pressure (about 40° C).

The initial protective reaction of the body to a high CO_2 content of inhaled air consists of a substantial increase in pulmonary ventilation through acceleration and, even more, through the deepening of respiration. This compensatory reaction is aimed at lowering the partial pressure of CO_2 in alveolar air and preserving the constancy of its composition, and its effect is sometimes much greater than that required by the altered composition of the gas medium. As a result, there is a decrease in the CO_2 content of alveolar air (hypocapnia) when the CO_2 content of inhaled air is 1.5 percent. These findings are in complete agreement with the curves obtained from I. M. Sechenov's formula by theoretical calculations based on the results of experiments. In breathing gas mixtures containing 3-3.2 percent CO_2 for 2-4 hours, the content and partial pressure of CO_2 in alveolar air in man scarcely changes. With CO_2 concentrations above 3 percent, a progressive increase in pulmonary ventilation does not produce the required effect and the CO_2 content of alveolar air grows.

After prolonged exposure to atmosphere containing up to 3 percent CO_2 (1.5-2 percent), the body is unable to compensate for the changes in composition of alveolar air by an increase in pulmonary ventilation and the latter decreases (inhibition of respiration) and CO_2 in alveolar air increases. Further adaptation is in the direction of pronounced deceleration of the cardiac rate, decrease in oxygen utilization (P. F. Vokhmyanin), drop in body temperature, and reduction in the activity of the oxidative enzyme systems--succinodehydrogenase and cytochrome oxidase (N. D. Popov, P. T. Grabchak). This marked slowing of the vital

rhythm is a protective function designed to limit the production of CO_2 in the tissues. However, the protective nature of these reactions is effective only in a state of relative adynamia.

Prolonged exposure to low concentrations of CO_2 changes the nature of the excitability of the respiratory and cardiovascular centers, as is evident from the fact that comparatively slight muscular or emotional tension, which causes some acceleration of respiration, is followed by a disproportionately sharp and prolonged pulse acceleration. The cardiovascular center remains highly excited for many hours after the gas medium returns to normal. At the same time, resistance to lateral accelerations (T. N. Zheludkova, O. Yu. Sidorov) and to breathing of oxygen at excess pressure (P. F. Vokhmyanin) diminishes. Normalization of the metabolic processes after prolonged exposure to high CO_2 concentrations by increasing the amount of oxygen in the gas medium or by administering enzymes and vitamins increases resistance to the aforementioned factors. It has been experimentally demonstrated that conditioning animals to hypoxia and accelerations increases resistance to CO_2 (Chzan Zhu-Go).

In our experiments, hypocapnia was induced in animals by enforced hyperventilation for 1-2 hours. The CO_2 content of the blood dropped to 12-17 percent by volume.

Apnea is the initial protective reaction to hypocapnia. However, prolonged hypocapnia actuates the mechanisms that intensify the production of CO_2 in tissues. This is shown by the increase in oxygen utilization and hyperthermia (Nguyen Lung). In hypocapnia, the rectal temperature rises 1.5-1.8^{0}, muscular temperature rises somewhat less, brain temperature rises least. These changes in temperature relations in hypocapnia have a definite biological significance. At the same time the vascular reflexes also change (V. leva). There are three groups of such changes: (1) inhibition of pressor and depressor reflexes; (2) inhibition of depressor and intensification of pressor reflexes; (3) inhibition of pressor and some intensification of depressor reflexes.

In severe hypocapnia, the depressor vascular reflexes become distorted. However, the aforementioned changes in the vasomotor reflexes cannot be regarded as compensatory.

The concept of protective reflexes to ensure homeostasis and keep the organism in equilibrium with the external environment emerges from I. P. Pavlov's theories on self-regulation, wherein the CNS and its higher divisions play a leading role.

Certain degrees of hyper- and hypocapnia impair CNS function and not only disrupt the balance between the excitatory and inhibitory processes but reduce their strength and mobility. The result is inhibition or impairment of the compensatory reactions aimed at maintaining homeostasis. Investigations concerned with preservation and intensification of the activity of the protective reactions are of great practical significance under these conditions.

AN INVESTIGATION OF HIGHER NERVOUS ACTIVITY AND SOME MOTOR REACTIONS IN MAN UNDER CONDITIONS OF BRIEF WEIGHTLESSNESS[1]

A. T. Zverev and L. A. Kitayev-Smyk

1. An investigation was made of (1) the speed of motor reactions to stimulation of the first and second signaling systems, (2) the speed and accuracy of motor reactions in performing very simple mathematical operations (addition and subtraction), and (3) accuracy in working with an indicator.

2. The subjects worked at a special panel, a box containing different colored bulbs and bulbs which when turned on caused figures to appear on the panel. On this panel were numbered tables, a telephone dial, and contacts, two injection needles of different diameters. Work at the indicator with a fluorescent dial was done in a darkroom.

3. When a red blub lit up, the subject had to connect the contacts and at the flashing of a 3-digit number--dial the same combination of figures with the telephone dial or toggle switches. In some flights, it was necessary to add to or subtract from the given figure a certain number. In working with the indicator, the subject had to move a lever to keep the arrow of the indicator, which was periodically deflected with a special timer, in the center. In some flights, work was done with the indicator when the subject was exposed to angular accelerations and Coriolis accelerations created by rotation on a special armchair.

4. A total of 139 experiments was performed.

5. In working with the contacts, the time required by most of the subjects (regardless of the degree of training) to execute the movement decreased during the takeoff of the plane. It decreased even more during

[1]The method of producing weightless conditions is described in A. M. Klochkov's report presented at this conference.

the initial acceleration but increased in the period of weightlessness, frequently exceeding the original level. It decreased again after the succeeding acceleration but increased during horizontal flight.

6. The changes in time interval from the time the toggle switches were switched on until they were switched off were similar to the changes in reaction time when working with the contacts.

7. The changes in length of the latent period when working with the figures were more or less the same as the changes in time of the motor reaction when working with the contacts and toggle switches.

8. The magnitude of the error made by the subject ("error in work") when centering the indicator arrow was 1 1/2-2 times greater during the initial and succeeding accelerations than during horizontal flight. It was 3-4 times greater in the weightless period.

9. As a result of angular acceleration, the magnitude of the "error in work" grew proportionately in all stages of the experiment by 10-15 percent.

10. Coriolis acceleration likewise caused the "error in work" to increase in all stages of the flight, particularly in the weightless period (8-10 times).

11. The resultant data were at variance with the subjective evaluations of the persons tested. They noted in oral reports that it was more difficult to work in the period of accelerations than in weightlessness. However, objective recording of the speed and accuracy of their work showed that the opposite was true.

12. The impairment of speed and accuracy of motor reactions observed in weightlessness may be due not only to changes in the tonic relations on the periphery, but to the development of inhibition in the corresponding points on the cerebral cortex as a result of a change in the level of proprioceptive afferent impulses in weightlessness.

SOME ASPECTS OF HEMODYNAMICS IN BREATHING OXYGEN WITH HIGH PRESSURE IN THE LUNGS

D. I. Ivanov

Breathing oxygen with high pressure in the lungs is now very common in aviation. It is the most widely used method of ensuring flight safety at altitudes of more than 12,000 m. Many Soviet and foreign investigators have studied the problem, and the characteristics of respiration under such abnormal conditions may be considered fairly well known. The nature of the ensuing functional changes suggests that two systems are most involved--respiration and blood circulation--especially the latter, since the cardiovascular changes are most pronounced.

These changes consist essentially of a marked rise in arterial and venous pressures, in the minute and systolic volume of the heart, and in the amplitude and rate of propagation of the pulse wave through blood vessels of the muscular type. Changes in EKG and, above all, in the ballistocardiogram are characteristic. The EKG shows an increase in the P wave, which most investigators regard as a sign of high pressure in the pulmonary circulation. The shape and magnitude of the systolic complex of waves on the ballistocardiogram change as do the relations between them by phases of respiration, an index of hemodynamics in the pulmonary circulation. Significant hemodynamic changes are also suggested by stasis on the periphery, as evidenced by an increase in the size of the extremities. Analysis of the published reports and our own investigations shows that the hemodynamic changes observed cannot be wholly ascribed to the effect of high pressure in the lungs, for secondary circulatory hypoxia plays a definite role in the process.

Despite the many studies of the problem, one of the most important aspects, to our way of thinking, has been virtually ignored, namely, the state of the blood flow--its linear and volumetric rate. In the past few years the author and some his colleagues made some studies along this line. One series of experiments--using dogs in acute and chronic experiments under ground conditions with different pressures in the lungs--dealt with the rate of blood flow in the pulmonary circulation and utilized the method of tagged atoms (D. I. Ivanov and G. G. Sturua, 1952). The blood was tagged with radioactive disubstituted sodium phosphate, a method of value in evaluating both the rate of blood flow and the functional capacity of the right ventricle.

This series of experiments showed that breathing oxygen with high pressure in the lungs decreases the rate of blood flow in the pulmonary circulation while the time required by the "indicator tag" to blend with the mass of circulating blood increases. We concluded that resistance to the flow of blood increases in the lungs and that systolic emptying of

the right ventricle becomes less complete. The magnitude of these changes varied with the intensity of the pressure created in the lungs, the state (anesthesia) and individual characteristics of the animal. The changes in blood flow become more intense as the experiment continued and severely impaired the hemodynamics of the pulmonary circulation. A slowing of the blood flow in the pulmonary circulation took place against a background of growing functional cardiac incompetence.

The use of special compensating suits employing the pneumatic principle mitigates, but does not relieve entirely, the effect of high pressure in the lungs. In experiments on intact (nonanesthetized) animals, the results were about the same, although somewhat less pronounced.

A second series of experiments was devoted to local tissue blood flow in man exposed to the same respiratory conditions as in the first series (V. S. Gurfinkel', D. I. Ivanov, A. Ye. Ivanov, and V. B. Malkin, 1957). This series also used the method of radioactive indication (Na_{24}). An isotonic solution of sodium bicarbonate with a total activity of 2-3 μc (in 0.2 cm^3) was injected subcutaneously or intramuscularly. Keti's method was used in the investigation. A curve showing the activity of the artificially created "depot" was constructed in a system of semilogarithmic coordinates.

The results of the investigations showed that an increase in pressure in the lungs regularly altered the dynamics of tissue blood flow. With breathing at a pressure of 20 mm Hg or more, the rate of local blood flow clearly decreased in most of the subjects; it did so less frequently when the pressure was 10 mm Hg. The external back pressure on the body, created by the special suit, became less effective when pressure in the lungs reached 50 mm Hg or more. The general direction of the curves showing changes in the radioactivity of the "depot" and the identity of the results in both series of experiments are grounds for believing that the patterns of blood flow in the systemic circulation are reflected here too. The intensity of the blood flow is the main factor in mobilizing the "depot". Permeability of the vascular membranes does not seem to play an important role in the process.

A third series of chronic and acute experiments studied the venous blood flow while the animals were breathing oxygen with high pressure in the lungs. The thermoelectric method as modified by M. Ye. Marshak (V. G. Voloshin, D. I. Ivanov, A. N. Mazin, and V. I. Popov, 1952) was used in the investigation. We found that the venous blood flow decreases, the degree varying with the pressure in the lungs and the time, i.e., duration of the experiment. A temporary increase may precede the decrease. There were three phases in the coronary blood flow changes: a

rapid and substantial decrease, a relative increase, then a slower progressive decrease. The degree and nature of the decrease in coronary flow was directly related to the speed with which pressure rose in the lungs. Transection of the vagus nerves had little effect. No direct relationship was observed between the coronary flow and magnitude and direction of the changes in arterial pressure.

The metabolic processes play an important part in the mechanism controlling the coronary flow, as demonstrated by our findings in experiments with probing of the venous sinus, in which we studied not only the blood flow but the arteriovenous difference in O_2 and amount of lactic acid and glucose in the outflowing blood (V. G. Voloshin, D. I. Ivanov, A. A. Kiselev). In some experiments there was a decrease in the arteriovenous difference in O_2 with a simultaneous decrease in the coronary flow and a markedly hypoxic EKG, suggesting the existence of a collateral blood flow through the system of arteriovenous anastamoses. Special experiments in which we employed the polarographic method showed that oxygen tension in the myocardium changes with change in the coronary blood flow while the temperature of the myocardium rises (V. G. Voloshin).

The external back pressure on the body, created by special "compensating suits", mitigates, but does not entirely relieve, the effect of high pressure on the coronary blood flow.

In a chronic experiment on an operated dog breathing oxygen with high pressure in the lungs, the coronary blood flow changed in the same direction as in the acute experiment.

The relations that develop when breathing at high pressure at great altitudes become more complex. At first the coronary blood flow may increase considerably and then rapidly decrease to a very low level, requiring immediate termination of the experiment. We observed a similar picture in ground experiments involving the breathing of gas mixtures deficient in oxygen. In breathing oxygen at high pressure under ground conditions against a background of a low coronary blood flow, we likewise noted at times a sudden increase followed by a rapid decrease to the point of complete cessation.

This blood flow reaction under high-altitude conditions is apparently due to the simultaneous action of two factors: high pressure in the lungs and primary hypoxia (hypoxic). The latter seems to be the more significant because it mobilizes to the fullest the functional reserves of the organism, and in a short time manages to maintain the blood flow.

A point worth emphasizing is that the nature of respiration is one of the most important factors that determine the level of venous blood

circulation in breathing O_2 at high pressure. Superficial breathing or temporary apnea when pressure is created in the lungs interferes with the flow of blood to the heart and causes the flow to decrease even more. It is quite possible that the initial phase of greater decrease in blood flow may be due to the impairment of respiration associated with high pressure in the lungs.

Our investigations show that breathing oxygen with high pressure in the lungs brings about significant changes in hemodynamics, resulting in circulatory hypoxia and marked changes in venous blood circulation.

CHANGES IN MAN'S PRINCIPAL PHYSIOLOGICAL FUNCTIONS AFTER PROLONGED EXPOSURE TO LOW BAROMETRIC PRESSURE IN A SMALL SPACE

D. I. Ivanov, V. B. Malkin, I. N. Chernyakov, V. L. Popkov, and Ye. O. Popova

An extremely important aspect of space flight is the necessity of remaining for long intervals in a small enclosed space under rarefied atmospheric conditions and relative isolation from familiar daily surroundings.

This study of the dynamics of man's principal physiological functions sought to simulate the above-named conditions, by:

(1) Determining the possibility of man's remaining for a prolonged interval (about 30 days) in a small chamber in a rarefied atmosphere corresponding to altitudes of 3000, 5000, and 7000 m with pO_2 ranging from 150-200 mm Hg.

(2) Studying the nature and direction of the functional changes brought about by disruption of the normal diurnal rhythm. When the work started (1959), only fragmentary data were available on these matters.

Investigations were carried out in a specially equipped pressure chamber with a useful capacity of 5 m^3, and gas composition, temperature, and humidity regulated by a regeneration unit. Each of two healthy young men was assigned a daily regimen, which was alternated in subsequent experiments. Regimen No. 1, which did not vary much from the normal

(the hours of sleep were mainly at night--from 0300 to 0900--and only 1500 to 1700 during the day), was more favorable than regimen No. 2. In the latter, the subject slept from 2030 to 0230 and during the day from 1200 to 1400. While awake, subjects followed the experimenter's instructions but spent their free time as they wished. An experiment lasted 10 to 30 days. Meals (4 times a day) consisted of canned food and concentrates with vitamins added. Feces and urine were collected in airtight containers and periodically removed from the pressure chamber.

During the preparation and performance of the experiments we studied the behavior and general condition of the subjects: EEG, EKG, respiration, arterial pressure, body temperature, cardiovascular and respiratory reactions to measured physical exercise and breath holding, energy expenditure (by Haldane's method), etc. The EKG was recorded in the 3 standard leads; the EEG in unipolar and bipolar leads from the occipital and frontal regions, then subjected to a frequency analysis. The general EMF of the EEG and EMF of the individual rhythms composing the EEG were also determined.

The physiological indices were recorded 4 times daily, the hygienic indices 6 times daily. In all, we performed 6 experiments, lasting from 10 to 30 days, with 7 subjects.

Analysis of the data of the hygienic investigations showed that (1) the pO_2 in inhaled air fluctuated between 150 and 200 mm Hg, (2) pCO_2--between 2 and 14 mm Hg, (3) air temperature in the pressure chamber--between 18 to 27° C, (4) relative humidity--between 30 and 75 percent. The latter occasionally dropped to 10-30 percent, at which time, subjects usually complained of dryness in the mouth, nose, and throat. Epistaxis was sometimes noted.

As mentioned above, barometric pressure in the chamber was maintained in each case at a level corresponding to altitudes of 3000, 5000, or 7000 m. The rapid shift from ground to high-altitude conditions and subsequent exposure to a rarefied atmosphere had no significant effect on the main physiological functions: indices were usually within the control values. For example, in experiment No. 1 (altitude of 3000 m), P-n's pulse and respiration fluctuated between 50 and 90 beats and between 10 and 23 respirations a minute, while the corresponding figures for P-v in experiment No. 2 (altitude of 5000 m) were 52-76 beats and 12-20 respirations and in experiment No. 4 (altitude of 7000 m)--54-73 beats and 12-20 respirations. Approximately the same values were noted for the cardiac and respiratory rates of these individuals in the control measurements.

No clear-cut relationship could be detected between the barometric factor and the changes in the other physiological indices (EEG, arterial pressure, body temperature, duration of apnea, energy expenditure, etc.).

Analysis of the EKG, however, revealed a left-axis deviation resulting from altitude meteorism.

Functional changes were more closely related to time spent at the "altitude". For example, in experiments involving a 30-day stay, a moderate but regular increase of 10-15 beats per minute was noted in the cardiac rate, starting on the 14th-15th day. This rate was either maintained or continued to increase, until the end of the experiment. While performing the orthostatic test, during the first 10-15 days, pulse rate rose by 10-35 percent and thereafter by 50 percent. Moreover, arterial pressure was even higher. All these changes were particularly marked when subjects were awake at night (regimen No. 2). The EEG at this time often showed a slight shift of frequency toward the slow rhythms. Subject F-k, during the first half of the experiment, exhibited considerable instability in the values of the recorded indices. All these changes may be regarded as the onset of incipient fatigue caused by prolonged exposure to the experimental conditions (Den-Su-I, Ye. M. Sklyarchik, A. V. Korobkov).

The decrease in basal metabolism (by an average of 15-20 percent below the original level), especially after a long stay in the pressure chamber, is noteworthy. The marked decline in overall activity of the subjects was most likely the reason for the decrease in gas exchange.

The nature and direction of physiological changes were largely determined by sleep and relaxation routines. In regimen No. 1, the one closer to normal, there was a distinct diurnal periodicity of functional changes (pulse and respiratory rates, body temperature, arterial pressure). The minimum value of the indices was usually noted during sleep at night, the maximum, while awake in the daytime.

In the less favorable regimen (No. 2), the diurnal periodicity of the functions studied not only leveled out, but often became distorted. Pulse and respiratory rates and body temperature during sleep were sometimes faster than during wakefulness. The EEG invariably revealed distinct diurnal fluctuations of the frequency spectrum. However, in this regimen, one could see the dominating frequency shift toward the slow oscillations in the nighttime period of wakefulness. When the subjects resumed regimen No. 1, disruptions of the diurnal periodicity of functions were less marked.

The foregoing data point up the need of conducting special investigations to find rational regimens of sleep and wakefulness for spacecraft crews. But we emphasize that the criterion for correct selection of an optimum regimen should be the time of day set aside for sleep, not merely the number of hours.

Analysis of our data indicates that a lowering of barometric pressure to levels corresponding to altitudes of 3000-7000 m with a partial

pressure of O_2 in inhaled air ranging from 150-200 mm Hg has no significant effect on the human organism. Prolonged (up to 30 days) exposure to these conditions with adequate retention of physical fitness is quite feasible. The observed functional changes are within physiological limits, transient, readily reversible, and unrelated to the effect of rarefied atmosphere.

In evaluating the condition of subjects, their resistance to prolonged exposure to experimental conditions, and the regimen chosen, one must take into account the nature of the changes in the diurnal periodicity of the physiological functions.

We should like to conclude by noting that the main views emerging from these investigations have been confirmed by the studies of A. G. Kuznetsov, N. A. Agadzhanyan, and others.

HYPOXIA AND CHEMICAL THERMOREGULATION

K. P. Ivanov

Reduction of the partial pressure of oxygen below a certain level in inhaled air suppresses heat production and lowers body temperature in animals and man. The extent of the corresponding "critical" oxygen tension and degree of impairment vary with the ambient temperature, rapidity with which hypoxia develops, type of organism, and several other conditions (Lintsel, 1931; Shick, 1948; Slonim, 1952; Goebel et al., 1953; Pichottska et al., 1955; Ivanov, 1959; others). Theoretically, this phenomenon ought to be able to serve as a method of locating the sources of controllable heat production in homoiothermal animals. From the practical point of view, an investigation of this factor is essential in selecting suitable temperature conditions for living beings in a closed space with possible changes in the gas medium.

During the past 5-6 years we tried to determine the physiological aspects of chemical thermoregulation and hypoxia, working principally with skeletal muscles, which many investigators believe to be the main source of controllable heat production (Tower, 1939; Hopfert, 1952; Barton and Adholm, 1957; Chatonnet, 1959.

Gas exchange and certain forms of muscular activity (cold tremor, "thermoregulation muscle tonus") were investigated simultaneously under a variety of conditions. The muscles were studied with a highly sensitive

electromyograph. Changes in gas exchange and electrical activity of the muscles in cold tremor and "thermoregulation tonus" were investigated both in the whole animal and in individual groups of muscles.

We discovered that in rats and rabbits at an ambient temperature of about 10-25° C a decrease in oxygen utilization during hypoxia coincides with depression of muscle electrical activity (Ivanov, 1959; Ivanov and Den-Su-i, 1960). A more drastic suppression of gas exchange during hypoxia occurs in relatively small animals (mice), in which, other things being equal, "thermoregulation muscle tonus" is comparatively high (Ivanov, 1960).

Gas exchange in rabbit femoral muscles in situ was determined in order to make a more precise quantitative evaluation of the energy efficiency of "thermoregulation tonus" and cold tremor as the physiological mechanisms of chemical thermoregulation. We found that "thermoregulation tonus" increases oxygen utilization by the msucles 30-150 percent; cold tremor, by 200-400 percent or more (Ivanov, 1962). In rabbits and rats, whose skeletal muscles constitute about one-half of body weight.

According to some indirect data (Motram, 1955), the muscles when the animal is fully resting take up about 30-35 percent of the total oxygen utilized by the organism in the absence of chemical thermoregulation. Judging by these figures, the animal's energy balance may be changed 40-50 percent in either direction solely by "thermoregulation tonus" (weak electric activity of resting muscle). The significance of cold tremor in this respect is even higher. Since in our experiments oxygen utilization during hypoxia fell about 50 percent below the original level, it is fair to assume that the resultant depression of "thermoregulation muscle tonus" or cold tremor was the main cause of the general lowering of heat production in the organism.

A positive correlation between suppression of electrical activity of muscles and gas exchange during oxygen deficiency has been confirmed by accurately recording, with an electronic integrator, the electrical activity of various muscles. Statistical analysis of the integrator readings indicated that peculiar qualitative changes in exchange likewise took place in the muscles during hypoxia.

While seeking the central mechanisms governing suppression of tremor and "thermoregulation tonus", we found that the particular effect is most likely unrelated to the general suppression of brain functions caused by hypoxia. At the time these forms of muscular activity are weakened, the electrocorticogram fails to reveal any specific changes attributable to oxygen deficiency in the cerebral cortex. At the same time, oxygen tension in the blood of the sagittal sinus of the brain remains fairly high--about 30 mm Hg (Ivanov, 1961).

It follows, then, that hypoxia may directly influence and inhibit the central thermoregulatory mechanism. It is possible, however, that suppression of the functions of chemical thermoregulation in hypoxia is likewise due to dysfunction of the peripheral apparatus of temperature sensitivity--the cold thermoreceptors. The sum of impulses flowing to the hypothalamus from the cold receptors of the skin, according to recent information, is positively correlated with the peak of heat production in the organism (Benzinger, 1962). On the other hand, as Dodt (1956) showed, hypoxia decreases the frequency of these impulses. This is obviously a matter that requires further research.

THE TIME RESERVE IN STEADILY DECREASING ALTITUDE

L. S. Isaakyan

1. The time reserve for remaining conscious at altitudes of 9-11 km (time from the moment of stopping the oxygen supply at a given altitude or time of a rapid climb to an altitude without an oxygen supply until syncope) has been fairly thoroughly studied by Soviet and foreign authors (V. A. Skrypin, 1957; A. Khichkok, 1953; Barron et al., 1958; others).

2. It is now a matter of considerable practical importance to study a somewhat different parameter--the time reserve which ensures retention of consciousness. It starts with the subject's reaching a given altitude (effected in 3-7 seconds), continues until the appearance of the earliest signs of oxygen deficiency, and includes a rapid emergency descent to an altitude of 4.5 km, started as soon as the first signs of acute hypoxia appear.

Since one of the factors in development of acute hypoxia here (rate of descent) is highly dynamic, we propose to call this parameter, in contrast with the ordinary "static" time reserve (TR_{st}), the "dynamic" time reserve in retaining consciousness (TR_{dyn}).

Consequently, unlike TR_{st}, TR_{dyn} expresses the development of decompensation of functions not only after exposure to hypoxia of constant intensity but, even more important, after a swift change of this factor in the direction of a decrease. The correlation between TR_{dyn} and TR_{st} can be represented by the following equality:

$$TR_{dyn} \approx TR_{st} \cdot (0.6\text{-}0.75) + X, \text{ where}$$

X is a time variable depending on the altitude at which the descent begins, especially on the rate of descent (at a given altitude X is equal to the time of emergency descent).

3. In designing experiments to determine the dynamic reserves in dogs, we utilized--in judging development of a state equivalent to altitude syncope in man--these criteria: pulse deceleration of 50-80 beats or more per minute in relation to the frequency measured after staying 5 minutes at the altitude; tonic and clonic spasms of the masseter, tail, and extremities; inhibition of protective and orienting reflexes in response to painful electrocutaneous stimulation and intense light stimulation; reduction in voltage of the EKG waves, arrhythmia, change in rate and nature of respiration, etc. We also assumed that the TR_{dyn} could be roughly calculated from the empirical formula:

$$TR_{dyn} \approx TR_{st} \cdot (0.6\text{-}0.75) + X.$$

Thus, our task was to determine experimentally the approximate values of the two parameters indicated in the formula (TR_{st} and X).

4. Eighty-four control experiments were performed on 9 dogs to determine the static time reserve at 9, 10, and 11 km altitudes (TR_{st}). The animals were raised to these altitudes in 1.5-2 minutes without oxygen and kept there until the above-mentioned signs of acute hypoxia appeared, after which they were given oxygen and "lowered" to the earth in 2-5 minutes. An hour before the rise and during the action of acute hypoxia, EKG, respiratory rate, reflexes, and skin temperature were recorded. External appearance and behavior were photographed on color film in all the experiments.

The control experiments demonstrated that the animals' static time reserve at altitudes of 9, 10, and 11 km averaged 15, 31, and 56 minutes, significantly, the relationships among these values are quite close to those established for man. For example, the human reserve at 11 km (30 seconds) in relation to the reserve at 10 km (60 seconds) is 1:2, or the same ratio as in the dogs (15:31).

This has led us to assume that, despite the great differences between human beings and animals with respect to altitude resistance, some of the biological mechanisms (if only temporary in nature) responsible for the compensation and decompensation of functions in both man and animals exposed to hypoxia have common features.

Forty-seven main experiments were performed on the same 9 dogs to determine the value of X for altitudes of 9, 10, and 11 km. The experiments were run exactly as the controls, except that the emergency descent to 4.7 km started as soon as decompensation of functions became apparent. The time of emergency descent ($t_{em} = X$) was regarded as the product of the mean value of the static reserve that we determined (TR_{st}) and the value of K, which changed in different experiments with the same animals from 1 to 5 ($X \approx t_{em} \approx TR_{st} \cdot K$, where K = 1-5).

These experiments show that a weakening of the signs of decompensation of functions during an emergency descent followed by their rapid restoration may be achieved if the values of K for altitudes of 9, 10, and 11 km are no higher than 2.5, 2.8, and 3.3, respectively. The values of X_9, X_{10}, and $X_{11\ km}$ can be calculated from these values along with the dynamic time reserves (from the empirical formula $TR_{dyn} \approx TR_{st} \cdot (0.6\text{-}0.75) + X$) corresponding to them.

5. In view of the foregoing on the common time relations in the development of acute hypoxia in dogs and in man as well as some other observations and published data on the matter (abstract from Canadian Aviation, No. 8, 1962), it is reasonable to assume that similar relations between TR_{st} and TR_{dyn} exist in man too.

EVALUATION OF THE DEGREE OF TENSION IN PILOTS EXECUTING LANDINGS IN VARIOUS TYPES OF MODERN AIRPLANES UNDER ORDINARY CONDITIONS

L. S. Isaakyan

1. According to observations of the State Civil Aviation Scientific Testing Institute (NII GVF), marked neuropsychic tension is noted in the majority of pilots of Civil Aviation Fleet (CAF) transport planes during the execution of landings ("on final") even under ordinary conditions (i.e., simple weather conditions and smoothly working equipment).

The appearance of tension is without doubt an unfavorable factor conducive to early fatigue and pilot error, and also determines the degree of complexity of piloting a plane of a given type. From this point of view, an evaluation of the degree of tension in pilots during

landings of various types of airplanes, even under ordinary conditions, is of great practical importance both for rationalizing the work routine of the flight crew (establishment of sanitary norms and distribution of the flight load) and for the resolution of various other problems (wages, constructive improvements in control elements, instrument panels, etc.).

2. The physiological mechanisms underlying the development of a state of tension in workers during predominantly mental-emotional work (this group includes pilots), have for a long time remained unstudied despite the multiplicity of jobs of this kind. Interpretation of various data permits the assumption that at the basis of these mechanisms is an extraordinarily high excitability of cortical conditioned-reflex communications in both signal systems, which are close to the critical (pessimal) threshold, and are not grouped with a defined and stable dynamic stereotype, and which work for the priority inclusion of new or little reinforced communications during a simultaneous irradiation of stimulation upon the hypothalamic structures and an intensive activation of the entire reticular apparatus of the central nervous system (B. K. Gurvich (1959), Yu. L. Komendantov (1959), Yu. K. Petrov (1956), Pshonik (1952), Morucci and Megun (1949), A. M. Zimkina (1955), D. A. Biryukov (1951), Ye. N. Sokolov (1955), K. K. Platonov (1957, 1950), N. V. Golikov (1952, 1956 and 1957), L. L. Vasil'yev and A. A. Knyazev (1926), L. S. Isaakyan (1958, 1962), and others).

External tension in pilots during landing (on final) is characterized on the whole by the same features which, as in "negligible tension", have been described in the reports of a series of authors (A. D. Arkhangel'skiy (1934), K. K. Platonov (1948, 1949, 1960), Ye. A. Derevyanko (1949), and others). However, it has a number of peculiarities, which includes a significant prevalence of vegetative functions (vasomotoric reactions, shifts in arterial pressure, pulse, breathing, electroskin resistance); and, sometimes, mimic components, a "residual" stimulation of vegetative functions which depends on a number of conditions, occasional phasic phenomena, etc. (M. P. Sheynin, V. V. Rassvetayev (1960), L. S. Isaakyan, D. S. Kuleshov (1962)).

3. Taking into account the practical need for establishing a methodology, which in the first approach and in a purely experimental plan would make possible a comparative evaluation of the degree of tension in pilots at the time they are engaged in landing various types of airplanes, this report, (which is based on observations and investigations of the State NII GVF and on some theses of technical cybernetics and neurophysiology) attempts to plan ways to develop such a methodology.

4. A questionnaire using a special form (No. 1) submitted to 100 pilots in various types of transport planes of the GVF showed that, from a subjective point of view, tension at the time of an ordinary landing

(often perceptible, as a "sense of anxiety, of concentration, of increased attention, of readiness to combat the unexpected, etc.") and always expressed by definite shifts in the vegetative functions, will depend on those physical efforts which must be applied to the control units, on the speed of planning and of the ground approach, and on the total time expended in completion of the landing during the on final.

Individual pilots indicate these and other factors as causes for the tension--the number of motors, the quality of the work and potential of the braking system, the relation between the length of the landing run of the plane and the actual length of the runway, the width of the plane tracks, the reserve of fuel in the event a second circle is required, individual flying hours on a given type of plane, the presence or absence of an inspector, etc. Since the first three causes occur most commonly and are experienced more often than the others by pilots, they were subjected to special study.

5. A study of recorded pilot exertions on the controls of various types of planes, showed that the physical efforts of pilots at the "on final" exerted on the control unit have a predominantly static character (against the background of which, separate dynamic exertions appear); both the static and the dynamic components of these efforts reach their greatest value on the wheel during control with the elevator in the period of piloting within a specific sector of the landing distance (from a height of 25 meters to the point of touchdown on the runway).

That comparatively greater physical efforts in airplane control exert a definite influence upon the development of tension can be understood if we remember the difficulty of piloting an "inert" airplane, the little-studied field of the relations between significant muscular efforts and those physiological processes which characterize neuropsychic tension, and, finally, the special role of static exertions with their immediate reverse chemo- and proprioceptive afferentations in the central nervous system which, to a greater degree than the interrupted afferentation during dynamic exertions, are able to disorganize the normal work of the cortical structures (V. V. Rozenblat (1958, 1960), N. K. Verashchagin and V. V. Rosenblat (1955), and others).

Because registration of pilots' efforts on the wheel, for deflecting the elevator in the landing distance, is an element of the standard method for testing airplanes, obtaining the quantitative characteristics of these values for different types of airplanes was found to be possible.

Taking into account that the maximum of the exertions (even the very rare use with the trimming tabs, which automatically "takeoff" exertions) is observed as a rule during the 10 seconds before and after touchdown, the total impulse of the static efforts ($F_{kg} \cdot t = P_{ti/kg/sec}$) was

calculated through a 20-second period as the area of the geometric figure formed by the time base and the dynamic exertion pulse envelope.

The role of the second factor of the greater speeds of ground approach and landing in evoking tension is associated by the pilots with the growing shortage of time for perception of the treatment of the incoming information and for the formation of adequate reactions.

Used for quantitative calculation of this factor (total quantity of information--I_{pos}) was the process which is widely employed in technical cybernetics, of computation of the amount of information as a logarithm (on the base 2) of the value m, where m denotes the number of possible answers to the given source of information (Hartley's Law). Calculations for all types of airplanes were carried out on the basis of a single orienting algorithm, expressed as a mathematical formula, and which characterizes the most typical sequence of shifting of the attention of the pilot and the influence on pilots of the landing distance.

The role of the time required for landing, as a factor intensifying the tension is evidently to be explained by the increase in the time during which the pilot undergoes tension. This factor (time) was directly taken into account by us in the orientation algorithm in calculating the total quantity of information and was indirectly evaluated by the intensity of those shifts in the vegetative functions (B) (arterial pressure, pulse, breathing, skin temperature, electroskin resistance, etc.) which could be registered in pilots on landing and were expressed as mean values. Five of the mean values characterizing the vegetative reactions of pilots on landing definite types of airplanes were analyzed by us (for simplification) as factors equivalently influencing the course of tension; they were expressed as single conditional units of a calculation in which each unit has a value of 10, and, according to the principle of the logical element "and", they were multiplied to form a product which reflects the resulting shifts in the vegetative functions (BP).

Undoubtedly, these vegetative-somatic shifts, which appear to be secondary in relation to the primary mechanism of tension, have a stimulating effect on the latter (A. M. Zimkina (1955); D. A. Biryukov (1951), and others).

Note: The possible range of changes in the maximal arterial pressure (90-190 mm Hg), pulse (80-140 beats/min), respiration (20-60 breaths/min) etc., was divided into 10 conditional units, the value of one unit represented 10 mm Hg, 6 beats/min, 4 breaths/min, etc. Later, all operations were carried out with conditional units (e.g., the arterial pressure of 140 mm Hg was expressed as 5 c.u., a pulse of 90, one c.u., respiration of 40, two c.u., etc.).

Thus, three factors, which, according to the subjective evaluation of the pilots, participate in the formation and stimulation of tension, were presented as objective quantitative values, which characterize, for each type of airplane, first, the total impulse of the static exertions of the pilot in moving the elevator in the course of the 20-second period (P_{ti}); second, the total quantitative information coming in with respect to time to the pilot through his distance and kinesthetic receptors (I_{pos}); and, third, the total shifts in the vegetative functions (BP, arterial pressure, pulse, and respiration, skin temperature, electroskin resistance).

The arbitrary, but necessary, assumption was made that all three factors (P_{ti}, I_{pos} and BP) to an equal degree and according to the principle of the sequential effect (the logical element "and") promote the growth of the tension. This assumption permitted the expression of the possible range of the values, P_{ti} (100-600 kg/sec) and I_{pos} (900-1500 I.U.) by the same conditional units used in the resulting values of the vegetative reactions.

A questionnaire on a special form (No. 2) for 78 pilots showed that the different types of airplanes of the GVF can be arranged in a definite order on the basis of the degree of complexity (tension) of piloting on landing. Comparison of the indicated order with the three quantitatively expressed factors characterizing the tension of pilots of various types of planes in the landing distance showed that each of these blended values directly, or, expressed in conditional units, on the whole repeat the indicated order of complexity of piloting various types of airplanes.

This statement suggests the attractive idea of expressing the intensity of neuropsychic tension of pilots in the landing distance by some conditional units, which in an integrative form, would reflect the quantitative level of each of the three factors, thus reflecting in some way the degree of tension of the pilot in the landing distance.

In principle it seems not important which mathematical method will be used to obtain this integrative index; it is important that this index be proportional to each of the three factors. This can be accomplished by adding them or multiplying them with subsequent logarithmization. The latter way, possibly, is more correct as, it, first, uses the law (acceptable in our reasoning) of the cybernetic structure of logical systems (all three factors operate on the principle "and" and, therefore they are multiplied); second, it rests on the sufficiently supported law of Fechner (1899), according to which a logarithmic dependence exists between sensations (tension in the simplest sense may be represented as a complexly

organized sensation) and the intensity of stimulation (Lazarev (1947), Weaver and Perron (1952), Weaver and Lawrence (1954) and others). This dependence is expressed in the formula $S = c \cdot \ln K$, where S is the intensity of sensation, c is the coefficient of proportionality, ln is the natural logarithm, and K is the value of the stimulus (Genetsinskiy, Lebedinskiy (1956)). Considering, that the coefficient of proportionality is unknown to us, while the natural logarithm is converted in strict dependence with a more accessible index--the decimal logarithm ($\ln N = 2.3 \log N$)--the integrative index of tension (S_H) can be represented by the following empirical formula:

$$S_H = \log K, \text{ where } K = BP \cdot P_{ti} \cdot I_{pos}$$

where all three values, BP, P_{ti} and I_{pos} are expressed in single conditional units of a scale graduated in units of ten. Both the weak and also the positive features of the formula presented must be noted. The former include an entire series of arbitrary assumptions, some of which are either known to be inaccurate (e.g., the equivalence of the effect on tension of the three factors BP, P_{ti} and I_{pos}) or doubtful (e.g., are these factors actually the leading causes of the development of the tension, or do more important ones exist); is it permissible to express these factors in single units, etc.? The positive side of the formula is that it permits a quantitative and, consequently, an objective presentation of the subjective opinion of a number of the pilots regarding the complexity of piloting in the landing of planes of different types. Furthermore, the formula sets forth the possibility for further precision, since the more that the problem is studied, the factors which form K, in particular BP, may increase without limit, and the integrative index of tension (S_H) becomes more and more accurate.

SOME RESULTS OF A CLINICAL AND PHYSIOLOGICAL STUDY OF SENIOR PILOTS OF THE CIVIL AIR FLEET

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The problem of age of transport pilots has practical and general biological interest for aviation physicians and flight administrators.

Advances in technology are making it necessary to retain in the Civil Air Fleet veteran, qualified pilots and to train personnel in the handling of new and more complicated equipment. An important question is how does age affect flying skill or mastery of new equipment.

References in the literature on this subject deal mainly with military pilots. Some authors (Armstrong, Lomonako, and others) base their prognosis of flying fitness on the psychological changes resulting from age and occupational activity. Economic and safety considerations justify retention of senior pilots as the most experienced and best qualified. Experience and published reports reflect an inverse relationship between the number of flight accidents, on one hand, and the flying hours and age of the pilots, on the other.

To determine age-related pathology of flying personnel, we made an analysis of the reasons for the disqualification of Civil Air Fleet pilots:

(a) Cardiovascular pathology (mainly, atherosclerosis)--33.6 percent;

(b) Otolaryngological diseases--9.1 percent;

(c) Changes in vision--7.2 percent.

Results showed a direct connection between age and number of flying hours and experience. No connection was found in 51.1 percent of the cases between the age of pilots and any other pathology that served as a reason for discharge. This group included diseases of the lungs, gastrointestinal tract, surgical, nervous, etc.

A group of CAF pilots were carefully examined in the hospital, with a variety of clinical, roentgenological (and roentgenographic), laboratory (including biochemical), and electrophysiological methods. The latter methods included electrocardiography, vectorcardiography, and rate of pulse wave propagation. Special investigations were made of the auditory, vestibular, and visual analyzers, higher nervous activity, visual memory, capacity and concentration of attention.

None of the pilots examined had any health complaints and they regarded themselves as very healthy and physically fit. They continued to fly before admission to the hospital and after they were discharged.

Results showed that the frequency of roentgenological, electro- and vectorcardiographic changes in the heart and speed of pulse wave propagation increased with age. Thus, roentgenological changes in the heart could not be detected in any pilot under 35 years of age, but were present in 61.3 percent of those in the 50-54 year age group; changes

in the aorta were found in 7.1 and 77.4 percent, respectively. EKG changes (decreased voltage of the waves, deviation of the electric axis of the heart, impairment of excitability, slowing of atrioventricular conduction) were almost twice as common in the older as in the younger group. Propagation of the pulse wave was accelerated in all pilots over 50.

These results made it possible to diagnose incipient signs of atherosclerosis in 4 percent of the pilots under 35, but with increasing age the frequency of atherosclerotic changes gradually increased.

A rough comparison of frequency of atherosclerotic changes with published results of a special examination of males (people with ground jobs and of the same age as the pilots examined) and the above-mentioned reasons for pilot disqualification indicate that atherosclerotic changes occur more frequently and at a younger age in flight personnel than in persons employed in ground jobs, a phenomenon also noted by some foreign authors.

In a functional test (20 squats in 30 seconds), extreme shifts in pulse rate and arterial pressure were no more common in pilots over 35 than in the younger men, and both indices returned to normal within 3 minutes. This signifies that, in senior pilots, the adaptive mechanisms of the cardiovascular systems to moderate physical exercise were at a fairly high level.

The vestibular-autonomic and vestibular-somatic reactions of all the pilots were at a fairly high level too, suggesting that the vestibular apparatus does not undergo unfavorable functional changes as a result of age or flying activity.

A decrease in auditory acuity at threshold values in the zone of intelligible speech was noted in 23.6 percent of the pilots under 39, in 41.4 percent of those in the 40-49 year group, and in 70 percent of those 50 and older. The degree of impaired hearing in these age groups averaged 4, 5, and 11 db, respectively. Individual variations in those over 50 sometimes came to 50-90 db at different frequencies. The frequency and degree of impaired hearing with air and bone conduction were more pronounced in the pilots over 50 than in the younger men.

Auditory acuity decreased mainly at the high frequencies--beginning with 2000-3000 cps--as a result of noise, age changes, and, in a great many cases, inflammatory diseases and injuries to the ear. However, in the vast majority of cases, loss of acuity did not affect efficiency.

Testing acuity by whispering alone was insufficient, because it fails to uncover defects in the range of sound perception frequencies.

Eyesight tests showed that night vision, color sensation, binocular vision, condition of the fundus ocili, and transparency of fluids were normal in pilots of all ages. After 40, however, there was a weakening of accommodation, as shown by removal of the nearest point of clear vision to the degree of presbyopia. In such cases, correction by glasses with an optical power of the order of two diopters and with bifocal lenses (for distant and close-up vision) adequately compensated for the weakening of accommodation and permitted satisfactory performance of duties.

Neurologically, there were no significant abnormalities, except for very delicate changes in static coordination in pilots over 45 and under 30.

An investigation of higher nervous activity, the visual analyzer, and some psychological functions showed that the mobility of the main nervous processes decreased slightly with age while the stability of the corresponding indices increased. The functions of higher nervous activity reflecting the ability to change rapidly from inhibition to vigorous action and to distinguish between similar stimuli were not adversely affected by increasing age.

In pilots over 45 years of age with considerable flying experience and many hours in the air, the indices of cortical excitability and mobility tended to decrease slightly as the stability of the corresponding indices declined.

Visual memory did not deteriorate with age, although the capacity and concentration of attention tended to decrease slightly along with high stability of these functions in the oldest pilots.

We concluded from our findings on Civil Air Fleet flying personnel that age is chiefly a problem of cardiovascular pathology, changes in visual function, and, in part, occupational changes in hearing. From the practical standpoint, the problem can be solved by early diagnosis of the commonest forms of atherosclerosis in its various manifestations and stages (mainly coronary sclerosis), correct prognosis and expert evaluation of efficiency, and adoption of preventive measures. There is no reason to set up for CAF flying personnel any age limitations on service suitability unrelated to pathology.

A THEORY CONCERNING GRAVITATIONAL INFLUENCES ON THE ORGANISM

P. K. Isakov

Adaptation reflects a quality of instability in an organism's internal environment. The range of adaptation to changes in the barometric pressure of air, ambient temperature fluctuations, content of injurious admixtures, partial pressure of oxygen in inhaled air, composition and quantity of food ingested, and workload (rhythm, duration, volume, etc.) has been fairly well studied.

The extraordinary progress of aviation technology has intensified research on the effect of accelerations on the organism. This branch of aviation medicine has now accumulated a large mass of experimental material supporting the basic theory of functional changes consequent to accelerations. To counter these changes a variety of preventive measures have been devised.

The high speeds and altitudes at which spacecraft now travel--brilliantly pioneered by the Soviets--have made it necessary to study a number of new factors, weightlessness in particular.

A fairly large amount of experimental material is now available on various effects of partial or total weightlessness, but there, as yet, no general theory to account for the mechanisms of weightlessness, just as with accelerations. A unified theory is needed to explain the effects of accelerations and weightlessness on the gravitational field.

The phenomena of a static state of changes in body weight are not encountered in man's normal environment nor likely to occur in any future enrivonment. Both acceleration and weightlessness (partial or total) almost always arise as a result of the dynamics of movement, which explains why living things are subjected throughout their lives to the unavoidable influence of accelerations and weightlessness. Such changes in body weight as may arise in the course of movement are, of course, insignificant in degree and duration. But their frequency and systematic quality are responsible for two kinds of influences on the body. On the one hand, the changes in weight have a formative effect on the morphological and functional structures. On the other hand, when the body encounters other physical parameters of weight changes while active, it tends to adapt. Naturally, both the degree and the range of adaptation to accelerations and weightlessness differ. The latter is determined by the fact that during an organism's life cycle, accelerations influence morphology and function much more frequently than does weightlessness. Moreover, accelerations, unlike weightlessness, may achieve multiple values.

The level of gas exchange, following acceleration, rises sharply, depending on intensity. Reported in 1957, this has recently been confirmed by foreign investigators. The increase in gas exchange is undoubtedly due to the muscle tone change directed at maintaining the position of the body when its weight increases. Some responsibility for the intensification of gas exchange and, consequently, the energy balance of the organism is also attributable to change in the cardiovascular, respiratory and other systems. There is also a similar relationship between gas exchange and weight change in partial or total weightlessness. In both cases the conditions for the maintenance of body position change from those that usually prevail throughout the life of the organism. Other reflexes of the muscular system are needed to maintain body position and perform coordinated movements.

There are as yet no scientific data that indicate how soon the organism regularizes gas exchange after exposure to accelerations or weightlessness, for the states of the organism investigated under these conditions were relatively brief. Another reason is the marked duration of transitional states in such experiments--from acceleration to weightlessness and vice versa. Transitional states are, of course, conditions that largely prevent establishment of a constant level of reflexes, including that of gas exchange, as an integral index of the state of the organism. Thus, there seem to be two prerequisites for determining time required for adaptation to acceleration and weightlessness. First, the periods of exposure to these factors must be much longer than the transitional periods and, second, the intensity of acceleration must not be more than double that which ordinarily prevails under ground conditions. The second prerequisite stems from the need to maintain equality in the effects of weightlessness and acceleration with respect to the degree of changes in body weight as compared with those characteristics of the ground surface.

The data presented in the table below illustrate the changes in gas metabolism after exposure to weightlessness created during plane flights along a ballistic trajectory (from G. F. Makarov's experiments). The figures do not exhaust the full range of changes noted in the experiments. In some cases, the differences in gas exchange in weightlessness were smaller than those mentioned in the table.

Conditions	Intake of O_2 (cm^3 in 1 m)	Release of CO_2 (cm^3 in 1 m)	Pulmonary ventilation (liters/m)
Ordinary.	320	260	8.4
In weightlessness	533	412	8.9
Period of aftereffects. . .	309	256	5.8

In other cases, a progressive lowering of the gas exchange level in weightlessness was observed below that which followed the initial exposure to this factor. It is important to note that oxygen utilization and release of carbon dioxide were much more intense in weightlessness than in the original state.

The figures cited here apply, to be sure, to brief periods of weightlessness lasting about 20-25 seconds. During this short period of time the body is more or less adapting to the unusual change in weight. How long does this state last? To what extent is it possible for the level of gas exchange to become normal on further exposure to weightlessness? There are as yet no answers to these questions. Nevertheless, it is important from both the theoretical and practical standpoints that they be found.

Turning now to the data characterizing the differential threshold of perception of gravity, we wish to point out that the pattern observed by Weber-Fechner changes after exposure to weightlessness and acceleration. For example, the following occurs after acceleration: In estimating the weight of objects with the arm immobilized at the elbow, the subject tended to judge the weight accurately. When the weight was determined with the entire arm, without immobilization the weight was overestimated. Undoubtedly such fluctuations in estimations also depend on the weight of the participating parts of the arm. A proportional increase in the weight of these parts during accelerations complicates estimation of weight. And the more the weight is increased when new parts are included (hand, forearm, shoulder), the more the overestimation.

Experiments under conditions of brief weightlessness confirmed the relationship noted during exposure to acceleration--the differential threshold of perception of gravity decreases during weightlessness (D. V. Afanas'yev's experiments).

The table presents the results obtained during immobilization of the body and hand of the subject when the threshold of perception of changes in gravity was determined by the first phalanx of the index finger. The results were the same when the threshold was determined with the entire hand, without immobilization.

It will be noted that in determining the thresholds of perception of gravity with different parts of the extremities (finger, hand) and

Range of changes in exertion	On the ground	During a horizontal flight	In weightlessness
540-650 r	0.13	0.13	0.09

Range of changes in exertion	On the ground	During a horizontal flight	In weightlessness
778-945 r	0.11	0.11	0.09

under different conditions of immobilization of the arm (immobilization of the hand, forearm, without immobilization), the results of the experiments were different. In other words, to obtain unambiguous results it is necessary to make a special selection of the original values of the changing exertions created by the device. The latter is due to the difference in weight of the parts of the arm participating in the perception of changes in gravity: the greater in weight of the part, the greater must be the original level of the variable exertion. With a further increase in the original level, there comes of course a time when the observed relationship in the differential threshold of perception of gravity is again disrupted. Our next task is to determine the mathematical relationships between the weight of the parts of the arm and the value of the original level of the exertion to be determined. This will make it possible to determine the necessary exertions when handling the levers in weightlessness.

The accuracy of movements in weightlessness, according to many investigators, is definitely related to the degree of adaptation to weightlessness. For example, in Beck's investigations, the greater the number of experiments, the more accurately did the subjects execute the assigned movements. According to M. A. Cherepakhin, the number of hits in the center of the target with arm movements in subjects adequately adapted to weightlessness was 86 percent; they exhibited similar accuracy during a horizontal flight. Just as in Beck's experiments, when visual control was excluded, the accuracy of arm movements diminished. Analogous relationships were also noted during the execution of assigned arm movements.

A comparison of similar experiments performed in connection with accelerations (V. V. Usachev et al.) reveals similar results. Change in arm weight (in accelerations or in weightlessness) impaired the joint function of the cutaneous and motor analyzers in estimating weight of objects. The shorter the periods of these changes, the less possible it was for ordinary correlations in the activity of the cutaneous and motor analyzers to return to normal.

These considerations naturally do not exhaust the entire physiological problem of gravity. It is far broader and deeper than the aspects examined here. Understanding of the body's compensatory reactions in a changing gravitational field will contribute extremely important, practical data and more accurate information concerning individual analyzers under normal terrestrial gravitation. Thus, a

solution of the physiological problems of gravity will also stimulate efforts to clarify many aspects of pathology under normal conditions.

EFFECT OF HYPOKINESIA ON CERTAIN INDEXES OF EFFICIENCY AND RESPIRATORY FUNCTION IN MAN

L. A. Kakurin, B. S. Katkovskiy, A. N. Kozlov and N. M. Mukharlyamov

This investigation studied physical fitness of man under prolonged conditions of limited motor activity. Strict bedrest with persons remaining horizontal was selected as the experimental model. Resultant motor, circulatory, and respiratory disorders were assumed to be caused by hypokinesia and hydrostatic blood pressure.

Four healthy males, 21-24 years of age, remained horizontal in bed for 20 days, with motor activity at a minimum, even when eating or being examined. Once every 3 or 4 days they were allowed to sit on a bedpan for 10-15 minutes. The experiment was monitored by physicians and technicians on duty round-the-clock.

Before and after the experiment, the subjects were given physical exercise tests (on a Belau apparatus) consisting of 100 climbs on a step 25 cm high for 5 minutes to the beat of a metronome (work rate 400-500 kg/min). While the subjects were in bed on the apparatus, a spirograph measured oxygen utilization and other respiratory indexes at rest. The following indexes were studied:

(1) Oxygen utilization, release of carbon dioxide, minute ventilation, and coefficient of oxygen utilization at rest.

(2) Excess (above the resting level) increase in oxygen utilization during physical exercise and in the restoration period (oxygen debt).

(3) "Restoration coefficient" (RC)--the ratio of the increase in O_2 during exercise to the oxygen debt. According to F. Belau (1959), A. D. Damir and M. V. Pyatnitskiy (1961), P. Ye. Lukomskiy (1962), and others, an increase in the "RC" coincides with general improvement in man and, conversely, a decrease in this index indicates a deterioration of physical fitness.

(4) Index of work efficiency--oxygen consumption in ml per kg of work.

The results are presented in the table below, the figures being combined for the 4 subjects.

Indexes	Before the experiment	Days after the experiment			
		1	4	7	10
Work in kg	2455	2391	2419	2428	2447
Increase in O_2 when working in ml.	3372	4433	3430	3567	3360
Oxygen debt in ml.	883	1787	1082	1157	938
"RC"	3.91	2.56	3.47	3.21	3.62
Ml of O_2 per kg of work. . . .	1.73	2.59	1.87	1.95	1.75

It is evident from the table that oxygen utilization (index of energy expenditure) during exercise increased from 3372 to 4433 ml (31.4 percent) on the first day after the experiment, while the oxygen debt increased by 102.1 percent (from 883 to 1787 ml). Individual fluctuations in O_2 increase ranged from +6.7 to +42.5 percent; in oxygen debt--+61.5 to +137.3 percent. On the following days, the O_2 utilization increase during exercise was virtually the same as at the beginning, but the oxygen debt, by the 4th day of restoration, was 22.5 percent higher, with individual fluctuations ranging from +15.3 to +41.3 percent. By the 7th day, it was 31 percent higher and, on the 10th day, 6.2 percent higher. On the 10th day of the restoration period, oxygen debt was below the original level in only one subject (by 8.9 percent); for the other three, it ranged above the original level by 8.5 to 20.2 percent.

The "restoration coefficient" decreased after the experiment by 34.5 percent (from 3.91 to 2.56); individual fluctuations ranged from -22.5 to -42 percent. In no subject--even by the 10th day--was this index completely restored.

After the experiment, there was a marked increase in the energy value of a unit of work. Oxygen consumption per kg of work on the first day of restoration was 49.7 percent higher than before the experiment (from 1.73 ml of O_2/kg to 2.59 ml of O_2/kg). Individual fluctuations ranged from +20 to +66.8 percent. On the 4th day after the experiment, this index was equal to the original level in only one subject, but 6.3 to 18.7 percent higher in the other three subjects. On the 10th day

of restoration, the mean index of work efficiency was close to the original level (1.1 percent higher). It was lower in two subjects (by 2.3 and 14.1 percent) and higher in two (by 6.5 and 16.3 percent).

In bed, the subjects tended toward decreased oxygen utilization. On the first day of restoration, oxygen utilization increased noticeably in all subjects while resting (sitting), but from the 4th day on, no increase in oxygen utilization was noted in those maintaining the same position.

After 20 days in bed, physical exercise involving 100-step climbs required much more effort than before the experiment: this personal evaluation of physical deterioration was confirmed by increased oxygen utilization during exercise, marked increase in oxygen debt, and decrease in the "restoration coefficient". Significantly, these indexes were not fully restored during the first 10 days of restoration.

The oxygen utilization decrease while in bed suggests a reduction in metabolic rate. The energy increase on the first day while sitting was apparently the result of adaptation to the horizontal position and impairment of hemodynamic processes.

Increased cardiovascular and respiratory demands during exercise correlative with the functional deterioration of these systems (increase in oxygen debt and decrease in the "RC") after prolonged hypokinesia imply that the tolerance of maximum "stress" loads on these systems and, in particular, the tolerance of overloads may be low.

Findings

1. Twenty days in bed cause marked deterioration of human physical fitness--partly from hypokinesia and, in part, from body's adaptation to a horizontal position.

2. Deterioration of work efficiency after remaining in bed makes heavy demands on the cardiovascular and respiratory systems.

OBTAINING VISUAL INFORMATION DURING INSTRUMENT FLYING

I. A. Kamyshev

To obtain visual information during instrument flying, we employed a method devised by K. K. Platonov that made use of synchronous recording

of readings of piloting instruments, and the pilot's glances and handling of the controls. Various elements were tested by Popov, Pikovskiy, Petrov, Derevyanko, and others, but synchronous recording of the abovementioned parameters proved impossible. The visual axis was interpreted in this study by a new modification of the standard method.

In 1960-1962, 31 flights on a TL trainer were carried out by 13 pilots to test this method and to study some of the matters connected with instrument flying, namely:

(1) Characteristics of control in pitch and banking;

(2) Relationship between reading of instruments and flying experience;

(3) Placement of piloting instruments.

According to data obtained on a UTI-MIG-15, a pilot handles the controls 90 percent of the time--even on a steady horizontal flight, the simplest mode of operation--and yet cannot prevent deflections. In instrument flying, the average number of separate glances is 86 a minute, i.e., every 2 seconds the pilot looks at 3 instruments. At times, the glances number 150 or even 200 a minute, i.e., every second the pilot looks at 3 instruments. These facts make it possible to describe the work pace and time deficit quantitatively. Largest effort is concentrated on the control stick in the right hand: pushing the stick to one side, causes the plane to bank and change course; moving it toward or away from the pilot changes altitude and vertical speed.

Characteristically, when changing course or banking, the pilot focuses on the AGI (fighter airplane gyro horizon) and GIK. For example, in going into a turn he looks at the AGI 74 percent of the time, but in pulling out of a turn he looks mostly at the AGI and GIK (86 percent of the time in pulling out). While handling the control stick, he controls the effect of the movement instrumentally, and as soon as the readings of the instrument are at a given figure, he moves the rudder to pull out. As a result, he accomplishes the desired bank in a single maneuver.

However, this concentration on one or two instruments adversely affects the control of the other parameters and is thus a possible cause of unnoticed deflections, e.g., in altitude or speed. Such deflections are particularly dangerous at low altitudes, as when coming in for a landing.

The eye movements of 6 pilots in 16 circlings on the TL were filmed from the place that the TL went into the 4th U-turn up to the inner homing radio beacon. We found that while making deflection shifts on the

landing course and circling according to the OSP-48 (instrument-landing equipment) system, the pilots looked at the AGI and GIK 88.4 percent of the time, but in circling according to the SP-50 system, they looked at the AGI, GIK, and PSP 97.6 percent of the time. Thus, only 11.6 percent (OPS) and 2.4 percent (SP-50) of the time remained for checking on altitude, speed, variometer, and tachometer.

Intervals between reading the altimeter, variometer, and speedometer were 24, 19, and 18 seconds, respectively. There were periods when none of the instruments was checked for 15-17 seconds. It is very likely that most plane crashes in the vicinity of homing radio stations are due to the fact that the pilot in making deflection shifts in line with the strip focuses for correction purposes on the AGI and GIK and thus fails to note loss of altitude and speed.

The advantages of the bank control system are speed and efficiency; its serious shortcoming is the required concentration on one or two instruments, which thereby jeopardizes the craft. When changing the vertical speed and altitude, the pilot cannot correct his movements by the method described above because the variometer and altimeter have a lag of about 3-4 seconds. The control stick is shifted late so that information from these instruments cannot be used to introduce corrections in the executed movements. The pilot makes the desired change in several tries: after moving the rudder, he must wait until the variometer arrow comes to rest at some division. Meanwhile, if the vertical velocity is not what is desired, a new movement has to be made, etc. This method of control is inefficient and time-consuming.

Comparison of control longitudinal and transverse axis controls shows that, even though both concentrate on a single lever--the control stick--their systems of instrument indication are different. Thus, the pilot is forced to use a variety of control methods, which increases his difficulties in handling the plane. Further research should be undertaken in the design of optimum systems of indication.

Subjects included pilots with varying experience in instrument flying and persons with no flying experience but who had distinguished themselves in handling the trainer. This made it possible to correlate the reading of instruments with flight experience. It was found that the more experienced the pilot was, the briefer was his glance, i.e., the less time he required to read the instruments. For example, the average time veteran fliers required to check the speedometer was 0.6 second as compared with 1 second by the nonfliers. Consequently, it would seem that experience increases the ability to read instruments quickly so that a great many parameters can be checked in a given unit of time and a mass of information obtained. By what means is the instrument reading time shortened? What processes can be trained for this purpose?

It is well known that on the ground the time required (0.3-0.4 second) to read an instrument (tachistoscope) is not affected by training and is approximately the same for fliers and nonfliers. During flight the reading process is not limited to perception of the instruments, but each instrument's readings must be correlated with those of other instruments, the previous readings, the flight mission, etc. In effect, they merge with the central dynamics of analysis, synthesis, and generalization of information received. Here is the likely source of the increase in the average amount of time spent in glancing at piloting instruments. The fact that experienced men require about 0.6 second as compared with the 1 second required by nonfliers indicates these processes are dependent upon training, and can, therefore, present a difficulty for pilots. To achieve the same effect under ground conditions, we must reproduce through technical means the dynamics of instrument reading and pilot movements.

It will be noted that we failed to observe a single instance in which the pilots acted in accordance with the simple or complex reactions that have been studied in detail in the laboratory. Even when a man noticed an unexpectedly large deflection, the time from the moment that he glanced at the instrument until he adjusted the control stick accordingly (latent period) averaged 1.99 seconds. During this time he usually checked 1 or 2 instruments affected by the deflection (e.g., altimeter, variometer, speedometer).

Moving pictures of eye movements made possible a new approach to the problem of placement of piloting instruments. They should be arranged according to their importance: the instrument that is looked at most frequently and longest is of greatest importance and should, therefore, be in the most convenient place. The moving pictures assigned chief importance to gyro horizon, which may be checked 35 to 70 percent of the time, depending on the mode of flight operation. The relative position of the other instruments around the gyro horizon is determined by the number of glances at each pair of piloting instruments. The problem can be solved mathematically on the basis of these data by using linear programming. This way of arranging the instruments guarantees minimum angular movements of the eyes in the instrument flying.

REACTIONS OF ASTRONAUTS TO BRIEF PERIODS OF WEIGHTLESSNESS

I. M. Kas'yan

This research was carried out on a two-seater airplane, in which weightlessness lasting 35-45 seconds could be produced, and on a laboratory airplane with weightlessness lasting 20-25 seconds. Intensities of accelerations and weightlessness were recorded on X and Y axes accurate to 0.01 unit. While executing a parabolic trajectory, accelerations of 1.5 to 3.5 ± 0.5 units were attained for 10-15 seconds. The intensity of acceleration in producing weightlessness did not exceed 0.02 to 0.07 unit on the Y axis or 0.02 unit on the X axis.

Each flight included 3 to 6 periods of weightlessness ("vertical climbs"), and intervals between "vertical climbs" were 10 to 15 minutes. During flight, the astronauts were either fastened by straps to a special chair or remained free and unfastened to move about as they wished through a "floating basin" under weightless conditions.

Bioelectric activity of the heart (EKG), arterial pressure, pulse and respiratory rates, and muscular strength of the hand (dynamometry) were recorded during flight.

Coordination of movements in weightlessness was determined by a "writing test", work on a special coordinograph, and free movement in the "floating basin".

The nature and degree of change in finely coordinated movements in weightlessness were studied by means of the "writing test" both when the men were fastened to the chair and in the course of free "flight" in the basin.

The recordings showed that when the astronaut was made fast to the chair, brief weightlessness had no effect on handwriting. In most cases of free movement in the "floating basin", he was unable to write down the assigned text.

In the coordinograph study, the astronaut followed a special program with a metal pencil, making successive contacts in 5 sockets on the device. These tests made it possible to compare the varying amounts of time spent on executing purposeful motor reactions before the flight, during exposure to accelerations, and under conditions of low weightlessness.

Results on the coordinograph showed no impairment of movements, but revealed that the duration of the test varied during different flight periods.

Throughout the parabolic flight, the astronauts functioned efficiently, rhythmically, and with no noticeable impairment of coordination. Coordination of movements was evaluated also from results of tests taken during free movement in the "floating basin".

Analysis of the motion pictures and visual observations showed that the astronauts were able to move about the "basin" only when assisted by tightened ropes or by pushing against the side of the cabin. Without such assistance, purposeful movement through a "floating compartment" is not possible.

No significant loss of accuracy occurred carrying out prescribed movements (turning the body to the right, to the left, around a longitudinal axis, front and back somersaults, etc.) with open and closed eyes in free movement in the basin. Although the astronauts, in the first "vertical climb", showed some wariness, tension, and constraint, in later "vertical climbs", they were able to keep the body position steady, to move about smoothly and without constraint, to move with greater efficiency and coordination. It is of interest that individual characteristics were significant in purposeful motor acts in weightlessness.

Also interesting was the fact that facial coloring, after the first "vertical climb", was not the same: it was quite pale in A. G. Nikolayev, but very red in P. R. Popovich. This reflected individual differences in autonomic-vestibular and emotional reactions to weightlessness (effect of the "novelty", etc.). These reactions were more pronounced during the first parabolic "vertical climbs" than during the later ones.

The fact that accurate movements can be carried out in weightlessness made it possible to provide a considerable assortment of natural food products (solid, semisolid, and liquid). These included sandwiches with smoked sausage and ham, meat patties and cabbage, grapes, pastry, chocolate, etc. Analysis of the frames of the films and visual observations showed that it is possible to eat all kinds of food freely and with no difficulty in swallowing.

Indexes of muscular strength, which was evaluated by manual dynamometry with free movement in the "floating basin", showed marked deterioration in weightlessness--by 5-8 kg and 4-7 kg for the right and left hand, respectively.

The rate of respiratory movements on earth before flight ranged from 14 to 24 cycles per minute. Accelerations of up to 3.5 units (before and after weightlessness) caused in Yu. Gagarin and G. Titov a slight increase (6-8 cycles per minute) in respiratory rate followed by normalization under weightless conditions. And, conversely, during

exposure to accelerations, respiratory rate in A. Nikolayev and P. Popovich scarcely changed, with an acceleration of 3-7 cycles per minute in weightlessness.

In all the astronauts, the cardiac rate on the ground before takeoff ranged from 54-94 beats/min. Acceleration produced a marked increase of 20-63 beats/min, but in weightlessness there was generally a slowing of the pulse by 16-66 beats per minute. However, in some cases (Nikolayev) it failed to reach the original values (during one "vertical climb" it was above the original level), while in others it was even below the original level.

Maximum blood pressure during accelerations rose by 10-28 mm Hg. Minimum pressure fluctuated within narrow limits and showed no regular changes. As the pulse accelerated in response to accelerations, the R-R interval on the EKG shortened. The intervals of the P-Q and Q-T complexes in most cases became somewhat shorter, while the amplitude of the waves changed within the limits of physiological fluctuations. In weightlessness there was a tendency for the EKG intervals to return to normal.

