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FINAL REPORT

Summer Institute in Space Biology

1968

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FINAL REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Research Grant NSR 05-007-089

Summer Institute in Space Biology

Space Biology Laboratory

University of California, Los Angeles

April 1, 1968 to November 30, 1968

Dr. J. D. French

Dr. W. R. Adey

Brain Research Institute

University of California, Los Angeles

November 30, 1968

SUMMER INSTITUTE IN SPACE BIOLOGY

FINAL REPORT

NSR 05-007-089

1968

The Space Biology Laboratory conducted its third Summer Institute in Space Biology this year. This five week program of lectures, discussions and field trips was for 30 junior and senior undergraduate students selected on a national basis from applicants with backgrounds in the life and physical sciences. The Institute is a recognition of the urgent need for highly skilled investigators in the many areas that lie within the realm of space science, and is an effort to interest young people in the prospect of a research career in one of the fascinating and significant areas. The course was also designed to give the students a broad and specific background in pertinent problems of mammalian physiology.

The students were selected on the basis of a letter of application, scholarship, and a letter of recommendation from a faculty member of their college. They were housed in the UCLA dormitories and given $80.00 a week to defray the cost of room and board and incidentals.

The Institute included lectures by teaching and research faculty drawn from the University of Southern California and Harbor General Hospital, as well as from a number of departments in the UCLA School of Medicine, and the Life Sciences Division and Biosatellite group at NASA Ames Research Center.

The curriculum provided a brief survey of physiological functions liable to modification in the space environment, including effects of weightlessness on cardiovascular and renal reflexes and on body fluid distribution; the effects of weightlessness and confinement on metabolic functions, with particular reference to skeletal muscular disturbances; and modifications of characteristic cyclic mechanisms in sleep, body

temperature control and endocrine functions. Central nervous functions were also discussed in relation to the stresses of acceleration and vibration, the effects of weightlessness on visual and vestibular components of motor performance, and the possible effects of the space environment on psychic functions. The special problems of experimental investigation in the space environment were considered in recoverable and nonrecoverable experiments, and included discussion of command and control programming, data acquisition and recording systems, telemetry and equipment reliability, and how these are related to the physiological problems being studied. Computational analysis of space flight records and telemetry data and the basic processes of analog-to-digital conversion, major computational methods, and display techniques were demonstrated. Ames Research Center provided material on exobiology and consideration of the origins of life, methods of detection of living systems, adaptation of organisms to exotic environments, and problems of technology including bioinstrumentation developments, space suit technology, and problems of human performance during prolonged space missions.

Trips to several research facilities gave students a first-hand experience with the topics covered in lectures. They were taken to Douglas Missile and Space Systems Division, where a visit to the Space Cabin Simulator and a review of the 60 day test in the simulator was the highlight of the tour. Dr. John P. Meehan, professor of physiology at the University of Southern California, guided the group through the centrifuge and environmental laboratories there. The students participated in experiments at USC on physiological monitoring of the cardiovascular system, the effects of an increased gravitational load on the cardiovascular system, and modern telemetry methods. These experiments, and the seminar afterwards in which the students discussed the results, were the highlights of the program. Eight days were spent at NASA Ames Research Center in San Jose where the students were exposed

to the research projects in progress at NASA's life science research center. While at Moffitt Field, a trip to Sealab III at Hunter's Point Naval Shipyard was arranged with the cooperation of the Navy Deep Submergence Project. This was particularly timely in that it identified the similarity of environmental problems facing those who would explore "inner" space with that of outer space penetration. The course concluded with a trip to the Jet Propulsion Laboratory where the space projects in progress and the Mission Control Area of the Space-Flight Operations Facility were visited.

An assignment was given in the third week of the institute to design a primate experiment for an orbiting space flight which would provide information on vestibular function. The class was divided into three groups, each of which contributed its unique proposal; a copy of each is included in this report. It should be noted that time did not permit editorial revisions of the reports; consequently, they should be regarded for their scientific validity and feasibility, rather than their editorial faults.

Details on the participating students, faculty, curriculum, syllabus, and the special reports are attached.

The success of the Institute can best be seen in the profound impression the program made on the students in ways likely to be lasting, and thus important to their future careers. A fourth such Institute is being planned for the summer of 1969.

UCLA - USC

FACULTY FOR SUMMER INSTITUTE IN SPACE BIOLOGY

JUNE 24 - JULY 26, 1968

DR. W. ROSS ADEY - Director, Space Biology Laboratory

DR. ABRAHAM COCKETT - Chief of Urology Service, L.A. County Harbor General Hospital

MR. PIERRE HAHN - Director, Biosatellite Project

DR. JOHN HANLEY - Assistant Professor in Residence; Assistant Research Psychiatrist

DR. JAMES HENRY - Professor, Department of Physiology, USC

DR. JAMES HAYWARD - Assistant Professor of Anatomy

DR. GUNNAR HEUSER - M.D., Assistant Research Anatomist and Assistant Professor of Medicine in Residence

MR. RAYMOND KADO - Associate in Anatomy, Specialist

DR. JOHN P. MEEHAN - Professor, Department of Physiology, USC

DR. AMOS NORMAN - Professor of Radiology

DR. JEAN LOUIS RIEHL - Assistant Professor of Medicine

DR. DONALD O. WALTER - Associate Professor of Physiology in Residence; Associate Research Anatomist.

DR. WALLACE WINTERS - Associate Professor of Pharmacology in Residence

AMES RESEARCH CENTER

FACULTY FOR SUMMER INSTITUTE IN SPACE BIOLOGY

JUNE 24 - JULY 26, 1968

DR. E. ANDERSON - Research Scientist

DR. JOHN BILLINGHAM - Chief, Biotechnology

DR. P. CALLAHAN - Research Scientist

DR. J. CHANG - Research Scientist

DR. C. CONLEY - Research Scientist

MR. J. FLORES - Chemist

DR. R. GRINDLAND - Research Scientist

DR. R. HAINES - Research Scientist

DR. J. HAYES - Research Scientist

DR. E. HUFF - Research Scientist

DR. R. JOHNSON - Research Scientist

DR. HAROLD P. KLEIN - Assistant Director for Life Sciences

DR. K. KVENVOLDEN - Research Scientist

DR. H. LEON - Research Scientist

DR. J. MALONEY - Research Scientist

DR. A. MANDEL - Cheif, Environmental Control Research Branch

DR. J. McDONALD - Research Scientist

DR. J. MIQUEL - Research Scientist

DR. E. OGDEN - Chief, Environmental Biology Division

DR. J. OYAMA - Chief, Physiology Branch

DR. R. PATTON - Chief, Human Performance Branch

DR. M. SADOFF - Cheif, Man-Machine Integration Branch

DR. H. SANDLER - Research Scientist

DR. J. SHAPIRA - Research Scientist

DR. D. SMITH - Research Scientist

MR. J. STEWART - Research Scientist

DR. J. VERNIKOS-DANELLIS - Research Scientist

MR. H. VYKUKAL - Research Scientist

MR. T. WEMPE - Research Scientist

MR. F. WOELLER - Chemist

DR. CHARLES WINGET - Research Scientist

DR. T. WYDEVEN - Research Scientist

NASA-UCLA 1968 SUMMER INSTITUTE IN SPACE BIOLOGY

NAME	ADDRESS	SCHOOL	MAJOR
Aldrich, Frederick	917 Thirtieth St. Des Moines, Iowa	Drake University	Mathematics
Anglin, Larry	P.O. Box 1353 Houma, Louisiana	Nicholls St. College	Pre-medical
Baker, Carolyn	1421 Grand Blvd. Cedar Falls, Iowa	Iowa State	Zoology
Benz, Christopher	4300 Hayvenhurst Ave. Encino, California	UCLA	Chemistry
Boger, Robert	1675 Glenhardy Rd. Wayne, Pennsylvania	Amherst College	Biophysics
Buckingham, Barbara-Jo	1220 Tollgate Dr. Oxford, Ohio	Miami University	Zoology
Camill, Phillip	228 Koster Lexington, Kentucky	University of Kentucky	Engineering
Churchill, Lynn	5308 BraeBurn Bellaire, Texas	University of Houston	Biology
Dalessandri, Kathie	1610 Margarita St. Ypsilanti, Michigan	Michigan Tech. University	Biology
Detko, George	4215 Huntington Rd. Huntsville, Alabama	Alabama College	Pre-medical
Frank, Kenneth	3102 Hawthorne St. Washington, D.C.	Amherst College	Biology
Firestone, Alan	639 Colonial Drive Youngstown, Ohio	Oberlin College	Biology
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Kirkland, Nathaniel	4415 Monument Ave. Richmond, Virginia	Southwest at Memphis	Biology
Lebowitz, Stephen	150 E. 182 St. Bronx, New York	City College of New York	Biology
Lewiecki, E. Michael	13 Estgate Lane Hingham, Mass.	Amherst College	Biology
Lowery, Thomas	352 Clifton Ave. Lexington, Kentucky	University of Kentucky	Engineering

Maroglio, Louis	209 N. Nanticoke Endicott, New York	Syracuse University	Engineering
Miller, John	6009 Ashland Drive Nashville, Tennessee	Memphis State University	Pre-medical
Novinger, Ann Marie	3944 Community La Crescenta, California	Los Angeles State College	Biology
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Rapp, William	410 N. Cherry St. Kenton, Ohio	University of Cincinnati	Engineering
Rothschild, Kenneth	46 Bucknell Dr. Hazlet, New Jersey	Rensselaer Polytechnic	Physics
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Schwartz, Richard	7720 Hampton Ave. Los Angeles, Calif.	UCLA	Chemistry
Schulof, Richard	453 Mayfair Drive Mill Basin, Brooklyn New York	Cornell University	Biochemistry
Tarquinio, Thom	1744 Kaiser Dr. Reynoldsburg, Ohio	Ohio State University	Microbiology
Vasil, Peter	4734 Monroe St. Gary, Indiana	Purdue University	Biology
Vinitsky, Alan	4418 Hahan Road Silver Spring, Maryland	University of Maryland	Zoology
Yamaguchi, Kent	2279 N. Brawley Fresno, California	Fresno State College	Chemistry

UCLA 1968 Summer Institute in Space Biology

Sponsored by the National Aeronautics and Space Administration

Brain Research Institute
University of California, Los Angeles
June 24 - July 26, 1968

UCLA Actitity Schedule

Lecture Hall 53-105
Health Sciences Center

DATE	DAY	LECTURER - ACTIVITY
June 24	Mon	Dr. John French - Welcome Dr. J. L. Riehl - Introduction Dr. W. R. Adey - Biological Communication
June 25	Tues	Dr. J. Henry - Environmental Adaptation and Homeostasis (Metabolic Functions)
June 26	Wed	Dr. J. Meehan - Cardiovascular Control Mechanisms
June 27	Thurs	Dr. J. L. Reihl, Dr. W. R. Adey, Dr. W. Winters } Functions of the Central Nervous System
June 28	Fri	9-12 - Special Interest groups 1-4:30 - Dr. Don Walter - Computer Methods
July 1	Mon	Dr. W. R. Adey, Dr. W. Winters } Functions of the Central Nervous System
July 2	Tues	9-12 - Dr. J. Hayward - Cyclic Function in Mammalian Organisms 1-4:30 - Dr. G. Heuser - Neuroendocrine Functions
July 3	Wed	Field Trip
July 4	Thurs	HOLIDAY
July 5	Fri	9-12 - Special Interest groups 1-4:30 - Dr. Don Walter - Data Processing
July 8 - July 16		Ames Research Center (See section labeled ARC)
July 17	Wed	Dr. Don Walter, Mr. Pierre Hahn, Dr. Winget (Ames) } Biosatellite Project
July 18	Thurs	Mr. R. T. Kado - Data Acquisition and Recording
July 19	Fri	9-12 - Special Interest groups 1-4:30 - Dr. Don Walter - Data Processing
July 20	Sat	Field Trip

DATE	DAY	LECTURE - ACTIVITY
July 22	Mon	9-12 - Dr. W. R. Adey - Telemetry Requirements 1-4:30 - Dr. A. Norman - Radiation Physics
July 23	Tues	9-12 - Dr. Don Walter - Data Analysis 1-4:30 - Dr. A. Norman - Radiation Biology
July 24	Wed	9-12 - Mr. R. T. Kado - Equipment Reliability 1-4:30 - Dr. A. T. Cockett - Body Fluid Distribution and Renal Functions
July 25	Thurs	Field Trip
July 26	Fri	9-12 - Dr. J. Hanley - Psychological Problems of Space Flight 1-4:30 - Dr. W. R. Adey - US and Soviet Manned Space Flight Programs

Cardiovascular Control Mechanisms

Dr. John Meehan

Physiologic Structure of the Cardiovascular System.

Body is composed of about 60% water. This fluid is distributed laregly within the cells, intracellular water, and between the cells, extracellular water. A small percentage is in the cardiovascular system.

Body composition:	Intracellular water	- 40%
	Extracellular water	- 15%
	Blood plasma	- 5%
	Solids	- 40%

The soft tissues of the body are supported by an endoskeleton. Because of this arrangement, all of the soft tissues of the body, with the exception of the brain, are readily affected by accelerations. We are concerned here with the effects of acceleration on the cardiovascular system. This will require consideration of the vascular system itself and all of the mechanisms that contrd. its function. Also, we must give attention to the mechanisms that play a role in determining the relative sizes of the extracellular fluid and vascular compartments. First, we will examine the architecture of the cardiovascular system and relate the structure to the function of the various parts of this system. Second, we will consider control mechanisms, both humoral and nervous. After this, then, we will proceed into discussions of the affects of acceleration on this system.

General Structure and Function of the Cardiovascular System

I. Heart:

A muscular four chambered affair usually divided into the right heart and the left heart for purposes of discussion. The right heart receives the blood from the systemic circulation and pumps it on to the lungs. The left heart receives blood from the lungs and pumps it on into the systemic circulation.

a. Contrast muscular development of the two sides of the heart.

b. Note reservoir function of the atria.

II. Systemic arterial system:

a. The blood distributing system - like the water mains of a city

b. A relatively high pressure system

1. Pulsatile pressure

2. Mean pressure

3. Pressure is a function of blood flow and vascular resistance

III. Arterioles:

a. The resistance vessels of the circulation

b. Function as stopcocks to control blood flow through tissues.

c. Can be affected by the autonomic nervous system, hormones and locally produced tissue metabolites.

IV. Capillaries:

a. The vascular structure involved in the supply of necessary nutrients to all of the tissue cells of the body.

b. The "Starling mechanism"

c. The lymphatics

V. Veins:

a. The collecting and storage vessels

b. Structure very different from arteries---much more distensible

VI. Blood volume:

a. Controlled to meet the needs of the vascular system for blood.

1. Requirements in exercise

2. Requirements for inactivity and bed rest

3. Requirements for changes in posture

Cardiovascular Control Mechanisms

I. Mechanisms responding to changes of pressure within the arterial system

a. Carotid sinus

b. Aortic arch

II. Mechanisms responding to changes of filling of the vascular system

a. Atrial sensory mechanisms

III. Effector mechanisms

a. Neural

b. Humoral

Effects of Gravity on the Cardiovascular System--Protection Against Changes in the Gravitational Field.

I. Adaptations to and faulty adaptations to gravity:

   a. The problem of the giraffe

   b. The problem of the human

II. Acceleration terminology

III. Methods of studying the physiology of acceleration:

   a. Centrifuges

   b. Rocket sleds

   c. Vibration and shaking devices

IV. Physiologic responses to acceleration

   a. Positive acceleration

   b. Transverse acceleration

V. Protective measures

   a. Pressure suits

   b. Seat position

VI. Weightlessness

   Effects on blood volume distribution

Nervous System

Dr. W. Ross Adey
Dr. Wallace Winters

The mammalian nervous system has achieved a level of evolutionary development without parallel in terrestrial forms. It has insured for man his unique place among mammals, and, at the same time, remains one of the most highly vulnerable body systems in hazards of aerospace flight. Moveover, the difficulties and subtleties of directly monitoring its functional state without interfering with required aspects of human performance have until recently minimized available knowledge.

Evolutionary Changes

We may briefly consider evolutionary changes that characterize the mammalian brain, and ways in which these developments relate to mechanisms of altering and arousal, the focusing of attention in orienting behavior, and the discriminative learning. Consideration of these higher nervous functions requires discussion of cortico-subcortical interrelations, and of sensory integrative processes occurring in subcortical structures that may be modified in the space environment.

The mammalian brain shows a preponderant growth in two regions. The cerebellum, covering the rear portion of the brainstem, enlarges progressively at three stages in evolution. Appearing initially in fish as an esentially vestibular organ, concerned with balance mechanisms, its size is substantially incremented in the reptilia with adoption of a land-living existence, and the accompanying development of pathways from limbs through the spinal cord. At this stage, it takes on the functions of integrating information from vestibular organs with proprioceptive impulses from muscles and joints in coordinated walking movements. The largest increment in its size relates to the massive growth of the cerebral hemisphere in the mammal. This huge cerebral growth is a manifestation of (1) development of sensory areas in the cerebral cortex for body sensations, and for sight and hearing, and (2) development of motor centers that control body movements and are substantially influenced by heavy reciprocal connections with cerebral hemispheres.

Cerebral System Organization

The great enlargement of the cerebral hemispheres, particularly in the primate produces lobes or swellings, named after skull bones under which they lie. Two of these lobes, the frontal and temporal, are especially involved in organized behavioral patterns. Frontal lobe tissue appears essential in complex social interactions, and in certain aspects of recent memory. Temporal lobe tissue is much more profoundly concerned in perceptual and learning processes, and its removal in man causes profound disabilities, characterized by Buey and Kbiver, who first described these effects in 1939, as "psychic blindness". These effects arise from disruption of paths that ascend and descend between temporal lobe tissue and central regions of the brainstem, the so-called "reticular formation".

Functions of the Reticular Formation

It is at the level of the reticular formation that the intrinsic processes associated with sleep and wakefulness occur. Again, these reticular centers send powerful projections to cerebral cortex, and receive back centrifugal impulses. Consciousness as a physiological process cannot be conceived as arising intrinsically in the reticular formation, but as residing in the complex inter-play between it and cortical zones.

Very importantly, the reticular formation is also activated by many sensory inflows, somatic, auditory, visual, vestibular and even olfactory. Modification of these inflows, and possible changes in accompanying states of sleep and wakefulness, in focused attention, and in coordination of hands and eyes, for example, may arise in states of weightlessness. These may involve subtle changes of mood, described as "euphoria", and commonly encountered by divers as "rapture of the deep".

Electrophysiological Correlates of Sleep and Wakefulness and Focused Attention

As recorded on the scalp in man and animals, characteristic electrical wave patterns (EEG) may be observed relating to states of sleep and wakefulness. These will be described in detail. It is possible to recognize in many awake records states ranging from psychological stress to boredom with a repetitive task. In sleep records, patterns shift with varying depths of sleep, and the dream state can be readily recognized.

Much additional information can be obtained from recording leads implanted in deep cerebral nuclei. This can be done in many animal species and even in man if great care is taken, and if the placements are needed for diagnostic or therapeutic purposes. It is possible to relate simulatneous activity in surface and deep structures to obtain a finer picture of the state of the brain than is possible from surface records only. The structures most sensitive to changing states of alertness are the midbrain reticular formation, and the amygdala and hippocampus of the temporal lobe. EEG activity in these structures occurs in patterns that are as characteristic as signatures, particularly in lower mammals, such as the cat and rabbit. Amygdala records show characteristic 35-45/sec waves in states of hunger, anger, sexual arousal and other states of emotional pertubation. Hippocampal wave patterns are much slower, with dominant frequencies at 4 to 7 cycles per second, and sensitively related in bursts at 4-5 cycles per second to orienting behavior, and at 6 cycles per second to discriminative performances. Recognition of fine patterns in these waves requires computer analysis as described elsewhere in this syllabus.

Drowsiness is characterized by bursts of increasingly synchronous waves at low frequencies (3 to 5 cycles per second) in cortical and many subcortical areas. This increased regularity characterizes sleep states. Deep sleep shows high amplitude waves at 1-2 cycles per second over the entire cortex. Dream sleep, on the other hand, shows a fast, low amplitude record resembling the awake state (but distinguishable by the computer), accompanied by fast eye movements.

Changes During Simulated Booster Accelerations and Vibration

Transverse accelerations up to 10G increase the energy in all parts of the EEG spectrum. Longitudinal accelerations driving blood out of the head deplete the cerebral circulation and may produce a "blackout". This occurs with an acceleration of 5G sustained for 30 to 50 seconds, and at similar acceleration levels in man and in quadripedal animals, such as the cat and goat.

EEG changes with approaching unconsciousness vary with the G-levels. If these go rapidly beyond 5G, cerebral circulation may be abruptly terminated, with rapid flattening of the EEG record. If the acceleration reaches 5-6G more slowly, there may be bursts of seizure discharges, particularly in structures of the temporal lobe, as circulation to the brain is slowly arrested. Recovery from such a "blackout" episode is through periods of abnormal, high amplitude slow waves, accompanied by disoriented behavior.

Vibration of the whole body in the monkey over a spectrum from 5 to 40 cycles per second produces "driving" in the EEG, at vibration frequencies from 10 to 15 cycles per second. During this "driving" discriminative performance may be slowed, and errors increased. Great care is necessary to eliminate electromechanical artifacts in this type of EEG recording, and computer analysis of these EEG records indicates that the "driving" is very probably a physiological phenomenon, initiated by powerful afferent stimuli in body tissues.

Functions of the Central Nervous System in Space

Dr. Jean Riehl

I. Functions of "man" in space is in fact the basic question

Arguments: Payload - (life support system) vs. CNS of man with capacity for decisions, judgement, observations. Also man's basic drive and desire for adventure and exploration.

II. Basic anatomy, histology and physiology of the CNS of primates.

A. Basic unit: the neuron

1. Extremely large in number

2. Component parts

a. Nucleus

b. Nucleolus

c. Membrane

d. Appendages

B. Accessory and supporting structures

1. Astrocytes (metabolic support)

2. Oligo (myelin deposition)

3. Microglia (phagocytosis)

4. Synapses

C. Function of neurons -- communications and control; astroglia may play role also.

The rest of the body could be thought of as a "life support system" for the CNS of man (or animal).

The way in which neurons and their appendages transfer information is not absolutley known. It is possible that phenomena akin to electrical signals are involved.

Electrical activity is common to all living matter (and inorganic)

D. Basic structure of matter

Concept of potential differences across membranes. (electrolytic gradients Na^+, K^+, Cl^-)

E. Properties of membranes (Eccles, Huxley, Hodgkin)

F. Characteristic electrical phenomena from the nervous system:

1. Action potentials; EPSP; IPSP; miniature potentials

2. Graded ("Dendritic") potentials. (Ramdom Walk)

3. Synaptic potentials

a. Micro-recorder-single units

b. Macro-recorder-cell aggregates - EEG relationships between the two.