Changes in physiological indexes during all phases of the parabolic flight were functional in character and gave evidence of the body's considerable compensatory and adaptive resources.

Besides the above-described investigations, a study was made of sensory reactions, during weightlessness, on the basis of each astronaut's subjective evaluation of his condition and feeling. P. R. Popovich described his condition during the experiments as follows: "With free movement in the "floating basin" in the first "vertical climb", there was some awkwardness and strain. In the second climb, I felt better and was able to orient myself and coordinate my movements. I turned 5 times around the horizontal axis of the body with eyes open and closed. In the next climbs, moving in the "floating basin" was pleasurable, etc."

In the course of familiarization-training flights on airplanes, Yu. A. Gagarin, G. S. Titov, A. G. Nikolayev, and P. R. Popovich successfully carried out the planned program and thereby demonstrated their fitness and emotional and mental stability to cope with weightlessness.

PATHOMORPHOLOGICAL VISCERAL CHANGES IN ANIMALS AFTER ACCELERATIONS

M. I. Kas'yanov and G. P. Mirolyubov

Since the landing of a spacecraft is accompanied by a shock overload (acceleration), a study of its effects on the organism is pertinent. Studies on pathomorphological visceral changes in animals throw some light on the mechanism of the injurious factor and along with physiological and biomechanical data help explain the effect of accelerations. The familiar works on visceral injuries resulting from impact (Rotmar, Green, and Ringsley, 1946; Rashmar, 1947; MacDonald, Kelly, and Key, 1948; Step, 1958; M. A. Brestkin, G. A. Komendantov, V. V. Levashov, et al., 1949; S. A. Gozulov, and P. K. Isakov, 1949; E. V. Marukhnyan and I. A. Tsvetkov, 1950; others) had different objectives and consequently are not completely relevant to the problems involved in ensuring safe landings. This report presents the data from two series of comprehensive investigations of landing impact.

In the first series with a single exposure, 20 animals (18 white rats and 2 dogs) were examined morphologically. The accelerations recorded in the experiments with the dogs and rats amounted to 35 and 100-870 units, respectively. All the experiments involved accelerations in a "back-chest" direction, except in the case of 3 rats where the direction was the reverse or "chest-back". Two rats were injected subcutaneously with hexenal before exposure. Three rats died within an hour after exposure--2 as a result of marked pulmonary edema (hexenal poisoning), 1 as a result of hemoperitoneum. The other animals (15 rats and 2 dogs) were sacrificed with ether anywhere from 5 minutes to 11 days after exposure. Immediate effects of accelerations included organ injuries (ruptures), focal hemorrhages without rupture of the organs, and fat embolism. Focal hemorrhages were noted most frequently in the lungs (19 animals), less so in the pia mater and medulla. Hemorrhages into perinephric tissue (2 out of 18 rats) and subcapsular hemorrhages in the spleen (in 1 of the 2 dogs, but in none of the rats) were very rare.

Transcapsular and subcapsular lacerations of liver tissue followed exposure to 400 units or more and were found in 11 out of the 20 animals. Rare injuries included transpleural laceration of the lungs in 1 rat and subcapsular lacerations of kidney tissue in 2 others. Different parts of organs were injured, depending on the direction of the impact through the abdominal and thoracic wall (hemorrhages in the ventral portions of the lungs when the animals were on their belly, hemorrhages in the spinal prevertebral portions when they were on their back), on organs striking against firm structures (skull, spine, thoracic ribs), and on organs striking against each other. In the last case, of particular importance are the heavy, firm organs, such as the liver and heart, and

the hollow organs with their contents (stomach, intestinal loops, urinary bladder). For example, the left lobes of the liver, which are the most frequently injured, are found between the heart and the stomach. In dogs, moreover, close to these lobes is the firm spleen. And the right central lobe of the lungs strikes against the heart while the bottom of the lower lobe of the right lung hits through the diaphragm against the liver, resulting in planar hemorrhages along the diaphragmal surface of the lung. Fat embolism was found in the lungs of only 2 rats (355 and 870 units).

In the hemorrhages and portions of injured tissues, changes regularly developed in the form of erythrocyte disintegration, resorption of the hemorrhages, and disintegration and resorption of the detritus. Reactive processes, mainly productive in nature, were clearly evident in the lungs and liver 3-4 days after exposure. Degenerative changes in this series of animals were noted in the ganglion cells of the brain and cerebellum. Ischemic changes in these cells were very common, acute swelling and disintegration of the cells, less common. These changes were found in some animals within 15 minutes of exposure, but regularly appeared toward the end of the first day. They were directly related to the intensity of exposure and length of life thereafter. Degenerative changes in the ganglion cells of the brain and cerebellum appeared sooner and after less intense action in the dogs than in the rats and with equal overloads they were more numerous. These degenerative changes were apparently part of the picture of brain concussion observed in the animals (tiny focal hemorrhages in the medulla, ischemic changes in the blood vessels and capillaries, changes in the ganglion cells) and they were directly caused by the accelerations.

The second series of experiments involved 7 dogs subjected to repeated (3-27) accelerations of varying intensity (35-300 units). The animals were killed with ether at different times after the experiments so that it was possible to trace the development of the processes over a period of 4-24 days. The average time between exposures ranged from several minutes to 1-2 days.

All phenomena appearing in the first series were observed also in the second series. However, owing to the repetition of the accelerations and longer life of the animals after the first impact, all changes were more pronounced than in the animals of the first series. Repeated accelerations gave rise to new hemorrhages and new foci of damaged tissue, as revealed by dissection and histological examination. The same animal had injuries and hemorrhages of different kinds, depending on the time they originated. Subcapsular hemorrhages in the spleen of 3 out of the 7 dogs were a feature of this series. The reason seems to be the considerable firmness and weight of this organ in dogs. None of the 18 white rats in the first series was found to have any hemorrhages in the spleen. On the other hand, none of the dogs had hemorrhages in the kidneys or perinephric tissue, as was the case with some of the rats.

The animals of this series had more pronounced reactive proliferative processes in the brain (focal and diffuse proliferation of glia), liver (histiocytic proliferation in the foci of injury), and, above all, in the lungs. Foci of atelectasis were observed in the lungs with a thickening of the interalveolar septa as a result of histiocytic proliferation and thickening of the collagenous fibers and bronchiolization of the alveoli; foci of bronchopneumonia were also found. In all 7 dogs, there were many more degenerative changes in the cerebral and cerebellar ganglion cells than in the first series. The morphological picture of brain concussion that followed the first impact was maintained by the subsequent trauma, when degenerative changes originated in new groups of ganglion cells. The changes were superimposed on the preceding ones so that on the basis of the morphological picture they constituted a traumatic disease of the brain.

New and what might be called destructive changes not observed in the first series appeared in the lungs and kidneys of the animals in the second series. These consisted of liquefaction of the mucosa of the large bronchi and disintegration of the wall of medium- and small-caliber bronchi into fragments followed by complete liquefaction of the bronchi, caused mainly by degeneration of the elastic tissue of the bronchi. Attenuation of the elastic tissue and fraying of its fibers were also noted in the interalveolar septa. In the kidneys, the glomeruli were destroyed with liquefaction of the capillary walls, shrinkage of the endothelial cells in the capillaries, and hyperchromatism of the endothelial cells. These changes were observed in all dogs but one, which died of focal bronchopneumonia apparently unrelated to the accelerations. The above-described destructive changes were undoubtedly trophic, pathogenetically related to the degeneration of the ganglion cells of the brain, chiefly the brain stem.

Summary

1. The accelerations used in this investigation caused tissue injury and hemorrhages in organs, fat embolism, and a morphological picture similar to that of concussion of the brain together with degenerative changes in the ganglion cells.

2. Traumas and focal hemorrhages developed in different parts of the organs, depending on the direction and intensity of the acceleration, on the striking of organs against the wall of cavities (skull, spine, throax), and on their consistency and relative position. The firm and heavy organs (liver, heart, stomach, intestinal loops, urinary bladder, and, in dogs, spleen) are of particular significance.

3. Reactive changes around the injured areas and focal hemorrhages as well as destructive changes in the lungs and kidneys required some

time to develop and become evident. The destructive changes were probably trophic and related to degenerative CNS changes.

4. In cases of repeated exposure (official variant of landing), unlike a single emergency landing, the possibility of cumulative effects as a result of repeated microinjuries stresses the need to reduce the permissible limits of accelerations on landing.

QUANTITATIVE EVALUATION OF OPERATOR IN A "MAN-MACHINE" SYSTEM

Yu. V. Kiselev

A great many complicated technical systems are now in existence, one component of which is the human operator. Such combinations are called "man-machine" systems.

Man's involvement in such systems gives rise to many problems, one of which is reliability. Reliability of a system is its ability to perform assigned functions dependably and with ease of repair. If reliability is to be increased, its precise quantitative evaluation is essential.

No single criterion of reliability--a characteristic by which it can be judged quantitatively, applicable to all objects, devices, and systems--has yet been found. Therefore, several criteria are now used, the commonest being the probability of trouble-free operation of a component or system over a given period of time.

Unfortunately, this criterion because mechanical failure and an "operator" failure are different in nature, is not applicable to the "human component." The breakdown of a machine can generally be repaired only by intervention from without, whereas spontaneous restoration of normal functioning is characteristic of the operator.

As in the case of the machine, it is impossible to select a criterion of reliability for the operator that would apply to all situations in life. This paper will examine the quantitative characteristics of the reliability of an operator performing a tracking task in a closed or open cycle in a semiautomatic control system.

For this task, the best criterion of operator reliability in a continuous process is the probability that with correct input data the parameter of operator output will be within permissible limits at any

moment of working time; in a discrete process, the probability of correct performance of each cycle of operations.

Operator reliability cannot be practically evaluated without a quantitative expression of the quality of the operations performed by man. An empirical curve of distribution density of the parameter in question is constructed on the basis of the measured quantitative values of the operator output parameter. In doing so, it is well to regard as the operator output parameter the operator error, i.e., the difference between what the operator actually puts out and what he should put out.

The area under the distribution curve bounded on the left and on the right by the maximum permissible values of the operator output parameter, determines numerically the reliability of the operator in the particular aspect.

The criterion of reliability examined means that it determines the average relative portion of working time during which the operator output parameter is within permissible limits--in the case of a continuous process--and the average relative portion of correctly performed operations--in the case of a discrete process. Operator reliability thus calculated can serve as a starting point for setting up time norms.

TRACE PHENOMENA IN THE CENTRAL NERVOUS SYSTEM AFTER PROLONGED OPTOKINETIC STIMULATION

V. A. Kislyakov and V. P. Neverov

Experiments were performed on rabbits to determine the characteristics of optokinetic nystagmus (OKN) after prolonged (1-1/2 hours) optokinetic stimulation. The optokinetic stimulus was a cylinder 2 m in diameter with 22 black stripes 5 cm wide on the inside. OKN was recorded by the electro-oculographic method. Statistical processing of data revealed significant decrease in OKN frequency in most of the animals.

If, after 1-1/2 hours of continuous optokinetic stimulation, a dark screen that blocked the sight of the stationary cylinder stripes was placed in front of the rabbits' eyes, the animals developed nystagmus in the direction opposite to the OKN. This phenomenon, which we called "reverse postoptokinetic nystagmus" (RPN), lasted 10 minutes. Subsequent experiments showed that traces of optokinetic stimulation may

persist in the CNS for a long time, manifested as RPN after 30 minutes and, in some cases, after 1 hour. These findings were obtained in experiments in which there was a delay in setting up the screen corresponding to these periods of time. A delay in the RPN indicates prolonged CNS retention of trace excitation, the latter having no effect on the motor neurons of the eye muscles. We performed other experiments to determine the relationship between RPN and the rate of the preceding optokinetic stimulation.

A series of experiments in which the animals were revolved a long time in such manner that they could see the surrounding objects showed that phenomena similar to RPN can arise in the CNS even after exposure to ordinary visual objects of stationary surroundings. After the revolving chamber is darkened, they show up in the form of prolonged nystagmus directed to the side opposite the rotation. The nystagmus is intensified by additional vestibular stimulation.

We concluded from the foregoing that RPN, which is characteristically directed to the side opposite OKN, is caused by the prolonged circulation of excitation in the brain structures. These properties of RPN make it possible to regard the phenomenon as a physiological model for studying the neural mechanisms of illusory reactions.

CHANGES IN ELECTRIC ACTIVITY OF THE CEREBRAL CORTEX AND SUBCORTICAL FORMATIONS IN ANIMALS EXPOSED TO BRIEF PERIODS OF WEIGHTLESSNESS AND ACCELERATION

A. M. Klochkov

1. Quite a few reports have recently been published dealing with the effect of weightlessness on human beings and animals. Most of the reports are clinical and physiological in nature, and include a description of the symptoms of vestibular and autonomic impairment and recordings of the main physiological functions (Ward et al., 1959; Stutman and Olsok, 1960; Grovelin et al.; Greybiat and Clark, 1961; Beck, 1962; others). There have also been, in response to the practical requirements of aviation and space medicine, a large number of physiological-hygienic investigations of physical fitness and coordination of movements in weightlessness (Geratewohl, 1957; Geratewohl et al., 1958; Geratewohl and Ward, 1960; Gazer, 1961; Beckman, 1961; others). However, other recent reports are detailed studies of the physiological mechanisms of the phenomena observed in weightlessness (King, 1961; Shock, 1961; Reynolds, 1961; others).

As for investigations of changes in CNS bioelectric activity in weightlessness, there are only isolated reports (Fiorica et al., 1962; Grandpère et al., 1962). This communication describes the data obtained in a study of changes in the bioelectric activity of different parts of the brain of animals exposed to brief periods of weightlessness and acceleration.

2. Weightless conditions were created by plane flights along a parabolic trajectory. Each period of weightlessness lasted 25-30 seconds, and was preceded and followed by accelerations (1.8-2g) lasting 12-15 seconds. In some cases, weightlessness without preceding or following accelerations served as a control.

Experiments were performed on two cats and one rabbit--kept in a screened cage--with chronically implanted surface and embedded electrodes. The biopotentials were derived in unipolar and bipolar fashion by means of a single-channel a.c. amplifier with recording on a loop oscillograph. The animals generally were nonanesthetized, except in a few instances when cats were lightly anesthetized with pentobarbital sodium.

Electric activity was recorded in the following regions of the cerebral cortex: (1) anterior portion of the suprasylvian and ectosylvian gyri, thought to be the site of the cortical projection of the vestibular function (Anderson and Hernandt, 1954; Michael and Ades, 1954; Ruwald and Snyder, 1956), (2) visual zone, (3) orbital zone. Electric activity in the subcortical formations was recorded in the anterior hypothalamus and medial and lateral geniculate bodies.

3. A partial amplitude analysis of the bioelectric activity of the cerebral cortex revealed that the magnitude of the changes after exposure to brief periods of weightlessness and accelerations differed from zone to zone. The most characteristic and pronounced changes were found in the cortical projection of the vestibular function and in the anterior portion of the suprasylvian and ectosylvian gyri.

Changes in electric activity in this zone followed this pattern: With the accelerations preceding weightlessness, the electrocorticogram showed evidence of pronounced desynchronization with increased frequency and decreased amplitude of the oscillations, which persisted until exposure to weightlessness. The amplitude of the oscillations grew during the first 5-7 seconds of weightlessness and there was a marked shift toward the slow waves (as compared with the electrocorticogram during the horizontal part of the flight). Instability of the main rhythm of the electrocorticogram and the presence of mixed waves was characteristic of the period of weightlessness. For a period of 25-30 seconds, the high-amplitude α-like waves were followed several times by a frequent low-amplitude wave, and vice versa.

These changes in electric activity occurred, although less pronounced, also in the visual cortex, especially after exposure to the accelerations. The effect of the latter on the electrocorticogram was more extensive and uniform in different regions of the cortex, whereas in weightlessness changes in the electrocorticogram were sometimes absent. For example, in the orbital cortex (projection, p. IX), acceleration was followed by indistinct desynchronization of the rhythm, but after weightlessness the picture of the electrocorticogram was virtually the same as that recorded during the horizontal part of the flight.

At the moment of transition from weightlessness to acceleration, a matter of 1-1.5 seconds, there was a regular burst of high-amplitude α waves lasting 2-3 seconds. They appeared somewhat less frequently during the transition from normal weightiness to acceleration and at the moment of transition to weightlessness. Thus, all the transitions from weightiness to weightlessness and vice versa were characterized by the appearance of a group of high-amplitude α waves, caused apparently by the effect of the angular accelerations that take place during the transition from one state of weightiness to another.

4. During derivation of the biopotentials from the subcortical centers (hypothalamus and medial and lateral geniculate bodies), electric activity was relatively resistant to weightlessness and acceleration. In the cases where there were changes in the bioelectric activity, they differed from those in the cortex. Acceleration tended to increase the number of slow high-amplitude oscillations or produce a picture of mixed waves, i.e., the desynchronization characteristic of the cortex did not occur here.

In weightlessness, the amplitude of the rapid oscillations (14-16 cps) increased and there were almost no very rapid or slow oscillations, i.e., here too the changes differed from those in the cortex.

What must be considered a peculiar reaction of the subcortical centers is the fact that the above-described changes did not take place at the very moment that gravity changed. Rather, they developed comparatively slowly and the picture of the preceding period persisted for 3-5 seconds after the change in gravity.

5. All the above-described changes were most pronounced in wakeful animals. In the experiments involving the use of light pentobarbital sodium anesthesia, the changes were approximately the same, but much less pronounced.

6. A comparison of the ordinary and control regimens showed the same changes in both cases, but more pronounced when acceleration came first, i.e., preceding acceleration intensified the changes that took place in shifting from normal gravity directly to weightlessness.

7. Our data showed that brief periods of weightlessness and acceleration induce CNS changes, the cerebral cortex being the most reactive, for its electric activity changed to a greater extent and did so more rapidly and regularly than in the subcortical centers.

The occurrence of pronounced and regular changes in the anterior portion of the suprasylvian and ectosylvian gyri is additional evidence in favor of the view of Anderson, Michael, Ruwald, and others that cortical representation of the vestibular function is found in this area.

The precedence of acceleration is not a serious technical hindrance to investigation of the effect of weightlessness on the organism. A negative feature of the method is rather the brevity of the period of weightlessness, which makes it difficult to investigate the slow-acting processes.

SOME SENSORY DISTURBANCES IN PERSONS EXPOSED TO WEIGHTLESSNESS[1]

L. A. Kitayev-Smyk

1. Observations were made of a group of subjects exposed, for short periods of time, to weightlessness and recordings were made of sensory, autonomic, motor, etc., reactions. Special methods were used to investigate visual disturbances, ataxia, and changes in kinesthesia and time perception.

2. Most of the subjects with little flying experience developed various spatial illusions at the start of weightlessness--a sensation of falling down accompanied by fear, sometimes quite pronounced throughout the period weightlessness, by illusions with no particular emotional coloring of being in a position with head down, on the chest, on the back, on the side, or by an illusion of climbing.

3. Those who initially had sensations of falling and fear developed in weightlessness the illusion that visible objects or parts thereof were moving, getting larger, dissolving, or bending. Some observed a violet halo around luminous objects. A study of light sensation in weightlessness revealed a heightened perception of colors, chiefly yellow.

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[1]For a description of the method of creating weightless conditions, cf. A. M. Klochkov's report to this conference.

Visual acuity at the start of weightlessness tended to decrease, but after a while, in some of the subjects, became normal or heightened. The visual reactions may have been caused by impairment of the integrative processes both in the centers and on the periphery of the visual analyzer, particularly by the decreased tone of certain eye muscles (rectus oculi inferior, rectus oculi lateralis, and ciliary).

4. Ataxia was investigated by means of "horizontal writing" and "diagonal writing" tests and by evaluating the results of aimed fire. In "horizontal writing" (the drawing of a horizontal row of crosses or other objects) the subject's hand slanted upward in weightlessness but downward in acceleration with eyes open or closed (to a lesser degree). If vision was not excluded, but the subject could not see the hand with which he was drawing, then it slanted downward in weightlessness but upward in acceleration, i.e., the result of the "elevator illusion". A similar reaction occurred with the eyes closed if the subject held on with his left hand to the board on which he was writing with his right hand. The "elevator illusion" generally did not occur in subjects with flying experience.

The results were about the same in "diagonal writing", i.e., drawing objects at a 45° angle to the vertical.

With aimed fire, the places of the hits shifted upward and to the right in weightlessness, downward in acceleration. The accuracy of fire decreased in weightlessness.

5. Changes in kinesthesia were studied by determining the accuracy with which the subjects performed prescribed muscular exercises. In weightlessness, less exertion was required by the nonfliers, but often more exertion was required by the fliers. The tone of the arm muscles, as determined from the maximum exertion, decreased in all subjects in weightlessness, to a greater degree in the extensors.

6. Changes in time perception, judged from the accuracy with which the subjects estimated a given period of time, were noted in weightlessness.

7. It is evident from the foregoing that weightlessness may impair the functioning of various sensory systems in man. Elucidation of the underlying mechanism requires further research.

THE BODY POSITION (POSTURAL REACTIONS) OF ANIMALS IN WEIGHTLESSNESS[1]

L. A. Kitayev-Smyk

1. Interference with the interaction of the motor, vestibular, and visual analyzers is undoubtedly the cause of the motor disturbances noted by several authors in human beings subjected to weightlessness. However, the mechanism of these processes and the role of the individual analyzers are obscure. Our investigations were undertaken to throw some light on these matters.

2. The behavior of various animals--fish, birds, and mammals (white mice, white rats, guinea pigs, rabbits, cats, and dogs--was studied during brief periods of weightlessness. We found that at the onset of weightlessness fish lose ability to orient in relation to the "top" and "bottom" of the aquarium. Birds demonstrate a motor reaction resembling "continuous upward flight", followed in the 2nd or 3rd period of weightlessness by calm suspension in a characteristic position with wings spread back. Mammals show high motor activity.

Motor reactions of the mammals all showed "running" elements, but there were individual variations from species to species. Thus, in mice and rats--rotary motion of the tail; in rabbits--drumming movements with the front paws. As adaptation to weightlessness developed, motor excitation disappeared and muscle tone changed. Motor excitation persisted longest in white mice and rats (through 8-10 periods of weightlessness) and disappeared soonest in dogs (2nd to 4th periods of weightlessness). In cats, the time required for adapting to weightlessness varied from animal to animal.

3. We investigated the effect of excluding visual and vestibular analyzers on behavior of rabbits and time they took for adaptation to weightlessness. Exclusion of vision markedly lengthened adaptation time, while motor excitation persisted through 20-30 or more periods of weightlessness. Unilateral labyrinthectomy gave rise to cyclical movements, with "running" elements that caused the animal to turn toward the destroyed labyrinth. Unilateral exclusion of the labyrinth prevented adaptation to weightlessness. Exclusion of vision had no effect on the nature of the reaction in the unilaterally labyrinthectomized animals. In bilaterally labyrinthectomized animals, before developing ground visual compensation of lost functions, motor reactions in weightlessness showed no tonic reactions and were practically the same as those

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[1] For a description of the method of creating weightless conditions, cf. A. M. Klochkov's report to this conference.

of intact animals. The bilaterally labyrinthectomized rabbits with acquired visual compensation did not exhibit motor excitation in weightlessness, but after vision exclusion, excitation appeared after a latent period of 1-3 seconds and was more intense than in the intact animals. Animals with excluded vestibular and visual analyzers failed to adapt through 20 or more periods of weightlessness.

4. We investigated in rabbits and cats "the residual vestibular sensation", the nature of the "turning" reaction, and the reaction to progressive movements. To determine the occurrence of a "vestibular afterimage", the animal with excluded vision was made fast at the trunk and head with back down. At various intervals of time after the start of weightlessness, the animal was let go and the "turning" reaction observed. Upon release, this reaction occurred no later than 5 seconds after the start of weightlessness.

Turning in weightlessness may have been due to the visual adjusting reaction with paws reaching toward the nearest surface regardless of whether it was the floor, wall, or ceiling. With turning of the trunk in weightlessness, the head of an intact animal lagged behind the trunk; it did not lag in a labyrinthectomized animal. When the animal in weightlessness with previously turned head was released, the head remained stationary in the intact animal and the trunk kept turning until it was in a straight line with the head; in the labyrinthectomized animal, the head turned with the trunk stationary.

If the animal was released in weightlessness after a rapid turning, it exhibited movements that turned it in the opposite direction. This reaction was observed throughout the period of weightlessness (about 30 seconds) and was intensified by excluding vision. Thus, the "turning" reaction in weightlessness can occur during the first few seconds under the influence of a "vestibular afterimage."

We failed to observe any reaction to progressive movements in cats and rabbits in weightlessness.

5. The occurrence of general excitation and heightened motor activity in various animals in weightlessness indicates this factor is an adverse stimulus primarily affecting the vestibular apparatus, with vision the decisive factor in developing adaptation to weightlessness. It has been established that the CNS also influences the organization of these processes. Shock demonstrated that motor activity decreases in cats after removal of those cortical areas where representation of the vestibular function is localized. Gazenko, Grigoryan, Kitayev-Smyk, and Klochkov found that removal of the cerebellum in cats prevents adaptation and sharply increases the tone of the spinal and occipital muscles and extensors of the extremities in weightlessness. Grandpère et al. described several EEG changes in rats in weightlessness.

EFFECT OF CENTRIFUGAL ACCELERATIONS ON THE VENOUS OUTFLOW IN THE CEREBRAL BLOOD VESSELS OF ANIMALS

V. Ya. Klimovitskiy

1. Of all the factors in intracranial hemodynamics, venous blood flow may be the most sensitive to accelerations. In investigations of this condition during flight, experimental models of impairment of cerebral blood circulation in centrifugal accelerations are essential, despite their limitations.

2. In continuous experiments with rabbits, venous outflow was investigated in the anterior sagittal sinus and major veins on the surface of the brain.

3. Blood flow (volumetric flow rate) was recorded by means of temperature-sensitive elements consisting of a microthermal resistance and heater placed on both sides of the blood vessel. A calibration curve for the temperature-sensitive elements was constructed in an acute experiment on the femoral vein of a cat and on the model. Thermograms were recorded either with a special apparatus with an independent power supply set on the centrifuge or through a commutator on stationary recording devices of various kinds. Heat was supplied by releasing fixed (in current and time) heat impulses in the heater of the temperature-sensitive element. As a consequence, values of the blood flow in arbitrary units were comparable for one animal and one element from experiment to experiment.

4. Centrifugal acceleration was produced in a head-pelvis direction in a centrifuge with a small arm and fixed number of revolutions. Near the animal's head, acceleration approximated 5 units; the pelvis was subjected to accelerations approximating 10 units. For the standard test, accelerations lasting 30 seconds at 30 minute intervals were readily tolerated, even when repeated several times. However, when continued steadily for 2-3 minutes, it was lethal for most of the rabbits.

5. The first centrifugation for 30 seconds had, as a rule, little effect on venous outflow. After repetition, a typical reaction developed in the form of a decrease in blood flow at the moment of centrifugation. Venous outflow increased considerably after centrifugation was halted. Finally, a decrease in venous outflow persisted, returning to normal only after 20-30 minutes.

6. Repeated centrifugation gradually intensified the reaction, especially in the first phase and aftereffect. These phenomena were summational and quite pronounced in the poorly "conditioned" animals. The phase of increased blood flow was very irregular, disappearing in some animals after repeated exposures.

7. The decrease in blood flow during centrifugation becomes more intensified from day to day, if animals, at the beginning of the experiment, are subjected to daily accelerations. After a one day's break, the first phase of the reaction became weaker and disappeared completely in the "well-conditioned" animals, giving way to a phase of increased blood flow or zero reaction at the time of centrifugation.

8. Blood supply to the brain may become inadequate after head-pelvis accelerations. Subsequent increase in venous outflow may stem from this and reflect the intensification of total cerebral blood flow.

9. Cerebral blood flow reaction to acceleration is simply a passive, mechanical shifting of blood toward the centrifugal acceleration. It has been found that a massive, mechanical shifting of blood at the time of centrifugation may be partially compensated or, contrariwise, may predominate over compensation, depending on the animal's condition and the sequence in which the accelerations are produced.

10. In most cases, temperature of the brain surface at the point where the temperature-sensitive element was placed changed, upon centrifugation, in a very stereotypical fashion. The background temperature curve at this time looked the same in most of the animals.

11. The suggested experimental technique may be used to investigate the conditioning of animals to the effect of mechanical overloads on cerebral blood circulation. The same model can be of value in studying the effect of some other flight factors (e.g., radiation) on cerebral blood supply.

PATHOGENESIS OF HEMODYNAMIC DISORDERS AFTER EXPOSURE TO A SUPERSONIC AIR STREAM

A. F. Kovalenko, Ye. Ya. Kaplan, V. P. Boyarkin and A. M. Klochkov

Earlier studies have demonstrated that an air stream at a subsonic speed with an exposure of 0.2-0.3 second causes insignificant functional changes in the organism. However, when the stream begins to exceed the speed of sound, it acquires new physical characteristics (jumps in compression) that undoubtedly have an adverse effect.

The pressure from an air stream of considerable intensity (R_{mech} 19,000 kg/m^2) and brief exposure (0.2-0.3 second) produces a sharp

impact. The purpose of this investigation was to determine the changes brought about in the cardiovascular and nervous systems by exposure to an air stream delivered at supersonic speed.

The first series of experiments dealt with the effect of an air stream (Vi = 1600 km/hour) on dogs whose arterial pressure, rate of blood flow, rate and rhythm of cardiac contractions, EKG, functioning of the brainstem centers (respiratory and vasomotor), and peripheral nerves of the sympathetic and parasympathetic nervous systems were recorded in acute experiments. The excitability of neural elements and rate of blood flow were determined after injection with such drugs as lobeline, epinephrine, pilocarpine, and acetylcholine. A study was also made of vascular reaction to stimulation of the pressoreceptors of the carotid zone (pressor reflex to constriction of the common carotid arteries on the right and left).

The second series of experiments was concerned with the effects of the air stream on animals with electrodes implanted in various cortical and subcortical regions. At the moment when the rate of the air stream reached a given intensity, a special stand with an attached animal was pushed into the stream for 0.2-0.3 second.

In most cases, the stream first caused an increase, then a slow return to normal, in the cardiac rate. Meanwhile, the EKG exhibited an increase in voltage of the "P" wave in the 3rd lead as compared with the "P" wave in the 1st lead, apparently the result of a change in the heart's position in the thoracic cavity. Decreased voltage of the "R" wave in the 2nd and 3rd leads is a sign of lowered myocardial function. A change in voltage and interval of the "T" wave in the 2nd and 3rd leads apparently results from impaired excitability of the ventricles due to the development of circulatory disturbances, hypoxia, and disrupted metabolism in the myocardium.

Our data indicate marked changes in excitability and conduction of the heart muscle after exposure to an air stream at supersonic speed.

When the required regimen was set up for an air stream with an intensity of Vi = 1600 mm/hour, a loud noise (about 120 db) developed and regularly increased both arterial pressure (by 10-15 percent) and the rate of blood flow (by 15-20 percent). However, the immediate effect of the stream was a marked lowering of arterial pressure (by 30-35 percent) and a slowing of the blood flow (by 20-30 percent). After 30-60 minutes, hemodynamic disorders became more pronounced and, in some cases, produced symptoms similar to those of traumatic shock. In addition, there was a change in neuroreflex regulation of vascular tone.

Under the influence of loud sound, the pressor reaction to constriction of the common carotid arteries became more pronounced than at the

beginning. The air stream caused a 20-30 percent decrease in the pressor reaction below the original level. This may have been due either to diminished sensitivity of the pressoreceptors in the vascular zone of the carotid sinus or to diminished excitability of the central and peripheral nervous formations.

In this connection, we thought it necessary to check the functional state of the respiratory and vasomotor centers and the excitability of the sympathetic and parasympathetic nervous systems. Under the influence of the noise made by the air stream, the excitability of the vasomotor center increased, as shown by the stronger pressor reaction to lobeline (by 10-18 percent) than at the beginning. After the direct effect of the air stream wore off, the pressor reaction to lobeline decreased (by 25-40 percent) and, in some cases, was almost entirely absent. There was a correlation between changes in the hemodynamic indexes and functional state of the vasomotor center.

The excitability of the respiratory center underwent a similar two-phase change. Loud sound increased its sensitivity; the air stream decreased it.

The functional state of the sympathetic nervous system changed as follows: sound stimulation (noise of the air stream) caused the pressor reaction to epinephrine to increase (by 10-15 percent), whereas the excitability of the sympathetic nerves diminished appreciably (by 15-20 percent) after the impact of the air stream. The decrease in excitability was paralleled by the development of hypotension.

The functional state of the parasympathetic nerves following strong sound stimulation and direct exposure to the air stream was little affected, as shown by the virtually imperceptible change in the depressor reaction to pilocarpine and acetylcholine.

Sound stimulation was accompanied by an intensification of bioelectric activity in the cortical and subcortical brain areas. Marked changes following exposure to the air stream (appearance of slow waves and decrease of amplitude of the biopotentials) were indicative of the development of cortical inhibition.

Bioelectric activity in the subcortical formations changed in two ways: in some animals, there was an increase in the biopotentials and accelerations of the rhythm; in others, there was a decrease in the amplitude of the biopotentials and a shift toward the slow oscillations. A comparison of electrophysiological changes in the cortical and subcortical centers with the hemodynamic changes shows their interrelationship. Intensification of bioelectric activity was accompanied by elevation of arterial pressure and rate of blood flow. Arterial pressure fell when the slow waves appeared, but rate of blood flow slowed.

Cardiac activity, hemodynamics (arterial pressure, rate of blood flow), and functioning of various nervous formations (cortex, subcortex, vasomotor and respiratory centers, sympathetic and parasympathetic nervous systems) vary with the degree of trauma inflicted by the air stream.

Whenever special protective measures were taken, the effect of the stream was less. Changes in the above-mentioned systems were vague.

EFFECT OF HYPOTHERMIA ON OXYGEN DEFICIENCY AT HIGH ALTITUDES

Ye. A. Kovalenko, V. I. Korol'kov and Ye. A. Il'in

The literature on emergency rescues at high altitudes still contains few references to drugs capable of increasing the organism's tolerance of certain extreme factors, notably acute hypoxia. Yet numerous theoretical studies and clinical medical practice indicate that there are quite a few ways of increasing resistance to various kinds of hypoxia. One of them is the creation of artificial hypothermia (I. R. Petrov, V. A. Negovskiy, Bigelow, P. A. Kupriyanov, A. N. Bakulev, V. I. Burakovskiy, G. V. Gubler, and others). It has been widely demonstrated that artificial hypothermia causes a sharp decrease in oxygen utilization and an increased resistance to different forms of acute hypoxia. The present study was undertaken to determine the effect of hypothermia on tolerance of acute hypoxia at high altitudes.

Experiments were performed on dogs with platinum electrodes implanted in brain tissue, with continuous recording, by an automatic integrating analyzer, of the EKG, pneumogram, electrocorticogram (EKoG), and electrothalamogram (ETG).

The partial pressure of oxygen (pO_2) in the brain was continuously recorded by the polarographic method in order to study the rate of deoxygenation of brain tissues. The pO_2 was read in relative units, with the pO_2 in brain tissues during the breathing of air by animals on the ground taken as 100 percent. Of 37 experiments performed, 20 were a control series on intact animals and 17 were on animals subjected to different degrees of hypothermia.

The animals were chilled in a special heat chamber. An hour before exposure, they were injected intramuscularly with 50 mg/kg of sodium amytal, 5 mg/kg of hexamethonium bromide, and 5 mg/kg of diphenhydramine hydrochloride.

The investigations involved rapid elevation (explosive decompression) of the dogs in a pressure chamber from an altitude of 4000 m to 15,000 m in 0.5 second and from 12,000 m to 27,000 m in the same time. During elevation to 12,000 m the animals breathed pure oxygen, but during rapid decompression to 27,000 m the oxygen was turned off and the animals breathed the surrounding air.

The main index of resistance to acute hypoxia was the time from the moment the animal reached the prescribed altitude until respiratory standstill and the so-called "survival time", i.e., the time the animal could be kept at the altitude and its vital activities subsequently restored under ground conditions.

In the control series with rapid elevation to 15,000 m, the animals not subjected to hypothermia died in 17-25 seconds, with spasms occurring in 23-25 seconds. Oxygen tension in brain tissues diminished rapidly, amounting to 17 percent of the original level in the cortex and 14-20 percent in the subcortical formations of the thalamohypothalamic region. At these altitudes, an initial tachycardia averaging 226 beats per minute gave way to a pronounced bradycardia of 50 beats per minute.

The EKG at the end of the altitude period, exhibited preterminal shifts in the form of decreased P and R waves, shifting of the S-T interval, and sharp increase in the T wave. The EKoG and ETG revealed intensified bioelectric activity, a sharp increase in amplitude of the oscillations with gradual predominance of the slow rhythms at a frequency of 4-6 cps, and, finally, complete suppression of bioelectric activity.

Respiratory standstill at this altitude was noted in the control animals 49 to 90 seconds after reaching it. If they were kept there for 2-3 minutes, respiration could not be restored after they were brought to the ground and they died despite prolonged artificial respiration and injection of drugs (epinephrine, lobeline).

In the next series of experiments with elevation to 15,000 m, it was impossible to prolong the time to respiratory standstill more than 2 minutes in anesthetized animals cooled to a body temperature of 30-32°. Moreover, the "survival time" did not increase markedly. While the animals were at the altitude, there was a sharp reduction of pO_2 in brain tissues--to 26 percent in the cortex and 40 percent in the subcortex. Pulse decreased to 141 beats per minute followed by bradycardia of 80 beats per minute. In some experiments the respiratory rhythm was impaired. No pronounced excitation or spasms occurred in this series of experiments, as they did in the control.

The next series of experiments involved cooling the animals to 22-24° after injection with the same drugs. It was possible to prolong the time they stayed at 15,000 m after which their vital activities could be restored. Respiratory standstill at this altitude also occurred somewhat later, after 2-5 minutes, with cardiac activity preserved 3-7 minutes but with marked EKG changes.

However, even in these cases, pO_2 in brain tissues fell sharply, constituting 18-30 percent in the cortex and 10-52 percent in the subcortex and at approximately the same intervals of time as in the cases without cooling. This, in our opinion, is proof that acute hypoxia can occur when there is a pronounced drop in partial pressure of oxygen in the lungs. In such cases, as our investigations showed, the oxygen present is rapidly washed out of the tissues. The data on bioelectric activity of the brain show that in hypothermia the amplitude of the bioelectric oscillations derived was somewhat less than that in intact and anesthetized animals. On the EKoG, the correlation between the frequency components scarcely changed while the bioelectric activity of the dominant rhythms on the ETG diminished: for the 2-4 cps frequency band--from 43.2 to 28.7 percent; for the 1-2 cps frequency band--from 35.3 to 18.4 percent of the total value of the EMF.

During the first 30 seconds that the chilled animals were at 15,000 m, the EKoG showed an intensification of bioelectric activity of from 24 to 37.6 percent for the 1-2 cps frequency band, from 26.5 to 29.1 percent for the 2-4 cps band, and from 10.9 to 15.5 percent for the 4-7 cps band. The same pattern was observed on the ETG. For example, by the 30th second, the bioelectric activity of the 2-4 cps frequencies rose from 28.7 to 35.4 percent, that of the 1-2 cps frequencies from 18.4 to 27 percent. After a few minutes at the altitude, bioelectric activity in the cortex and thalamic region was completely suppressed.

In the next series of experiments, intact animals were rapidly elevated from 12,000 m to 27,000 m. After 10 seconds, pO_2 in the cortex dropped abruptly to 16 percent of the original level and after 40-50 seconds--to 10-13 percent. Respiratory standstill usually set in after 15-40 seconds. The entire complex of hypoxic disorders developed much more rapidly. Also, at 27,000 m, along with extremely acute hypoxic conditions, the animals developed altitude tissue emphysema, reflected in marked swelling of the body and desquamation of skin.

Cooling the animals to a body temperature of 22-30° slightly lengthened the time before respiratory standstill as compared with the control animals, but by no more than 1-1/2 to 2 minutes. However, keeping the animals at these altitudes more than 2 minutes made it impossible to restore vital activities after they "descended". The picture of EKG

changes, bioelectric activity of the brain, and pO_2 decrease curve in brain tissues was virtually the same as that at 15,000 m, but it developed much more quickly. It is interesting to note that the altitude tissue emphysema in the animals cooled to 22-23° persisted, but was less distinct, a sign that the emphysematous bubble contained both the fumes of tissue liquids and gases rapidly flowing from the tissues with these sharp degrees of decompression, as shown in special experiments.

The following conclusions can be drawn from our investigation:

(1) Shallow hypothermia (30-32°) of animals quickly elevated to high altitudes does not increase the time before respiratory standstill and does not prolong "survival time" at these altitudes.

(2) Deeper hypothermia (22-23°) helps to increase the time before respiratory standstill at an altitude of 15,000 km, but by no more than 5 minutes, and at 27,000 m, by no more than 2 minutes. "Survival time" at 15 km with hypothermia of 22-23° is somewhat longer, 7-10 minutes, but at 27 km, no more than 2-2-1/2 minutes longer.

The reason for the comparatively slight increase in time before respiratory standstill and in "survival time" may have been the physical factor of the sharp and rapid deoxygenation of tissues, brain tissues in particular, as shown by the study of pO_2 dynamics. In our opinion, this is one of the more important characteristics of acute hypoxia at high altitudes as compared with the various kinds that may occur under ground conditions, when hypothermia is a very effective preventive agent.

EFFECT ON BRAIN OXYGENATION OF BREATHING OXYGEN DURING ACCELERATIONS

Ye. A. Kovalenko, V. L. Popkov and I. N. Chernyakov

Some investigators believe brain hypoxia is one of the effects of prolonged accelerations (P. K. Isakov, D. Ye. Rozenblyum, I. M. Khazen, A. A. Sergeyev, Armstrong, and others). This view is based both on indirect evidence (Akesson, Bjursted, V. B. Malkin, V. V. Usachev, A. S. Barer) and on a direct study of oxygen tension in brain tissues (A. Ye. Kovalenko, V. L. Popkov, I. N. Chernyakov).

There is information also concerning the favorable effect of breathing oxygen at ordinary atmospheric conditions and, of excess pressure on tolerance of accelerations (V. I. Babushkin, E. V. Marukhanyan, Chernyak, Watson).

In the light of the foregoing, we thought it would be of interest to study the dynamics of O_2 tension in brain tissues after exposure to accelerations under conditions involving the breathing of air and oxygen.

Experiments were performed on dogs with platinum electrodes chronically implanted in brain tissue. The partial pressure of oxygen (pO_2) was determined by the polarographic method in relative values (as a percentage of the original). At the same time the EKG, pneumogram, and EEG were recorded. Accelerations of from 2 to 12 g were produced by revolving the animals in a centrifuge for 1-3 minutes in longitudinal and lateral directions. Nineteen dogs were rotated 230 times.

The first group of experiments studied the dynamics of pO_2 in brain tissues after accelerations with the breathing of air. The degree and nature of changes in the pO_2 were found to be determined by the intensity, direction, and duration of the accelerations, as well as individual characteristics of the animals. After accelerations of from 2 to 6 g, there was frequently at the beginning of the rotation a brief rise in pO_2 of 5 to 10 percent above the original level, which was followed by a drop. No such rise was noted in anesthetized animals. Accelerations of greater intensity invariably caused a drop in brain pO_2, particularly marked with head-pelvis accelerations, averaging with 4-6 g (1 minute duration) 84-92 percent of the original level, with 10-12 g, 60-70 percent. Often a low pO_2 level persisted even after rotation was halted.

In view of the resultant severe hemodynamic disorders, pelvis-head accelerations were used only up to an intensity of 8 g. The pO_2 level with this direction of the accelerations fell only slightly, amounting after 4, 6, and 8 g to 90, 86, and 84 percent, respectively.

Lateral accelerations (back-chest, chest-back) of 2-8 g lasting 1 minute did not appreciably reduce brain pO_2. With 10 and 12 g, the pO_2 level fell to 87 and 80 percent, respectively. Prolonging the exposure to 3 minutes resulted in a more pronounced drop in the pO_2. With 8, 10, and 12 g, it dropped to 85.9, 77.6, and 60 percent,

respectively. Moreover, in some experiments with 3 minutes' rotation, the animals' general condition deteriorated sharply. The EKG showed bradycardia, extrasystole, decrease in the P and R waves, and sharp increase in the T wave. Respiration became less frequent and the inhalation phase lengthened appreciably. On the EEG could be seen a marked predominance of the slow rhythms (up to 4-5 cps), increase in the amplitude of these rhythms, and, at times, complete suppression of the bioelectric activity of the brain. In some cases it was necessary to resort to artificial respiration to prevent death.

An interesting fact, one with practical significance, emerged from the experiments with lateral accelerations. When the animal's head was placed 15-20 cm above the horizontal platform to which its trunk was fastened, pO_2 fell more sharply than when the head was secured at the level of the trunk. The drop in pO_2 in the first case was within approximately the same limits as with the head-pelvis accelerations.

A second group of experiments involved rotating the animals while they breathed oxygen. Chest-back and back-chest accelerations of 1, 10, and 12 g lasting up to 3 minutes caused a much smaller drop in brain pO_2 than when rotation was accompanied by breathing air. When air was breathed, these accelerations decreased pO_2 to 85.9, 77.6, and 60 percent; when oxygen was breathed, the pO_2 level was 107, 98, and 93 percent, respectively. When breathing oxygen, the dogs were more resistant to accelerations, EKG and pneumographic changes were less pronounced, and the pO_2 level was higher than in the control rotations after head-pelvis accelerations. Oxygen breathing at an excess intrapulmonary pressure of about 300 mm Hg with lateral accelerations produced an even more pronounced positive effect, which was clearly manifested only with accelerations of about 10 g.

Our investigation shows that prolonged accelerations invariably decrease brain oxygenation, especially when applied in a head-pelvis direction. This suggests that oxygen deficiency of the brain is important in the pathology caused by accelerations. Further evidence is provided by the fact that breathing oxygen helps to keep pO_2 with accelerations of up to 10 g on a level close to the original and greatly increases the tolerance of accelerations. In addition, a relatively moderate drop in brain pO_2 after accelerations that cause severe impairment and incomplete correction of this impairment when the animals are rotated

while breathing oxygen, when pO_2 remains at a fairly high level, implies that other factors too are involved in the disorders caused by accelerations.

MORPHOLOGICAL LABYRINTHINE CHANGES IN DOGS EXPOSED TO RADIAL ACCELERATIONS

R. Ye. Kogan and S. S. Makaryan

We were unable to find anything in the literature on the morphological changes that accelerations cause in the inner ear, except the well-known studies of Wittmaak (1909) and Magnus (1924).

In 1961 we made a study of inner-ear morphology of dogs exposed to single and repeated accelerations, with the intensity in the head region ranging from 1 to 14.5 units for 1 to 20 minutes and at various angles of trunk inclination from the rotation axis.

Examination of the temporal bones revealed hemorrhages in the mucosa of the bulla, the meatus acusticus internus, and the perilymphatic spaces of the inner ear. Hemorrhages were more common in the perilymphatic spaces of the cochlea than in those of the vestibular apparatus.

After comparing our results with those of Kimura and Perel'man (1956, 1957) on obstruction of the inferior cochlear vein, we concluded that hemorrhages in the perilymphatic spaces of the cochlea and vestibular apparatus are clearly related to impairment of blood outflow from the inner ear.

The present study, however, deals with morphological changes in the labyrinth of 11 dogs exposed to accelerations of varying intensity, duration, and direction--"head-pelvis" and "pelvis-head" while lying and when the rotation axis passed through the cardiac region. The temporal bones of the animals were removed as quickly as possible and immersed in Held-Wittmaak fixing fluid within 15 minutes. A hole was drilled in the bulla to permit better impregnation of the inner ear with the fixing fluid.

Dogs 24, 29, 30, and 31 (1 series) were subjected once, in the pelvic region, to accelerations of from 6 to 14 units lasting from 8 to 18 minutes. All but dog 31 died during the experiment. Dog 31 was sacrificed with an electric current on the next day. Table 1 shows the experimental conditions and the morphological inner-ear studies.

Table 1

No. of dog	Acceleration in the pelvic region, units	Duration of rotation in minutes	Outcome	Hemorrhages	
				Left ear	Right ear
24	6.0	18	Died	Slight in sacculus; scala tympani of main and middle spirals	In fenestra ovalis and fenestra rotunda In bulla cavity Slight in scala tympani of main spiral
30	14.0	12	Died	None	Extensive in perilymphatic spaces of cochlea
29	12.5	20	Died	Slight in bulla	In middle ear (fenestra ovalis, f. rotunda, bulla)
31	12.0	8	Sacrificed next day	None	In niche of fenestra ovalis

It is evident from the data that hemorrhages in dogs 24 and 30, were in the inner ear but in dogs 24, 29, and 31 they were in the central ear. Hemorrhages were more common in the right than in the left ears. There were no hemorrhages in the left internal ear of dogs 29, 30, and 31. Dog 30 was of particular interest, for it had extensive hemorrhages in the perilymphatic spaces of all the spirals of the cochlea in the right ear, while its left ear was normal. Dog 24 was exceptional in that it had extensive hemorrhages in the left inner ear, but only insignificant ones in the scala tympani of the main spiral in the right ear. Hemorrhages were particularly massive in the middle ear--in the bulla and niche of the fenestra ovalis and fenestra rotunda.

Thus, accelerations of up to 14 units in the pelvic region produced hemorrhages of varying severity in the inner and middle ears. In the former, they were concentrated mainly in the perilymphatic spaces of the cochlea, not in those of the vestibular apparatus.

The second series of experiments involved accelerations in which the rotation axis passed through the cardiac region. Dogs 26 and 33 were exposed once in the head region to accelerations of 10 to 13.5 units lasting 7 to 17 minutes; dog 32, to accelerations gradually increasing in intensity from 7 to 17 units lasting a total of 57 minutes. These animals died during the experiment. There were no hemorrhages in the inner and middle ears of dogs 26, 32, and 33. Table 2 notes the experimental conditions and results of the morphological investigations.

In the third series of experiments, when the rotation axis passed through the pelvic region, dogs 23, 25, 27, and 28 were exposed once in the head region to accelerations of 2.3-5.7 units for 16-17 minutes.

Table 2

No. of dog	Accelerations in the head region, in units	Duration of rotation in minutes	Outcome	Hemorrhages	
				Left ear	Right ear
26	10	17	Died	None	None
33	13.5	7	Died	None	None
32	7	20			
	9	13			
	10	10			
	14	14	Died	None	None

Table 3

No. of dog	Accelerations in the head region, in units	Duration of rotation in minutes	Outcome	Hemorrhages	
				Left ear	Right ear
23	5.7	16	Died	None	Slight in sacculus
25	3.7	16	Died	None	Slight in sacculus
27	3.7	14	Died	In internal ear, in niche of fenestra ovalis and f. rotunda	Slight in scala tympani of main spiral In meatus acusticus internus, in mucosa of bulla
28	2.3	17	Sacrificed next day	In scala tympani of main spiral and meatus acusticus internus	In scala tympani of main spiral

All but dog 28 died during the experiment. Dog 28 was sacrificed with an electric current on the next day (Table 3).

All dogs showed only very slight inner-ear hemorrhages. For example, dogs 23 and 25 had only tiny hemorrhages in the sacculus of the right ear, but none in the left ear. Dogs 27 and 28 had slight hemorrhages in the scala tympani of the main spiral and in the meatus acusticus internus. Hemorrhages were noted only in the left middle ear of dog 27.

The dogs of this series had less extensive hemorrhages in the middle ear than did the animals of the first series, when the rotation axis passed through the head region. It will be noted that the accelerations applied to these animals differed both in direction (opposite) and in intensity (less).

Thus, study of labyrinthine sections of animals subjected to head-pelvis and pelvis-head accelerations revealed hemorrhages in the middle ear and in the perilymphatic spaces of the cochlea, apparently the result of venous stasis. No middle- or inner-ear hemorrhages were found when the rotation axis passed through the cardiac region.

Findings

1. Accelerations of varying intensity and duration applied in head-pelvis and pelvis-head directions produced hemorrhages in the middle and inner ears of animals. Middle-ear hemorrhages showed mainly in the perilymphatic spaces of the cochlea and in the sacculus.

2. No middle- or inner-ear hemorrhages were found in dogs that died during an experiment in which the rotation axis passed through the cardiac region.

SPEECH AUDIOMETRY AS A METHOD OF FUNCTIONAL DIAGNOSIS IN FITNESS EXAMINATIONS OF FLIGHT PERSONNEL

V. M. Kozin

Functional diagnosis is now commonplace because of the large number of civil and military flight personnel and the complicated flight conditions and piloting techniques posed by new, high-speed equipment.

Indeed, new selection and training techniques for spacecraft crews have come into being.

Testing of hearing is an important part of the examination of flight personnel in the Civil Air Fleet. Besides whisper acoumetry, tuning-fork investigation, and tonal audiometry, the examination includes speech audiometry, which is of value not only in selecting persons suitable for work under noise and vibration conditions, but in instituting preventive measures for persons already working under such conditions.

Clinical methods for early diagnosis of impaired hearing are very time-consuming when large numbers of persons have to be examined. To save time, hearing tests are sometimes made with only speech frequency (500, 1000, and 2000 cps) tones, but these provide little information on perception of low and high frequencies. Since the incipient stages of impairment of the sound-conducting apparatus and cochlear dysfunction cannot be detected without testing the perception of low and high tones, this method is not very effective.

Our methods of testing hearing by using speech audiometry to determine the perception of groups of words with various frequency characteristics can be used on a mass basis. Speech audiometry helps to reveal incipient impairment of hearing, the degree of impairment being expressed in decibels, and its frequency characteristics in relation to word group.

For speech audiometry we used a MAG-8 tape recorder from which a written text was delivered through an attenuator with 5 db scale divisions to telephones with rubber earpieces. We have been working of late with a model 465 speech audiometer manufactured by "Krasnogvardeyets". The calibration of both audiometers and the quality of the tape recording were the same.

A small, specially equipped, dismountable sound-suppressing chamber permitted testing not only in the clinic with a sound background of 36-40 db, but, when necessary, directly where personnel were working. (The sound-suppressing capacity of the chamber for pure tones ranged from 36 to 64 db, depending on their frequency characteristics.) The examinee was alone in the chamber, and two-way communication was maintained by means of a microphone. One examination took 10-12 minutes.

The examinee was supplied speech in each ear separately with an intensity equal to an intelligibility of 80 percent of the words supplied. Lists of words containing all the Russian phonemes and lists of monosyllabic words with words of medium and high frequencies and with words of low frequencies were used in preparing texts for tape recording. (The lists were prepared by G. I. Grinberg.) The table consisted of three groups of words: general-frequency, high- and medium-frequency, and low-frequency. These were successively recorded on a

single tape with sufficient intervals between words to enable the examinee to repeat what he heard and with pauses between every 10 words.

Recordings were prepared in four versions. In general, one version was sufficient for the investigation of each ear. Findings were recorded in decibels for each group of words separately and placed on a tonal audiogram blank at the appropriate level in a straight line: data on the general-frequency group of words in the 256-4000 cps frequency range; data on the medium- and high-frequency group of words in the 750-4000 cps frequency range; and data on the low-frequency group of words in the 100-256 cps frequency range. O. V. Solovey found that the values of audibility thresholds in speech hearing tests are 8-12 db higher than the tonal threshold values in the range of 320-4500 osc/sec. On the basis of these figures, we adopted for normal hearing the following thresholds of intelligibility for 80 percent of the words: for the general-frequency group of words--8 db above the tonal threshold; for the high- and medium-frequency group of words--13 db above the tonal threshold; and for the low-frequency group of words--18 db above the tonal threshold.

Examinees perceived the general-frequency group of words with a lower level of reproduction than the high- and low-frequency groups, apparently because it included mostly polysyllabic words, which are heard much more easily when transmitted at the level of threshold audibility.

A comparison of the data obtained by whisper acoumetry and tonal audiometry with our method of speech audiometry shows that the latter confirms the findings of tonal audiometry and makes more precise the findings of whisper acoumetry.

Any abnormalities in whisper acoumetry or in the tonal audiogram and low perception of speech should alert the doctor to the need of making a comprehensive ear examination.

Testing hearing with words is the most natural way of determining this analyzer's functional capacity under flight conditions. Since the proper hearing of words, especially in communication, is sometimes crucial on the job, we are continuing to improve the use of speech audiometry in physical examinations.

Speech audiometry is presently being employed with a noise background of 70-80 db and involves the use of "blank" noise. This is a result of efforts to approximate actual flying conditions when examining personnel that uses a method for testing hearing against a background of noise made by various kinds of airplane motors recorded on tape and played back in a sound-suppressing chamber at intensities equaling those found in cockpits.

Another development is an audiometric method employing tables containing the specialized vocabulary that can more accurately characterize the functional capacity of the auditory analyzer under the examinees' actual working conditions.

Our method of testing hearing through perception of groups of words with different frequency characteristics has these uses:

(a) As an independent method in mass prophylactic examinations for detection of the initial stages of hearing impairment.

(b) For dynamic observation of persons with impaired hearing and for checking of the results of treatment thereof.

The method is recommended for both qualitative and quantitative testing, especially in initial screening of personnel, because whisper acoumetry does not always indicate hearing impairment.

EFFECT OF FLIGHT FACTORS ON THE ADJUSTING REFLEXES

G. L. Komendantov

It is well known that body balance is maintained by the adjusting reflexes (Holz, V. M. Bekhterev, Magnus, V. I. Voyachek, Sherrington, I. S. Beritov, L. A. Orbeli, and others). These oldest of reflexes, which act against the force of gravity, are constantly functioning. Operating simultaneously and closely coordinated with them are a variety of other and younger motor reflexes, including the most complex of all, the working movements (L. A. Orbeli, A. N. Krestovnikov, Sherrington).

Thus, any change in executing the adjusting reflexes inevitably affects to some degree man's efficiency. This explains aviation medicine's strong interest in the effect of various flight factors on these reflexes. The few published reports on the problem relate to the effect of "elevation" in a pressure chamber and of breathing mixtures of oxygen-deficient gases on post-rotation nystagmus of the eyes and head, galvanic nystagmus of the eyes, labyrinth reflexes to the extremities and to the position of the head, the straightening reflex from the original position of lying on one's side, and the reflex of readiness to jump (Gellhorn and Spiesman, 1935; I. Ya. Borshchevskiy and A. P. Popov, 1936; Gellhorn and Storm, 1938; Sikorsky, 1938; Ya. A. Kizel'shteyn, 1939; Stephen, 1939; A. P. Popov, 1940; A. A. Pukhal'skiy, 1940; Raverdino and Stieglich, 1940; N. G. Savin, 1946; G. L. Komendantov, 1948, 1955; others. Most of the investigators either failed to find any

important reflexes or, if they did, noted their weakening at "altitudes" of 5000-7000 m or their disappearance at 8000-10,000 m.

Our investigations dealt with the effect of the following factors on individual adjusting reflexes and on body balance as a whole in human beings and animals: "elevations" in a pressure chamber, breathing of gas mixtures with low oxygen content, breathing of gas mixtures with little oxygen but high carbon dioxide content, increased pressure in the cavities of the gastrointestinal tract (simulation of altitude meteorism), constriction of the common carotid artery (anemia), and intense and prolonged accelerations.

1. We found that post-rotation nystagmus slows in rabbits "elevated" in a pressure chamber to 5000 m or more (decrease in the total number of nystagmic movements with unchanged duration of the reaction). At 6000-6500 m in most cases and at 7000-9500 m, there is generally an increase in the number of nystagmic movements with a simultaneous lengthening of the reaction. The time the animals were kept at the "altitudes" was 1 hour and 38 minutes.

Proprioceptive cervical and lumbar compensatory reflexes to the eye muscles and muscle of the third eyelid were studied both while the animals were in the pressure chamber at various "altitudes" (2000-11,000 m) and when they were breathing gas mixtures containing 1.8-11 percent oxygen (17,000-50,000 m). The exposure lasted from 1 to 58 minutes.

Meanwhile, we observed phase changes in the amplitude of the contractions of the antagonistic eye muscles, muscles of the third eyelid, and respiratory rate--indications that the induction relations among the different parts of the brain (medulla, midbrain, etc.) had become intensified. We also noted a transformation of the rhythm, loss of individual reflexes or groups of reflexes, slowing of the rate of contraction, appearance of "altitude" nystagmus, and other impairment of reflexes.

The reflexes to the muscle of the third eyelid were less stable than to the eye muscles, whereas the lumber reflexes were less stable than the cervical.

2. The addition of carbon dioxide (4.2-5.8 percent) to gas mixtures deficient in oxygen (corresponding to altitudes of 9000 to 17,000 m) generally increased altitude resistance in rabbits, and the decrease in tone of the eye muscles and muscle of the third eyelid was either not too sharp or not observed at all.

3. Experiments involving simulation of altitude meteorism in rabbits by raising the pressure in the gastrointestinal cavities and esophagus 20-150 mm Hg revealed that in most cases this action caused

ocular caloric nystagmus to slow while the relations among the amplitudes of the contractions of the antagonistic eye muscle changed. A bilateral vagotomy did not prevent this effect, and subsequent transection of the posterior columns of the spinal cord excluded inhibition. Inflating the stomach during respiration with gas mixtures deficient in oxygen first stimulated, then inhibited it. Under these conditions, too, the compensatory lumbar reflexes were less stable than the cervical.

4. Rendering the brain anemic by constricting one of the carotids in rabbits for 30-60 seconds caused a marked change only in post-caloric nystagmus (effect on the induction processes).

5. Rabbits, cats, and dogs were exposed for 0.4 second to 4 seconds to air streams at high speed (700-1395 km/hour). The adjusting reflexes in rabbits were found impaired, beginning with speeds of 900-1000 km/hour (1 second exposure); in the cats and dogs, at 1100-1200 km/hour with the same exposure. The labyrinth reflex to the position of the head and the straightening reflexes from the original position of lying on one's back and with the back dropping down proved least stable.

6. In rabbits, dogs, and monkeys exposed to intense (11.3-34.7), brief (0.07-0.15 second) accelerations in a head-pelvis direction with a large gradient of increase (to 474 seconds), the adjusting reflexes became impaired only when the tissues were injured: in the dogs, somewhat less than 25; in the rabbits, at the 28-30 level; and in the monkeys, apparently with greater accelerations than 30-35. Investigation of the effect of these accelerations on human beings showed the intensities to be in the 4 to 22.7 range, duration--0.7 to 0.26 second, and gradient of increase--to 345 seconds.

The adjusting reflexes cannot keep the head and upper part of the trunk of man from large and sharp inclinations with free fixation, starting with accelerations of 5.6 to 9, with a still small rate of increase (70 to 100 seconds).

A suitable position, proper fastening of the body, and a well designed armchair not only help to increase the tolerance of such strong mechanical factors but preserve the necessary level of efficiency and body balance (original position). Investigation of the balance function during the aftereffect period (after 10 minutes) showed that it was completely restored by this time.

7. With exposure of human beings to prolonged accelerations in head-pelvis and chest-back directions, a heavier load (more so with head-pelvis accelerations) was borne by the adjusting reflexes because of the need to maintain the balance of the body, which seemed to increase in weight several times.

Intensification of the adjusting reflexes caused nervous system excitability (irradiation of weak excitation) first to increase and then decrease as a result of external inhibition, which affected the existing conditioned-reflex activity (one of the mechanisms underlying the effect of accelerations) accordingly.

8. Model experiments on rabbits revealed that, when cortical motor acts interacted with the adjusting reflexes, the former suffered most, to the point of complete disappearance when they interacted with multidirectional reflexes (the ordinary combination of two adjusting reflexes and their struggle for a common final path).

SOME RESULTS OF A STUDY OF THE CARDIOVASCULAR SYSTEM IN FLIERS ON DIFFERENT FLIGHTS

S. Ye. Komshalyuk

Heart and blood vessels constitute one of the most reactive systems in the body. Even minor changes in the internal and external environments cause changes in pulse rate, vascular tone, blood pressure--adaptive reactions designed to sustain the required level of physical and mental activity. Therefore, the physiologists of work attach special significance to cardiovascular condition in performing given tasks. Since flying entails considerable nervous and emotional strain, study of the cardiovascular system, especially during flight, is not only of scientific but of practical value in devising measures to protect the health of airmen.

N. M. Dobrotvorskiy (author of the book Letnyy trud (Flying), 1930), P. I. Yegorov, and others thought it very important to study the cardiovascular system. However, for a long time, owing to the lack of specialized miniature equipment that could be carried on board the aircraft, this could be done only before and after flights.

The first investigations of the cardiovascular system of airmen during flight were carried out on multiplace airplanes--at first on transport, then on military planes (G. Diringshofen, 1938, 1943; M. S. White, 1940, R. Ye. Kirsh, 1944; A. V. Kaminskaya, 1953; others).

Development of miniature equipment made it possible to record cardiac and respiratory rates and other indices during flight without the presence of an investigator and without interrupting the airman's activities on any kind of plane, including single-seaters (V. I. Babushkin,

V. V. Usachev, A. S. Antoshchenko, V. A. Myazdrikov, N. P. Sergeyev, and others).

This investigation was aimed at studying the cardiovascular system of men while carrying out long flights with a complex mission. We found that these flights create a great deal of nervous, emotional, and physical strain, one index of which is the state of the cardiovascular system. For example, at critical times the cardiac rate of veteran pilots ranges from 140-160 a minute while that of trainees is 180 a minute. The increase in cardiac rate is paralleled by an increase in respiratory rate, amounting to 40-45 and, in some cases, 50 respirations a minute. Similar changes in cardiac and respiratory rates were observed in pilots getting training on high-altitude, high-speed airplanes.

Thus, analysis of the literature and our own data shows that during initial flights on new airplanes, regardless of type, or in the execution of complex flight missions, cardiac rate may rise to 140-160 and even 180 a minute. In time, as the plane is mastered and familiarity with the mission is gained, the nervous and emotional strain diminishes while both the cardiac and respiratory rates decrease.

However, there are important differences with respect to the load on the cardiovascular system of pilots of high-altitude and high-speed airplanes and that of pilots completing long flights with a complex mission. Whereas the former can relax after a short flight, the latter must continue with many hours of flying after completing a mission inevitably accompanied by high nervous and emotional tension. Hence, there are differences in cardiovascular condition after different kinds of flight. After high-altitude, high-speed flights, the indexes of the cardiovascular system are restored in 30-50 minutes, but after flights with a complex mission, restoration requires several hours. This can be clearly seen on the EKG changes--essentially an increase in the T waves and a change in the R waves--indicative of impaired trophism of the myocardium.

Blood cholesterol increases under high nervous and emotional tension. Frequent impairment of internal fluids (such as increase in blood cholesterol) and cardiovascular strain may cause organic injury.

It will be noted that significant cardiovascular changes during long flights with a complex mission occur only in those with major responsibilities. In those with minor obligations, emotional stress and physical strain are less, while cardiac and respiratory rates are proportionately less (to 120 and 30 per minute, respectively). The cardiac rate does not change in crew members not involved in execution of the mission.

Pulse increase before flight and decrease following flight are evidence of the important part played by nervous and emotional factors in cardiovascular strain.

Findings

1. Cardiovascular changes in airmen during flight depend largely on the complexity of the mission and on the degree of newness of the flight.

2. The cardiovascular system experiences considerable strain during complex flight missions and in the course of gaining familiarity with new airplanes.

3. In connection with pilot familiarization with new planes or execution of complex flight assignments, aviation physicians should give both preflight and postflight physical examinations to study the nature and time of restoration of physiological functions, with focus on the cardiovascular system (using the EKG, measurement of blood pressure, and other methods).

4. To decrease the effect of adverse flight factors, it is essential to increase tolerance by physical conditioning and efficient routines, taking into account the degree of changes in the body which depend on the duties of the crewmen during flight.

HISTOMORPHOLOGICAL CHANGES IN DOG PANCREAS AFTER EXPOSURE TO LATERAL ACCELERATIONS

Yu. N. Kopayev

Morphological changes in the organs and tissues of an organism subjected to intense accelerations are of great concern to space medicine. The purpose of this investigation was to study the effect of single lateral accelerations on the histomorphology of the pancreas in dogs.

There are just a few published reports on morphological visceral changes in animals exposed to intense accelerations and virtually none on the pancreatic effect of this factor. For example, Hell and Granmore (1953) merely mention the fact that intense accelerations cause considerable shift and deformation in animal viscera and also bring about a redistribution of blood in the vascular bed. Beckman et al.

(1953) found that monkeys exposed to accelerations of 40 g develop interstitial hemorrhages in some of the viscera (lungs, kidneys, liver, etc.) with formation of foci of degeneration and regeneration. More recently, data were published on the effect of space flight factors on experimental animals: V. G. Petrukhin (1962) observed hemodynamic disorders such as hyperemia, perivascular edema, and tiny hemorrhages, as well as degenerative changes in some of the viscera, including the pancreas.

We performed two series of experiments involving 28 male dogs weighing 10-15 kg. The first series studied the effect of 8 g accelerations in a chest-back direction for 3 minutes; the second, the effect of 12 accelerations in the same direction for 1 minute. Five intact animals of the same sex and weight served as controls. The animals were sacrificed with ether fumes 1 hour, 1, 3, 7, 15, 30, and 60 days after exposure--2 animals at each time period. Pancreatic fragments obtained by sagittal dissection were fixed in 10 percent formalin, Zenker's fixing fluid in A. A. Maksimov's modification, and Carnoy's fixing fluid. Paraffin and celloidin sagittal sections 5 and 10μ thick were treated with a variety of histological and histochemical methods: hematoxylin-eosin, azure II-eosin, Mallory's azocarmine, for RNA with methyl green-pyronin, and for DNA by Feulgen's method.

Analysis of the material obtained in the first series showed marked venous hyperemia in the pancreas 1 hour after exposure. The interlobular veins were markedly dilated and their lumens filled with blood, with leukocytes on some of the margins. Around the interlobular veins in some parts of the organ were hemorrhages about 500-800μ in diameter caused by rupture of the vascular wall (hemorrhagia per rhexin). There was pronounced spasm of the small interlobular arteries and arterioles at this time. In the gland parenchyma proper, sinusoid capillaries of the islets were considerably dilated and overflowing with blood, while the capillary network of the exocrine glandular tissue retained its usual appearance.

An hour after the experiment, venous hyperemia in the pancreas was even more pronounced, but more significant changes appeared in its arterial system. Parts of the interlobular arteries and arterioles showed signs of plasmorrhagia accompanied by vacuolation and desquamation of the endothelium, as well as fraying and partial destruction of elements of the muscular and outer coats of the blood vessels. Some parts of the organ had fresh microscopic hemorrhages around these altered vessels apparently caused by diapedesis (hemorrhagia per diapedesin). In two cases, parietal leukocytic thrombi were found in the lumens of the interlobular arteries.

By the end of the third day, the general picture of the gland's arterial and venous bed was close to normal. However, as a result of the

previous changes in parts of the organ, the interlobular blood vessels were surrounded by fairly distinct hemorrhages, which were gradually resorbed between the 7th and 15th days, accompanied by moderate leucocytic and fibroblastic reactions.

Changes in the parenchyma proper were reflected in reversible dystrophic and irreversible degenerative processes. Dystrophic changes--noted in glandular tissue soon after exposure (1 hour - 1 day)--affected extensive areas. These changes were manifested in a marked decrease in the amount of RNA in the homogeneous zone of the exocrine glandular cells and in a significant reduction in the amount of zymogenic granules in their apical parts. The secretory cells of the islets appeared empty at this time, with almost no proenzyme granules. Moreover, a careful cytological investigation of the early specimens (1 hour - 1 day) showed the relatively frequent phenomenon of ejection of the nucleolus from the nucleus in the exocrine glandular cells. This process was accompanied by partial chromatolysis of the nuclear substance and was particularly distinct in specimens treated for DNA, a phenomenon that warrants more detailed study. The above-mentioned dystrophic changes in the gland parenchyma gradually became normalized 3-7 days after exposure, at which time the tissue regained its usual appearance.

Degenerative changes in the parenchymatous elements of the pancreas were local in character and affected comparatively small areas near the hemorrhages. In these portions, the glandular terminal sections and individual secretory cells died soon after exposure. Sometimes the foci of degeneration embraced small lobules in which the glandular elements gradually atrophied and degenerated. Comparatively weak leucocytic and macrophagic reactions were noted in the areas where the parenchymatous elements died. Seven to 15 days after exposure, abnormally large development of the small efferent ducts and intercalary sections along with mitotic division of the centroacinar cells were noted in some parts of the gland parenchyma. These were apparently a form of compensatory-restorative reaction. All the pancreatic changes that arose after exposure to the accelerations were compensated by the 30th day after the experiment.

The second series of experiments involving exposure of animals to 12 lateral accelerations for 1 minute showed the same histomorphological changes--but not quite so pronounced--as in the first series.

Thus, study of the pancreas of our experimental dogs shows that the main changes that followed single lateral accelerations of 8 and 12 g were the disorders caused by the impairment of blood circulation. In addition, definite degenerative-dystrophic changes took place early in the parenchyma of the organ. These subsequently gave way to phenomena of a compensatory-restorative nature. The various changes that arose in the pancreas after the accelerations were all adequately compensated within 30 days of exposure.

THE LATENT FORM OF MOTION SICKNESS

V. I. Kopanev

It is well known that in traveling on water, in the air, or on land, varying degrees of vertical and angular accelerations may cause motion sickness in persons with low statokinetic tolerance. According to some investigators, people differ in susceptibility to swaying motion and type of vehicle. Hill (1936), M. Krivoshein and A. Sandler (1937), and R. A. Okunev found that motion sickness affects more than 90 percent of those traveling on boats, about 11 percent of those on propeller-driven airplanes, and 1-3 percent of those on jet planes (A. V. Chapek, L. S. Isaakyan, et al., 1959).

Classifications of motion sickness depend on type of transport, main clinical symptom, etc. With respect to severity of sickness, a distinction is now made between: (a) the manifest form characterized by vomiting and other autonomic reactions, and (b) the latent form with only slight deterioration in the sense of well-being and moderate impairment of efficiency (Maitland, 1931; G. Shubert, 1937; Hemingway and Green, 1945; V. I. Kopanev, 1961; others). The latent form is more common and generally occurs in the initial stage of each case of the manifest form, although it is also found independently.

Our investigation, using essentially healthy males 19 to 36 years of age, sought to determine the functional state of the visual analyzer in the latent form of motion sickness. We used the method of "adequatometry" (P. O. Makarov, 1952, 1960) to determine the excitability of the visual analyzer from three thresholds (adequate optical rheobase, adequate optical chronaxie, adequate optical topaxie) and its lability from the critical interval of discreteness. Visual acuity was measured on a Belostotskiy-Gofman apparatus. Swaying movements--produced at the rate of 16-17 per minute--lasted 30 minutes and were terminated when subjects complained of slight nausea, sensation of heat flushes in the head, etc. Accelerations did not exceed an intensity of 0.15 g. This minimal acceleration and the individual approach to the duration of the swaying produced only the latent form of motion sickness with no autonomic changes. Blood pressure, pulse, and respiration were periodically checked during the experiment.

Control experiments were run in order to determine the effect on the visual analyzer of a darkened chamber with no swaying movements for the period of time corresponding to the duration of the experiment (2 hours and 40 minutes). Indexes of excitability and lability of the analyzer were found to be relatively steady, 30-50 minutes after the light was turned off.

Since swaying movements were not started until the subjects spent at least 50 minutes in darkness, any changes observed in the functional state of the visual analyzer could be attributed to motion sickness.

Results of the experiments showed that the visual analyzer's excitability thresholds rose while its lability decreased. For example, the rheobase during the first 5 minutes of swaying increased by 52 percent (from 15.9 to 23.7 relative units). Though it subsequently fell slowly, it remained above the original level until the end of the experiment. Chronaxie reached a maximum after 15 minutes of swaying--24 percent above the original level (from 35.7 to 44.2 msec), remaining high for 35 minutes. Topaxie gradually increased, reaching a maximum after 15 minutes of swaying (52 percent above the original level, from 86 to 131 mm^2). When the swaying movements stopped, topaxie quickly returned to normal. The critical interval of discreteness changed as soon as the swaying movements were started, reaching a maximum after 25 minutes (18 percent above the original level, from 67.3 to 79.1 msec) and remaining at this level with a slow shortening of the interval until 25-45 minutes of the aftereffect period.

Visual acuity decreased in 12 persons, increased in 7, and remained unchanged in 7. The pulse increased by 5-20 beats; blood pressure, by 5-20 mm Hg. From the start of the swaying movements, the respiratory rate generally matched their rhythm.

The functional changes of the visual analyzer were directly related to resistance to swaying movements. In 13 subjects resistant to 30 minutes of swaying, there was an increase in the indexes, but it was less pronounced and it occurred some time after the start (10-15 minutes) rather than immediately.

In 7 subjects, chronaxie and the critical level of discreteness did not lengthen, but shortened, during the first 10 minutes, indicating increased excitability of the visual analyzer. In 13 persons with low resistance to swaying movements (they complained and the duration of the action was shortened), changes in excitability and lability of the visual analyzer were more marked and set in as soon as the action was started). Yet in these cases, too, the initial measurements of the rheobase, chronaxie, topaxie, and critical interval of discreteness frequently were below the original values. This occurred also when investigating visual acuity: a decrease, as a rule, in those with little tolerance of swaying movements; an increase in those with high tolerance.

These findings are particularly interesting because, although the subjects generally thought their condition quite satisfactory and their autonomic reactions were slight, an objective investigation showed a

decrease in the excitability and lability of the visual analyzer and in visual acuity.

In some cases, excitability first increased, but later decreased, a situation comparable to phases 1 and 2 of motion sickness (G. L. Komendantov and V. I. Kopanev). The first and very short phase is marked by excitation irradiating from the neural structures responsible for spatial orientation, chiefly from the vestibular analyzer, to the adjacent CNS regions, including the visual analyzer. With intensification of excitation, negative induction gives rise to inhibition of these regions (phase 2), resulting in decreased excitability and lability of the visual analyzer.

The results of our study of the latent form of motion sickness point up the need of carefully observing persons whose work exposes them to slight angular and linear accelerations (fliers, drivers, seamen, etc.) regardless of whether or not they have any complaints.

Latent forms of impaired compensation are probably produced also by other unfavorable environmental factors such as oxygen deficiency, noise, and vibration.

Findings

1. Most subjects with the latent form of motion sickness exhibited a decrease in excitability and lability of the visual analyzer and slight changes in blood pressure and the cardiac rate.

2. A definite relationship was detected between these changes and degree of statokinetic tolerance.

TRAINING MAN FOR SPACE FLIGHT

A. A. Koreshkov

The efficiency and endurance displayed by the astronauts were the result of scientific selection and training methods. These methods recognized space flight factors regarded a priori as psychological and physiological stressors (intense accelerations, dynamic weightlessness, novelty, natural danger, loneliness, isolation, confinement in a small space, sensory inadequacy, artificial day and night). Analysis of these factors showed that the astronaut must have good health, particularly a

sturdy cardiovascular system, good physical development, adequate mental and physical fitness, and high emotional stability characterized by a sthenic reaction to danger. Other qualities of importance include vestibular stability and favorable experience with weightlessness and maximum tolerance of noise, loneliness, isolation, confinement, and sensory inadequacy.

This report examines cardiovascular reactions during parachute training, exposure to vibrations, and prolonged confinement and isolation. It reports also on the ability of a group of experimenters to work harmoniously together under these conditions.

The parachute training plan included mastering the techniques of jumping clear of the plane, controlling the body during the period of free fall until the parachute opened, calculating the time until the parachute opened, controlling the parachute during descent, and landing on land or water with ordinary and special equipment (diving suit). The program called for increasingly difficult jumps: (1) in the daytime in good weather, (2) in the daytime in foul weather, (3) at twilight, (4) at night under a starry sky, and (5) at night in foul weather. During the parachute training period, a cardiovascular check was made 1-2 hours before a jump, just before landing in an airplane, and then 45-60 minutes after the assignment was completed. One to 2 hours before a jump, the EKG was recorded, arterial pressure measured, pulse taken and its nature recorded (filling, tension, synchronism). The pulse rate and its characteristics were recorded before landing in a plane. The physical examination after a jump was the same as that given 1-2 hours before landing in a plane. The table presents averaged figures obtained in a cardiovascular examination of Yu. A. Gagarin before and after jumps.

Pulse Rate Before and After Parachute Jumps
(Mean Values)

Original value	Before landing in an airplane		After landing		
	1st day of jumps	2nd day of jumps	1 minute	3-7 minutes	1-1/2 to 2 hours
77	85	96	167	124	81

As these figures make evident, Gagarin showed high cardiovascular tolerance of the physical and emotional stress in parachute jumps. Pulse rate and EKG recordings for the other astronauts revealed the high degree of stability they all possessed.

Tolerance of solitude, isolation, confinement and, as a result, sensory inadequacy was determined by recording reactions during a prolonged stay in a sound-suppressing chamber. EKGs were recorded and pulse was taken several times a day. On the last day the men spent in the chamber, the pulse was somewhat faster than on the first day. Pulse rate dynamics throughout the chamber interval provide evidence that the figures are not accidental. EKGs showed normal myocardial function.

Investigation showed rapid adaptation to the effect of vibrations on vital functions and, after overcoming transient and indistinct symptoms of sinus arrhythmia, complete tolerance.

Of great practical and theoretical interest to space medicine is the ability of a group of people to adjust to each other and work harmoniously under conditions of prolonged confinement. According to leading foreign experts, who have organized small groups of people to stay together under similar conditions (through the winter), this is a virtually insoluble problem--a view based on the neo-Freudianism that is currently fashionable abroad, especially in America.

Participating in our study were several experimenters who remained, for an extended period, in a specially equipped soundproof chamber, their work and rest followed a designated program. Their physiological and psychological reactions showed that a group of Soviet citizens, fully aware of the importance of the mission can remain together for a long time isolated and confined to a small place without any deterioration in relations. They also showed that these relations are determined primarily by the moral qualities of the individuals concerned and by the extent to which they can coordinate their mental activity.

With respect to physiological functions, especially the cardiovascular, no marked abnormalities were noted in any of the members of the group.

WEIGHTLESSNESS FROM THE STANDPOINT OF TERRESTRIAL PHYSIOLOGY

P. A. Korzhuyev

The problems deriving from the conquest of space require solution largely under terrestrial conditions. A very important and too little understood problem is weightlessness. Its uniqueness is primarily that it is still impossible to produce prolonged weightless conditions on earth for study of their effects on animal and human organisms.

Despite our ignorance of the subject, there is a tendency to regard prolonged weightlessness as harmless, chiefly because astronauts Nikolayev and Popovich were exposed to it for several days with no adverse effects. It would seem preferable, in our opinion, to attempt an objective evaluation of this factor before drawing any final conclusions. The solution, we believe, must be based on the assumption that one of the fundamental laws of biology--the unity of organism and environment--is just as valid for outer space as it is for our planet, and to plan our research on this basis. One aspect of the research will be discussed in this report.

Enough information is now available about the biology of present-day animals, the vertebrates in particular, to permit some judgments about the probable effects of prolonged weightlessness. However, despite our knowledge, one factor still remains insufficiently understood--gravity. This has not been taken into account in describing either the animals themselves or their habitat. The fact that the force of gravity is not the same under terrestrial and aquatic conditions will help to elucidate its role both in the life of organisms and in the evolution of present-day animals.

Available experimental data on the morphology and physiology of certain vertebrates help to understand the influence exerted by gravity. Specifically, the quantitative data on blood, hemoglobin, and characteristics of the centers of hematopoiesis in some fish, birds, and mammals indicate that, philogenetically, a sharp boundary line can be drawn between aquatic and terrestrial vertebrates.

We have shown that in the course of evolution toward a terrestrial mode of life, the amount of blood and hemoglobin increased in the first creatures to settle on dry land. Quantitative analysis of the centers of hemoglobin and erythrocyte synthesis in the vertebrates studied revealed that the increase was due chiefly to the appearance of a new center of hemoglobin synthesis--bone marrow, which arose as a result of intensified gravitational force. Overcoming this force was indispensable to terrestrial creatures in obtaining food, and gaining protection from enemies and unfavorable conditions.

In the light of the foregoing, it is to be expected that the better adapted a vertebrate is to terrestrial conditions and the higher it is on the phylogenetic ladder, the better developed will be the centers of hemoglobin synthesis in the form of bone marrow. Existing evidence, although still very meager, supports this view. The amount of bone marrow in such a fleet animal as the mature reindeer is 7 percent of body weight, and as much as 13 percent in a newborn reindeer. On the other hand, it scarcely exceeds 1 percent in a sluggish animal like the guinea pig, which may spend its entire life in a cage. A quantitative comparison of the hematopoietic centers in fish and in terrestrial

animals shows that the rate of hemoglobin synthesis is tens and hundreds of times greater in the latter.

These data tend to support the view that terrestrial vertebrate evolution is essentially development of adaptations to the force of gravity, a process entailing intensified expenditures of energy by liberation of large amounts of oxygen. The uptake of the necessary amount of oxygen was determined by the presence of hemoglobin, the synthesis of which had to increase sharply.

Increased oxygen need could not in itself have been sufficient to change the centers of hemoglobin synthesis, for, if so, simple intensification of the ancient centers of hemoglobin synthesis would have been enough. The main reason for the change in the centers was apparently the unequal load on different parts of the organism under terrestrial conditions. If this assumption is correct, more active animals should have greater amounts of bone marrow, let alone a heavier skeleton. Accordingly, the higher vertebrates, which are not only better organized but more active, should have the heaviest skeleton. It is worth noting that an increase in skeletal weight is determined by the weight of the bone-marrow fraction since it sometimes constitutes about 45 percent of the entire skeleton.

Thus, if the vigor of the centers of hemoglobin synthesis is determined by gravity, removal of gravity should result in a depression of bone marrow, in a reduction of its activity. Applied to space flight conditions, this would mean that after prolonged exposure to weightlessness, when the force of gravity on the organism is completely excluded, bone-marrow activity would no longer be stimulated by the ordinary terrestrial factors and depression would set in, followed by degeneration of these structures.

We believe, therefore, that an essential requirement for extended space flights, which are not as remote as they seemed a few years ago, is determination of the effects of weightlessness and setting up optimum conditions to prevent any injurious consequences. Current attempts merely to discover the possible effects of essentially brief periods of weightlessness on various objects can be ignored, for they add little to our understanding.

DEVELOPMENT AND PRESERVATION OF A HIGH LEVEL OF MOTOR FUNCTION AS A PROBLEM IN THE PREPARATION AND EXECUTION OF EXTENDED SPACE FLIGHTS

A. V. Korobkov

Man evolved in a state of constant interaction both with natural factors (air, temperature, natural radiation, gravitational field, time, space, electromagnetic field, etc.) and with social factors involving a variety of relationships during work, at home, etc. The motor function played an important and specific role in this process.

Terrestrial conditions do not exist during space flight, during which various mental, autonomic, and motor processes--controlled by reflex and humoral mechanisms through a vast flow of information generated by stimulation of different analyzers--change or become extinguished. Weightlessness, hypodynamia, and isolation largely reduce the flow of information produced by human motor activity.

The motor function in man, which represents a form of "protest" against the gravitational forces, is, so to speak, one of the important biological links between his various autonomic and mental functions. To illustrate this, we investigated the value of physical training in maintaining mental, motor, and autonomic stability and in preserving the relative constancy of the organism's internal environment under varying states and environmental conditions. At the same time we studied man's equilibrium processes and actions in the surrounding environment (social and natural) with exposure to gravitational forces, time, space, altered gas medium, etc.

Our study of the changes that take place in different organs and systems under conditions of hypodynamia and isolation showed that mental as well as motor and autonomic functions are affected. The marked decrease in resistance to radiation after hypodynamia indicates that the lack of physical movements and ensuing reflex and humoral stimulation exert a profound and unfavorable effect on intimate processes in various organs and tissues. However, the performance of physical exercise in the course of hypodynamia restores the quality of these functions.

Further research on resistance to radiation and tuberculosis confirmed our view of the great importance of hypoxemia and hypoxia created by sufficiently intense and prolonged physical exercise in increasing resistance. This was clearly demonstrated in animals, experimentally infected with tuberculosis, whose death was directly linked to decreased endurance of static exertions which are accompanied by a large oxygen debt and high resistance to hypoxemia. Speed and strength were less affected, although decrease in resistance to ionizing radiation, which

we frequently observed, was also accompanied by decrease in strength, speed, and endurance. On the other hand, preliminary physical training increased resistance.

We concluded from the foregoing that stability of the internal environment is related to a high level of motor activity and development of a definite interdependence of the qualitative characteristics of this activity. The influence of this "interdependence" seems to be due to the activation and interaction of certain trophic and autonomic reactions concerned with speed, endurance, and dexterity.

Presenting animals with optimal electrical stimuli as equivalents of physical exercise results in intensified emotional reactions and resistance due to the trophic influences of CNS and hormonal factors.

Since the various organs and systems interact, each function affects the whole organism, and, therefore, stability and environmental balance depend on integral interaction in the entire range of activity.

Treadmill experiments (A. V. Korobkov, 1960, 1961, 1962; V. A. Shkurododa, 1961, 1962) on humans with various degrees of physical conditioning revealed a complex picture of interaction and mutual compensation chiefly in the motor and autonomic functions ("spectrum" of reactions) as well as in certain physiological aspects of motor and autonomic functions. A principal discovery (reflecting the integrated aspect of resistance) was that persons in good physical condition were resistant both to individual functions and to the entire "spectrum" of reactions, whereas untrained persons showed much less definiteness and inner unsteadiness. Physical conditioning, we found, plays a major role in the development and resistance of several psychic functions and mental efficiency.

Our data (Korobkov et al., 1962, 1963) showed that conditioning the processes of environmental balance and motor stability contributes to the formative influence of the ambient factors themselves in the development of motor and autonomic functions. Conditions in a gravitational field form the topography of the strength, speed, endurance, and structure of different neuromuscular structures, tone of various muscle groups, direction of the trophic influences of the CNS, and vascular tone regulation.

It is a reasonable generalization that existence in time and space is responsible for the development of mental as well as motor skills and qualities, and conditioning helps to perfect their topography.

The effect of physical conditioning and environmental factors stems from activation of various analyzers, particularly, the motor analyzer. Vigorous motor activity, static exertions, and increased muscular

tone, by stimulating a vast flow of sensory information that contributes through the reflex mechanisms to stability of higher nervous activity, have both a trigger and a trophic effect on various tissues, activate endocrine gland function, and favorably influence the resistance of the vestibular apparatus to accelerations. Preliminary physical training and physical exercise during flight can help shape man to achieve a balance between his internal and external environments.

In the light of the foregoing, we regard a program of motor activity, in which physical exercise plays an important part, as a means of preserving the terrestrial "spectrum" of information, which is required to ensure the optimal condition of the biological environment of the organism and, as a result, enhance psychic activity and mental efficiency.

EFFECT OF LATERAL ACCELERATIONS ON DOG LUNG HISTOLOGY

Yu. N. Korolev

The tolerance of lateral accelerations by the respiratory organs is determined by certain pathophysiological changes--dyspnea, retrosternal pain, hemoptysis, and deoxygenation of arterial blood (A. R. Kotovskaya, S. I. Lobashkov, S. F. Simpura, P. M. Suvorov, and G. F. Khlebnikov, 1962; Müller, 1961). The direct causes of circulatory and respiratory dysfunction after lateral accelerations are changes in pulmonary ventilation and redistribution of blood in the pulmonary blood vessels (P. V. Vasil'yev, A. D. Voskresenskiy, and O. G. Gazenko, 1963; A. A. Kiselev, 1962). Hemodynamic changes in the pulmonary circulation after accelerations have been investigated roentgenologically (A. R. Mansurov, 1956; Müller, 1961; Hershgold, 1960). The authors noted that the pulmonary lobes from behind were less transparent than usual, a sign of the blood flowing back to the posterior sections of the lungs (an apparent "separation" between blood and air, which creates unfavorable conditions for pulmonary ventilation).

A few investigators have observed structural changes in lung parenchyma after various kinds of accelerations. Beckman et al. (1953) exposed a female chimpanzee to a positive acceleration of 40 g for 15 seconds; autopsy, an hour later, showed edema, hemorrhage, and local atelectases in the lungs. Lung parenchyma were overflowing with venous blood, with thrombi in the lumens of the small veins. V. G. Petrukhin (1962), investigating the viscera of mice and guinea pigs carried on space vehicles, observed pronounced hyperemia and perivascular edema in the lungs 2-3 days after the flight.

However, these morphological findings do not provide conclusive evidence of dynamic pulmonary changes. The purpose of this investigation was to study the structural changes in the lungs of dogs after a single exposure to lateral accelerations in a back-chest direction.

Two series of experiments were performed on 28 male dogs weighing 10 to 15 kg. The first consisted of a single positive acceleration of 8 g for 3 minutes; the second, a single positive acceleration of 12 g for 1 minute. The animals were sacrificed 1 hour, 1, 3, 7, 15, 30, and 60 days after the experiment with ether fumes. The material was fixed in Zenker-formalin, 10 percent neutral formalin, and Carnoy's fixing fluid and treated by the following methods: hematoxylin-eosin, azure II-eosin, Mallory, Van Gieson, Tentser-Unna; impregnation by Karup's method. The lungs of 5 male dogs weighing 10-15 kg served as the control.

Because of the similarity of changes noted in the first and second series, they are herewith described together. Gross inspection after 1 hour and after 1 day revealed hemorrhages 0.2·0.2 cm to 2·3 cm in size primarily located on the posterior surface of the lungs or in the root zone. On the 3rd and 7th days after the accelerations, elevated grayish-red spots were noted on the pleural surface with dark-red zones of atelectasis between them. At this time some of the animals had confluent foci of pneumonia occupying a large part of the lobe. Much later (after 30 and 60 days) some of the animals showed sclerotic patches of different sizes under the altered pleura.

Microscopic investigation after 1 hour, and again after 1 day, revealed hyperemia, thickening of the interalveolar septa, and activation of their septal elements. The lumens of the alveoli contained cells of desquamative epithelium. The blood vessels were dilated and filled with blood while the surrounding connective tissue was loosened by a transudate. Some of the small blood vessels showed signs of stasis, with a slight infiltration of small cells. Hemorrhages and atelectases of different sizes could also be seen. The former originated both per diapedesin and as a result of rupture of blood vessels (small veins and arterioles). Blood not only filled the alveoli but was present in the interalveolar septa, alveolar ducts and bronchioles. Near the hemorrhages were lacerations of the elastic fibers of the interalveolar septa. Argyrophile fibers were coarse, swollen, and twisted. Also, there was a focal decrease in the impregnation properties of the argyrophile fibers.

Patches of bronchopneumonia and confluent bronchopneumonia were noted 3 and 7 days after the experiment. There was a proliferation of cellular elements and leucocyte infiltration in the thickened alveolar septa. Some of the alveoli had a serous exudate; others contained cells of alveolar epithelium and leucocytes. Bronchitis, peribronchitis,

and bronchiolitis were pronounced. The alveoli surrounding the pneumonic foci had thickened interalveolar septa and a serous fluid with a few alveolar cells.

In cases of pneumonia of the serous-desquamative type, the alveolar cavities contained numerous cells of alveolar epithelium with many rounded cells and vacuolated cytoplasm among them. Argyrophile fibers in these areas were difficult to impregnate.

Investigation of the lungs after 15, 30, and 60 days showed focal sclerosis in some areas against a general background of normal lung tissue. The connective tissue was proliferating along the interalveolar septa and sometimes completely filled the alveolar cavities; it was also proliferating under the pleura and between the lobules.

Results of our investigation show the following early (1 hour, 1 day) characteristic changes in lung histology: hyperemia, edema of lung tissue, and hemorrhages, all indicative of impaired hemodynamics in the pulmonary circulation under the influence of accelerations. Later (3 and 7 days), inflammatory phenomena developed in lung tissue. Still later (15 and 60 days), there was focal sclerosis of lung parenchyma due to organization of the previously existing hemorrhages or to pneumonia. The above-described changes did not affect the respiratory function significantly. Compensation was quite pronounced.

EFFECT OF LATERAL ACCELERATIONS ON DOG KIDNEY HISTOLOGY

V. V. Korolev

The few morphological studies of the effects of accelerations on the kidneys and on the excretory system as a whole dealt mainly with low intensity exposures. Senelar et al. (1959), subjecting dogs to accelerations of 2.5 g in the head-pelvis direction, found on autopsy marked hyperemia of the glomeruli, dilatation of the peritubular capillaries, and ruptures of the venous walls. The brush borders disappeared in the renal tubules while granular casts were sometimes found in the lumens of the collecting tubules.

In another study, Senelar and Luber (1960) subjected dog kidneys to positive accelerations of 2.5 g lasting from 10 to 60 hours and found capillary and venous hyperemia of renal cortical and medullary substance, numerous interstitial hemorrhages, desquamation of the epithelium of the renal tubules, and the formation of casts. Dogs dissected 3 months

after the experiment had interstitial and glomerular sclerosis and marked degenerative changes in the tubules. The authors believe that summation of the effects of centrifugation caused progressive impairment of neurovascular tone and persistent increase in passive blood filling, which produced sclerosis and degenerative changes in the tubules of the nephrons. However, these conclusions were drawn from an experiment involving only a small number of animals.

Beckman et al. (1953) subjected anthropoid apes to positive accelerations of 40 g for 15 seconds, and at autopsy, an hour after the action, they noted enlargement of the kidneys, overflowing of the glomeruli with blood, and dilatation of the tubules. V. G. Petrukhin (1962), who studied the viscera of mice 2-3 days after they were carried on space vehicles, found impaired kidney circulation in the form of hyperemia, perivascular edema, and small hemorrhages.

The present investigation studied morphological changes in the kidneys of dogs subjected to single lateral accelerations. The experiments were performed on 28 male dogs weighing 10-15 kg subjected once to accelerations of 8 g for 3 minutes or 12 g for 1 minute. The animals were sacrificed with ether fumes 1 hour, 3, 7, 30, and 60 days later--2 animals at each period. The kidneys of 5 animals served as the control. The material was fixed in 10 percent neutral formalin, Carnoy's fixing fluid, and Zenker-formalin in Maksimov's modification, and then embedded in paraffin. Sections 5μ thick were stained with azure II-eosin, hematoxylin-eosin, and by Mallory's method. Histochemical reactions to RNA were determined by Brachet's method, as were reactions to mucopolysaccharides (PAS-reaction). Sections 10-15μ thick, prepared in a freezing microtome, were stained for lipids with Sudan III.

The morphological changes in the kidneys, as noted in the series of experiments, included injuries to the vascular system and degenerative changes in the renal tubules.

An hour after the accelerations, microscopic investigation revealed marked hyperemia of the cortical and medullary substance in both kidneys. There was considerable, frequently uneven dilatation of the capillaries of the vascular glomerulus and transudation of plasma into the cavity of the glomerular capsule as well as diapedesis and limited hemorrhages around the renal corpuscle near its vascular pole. The peritubular capillaries and venules were also dilated and were compressing the tubules of the nephrons. The brush border of the proximal portions of the nephrons had peeled off in places and their lumens were dilated and filled with fine pyroninophil granules which, according to Oliver (1948), are plasmatic proteins subjected to calcium reabsorption. These phenomena were indicative of increased glomerular permeability. Cells with pycnotic nuclei were found in the walls of the straight tubules of

the nephrons. The walls of the distal tubules and ascending portions of the loop of Henle contained degenerating cells with an amorphous sediment in the lumens.

The hyperemia of the renal cortical and medullary substance persisted for the first three days. The capillaries of the vascular glomeruli, especially in the juxtamedullary zone, were unevenly dilated and filled with blood. At the same time we noted the collapse of the loops of the glomerular capillaries, diapedesis, and transudation of blood plasma into the cavity of the glomerular capsule. There were, in addition, some instances of lipid infiltration of the glomerular capillaries, and the peritubular capillaries were dilated. The walls of the small veins were ruptured, with hemorrhages around the small blood vessels and leucocytic infiltration of the tunica adventitia and, in some cases, lipid infiltration of the vascular walls. As for the tubules, the changes were most distinct in the distal portions of the nephrons: the protoplasm of some cells was vacuolated, the nuclei were hyperchromic and pycnotic, and degenerated cells filled the dilated lumens of the tubules.

Traces of capillary and venous hyperemia were still evident on the 7th day. Around the juxtamedullary glomeruli could be seen fresh circumscribed hemorrhages. The afferent arterioles of these glomeruli were dilated and the endothelium of the capillaries contained lipid inclusions. Delicate collagenous fibers appeared on the sites of the old hemorrhages around the glomeruli. Degeneration comparable to that described above was most pronounced in the ascending portions of the loop of Henle and distal tubules of the juxtamedullary nephrons.

The venous and capillary hyperemia persisted for 15-30 days. Fresh hemorrhages appeared around the juxtamedullary nephrons, between the tubules and cortical substance, and around the veins on the border between the renal cortical and medullary substance. Connective tissue proliferated around the glomeruli and small blood vessels at the site of the old hemorrhages. The proximal portions of the nephrons at this time were similar in structure to those of the control animals, but the walls of the ascending portions of the loop and distal tubules contained degenerating epithelial cells that had peeled off in layers and filled the lumens of the tubules.

By the 60th day, hemorrhages could no longer be found in the kidney parenchyma: focal proliferation of connective tissue appeared at the site of the old hemorrhages.

Thus, the morphological changes noted in our experiments were occasioned primarily by the hemodynamic shifts that arose as a result of the accelerations. Ames et al. (1951) have shown that positive accelerations of 2-3 g for 15 seconds increase venous pressure in the kidney

blood vessels about 4-4.5 times (from 1-5 to 7-18 mm Hg) while arterial pressure falls 1.5-2 times. During the first few hours and days after the experiments we noted venous hyperemia and focal hemorrhages around the glomeruli and between the tubules, and increased permeability of the walls of the capillaries of the vascular glomeruli, as indicated by the erythrocytes found in the lumens of the tubules. The hemorrhages that appeared later (after 7, 15, and 30 days) were apparently caused by increased vascular permeability and decreased neurovascular tone (Senelar and Luber, 1960) resulting, perhaps, from the ether fumes used to kill the animals. The above-mentioned vascular changes obviously caused tissue anoxia in the kidneys and mechanical compression of the tubules of the nephrons, which led to degenerative changes. It will be noted that the distal portions of the nephrons, which are highly sensitive to anoxia and other injuries (Smith, 1951), were affected most of all.

The morphological changes were more pronounced in the first series of experiments than in the second, especially in the vascular system. Hemorrhages into the cavity of the glomerular capsule and kidney parenchyma were more numerous and ruptures of the venous walls were seen more frequently.

Beginning with the 7th day, signs of organization of the old hemorrhages around the glomeruli and between the tubules of the nephrons appeared and gradually increased. Degenerative impairment of the distal portions of the nephrons remained a long time (about 30 days), but the structures of the proximal portions were restored much sooner. Consequently, the changes that arise in the vascular system and parenchyma of the kidneys after accelerations are unstable and eventually become adequately compensated.

PSYCHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF THE WORK OF AIRPLANE CREWS IN CONNECTION WITH IN-FLIGHT REFUELING

F. P. Kosmolinskiy

One of the most difficult aspects of flight training is to refuel in the air on long flights. The danger of delicate maneuvering of the plane causes considerable nervous and emotional strain in the crew, with marked decrease in efficiency. Our 1960-1962 investigations (F. P. Kosmolinskiy, S. Ye. Komshalyuk, N. A. Fedorov, I. M. Khazen, I. Ye. Shramko, I. G. Dlusskaya, and others) showed that strain is manifested primarily in autonomic changes. Veteran pilots manifested a cardiac

rate of 145-160 a minute; trainees, up to 180, thereby exceeding the original values 2 to 2-1/2 times. Respiratory rate also increased from 35-50 a minute, i.e., 2-1/2 to 3 times above the original values.

Long flights were followed by 5 percent weight loss (mainly through dehydration) and a decrease in some physical indexes: strength of the respiratory muscles, maximum muscular force, and muscular endurance (up to 50 percent), characteristic nervous and mental changes, and changes in the indexes used to judge attention (span and shifting of attention, rate of visual perception). The latent period of sensorimotor reactions lengthened as did the time of dark adaptation of the visual analyzer. The thresholds of electric excitability of the eye (phosphene) and of the critical frequency of coalescence of flickerings were raised and the conditioned reflexes in response to given muscular exertion were impaired. All these abnormalities were quickly repaired, as a rule, but in a few instances persisted for some time (about 2 days).

With increasing skill, autonomic manifestations of nervous and emotional strain and CNS functional changes as detected by physiological and psychological methods, clearly improved.

Emotional excitement (accompanied by a sharp increase in cardiac and respiratory rates) may, according to the literature, sometimes give rise, as a result of hyperventilation, to hypocapnic, hypoglycemic, and secondary hypoxic manifestations. These, in turn, influence the cortical and, consequently, the mental processes.

Strong nervous and emotional stress may be expected to bring biochemical changes. To test this, in 1961-1962, we studied urinary excretion of 17-hydroxycorticosteroids and of ascorbic acid, and checked the cholesterol content of the blood (F. P. Kosmolinskiy, A. S. Kontsov, I. G. Dlusskaya, N. A. Vorob'yev, I. M. Khazen, and others). Ascorbic acid metabolism--an index of body reactivity (B. A. Lavrov)--is extremely complex, for it depends on many endogenous and exogenous factors. There is an abundance of information on the very close relationship between the metabolism of vitamins (particularly vitamin C), cholesterol, and corticosteroids.

Our investigations showed that in fliers whose work did not entail unusual nervous or emotional strain, urinary excretion of ascorbic acid was within normal limits (0.6-1 mg percent). No unusual changes were noted in corticosteroid excretion under these conditions.

On the other hand, in fliers whose work did entail extreme nervous and emotional and physical strain, there was increased urinary ascorbic acid excretion--both after a flight and, in some cases, for 1 or 2 days thereafter. No such changes were noted in other members of the same

crew who had less responsible jobs. These persons served as a unique additional control.

Our findings of exceptionally high elimination rate of ascorbic acid (5, 8, 20, and even 30 times above normal) are at variance with published data indicating a decrease after flights (V. M. Vasyutochkin, Yu. F. Udalov, and others). However, Gadzhiyev's work with mountain climbers at great heights (1961) yielded data similar to ours.

We noted similar changes under comparable observation conditions, even when the fliers were given vitamin supplements. Excretion of 17-corticosteroids increased 2-3 and sometimes 5-6 times. A definite relationship was found between the excretion of 17-OH-KS and that of ascorbic acid. Blood cholesterol was much higher than in the control group (184 and 135 mg percent, respectively). It rose in the pilots after flights to 196 mg percent, but there was no such rise in the other members of the crew.

Emotional stress in flight personnel was reflected in the EKG indexes. After flights, the EKG of the captains showed characteristic changes in the R and T waves and in the S-T interval (P. V. Buyanov, S. Ye. Komshalyuk, and F. P. Kosmolinskiy, 1962).

The conclusion may be drawn that physiological and biochemical changes noted in the personnel after long flights with refueling in the air are directly related to the complexity of the mission.

EFFECT OF PROLONGED LATERAL ACCELERATIONS ON MONKEYS

A. R. Kotovskaya, P. V. Vasil'yev, B. A. Lapin, S. F. Simpura, I. S. Grishina and V. I. Kulinskiy

At certain stages in space flight the human organism is subjected to accelerations which sometimes attain critical values, causing various functional impairments, particularly, circulatory and respiratory disorders.

Although a substantial number of studies have dealt with the tolerance limits and functional impairment of accelerations in man and animals, many of them deal only with accelerations applied in a lengthwise direction in relation to the main blood vessels of the body and most were performed on rabbits and dogs.

The resultant data are undoubtedly of great value, but their plausible extrapolation to man required experiments on monkeys, which are close to human beings in several anatomical and physiological respects and can be used for modeling certain pathological processes, particularly in the cardiovascular system, which cannot be duplicated in any other species of animals (B. L. Lapin, 1963).

The main purpose of this investigation with 16 female monkeys (11 rhesus monkeys and 5 baboons) was to study cardiovascular and respiratory reaction to "chest-back" accelerations and to determine the duration of tolerance of 12 accelerations.

The experiments were performed in a centrifuge with a radius of 7.25 m revolving at the rate of 0.1 g/sec. The body was in a semi-recumbent position in the chair, the back of which was at a 25° angle to the ground. A special suit was used to secure the animals to the chair. None of the animals was anesthetized.

The signs of marked dysfunction of external respiration and blood circulation (prolonged respiratory arrest or standstill, pronounced bradycardia or disorders of automatism, excitability and conduction of the myocardium) served as criteria for the limits of tolerance.

While being rotated, the animals were kept under constant television observation. Motion pictures were taken and sound communication was maintained with the cabin of the centrifuge.

Before rotation, the animals sitting in the chair reacted satisfactorily to the surroundings and eagerly ate up titbits offered them. No pathological abnormalities were noted in the cardiac or respiratory indexes. However, all the monkeys had pronounced tachycardia.

Initial reaction to rotation was an orienting response and some motor restlessness. At the same time, respiration became more frequent and deeper. As accelerations increased, the animals pressed against the chair, restless and sometimes screaming. As rotation speed increased, cardiac and respiratory rates intensified even more. With accelerations of 12 units, the pulse rate rose from 152-186 to 190-230 beats/min, while the respiratory rate rose from 24-36 to 38-54. By the time the accelerations were halted, the cardiac rate had sometimes slowed by 60-80 beats/min.

Signs of sinus tachycardia with a marked shortening of the EKG intervals were evident during rotation. The T-P interval changed the most, for it disappeared as the cardiac rate increased while the T and P waves merged into a single arc. The QRS interval changed the least. The Q-T intervals (time of electric systole) changed in accordance with the cardiac rate.

With intense accelerations, the EKG revealed impairment of the cardiac rate in the form of single, or less commonly group, extrasystoles. The electric systoles were chiefly of ventricular and, in just a few monkeys, of atrioventricular origin. In some cases, they originated in several places. Most of the animals at this time had sinus arrhythmia. Some experiments yielded evidence of impaired heart conduction in the form of a sinoatrial block.

Appreciable changes were noted in the voltage of the EKG waves. The P wave during the action of the "square" was less common in the front and bottom leads (electrode placement by Nebo's method), while in the back lead it decreased on the average 1-1/2 to 2 times as compared with the original value. In some instances the P wave disappeared almost entirely in the bottom lead. The T wave decreased during the accelerations. It became isoelectric during the "square", sometimes smoothed out, biphasic, and occasionally negative.

Changes in cardiovascular indexes were transient, disappearing in the first 10-20 minutes of the aftereffect period, although occasionally persisting for 20-30 minutes. The respiratory rate was more or less restored in the first 10-15 minutes.

These disruptions of bioelectric myocardial activity were caused by a number of factors, mainly myocardial hypoxia, owing to impairment of coronary circulation, oxygen deficiency of the blood (dysfunction of external respiration), and, in some instances, focal hemorrhages.

It is interesting to note that in a study of catecholamines based on the trihydroxyindole method, the heart of monkeys sacrificed 30 minutes after rotation was found to contain little norepinephrine but a good deal, sometimes very large amounts of epinephrine. The adrenals at this time showed very little epinephrine.

When rotation was halted, the animals were generally sluggish and apathetic. The facial skin was pale while the buccal mucosa was cyanotic. Respiration remained rapid and deep. One monkey remained in a critical condition resembling collapse and died 20 minutes after the end of the rotation. On dissection it was found to have a fresh myocardial infarct in the anterolateral wall of the left ventricle (V. G. Petrukhin). The other animals regained their normal appearance 5-10 minutes after the end of the rotation and began to react to external stimuli, although they remained sluggish and inhibited for 10-15 minutes more. After 25-30 minutes in the vivarium, they became active and eagerly took food.

General observations of the behavior and condition of the animals before, during, and after rotation and the results of cardiac and respiratory checks showed that monkeys can tolerate accelerations of 12

units in a "chest-back" direction for 1 to 4-1/2 minutes (baboons average 3 minutes and 29 seconds; rhesus monkeys, 4 minutes and 45 seconds).

Thus, analysis and comparison of our data with observations on human beings indicate that monkeys show promise for studying the pathogenesis of many functional disorders caused by accelerations.

EFFECT OF ACCELERATIONS ON LIVER STRUCTURE

Ye. F. Kotovskiy

Morphological investigations of organs and tissues of animals subjected to accelerations constitute an important activity of aviation and space medicine. This report presents the results of a histological study of the liver of animals subjected to lateral accelerations under experimental conditions.

References in the literature on this subject are few. One such, by a team of American scientists (Beckman, Ziegler, Diaen, and Hunter, 1953), dealt with monkey tolerance of accelerations, and found that chest-back accelerations of about 40 g cause foci of degeneration and regeneration in the liver. Using the method of freezing white rats in liquid nitrogen right in a centrifuge, Hell and Cranmore (1953) found that head-pelvis accelerations of 15-19 g cause marked visceral deformity and redistribution of vascular blood. The liver is sharply stretched in the direction of the accelerations; blood flows out in the same direction. V. G. Petrukhin (1962) investigated viscera of animals carried on Sputniks 2, 4, and 5. He found in the liver venous stasis and granular, vacuolar, and fatty degeneration of hepatic cells. These changes disappeared by the 60th day after the flight.

We used 28 male dogs (2 groups of 14 animals each) weighing 10-15 kg. The first group was subjected to 8-fold accelerations in a chest-back direction for 3 minutes; the second group, to 12-fold accelerations in the same direction for 1 minute. Five dogs of the same age and weight served as the control. Two animals were sacrificed with ether fumes 1 hour, 1, 3, 7, 15, 30, and 60 days after the experiment. Fragments of liver were taken from the ventral, central, and dorsal portions of the left lobe. Paraffin and celloidin sections and sections prepared in a freezing microtome (5, 10, and 20μ thick, respectively) were stained with hematoxylin-eosin, Sudan III, methyl green pyronin, and by Mallory's method.

Results

The first and second groups showed similar morphological and histological liver changes, essentially of two kinds: (1) vascular changes, and (2) changes in hepatic cells and bile duct cells. The vascular changes apparently began to set in while the animals were in the centrifuge. An hour after the experiment, the central, collecting, and, above all, interlobular veins as well as the intralobular capillaries were markedly dilated and overflowing with formed blood elements. Many of them showed leucocytes on the margins, some emigrating to the vascular wall and surrounding tissue. Some of the large interlobular veins were destroyed, apparently because their walls ruptured during the experiment. At the site of the destroyed veins and in the surrounding tissue were the foci of hemorrhages, the size of the liver lobules. Most of the interlobular arteries preserved their normal structure. A few showed leucocytic infiltration of the connective tissue. Vascular changes progressed during the first three days: many of the interlobular veins were characterized by desquamation of endothelium, wrinkling and disintegration of nuclei of the smooth-muscle elements, and saturation of varying portions of the walls with blood. Destruction of the vascular walls gave rise to "secondary" hemorrhages, usually small and localized around the blood vessels.

Besides the small perivascular hemorrhages, we noted at this time other hemorrhages as large as or larger than the liver lobules. Small hemorrhages were also found within the liver lobules along the sinusoid capillaries. The impairment of blood circulation was paralleled by impairment of lymph circulation. During the first three days we noted marked dilatation of the interlobular lymphatics and the appearance of perisinusoidal spaces between the sinusoid capillaries and trabeculae. The hemorrhages formed during the first three days were later resorbed. Macrophages, Kupffer and endothelial cells of the interlobular blood vessels participated in this process. The protoplasm of all these cellular forms contained masses of dark brown granules, apparently hemosiderin pigment. The processes of hemorrhage resorption continued up to 30 days.

The most pronounced parenchymatous changes occurred during the first week of the experiment, the period of marked vascular disorders. These changes were (1) irreversible, (2) degenerative, and (3) reversible dystrophic processes. The first type were local and affected small portions of the parenchyma near the hemorrhages. The dystrophic changes, however, involved large portions of the glandular parenchyma, with death of the liver cells in the region of the hemorrhages. The more massive the hemorrhages, the larger was the portion of the parenchyma undergoing necrosis. In some cases, the blood that flowed out of the vessels broke up the lobules into individual segments, which later disintegrated. Small foci of degeneration of liver cells also appeared in the liver lobules near the capillary hemorrhages.

Destruction of liver cells in these areas was accompanied by rapid fatty infiltration and pigmentation of their cytoplasm. Solitary or small groups of dead liver cells were found in the lumens of the large interlobular and collecting veins, apparently due to destruction of their walls. The hepatic cords atrophied near the hemorrhages to about half their normal thickness because of compression by the extravasated blood. A comparatively faint leucocytic and macrophagic reaction was noted in the areas of destroyed parenchymatous elements. The degenerative processes continued for 7-15 days. Reversible dystrophic phenomena of different kinds, which developed during the first week of the experiment in the liver cells not affected by these processes, were manifested in a decrease in RNA and appearance of fat drops and pigment granules in the liver cell protoplasm. On the first day of the experiment, pyroninophil granules appeared only in the perinuclear zone of the protoplasm, the remainder of the cytoplasm not staining with pyronin. Also, many of the liver cells were characterized by a peculiar process involving the emergence of nucleoli from the nuclei into the cytoplasm, which interfered with the synthesis of RNA in the cells. Small drops of fat accumulated in the cytoplasm of the liver cells, but disappeared on the 7th day. However, large drops of fat were seen one hour after the experiment in a few liver cells on the periphery of the lobes. As a result, the liver cells came to look like fat cells. These cells eventually degenerated.

In some animals, liver cell cytoplasm was found to contain small brown granules--apparently bile pigment--which are characteristic of a congestive liver. The interlobular bile ducts changed considerably. At first there was fatty infiltration and vacuolation of the cytoplasm of the cells and occasionally desquamation of the cells in the bile duct walls. From the 3rd day on, there was a rapid growth of the ducts, as shown by the formation on the duct walls of numerous cell "buds", which then turned into cell strands and tubules which frequently penetrated between the hepatic cords deep into the lobules. By the 30th day of the experiment, the aforementioned changes in the vascular bed and parenchymatous elements were compensated by hypertrophy and multiplication of the liver cells. Occasional instances of mitosis were found the day after rotation. By the 7th-15th days, the number of binucleate liver cells had increased by about 4 percent, and there was evidence of metaplasia of bile duct cells into liver cells.

The fact that the liver changes and the hemorrhages were much more common in the dorsal portions, proves that the injurious effect of accelerations on the liver is greater in the direction in which they are applied to the body. The changes in both groups of dogs were similar, although they varied in intensity. The scale of the changes was far greater in the dogs of the second group. Apparently, under the given experimental conditions, the degree of liver vulnerability is related more to the duration of the accelerations than to their intensity.

THE USE OF HYPERVENTILATION IN SELECTING CANDIDATES FOR FLYING SCHOOL

A. K. Kochetov

Hypocapnia, which, together with hypoxia, is regarded as the possible cause of decreased piloting efficiency at times of great emotional stress, is receiving considerable attention. Some authors believe that hyperventilation, which sometimes reduces the pilot's psychomotor efficiency during flight, increases with the speed of the plane (Balke et al.). Hence, a hyperventilation test is highly important in selecting candidates for flying school or in examining pilots. This functional test combined with the EEG can be used to detect latent CNS pathological impairment and to identify individuals with high sensitivity to hypocapnia.

Flying school candidates were given EEG's in 1961-1962. The biopotentials of the brain were recorded on an 8-channel Al'var oscillograph from the right and left hemispheres--bipolarly and unipolarly--from the forehead, temple, and occiput while an EKG was recorded at the same time in the three standard leads. The men were examined at rest, sitting in a lighted room with eyes open and closed, and with voluntary hyperventilation.

Hyperventilation with recording of an EEG can be achieved in a variety of ways. In the commonest method, the examinee is asked to breathe as deeply as possible once every 2-3 seconds, continuing for 3 minutes during which time the EEG is recorded. We did not adopt this method since it is not effective in detecting individual sensitivity to hypocapnia. For example, we observed that some persons, including well-trained athletes, would complain, after 10-12 respirations, of such disagreeable sensations as parasthesia, dizziness, and impaired vision, whereas persons tolerant of hypocapnia continued to feel well for a long time.

The method we used detected individual differences in sensitivity to hypocapnia. The examinee was asked to breathe deeply at any rate he wished until he experienced disagreeable sensations, which he reported to the experimenter. The time, noted on the EEG, was recorded both before and after the sensations for the 30-40 seconds (depending on the EEG changes) during which hyperventilation continued.

In some examinees, the alveolar air was collected at the onset of the disagreeable sensations and again when slow oscillations distinctly appeared on the EEG and the CO_2 content was determined. It was thus

possible to determine the degree of hypocapnia when the subjects experienced disagreeable sensations and to compare the data with the corresponding changes on the EEG.

Development of the hyperventilation syndrome was marked by changes in general condition. Some subjects became pale, others red, with a sharp increase in the tremor of the closed eyelids and fingers when the hands were outstretched. Handwriting, in some cases, changed and errors, including perseveration, occurred.

At different times the examinees mentioned feeling unusual and, for the most part, disagreeable sensations. In half of the subjects, the first symptom was paresthesia, "the crawling of small ants" on the hands or face; in others, the sensations were like "pins and needles" in the leg.

As hyperventilation continued, the examinees began to complain of dizziness, general weakness, sensation of "heat or cold", light flashes or a gray shroud in front of the eyes, etc.

The disagreeable sensations occurred with different degrees of hypocapnia. For example, in some individuals they arose when the P-CO_2 in alveolar air dropped to 28-30 mm Hg, whereas others did not complain even when the P-CO_2 dropped to 20-22 mm Hg.

Six persons exhibited pathological symptoms which persisted for 10-15 seconds after hyperventilation was halted. Four developed lagophthalmos; one had spasmodic twitching of the fingers and eyelids; one had a loss of convergence and smoothing out of the right nasolabial fold. Three persons were disqualified on the basis of a neurological examination and EEG data.

In the hyperventilation syndrome, no clear-cut relationship was noted between subjective sensations and brain bioelectric changes. While the examinees were experiencing the disagreeable sensations characteristic of hypocapnia, their EEGs showed a variety of changes: appearance of solitary or diffuse high-amplitude slow oscillations and activation of the α or β rhythms. At the same time, some subjects had EEGs on which the Δ or θ waves became dominant even before they experienced any disagreeable sensations.

The EEG changes were phasic. At the beginning of hyperventilation the high-frequency oscillations were activated and, at times, so was the α rhythm. Later, as hypocapnia set in, the EEG revealed single or small groups of slow high-amplitude waves (about 200 μv) of about 3-6 cps, which quickly disappeared after hyperventilation was halted. Thus, the phase changes in hypocapnia are very similar to the EEG changes described in acute hypoxia.

In conclusion, we wish to point out that the hyperventilation test, with simultaneous EEG recording, is sometimes of value in detecting rather delicate CNS impairments and in identifying persons with low tolerance of hypocapnia. The latter is important in flying because the complex situations that arise during flight increase the pilot's emotional stress, a leading cause of hyperventilation.

PRINCIPLES GOVERNING THE OBJECTIVE EVALUATION OF THE THERMAL STATE OF THE BODY

V. I. Krichagin

Essential in evaluating the airman's body reserves in flight, during and after takeoffs, during 24-hour details requiring the handling of modern special equipment, is an index of his thermal state. This entails ascertaining the degree of pressure exerted by the body's thermoregulatory mechanisms in order to forestall serious disorders caused by overheating or supercooling and to determine the varying effects of this pressure on efficiency. All findings indicate that the objective and subjective data pertaining to the thermal state should be comprehensively evaluated.

1. General Evaluation of Adaptability to Environmental Conditions

On the basis of published data and personal observations, we prepared a table that provides an estimate of the possibility of maintaining body heat balance under various thermal conditions. It may also be used for provisional analysis of the experimental data from the thermal gradients between the surface of the skin and clothing, air and surrounding objects in relation to thermal insulation of clothing, etc.

2. Evaluation of the Thermal State from Objective Characteristics

On the basis of numerous reports by Soviet and foreign investigators and our own investigations, we suggest these gradations of thermal states (in a condition of relative rest).

(a) Comfortable state: complete absence of subjectively sensed information on the thermal state (absence of a dominant heat focus of excitation in the cerebral cortex).

Objective data:

(1) Net weight loss (by imperceptible perspiration--50 ± 10 grams/hour).

(2) Absence of visible signs of perspiration.

(3) Rectal temperature--37 ± 0.4°.

(4) Axillary temperature--36.5 ± 0.5°.

(5) Changes in rectal or axillary temperature--by no more than ±0.2° per hour.

(6) Weighted mean skin temperature--33.3 ± 1.0° C.

(7) Difference between trunk and extremities temperature within 3 ± 0.5° C.

(8) Temperature and humidity of underclothing air within the limits of evaluation of heat sensation from underclothing air.

(b) State of Slight Pressure Exerted by the Physiological Mechanisms That Block Heat Emission: mild sensations evaluated as "cool"; often regarded as "comfortable" in the presence of a stronger functioning dominant or good heat protection of the extremities (a basic receptor field). Coolness is clearly perceived only after a loss of 30-40 large calories of heat, i.e., after a long period of time.

Objective data:

(1) Slight pallor; collapse of surface veins on forehead and extremities.

(2) Net weight loss--at or below the comfort level.

(3) Rectal and axillary temperatures drop at the rate of no more than 0.2° per hour to a point below the comfort level.

(4) Weighted mean skin temperature--31.3 ± 1° C.

(5) Difference between trunk and extremities temperature--4.5 ± 0.5° C.

(6) General physiological indexes (pulse, respiration, metabolism, etc.) remain virtually unchanged.

(7) Temperature and humidity of underclothing air fall in region 1 on the table mentioned above.

(c) State of Strong Pressure Exerted by the Physiological Mechanisms That Block Heat Loss by the Body: distinct sensation of general and local coolness, felt when the body loses 70-90 kcal of heat; reflects a more rapid body heat loss.

Objective data:

(1) Greater systemic pallor, sometimes local reddening of exposed parts of the face and hands with some bluish (congestive) tinge.

(2) Rectal temperature--35.5 $\pm$ 0.4° C.

(3) Weighted mean skin temperature--29.3 $\pm$ 1.0° C.

(4) Difference between trunk and extremities temperature--from 5 to 15° C.

(5) 10-15 percent increase in metabolic rate without shivering and 20-50 percent increase with periodic shivering.

(6) Acceleration of pulse by 10-15 beats/min.

(7) Temporary stabilization of temperature characteristics after inclusion of chemical thermoregulation.

(d) State of Marked Coolness of the Body (Followed by Breakdown of Compensation): definite sensation of "very cold", which develops after body loses more than 180-200 kcal of heat; reflects rapid body heat loss.

Objective data:

(1) Drop of rectal temperature below 35° C.

(2) Progressive drop of weighted mean skin temperature below 28° C.

(3) Progressive drop of extremities temperature until loss of skin sensitivity and complete freezing starting with the hands and feet.

(4) Sharp temporary increase in metabolic rate to 300° and corresponding pulse acceleration to 120 beats/min, which stops after rectal temperature falls below 33.5-34.0° C.

(5) Stable temperature characteristics (temporary breakdown of compensation).

Overheating can be differentiated in about the same way.

(a) State of Slight Pressure Exerted by the Physiological Mechanisms That Increase Heat Emission by the Body: a sensation of "warm"; rather sharply distinguished from the comfortable state by increased heat emission due to evaporation.

Objective data:

(1) Slight reddening of the skin, veins distinctly visible on the forehead and extremities.

(2) Rectal temperature--37.0-37.2° C.

(3) Axillary temperature--36.6-37.0° C.

(4) Increase in net weight loss of about 250 g/hour; perspiration evident on various parts of the body.

(5) Weighted mean skin temperature--34.9 ± 0.7° C.

(6) Difference between trunk and extremities temperature--1.8 ± 0.7° C.

(7) Acceleration of pulse by 7-10 beats/min.

(8) Temperature and humidity of underclothing air fall in region 3.

(b) State of Strong Pressure Exerted by the Mechanisms That Increase Heat Emission by the Body: distinctly unpleasant sensation of "hot".

Objective data:

(1) Marked reddening of the skin, swelling of the surface veins of the face and extremities.

(2) Rectal temperature unchanged or elevated only 0.3-0.4° C.

(3) Net weight loss due to perspiration evaporating or running off at the rate of 250-400 g/hour.

(4) Excessive perspiration, wetting clothing.

(5) Weighted mean skin temperature--36 ± 0.6° C.

(6) Difference between trunk and lower extremities temperature less than 1° C (skin temperature of the lower extremities and forehead

is characteristically higher than that of the upper extremities and trunk, respectively).

(7) Acceleration of pulse by 8-15 beats/min.

(8) Temperature and humidity of underclothing air fall in region 4.

(c) State of Sharp Pressure Exerted by the Mechanisms That Increase Heat Emission by the Organism (Followed by Breakdown of Compensation): severe, intolerable sensation of "very hot"; indicates ambient temperature is beyond the adaptive capacity of the body.

Objective data:

(1) Marked reddening of the skin and swelling of the veins (pallor upon decompensation).

(2) Net weight loss of from 400 to 2000 g/hour, hidrosis.

(3) Weighted mean skin temperature--more than 36.6° C.

(4) Progressive elevation of rectal temperature--by more than 0.3° C per hour.

(5) 15 percent increase in metabolic rate (with elevation of ambient temperature each degree above 37°).

(6) Acceleration of pulse by more than 15 beats/min, maximum--140 beats/min.

(7) Stability of temperature characteristics temporary, maintained from 30 minutes to 8 hours, depending on severity of environmental conditions.

(8) Temperature and humidity of underclothing air beyond the zone in which a balance can be maintained.

The limit of tolerance is reached when the body accumulates excess heat amounting to 1.43 kcal per kg of weight (100 kcal for an adult male weighing 70 kg).

The data outlined above can be used as criteria for evaluating the body's heat state. Allowance has to be made, of course, for individual deviations and exceptional cases.

CHANGES IN SOME PHYSIOLOGICAL FUNCTIONS RESULTING FROM EXPLOSIVE DECOMPRESSION

A. G. Kuznetsov, A. S. Tsivilashvili and A. R. Mansurov

It is well known that cabin depressurization in high-altitude planes subjects the crew to pressure drops. The drop may be slow (motor failure, slight damage to the cabin wall) or rapid (explosive decompression: rupture of the canopy, severe damage to the cabin wall). Explosive decompression causes significant physiological changes, varying with the magnitude, rate, and number of pressure drops.

In this investigation of physiological effects of large and rapid pressure drops, dogs and rabbits were placed in a specially constructed chamber in which barometric pressure was reduced for 0.3-0.004 second. The parameters of explosive decompression were predetermined. Procedures included: recordings of respiration (rate and rhythm), biopotentials of the respiratory muscles, EKG, and arterial blood pressure; roentgenography and cinefluorography (8-16 frames per second) of the thoracic and abdominal organs and roentgenokymography of the diaphragm and ribs of intact animals; action currents from the diaphragm and vagus nerves of anesthetized dogs and nonanesthetized rabbits.

Immediately after the pressure was reduced, all animals experienced respiratory arrest (apnea) lasting 2-15 seconds, which sometimes returned for 3-4 seconds after the first inhalation. Although respiration was then restored, its rhythm and depth were usually impaired--shallow breaths followed by deep ones. Normal rhythm and depth were generally restored as the animals were being lowered to an "altitude" of 5000-6000 m.

Suspension of respiration for several seconds after explosive decompression is probably reflex in nature, the result of receptor stimulation caused by distention in lungs and gastrointestinal tract.

Fluorograms of animals with body unbandaged made 0.02 second after pressure drop revealed various changes, chiefly in the lungs, diaphragm, and heart, as well as a marked enlargement of gastrointestinal gas bubbles and formation of vapor and gas in the organs and tissues.

Roentgenokymograms of the diaphragm and ribs showed marked impairment of external respiration. In most cases, respiration was very frequent and more shallow than at the start.

There are references in the literature to the neuroreflex nature of respiration inhibition by creating excess lung pressure. A. G. Kuznetsov, G. V. Altukhov, and N. A. Agadzhanyan demonstrated in nonanesthetized

animals that increased intrapulmonary pressure following vagus transection does not inhibit respiration. However, since no direct experimental data were obtained during explosive decompression, a series of experiments was run on nonanesthetized rabbits with recording of the action currents of the vagus nerves, which invariably yielded an intensified flow of impulses as soon as the pressure was reduced. Bioelectric activity generally remained high throughout the period of apnea. Results showed that the period of apnea was characterized by a heavy flow of impulses through the vagus nerves, the maximum occurring 2 seconds after explosive decompression.

It was of some interest to determine the state of the respiratory center at a time when there were no respiratory movements of the thorax, for which the biopotentials were recorded from the diaphragm. In all the experiments, impulses flowed steadily from the diaphragm after explosive decompression against a background of apnea. These data imply an obvious lack of inhibition of the respiratory center under these conditions. Marshak and Mayeva (1961), who observed a similar phenomenon in animals exposed to hypocapnia, came to the same conclusion.

A study of the biopotentials of the intercostal muscles and obliquus abdominis externus and internus showed that in all cases explosive decompression was followed in a few seconds by a continuous flow of impulses from these muscles. Amplitude and duration of the impulses varied with magnitude and speed of the pressure drop: substantial with great intensities and speeds, achieving in some experiments 300-400 mv and 3-4 seconds, respectively. Maximum EMG amplitude occurred 1-3 seconds after a pressure drop, then gradually decreased until it disappeared entirely only to reappear with restoration of thoracic respiratory movements. Muscular contraction, for the most part, coincided with exhalation.

Other authors (A. G. Kuznetsov, M. I. Vakar, V. S. Gurfinkel', et al., 1953) first noted the stimulation of a flow of continuous impulses from the respiratory muscles by explosive decompression--apparently a protective reflex in response to excess pressure arising in the lungs and gastrointestinal tract. It is worth noting that vagus transection did not obliterate the biopotentials of the respiratory muscles, indicating the vagus nerve is not the only stimulus of this reflex. Other causes are indirect pathways represented by the nerve fibers that form part of the sympathetic chain, and the proprioceptors of the muscles and ligaments in the thoracic skeleton.

It was later found that explosive decompression intensifies the biopotentials not only from the respiratory muscles but from muscles not directly involved in respiration, particularly the femoral muscles.

In most of our tests, explosive decompression was followed in a few seconds by a decrease in the cardiac rate (bradycardia), a result observed also by other authors (Hitchcock, 1953; Gelfan, Nims, and Livingston, 1950; others). Bradycardia in animals subjected to explosive decompression was more pronounced 2-3 seconds after the pressure drop. Like apnea, bradycardia is reflex in origin and caused by distention of the lungs and gastrointestinal tract due to excess pressure. To prove its reflex nature, vagus transection and exclusion of the parasympathetic nerves by atropinization were performed experimentally: in all animals, the cardiac rate generally increased after explosive decompression; occasionally it remained unchanged.

As mentioned above, arterial blood pressure was measured in some of the rabbits. In the carotid artery at the time of explosive decompression, blood pressure increased by about 50-70 mm Hg. After the pressure drop, blood pressure usually fell within 1-2 seconds to a lower level than before (70-90 mm Hg below normal). At the same time, pulse pressure rose sharply to the point of total disappearance of the pulse oscillations.

The transient elevation of arterial pressure during explosive decompression was apparently due to the mechanical effect on the blood vessels of the mediastinum. The subsequent decrease in arterial pressure was probably reflex in nature and caused by the marked elevation of intrapulmonary and intraabdominal pressure following explosive decompression. This assumption found support in the experiments with a vagotomy, in which, after a temporary decrease, arterial pressure again rose and remained high for several minutes. This was obviously caused by exclusion of the impulses proceeding to the CNS from the lungs and gastrointestinal tract through the vagus nerves, which were transected here.

The data show that explosive decompression causes, in a very short time, major changes in main physiological functions. These changes are reflex in nature and vary with the type of decompression.

CHANGES IN RESPIRATORY AND CARDIOVASCULAR FUNCTIONS AFTER PROLONGED EXPOSURE TO LOW BAROMETRIC PRESSURE

A. G. Kuznetsov, N. A. Agadzhanyan, Yu. P. Bizin, N. I. Yezepchuk, I. R. Kalinichenko, L. I. Karpova, I. P. Neumyvakin and M. M. Osipova

Conquest of outer space must await solution of many biomedical problems especially those relating to the gas exchange and cardiovascular effects of prolonged exposure to rarefied atmosphere. There is a limited number of published reports on the subject (D. K. Ivanov, V. B. Malkin, V. L. Popkov, Ye. O. Popova, and I. N. Chernyakov, 1961; V. P. Zagryadskiy et al., 1961; Welch, Morgan, and Thomas, 1961).

This project involved extended exposure of two subjects to low barometric pressure corresponding to an altitude of 7000 m (with a partial pressure of oxygen of 150-160 mm Hg), and study of the dynamics of gas exchange, cardiovascular function, and peripheral blood. Gas exchange was investigated while the subjects were resting (basal metabolism), and during and after physical exercise (40 squats in 2 minutes) using the combined Douglas-Haldane method and spirometabollograph. For fuller understanding of respiratory function, measures were taken of the minute ventilation (MV), vital capacity, and volume of reserve and additional air.