4. Nature of EEG data

G. Neuro-Transmitters

III. Organization of CNS in Primates (man)

A. Active tissue - Parenchyma

B. Supportive tissue - stroma

C. Can be divided into:

1. Telencephalon

2. Diencephalon

3. Mesencephalon

4. Myelencepahlon (medulla, pons, cerebellum)

5. Cord - 2 way traffic

a. Ascending tracts

b. Descending tracts

6. Sensory vs. motor

7. Mid brain

8. Thalamus (nuclei) Reticular Act. System

9. Cortex - "areas" visual, auditory, etc.

10. Limbic system - (attention focusing, amygdala, hippocampus and laying of memory)

B. Functional aspect

1. Pyramidal system

2. Extrapyramidal system

C. Sensory receptors - special senses:

1. Cochlear

2. Semi-circular canals

3. Retina

4. Non-specific (spindle mechanism)

D. Central Control of Sensory Receptors

1. Retina (Bonvallet, Hugelin, Dell)

2. Auditory (Hernandez-Peon, Worden)

E. Central integration of sensory (afferent) input (RAS)

Example: M L F integration of EOM - auditory (cochlear) vestibular and neck proprioception and vision

Position-sense, head, neck, body

Disruption of one: → Nystagmus, vertigo, disequilibrium

Effects of Acceleration and Weightlessness on:

Cochlea
Proprioceptors } --- "trichotomy"
VS - vision

<u>Electrical correlations of CNS activity</u>

- single unit

- vs envelope (extracellular) recording

- vs EEG (surface)

Gross changes in EEG correlate fairly well with - local lesion
- metabolic changes
- hyperexcitability state (epilepsy)

Intimate details of EEG patterns not yet fully understood

Basically EEG is a random (stochastic) process; a mixture of frequency-voltage complexes.

Many generator sources.

Alpha, beta, delta, theta waves can be recognized in the normal

Blocking reactions and changes with sleep are recognized also and common in the normal.

Intuitively, one would suspect that there are relationships between EEG and CNS states of consciousness, since at extremes of activity the correlation is good, however, in intermediate stages correlation is not so direct. Hence, a search for more precise and more exacting methods of analysis.

Originally: Visual, then frequency, analysis (Fourier theorem) (Grey - Walter)

Later on: Period analysis, auto and cross-correlation analysis, power spectrum, analog analysis.

Today: There seems to be a fair correlation between EEG and CNS states of consciousness. Prolonged or delayed response to arousal (or loss of arousal). Failure to continue on a task, wrong decisions, etc., deterioration in vigilance, performance, learning.

CONCLUSION: CNS of man (and primates) is an enormously complex structure with extreme redundancy of functions, the nature of which is still largely unknown, but which is (probably) knowable.

SUGGESTED READING

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WL 102 B739e 1960

Davson, H. A textbook of General Physiology QT 4 D312t 1964

Flaherty, B. Psychophysiological Aspects of Space Flight
WD 700 F597p 1961

Magoun, H. Handbook of Physiology, Neurophysiology Vol I
AT 4 H 187

CYCLIC FUNCTION IN MAMMALIAN ORGANISMS

Dr. James Hayward

I. General concepts of cercadian rhythms

A. Definition - ultradian, cercadian, infradian

B. Scope - biological clock, zeitgeber-entraining agent

C. Physiological Systems - ontogeny, neural substrate

D. Exogenous and endogenous components

II. Neuroendocrine organization

A. Neurosecretion - humoral vs. synaptic communication

B. Neurohypophysis and body water - posterior pituitary

C. Adenohypophysis and portal vessels - releasing factors-target glands

D. Hypothalamic connextions - neural organization

E. Feedback mechanisms - humoral, "receptor" neural elements

SUGGESTED READING

Aschoff, Jergen (Ed.) Circadian Clocks QH 527 A813c 1965

Bard, P. Medical Physiology QT 104 B235m 1961

Biological Clocks, Cold Spring Harbor Symposia on Quantitative Biology Vol. 25 QH 527 C673b 1960

Bunning, Erwin The Physiological Clock (Second Edition) QH 527 B862p 1964

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Martini, L. and Ganong, W. R. Eds. Neuroendocriniology Acad. Press, NY, 1967

Ruch, T. and Fulton, J. Medical Physiology and Biophysics QT 4 R827m 1960

Sollberger, A. Biological Rhythms Research QH 527 S688b 1965

Neuro-Endocrinology

Dr. Gunnar Heuser

Hypothalamic and pituitary function will be reviewed. The discussion will center on normal and abnormal function in man.

I. Behavior

The role of the hypothalamus and the pituitary gland (including its target glands) in the modulation of various aspects of behavior including motor activity will be discussed. It will be pointed out that disease in the hypothalamus or the pituitary gland does effect various perimeters of behavior.

II. Sleep Seizure Mechanisms

Sleep-waking cycles as they occur in physiological and pathological conditions will be discussed, particularly their relation to epileptic and endocrine events. It will be pointed out that disease in the hypothalamus may directly effect sleep wakefulness patterns, but also that a number of hormones if deficient or present in excess have a profound effect on these patterns.

III. Appetite

Clinical disorders of appetite run from the manifestations of an increased food intake (obesity) to almost complete starvation (anorexia nervosa). The role of the hypothalamus and the pituitary gland in appetite and actual food intake will be discussed.

IV. Water Metabolism

The regulation of thirst and conservation of water as it occurs under physiological and pathological conditions will be discussed with reference to the hypothalamo-pituitary system.

V. Temperature Regulation

Central and peripheral mechanisms responsible for heat loss and heat preservation will be reviewed.

The integration of endocrine function at the central nervous system level will then be reviewed.

1. The adrenals which secrete hydrocortisone and aldosterone
2. The ovaries which secrete estrogens and progestins
3. The testicles which secrete androgens
4. The thyroid which secretes thyroid hormone

Next, the role of the pituitary gland (hypophysis) in regulating the function of the above glands is discussed. In addition, it is pointed out that some pituitary hormones have effects on non-endocrine targets:

1. Growth hormone effects growth and metabolism
2. Prolactin is necessary for lactation
3. Antidiuretic hormone prevents loss of water from the body by keeping the urine "concentrated"

Finally, the control of all these endocrine systems by the hypothalamus (a part of the brain) is discussed.

Integration and feedback control of all neuroendocrine systems at the hypothalamic level is stressed with examples from typical situations in health and disease.

SUGGESTED READING

Williams, R. Textbook of Endocrinology, 1968.

DATA ACQUISITION AND RECORDING

R. T. Kado

Bioinstrumentation in the space environment is a more specialized art than its counterpart in the earth environment. The outline to follow structures the lectures which will attempt to provide an overview of this field. Specific problem areas will be discussed and examples will be given. It is hoped that this lecture may provide the listener with some ideas which may evolve into real solutions to the problems of bioinstrumentation.

I. Introduction

A. Why physiological monitoring?

1. Biological studies in the space environment essentially involve the response of the biological organism to the new environment. These responses are not the same as those obtained in diseased or pathological states but the methods used in monitoring have their origins in this branch of the biological sciences.

2. The biological organism may be considered as a system which responds in certain ways to variations in the input parameters.

   a. Atmosphere; pressure and gas content

   b. G forces; rates and orientation

   c. Radiation; at all energy levels

   d. Diet; food content and water

   e. Infection

   f. Sensory; visual, auditory, olfactory

   g. Proprioceptive; limbs, gut and torso

3. The biologic system is responding by attempting to maintain a normal life function and by having emotional experiences as well. These responses of the system are mainifested in some observable ways.

   a. Activity; general level of physical capability

   b. Respiration; rate and volume

   c. Metabolic; rate and basal levels

d. Cardiac; rate and volume

e. Vascular; circulation and tissue perfusion

f. Behavioral; perception, performance capability

B. Physiological and electrophysiological parameters

1. May be sensed as in electrophysiological parameters (biogenic potentials).

2. May be transduced as in physiological parameters (pressure and volume).

3. Almost without exception measurement process interferes to some degree with the organism.

4. Should be used in combination to be most useful in assessing physiological state.

C. Nature of the data signals

1. Almost always converted into a time dependent electrical signal.

2. In the frequency range from DC to 5000 Hz.

3. Having dynamic ranges as high as 100 to 1.

4. Very susceptible to artifactual disturbance.

II. The physiological useful parameters

A. Electrophysiological parameters. These are potentials of bioelectric origin.

1. From the eyes.

a. Electrooculogram (EOG)

(1) (Measures eye movement) origin in the dipole between cornea and retina (cornea +).

(2) Small amplitude 100 μV to 500 μV.

(3) Frequency range DC to rise times up to 1 msec.

(4) Square wave if recorded DC sawtooth if recorded AC.

b. Electroretinogram (ERG)

(1) DC recording directly from cornea.

(2) To study retinal responses to light, color, etc.

2. From the heart, the electrocardiogram (ECG)

a. Origin in heart tissue

b. Measureable over the upper body

(1) Right to left arms.

(2) Across thorax.

(3) Along sternum.

(4) Leg to arm.

c. Small amplitude 10 μV to 1 mV, depending on electrode location.

d. Frequency range 0.1 to 100 cps.

e. Repeating waveform with named components.

3. From the brain, the electroencephalogram (EEG).

a. Very small amplitudes 5 μV to 200-300 μV.

b. Low frequency basic waves 0.5 to 100 cps.

c. Complex overall waveform.

4. From the muscles, the electromyogram (EMG).

a. Origin in the motor neuron and associated muscle fibre.

b. Measureable within, or over, any muscle group (skeletal).

c. Amplitudes range from 25 to 5000 μV.

d. Frequency ranges 20 cps to over 1000 cps.

5. From the skin, the galvanic skin response (GSR), also the galvanic skin resistance.

a. Origin apparently in the skin in response to psycho-physiological changes.

b. Measureable as changes in:

(1) DC resistance.

(2) AC resistance.

(3) DC potential.

c. Measured on the skin of the hands, feet, forehead, best responses where sweat glands are most abundant.

d. Amplitudes vary from a few kilohms to hundreds of kilohms depending on placement and type of electrode.

e. Frequency range DC to 10 cycles/second.

f. Effects of changes in polarization with release of electrolytes in perspiration are not yet clearly defined.

6. From the viscera, the electrogastrogram (EGG).

7. Others may be obtained from implanted sensors or electrodes.

B. Transduced physiological parameters

1. Blood pressure, phasic and steady.

a. Directly by cannulation

b. Indirectly by auscultation.

c. Indirectly by plethysmographic methods, optical and electrical

2. Respiration volume and rate.

a. Gas flowmeter in air passage.

b. Transduced from the chest wall by mechanical transducer or impedance pneumograph.

(1) Measured by impressing high frequency AC across axillary leads (20 to 50 KC).

(2) Amplitude varies with circuitry need.

(3) Frequency range DC to 5 cps (DC component may be removed)

(4) This method does not always give a true indication of tidal volume.

3. Cardiac output

a. Impedance plethysmography.

(1) Origin in limbs ordigits, changes with blood pressure and volume changes.

(2) Measured between electrodes by high frequency AC (1 KC to 100 KC).

(3) Amplitude varies with circuitry.

(4) Frequency range DC to 20 cps, shows systolic pressure waves.

b. Ballistocardiography.

C. Useful physiological parameters requiring analysis instrumentation.

1. Respired gasses.

2. Urine volume and ion and catecholamine content.

III. Requirements for electrophysiological sensors and physiological transducers.

A. For use on human subjects, no subdermal implantation is possible.

1. Electrodes must be attached firmly to avoid artifacts, but must be easily removed.

2. Contacting jelly electrolytes must be non-irritating and provide good contact but must be easily removed.

3. Electrode polarization problems made DC recording very difficult.

B. For use with animal subjects, electrode implantation techniques have been developed.

1. Materials must be compatible with the parameter and non-irritating.

2. Lead exterorization should be as atraumatic as possible and free of infection.

3. Connection points must be placed so as to be inaccessible to the animal. This is a special problem with primates.

C. Transducers in general are not sufficiently well developed for use in the space environment.

1. Blood pressure measurements are best made by directly cannulating the vessel. A practical method is by ausculation (cuff and microphone) but is subject to artifacts from movement of the arm.

2. Respiration rate and depth may be measured indirectly.

a. Depth of respiration is estimated by plethysmography techniques or air way sensors.

(1) Plethymosgraphic techniques are not yet absolute volume measures.

(2) Air way sensors must be designed to have little or no dead space which may hold expired gasses to be re-inspired.

b. Rate is easily obtained from the depth transducer.

c. Gas analysis for metabolic rates is still another problem.

3. Temperature

a. Surface (skin) and depth (core).

b. The most common method today is to use the thermistor probe.

(1) Can be fabricated into almost any probe configuration.

(2) Simple principle of operation.

(3) Reliable and rugged.

4. Other transducers, ear oximetry, digital plethysmography and muscle tonicity are not yet adequately developed.

IV. Amplifiers and signal conditioners, with but one exception, are keeping up with the requirements of the spacecraft environment within the state of the art. In fact with the availability of solid state devices, there has never been a particular problem in making appropriate electronics. The one exception is a sufficiently stable DC amplifier which can amplify low millivolt DC signals without drifting. The chopper stabilized amplifier as they are currently used in the laboratory are not adequate for use in the space program.

The basic problem with Bioinstrumentation in the Biospace Technology still lies with the shortcomings of the sensors and transducers.

V. Noise and artifact problems are more acute in biological measurements because the signal amplitudes are low and because the usual noise and artifact sources have the same frequency ranges as the data.

A. Instrumental noise.

1. Thermal noise in amplifiers.

2. Sampling noise from data commutation.

3. Cable movement noise and other mechanically induced noise.

4. Electrode "popping" and changing half cell potentials.

B. Electrical noise.

1. Electromagnetic interference (EMI) from motors, solenoids, relays, radar, communications transmitters and switches.

2. Electrostatic noise from the same sources as above but coupled capcitively into high resistance events.

SUGGESTED READING

Milsum, J. H. Biological Control Systems Analysis

Venables, P. H. and Martin, I. A Manual of Psychophysiological Methods

Telemetry Requirements

Dr. W. Ross Adey

The use of radiotelemetry and ultrasonic telemetry in recent years has greatly expanded the scope of physiological recording in freely moving individuals, particularly in hazardous environments.

Radiotelemetry may be used over short distances, as in a cockpit or space capsule, or over hundreds of miles from a capsule to ground. Ultrasonic telemetry has been widely used in underwater transmission from man and aquatic mammals.

Basically, the physiological signal must produce a modulation of a radio signal. This can be done by amplitude or frequency modulation, or by changes in the amplitude, frequency or pulse-width of trains of pulses (pulse-code modulation, PCM).

The system used depends on the number of channels of physiological data to be transmitted. With a single channel, and a short transmission distance, frequency modulation of a small radio transmitter may be adequate. These systems are rarely successful for long periods, due to thermal and mechanical instability, and are unsuited to multichannel transmission, since oscillators frequently drift into the band pass of adjacent channels.

For these reasons, multi-channel transmission usually involves frequency modulation by the physiological signal of an inherently stable audio oscillator. This frequency modulated audio signal is then applied to a radio transmitter which may be amplitude modulated (FM-AM system) or frequency modulated (FM-FM system).

In recent years, missile telemetry systems have used digital transmission methods. The analog physiological signal is converted to digital form, samples in a sequential fashion with other physiological signals (commutation and multiplexing). Over long transmission distances such systems offer greater reliability, but require special encoding and decoding systems.

The power of the radio transmitter, and the antenna directional characteristics are determined by the path distance over which telemetry must occur. Extremely small powers are satisfactory over distances of a few feet (fractions of a microwatt) so that it may be possible to power such devices from the tissue signals themselves.

SPACE RADIATION BIOLOGY

Dr. Amos Norman

Figure I

Shows the incidence of leukemia in man versus the absorbed dose of radiation. It is typical of the data in radiation biology in showing the probability of a biological response (in science, probability is equated to frequency) as a function of the physical dose (one rad is equal to an energy deposition of 100 ergs per gram). The reason we can speak only of the probability of the biological response to a given dose of radiation can be traced to two factors: the nature of the physical universe is such that the interaction of radiation with matter can be described only in probability terms; the complexity of the living organism is so great that only a statistical description of its response to a given stimulus is feasible.

Figure II

Lists the radiation doses which will cause 10, 50, and 90 percent of the population to exhibit a number of unpleasant reactions varying from anorexia (loss of appetite) to death. Most of the effective doses shown lie in the range of 50 to 500 rads -- what is the potential source of such large amounts of radiation.

Figure III

Shows radiation doses for 14 solar-particle events -- the greatest radiation hazard -- behind various amounts of shielding.

Figure IV

Shows estimates of the maximum and minimum dose expected in space missions lasting from one week to four years. A comparison of the doses in Figures III and IV with the corresponding biological responses in Figures I and II shows clearly why we worry about solar flares during even short space missions.

One rad corresponds to a temperature rise in tissue of only about 2×10^{-6} degrees centigrade; thus to measure absorbed dose calorimetrically is very difficult. Instead, to make such measurements we ordinarily take advantage of two factors: firstly, the radiation hazard is due to ionizing radiation, that is, to radiations that create ions by stripping electrons from molecules; secondly, the currents resulting from the collection of the ions in gases (ion chambers) exposed to the ionizing radiations of interest can be measured easily. Therefore, the problem of measureing absorbed dose in tissue becomes one, in practice, of relating the total charge collected in a gas to the energy absorbed in tissue.

Figure V

The results of such measurements in proton beams are shown in Figure V together with the ionization chamber used. In the laboratory you will have the opportunity to calibrate typical ionization chambers and to observe the effect of shielding on radiation fields.

Various factors modify the biological response to radiation including, most importantly, the distribution of dose in the body and in time. The time dependence arises from the ability of cells and tissues to repair a portion of the radiation damage. There is good evidence that the irreversible damage to tissue is largely due to unrepaired or mis-repaired damage to the chromosomes. You will have the opportunity to study chromosome aberrations in irradiated cells, and to discuss the possible relationship of such aberrations to radiation-induced leukemia. The induction of leukemia will serve as a model for the roles of mutations and selection, the driving forces in evolution, in shaping the biological future of man.

SUGGESTED READING

Langham, W. H. (Ed.), Radiobiological Factors in Manned Space Flight. NAS-NRC, Washington, D.C., 1967 (Typical committee job -- sound but dull)

McKusich, V. A. Human Genetics. Prentice-Hall, Inc., 1964. (Excellent -- may scare you out of having children)

Assessment of Equipment Reliability

(Instrumentation for Research in Stressful Environments)

R. T. Kado

I. Reliability of Measurement Depends Heavily on the Reliability of the Entire System

- A. Special Sensors are Required for Active Environment
  - 1. Specialized electrodes
  - 2. Requirements for transducers
- B. Artifact Free Cabling and Connectors
- C. Ruggedization of Components
- D. Typical Requirement for Space Flight Equipment (NASA Specs)

II. Material and Methods Leading to High Reliability

- A. Considerations in Choosing Components
  - 1. Constructed to survive shock, vibraton and temperature variations
  - 2. Not influenced by ageing or corrosive environments
  - 3. Not likely to influence adversely, the properties of other components incorporated into the system
- B. Construction and Fabrication Techniques for High Reliability
  - 1. Provide adequate thermal properties
    - a. Especially for high power circuits
    - b. Heat sinking - preventing hot spots
    - c. Must be considered in encapsulation designs
  - 2. Mechanical shock absorption
    - a. Many components are low mass - low inertia however
    - b. Use of component support clamps
    - c. Solder vs. welded joints
    - d. Encapsulation materials and their relation to the application

C. Sensors for acquiring Physiological Data Stressful Environment

1. Electrodes. EKG, EEG, GSR, ZPG.

a. Requirements for stability of interface

b. Requirements for permanance of attachment

c. Electrolytes

2. Temperature sensors

3. Microphones

4. Implanted sensors

a. Electrodes, materials and methods

b. Transducers

(1) Pressure intra - and extra-vascular

(2) Temperature

(3) Flow

(4) Movement

D. Examples of Signal Conditioners for Acquisition of Data in Stressful Environments

1. SBL EEG System

2. USC B.P. Impedance pneumograph

3. Commercially available units

Body Fluid Distribution and Renal Function

Dr. A. T. Cockett

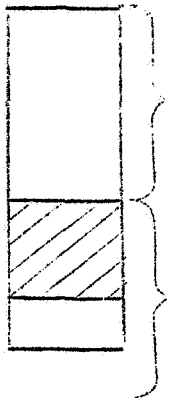
I. Distribution of Body Fluids

A. General Principles

1. 60% of body weight = H_2O

a. Distributed in ionic equilibrium related to cations Na^+ and K^+

2. Distribution of total body water



73% is intracellular

Intercellular→

27% is extracellular

Intravascular→

3. Maintenance of water balance

a. Intake = Output

b. Water is lost:

(1) Respiration-water vapor) = 1000 ml/day

(2) Sweat

(3) Urine - 1500 ml/day

(4) Abnormal conditions: e.g., vomiting, diarrhea

c. Intake

(1) Water

(2) Food

4. Environmental factors affect fluid distribution

a. Warm environment perspiration with evaporation

(1) Dehydration

b. Rise in body temperature, e.g. fever ($1^{\circ}F$) raises body metabolism by 7%

(1) Further dehydration

c. Limited intake - urination is cumbersome in a closed compartment or in a space capsule

B. Gravitational influences on Fluid distribution

1. Effects of increased gravity

a. Fluid distribution:

(1) Gravity vs. immersion in water

(2) Similarity of immersion experiments to zero gravity

b. Electrolyte readjustments

(1) Sodium and other electrolytes

c. Effects of posture and fluid shifts

(1) Upright vs. recumbant position and shift of sodium and water.

2. Weightlessness

a. Fluid distribution

b. Electrolyte readjustment

c. Orthostatic hypotension

3. Decalcification of Bones

a. Unsolved problem

b. Reasons for decalcification

c. How to reverse this tend

C. Renal Regulation of Fluids and Electrolytes

1. Normal Person - Urine

a. pH 5.5

b. Specific Gravity 1.023

c. No sugar, No protein; cellular debris are absent

2. Function of Kidney

a. Fluid regualtion - maintenance of acid-base balance

b. Excretion of toxic catabolic products

3. Some Details of Fluid Regulation - ADH

a. Antidiuretic hormonal system

b. Renin - angiotensin - aldosterone system

4. Some of details regarding acid base regulation

a. Na^+, K^+, H^+ and NH_3 exchange in nephron

5. Effects of Zero Gravity on Renal Blood Flow and Fluid Regulation by Kidney

a. Data from Manned Space Flight

II. Biomedical Problems During Manned Space Flight Related to Fluid and Electrolyte regulation

A. Dehydration

B. Closed Environment and Toxic Agents

C. Problem of Infection and Dehydration

D. Muscle Metabolism Deranged - and the Increased Possibility of Phosphatic Stones in Urine

1. Creatine excretion; Creatine clearance of phosphatic calculi (stones) in urinary tract

E. Bony Decalcification and Calculi in Urinary Tract

1. Prevention by Increased Hydration

2. Prevention by isometric exercises

3. Prevention of artificial gravity

SUGGESTED READING

Bourne, G. Medical and Biological Problems of Space Flight WD 750 B667m 1963

Brown, J. Physiology of Man in Space WD 750 B813p 1963

Henry, James P. Biomedical Aspects of Space Flight WD 750 H396b 1966

Psychiatric and Psychological Aspects of Space Flight

Dr. John Hanley

I. Scope and Limitations

The presentation will be limited to a discussion of mental and emotional factors which may influence performance, and no speculative psychoanalytic or other metaphysical descriptive explanations will be offered. Where possible, organic correlates, psychically active drugs, and disorders which are illustrative of the phenomena under consideration will be presented, as will data from simulated and in-flight reports. Through anecdotal material will be largely eschewed, relevant experiences from situations which model expected space conditions will be drawn on.

II. Assessment of the Mental State

An operational definition of psychiatry would include the diagnosis and treatment of mental disorders, and at the core of the psychiatric evaluation is the assessment of the mental state. Estimates of the individual's orientation to time, place, person, and situation; examination of mood, remote and recent memory functions, intellectual abilities and judgemental capacities allow certain broad conclusions to be drawn about overall mental function.