For comparability, the value of the MV and oxygen utilization were reduced to 0° C and 760 mm, and a correction was made to allow for the respiratory coefficient (RC) effect. Due to the lack of tables showing values of the coefficient (F), we compiled a conversion table to suit the rarefaction conditions in order to bring the gas saturated with water vapor to a dry state, 0° and 760 mm Hg.

In our investigation, prolonged exposure to an artificial atmosphere reduced oxygen utilization by subjects at rest by 6-17 percent the first month, and by 34-36 percent the second month; somewhat less pronounced was the decrease in release of CO_2. As a result, the respiratory coefficient gradually rose from 0.75-0.82 to 0.97-1.1.

The amount of heat emitted dropped 7.5-14 percent the first month, and 28-34.5 percent the second month. The MV decreased 5-10 percent the first month, and 9.5-25 percent the second month.

By the end of the experiment, the cardiac rate decreased by 8-10 beats (20 percent) on the average, and the maximum and minimum arterial blood pressure decreased by 10-16 percent and 7-8 percent, respectively.

The fact that the pulse rate decreases after prolonged exposure to low barometric pressure has been noted also by other authors (D. I. Ivanov, V. B. Malkin, et al., 1961; A. D. Seryapin, 1961; others).

In analyzing these data, it should be borne in mind that the cholinergic action of the vagus nerve is impaired under conditions of relative adynamia. The predominance of the adrenergic action of the sympathetic nerve results in metabolic changes in the blood vessels and tissues (Raab, 1955).

The literature has references to changes in blood pressure after exposure to low barometric pressure (Morgan, Ulvedal, and Welch, 1961). These changes are reflected in decreased diastolic pressure with simultaneous impairment of myocardiac excitability, as shown on the EKG. Our experiments failed to detect any significant EKG changes in subjects remaining a long time at a high altitude; there was merely a slight decrease in the maximum values of the R and P waves.

In checking the functional capacity of the body in response to measured physical exercise, the orthostatic and Valsalva tests were made in order to ascertain the degree of deconditioning. Results show that the reactions to the functional tests varied with the duration of the experiment. At the end of the experiment, there was generally a considerable increase in the pulse in response to measured physical exercise. At the same time the periods of pulse restoration to the original level lengthened while "negative phases" of blood pressure developed, a phenomenon regarded by most authors as an indication of cardiovascular fatigue--autonomic-vascular instability (S. S. Mindlin, 1930; Gorinevskaya, 1944; B. A. Ivanovskiy, 1935). These events were probably brought about by general asthenia, decreased vascular tone caused mainly by insufficient motor activity, and diminished flow of afferent impulses.

In addition to investigating gas exchange and the cardiovascular system, we examined the peripheral blood supply under rarefied atmospheric conditions. Owing to extreme instability, the blood system reflects at the same time all the physiological changes resulting from exposure to a variety of environmental factors--physical, chemical, mental, etc.

We found that the hematological changes were very slight--only a trivial increase in the erythrocytes, reticulocytes, and hemoglobin. The increase in erythrocytes and hemoglobin was probably caused by blood clotting, which may occur at high altitudes following disruption of the water balance. This mechanism of erythrocytosis cannot be ruled out entirely, but it does not seem to be the only one.

The leucocyte count was within normal limits. The absolute number of eosinophils in the second half of the experiment was 1-1/2 to 2 times below the original values. An investigation of the phagocytic activity

of the neutrophils showed that the phagocytic number and phagocytic index increased by the end of the experiment. The increase in phagocytic activity was preceded by an inhibition phase.

The above-described changes in gas exchange, like the other physiological functions, were largely due to hypodynamia, which caused the metabolic level to drop. This was shown by the fact that the gas-exchange function became virtually normal 8-10 days after the end of the experiment and the subjects resumed their regular activities.

It is our view that in itself the factor of low barometric pressure (308 mm Hg) with normal partial pressure of oxygen (150-160 mm Hg) has no significant effect on the body, specifically, on the gas exchange function. If rarefaction has some biological effect, it is probably realized through water metabolism.

CHANGES IN THE VECTORCARDIOGRAM OF FLIGHT PERSONNEL IN EARLY STAGES OF HYPERTENSION

Ye. I. Kuznetsova

Vectorcardiography has not yet found the application it deserves in aeromedical practice. Only a few reports are available in which this method has been used in examining individual personnel. In our work we have tried to find earlier supplementary criteria for evaluating the condition of the cardiovascular system in flight personnel.

Our report presents material based on data from a study of 55 individual fliers, 30 to 49 years old, of whom 25 were normal and 30 had a diagnosis of hypertension in the first stage A-B according to L. A. Myasnikov's classification.

All individuals were given a general clinical examination. Vectorcardiograms were first analyzed by comparing them with electrocardiographic data and data from X-ray examination, then recorded by the 5-plane system of I. T. Akulinichev. Results were treated statistically for reliability and incorporated into the table.

The table makes it evident that the average value of the maximum vector of the QRS loop in hypertensive patients has a tendency to increase in all 5 planes. This apparently stems from an increase in the difference of the bioelectric field of the myocardium.

Average Data of Vectorcardiogram Analysis

	Planes / Groups examined	I	II	III	IV	V
Basic axis of the QRS loop in five planes (Akulinichev method)	Healthy	29.1	30.2	29.6	21.2	14.2
	Hypertension, first degree A-B	34.3	34.8	34.6	23.5	15.8
	Reliability	90	90	90	-	-
Angle of deflection of the basic QRS axis in degrees by planes	Healthy	97.4	85.3	88.5	-71.8	-86.3
	Hypertension, first degree A-B	91.4	86.7	93.2	-83.0	-91.6
	Reliability	90	-	90	90	-
Basic axis of T loop in mm	Healthy	8.0	8.6	7.9	6.6	3.7
	Hypertension, first degree A-B	7.2	7.5	7.5	6.6	4.6
	Reliability	-	90	-	-	95
Angle of deflection of the basic axis of the T loop in degrees	Healthy	93.3	92.9	72.6	-95.8	-80.5
	Hypertension, first degree A-B	93.3	92.9	83.6	-90.5	-91.3
	Reliability	-	-	98	-	90
Angle QRS-T in degrees	Healthy	6.3	9.3	13.0	8.5	10.5
	Hypertension, first degree A-B	15.8	13.8	15.6	15.9	21.2
	Reliability	99	-	-	90	-

Note: Reliability is expressed in percent; plus values are expressed without the sign.

It must be noted that with the increase in the maximum axis of the QRS loop, a simultaneous deformation of this wave is observed in a number of cases because the formation of an additional axis resulting from a rise mainly in its terminal deflection, which also leads to a broadening of the loop. A broadening of the loop is noted quite frequently in projections I, II and IV in our material.

An additional axis is frequently seen isolated only in projection IV, which supports the concept, judging from the literature, that the indicated changes develop earliest in the apical region.

In most hypertensive patients, the direction of registration of the QRS loop is counterclockwise in projection I and clockwise in projection IV. These data testify to the tendency of the vector components of the period of depolarization to deflect to the left and back, which also supports our feeling concerning the primary localization of the process, conditioning the difference in bioelectric potentials in the region of the apex of the heart. In patients in the initial stage of hypertension, however, a regular change is noted in the direction of the vector of repolarization in plane III, i.e., from the front back and to the left. Besides, the integral vector of repolarization is regularly increased in projection V, and has a tendency to change in projection II. This can be regarded as an initial intensification of metabolic processes of the myocardium.

Thus, vectorcardiography makes it possible, at very early stages of hypertension, to determine the fine metabolic changes which lead to a disturbance of the myocardium's regular bioelectric polarity.

EKG CHANGES IN FLIGHT PERSONNEL AFTER PROLONGED NONSTOP FLIGHTS

N. M. Kulikova

The execution of prolonged nonstop flights by the crews of turboprop airplanes introduces the question of the degree of fatigue of flight personnel in fulfilling such trips.

It is known that a pilot's ability to work is determined to a significant degree by the functional condition of his CNS, cardiovascular, and other systems. From the point of view of the cardiovascular system definite negative shifts are not infrequently observed during flight activities. Definite changes, produced by fatigue, were detected during EKG examinations. Thus, A. E. Krimsteyn examined flight personnel and

noted that in periods of biweekly and monthly flight loads, changes appeared in the EKG characteristic of the recovery period after severe but "bearable" physical stresses. The author points out that two or three flights evoked changes corresponding to a significant but "bearable" stress. In daily stress the EKG changes for pilots corresponded to moderate or significant but well endured loads, while for navigators the changes corresponded to highly wearying or excessive flying loads.

The influence of fatigue on the character of the EKG was also shown in the work of Têng Su-I, where the EKG of practically normal students at the time of an examination session, showed simultaneously and in parellel an increase in the systolic index with shortening of the cardiac cycle (R-R and QRST).

The present work sought to determine by the EKG method changes in the cardiovascular systems of flight personnel who were carrying out 8-9 hour nonstop trips in turboprop planes on the Moscow-Khabarovsk-Moscow route. The EKG's were recorded 1 hour after the plane landed in the airport, 24 hours after rest in Khabarovsk, and 2-3 days after rest in Moscow. The recording was done at the prophylactic airports in Khabarovsk and Moscow on the EKP-60 apparatus with 3 standard leads and in the third lead at the height of a deep breath. The EKG was recorded both at a resting state (in a lying position) and after a stress dosage (15 knee bends in the course of 20 seconds). In all, 226 EKG's were registered and analyzed by studying the frequency and character of the rhythm, the duration of intervals (P, PQ, QRS, QRST), the value of the systolic index, the direction of the electrical axis of the heart (according to the table of Pis'menniy), the voltage of the P, R and T notches in the 3 standard leads.

EKG indexes for all members of the crews during observation both after flight and after rest did not exceed the limits of normal, physiological values. Comparison of initial data (after 2-3 days of rest) with the EKG data after flight revealed the following.

After flights, all the cabin captains and the majority of the copilots and navigators maintained a sinus normal rhythm. Four of the copilots in the resting condition registered a sinus arrhythmia which disappeared after a load dosage, and 6 individuals showed a sinus arrhythmia after a stress.

After 8-9 hour nonstop flights, the majority of the cabin captains (70 percent) in a resting condition presented an increase in frequency of rhythm of the heart contractions, averaging 10 beats per minute. The majority of the copilots and navigators (66.6 percent) presented a decrease in frequency, averaging 9 beats per minute. After a stress dose, almost all crew members showed an increased frequency in the

rhythm of heart contractions, expressed in almost the same degree in the cabin captains and the rest of the crew.

Intraatrial and intraventicular conductivity in all of those examined did not change. A slowing of the atrioventricular conductivity by 0.02 second was noted in 1/3 of the cabin captains. In the remaining members of the crew no change was observed in atrioventricular conductivity. After a stress dosage, no disturbances were registered in the conduction of the sinus impulse by the conducting system of the heart.

The value of the systolic index (SI) for the majority of the crew members agreed with the normal for the given rhythm. In some of the cabin captains examined it exceeded the normal. Thus, in the resting state in 22 percent of the cabin captains the SI exceeded the normal by 6-15 percent. After a physical stress the SI value for the cabin captains exceeded the normal in a large percent of the cases (47 percent). In 20.5 percent of the cases an increased SI was noted in the copilots and navigators (6-10 percent in comparison with the normal for the given rhythm).

After a flight the majority of the flight personnel examined at a state of rest showed a counterclockwise displacement of the electrical axis of the heart (EAH). Thus, in 75 percent of the cabin captains the EAH shifted 12° on the average; in the copilots and navigators a similar deflection was noted in 61.9 percent. After a stress dosage the EAH in the majority of the crew members shifted 9° clockwise on the average, a larger percentage of the cases in the cabin captains (78.4 percent) than in the other crew members (61.3 percent).

Changes in the voltage of the EKG notches appeared as a lowering of the value for the T notches. Thus, in 1/3 of the cabin captains, a lowering of 0.5-1 mm in the T notches was noted in the first and second leads. At the same time, the copilots and navigators registered an increased T voltage in the three standard leads (T_I to 1 mm in 42.9 percent; T_{II} to 1.4 mm and T_{III} to 1.1 mm in 66.1 percent). After a stress dosage the majority of the flight personnel presented a decrease in the voltage of the EKG notches, expressed mostly by the cabin captains.

The changes referred to above in the frequency of the heart rhythm after flight are probably associated with changes in tone of the extracardial nerves. The lengthening of the auriculo-ventricular conductivity with simultaneous acceleration of the rhythm of the heart contractions, noted in the cabin captains, can be viewed as the result of a disturbance in the usual correlation of the tone of the extracardial nerves, or as the result of a lowering of the conductivity of the atrioventricular node under the influence of fatigue. The counterclockwise shift of the

EAH can be related to an increase in bioelectrical activity of the left ventricle associated with changing conditions in the blood circulation as a result of a load such as a prolonged nonstop flight. The tendency to post-flight rhythm acceleration noted in the cabin captains, with simultaneous increase in the systolic index and decrease in the T notch voltage, testifies to a lowering of the functional capacity of the myocardium, probably as a consequence of post-flight fatigue. The post-flight increase in the T notch voltage with simultaneous shortening in the rhythm frequency noted in the copilots and navigators can be related to the influence of hypoxia on the myocardium.

The following conclusions can be drawn from a generalization of the results of EKG examinations of flight personnel after prolonged nonstop flights:

(a) EKG indexes in all crew members after prolonged nonstop flights do not exceed the limits of normal physiological values.

(b) After 8-9 hour nonstop flights, cabin captains both in a state of rest and after a stress dosage present changes in the EKG, indicating a lowering of the functional capacity of the myocardium, which are more expressed than in the other crew members.

(c) Changes noted in the EKGs after flights possessed a functional character; after 24 hours of rest the observed shifts were fewer in number and completely disappeared after 2-3 days rest.

(d) Post-flight changes in the EKG are to be regarded as the effects of fatigue arising as the result of stresses such as prolonged nonstop flights.

PARTICIPATION OF L. A. ORBELI IN THE DEVELOPMENT OF THE PROBLEM OF COSMIC PHYSIOLOGY

A. V. Lebedinskiy

The organization of experiments which were inaccessible to earlier workers in the field represents notable milestones in the development of physiology. The flight of man into the cosmos is such an experiment, the significance of which for the development of biological sciences has not yet received its full evaluation. As a result of this experiment mankind has savored not only the unconquerable power of scientific thought which

preserves the life of man on our entire planet, but also the wonderful possibilities of perfecting his organism by producing a healthy existence for it under unusual conditions.

One of the important reasons for success has been the development according to plan of the unfolding of the preparatory scientific work, the spirit of genuine collectivism in this gigantic labor. It would be simply unpardonable, summing up the results now, to forget its origins in the science of our country.

Thoughts about the possibility of cosmic flight were born long ago in the minds of scientists who were able to combine exact knowledge with scientific fantasy. Biologists will always hold dear the names of Tsiolkovskiy, the Schluesselburger Nikolay Morozov, who pondered over a number of important biological facets of this experiment. However, the immediate organizer of biological preparation for cosmic flight, who turned first to biology, was N. A. Rynin, the initiating founder of the Section of Aviation Medicine, NIAI, the actual organizer of which was A. A. Sergeyev. A participant in the development of problems studied by the Section was one of Pashutin's eminent students, the pharmacologist A. A. Likhachev. In this Section, and at the Department of Physiology of the S. M. Kirov Military Medical Academy, headed by Academician L. A. Orbeli, work was accomplished to complete the medico-biological support of the flight of the stratosphere balloon USSR-2, piloted by P. F. Fedoseyenko and which had on board the physicist I. D. Usyskin and the engineer A. B. Vasenko.

The scientific knowledge yielded by the ascent of the stratosphere balloon USSR-1 to a height of 18,600 meters (September 1933) and USSR-2 (January 1934) sparked the prominent research role of the problems of "stratospheric medicine," which was the genuine precursor of cosmic medicine. They found their reflection in the work of the All-Union Conference on the Study of the Stratosphere, convened in 1935 by the AS, USSR.

One report (by L. A. Orbeli) that received great attention at the Conference, proposed solutions of a number of fundamental problems, which are still important to research workers in the field of cosmic biology and medicine.

Orbeli's basic idea consisted of a demand for the cooperation of the strong features presented by the various specialties and for their realization in a definite plan. But, since L. A. Orbeli was a research scientist, for whom it was organically unusual to stop at wishes alone, tried to map out the basic content of the proposed plan of research. His work plan followed from the basic goal which he presented to the physiologists in providing for the flight of man into the stratosphere. It consisted of making it possible for the stratonaut to "actively

introduce himself" into space beyond the earth's limits, and, while under these unusual conditions, to continue to be a scientist investigating the unknown. This "activity" under any conditions was the motto of L. A. Nedarov the same man to whom we find pages dedicated in the book "Dramatic Medicine" by Hugo-Glazer, which describe his personal participation in experiments set up to study the effect of increased atmospheric pressure on the organism.

The scientific facts discovered by L. A. Orbeli led to the convictions that it is possible for a man to preserve his activity under conditions difficult for the organism. It is well known that L. A. Orbeli's world outlook was formed in Pavlov's laboratory during many years of extended personal contact with his teacher. The basic feature of Pavlov's teaching that won him over at once and retained his scientific interest for a long (and has the most immediate connection with the theme of our report).

Of course, the basic element of Pavlov's creative work was the discovery pertaining to higher nervous activity. This discovery not only let to the establishment of the laws of behavioral reactions and of the intricate reflex regulation of functions, but also presented very convincing natural scientific evidence of secondary consciousness. Simultaneously, especially from the time of the discovery of the second signal system, it was a fascinating presentation of the evolution of the adaptive mechanisms of the animal organism, and of the enormous possibilities for its perfection.

Research showed that changes of this kind can proceed in the more vitally important organs; the substrate of these actions is the nervous system as I. P. Pavlov had already shown in the eighties of the last century in connection with the influence of a reinforcing nerve on the heart muscle. These very experiments guided L. A. Orbeli to the setting up of experiments to study the influence of sympathetic innervation on the exhausted skeletal muscle.

We often underestimate the impressions which the Orbeli-Ginetsinskiy study made on the development of scientific inquiry in those years. It clearly illustrated the possibility of functioning under difficult conditions, outside the framework of the usual laws of regularity, beyond the apparent limits of working capacity. The greater adaptive capacities of the mechanisms of higher nervous activity, discovered by I. P. Pavlov, the concrete facts about the adaptive capacities of the organs and systems of the organism revealed by L. A. Orbeli, and, finally, the cortical mechanisms of mobilization of the adaptive capacities of the organism as a whole (which were systematically studied by K. M. Bykov) are different but necessary links in the concept of human physiology under extreme conditions, of which cosmic medicine represents a higher practical application.

Let us return to the Orbeli report, which is one of the pioneer events in this field. In speaking of the plan of work in the coming field of physiology of stratospheric and cosmic flights he pays due attention to the need for broad study of diverse biological specimens under these conditions. But L. A., in addition, and with all determination, emphasizes the essential role of physiology--it is, primarily, the study of highly developed organisms, and, in particular, of man. As we have already said, these investigations must be subordinated first of all to one basic task--support of the active intrusion of man into stratospheric space. This indicated the need to establish those conditions of flight in which the mental capacity of the man-investigator is preserved completely, with full comprehension of the entire gamut of his experience and sensation. From this flowed the task of studying the analytical functions of the stratonaut and, primarily, the condition of his visual functions.

It is almost 30 years since the work of the first Conference on the study of the stratosphere. The conditions of cosmic flight turned out to be somewhat different from those of stratospheric flight. Study of stratospheric flight revealed ways of physiological support of a stay within the hermetically sealed space of the stratospheric cabin and of living inside a diving suit (V. A. Spasskiy, A. P. Apollonov, M. P. Brestkin). This showed once more the need to organize and achieve a practical experiment involving the preparation of an astronaut, and realization of a method to observe the state of his organism in the process of flight. The pertinent materials are well known and there is no need to dwell on them in more detail. It must only be emphasized that this indisputable success which fell to the lot of our scientists in the organization of control over the condition of the organisms of our astronauts flows to a significant degree from the collective way, characteristic of our science, of developing scientific problems, the cooperation of biologists and engineers about which L. A. talked in his speech.

The scientific results obtained from the cosmic flights of Yu. Gagarin, G. Titov, A. Nikolayev and P. Popovich have been published (V. V. Parin, N. M. Sisakyan, V. N. Chernigovskiy and V. I. Yazdovskiy, and others), and their value is undoubted and indisputable. The general conclusions which can already be drawn from these foundations have no less significance.

When he stood before the Conference, L. A. Orbeli emphasized the inevitability of the theoretical inferences, "the importance for theory", as he said, of the new direction of the investigations. Their realization has actually enriched science, at the very least, in a number of respects. We would like to dwell on only two problems, both of fundamental importance.

"Active" injection into the stratosphere in that year and into cosmic space in our day assumes the flight of a man-investigator, a scientist. For precisely this reason the condition of the higher nervous activity of the astronaut attracts special attention. Among the various problems faced by physiologists the study of the analyzing function acquires essential importance.

Study of the analyzing function is not infrequently carried out in a one-sided way, separated from reality. The characteristic feature of the environmental conditions, the analysis of which is carried out in man, is the synthetic character of the actual stimuli, their spatial and temporal stereotypia. This was shown with complete precision by I. P. Pavlov and his students as they studied the synthetic conditional reflexes and the phenomena of the dynamic stereotype (P. S. Kupalov, E. A. Asratyan, G. V. Skipin, L. G. Voronin and others). L. A. Orbeli proposed the term "interaction of afferent systems", especially for the phenomena exhibited by this physiological mechanism which had been discovered by analysis of human sensations.

This subject, which was studied for many years in his laboratory and the laboratories of other research scientists (S. V. Kravkov, G. Kh. Kekcheyev and others), was shown to be of decisive importance in cosmic physiology. The effect of overwork involving the specialized and generalized proprioceptive afferent systems, the skin and interoceptive analyzers, the condition of weightlessness--all these form an unusual ensemble of stimulation, conditions of interaction of the afferent systems which are new in comparison with terrestrial conditions.

A more serious reorganization occurs which is summed up as the result of the individual experience of the system of analyzer interaction. In practice, this problem has not been adequately studied, although some attempts to study interaction within the limits of the vestibular analyzer were begun by V. I. Voyachek and K. L. Khilovym and continued by Yu. G. Grigor'ev and his coauthors with the application of modern methods. The work showed from the start the complexity of the physiological mechanisms of interaction of the visual and vestibular analyzers (E. Sh. Ayrapetyants, V. A. Kislyakov, our findings).

L. A. Orbeli drew attention of future research workers to the characteristics of the environment in which the crew of the stratospheric craft exist. He spoke first of our then inadequate information about the biological role of an entire series of environmental factors, in particular of those effects on man which cosmic rays might have. Orbeli did not raise the problem casually. In his time, when he personally assisted in the experiments of Zvaardemaker, Orbeli became interested in radiological problems. Many years later he entrusted T. K. Dzharak'yan and me to repeat these experiments and organized in the postwar years a special laboratory for the study of the effect of

ionizing radiation on biological specimens. Studies at the present time have shown sufficiently well the possible effects of radiation on the astronaut organism and have measured the actual dose which our first discoverers of the cosmos sustain.

The question of the effect of these small doses of ionizing radiation on the organism is gaining special interest in connection with the total problem of the effect of the environment on the human organism. This problem has been well studied under the conditions of living things on our planet. However, conditions in the cosmos compel a review of the many opposing conditions and an evaluation of a number of features from a new point of view.

Actually the disturbance in the interaction of the afferent systems--inevitable in cosmic flight--probably can be compensated by the formation of new coordinated associations with the sensory sphere. The development of stereotypes under these conditions lies within the limits of the adaptive capacities of the organism.

But there are other factors in this newly conquered living environment, one of which is ionizing radiation. It is possible that adaptational, adjustive mechanisms against the action of these factors exist if the dose of radiation obtained in the cosmos exceeds the natural level of radiation on our planet and this radiation differs in its physical character from the natural background radiation.

This question is quite complex. At the present time large amounts of factual material have been collected which characterize the radiosensitivity of living specimens not only to "earthly" forms of radiation but also, for example, to high energy protons, in connection with some of the components of primary cosmic radiation. Some generalizations have been made which emphasize the many existing features of the biological effect of radiation, as a factor of the living environment, on the planet earth and in cosmic space (A. V. Lebedinskiy and Yu. G. Nefedov). All of this taken together requires that especially active reference be made to the development of the problem, again that introduced by Academician L. A. Orbeli, concerning the possibility of producing an increase in the resistance of the organism to the effects of radiation (1955).

We now know that the peculiarities of the living environment are not limited only to changes in the condition of the effect of the gravitational field, to an increase in the natural level of radiation. It is necessary, evidently, to take into account the effect of a factor such as the electromagnetic radiation of the planets.

This problem also disturbed Orbeli. Different facets of the problem evoked interest; such as man in extreme environmental conditions.

He was an initiator at that time, and, with the physicists M. A. Bonch-Bruyevich and M. M. Shuleykin, he was a consultant for a great series of experiments by his coworkers on the problem of the effects of electromagnetic oscillations on the organism and especially on the nervous system. This research was the first modern work on the study of the effects of metric and centimeter waves on the nervous system, the results of which leave no doubt of the biological activity of this factor.

The research worker of our time recalls with appreciation the earlier workers in his field who have bequeathed to him facts, reflection on which advances him toward the discovery of new and unknown things in science. A completely special feeling arises in relation to the scientist who thought of the worker of the future and paved the way for his research. L. A. Orbeli belongs to this group of scientists. And now, after man's conquest of cosmic space, we must not forget his interest in the problem of life beyond the earth, which was then only contemplated in its murky contours. He actively penetrated into the future, into a science which is now the science of our time, and brought us closer to the solution of the most important problems of natural science.

SOME PHYSIOLOGICAL ASPECTS OF THE SYSTEM OF ASTRONAUT SELECTION AND TRAINING

(Based on an evaluation of the functional condition of the vestibular analyzer)

A. V. Lebedinskiy, N. I. Arlashchenko, B. B. Bokhov,
Yu. G. Grigor'yev, L. N. Kvasnikova and Yu. V. Farber

The problem of a physiologically substantiated system of selecting pilots and astronauts now looms very high, in view of the increasingly complex conditions of flying in modern aviation facilities and the practical realization of manned space flights in our country. One of the most important features of such a selection system is the investigation of the functional condition of the analyzer of the body position and movements in space (V. I. Voyachek, K. L. Khilov, G. G. Kulikovskiy, etc.).

The evaluation of the analyzer as a complicated system formed in a process of evolution should be one of the basic physiological principles underlying the development of a selection system. The required information is produced by a number of analyzers (vestibular instrument and visual analyzer), the retina, and eye-muscle apparatus (motor analyzer and, in a number of cases, interoceptive analyzer). The fact that an analysis of the position and movements of the human body is to a large extent formed in the process of ontogenesis leaves no doubt that the mentioned process is realized by conditioned reflex mechanisms of various complexity (synthetic and chain conditioned reflexes, stereotypy, etc.).

The performance of every analyzer is generally accompanied by vegetative reactions, which can be particularly pronounced under certain conditions of the functions of the analyzer of the body position and movements in space. This may be a matter of great practical importance, reflecting undesirable complications in space flight. Experience shows that one cause of a vegetative reaction might be the failure of information on the position and movements of the body, resulting in derangement of the stereotype developed in the course of experience (the disruption of the interrelation between the afferent systems in the conditions of space flight).

In addition to a thorough and differentiated investigation of each of the components of the analyzer system, these considerations call for a study of (a) the interaction of these components and (b) the condition of the vegetative functions in the case of unusual conditions of analyzer interaction (space flight conditions).

The unusual conditions of analyzer functioning in space flight imply: (a) a limitation of the information customary in terrestrial conditions

resulting in the derangement of the stereotype, and (2) the inclusion of additional stimulants in this background (vibration, noise, etc.). Moreover all this may take place against the background of a changed functional condition of the vestibular analyzer (especially its higher sections) under the affect of ionizing radiation (Yu. G. Grigor'yev, A. V. Moskovskaya, V. V. Petelina, A. A. Sveshnikov, A. V. Sevan'kayev, etc.). Complications disrupting the normal functioning of the cortical mechananisms, as a result of the changing cerebral blood circulation (R. M. Gerasimova), are also possible in extreme conditions.

A Differential Study of the Functional Condition of a Vestibular Analyzer

The data on a differential investigation of the vestibular analyzer will be outlined in this report, and some information on the interaction between the receptor formations of the nonauditory labyrinth will be cited. It should be emphasized that the vestibular analyzer is considered as a complicated system with possible interaction phenomena within it.

Still not available is an adequate system of differential investigations of various receptor systems of the nonauditory labyrinth even though all the prerequisites are available for that purpose: an otolithic reaction (V. I. Voyachek) for the study of the interaction of the otoliths and semicircular canals; a four-pole swing test (K. L. Khilov) for the study of the otolithic function; and, finally, various modifications of rotary tests (Barani, Bais-Fisher, Egmond, etc.) to stimulate the semicircular canals.

In each individual case, the investigation calls for a strict observance of the conditions required by the adequacy of the stimulus and, in this connection, its accurate quantitative evaluation. These requirements are satisfied by rotary devices (A. Kh. Minkovskiy, Hollpike, Flur, etc., etc.) designed for the exclusive investigation of the semicircular canal functions by the use of preset magnitudes of angular accelerations and velocities.

The experience in operating the new VU-2 installation (Yu. G. Grigor'yev and B. B. Bokhov), contained in an analysis of the published information as well as in the data produced by the authors themselves, revealed the practicality of investigating the functions of a vestibular analyzer in these directions:

(1) Determining the threshold sensitivity of the semicircular canals to an adequate stimulus.

(2) Determining the reactivity curve produced by the use of angular accelerations of various magnitude.

(3) Evaluating the adaptivity to the effect of angular accelerations.

(4) Testing, utilizing Coriolis acceleration whose final reaction apparently results from the stimulation of various receptor formations of the nonauditory labyrinth.

Threshold Sensitivity

The method of determining the threshold sensitivity of the semicircular canals to an adequate stimulus has until recently played an auxiliary part in the investigation of the function of the vestibular analyzer (V. I. Voyachek, A. P. Popov, Voletts, etc.). This has been due to the lack of an appropriate apparatus for the development of a standard series of angular accelerations from test to test. There has been a growing interest recently in the evaluation of the vestibular sensitivity in clinical practice (V. I. Olisov, Montandon, etc.), where minimal angular acceleration is used for determining the threshold sensitivity of people suffering from various diseases (labyrinthitis, Meniere's disease, hypertension, hearing disorder, and brain tumor). In a number of cases, a low sensitivity that cannot be detected by the usual rotation can be easily determined by the use of threshold tests.

The methods we used for determining the threshold sensitivity include the definition of the thresholds of both positive and negative acceleration. The examinations of fairly healthy people (50 subjects) revealed, first of all, that the fluctuation range of threshold sensitivity is small, within $0.1\text{-}0.5^{\circ}/\text{sec}^2$ (acceleration effect lasting 20 seconds) to positive acceleration and $1.5\text{-}5^{\circ}/\text{sec}^2$ (in 0.15 seconds) to negative acceleration (stop-stimulus). But the results of special experiments indicated that the threshold of vestibular sensitivity can change several times under the effect of various stimulants and physical factors of the external medium, including inadequate ones.

The available factual material justifies the belief that a study of vestibular thresholds will be most useful in cases of early latent disruptions of the analyzer activity which cannot be detected by other means, and may be used for adapting the vestibular analyzer to various conditions.

Reactivity Test

The most widespread and universally recognized method of investigating the function of the semicircular canals consists of various rotary tests (Barani, Voyachek, Beis-Fisher, Egmond, etc.). Such tests amount to a study of the reactions occurring at the time of the deceleration of the chair following a certain period of uniform rotation.

Obviously, the major methods to be used in the future will be the method of minimal stimuli (Beis, Fisher-Arslan, etc.) and the method of successive rotations with an increasing intensity. The basic problem to be solved is the selection and evaluation of an appropriate reaction in order to characterize the functional state of the vestibular analyzer under the effect of the growing intensity of the stimuli. Our observations of people show that vegetative reactions do not occur under the effect of stimulants within the range indicated by the authors of "cupulometry". And since the condition of the vestibulo-vegetative complex is of decisive significance for an evaluation of suitability for flying service (V. I. Voyachek, K. L. Khilov, etc.), it is obvious that in order to establish distinct vegetative displacements we must use the ones that lend themselves to a quantitative characterization. It is also a known fact that the amplitude, duration, and speed of the nystagmic reaction are, as a rule, inadequate indices of the actual state of the test subject's vestibular function.

Our own investigations justify our belief in the future use of a method based on a longer duration of the effect of the stimulant rather than on its increased strength, as well as on the evaluation of the quantitative relationships among the magnitudes of the stimulants of sensory, somatic, and vegetative reflex reactions.

It should be borne in mind that the latter are brought about by a variety of mechanisms. The participation of the reticular formation in the appropriate effects may be judged from the results of the following tests. After the introduction of one mg/kg aminazine into rabbits, the vegetative reactions to vestibular stimulation grow much weaker and even disappear. Under these conditions, the reaction in the form of a nystagmus continues, or even grows more intense. These relationships continue also after the exposure of the animals to ionizing radiation.

Vestibular Adaptation

Numerous experiments have shown that the training consisting of the systematic irritation of the vestibular apparatus by various exercises and rotary tests enhances the vestibular stability of the test subjects. Here the speed of human adaptation depends on the particular individual. This brings up the problem of developing a test for the objective evaluation of the degree of adaptation.

A successful attempt of this type was made by Egmond who recorded the nystagmic reaction under the effect of repeated stimulants. But the duration of the nystagmus is apparently an inconclusive indicator for any definitive prognostic conclusions, as this would leave the vegetative complex out of account. This prompts the assumption that only an overall evaluation of the vestibulo-vegetative, vestibulo-somatic, and sensory reactions to repeated stimulants reveals the actual picture of

the adaptive characteristics of a vestibular analyzer. Relevant laboratory investigations are currently under way.

Coriolis Acceleration

The purpose of using the Coriolis acceleration as a selection test is to study the summary reaction, interaction, and mutual influence of various labyrinth receptors to the stimulation produced by the combination of two vector magnitudes--angular and linear velocities. The test is of special practical interest, as the possibility of a Coriolis force emerging during the flight is very real.

Laboratory investigations involving the periodic effect of Coriolis acceleration against the background of a slow rotation revealed that even a short-lived rotation is conducive to a pronounced disruption of the gait and changes in skin temperature and pulse frequency. As for the vestibular analyzer, it revealed a lower threshold sensitivity to Coriolis acceleration with the thresholds of angular acceleration remaining unchanged. Thus, the first results showed that such investigations had a promising future.

Interaction in the System of the Analyzer of the Body Position and Movements

The most interesting feature of these investigations was the study of the interaction between the optical and vestibular analyzers begun by G. Ye. Zhukov in I. P. Pavlov's laboratory. The resulting experimental data are, as a rule, indicative of the inhibiting effect of the retina on the vestibular analyzer. This phenomenon has been confirmed by the experiments in our laboratory involving the use of precise methods of evaluating the reactivity of the vestibular analyzer, and taking into account the intensity and duration of a luminous stimulant.

It appears that the result of the interaction between a luminous and vestibular stimulant is determined by the functional condition of the vestibular analyzer. The tests have revealed that when the excitability of the vestibular analyzer is increased and a spontaneous nystagmus appears, the latter is clearly inhibited under the effect of the luminous stimulation of the retina. The excitability in these experiments was increased by placing an applicator in the perilymphatic space of the inner ear vestibule. As proposed by A. B. Malinin, the applicator (a ball consisting of ion-exchange resins and measuring about 1 mm in diameter) was saturated with a radioactive promethium isotope Pr^{147}. The Pr^{147} is characterized by a beta-radiation of a very low energy (0.22 kev), which makes it possible to use this isotope to produce local damages on the microscopic structures. The capacity of the source on its surface

amounted to $6.17 \cdot 10^3$ radian/hour. At a distance of 250 microns, equal to the thickness of the sensitive layer of the utricular macula, the radiation intensity amounted to 48 radian/hour.

After 24 hours, the continuous effect of the ionizing radiation on the sensitive concretions of the ear labyrinth, recorded in the dark by an oculogram, revealed the presence of a "spontaneous" nystagmus in the animal. The effect of the light resulted in the immediate cessation of the "spontaneous" nystagmoid movements of the eyes. In the following days, as the excitability of the vestibular instrument was further increased, the inhibiting effect of the light became less pronounced.

THE PROLONGED EFFECT OF SLOW CORIOLIS ACCELERATIONS ON THE HUMAN ORGANISM

A. V. Lebedinskiy, N. I. Arlashchenko, V. Ye. Busygin, R. A. Vartbaronov, A. S. Veselov, N. A. Volokhova, Yu. G. Grigor'yev, M. D. Yemel'yanov, T. V. Kalyayeva, Yu. V. Krylov, B. I. Polyakov and Yu. V. Farber

A prolonged stimulation of the vestibular analyzer produced a so-called airsickness syndrome (V. I. Voyachek, K. L. Khilov, A. P. Popov, Witt, Schubert, Graybil, etc.). These reactions are determined by the functional changes in the nervous system and, possibly, by the disruption of the humoral control mechanisms. There are very few publications on the nature of the developing reactions to a prolonged stimulation of the vestibular analyzer by slow Coriolis accelerations (S. F. Stein, S. G. Chebanov, Graybil, Clark, Zariello, etc.). At the same time, the astronaut's tolerance of the Coriolis acceleration in orbital flight conditions is now a matter of great practical importance. A scientific substantiation of the magnitude of artificial gravitation produced in spacecraft calls for a physiological investigation into the protracted effect of the Coriolis acceleration on the human organism.

Coriolis acceleration effects on the human organism have been studied in a slowly rotating chamber (MVK-1), a Soviet-made installation for the investigation of the organism's reactions to the prolonged effect of slow Coriolis acceleration.

The MVK-1 is a closed cylindrical chamber measuring 2.1 meters in diameter and 2.3 meters in height. Its equipment consists of two armchairs for the test subjects, an electric light and ventilation system and a

device for the continuous recording of the physiological functions during the rotation.

Thirteen healthy persons participated in the first series of experiments, in which the chamber was rotated 1-5 hours at a constant angular speed of 5.3°/sec. The second series of experiments (which was carried out jointly with R. A. Vartbaronov and Yu. V. Krylov and in which the chamber was rotated for 24 hours at constant angular rotation speeds of 5.3, 10.6 and 21.2°/sec) involved the use of four test subjects. A Coriolis acceleration was produced periodically by tilting the body and head in planes perpendicular to that of the stand rotation at the rate of one movement per second. In the control investigations (remaining in the chamber when it was not rotating), the test subjects observed all the experimental conditions.

The general condition and neurological state of the test subjects were examined, their coordination of movements was tested, the thermoregulation function was evaluated, and the peripheral blood was investigated before and after the rotation. The functional condition of the vestibular analyzer of the test subjects was studied in a VU-2 device (Yu. G. Grigor'yev and B. B. Bokhov (1961)) for the sensory (a feeling of counterrotation), somatic (nystagmus), and vegetative (maximum arterial pressure, the propagation speed of the pulse wave, the pulse and respiration frequency) components of the vestibular reaction to stimulations under threshold and superthreshold conditions. Observations were made during the rotation of the microclimate in the chamber; thermoregulation of the test subjects was studied, and the functional condition of the cardiovascular system, respiration, and auditory analyzer was determined, as were the working capacity of the test subjects and the condition of their peripheral blood.

The periodic effect of the Coriolis acceleration on the test subject kept in an MVK-1 (at a speed of 5.3°/sec) for 1 hour and 5 hours revealed no considerable functional disruptions. The subjective phenomena occurring in a few of the test subjects under the operating load appeared in the form of mild dizziness, a feeling of heaviness in the head, and unpleasant sensations in the epigastric region. There were changes in the skin temperature and more pronounced disruptions in the coordination of movements (there were twice as many errors in the exercises involving "a complicated walk").

A further increase in the speed (up to 21°/sec) and duration (up to 24 hours) of the chamber rotation resulted in more pronounced phenomena, particularly in persons with a low vestibular stability. Increased somnolence and apathy as well as a reduced mental and physical capacity were noted. After several (1-5) hours in the MVK-1 chamber, the abovementioned disturbances were considerably alleviated, and the general feeling of the test subjects was improved, probably through adaptation to

the effect of Coriolis acceleration. The required adaptation period in this case was prolonged in proportion to the increasing rotation speed. (It should be pointed out that in one case of a 21.2°/sec rotation speed, a test subject with a low vestibular stability revealed no adaptation at all.)

In most of the test subjects the body temperature in the course of rotation was reduced by 0.2-0.8°C; in one of the subjects with a high vestibular stability it systematically went up 0.5-1.0°C. In addition, a rotation speed of 10.6-21.2°/sec produced characteristic changes in the skin temperature of the wrist (an average increase of 1.5-3°C) and shin (an average drop of 1.5-4.5°C in the first hours of the test) areas.

An investigation of the cardiovascular system revealed a considerable strain with an occasional distortion of the pulse reaction; a considerable reduction of the diastolic wave on the seismocardiogram, as shown by ortho- and spheno-static tests; and a considerable fluctuation of the duration of the mechanical and electrical cardiac systoles.

The changes of the morphological composition of the blood at all rotation speeds were of a reactive nature associated with the redistribution of the positive elements.

An investigation of the auditory function showed a drop of the auditory sensitivity in the middle of the test by 10-25 decibels at a rotation speed of 10.6-21.2°/sec. An examination of the simple sensorimotor reaction to sound and light revealed an increase in the latent reaction period in the first hours of rotation at a speed of 21.2°/sec.

An upset body equilibrium, as indicated by a staggering walk which was particularly pronounced when the eyes were closed, was noted immediately after the rotation in an MVK-1 chamber.

In the first 2-3 days after the experiment, all the test subjects complained of headaches, nausea and disturbed sleep. The reactivity of the vestibular apparatus to angular accelerations in the aftereffect period remained unchanged. On the other hand, there was a tendency to a reduced sensitivity to a Coriolis acceleration and a reduction of the vegetative manifestations produced by the otolithic reaction in all the test subjects.

The above-mentioned observations justify the assumption that the main reason for the development of vestibular disturbances during a slow rotation is the combined stimulation by the slow Coriolis accelerations of the otolithic apparatus and the semicircular canals; this is conducive to a summation of the afferent impulses. The lengthy afferent flow from a vestibular receptor of an unusual nature accounts for the inclusion of a number of neurohumoral mechanisms (stress reaction is one

of their possible manifestations). If the force of the vestibular stimulation does not exceed the tolerance level, it may lead to development of an adaptation.

Conclusions

1. The lengthy rotation of the test subjects with a normal vestibular sensitivity at speeds of 5.3, 10.6, and 21.2°/sec produces functional changes in the CNS and the cardiovascular system, and a disruption of the thermoregulation and the equilibrium function.

2. The extent of the vegetative disruptions is directly related to the rotation speed and the degree of vestibular sensitivity of the test subjects.

3. The cumulative effect of the Coriolis acceleration on most of the test subjects was conducive to a state of adaptation which was noted 1-5 hours after the beginning of the rotation.

4. The threshold and maximum tolerable Coriolis accelerations with reference to the conditions of the experiment we selected have been established.

5. The mentioned investigations justify the recommendation of a lengthy slow rotation for purposes of laryngo-oto-rhinological expertise and training.

LABOR HYGIENE AND OCCUPATIONAL PATHOLOGY INVOLVED IN THE WORK WITH CENTIMETER WAVE GENERATORS IN THE CIVIL AIR FLEET

A. Ya. Loshak

The development of new aviation facilities and the constantly growing traffic of airborne passengers and freight call for a continuous improvement of the flight safety systems. The radar stations (RS) play an important part in this effort.

The service personnel engaged in the operation and repair of these installations are subject to exposure to UHF electromagnetic energy and a number of other unpleasant factors (discomforting microclimatic conditions, noise, soft X-ray radiation, etc.).

Most of the information available in Soviet and foreign literature on the characteristic features of the radar station operations (N. F. Galanin and coauthors, N. I. Matuzov, A. I. Senkevich, V. A. Spasskiy, N. V. Tyagin, Khadukh, etc.; Khauf and Zatichelli, etc.) characterizes the conditions of the operators' work and not of the engineering and technical personnel. The latter groups have a more continuous and closer contact with radiation. Moreover, almost all of the mentioned publications contain a very detailed description of the general hygienic factors and only a reference to the harmful specific effect of the UHF field, and they do not provide a quantitative evaluation of that factor even though it is the radiation dose that is primarily responsible for the pathogenic effect of the microwaves.

In addition to providing a hygienic evaluation of the entire complex of injurious factors observable in the operation of a radar station, this report focuses major attention on the causes of UHF-radiation of the engineering-technical personnel of a radar station, as well as the intensity and duration of this effect in the course of a working day.

Our information reveals that radar service crews are systematically exposed to UHF energy which originates primarily in the antennas and, to a lesser extent, in the r-f units and waveguides (if they are inadequately shielded or not closely coupled). In such cases, radiation may be emitted from several sources simultaneously. The radiation intensity fluctuates from units of microwatt/cm^2 to several thousand microwatt/cm^2, and is determined by the type of radar station, the conditions of its operation and the observance of the safety regulations.

The duration of the radiation during a working day, in addition to the above-mentioned causes, depends also on the conditions of work, and the nature of the repair and routine operations, which may last one to several hours.

The most significant factors determining the intensity of the irradiation of people, according to our information, include: (a) the type of station, (b) the height of the installation and the operating tilt angle of the antenna, (c) the distance to the antennas and (d) the local topography.

The data on the flux density of the UHF energy (depending on the distance to the antennas, the height of the installation and their tilt angle) produced in the operation of various types of radar stations have been arranged in special tables.

The measurements made by our own methods reveal an inverse relationship between the intensity of the UHF-radiation at the place of the measurement and the height of the installation as well as the tilt angle of the antennas. These data show also that the adjacent territory is

subjected to periodic radiation of a great intensity when the antenna areas are characterized by a low elevation and negative angle.

The biological significance of periodic radiation has not been adequately studied even though the urgency of this problem is obvious. The tendency to increase the permissible levels of periodic radiation should be carefully substantiated and should not, it seems to us, be applied to the radar station personnel who are frequently exposed to continuous rather than periodic radiation with varying intensity. This is all the more reason why we should not accept the definition of the actual radiation time (and this implies also the permissible radiation level) on the basis of the rotation periodicity or the antenna scanning and the width of the beam.

With respect to the manifestations of the chronic effect of the UHF field on the radar station personnel, the literature shows no unanimity of opinion. While some of the authors believe that the observable changes in the health of the radar workers are due to the violations of the general hygienic conditions of work and overfatigue (M. S. Kagan, V. D. Lindenbraten, Barron and coauthors), many Soviet and foreign researchers attribute such changes to the specific effect of microwaves (G. A. Krivkov, N. V. Tyagin, Berest, etc.; Edel'vayn, Koritovskiy, etc.; Manezarskiy, Marek, Serel, etc.).

A clinico-physiological examination of radar station personnel and the compilation of medical documentation revealed a number of cases of complaints and objective information characteristic of an asthenovegetative syndrome specific to the chronic effect of UHF energy. It was noted that the number of complaints and the nature of the changes increase with the length of service, most frequently among the service personnel operating the radar facilities within 10-centimeter and decimeter ranges. The frequency and depth of the changes are also affected to a large extent by climatic conditions--the changes recorded in the southern latitudes were more frequent than in the central and northern latitudes.

The investigations made into the higher nervous activity and fatigability justify the assumption of some predominance of inhibiting processes in the contingent under study which, according to M. S. Bychkov, also indicates a pronounced asthenic process in them.

A study of the working characteristics at the radar stations has made it possible to propose a number of recommendations to improve the sanitary conditions of the service personnel for the express purpose of reducing the UHF radiation. These recommendations provide for the most rational principles governing the arrangement of the equipment and the planning of the radar sites, from a sanitary point of view; for design changes in the shielding system at certain radar stations; and for a

number of organizational measures, including the establishment of specified sanitary safety zones. The establishment of the latter will be based on the measured radiation emitted by the different radar antennas, and not on any calculation, inasmuch as such calculations do not produce any satisfactory results.

The constantly expanding use of radar stations in the civil air fleet, the expected introduction of new wave bands, the increasing capacity of the transmitters, and preferential use of antennas producing high directional radiation beams, as well as the current safety measures at the radar stations require the medical worker to make a systematic study of the labor conditions and the health of the people operating these installations.

Conclusions

1. The engineering and technical personnel of the radar stations of the civil air fleet are systematically exposed to direct and scattered UHF-radiation of varying intensity, from single units to several hundred (precision approach and dispatcher radar stations) and thousands of microwatt/cm^2 (circular scanning stations).

2. An examination of the personnel revealed in some of them symptoms of functional astheno-vegetative disruptions, the frequency and extent of which are determined by the length of service, the type of station, the shielding system, and climatic conditions.

3. The prevention of the injurious effect of the microwaves on the radar service personnel should be based primarily on organization and planning measures, followed by the use of protective devices.

4. A number of measures have been proposed to prevent the effect of the UHF-field on the radar station personnel: sanitary safety zones for different types of stations, new principles of planning and distributing radar facilities, some design changes in the shielding system, as well as new methods of dosimetric measurements and sanitary investigation of the radar facilities.

5. The data on sanitary-dosimetric and clinico-physiological investigations emphasize the necessity for a regular control over the conditions of work and health of radar station personnel.

THE VIBRATION AND RADIATION EFFECT ON THE ACIDIFYING PROCESSES IN THE BRAIN TISSUES OF RATS

L. D. Luk'yanova

One of the important factors of space flight is vibration, which produces a large variety of functional disturbances in the animal and human organisms. There are indications in the literature that one of such disturbances is an increasing consumption of oxygen in proportion to the vibration frequency and amplitude. Bearing in mind that the rate of oxygen consumption by the brain is very high, and that the continuous supply of oxygen to the brain is an indispensable condition of its normal activity, the great importance of studying the acidifying processes in the brain tissues becomes obvious.

This project involved an investigation of one of the major factors characterizing the oxidation rate in the cell, and the partial oxygen pressure or tension (pO_2) in various sections of the brain.

The pO_2 was measured by the "oxygen cathode" method, which is based on the principle of polarographic analysis. A platinum electrode was implanted in the animal's brain, and a chloro-silver nonpolarizable electrode introduced subcutaneously. Feeding negative electricity to the platinum electrode of the lobes produced an electrolytic oxygen reduction in the solution which generated a current proportional to the oxygen concentration that could be measured.

It was shown that the vertical vibration of the animals (frequency 70 hertz, amplitude 0.4 mm, duration of effect 15 minutes) produces very regular changes in the consumption of oxygen by the brain tissues. The consumption of oxygen, beginning with the first effect, is sharply increased. The vibration is followed by an undulating development of an inhibition process characterized by a reduced consumption of oxygen by the brain tissues, and lasting two hours. The following hours reveal a normalization of the process.

In animals subjected to repeated vibrations (up to 10 times), the brain consumption rate of oxygen during the vibration increases faster, and diminishes more slowly, than in animals subjected to vibration only once. However, there are periods of apparent normalization. Some increase has been noted in the total oxygen content of the brain tissue at the end of the vibration and for some time after it.

The changes in oxygen consumption rates in the different regions of the brain under the effect of vibration are expressed in different ways. These are most conspicuous in the motor region of the cerebral cortex. Irradiated animals (minimum lethal dose 600 radians) revealed a

decreased oxygen consumption immediately after their exposure, but such consumption was back to normal 1-2 days later. However, an investigation of the pO_2 changes in the brain tissues of the animals subjected to a combined effect (vibration followed by irradiation) revealed a predominance of the vibration effect.

The reaction of various animals to the effects under investigation was qualitatively similar, but its duration and intensity were largely determined by the individual characteristics of the animals.

AN ELECTROENCEPHALOGRAM OF AN ACUTE HYPOXIC (sic) HYPOXIA

V. B. Malkin

We have studied the bioelectric brain activity in fairly healthy young people in various stages of hypoxia for a long period of time. The electroencephalograms (EEGs) were accompanied by electrocardiograms (EKGs), a recording of the respiratory movements, arterial blood pressure, and a determination of the oxygen-saturation of the arterial blood. The EEG was accompanied by a psychophysiological examination, including a study of the rate of simple conditioned motor reactions, the recording of a well-memorized text, the solution of simple arithmetical problems, as well as a recording of the general feeling.

The purpose of the investigation was to determine the diagnostic significance of the various changes on the EEG in the process of establishing the test subject's individual resistance to hypoxia, as well as a study of certain aspects of the physiological mechanism which determines the various forms of EEG changes in cases of oxygen insufficiency. Animal experiments have sought a solution to the latter problem.

Some test subjects raised in a pressure chamber to an altitude of 5,000 meters felt quite satisfactory after 30 minutes at that altitude, but a psychophysiological examination revealed a significant disruption of the functional state of the CNS, as could be gleaned from the loss of certain practices acquired in the process of education: these included such grammatical mistakes as the omission of latent sounds, the misspelling of words with unaccented vowels, etc. A visual as well as a spectral analysis of the EEG, accompanied by a determination of the bioelectric intensity of the various parts of the spectrum, failed to detect any deviations from the norm.

It has been established that the initial symptoms of a disrupted activity of the CNS in conditions of a moderate hypoxia can occur while the EEG remains within the norm.

A study of the EEG changes produced by the development of hypoxia at altitudes of 6,000-7,000 meters has established that in the initial phase of hypoxia during the development of compensatory reactions on the part of the respiratory and cardiovascular organs, the EEG as a rule reveals an activated β-rhythm. The activation of the α-rhythm, which Kornmueller, etc., believed to be the initial phase of EEG changes, has, according to our information, been noted in less than 50 percent of the investigations, and it occurred after the activation of the β-rhythm.

In some cases, the various EEG phase changes, in point of time, were not strictly defined so that one phase appeared to be running into another as it were: (the β-activation phase into the α-rhythm activation phase or the θ-wave phase).

The predominance of θ waves on the EEG coincided with the manifestation of visible disruptions of the activity of the CNS--a frozen pose--initial distortions of the handwriting, and insignificant increase in the latent periods of conditioned motor reactions. It has been established that the θ-rhythm domination phase on the EEG, and in some cases also the Δ-phase, can be divided into two phases: a phase of a stable θ- or Δ-rhythm, when the external stimulation and the performance of various assignments by the test subject do not produce substantial EEG changes, and a phase of unstable θ- or Δ-rhythm, when the effect of external stimulants or the performance of various tasks by the test subject (recording his feeling, solving some problems, etc.) results in the disappearance or sharp reduction of the number of θ- and Δ-waves, and the activation of high-frequency oscillations on the EEG.

The EEG thus indicated a "waking" reaction as it were. It was shown that the growing intensity of the bioelectric brain activity in the low-frequency spectrum (2-6 hertz), which was more than double the standard norm, usually indicates incipient functional disturbances of the CNS amounting to a certain reduction of working capacity. A further intensification of the bioelectric activity in the low-frequency spectrum by 200-300 percent is indicative of profound disturbances of the CNS, including the loss of consciousness.

Serious hypoxia conditions, crude distortions of the writing process, and clonic spasms in the writing hand produced the same changes on the EEG as the loss of consciousness. Thus the qualitative or quantitative indicators characterizing the loss of consciousness cannot be ascertained on the basis of a visual analysis of the EEG or a spectral analysis of it, including a calculation of the bioelectric intensity in various regions of the spectrum.

The EEG did not indicate any predominance of slow oscillations in cases of people with a low resistance to hypoxia whose sharp drop in pulse frequency put them in a state of near collapse. In such cases the EEG revealed a reduced biocurrent amplitude, the latter being accompanied in individual cases by an increasing number of high-frequency oscillations; after that, the EEG of some test subjects showed sluggish and slow oscillations of a relatively low amplitude.

A very essential feature of these experiments, conducted against the background of a flattening EEG curve and a β-rhythm activation, is that the test subjects revealed external symptoms of a developing cortical inhibition: torpidity, a frozen pose, a longer latent period of motor reactions, etc.

Thus the predominance of slow waves is not the only form of EEG changes produced by the development of profound hypoxia-connected disturbances of the CNS. In this case, cortical inhibitions may be manifested as a result of the predominance of high amplitude slow oscillations on the EEG, as well as a flattening of the curve and the activation of the β-rhythm.

The EEG data justify the assumption of the existence of two physiological mechanisms disrupting the activity of the CNS: (a) the development of an inhibition process, in the case of predominant slow oscillations on the EEG, as a result of the direct effect of the oxygen shortage on the neurons of the cerebral cortex; (b) the disruptions of the activity of the CNS against the background of developing vegetative disturbances and lower biocurrent amplitudes on the EEG are probably determined by the inductive inhibition effect on the cortex coming from the subcortex whose irritability shows a sharp increase.

Investigations of animals suffering from acute hypoxia revealed changes in the EEG beginning with the appearance of the first barely noticeable disruptions of the CNS and leading to the development of clinical death. During the development of hypoxia, all the test animals regardless of species (dogs, cats, rabbits, or rats) produced phase changes in the EEG. They were manifested in the successive alternation of activated high-frequency oscillations (desynchronization phase), and activated slow oscillations (hypersynchronization phase). The depression of the biocurrents was the concluding phase of the EEG change. It manifested itself in the gradual reduction of the biocurrent amplitude, in the appearance of "complete silence" periods and individual spurts, or discharges, coinciding with the rare terminal respiratory movements.

A definite correlation between the clinical picture of the developing hypoxia and the EEG changes was established when the animals were raised in a pressure chamber to altitudes of 1,200-6,000 m at speeds of 25-100 m/sec. The activation of the β rhythm coincided with the initial

stage of compensatory reactions on the part of the respiration and blood circulation. The predominance of high-amplitude slow oscillations in the EEG coincided with the genesis of chronic spasms and the sharp reduction in the frequency of heart contractions. A fading bioelectric activity was noted simultaneously with the appearance of profound disturbances of the CNS: the loss of a normal posture, the disappearance of conjunctival reflexes, the loss of the pain sensation, and a disturbance of rhythmic respiration.

The experiments in which the test animals revealed an extremely rapid increase in hypoxia in the first 1-2 seconds at an altitude of 15,000-16,000 meters showed that the correlation between the EEG changes and the clinical picture of the state of hypoxia is determined by the growing rate of hypoxemia. There was no β-rhythm activation phase in these experiments, and the chronic spasms frequently coincided with the depression of bioelectric activity.

The experiments involving repeated ascents of the test animals to great altitudes revealed (in the second and third ascents) a lack of a hypersynchronization phase so that the depression of the bioelectric activity was not preceded by the domination of slow oscillations in the EEG. It has thus been shown that individual EEG phases may be absent in certain cases of developing acute hypoxia.

Investigations have been undertaken jointly with N. A. Asyamolova, Yu. V. Izosimov and K. K. Monakhov with a view to studying the mechanism governing the development of the phase changes in the EEG; these experiments involved the cutting of the brain, in one series of test animals, above the frontal tubers of the lamina quadrigemina, and the isolation of the cerebral cortex stria, in another series of animals in order to eliminate the effect of the incoming afferentation of the cortex and establish the direct effect of the oxygen shortage.

The development of acute hypoxia in the animals of the first series was not indicated in the desynchronization phase of the EEG, which confirms the previous investigations by Dela and Bonvale. Despite the separation of the cortex and the nearest subcortex from the lower brain formations during the development of hypoxemia, there was an indication of developing chronic spasms which were of shorter duration and less intensive than in the intact animals. Thus the functional preservation of the cortex does not determine the mechanism governing the development of chronic spasms in cases of hypoxia, as has previously been indicated by certain researchers (V. V. Strel'tsov, N. A. Nechayev, etc.).

The tests involving the isolation of the cortical stria revealed an intensified discharge activity during the ascent to altitudes of 4,000-10,000 meters and the development of hypoxia. This justifies the assumption that the hypersynchronization phase of hypoxia may be produced by the humoral effect of the oxygen shortage in the blood on the neurons of the cerebral cortex.

An investigation of the electric excitability of the stria at altitudes of 3,000-10,000 meters revealed a lower threshold of the induced potential. At altitudes of 10,000 meters and higher, the threshold continued to rise intermittently. The threshold changes were not strictly correlated with the desynchronization and hypersynchronization phase. Thus the EEG information shows that the cerebral cortex is directly affected by hypoxemia or the metabolites resulting from its development.

THE CHARACTERISTIC FEATURES OF THE CLINICAL COURSE AND THE EXPERT'S OPINION OF FLIGHT PERSONNEL AFFLICTED WITH STOMACH AND DUODENAL DISEASES

Ye. T. Malyshkin and B. L. Gel'man

1. Of all the digestive illnesses, the chronic disease of the gastro-duodenal section of the gastrointestinal tract is one of the most frequent reasons for the disqualification of flight personnel, and the second most frequent internal disease.

We have set ourselves the goal of studying the characteristic features of the clinical course and expert opinion concerning flight personnel afflicated with stomach and duodenal diseases. Eighty-eight persons suffering from ulcers and 101 chronic gastritis patients have been examined over a number of years in the therapy department.

In addition, we have obtained and processed the necessary information on the case histories of 310 persons, 124 of whom had suffered from ulcers and 186 from chronic gastritis.

2. A study of all the data obtained from the case histories, as well as the information on examined persons, failed to reveal any obvious direct connection between the stomach and duodenal diseases of our patients and the effect of specific factors characteristic of the flying profession, or the intensity and duration of flying.

3. In the general clinical picture of the disease, including the chronic development as well as aggravated ulcers and chronic gastritis, there is one point in common, and that is the benign course of the mentioned diseases.

4. An X-ray examination revealed, in many patients, an ulcerous "niche" surrounded with an inflammatory torus, but there was not a single instance of that niche reaching a considerable size. Not a single case

of penetrating ulcers was observed nor any crude cicatricial stomach deformations.

An X-ray examination of all the patients after their treatment failed to uncover a single ulcerous "niche", which is also indicative of the relatively benign course of the disease.

5. An examination of the gastric secretion by the fractional method following a cereal breakfast and the use of an M. G. Solov'yey fine catheter with olive oil revealed that gastric secretions were disrupted most frequently in patients suffering from duodenal ulcers.

The use of the above-mentioned methods of investigation was based on the results of our investigations into the comparative characteristics of the methods employed over a number of years in the examination of gastric secretion (B. L. Gel'man, G. P. Mikhaylovskiy, R. M. Basov and P. M. Suvorov). These showed that a cereal breakfast is the best physiological stimulant of gastric secretion. The examination of the secretory activity of the stomach gland by the use of Dr. M. G. Solov'yey's fine catheter with olive oil makes possible a continuous study of the secretory function of the stomach (complex reflex neurochemical) with the use of the same stimulant.

The dynamic observations of a number of patients examined a second time revealed a continuing high level of acidity and secretion. We find an explanation for this in Yu. I. Lazovskiy's experimental work, which showed that an increased secretory function of the stomach glands, brought about by the stimulation of the vagus nerve, leads to an intensified regeneration and hyperplasia of the glandular apparatus, especially in the pylorus zone.

6. A study of the characteristic features of the higher nervous system by the method of conditioned motor reflexes, preceded by appropriate instructions, revealed pronounced differences in the cortical processes in both the stages of remission and aggravation of 111 of the ulcer and chronic gastritis patients under study (G. P. Mikhaylovskiy).

The greatest disruptions in the cortical processes in the form of a disequilibrium and restricted mobility were found in the majority of people suffering from chronic gastritis and ulcers in an aggravated stage. In the case of the former, this was accompanied by a weakening of the inhibition process; in the latter, by a weakening of the stimulation process, indicated by a deeper disruption of the cortical processes. Repeated examinations of the ulcer patients in the remission stage (as compared to an aggravated stage) established a partial or complete normalization of the cortical processes.

7. The method of individual approach has been widely used in medical examinations of flight personnel suffering from chronic stomach and

duodenal diseases. This method calls for a study of a complex of problems affecting the patient himself (the conditions and nature of his work and diet, his actual working capacity, the rewarding aspect of his job and its purposefulness) as well as the characteristic course of the disease.

8. Patients suffering from chronic stomach and duodenal diseases should be kept in flight service and, if possible, on the same types of planes they have been accustomed to. The retraining of such patients even under favorable conditions of the disease would be impractical, as the retraining process eventually produces additional neuropsychic tension which may affect the course of the disease and contribute to its aggravation.

9. In view of the development of aviation technology and the associated changes in the various functions of the human organism, particularly the very pronounced disruptions of the functional activity of the gastrointestinal tract, the complex effects produced on the human organism by a number of modern flight factors call for a revision of expert medical opinion on the persons suffering from chronic stomach and duodenal diseases. We do not consider it advisable in the future to make use of any flight personnel discovered to be afflicted with stomach or duodenal ulcers, as well as chronic gastritis with a pronounced painful syndrome or a tendency to aggravation.

ON THE DIAGNOSIS AND EXPERT MEDICAL OPINION OF FLIGHT PERSONNEL AFFLICTED WITH ATHEROSCLEROSIS

Ye. T. Malyshkin, N. A. Gol'din and V. M. Tolstov

A historical review of the study of the pathogenesis, epidemiology, and etiology of atherosclerosis emphasizes the complexity of the pathogenic nature of that disease, its widespread occurrence among the population in most countries and the increasing frequency and gravity of the disease with advancing age.

Numerous researchers point to the widespread occurrence of atherosclerosis among flight personnel. In particular, in a histological examination of the myocardium of 222 pilots who died in aviation accidents, V. Glents and V. Stembridge found, in 70 percent of cases, atherosclerotic changes in the wall of the coronary artery. In 21 percent of the dead pilots, mostly between the ages of 30 and 40, the lumen had been narrowed by the presence of atherosclerotic plaques. In three of

the pilots whose flight had ended in disaster they diagnosed an acute infarct myocardium.

According to O. Koldovski, Novak and F. Vorel, pilots develop atherosclerosis considerably earlier than people of other professions. It is particularly difficult to diagnose the early occurrence of atherosclerosis because of the well-known fact in clinical practice that these forms of atherosclerosis are, as a rule, asymptomatic and of an undetermined duration. Nevertheless, it is in this early stage that the diagnosis of atherosclerosis is extremely important for its treatment and prophylaxis.

We have made use of a number of complex clinico-physiological, instrument and laboratory investigations for the purpose of diagnosing the early forms of atherosclerosis. In addition to the usual general clinical examination, this diagnostic complex pursued three major purposes.

The first purpose of these investigations was to establish metabolic changes; this was done by examining the protein fractions of blood serum by the electrophoretic method; determining the cholesterol and its fractions, the lecithin-cholesterol index, the lipoproteins; determining the functions of the thyroid gland by the use of radioactive iodine-131, the basal metabolism, and the penetrability of the vessels.

The second purpose was pursued by carrying out a complex of electrophysiological examinations (EKG, ballistocardiogram (BKG) and vectorcardiogram (VKG)), in a state of rest and after normal activity, as well as under special work loads which are most characteristic of certain types of the flying profession. Such workloads included a number of hypoxic tests used under normal and reduced barometric pressure, as well as by the method of breathing an oxygen-poor gas mixture under excessive pressure. The same group of examinations included tests with physical loads, with glucose loads, and a rheocardiographic examination of the myocardium.

The realization of the third purpose involved a determination of the propagation rate of the pulse wave, piezography, and rheovasography from the lower extremities, through the employment of a number of clinico-physiological investigations. The investigations also called for an X-ray of the thoracic and absominal aortas, the carotid and iliac arteries, and roentgenokymography of the heart and aorta.

The investigated persons were divided into four groups for convenience of examination. The first group consisted of patients in the first stage of hypertension; the second included patients with diagnosed atherosclerosis of various localization, and characterized as a rule by lack of pain or complications; the third was made up of patients whose

hypertension was accompanied by other diseases originating from the atherosclerotic process; the patients of the fourth group did not reveal any of the diseases listed for the first three groups, but a diagnosis established a disrupted fatty metabolism, myocardiodystrophy, mild disruptions of the cardiac rhythm of a functional and organic origin, and a neurocirculatory dystonia.

An analysis of all results justifies the following basic conclusions of practical importance.

Conclusions

1. We must considerably improve the diagnosis of atherosclerotic manifestations in the examination of the flight personnel for purposes of medical aviation expertise by introducing compulsory functional-diagnostic investigations that would broaden the possibilities for an objectively substantiated diagnosis of atherosclerosis.

2. In case of a well-substantiated diagnosis of atherosclerotic cardiosclerosis, even if not accompanied by an insufficiency of general and coronary blood circulation, continued flying on supersonic planes should not be permitted.

3. In the case of atherosclerosis of any other localization accompanied by an overall satisfactory functional condition of the cardiovascular and other systems, the pilot should be permitted to serve only in auxiliary types of aviation, if no retraining is required.

4. Of all the information obtained in the functional investigations, the careful study of the case history, the data on the physical and general clinical examinations make it possible to diagnose latent atherosclerosis considerably more frequently than would be possible without the use of the mentioned methods of investigation.

VESTIBULAR REACTIONS UNDER THE EFFECT OF VARIOUS ANGULAR ACCELERATIONS

S. S. Markaryan

When flying a plane, particularly in advanced flying and catapulting, the pilot is subjected to the effects of angular acceleration (V. I. Voyachek, K. L. Khilov, Yc. M. Yuganov and I. Ya. Borshchevskiy). The

intensity and duration of the angular acceleration effect have undergone substantial changes since the time of the piston-type plane.

There is little reference in the literature to the effect of intensive angular accelerations on vestibular reactions, and a study of this problem is therefore a matter of practical and theoretical interest.

We have studied the effect of angular accelerations on 13 normal test subjects at different positions of the body, ranging from a sitting position, 0° to a 90° angle. The duration, acceleration, and deceleration of the rotation to 1 rps in each case amounted to 12, 9, 6 and 3 seconds which corresponded to the angular accelerations of 30, 40, 60, and $120^{\circ}/sec^{2}$. Each test subject participated in 4 tests. A total of 120 investigations were made.

The test included a recording of the nystagmus with open eyes looking straight ahead, the pulse frequency, respiration, and an EEG. The investigations took into account the feeling of the test subjects and their own account of the duration and nature of the illusion, as well as the results of their subtraction of figures. Pulse frequency, arterial pressure, muscular strength of the arm and body stability were determined before and after the test.

The investigations revealed that the nystagmus fluctuates individually at various angular accelerations and body tilts: 5(9)-31(82)[1] during the acceleration of rotational velocity and 5(8)-24(64) during deceleration. The test subjects examined during their nystagmic reaction were unable to read the instruments or distinguish the cross sections of the rings on the choline table for 30 seconds and longer (the objects appeared to flicker before their eyes).

As the angular accelerations increased, the nystagmic reactions of the test subjects appeared earlier, and the amplitude in most cases revealed an increase. But the duration of the nystagmus and the illusions of counterrotation did not always reflect the magnitude of angular accelerations.

No definite relationship has been found between the extent of the nystagmus and the sensitivity of the vestibular analyzer. Three to five seconds after their nystagmus with open eyes, the investigated subjects, regardless of their vestibular sensitivity, revealed either a "post-post"

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[1] The figures before the parenthesis denote the duration of the nystagmus in seconds, and those within the parentheses the number of nystagmic impacts during that period.

or an inverse nystagmus when their eyes were closed. Their duration and amplitude were occasionally greater than those of the original nystagmus. The nystagmic reaction under the effect of angular accelerations tended to decrease as the body was inclined back from the vertical axis. This became noticeable at a 65° angle of body inclination, and more so at 80 and 90°.

The test subjects experienced illusory sensations under the effect of angular acceleration. The duration of the counterrotation illusion in these conditions fluctuated from 4 to 84 seconds. In most cases the counterrotation illusion diminished with increasing angular accelerations. The difference in the duration of the counterrotation illusion, as determined by the angle of body inclination and the angular accelerations, could not be ascertained. There was no appreciable difference in the duration of the counterrotation illusion in persons with a higher vestibular sensitivity and those with a low sensitivity.

Following the cessation of the illusory sensations, the majority of the investigated subjects appeared to experience such sensations all over again when they closed their eyes or held their breath, and sometimes also when they engaged in subtracting figures.

An average pulse frequency increase by 6 beats per minute, and respiration by 2 per minute, were observable under the effect of angular accelerations, particularly the acceleration of rotational velocity. No substantial changes in the bioelectric activity of the cerebral cortex were noted under the effect of a constant rotational speed except in persons with a higher vestibular sensitivity. This group of test subjects revealed a lower amplitude of the α-rhythm or an intensified β activity.

In the course of rotation, beginning with a 45° angle of body inclination the test subjects were under the impression that they were rotating in an upside-down position and returning to their initial position when the rotation stopped. At a 30° angle of body inclination, they had the sensation that they were rotating while lying flat on their backs, and when the rotation stopped they felt their bodies rising. Beginning with a 65° angle of body inclination, and particularly 80-90°, they felt as if their internal organs shifted upwards, experienced a constriction of the larnyx and a difficulty in swallowing. Hyperemia of the eyelid mucosa and an intensified flow of blood into the sclera vessels were observed in the subjects after these tests.

After a twofold acceleration effect, the test subjects with a higher vestibular sensitivity revealed a deteriorated feeling, general weakness, heat in the body and the head, giddiness, nausea, perspiration, cold wrists, and paleness. All these symptoms disappeared 20-40 minutes after the test. A deteriorated feeling in this group of

subjects was observed also in the course of rotation as they changed the position of the head forward, backward, to the right or to the left.

The pulse frequency of these subjects was reduced by 3-18 beats per minute after the test. The maximum arterial pressure in most of the subjects went down an average of 8 mm of the mercury column, and the minimum pressure in almost all cases rose an average of 11 mm of the mercury column. These changes were particularly pronounced in the tests performed under a load. In many of the subjects the muscular efforts of their hands were 204 kilograms weaker, and their body equilibrium was upset (as shown by a sensitized Romberg test).

Conclusions

1. The duration and intensity of the nystagmic reaction produced by the effect of angular accelerations on man depend on the position of the body in relation to the vertical rotation axis: the nystagmus gradually diminishes with the increasing angle of body inclination (from 0 to 90°), while the sensory reaction in the form of a counter rotation illusion continues.

2. In the first 30 minues or more of the nystagmic reaction it is impossible to read the aerial navigation instruments or the signs on the choline table.

3. An upset body equilibrium in various degrees was found in the majority of the test subjects after the effect of angular accelerations.

4. Changing the position of the head during the rotation or after one-two effects of angular acceleration produces vestibulo-vegetative reactions in persons with a higher vestibular sensitivity: general weakness, paleness, perspiration, and nausea.

5. The use of repeated effects of angular accelerations may be recommended for the purpose of training flight personnel in use of the vestibular analyzer.

REACTIVE CHANGES IN THE INGUINAL LYMPH NODES UNDER THE EFFECT OF VARIOUS OVERLOADS ON THE ORGANISM OF DOGS

Yu. V. Mashkovtsev

The successful space flights bring up the question of a thorough and all-round morphological investigation into the effect on the organism of various factors of these flights. Of particular importance among them is the effect on the organism of the G-force during the take-off and landing of the ship. It is important to ascertain not only the extent of damage produced by such a factor but also, if possible, to utilize the protective and compensatory mechanisms of the organism to counteract such effects. The important protective organs are the lymph nodes in which the antibacterial and antiendotoxic immunity is produced and the blood cells (lymphocytes) are manufactured. We have not been able to find any study of the capacity of the lymph nodes to counteract the effect of the G-force. But we know the work of M. A. Arsen'yeva, V. V. Antipova, V. G. Petrukhin, T. L. L'vova, N. N. Orlova and S. S. Il'ina (1961, 1962), who studied the changes in the red marrow, spleen, and thymus gland of mice under the effect of various factors of space flight.

The examination of animals after the effects of radiation, following an experiment on a vibrating stand and in a centrifuge, as well as an examination of animals completing a flight in artificial satellites, revealed that the greatest changes in the hemopoietic organs occur under the effect of mechanical factors. They showed that an inhibition of the hemopoiesis took place in the hemopoietic organs (marrow, spleen) in the first 10 days after the flight in spacecrafts--this was followed by a later stimulation of the hemopoiesis, and its restoration by the 30th day.

The purpose of our investigation was to study the condition of one of the lymphoid organs (inguinal lymph nodes) under the effect of G-forces. The experiment was carried out with dogs which were subjected to transverse (chest-back) accelerations of varying magnitude and duration. There were two series of tests. In the first series, the experiment lasted 3 minutes under an 8-G load factor. In the second series, the experiment lasted 1 minute under a 12-G load factor. The tests involved 28 mongrel dogs (14 in each series), all of which had been immunized against the plague 2 weeks before the tests. The animals were sacrificed by the use of ether fumes in different periods: 1 hour, 24 hours, 3, 7, 15, 30 and 60 days after the G-force effect. The lymph nodes were taken from the left and right inguinal regions, fixed in "cenkerformol" (formaldehyde) by the Maksimov method and placed in a Carnoy liquid. The whole thing was then covered with paraffin. Slices measuring 5μ in thickness were stained azure with 11-eosin, and methyl green pyronine by the

Brache method. The area of reactive centers was measured and the mytoses added up on the cross sections of the left lymph stained by the Brache method.

The changes in the lymph nodes under an 8-G acceleration effect lasting 3 minutes and 12-G lasting 1 minute are in principle monotypical, but the duration of the load effect is a determining factor; the changes in the histological structure of the lymph nodes in the first series are therefore usually more pronounced and last longer than in the second series.

The number of lymphocytes in the lymphoid follicles is reduced in the first hours following the G-force effect in the inguinal lymph nodes of the dog. In one of the dogs of the first series (1 hour) the lymphoid follicles were found to be destroyed, with the result that the entire central part of the follicles consisted only of reticular tissue.

In our investigations, the method of measuring the sizes of the reactive centers was used. Maksimov and Blum (1957) singled out four stages in the condition of the reactive centers, depending on the hemopoietic activity: in the first stage, the centers are the largest and are characterized by the appearance of individual division cells; in the second stage, the sizes of the reactive centers are further increased as is the number of mytoses in them; a decreasing number of mytoses and small sizes of reactive centers are observed in the third and fourth stages. The changing activity of the albuminous synthesis in the reactive centers is just as undulant. This means that the hemopoietic activity of the lymph nodes can be judged by the increasing size of the reactive centers and the increasing number of mytoses in them.

In the first week following the experiment, the reactive centers in the first series of tests were reduced in size, as compared to the norm, and the number of division cells in them was small. Beginning with the second week, the average reactive centers were doubled in size (from 0.44 mm^2 to 0.76-0.95 mm^2), the area of the largest reactive centers was also doubled (in seven days), and increased 3-4 times (in 15 days), and new reactive centers with indistinct boundaries (first stage centers, according to Maksimov and Blum (1957)) came into being, as compared with the control centers. The total area of reactive centers per test sample in the dogs over a period of 7-15 days was 2.5 times as large as the total area of the reactive centers in the control dogs (0.5 mm^2 for test animal, 0.2 mm^2 for control animal). The increasing size of the reactive centers was accompanied by 100-150 percent increase in the number of the division cells in them with medium lymphocytes predominating these cells. Hyperchromatic cells appeared at the same time. The protoplasm of the latter, when stained by the Brache method, had an

intense rose color, and 1-3 large pyronophilic nucleoli were noted in the nucleus. In 30-60 days the cortical substance of the lymph nodes retained the usual appearance in only 2 dogs of this series. Two other animals revealed a sharp irritation of the lympho-poietic growth. In one animal, killed 30 days after the test, the average size of the reactive centers increased 5 times, the area of the most reactive center 15 times, and the number of the reactive centers was doubled, in comparison with the lymph nodes of the control dogs. The number of division cells in the reactive centers of that dog was 2.6 times larger than that of the control dog. In the animal killed 60 days later, the average size of the reactive centers was doubled, the area of the largest reactive center showed a fourfold increase and the number of division cells in the reactive center increased 2.6 times in comparison with the control animal.

In the second test series, the increasing sizes of the reactive centers (1.5 times) were noted on the third day after the experiment (from 0.04 mm^2 to 0.06 mm^2). The area of the largest reactive centers was increased 3-4 times, and the number of the reactive centers themselves was doubled as compared to the control data. New reactive centers were seen to appear. There was a simultaneous 50-100 percent increase in the number of division cells in the reactive centers. In the second week after the experiment, the substantia corticalis of the lymph nodes returned to normal in all the dogs except two (15-30 days after the experiment) in which the reactive centers increased 100-70 percent and the number of division cells in them 200-70 percent, as compared to the control data. Two months after the experiment, the substantia corticalis had regained its usual appearance and showed a few small reactive centers.

An increase in the number of macrophages was noted within 1 hour after the experiment in the intermediate sinuses of the substantia medullaris of almost all the lymph nodes under observation. The reticular cells lose their processes in this connection, grow larger in size and become rounded, and their protoplasm becomes oxyphilic. Captured erythrocytes can be seen in the protoplasm of some of the macrophages. One day after the experiment, the pulpy columns of the substantia medullaris in both dogs of the first series and one dog of the second series revealed the presence of neutrophilic leucocytes which disappeared by the third day.

The intensification of the hemopoietic function in the lymph nodes during the 7-15 days after the experiment (first series) is, in our opinion, a compensatory mechanism which maintains the number of lymphocytes in the blood at a permanent level. The intensified formation of macrophages we observed in the first hours after the G-force effect is apparently a characteristic result of the load factor and coincides with the investigations of the blood of the animals in the Soviet artificial

satellite which revealed an intensified phagocytic activity of the leucocytes (O. G. Gazenko (1961)).

Thus the load factors in the first series (which lasted longer) produced a more powerful effect on the lymphopoietic tissue as compared to the shorter but heavier loads of the second series. The destruction of the lymphoid follicles in the first days after the G-force effect was eventually replaced by a regeneration phase. The proliferative processes in the lymphoid follicles were depressed in the week after the overload, and the regenerator processes originated at the end of the first week. An intensified but short-lived formation of macrophages occurred in the sinuses of the lymph nodes in the first hours after the G-force. The histological structure of the lymph nodes returned to normal 2 months after the G-force effect.

THE DYNAMICS OF THE MORPHOLOGICAL CHANGES IN THE CEREBRAL CORTEX OF DOGS FOLLOWING THE EFFECT OF A TRANSVERSE ACCELERATION

D. I. Medvedev

The changes occurring in the CNS and, particularly, in the cerebral cortex under the effect of accelerations have been studied primarily by way of physiological investigations and clinical observations. These efforts have focused attention on the disturbances of the visual function (Frankenhauser (1957), Miller, Mitchel, Riley, Bondurant and associates (1958), A. B. Flekkel', E. V. Marukhanyan (1959), etc.,) the changes in the conditioned reflex activity (V. I. Babushkin, P. K. Isakov, V. B. Malkin, V. V. Usachev (1961)), and the bioelectric activity of the cortex (Jasper and associates (1942), A. Ya. Rosin, G. P. Mikhaylovskiy, P. M. Suvorov (1959), A. N. Razumeyev, P. M. Suvorov (1962)). Thus the two-phase feature of the changes in the bioelectric activity of the cortex under the effect of accelerations has been established by Jasper and his associates. The first phase of these changes indicates the appearance of a stimulus in the CNS; the second stage reflects the development of inhibition processes in the cortex.

V. I. Babushkin and his associates explain the disruption of the conditioned reflex activity occurring after the acceleration effect "by the development of an external inhibition in the cortical cells of the motor analyzer".

Most of the authors associate the functional disruptions observable in the cortex with the disturbed activity of the cardiovascular system

and special hemodynamic conditions arising in the organism under the effect of acceleration (V. I. Babushkin (1959), A. Ya. Rosin and associates (1959), E. V. Marukhanyan (1961), Yu. Ye. Moskalenko, O. G. Gazenko and associates (1962), etc.).

Very few morphological investigations have been made of the effect of acceleration on the cortex. A. S. Barer (1958) observed the appearance of cells with a vacuolar degeneration in the brain, a considerable number of amitoses, and a thickening of the blood vessel walls after numerous acceleration effects. I. M. Khazen (1958) also discovered a distinct amitotic division of nerve cells in the brain. The appearance of corrugated cells and shadow cells in the cerebral cortex of mice, following their flight in artificial satellites, as well as the solution of the Nissl substance and the resorption of individual cells or groups of cells with lucid foci are indicated in V. G. Petrukhin's work (1962).

This report deals with a study of the dynamics of the morphological changes in the motor analyzer region of the cerebral cortex of dogs under the effect of a single transverse acceleration. Two series of tests were made: in the first, the animals were subjected to an 8-G acceleration effect for 3 minutes; in the second, to 12-G for 1 minute.

One hour and 1, 3, 7, 15, 30, and 60 days later the dogs were killed with ether fumes, and samples were taken for microscopic investigations. Small pieces of brain were placed in 10 percent formalin, and 96° alcohol as well as Carnoy liquid, and then covered with celloidin and paraffin. The test samples were stained with hematoxylin-eosin and thionine by the Nissl method, and pyronine by the Brache method, in order to find ribonucleic acid, and by Schiff's reagent with periiodate for the purpose of detecting mucopolysaccharides and glycogen. The visible changes revealed in an external examination and the opening of the brain consisted merely of blood-filled brain vessels and soft meninx.

An investigation of the histological preparations in the aforementioned region of the cortex revealed small hemorrhages, detectable only under a microscope, into the brain tissue. In many cases, the vascular walls of the small arteries were considerably disintegrated; occasionally they were ruptured. Hemorrhages were found mostly in the gray substance region or on the boundary between the gray and white substances of the cortex, especially in the dogs of the first series of tests which had been killed 1 hour, 1 day and 3 days after centrifugation. Only a few hemorrhages were observed shortly after the experiment in the second series of tests.

An examination of the nerve cells, stained by the Nissl method, showed that the nerve cells of various cortical layers react in different ways to the acceleration effect. It is a known fact that Nissl classified the nerve cells as karyochromic and somatochromic, depending

on the relationship between the nucleus and the protoplasma. He defined the karyochromes as cells in which the nuclear mass predominated the protoplasmic mass (in the cortex these are known primarily as cells of the II, IV and VI layers). The somatochromes are cells with a large quantity of protoplasm (most of the pyramidal cells of the III and V layers of the cortex).

Characteristic of the karyochromic nerve cells of the II and VI cortical layers of the motor analyzer are chromatolysis and cytoplasm vacuolization. The Nissl substance of many such cells disappeared almost completely, and the cells took on the form of a hollow vesica containing a well-stained nucleus. All that could be seen between the nucleus and the cell membrane were almost colorless cytoplasmatic colunms and small individual islands of Nissl substance.

The Nissl substance was seen to concentrate, after centrifugation, around the nuclei of the nerve cells in the gigantic pyramidal Betz's cells; the sorptive properties of the cytoplasm and karyoplasm were enhanced, and the cells began to be diffusely stained with thionine. At the end of this process, the boundary between the nucleus and the cytoplasm became almost indiscernible. At the same time, the periphery of the cytoplasm was found to be free of stain, representing an optically empty space. Many pyramidal cells in the third layer of the cortex were also found to be rapidly stained with thionine.

The above-described changes of the nerve cells were more pronounced in the first series of tests than in the second. In the course of time, all these changes were reversed, and a month later, particularly 2 months after the effect, most of the nerve cells of all the cortical layers acquired the usual microscopic structure.

Paralleling the development of these structural nerve-cell changes in the first 2 weeks after the effect was the growing activity of oligodendroglia whose cells were grouping around the nerve cells in larger than usual quantities. The introduction of oligodendrocytes into the cytoplasm of the nerve cells and the death of individual nerve cells were noted occasionally. These phenomena could be most clearly observed about a week after the effect.

An increase in the number of binuclear cells was noted in later periods. The frequent shifts of the nucleoli toward the periphery of the nuclei, and frequently even the complete escape of the nucleoli from the nerve cell nuclei, attracted special attention. In this case the nucleolus was found either in the cytoplasm of the nerve cell or even emerged outside the cell, remaining alongside it.

In both test series, the amount of ribonucleic acid in the nerve cells of the cortical region investigated 1 hour after the effect was found to have been considerably increased. It was somewhat reduced by

the end of the first day, but was still above the norm. Fifteen, 30, and 60 days later the amount of ribonucleic acid in the nerve cells of the test animals was exactly the same as in the control dogs.

An intense Schick-positive staining of some of the cytoplasm of a number of Betz's ganglionic nerve cells was detected in some of the animals of the first test series in the early stages (1 hour and 3 days after the effect). Such staining, but considerably less pronounced, was occasionally observed in the dogs of the second test series in later periods (30 days after the effect). The nature of this staining process--and its connection with the effect characteristics--is still unclear.

The investigation has thus shown that, under the effect of the above-mentioned accelerations, a large number of morphohistochemical changes take place in the area of the motor analyzer of the dog's cerebral cortex. Some of those changes (the hemorrhages, for example) are undoubtedly induced by the acceleration, while others possibly reflect the compensatory reactions of the nerve tissue. We are inclined to the latter opinion, in view of the fact that the above-described changes of the Nissl substance, the enhancement of the sorptive characteristics of the protoplasm, and the increase in the number of hyperchromic cells among the large and small pyramids of the III and V cortical layers, as well as the vacuolization of the karyochromic cells of the II and VI layers of the cortex, are in many ways similar to the morphological pictures in the cerebral cortex described by B. N. Klosovskiy and Ye. N. Kosmarskaya (1961) during the period of carotid inhibition. This assumption is confirmed by the above-cited observations of the physiologists (Jasper and associates (1942), and V. I. Babushkin and associates (1961)). From these positions, the increasing content of ribonucleic acid in the nerve cells, observable in the first periods after the effect, may be regarded as a compensatory increase in the ribonucleic proteins, that is, as a reaction to the functional tension experienced by the cortical cells under the acceleration effect.

At the same time, the few instances of nerve-cell death and the increasing number of binuclear cells are evidence of definite reactive changes in the cerebral cortex. It should be admitted, however, that these phenomena are very few in number, and that the overwhelming majority of the changes occurring after the acceleration effect are of a reversible nature.

A comparison of the results of the first and second series of tests shows that the changes in both series are of a homogeneous nature. But the changes occurring in the first series of tests are more pronounced than in the second.

THE EFFECT OF A PROLONGED HYPOKINESIA ON THE HUMAN BLOOD CIRCULATION

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Hypokinesia in man has now attracted the attention of specialists in various fields of medicine. Industrial physiologists see in this the necessity of solving not only special problems but also social ones, inasmuch as any technological advance and improvement of living standards are in the long run conducive to a reduced use of the muscles. In clinical medicine, it is important to establish the effect of prolonged restriction of mobility associated with confinement to bed during a pathological process. This problem is of particular importance for the specialists in aviation and space medicine. Although there are grounds for the belief that technological advances will lead to the development of systems in which the effect of acceleration, vibration, and isolation on the flight crew will play a secondary part, nevertheless, the duration of space flights by man will be considerably extended. Prolonged weightlessness will result in the human adaptation to new conditions, and a reduced tolerance of physical loads in conditions of higher gravitation.

The reduction of the muscular effort and the lack of a hydrostatic blood pressure will play a definite part in the disruption of the mechanisms regulating the blood circulation in man in a state of prolonged weightlessness.

This investigation involves the use of a regimen of confinement to bed as a factor approaching certain hypodynamic and circulatory effects of weightlessness. The test subjects were four men, 22 to 24 years of age, judged to be in perfect health by a commission of medical experts. These men were kept in a horizontal position for 20 days, and allowed to sit up in a spacecraft once every 3-4 days. They had been subjected to all sorts of clinical and physiological examinations before and after the experiment, including an examination of the pulse, arterial pressure, the blood-flow rate, venous pressure, the mass of the circulating blood, the beat and minute volume, the rheography of the head and shins. An analysis of the dynamics of the cardiac activity was made by the Blumberger and Holdak polycardiographic method, which made it possible to determine the time of the asynchronous, isometric, and isotonic contraction of the heart, the tension phase, the protodiastolic period, the duration of the mechanical and electrical systole and diastole of the left ventricle, and the intrasystolic indicator. The minute volume of the heart was determined by the method of diluting T-1824 paint

(Stuart-Hamilton) and by a physical method (Bremser-Ranke); a calculation was made also of the peripheral resistance.

The investigations were made in a state of rest and after a functional load. These included 30 rhythmic knee-bends, each lasting 1.5 second, and passive orthostatic shifts of the test subjects on an inclined table, and also 20-minute stationary periods.

Compared to the initial data, the changes of the mentioned indicators during the confinement to bed were as follows: the pulse frequency dropped an average of 14 beats per minute (from 9 to 25), and the pulsing arterial pressure was found to be reduced in all the test subjects by an average of 11.2 mm Hg (from 4 to 19). The beat volume was reduced by an average of 6 milliliters, and the minute volume by 1.6 liters (from 1 to 2.2). The peripheral resistance rose an average of 514.2 dyne/cm^2/sec. Two of the test subjects revealed a shorter period of isometric contraction (1 to 0.015 second, and another to 0.02 second) and a 5 percent increase in the intrasystolic indicator. A slower blood-flow rate and a lower venous pressure (by 50 and 20 mm on the aqueous column) were observed in two of the test subjects. The rheographic data on the flow picture revealed a slower rate of blood flow into the shin vessels and no substantial changes in the blood flow into the cephalic vessels.

After the period of confinement in bed the following changes occurred, as compared to the initial data: the pulse frequency in all the test subjects rose from 18 to 34 beats per minute, the increase in the pulse pressure was accompanied by a corresponding rise in the minute volume, and the peripheral resistance was reduced on an average of 238 dyne/cm^2/sec.

The knee-bend exercise test revealed a rising pulse frequency, which is characteristic of muscular effort, and changes in the arterial pressure and the phases of the cardiac cycle: a shorter phase of the isometric and isotonic contraction of the mechanical systole, and an increasing intrasystolic indicator. Before beginning of the bed-confinement regimen, these changes were insignificant; restoration as a rule occurred three minutes after the knee-bending exercise, while after the end of the bed-confinement period, particularly in the first days, these changes were greater and restoration could not be observed in the first 7 minutes after the end of the test. Although the mentioned changes did not extend beyond the range of physiological fluctuations, their tendency was indicative of a weakening of the organism's regulatory systems.

In the case of a passive upright posture, the diastolic pressure rose after the experiment by 5-15 mm Hg in the second and fourth positions (with the head up) as compared with the initial data. A rheographic

examination revealed a reduced flow of blood into the shin vessels (a lower amplitude) in 4 of the test subjects, and into the cephalic vessels in 2 of the subjects. These changes were more pronounced after the bed-confinement regimen. At the end of the upright posture test following the bed-confinement regimen, 2 of the test subjects showed pronounced changes in the form of the shin reogram; the latter was characterized by the appearance of a systolic plateau and an increase in the diastolic wave, indicating a changing tonus of the vessels in the lower extremities.

The data produced by an active orthostatic 20-minute test of 3 subjects, as compared to the data obtained under the same conditions before the test, revealed a faster pulse frequency, an increasing diastolic pressure, and reduced pulse pressure. Subjectively, that condition was characterized by general weakness, giddiness, perspiring scalp, and in some cases nausea. An objective investigation revealed a considerable paleness, visible mucosae, and an acrocyanosis. The clinical picture resembled that of a presyncope.

In the case of a person kept in a horizontal position for 20 days, his muscular activity previously used to compensate for the force of gravity to maintain the body in a vertical position, was not utilized to an insignificant extent. There was a decrease also in the hydrostatic blood pressure which, as a stimulus of the sympathetic regulators of the blood circulation, frustrated the adaptive capacity of the cardiovascular system to the changing direction of the force of gravity.

It may be assumed that a similar tendency of the functional changes of the cardiovascular system will occur in a person returning to terrestrial gravitation after a long period of weightlessness.

SOME PROBLEMS OF PROFESSIONAL SELECTION

V. D. Nebylitsyn and B. M. Teplov

The required preliminary conditions for the efficient and effective selection of people for a certain type of activity are:

1. A familiarity with the actual structure of the working operations and practical requirements of the type of activity under consideration.

2. The development of the most suitable selection methods which must meet the following minimum requirements: theoretical substantiation, practical authenticity ("validity"), statistical reliability, and the

highest possible standardization of the tests. These requirements are similar to those applying to most of the tests in professional selection used in the western countries, but only to a point: the difference is that according to the apologists for the present practice of "testology", the requirements of theoretical substantiation do not and cannot apply, which makes "testology" a pseudo-scientific system of blind, roughly oriented, and empirical tests. We, on the other hand, propose the requirement of theoretical substantiation and a familiarity with the psychological nature of the applied tests. This requirements must be decisive in the system of selection, and it should be observed in order to reduce the possible errors to a minimum.

3. A precise and definitive quantification of the evaluations. This condition may seem to be technical rather than basic, but we are inclined to ascribe first-rate importance to it, inasmuch as without a quantitative approach to the selection parameters, there would inevitably result a distribution of candidates only on the basis of descriptions and undifferentiated subjective characteristics. It is not at all necessary to insist on absolute quantitative indicators from the very beginning. In practical problems this requirement may be met (at a certain level of our knowledge) by determining the rank, that is a relative evaluation to some extent (which incidentally may coincide with the absolute evaluation), indicating the individual's status in the given concrete population or in relation to some definite statistical "norm".

The purpose of every selection is to predict at least two basic characteristics of the individual: first, his educational progress, that is his "capacity for learning", and, second, his efficient behavior under any complex situation including extreme conditions, that is his "operational effectiveness". These two characteristics should be carefully separated, for even though they occasionally coincide, there are numerous examples in the literature of an opposite nature; for example, an operator showing excellent progress in training, such as flying a plane, may prove to be inconsistent in a battle situation, which may require a number of individual qualities in addition to his formal knowledge and habits. It is also true, however, that successful activity in an operational situation is impossible without a good preliminary training. The determination and prediction of the ease with which a candidate may acquire the required system of knowledge and habits, and his "learning capacity", are therefore a matter of great practical importance.

The tests used in foreign countries, such as "instrument" tests, cannot pretend to detect any dynamic indices. It should always be kept in mind, however, that selection as now practiced is primarily a selection for purposes of training in a certain profession or skill, for learning a certain system of habits and knowledge. But if that is so, and if the prime purpose of the selection is the singling out of certain

persons likely to acquire the system of required habits and knowledge and who show a better capacity for learning with relative speed and success, would it not be practical, instead of trying to detect the habits already possessed by the individual (which in effect the current tests, attempt to do), to try and find out the rate and success with which the individual might acquire new habits and knowledge specific to his selected profession or skill?

We believe the answer to this question may be only positive: in the case of activity involving primarily a system of a certain set of habits and skills, the specific capacity will assert itself in the form of the individual's ability to acquire such habits and knowledge. Thus, the above proposal amounts to the replacement of the procedure involving the establishment of the statistical picture of available habits and knowledge by a system of checking and measuring a given individual's capacity for acquiring new habits specific to a given activity for learning, training, and exercising. In this case the quantitative index might be speed of reaching an individual "ceiling", the level of that "ceiling", the scattered results obtained in the process of learning, the number and distribution of mistakes, etc.; the conclusion in such a case should be based not on any single index but on a large number of indices whose relative significance should be determined beforehand.

But the actual working situation requires not only a great deal of training on the part of the operator but also a large number of strictly personal qualities, some of which can be easily cultivated and developed while others are more persistent, inert, and practically unaffected by the life of the individual. The characteristics of the first category include primarily the individual's moral qualities and his volitional characteristics. The qualities of the second group, as manifested in the man's behavior, are closely associated with the individual's neuro-physiological characteristics, and that association, even if not fully detected, can be more or less pointed out or presumed. We have in mind such individual characteristics as emotional balance, self control, a sense of timing, a capacity for concentration, a psychic endurance, the degree and distribution of attention, reorientation, etc. All of these may be interpreted as more or less related manifestations of the individual's nervous system, and as such might lend themselves to a fairly exact interpretation and experiment definition.

Despite the considerable difference between these two groups of personal qualifications, both play a very important and probably decisive role in the description of the individual which is directly associated with his "operational effectiveness" and which we shall refer to as "reliability", bearing in mind first of all the "durability", stability, and the persistence of the individual in the performance of his functions. Here the role of the second group of characteristics, associated with those of the individual's nervous system, apparently

increases with the growing complexity of the actual situation and the increasing responsibility of the person involved in it. If in many of these situations (possible the majority of them) the particular nervous processes of a machine-operating individual are not very important, the characteristics of the nervous system in situations characterized by a high degree of tension ("extreme situations") do make a difference: some individuals will act in such situations better than others just because there is a greater affinity between their nervous system and the conditions of work. The unique "compensation" for the missing characteristics, which are occasionally extraneous to the characteristics of the nervous system, becomes increasingly difficult in such extreme situations. In such cases, the individual's deeply ingrained natural characteristics take over, and these include the inborn characteristics of his nervous system.

If a definition of these characteristics is important in order to help the individual determine the ways and means of "compensating" for the qualities he lacks, where such compensation is possible and practicable, it is all the more necessary in the selection of candidates for work in extreme conditions. Herein lies the chief reason for studying the characteristics of a person's nervous system.

THE SANITARY ASPECT OF THE WORKING CONDITIONS AROUND ULTRAHIGH FREQUENCY GENERATORS

M. I. Netreba

The service personnel of radar stations and the people within the range of their radiation are subjected to the effect of the UHF field. The extent and nature of the harmful effect are determined by the working conditions in servicing the generators and by their parameters which include: the power of radiation, the wavelength, the pulse frequency and its duration, the distance from the radiation source, etc.

The main parameter determining the evaluation of the working conditions among UHF installations from a hygienic point of view is the amount of energy affecting the service of the body. The radiation time and the density of the UHF-field current must be controlled in order to evaluate the effect.

Different types of UHF electromagnetic oscillators have been introduced into the national economy as well as in the Civil Air Fleet in recent years. UHF generators of the centimeter band (35-3 cm) are used on a large scale in the Civil Air Fleet.

The introduction of these installations was followed by complaints to the Ukrainian Territorial Administration of the Civil Air Fleet about the deteriorating health of the workers servicing the UHF generators. The workers complained of headaches, fatigue, sleeplessness, general weakness, pain in the pupils of the eyes, the heart, etc. Most of the complaints came from those employed directly in the radar installations.

These deteriorating effects were usually noted by the end of the working day. These reports prompted the medical service of the Ukrainian Territorial Administration of the Civil Air Fleet to make a study of the working conditions at the airfield radar stations. Measurements made with the "Medik" M4-2 apparatus (sensitivity 0.5 microwatt/cm^2) at various distances from the radiation sources (up to 600-950 meters) showed the highest radiation density (over 100 microwatt/cm^2) on 13 installations at distances of 25 to 600 meters from the radiation source (antennas). Intensities in excess of 10 microwatt/cm^2) were established on the work benches as well as in the area of 15 installations. It should be pointed out that (a) the measurements were made after the antennas had been brought to a stop, as we do not know how to make such measurements with a rotating antenna, and (b) the highest densities of the UHF current were found mostly at the large circular scanning radar stations. The radiation of the dispatcher installations was, as a rule, within the permissible range.

The duration of the working day plays a considerable part in the UHF-field effect on the service personnel. Not at all the installations was the working day of the personnel subject to the existing regulations. Thus, at four of the investigated installations the working day was arbitrarily extended (for a number of reasons) to 8-10 hours, instead of the 6-7 hour day. Measurements revealed higher densities of the UHF-field current at those installations (over 10 microwatt/cm^2).

The first complaints about health came from the above-mentioned four installations. Later, when complaints began to come in from persons working a normal workday on UHF oscillators, a thorough medical checkup for service personnel and a study of the working conditions at those installations were instituted.

The maximum UHF radiation density around the dispatchers working on the landing radar stations amounts to form 0 to 10 microwatt/cm^2; around radio technicians and engineers serving the huge stations intensity varies from 1.5 to several hundred microwatts per square centimeter. The radio technicians are subjected to a higher radiation intensity during the tuning and adjusting of their antenna devices, and frequently they also receive the radiation from the neighboring radar stations as a number of airports have two radar stations in the same area. Thus, it

has been established that at some radar stations the density of the UHF radiation amounted to 60-600 microwatt/cm^2 at distances of 25 to 600 meters from the antenna. In most cases it takes 1.5-2 hours to tune and adjust the antennas.

An analysis of the medical examinations of the service personnel revealed that the subjective complaints had come first from the shift engineers and radio technicians, then from the dispatchers and particularly radio technicians working overtime and finally from the radio technician working a normal workday.

A clinical investigation of 10 radio technicians and shift engineers on a longer workday revealed very pronounced functional changes (in the form of asthenic and vegetative reactions) in their various organs and systems. The latter were manifested as a weakening of the stimulating processes, sluggishness, increased fatigability, pains in the cardiac area and diffuse dermography. Similar disruptions were found in three of the workers (senior and on-duty engineers and radio technicians). One of them, with advanced symptoms, was removed from his radar station job altogether, and the other two for 6 months. Changes in the peripheral blood were found in 14 engineers and radio technicians: an increase in the percentage of reticulocytes (from 1 to 3 percent); no such changes were noted in the persons not connected with radar station work. All these symptoms were discovered in the men working at the radar stations for 5 years and longer. Pronounced changes in the organon visus were found in one case (the man had been working at a radar station over 10 years).

Organic changes were not found in the cardiovascular and nervous systems of those investigated. It should be pointed out that the shortening of the workday for service personnel at the above-mentioned 4 stations and at other installations, together with additional changes, including the introduction of special shielding devices for the workers, have reduced the effects on the peripheral blood and the nervous system to a vanishing point.

It was at this time that the medical service looked into the matter of soft X-ray radiation in the control panel rooms of the radar stations. Such radiation was found only in the control panel room of the Radian station where it was 10 times above the norm. It was not found at any other radar station. Laboratory tests were made at the same time of the microclimate in the working buildings, including the measurement of the temperature and air humidity, the CO_2 content at the beginning and the end of a work shift as well as the noise level in the buildings. Artificial and natural illumination were also measured.

The results of these investigations revealed that the air humidity in the working buildings was normal. The temperature in the control panel rooms was above the comfort level, the illumination of the indicator screens was inadequate, and the CO_2 content in the building was somewhat increased. The noise was found to be within the permissible range except in the rooms containing the receiving and transmitting apparatus where it exceeded that level by 12-40 decibels. The ozone and nitrogen oxide content in the machine halls was within the normal range.

It may be seen from the above that the indicators of the microclimate in the working buildings do not as a rule exceed the established norms, nor do they produce any adverse effect on service personnel.

Conclusions

1. The regulations governing the duration of the workday for radar station engineers and radio technicians should be strictly observed.

2. Individuals should not be hired for these installations without preliminary special and thorough medical examinations.

3. Individuals whose health has been specifically affected in any way by UHF radiation should be transferred temporarily to other jobs.

4. Individual protective facilities should be developed for service personnel engaged in tuning and adjusting the antennas as well as in the repair of the indicator facilities.

5. All required protective measures (screening, etc.) should be rigidly observed.

6. No communication or other facilities should be located within the danger zone of the radar station.

THE ROLE OF THE SINOCAROTID REFLEXOGENIC ZONE IN THE REACTION OF THE BLOOD SYSTEM TO REDUCED BAROMETRIC PRESSURE

Yu. V. Nikolayenkov

A study of the ways in which the compensatory changes in the blood system are developed and regulated in conditions of low barometric pressure is a matter of great interest for the development of methods designed

to increase the organism's resistance to unfavorable conditions of the external medium. It is very important to study the control of the compensatory reactions of the blood system under the alternating effect of reduced barometric pressure, inasmuch as this particular effect is a frequent occurrence in the external medium peculiar to the work of the flight personnel. The investigations of the role of the sinocarotid reflexogenic zone in the reaction of the blood system to low barometric pressure are few and contradictory. L. I. Ardashnikova (1952), Grant (1951), Terzioglu, Geral', and Bardavit (1955) disprove the participation of that zone in the mechanism of the mentioned reaction. N. N. Beller (1957) believes that the chemoreceptors of the sinocarotid zone do not participate in the redistribution reactions but play an essential part in the mechanism of the true erythrocytosis occasioned by a reduced barometric pressure.

Our investigations of 14 adult male dogs involved the changes in the peripheral blood and bone marrow under the effect of alternating low barometric pressure within 267 mm of the mercury column, produced by a series of "ascents" in a pressure chamber to an "altitude" of 8,000 meters for 2 hours in the course of 6 days. The speed of the "ascent" and the "descent" was 15-20 meters/sec. The peripheral blood indicators--the hemoglobin content, the number of erythrocytes, reticulocytes, and the hematocrit indicator--were examined before the "ascent", immediately after the "descent", and then at 30-minute intervals over a varying period of time (from .5 to 1.5 hours) as well as 24 hours after the series of "ascents". Spinal punctures were made before and after the series of "ascents". The functional condition of the erythropoiesis was studied by means of a radioactive iron isotope (Fe^{59}). The acid erythrogram method was used to investigate the stability of the erythrocytes.

After remaining at an "high altitude" for a while, the intact animals revealed an increasing content of erythrocytes (from 205,000 to 1,675,000 per 1 mm^3), hemoglobin (from 5 to 18 units on the Sali scale), reticulocytes (from 3 to 20 $^0/00$ and a higher hematocrit indicator (from 3.5 to 9.5 units). Thirty to sixty minutes after the descent, most of the peripheral blood indicators returned to the initial position.

After a series of "ascents", the dogs revealed an increasing quantity of erythrocytes (by 650,000-900,000 per 1 mm^3), reticulocytes (by 12-15 $^0/00$), a growing hemoglobin content (by 8-11 units on the Sali scale), and a higher hematocrit indicator (by 4-6 units). The bone-marrow picture indicated an increasing content of the elements of an erythroblast series and an accelerated maturation of the erythroblasts (an increase in the quantity of oxyphilic erythroblasts by 11-14 percent, according to partial erythrograms).

The tests involving the intravenous introduction of labeled iron (in the form of ascorbate Fe^{59}, 1 microcurie per 1 kilogram of weight) revealed the characteristic features of its utilization by the animals after a series of "ascents" in a pressure chamber. Eight to 11 percent of the iron introduced into the control animals was still there 6 hours later. On the second day, the quantity of the iron in the blood revealed a gradual increase reaching a maximum by the 9-10th day (43-47 percent of the introduced dose). Only 3-5 percent of the iron introduced into the animals' blood after a series of "ascents" remained in it 6 hours later; the maximum recurrence of the radioactive iron was observed on the fourth and fifth day when it amounted to 93-95 percent of the introduced dose.

An investigation of the erythrocyte distribution by stability, by the method of acid erythrograms, revealed that on the first or second day the reduced barometric pressure produces a stretched erythrogram, and a rise of its right wing which is indicative of an increasing number of stable erythrocytes in the blood. A drop in the stability of all the erythrocytes, however, was noted in the following days, and manifested in a shift of the erythrogram to the left. On the fifth and sixth days of the effect, and 24 hours after the series of "ascents", the stability of the erythrocytes began to rise again. The normalization of the peripheral blood was noted 7-10 days after the end of the "ascent" series, and of the bone marrow after 1-1.5 months.

A twofold denervation of the sinocarotid zones produced anemia. Following restoration of the blood composition after denervation, the animals were subjected to the effect of a reduced barometric pressure. Immediately after the "descent", the blood of the animals with denervated carotid sinuses revealed the same changes as the intact animals.

But the normalization of the peripheral blood following the "descent" of such animals was usually delayed. Thus, 30 minutes after the "descent", these animals unlike the intact animals, not only failed to show a decrease in the number of erythrocytes, the percentage of hemoglobin and the hematocrit indicator, but in a number of cases they even revealed a tendency to increase. The normalization of the peripheral blood was 30-60 minutes later than in the intact animals.

No changes were found in the peripheral blood of the operated animals after a series of "ascents". The punctated bone marrow indicated some irritation of the erythroblast growth, but no accelerated maturation of the erythroblasts was observed. Only 6-8 percent of the radioactive iron introduced into the operated animals after a series of "ascents" was found to have remained 6 hours later; the maximum recurrence of that iron was observed 7-8 days later, when it amounted to 63-72 percent of the introduced dose.

An investigation of the acid erythrograms showed that the phasic stability changes observed in the intact animals under the effect of low barometric pressure were absent in the operated animals. The erythrocyte stability either did not change at all or showed a tendency to decrease.

The increasing number of erythrocytes, the higher hemoglobin percentage and hematocrit indicator, as well as the reticulocytes and the growing erythrocyte stability noted in the intact animals, are indicative of an intensified erythropoiesis; this is confirmed by the bone-marrow picture and the investigations involving the use of a radioactive iron isotope, as it is known that the radioactive iron introduced intravenously disappears from the plasma in the first hours and reappears in the blood as part of the hemoglobin of the newly formed erythrocytes.

The changes in the peripheral blood immediately after the "descent"--erythrocytosis, a higher hemoglobin percentage and hematocrit indicator, reticulocytosis, and increasing erythrocyte stability in the first two days--are occasioned by the redistribution of the regular blood elements and of the ejection of the reserve of young erythrocytes from the bone marrow.

The denervation of the carotid sinuses disrupts the usual reaction of the blood system to reduced barometric pressure: the irritation of the erythroblastic series, as confirmed by investigations with the use of radioactive iron, reveals a disruption of the erythroblast maturation process, a delayed restoration of the peripheral blood following the effect, and a disruption of the phasic changes of the erythrocyte stability.

The results of the tests indicate that the sinocarotid reflexogenic zone is an important link between the reaction of the blood system to reduced barometric pressure and the related oxygen starvation of the organism. The exclusion of the reflex impulse from the interoceptive zone of the carotid sinuses results in a disruption of the usual reaction of the blood system to hypoxia. It also disrupts the processes of blood formation, distribution, and destruction.

EVALUATING SOME OF THE ORGANISM'S REFLEX REACTIONS TO BREATHING UNDER INCREASED INTRAPULMONARY PRESSURE

P. V. Oblapenko

A considerable increase in the intrapulmonary pressure over a more or less lengthy period of time (several minutes) is something unusual for the organism, as in its entire evolutionary development the organism had to deal with such phenomena (coughing and sneezing) that last extremely short periods of time. Naturally, the human and animal organisms do not have any specific reflex reactions designed simultaneously to eliminate all the disruptions of the hemodynamics occurring in various sections of the vascular channel under the effect of mechanical pressure forces. The organism, therefore, makes use of the available unconditioned reflexes to restore normal blood circulation.

Breathing under increased pressure produces conditions and reasons for the use of many of these reflex reactions, but these do not always agree with one another and frequently overlap; far from eliminating the hemodynamic disruptions, they occasionally even intensify them thereby losing their adaptive capacity.

Foremost among the reflexes contributing to the restoration of blood circulation are those which raise the tonus of the peripheral vessels and accelerate the cardiac rhythm: from the sinocarotid and aortal zones in case of a reduction in the arterial pressure within the large circulation, from the orifice of the caval veins and vessels of the portal system in the case of rising pressure in them, and from the lungs as they stretch, etc.

At the same time there are reflexes operating in the opposite direction: from the pulmonary arteries (Shvigka-Parin) and the right heart (Aviado) in connection with the rising blood pressure in them as well as the mechanical contraction of the heart by the stretched lungs. These reflexes produce a bradycardia and a dilatation of the peripheral vessels, particularly of the spleen (Parin). Their unfavorable effect is manifested mostly in the initial respiration period under excessive pressure when the hemodynamic conditions in the lesser blood circulation undergo a sudden change which produces the conditions in which these reflexes are activated; these are followed later by compensatory reactions. But the negative effect of the reflexes from the cardiac and pulmonary arteries obviously applies also to the entire period of respiration under pressure, as the causes producing those reflexes remain throughout that period.

It is now commonly believed that when breathing under pressure, bradycardia is a bad prognostic symptom. It is obvious that the already mentioned reflexes play a fairly important role in producing it. It

should be assumed, in addition, that a very frequent pulse is also a bad prognostic symptom.

In our experiments with dogs involving a systolic frequency of 200 and more per minute, the blood pressure was not always restored to the initial level. In the initial period, when the beat volume of the left heart is sharply reduced, tachycardia can be of some use by increasing the minute volume. But eventually, as the compensatory reactions begin, the amount of blood entering the heart increases, and the frequent heart rhythm, as had been established by I. P. Pavlov, not only increases but frequently decreases the output of the heart, resulting in a reduced arterial pressure. It is obvious that in these conditions a moderate increase in the frequency of the cardiac rhythm, which takes place after 1-2 minutes of respiration under pressure, is better for the organism; by that time the systolic frequency in the dogs is, as a rule, reduced from 170-200 to 130-140 per minute.

This reaction of a slower cardiac rhythm occurs under the effect of the parasympathetic nervous system and is adaptive in nature. That was proved in tests involving the elimination of the parasympathetic influences on animals with a high and low vagotomy, as well as on atropinized animals. Those experiments established that for the absolute majority of the intact dogs and animals with a low vagotomy an excessive pressure of 300-400 mm of the aqueous column (without the use of external counterpressure) was quite tolerable, whereas for 50 percent of the dogs with a high vagotomy it was excessive, and prevented the restoration of blood circulation function. These dogs were able to tolerate an excessive pressure of only 200-250 mm of the aqueous column. Approximately similar data were obtained in the test with atropinized animals.

It is apparent, then, that the parasympathetic nerve running through the vagus nerves and, further, through the efferent cardiac nerves, moderates the systolic frequency and increases the rest period of the myocardium, thereby reducing its fatigability. That effect of the vagus nerves prompted I. P. Pavlov to call them "cardiac rest regulators". When respiration takes place under increasing pressure, then the load on the right heart grows heavier because of the difficulty in the lesser blood circulation; and the role of the vagus nerves as cardiac rest regulators increases because the right ventricle is less adapted than the left one to this type of functioning. However, the positive action of the parasympathetic fibers is not only to reduce the frequency of the cardiac rhythm and create better conditions for the restoration processes in the myocardium but also to produce a trophic effect (Smirnov, Kozenko, and Parin).

The pressure in the pulmonary arteries increases when respiration takes place under intrapulmonary pressure due to the resistance to the blood flow in the lesser blood circulation. This leads to a reflex opening of the artereovenous anastomoses in the lungs (Boyno-Radzevich,

Ryvkind) with the result that the venous blood, bypassing the pulmonary capillaries, reaches into the pulmonary veins and further into the left heart. Such a reaction reduces the load on the right ventricle, protecting it against fatigue. But part of the blood, going through the bypasses, does not become saturated with oxygen.

It is possible that in terrestrial conditions the mixture of that part of the blood with the oxygenated blood would not particularly affect the supply of oxygen to the organism's tissues. At high altitudes, however, where the partial oxygen pressure in the lungs is known to be less than in ordinary conditions, and the organism is in a state of oxygen starvation, the reflex opening of the artereovenous anastomoses in the lungs will produce unfavorable conditions for the organism's existence. Thus it may happen that at very high altitudes the effect of this reaction will be negative rather than positive. This circumstance should be borne in mind when designing oxygen apparatus and care should be taken that the partial oxygen pressure in the lungs when breathing under excessive pressure at high altitudes is not lower than under normal conditions (on earth).

The significance of this investigation is that it provides a better understanding of the physiological mechanisms of the reactions occurring when special oxygen instruments are used; it also facilitates a proper evaluation of these reactions and a definition of the stability of the organism in training flight personnel to breathe under higher pressure.

STUDYING THE NYCTOHEMERAL RHYTHM OF FUNCTIONS IN CONDITIONS OF LIMITED MOBILITY

N. Ye. Panferova

The nyctohemeral rhythm of the physiological function is determined by the formation of a dynamic stereotype of the workday elements and the rest and sleeping periods. An important prerequisite for formation of the nyctohemeral rhythm are the elements consolidated in the process of evolution through heredity--the typological characteristics of the nervous system (A. D. Slonim).

According to Kleytman, Titel'baum and Gofman, daily body temperature fluctuations are observable also in newborn babies. But a pronounced nyctohemeral rhythm appears only in the second year after birth. The nyctohemeral rhythm becomes clearer with increasing age. The authors associate the appearance of the daily functional fluctuations with the

development of a child's activity. In an adult person, the nyctohemeral rhythm of the physiological function is relatively stable.

A number of authors (Metz, Nielsen, etc.), believe that the capacity for work--particularly in the performance of a job that does not require much energy, such as mental work--is closely associated with the nyctohemeral rhythm of the physiological functions. A man's lower capacity for work at night is, according to Metz, due to the lower body temperature. The increasing body temperature during the day produces conditions for faster biochemical processes in the organism thereby creating better prerequisites for greater human activity.

Body temperature, pulse frequency, and blood pressure are closely associated with vigorous activity. K. M. Smirnov, A. D. Slonim, S. O. Rutenburg and M. D. Tsybin indicate in their work that the nature of the daily curve of body temperature and pulse frequency changes with the specific gravity and physical and mental strain of the work performed by man.

In conditions of weightlessness, during the space flights, muscular efforts will apparently be at a minimum. It would therefore be interesting to determine the changes that may be produced by a maximum possible limitation of muscular work and movements on the nyctohemeral rhythm of body temperature, pulse frequency, respiration, and blood pressure.

The experiments involved in the study of limited mobility were carried out in two series using 11 people, four in the first series and seven in the second: in the first series, test subjects were kept flat on their backs for 2 to 10 days in special armchairs in a position conducive to a maximum muscular relaxation; in the second series, they were kept for 1.5-11.5 days in a lying position in water. Body temperature, pulse frequency, and blood pressure were measured every 2 hours by members of special teams on duty.

During those tests, the daily conditions were maintained as close to the usual conditions as possible, with the exception of motor activity. During the day, the test subject was, as a rule awake, and the changes made during those periods did not require any motor activity. The test subject listened to radio transmission, music, literature readings, and took an active part in conversations. He took a nap whenever he felt like it. At night he was kept in semidarkness, in conditions conducive to sleep.

Maximum immobility was an indispensable condition of all the tests. With the exception of the sleeping period, the body temperature was taken under the tongue every 2 hours around the clock, the pulse frequency was counted, and the respiration checked; the arterial pressure was also measured in the test subjects of the first series.

The investigations revealed that the nyctohemeral rhythm of the functions under study, particularly the body temperature, changes in most cases of limited mobility. The changes of the nyctohemeral rhythm are more pronounced when the test subjects are kept in water.

The typical daily changes of the pulse frequency, respiration, maximum and minimum blood pressure and body temperature could be traced in the case of test subjects G. and A. who were kept for 8.5 and 10.5 days in terrestrial conditions of limited mobility, and test subject S. who was kept in conditions of aqueous hypodynamia for 11.5 days.

The daily pulse frequency fluctuations during the first days of the hypodynamia were within the range of 10-15 beats per minute; the respiration frequency was 5-8 respirations per minute; and the maximum and minimum arterial pressure was within the range of 10-15 mm Hg. The changes of the daily fluctuations of these functions in conditions of prolonged limited mobility were manifested as a tendency to obliteration, that is, a reduction in the amplitude of these fluctuations.

In the first 2 days the configuration of the daily curves of the body temperature was, as a rule, similar to that described by Mosso. In the following days the curves revealed a sharp change. The daily curves of the body temperature were characterized by a rapid rise to 36.9-37.1° by 10-1200 hours (on the sixth day in the case of test subject G., and the seventh and ninth days in the case of A.); they remained at that level until 20-2200 hours within a fluctuation range of 0.1-0.2°, and were then followed by a gradual drop or new rise. In subject A., for example, the body temperature rose again to 37.1° by 2400 hours.

It is interesting to point out that the configuration of the curves during the hypodynamia was not stable, the body temperature curves of the same test subject revealing sharp changes on different days.

In test subject G., the body temperature fluctuated at the 37.1-36.9° level on the sixth day of the hypodynamia from 10 to 2200 hours. On the seventh day the body temperature rapidly rose to 37.1° by 1400 hours, then dropped to 36.4° by 1600 hours, remained at that level for 6 hours and began to rise again by 2400 hours.

After 8 days in water, the daily curve of the body temperature fluctuation in test subject S. was distorted. If in the first day of the hypodynamia the highest body temperature noted at 1800 hours was 37.2°, the lowest body temperature recorded at 1800 hours on the ninth day was 36.2°. On the tenth day there were practically no daily fluctuations in subject S. between 8 and 2000 hours, and his body temperature remaned at 36.5-36.6°, and only by 2200 hours did his body temperature rise to 37.0°.

The information obtained in this project justifies the conclusion that vigorous muscular activity is an important component required for maintenance of a daily functional stereotype. A limitation of human motor activity results in a disruption and change of the adaptive reactions developed in the process of the phylo- and ontogenesis. Obviously, a disruption of these adaptive reactions is not a matter of indifference to the organism.

The maintenance of the nyctohemeral rhythm of the functional fluctuations is apparently an important ingredient in the preservation of a person's capacity to work. The development of a pattern of work and rest for professions characterized by limited mobility should therefore provide for measures designed to maintain a normal nyctohemeral rhythm.

THE ACHIEVEMENTS AND GOALS OF SPACE MEDICINE

V. V. Parin

(The text of this report has not been submitted.)

SOME STRUCTURAL PRINCIPLES OF FLIGHT CONTROL AND NAVIGATION SYSTEMS

Yu. A. Petrov

The history of the development of instruments installed in planes for the use of pilots in flight shows that the evolution of these instruments has been characterized by an increasing scope of information received by the pilot, and a higher degree of information reliability.

In visual flight, such instruments are required as extensions of the human sense organs. They enable the pilot to make a thorough analysis of the range of the processes under his control which cannot ordinarily be perceived. This applies to the speed and altitude of flight and temperature control (oil, cylinder heads, exhaust gases, turbine operations, and other flight parameters). In night flight, in cloudy weather, and in fog the instruments are the only source of reliable information on the position of the plane in space and its progress.

Now that automatic and semiautomatic flight control systems have come to the aid of the pilot on a large scale, the very approach to flight instruments is undergoing a change. First of all, it is possible to prevent the pilot's attention from being over-taxed by secondary information on the performance of the power plant (motor or engine). The pilot's attention should be focused only on the emergency features of the motor operation, that is, when the failure of the automatic facilities calls for other measures designed to correct an emergency situation. It is also becoming possible to relieve the pilot's attention of all other auxiliary information. The pilot should always be free to concentrate on the following aspects of the flight:

(a) Where and in what position is the plane.

(b) In what stage is the implementation of the preset flight program.

(c) Actual flying conditions as compared with the prescribed ones.

(d) Performance of the apparatus installed in the plane.

In order for the pilot's perceptive process to be fairly simple and reliable, the cockpit instruments must meet a number of requirements in respect to nomenclature, general shape and appearance, rational sizes, combinations of certain groups of instruments, and overall design.

From the point of view of nomenclature, the various problems of flight control and the required information on a number of auxiliary or short-duration processes call for an excessively large nomenclature of instrument indicators. Various indicators should be designed to control the spatial position of the plane, fly the plane at a preselected altitude and an optimal speed in the desired direction, and control the performance of the power installation and auxiliary devices. It would be expedient in this connection to supply the pilot with the part of the information required for the implementation of a particular stage of the flight program. In addition, some instruments, especially of the auxiliary type, should be connected only when the parameter (process) they control shows a dangerous deviation from the normal course.

That the instrument panel, particularly a single instrument, should be characterized by a single indication principle becomes obvious at first glance. The general aspect of this principle is indisputable. A mixture of principles--"from the plane" and "into the plane" on the same panel--has an adverse effect on the pilot's orientation in the events under control. In the solution of certain concrete instrument-indicator problems, however, certain departures from this principle are not only possible but also necessary. Such a necessity was exemplified by the change from the gyro horizon AGK-47B and AGI-1. Although it is easier to read the gyro horizon AGK-47B than the gyro horizon AGI-1, the latter

has a definite advantage in the range of its action. While the AGK-47B is limited to a very narrow range of permissible lateral and longitudinal pitch, the AGI-1 is subject to no such limitations.

A study of published information and experimental tests appears to favor the following system of instruments. All indicators are divided into two basic groups:

1. Information indicators. Their purpose is to "extend" and strengthen the sense organs in such a way as to make it possible for the pilot to control the conditions and nature of the flight, as well as the performance of the power plant and the auxiliary apparatus.

2. The command indicators. The purpose of these indicators is to alert the pilot to his next move. Such prompting may be concrete or general. Certain information indicators are of a command nature. For example, when the exhaust gas temperature reaches a high point, the pilot knows that he must reduce the gas, but this is not a strictly command instrument because the latter should be equipped with an arrow indicating not 900° but a command inscription saying "remove gas".

The information indicators include: (a) abstract quantitative indicators (altitude, speed, Mach number, etc.); (b) visual indicators characterizing primarily the spatial position of the plane; this includes banking, pitching, and direction characteristics; (c) signaling devices: strictly speaking, signaling can be attention attracting (if a light flashes near the instrument or the apparatus), warning (when a light flashes indicating something is wrong), directing (if the signal directs the pilot's attention to a concrete group of instruments or a certain lever), and informing (in which case the signal informs of an event that has already occurred, as for example "no oil"). There are sound and light signals, the latter appearing in the form of indifferent bulbs or illuminated inscriptions. The signaling devices are characterized by the following qualities: (a) attention-attracting elements, and (b) information on a particular event or condition.

The signaling devices may also be of a commanding type. For example, as the plane is about to land there appears an inscription saying "lower landing gear".

The command indicators, unlike the first group of information indicators, are not primarily designed to enhance the pilot's analytical possibilities in flight. They should be made in the form of zero-instrument indices, or devices indicating scratch marks or, finally, in the form of command inscriptions, already mentioned.

There is a direct relationship between the urgency of the problems of engineering psychology and the rate of development of aviation technolgy.

PATHOMORPHOLOGICAL CHANGES INDUCED IN ANIMALS BY ROTATING THEM AROUND AXES RUNNING THROUGH THE PELVIC-CARDIAC-CEPHALIC REGION

V. G. Petrukhin

Very little is known about the pathomorphological changes produced in the organs by various types of acceleration occurring in aviation practices. The purpose of this investigation is to define certain changes of the internal organs in dogs subjected to rotation around an axis running through various sections of the body. A study of such overloads is important for the development of prophylactic measures, especially when bailing out in emergencies.

Our investigations involved 47 dogs, of which 41 were subjected to the effect of overloads varying in direction, magnitude, and duration, on special rotating stands. The tests and physiological investigations were carried out by S. S. Markaryan, E. V. Marukhanyan and I. A. Tsvetkov.

In the first series of tests the rotation axis ran through the pelvic region, with a body tilt angle toward the axis varying from 20 to 90°. The animals were subjected to single and repeated effects each of which lasted from 4 to 20 minutes, and the overloads created at the head level amounted from 2.5 to 14 (22 dogs).

In the second series, the rotation axis was perpendicular to the body and ran through the cephalic region. The animals were subjected to a single effect amounting to from 6 to 17.2 and lasting 3-20 minutes (5 dogs).

In the third series, the rotation axis ran through the cardiac region, thereby creating an overload at the head level amounting to from 6 to 14 and lasting 7-23 minutes (5 dogs).

In the fourth series, the animals were rotated around an axis running through the pelvic region for 4 seconds at a maximum angular acceleration from 180 to 320, and a trip-out of 200-400°/sec^2; the overload at the head level was from 9 to 14. The rotation time at a maximum speed did not exceed 2 seconds (angular accelerations; 9 dogs).

In 23 cases, the animals died during the test. Eighteen of the animals were killed at various periods ranging from 30 minutes to 12 days after the end of the test. Six dogs were examined for control purposes. All the dead animals were subjected to a careful pathoanatomical investigation followed by a histological processing of organ specimens, according to the commonly accepted methods.

The morphological examinations revealed that the lengthy radial accelerations simulated on a rotating stand, regardless of the location

of the rotation axis (the pelvic, cardiac or cephalic region) and the body tilt angle toward the rotation axis, produce considerable changes in the organism when the overload exceeds 2.5 and lasts 20 minutes. If the overload increases more than sixfold, the animals die during the test in most cases. The dogs were found to tolerate the rotation-produced overload more easily when the rotation axis ran through the cephalic region than through the pelvic or cardiac region. The difference between the overloads (under an effect lasting 20 minutes) was 1.5-2 and 2-3, respectively. In the case of shorter effect periods but great overloads, this difference is considerably smaller. The animals can withstand greater accelerations by almost 2-2.5 overloads when the body is inclined toward the rotation axis at an angle of 20° as compared to 90°. The difference in the tolerance of overloads by individual dogs in all directions did not exceed 1.5-2. The maximum tolerance of the dogs under the effect of angular accelerations was the accelerations exceeding $480^{\circ}/sec^2$ at a rotation with a maximum overload lasting over 2 seconds (not counting the time used in acceleration and deceleration). Although the accelerations in the different tests were in opposite directions, the pathomorphological picture of the changes was almost identical.

Whenever the animals died during the tests, or were killed in the first 30 minutes after completion, their right heart cavities, caval veins, and pulmonary arteries were found to be sharply dilated with blood, and there was a plethora of the pia mater of the liver near the radix pulmonis. The latter also revealed hemorrhages and atelectasis on the dorsal and diaphragmatic surfaces.

The only difference was as follows: overloads in the head produced hemorrhages in the mucous membranes of the eyes, in the accessory cranial cavities, and pia mater; the pelvic organs were anemic. A shift of the overloads to the pelvis reversed the picture. The hemorrhages were more pronounced in the case of angular accelerations.

There was no indication of blood redistribution in the animals killed a day or more after the test. The hemorrhages were gradually resorbed. A microscopic examination failed to disclose any disruptions specific to accelerations in a certain direction.

The changes in the brain began with perivascular adema and hemorrhages (the latter were more frequent under the effect of angular accelerations but very rare in positive accelerations). This was followed by an edema around the ganglion cells and nerve fibers. Dystrophic processes (of the ischemic type) appeared at the same time in the ganglion cells, reached their maximum by the second day, and lasted until the animals died. There was an increase in the number of gliosis elements around the changed ganglion cells and capillaries between the first and seventh day.

Anemia, an edema of the connective tissue layers, small hemorrhages, and a reduced glycogen content in the muscular fibers were found in the hearts of the animals that had died during the test. The animals killed 30 minutes and more after the test also revealed symptoms of albuminous dystrophy (eosinophilia, fuchsinophil granule, homogenization, and the loss of striation), less often fatty dystrophy and on still rarer occasions the death of individual muscle fibers. In the course of time the glycogen was gradually restored, the dystrophy disappeared, and between the third and seventh day the heart returned to normal (with the exception of cases accompanied by the death of muscle fibers).

The lungs of the animals that died or were killed 30 minutes after the test revealed wide open arteriovenous anastomoses, hemorrhages, atelectases, and perivascular edema. The animals killed later under similar conditions frequently revealed catarrhal pneumonia.

A granular and vacuolar dystrophy, changing to a fatty dystrophy a day later, developed in the liver immediately after the capillaries had become filled with blood; the connective tissue layers were affected by edema and occasionally also by a hemorrhage.

Symptoms of a reduced quantity of lymphoid elements in the follicles were found in the spleen, as well as a hyperplasia of the reticular cells and an accumulation of hemosiderin in the pulp. A larger quantity of the latter was found also in the Kupffer cells of the liver.

In addition to a turbid swelling and vacuolization of the epithelium of the winding canals, the kidneys occasionally revealed a vacuolization of the endothelium of the glomeruli and a spasm of the "lead-in" arteries.

A reduced quantity of lypoids in the cortical layer was found in the adrenal glands of the animals killed a day after the test.

Thrombi were found in some cases in the pulmonary, liver and pericardium veins.

The disturbance of the blood circulation in the other organs appeared in the form of edemas, venous stasis, and occasionally also hemorrhages.

Repeated acceleration effects failed to reveal any marked increase in the animals' resistance to overloads. An investigation of the animals found the consequences of former sharp changes, the number and quality of which depended primarily on the frequency of the overloads and the time that had since elapsed.

Hydrocephalus was found in 2 of the 8 dogs, thrombosis of the right auricle and atrium cordis in 2 others, and foci of bronchopneumonia or

small pneumosclerotic foci in all of them (depending on the time they had been killed); there was a mild hypertrophy of the ventricles and occasional foci of micromyomalacia with symptoms of cicatrization; small rarefaction foci were found in the brain, and symptoms of a chronic stasis in the liver; organized and rechanneled thrombi were observed in the pulmonary, cardiac, and liver vessels.

It should be emphasized that hemorrhages in the mucous membranes of the nose and eyes represent a dangerous symptom. Our observations of all the animals affected by such hemorrhages revealed considerable changes in all the organs, and extensive hemorrhages in the lungs.

It should be assumed, on the basis of the above, that the chief reason for the morphological disruptions produced by prolonged accelerations is the disruption of the blood circulation in the organism accompanied by a blood stasis in the lesser circulation and the opening of arteriovenous anastomoses in the lungs. Inadequately aerated blood enters the left heart, a hypoxia of the myocardium and the brain develops, and the combination of hypoxia with higher pressure in the vessels increases their porosity and develops edema and hemorrhages. The results of hypoxia, venous stasis, and edema are dystrophic and necrobiotic processes in the cells of the brain, myocardium, liver, and other organs. The hemorrhages and edema contribute to the inflammatory processes in the lungs. The disruption of the fluid circulation in the brain plays an important part in the genesis of the changes.