III. Symptoms of Aberrant Function and Disorders in Which They Occur

Since the stage at which a candidate is seriously considered for space flight crew virtually automatically rules out serious mental disorder, one may realistically challenge the relevance of the psychiatric aspects. It is, however, of the utmost importance to keep in mind that there are many situations and conditions in which there may be elicited certain responses which indicate aberrant function without in actuality implicating a specific mental disorder. Thus, a subject may experience hallucinations and delusions under conditions of extreme isolation or sleep deprivation, for example, and still not suffer from schizophrenia, an illness in which these symptoms are frequently found. It is therefore necessary to have some acquaintance with the common mental illness in order to be able to make where possible certain vital distinctions.

The cause or causes of the major mental illnesses which include schizophrenia, mania, depression, and the degenerative dementias exemplified by Pick's and Alzheimer's disease are wholly unknown but have impressive genetic, biochemical, and metabolic aspects and are at times mimicked exactly by endocrine disorders such as parathyroid disease. With the limitations of causal information in mind, one might consider for tutorial convenience schizophrenia as including disturbances in thought and affective apparatuses and mania and depression as disorders of mood. The dementias panoramically display malfunctions of thought, mood, orientation, and complex social behavior.

IV. Psychically Active Drugs

Certain compounds have reproduced in humans and experimental animals superficial resemblances to these illnesses or, at least, to some of the symptoms therein. Mescaline and lysergic acid diethylamide are examples of hallucinogens, and reserpine has been responsible for suicidal psychotic depressions indistinguishable from the spontaneously occurring disorder. Dextrarotatory amphetamine sulfate induces a mild hypomanic state which qualitatively resembles the serious major illness. Toxic doses of a number of compounds of which the barbiturates are frequently seen clinically imitate and are included in the organic psychoses in which are seen profound disturbances of orientation, attention, memory and moment-to-moment behavior.

V. Flight

It must be immediately stressed that the psychological and physiological effects of prolonged weightlessness are not known. Though it is possible to simulate some of the aspects of space flight here on earth, they nevertheless take place in a one-G field. Fragmentary data from balloon, high performance aircraft, sub-orbital and orbital flight indicate that the pilot may experience disturbing sensations which adversely influence monitoring ability; he may grossly overestimate his own performance; he may undergo the detachment of the "break-off" phenomenon; and he may experience profound elation during the parabolic curve of the Keplerian trajectory. The extent to which such mood elevation may contribute to errors of judgement is a provocative question. In addition to the consequences of the zero-gravity state, he must, under the constraints of confinement and relative social isolation, perform during the physical processes of acceleration, rotation and oscillation; maintain the attitude of the spacecraft in roll, pitch, and yaw; and he must be able to operate despite the marked autonomic changes heralded by lift-off, insertion, and re-entry phases of the flight.

Field Trip to Ames Research Center

Moffett Field, California

July 8 - July 16, 1968

NASA - Ames Research Center

Life Sciences Research Laboratory (Bldg. N-239)

Conference Room B-39

SCHEDULE

July 8, 1968 (Monday)

10:00 am to 11:30 am	The Motivation for and Challenge of Exobiology	Dr. Harold Klein, Asst. Director for Life Sciences
11:30 am to 1:00 pm	Lunch	
1:00 pm to 2:30 pm	Research In Space Medicine	Dr. John Billingham, Chief, Biotechnology
2:30 pm to 4:00 pm	Weightless Laboratory	Dr. Charles Winget Research Scientist
4:00 pm	Adjourn	

July 9, 1968 (Tuesday)

8:30 am to 10:15 am	Chemical Evolution and the Origin of Life	Dr. Harold Klein
10:15 am to 10:30 am	Coffee Break	
10:30 am to 11:15 am	Organic Geochemical Aspects of the Origin of Life	Dr. K. Kvenvolden Research Scientist
11:15 am to 12:00 pm	Some Mechanistic Studies of Chemical Evolution	Dr. J. Chang Research Scientist
12:00 pm to 1:00 pm	Lunch	

July 9, 1968 (Tuesday - con't.)

1:00 pm to 2:30 pm	Laboratory Visits (Exobiology Division)	
	Room 306 Synthesis under Primitive Earth Conditions	J. Flores Chemist
	Room 314 Atmosphere of Jupiter	F. Woeller Chemist
	Room 317 Mass Spectrometry	Dr. J. Hayes Research Scientist
	Room 32[illegible] Organic Geochemistry	Dr. K. Kvenvolden
2:30 pm to 2:45 pm	Coffee Break	
2:45 pm to 4:15 pm	Mars	Dr. Harold Klein

July 10, 1968 (Wednesday)

8:30 am to 10:00 am	Life Detection	Dr. R. Johnson Research Scientist
10:00 am to 10:15 am	Coffee Break	
10:15 am to 12:00 pm	Visit Life Detection Branch	
12:00 pm to 1:00 pm	Luncheon	
1:00 pm to 4:00 pm	Tour of Facilities (Ames Research Center)	

July 11, 1968 (Thursday)

8:30 am to 8:50 am	Introductory Remarks (Environmental Biology) and Introduction to Cardiodynamics	Dr. E. Ogden Chief, Environmental Biology Division
8:50 am to 9:10 am	Gravitational Studies in Growth, Nutrition, and Longevity	Dr. J. Oyama Chief, Physiology Branch

July 11, 1968 (Thursday - con't.)

9:10 am to 9:30 am	Uses and Hazards of Drugs in Space	Dr. J. Vernikos-Danellis Research Scientist
9:30 am to 9:45 am	Coffee Break	
9:45 am to 12:00 pm	Laboratory Visits (Environmental Biology Division)	
12:00 pm to 1:00 pm	Lunch	
1:15 pm to 4:15 pm	Bioscience Bldg. (N-236) Class will form into four (4) groups for Experimental Pathology Demonstrations and Rotate every 45 minutes until 4:15 pm	
	A - Histochemical Studies of Brain Damage	Dr. J. Miquel Research Scientist
	B - Stress Endocrinology	Dr. E. Anderson Research Scientist
	C - Bone and Wound Healing Under Gravitational Stress	Dr. C. Conley Research Scientist
	D - The Use and Care of Experimental Animals, Health, Humanity, and Housekeeping	Dr. P. Callahan Research Scientist

July 12, 1968 (Friday)

8:30 am to 9:00 am	Intracellular Proteolytic Enzymes in the Physiological Response to Stress	Dr. J. McDonald Research Scientist
9:00 am to 9:30 am	Role of the Growth Hormone in Adaptation	Dr. R. Grindeland Research Scientist
9:30 am to 10:00 am	Biological Rhythms	Dr. Charles Winget Research Scientist
10:00 am to 10:30 am	Otolith Film	
10:30 am to 10:45 am	Coffee Break	
10:45 am to 11:15 am	Group Discussion	

July 12, 1968 (Friday - con't.)

11:15 am to 11:45 am	Individual Discussions	
11:54 am to 1:00 pm	Luncheon	
1:00 pm to 1:10 pm	Introductory Remarks (Biotechnology)	Dr. J. Billingham
1:10 pm to 1:30 pm	Some Problems in Human Performance	Dr. R. Patton Chief, Human Performance Branch
1:30 pm to 3:30 pm	Form into three (3) groups (rotate) for laboratory visits and discussions	
	A - Vision in the high luminance Space Environment	Dr. R. Haines Research Scientist
	B - Decision making and the Prediction of events with Statistical Structure	Dr. E. Huff Research Scientist
	C - Autonomic and EEG Correlation of Perception and Performance	Dr. D. Smith Research Scientist

July 15, 1968 (Monday)

8:30 am	Introduction	Dr. J. Billingham
8:30 am to 10:45 am	Laboratory Visits by Groups	
	A - Measurement of Blood Vessel Diameter in the Living Lung	Dr. J. Maloney Research Scientist
	B - Cardiovascular Bioinstrumentation	Dr. H. Sandler Research Scientist
	C - Physiological Effects of Hyperbaric Oxygen	Dr. H. Leon Research Scientist
11:45 am to 1:00 pm	Luncheon	
1:00 pm to 1:30 pm	Introduction - Interaction Between Men and Systems	M. Sadoff Chief, Man-Machine Integration Branch
1:30 pm to 2:30 pm	Form into two groups, visit Biotechnology Facilities	

July 15, 1968 (Monday - con't.)

1:30 pm to 3:30 pm	(Groups - con't) A - Capability for Precise Control Tasks B - Pilot Preception of Rotation	T. Wempe Research Scientist J. Stewart Research Scientist
3:30 pm to 4:15 pm	Discussion	

July 16, 1968 (Tuesday)

8:30 am to 8:45 am	Introduction Life Support System	Dr. A. Mandel Chief, Environmental Control Res. Branch
8:45 am to 9:15 am	Closed Ecological Systems	Dr. J. Shapira Research Scientist
9:15 am to 9:30 am	Problems of IVA and EVA Simulation (Movie and Demonstration)	H. Vykukal Research Scientist
10:00 am to 10:15 am	Coffee Break	
10:15 am to 11:00 am	Oxygen Regeneration and Carbon Dioxide Concentration	Dr. T. Wydeven Research Scientist
11:00 am to 11:45 am	Discussion	
11:45 am to 1:00 pm	Luncheon	
1:00 pm to 2:30 pm	Board bus for Visit to Biosatellite Facilities and discussions	
2:30 pm	Leave for San Jose Airport, board flight to Los Angeles	

SCIENTIFIC MOTIVES BEHIND RESEARCH IN SPACE BIOLOGY
DEFINITION OF "SPACE ENVIRONMENT" - MEDICAL ASPECTS

John Billingham

Basic Problems

To what extent can more be learned of the basic nature of human biology as a result of experiments on animals and man in the space environment? How well is man capable of adapting to a completely new physical characteristic of the environment - weightlessness? How does his adaptation compare with other animals? These basic biomedical questions are attacked in two ways - by experiments in simulators on the earth's surface and by experiments in vehicles in the space environment. They are not directed towards obtaining answers to practical questions about what will happen to man, although such answers will frequently be obtained from the results of the basic questions. Few basic experiments have yet been carried out in the space environment, though there has been considerable work on the ground. Cases are cited for each instance - for example, the simulation (by various means) of weightlessness in laboratories on the ground, and the Gemini flight experiment on the vestibular system during weightlessness.

Applied Problems

A. What is the probability of the development of disease conditions, medical or surgical, in space flights of the future; how can these probabilities be reduced to a minimum by selection of crew members and preventive medicine techniques; how are they treated if they should occur; and what is the effect on the mission? These are questions which relate conventional clinical medicine and surgery to the unique situation of space flight.

B. What physiological, psychological or pathological effects might be produced in astronauts as a result of their exposure to the space environment, particularly in long duration missions in the future; are any of these effects likely to constitute a significant hazard to crew safety or mission success; to what extent can they be prevented by selection, the provision of protective devices, or medical treatment? Note that this is a different category from the occurrence of ordinary clinical diseases such as appendicitis or diabetes. The factors of primary interest are: i. the effects of weightlessness on the cardiovascular system, body fluid balance and the central nervous system; ii. the effects of ionizing radiation on large animals and man; iii. the consequences of prolonged confinement in future multi-man space missions; and iv. the effects of variation in other physical characteristics of the environment on performance and safety - for example, sustained acceleration, vibration, impact, noise, blast, changing atmospheric pressure and composition, heat and cold, and toxic chemical substances.

C. What is the best way to use man in a space vehicle, and how can his unique capabilities be extended by technical devices or medical procedures? Complex space missions of the future will demand a carefully constructed

interaction between four different elements: i. the astronaut; ii. vehicular and extravehicular systems; iii. the mission control team and the ground; and iv. systems on the ground (particularly simulators and computers). What functions should be assigned to each? What command system should be employed between ground control and astronaut? Which aspects of vehicle control, extravehicular activity, and flight experiments are best done automatically by machine and computer, and which are best done by man? How are crew members selected for different types of missions? In some instances, the answers are clear. For example, selection of actual landing sites for a manned planetary surface vehicle is a decision of such complexity that it is clearly a task that would be better done by man than by fully automatic systems. In contrast, the computation of required thrust vectors for mid-course guidance corrections on interplanetary missions, particularly if these are required rapidly, is best carried out by computer, with man acting in the role of monitor. Other questions are much more difficult to answer. For example, to what extent should booster control during lift off and ascent into earth orbit be under manual control?

D. What are the requirements for the support of life in space flight, and how can they be met? Man needs food, water and oxygen to survive, and these must be provided continuously during the mission. The technology associated with the maintenance of this supply can become complex for long duration missions, particularly with respect to food. If partial or complete closure of the ecological system is attempted in order to save mass, biomedical and technological problems become even more complex since human metabolic waste products must be converted back into palatable and digestible water and food.

Summary

Basic and applied biomedical factors in the space environment are described. The basic goals speak for themselves. The applied goal is to link together the numerous biomedical and technological factors so that the most reliable of all possible combinations of man and machine is arrived at for any particular mission or type of mission. Research in achieving this goal must be directed towards a constantly increasing confidence in knowledge of relevant human and interacting machine characteristics and capabilities, so that reliability may be calculated more accurately.

SUGGESTED READING

General

Henry, James P., Biomedical Aspects of Space Flight, Holt, Rinehart and Winston, Inc., N.Y., 1966.

Detailed

Gillies, J. A. (Ed.), A Textbook of Aviation Physiology, Pergamon Press, Pergamon Press, Oxford, N.Y., 1965.

BIOMEDICAL RESEARCH IN RELATION TO THE SPACE ENVIRONMENT

Dr. John Billingham

The physical environment of space and of the vehicles in which man may be confined in space may impose on him many different types of stress. It is clearly very important to know how the human body reacts to these different stresses, both on their own and in combination with other stresses. This portion of biomedical research is best described as environmental physiology. If the stresses are sufficiently severe, they may cause damage to physiological systems, and it becomes necessary to know something of the pathology of the reactions concerned. Finally clinical conditions, such as diabetes or appendicitis, may develop on a long duration space mission, so it becomes necessary to know something of the probabilities of the development of such conditions in an astronaut group, and methods for their prevention and treatment.

The biomedical research activities in relation to the space environment are therefore compounded of environmental physiology and pathology, and environmental and preventive medicine. Sometimes the behavioral sciences are included; sometimes not. Given below is a list of the various factors, the effects of which are particularly relevant as biomedical problems in the space environment.

1. Weightlessness.

2. Ionizing radiation.

3. Variations in the force fields: sustained acceleration, noise, blast, vibration and impact.

4. Changes in gas pressure and composition.

5. Thermal environment.

6. Electric and magnetic fields.

7. Variations in the quantity and quality of those things essential for maintenance of life, namely food, oxygen and water.

8. The effects of emotional stress on body systems.

In each case, the spacecraft designer or mission planner would like to know what is the response of the human body to any intensity frequency, or phasing of the environmental factors concerned, and he would like to know the answer in terms of a probabilistic figure. For example, what would be the proportion of men between the ages of 25 and 35 who would develop loss of appetite when exposed to whole body irradiation with 130 MeV protons at a level of 150 rads; and what proportion would die if exposed to 500 rads.

The main function of biomedical research is to try and answer these

questions, on a probilistic basis, for all the stresses involved. Large scale research programs are frequently needed to do this, and a considerable amount of the research involved must necessarily be animal experimentation.

An excellent introduction to some of these problems is given in "Biomedical Aspects of Space Flight," by James P. Henry.

THE USE AND CARE OF EXPERIMENTAL ANIMALS

Dr. Paul X. Callahan

I. Research utilizing animals can only be as good as the animals themselves. Examples are:

   A. Animal health as a factor in drug response. (LD_{50}, standard deviation, potentiation.)

   B. Animal health influencing recovery from surgical (or other) procedures.

   C. Animal health influencing normal physiology. (EEG, cardiovascular physiology and blood vessel tone, endocrine function, etc.)

II. Production and maintenance of good research animals involves many factors.

   A. Health.

      1. Recognition of a healthy animal.

      2. Requirements for a healthy animal.

         a. Food and water.

         b. Caging, exercise, etc.

         c. Physical environment.

      3. Germ-free versus "normal" animal.

   B. Humanity.

      1. Responsibility to the animal.

      2. Legal ramifications.

      3. Inhumanity can affect research results.

         a. Inhumanity breeds a certain attitude and approach which animals sense.

   C. Housekeeping.

      1. Primary enclosures.

      2. Secondary enclosures.

      3. Cleaning procedures.

4. Monitoring procedures (health).

5. Logistics.

6. Animals in space.

III. Basic information on care of experimental animals.

A. Guide for Laboratory Animal Facilities and Care. Public Health Services Publication No. 1024. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (1965).

B. Basic Care of Experimental Animals, Animal Welfare Institute, P.O. Box 3492, Grand Central Station, New York, New York 10017 (1965).

C. Standards for the Breeding, Care, and Management of _____. (Series of standards of various laboratory animals.) Committee on Standards, Institute of Laboratory Animal Resources, NAS-NRC, Washington, D. C. 20418.

Further (or more detailed) references are available in the first two citings.

IV. Tour of animal colony and facilities with general comments as to use of animals in current research.

BONE AND WOUND HEALING UNDER GRAVITATIONAL STRESS

Dr. Charles C. Conley

Introduction

In preparing for maximum usefulness of man in space as well as providing for his safety, NASA must determine to what extent injuries occurring during space missions can be treated without return to earth. Since current spacecraft design does not afford long-term artificial gravity, this means in-flight recovery from injury would have to occur under weightlessness. In the proposed in-flight and ground-based animal experiments, it is our purpose to study whether weightlessness or increased gravitational stress can be shown to affect the healing of bone and skin.

Background Observations

The association of bone atrophy with disuse has long been established experimentally and clinically. Recent studies (Vogt, et al., 1965) on healthy volunteers confined to bed and on astronauts (Mack, et al., 1966) exposed to weightlessness have provided radiographic evidence of bone demineralization at two sites in both groups and negative calcium balance in the bed rest group. The demineralization was not limited to the weight bearing bones, it was, in fact, greater in the astronauts' fingers than in their heels. This would imply a generalized skeletal effect of O-G, except that on earth the hands are frequently involved in weight bearing in proportion to their size. But the possibility remains that the loss of bone density and body calcium associated with O-G (zero gravity) is truly a generalized skeletal response to an unusual reduction in total loading of the musculo-skeletal system.

Theoretical Considerations, Bone

Studies on humans are essentially limited to radiographic and mineral balance techniques; but observations on the healing of bone fractures in experimental animals provide an opportunity to assess the bone-forming capacity directly. The classic work of A. W. Ham (1952) presents an histologic basis for appraisal of the capacity of an animal both to form the collagenous osteoid intercellular bone substance and to calcify this matrix promptly, in a structurally effective manner. A time table of healing progress has been established in terms of cell differentiation, proliferation and matrix formation; and the general architecture of the trabecular callus provides a definitive estimate of healing success with respect to time. Such observiations form the basis of our bone study.

Theoretical Considerations, Skin

Disuse atrophy of bone involves more than mineral loss, in that there is also degeneration of the collagenous matrix (Bartter, 1957). Hydroxyproline is virtually unique to collagen, and while studies on astronauts, thus far, have failed to show hydroxyproline loss comparable to the degree of bone

demineralization seen during flight (Vogt, et al., 1966), experimental autoradiographic studies (for example, Grillo, 1964) have shown that the incorporation of this amino acid into collagen is a prominent feature of new bone formation as well as skin healing. Houck (1966) has presented evidence for a generalized mobilization of dermal collagen during bodily stress, including wound healing. Since collagen can be readily stained by standard light microscopy techniques, we have included histological observations on the fate of this protein along with epithelial and other changes in the healing skin of our experimental and control animals.

Thus, because collagen as well as calcium can be expected to be mobilized during weightlessness, both skin and bone healing can reasonably be expected to be altered, in fact, both repair processes may well be accelerated at 0-G.

Experimental Approach

Until fractures and skin wounds can be made experimentally during space flight, it will not be possible to test for an antecedent 0-G effect upon subsequent healing. But, since bone healing remains an active process for weeks after injury, there is ample opportunity to observe a weightlessness effect if fracturing is performed just prior to launch. Similarly, since it has been shown that acceleration of epidermal mitosis rates during healing does not begin until the second day or later after incisional wounding (Sullivan and Epstein, 1963), and, since collagen does not appear in significant amounts in wound repair until the fifth day, with production continuing for weeks (Dunphy and Udupa, 1955, Grillo, et al., 1958, and Ross and Benditt, 1961), the skin wound experiment can be prepared on the ground immediately prior to launching with ample exposure to 0-G during the healing process.

Current Studies

Our work has begun with centrifuge studies on rats. Our two major objectives were to develop an experimental 'breadboard' for eventual installation into a flight package, and to determine whether increased gravitational loading will affect bone and skin healing.

1. Femoral Lesion:

In our first run, young adult male rats were placed at two g-load levels, 3.5 g and 4.7 g, for 4 and 8 weeks. Femurs were notched just prior to placement on the centrifuge. Dr. P. B. Mack, of the Texas Woman's University, collaborated with us by performing the densitometric measurements on our film.

Neither the histology of the skin or of the bone wounds showed significant or consistent differences between the experimental and control groups. No differences in the densitometry of the bones were demonstrable because of the excessive overlay of the soft tissues over the femur and the wide separation from the wedge required by this bone's anatomical location.

An interesting positive finding, however, was the persistence in the growth of bone length in centrifuged animals as compared with the marked retarding of general body growth. The differences in the ratios of these two parameters between the experimental and control groups were significant at the 99% level.

2. Tibial Lesion:

We have begun a new series of centrifuge experiments with two major changes in technique:

a. We are notching the rat tibia which is a superficial bone, avoiding the soft tissue overlay problem. In addition, the change of bone permits closer approximation of the wedge for better densitometry.

b. We are using a modified pair-feeding technique to equalize the dietary differences between experimental and control groups.

SUGGESTED READING

1. Bartter, F. C. Am. J. Med., 22:797, 1957.

2. Dunphy, J. E. and Udupa, K. N. New Eng. J. Med., 253:847, 1955.

3. Grillo, H. C. et al.: Ann. Surg. 148:145, 1958.

4. Grillo, H. C., In: Montagna, W. and Billingham, R. E., (Eds.), Wound Healing, N.Y., Macmillan, 1964.

5. Ham, A. W.: J. Bone and Joint Surg., 34A:701, 1952.

6. Houck, J. C. Drug Induced Cutaneous Enzymes and Collagen Metabolism, Environmental Biology Division Seminar, NASA, Ames Research Center, 1966.

7. Mack, P. B., et al., In: Manned Spacecraft Center, Gemini Mid-Program Conference, Washington, D.C., NASA, SP-121, 1966.

8. Ross, R. and Benditt, E. P. J. Biophys. and Biochem. Cytol. 11:677, 1961.

9. Sullivan, D. J. and Epstein, W. L. J. Invest. Dermatol., 41:39, 1963.

10. Vogt, F. B., et al. The Effect of Bed Rest on Various Parameters of Physiological Function, Part XII, Washington, D.C., NASA, CR-182, 1965.

ROLE OF GROWTH HORMONE IN ADAPTATION TO STRESS

Dr. Richard E. Grindeland

Growth hormone, as the name implies, is the preeminent regulator of skeletal and soft tissue growth, and it is this function which was responsible for its discovery. Dwarfism or gigantism of animals results from deficiency or excess, respectively, of the hormone in the young animal. In the adult organism, the growth-promoting effects of this hormone are thought to play a part in tissue repair and perhaps in the compensatory hypertrophy of organs, (i.e., growth of an organ due to increased work-load). Although the mechanism(s) by which growth or somatopropic hormone controls growth is not understood, the hormone is known to affect profoundly numerous metabolic processes.

1. Metabolic Effects of Growth Hormone

a. Protein metabolism. The most characteristic effect of GH is the retention of nitrogen as protein. Plasma amino acids are decreased, urea formation is reduced, and protein synthesis is increased with a net gain of protein (positive nitrogen balance).

b. Fat metabolism. GH stimulates mobilization (and oxidation) of body fat stores.

c. Carbohydrate metabolism. Chronic administration of GH results in elevated plasma (hyperglycemia) and urinary (glycosuria), glucose levels due to inhibition of glucose utilization by most tissues of the body. In dogs and cats, prolonged treatment with GH will result in permanent diabetes mellitus, and dogs which have been pancreatectomized show alleviation of the diabetes when their pituitary glands are removed. During fasting, this action of GH allows the organs crucial for survival (nervous system and heart) to preferentially utilize available glucose.

2. Control of GH Secretion

Control of growth hormone secretion is now thought to be by means of growth hormone releasing factor (GRF) emanating from the hypothalamus, in response to appropriate stimuli and carried to the pituitary gland by means of blood vessels (hypothalamic-hypophyseal portal system). The intimate relationship of nervous system to pituitary gland permits very rapid changes in GH secretion in response to appropriate changes in the internal or external environments.

3. Measurement of Plasma GH

Circulating GH cannot be measured by chemical or bioassay techniques since, in human beings under basal conditions, there is about 1 mμg (nanogram) of GH per milliliter of plasma. Numerous methods now available all depend on the specificity and sensitivity of immunoassay.

Antibodies to human GH (HGH), for instance, are produced in rabbits. Purified HGH is labelled with radioactive iodine and an excess of labelled hormone is allowed to react with the antibody. The antibody-bound (B) and free GH are separated by various means and counted with a radioisotope counter. As unlabelled ("cold") GH, either from a standard purified preparation or a plasma sample, is added the cold and labelled GH compete for the antibody, causing displacement of labelled GH from the bound to free fractions. The change in B/F GH is a measure of the added GH. By some techniques, less than 0.05 mμg (50 μμg) of hormone can be measured.

4. Results of Immunoassay Studies

Emotional stress, physical activity, fasting, lowering of blood glucose levels, cold exposure, pregnancy, and blockage of glucose metabolism by administration of 2-deoxyglucose, a competitive inhibitor of glucose utilization, all evoke very abrupt increases in plasma GH levels. From these data, it appears that the major rule of GH is to assure the vital organs of a continuing energy supply in the face of stress by mobilizing fatty acids for use by non-nervous tissue and inhibiting the use of glucose by these tissues. Since the brain relies on glucose as an energy source, the significance of this action to the preservation of the organism is apparent.

5. Significance of GH During Space Flight

Because of the central role of GH in metabolism, particularly of the nervous system and heart, one might expect severe metabolic derangements as a result of deficient or excessive levels of the hormone, and it is, therefore, highly pertinent to measure GH under space flight conditions. Since muscular activity is the most potent known physiological stimulus to GH secretion, it is possible that conditions not requiring muscular work (weightlessness) may lead to abnormally low GH levels and, conceivably, difficulty in maintaining an adequate plasma level of glucose. Alternatively, exaggerated GH secretion for prolonged periods, as a result of emotional stress, may become diabetogenic. Understanding of the physiological control of GH secretion may permit the manipulation of GH secretion by drugs.

6. Work at Ames

Elucidation of the physiological role of GH in space flight requires the use of experimental animals in addition to man. To that end, three species of GH have been isolated at Ames (rat, rabbit, and cat GH), antisera produced, and methods for immunoassay of the hormone in man and rats worked out. Ground-base studies on the hormones are in progress. In the course of isolation of rat GH, it was observed that a plasma proteolytic enzyme (plasmin, fibrinolysin) altered the molecule chemically and immunologically but did not affect it biologically. These results suggest that:

a. the storage (pituitary) and circulating forms of the hormone may be different, and

b. the biological and immunological properties of native GH reside in different portions of the molecule. The implications of the plasmin degradation of GH will be discussed in the oral presentation as will the effects of stress on plasma GH titers.

VISION IN THE HIGH LUMINANCE SPACE ENVIRONMENT

Richard F. Haines

Introduction

It has been known for some time that objects can be made to appear quite different than they appear under "usual" viewing conditions. Everyone is familiar with illusions of one sort or another. It has been only recently, however, that this poor correspondence between physical object and perceived object has been encountered in the "normal working environment" of the observer...the astronaut in space.

In this presentation I will attempt to give you some idea of what objects look like to the astronaut in space. I will also try to provide some of the possible reasons why they appear as they do. The following outline and recommended readings will give you an idea of the range of topics to be discussed and the general nature of the slides of NASA Gemini orbital flights and Lunar Surveyor mission data which will be shown.

Outline

1. Physical Aspects of the Visual Space Environment
    a. energy (luminance) aspects
    b. spatial aspects
    c. temporal aspects
    d. wavelength aspects
2. Perceptual Aspects of the Visual Space Environment
    a. brightness ranges encountered
    b. field of view conditions
    c. viewing time considerations
    d. color
3. Sunrise Sequence as Seen From Earth Orbit (slides)
4. Visibility of the Earth's Surface as Seen From Earth Orbit (slides)
5. Visual Effects of Solar Illumination in Space (slides)
    a. the "hard" shadow effect

b. the earth's albedo

c. the day-night appearance of the earth as seen from earth orbit

d illusory effects observed in space

e loss of depth cues

6. Appearance of the Lunar Surface Under Varying Illumination Conditions (slides)

7. Laboratory Simulation of the Visual Space Environment

a. some data related to vision in the high luminance environment

b. demonstration of the "hard" shadow effect in the laboratory

c. demonstration of various high luminance objects (brief tour of the High Luminance Vision Laboratory)

Question:

In observing objects in space that reflect solar radiation (light) into the observer's eyes these objects tend to appear:

a. slightly more reddish than under lower luminances

b. a little smaller than they do under lower luminances

c. more distant than do objects under lower luminances

d. slightly larger than the same object under lower luminances

e. slightly more bluish than under lower luminances

SUGGESTED READING

Baker, C.A. (ed.), Visual Capabilities in the Space Environment, Pergamon Press, New York, 1965, pp. 165-172, 1-27, 29-35, 121-141, 149-154.

Anon., Loss of Vision from High Intensity Light. AGARD Conference Proceedings No. 11, 1966, (A symposium sponsored by the Aerospace Medical Panel of AGARD - NATO, held in Paris, France, March 16-17, 1966.

Benson, O.O. Jr., and Strughold, H. (eds.), Physics and Medicine of the Atmosphere and Space. John Wiley & Sons, Inc., New York, 1960.

LIFE DETECTION

Dr. Richard D. Johnson

Abstract

In consideration of techniques for searching for extraterrestrial life on Mars, one must consider questions of the following nature. Why look for extraterrestrial life, what are the chances of success, what will we learn, what will it cost. Then one must explore the nature of this possible life by asking if it will look like life on earth, are we more likely to find one form of life than another, how do the environmental parameters of the planet guide us in selecting possible experiments. Life as we know it here on earth must be examined both chemically and biologically to ascertain what attributes of life help us to identify the unique characteristics of living systems. How do we test for these attributes? Are they applicable to possible life forms on Mars? From these ideas of what kind of idealized experiments are desired, the focus must be shifted to the practical. Can small instrumental packages be designed for these experiments? What are their requirements as to weight, volume, power, temperature, data, etc. How do various experiments complement one another? Are small or even large remote laboratories feasible? Then one must ask questions about Mars, where do we want to look, when, for how long, and match these requirements with launch capabilities and opportunities. Through group discussion of questions of this type, it is hoped that the class will generate and assimilate a feeling for extraterrestrial life detection.

THE MOTIVATION FOR AND CHALLENGE OF EXOBIOLOGY

Dr. H. Klein

A. The main purpose of this lecture is to try to set the stage for subsequent more detailed lectures.

B. Biology is the science of life. Since we know of life only on earth, this defining of the science has restricted biologists to "earth-bound" researches. In contrast to other sciences, such as physics and chemistry "universal" laws of biology have been confined to this planet. "Exobiology" releases us from this constraint.

C. What "universal" laws, what "generalities" would the (exo) biologist wish to verify by studying extraterrestrial organisms? Before indicating answers to these questions, a brief review will be made of some common attributes of life on earth.

1. Chemical composition
2. Cellular structure
3. Energy metabolism
4. Synthetic processes
5. Information storage and transmission
6. Evolution

D. Why should we even consider the question, "is there life on other planets?" According to contemporary thinking, "life" can be considered to be a natural development in the life of a planet. Furthermore, there is no a priori reason to assume that the planet, earth, developed uniquely in this regard.

In this connection, a brief introduction will be made to studies on the "origin of life." The possibility that life, originating on one planet, could be dispersed subsequently throughout space, will also be mentioned. And the importance of the moon as a possible repository for "spores" or "seeds" from "outer" space will be indicated.

E. Regardless of the mechanisms by which they got there, the immediate practical problem is to obtain evidence for the presence of extraterrestrial organisms. What approaches are being used?

1. At present:

   a. Direct evidence for life is being sought in certain types of meteorites.

   b. Indirect evidence is being sought in a variety of approaches. Astronomical studies of our neighboring planets have yielded information concerning planetary environments (temperature range, composition of atmosphere, water content of atmosphere, etc.) from which inferences can be made regarding the possibility of life.

2. Within the next decade:

   a. There will obviously be intensified efforts to obtain information from meteorites. This could take the form of trying to collect samples above the earth's atmosphere or, more probably, from the surface of the moon.

   b. Astronomical observations could yield much valuable data if obtained above the earth's atmosphere. Also, the use of such instruments on space vehicles that pass near a planet ("fly-bys") or on vehicles that orbit a planet, will enable us to obtain information on the geographic variation of some of the important parameters. This kind of information, in turn, will lead to the development of more refined "simulation" devices.

   c. It should become possible to land unmanned, and later, manned space vehicles on neighboring planets.

PROBLEMS INVOLVED IN THE DETECTION OF LIFE

Various approaches have been suggested for possible use in "life detection" devices for potential use in space exploration. These have covered the spectrum from apparatus to detect specific chemicals, through devices of methods to assay for growth of micro-organisms, to complex automated laboratories capable of conducting a variety of integrated procedures.

Some of the assumptions on which these different procedures are based will be examined. Evidence will be brought forth concerning the possibility of obtaining ambiguous results, and other inherent difficulties in this important undertaking will be examined.

PHYSIOLOGICAL EFFECTS OF HYPERBARIC OXYGEN

Dr. H. A. Leon

Aside from the construction of the space cabin itself, perhaps the most important factor to be considered for manned space flight is the space cabin atmosphere. The selection of an ideal space cabin atmosphere requires thorough analysis of the physiological, engineering and logistical considerations of the problem. Foremost among these is the optimum oxygen partial pressure. Although the lower limits of oxygen can be defined by the appearance of hypoxia, the upper limit where oxygen toxicity becomes a factor is ill-defined since the expression of oxygen toxicity symptoms are time-related as well as pressure related. The effect of moderately elevated oxygen pressures on lung and peripheral tissue will be discussed. Other factors which interact and contribute to the final choice of a space cabin atmosphere will be discussed.

MEASUREMENT OF THE BLOOD VESSEL DIAMETER IN THE LIVING LUNG

Dr. John Maloney

In this session we shall discuss three topics: the function of the lung; the structure of the lung; and the flow of blood through the lung. The principles of two methods of measuring the distribution of blood flow in man's lung shall be described and the factors which influence the distribution of blood flow in the lung discussed.

One of these factors is the expansion of the small pulmonary blood vessels so the pressure inside them is increased. Current work in this field shall be demonstrated and students shall be given an opportunity to take part in a brief laboratory period in which they will view and take photographs of the small blood vessels in the living frog lung.

INTRACELLULAR PROTEOLYTIC ENZYMES IN THE PHYSIOLOGICAL RESPONSE TO STRESS

Dr. J. Ken McDonald

Atrophy of Tissues

The condition of weightlessness would be expected to induce in the mammalian organism a disuse atrophy of certain tissues (skeletal and heart muscle, bone, cartilage). One of various metabolic parameters which would be expected to be markedly altered in the course of an atrophic process is that concerned with the metabolism of cellular protein. Since the intracellular protein mass appears to be maintained by an equilibrium between biosynthesis on the one hand, and degradation (and secretion) on the other, disuse atrophy could arise from a reduced rate of protein biosynthesis, from an accelerated rate of degradation, or from a combination of the two. It is evident, therefore, that the understanding of the potential effects of prolonged weightlessness on cellular protein mass would presuppose a basic understanding of the mechanisms whereby proteins are synthesized and degraded within the cell, and of the normal mechanisms which regulate the rates of these respective processes.

The biochemistry of protein biosynthesis is being extensively and vigorously investigated in many laboratories, but the effort being expended on the investigation of intracellular protein degradation is barely perceptible. This state of affairs is reflected in the fact that it is not possible at the present state of our knowledge to describe the metabolic degradation of even one intracellular polypeptide or protein. It would appear to be obligatory, therefore, that the mechanism of intracellular protein degradation be thoroughly explored in view of the anticipated effects of weightlessness on tissue protein metabolism.

Physiologically Active Peptides

Another reason for investigating the proteolytic enzymes with reference to potential value in space biology rests on the fact that the action of these enzymes on certain endogenous tissue or plasma proteins results in the production of highly potent physiological effects in response to external injury or stress. For example, one of the most potent vasodepressors known is the polypeptide, bradykinin, which is formed by the action of a proteolytic enzyme normally present in the plasma in an inactive state but, which when activated in response to stressful stimuli, releases bradykinin (a nine-amino acid peptide) from a plasma globulin. Such peptide products are currently thought to be instrumental in the production of shock, as manifested by increased vascular permeability and lowered blood pressure.

Another potent polypeptide formed through the action of a proteolytic enzyme in the blood is angiotensin (an eight-amino acid peptide) which shows the reverse effect, namely, an elevation of blood pressure and, in addition, the release from the adrenal glands of aldosterone, a steriod hormone that regulates the retention of salt by the kidney.

Finally, once their intended physiological effects have been produced, these polypeptides are then degraded to inactive forms by other proteolytic enzymes which are not as yet fully characterized with respect to their properties or specificities. It is evident, therefore, that proteolytic enzymes regulate and terminate the physiological responses to stress.

Destruction of Protein Hormones

A third reason for inquiring into the role of proteolytic enzymes rests on the fact that hormones such as growth hormone, adrenocorticotropic hormone (ACTH), parathyroid hormone, thyrocalcitonin, vasopressin, and insulin are polypeptides or small proteins, and as such are degraded into inactive products through the action of the proteolytic enzymes. Since it is anticipated that hormones such as growth hormone, ACTH, parathyroid hormone, and thyrocalcitonin may be significant factors in off-setting any detrimental atrophic changes occurring in protein and calcium metabolism during prolonged weightlessness, it would appear desirable to establish the mechanism by which these hormones are inactivated and degraded by endogeneous proteolytic enzymes. Should the prolongation of action of these hormones be desired, it would be well to understand the means by which their degradation could be delayed or inhibited. Conversely, if the action of any hormone is excessive and detrimental, their degradation could be enhanced.

At the risk of repetition, what has been said regarding the degradation of intracellular proteins also holds true for the protein hormones. We are in total ignorance as to the enzymatic mechanisms responsible for the inactivation of these hormones. For example, it is known that the hormone ACTH, which is actively secreted by the pituitary gland in response to stressful stimuli, has a half-life in the blood of only 3.5 minutes, but it is not yet known where in the body, and by what enzymes, ACTH is inactivated.

Progress at Ames

Investigation of intracellular peptidases in our laboratory has led to the recognition of a spectrum of peptidases - eight in number - which catalyze the inactivation and breakdown of hormones such as ACTH, growth hormone, glucagon, and of cellular proteins in general. One of these intracellular enzymes, Proteinase I, is pepsin-like in specificity and is localized within intracellular structures (lysosomes) of the pituitary cell. Hormone granules contained in the pituitary are either secreted from the gland or else are phagocytized (ingested) by lysosomes when the stimulus for secretion is not provided by the hypothalamic region of the brain. Within the lysosomes, Proteinase I and other peptidases hydrolyze the protein hormone to relatively large peptides which then diffuse into the cytoplasm of the cell, and are there hydrolyzed to the constituent amino acids, and become available for reutilization in synthetic reactions.

Our studies have provided a basis for an understanding, for the first time, of the mechanism of intracellular protein turnover in terms of specific

enzymes. Studies are currently underway to fully determine the properties of these enzymes with regard to specificity and to requirements for activators or inhibitors. As the properties of these enzymes become more clearly delineated, it will become possible to test the effects of inhibiting or activating these enzymes on such fundamental life phenomena as growth and development, aging, and adaptation to stress.

The oral portion of this presentation will describe the properties of some of these enzymes, as well as the exact nature of their attack on protein hormones such as ACTH, glucagon, and growth hormone. The distribution of these proteases among different tissues, their usefulness as indicators (by their presence in the blood) of damage to specific tissues, and their contribution to the atrophy of weight-bearing skeletal muscle will also be discussed.

HISTOCHEMICAL STUDIES OF BRAIN DAMAGE

Jaime Miquel

Brain damage is usually studied in biopsy or autopsy tissue by the methods of classical neuropathology. Morphological alterations of the nerve or glia cells are revealed by staining of frozen or paraffin sections with haematoxylin-eosin or by use of metallic impregnation. Although these techniques have provided a wealth of information, they are not sensitive enough to reveal borderline pathological conditions. On the other hand, the use of histochemical methods allows detection of incipient pathological processes in which altered metabolic conditions are not accompanied by obvious morphological changes. The use of the periodic acid-Schiff (PAS) method for demonstration of polysaccharides has proved particularly fruitful. Increased glycogen accumulation has been observed in human brain in tumors, edema and other morbid processes and also in experimental pathological conditions in the rat, cat and monkey brain. Of particular relevance to the study of brain responses to abnormal environments is the finding of changes in the glycogen content of astrocytes following exposure to ionizing radiation and also in injuries induced by anoxia and hyperoxia.

The biochemical mechanisms involved in the abnormal glycogen accumulation are yet not fully understood. A decrease in oxidative metabolism has been considered the most likely cause for the glycogen increase in areas of stab wounds and in radiation injury. Oxidative transformation of pyruvate in nervous tissue is one of its most radiovulnerable metabolic processes. It is conceivable that decreased utilization of pyruvate results in a block in the utilization of glycogen or stimulation of the glycogen synthesis. Radiation-induced disorganization of cellular membranes may also play an important role in the pathogenesis of the glycogen increase. Exposure of the guinea pig brain to X-rays results in increased permeability of capillary endothelium and pericytes. This was revealed in electron microscope preparations by increased pinocytosis. Leaky vascular walls and injured glial and neuronal membranes must result in deranged homeostasis, with ensuing metabolic disturbances. In particular, alterations in the concentration of Na, K and Ca in the various brain compartments might influence the respiration rate.

Failure of the homeostatic mechanism also occurs in the brain tissue injured by oxygen lack. Asphyxiation of the CNS results in an increase in the impedance of the cerebral cortex which is accompanied by movement of chloride and water from an extracellular space into apical dendrites. An increase in permeability of cell membranes for sodium has been proposed as the underlying mechanism. During anoxia the normal ion distribution in the cortex is rapidly transformed into a Donnan equilibrium, in which all the ions can move freely through the membranes, with the exception of the proteins which remain intracellular.

Whatever the biochemical mechanisms involved, investigation of the glycogen changes in brain might prove the most suitable approach to the study of the effects of cosmic heavy ions on the brains of animals exposed to the space

GRAVITATION EFFECTS ON THE CARDIOVASCULAR SYSTEM

Dr. Eric Ogden

I. A. Observed Effects in Orbital Flight

1. Heart rate changes
2. Postural hypotension on return
3. Changes in total body water
4. Changes in plasma volume
5. Changes in total red cell mass

B. Research on Postural Hypotension

1. Deconditioning - the space-adapted state
   a. Organ weight and organ work
   b. Cardiac hypertrophy and atrophy
   c. Hormonal considerations
2. Deconditioning and cardiac filling
   a. The tilt table
   b. Lower body negative pressure
   c. Bed rest
   d. Immersion
3. Fluid Distribution
4. Storage Capacity
   a. P/V ratios on peripheral veins
   b. P/V ratios, wave studies, and distensibility studies on great veins.

GRAVITATIONAL STUDIES ON REPRODUCTION, GROWTH AND METABOLISM

J. Oyama

To environmental biologists the phenomenon encountered in space flights of weightlessness is perhaps the most intriguing aspect of space exploration. How prolonged exposures to weightlessness of organisms which have evolved under the invariant earth's gravity will be affected in terms of their structure, function and behavior remains to be determined. A corollary and more general problem is how gravity per se influences and controls life forms and processes. One aspect of this problem, that is, the effect of increased-G exposures, can be immediately explored by use of the centrifuge. There has been up to now relatively little research on the effects of prolonged centrifugation on mammalian organisms. Currently in the United States there are three major laboratories involved in chronic centrifugation research: U. of Calif., Davis (Dr. A.S. Smith); U. of Iowa (Dr. C.C. Wunder); and Ames Research Center (Dr. J. Oyama). In view of the relative newness of this research field, it is not surprising that there are substantial areas which have not been studied at all.

The Ames effort has been largely directed in the following areas and experimental results will be presented to elaborate the significant findings:

1. Reproduction under increased-G.

Tolerance levels. Survivibility of young. Effect on gestation period. Vestibular response of centrifuge born and reared animals compared to normal animals.

2. Growth under increased-G.

Comparison of growth curves as function of G-load. Food consumption. Maximum attainable size as function of G-load. Chemical compositional changes of selected organs and tissues.

3. Metabolism under increased-G.

Changes in patterns of intermediary metabolism of carbohydrate, fat, and protein. Hormonal concentration changes. Basal metabolism studies. Temperature regulation as influenced by increased-G exposure.

The results and findings of these hyper gravity studies will be discussed as they contribute to various hypotheses on the effects of prolonged weightlessness or sub-G exposures on growth, development, aging, and longevity of animals as well as on possible effects encountered when animals, including humans, are returned to earth following extended periods of space flight or from the moon.

SOME PROBLEMS IN HUMAN PERFORMANCE

R. M. Patton

A. Despite automation, man has been increasingly involved in the operation of systems designed to accomplish aerospace missions.

   1. Man has unique capabilities that are difficult, perhaps impossible, for the machine to duplicate.

   2. Man can act as a back-up in the event of failure of the hardware components of the man-machine system.

B. The ultimate purpose of human factors studies is to insure that man's limitations are not exceeded, and that his capabilities are fully utilized. These are equally important.

C. The purpose of laboratory research in the area is to develop information concerning these capabilities and limitations.

D. The concept of information input, processing, and output forms a useful framework for describing the activity of the Human Performance Branch. One of our research programs, to be described in detail by Dr. Haines, involves the consideration of a particular type of stimulus input, light of high intensity, and investigates man's limitations in visual performance under such conditions. A second program, to be described by Dr. Huff, investigates the way in which biases affect human decisions. Finally, Dr. Smith will describe work directed toward establishing the relationship between physiological states, and performance effectiveness.

INTERACTION BETWEEN MEN & SYSTEMS

M. Sadoff
T. Wempe
J. Stewart

The proper definition of man's role in complex machine systems, or the optimum allocation of function between man and machine, depends to a large degree on detailed knowledge of man's ability to perceive and integrate information and to take appropriate control action over a wide range of machine characteristics and operational environments. Specific examples of pertinent research or analysis to obtain some of this required information include:

1. Effects of severe environmental factors such as sustained acceleration, or vibration, on man's ability to take appropriate and precise control action in spacecraft or aircraft operations

2. Manned vehicle systems analyses and human capabilities for precision control

3. Man's ability to perceive non-visual sensory information, e.g., rotary motions at threshold and supra-threshold levels.