The main reason for the injuries sustained under the effect of angular acceleration is apparently the sharp "striking" increase in the venous pressure and the sharp displacement of the organs. The effect of disrupted hemodynamics in these cases probably plays a secondary part.

THE PATHOMORPHOLOGY OF TRANSVERSE OVERLOADS

V. G. Petrukhin and M. M. Sokolova

Acceleration produces the only effect of its kind that so rapidly and crudely disrupts and distorts the blood circulation and, naturally, will produce morphological changes in the organism when that effect is powerful enough. However, morphological investigations, especially those concerned with the effect of transverse acceleration, have been practically nonexistent.

This project summarizes information on the pathomorphological changes in 52 dogs and 13 monkeys subjected to the effects of transverse

accelerations. Seven dogs and 1 monkey were examined for control purposes. The tests in a centrifuge and the physiological investigations were carried out by A. R. Kotovskaya, S. F. Simpura, A. V. Yeremin and V. A. Arkhangel'skiy.

All the tests may be divided into four series. In the first series, the dogs were subjected to the effect of an eightfold overload for 3 minutes in the chest-back direction; in the second, to a twelvefold overload lasting one minute; in the third, to a twelvefold overload for three minutes; and in the fourth, the female monkeys were subjected to a twelvefold overload lasting from 3 to 5 minutes (depending on the electrocardiographic changes) with the back of the armchair inclined at an angle of 20 to 45° toward the horizontal. After the tests all the animals were sacrificed by ether; some immediately, other 1 hour later, and 1, 3, 7, 15, 30 and 60 days later.

The results of the morphological investigations revealed that the nature of the changes in the animals' organs in all four series of tests were identical. But the extent of the affection was somewhat different, the animals of the second and third series revealing more extensive lesions.

An investigation of the animals killed less than an hour after the effect showed that the right heart cavities, the vena cava, the pulmonary arteries, and liver veins were overfilled with blood. The diaphragmatic lobes of the lungs on the dorsal side were also overfilled with blood. Small or large hemorrhages were found in the same lobes closer to the radix, as well as in the central lobe of the right lung and cardiac portion of the left lung in most of the animals under the pleura. Hemorrhages were observed also deep in the tissue. Brain, liver, and kidneys were plethoric; myocardium was flaccid and anemic.

Disrupted blood circulation was not observed in the animals killed 8 days and longer after the experiment. Macroscopic changes were found only in the lungs.

A microscopic examination of the brain 1 hour after the effect revealed a slight edema of the meninx and substantia medullaris. Dystrophic processes (of the ischemic type) appeared 1 day later in the ganglion cells (chromatolysis, swelling, and vacuolization) extending to the formation of tissue cells. These changes reached their maximum by the third day, followed a little later, by proliferative processes of the gliosis cells, the latter frequently concentrating around the damaged ganglion cells or certain capillaries. In 7 to 15 days, the ganglion cells of the cortex were back to their usual structure. In some cases, the symptoms of glia proliferation lasted 30 to 60 days.

Eosinophilia of the muscular fibers (occasionally with the loss of striation) and a fuchsinophil granule in the protoplasm were observed in

the heart 1 hour after the test, in addition to the anemia and the edema of the connective tissues. By the end of the day the edema diminished, and symptoms of albuminous dystrophy increased. After the third day, the dystrophic processes gradually diminished, and by the 15th day the myocardium returned to its usual condition. In some animals of the third and, particularly, the fourth series of tests, fatty dystrophy and small foci of micromyomalacia were found in the myocardium of the left ventricle. A histochemical test showed a reduced glycogen content in the myocardium of the animals killed immediately after the effect. This pattern was particularly prominent in the animals of the fourth series of tests (monkeys). By the end of the day the glycogen content in the myogenic fibers of the heart was higher than usual in the animals of the first and second series; in the animals of the fourth series of tests, the superregeneration phase occurred later, by the third day.

A pronounced plethora, particularly in the root zone and closer to the dorsal side, was observed in the lungs of all the animals 1 hour after the test. The arteriovenous anastomoses were wide open, and most of the animals revealed hemorrhages and edemas. The latter, as a rule, developed into an inflammatory process 1 to 3 days later. By the seventh day most of the hemorrhages were resorbed, and the severe inflammatory processes abated. In only half of the cases did symptoms of a productive reaction develop in the foci of the remaining inflammation. Fifteen to 30 days later, infiltrates from the lymphoid cells and histiocytes and a (focal) intumescence of the interalveolar septa were discovered near the bronchi in a few animals.

By the end of the day, a granular and occasionally vacuolar dystrophy developed in the liver against the background of a considerable venous stasis. Between the third and seventh day, however, the liver regained its normal structure. An accumulation of hemosiderin was observed in the Kuppfer cells during these periods.

The changes in the kidneys 1 hour after the effect were characterized by a considerable plethora of the tissue. A granular and occasionally a vacuolar dystrophy eventually developed in the epithelium of the winding canals. An increase in the cells (of the histiocytic type) around the "lead-in" arteries was observed in some cases between the 7th and 15th day. No changes were noted in the kidneys by the 30th day.

A decrease in the number of lipoids was observed in the substantia corticalis of the adrenal glands 1 day after the experiment. At the same time, there was a decrease in the number of lymphoid cells in the spleen follicles.

The above-described pathomorphological picture of the brain and myocardium affection is by its nature similar to the changes produced by hypoxia. The transverse overloads apparently disrupt the blood supply

to the brain and myocardium, while the wide open arteriovenous anastomoses in the lungs, the venous stasis and the edemas around the vessels contribute to the genesis of hypoxia in these organs.

The changes in the lungs can probably be explained by the fact that the blood, because of its mobility (displacement), flows to the dorsal departments under the effect of acceleration. In view of the "increasing weight" of the fluid column, however, the right ventricle is unable to "push" the blood through the entire lung tissue, thereby producing the conditions for a stasis in the areas near the roots. A rising blood pressure in the pulmonary vessels results in the transudation of the plasma and erythrocytes and the breakup of the capillaries. Eventually the resorption of the edemas and hemorrhages produces an inflammatory process similar in type to traumatic pneumonia.

In summation, accelerations produce in animals a large number of morphological changes, mostly reversible, in the cerebral cortex, heart, lungs, liver and other organs associated primarily with the disruption of the blood circulation in the entire organism.

SOME PROBLEMS OF THE HUMAN PERSONALITY IN AERONAUTICS, AVIATION AND ASTRONAUTICS

K. K. Platonov

As a historically new and rapidly changing type of human activity in very specific conditions, flight has revealed certain patterns which are at times less noticeable in other cases of interaction between the human being and the surrounding medium. It also reveals more clearly the personal attitudes of the human being and his personal qualities.

Aeronautics, aviation, and astronautics, since their genesis, have attracted the attention of various scientists, and have produced conflicting opinions concerning personality and its role in flight. The problem raised in the heading of the report, extends beyond aviation medicine, and its significance goes far beyond historic interest.

The prerequisites for this type of a review of the problem are: the publications of recent years on the history of Russian aviation medicine and psychology; the common point of view achieved at the All-Union Conference in May 1962 on the philosophical aspects of the physiology of the higher nervous system and psychology, and the achievements in aviation and space medicine discussed at that conference. It is particularly important to discuss the problem raised in the heading of the

report in the light of the resolutions adopted by the June Plenary Session of the Central Committee of the CPSU of this year.

We shall cast a glance at the past because, as is known, there is no theory without history, and the past yields a lesson for the future.

Flying in a balloon, man was relatively inactive. The progressive tendency of the first aeronauts (S. L. L'vov (1803) and Ya. D. Zakharov (1804)) prompted them to overcome the sensational glory of "fearlessness" on the part of aeronauts. Their attention was rightly directed to the study of the gnostic qualities of the human being. M. A. Rykachev (1882), who no longer pursued that goal, was the first to provide a fairly substantial list of qualities required by an aeronaut--a brief description of professional skill which still applies to pilots as well as astronauts. Elaborating a bit, it may be said that aeronautics (which is again on the agenda!) presented a number of basic requirements in the field of gnostic qualities; aviation superimposed psychomotor requirements on them, and astronautics added both of the requirements to the intellectual, volitional, and moral qualities of the personality.

According to S. P. Munt (1897), his first investigations in a balloon were designed to establish the necessary expert requirements and prevent accidents. Those were, indeed, complicated physiological and psychological requirements, for it was only natural that at that scientific level the study of the human personality coincided with the psychological study of man in flight.

The aviation age was started in accordance with N. Ye. Zhukovskiy's (1893) classical thesis that "Man in flight will be propelled not by his muscles but by his mind". The first articles requiring the legalization of an expertise for pilots (S. A. Beknev, 1911 and L. I. Shif, 1912) justly advocated a medical and psychological selection. The beginning of medical aviation expertise (1911) coincides with the first experimental psychological examination of the aviators in the world, conducted by V. V. Abramov in V. M. Bekhterev's clinic as part of a study of the higher creative features of the human personality.

An analysis of that period shows that the study of man in flight began as a combined study of the human being as an organism and a personality. Two distinct approaches (both are still in force) were soon made to the to the psyche of the flier: personal and functional, both of which are combined with the mechanistic approach. These approaches were soon clearly manifested in P. N. Nesterov's fight for a conscious piloting of a plane and against the idea of instinctive piloting which had been borrowed from abroad.

The discussions at the Third All-Russian aeronautical congress (8-13 April 1914) also reflected these two lines. At that congress, the

progressive idea, which is still in force, was not only a defense of the development of flying capacities (N. A. Yatsuk), but also a defense of the concept of flying capacities as personal qualities, not only as flying habits (A. F. Prussis). It is interesting to point out that a similar discussion, which should be viewed from these same positions, was recently repeated (December 1959-February 1960) in the newspaper Sovetskaya Aviatsiya (Soviet Aviation) under a subtitle "Talent or effort?".

The discussion begun in 1914 grew sharper in the first half of the twenties when the first point of view was defended by S. Ye. Mints, who considered the synthetic methods of examining the military student for selection purposes only as the first stage of the following dynamic study of the "students psychology". The second point of view was defended by the psychological technicians--isolated from psychology, who replaced the analytical methods of investigating the military students--first used by A. P. Nechayev, by testing. The latter approach to the human personality in the second half of the twenties and early thirties became official. But the struggle against it, conducted from correct positions, did not come to an end but took the form of a struggle for the psychohygienic trend (N. A. Molodtsov, S. I. Subbotnik, S. P. Ronchevskiy and, eventually, I. V. Kontorovich). The views of N. A. Molodtsov, the founder of Soviet aviation medicine expertise, have been unjustly forgotten. His idea of combining as much as possible the psychological study of the personality in the course of selection with the related study of the psychohygienic performance now deserves special attention. It is in this particular direction, but in combination with the contemporary views on the formation of the pilot's individual characteristics and flying capacity, that work should be further developed into a definite system.

The dissatisfaction with the psychotechnical investigations and the protest against them, in addition to healthy criticism, took the form of a biological evaluation of the flyer's personality. Those biological views, which swept across aviation medicine in three waves, delayed the psychological investigations and the publication of the projects already completed, but most of all they interfered with the development of the proper methods and positions required in the investigation of the flyer's personality.

Those waves had, of course, originated outside the field of aviation. But in aviation they took the form of a fight against psychology, characterized by three typical features: first, it was concentrated primarily in the area of individual psychology; second, the purpose of the struggle was not to improve the study of individual psychology but to put an end to it; third, this struggle was protracted in nature and continued even after it had already been completed in other areas.

The first wave of the twenties was determined by a wide prevalence of reflexological views among the aviation doctors, with N. M. Dobrotvorskiy

as the proponent of such views. This situation continued in aviation even after the "reflexological discussion" (1930-1931).

The second wave was characterized by an erroneous understanding of the resolution adopted by the Central Committee of the All-Russian Communist Party (bolsheviks) "On the Pedological Distortions in the System of the People's Commissariat of Education" in 1936. Instead of the expected enhancement of the psychological effort, the result of this wave in aviation was the administrative suppression of the psychological investigations and the study of the personality problem.

The third wave in this biology trend was characterized by the misunderstanding of the meaning of the "Pavlov session" (1950) and an ignoring of the thesis with which K. M. Bykov used to begin his lecture: medicine, as the science of man, should also be based on biology and psychology.

Despite the fact that the All-Union Conference on the philosophical aspects of the physiology of the higher nervous system and of psychology (May, 1962) and the following joint resolution of the Presidiums of the USSR Academy of Sciences, USSR Academy of Medical Sciences and the RSFSR Academy of Pedagogical Sciences, called attention to the struggle against the biological trend and the negative attitude to psychology as its manifestation, the "biologization" trend in aviation medicine has not completely abated to this day.

The struggle between the progressive and "biological" views of the flyer's personality was manifested also in the history of the individual approach to the aviation medicine expertise. The progressive side in this case was represented by the struggle for higher personal and psychological qualities of the flyer, as part of the flight and medical qualifications, to be included in the expertise along with the results of the experimental psychological investigations. Here the progressive feature was the effort made in the theory of the individual approach to the expertise in aviation medicine (N. A. Molodtsov, G. R. Grayfer, Ya. F. Samter, etc.). The opposition to this, as a rule, leaned heavily on the biological views. It was not accidental that not a single project was carried on in this field during the last "biological" trend. The theory of the individual approach in this expertise, which is part of the theory of personality, is now practically dead. And yet it is this theory that is so urgently required not only for an expertise for flight personnel; the time is not far off when it will be required also for astronauts.

The June Plenary session of the Central Committee of the CPSU, dealing with ideological problems, promptly raised the personality problem before the representatives of various sciences. Lying in the area between aviation psychology and aviation medicine are a number of important practical problems of the personality which call for an urgent solution.

In addition to the already discussed problems, these include primarily a study of the social aspects of personality (orientation and moral qualities) and their role in the general structure of the personality as well as in the compensation for various defects of other aspects and somatic defects. Included here is the personality criterion for the selection of military pilots, which is unjustifiably treated separately from the prediction of the training course. Included here also is the study of personality reactions to unfavorable flight factors, particularly, hypoxia and overloads. It is impossible to resolve all these problems without regard to motivation which (in the case of hypoxia) has just been initiated by G. D. Naroditskaya (1949). The problem of flight fatigue cannot be completely resolved without taking motivation and personality compensation into account (Ye. A. Derevyanko). Still to be thoroughly studied is the problem of personality relations as well as relations among personalities. Herein lies the psychological basis for the selection of flight crews. Some theoretical experimental prerequisites for the successful solution of this very important problem are already available, but engineering psychology in aviation has only begun to develop its own dynamic aspect and to deal with the personality aspects, particularly the aesthetic requirements, of crew selection.

The complex study of man in flight, not only as an organism but also as a personality, which took shape spontaneously under the effect of practical requirements and was delayed by three trends of "biological" views, must become a theoretically substantiated program for the further development of aviation and space medicine. The art of flying must be studied in combination with the personality. Developing along the lines of aviation medicine (and particularly in close association with aviation medicine expertise), aviation psychology has already laid a fairly solid foundation and, basing its efforts on the physiology of the higher nervous system, should proceed to the completion of its superstructure, the theory of personality and personality relations. The implementation of this task is not an easy problem; it is considerably easier to study the separate functions. But the implementation of this very complex requirement will save aviation medicine from a recurrence of the "biologizing" errors.

EVALUATING THE EFFECTIVENESS OF THE EXPERIMENTAL METHODS USED IN THE PSYCHOLOGICAL SELECTION OF AVIATION CADETS

B. L. Pokrovskiy, T. I. Zhukova and V. P. Zukhar'

One of the important problems in the psychological selection of aviation cadets is to evaluate the effectiveness of individual methods. The major requirements for selection techniques are predictability and reliability. Predictability is characterized by the correlation of the methodological data with the successful mastery of the art of flying. A close correlation can be achieved when the methods reveal the individual psychological characteristics of the personality which are very important for the flying profession. Reliability is characterized by the constancy of the results achieved on repeated application of a given method. It means that the investigation results are not accidental but reflect certain definite patterns.

We verified predictability by comparing the investigation results with a given flight progress. This was done by two methods. In some cases the experimental data were compared with the psychological characteristics revealed in the course of flight training. Thus, the methods designed to study particular aspects of attention were compared with the quality of the attention shown in the flights: its distribution, the ability to combine various activities and watch several instruments simultaneously, discretion, etc. The evaluation of the predictability of the tests designed to study the characteristics of the development of new habits and the changes of old ones took into account the speed and ease with which the flying habits were acquired (the number of test and control flights, the mastery of new types of flights), the extent to which these habits have been mastered, the effect of interruptions on piloting, typical errors, etc.

In other cases it was found more expedient to compare the investigation results with the general flying progress.

The investigations revealed considerable differences in the effectiveness of the methods. Some of them were characterized by a fairly high degree of predictability; others were completely unsuccessful. We shall cite the example of a group of cadets examined during their admission to school in 1958. Eight different tests were used: adding and switch manipulating, "folium-vibrometer", finding numbers and manipulating switches, distributing numbers, and entangled lines. An analysis revealed that the test results appeared in the above-listed order, in point of effectiveness. The shortcomings in the psychological qualities of the persons successfully completing their methodical assignments of "adding and switch manipulating: and "finding numbers" were less than one-half than among the persons completing those assignments unsatisfactorily. At the same time, the shortcomings of the attention in flight

were equally frequent (in 40 percent of the cases) among the cadets who rated an excellent and good grade in the completion of the "entangled lines" tests, and those who put in a poor performance. The distribution of numbers produced similar information.

A comparison of the results of the experimental psychological investigations with the general flying progress shows the same general picture. The data on a group of cadets from one of the flying schools may serve as an example. They were divided into two groups: those whose performance of a task by a particular group of methods was rated excellent and good, and those with an average and poor rating. The percentage of the slow cadets who should not have been admitted to school was determined in each group.

The figures are cited in the table (see page 349). That table shows that the cadets performing their tasks successfully by the first three methods include approximately half as many poor students as those completing their tasks with an average and poor rating. The "scales estimating" tests was found to be absolutely useless.

A comparison between the groups of cadets completing their experimental task with a consistent "excellent" rating, and those with a consistently "poor" rating produces still more contrasting results. Thus, among the cadets completing their addition and switching test with an "excellent" rating, the number of poor students was 4.7 times smaller than among the poor performers; the number was 3.4 times smaller in the compass-reading test, etc.

The reliability of the results was checked in repeated investigations of the group of cadets by the same methods and in practically the same conditions after one year (1959, 1960). The differences between the evaluations of their performance in the first and second time were calculated. The correction-making tests, numbers finding, addition and switching operations, and compass reading revealed a fairly high performance similarity in the first and second tests amounting respectively to 82, 86, 93 and 75 percent. The reliability of the "tube tachistoscope" and "scale estimating" tests was found to be inadequate.

A special checkup on the effectiveness of the methods we had adopted for practical psychological selection purposes revealed that while the investigation results obtained by means of an entire complex of methods correlated with the quality of the flying progress (with a 99 percent probability), the probable correlation based on individual methods was always below 95 percent.

It follows from the above that the results of the investigation by the same methods carried out at different schools and compared in different ways reveal a systematic recurrence. The cadets performing their

No.	Methods	Percentage of students showing poor flying progress among those completing the prescribed assignments		
		Excellent and good	Satisfactory and poor	Ratio
1	Addition and switch manipulation	21	47	1:2.2
2	Correction-making test	22	46	1:2.1
3	Number finding and switch manipulation	25	51	1:2.0
4	Compass reading	24	40	1:1.7
5	Finding numbers	31	46	1:1.5
6	Tube tachistoscope	27	41	1:1.5
7	Scales estimating	34	31	1:0.9

tasks by the most predictable methods contain about half as many slow students as the poor performers. Such an analysis makes it possible to choose the most expedient methods for psychological selection purposes. But such a selection can be made only by the use of a complex of methods designed to investigate the characteristics of the various psychic processes and the personality as well as a combination of both of them.

SOME REASONS FOR ERRORS MADE BY THE PILOTS IN INSTRUMENT FLYING

V. A. Ponomarenko and A. G. Shishov

Any complication in flight requires a rapid orientation and proper action on the part of the pilot. The failure to observe these two conditions produces a situation that might lead to an accident. Instrument flying is an emergency situation the outcome of which depends on the proper action on the part of the pilot. A study of over 50 cases of flying and navigation instrument failure shows that proper action is frequently preceded by erroneous action. There are a number of conditions that contribute to the pilot's errors.

Such conditions are produced by the lack of a signal system to indicate the failure of an instrument and permit discovery of such failure in time. The untimely discovery of the failure, in turn, is due to the inertness of the instrument which causes a flow of misinformation to the pilot. These conditions complicate the changeover to a new stereotype of activity in view of the fact that the failure of the instruments comes as a surprise to the pilot who is not prepared for it. The major reason for this entire cause-and-effect chain of pilot's errors is the misinformation, which leads to a dangerous bank and pitching moment, reduced speed, etc., thereby enhancing the danger of an emergency situation.

A wrong bank indicated by a failing gyrohorizon requires the pilot to remedy this situation immediately, and the result is that he unwittingly commits a crude error. A premature descent and a change in the landing course due to a failing compass are due not so much to the complexity of instrument flying as to the late discovery of the failure, to the search for the cause by way of trial and error. If the late discovery of the failure (due to the lack of a signal system) is conducive to wrong action, the search for the cause by way of trials connected with the misinformation merely serves to compound the already committed error. This is a result of the psychological conflict between the incoming information and the pilot's perception. Speedometer failure during a night flight in poor weather conditions gave the pilot the wrong information on increasing speed, and led to his erroneous action. Despite the fact that the gyro horizon indicated the required pitching moment, the pilot kept increasing it until the lack of pressure on the control stick made him realize that the speed was extremely low.

The pilot normally looks at the instrument and perceives the initial and final position of the arrow; at the same time he perceives kinesthetically the position of the lever. Thus, the movement of the arrow provides a constant flow of information to the pilot in the form of visual and kinesthetic impulses.

In this case, the contradictory information between the visual and kinesthetic perception serves to prolong the search for the reason behind the increasing speed, thereby jeopardizing the flight. In this connection, we are right in saying that the lack of a signal warning of instrument failure not only complicates the work of the pilot but creates conditions that might be conducive to an accident. The late discovery of the instrument failure by analyzing the errors already committed increases the pilot's psychological strain and undermines his confidence in the outcome of the flight; lack of confidence in the indications of the other instruments is very dangerous. While increasing his speed in the clouds in one of the flights, the pilot noted that the speedometer actually indicated reduced speed. Trying to maintain that speed by increasing the revolutions of the motor, he did not suspect that the trouble lay in instrument failure, even though, after bringing the plane

up to top speed, his instrument still indicated reduced speed. The pilot usually correlates the indications of the variometer, gyro horizon and speedometer; in this case, their contradictory information merely served to confuse him. Instead of changing to instrument flying he made his first mistake: he began to descend at a great speed. The speed-indicating arrow continued to drop even though the pilot had already changed his course into a dive. Receiving the wrong information, the pilot was unable to determine at first which of the instruments had failed him, as he had already begun to distrust the indications of the variometer as well as the tachometer. The distrust in the instruments enhanced the pilot's psychological tension "... I literally 'ran back and forth' on the instrument panel in the painful search for the failing instrument. My body felt heavy and I experienced the unpleasant sensation of a lack of self-confidence. When the noise and pressing effort on the control stick told me that I was moving at a great speed, I realized that the speedometer had broken down. Constraint and lack of confidence disappeared without a trace".

This lack of confidence in the instruments, caused by lack of a direct and reliable warning system of instrument failure, is nothing unusual--it is the result of contradictory information. Thus, we can see that the contemporary warning system of major instrument failures does not release the necessary information for immediate perception or for making a decision based on analysis of that failure. The best signaling system of instrument failure is one that can be clearly perceived by the peripheral vision. Particularly desirable would be an indicator in the form of a tape with black and white stripes. Instrument failure would initiate the movement of that tape, easily perceived by the peripheral vision, thus reducing the time it takes to find the failure.

In conclusion, we should like to point out that the reason for the errors made in instrument flying, in addition to the misinformation, is the physical dissimilarity between the major and auxiliary instruments. It is difficult to imagine a completely satisfactory replacement of the arrow-type speedometer or variometer by such instruments as a tachometer or gyro horizon. The indications perceived by the pilot in this case inform him only indirectly of the current parameters. This fact is due to the impossibility of arranging two sets of instruments on the instrument panel. In this connection, the use of a sound signal system that would indicate the required parameters for the auxiliary instruments in the different stages of the descent, should the main instruments fail, would greatly reduce the mental strain of the pilot, thereby reducing the number of his errors.

Conclusions

1. The lack of a warning system indicating instrument failure and the flow of misinformation to the failing instruments are the major cause of pilot errors in instrument flying.

2. The physical dissimilarity between the major and auxiliary instruments is a concomitant condition of erroneous action.

3. The introduction of the proposed failure-warning signals is one of the methods of improving flight safety.

SOME METHODS OF IMPROVING THE PERCEPTION OF PARAMETERS CONTROLLED BY A HUMAN OPERATOR

V. A. Popov, A. M. Pikovskiy, Yu. V. Kiselev and Yu. V. Krylov

Modern aviation and space facilities raise a number of new problems connected with the control of the flying apparatus. Since the proper functioning of these systems depends to a considerable extent on the accurate performance by the human operator of individual operations of the semiautomatic control systems, it is, therefore, urgent to develop means for improving human perception of the parameters to be controlled.

Recent literature has increasingly stressed the design of such instruments whose indications are directed not to one but to two and more human analyzers. Most modern instruments are equipped with a visual type of indication (an arrow, an electron beam tube, etc.). In actual practice, however, there are cases when visual indication is difficult: for example, when the illumination is weak or subjected to great changes, or when the operator's attention is frequently distracted from the instrument.

If each particular value of the measured parameter is indicated not only by a certain position of the arrow on the instrument but also by a definite frequency or tonality of a sound signal, we will have an instrument equipped with a visual and auxiliary sound indication system. The development of such instruments calls for a familiarity with the differential audio-frequency thresholds in actual working conditions.

A large number of publications deal with the definition of the differential audio-frequency threshold, but this information cannot be used for two reasons: (1) the differential thresholds have been determined

by the authors' external soundproof conditions which do not correspond to those of the operator's work, (2) the changing audio frequency in the mentioned investigations was of a discrete nature. But in the sound indicator in which we are interested the tonal frequency should be changing continuously as the parameter to be controlled is, as a rule, undergoing continuous change.

In our investigations, the planned changes in the frequency separation were made by means of the sound generator 3G-2A at a speed of 3-5 hertz per second and at frequencies of 685-1,800 and 3,400 hertz. The external auditory interference level amounted to 75-80 decibels. A total of 256 experiments were made, revealing that the differential audio-frequency threshold, by the mentioned terms of the definition, amounts to 0.02 of the frequency under consideration. This is the figure that should be used to calculate the sound indicator.

There is no doubt that if the information on the changing parameter under control flows through a visual as well as a sound channel, when observation of the visual indicator is difficult, the perception of the mentioned parameter can be improved. But can the perception of a parameter be improved by an additional sound indication if the operator's attention is concentrated on the visual indicator? Solution of that problem required the investigation of certain aspects of the interaction between the auditory and visual analyzers. This was done with a test jig consisting of a 3G-2A audio-frequency generator which was connected to an ICH-6 frequency meter in such a way that every position of the frequency meter arrow corresponded to a certain value of the sonic frequency in the generator. The sound in the generator was changed by a smooth and even turn of the generator detuning knob by an electric motor. The changing sound was recorded on a circular calibrating generator scale where a shift of the control handle by one scale division corresponded to a frequency change of one hertz.

The experiment was made by three methods. The first method, in which information on the changing parameter was fed only to a sound channel, was similar to the one used to define the differential frequency thresholds (altitude). With 6 to 8 signals for each of the frequencies under consideration--685, 1,800 and 3,400 hertz--the information on the changing parameter was fed only through the visual channel. The test object was then asked to pay close attention to the position of the arrow on the frequency meter indicator. A turn of the detuning knob of the audio-frequency generator changed the position of the arrow on the frequency meter. The sensitivity of the frequency meter arrow at 685, 1,800, and 3,400 hertz frequencies was 0.0045 degree/hertz, 0.0018 degree/hertz and 0.0009 degree/hertz, respectively. Noting the deflection of the arrow, the test object pressed a button which brought the arrow to a stop.

By the last method, the information on the changing parameter was fed simultaneously through a visual and sound channel. A button was to be pressed as soon as the change in the parameter was discovered on either of the two channels. In all the methods, the deflections were recorded by the number of divisions on the detuning scale of the audio-frequency generator. The frequencies under consideration as well as the alternation of the auditory and visual indications were constantly changed in order to exclude the operator's training effect. A total of 756 tests were made and each experiment was repeated 6-8 times.

All experimental results were statistically processed, the data for each test subject were averaged up, and the percentage ratio of the minimum parameter deviations noted by the test subject (based on separate visual or auditory information) to the minimum parameter deviation, as reported simultaneously through two channels, were calculated. An indication of over 100 percent meant that the parameter perception based on simultaneous information coming from the visual and auditory channels was improving, and if less than 100 percent it meant deterioration.

The average ratio, reflecting the interaction of the analyzers in the test subjects, was 110 percent at 685 hertz, 111.9 percent at 1,800 hertz, and 106.2 percent at 3,400 hertz. The same ratio for a general overall 95 percent probability lies within the following ranges: at 685 hertz, 110.0 $\pm$ 4.3 percent; at 1,800 hertz 111.2 $\pm$ 5.5 percent and at 3,000 hertz 106.2 $\pm$ 4.1 percent. Thus if the information on the changing parameter is fed through the visual and auditory channels at a time when the test subject's attention is concentrated on the visual indicator the improvement in the parameter perception accuracy amounts to about 6-11 percent.

Individual test subjects find it considerably earier to perceive the parameter under control if the appropriate information is fed simultaneously through the visual and auditory channels. In this case, the above-mentioned ratio amounts to 135-155 percent. But the problem involving the stability of this effect in individual test subjects is subject to a further study. In particular, it would be practical to make such an experiment in a dynamic trainer in which the nature of the operator's activity is most similar to his actual conditions of work.

Conclusions

1. A combination of visual and auditory indication improves the perception of one parameter as compared to either visual or auditory indication by 6-11 percent. In certain test subjects such an improvement amounts to 35-55 percent.

2. The calculation of the sound signal for instruments with a dual indication system should be based on the fact that the differential audio-frequency threshold is not less than 0.02 of the frequency under investigation.

3. Semiautomatic control systems whereby the parameter is subject to the most accurate determination on the part of the operator should be equipped with a dual indication system (visual and sound). It is desirable to select the type of operators who reveal a higher capacity for determining the changes of any parameter in conditions of analyzer interaction.

THE REACTION OF THE ORGANISM TO THE INFORMATIONAL CHARACTERISTIC OF A STIMULUS

V. A. Popov and A. S. Khachatur'yants

One aspect of research in aviation medicine deals with the processes of airplane piloting. Considerable success in this field has been achieved by the development and utilization of complex devices designed to record the various aspects of pilot activity and condition in flight (K. K. Platonov, V. A. Popov, A. M. Pikovskiy, Ye. R. Derevyanko, etc.). But despite their value, these efforts were primarily descriptive in nature. The development of cybernetics and the theory of information made it possible not only to attempt a quantitative description of the elements involved in the piloting process but also to determine the new aspects of their analysis.

The dependence of the characteristics and speed of a human reaction on the varying probability of a signal appearance has been investigated in a number of publications (by R. M. Zarakovskiy, M. A. Alekseyev, etc.). These efforts were limited to a study of the elements characteristic of the time the test subject is introduced into a probability medium. Of undoubted interest also are the characteristic reactions to the signals of such a system whose probability characteristics have already been learned by the test subject. The methods developed have enabled us to record these characteristics fairly accurately; they may be looked upon as a laboratory model of elementary activity based on a purposeful preselected probability characteristic of the surrounding events.

The experiments were designed to study the changes in the test subject's reactions to a surrounding medium characterized by various probabilities under the effect of various specific factors. It would be

expedient, first, to trace the changes as the (informational) characteristic of each of the signals forming the model of the external medium fades from the memory of possibilities. In the experiments, the informational complex to be assimilated by the test subject consisted of 5 sound signals occurring at such a frequency that their informational characteristics corresponded to 0.5, 1.78, 3, and 4 beats. A repeat of these test programs every hour revealed a peculiar picture of the informational value of certain individual signals fading from the memory of the test subject. Cited in Table 1 are the generalized results of the tests with 10 subjects.

Table 1

Informational characteristics of signal (in beats)	Effective duration (in hours)
0.5	5
1.78	6.5
3	29
4	55

It may be seen from the table that there is a definite relationship between the duration of the informational significance of the signals in the memory and the magnitude of that significance. Attention is called to the fact that this relationship is logarithmic rather than linear in nature.

The changes in the hidden time of the reaction to each signal of the mentioned complex amounted to a progressive reduction of that time. In the graphs containing an outline of function t = f (H), the test result curves for each hour changed their slope and approached the X-axis. The comparison of the submitted and following information was made easier by calculating the derivative function t = f (H), that is by determining the magnitude $\frac{1t}{dH}$ referred to by us as the tension factor. In the cited experiment, that factor took on the following values: 0.06 sec/beat one hour later, 0.04 sec/beat two hours later, and 0.02 sec/beat five hours later.

In the following series of tests, immediately after assimilating the informational structure of the color-signal complex, the test subject was subjected to a prolonged effect of acoustical noise with an intensity up to 104 decibels. By the end of the third hour, the function t = f (H) was seen to be disrupted; if the noise effect was continued

after that, the restoration of the function began 20-25 minutes later. The quantitative characteristic of these changes can be traced by comparing the tension factors (Table 2).

Table 2. The Changing Tension Factor Under the Effect of Noise

Time of change	Tension factor
After the introduction into the informational medium.	0.14
After one hour of noise	0.09
After two hours of noise.	0.04
After three hours of noise. . . .	function disrupted
After a 20-minute rest.	0.08

An entirely different type of changing tension-factor was produced when the test subject was under the effect of alcohol. The introduction of alcohol (0.5-0.75 ethyl alcohol per 1 kg of weight; per os) made the reactions more sensitive and increased the tension factor. Two hours later, the observable normal effect of this informational structure was almost completely demolished, and the tension factor could not be determined. Six hours later, the functional relationship was restored, and then died away at a smooth but somewhat faster than usual rate. The development of these events is outlined in Table 3.

Table 3

No.	Data reading time	Tension factor in sec/beats
1	Introduction.	0.16
2	every 30 minutes.	0.29
3	every hour.	0.33
4	every 2 hours	function disrupted
5	every 3 hours	function disrupted
6	every 4 hours	0.05
7	every 5 hours	function disrupted
8	every 6 hours	0.16
9	every 12 hours.	0.09
10	every 15 hours.	0.02

A similar system was also used for the study of other deleterious factors, such as oxygen deficiency, barometric pressure drops, a prolonged unchangeable position, etc. A comparative analysis of these data showed that the shorter retention period of the informational significance of the signals in the human memory was a common feature of all the tests. The nature of this type of memory loss is largely specific to the effect of individual factors.

Conclusions

1. The demolition of the probability characteristics of the signals mastered by man is accelerated under the effect of deleterious factors on the organism.

2. The characteristic reactions of the human being to a variety of stimulus probabilities may serve as a criterion for estimating his capacity for work under the effect of various factors on the organism.

ELECTROCARDIOGRAMS IN DOGS DURING EXPOSURE TO CERTAIN ALTITUDE FACTORS

V. L. Popkov and I. N. Chernyakov

The normal EKG of dogs has several specific features: the average pulse in dogs is twice as fast as in man; respiratory sinus arrhythmia is more sharply pronounced; inversion and polymorphism of the T wave with displacement of the ST interval above and below the isoelectric line is not a pathological sign; and the Q and S waves are not constant and are sometimes missing under normal conditions (Sapov (1955), Gurevich, Kvitnitskiy (1956), Homazyuk and others (1960), Petersen and others (1951), Grollman and others (1952), Fabre and others (1955), Bober (1956), and other writers). These characteristics of dog EKGs have been taken into consideration in our analysis of the experimental material. The experiments were conducted on 11 dogs.

A total of 373 EKGs (with the three standard leads (I, II, and III)) were taken on 11 dogs. The animals--immobilized in a prone position while EKGs were being taken--were subjected to hypoxic hypoxia (in a pressure chamber atmosphere with an oxygen deficiency equivalent to an altitude of 9 km), to the effect of respiration of high-pressure sea level and high-altitude atmospheres, and to the effect of a pressure reduction of 0.3 abs atm.

Under normal conditions, the EKG P wave in all experimental dogs was positive for the three standard leads. Only one EKG showed an isoelectric P_3, and in another case a weakly negative P_3P_1 fluctuated between 0.05 and 0.2 mv in the initial tests (instead of between the more frequent limits of 0.1 to 0.15 mv). The largest of all the waves, the $P-P_2$, varied from 0.05 to 0.45 mv, with an average value of 0.25 mv. The P_3 normally varied within the extreme limits of +0.3 mv to -0.1 mv, with an average value of +0.1 mv. During hypoxic hypoxia (pressure chamber oxygen deficiency equivalent to an altitude of 9 km) a drop in the P_1, P_3, and especially the P_2 waves, was noted. The lower limit values of P_1, P_2, and P_3 were consistent with normal P wave variations. The variations of P_1, P_2, and P_3 during respiration of high-pressure sea level atmospheres did not exceed the normal limits. After reduction of ambient pressure by 0.3 abs atm, and during respiration of high-pressure high-altitude atmospheres, P_1, P_2, and P_3 increased but did not exceed the upper limits of normal P wave variation. The P wave increase was dependent on the amount of excess pressure.

The limits of EKG R wave variation in the initial tests were 0.4 to 1.8 mv for R_1, 1.0 to 1.8 mv for R_2, and 0.55 to 0.8 mv for R_3. The effect of acute hypoxia (oxygen deficiency equivalent to an altitude of 9000 m) produced a regular decrease in R values for all three standard leads (a decrease of 0.1 to 0.3 mv in R_1, 0.05 to 0.5 mv in R_2, and 0.05 to 0.3 mv in R_3). During respiration at high-pressure, sea-level atmospheres, R_2 usually remained constant or else increased by 0.05 to 0.3 mv. R_1 and R_3 were characterized by opposite-tending changes: in the majority of experiments, R_1 decreased by 0.1 to 0.2 mv while R_3 increased by 0.05 to 0.3 mv. It is interesting to note that R variations changed in the same manner after the 0.3 abs atm pressure drop and during respiration of high-pressure, high-altitude atmospheres: R_1 decreased by 0.1 to 0.3 mv, R_2 remained constant or increased by 0.05-0.4 mv, and R_3 increased by 0.05 to 0.3 mv. No direct ratio between R values and the pressure increase of the respired atmosphere was noted. The R wave variation under

the above-mentioned conditions did not exceed the normal limits of R fluctuation. The observed tendencies of R change with increased pressure are probably due to the altered position of the heart in the chest cavity under these conditions.

It was noted that of all the EKG waves observed in dogs, the Q and S waves were the least stable even under normal conditions, disappearing and reappearing on successive recordings of the same dogs made at various times. In the initial tests, the Q_1 and Q_2 values varied from 0.0 to 0.3 mv; in approximately 50 percent of the normal EKGs, Q_1 and Q_2 were not observed at all; Q_3 was nearly always absent under normal conditions. Hypoxia, reduced pressure, and respiration at high-pressure, sea-level, and high-altitude atmospheres caused new Q_1 and Q_2 waves to appear and a Q_3 wave to be formed in the EKG. During respiration at high-pressure, high-altitude atmospheres, all three waves (Q_1, Q_2, and Q_3) were observed in the majority of the EKGs. The value of Q usually did not exceed 0.2 mv; i.e., it remained within the limits of normal variation.

Under normal conditions, the S_1 wave was absent from the dog EKG. S_2 and S_3 varied from 0 to 0.7 mv (S_2) and from 0 to 0.9 mv (S_3). During hypoxia and following the pressure drop of 0.3 abs atm, S_2 and S_3 usually decreased. During respiration at high-pressure, high-altitude atmospheres, an S_1 wave appeared in the EKGs, but its value did not exceed 0.05 to 0.1 mv. Variations of S_2 and S_3 in high-altitude tests remained steady within the limits of 0.05 to 0.15 mv.

The T wave in the dog EKG was characterized by a great diversity of configuration and even under normal conditions might be isoelectric, negative, or even two-phased (both positive and negative phases) on successive recordings made on the same dog at different times. As a rule, T_1 was negative under normal conditions; T_2 was the most variable and might equally well be positive or negative; T_3 was positive in the majority of cases. In individual instances, during the initial tests,

T_2 and T_3 were two-phased. ST_2 and especially ST_3 frequently dropped below the isoelectric line on the normal EKGs, which is not a pathological sign in the dog EKG. Under the effect of hypoxic hypoxia (pressure chamber atmospheres), negative T_2 and T_3 waves showed an increased shift in the negative direction, and positive T_2 and T_3 values dropped; during hypoxia, the two-phased T_2 was the most frequently observed. The delivery of excess pressure in G Sh and VKK sea-level atmospheres, the 0.3 abs atm drop simulating high altitudes, and respiration at high-pressure, high-altitude atmospheres all produced a shift of T_1, T_2, and T_3 in the electropositive direction (values of negative T_1, T_2, and T_3 decreased and positive T_1, T_2, and T_3 values increased).

Under normal conditions, the PQ interval was extremely stable, varying from 0.09 to 0.12 sec in different individual dogs (in most cases 0.10 sec). Following reduction in pressure, and during respiration of high-pressure sea-level and high-altitude atmospheres, the PQ interval tended to decrease to 0.09 to 0.08 sec.

The QRS interval was one of the most stable values in dog EKGs, both under normal conditions and during physiological effects. In the initial tests the QRS was always from 0.05 to 0.06 sec. During respiration at high-pressure, high-altitude atmospheres, the QRS was equal to 0.05 sec.

The QT interval is normally from 0.19 to 0.20 sec. During exposure of the organism to external factors (hypoxia, reduced pressure), QT varied from 0.17 to 0.21 sec. On some of the EKGs recorded during respiration of high-pressure, high-altitude atmospheres, QT decreased to 0.16 sec.

The RR interval was the most labile interval in the dog EKG, varying from 0.34 to 0.60 sec under normal conditions. The systolic index (based on the smallest RR interval in the EKG) normally fluctuated from 35 percent to 60 percent (average 45 percent); this is associated with the very marked instability of pulse typical of dogs (respiratory sinus arrhythmia). During exposure to hypoxia, the systolic index usually increased to 53 percent to 64 percent. During respiration at high-altitude atmospheres at high pressures, the systolic index varied from 40 percent to 63 percent (an increase of 8 to 31 percent over initial test values). The experimental material given above permits us to draw the following conclusions:

1. The method of dog EKGs combined with other study methods permits evaluation of the nature and direction of physiological changes accompanying exposure of the organism to certain factors of high-altitude flight (hypoxia, reduced ambient pressure, and respiration of excess pressure atmospheres).

2. The consistent nature of EKG changes in dogs after reduction in ambient pressure, as well as the differences between the EKGs of dogs exposed to excess pressure and those of dogs exposed to hypoxia, indicates that the factors determining these EKG changes are the delivery of excess pressure in VKK and G Sh barochambers and the resultant alteration in the position of the heart within the chest cavity.

3. Study of the characteristics of EKGs in dogs permits us to conclude that the changes in dog EKGs accompanying the respiration of excess pressure atmospheres are the result of physiological adaptation of the organism to its environment and do not exceed the limits of normal EKG variations in dogs.

EFFECT OF OXYGEN STARVATION ON MOTION SICKNESS

N. A. Razsolov

The investigation of rocking accompanied by moderate hypoxia is of great importance in aviation practice. However, up to the present, only a few works have dealt with this problem (V. I. Boyachek, K. L. Khilov, I. Ia. Borshchevskiy, A. P. Popov, B. V. Tolokonnikov and others), and these have by no means covered all aspects. Consequently, there is obvious need for more elaborate study of this problem.

Our research on the effect of oxygen starvation on motion sickness utilized 3 men and 2 women, 25-35 years old, who, following determination of physical fitness, were subjected to cumulative studies of the vestibular apparatus after G. G. Kulikovskii in double experiments with rotation (OP_1) in three planes, rocking on four-pole (or four-valve) swing during 15 minutes and once again in double experiment with rotation (OP_2). Four subjects showed relatively high statokinetic stability: one showed zero degree of OP_2, two showed first degree of OP_2, one showed a vegetative reaction of second degree of OP_2. Only one subject

(female) experienced vomiting during the 7 minutes of rocking on the swing--second degree (K_2).

Rocking was instituted by the double rotation method (N. N. Lozanov, 1938) in a Barany armchair with a speed of 1 rotation per 2 seconds. During 30 rotations, the subject bent his head and torso forward 15 times to the horizontal plane and straightened up an equal number of times. Rotation was always toward the right, clockwise. During rotation, the eyes were closed; no bandages or screens were used. There were 5 rotation tours, at intervals of 4 minutes. The start of the illusion of "rocking" was recorded during rotation, and, following each tour, these reactions were tested: pulse frequency, arterial pressure by the oscillographic method, the duration of the illusion of counterrotation, hyperemia or pallor of the face, hyperhydrosis, nausea and vomiting and other symptoms of motion sickness. After this, the subject was requested to perform measured dynamometrics by compressing a hand dynamometer in his right hand with an effort equal to one-half maximum manual dynamometrics and then performing a correction text for 2 minutes. Subjects in the initial trial tests (not taken into consideration) performed correction tests of 2 minutes, 20-30 times, always crossing out the letters "K" and "R" on same type correction blanks; consequently, in the tests under consideration, they attained high-quality, highly stable productivity. On 3 people, initial average productivity for 2 minutes amounted to 1600, 1187 and 1208 marks, and in 2 it was 840 and 805 marks (or signals).

The present work covered three types of control investigations. In the first, the subjects were in the pressure chamber, but not subjected to oxygen starvation (shortage) or rocking. These subjects, for whom pulse frequency and arterial pressure were registered, performed regularly measured dynamometrics and correction tests. In the second, the subjects were subjected to rocking in the pressure chamber, but without lifting (elevation). In the third, the subjects were elevated to a height of 4000 m. Subjects in the principal test were subjected to rocking at a 4000 m altitude. There was a total of 53 tests: each subject performed 2-3 introductory get-acquainted tests, 6 control tests each and 2 principal tests each. To eliminate training, the tests were done on every 5th day (with an interval of 4 days). At the completion of testing, which lasted 2 months, all subjects showed approximately the same degree of vegetative reactions.

Results of Investigation

In spite of the fact that our method of rocking differed from that of N. N. Lozanov in number of rotations and that we used a different method for registering arterial pressure, we still found it possible and convenient to evaluate the degree of vegetative reactions by the scale of statokinetic stability as determined by the cardiovascular reflex (Lozanov and Baichenko, 1938).

In 4 subjects, changes in pulse frequency, as well as maximum and minimum arterial pressure in all tours of rocking on the ground (averaging from the figures from two tests), were expressed, in the majority of cases, by 5-4.5 points (or marks), and only twice dropped to 3.5 and 3.75 points, at which time the subjects felt nauseated. One female subject had vomiting during the third tour of on-the-ground rocking, her statokinetic stability decreasing to 3.0 points (marks); after 4 minutes her general condition improved and she was able to continue rocking, and in tours IV and V her score rose to 4.0 and 4.25 points. During the rocking at the 4000 m altitude, the statokinetic stability, as evaluated by the cardiovascular reflex, dropped to 0.5-0.25 points in 4 stable individuals in the majority of tours. One female subject, after the third tour, experienced vomiting, with a stability rating of 3.25 points; after a 4-minute rest period, vomiting ceased, but, after tour V of rocking, vomiting resumed, with stability at 3.5 points. Average arterial pressure during rocking and in a state of oxygen starvation changed very insignificantly.

During the first tours of rocking, all subjects noted the illusion of "rocking," which started with the 10-20th rotation and continued to the end of rotation. In subsequent tours of rocking, "rolling" appeared with the 14-25th rotations; in some statokinetically stable individuals it did not appear at all. In most cases, the illusion had the nature of "rolling motion," with subjects being "thrown" from side to side. After the rocking stopped, all subjects in the first tours experienced an illusion of counterrotation, lasting from 3 to 25 seconds. In subsequent tours of rocking, the duration of this illusion was reduced to 2-10 seconds.

During rocking under conditions of hypoxia, no essential changes were observed in the nature and duration of the illusions of "rolling" and counterrotation, as compared to the rocking under usual conditions.

After completing 50 tours of rocking under usual conditions, hyperemia of the face was reported 12 times; pallor of the face, 15 times; hyperhydrosis, 20 times; feeling of warmth, 8 times; nausea, 13 times; vomiting, twice; fatigue and headache, 5 times. When rocking under the conditions of hypoxia, hyperemia of the face was observed 16 times; pallor of the face, 14 times; hyperhydrosis, 7 times; nausea, 13 times; vomiting, twice; euphoria, 5 times; fatigue and headache, 8 times.

In the first control examination, averaging 2 minutes for each of 50 control tests, 1127 marks, or points were reviewed. Permissible errors here were taken to be 0.24 marks (points). During rocking under usual conditions, average productivity was lowered to 1071 points (95 percent of the initial level), the number of errors went up to 0.36 points (150 percent of the initial level). At the 4000 m altitude productivity of the control test went up to 1167 points on the average

(103.5 percent of the initial level), and the number of errors went up to 0.46 points (191 percent of the initial level). When rocking under conditions of hypoxia, productivity was 1148 points (101.8 percent of the initial level), and the number of errors went up to 0.54 points (225 percent of the initial level).

Under the usual conditions, the average error in the rationed hand dynamometry in 50 measurements, not taking into account the points of errors over (+) or under (-) the given figure, was 1.18 kg. Here, the sum of errors with the plus sign was 40 kg, and the sum total of the points of errors with the minus sign was 19 kg, the ratio being 2.1:1.0. During the time of rocking under the usual conditions, the average error was equal to 2.18 kg (187.7 percent of the initial starting level). The sum total of errors with the plus sign was equal to 99 kg, that with the minus sign, 10 kg, the ratio being 9.9:1.0. Under conditions of oxygen starvation, the average error proved to be 0.96 kg (81.3 percent of the initial starting level). The sum of errors with the plus sign was 36 kg, those with the minus sign, 12 kg, the ratio being 3:1. During rocking under conditions of oxygen starvation the average error of the rationed dynamometry was 2.42 kg (205 percent of the normal). The sum total of the errors with the plus sign was 100 kg, those with the minus sign, 11 kg, for a ratio of 9:1.

Conclusions

1. Rocking after the method of twofold rotation makes it possible to elicit a latent form of rocking in statokinetically stable people and a marked form of rocking in less stable persons.

2. During rocking under conditions of oxygen starvation, vegetative reactions are intensified.

3. During both latent and marked forms of rocking, higher nervous activities are disrupted, apparently, at the expense of weakened inner cortex inhibition, causing a poorer quality performance of correction test and rationed manual dynamometry.

4. Oxygen starvation at the 4000 m height apparently results in weakening the inner inhibition, which is reflected in poorer performance of the correction tests.

5. During rocking under conditions of oxygen starvation, a still greater cumulative disturbance of higher nervous activity is observed.

THE IMPORTANCE OF THE STUDY OF TYPES OF HIGHER NERVOUS ACTIVITY IN MAN IN SELECTING AND TRAINING FLIGHT PERSONNEL

A. A. Rogov, T. T. Gorlanova, M. M. Kantorovich and N. T. Kovaleva

The very rapid development of aviation technology, both in the field of air transport, and in the utilization of cosmic space, imposes greater and greater demands on the pilot's organism as a whole and his nervous system in particular. Up to the present time, insufficient attention has been devoted to the study of the higher nervous activity of man, although this problem is of great importance in flight and cosmic medicine.

Underestimation of the type-specific characteristics of higher nervous activity may be one of the causes for the diminution of efficiency during flight, especially under complex or difficult conditions. Consequently, contemporary study of type-specific nervous system characteristics is of great importance in selection and training of flight personnel and particularly of astronauts.

Even in I. P. Pavlov's lifetime, his school had maximum recourse, in classifying types of human nervous system, to clinical histories with exhaustive anamesis records (B. N. Birman, S. N. Davividenkov, L. B. Gakkel' and others). L. B. Gakkel', Z. I. Biryukova and F. P. Mayorov and others have prepared special questionnaires to evaluate characteristics of higher nervous activity in humans. It should be noted that medical history data should be supplemented with material from observations of the behavior and disposition.

For objective study of specific traits of the nervous system of normal man, we used the method of vascular reflexes, combined with the medical history and observation of behavior.

Selection of the vascular reaction, as an index of nervous processes in the cerebral cortex, was not accidental. In their works, K. M. Bykov, A. A. Rogov, A. T. Pshonik, and others have established a close interrelation between the higher CNS spheres of the vascular system. Many authors (Rogov, Pshonik, Suvorov, Derkach, Kovaleva, Gorlanova, and others) have shown that the cortical processes exert an influence on the nature of the plethysmographic curve.

We observed a group of healthy individuals, most of whom worked and lived under identical conditions, and recorded their vascular reactions plethysmographically by A. A. Rogov's technique. Background plethysmograms, which were studied under nonconditioned and conditioned vascular reflexes, furnished--by their configuration changes and undulating variations--preliminary data for evaluating the chief characteristics of the nervous system. Thus, for well-balanced individuals, the

background plethysmograms beginning with the very first test have a smooth curve appearance. If at any moment there is any undulation, it soon disappears completely.

Background plethysmograms of persons with a severely unbalanced type of nervous system, as a rule, are undulating, and may retain a wavy ripple effect during the time of stimulation.

In weaker types, with balanced traits, background plethysmograms appear as smooth curves; while in persons with unbalanced traits, plethysmograms, as a rule, show constant undulation.

In view of the great variety of vascular reactions in people of different types of higher nervous activity, evaluation from background plethysmograms alone is insufficient. Thorough understanding requires taking into account vascular reactions in response to the effect of both nonconditioned and conditioned stimulations.

Vascular reactions to nonconditioned stimuli vary in degree of marking. Variations (or differences) in vascular reactions, as shown by our data, depend upon the type-specific characteristics of higher nervous activity in man.

In individuals with well-balanced nervous systems nonconditioned vascular reflexes are pronounced and characterized by a considerable drop in plethysmogram, i.e., marked compression of the blood vessels. In individuals with severely unbalanced nervous systems, they are quite pronounced, inconstant, and appear against the background of an undulating curve. In individuals with weak nervous systems, as a rule, they are either poorly expressed or absent, and of an inert nature. In individuals of weak type, with traits of equilibrium, they appear against the background of a smooth curve; in the same persons with traits of imbalance, they appear against the background of undulating plethysmogram.

The following discussion utilizes Pavlov's nervous system types, which he based on his doctrine of conditioned reflexes.

Conditioned vascular reflexes in individuals with well-balanced mobile nervous systems (sanguine) are distinguished by rapid formation and quick stability, with little change in magnitude after formation. As a rule, they appear against the background of smooth plethysmograms. Differentiated inhibition is developed comparatively rapidly with 7-8 applications of negative inhibition and they become stable after 42 applications of stimulants without reinforcement.

In individuals with well-balanced inert nervous systems (phlegmatic), vascular conditioned reflexes do not particularly differ from those of people with well-balanced mobile nervous systems, although

vascular reactions to stimulation take place more slowly and show a slower return to their initial starting level.

In persons with greatly unbalanced nervous systems (choleric), as distinguished from those with well-balanced processes, the positive and negative vascular conditioned reflexes are subject to considerable fluctuations, frequently appearing against the background of an undulating curve.

In individuals with nervous systems, (melancholic) with traits of equilibrium, vascular conditioned reflexes develop with great difficulty, are unstable and primitive in scope. and sometimes may even be paradoxical. Differentiated inhibition is frequently formed more quickly than in individuals of other nervous system types. In individuals of the weak type, with traits of imbalance, these reactions occur against the background of an undulating curve.

It should be noted that evaluation of nervous system types should be based not on one single trait but on the sum total of all indexes.

In this manner, the nature of vascular reflexes in combination with medical history and observations of behavior may serve as objective criteria in selecting candidates for flight service. It may be assumed that the ideal is the well-balanced mobile type of nervous system and in our opinion, astronauts should be of this type.

The study of the specific characteristics of nervous system types in normal man may offer additional insights in selecting and training specialists in aviation and cosmonavigation.

SOME REGULAR PATTERNS IN THE EFFECT OF ACCELERATION ON THE ORGANISM

D. Ye. Rozenblyum

1. This article presents some of the author's theoretical conceptions on the physiological effects of acceleration on the organism.

2. Deviations from normal gravitation, in the direction of imponderability or of increased gravitation, conditioned by the effect of radial accelerations, introduce life activity changes of varying nature and scope, depending upon the index of change in gravitation field, the position of the animal in the evolutional scale, and individual characteristics.

3. In physiological reactions to mechanical stimuli, involving accelerations of different physical nature, we may determine some general, even though not identical, traits, and contingent essential differences.

4. In the effects of radial accelerations, depending upon their physical parameters and the functional state of the organism, we may distinguish two basic phases: (1) the phase of relative compensation, and (2) the decompensation phase.

5. In the phase of relative compensation some functions, mostly the vital ones, are intensified, and others are temporarily inhibited by way of compensation; the mechanical forces exceed the thresholds of individual stability. This phase is neither perfect, nor stable; multiple factors, which inhibit the defense neurohumoral mechanisms, easily destroy the attained adaptation. It is important in demonstrating the physiological mechanisms of adaptation to radial accelerations.

Since the field of centripetal acceleration is equivalent to the acceleration of earth gravitation, one is justified in concluding that the physiological systems of adaptation to earth gravitation carry the load of the fight against increased gravitation.

The author discusses at some length the role of the defense tonic muscle reflexes, in this situation, with various starting mechanisms; the role of the mechanisms of regulating blood circulation in particularly important vital organs; the mechanism of compensation of ventilation insufficiency, should it arise; and the role of vestibular apparatus.

6. Study of the decompensation phase permits delineation, in the chain of mutually connected phenomena, of some leading links, which normally limit transference of accelerations.

7. Data are reported on the physiological analysis of high stability (resistance perhaps) of insects during acceleration; this is of interest in the theory of effect of acceleration on biological objects.

8. Possible remote chronic effect of radial accelerations are discussed.

THE NERVOUS SYSTEM'S ROLE IN THE ORGANISM'S REACTIONS TO ACCELERATIONS

B. M. Savin

The gravitational field is one of the few constants in the environment, and even though gravitation appears, at first glance, of little significance, it is precisely that which played the determining evolutionary role in the development of a number of functions and formation of new structures.

Although man is often obliged to face changes in the intensity of gravitation, in most cases, the range of variations (natural or artificial) seldom exceeds $\pm$ 0.5 gram. However, flying conditions encountered on high-speed planes are quite different from those met in cosmic aircraft. From the moment of takeoff to landing, the crew of a cosmic airship is constantly under gravitational conditions different from those on earth. The cause of this is not so much the lessening of natural gravitation, associated with the departure of the cosmic airship from the earth's surface, but rather the effect of outside forces, imparting acceleration to the cosmic airship and the astronauts within it. Depending upon the magnitude of the forces in operation and their direction with reference to the vector of the gravitation field on earth, two dissimilar states may arise during transmission of acceleration: "overloading" (excess load or surcharge) and partial or complete dynamic incompatibility. From the purely mechanical point of view, both states represent various degrees of mechanical tension of the body structures (deformation).

In overloading, the deformation is more marked than under usual conditions on the surface of the earth when the body merely undergoes the effect of the earth's attraction. Under dynamic incompatibility (partial or complete), mechanical tensions in the body structures are either sharply diminished or completely absent. In this manner, the state of dynamic incompatibility represents a particular case of overloading, in which the excess is near zero value.

Some of the most prominent manifestations of the changes in physiological functioning of the organism under artificial increase in gravitation (overload) are disturbances of hemodynamics. Scientific works have manifested, until rather recently a perfectly unjustified tendency to limit mention of this problem. This was reflected in the attempt on the part of the research workers to disclose only such regular patterns (laws) of the changed hemodynamics which are conditioned by purely mechanical causes (hydrostatic factors). Actually, in cardiovascular functional changes during overload, an exclusively important role belongs to the neural reflex reactions. Depending upon the amount of overload and its direction with reference to the axis of the body, the duration

and repetition of the effect of the reflex reaction on the organism may exhibit considerable variations. In one case, they may be favorable for the equilibrium of the organism under the changed mechanical conditions of its environment, and in such case the reactions should be considered totally as compensatory; in other cases, the appearance of these reflex reactions facilitates the appearance of even more marked disturbances in the state of hemodynamics. These differences in the reflex mechanisms of circulatory regulation are based on shifts in CNS functional state and, primarily, in the condition of the vasculomotor center and the vagus nerve centers.

An analysis of the changes in cardiovascular function during overload permits delineation of a number of different phases or periods, each reflecting the shifts (displacements) in the functional state and in the centers which regulate the cardiovascular system. The sequence of these periods is as follows: compensatory reaction (latent), high compensation, development of decompensation, restoration of compensation, return of the cardiovascular regulating mechanisms to initial state. The first four periods, from the standpoint of time, belong to the moment of reciprocal intereffect of the organism and the changed conditions of gravitation; the last two, to the aftereffect.

When the organism experiences functionally permissible overloadings, then only such states which take place in the form of the first three periods are typical for the cardiovascular centers. When the overload effect becomes too strong for the organism, the second and third periods are obliterated and almost immediately there occur some pathological reflexes which result in decompensation phenomena.

Research has established that with functionally permissible overloads the leading role in cardiovascular functional changes belongs to the appearance of an unusually powerful combination of stimulations. The principal role then belongs to those stimulations which come from the side of the baroreceptors of the vascular system, in particular the receptors of the veins. Under overloads which approach the limits of tolerance, disturbances of the cerebral circulation begin to assume great importance and new interrelationships create a peculiar, vicious circle. In the functional state of the vascular motor center, phase states, typically, appear, characterized by paradoxical reactions, in particular, a depression reaction to the elimination of the inhibitory influences from the side of baroreceptors of the sinocarotid zone.

Functional disturbances of the reflex mechanisms that regulate the cardiovascular system are reflected in the organism's decreased capacity for adaptation and other phenomena which are alleviated only by sectioning of the vagus nerve.

In the systematic effect of overloads, the organism's capacity to balance the changed conditions of gravitation increases sharply. In

planning training for the effect of overloads, the leading role belongs to the higher CNS branches.

ELECTROENCEPHALOGRAPHIC EXAMINATION OF FLIGHT PERSONNEL DURING LONG FLIGHTS

L. V. Sadovnikova

To examine personnel who fly gas-turbine planes--in 8-9 hour flights--we used, along with other physiological methods, the method of electroencephalography (EEG), which has recently been used successfully to solve problems of physiology of labor.

Flying is one example of complex work entailing physical, nervous, and psychic tension. Of practical interest here is the use of EEG to evaluate the mobility of CNS processes.

Data on the effect of flight on the pilot's brain biopotentials are available in the UDS (Soviet) and foreign literature. These bioelectrical activity data pertain only to flight on military reactive planes, for flights of short duration and have nothing to do with EEG changes after long flights on passenger gas-turbine planes.

EEG's of ground workers, (e.g., engineers of Diesel engines and locomotives), following prolonged (7 hours and longer) driving of the engine, have manifested a drop in amplitude of the α rhythm, a decrease in its frequency, as well as shortening of the period of reconstruction of alpha-activity after light stimulation of the eye. The authors (M. G. Babadzhanyan and A. M. Volkov) believe these changes indicate an accumulation of fatigue with formation of stagnation phenomena in the cerebral cortex.

Analysis of EEG data on the flight personnel, after long flights, showed the following:

All members of the crew fully preserved the expression, quantity, and periodicity of the α rhythm. Simultaneously, there occurred a drop in voltage of the amplitude of biopotentials (α, β, and others). Decreased amplitude, for instance, of α waves, was within the limits of 10-25 microvolt, which was from 14 to 33 percent of the initial starting figure.

Such EEG indexes as depression and latent and restoration periods of the α rhythm after striking light to the eyes (or exposing eyes to light) change in the sense of lengthening.

The EEG, taken after the flight, showed no essential changes in the expression of slow waves. Insignificant increase in the number of such waves was observed in 36.4 percent of the examined individuals. In these cases, the amplitude of the waves was lowered, although their duration remained constant. Restoration of EEG components during rest occurred gradually, but not sooner than in 1.5-3 days.

The data show no EEG differences for the various flight professions (captains of the airships, second pilots and pilots), nor for day and night flights.

Analysis of changes in brain biopotentials for personnel performing long nonstop flights on gas turbine planes, leads to the conclusion that there is a decreased bioelectrical activity of the cerebral cortex and a decrease in neural mobility with prevalence of inhibitory processes which may be considered a result of CNS fatigue.

Dependence of the aforementioned changes upon fatigue is proved by the time (1.5-3 days) required to restore EEG components during rest. EEG changes, including changes in other physiological functions, permit recommendation of standardization of after-flight rest periods.

FUNCTIONAL STATE OF THE VESTIBULAR ANALYZER DURING THE FIRST FEW HOURS FOLLOWING IRRADIATION WITH DIFFERENT DOSES

A. V. Sevan'kayev

The problem of the effect of ionizing irradiation upon vestibular analyzer function is now assuming great importance. Under cosmic flight conditions there is a possibility of functional shifts in the vestibular analyzer, one cause of which may be penetrating irradiation.

Having at our disposal new techniques for quantitative evaluation of the functional state of the vestibular analyzer and of radiation effect, we decided to collect relevant data during the first few hours following irradiation with various doses. (Investigation was done under the direction of Prof. M. P. Domshlak and Doctor of Med. Sciences Yu. G. Grigor'yev.) The data obtained may be of use in developing measures to guarantee normal functioning of the vestibular analyzer--a requisite under conditions of cosmic flight.

Experiments were done on 120 rabbits with a new setup that permitted adequate stimulation of the labyrinth and a wide range of angle accelerations and velocities from the subthreshold and threshold to suprathreshold rates (Yu. G. Grigor'yev, B. B. Blokhov, "New Apparatus for an Adequate Stimulation of Vestibular Analyzer, Making Use of a Wide Diapason of Angle Acceleration and Kryolis Forces (or powers) in Clinical and Experimental Examination." Zhurn. "Vestnik otorinolaringologii," No. 6, 1961). Adequate labyrinth stimulation of practically any desired magnitude and current-surveying rings permitted objective registration of the vestibulo-somatic (nystagmus) and of some vestibulo-vegetative reflexes (frequency of respiration and pulse). Subdivided into 6 series (20 rabbits in each series), the animals were subjected to total irradiation in doses of 50, 100, 500, 800 and 5000 r. Evaluation was performed on the threshold sensibility and reactivity of the vestibular analyzer to adequate stimulation two or three times before, immediately following, and 2 and 5 hours after stimulation. Control and experimental animals were examined at the same intervals.

The initial reactions of any analyzer to stimulation are functional and are usually manifested by changes in sensitivity thresholds. The table shows that in the series I and II of the experiments, i.e., after irradiation with doses of 50 r and 100 r, 23 of the 40 rabbits reacted to the irradiation, 13 manifested lowered threshold sensitivity, and the remaining 10 showed heightened sensitivity. Results obtained with the "test for reactivity", i.e., after the use of gradually increasing adequate stimulation (30, 60 and 120°/sec., with subsequent "stop-stimulus") likewise indicate an increase in stimulation of the vestibular analyzer.[1]

In the III series of experiments (dose, 500 r), 18 out of 20 rabbits reacted to irradiation and manifested the same type of reaction with a tendency to inhibit the function of the vestibular analyzer. The maximum drop of threshold sensitivity and reactivity was observed 2 hours after radiation. Five hours after stimulation, the analyzer's reaction approximated the reaction in the control animals.

An increased dose (800 and 5000 r) resulted in still greater inhibition of analyzer function. Five hours after termination of radiation

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[1]The average rate for the duration of nystagmus (D_{avg}) which took place in response to the "stop-stimulus" at the speeds of 30, 60 and 120°/sec, was calculated according to the formula: $D_{avg} = \frac{D - D_0}{D_0 \cdot n}$, where D_0 is the duration of nystagmus for each rabbit before radiation, D is the duration of nystagmus after irradiation in the corresponding period of observation, n is the number of animals in series.