We shall cover briefly here some relevant results in each of these areas, and, where appropriate, these results will be augmented by laboratory demonstrations during the visit to Ames Research Center.

EFFECTS OF SEVERE ENVIRONMENTAL FACTORS

M. Sadoff

Spacecraft and aircraft operations involve, during certain flight phases, the imposition of sustained accelerations, vibration and jostling and, possibly, combinations of these on the pilots or astronauts. For the Apollo mission, for example, moderate sustained accelerations and vibration will be experienced by the crew during the launch phase, and large accelerations will be encountered during the earth reentry phase. For the projected supersonic transport, structural vibrations will be experienced at the crew station during adverse weather operations. The required degree of automatic control for these vehicles (the proper allocation of function between man and machine) is contingent, in part, on the astronauts' or pilots' ability to perform precise control and monitoring tasks under these adverse conditions.

Previous studies, e.g., items 1 and 2 in suggested reading list, have provided some of the desired information. For example, in reference 1, it is shown that task errors in precision control tasks build up rapidly above about 6 g sustained acceleration. The rate of increase above 6 g was dependent on

the direction of the g vector with a much greater increase in error associated with inertial forces directed down along the spinal axis ("eyeballs-down" acceleration). It was also shown in reference 1 that control task errors increased rapidly as vibration levels exceed ± 1.5 g at a bias (sustained) g level of 3.5 g "eyeballs-in."

In reference 2, crew station acceleration responses (primarily vibration due to fuselage bending) during simulated thunderstorm turbulence penetrations with a representative current jet transport were implicated as possible contributing factors to several incidents involving marginal or complete loss of control observed during this study.

In the next section, one of the important methods used to analyze and predict pilot performance in complex man-machine systems is briefly described and discussed.

THE ENGINEERING APPROACH TO MANNED VEHICLE SYSTEMS ANALYSES

T. E. Wempe

General

A major problem almost always encountered in the design of aerospace vehicles exists in the matching of the vehicle characteristics with the capabilities of the human controller. Due to the adaptability and reliability of the human pilot, it is inevitable that, at least in the near future, all aerospace vehicles will include provision for the human in the control system. In fulfilling this requirement, the current trend is to treat the pilot as a definable part of the system in the same descriptive terminology as the rest of the system. However, this has not always been the case--- classically, handling qualities concepts were based on engineering knowledge of vehicle characteristics combined with the opinions of test pilots. Though that technique was generally adequate to describe a given aircraft in terms of pilot opinion, and more generally to catalog pilot reaction to some design parameters, it did not explain the mutual interaction between the vehicle and the pilot, nor did it lend itself to extrapolation to new situations and novel vehicle characteristics.

To achieve understanding and the capability to extrapolate, a mathematical theory was required which could be used to explain old findings and to predict new ones. For handling qualities a theory of this kind has been in the process of construction, refinement, and successful application for some years. It is based on the methods of control engineering, and treats the pilot-vehicle system as a closed-loop entity. Applications of this technique have resulted in the following:

1. The estimation of pilot-vehicle system dynamic response, stability and average performance.

2. The determination of barely controllable vehicle dynamics and controllability boundaries.

3. A delineation of those features of vehicle dynamics which are most likely to affect the handling qualities.

4. An indication of the type of additional system equalization desirable to achieve better pilot control. (Equalization can be accomplished by modifications in the display of information to the pilot, the control system or the vehicle.)

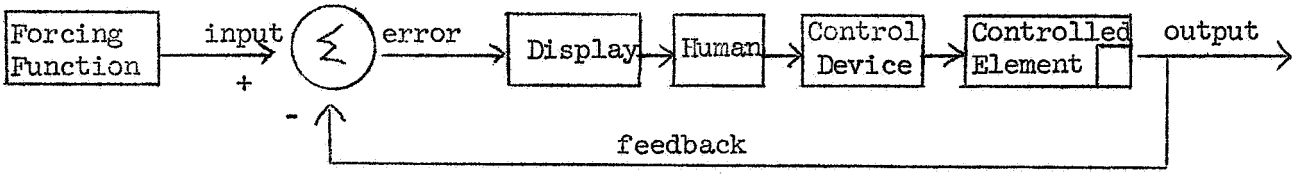
5. A determination of the maximum forcing function or signal band-width compatible with reasonable control action on the part of the pilot.

6. A mathematical description of pilot behavior (called the human describing function) in a particular control situation.

Though the first manned vehicles analyzed by this servo system approach were aircraft, the analytic technique has successfully been applied to helicopters, spacecraft, submarines, and even automobiles. Current research trends in this field include refinement of the human describing function model; the inclusion of decision processes, physiological processes, and data handling rates in the model of the human; and the interactions of these models with displays and control systems.

Example

The simplest model of a human in-the-loop system is the single loop system shown below:



This simple block diagram could be used to describe the pitch control of an aircraft or the heading control of an automobile being driven across a desert to an observable destination. In the former case the disturbance or forcing function would originate in atmospheric turbulence and in the latter case cross winds or an uneven surface. In both cases, the human only perceives the error between his actual heading and the desired heading (this is called "compensatory" tracking as opposed to "pursuit" tracking where the human also can perceive the magnitude of the disturbance or forcing function as well as the error). The control device (steering wheel in the automobile) is that device which the pilot or driver pulls or twists in an attempt to minimize the

error. The error display in the aircraft is the pitch attitude instrument; in the automobile it is the perception of the difference between the direction that the automobile is heading and the direction to the desired destination. For both the aircraft or the automobile the controlled element could be approximated by a rate element, i.e., for a constant deflection of the control device the error would increase or decrease at a constant rate if there were no disturbance.

In Laplace notation (the language of servo engineers since it simplifys the differential equations usually encountered) the relationship between the system output and the system input, in this case the forcing function, for this rate controlled element system is:

$\frac{\text{Output}}{\text{Input}} = \frac{H}{s + H}$, where H is the describing function for the human and s is the Laplace operator.

Since the Laplace operator s can be replaced by frequency (which originates in the forcing function) the above system will have a gain of approximately one for any frequency if H is equal to a constant that is much larger than the forcing function bandwidth (or the largest value of s). What this means in the example of the automobile is that if the driver makes a steering correction that is large but always proportional to the heading error (and also in the opposite direction to obtain negative feedback), then whenever the automobile would have been deflected one degree to the left a correction of one degree to the right would have occurred at the same time, resulting in a zero heading error. The greatest flaw in this supposition is that the driver can behave purely as a large gain in the system. He actually cannot perform in this manner because he has an inherent time delay (about .15 seconds of neuromuscular delay) built into whatever response mode he assumes; thus, at high frequencies he invariably becomes out of phase with the error, and if his gain is too high, he will increase rather than decrease the error. Consequently, he has to compromise and select a gain much less than optimum, yet one that for his capabilities minimizes the error--- which in practice he does rather effectively. Measured describing functions for human subjects in this kind of a control system can almost always be fitted by:

$H = Ke^{-ts}$, where k is a gain and e^{-ts} is the Laplace equivalent of a delay of t seconds in the function.

Though this example is trivial, the same technique is used to describe more complex manual control systems where, with the knowledge of human limitations acquired through laboratory experiments, predictions relative to performance can be made.

The Model of the Human

Human describing functions have been measured in a large variety of control tasks. These results indicate that humans have certain limitations due to their anatomical and neurological structure, namely, the time delay

mentioned above and, in addition, a constant lag effect. The human operator can also make certain adaptations, namely, he can change his gain, he can introduce a lead effect, and he can create a lag or filter effect. In the example of the rate controlled element system, the human operator uses his ability to generate a lead effect to cancel his inherent lag such that the neuro-muscular lag does not appear in measures of his describing function.

Referring back to the block diagram used in the example, if the feedback line were temporarily removed, the resulting relationship between the output and input is called the "open-loop transfer function." In the example of the automobile the open-loop transfer function is:

$$\frac{\text{Output}}{\text{Input}} = \frac{H}{s} = \frac{Ke^{-ts}}{s}$$

And, as mentioned before, good control is obtained if K is always larger than s (recalling that s represents a frequency in the forcing function). Stated in a different way, the frequency at which K/s equals one is the "cross-over frequency" and if this cross-over frequency is greater than the highest important frequency in the input, good control is obtained.

If the controlled element were different from the rate element used in the automobile example, but the human operator were able to provide sufficient equalization to make his describing function together with the controlled look like the open loop formula given above, then good control would be obtained if the cross-over frequency were high enough. Since human operators do tend to do this, the formula above is referred to as the cross-over model of the coupled pilot and controlled element and can be used as an approximation of the open-loop pilot-vehicle transfer function for a great variety of controlled elements.

In the final section, we shall discuss, briefly, some research directed at human sensitivity to non-visual sensory information, specifically, the ability to perceive rotational motion.

HUMAN PERCEPTION OF ROTATION

J. D. Stewart

Only a few scientific studies of the perception of rotation by man and the related phenomena of giddiness, dizziness and motion sickness were reported in the literature prior to the twentieth century. Since then there has been an expanding literature of thousands of reports on the topic including experimental and clinical work. An important contributing factor to the increase in this literature is the importance of these factors in aircraft and spacecraft operations. It became apparent early in the development of aviation that the vestibular apparatus (mans' principal non-visual sensors of

orientation and motion) played a critical role in blind flying and is still significant in current operations of aircraft and spacecraft.

The principal non-visual sensors that contribute to the perception of rotation are the semicircular canals that are located in the non-acoustic portion of the inner ear. Each semicircular canal forms about two-thirds of a circle with the remainder of the circuit being completed by the utricle. Near one "end" of each canal adjacent to the utricle is an enlarged section called the ampulla. Within the ampulla the sensory epithelium forms a ridge referred to as the crista. The crista supports the sensory cells, each of which has many hair-like projections that pass into and support the cupula. The cupula acts as a spring-restrained flapper-valve that, together with the crista, forms a seal across the ampulla. A fluid, endolymph, completely fills the canal. Angular accelerations (changes in rotation rates) in the plane of the canal cause the endolymph, due to its inertia to flow through the canal, deflecting the cupula from its rest position (actually looking at this system from outside, the endolymph remains fixed and the canal moves). Deflection of the cupula supporting sensory cells gives rise to the sensation of turning. To allow the perception of rotation about all body axes each inner ear has three approximately orthogonal semicircular canals.

The foregoing physical description of the operation of a semicircular canal has given rise to a mechanical analogy for the motion of the cupula and, hence, within limits, the perception of rotation. This analogy compares the semicircular canal with an over damped torsion pendulum where the supporting hair cells provide the restoring force or the spring effect of the supporting rod of the pendulum and the inertia of the pendulum bob or disk is analogous to the inertia of the endolymph. The effects of the viscosity of the endolymph on the performance of the canal is quite large due to the small dimensions and low inertia of the system and corresponds to an overdamped response of the mechanical system. This analogy for the operation of the semicircular canals has resulted in the formulation of a mathematical model that allows the relative deflection of the cupula to be computed for any angular acceleration input. One interesting and troublesome characteristic that results from the damping is the large time required for the cupula, once displaced, to return to its rest position when moving under the effects of its own elastic restraint. For most people, approximately 30 seconds are required for the cupula to return to within five percent of the maximum deflection. It will also take about the same amount of time for the sensation of motion to die out. Under normal circumstances a person experiences no unusual problems when he turns his head since the initial acceleration must be followed immediately by a deceleration since the neck limits the angle through which the head can be turned. Therefore, the cupula deflections caused by acceleration and deceleration will cancel each other and the turning sensations will not persist.

There are, however, conditions where man is operating or riding a vehicle where the above characteristics, together with the existence of a small but not zero threshold for the perception of angular acceleration, can lead to severe problems. In the case flying under conditions of limited visibility, these

problems become extremely serious and have lead to many fatalities when either the proper instruments or instrument techniques have not been employed. Since the sensed quantity is angular acceleration and not angular velocity, it is entirely possible for a pilot to be turning at a relatively high rate without realizing it since, if the rotation has been maintained at a constant velocity for some time, the cupula will have returned to its rest position and he will have no sensation of turning. If somehow he realizes he is turning and attempts to apply an acceleration to stop the turning, he may actually experience a false sensation of turning in the opposite direction, even though he is not turning. This, of course, results from the fact that the applied acceleration is in one direction only and the supula requires 30 seconds to return to near zero position. If the pilot does not ignore this turning sensation he may cause the aircraft to reenter its original turn.

The first turn can be entered intentionally or accidentally. A spin, if allowed to continue for more than 20 or 30 seconds, can be especially dangerous, particularly for pilots inexperienced in spin recovery. Another method of entering the turn, that is particularly insidious, is when the pilot is completely unaware that he is turning. This unperceived turn is a threshold phenomenon and results when the accelerations leading to the turn are less than the pilot's threshold. Even though thresholds are low ranging from about 0.07 to $2^{o}/sec^{2}$, it is entirely possible to reach dangerous turning velocities within 20 to 30 seconds. This has resulted in aircraft entering a downward spiralling turn that frequently doesn't end until the aircraft strikes the ground. It is for this reason that much effort is being expended to develop improved instruments for displaying attitude information to the pilot.

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Effects of Severe Environmental Factors:

1. Sadoff, M. & Dolkas, C. B. "Acceleration Stress Effects on Pilot Performance and Dynamic Response," IEEE Transactions on Human Factors in Electronics, (2) 8:103-112, June 1967.

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The Engineering Approach to Manned Vehicle Systems Analyses:

3. Baty, Daniel L. Information Processing Rate as Influenced by Degree of Response Difficulty: A Discrete Tracking Task, Third Annual NASA-USC Conference on Manual Control, Los Angeles, California, 1-3 March 1967. NASA SP-144.

4. McRuer, D. and Graham, D. Human Pilot Dynamics in Compensatory Systems: Theory, Models and Experiments with Controlled Element and Forcing Function Variations, Air Force Flight Dynamics Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, July 1965. Technical Report AFFDL-TR-65-15.

5. McRuer, D. and Jex, H. "A Review of Quasi-linear Pilot Models," IEEE Transactions on Human Factors in Electronics, (3) 8, September 1967.

Human Perception of Rotation:

6. Gernandt, B.E. "Handbook of Physiology - Section I Neurophysiology," American Physiological Society, John Field (Ed.), 1959.

7. Gibson, J. J. The Senses Considered as Perceptual Systems, Boston, Houghton Mifflin, 1966.

8. Roberts, T.D.M. Neurophysiology of Postural Mechanisms, Plenum Publishing Corporation, 1967.

9. Stevens, S.S. Handbook of Experimental Psychology, Wiley, 1960. (Note: pp. 1191-1223, Wendt, G.R.)

CLOSED ECOLOGICAL SYSTEM

J. Shapira

The design considerations are dictated by the metabolism of the crew. The parameters of greatest concern have been set at the following values for design purposes. These are not "normal" values but rather the expected upper daily limits.

Daily Life Support Requirements (Kg)

Food (dry)	0.78	Expired CO_2	1.05
Oxygen	0.85	Water, urine	1.88
Water, drinking	3.50	Water, resp., pers.	2.68
Water, wash, etc.	1.50	Water, feces	0.15
		Solids, feces and urine	0.10

If only stored supplies of food, water and oxygen were provided and all waste were processed minimally, the total weight (including storage) per man per day at liftoff would be about 10 Kg. Thus, on a 400 day Mars flight with a crew of eight men, the total weight would be 32,000 Kg (35 tons). Total regeneration of water, oxygen and food from waste could reduce the weight of the life support system by 80%.

On a weight basis, recover of water would result in the greatest savings. Currently, the most promising systems are:

1. forced air evaporation-adsorption
2. "multifiltration" (only for wash water and condensate)
3. vapor compression-adsorption
4. vacuum distillation-pyrolysis
5. electrodialysis

Test results with (1) and (2) have been satisfactory in 6-24 hour runs. Bacterial contamination could be a major problem.

Recovery of food is a very difficult problem but might produce weight savings.

1. Bioregenerative Systems

   a. Algae - Advantages include possibility of using sunlight and ability to remove CO_2 from cabin atmosphere and return O_2.

   b. Hydrogenomonas bacteria - Use H_2, (from water electrolysis) as energy source, CO_2 from cabin atmosphere as carbon source, and urea as nitrogen source.

2. Physicochemical Systems

   a. Formose Sugars - Synthesized via

      $CO_2 \longrightarrow CH_4 \longrightarrow HCHO \longrightarrow$ sugars

   b. Glycerol and its Derivatives - Synthesized via

      $CO_2 \longrightarrow CH_4 \longrightarrow HCHO \longrightarrow C_3$-sugars $\longrightarrow$ glycerol, etc.

Advantages include high theoretical efficiency and ability to utilize by-products of currently best developed regenerative atmosphere control system.

SUGGESTED READING

"Conference on Nutrition in Space and Related Waste Problems," Tampa, Florida, 1964. NASA SP-70.

Human Ecology in Space Flight. Calloway, D. H. (Ed.), N.Y. Academy of Sciences, 1966.

ELECTROENCEPHALOGRAPHIC AND AUTONOMIC CORRELATES OF PERCEPTION AND PERFORMANCE

David B. D. Smith

I. Electrical Activity in the Central Nervous System (CNS)

A. Intrinsic Electrical Activity: Electroencephalogram (EEG)

1. Demonstration and description of the EEG and its frequency components of alpha, beta, theta, and delta waves.

2. Relationships of the EEG to behavioral states of sleep, alertness, consciousness and attention.

B. Specific Electrical Responses: Evoked Potentials (EP)

1. Demonstration and description of EP to sensory stimuli and their specific and nonspecific components.

2. Evoked potential correlates of selective attention and alertness.

C. D.C. Potential Changes: Contingent Negative Variation (CNV)

1. Demonstration and description of the CNV.

2. The CNV as an electrical sign of association and expectancy.

II. Environmental Effects on the Electrical Activity of the CNS

A. Hyperoxic and hyperbaric environments

B. Other stressful aerospace environments.

III. Autonomic Nervous System Activity as an Indice of Psychological States

A. Heart rate changes used as an illustration of how autonomic nervous system feedback acts to reduce or enhance the effects of sensory stimulation.

SUGGESTED READING

1. Brazier, M.A.B. The Electrical Activity of the Nervous System, Macmillan, New York, 1960, Chapters 16, 18.

2. Walter, W.G. Brain Mechanisms and Perception, Brit. J. physiol. Optics, 22, 1965, 1-9.

3. Lynn, R. Attention Arousal and the Orientation Reaction, Pergamon Press, Oxford, 1966, Chapter 1, 2.

4. Haider, M., Spong, P. and Lindsley, D.B. Attention, Vigilance and Cortical Evoked Potentials in Humans, Science, 145, 180-182.

USES AND HAZARDS OF DRUGS IN SPACE

J. Vernikos-Danellis

Since time immemorial man has been concerned about his well-being and has turned to nature and to chemistry to find means and material to maintain or improve his state of health. It is therefore not surprising that a certain number of drugs have been carried in all Soviet and American Space missions since exposure to the adverse environmental conditions of space might be expected to alter the physiological state of a living organism.

A. Drugs have been selected for the following uses:

1. To stimulate natural compensatory adaptation mechanisms to increase tolerance to extreme flight factors.

2. To treat an illness.

3. To enhance performance, eliminate fatigue and emotional stress.

B. There exists some evidence that exposure of an animal to altered environmental factors may affect the intensity, duration or even mode of action of drugs. This may be due to an alteration in:

1. absorption of the drug

2. distribution, e.g., changes in blood-brain barrier may determine extent of effect of drug on central nervous system

3. uptake and binding

4. action, e.g., drugs which act by causing the release of a physiological neurotransmitter would depend on the availability of that transmitter

5. rate of metabolism, e.g., inhibition of enzymes responsible for metabolism of drugs would result in prolonged duration of action

6. metabolic pathway, e.g., metabolism of a drug may proceed rapidly to one step but no further and result in accummulation of toxic metabolite

7. excretion, e.g., alkaline pH of urine results in decreased excretion of dextroamphetamine

It is therefore important to determine alterations in the physiologic response to pharmacological agents because man in space may not only be exposed to undesirable therapeutic effects but even to injurious consequences. This is of extreme importance, mainly because during a space mission medical control of physiologic responses to drugs is quite difficult, and rendering qualified and specialized medical assistance may be impossible.

C. Research in space pharmacology is concentrating on:

1. The study of pharmacological agents that enhance physiologic tolerance to unfavorable space factors and the undesirable side-effects of drugs that alter desirable physiologic responses:

   a. CNS depressants, tranquillizers, hypnotics, etc., also depress the hormone secretion in response to stress

   b. the CNS stimulant caffeine, potentiates the endocrine response to stress

   c. prolonged administration of Lomotil used to control diarrhoea and which contains atropine may alter visual acuity.

2. Changes in toxicity of drugs in space environmental stresses.

3. The study of the pharmacodynamic properties of different drugs based on various physiologic responses.

4. Finding optimal dosage and method of administration for different drugs under simulated space flight conditions and development of new compounds with specific effects suitable to space flight conditions.

5. Interaction of two or more drugs administered in the space environment.

6. Use of drugs as tools to understand actual effects of space factors on the human body.

WEIGHTLESS LABORATORY

C.M. Winget

I. Introduction

Recent successes in science and technology permit a planned systemic study of biological material in the weightless laboratory.

Many facinating problems of investigation are opening up for the biologist which focus on three fundamental problems: the modes and conditions of extra-terrestrial life, the biological conditions for ensuring successful human space flights and the maintenance of life on planets; the influence of external factors in space on the Earth's flora and fauna.

The biological space investigations on board the weightless laboratory will be concerned with many aspects and methods which are of fundamental importance. However, the foremost justification for a program in comparative weightless physiology is the functional adaptation to a changed environment can occur and an understanding of the mechanisms by which such adaptation occurs provide a basis on which to predict the effect of a future stress. Animals can respond to environmental stress either by adjusting (altering themselves) to correspond with the environment, or by changing their physiologic state by means of protective mechanisms to withstand environmental changes. Each type of response permits survival and is, therefore, adaptive. When an environmental stress is removed an animal tends to return to its previous mean state; that is, recovery stops at a point of body function equilibrium. Therefore, it is the task of comparative physiology to learn the extent and kinds of lability permitted by a given genotype in the space environment. Unique components of the space environment of importance to biological systems are weightlessness, weightlessness combined with radiation, the imposition of an environment removed from the Earth's 24-hour rotational periodicities (particularly effects on biorhythms) and cosmic radiation with energies and particle sizes unmatched by anything produced artificially on Earth.

The current view of animal studies in the weightless laboratory is distorted by a transient fact of history because of the unpredictably successful manned orbiting spacecraft, many including biological experiments. The Russians have already used 14 orbiting spacecraft, and the Americans have used 10 orbiting spacecraft. Some of these have been purely biological flights while most have carried "piggyback" experiments with limited space and weight; yet these few experiences represent a very small proportion of the total requirements placed on man if he is to successfully explore the solar system and the other celestial bodies in flights that will necessitate exposure to the space environment for considerably longer periods of time.

The Russian scientists have flown 56 different species and kinds of preparations of living organisms. Their results suggest that weightlessness might have some effect on the mitotic mechanisms of *Tradescantia microspores*, and that weightlessness produces a number of important effects on the physiology and behavior of the dog. (The Soviets use the dog as the human precursor.)

The Soviets have stated, "The most important scientific attainment thus far has been the discovery that weightlessness by itself has no mutagenic effect" (Gazenko & Parfenov 1967). There is no evidence that environmental stress per se can induce genetic change. However, combined genetic and physiological studies on animals at the limits of their physiologic norm may result in a genetic "adaptation." The weightless laboratory will permit the quantitative assessment for a given gene complex. This will require extensive combined genetic and physiological studies on animals in the Zero G environment.

The results from the presently approved NASA programs, when carried to completion of course, will lead to the techniques required for longer and often more dangerous space voyages.

The future animal experiments of the approved series will permit a statistical evaluation of biological mechanisms and a meaningful extrapolation of data and will permit probability statements concerning physiological mechanisms which presently are not forthcoming.

The fact that animal experiments may give the same results that have already been recorded for astronauts is no reason for not funding the animal experiments. As a matter of fact, if the circadian mechanisms are not altered in the 30-day or 21-day Biosatellite, as they apparently were not in the Gemini series, a new working hypothesis for the biologic clock will need to be formulated. At least from the academic point of view, this would be most interesting.

In short, experimental models to be tested in the weightless laboratory will be quantatized in the ground-based environment (G_S=1), hypergravity environment (G_S>1) and in the hypogravity (G_S<1) and all have implications to future manned space flights.

Because of time limitations this lecture will be restricted to the unmanned biological satellites. A basic scientific program making use of the satellite laboratory might be divided into the three general areas previously mentioned.

II. Several biological phenomena are thought to be affected by changes in gravity for plant development, embryonic development and metabolic activity in mammals.

A. Experiments have been flown or are scheduled for flight to evaluate changes in biologic parameters in a weightless environment:

1. Biosatellite A/B

2. Biosatellite C/E

3. Biosatellite D/F

4. Discoverer series

5. Mercury MA-5

6. Cosmos, Sputnik, Vostok and Voskhod series

B. Weightlessness-radiation experiments have been flown by both the Soviets and NASA.

1. Biosatellite A/B

2. Discoverer series

3. Cosmos, Sputnik, Vostok and Voskhod series

C. Biorhythms experiments are limited to a few observations made of the astronauts. There is a single approved rhythm study in the Biosatellite program and the possibility of one flight in the Biopioneer series.

III. The advantages and disadvantages of the manned and unmanned weightless laboratory.

A. Desire for visual laboratory observation

b. Equipment requirements

C. Availability

D. Exposure times

BIOLOGICAL RHYTHMS

C. M. Winget

Introduction (Suggested reading Solberger pp. 1-17)

This lecture (30 minuted) is to be a discussion of biological rhythmic mechanisms. The significance of these mechanisms to aeronautics, astronautics and to other life sciences will be indicated. Furthermore, this lecture is meant to be adjunct to other biorhythm discussions in this series, and a focusing on the application of biorhythms to aerospace medicine problems.

All living systems unicells to multicells, plants, and animals, including man, have not one but many timing devices. The biological timing mechanisms merit great interest, not only from the academic point of view but, as will be indicated, because of the information gained on the functioning of various organ systems and on the pathophysiological function of the total organism.

Background (Suggested reading Cold Spring Harbor Symposia 25:1-9, 1960; Bunning pp. 9-11)

The importance of periodicity in living phenomena has never been underestimated but it is only recently that it has been studied scientifically and systematically. Over 200 years ago the astronomer DeMarian first described experiments with plants showing periodic leaf movements. Gierse in 1842 first described daily body temperature rhythms in humans. Darwin in 1880 published a book entitled, "On the Power of Movement in Plants." These and other works have been the impetus for numerous clinical and physiological studies that indicate there is apparently no organ system and no function which does not exhibit a rhythm. It does not matter which physiologic parameters are being measured (e.g., dividing cells, volume of urine excreted, reaction to drugs, rate of problem solving) there is usually a maximum value and a minimum value in each 24-hour period. However, it was not until about 1950-1954 that students of rhythms recognized and treated their problem as one of time measurement. Along with this goes the discovery that many rhythms in plants and animals are temperature independent at least over a wide range of temperatures and that they are phase related to the photoperiod.

Physiologic Frequencies (Suggested reading Aschoff X-XIX, 1965)

A. There are many components to the broad spectrum of physiologic rhythms. For example are the following frequencies:

1. Circannian rhythms or annual rhythms and examples;

2. Infradian rhythms or rhythms with periods of several days or weeks and examples;

3. Selenian rhythms or rhythms with a period of approximately 28 days and examples; and,

4. Circadian rhythms or rhythms with a period of approximately 24 hours and examples.

B. The terms used to describe various features of rhythms can easily be defined by considering the rhythm as a quantity which varies periodically with time, for example, in the form of a sign wave (a gross oversimplification for any known daily rhythm).

1. Period

2. Amplitude

3. Phase

Circadian Rhythms in Man

Man requires regular physiological rhythms. These rhythms are closely related to the physical day-night cycle of the earth. In fact, they are synchronized with the day-night cycle of the earth found in the time zone of local habitat.

A. Phase shifts observed in crossing many time zones.

1. comparison between north-south and an east-west flight

2. astronautical flights

B. Desynchronosis

C. Injury effect on the circadian time scale

D. Drug effect on the circadian time scale

NASA Interest in Biorhythms

A. Pilot safety and efficiency of the commercial jet liner

B. Astronaut safety and efficiency

C. Living on other planets

1. Moon

2. Mars

3. Other planets

OXYGEN REGENERATION AND CARBON DIOXIDE CONCENTRATION

T. Wydeven

Oxygen Regeneration

Several different techniques have been proposed for recovering breathable oxygen from either waste water or carbon dioxide aboard a manned spacecraft. The physicochemical systems for oxygen recovery appear, at the present time, to offer more promise from a minimum weight, volume and power viewpoint than do the biological systems (e.g., algae). The following are some of the physicochemical schemes which have been proposed for oxygen reclamation.

1. Bosch Reaction Coupled with Water Electrolysis:

   Reduction $\quad CO_2 + 2H_2 \xrightarrow[\text{Fe cat.}]{1300^\circ F} 2H_2O + C$

   Electrolysis $\quad 2H_2O \longrightarrow 2H_2 + O_2$

2. Sabatier Reaction Coupled with Water Electrolysis:

   Reduction $\quad CO_2 + 4H_2 \xrightarrow[\text{Ru cat.}]{357^\circ F} CH_4 + 2H_2O$

   Electrolysis $\quad 2H_2O \longrightarrow 2H_2 + O_2$

3. CO_2 Electrolysis:

   a. Using a Solid Oxide Electrolyte:

      Overall Electrochemical Process: $\quad 2CO_2 \xrightarrow{1560^\circ F} 2CO + O_2$

      Chemical Step: $\quad 2CO \xrightarrow{750^\circ F} CO_2 + C$

      CO_2 is recycled back to the electrolysis cell.

   b. Using a Molten Carbonate Electrolyte:

      Electrochemical Step, Cathode Reaction: $\quad 4Li^+ + 4e \longrightarrow 4Li$

      Chemical Step: $\quad 4Li + CO_2 \longrightarrow 4Li^+ + 2O^= + C$

      Electrochemical Step, Anode Reaction: $\quad 2O^= \longrightarrow O_2 + 4e$

      Overall Reaction: $\quad CO_2 \xrightarrow{1022^\circ F} C + O_2$

4. Water Electrolysis:

$$2H_2O \longrightarrow 2H_2 + O_2$$

In all of the above schemes for reclaiming oxygen from expired carbon dioxide it will still be necessary to reclaim some oxygen (.36 lb) from waste water. The reason for this being that the oxygen man takes in per day (2 lb) ends up primarily as carbon dioxide (2.25 lb) but some water is also produced in the metabolic process. Water electrolysis has generally been the method chosen for recovering oxygen from waste water because of the simplicity of this technique relative to e.g., the complexity of the schemes proposed for reclaiming oxygen from carbon dioxide. The seminar will include a discussion of the advantages and disadvantages of the various approaches to oxygen recovery as well as the mode of operation and state of development of the systems designed to carry out the above outlined processes.

CO_2 Concentration

All of the techniques, except 3(b), listed under oxygen recovery from carbon dioxide require concentrated carbon dioxide for successful operation. This means that a CO_2 concentrator subsystem must be a part of the spacecraft life support system. (Carbon dioxide electrolysis using a molten carbonate electrolyte, 4(b), is designed to be fed cabin air directly without concentrating the CO_2).

Again, several schemes have been proposed for concentrating carbon dioxide. Among these are carbon dioxide adsorption on a molecular sieve or other adsorbent, permeation of CO_2 through a permselective membrane and electrodialysis. A discussion of the state of development of the above named CO_2 concentration systems will be presented including a discussion of the pertinent chemical and mathematical equations applicable to the different processes. The advantages and disadvantages of the proposed methods for CO_2 concentration will also be presented.

References

Atmosphere in Space Cabins and Closed Environments. Karl Kammermeyer (Ed.), Appleton-Century-Crofts, New York, 1966.

ADVANCED PROTECTIVE SYSTEMS DEVELOPMENT FOR IVA AND EVA

H. C. Vykukal

Continuing problems exist which, unless solved, will significantly affect man's ability to do meaningful and useful work in space and on planetary surfaces. The most significant problem is the development of a space suit system which does not encumber or reduce man's effectiveness in space. The primary considerations which affect the performance of space suits are:

1. mobility
2. reliability
3. leakage
4. pressure

Recognizing the overall problem areas, the Ames Research Center initiated studies of advanced suit design concepts. Although man will be required to perform within and outside (EVA) the primary spacecraft, it was decided that an attempt to develop an optimum suit system satisfying both requirements would compromise the suit design. As a result, emphasis has been placed on improving the mobility and reliability of the EVA suit system.

The resulting effort has produced the Ames AX-1 hard space suit. The suit demonstrates the following advancements in the state-of-the-art.

1. Suit reliability and useful life has been significantly improved because of the use of hard materials in the suit structure.

2. Mobility has been improved by an order of magnitude with the development of the stovepipe joint concept utilized in the AX-1. Typical comparative values of current suit torques vs AX-1 are:

	Soft Suit	AX-1
Shoulder Torque	20 ft lb	2 to 4 ft lb
Pelvis Torque	10 to 60 ft lb	2 ft lb
Elbow Torque	3 to 6 ft lb	.8 to 1.5 ft lb

3. Leakage of the AX-1 is 400 scc/min as compared to soft suit leakage which can be as high as 3,000 scc/min (1,000 scc/min for a new suit). Projected leakage for the AX-2 presently in development will be < 100 scc/min.

4. Higher operational pressures (AX-1, 5 psig) are permitted with AX-1 concept. Current suits, which operate at 3.7 psig, would become essentially unusable at 5 psig since the torques and mobility are a direct function of operating pressure. (AX-2 will operate at 7.5 psig pressure thus allowing for the use of mixed gas mixtures.)

The development of the Ames AX-1 hard suit concept provides basic concepts for continued development of complete hard space suit systems.

A locomotion and restraint aid concept has been developed and tested at the Ames Research Center which provides an astronaut locomotion and task performance capabilities comparable to his abilities in earth's gravity. The system eliminates the need for cumbersome tethers, powered locomotion mechanisms, foot stirrups, etc., as proposed for use in orbital space stations and provides the astronaut with a means for walking, sitting, and standing in a zero gravity environment. The problem of locomotion and restraint in zero gravity was solved by providing an artificial gravity force which holds the subject against the spacecraft structure resulting in normal traction forces and center of gravity control. This was accomplished by mounting a trolley on a track with constant force springs attached to a torso harness. The force of the springs (60 lb) allows for the subject to walk, sit, and perform normal tasks comparable to his abilities at one "g." One important problem that has been minimized is that by utilizing this concept, the development of many special space tools are no longer necessary. Neutral buoyancy studies have verified the concept.

SUGGESTED READING

Roth, E.M. Bioenergetics of Space Suits for Lunar Exploration. NASA, SP-84, 1966.

DETERMINATION OF CHANGES IN SENSITIVITY THRESHOLDS AND ELECTRO-PHYSIOLOGY OF THE OTOLITH DURING PROLONGED WEIGHTLESSNESS

INVESTIGATING TEAM

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Introduction

The purpose of the following proposed experiment is to evaluate the changes that occur in the vestibular apparatus when it is subjected to weightlessness for long periods. In the near future, man will set out to explore neighboring and more distant planets in our solar system. Voyages of his type would involve periods of several years. It is, therefore, important to learn how changes in the vestibular function will affect man, and whether he will adapt and perform satisfactorily in this environment. Thus far, the U.S. has gained some insight into behavioral and physiological changes in men subject to zero g's up to fourteen days. There are some indications that decalcification in space may be reversed with simple isometric exercises. On the other hand the extreme disorientation that took place when our astronauts tried to perform simple tasks in space, may reflect some of the maladaptions of the vestibular apparatus in space.

Performing similar tasks inside the living quarters of a large interplanetary space ship which would permit mobility may result in complete disruption of an astronauts ability to work. On the other hand, if the astronaut could adjust to any changes in the vestibular apparatus, it is very likely he could make long voyages in space without creating an artificial g environment. Furthermore, examining the vestibular apparatus on the cellular and organ level by monitoring its electrical output may provide physiologist with fundamental data otherwise unobtainable.

This experiment is primarily concerned with the otolith and how it reacts to linear acceleration in an otherwise zero-g environment. Our primary interest is in the otolith rather than the semicircular canal, because we anticipate less change in the semicircular canal's normal functions in response to angular acceleration as opposed to linear. Of course, the coriolis force, which accompanies movement in a rotating coordinate system, would

impose severe limitations upon space travelers, if they elected to create an artificial environment. The basic design of our experiment if flexible enough to allow evaluation of the coriolis effect on the vestibular apparatus, although the following experiment is designed to reveal most clearly the effects of weightlessness on the threshold sensitivity of the otolith.

Experiment

The basic hypothesis of this experiment is that the sensitivity of the otolith will change detectably under weightless conditions. The otolith has evolved and developed under a constant gravitational acceleration of one G, and the hair cells are constantly acted upon by the gravitational pull on the otoconia and gelatinous mass. This might be considered the normal or ground state of the utriculus and sacculus. Under weightlessness, with no movement, the hair cells may not fire at all or their firing patterns may be altered. During movement under weightlessness, the otoconia will stimulate the hair cells in an unnatural pattern for any particular movement. It seems likely that these altered stimulations, and the resulting altered firing of the neurons, will cause some change in the sensitivity of the otolith during space flights.

It is also hoped that during the 30-day prolonged weightlessness the otolith brain sensitivity will change. The change should be caused by the brain's ability to alter its interpretation of the neuronal firings. The brain might be able to adapt to the weightless firings of the vestibular neurons and enable the money to make adapted responses under weightless conditions. In order to evaluate these changes, the threshold level of otolith will be determined and electrical activity of otolith will be monitored.

This experiment is being done with a monkey, as opposed to a human subject, for two reasons. First, the implantation of electrodes in the vestibular

nerves will be a delicate operation which probably should not be attempted on a human. Second, the vestibular apparatus of the monkeys are morphologically and anatomically similar to that of man, and the thresholds to linear acceleration of monkeys and man are similar. Of the available monkeys, we have chosen to use the macaque genus, which is exceptionally immune to motion sickness. This will lessen the possibility of having to stop the flight short of 30 days, and will also increase the probability that the tests will be carried out with a healthy animal.

On the ground a group of monkeys will be trained to detect linear accelerations. This may be done by placing a monkey in a simulated capsule as he would be restricted in the actual space module; (the simulator being located at the end of a centrifuge arm). Immediately in front of the monkey is the eye-hand coordination panel and a button. Once the monkey is restricted in his capsule, the capsule is darkened and shortly before the test is to begin (30 sec.) a buzzer sounds to alert the monkey. The monkey is then subjected to high levels of acceleration by the centrifuge. The monkey will press the button initially as a result of random motion and eventually as a result of sensitivity to linear acceleration, and receives a food pellet as a reward. At other times the capsule will be darkened, the buzzer sounded and no acceleration applied. Noise and some small vibration from the centrifuge will also be simulated on the ground in order to standardize zero acceleration trials. The monkey should not respond by pushing the button. If he does, he receives a shock. Eventually, after long periods of training, the monkey will push the button when he senses that he is receiving an acceleration and not pressing when not sensing an acceleration. Once this has been accomplished for all of the monkeys, we determine the "on-earth" threshold by gradual accelerations and the monkey's responses. Having obtained one base line date in this fashion, we are able to launch our monkey and note changes in thresholds

under the weightless condition relating to his changes in sensitivity and correlating with disorientation problems. During the actual flight, a ground monkey simulates flight on the earth in order to serve as an extra source of base line information and to determine any change not encountered by our previous "ground-test" monkeys. It will be necessary to limit the number of monkeys to 3 at the time of surgery (electrode implantation) and to choose on the day before launch the actual monkey which is to fly.

Equipment

A basic requirement to detect changes in the sensitivity threshold of the otolith in outer space is providing a mechanism for producing linear acceleration in any direction with respect to the monkey. The most obvious means of doing this would be to accelerate the entire space craft in the desired direction. This method gives rise to several problems which may exceed the present or near future level of space technology.

Repeated accelerations of varying duration of .2g (ten times maximum earth threshold for a man) of a 1,000 lb. space craft would require a force of about 6,000 lbs. This is well out of the range of all existing thrust systems designed for orbiting space crafts. One solution would be to mate the space craft with a large booster capable of providing large thrusts such as the Agenda D. This would provide the necessary acceleration, but in only one direction. Furthermore, a linear acceleration of .2g for a small duration of times present a problem of trajectory logistics. Transfer from one stable orbit to another during linear acceleration would introduce a component of earths gravitation. If this force was constant during the orbit transfer, the linear acceleration could be considered to act along the constant resultant, but preliminary calculation show that this is not the case.

An alternative to accelerating the entire ship in one direction, would be to spin it at a constant angular velocity, thus producing a radial acceleration

seen by the monkey as a linear acceleration. By rotating the monkey with three degrees of freedom in the spacecraft, the different thresholds of the otolith as a function of spatial orientation could be found. The technical problems associated with this mechanism are considerable in that the angular acceleration (rate of onset) has to be carefully controlled so to eliminate any sudden impulse. This type of control system necessitates new innovations in space design engineering.

A more feasible and practical system is an orbiting centrifuge. A device of this type is described by Ralph W. Stone, Jr., William Letko, and W. Ray Hook of the Langley Research Center, in an article entitled "Examination of Possible Flight Experiment to Evaluate an Onboard Centrifuge as a Therapeutic Device." They suggested that an onboard centrifuge be used as a therapeutic aid to correct the maladaption of the vestibular apparatus used. This centrifuge has been designed to be accommodated in both the MORL and the Apollo-Lem vehicle. The Centrifuge would fit below the LEM adapter envelope. If such a thirty day earth orbit flight were proposed for the Apollo, this could serve as a secondary experiment. The monkey could then be taken out of the centrifuge at the completion of the mission and re-enter in the command module.

The use of a centrifuge to provide linear acceleration in space has several advantages over other methods studied as long as it is possible to keep the angular acceleration below the threshold of the monkey. Since the linear acceleration required is so small, the angular accelerations can be kept below the threshold by starting up the fuge very slowly. This will also make it easier for the spacecraft stabilizers to keep the spacecraft from rotating in the opposite direction of the centrifuge capsule. When the centrifuge is not in operation the capsule will be locked in one position along the circumference. The capsule (which will have 180° of freedom in three directions) will be locked in a position such that the monkey will be "eyeballs in" during launch and

re-entry, if re-entry is made in this same vehicle.

Since the monkey will be restrained in the capsule of the centrifuge for the duration of the flight, it will be necessary to provide slip rings for communications between the centrifuge capsule and the spacecraft--for electrical signals such as biological implants, accelerometers, capsule orientation motors and sensors, food pellet dispenser, and response button. In order to save weight on the capsule though, water and waste removal equipment should be located at the stop position.

A vibration and audio speaker should be mounted on the capsule to provide stimuli for a false test which are identical to the stimuli present during an actual test. These false tests are necessary to keep the monkey from learning to respond every time the lights go out and he feels vibration.

Electrophysiological Changes of Vestibular Apparatus and Related Central Nervous System

A. Implantation and Microactivity of Vestibular Nerve

It would be interesting to correlate the behavioral response of the monkey to actual sensory perception as detected by microelectrodes implanted within the vestibular nerve. Though the utricle and saccule are known to respond to linear acceleration, the role of semicircular canals with respect to linear acceleration is still unknown.[1] This question might also be resolved with the use of microelectrodes.

The accompanying diagram of the right inner ear illustrates the innervation of the sense recepting regions of the vestibular apparatus. The nerves from the ampullary receptors are the smallest branches of the vestibular nerve, and thus hardest to implant. However, response from the ampullary receptors

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[1]Textbook of Aviation Physiology, (ed.) J. A. Gillies, 1965, p. 1086.

alone can be recorded in another fashion, by implanting fine-tipped electrodes in the two locations specified on the diagram. Electrode #1 will pick up all responses to linear acceleration (and any other stimulae detected by either the utricle or saccule), while electrode #2 will detect mixed responses from both semicircular canal and otolith sensors.[2] Therefore, as Channel 1 data can be correlated to input linear acceleration, and the monkey's detection threshold, a spectral analysis combining Channel 1 with 2 will yield a signal response from the smpullae alone. That is, subtracting Channel 1 from Channel 2 should give a resultant signal corresponding to detection of linear acceleration by the semicircular canals.

Ground based studies simulating space conditions (except for weightlessness) and including variable and intermittent linear accelerations will give baseline data for both channels. The ground determined threshold response from the monkey may then be related to a frequency and/or amplitude response of the vestibular apparatus itself. Space studies may hope to show that the probable behavioral change in threshold responses to linear acceleration in zero gravity environment is a result of CNS adaptation and not decreased (or increased) sensitivity of the vestibular apparatus itself; or that the presence of a constant vertical component of linear acceleration (as in the 1G environment) alters sensitivity to other components of linear acceleration by vector or addition. It is conceivable that a vector model for detection of linear acceleration may be discovered.

B. Electro-encephalogram and Electro-oculargram Parameters

The EEG measurements of the parieto-occipital cortex is necessary to test the integrity of these areas since they are essential to normal spatial orientation.

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[2] "Relationship between the unit activity of the utricle-saccule of the frog and information transfer," T. Gualtieroth and D. Alltucker, Nasa Symposium, 1966.

EEG's of amygdaloid and hippocampal regions, and the midbrain reticular formation are necessary to insure that the monkey is focusing attention, in order to achieve spatial orientation.

EEG's of amygdaloid and hippocampal regions, and the midbrain reticular formation are necessary to insure that the monkey is focusing attention, in order to achieve spatial orientation.

As stated by Dr. W. Ross Adey: "In particular, it would appear that the isolated pursuit of vestibular functions without regard to higher levels of neural integration in orienting mechanisms, may disregard quite fundamental aspects of these integrative processes."[1]

The implantation of bipolar 29 gage stainless steel electrodes insulated except at the tips and separated by 2mm., stereotaxically inserted into:

1. amygdaloid and hippocampal regions of temporal lobe, and
2. midbrain reticular formation

has been conducted by Dr. W. Ross Adey on a monkey for the 30 day Biosatellite experiment. Also, the stainless steel screws are used as surface leads to measure the EEG of the parietal and occipital cortex.

The EOG (electro-oculargram) measures the eye movements during the orienting response by measuring the potential changes in extraocular muscles. The EOG is also valuable as a test for alertness in mental activity, and for a control in case the eye muscle potentials are picked up by the EEG electrodes.