Changes in the Threshold Sensitivity of the Vestibular Analyzer During the First 5 Hours Following Irradiation, in Each Series of Experiments

Dose in roentgens	Number of rabbits in series	Number of rabbits which reacted to irradiation	Nature of reaction		Number of rabbits not reacting to irradiation
			Lowered threshold sensitivity	Heightened threshold sensitivity	
50-100	40	23	13	10	17
500	20	18	18	-	2
800	20	20	18	2	-
5000	20	20	18	2	-

stimulation there was a tendency to restoration of the initial response to stimulation.

After irradiation, particularly with doses of 500, 800 and 5000 r, the animals revealed disturbances in the normal force ratios in the vestibulo-vegetative reactions. Instead of the usual intensity and duration of reaction in proportion to the increased growth of adequate stimulation of the vestibular apparatus, there was observed a nearly one-type pattern of changes in respiration in response to weak and strong stimulations (compensating phase). In some animals, changes in respiration occurred only in response to sufficiently intense labyrinth stimulation (120°/sec) and also, were less significant following than before radiation.

In this manner, there has been established the range of irradiations with doses of 500-5000 r which results in disruption of functional state of the vestibular analyzer in the sense of lowering its response to stimulation and reactivity. Of great importance is the fact that, within the dose range of 500 to 100 r, in some animals there was observed an entirely different kind of functional change--increased response to stimulation. As a practical measure, it is significant that irradiation with 500 r and above suppresses not alone the vestibulo-somatic reflex, but also the vestibulo-vegetative reactions, which reflects the lesser probability of the appearance of corresponding disturbances in the vestibular analyzer under the combined effect of ionizing irradiation and adequate stimulation of the semicircular canals. The diverse tendencies in the changes of the response to stimulation and reactivity of the vestibular analyzer, with irradiation with lesser and greater doses, leads us to assume prevalence of reaction, under these conditions, in the different portions or functional mechanisms of the analyzer.

HISTOCHEMICAL EXAMINATION OF THE CHANGES IN THE DISTRIBUTION OF THE EFFECT OF DEHYDROGENASE SUCCINATE, CARBOANHYDRASE, ALKALINE AND ACID PHOSPHOMONOESTERASE, ADENOSINE TRIPHOSPHATASE AND SULFHYDRYL GROUPS OF PROTEINS IN INNER ORGANS IN ACUTE STATE OF OXYGEN STARVATION

S. N. Sergeyev

Histochemical studies of the changes in the activity of the ferments in various organs and systems of the organism in hypoxia are inadequate. Various histochemical changes have been demonstrated in the distribution of activity of succinate dehydrogenase and acid phosphomonoesterase in different sections of the brain (Ye. Yu. Chenykayeva (1961), Kholle (1955), Baranskiy (1959), Appel', Nereanti and Markovitsi (1960), Bekker and Barra (1961)), as well as alkaline phosphomonoesterase in the liver and kidneys (Tsimmerman and Getslaf, 1961). The literature shows no histochemical studies on the subject of the changes in distribution of carboanhydrase, adenosine triphosphatase, or sulfhydryl groups of albumins. However, it should be noted that in hypoxia there have been demonstrated some changes in the activity of carboanhydrase in the substance of the brain and blood, Ye. M. Kreps (1946), V. V. Strel'tsov and I. M. Khazen (1946), Ye. Yu. Chenykayeva (1947).

The above-mentioned studies were done under relatively long-lasting conditions (calculated in hours) while the organism remained under the effect of decreased partial pressure of oxygen in the exhaled air. However, of great theoretical interest and of vast practical importance is the revelation of the earliest possible structural shifts in the organism caused by hypoxia. These are expressed in the reconstruction of the activity of ferment systems which participate in the performance of alkaline-reconstruction processes (succinate dehydrogenase and carboanhydrase) in the organism and which play a prominent role in the dynamics of the exchange (phosphatase). This, in turn, is of great importance for the discovery of intimate mechanisms of the organism's reaction to oxygen deficiency and, on the other hand, for the elaboration of methods of early microscopic diagnosis of the state of acute hypoxidosis of the tissues.

During the past few years, we carried on some histochemical research--using white rats with acute oxygen deficiency, produced by means of lowering partial pressure of oxygen in the inhaled air, (during ascension in altitude chamber)--on the activity changes of the ferments of oxydation and phosphorous metabolism (succinate dehydrogenase, carboanhydrase, acid and alkaline phosphomonoesterase and adenosine triphosphatase), as well as sulfhydryl groups of albumin in certain inner organs (myocardium, liver, kidneys).

For this investigation, we made experimental studies on the activity of the mentioned ferments, both in acute hypoxia, with fatal outcome within a few minutes (with quick drop in barometric pressure to 145 mm Hg which causes the death of the organism within 3-5 minutes), as well as with the animals in the altitude chamber with pressure of 183 mm Hg during 10 minutes with subsequent sacrifice of the animal. Each experimental animal had a control mate which was sacrificed by decapitation at the same time as the experimental animal.

At autopsy, identical organs from the experimental and control animals were mounted on the microtome table in one block and frozen with solid carbon dioxide. This permitted obtaining a single section from both identical organs from experimental and control animals, and facilitated comparative investigation of the activity changes of the ferment, excluding the influence of such factors as uneven thickness of sections, the quality of the batch of reagent and other potential changes, which elude exact evaluation but are capable of influencing changes in the activity of the ferment in the section.

Sections of the fresh nonfixated tissues, 12 microns in thickness, were prepared in the cryostat at T = -18°C, and were laid on object glasses. Examination of the activity of succinate dehydrogenase was done with nitro-ST after Nakhlas (1957), carboanhydrase after Kurata (1953), in Khoysler modification, acid and alkaline phosphomonoesterase with β-glycerophosphatase after Vakhshteyn and Meyzel' (1957). Examination of the sulfhydryl groups of albumins was done with DDD and diazol black K after Barnet and Zeligman (1952). Control sections with reaction to succinate dehydrogenase, acid and alkaline phosphatase and adenosine triphosphatase were incubated without substrate, with reaction to carboanhydrase--in the presence of acetozolamide; with reaction to sulfhydryl groups, blocking was accomplished with monobrom acetic acid. To obtain survey specimens, the sections were stained with hematoxyline eosin and scarlet red for fat. Under microscopic examination of the specimens, the qualitative changes were studied in the localization of the ferment, as well as in a series of cases which received quantitative evaluation of the changes in the activity from the data of measurements of the relative optical density of the sections with the histophotometrical method.

Microscopic examination of the experimental animals has demonstrated, in most of the cases, a certain depression in the myocardium of succinate dehydrogenase activity, preeminently in the middle layers of the myocardium. In the liver of most of these animals there was observed considerable inhibition of the activity of this ferment, mostly in the central portions of the lobule; in some of these, along the periphery of the lobules, around the septal veins, groups of cells were found with a marked increase in ferment activity. No changes were noted

in the activity of this ferment in the kidneys, although in some there was seen a poorly expressed decrease in the deposits of formasine.

With the reaction to carboanhydrase, a considerable increase in the activity of carboanhydrase of the myocardium was generally observed. In the overwhelming majority of these animals there occurred sometimes considerable inhibition in the activity of liver carbohydrase. In a number of cases, it was possible to observe some inhibition of the activity of the carboanhydrates in the proximal portions of the convoluted tubules in the kidneys, and occasionally there was seen increased deposits of sediment in the epithelium of single isolated convoluted tubules in the distal portions.

No changes were found in the activity of the ferment, acid phosphomonoesterase, in the myocardium. In the liver, in the overwhelming majority of cases, considerable inhibition of the activity of the acid phosphatase was observed, mostly at the expense of decreased sediments in the cytoplasm of the parenchymatous cells. In the kidneys of the experimental animals, in a number of cases, a certain diminution of activity of the ferment in question was revealed in the epithelium of the convoluted tubules.

Investigation of the changes in the distribution of activity of the alkaline phosphomonoesterase showed, in some cases, a uniform decrease in sediments in the muscle fibers of the myocardium. However, the walls of the finer blood vessels and intermuscular capillaries showed high degree of activity of the ferment. In the liver of these animals, against the background of general relative decrease in sediments in the central portions of the lobules of the liver, a marked increase was observed in the activity of the ferment in the cells and in the walls of the capillaries along the peripheral hepatic lobules around the septal veins. In the kidneys, in single isolated observations, there was noticed indistinctly expressed uniform decrease in the activity of the given ferment.

In studying the changes in the activity of the adenosine triphosphatase, in a small number of cases, some decrease was seen in sediments in the sarcoplasm of the muscle fibers of the myocardium. The activity of the ferments in their nuclei, as well as in the walls of smaller blood vessels and intermuscular capillaries, remained on a high level. In the liver, in a number of cases, there was noted a considerable slackening of the activity of the given ferment in the cytoplasm of the parenchymatous cells. In the kidneys of these animals no definite changes were revealed in the degree of activity of the adenosine triphosphatase as compared to the control animals.

In examining the sulfhydryl groups in the myocardium, liver, and kidneys, no marked changes were discovered in the staining of the tissue elements; as a rule, an intense blue staining was observed in the

majority of structural elements of the organs (double combination), indicating a high concentration of the sulfhydryl groups in the tissue proteins.

In the sections, stained with hematoxyline eosin and scarlet red, no morphological changes were seen.

It should be noted that in the dead animals, the mentioned changes in the activity of the ferments varied only in the degree of intensity.

In this manner, experimental study of the changes in the activity of the succinate dehydrogenase, carboanhydrase, acid and alkaline phosphomonoesterase, and adenosine triphosphatase showed typical peculiarities in distribution of the ferments of the oxidizing and phosphorous metabolism in acute hypoxia, which are already to be seen during the first minutes and which consist, as a rule, of a certain relative inhibition of the activity or (which is true of the carboanhydrate of the myocardium) its intensification or, finally, in its dissemination among the various functional structural formations within the same organ (as in the case of the carboanhydrase in the kidneys). On the other hand, it has been demonstrated that histochemical changes in the activity of the ferments develop much earlier than the changes in other important biologically structural components of the tissue of the organs under study--the sulfhydryl groups of proteins.

Experimental data indicated an extremely rapid reaction, on the part of the ferment systems of the organism, to the disruption of the oxygen supply. These data may be useful in differential microscopic diagnosis where death is due to acute hypoxia.

CONTEMPORARY PROBLEMS IN AVIATION PHYSIOLOGY

N. P. Sergeyev, V. A. Sergeyev and F. P. Kosmolinskiy

Flying, under severe conditions, differs considerably from any other mass profession and involves a number of specific traits.

The main characteristic of flying is tension--in the nervous and emotional sense. Tension is reflected in all of the pilot's behavior and in the functional state of his basic physiological systems.

The pilot's work is characterized by a definite goal and an exertion of will that results in sthenic type reactions. At the same time, flying not infrequently is associated with negative emotions.

It has been established that nervous and emotional tension in the pilot increases when flying planes with high flight tactical data, and when adjusting to new type places and new complex flight missions (N. P. Sergeyev, A. A. Vorona, N. A. Agadzhanyan, D. V. Abayev, V. G. Kuznetsov and others).

The same level of energy expenditure in a pilot and in some representative of any other profession with average physical load--for an equal period of working time--will cause, in the pilot, considerably greater physicobiochemical shifts, caused not by the physical load but by the stress reaction (N. P. Sergeyev, D. I. Ivanov and others, 1960, V. M. Vasyutochkin, 1961).

These shifts, first of all, occur in the vegetative vascular reactions and in the mechanisms of neuroendocrinal regulation. Hyperactivity in the flier's organism, which does not correlate with the effect of physical factors of the flight, results in a peculiar state of supercompensation of the physiological shifts. A characteristic picture appears of adaptation syndrome under the conditions of intensified activity of the subcortical processes and inductive inhibition of the regulating functions of the cerebral cortex. The attendant hyperfunction in the hypothalamus hypophysis suprarenals results in a prolonged after-effect which camouflages and distorts both the physiological processes of adaptation of the organism to special factors of the flight, and the appearance of fatigue processes.

Nervous and emotional tension in flying influences basic physiological processes, and not infrequently promotes "stagnation" phenomena and under unfavorable conditions. If repeated many times, it may be the cause of a number of pathological processes, such as atherosclerosis and hypertonia. Many research workers emphasize the apparent association of obesity and atherosclerosis in fliers, not so much from nutritional errors, as from occupational nervous and emotional tension (O. Koldobski, P. Novak, F. Varel, 1960, V. M. Basyutochkin, 1961). On autopsy material, V. Glentts and V. Stembridge, 1959, and F. Vorel, 1961, have shown atherosclerotic changes in 70 percent of the flight crew, including young pilots.

In our studies (F. P. Kosmolinskiy, V. A. Sergeyev, I. M. Khazen, 1961-1962) we established a correlation between the degree of nervous and emotional tension during flight and the development of obesity among the flight personnel (various groups of fliers, with the same nutritional intake, but carrying different flight loads and with different flight assignments have been examined).

Comparison of data on cardiovascular disease for different professional groups (materials from the Institute of Public Health and History of Medicine, N. A. Semashko Memorial, 1961) and flight personnel (L. S.

Isaakyan, 1962, personal observations) leads to the conclusion that there exists a definite relationship between cardiovascular pathology and the professional activities of fliers.

Unquestionably, the great nervous and emotional tension accompanying flights increases heart activity, and necessarily affects the cardiovascular system. Thus, some typical EKG changes, discovered among a flight crew performing intensive flights, were apparently of emotional origin: increased voltage of the R and T waves in all leads, peculiar steep rise of the S-T interval in the second lead, and others (P. V. Buyanov, S. Ye. Komshalyuk, F. P. Kosmolinskiy, 1962).

The same holds true for the various biochemical changes the flier experiences under nervous and emotional tension: cholestrinemia, increased production of steroid hormones, and elimination of ascorbic acid from the organism (G. A. Arutyunov, Yu. F. Udalov, I. S. Balakhovskiy, N. A. Vorob'yev, I. G. Dlusskaya, I. M. Khazen, F. P. Kosmolinskiy and others).

The second special feature is that aviation progress has changed flying from a mental and physical activity to one that is more and more purely mental.

Improvements in the tactical qualities of planes have eliminated much of the pilot's muscular activities and substituted automatic and semi-automatic flight control equipment, such as booster systems, servo-units, and amplifiers.

Technical development, by placing in the pilot's cabin more and more new aggregates, semi-automatic observation gadgets, radio equipment, and control apparatus, has made the work of the flier nearly equal to that of the operating engineer. The system of pilot training has changed and new professional requirements have arisen to meet the needs of complex aviation technology.

The complex equipment in the pilot's cabin, theoretically intended to facilitate the work of the operator and, unquestionably, improving his armature, at the same time has its disadvantages: great flow of information from the indicators, need of constant control over the work of the semi-automatic equipment, piloting of the plane, control of the motor and a number of aggregates--all these create overloading of CNS and analyzers, particularly the visual analyzer. Constantly increasing speed reduces the time available for pilot reactions, and may cause errors of navigation. Thus, I. A. Kamyshev estimates that, during the most crucial part of the flight, the pilot's eye travels with great speed over the apparatus, fixating up to 200 indications per minute. This allows insufficient time for the mental evaluation of a quickly changing environment and for definitive decisions. Consequently, the

work of the pilot skirts the edge of the nervous system's physiological limits.

The third requirement of flying is working under the dynamic factors of flight (acceleration, overload, noise, vibration) and the unusual hygienic conditions posed by the limited space of the cabin, special equipment, fixed position of the body in the seat and oxygen respiratory apparatus.

Associated with these requirements of flying are the problems of aviation physiology pertaining to facilitation of work, prophylaxis of professional pathology, and improved performance of the flier.

Along with these conditions, common to flying, there are requirements peculiar to each type of plane, the nature of flight assignment, and the functional duties of the crew members. Thus, there is a need to draw up recommendations for improving the organism's capacity to resist the unfavorable factors of flying.

These changing conditions of flying and the complexity of maintaining them at optimum level require the combined efforts of physiologists, public health specialists, hygienists, psychologists, and such other specialists as engineers and architects.

Aviation medicine is commonly subdivided into disciplines like aviation physiology, hygiene, psychology, and medical flight experts. The time seems now ripe for discussion of a new, quite independent department of aviation medicine--the physiology of flight work. Like physiology of labor, the physiology of flight brings together a number of sciences. It studies the effects of the organism's encounter with flying and its capacity for work and fatigability and individual behavior traits under flying conditions.

At present, these basic problems in flight physiology have assumed great scientific and practical interest. Scientists are seeking to develop methods of increasing the flier's resistance to the damaging effects of flying, and to normalize and organize his work conditions.

Aviation medicine deals with problems of rationalization of labor in the "pilot-airplane" system, and with the problems of engineering psychology, a new discipline with the methods of psychology, cybernetics, and bionomics. In our day, it has become quite obvious that in constructing machines for efficient operation by man, it is necessary to consider not only man's anatomy and physiology, but also his psychology.

The problems of creating technical means of pilot defense against injurious factors and of removing the physiological limits of flight

tolerance are solved jointly by constructing engineers, contractors, and hygienists, with the essential participation of aviation medicine specialists.

Changes in the conditions of flying have stimulated a need for new methods of investigation. No longer effective are such formerly important methods as chronometrical timing of operations, calculation of energy expenditures, determination of caloric content of the food ration.

Under contemporary conditions, methods of studying the flier's higher nervous activity and his personal behavioral traits, assume particular importance. It is necessary to establish the level of nervous and emotional tension, the degree of difficulty in the performance of the flight mission and evaluation of reserve potentialities of the organism.

If formerly it was possible to judge the degree of physical difficulty of a job, from certain vegetative changes (pulse frequency and respiratory movements), at present such changes are successfully used as criteria for evaluating nervous tension and emotional excitability during flight. Physiologists, studying flying fatigue, find it necessary to gain a differential approach to the data obtained in physiological investigation, depending upon the nature of the work performed, individual psychophysical peculiarities of each flier (the type of higher nervous activity) and his attitude to his work.

From the practical standpoint, it is important to study fatigue and capacity to work from the special traits and signs manifested in the course of basic CNS nervous processes (phase conditions), both during and after flight. Schedules of work, rest, and nutrition must be studied if a high level of work capability is to be maintained. Along with determination of optimal intervals between flights, an extensive elaboration of methods for restoring work capability is needed, in association with study of the dynamics of physical condition, tension mechanisms, and occupational diseases among the aviation crew. At the same time, experts in the field of aviation physiology must provide recommendations for a rational approach to regulation of schedules of work, rest and nutrition, intelligent operation of special equipment and oxygen supply, general and special physical training and supervision of health.

The problem of pilot work capability is closely associated with problems of improving resistance of the organism to extreme flying conditions. This may be achieved both with specific methods of training (for the effect of some concrete factor in flight, like overloading), and with nonspecific methods that influence the homeostatic mechanisms of the organism.

Improvement of the organism's resistance to modern flying conditions requires new nutritional products which possess the properties of physiological stimulation and normalization. In view of the enormous influence of the qualitative composition of the food upon nervous processes, nutrition in flight should be studied again with the object of increasing the specific weight of foods which include some full-value proteins and highly unsaturated fatty acids. It is also necessary to review vitamin content and the place of salts and microelements in nutrition. The substances assimilated by the organism should provide the most favorable biochemical conditions for the higher CNS processes. Some new forms of rations on board should be prepared on short order.

The physiology of flight work, being physiology of activity and work behavior, includes study of the problems of muscular activity of the flier (motor reactions in response to received information, coordination of movements, static and dynamical loads, etc.), which, in turn, is closely associated with increasingly important problems of physical training of the pilot.

For successful development of an extensive plan of work in the field of flight physiology it is necessary to consider the selection and perfection of the methods of examining the flight personnel. It is necessary to put into practice in experimental work, complete examination of the flight personnel by clinical, physiological, biochemical and psychological methods, including the dynamics of the processes studied and individual differences among fliers. At the same time, some uniformity should be attained in the methods and standardization of examining equipment, so that the study of flying may be carried out on a wide scale.

In this manner, under contemporary conditions, the need arises for extensive research in the field of aviation physiology. This constitutes a special division in aviation medicine and physiology of labor--that of physiology of flying.

THE ROLE OF REDUCED REACTIVITY OF THE ORGANISM IN RESISTANCE TO EXTREME INFLUENCES (ACCELERATION, RADIATION)

N. N. Sirotinin

The best example of lowered reactivity among mammals is that which occurs during winter hibernation (N. N. Sirotinin, 1934, 1939). It has long been known that, while in deep winter hibernation, animals better tolerate hypoxia (Paul Bahr, 1878, N. V. Kravkov, 1903, N. N. Sirotinin,

1940, N. A. Alkhangel'skaya, 1949), as well as a number of other pathogens (intoxication by various poisons, in particular, bacterial toxins).

Research on the effect of winter hibernation on resistance to transversely directed radial acceleration was first done in 1946. It was found that bats, hedgehogs, marmots, and hamsters will tolerate much greater accelerations during deep winter sleep. Bats showed the greatest tolerance.

Tolerance of acceleration depends upon the depth of sleep; in the spring, before awakening, it is reduced and approaches that of the state of waking. Because of reduced reactivity in the hibernating animal, acceleration produces no great degree of changes in circulation and respiration--except for marmots, which do show increase in cardiac function and respiration, the latter occasionally even stopping, although this does not result in death.

Increased resistance to acceleration during winter hibernation is associated, first of all, with increased resistance to hypoxia, as demonstrated with radial acceleration in our laboratory by E. O. Teplitskaya (1946-1959), and others (Neis, Idel'berg, Charlend, Rozenbaum, 1954, A. A. Sergeev, 1957, E. A. Kovalenko, 1963). Discovery of hypoxia of the brain with this effect was later confirmed in our laboratory by I. F. Sokolyanskiy. We observed increased resistance to radial acceleration in rats adapted to hypoxia in an altitude chamber, and in mice, rats, and guinea pigs acclimated to high mountain temperatures.

V. I. Danileyko (1958, 1959), in our laboratory, found that hypothermia in rats results in increased resistance to radial acceleration; this was confirmed by A. A. Sergeev, 1957, and G. D. Glod, V. S. Oganov, N. N. Timofeev, 1962. S. Troyan and L. Ilek (1961) observed increased resistance to acceleration during ontogenesis in rats under the influence of pentobarbital and chlorpromazine. The obtained rates of resistance vary with different authors, and, apparently, depend upon the degree of hypothermia: the deeper hypothermia, the greater the resistance to radial acceleration.

V. I. Danileyko (1958) discovered that barbamil narcosis will cause, in rats, a certain increase in resistance in rats to the effect of acceleration.

Comparison of the various influences of increased resistance to acceleration shows deep winter hibernation to be most effective, followed by deep hypothermia, and, least effective of all, narcosis.

The literature contains numerous references to increased radioresistance resulting from different forms of hypothermia, but much less data on the increase of such resistance during winter sleep. Our

research, carried out with E. I. Chayka (1959), shows that deep winter hibernation increases radioresistance more than does hypothermia. On the basis of the obtained data (1957, 1959), we may assume that animals during winter sleep and deep hypothermia are suitable objects for investigation during prolonged and remote cosmic flights. Some of our new data once again confirm this assumption.

SOME NEW INDEXES OF HEMODYNAMICS, OBTAINED BY MEANS OF THE MECHANOCARDIOGRAPHIC METHOD

M. N. Syviritkin

The flier, under conditions on contemporary planes, experiences a number of unusual factors which impose extremely great demands on the cardiovascular system. In this connection, an improved and more detailed evaluation of the circulatory condition of flying personnel by the medical flight commission hospital becomes of great practical importance. Existing methods of medical flight specialization still do not furnish complete knowledge of the functional condition of heart and blood vessels.

Determination of the duration of the various phases of cardiac activity by EKG, phonocardiograms, ballistocardiograms, electrokymograms, and other devices is unquestionably valuable, but still does not offer sufficient quantitative knowledge of the strength of heart contractions. The volume speed of blood outflow from the left ventricle into the aorta (VSO) was used in evaluating the strength of myocardial contractions in dogs by I. P. Pavlov back in 1883-1887, but no VSO studies have yet been done on man. (This perhaps could be explained by the absence of proper methods for simultaneous registration of systolic heart volume and time of expulsion.) Now, however, popularization of the mechanocardiographic method of Prof. N. N. Savitskiy, permits evaluation of both VSO and the power of contractions of the left ventricle.

As we know, simultaneous registration of tacho-oscillograms and sphygmograms by mechanocardiographic means permits determination of important hemodynamic indexes such as: arterial pressure, systolic and minute volume of circulating blood, time of expulsion, speed of propagation of pulse wave along the vessels, and peripheral resistance. Knowing the value of the systolic volume (CV in cm^3) and the expulsion time (t in seconds), we can calculate the volume speed of blood expulsion into the aorta. The VSO represents the quotient from the division of CV by t.

$$VSO = \frac{CV}{t} \text{ cm}^3/\text{sec}.$$

The rate of the values of VSO and average hemodynamic pressure (My) permits calculation of the strength of the contractions of the left ventricle (P).

Strength (P) is a unit, measured by work (A), performed during a unit of time (t), for instance, in 1 second. Hence, the formula for strength of contractions of the left ventricle is expressed as:

$$P = \frac{A}{t} = \frac{CV}{t} \cdot My = VSO \cdot My \text{ watt}.$$

Under conditions of basal metabolism, we determined the strength of contractions of the left ventricle and the volume speed of expulsion (outflow) of blood for 150 trained and 150 non-trained healthy individuals, ages 19 to 25 years. Average rates for both items proved to be practically identical for both groups: P = 2.64 to 2.65 watt and VSO being 253 cm^3/sec, respectively. However, the non-trained individuals showed greater variations in rates than did the trained ones. Thus, for VSO in the trained, σ amounted to 45, m - 3.6, and in the non-trained, σ was 57, m = 4.7. The two indexes in patients with neurocirculatory dystonia of the hypertensive type proved higher than in the normal individuals.

Studies on the volume speed of blood expulsion into the aorta and the power of contractions in the left ventricle in healthy persons and in a number of pathological states, carried out in combination with the general clinical methods of investigation, have shown the great importance of these hemodynamic factors in evaluating myocardial contraction. Introduction of the two hemodynamic indexes into the practice of specialized flight medicine will permit more expert decisions.

METABOLIC CHANGES UNDER THE EFFECT OF PARACHUTE JUMPING

Yu. K. Syzrantsev, Yu. F. Udalov and N. A. Chelnokova

Flying personnel, in mastering life saving techniques, periodically perform parachute jumps, since preparation for the jump and the jump itself are associated with considerable nervous and emotional tension.

To determine the effect of this tension, we studied the influence of parachute jumping on certain aspects of metabolism, utilizing individuals of varying experience in parachute jumping. We studied expenditure of energy and indexes of protein metabolism and metabolism of vitamins, and determined the cholesterine and nucleic acid content in blood.

These facts have been established: (1) changes in metabolism result not only from the parachute jump itself, but occur long in advance of the jump, as a consequence of nervous and emotional tension; (2) an increase (by 17-22 percent) of gas exchange (gaseous metabolism) begins immediately following the order to jump and lasts throughout the entire interval preceding the jumping.

The data characteristic for the gas exchange are summarized in Table 1.

Table 1. Changes in Certain Indexes of Protein Metabolism Associated with Parachute Jumping (24 hour indexes)

	Elimination from the organism of the terminal products of protein metabolism		
	Total nitrogen	Nitrogen urea	Nitrous ammonia
Control	9.3	4.53	0.54
On the days of parachute jumping	11.0	6.0	0.73
On the days after jumping	10.6	5.52	0.59

These data clearly demonstrate: (1) increased elimination of total nitrogen and nitrogen urea on the day of jumping and on the day following the jump, and (2) the intensified protein metabolism consequent to the great emotional and physical load to which the organism is subjected. The increased Gosselbach coefficient (the nitrogen ammonia and total nitrogen ratio) during the same 24 hours when the jumping took place indicates qualitative changes in the protein metabolism, as well as considerable nervous and emotional tension. (Ammonia, as we know, increases during nervous excitement.) Increased nitrogen elimination was noted also on days when scheduled jumps were cancelled--again reflecting the significant role of emotions and pointing to the conditioned reflex character of metabolic changes.

Many investigators believe that physiological tension produces changes in protein metabolism, characterized by a lowered resynthesis of protein. However, since urea elimination on jumping days did not increase, it may be assumed that increased decomposition of nucleic acid does not take place. It should be noted, however, that the blood nucleic acid content, on the day of the jump, dropped to 280 mg percent, as compared to 360 mg percent on the day of control.

Results indicate that changes in protein metabolism during the parachute jump training are similar to those manifested under conditions of prolonged flight. Studies on vitamin metabolism during parachute jumping have shown that the organism has a greater need for vitamins at that time.

Data on excretion of vitamins for 24 hours are given in Table 2.

Table 2. Changes in Rates of Vitamin Metabolism Associated with Parachute Jumping

	Elimination of urine in 24 hrs			
	Vitamin B_1 µg	Vitamin B_2 µg	N_1-methyl-nicotinamide, mg	4-Pyridoxic acid, µg
Control (24 hrs without jumping)	350	44	1.9	450
On the days of parachute jumps	230	37	1.0	395
On the days following the jumps	270	30	1.3	490

A drop in the indexes of vitamin metabolism indicates not only an increased vitamin requirement but also a marked emotional tension on jumping days. It is important to emphasize the greatest changes were found in metabolism of vitamin B_1--the vitamin which participates directly in transmittal of nervous stimulation, and in nicotinic acid exchange, which is closely associated with CNS function.

Another index with prognostic significance is the blood cholesterol content. Increased blood cholesterol was observed not only on the day

of jumping, but also on the following day. From a prognostic standpoint, increased blood cholesterol, especially against the background of altered vascular tonus, is considered a forerunner of atherosclerosis.

VITAMINS IN THE DIET OF AVIATORS AND ASTRONAUTS

Yu. F. Udalov

Solution of the problem of establishing norms for the amounts of basic nutrients, including vitamins, in the diet of aviators and astronauts is of great practical and theoretical importance.

Dietetic requirements currently established for the population of the USSR, including vitamin requirements, are based mainly on the calculation of energy expenditures. At the same time, it is extremely important to determine in what ways the body's requirement for nutrient substances, including vitamins, is changed by nervous tension or other unfavorable environmental factors which do not substantially alter the level of energy expenditure.

The problem has arisen out of technological progress in industry, transport, agriculture, and military science, which has reduced the number of professions involving high energy expenditures while at the same time gradually increasing the number of workers in automated industries who are engaged in control of industrial processes or adjustment of machines and assemblies.

These professions include the work of aviators and astronauts, whose activity involves considerable neuropsychiatric tension and the effect of numerous external environmental factors on the organism. The level of energy expenditure for aviators and astronauts is low and presupposes a low vitamin requirement if the calorie requirement of the diet is taken as a basis for calculation.

Examination of a large number of flight personnel completely contradicts this supposition. The results of mass examinations of flight crews disclosed a decrease in the amounts of vitamins B_1, B_2, B_6, C, and occasionally PP available to the body, although the amounts of these vitamins present in the diet corresponded to the established normal requirements of the body for the energy expenditure involved. These data led to the assumption of an increased vitamin requirement for aviators.

From the examination of various groups of flight personnel it has been successfully established that the body's vitamin deficiencies are more serious when flight activity is more intense. Thus, other conditions being equal, the indexes of vitamin metabolism are more favorable in pilots of propeller-driven aircraft then in jet pilots. An analogous relationship was discovered in the examination of flight personnel flying a single type of supersonic aircraft, where one group was making test flights and the other was making ordinary flights.

A comparison of the biochemical indexes of vitamin metabolism is given in the table.

Indexes of the Metabolism of Vitamins B_1, B_2, B_6, and PP in Different Groups of Flight Personnel

	Amount excreted in the urine			
	Vitamin B_1, μg	Vitamin B_2, μg	4-Pyridoxic acid, mg	N_1-methylnicotinamide, μg
Test pilots	13 ± 1.0	52 ± 9.4	1300 ± 120	6.76 ± 0.7
Pilots	197 ± 9.0	192 ± 6.2	917 ± 11.1	12.4 ± 0.98

Only the vitamin B_6 (4-pyridoxic acid) metabolism index showed no changes proportional to the nervous and emotional stress of flight activity. For vitamins B_1, B_2, and PP the relationship is shown clearly enough.

The basic element in the professional activity of the aviator is flying. Study of the effect of different types of flight missions on the body's vitamin metabolism has established that vitamin consumption is substantially higher on days when flights occur. It is important to note that regularly scheduled flights lead to a gradual increase in vitamin deficiency, which can be avoided either by scheduling considerable intervals between flying days, or by means of regular vitamin enrichment of the flier's diet.

The bodily requirements of aviators are also dependent on the effect of climatic factors. Other conditions being equal, the indexes of

vitamin metabolism were lower among flight personnel of units stationed in extreme climatic zones (subpolar regions, the Arctic, and the far south) than among personnel stationed in the temperate zone. The increased vitamin consumption is the result of physiological stress, especially that due to acclimatization.

Numerous experiments have shown that a number of factors encountered by the aviator or astronaut in flight have an effect on vitamin metabolism in the body. Vitamin consumption increases during exposure of the body to vibration, prolonged accelerations, or increased ambient temperatures. Vitamin requirements increase at high altitudes even when the partial oxygen pressure of the respired air is maintained at the normal level. The body's vitamin requirements are substantially increased under conditions of strict isolation. Vitamin consumption is increased during testing of emergency lifesaving gear and also during parachute jumps.

In principle, the single type of reaction of the body to various kinds of physiological and mental effects makes it possible to assert that the basic factor which increases the vitamin requirements of aviators and astronauts is the state of physiological stress.

Of practical importance to space flight is the specific increase of the body's vitamin B_6 requirement in response to vestibular stimulation (short periods of weightlessness). Pyridoxine is also an important prophylaxis against vestibular dysfunctions. This need for increased vitamin content in astronaut rations was realized on the first space flights. Thus, the astronaut's diet must be enriched with vitamins during the period of training and especially during flight.

The significance of vitamin enrichment of the diets of aviators and astronauts goes substantially beyond prevention of vitamin deficiencies. First of all, vitamin enrichment is a means of increasing the body's resistance to unfavorable environmental factors, infections, and the like; it results in increased work capacity and reduces fatigue.

Vitamins have a normalizing effect on several metabolic indexes which are affected by flight. Of especially practical importance are data on the positive effect of vitamins on lipoid metabolism and particularly on cholesterol blood levels, significant in the prevention of atherosclerosis among flight personnel. In addition, systematic vitamin enrichment is also a practical measure directed at lowering the incidence of illness and work loss among flight personnel.

On the basis of numerous experimental studies it has not only been possible to establish the role and significance of vitamins under various conditions encountered in the activity of aviators and astronauts, but

also to establish the actual amounts required by the body. The laws which have been discovered governing vitamin metabolism under conditions of physiological stress, and the resulting recommendations, are not applicable solely to flight personnel and astronauts. They can be extended to other professional groups having similar working conditions, and to military personnel.

CHANGES IN EXCITABILITY AND LABILITY OF THE VISUAL ANALYZER UNDER CONDITIONS OF PROLONGED NONSTOP FLIGHTS IN MULTIPASSENGER TURBOPROP PLANES

A. I. Ustinova

In studying the excitability and functional motility of the visual analyzer during flight work, we will take as a point of departure N. Ye. Vvedenskiy's concept of the parabiotic process as the general reaction of the living substrate to external stimulation, and of the general mechanism in the organism of neural regulation, on which the lability of nervous centers is based.

Excitability and lability of the visual analyzer--quantitatively measured by the level of electrical sensitivity--maximum perception of rhythmic optical and electrical fluctuations per unit of time, and duration of after-reactions (negative after-image and its latent period) have been studied for many years. These studies have shown the limited adequacy of changes in these indexes resulting from flight stress, work done, type of aircraft, and other factors--changes which we have used as the physiological basis for scheduling work and rest periods for passsenger airplane pilots. The total effect of all flight factors on the CNS as a whole results in the development in flight crew members of phase states of visual analyzer excitability and lability during the course of 8- to 9-hour flights. This is manifested in the different direction of changes and the degree of negative shift in the 3rd to 4th and 8th to 9th hours of flight.

During the first 3 to 4 hours of flight most members of the flight crew showed either an increase in these indexes or maintenance at initial (takeoff) levels. In the 8th to 9th hours of flight (before landing at the terminal airport, the basically prevailing observations (in up to 77 percent of the investigations) were lowering of the indexes of excitability and lability of the visual analyzer and an almost two-fold increase in the degree of negative shift of several indexes. These phases we have interpreted as different stages in the development of

fatigue: the first corresponds to the period of becoming accustomed to the rhythm of activity or breaking-in period, and the second to the deterioration state (fatigue) (N. Ye. Vvedenskiy (1886) and others).

During the postflight rest period at the terminal airport (Khabarovsk), which lasted 24 to 27 hours under dispensary conditions, restoration of functions to initial level occurred in the majority of the subjects, although obviously this restoration was not quite stable, since the dynamics of change in function on the return leg (Khabarovsk--Moscow) showed a less clearly expressed positive phase in the 3rd to 4th hours of flight and the degree of reduction of the visual analyzer functions studied was much greater at any given stage of the flight. It should be noted that the rapid change in time zones (totalling 7 hours) and the consequent disruption of the habitual sleeping-waking and alimentary rhythms of the passenger airplane pilots had an effect on the quality of the rest period; the effect of the latter is confirmed by data on sleep movements.

The dynamics of change in excitability and lability of the visual analyzer during 8- to 9-hour flights we have observed, agree with the shifts in flight dynamics obtained during studies of maximum muscle power and static tenacity, half maximum strength of the right wrist, and also during psychological investigations of the scope, concentration, and distribution of attention.

The identical tendency of these changes assures us that all are based on a single process--fatigue of the CNS.

Analysis of the research data made 1 to 1.5 hours after landing, when the nervous and emotional stress of landing is subsiding, show that in most subjects (up to 77 percent) changes in function are in the direction of decrease from the initial level (based on investigations made after 2 to 3 days of rest). The degree of decrease of individual indexes is from 69 percent to 112 percent. It was also discovered that in flight commanders, negative shifts were more pronounced than in the remaining members of the flight crews, and that night flights of equal duration led to more intensive decrease then daylight flights.

Comparison of these data with similar data obtained after 8-hour flights on various aircraft with gas turbine engines showed no essential difference in the incidence or degree of negative changes. However, the degree of decrease in indexes following 8- to 9-hour nonstop flights in multipassenger planes significantly exceeded similar shifts we obtained among members of the crews of IL-18 aircraft following a normal daily flight load (6 to 7 hours).

The above-described studies of excitability and lability of the visual analyzer under conditions of prolonged nonstop flights in

multipassenger turboprop aircraft have provided, besides other data, a basis for working out and putting into effect practical recommendations for the establishment of work and rest norms for flight crews.

SOME METABOLIC INDEXES IN THE ASTRONAUTS YU. A. GAGARIN, G. S. TITOV, A. G. NIKOLAYEV AND P. R. POPOVICH

T. A. Fedorova, L. T. Tutochkina, M. S. Uspenskaya, M. M. Skurikhina and Ye. A. Fedorov

Examination of astronauts, by a special combination of analyses, before and after flight on spacecraft has provided definite data on biochemical changes occurring under such conditions. Biochemical tests were chosen which show significant deviations from the norm in "stress" states and under the effects of ionizing radiation.

The study of several radiation-sensitive biochemical indexes was of interest, inasmuch as it may be possible, during future prolonged flights traversing zones of dangerous radioactivity, to differentiate the bodily changes caused by radiation from those caused by other space flight factors.

Method of Investigation

Biochemical blood and urine studies were conducted on astronauts under hospital conditions, following intensive training and after rest periods, and at the spacedrome before space flight and after return to the earth (for a period of several days).

These blood studies consisted of refractometer determination of: (a) total protein content of the serum; (b) relative protein fraction by means of electrophoresis on paper using a veronal buffer of pH 8.6; (c) concentration of low molecular weight acid mucoids in the serum by means of Weimer and Moshin's modification of Winzler's method, and (d) nonspecific serum cholinesterase activity according to Zubkova and Pravdich-Neminskaya.

Urine studies included: (a) amount of Dische-positive substances present by means of Stumpf's[1] modification of Dische's 2-desoxyribose

[1]This reaction makes it possible to determine the total content of intermediate DNA-metabolism products (Footnote continued on following page.)

reaction; (b) DN-ase activity of the urine by Pravdina's viscosometric method, amounts of free and bound 17-21-hydroxy-20-ketosteroids present by Silber and Porter's method, mucoid content by Winzler's method (after 5-day dialysis of the urine), and (c) creatine and creatinine content by Taussky's method. In addition, clinical studies of the peripheral blood and urine of the astronauts were made before and after flight.

1. Results of Blood Studies

The most characteristic change in the protein composition of the blood serum of the astronauts in the training period preceding space flight was a slight increase in the relative protein content and some decrease in β- and γ-globulin and mucoid levels, such as is ordinarily observed in athletes in training and during contests, and which is connected with increased physical strain and emotional tension. Some types of astronaut training had a still greater effect on the body, as for example in A. G. Nikolayev and P. R. Popovich on 1 June 1962. During rest periods, shifts in blood serum protein content and serum mucoid content as a rule returned to normal.

Biochemical analyses of the blood of the various astronauts were conducted at different intervals following space flight: in Yu. A. Gagarin, from the 8th to 10th days following return to Earth; in G. S. Titov, from the 10th to the 12th day; and in A. G. Nikolayev and P. R. Popovich, on the day of landing and for 14 days thereafter. After space flight, the total protein content in the blood of the astronauts rose somewhat, and some increase in the protein serum level occurred during the first 24 hours after space flight. It is interesting to note that an increase in the total protein concentration in the blood of Belka and Strelka also took place in the first 6 days after flight. No essential changes in cholinesterase activity in the blood serum were noted after flight.

The results of clinical studies of peripheral blood showed that no basic deviations from normal occurred in Yu. A. Gagarin either before or after flight, while in G. S. Titov, A. G. Nikolayev, and P. R. Popovich, leucocytosis was observed on the day of landing. Further, A. G. Nikolayev and P. R. Popovich displayed lymphopenia and a tendency to eosinopenia. These shifts were of short duration and were characteristic of the development of a "stress" reaction in the organism.

(purine and pyrimidine compounds) (Z. Dische, 1957), and also occurs when the total amount of creatine, analine, and zanthine present in the urine exceeds 1 mg per studied unit volume.

2. Results of Urine Studies

Clinical urinalysis of the astronauts showed that there were no deviations from normal during the prelaunch period. During the first 24 hours after return from space flight, turbidity, hyaline casts (from 8 to 15 in the preparation), and uric acid crystals were noted in the urine of A. G. Nikolayev and P. R. Popovich. In addition, traces of protein and occasional erythrocytes and leucocytes were found in the field in the urine of P. R. Popovich, probably due to reversible changes in the renal filter such as are sometimes observed after physical strain or during strong emotions.

Excretion of Dische-positive substances and enzymic activity of acid DN-ase in the urine of the astronauts decreased during training and after flight. During rest periods their content in the urine returned to normal. The general trend of changes in the amount of these substances present in the urine during the prelaunch period and after flight was opposite to that observed when the organism is subjected to the action of ionizing radiation. Changes in the urinary excretion of Dische-positive substances did not correspond with changes in the volume of urine output in the majority of cases. Following return from space flight the 24-hour urine volumes of all astronauts increased from 25 percent to 75 percent.

Also observed were changes in the amounts of hormones of the adrenal cortex, and free and glucuronic-acid-bound 17-21-hydroxy-20-ketosteroids in the urine. Urine level of hydroxycorticosteroids increased somewhat during preflight training periods in all astronauts, but afterwards returned to normal during rest periods. The amounts of bound hydroxycorticosteroids in the urine before space flight varied within normal limits.

After flight, the amount of free hydroxycorticosteroids in the urine increased sharply to 2.5-3.5 times the normal value. In Yu. A. Gagarin, this increase was even more considerable, amounting to 10.7 times normal. The amount of bound steroids in the urine of Gagarin, Titov, and Popovich corresponded to the normal upper limit, while in Nikolayev it was a little above it.

The increase of urinary steroids after space flight indicates functional stimulation of the adrenal cortex and may be regarded as an adaptive reaction that increases the body's resistance to the effect of various factors connected with flight and landing. Their normalization even in the case of a very great increase (Gagarin) shows that the effect of the various factors being tested by the astronauts did not exceed the physiological capacity of the adrenal glands.

During the period of preparation for space flight, mucoproteid urine levels exceeded normal values in some cases; this is apparently

attributable to fatigue. As is known, the mucoid urine level can be increased by various factors, particularly heavy muscular labor. After space flight the amounts of these substances in the urine was either normal or close to normal; later observations revealed an increase in the urine of G. S. Titov.

Determination of creatine and creatinine in the urine was performed only for A. G. Nikolayev and P. R. Popovich.[1] Before space flight the creatine and creatinine urine levels remained within normal physiological limits for both astronauts: trace quantities of creatine were observed, and the creatinine content was from 1.0 to 1.5 g for 24-hour urine.

During the first 24 hours after return from space flight the amount of creatinine in the urine increased significantly in both Nikolayev and Popovich, attaining values of 2.01 and 2.60 g for 24-hour urine, respectively. During this period the creatine content did not change--only traces of it were observed. Follow-up for 14 days after landing showed normalization of creatinine content in 24-hour urine to 1.76 g for Nikolayev and 1.36 g for Popovich.

The increased creatinine urine levels in the astronauts reflected increased physical strain encountered in flight and during landing, and intensification of muscular labor, both leading to increase in muscular protein catabolism.

Thus, the totality of biochemical changes observed in the organisms of the astronauts during preparation for space flight and after landing indicates that changes in several metabolic processes are reversible and quickly restored, and are characteristic of the development of a short-term "stress" reaction in the body.

EFFECT OF ANGULAR ROTATION VELOCITIES ON THE STATE OF SEVERAL VISUAL FUNCTIONS

A. B. Flekkel'

Speed of rotation in free fall and the consequent acceleration at the level of the head may attain high values, which, despite their short

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[1]Determination of the creatine and creatinine content of the urine of A. G. Nikolayev and P. R. Popovich was performed by V. D. Blokhina and L. P. Furayeva.

duration, are dangerous to human life. The literature contains limited information on the effects of acceleration during small radius rotation, most of which refers to animal experiments or to experiments in which humans were subjected to rotation for brief periods.

In studying the effect of angular rotation velocities on the state of various physiological systems, it was essential to investigate several visual functions: visual acuity, critical flicker fusion frequency, and field of vision. These functions were determined before rotation, during exposure to angular rotation at different speeds, after braking the chair, and, in addition, on the following days. Ophthalmoscopic examinations and examination of the outer coating of the eye were made before and after rotation. Subjects were in a sitting position and lying supine: in the first position, visual functions were measured after rotation around an axis in the vicinity of the pelvis; in the second position, after rotation around axes in the vicinity of the heart, head, and feet.

Examination of the data obtained from rotation in the sitting position reveals a definite dependence of the state of the visual functions on the angular velocity of rotation and the degree of inclination of the subject's trunk from the vertical axis. With increased inclination of the subject's trunk from the vertical axis, equivalent effects on the visual functions occurred at correspondingly smaller angular velocities. For example, a 15 percent to 20 percent reduction in flicker fusion frequency occurred at a rotation velocity of 1.75 revolutions per second (rps) when the chair back was vertical, but at a velocity of 0.5 rps when the chair was tilted 90° from the vertical. Similar changes were noted in visual acuity and field of vision.

In evaluating the effect of the factors under study, we confined ourselves to intensities and periods of exposure sufficient to cause a pronounced (15 percent to 20 percent) impairment of visual function, without establishing the limits of tolerance past which anatomical trauma of the visual analyzer or severe visual dysfunctions would occur.

In individual cases, when the ratio of angular velocity and inclination of the trunk from the vertical exceeded the values indicated above (2 rps with the chair back vertical and 1.75 rps with the chair back tilted at 20° and 30°), the impairment of visual functions amounted to 25 percent to 30 percent of the initial values. With the trunk inclined 45° and more, even when small angular rotation velocities were used, some individuals developed hyperemia of the mucous membrane of the lids and vessels of the eyeball, and a noticeable dilatation of the vessels of the fundus.

During rotation in the supine position the dependence of the state of the visual functions was determined by the position of the axis of rotation with relation to the body of the subject. The effect on the

visual functions was considerably greater when the axis of rotation passed through the vicinity of the head and the feet, and smaller when it passed through the vicinity of the heart.

An impairment of visual functions imposing a 15 percent to 20 percent limitation on visual efficiency occurred at 1.0 rps with the axis of rotation passing through the vicinity of the heart, at 0.5 rps with the axis of rotation in the vicinity of the head, and between 0.25 and 0.5 rps with the axis of rotation in the vicinity of the feet.

As a rule, changes in the visual functions were also dependent on the duration of exposure to angular rotation. The maximum impairment of visual functions occurred in the 5th to 6th minutes of rotation, after which the excitability of these functions gradually was restored. Full restoration of function was observed in the 4 to 5 minutes after rotation.

The stabilization and restoration of the somewhat impaired visual analyzer functions during rotation is probably the result of compensatory reactions of the vascular system which have by that time been triggered by simultaneous circulatory disturbances.

Analysis of the results of these studies indicates that the amount of change in the visual functions occurring during rotation around axes variously oriented with respect to the body depends to a considerable degree on the magnitude of the acceleration thereby produced in the most distant part of the body. Thus, change in the visual functions becomes noticeable when acceleration at the head of the subject attains a value of 0.5 to 1.0 g. A 15 percent to 20 percent impairment of these functions occurs at an acceleration of 1.5 to 4.0, and a 30 percent impairment at an acceleration of 2.0 to 5.5.

Severe visual dysfunctions in the form of hemorrhage into the membranes of the eye, displacement of visual axes, painful sensations, color distortion in the field of vision, or loss of consciousness, such as are observed during radial pelvis-to-head accelerations, were not encountered in the course of our experiments. However, in two cases a state bordering on swooning occurred during rotation in the supine position about the head at a velocity of 1.0 rps.

It should be noted that the characteristics observed in changes in visual functions during exposure to angular rotation at various speeds were significantly similar to those of changes in the motor coordination and other physiological functions of the subject.

REACTIVITY OF THE ORGANISM AND METHODS OF INCREASING ITS RESISTANCE TO CERTAIN FLIGHT FACTORS

I. M. Khazen

This article sums up our experimental findings on the resistance of animals to hypoxia, acceleration, rolling motion, explosive decompression, microwaves, and X-rays. We also studied the characteristics of the adaptation reactions of man to hypoxia, acceleration, etc. This enabled us to adopt a somewhat broader approach to the analysis of the common specific and nonspecific clinicophysiological and biochemical features noted after exposure to the aforementioned stress stimuli. We endeavored to gain some idea of the correlations between the various functional systems developing under the influence of a given stimulus or set of stimuli and thereby obtain some criteria for judging the reactivity of the organism. There is no need to show that such integrative indicators are of considerable importance in programming medical cybernetic apparatus.

Among the factors tested, we paid particular attention to oxygen deficiency since hypoxic conditions, which we judged from tissue processes, may also occur after exposure to several other stimuli. Thus, tissue adaptation to hypoxia is of significance in solving problems connected with increasing resistance to acceleration, explosive decompression, radiation, and other flight factors.

The steady improvements being made in oxygen respiratory apparatus and other means of supplying man with oxygen in the pressurized cabins of airplanes not only do not exclude, but they dictate the need of continuing the search for methods of increasing resistance to the maximum.

In addition to the general clinicophysiological methods, we made extensive use in all our investigations of the neuroglandular apparatus of the digestive system as a highly sensitive indicator (I. P. Razenkov) in studying the general homeostatic reactions to very powerful environmental factors. We invariably started with the assumption that adaptation as "a precise relationship of elements among themselves and between themselves and the external environment" (I. P. Pavlov) is determined not only by the response of the neuroglandular apparatus to the stimulus directly, but also by the aftereffects. However, the aftereffects, as a set of metabolic and structural changes, are an important indicator of the reactivity of the individual functional systems in the integral organism. This indicator found practical application in our early investigations that were concerned with the limits of adaptation to hypoxia in the established fact of "breakdown of adaptation" and its precursors (1939-1940).

The results of experiments on dogs and on human beings showed that in hypoxia the gastric glands are more reactive than the other digestive glands, thus explaining the comparatively pronounced impairment of the processes of gastric secretion. For example, in experiments that the author performed on himself on Mt. Elborus (highest peak in the Caucasus), a "breakdown of adaptation" occurred at 4,800 m against a background of a sense of well-being and normal fitness. Besides a complete loss of hydrochloric acid from the gastric juice with traces of blood therein, there occurred twitching of the abdominal press muscles. These phenomena were persistent and they continued at different altitudes after descending from "Priyut Pastukhova" and on the plain for 3 weeks.

In a comprehensive pathogenetic analysis of these manifestations made in the laboratory of I. P. Razenkov, Yu. M. Lazov found them to be related to structural changes in the mucosa of the body and fundus of the stomach. For example, keeping dogs at an altitude of 8,000 m and exposing them for 4-6 hours to a stereotypic repetition of elevations (every other day or two) resulted in increasing involvement of the structural elements. There was almost solid necrobiosis of the epidermis, necrosis of individual small arteries, transformation of the chief and secondary cells into an indifferent type of epithelium, etc. However, from about the 15th elevation on, signs of regeneration began to set in and the process continued until complete repair (63rd elevation) of the acute changes that developed during the preceding actions. Under similar conditions, we failed to observe any significant morphological changes in either the pylorus or intestine. These facts must be regarded in a new light. They now have theoretical significance as compensatory-reparative manifestations since they indicate the presence of potential and by no means fully understood compensatory-adaptive resources in the organism. It is reasonable to assume that in extreme circumstances the glands of the body and fundus of the stomach assume a regulatory role. Support for this view comes from the similar pattern of morphological changes in the adrenal cortex. Prolonged exposure to hypoxia is followed by degenerative exhaustion of the cortex and then by complete restoration (L. A. Langley, M. E. Sawyer, J. Stickney, and E. Van-Lear). Since the structural changes in the glands of the body and fundus of the stomach coincide in time with the structural changes in the adrenal cortex and they are in the same direction, the assumption that the function of these organs is interlinked is justified.

The interlinking of gastric secretion and activity of the pituitary-adrenal system was demonstrated in our laboratory in experiments on animals and on human beings exposed to accelerations (1957-1963). Inhibition of secretion and the duration of the aftereffects are common characteristics in hypoxia and under these conditions. Prolonged aftereffects were also noted in the metabolism of biogenic amines (histamine, serotonin, epinephrine, norepinephrine, acetylcholine) both in the blood and in some tissues. These could not but cause impairment

of carbohydrate, fat, protein, mineral, metabolism, etc. after sustained and frequent exposure to accelerations. Moreover, in experiments on rats intentionally exposed to harsh conditions (10 g for 1 minute, up to 120 actions in the course of a single month), it was found that conditioned reflexes were more or less preserved despite deep structural impairment of brain, heart, liver, kidney, and lung tissues.

After accelerations, the rate of restoration of certain impaired functions of the gastrointestinal tract was slow and unusual in some respects as compared with respiratory and circulatory functions. After exposure, for example, to positive radial accelerations, changes in the bioelectric activity of the brain and heart were restored by the third minute, but the aftereffects lasted dozens of minutes in the salivary glands, hours in the gastric glands, and many days in the intestinal glands. Consequently, to predict the course of adaptation to extreme stimuli, one must also take into account these features, i.e., all the aftereffects in the functional systems, which throw light both on the correlation of functions in the integral organism under the influence of a given stimulus and on the latent effects of stresses in the abscence of acute reactions.

The results of the experiments show that the various impairments that follow accelerations, as in the case of hypoxia, are considerably mitigated if many days intervene between repetitions of the action. However, determination of the time intervals is closely related to the characteristics and duration of the aftereffects.

We observed similar common characteristics in experiments on dogs and human beings, including ourself, under the influence of "bumpiness" in airplane flights.

The data presented above enabled us to investigate the limits of adaptation and the potential adaptive-compensatory resources of the organism with respect to other factors such as explosive decompression and small doses of X-rays. The limits of adaptation are quite relative and they can be considerably extended if the characteristics of the stimulus and the original functional state of the organism are taken into account. This view clearly broadens and amplifies the concept of "adaptation energy" introduced by H. Selye in his theory of stress. It seems to us that it is a question here of potential adaptability, the neurohumoral mechanisms of which are controlled by the central nervous system.

Thus, when exposed to extreme stimuli (oxygen starvation, accelerations, rocking movements, vibrations, etc.), the gastrointestinal organs are incorporated in the general defense systems of the body and the duration of the aftereffects is one of the important indications

of the condition of the neurohumoral regulatory mechanisms. Extreme, frequent stress can produce pathological impairment suggestive of exhaustion.

This has given rise to the idea of prophylactic intervention, which includes measures aimed at preventing the regulators from becoming incompetent. The approach also worked in the case of exposure to X-rays, microwaves, and explosive decompression. For example, irradiating rats three times at 7-day intervals with a daily dose of 50 r and total dose of 150 r (L. I. Kotlyarevskiy and coworkers) caused marked impairment of cortical dynamics. A decrease in the conditioned reflexes was followed by a sharp increase, with the development of phase phenomena and disruption of active inhibition. The aftereffects persisted a long time. Complete restoration in rats with a strong type of nervous system required 96-130 days.

In an investigation that we conducted jointly with N. M. Gurovskiy, Myasnikov, and Mirolyubov, we took into account the duration of the aftereffects and the original functional level. A second exposure to a somewhat larger dose (60 r) was carried out 25 days later, i.e., at a time of relatively complete restoration of conditioned activity to the original level. The result here was that the period of the aftereffects lasted 15 days. A third exposure to the same dose after complete restoration of the conditioned reflexes resulted in even smaller changes and the animals' resistance to subsequent exposure to a larger dose was increased.

The idea of using microwaves (a natural element in the environment) as a means of increasing resistance to hypoxia occurred to us during the comprehensive Elborus expeditions of 1939-1940. Our aim, essentially, was to influence the processes of tissue respiration and thereby make the tissues more resistant to injurious agents. UHF electromagnetic fields help to increase the tone of the neural regulators, encourage the anoxybiotic processes, activate the antihistamine enzymes and other substances that increase resistance, stimulate epinephrine reactions, etc. We appraised the effectiveness of microwaves from general clinicophysiological reactions and from the functional state of the pancreas and intestinal glands. We observed that this physical factor has a correcting role in hypoxia. There was a complete absence of aftereffects either at the time when the microwaves were used or during subsequent experiments performed for almost 4 months without this factor.

Our findings on the effectiveness of microwaves are in agreement with data recently published in the scientific press.

Physical training, as a general means of increasing resistance to flight factors, is of major importance. In model experiments on rats (in a comparative-physiological series, man is the most resistant), we

showed that training rats just by allowing them to swim prevented them from dying when terrestrial pressure dropped from 760 to 40 mm. Ordimarily, 85-90 percent of the untrained animals died.

A comparison of our data with the results of experiments in which such pharmacological agents as atropine, histamine, etc. were used revealed some other characteristics of the regulatory mechanisms of the autonomic nervous system that prevent or mitigate the impairment (mainly very acute hemodynamic disorders of the lesser circulation--F. I. Pozharskiy, D. Ye. Rozenblyum, I. M. Khazen) characteristic of explosive decompression.

It might appear that the different means that we used to increase resistance to flight factors cause a nonspecific general adaptive reconstruction of functions. In fact, however, quite pronounced specific reactions take place here. For example, atropine eliminated the pathological reflexes from the cavity-type and other organs. Histamine caused changes in the neuroendocrine components of regulation in addition to directly increasing pulmonary muscle tone and strengthening resistance of the lungs to distention. Conditioned-reflex reconstruction of functions was achieved by familiarizing and simulated drops in pressure. It is evident that the extent of resemblance is determined by the overall effectiveness of the prophylactic intervention, although the methods of achieving this effectiveness are completely different and specific.

The theoretical and practical value of the characteristics of the aftereffects noted in our experiments as general indicators of reac tivity and lability (N. Ye. Vvedenskiy, A. A. Ukhtomskiy) is quite obvious.

Thus, our study of the regulation of functions after exposure to extreme stimuli shows that the better known the mechanisms of the adaptive-compensatory processes are, the better will be the ways and means of increasing resistance to flight factors.

To increase resistance to many flight factors on airplanes, attention should be directed to the following:

(1) Perfecting methods of general and specific physical training with due regard for the adaptive-compensatory capabilities of the organism;

(2) Staying in a mountain climate together with a rational diet to effect permanent adaptation to various environmental factors acting together;

(3) Controlling the processes of metabolism and energy during flight, which requires developing a rational diet during flight to preserve the relative stability of the internal environment and thereby ensure adequate physical fitness and health.

HISTOPHYSIOLOGICAL CHANGES IN ANIMALS EXPOSED TO ACCELERATIONS

I. M. Khazen, E. M. Kogan and A. S. Barer

Earlier investigations conducted in our laboratory revealed that the higher divisions of the CNS play an integrating role in the mechanisms of regulation and compensation of functions following exposure to centripetal accelerations. However, after repeated exposures the regulatory systems, especially the sympathetic-adrenal, become incompetent, giving rise to a variety of clinicophysiological as well as morphological manifestations. The latter often occur despite the externally satisfactory general condition of the animals and the relatively good state of preservation of the conditioned reflexes.

In one series of experiments (12 rats), we applied accelerations of 10 g for 1 minute with an increase of 2 g per second. The experiments were performed once a day at 7-day intervals for 8 weeks.

In another series (50 rats in groups of 8 and 9), the animals were systematically exposed to accelerations of 10 g per minute 4 times a day at 30-minute intervals.

In a third series, 12 rats were exposed to 5 g in 20 minutes, the other conditions being the same as in the first series.

The animals were decapitated as soon as the centrifuge was stopped. Tissues were obtained from the brain, heart, lungs, liver, and kidneys for histological investigation. The specimens were stained with hematoxylin-eosin and by Nissl's method.

Results

The specimens from the organs of the first series of rats revealed vague signs of stasis only in a few cases.

The specimens from the second series of rats exposed 4 times to accelerations (10 g-1 minute at 30-minute intervals) exhibited marked

changes in various organs and tissues. For example, the cerebral vessels were dilated and overflowing with blood, with slight perivascular and intercellular edema. The heart muscles were somewhat loose and edematous. The myocardial capillaries were dilated and congested, with polarization of the formed elements and plasma. Some hyperemia was noted in the blood vessels of the lungs. The liver was characterized by intercellular edema with plasmorrhagia. In the central veins--stasis. The Kupffer cells were edematous, their nuclei rich in chromatin. In the kidneys--some hyperemia. The epithelium of the gastric mucosa was hyperemic. Except for signs of stasis, no changes were noted in the wall of the small intestine. The adrenal cortex was lacking in lipids.

On the second day of the experiment, i.e., after 8 exposures to the accelerations, stasis was particularly pronounced in the arterial and venous vessels, with separation of the plasma from the formed elements of the blood. In most of the cerebral capillaries, the nuclei of the endothelium were swollen and edematous, some of them being in the lumen of the blood vessels. The muscular layer of the wall of the cerebral arteries was also changed. For example, the nuclei of the muscle cells were twisted like a spiral and crowded to the periphery, resulting in the formation of nonnucleated areas. Characteristic changes were also noted in the liver. The structure of a large part of the lung tissue was preserved but filled with a hemorrhagic exudate.

More pronounced changes were observed in the animals after 16 exposures, i.e., on the 4th day. The external layers of the cortex and capillaries of the brain were edematous. The walls of some of these capillaries showed degenerative changes and their lumens were filled with leucocytes. There were also major changes in the myocardium. The intermuscular capillaries were filled with blood and dilated. Areas of muscular tissue could be seen with pronounced intermuscular edema and weakly staining nonnucleated cells. There were also significant changes in the lungs, the tissue of which was saturated with a hemorrhagic effusion that filled the alveoli and many of the small bronchi. The pulmonary blood vessels were markedly changed. Individual portions of the muscular layer were missing, while the surviving nuclei of the muscle cells had moved to the periphery where they collected in compact masses resembling a palisade. The adventitia of the blood vessels formed a scalloped border and their walls were saturated with a protein effusion. Vicarious emphysema was noted in some portions of lung tissue. Some portions of the kidneys revealed destruction of the nephrons and proliferation of connective tissue therein.

The greater the number of exposures, the more pronounced was the proliferation of connective tissue. For example, after 24 exposures, i.e., on the 6th day of the experiment, the lung tissues had thickened interalveolar septa as a result of proliferation of connective tissue. Besides stasis, there were many leucocytes in the blood vessels.

The signs of degeneration also embraced individual bronchi, where the epithelial and muscular layers were particularly affected. The degenerative changes in the myocardium noted above were more widespread at this time and there were portions of muscular tissue with nonnucleated cells. The marked proliferation of connective tissue covered some of the renal glomeruli almost completely.

The proliferation of connective tissue intensified during the subsequent stages of the experiment. After 32 exposures, i.e., on the 8th day, the interalveolar septa of the lungs were thicker. There was also marked thickening of the muscular layer of the arteries in different organs. As before, the signs of stasis with polarization of the formed elements and plasma were pronounced. The liver was characterized by edema of the interlobular bile ducts, while the brain was the site of congestion and dilatation of the vascular bed. Another noteworthy fact was that the nuclei of the main mass of cortical cells had two or more nuclei each. This was particularly noticeable in the external layers of the cerebral cortex.

In the animals exposed 120 times, i.e., on the 30th day of the experiment, the changes were even more pronounced. Of particular interest were the morphological changes in brain tissue, especially the signs of degeneration with vacuolar degeneration of a great many nerve cells. There were other nerve cells, similar to those described by some histologists as nerve cells, which were in various stages of amitotic division.

Specimens from rats of the third series (accelerations of 5 g - 20 minutes) revealed marked hyperemia, perivascular and interstitial edema of brain tissue, edema and fraying of the myocardium, hemorrhagic effusions in some pulmonary alveoli, and signs of degeneration of lung epithelium.

Thus, analysis of the factual material shows that there is a pattern of increase in the morphological changes in various tissues and lungs of animals in relation to the frequency of exposure. For example, after frequent daily exposures, the morphological changes noted during the first days of the experiment were acute in nature (hemorrhages, rupture of the vascular walls, stasis, etc.), but later the proliferation of connective tissue and deep degeneration of different cell structures became predominant.

By way of contrast, in the first series of experiments (7-day intervals between experiments), even 8 exposures (10 g - 1 minute) did not result in noticeable morphological changes. Signs of cumulation were not found in these experiments.

A definite relationship was noted between the morphological changes and duration of action after 8 exposures to accelerations of lesser intensity but greater duration (5 g - 20 minutes) at equal time intervals over 7 days. The ensuing morphological changes were distinct. In all the variations of the experiments, the reaction of the cardiovascular system was most pronounced. One of the first and most characteristic manifestations of accelerations is impaired permeability of the vascular wall. This was also shown by the passage of formed elements per diapedesin, a feature of acute hypoxia.

The morphological data presented in this report have been confirmed by V. G. Petrukhin, Ye. F. Kotovskiy, and others. They occur regularly and show that the changes in the tissues investigated are related not only to the intensity, direction, duration, frequency, and intervals between exposure, but to the functional state of the organism.

SOME RESULTS OF MANNED SPACE FLIGHT AND PROBLEMS IN SPACE BIOLOGY AND MEDICINE

V. I. Yazdovskiy

(Text of the report not included.)

THE EFFECT OF ADEQUATE STIMULATIONS OF THE VESTIBULAR APPARATUS ON THE ELECTRICAL POTENTIAL OF THE STOMACH

V. T. Khlebas and N. P. Kozhukhar'

A number of recent reports written for the most part by native Soviet authors (N. M. Sisakyan, V. V. Parin, V. N. Chernigovskiy, V. I. Yazdovskiy (1962), V. I. Yazdovskiy, M. Yemel'yanov, N. Gurovskiy (1962), O. G. Gazenko, A. M. Genin, Ye. M. Yuganov (1961) and others) have shown that a stay by man in a prolonged state of weightlessness is accompanied in individual cases by vegetative disturbances.

They assume that prolonged weightlessness can lead to the development of motion sickness which arises as a result of an increase in excitability of the receptors of the semicircular canals of the vestibular apparatus and accumulation of the effect of Coriolis acceleration.

Study of the mechanism of vestibulo-vegetative disturbances, the establishment of the causes of their occurrence, and an explanation of the possibilities of an increase in man's working capacity in space is of great importance.