It is expected that data analysis of the EEG through standard digital methods that have been developed recently, as applied to stochastic processes, would prove valuable. Some computations would include auto- and cross-spectral densities, including phase andles, shared amplitudes, and coherence functions. Analysis of EEG's by studying Gaussian distributions has been done recently in which mistakes in decision-making can be detected. These may be due to lack of concentration, so that this type of analysis would be valuable in

determining whether the decision not to respond is due to acceleration below his threshold or just a lack of awareness toward the decision-making process.[2]

References: 1. W. R. Adey, "Central Nervous Cardiovascular, and Visuomotor Studies Relating to Spatial Orientation in a 30-Day Primate Flight." 2nd Symposium on The Role of the Vastibular Organs in Space Exploration, Nasa Ames Research Center, 1966.

2. Almutt, Richard, Techniques of Physiological Monitoring - Vol. III - Syatems, RCA Service Comp., Cherry Hill, Camden, New Jersey, October, 1964.

Monitoring Parameters Indicative of the Primate's General Physiological Status

A. Phisiological Parameters

The requirement of monitoring the general physiological state of the primate during space flight is of great importance. Deviations in the general physiological condition of the subject are likely to produce changes in experimental parameters; therefore, in order to avoid misinterpretation of inflight data, any deflection from homeostasis should be determined. Body functions that should be monitored are the electrocardiogram (ECG) pulmonary wave form, blood pressure, deep body temperature, and the galvanic skin response (GSR). The electrocardiogram permits the monitoring of the heart rate and rhythm by detection of the electrical potentials generated by the contracting cardiac muscles. The pulmonary wave form can be detected by measuring changes in impedance associated with the expansion and contraction of the thoracic cavity. Both the ECG and the pulmonary wave-form can be monitored using the Gemini electrode set consisting of three chest leads attached to the body of the subject with electrolytic paste. Blood pressure should be monitored in order to gain

information concerning the interacting factors of blood viscosity and the diameter of the blood vessels. Insertion of a pressure sensitive transducer by means of intra-arterial catheterization is an appropriately direct method of measuring the subject's blood pressure. A very valuable index of the overall physiological state and of reactions to physiological stresses is the deep body temperature. Any implanted thermistor would be able to monitor this. Another index of his anxiety--reaction to stress is the GSR, which is a slow change in resistance of the skin measured between two points. The ungrounded, bipolar electrodes are placed on the soles of the feet to measure the activity of the sweat glands.

B. Environmental Control Systems

In biosatellite flights the life support system is an extremely complicated problem which requires much attention and effort. In this otolith function experiment it is essential that the monkey be maintained in a biologically acceptable environment. Ideally this would be identical to the normal earth environment of the preflight training and testing period. All variables, except for the test linear accelerations, should be kept at earth levels. However, if such control is not possible the variables should be monitored so that exact records of the experimental conditions are recorded and telemetered for monitoring the monkey's general state of health and for possible correlation with any unexpected results. Hopefully the findings of the 30-day biosatellite experiments may be used as in flight base line data, while additional ground data can be gained by preflight simulations. Control of atmosphere composition, atmospheric pressure, relative humidity, temperature, food, water, waste, radiation, noise, and vibration should be considered and acceptable values determined.

1. Atmosphere Parameters

   a. Composition of the air

      A controlled terrestial atmosphere shall be maintained so a two gas system consisting of 20% O_2 and 80% N_2 will be used.

   b. Air pressures

      The terrestial total air pressure at sea level is 760mm Hg (14.7 psia). In the vacuum of space, however, a lesser value in the capsule would be more efficient, reducing both the mechanical strain on the capsule and gas loss due to leakage. However, at pressures lower than 5 psi ventillation becomes a problem. Therefore the total pressure should be in the range of 360mm Hg (7 psi) to 760mm Hg (14.7 psi).

      The most effective partial pressures of O_2 and N_2 will need to be determined. Probable limits might be 150mm Hg (2.9 psi) to 185mm Hg (3.6 psi) for O_2 and 180mm Hg (3.5 psi) to 610mm Hg (11.8 psi) for N_2 partial pressure. If practical 1 atm total press should be maintained.

   c. CO_2

      Expired CO_2 should be kept below 7mm Hg (0.5 to 1% at 1 atm) and the excess filtered by means of lithium hydroxide.

   d. CO should be kept below 0.001%.

   e. Contaminating gases and particles may be controlled by filters such as activated charcoal. This air processing rate must be adequate to maintain balance.

   f. Comfortable relative humidity values should be determined.

   g. Comfortable temperature values should be determined 70-73°F.

2. Metabolic Parameters

   a. Food

      (1) A diet of banana flavored pellets which will be used for

rewards and will be supplemented.

(2) A natural food of low laxitive nature so bowel activity is minimized.

b. H_2O

Portable water can be recovered from fuel cells or recovered from urine.

c. Wastes

(1) Feces should be quick frozen or sterilized and dryed so that bacterial contamination of the atmosphere is avoided.

(2) Urine will be processed to obtain water.

3. Other Parameters

a. Noise

b. Vibration

c. Radiation hazards

References

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Nadel, Aaron B., Supporting Man in Space: 1970-1973, Research Memorandum, RM 5TMP-85, 30 November 1959, Technical Military Planning Operation, G. E. Co., Santa Barbara.

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Telemetry

The telemetry requirements are almost identical with those for the Biosatellite II. Most of the measurements need be made only during a test (while

the centrifuge is rotating). Since each test will be conducted while the spacecraft is within line-of-sight communication with the ground receiver, information such as that in Group I may be real-time transmitted while information such as that in Group II will be monitored continuously and stored on a magnetic tape recorder and transmitted upon a command from the ground.

Very few parameters can be pre-programed before the before the flight so information such as that in Group III will be transmitted from the ground to the spacecraft throughout the tests.

Group I

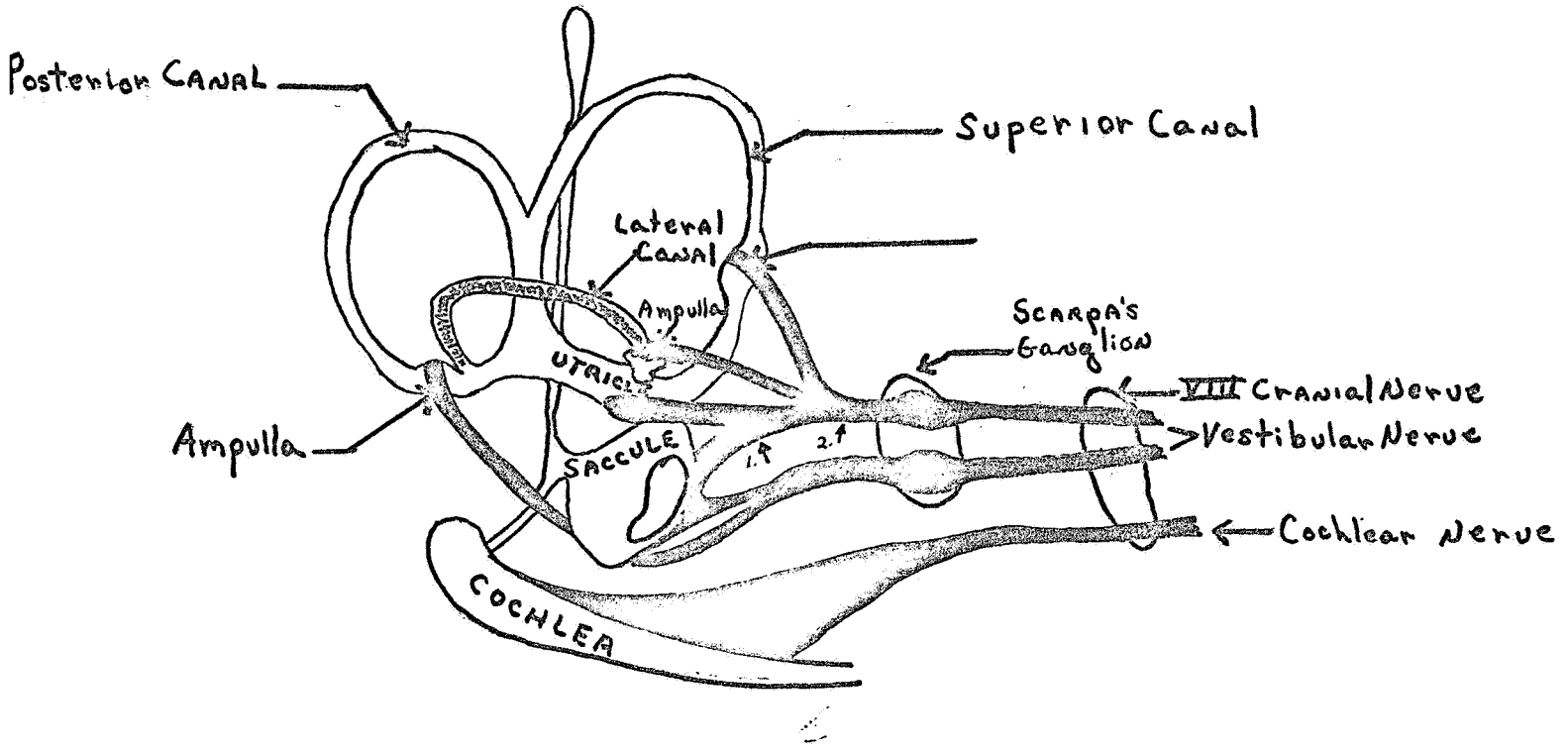
	Information	Frequency Spectrum (Hz)	Channels
1.	EOG	0-80	2
2.	EEG	0-80	10
3.	Carnical Nerve	0-333	2
4.	EKG	0.1-100	1
5.	Cabin Audio Noise	60-2000	1
6.	Cabin Temperature	0-1	1
7.	Cabin Pressure	0-1	1
8.	Response Button	0-1	1
9.	Orientation of Capsule	0-1	3
10.	3 accelerometers	0-1	3
11.	Water and Food Intake	0-1	2
12.	GSR	0-1	1

Group II

1.	Body Temperature	0-1	1
2.	Blood Pressure	0-200	1
3.	ZPG	0.01-20	1

Group III

Information	Channels
1. Food Pellet Dispenser	1
2. Electrical Shock	1
3. Cabin Illumination	1
4. Capsule Orientation	3
5. Centrifuge Drive	1



MEMBRANEOUS LABYRINTH OF RIGHT EAR

(1, 2) ↑ arrows indicate placement of microelectrodes

CHANGES IN VESTIBULAR FUNCTIONS IN SPACE

Chairman:	Philip Camill, Jr.	EE
	David Downing	EE
	Richard Scholof	Chem.
	Ken Schwartz	Chem.
	Carolyn Baker	Zoo.
	Alan Vinitsky	Zoo.
	Kathi Dalessandri	Bio.
	Al Firestone	Bio.
	Steve Lebowitz	Bio.
	Mike Lewiecki	Bio.
	Fred Aldrich	Math.

JULY 26, 1968

Introduction

For centuries, man wondered and dreamt about space flight. Now that the dreams are reality, man can no longer be satisfied with merely rocketing astronauts and cosmonauts about space. With the exception of the limited Biosatellite flights, all of the U.S.A. space flights have been mainly done to demonstrate our rapidly advancing engineering technologies to the world. These flights have typically been little concerned with the scientific and medical problems man may encounter in the space environment.

Specifically, we propose to investigate the function of vestibular systems in space. To date, both the U.S. astronauts and the Soviet cosmonauts have experienced varying degree of disorientation and nausea while in space. In addition, we have additional data from scuba divers who have experienced slight to severe disorientation when under water, a situation which simulates the weightless environment in most respects (Walter, 1968). What is definitely missing in our knowledge is a controlled experiment primarily designed to examine vestibular function in space, especially to determine what sort of adaptation may occur in long-term flights.

Toward this end we propose to orbit 2 Macaque monkeys via a Gemini-Titan booster for a mission of 30 days duration. One monkey is normal, and one is completely without labyrinth function. Macaque monkeys have been selected for the experiment because they have been extensively used in Biosatellite; and, thus, there is a large amount of base-line data available. In addition, the necessary instrumentation, including chronically implanted brain electrodes, cannot be done on man. (With man, contact electrodes would of necessity have to be used and these are much less desirable from the standpoint of recording desired electrical activity and reproducible of results. In addition to monitoring 8 channels of EEG from each monkey (detailed under Procedure), EOG, ENG, GIG, and other parameters will be monitored. These date will be telemetered

to ground stations and recorded there for analysis. These in-flight studies, combined with base-line studies done on the ground, will provide invaluable data and information to help further our understanding of man's response to the zero gravity environment.

Primary Investigation

Introduction

The sensitivity of nystugmography as an indicator of vestibular function is well recognized. As Eviatar (1968) notes, the phenomenon, "constitutes the primary approach to the study of disorders of the vestibular system in man." The importance of testing this parameter has been emphasized on recent Soviet manned flights during which electro-oculographic measurements were made (Baevskii, 1966). The technique of electro-oculography or electronystagmography (ENG) provides data which cannot be obtained by other methods (Philipszoon, 1967) and displays it in a suitable form for computer analysis (Eviatar, 1968; Johnson, et al., 1967; Herberts, et al., 1968).

Numerous factors are known to affect nystagmus: vestibular end organs (utricle, saccule, and semicircular canals), vestibular nerves, vestibular nu nuclei, medial longitudinal fasiculus, third, fourth, and sixth cranial nerves and their nuclei (Mahoney, 1957), reticular formation, cerebral cortex (Eviatar, personal communication 1968) and extrinsic eye muscles.

Although the precise control by the semicircular canals has been recognized, the remaining factors have not been elucidated. Recently, however, indications of otolith function were detected (Guedry, 1964, 1968; Janeke and Jongkees, 1968; Jongkees and Philipszoon, 1961). Specifically, Eviatar (1968) used vector analysis of nystagmus records which were obtained during labyrinthine surgery to resolve canal and otolithic components.

Various techniques may be used to induce nystagmus including rotational (Jongkees, Philipszoon, 1964), optokinetic (Honrubia, et al., 1968), and calorie

stimuli (Aschan, 1964; Eviatar, 1968, Hincliffe, 1968). In addition body position may produce nystagmus in certain pathological conditions. We intend to use these methods to detect changes in vestibular function during and following a 30-day space flight.

I. Positional Nystagmus

Positional nystagmus (i.e., spontaneous rhythmic eye movements in response to varying orientations to the g-vector) is rare in normal human subjects) but is more frequent in pathological conditions (Jongkees and Philipszoon, 1964). Comparison of pre-flight and post-flight data might, therefore, indicate gross vestibular disturbances.

Technique

Base-line data will be obtained on monkeys in the six positions suggested by Jongkees and Philipszoon (1964) and compared with similar post-flight records from test monkeys. No in-flight data will be collected since zero gravity precludes detection of position.

Data will consist of ENG's from four channels: horizontal, vertical, and two diagonals (Eviatar, 1968). (See 30-day biosattelite for method of EOG electrode implantation.) A means to insure mental alertness is needed to prevent cortical inhibition of nystagmus (Eviatar, unpublished monograoh). Electrical or sound stimulation are possibilities which are being considered and which will be tested for effectiveness. For optimal recording of nystagmus, the subjects are tested with their eyes open while in a dark room (Eviatar, 1968). An attempt will be made to train the monkeys to hold their eyes open. However, records can still be interpreted whether eyes are open or closed (Jongkees and Philipszoon, 1964).

Measurements

1. Body position
2. ENG

Expected Results

Monkeys exhibiting pre-flight positional nystagmus will not be considered for this study. The probability of post-flight positional nystagmus is not known. If such is detected, the response of the four channels will be analyzed by vector analysis (Eviatar, 1968), and an attempt will be made to determine the affected region.

II. Rotational Nystagmus

Rotational nystagmus (i.e., rhythmic eye movements in response to angular acceleration has been studied by numerous investigators. Within normal limits the speed of the slow phase is a linear function of cupular deflection as determined by the rate and duration of acceleration (Henriksson, 1955). Additional calculations have led to quantification of certain response parameters. For example, the time of onset of nystagmus in the human is approximated by the equation:

$$t = 10 \log_e \left(\frac{a}{a - .25} \right)$$

where t = time in seconds

a = magnitude of angular acceleration in deg./sec^2.

Comparison of t - values in all phases of the experiment (before, during, and after the flight) will offer a sensitive indication of changes in threshold values. Vector analysis will also reveal minor as well as major changes in the response.

Technique

Pre-flight calibration of the ENG will be conducted on monkeys which are in a horizontal position, facing a panel in a darkened room. Eight lights arranged on the octagonal panel are flashed alternately, and the graphic representation of known eye movements (20° of eye movement per 20mm movement of the needle on the ENG) is thus obtained. The calibration will be performed for each of the

four channels in order to compare accurately between channels (Eviatar, personal communication, 1968)

Angular acceleration in the absence of visual cues will be produced by thrust-controlled rotation of the spacecraft about the monkey's head-to-toe axis. Accelerations of 2 or 4 deg./sec^2 will be sustained for 20 seconds, and a constant velocity will be maintained for 2 minutes, followed by deceleration at 2 or 4 deg./sec^2 (Jones, 1966). A three minute rest period will be allowed between successive trials. Tests will be repeated until the monkey has received a total of three trials at each of the two acceleration levels and in each of the two directions of rotation. As mentioned previously, a method of assuring mental alertness during the entire test profile is required, and the spacecraft will be darkened to eliminate visual cues.

Base-line data will consist of the normal responses of untreated monkeys and completely labyrinthectomized (LD) monkeys over a wider range of acceleration levels to establish response curves, especially of latency values.

Measurements

1. Rate of rotation
2. ENG

   Time to onset of nystagmus
3. Additional functions to be monitored simultaneously as described elsewhere.

Expected Results

At this rate of stimulation one test should not affect the results of the next. (Fluur, et al., 1967). There is no a priori reason that there will be a marked change in the behavior of the semicircular canals as they respond only to change. The zero gravity environment may, therefore, merely involve a revised threshold (Grose, 1967). Thus ENG records comparable to those obtained during baseline recordings are expected. The effect on c anal threshold,

however, should be reflected in a deviation from normal pre-flight latency times. By comparison, zero gravity consistutes physiological differentiation of the otolith. Thus the vector analysis of the ENG should reveal marked changes in otolithic components.

Since the appearance of nystagmus under these conditions is primarily initiated and controlled by the vestibular apparatus, we would not expect the LD monkey to show nystagmus. However, possible effects of the factors other than the labyrinth (as discussed earlier) cannot be predicted. The procedures used for this rotational nystagmus can also be used to determine the threshold levels of the vestibular apparatus. The only difference would be a gradual increase in acceleration of the thrusters and have the monkey respond at his first sign of acceleration. This procedure could be done in two rotational modes by merely rotating the thruster boom 90°. In other words, the threshold values of the vestibular apparatus could be determined by this apparatus virtually with no additional equipment needed.

III. Optokinetic Nystagmus

The oculo-motor response recorded in these studies is a means of stabilizing the retinal image during angular movement of the head. In addition to the vestigular functions which the previous experiments were designed to test, the response also normally involves the action of optokinetic (visual) inputs. Several tests have been designed to determine the mechanism by which these inputs are perceived and the information processed. Specifically, Honrubia, et al., (1968) suggest the cortical role in "look" nystagmus and the subcortical influence in "stare" nystagmus in human subjects. The present test is designed to establish the characteristics of the "stare" nystagmus of the monkey in zero

gravity primarily to serve as a basis for the next experiment.*

Technique

Stimulus for producing the optokinetic nystagmus is a striped drum rotating around the monkeys heads. The program of drum rotation will be the same as that employed in carbon acceleration during tests for rotational nystagmus. (During this time the cabin will be stabilized. Normal cabin lighting will be on.)

The possibility that the monkey will not look at the moving drum or will alternately follow its movement or will stare at an angle fixed with respect to its body requires some device to cause the monkey to stare straight ahead. Therefore, the drum will include a transparent strip 1 cm wide (see equipment for further description). A white light behind the drum and slit and directly in front of the animal will be lighted for 3 seconds during each test (at times varying from test onset), and a pellet will be available to the monkey during that time. Thus, the monkey must look forward during the test time preceding light presentation in order to receive the reward.

Base-line data will consist of the normal responses of untreated monkeys and LD monkeys over a wider range of acceleration and sustained velocity levels to establish a response curve.

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*We do expect to find the "stare" nystagmus in the monkey, as the subcortical influence has been found in such other animals as the cat (Honrubia, et al., 1968). At present it is not known whether or not "look" nystagmus (found in man, but not in the cat) is present in the monkey. If this cortical influence can be shown, then in-flight tests for it would also be significant as applied to manned flight. For example, if a pilot were in free-fall during an abnormal rotation of the spacecraft, could his responses be anticipated? And if so, what means would be available to him to minimize the disturbing condition? The differentiation of factors influencing optokinetic nystagmus is not directly related to the present study of vestibular function and is, therefore, only noted with the suggestion that such tests might be included on the flight as secondary tests.

Measurements

1. ENG
2. Pellets eaten
3. Temporal and spatial patterns of stimuli
4. Additional functions to be monitored as described elsewhere.

Expected Results

Both normal and LD monkeys should show optokinetic nystagmus. At this time, the possible differences between the two monkeys and deviations from ground-based data cannot be predicted.

IV. Optokinetic and Rotational Nystagmus

Under conditions of normal gravity and amplitude angular movements, optokinetic, and vestibular influences normally work together to stabilize the retinal image. However, as Jones (1966) notes, in-flight, "where angular movements are frequently of much larger amplitude and longer duration than on the ground, this nicely concerted action of optokinetic and vestibular influences may break down. Recording under conditions providing both vestibular and optokinetic stimuli provides an additional measure of changes in vesticular function, measures the effects of the vestibular apparatus, on an additional parameter (optokinetic response), and may allow some determination of the relative importance of various orienting mechanisms in zero gravity.

Technique

Acceleration profiles for the drum (optokinetic stimulus) and the spacecraft (vestibular stimulus) will follow the program previously described. Accelerations of the two systems will be initiated simultaneously and will be of equal magnitudes, but of opposite directions. To simulate this condition, base-line data will be collected on monkeys rotating within a stationary drum.

The reward system as previously employed will be used.

Measurements

1. ENG
2. Pellets eaten
3. Temporal and spatial patterns of stimuli
4. Additional functions to be monitored as described elsewhere.

Expected Results

In the LD monkey, there should be no vestibular nystagmus, and the records obtained should be comparable to those made during optokinetic stimulation alone. However, as previously noted, rotation may have influences not mediated by the vestibular apparatus.

During acceleration, both vestibular and optokinetic forces are acting. It is difficult to predict the manner in which these two parameters will interact in the zero gravity environment. Jones (1966) has discussed the relationship between the two under several rotational schemes and indicates that under certain conditions the optokinetic response is dominant, while under others the vestibular influence appears to be the most significant. We would expect some change in relative strength of the responses under the various conditions tested.

V. Caloric Nystagmus

Initiation of nystagmus by caloric means is a common clinical procedure. Several explanations of the phenomenon have been proposed (Kellogg, and Graybiel, 1967). In 1906, Bárány suggested that heat conducted via the temporal bone to the semicircular canals initially resulted in a differentiated specific gravity in the endolymph, creating convection currents within the canal. Bartell attributed the response to a nerve effect, while Kabrak proposed that vascular reaction with construction of vessels in the labyrinth periphery caused an endolymph flow. The possible influence of pressure changes was noted by van Caneghem. Caloric stimulation during zero gravity conditions is expected

to give information which may elucidate the factor or factors involved.

Technique

Stimulation will be provided by an adaptation of the dry colorization technique developed by Eviatar (personal communication, 1968). This involves the use of a lubricated thin rubber tube placed in the external auditory canal through which water can be circulated. Both cold (30°C effective temperature, i.e., 25° circulated water) and warm (44°C effective temperature) stimulation will be used.