Significant disturbances of vegetative functions were observed by many scientists in experiments on animals after a 10-12 minute sickness-inducing motion. Significant reflex disturbance of the functional activity of the organs of digestion were found in this complex of vegetative shifts.

The present work has attempted to explain the effect of strong adequate stimulations of the vestibular apparatus upon the secretory-motoric potential of the stomach which is one of the most important indexes of its functional condition. Reports by V. I. Venchikov (1954), Ye. F. Bogovarova (1945), Resnikova (1961) and others, established that a definite relationship exists between the secretory-motoric functions and the potential of the stomach. The more the secretion of the glands, the lower the biopotential of the stomach; the stronger the contractions, the greater the amplitude of oscillation of the potential.

Research Method

The investigations were carried out in chronic experiments on dogs with a stomach fistula (Basova) on an empty stomach. To obtain adequate stimulation we employed a rotating circular table with an electric drive (V. T. Khlebas, N. P. Kozhukhar, I. F. Sokolyanckiy (1963)) and a Zhilov-type swing adapted for work with animals. The number of revolutions of the table was 30 per minute; the frequency of rockings was 60 per minute;

the amplitude of the rocking was 90°; the length of the bar was 3.4 meters.

The biopotential of the stomach was led off by clay non-polarizing electrodes, one of which was inserted into the stomach through the fistula; the other was attached to the skin of the back between the third and fourth lumbar vertebrae. The signal went to a direct current amplifier and to the registering system (N. P. Kozhukhar, I. Ya. Serdyuchenko --unpublished work).

Before beginning the recording of the potential, the stomach was washed out with warm water (34-36°C), the electrode was inserted and the animals were maintained for the course of an hour in a condition of rest. After this the control recording of the initial potential was made, the stimulus was then engaged and the registration of all subsequent changes was continued during the action of the stimulus and after switching it off.

The animal was placed on the stand of the rotating table, its head was fastened in a natural position and it was located 40-50 cm from the center. In the swing the animal's extremities were also fastened down.

Results Obtained and Their Discussion

We studied the effect of adequate stimulations on the character of changes in bioelectric potential in three dogs in chronic experiments. Prolonged rotation (from 10 to 60 minutes) caused in the overwhelming majority of experiments a lowering of the bioelectric potential of the stomach of 8-24 mv, which amounted to 6-50 percent of the initial value which was within the limits 40-48 mv.

It must be pointed out that stimulation of the vestibular apparatus by rotation in our experiments caused a lowering of the potential of the stomach of approximately the same magnitude as feeding of the animals with fat and irritation of the vagus nerve with an electric current in the experiments of other authors (A. I. Venchikov (1954), Ye. F. Bogovarova (1945)). The initial potential in the reports of these authors was equal on the average to 48 mv.

As a rule lowering of the potential set in during the stimulation, 8-20 minutes after its initiation; before this point an insignificant rise of potential was observed. The potential stayed at the lower level after which a slow rise (recovery) set in over a period of 30-40 minutes, sometimes significantly longer, and in individual cases the potential did not return at all to the initial value, for a period of one hour after cessation of the rotation.

In nearly all experiments with the dog "Chernushka", in addition to the changes in the potential, the typical symptom complex of seasickness was achieved, which was manifested by increased salivation, urination, vomiting and defecation, while only salivation was observed with the dog "Ryzhik".

In the dog "Chernushka", the time of action of the stimulation necessary to obtain maximal lowering of the potential was steadily shortened (from 35 to 13 minutes).

Changes in the potential of the stomach of some other character were obtained in the third dog "Zhuk". In all experiments with her, with the exception of one, an increase of potential of 5-10 millivolts was obtained instead of the decrease observed in the other dogs. With this dog, not once was vomiting seen; the rise of potential in her set in gradually in the 30-40 minute period after beginning the rotation, while the initial magnitude of the potential did not differ from the usual value.

An analysis of the results obtained allow the conclusion that the fall in potential is the result of an excitation of the gastric glands under the influence of strong rotational stimulations of the vestibular apparatus.

Depending on their strength, these processes approach and sometimes exceed the reflex stimulation of the digestive glands during feeding. After cessation of the stimulation of the vestibular apparatus the potential of the stomach was restored faster than in the process of digestion. All of this testifies to the protective character of these reactions.

Strong stimulations of the vestibular apparatus by rotation leads to significant shifts in the secretory function of the stomach which are reflected in changes in the bioelectric potential.

We obtained a series of electrograms which recorded the changes in the potential of the stomach reflecting the hunger period, and, in addition, the rhythmic contractions of the stomach muscles beyond that period; the frequency of these contractions was 0.5-1 per minute with the average amplitude 5-6 mv. Vomiting was reflected in the EGG in the form of individual rapid oscillations of the potential of large amplitude (10-15 mv).

We carried out a second series of experiments which was essentially a study of the effect of motion-induced sickness on the biopotential of the stomach.

Results of these experiments showed that motion-induced sickness appears to be a stronger force than rotation as a stimulator of the

secretory-motoric function of the stomach which is manifested in a significantly greater lowering of its electric potential during a shorter time of action. Thus, with motion-induced sickness, the potential of the stomach is lowered by 11-30 mv while with rotation it is lowered 8-12 mv.

Especial attention is warranted by the results obtained in experiments on the dog "Zhuk". Whereas rotation led to an increase of potential of 5-10 mv, motion-induced sickness, on the other hand, caused an 8-15 mv lowering of it. The time of action of the stimulation to achieve the effect was, in the dog "Chernushka" 3-12 minutes, in "Ryzhik" 11-13 minutes, and in the dog "Zhuk" 17-18 minutes which testifies to the greater resistance of the organism of this animal to strong, unusual vestibular influences.

Characteristic of the initial potential of the stomach with the motion-induced sickness was its tendency to rise depending on the increase in the number of experiments carried out. Thus, for example, in the dog "Chernushka" it rose from 45 mv in the first experiment to 75 mv in subsequent tests: in the dog "Zhuk" it rose correspondingly from 55 to 63.

It must be assumed that in the course of training (setting up of the experiments) the dogs develop defensive reactions to strong stimulations which cause the unsuitable reactions of the secretory-motoric apparatus of the stomach.

Conclusions

1. Strong and prolonged adequate stimulations of the vestibular apparatus cause changes in the bioelectric potential of the stomach which are reflected as a rule in a lowering of the potential.

2. Results obtained support the position that lowering of the potential of the stomach coincides with excitation of the gastric glands.

3. Motion-induced sickness is stronger than rotation as a stimulator of the gastric glands.

4. Secretory-motoric reactions of the stomach to stimulations of the vestibular apparatus of different animals are not identical in intensity.

5. Electrogastrography may be used as a method to study the digestive functions of animals under conditions of cosmic flight.

THE STATUS OF ANTICOAGULATING MECHANISMS UNDER CONDITIONS OF PROLONGED HYPOKINESES

Ye. I. Chazov and V. G. Ananchenko

We have not found reports in native Soviet or foreign literature which concern the study of anticoagulating mechanisms under conditions of prolonged hypokinesic states. At the same time this problem has undoubted interest since some changes characteristic of prolonged hypokinesis (disturbance of vascular permeability, disorders in blood circulation) can undoubtedly increase the tendency to thrombus formation. It was suggested that we study the status of the thrombus-forming properties of the blood in 12 volunteers under hypokinesic conditions. To judge the anticoagulation capacities of the organism we studied the content of free heparin in the blood by the Piptei method, the fibrinolytic activity of the blood by the Bidwell method, the plasma heparin tolerance by Hormsen's method, and thromboelastography by Hartert's method (using the "Hellige" thromboelastograph). Three series of investigations were carried out on practically healthy subjects aged 19 to 20.

In the first group studies were carried out of all the above listed indexes in 4 subjects before and after a 3-day period under hypokinesic conditions. In 3 of them we were not able to find any regularity at all in changes of state of the thrombus-forming properties of the blood.

Thus, blood heparin before and after the investigation fluctuated within the same levels of 5-6 units/ml; the plasma heparin tolerance (15-17 minutes), the level of blood fibrinogen (250-300 mg percent) and the fibrinolytic activity (25-30 percent) were normal before and after hypokinesis. In only one subject of this group was a rise noted in the content of blood heparin (to 10 units/ml), an increase in the plasma heparin tolerance (to 22 minutes), an increase in the fibrinolytic activity of the blood (to 62 percent). These changes were established on the thromboelastogram. It must be noted that after the tests on the centrifuge, following immediately after a 3-day period in bed, in only one case of the four, was the appearance noticed of small hemorrhages into the subcutaneous cellular tissue.

More regular changes were obtained in the second series of investigations with prolonged hypokinesic states, when 4 subjects were in a state of absolute rest for a period of 20 days. It was found that prolonged hypokinesis in healthy persons leads to an increase in the anticoagulating and lytic properties of the blood, which leads to lessening the possibilities for thrombus formation. Most expressed was the increase in the fibrinolytic activity of the blood, which in 3 cases reached 100 percent and in one case only, rose from 34 percent to 50 percent. In this subject, changes were not observed in the content of blood heparin,

while in the 3 others its content rose 2 units/ml. Changes were marked in the plasma heparin tolerance, reflecting in a significant degree the possibilities of thrombus formation. In 3 cases the plasma heparin tolerance rose from 15-17 minutes to 22-26 minutes and only in the very same case of Subject M, where there were no changes with respect to blood heparin and the fibrinolytic activity was insignificantly lowered, the plasma heparin tolerance not only did not rise but it was even lowered a little (from 17 to 12 minutes).

In all 4 subjects, at the end of the period of hyperkinesis, the values for blood fibrinogen were lower (100-250 mg percent). The character of the thromboelastograms supported the data of the biochemical studies. Thus the results of the investigations were found to be directly opposite to those assumptions which were mentioned in connection with the possibilities for thrombus formation in hypokineses. How is this explained? Most probably, the increases observed in the anticoagulating and lytic properties of the blood are associated with the functions of the defensive anticoagulating systems of the organism, responding in a similar way to the appearance during hypokinesis of conditions, which increase the tendency to thrombus formation. This does not exclude the situation that the changes observed take on the character of a "stress", associated with the stay of a healthy man under conditions which are unusual for him.

The changes observed in the character of the thrombus-forming properties of the blood must be studied during prolonged hypokineses, as a factor conducive to the occurrence of petechias, hemorrhages, the appearance of which has already been noticed particularly by Dietrich and coworkers.

In this connection undoubted interest is suggested by the data observed in the third series of studies. This group of 4 subjects also remained in a prolonged bed regimen, but systematically carried out a complex of definite physical exercises. It was found that in this group of healthy people no increase was noticed in the fibrinolytic activity of the blood and in the content of free heparin. Probably, carrying out the complex of physical exercises in the period of hypokinesis can be a factor which prevents the occurrence of similar reactions to a rise in the anticoagulating and lytic properties of the blood.

THE EFFICACY OF THE PHARMACOLOGICAL PREPARATION NII IN COMBATING MOTION SICKNESS OF AIR TRANSPORT PASSENGERS

A. V. Chapek

Among the many thousands of passengers of various ages and states of health who daily employ modern air transportation, people are encountered who suffer in flight from airsickness of different etiologies.

According to our findings over many years of study, 12-13 percent of the people are subject to motion sickness in flight on piston-driven airplanes, and 2.5-3 percent in flight on planes with gas turbine engines.

For prophylaxis of passenger airsickness and to furnish comfortable flight conditions, the problem of developing reliable agents to combat motion sickness, including therapeutic agents, is a very current task.

It is known that for prophylaxis and therapy of motion sickness on various kinds of transport (sea and other types) many pharmacological agents have been suggested. However, the therapeutic agents used in practice do not always give a positive effect especially against the motion sickness of flight passengers.

Starting from modern concepts of the pathogenesis of motion sickness (V. I. Voyachek and others) in transport including flight transport, and, also, influenced by the extra-labyrinth and emotional causes of motion sickness in flight, we tested the efficacy of a new therapeutic substance--NII tablets (prepared by the S. Ordzhonikidze Chemico-Pharmacological Institute, Ministry of Health, USSR) for motion sickness of passengers in flight.

The therapeutic preparation NII, which contains camphorated scopolamine, hyoscyamine and nicotinic acid, exhibits a stimulating action on the central nervous system and lowers the excitability of its parasympathetic section. The nicotinic acid which is part of the tablet has a positive action on disorders of the internal organs (heart, liver) and on ulcers. It exhibits a vasodilating action (M. D. Mashkovskiy). Side effects of the tablet are dryness in the mouth and reddened countenance. After ingestion these effects go away automatically.

The efficacy of the therapeutic agent, the tablet NII, was confirmed under laboratory conditions with experimental motion sickness and in flight. In flight we carried out two series of experiments; in one series of tests, passengers who were subject to motion sickness were given NII tablets, in the other, aeron,[1] as a control. The NII tablets and aeron were given for prophylaxis and therapy of motion sickness.

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[1]Tr. note: Aeron consists of camphorated scopolamine and camphorated hyoscyamine.

Both series of tests were carried out on flight journeys at an elevation of 2000-3000 meters on piston airplanes on the Far East and other routes (Moscow-Irkutsk-Khabarovsk-Moscow and others).

Individual flights lasted an average of 2.5 to 30 hours with stops. The total number of hours in flight in the first series of experiments was 470 hours, in the second, 514 hours. Under observation in the first series of experiments were 460 people, and in the second, 560 people, in all 1020, aged 5 to 70; of these 136 were exposed to motion sickness, 68 in each series of experiments.

An experiment under laboratory conditions checked the resistance to experimental rocking (on a four bar K. L. Khilov swing) and to V. I. Voyachek's OP test using subjects who were suffering disturbance of the vestibular-vegetative apparatus to an average and severe degree without administration of NII tablets and after their use.

The following was used as a criterion for evaluation of the positive action of the pharmacological agents, NII and aeron tablets: the absence or cessation of vestibular-vegetative symptoms of motion sickness in passengers (turning pale, sweating, weakness, nausea), good or satisfactory subjective feeling in passengers and in test subjects who had disturbances of the vestibular apparatus at the time and after movement on the four bar swings with use of the therapeutic agents.

Experiments under conditions on the ground in people with disturbed vestibular-vegetative apparatus on the rotating chair ($OP_{I \text{ and } II}$) and on the four bar swings without the use of the therapeutic agents and after ingestion of the NII tablets showed the following: In those people suffering to an average and severe degree from disturbances of their vestibular-vegetative apparatus, of various etiologies, the test on the rotating chair (OP) and on the four bar swing was accompanied by perspiration, nausea and vomiting in 2-5 minutes of rocking; when the test was repeated, after ingestion of NII tablets, these same people (with a disturbed vestibular-vegetative apparatus) withstood well the OP_I, 15-minute rocking, and OP_{II} and symptoms of motion sickness were not noted in them.

Experiments with experimental motion sickness on the four bar swings conclusively showed that use of the NII tablets curbed well the manifestation of symptoms of motion sickness in people suffering from disturbances of the vestibular-vegetative apparatus to an average or severe degree.

Results of tests in flight, using NII and aeron tablets for passenger motion sickness showed the following: (a) NII tablets showed better and excellent effects in 31 passengers, and a satisfactory effect in 25

people out of 68 (82 percent); (b) aeron showed a better effect in only 15 people, and a satisfactory effect in 12 people (less than 18 percent), and (c) aeron--in 25 people (26 percent).

According to reports by passengers and observations by a physician and plane flight personnel, the NII tablets helped well and excellently against motion sickness and improved the general condition of passengers suffering the effects of rocking in flight. After ingestion of NII tablets the passengers did not experience nausea and other unpleasant symptoms of motion sickness. The NII tablets did not cause side effects.

In those cases where aeron did not show a satisfactory effect against motion sickness, NII tablets did give a positive effect. Passengers--who suffer from motion sickness to a serious degree, in whom vomiting usually appeared right after takeoff or in 15-20 minutes of flight--after ingestion of NII tablets 30 minutes before flight, withstood well the prolonged flight, the associated acceleration during flight, the landing and bumping.

Our investigations, carried out under laboratory conditions on the four bar swing and directly on prolonged flight journeys which involved weak, moderate and strong bumping, permit the following conclusions:

1. In people suffering from disturbances of the vestibular-vegetative apparatus to an average or severe degree, prophylactic ingestion of NII tablets has a positive effect--rocking is borne well without manifestation of symptoms of motion sickness, at the time and after a 15-minute rocking on the four-bar swing; under flight conditions the NII tablets showed excellent, good and satisfactory efficacy in 82 percent of the cases of passenger motion sickness; aeron gave good and satisfactory efficacy in 74 percent of the cases.

2. In degree and quality of efficacy, NII tablets surpass aeron and other therapeutic agents known to us (medinal, difazin and others) suggested for motion sickness on a transport.

3. The pharmacological preparation--NII tablets directed for prophylaxis and therapy of air diseases, can be recommended for use among passengers of air transport, subjected to motion sickness.

NII tablets, as a therapeutic agent for motion sickness on air transports, have been approved by the Pharmacological Committee of the Ministry of Health, USSR.

It must be noted in conclusion that, in addition to the use of effective therapeutic agents against motion sickness in flight passengers, it is necessary to have comfortable hygienic conditions in the passenger cabins of the planes in the form of the microclimate, lowering

of the intensity of the general level of noise, vibration and adherence to the parameters of vertical speed of descent of the planes during turning for a landing.

THE INFLUENCE OF AGE-ASSOCIATED CHANGES IN OLDER PILOTS DURING RE-LEARNING IN THE NEW AVIATION TECHNOLOGY AND DURING PERFORMANCE

A. V. Chapek, V. P. Yerokhin and I. P. Poleshchuk

Study of the influence of age-associated changes on pilots during re-learning in gas turbine planes is of definite theoretical and practical interest and is directed toward assuring the safety of the pilots.

In the native Soviet and foreign literature available to us, we were unable to find special reports devoted to the study of the influence of age-related changes on pilots older than 40 years during piloting of modern gas turbine planes. As far as we know, no one has studied this problem.

The aviation agencies (Sabena, SAS, KLM and others) of capitalist countries recommend establishing the age limit of 43-55 for persons assigned to re-learning piloting in gas turbine planes. It is not possible from the available literature sources to establish the criteria on the basis of which the agencies in foreign countries establish the indicated age limit.

The methodology in the present report provided for studies of physiological functions and the quality of flying progress and of flying work by pilot-students and pilot-instructors aged 40-50, and aged 30-39, as a control procedure.

Pilots were studied under conditions on the ground and in flight for the following: higher nervous activity, memory, shifting of attention, visual sequential form, cerebral biopotentials, arterial pressure, and the quality of the development of skill in experimental estimation of short intervals of time.

Evaluation of flying progress and of the quality of piloting by the pilot-students was carried out by instructors who used a five-point system. This practice-proven method of evaluation of the quality of piloting, is most credible and this has been shown by many years of observation by instructor personnel.

The results of the physiological studies were as follows:

1. The correlation of the basic nervous processes in pilot students is on the same level, in all age groups, the number of disturbances of the differentiators does not increase with age; there is no foundation for considering that older pilots (40-50 years) have age-associated disturbances in their basic nervous processes.

2. The average magnitudes of numbers kept in mind, which is characteristic of the visual memory in pilots of the older group and of the control group, are approximately equal; consequently, it is wrong to speak of impaired memory in older pilots.

3. The length (duration) of performance of the test on shift of attention in pilots of the older age groups takes more time than in pilots of the control group; however, the quality of the shifting of attention in pilots of the older group is better than in the pilot-students of the control group.

4. The average magnitudes of duration of the visual sequential form and its latent period do not indicate a decrease in the function of the cortical section of the visual analyzer in older pilots.

5. The formation of conditioned-reflex contact communications, indirectly characteristic of the quality of the development of skill, takes place in a completely successful manner in older pilots and with the same regularity as in pilots of the control group (30-39 years).

6. The time of execution of simple sensory-motoric reactions in all pilot-students is approximately the same; the speed of a simple reaction is not impaired with age.

7. The restoration of functions of higher nervous activity (to the initial condition) after extended flights by older pilots proceeds more slowly than in pilots of the control group; here, evidently, is a manifestation of the influence of the changes on the process of restoration of the functions of the organism after pronounced fatigue--of a 10-hour flight.

In all pilots, independently of age, the cerebral biopotentials (L. V. Sadovnikova) after prolonged flight preserved their clarity, regularity and expression of α-activity in the regions of the brain; after prolonged flights, the intensification of the process of inhibition was more pronounced in older pilots than in pilots of the control group.

The average magnitudes of the pulse and arterial pressure in pilot-students and instructors of different ages did not give any actual

deviation at all from the accepted norm in the clinic and in physiological states; however, in individual pilots from 40-50 years of age, a lowering occurred in the acuity of vision to 0.7-0.8 and of hearing to 1.5-1 m on reception of whispered speech. Lowering of the acuity of vision and hearing in the older pilots examined, according to the statement of the instruction personnel, does not show a negative influence on flying work, progress and quality of piloting.

According to the results of a questionnaire the overwhelming majority of older pilot-students do not notice in themselves increased weariness after educational, duty and journey flights. They also do not show absentmindedness, forgetfulness or ineffective operation in flight, which could be associated with the influence of age-related changes.

Accumulation of skill in older pilots, judging by the formation of conditioned-reflex contact communications, both under experimental conditions and in the process of re-learning, of piloting gas-turbine planes, proceeds as successfully as in the control group pilots.

Flying progress and the quality of piloting by pilot-students of the older age groups and control groups was evaluated by the instructors on the five-point system as "good" and "excellent".

Generalization of the experimental material permits the conclusion that the tests do not succeed in finding a difference on the psychophysiological plane between pilot-students of the older age groups (40-50) and of the control group, which could be negatively manifested in the progress of the process of re-learning piloting in gas-turbine airplanes. In a number of cases, representatives of the mature age (45-49) have some pre-eminence. This can be partly explained in that the group of older pilots is made up of more capable pilots, who have remained in the ranks of aviation as a result of special and natural selection.

Age-associated changes (decrease in acuity of vision and hearing) in older pilots, judging by the results of an experimental study and an evaluation of flying progress do not show a negative influence on pilots possessing skills of piloting in planes with gas-turbine engines.

The materials of the experimental study under laboratory conditions and in flight in the process of flying training, and also the observations by the instruction personnel, permit the conclusion that an age limit for pilots, assigned to re-learning piloting in gas-turbine engines, is apparently 45 years of age. Further studies will be needed to make this limit more precise.

SOME MICROORGANISMS AS INDICATORS OF SOLAR ACTIVITY AND PRECURSORS OF SOLAR FLARES

A. L. Chizhevskiy

A concrete solution of the problem of the effect of solar emissions on living things is difficult to find owing to our inadequate knowledge. However, the mass of available statistical data and some microbiological experiments are now bringing the solution closer. The most important consequence will be our ability to forecast astrophysical phenomena (e.g., flares) accurately several days (4-6) in advance. Observations of this kind will then have enormous practical significance both for space science and for clinical medicine.

Our investigations, which date back to 1915, showed that nerve cells and certain microorganisms are highly sensitive to solar activity, to the passage through the central meridian of the sun of spots, protuberances, flocculis, and very intense flares, emissions of solar matter. A "ruggedization" of the spectrum takes place during a flare. The heavy streams of hard X-rays and high-energy corpuscles in the space around the sun are extremely dangerous to unprotected man.

After studying in detail the daily or 10-day dynamics of epidemics, not only were we able to calculate the closeness of the relationship between epidemics and cyclic activity of the sun, but in some instances found that sharp peaks in the epidemics forecast astrophysical phenomena. This "early warning" was quite accurate in the case of mortality from infectious and cardiovascular diseases (myocardial infarct, insults, sudden death). However, the maximum of epidemic development (annual figures) sometimes occurs a year after a maximum of cyclic activity, forming a correlation coefficient of 0.8-0.9, with insignificant errors (±0.009 to ±0.02). I have studied the pattern of plague, cholera, influenza, diphtheria, scarlet fever, dysentery, and other epidemics over a long period of time and in many countries. I studied the relationship between most plagues of the 19th and 20th centuries and solar activity and noted some important details that had previously escaped the attention of epidemiologists. The results of my studies, published in 1924-1930, were edited, in part, by Prof. N. A. Semashko who considered them highly significant. A portion of my monograph (pages 1-240) on the subject was published in 1938 by the Paris Academy of Medicine. Entitled Les Epidémies et les Perturbation Électromagnétiques du Milieu Extérieur, the work was edited by a member of the Academy, Prof. Leniel-Lavastine.

Since no one knew which is most dangerous to man outside the earth's atmosphere--electromagnetic radiation of excited places on the sun, or emission of high-energy particles during major flares, or perhaps the two together (Z-radiation)--it became necessary at the end of the 1920s

to find an extremely sensitive biological reaction capable of forecasting possible early (within a few days) emissions of solar matter in the atmosphere that are unpleasant or even dangerous to man. Konstantin Eduardovich Tsiolkovskiy had some conversations with me on the subject.

It is reasonable to assume (and he emphasized the word "assume") that some "perturbed" places originate in the interior of the sun rather than on the surface and that emissions emanate therefrom to which certain sensitive nerve cells or microorganisms respond. The theory of excited places originating deep in the sun has been elaborated by heliophysicists in the Soviet Union and abroad (Hoyle, Bjorknes, Alven, Valen, and others).

"To direct a stellar spacecraft in another orbit and enable it to avoid entering a flux of dangerous solar radiation, we must know several days in advance the time that this dangerous radiation will occur," Konstantin Eduardovich told me. The daily or 10-day curves of epidemic outbreaks, whose peaks clearly anticipated the instrumental recording of solar activity, encouraged him greatly. After studying these curves, he asked me to try to produce a similar effect in the laboratory. I started to work on the problem in 1929. Several years passed, however, before the main outlines of the experiments became more or less clear. It was necessary to study hundreds of different strains of bacteria with different methods of cultivation, nutrient media, and incubator temperatures. Our persistence was justified, for we found suitable microorganisms and developed a method of tracing their reactions to perturbations of matter inside the sun, thus making forecasts possible.

We were joined by the Kazan bacteriologist and diphtheria specialist S. T. Vel'khover who had been influenced by our earlier investigations of diphtheria epidemics (1924-1930) in a number of countries. In a joint work carried out shortly before World War II, we obtained in bacteria a "lead effect" that preceded the astrophysical instrumental data by 4 to 5 days, i.e., when no distinct changes could as yet be detected in the surface layers of the sun. Together with our earlier statistical curves and results of numerous experiments, it was a positive achievement. The mean of 19 superpositions along the "0" axis ("day of ejection") was highly significant.

It seems that peculiar inclusions in certain microorganisms are a very sensitive detector of the aforementioned radiations. By a change in their delicate properties at the atomic-molecular level, they signal powerful nuclear processes taking place inside the sun.

The foregoing suggests that we now have available methods of predicting the solar emissions that are most dangerous both to human beings outside the earth's atmosphere (astronauts) and to sick persons on earth.

SIGNIFICANCE OF PARASYMPATHETIC NERVOUS SYSTEM TONE IN INCREASING RESISTANCE TO FLIGHT FACTORS

M. D. Chirkin

This report presents the results of the author's investigations, carried out at different times, on the interaction of the body and unusual environmental factors and a comparison of the data with the literature. The author was concerned with the physiological mechanisms that increase human tolerance of flight factors (low barometric pressure, oxygen deficiency, accelerations, altitude meteorism, etc.). One of the most important of these mechanisms is change in the tone of the parasympathetic nervous system, chiefly that of the vagus nerve center, which is constantly regulated by the cerebral cortex. We shall try to support our view with factual data obtained from our investigations and observations.

In one of his lectures, I. P. Pavlov said that "to some extent the vagus nerve is the nerve of rest, the nerve that regulates cardiac rest."[1] Slowing of the cardiac rate may depend on the reflex or tonic influences emanating from the vagus nerve center. In developing this position of Pavlov, A. I. Smirnov and co-workers (Ye. Turbina, I. D. Olefirenko and V. F. Shirokiy, 1924, 1926, 1927, 1929) divide animals into groups: those possessing pronounced vagus nerve center tone, those with weak tone, and those with no tone at all. Man, dogs, and hares belong to the first group. Animals like rabbits, puppies up to 3 weeks old, and frogs have very weak tone or none at all.

Strong tonic excitation of the vagus nerve center that develops in dogs with age prevents reflex slowing of the cardiac rate (I. A. Arshavskiy, 1951).

High tone of the vagus nerve centers makes prolonged muscular exertion possible (man, dogs, horses, and hares). Such exertion is impossible for animals with weak tone (rabbits, cats), not to mention animals with no tone (frogs). This view of the part played by high tone of the vagus nerve centers in making prolonged physical exertion possible has been confirmed by investigations, observations, and practices of sports medicine.

Moderate sustained physical exertion (long distance running, bicycling, ski marches, etc.), in which a state of relative equilibrium

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[1]Collected Writings, USSR Academy of Sciences Publishing House, Vol. 5, p. 323, 1952.

develops between the rate of formation of disintegration products in the body and the rate at which they are destroyed by oxidation, results in slowing of the pulse--bradycardia at rest, increase in the systolic volume, and relatively low systolic blood pressure--and hypotention ranging from 95 to 105 mm Hg (V. S. Farfel', 1941; M. Ye. Marshak, 1946; A. N. Krestovnikov, 1954; N. V. Zimkin, 1955).

During the first year of training, the pulse rate at rest, according to Mitchell, averaged 74 beats/min, the second year - 68, and the third year - 53.

Our observations on a large number of participants in the All-Russian Sports Competitions in Moscow showed that a week before a meet, the pulse rate in sprinters averaged 72 beats/min, middle-distance runners - 66, and long-distance runners - 57, in 5 of whom it fluctuated between 44 and 46 (M. D. Chirkin, 1924). The reason for this reorganization of the autonomic nervous system seems to be that physical exercise is accompanied by increased tone of the sympathetic nervous system, but in the rest period this predominance shifts to the parasympathetic nervous system, thereby enabling man to function more efficiently. At the same time the rhythm of cardiac and respiratory activity improves. We also encountered such phenomena in our experimental investigations involving the simulation of altitude meteorism by increasing pressure in the cavities of the gastrointestinal tract (1948-1955).

These investigations were of comparative physiological nature, with frogs, dogs, and human beings the subjects. Those on dogs involved their breathing both atmospheric air and gas mixtures deficient in oxygen (corresponding to altitudes of 6000 and 8000 m above sea level).

In the experiments on frogs under these conditions, we observed marked impairment of the cardiac rate to the point of temporary cardiac standstill. These pronounced interoceptive reflex influences on the heart, recorded by mechanograms and electrocardiograms, were obviously caused by insufficient tonic excitation of the vagus nerve centers in the cold-blooded animals because they were relieved by administering atropine.

In chronic experiments on dogs, reflex changes in cardiac and respiratory activity were less pronounced, although they became intensified after oxygen deficiency.

In the experiments on human beings, moderate stimulation of the mechanoreceptors of the stomach or large intestine (pressure in a balloon of about 20 mm Hg) failed to elicit any significant reflexes to respiration and cardiac activity, being manifested only after high pressures (impairment of the respiratory rhythm, sinus arrhythmia of cardiac contractions).

Thus, the higher an animal is on the phylogenetic ladder and, therefore, the stronger the tone of its vagus nerves, the less disagreeable are the interoceptive influences (such as altitude meteorism).

Our findings agree with those of K. M. Bykov, V. N. Chernigovskiy, P. P. Goncharov, V. A. Lebedeva, and others.

The same phenomena occur in air or motion sickness. The symptoms of dysfunction in airsickness are due mainly to increased tone of the parasympathetic nervous system. This condition is known to arise when the analyzers sense periodic changes in body position (due to tossing, bumpiness, yawing, etc.). This is the basis of V. Ya. Voyachek's otolith theory of motion sickness.

Suitable physical exercises may mitigate the effect of these reflex influences and this, in turn, helps to restore the dysfunction that arises even in the latent form of motion sickness (rolling motion with acceleration of 0.15 g). The disturbances affect visual acuity, upward shift of the dark adaptation curve, etc. (V. I. Kopanev, 1961).

Motion sickness is prevented or treated by a wide variety of drugs that decrease the tone of the parasympathetic nervous system, thereby providing symptomatic relief (Kevil, 1934; Smith, 1948; Holling et al., 1944; D. M. Gorodinskiy, 1930; I. Ya. Borshchevskiy, 1937, 1939; and others).

This may seem to contradict the views we set forth above. However, the favorable effect resulting from the use of drugs may be due not only to inhibition of the parasympathetic nervous system centers but to some other factor. Evidence of this comes from experiments aimed at activating the functions of the reticular substance by the administration of dibazol (2-benzylbenzimidazole hydrochloride) (V. I. Kopanev, 1961).

It is our intention to perform a series of experiments on the role played by the brainstem reticular formation in heightening the tone of the parasympathetic nervous system during physical training designed to increase endurance. It seems to us that this approach to scientific physical preparation of pilots and astronauts deserves careful consideration.

Conclusions

1. Physical exercises that increase endurance result in intensified parasympathetic tone.

2. With intensified parasympathetic tone, resistance increases to unfavorable and unusual environmental agents.

3. It follows, then, that in devising a program of physical preparation of air pilots and astronauts, considerable attention should be paid to increasing their endurance.

EFFECT OF BRIEF PHYSICAL TRAINING ON THE SURVIVAL OF WHITE RATS KEPT UNDER CONDITIONS OF PROLONGED HYPODYNAMIA AND ISOLATION

V. A. Shkurdoda

Activity of the neuromuscular apparatus is a prerequsite of the normal development and existence of the human organism. Recent investigations have shown that limiting motor activity decreases the competence of the motor apparatus, impairs the accuracy of perception of kinesthetic stimuli, and lengthens the period of complex and simple motor reactions. Prolonged immobility has a marked effect on the subjective sense of well-being and sharply reduces efficiency.

The purpose of this investigation was to determine the specific effect of systematic training on tolerance of hypodynamia and isolation and in so doing to ascertain the degree of resistance to ionizing radiation in animals subjected to various motor regimes.

Experiments were performed on white male rats. The experimental animals were kept for 20 days in small solitary cells that prevented them from moving about. Food and water were placed in specially constructed boxes in such a manner that the animals could eat without getting out of the cells. Hygienic conditions were strictly observed in attending the rats.

The control rats were placed in an ordinary cage that was large enough to enable them to jump, run, rest on their hind paws, lie stretched out by themselves, or occupy any corner and bunch together when sleeping.

Rats from each of the experimental groups were kept in solitary cages for 20 days continuously.

The rats of the first group were taken out of the cages daily for 30 minutes and immediately actively trained on vertical poles.

The rats of the second group were transferred at this time for 30 minutes to a more spacious cage (passive rest).

The rats of the third group were left to sit in the cages during the 20 days.

Both the training and the passive rest were carried out daily for the 20 days at the same time of the day.

After the 20 days of hypodynamia and isolation, all four groups of rats were x-irradiated with a dose of 750 r.

During the experiments the animals were kept under observation in order to study the effect of prolonged hypodynamia and isolation and then their tolerance of radiation sickness.

Survival of the animals after irradiation was observed for 20 days.

Measurements were made before the experiment, during hypodynamia and isolation, before irradiation, and during radiation sickness until the end of the experiment.

Our investigations showed that the animals kept under the conditions of hypodynamia and isolation exhibited varying degrees of tolerance, depending on the amount of motor activity.

We concluded from analysis of the various indexes of motor and autonomic functions that under the conditions of hypodynamia and isolation vigorous muscular activity rather than passive rest is required to maintain resistance.

Observations on the first and second group of rats withdrawn from their cages for training or for passive rest revealed a great variety of behavioral manifestations by the animals allowed to move freely.

Physical training probably helps to ensure the equilibrium and mobility of the nervous processes, one of the factors in resistance to hypodynamia and x-irradiation. Another important factor is the favorable effect of training on the interaction of the motor and autonomic functions of the organism.

In the process of hypodynamia, 6 percent of the animals given brief training died as compared with 41 percent of the untrained animals.

The favorable effect of physical training on tolerance is due, in our opinion, to the stream of proprioceptive impulses from the muscles, which exert a tonic influence on the central nervous system.

As mentioned above, the survival rate of the animals kept in hypodynamia and isolation but given training and passive rest was very high. But the rats exposed to irradiation after hypodynamia were found to

possess varying degrees of resistance to this powerful stressor. The most resistant were the animals given brief active training. The animals allowed passive rest under the conditions of hypodynamia were the least resistant.

The training exerted a vigorous mobilizing effect on the reflex and other vital mechanisms concerned with maintaining bodily resistance to a great variety of unfavorable factors. Thus, hypodynamia and isolation were unable to disrupt the connections firmly established by training nor did the powerful stressor (irradiation) subsequently applied have a destructive effect on most of the animals in this group. This assumption is supported by the weight stability, blood picture, rate of reactions, and body temperature noted in the trained rats.

Our investigations of animals amplify our knowledge of the effect of physical training on human beings who work under conditions of limited mobility and isolation. The results of our investigations and those of other authors indicate that purposeful physical training is of considerable value in increasing resistance to ionizing radiation. Two to three times more trained animals kept under the conditions of hypodynamia survived than untrained animals.

The level of vital activity of the trained animals, judging by the objective data, was higher at all stages of the investigation than that of the untrained animals. Passive rest during hypodynamia and isolation improved the survival rate, but the animals were less resistant to x-irradiation.

EFFECT OF PARACHUTE JUMPS ON THE ADAPTIVE REACTIONS IN PERSONS OF DIFFERENT AGE GROUPS

S. N. Shurgin and A. N. Mazin

Parachute jumping, according to the literature, is a complex neuropsychological task associated with marked changes in the autonomic functions of the body. Each jump, even after numerous repetitions, entails emotional stress. A specific characteristic of military parachute jumping is that it is done under a variety of conditions, often unfavorable. Moreover, it involves severe physical exertion both in the preparation period and after landing.

The main purpose of this investigation was to study the effect of parachute jumps from new types of aircraft on persons in different age

groups (27 men in 7 stages). It began a day before a jump and ended the second day afterward. In view of the familiar published data concerning the influence of the emotions on cardiac activity and blood composition (Cannon, Bekhterev, and others), emphasis was placed on changes in cardiovascular reactions and blood composition.

After landing in a plane at the airport, the pulse rate of the subjects was 80-110 beats/min. During preparation for the first jump, the pulse averaged 87 beats/min, second jump - 100, third jump - 93.

While flying in the plane, there was a further acceleration of the pulse to 90-120 beats/min. Averaging the figures for three flights, the pulse rate was 95, 96, and 101 beats/min.

The pulse rate increased again when the parachutists opened the hatch. The average for 3 groups was 112, 128, and 129 beats/min, but it reached 130-140 beats/min in individual cases. The highest pulse rate was noted as soon as the subjects landed, the average for three jumps being 117, 130, and 148 beats/min, and, in a few cases, 150-160 beats/min.

Investigation of the blood showed an increase of 10,000 to 12,000 leucocytes after a jump. The number of segmented neutrophils rose to 70 to 75 percent, while the number of lymphocytes dropped to 18 to 20 percent. Investigation of heparin and prothrombin time (data of P. I. Gvozdev) showed that the maximum ejection of heparin occurred before and after jumps, resulting in an increase in heparin time and in a lowering of the prothrombin index.

According to I. S. Balakhovskiy, the changes produced in the metabolism of the adrenocortical steroid hormones by parachute jumps are indicative of a pronounced reaction by the endocrine glands and comparable to reactions to stress.

The results of a functional test--3 minutes' running in one spot--revealed the dynamics of arterial pressure and cardiac rate at different stages of the investigation. Analysis of the data made it possible to divide the subjects into two groups. The first included men under 30 years of age, those possessing more adequate adaptive reactions of the cardiovascular system. The second group--men 30-40 and older--exhibited changes in cardiovascular reactions of less lability, which obviously may result in less adequate adaptive reactions.

According to the electrocardiographic data, the functional changes in the 30-40 year old group were more pronounced and they tended to persist into the restorative period. The systolic index increased by more than 10 percent, a sign of functional incompetence. Moreover, sinus arrhythmia and instances of atrial extrasystole were noted after jumps.

Investigation of the oculocardiac reflex and orthostatic test provided some information on changes in the tone of the parasympathetic and sympathetic nervous systems. In some of the men under 30, no significant fluctuations were noted in the tone of the parasympathetic nervous system throughout the investigation. Sympathetic tone increased markedly from the 1st to the 4th stages (in the landing area) followed by a decrease. In the others--the men over 30--the parasympathetic tone increased, reaching a maximum in the 4th or 5th stage. The subsequent stages were characterized by a decrease, although normal tone was generally not restored by the 7th stage (second day after landing). The increase in sympathetic tone was less pronounced in this group than in the other.

Investigation of maximum strength and time of holding arms in a horizontal position with 2 kg weights showed that the changes were most pronounced in the 4th stage, i.e., immediately after a jump. These characteristics were generally restored on the next day.

Conclusion

The results of our investigation show that while preparing for a jump, during flight in the plane, and after a jump from a new type of aircraft, parachutists develop prolonged emotional stress accompanied by more pronounced changes in physiological characteristics than they do in the case of jumps under other conditions.

Some characteristics of the cardiovascular system and autonomic nervous system in the older men are not completely restored by the 2nd day after a jump. We therefore recommend that their workload be reduced and routine activity be reorganized for the two days after a jump.

PHYSIOLOGICAL REACTIONS IN WEIGHTLESSNESS

Ye. M. Yuganov

Theoretical considerations and some experimental data show that in weightlessness we must expect changes in function of the vestibular, motor, and tactile analyzers, impairment of functional interrelations and resultant developments of disagreeable sensations, changes in muscle tone and in cardiovascular and respiratory activity. Experimental proof that such changes can arise and a determination of the nature and intensity of reactions under these conditions is of theoretical and practical importance in predicting the efficiency of man during extended space

flights and in improving the system of selecting and training astronauts. Some questions cannot be answered without biomedical experiments carried out during actual flights. But it is clear that much can be learned in laboratory and airplane investigations.

We believe that data on the effect of brief weightlessness on animals and man can be properly extrapolated to conditions involving prolonged weightlessness in direct proportion to the number of experiments that are performed and to the accuracy with which the main qualitative functional changes are determined. This was the thinking that led to the numerous experiments carried out in 1960-1962 dealing with the effect of brief weightlessness on animals and man.

Owing to the importance of determining the functional characteristics of the vestibular analyzer and the physiological mechanisms responsible for "space sickness", studies were made on the excitability of the vestibular analyzer in weightlessness. Its function was evaluated from its thresholds of excitability in response to a galvanic current and from the intensity and nature of the vestibular reactions in man subjected to strictly measured angular and Coriolis accelerations. It was found that brief weightlessness gives rise to highly regular changes in the indexes of vestibular reactions--the latent period before manifestation of the reactions lengthens while their intensity diminishes. This is proven by the shortening of the period of postrotation nystagmus, decreased duration of the illusion of counterrotation, reduced intensity of protective movements after angular accelerations, lengthening of the latent period before the "illusion of swaying" arises, by an increase in the minimum speed of correction causing the trunk to bend on exposure to Coriolis accelerations, and, finally, by a regular rise in the thresholds of excitability in response to a galvanic current.

These facts suggest that in weightlessness the excitability of the receptors of the semicircular canals decreases rather than increases after angular or Coriolis accelerations. This cannot be due to the direct effect of weightlessness on the semicircular canals, for the loss of endolymph and cupula weight does not signify a loss of mass nor does it cause changes in the inertia of the endolymph.

It is reasonable to assume that the aforementioned phenomena are determined by changes in the reciprocal relations between the semicircular canals and the otolith apparatus. The nature of the observed changes indicates that impulses from the otoliths inhibit the semicircular canals in weightlessness much more than they do under ground conditions. As a result, there is a lowering of "excitability" of the semicircular apparatus of the vestibular analyzer. Control experiments showed that these changes are the direct effects of weightlessness on the otoliths rather than of preceding accelerations. We believe that weightlessness does not lead to functional exclusion of the otolith apparatus, to a peculiar

physiological delabyrinthization thereof. It seems, instead, to be an unusual minus-stimulus for the otoliths.

If weightlessness, like some other stimuli, can be conceived of as having the property of cumulation, the summation of the nervous processes that it activates in the cortical and subcortical formations can probably produce the symptoms of space sickness. This cannot be ruled out as one of the main causes of the vestibular discomfort suffered by G. S. Titov in his flight on the Vostok.

Characteristics of vestibular analyzer function in weightlessness were reflected in the state and activity of several systems of the organism. Mechanographic and electromyographic investigations of intact, decerebrated, and delabyrinthectomized animals as well as experiments involving human beings demonstrated that the tone of the antigravitational skeletal musculature may decrease in weightlessness. Suffice it to mention that the amplitude of the biopotentials of the neck muscles of man, which ranges from 130-180 mv under ground conditions, dropped to 40-50 mv in weightlessness, and in some instances there were phenomena resembling the picture of bioelectric silence. The value of the biopotentials of the femoral flexor in animals usually decreased in weightlessness 1.5-2.5 times below the original level. It was experimentally demonstrated that the effect of weightlessness on changes in tone of the the antigravitational musculature is much less pronounced when the vestibular analyzer is excluded.

The significance of motor-visceral relations in the regulation of cardiovascular and respiratory activity is well understood. It was right to assume that in weightlessness changes in the motor sphere, particularly the decrease in tone of the skeletal musculature, may be responsible for the tendency for disagreeable physiological effects to be manifested in the cardiovascular system too. Accordingly, it was important to study the state of those indexes of blood circulation function whose manifestation varies with tonic contraction of the muscles. It is absolutely essential in this respect to determine venous pressure. Experiments on animals showed that in weightlessness the value of venous pressure in the right atrium and ventricle regularly decreases from the original 0+5 mm Hg and +15+25 mm Hg, respectively, by 15-25 mm Hg. Analysis of the changes in nature of respiration showed that it is virtually independent of the characteristics of respiratory function in weightlessness. The changes in venous pressure were found to be directly related to a decrease in the tone of the skeletal musculature. The physiological changes noted may have also been caused by direct reflex changes in the tone of the venous blood vessels.

To elucidate the role of this mechanism, investigations were carried out on the vessels of the fundus oculi, the functional state of which is known to be almost independent of the tone of the skeletal muscles and

respiration. The method of calibrometry with photographing of the fundus oculi was used to determine any increase in diameter of the retinal veins in weightlessness over their original size. These investigations showed that the changes observed in the venous system are determined by dilatation of the veins as a result of direct reflex influences from the gravireceptors and of indirect influence on the tone of the veins due to decrease in the tone of the skeletal muscles. The lack or indistinctness of such changes in delabyrinthectomized animals shows that reflexes from the vestibular analyzer play an important role in these mechanisms.

It is conceivable that in prolonged weightlessness changes in vestibular analyzer function, muscle tone, and some characteristics of venous circulation may become more pronounced and thus affect human efficiency. The creation of artificial gravity may well be one of the important measures designed to enable man to function normally in space.

Relevant investigations on animals revealed that, on the basis of postural reflexes and general motor activity, the artificial gravity produced by accelerations of 0.3 g can be regarded as the minimum effective value needed to prevent weightlessness from having unpleasant effects on the motor reactions of animals.

EFFECT OF AIRPLANE NOISE ON MAN AND NOISE CONTROL MEASURES

Ye. M. Yuganov, I. Ya. Borshchevskiy, Yu. V. Krylov
and V. S. Kuznetsov

One of the most disagreeable of the many physical factors to which man is exposed during airplane flights and on the ground is the noise made by motors and airplanes. Pilots, engineers, and technicians, while in the air or engaged in takeoff operations at the airport, are subjected to noise whose intensity exceeds the threshold of pain (130 decibels). The noise level of a piston engine or airplane is 108-120 db, that of a jet engine or airplane 120-140 db or more.

Depending on their duration, intensity, and frequency, sounds change within broad limits and they may provoke a variety of reactions by the auditory analyzer from weak and reversible phenomena of adaptation and hearing fatigue to pathological conditions. After prolonged exposure or weakening of the nervous system, these changes become more pronounced and persistent as they assume the nature of a chronic process in the form of hardness of hearing and deafness.

The specific effect of noise with an intensity of 120 db is generally manifested in sensations of pressure and clogging of the ears. Noise of 160 db can cause acoustic trauma.

The reactions to sound stimuli by flying and technical personnel differ. Many of the latter have a progressive, vague reduction of hearing. Personnel at test stations have a more pronounced impairment with a tendency toward rapid progression. Still others seem to have good hearing despite many years of exposure to loud noise. All this indicates that the nature, degree, and dynamics of hearing impairment are largely related to the nature of the work and to the individual reactivity of the auditory analyzer to noise.

Noise has an adverse affect not only on human hearing, but on the body as a whole, for it causes fatigue and decreases efficiency. There are indications that noise stimulates the vestibular as well as the auditory analyzer. It impairs visual acuity, respiratory rate, cardiac activity, and blood pressure. It changes the size of the spleen and kidneys, reduces the number and amplitude of gastric contractions, and increases gas exchange. After prolonged exposure to noise, people develop insomnia, timidity, slowing of mental reactions, and inattentiveness.

It has been observed that persons whose work involves the testing of jet airplane engines and getting planes ready for the takeoff sometimes develop after a long period of time disagreeable subjective sensations in the form of a ringing in the ears, poor hearing, fatigue, and loss of efficiency. Nervous fatigue may afflict those with an unstable nervous system. Noise has less of an effect on flying personnel because they are in a pressurized cabin and use interphone headsets, hermetic suits, and other sturdy protective devices.

The effect of noise is much less at airports than at jet engine test stations. This explains why the workers at these stations complain more about their irritation, ready fatigability, impaired efficiency, sense of clogging of the ears, and poor hearing.

For effective control of auditory function in personnel exposed to loud noise, they must be given, in addition to a preliminary examination, a regular annual audiometric checkup to detect in time signs of hardness of hearing and deafness. This is also important for flying fitness examinations. It is highly desirable in acoumetry not to limit the test to whispered speech and tuning forks; modern methods of audiometry should also be used.

The personnel can no longer be protected by individual devices (noise filters) because the absorbing property of most of the common devices ranges from 10 to 12 db, which is insufficient for 130-140 db jet engine noise.

There are two ways of controlling noise: (1) installation of special equipment, and (2) individual devices. Attention should be focused on (1) for supersonic aircraft. There are two basic methods of suppressing noise. One is to use absorbers placed in the front and rear of the plane. The other is to keep the plane inside the test hangar. The absorbers can be mobile, stationary, or semistationary. Stationary and mobile sound absorbers are effective for a total noise level of about 20 db. Mobile absorbers may be placed anywhere in the test area. In the case of stationary absorbers, the tail of the plane is moved into a sound-absorbing box or tunnel. Special equipment is available for simultaneous testing of four airplanes with a single sound-absorbing device.

Besides technical equipment, individual devices are recommended. One of the main reasons for the difficulty of the problem is that the human ear is not equally sensitive to all sounds. Hence the requirements for noise suppressors are highly complex. It is impossible to design a universal device to afford protection from sounds that vary greatly in frequency and intensity. Several types will be necessary, depending on the noise level, working conditions, and individual needs.

As far as aviation is concerned, the following two methods of individual protection are the most effective: (1) plugging of the external auditory meatus, and (2) insulation of the entire parotid region from noise by special devices.

In designing protective devices for engineers and technicians, one must bear in mind that they work mostly at airports and test stations at different times of the year and that the work continues for a few minutes to several hours with short breaks. Three types of protection are recommended for these people: (1) special helmets, (2) ear muffs, and (3) plugs.

Individual protective devices and special equipment are not enough. Efforts must also be made to reduce the noise of the source itself (engine).

It is a very good idea to reorganize the work routines for this category of personnel, arranging the work day to include short rest periods in a quiet place. When designing airports and test stations, provision should be made for soundproof places where the personnel can relax.

Test stands should be equipped with special telephones to facilitate communication. The soundproofing of existing test stations should be improved, with rubber or wooden screening and mats used to reduce the effect of vibration.

EFFECTIVENESS OF CERTAIN METHODS OF SELECTING PERSONNEL BY VESTIBULAR TESTS

Ye. M. Yuganov, S. S. Markaryan, I. I. Bryanov,
I. A. Sidel'nikov and R. A. Vartbaronov

When flying in a modern plane, man is exposed to angular, Coriolis, and linear accelerations, which change various functions of the body, including the activity of the vestibular analyzer. During flights two types of vestibular reactions develop which may adversely affect the pilot's efficiency and physical fitness: (1) illusions that make it difficult for the pilot to orient himself, and (2) vestibular-autonomic reactions that cause a deterioration in his general condition. The methods of vestibular selection used should make it possible to predict with reasonable accuracy whether the aforementioned reactions will occur during a flight. The idea of reflex interaction of the afferent systems is the basis of the methods that we recommend. These methods are aimed at detecting any tendency toward spatial illusions and at determining the thresholds and intensity of vestibular reactions to the simultaneous inhibitory effect of stimuli from two analyzers (motor, visual, etc.).

A Method of Determining the Threshold of Vestibular Excitability and Sensitivity to the Illusion of Banking

The examinee sits with eyes closed in a rocking chair with an unsteady base. A pulse current with a frequency of 10 cps stimulates the vestibular apparatus for 3 and 10 sec. If the body does not deviate, the current is gradually increased (but no more than 3 ma) until the body clearly tilts to the side opposite the labyrinth stimulated.

When determining the threshold of vestibular analyzer excitability to a pulse current with simultaneous presentation of visual stimuli, the examinee continues to sit in the chair and stare at a lighted 2.5 w bulb located 60 cm from the center line at eye level. Note is taken of the amount of current required to cause a sensation of banking toward the stimulated labyrinth and a loss of balance. The strength of the inhibitory influences from the visual analyzer in relation to the vestibular analyzer is judged from the difference in amounts of current that provoke the banking reaction in the subject when his eyes are closed and when he is looking at the light.

The kymograph (oscillograph) recording shows the intensity of the motor reaction that accompanies the illusion and serves as an objective criterion thereof. Thus, the sensitivity to false sensations is characterized by the current during a total exposure to the stimulus of 10 sec. It normally ranges from 1.5 to 2.5 ma. Smaller values of the current indicate a heightened sensitivity to illusions of banking during flight.

Method of Investigation on a Revolving Chair with an Unsteady Base

This test is intended to detect the capacity of the motor analyzer to inhibit vestibular reactions following artificial impairment of the functional interrelation between the analyzers of spatial orientation. The subject, with eyes closed, is rotated to the right (10 revolutions per 20 seconds), then 3 minutes later to the left. After each rotation is halted, the chair is mechanically shifted to the unstable base. Meanwhile, the subject feels a loss of balance and impairment of spatial orientation. In those persons who are inclined to suffer impairment of spatial impairment during flight, the sensation of counterrotation is pronounced. There is a loss of balance for 30 seconds or more with complete disorientation in space and, for 10-15 seconds, occurrence of autonomic reactions.

The aforementioned methods are recommended as means of determining the predisposition of fliers to develop the commonest spatial illusions. They enable one to predict (in 80 percent of the cases as compared with 25 percent for the old methods) the possibility of occurrence (and mechanism of manifestation and inhibition) of illusions during actual flights. It is urgent that an effective method be available to evaluate vestibular-autonomic sensitivity. Accordingly, we devised the following techniques, which are based on the cumulative and simultaneous stimulation of the ampullar and otolithic apparatuses of the vestibular analyzer.

Methods of Determining the Intensity of Autonomic Reactions to Cumulative, Intermittent Exposure of the Vestibular Analyzer to Coriolis Accelerations

The subject is first examined for spontaneous vestibular disorders and for good tolerance of the "O.P." test. While being rotated on a Barany chair at the rate of 180°/sec for 20 seconds, the subject, with eyes closed, bends his head rhythmically to the side 16 times in 20 seconds. When the chair is stopped, the subject is asked to hold his head straight and open his eyes, after which he is checked for autonomic reactions (pallor, hidrosis, nausea). If none of these is present, the investigation continues 1 minute later (rotation in the opposite direction). If the tolerance is good, the next investigation is changed. Under the same experimental conditions, the subject bends his trunk forward 8 times in 20 seconds. The interval between rotations should not be more than 1 minute in length. If pallor, hidrosis of the facial skin, or nausea appears during this time, the investigation is halted and the subject disqualified. Marked protective movements with a total absence of autonomic reactions are not a cause for blocking admission to flying school since these reflexes are easily weakened by appropriate training. Those persons are deemed qualified who readily tolerate the entire investigation.

Another method is based on determination of the intensity of autonomic reactions to cumulative, intermittent exposure of the vestibular analyzer to Coriolis accelerations. Sitting in a Bárány chair, the subject is rotated at 180°/sec while moving his head backward and forward 35°. Note is taken of the time necessary for autonomic disorders to become manifest. It differs from subject to subject, amounting in individuals with high resistance of the vestibular analyzer to 4-6 minutes and in individuals with marked sensitivity to 1-2 minutes.

Still another method is a 2-minute test for tolerance of the cumulative effect of Coriolis accelerations. At first the so-called C (Coriolis) index is determined at a rotation speed of 180°/sec by the Voyachek-Khilov method. Then, against a background of steady, even rotation of the Bárány chair at 180°/sec for 1 minute, the subject with eyes closed sits up and bends over at a rate corresponding to the C index every 5 seconds at the doctor's order. The experiment is repeated every 50 seconds with rotation in the opposite direction. Note is taken of the autonomic reactions and subjective sensations.

The test, given to 200 subjects, showed that individuals capable of readily tolerating 2 minutes of rotation can easily withstand swaying in Khilov swings and O.P.--10.

The three methods of investigating vestibular-autonomic sensitivity described above are helpful in determining the latent forms of vestibular-autonomic disorders that cannot be detected by any of the methods now used in flying fitness examinations.

SENSORIMOTOR COORDINATION IN EXTENDED WEIGHTLESSNESS IN ACTUAL SPACE FLIGHT

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The flight programs of Vostok 3 and Vostok 4 called for a study of the effect of extended weightlessness on sensorimotor coordination in astronauts A. G. Nikolayev and P. R. Popovich. Appropriate laboratory tests were made beforehand. According to the program, the men had to take the following tests:

(1) The astronaut stretches out his hands toward some instrument in the front part of the cabin. In doing so, he remembers the relative location of hands and their position relative to the orienting instrument. Then, closing his eyes, he has to count off 20 seconds after which he

opens his eyes and gauges the position of the hands. The result is noted with arrows in the logbook in case they deviated from the original position. The extent of the deviation is given in centimeters.

(2) With eyes open and then closed, the astronaut draws with a pencil a spiral containing 3 loops, a 5-pointed star in an unbroken line, 2 vertical and 2 horizontal lines. The hands, one of which holds the logbook, the other the pencil, are outstretched.

The rationale of these tests is that in weightlessness, vestibular-postural mechanisms are of importance in forming a motor habit. If impaired, they may affect sensorimotor coordination.

A series of experiments simulating space flight with performance of the above-mentioned tests was carried out before the flights in a model of the Vostok in order to be able to evaluate the results of the tests taken during the flights themselves. There were also some tests in the laboratory. The results were carefully written up and then compared with the notations in the logbooks of Vostok 3 and Vostok 4.

The comparatively simple first test was performed with approximately the same accuracy on the ground and in weightlessness. In any case, even the most critical comparison of the reports of the laboratory experiments and the logbooks reveals no basis for regarding weightlessness as a factor with negative effect on the static tension of the human musculature.

Analysis of the results of the second test taken on the ground and in space showed that all the subjects did better with their right hand than with their left, which is understandable since they were all right-handed persons. These differences, to be sure, were not the same for the various subjects. In some of them, the results of drawing the spiral and star and, to a smaller degree, the parallel and vertical lines, were sharply different when vision was excluded. In others, the results of the test taken with both the right and the left hands were more or less the same.

Also noteworthy is the fact that execution of the second task varied in quality from subject to subject. Some drew the figures very well, while others did so poorly, especially the spiral and star. The differences noted when the second test was taken with open and closed eyes were likewise quite pronounced in the different individuals, varying from poor to very good.

A comparison of the results of the first and second tests taken on the ground showed that weightlessness did not impair sensorimotor coordination. The figures drawn in weightlessness were actually better than those drawn on the ground, an observation agreeing with the astronauts' reports. "All the tests," P. R. Popovich said, "were better in weightlessness than on the ground. I drew very well. My hand was very

steady. I pencilled straight lines, even with my left hand. The right hand did exceptionally well."

A comparison of the results of the second test taken by the astronauts in weightlessness with those of the subjects who had the best performance on the ground clearly showed that the quality of the astronauts' drawings was no worse, indeed it was even better than that produced by the subjects on the ground. Thus, with respect to both the background data obtained on the astronauts in simulated space flight and the data on the best subjects among those invited to participate in the investigation, the results of the second test taken in the course of space flight indicate that prolonged dynamic weightlessness has no appreciable effect on sensorimotor coordination. This is also borne out by the observations of A. G. Nikolayev and P. R. Popovich. According to Popovich: "I worked with eyes closed with all the switches. I tried to work in the darkness. When you go into the shadows, you cover the illuminators. Even when you strike with your hand wherever you wish. I am lying down, but I know that the radio switches are here. I stretch out my hand and turn it on."

"It is quite possible to work with equipment in weightlessness," Nikolayev declared. "Writing and drawing in weightlessness are just the same as on the ground. All movements are coordinated."

Nor was any impairment of coordination in space flight noted in astronaut G. S. Titov who, as we know, experienced some vestibular-autonomic reactions.

Thus, the special tests taken to reveal sensorimotor coordination, the handling of spacecraft equipment, and the handwriting of the astronauts show that weightlessness has little effect on sensorimotor coordination. However, it should be kept in mind that the facts recorded in space flight did not relate to motor coordination at the very beginning of weightlessness. At any rate, we were unable to discover any significance that it may have had as a novelty factor. There is, however, some reason to believe that the influence of novelty resulting from a modification of gravity, that is to say, from reducing it to zero, is a fact that warrants our attention. Note, for example, Popovich's statement that the novel sensation of weightlessness causes strain in working. However, it was impossible to determine the duration or intensity of this strain or its effect on efficiency during the flights of Vostok 3 and Vostok 4.

RADIATION REACTIONS AND CHEMICAL PROTECTION OF ANIMALS EXPOSED TO HIGH-ENERGY PROTONS

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The purpose of our investigations was to determine the immediate and long-range effects on animals of exposure to 660 mev of protons generated on a OIYaI synchrocyclotron, the relative biological effectiveness (RBE) of which has been little studied.

It has been reported that the RBE of protons, as compared with X-rays, judging by such indexes as mouse and rat survival rates and changes in peripheral blood, was 0.5-0.6 (1, 4, 5). The mutagenic effect of protons, as determined in an investigation of the rate of recessive lethals in the sex chromosome of Drosophila, was close to that observed after exposure to X- and γ-rays (4, 6). It has also been demonstrated that mice can be chemically protected against the action of protons, and the value of the oxygen effect in so doing was made clear. Finally, protons have been found to exert a high blastomutagenic effect, with tumors discovered in 50 percent of the rats that died or were sacrificed.

This report presents the data obtained in the following analysis of the biological effect of protons and of chemical protection therefrom in comparative experiments involving the use of the γ-rays of CO^{60}. The method was described in detail in an earlier report (4). The experimental animals were stockbred mice and rats and mice of the BALB and C-57Bl strains. All the figures were statistically processed.

Hematological and Cytological Analysis of the Effect of Protons and γ-Rays on Hematopoiesis

In comparative experiments on mice receiving whole-body radiation of 500 rad, the degree of injury to the hematopoietic organs was less pronounced after protons than after γ-rays. The depression of hematopoiesis in the bone marrow and spleen of animals irradiated with protons was shallower and shorter-lasting, and regeneration set in earlier.

This difference was particularly evident in the dynamics of the characteristics of the peripheral red blood. γ-rays caused deep and prolonged anemia with a drop in the erythrocyte count to 44 percent of the original level and a decrease in the hemoglobin concentration to 51 percent, whereas protons caused only a slight and temporary decrease in these characteristics.

Similar differences were noted in the leucocytes, especially the neutrophils. After irradiation with protons, lymphopenia was fairly deep, but less pronounced, although damage to the lymphoid tissue of the spleen (from specimens and impressions) was substantial.

The results confirm the view that the state of the peripheral blood does not reflect the true depth of radiation injury to hematopoiesis. These results can be used in radiobiology only as data for general orientation purposes.

The experiments on white mice were concerned with early destructive changes in bone marrow (starting within a few hours of exposure), dynamics of mitosis and cell kinetics with chromosomal injuries. Protons caused a typical radiation degeneration of bone-marrow cells (most pronounced after 3 hours), inhibition of mitotic activity the first 5-12 hours, and injuries to the chromosomal apparatus (most pronounced after 12 hours, judging by the number of aberrant cells). Judging by all these criteria, particularly the number of degenerating and aberrant cells, there was a strict dose relationship in the 250-1000 rad range. The high sensitivity and strict dose relationship of the aforementioned changes in bone-marrow cells make it possible to use them for the purpose of biological dosimetry.

In all three characteristics, the effect of γ-rays was more pronounced; the RBE of the protons = 0.5-0.7.

Preliminary injection of the mice with radioprotectors--S, β-aminoethylisothiuronium (AET), mercaptoethylamine (MEA), and 5-methoxytryptamine (5-MOT)--reduced the number of degenerating and aberrant bone-marrow cells in proportion to the effect of these compounds on the survival rate. A combination of MEA and 5-MOT was the most effective. It enabled 50 percent of the animals irradiated with a dose of 1900 rad to survive. We can thus safely assume that the mechanism of chemical protection consists chiefly in a weakening of the primary radiation injury and resultant stimulation of the processes of regeneration. With fractional irradiation, the protective effect of these drugs was sharply decreased or lost.

Effect of Protons on the Reproductive Function

In experiments on male mice of the BABL strain irradiated with 500 and 700 rad, reversible changes were noted in the weight of the testes due to death and subsequent restoration of the germ cells. Histological analysis of speciments using Vogt and Kouning's method revealed evidence of the typical sterilizing effect of protons that has been described in detail for other kinds of radiation. However, the biological effect of the protons was less marked than that of the γ-rays (OBE = 0.6-0.7) and it was strictly related to the dose.

The use of a variety of protectors did not prevent the sterilizing effect of the protons, but it did help to reduce the loss of weight of the testes and shorten the period of sterility.

The reproductive function was almost completely restored (disregarding genetic aftereffects) within 4-7 months of exposure to 1300-1600 rad of protons in white mice protected with AET, MEA, 5-MOT, or cystamine. The first generation of mice (290 animals) produced by crossing protected males with intact females developed with no apparent somatic injuries.

Analysis of Somatic Mutations Caused by Proton Irradiation

Using as a model the regenerating liver of white rats exposed to single whole-body irradiation with 150 rad of protons or γ-rays, we studied the resultant chromosomal injuries in the form of bridges and acentric fragments appearing in dividing liver cells. Liver regeneration was brought about by removing the large left and anterior right lobes of the organ. The operation was performed 24 hours after irradiation, and 30 hours after hepatectomy (during the first wave of increased mitotic activity) the animals were sacrificed and specimens prepared.

The control animals were found to have 6.9 percent aberrant cells, but after exposure to the protons and γ-rays - 20 and 29 percent, respectively. Thus, judging by the number of latent injuries to the chromosomal apparatus of the somatic cells, the protons were less effective (RBE ≈ 0.7).

Effect of Protons on Blood Protein Fractions

The method of paper electrophoresis was used to investigate protein fractions in white rats 1, 3, 6, 10, 20 and 30 days after whole-body irradiation with 500, 800, 1000 and 1400 rad of protons.

The changes in content of the protein fractions were most pronounced during the first 10 days. The maximum deviations occurred on the 1st, 6th and 10th days, with a tendency toward normalization on the 3rd and after the 20th day. The degree of deviation in content of the individual fractions from the control values increased with the radiation dose. The most characteristic changes--marked decrease in albumins and γ-globulins with increase in the other globulin fractions--took place the first 10 days after irradiation with doses of 800-1000 rad. Since the protein fractions were not completely restored by the 30th day of observation, protein metabolism was still impaired.

Long-Range Effects of Proton Irradiation

Further information was obtained on the high blastomutagenic effect of protons. Of 85 rats examined, 39 were found to have tumors in different sites and in 25 of these animals there were multiple tumors.

Experiments on stockbred white mice showed that although chemical agents increased the animals' radioresistance, they did not prevent the subsequent development of neoplasms. Of 65 animals that died quite some time after irradiation with 1300-1500 rad of protons (preceded by the injection of drugs), 14 developed leukemia and 4 had a sarcoma.

The results of our investigations provide new information on the biological effect of high-energy protons that is useful for both theoretical and practical purposes.

Translated for the National Aeronautics and Space Administration
by John F. Holman and Co. Inc.

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