Water of the appropriate temperature to run through the tubing in one ear for 40 seconds. Nystagmus is recorded for 3 minutes, and an additional 7 minutes is given between tests. Each ear will be subjected to two tests at each temperature. This cycle of experiments should be conducted 5 or 6 times during the flight.

Measurements

1. ENG
2. Water temperature
3. Additional functions to be monitored simultaneously as described elsewhere.

Expected Results

In the no gravity environment, cold calorization of the right ear produces a left-moving nystagmus in normal subjects. No response would be expected from the LD monkey. Base-line data will include component analysis to determine more precisely the areas stimulated.

Experiments on human subjects during weightlessness in parabolic flight suggest that there is no caloric nystagmus. This is compatible with the assumption that the response is due to changes in specific gravity and suggests that a direct effect on nerves or circulation is not the primary cause. The possible influences of swelling and pressure have not been eliminated by such

treatment (Kellogg and Garybiel, 1967). However, in Kellogg and Graybiel's experiment, monitoring of the response was limited to a few seconds, and the researchers recognized the inadequacy of the test. It is therefore desirable to monitor the response during prolonged weightlessness.

VI. Additional Physiological Parameters

Using a rocking technique to vestibular apparatus Apanasenko (1964), Apanasenko (1966) measured EMG changes in the weight-bearing muscles of guinea pigs, before, during, and after vestibular stimulation. He noted that there was a sustained increase in the average firing rate after two weeks with 15 minutes of stimulation per day. The increased tonus resulting from frequent vestibular stimulation in this experiment will be monitored by two general techniques.

Techniques

The EMG of the gastronemius will be recorded by standard methods. In addition, Calcium, creatine, and creatinine levels in the urine will be monitored by procedures similar to those developed for the 30-day Biosatellite.

Measurements

1. EMG
2. Ca^{++}
3. Creatine
4. Creatinine

} levels in the urine

Expected Results

The EMG of the normal monkey should show a higher general level of activity than that observed in the CLM, as the latter receives no visbular stimulation. We also expect that the increased tonus may result in decreased Ca^{++} creatine levels in the urine of the normal monkey as compared with those of the CLM's.

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Destruction of the Vestibular Apparatus

There are three possible approaches to the problem of the destruction of vestibular receptors necessary for our experiment. Two methods, surgical destruction of the utricle and sacculus and doing induced destructing the fair cells, will both probably lead to deafness in the animal in addition to the desired vestibular destruction. The third possible method of ultrasonic destruction of the vestibular receptor, will not impair hearing and will thus avoid the addition of yet another stress factor to the already distraught animal. The technique for uthosonic destruction of the vestibular receptors was described by Arslan. This technique also needs less recovery time due to the less erious expects of the surgery involved as compared with surgical destruction of the lobyrinthes system.

Another reason for not using the apparently simple drug technique is that the drug may have sick effects which will disturb the results of our experiments. However, some ground based studies will have to be done to determine the precise effects.

The best reason for using the surgical method is that once the surgery has been completed, the destruction of the vestibular system is assured. To determine if the other two methods are effective, it will be necessary to complete some more ground based studies.[1]

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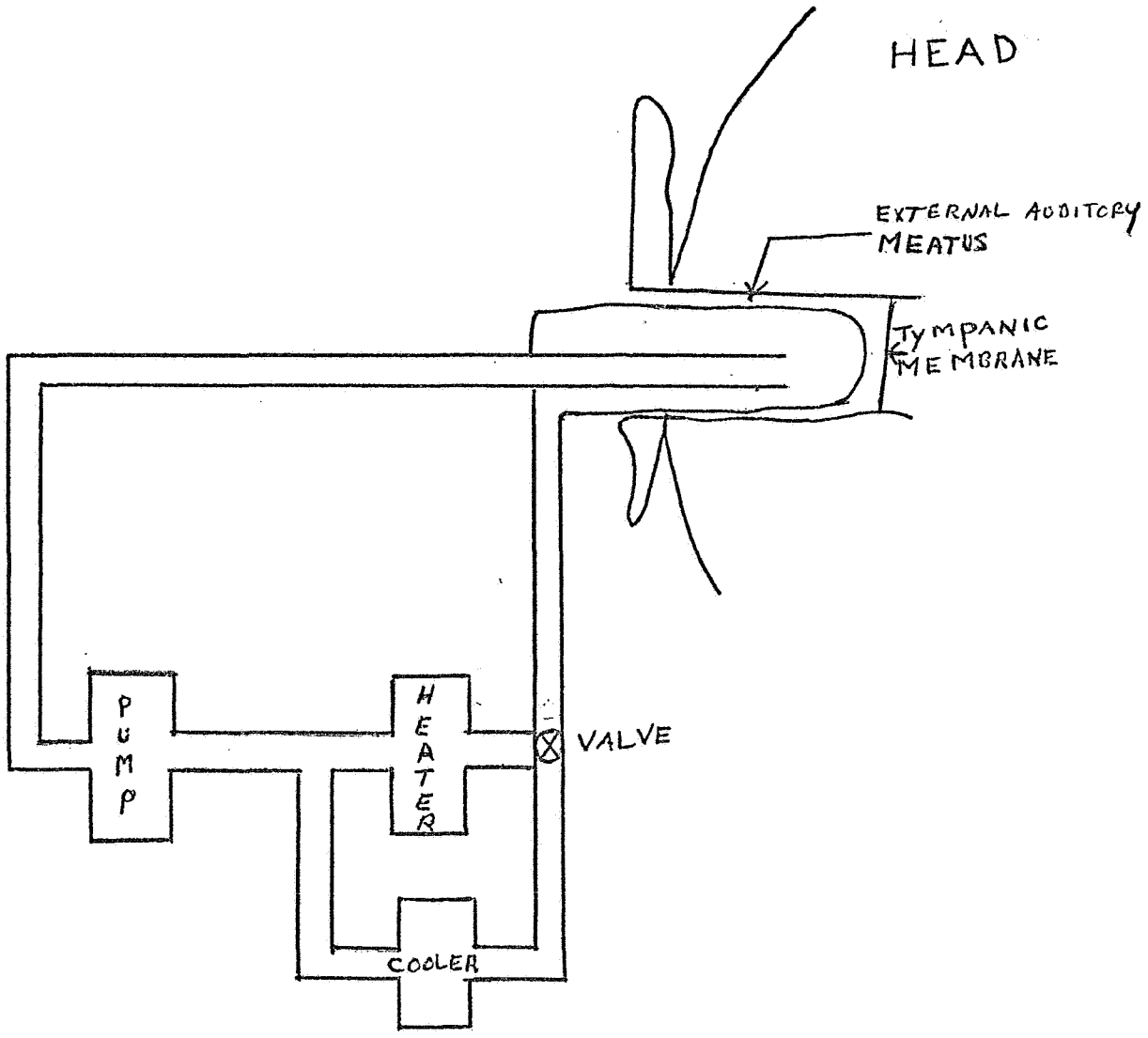
[1] "Ultrasonic Destruction of Vestibular Receptors," M. Arslan in The Vestibular System and It's Diseases, Ed. R. J. Wolfson, University of Penn., Pren. Philadelphia, 1966.

DRY CALORIC EXPERIMENT APPARATUS

(Diagramatic)



Secondary Investigation I

All of the following experiments have the standard feature of determining:

1. Base-line data: labyrinthine stimulation (rotatory or caloric) and non-stimulation of the normal and labyrinthine defunet (LD) monkey in normal environment.

2. Repitition of tests in zero gravity.

3. Set standards for each response measured in base-line experiments.

4. Using LD monkey as a control, analyzing the changes of the vestibular systems of the normal monkey and those caused by the changes of the vestibular systems of the normal monkey and those caused by the properly functioning.

I. Vestibular Affects on Uegetative System

Title: Changes in Skin Resistance From Labryinthine Stimulation in Zero Gravity.

Justification: On labyrinthine stimulation by thermal or rotatory means a fall in skin resistance can be recorded (Behr, 1955). Measurement of skin resistance is a very sensitive method for indicating the influence of the labyrinth on the vegetative system. Vertigo often associated with vegetative symptoms that are results of vestibular vegetative reflexes, yielding much sickness. Since motion sickness is a combination of somatomotor and vegetative reaction (contraction of the diaphram and abdominal muscles increasing the intra-abdominal pressure, relaxation of the stomach, contraction of the duodenum, etc.), it is important to correlate increased labyrinthine activity (which would lead to motion sickness) and skin resistance, so that in manned space flights, motion sickness could be foreseen and if possible prevented by appropriate drugs or other measures.

Aim: To monitor skin resistance changes during labyrinthine stimulation (caloric and rotatory) in zero gravity by GSR conditions in both a normal and

labyrinth defunct control monkey. This data will be compared to base-line data so that significant changes due to zero gravity labyrinth stimulation can be formed.

LD ⟶ Labyrinth Defunct

Procedure: The GSR electrodes are placed on the feet.

During rotation and caloric stimulation, both on the ground and with zero gravity, the GSR is monitored in both the normal and labyrinth defunct monkey. They can be compared to labyrinth unstimulated data in both environments. Any changes in skin resistance can be determined, and the affect of zero gravity and labyrinthine stimulation on skin resistance can be analyzed.

Measurements:

Record During Stimulation or Control ⟶

Normal Monkey	L.D.M.	
		1G - no stimulation, GSR
		1G - rotatory, GSR
		0G - no stimulation, GSR
		0G - rotatory, GSR
		0G - caloric, GSR

We are most interested in changes of skin resistance in zero gravity between normal and LD monkeys as compared to base-line studies during labyrinth stimulation.

Predicted Results: In both environments, skin resistance should decrease upon labyrinthine stimulation for the normal monkey only. There should be a greater resistance change in zero gravity stimulation than in similar comparisons in a ground environment.

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II. Vestibular Affects on Circulatory System

Title: Vestibular Affects on Carotinoid Blood Pressure in Zero Gravity

Justification: Experimental studies have shown that labyrinthine stimulation in decerebrate or anesthesized animals produce blood pressure changes, (Oppenheimer, 1947). It has been extensively studied, and shown that motion sickness produces changes in blood pressure (Maitland, 1931). Furthermore, these changes in blood pressure have been shown to effect cerebral circulation) Spiegel, 1944). This change in circulation may represent an important factor in the genesis of both the vertigo syndrome and orientation disturbances. To see if any blood pressure changes to the brain (carotid artery) occur in zero gravity under labyrinth stimulation is a first step in surveying possible reasons for disorientation of astronauts, so that these effects can be subsequently studied and, if possible, minimized.

Aim: To monitor blook pressure changes during labyrinthine stimulation (caloric and rotation) in zero gravity conditions in both a normal monkey and labyrinth defunct control monkey. This data will be compared to base-line data so that the zero gravity effect can be determined.

Procedure: A blood pressure recording catheater is implanted in the carotid artery of the normal and labyrinth defective monkey. The data can be recorded and telemetered to earth. Long-term studies for adaption will also be studied.

Measurements: During rotation and caloric stimulation blood pressure readings are recorded, both on the base-line experiments on the ground, and while

in a zero gravity environment. In both cases, the differences in blood pressure of the labyrinth defective and intact monkeys are compared to see if labyrinth stimulation caused any changes. Base-line studies can also be compared to see if zero gravity yields even greater blood pressure changes. Long-term studies can be analyzed to test for adaptation.

Predicted Results: We would expect blood pressure changes (both increases and decreases) upon labyrinth stimulation, with greater changes in zero gravity. Though the changes might be caused by the trauma of the experience, we feel that the base-line ground studies on the same animals will eliminate this since the animals will be exposed to these stimuli many times before the actual flight.

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III. Vestibular Affects on Auditory System

Title: Auditory Correlations to Labyrinthine Stimulation in Zero Gravity.

Justification: The ampulla of a semicircular canal of a pidgeon has been excited by a sound stimulus (Tullio, 1929), resulting in a deriation of the

head to the opposite side. Under these conditions, sound stimuli of 100 to 300 cycles/sec. produce microphonic potential waves in the respective crista (Bleeker, 1949).

It has been shown that removal of vestebular organs can immunize dogs and cats against motion sickness. (Kreicil, 1893). People whose labyrinths have been destroyed by disease are also immune to motion sickness. Chronic deaf mutes similarly do not become sick. In fact, clinical research has uncovered many pathological audiologic correlates of vestibular disorders. It is reasonable that the pathology of one portion of a system might affect another portion of it. Hence, it would be important to see whether labyrinthine stimulation in a streeeful environment would cause any changes in auditory function, since this could become dangerous for man in his space work.

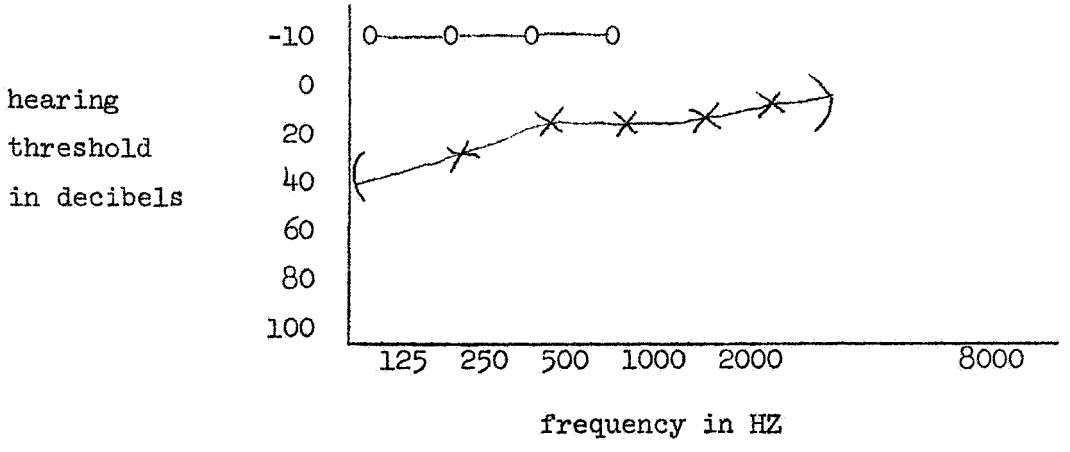
A recent study at Temple University Medical Center indicated that patients who complained of "dizziness," but who had normal audiologic findings tended to have normal vestibular examination as well, and laryngologists and nearologists suspected they had psychdogical or non-organic "dizziness" (Rosenberg, 1967).

Hence a sample test (monkey hears sound, presses lever to get reward only after sound, a simple variation of the clinical audiogram) to determine auditory function during labyrinthine stimulation (caloric or rotatory) under stressful environment could serve as an indication for man of any auditory changes that might be expected under these conditions.

Aim: To see whether labyrinth stimulation (rotatory or caloric) in a zero gravity environment will affect the ability of normal monkeys to hear the range of frequencies and of sounds heard with no labyrinthine stimulation, and to determine if the decibel threshold level for the normal animal is reduced.

Procedure: Both the normal and LD monkeys are given vigorous training to elicit the desired responses. Namely, when a frequency tone is applied to their ears through a headphone, they press a lever to get a reward. The length of time between tone application is altered, and the response must be immediately after tone cessation, or no reward can be received. This will reduce random lever pressing by the monkeys and make the tests more significant. (Note: a further reward could be the stopping of the labyrinthine stimulation upon pressing the lever correctly after hearing a tone. Obviously, preparations must be made to prevent contunual pressing of the lever by the monkey, so that no rewards can be obtained for any lever pressing over 2 seconds in duration.)

The frequencies are reduced and increased to determine the range that is heard. We assume when the animal does not respond correctly for a number of times, that the limit is reached. Similarly, the animals are exposed to decreasing amplitudes of each frequency heard to determine his threshold level. An audiogram can be constructed from the result:



Measurements: The process of making the Audiogram would be repeated for both monkeys in both ground and zero gravity environments, in both labyrinthine unstimulated and stimulated (rotatory and caloric) environments and the audiograms compared. We are most interested in determining hearing loss

(either amplitude threshold or frequency range) for the normal monkey undergo labrinthine stimulation or zero gravity, as compared to no stimulation, and any increase in hearing loss going to zero gravity (with stimulation) as compared to stimulated ground results.

Predicted Results: The labyrinth defective monkey should show marked hearing reduction (both amplitude and frequency). We feel that labyrinthine stimulation in zero gravity would not produce any significant changes in auditory function, since the many stimuli on the vestibular organs under normal conditions have no noticeable effects on hearing.

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IV. Vestibular Affects on Vision

Title: Optical Changes From Vestibular Stimulation in Zero Gravity.

Justification: Vision is an important factor in man's adjustment to unnatural environment (Guedry, 1966). Therefore usual discrimination tasks presented to monkeys during rotation (labyrinthine stimulation) in a zero gravity environment will yield information on how man's optical senses could be affected under similar conditions in space.

Aim: To perform the same visual discrimination tests on a normal and LD monkey, as was performed in Biosatellite II, except the tests are now to be performed during labyrinthine stimulation (rotatory). By company results of both monkeys to ground non-rotation and rotation studies, the effects of labyrinthine stimulation in zero gravity on visual discrimination can be determined.

Procedure: Both monkeys are thoroughly prepared in working the visual discrimination apparatus for rewards first while sitting still, and then while rotating. The test apparatus is the same as that on Biosatellite II; that is, a geometric shape is shown in the center area, it then goes off and ten seconds later the outer circular areas are lit with the (3 or 4) figures, one of which is the same that appeared before. If the monkey chooses the correct one, by pressing, he gets a food reward. This test is repeated in zero gravity in both non-rotation and rotating situation.

Measurements: The following is recorded daily:

	Normal Monkey	LD Monkey
0/0 correct selections for 1 - 0-G non-rotation discr		
2 - 0-G rotator discr.		

and similar records are made, preflight for ground tests. Also, habituation for 30/60 days can be (i.e., decrease in 0/0 wrong answers) studied.

Predicted Results

We would expect, slight or only intelligence difference responses in non-rotating ground base tests for both monkeys. Opun rotating in normal environment, if the LD monkey could maintain attention, we would expect slight, if any decrease in 0/0 corrections; and in any case, less than the normal monkey. We would expect similar results in non-rotating zero gravity en

environment and the most striking differences in the rotating zero gravity environment, with the normal monkey showing a much greater decrease in 0/0 correct responses.

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V. Neurological-Vestibular Correlates

Title: Monitoring the Cortical Projections of the Labyrinth of Monkeys in Zero Gravity.

Justification: From previous experiments it has been shown that labyrinthine impulses reach the area of transition of the temporal to parieto-occipital region of the brain by extra-cerebellar pathways (Aronson, 1933). These areas correspond to secondary visual area of the brain (evidence: could be optical-vestibulas correlation), where integration of usual as well as others sensory modalities take place upon labyrinthine stimulation (i.e., rotational can increase in potential discharges in these areas of the cortes have been noted (Grussey, 1959). It has been postulated that the impulses are transmitted to the cortex by multisynaptic systems such as the porto-meseneephallic retralar formations and nonspecific therlamic relay nuclei (Spiegel, 1967).

Hence, EEG recordings and evoked response results of the temporal lobe near the paretcal and occipital lobes and the other areas mentioned, can serve as a guideline to neuro-vestibular mechanistic changes under stress

(labyrinthine stimulation) and possibly elicit the impulse pathway for vestibular responses. Since man's proper brain function is obviously needed in long-term space missions, preliminary studies of neuro-vestibular responses are necessary.

Aim: To monitor (during labyrinth stimulation) the EEG of the normal and LD monkey in those areas of the brain sensitive to vestibular impulses in order to decipher any changes brought about by labyrinthine stimulation in a zero gravity environment.

The monkey should be blindfolded when awake tests are performed to prevent other sensory responses which could interfere with the experiment.

Procedure: Electrodes are implanted in the monkey's brain using the same technique as Biosatellite II. Probes must cover the temporal, panetal and occipital regions. Various deeper probes should cover the thalamic and pontomescrephallie veticular formation areas. (Note: in fact, these monkeys who have already been implanted for Biosatellite II can be used.)

Many base-line studies have been done ob the normal monkey. Similar tests are run on the LD monkey and recordings are made for both during labyrinth stimulation (caloric or rotatory) under normal gravity. The tests are repeated at zero gravity for each monkey and during the visual discrimination experiment. Checking and evoked response tests can also be done in the various environments.

Measurements: The EEG and evoked response results are monitored in all the situations mentioned above. Of particular importance is analysis of habituation in evoked responses after many daily tests in any particular environment. Computer analysis could yield frequency plots which might uncover any abnormalities, and patheays of impulses to the cortex (by determining which subcortical regions are activated on labyrinthine stimulation) when stimulated in zero gravity.

Predicted Results: We would expect to find temporal stimulation, and a sub-cortical stimulation (pathway) upon labyrinthine stimulation, which would not be present during non-stimulatory conditions in the normal monkey and never present in the LD monkey. We would not expect significant changes in the zero gravity environment, but possible slight increases (due to ↑ action of semicircular canal in stimulation) or decreased (due to ↓ action of otolith in OG) of potentials in all tests.

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Spiegel, E. A., "Anatomy and Physiology of the Cortical Projections of the Labyrinth," Dizziness and Vertigo (Speck, M., Ed.), Grune and Shalter, N.Y., 1967, pp. 75-38.

VI. Neuro-Vestibular Reflexes

Title: Monitoring Vestibulo-Spinal Reflexes in Monkeys Under Zero Gravity.

Justification: Balance and spatial orientation are maintained by streams of afferent impulses, many of which are generated by the vestibular system. Since these impulses lead to action by muscles and tendons, any impairment of vestibulo-spinal reflexes under labyrinthine stimulation at zero gravity could seriously impair ability of locomotions and equilibrium in astronauts. Hence, test of monkey vestibulo-spinal reflexes in this environment are needed to determine any abnormal reflexive changes when under such zero gravity stimuli, that might be expected in man as well.

Aim: To evaluate electrically, the vestibular spinal reflexes of a normal and LD monkey, during labyrinthine stimulation in a zero gravity environment.

By comparison of the two, we can evaluate any changes caused by the stimulators.

Procedure: Torok and Kahn (Torok, 1960) have developed a method whereby vestibulo-spinal reflexes can be evaluated electrically. The monkeys are harnessed into their chairs, and as the rotatory stimulus (labyrinthine stimulus) progresses, recordings of his lateral sway are made. Other body movements must be suppressed by use of the special couch.

It has been shown that coloric stimulation produces lateral twists of head, neck and body in the direction of the slow phase of the nystagmus in normal people (Hendriksson, 1962). Hence the pressure connections to these areas can monitor the reflexes, or lateropulsions. These are taken for both rotatory and caloric stimulation.

The same tests are repeated in a normal environment and comparison of the normal and LD monkeys in both situations are made.

Since light may interfere, the capsule should be darkened for this experiment.

Measurements: Latero pulsion recordings are made for both animals, in both environments while under rotatory, and then caloric stimulation. The Hendriksson apparatus, for example, can record the reflexes on standard chart paper.

Predicted Results: We would expect the reflexes of the LD monkeys to be less than the normal monkey in all tests, regardless of environment. Since there is already some correlations of vertigo and caloric stimulation, and also of vertigo and weightlessness, we would expect the greatest discrepencies in zero gravity calorid stimulations.

Bibliography:

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General Ref.:

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Secondary Investigation II

Urine Analysis

Aim: To analyze the urine for catechal amines, 17-hydroxycorticosteroids, uropepsin, epinephrine and norepinephrine in a normal and a labyrinth defective macaca nemestrina monkey under zero G conditions using a ground control monkey as a reference. During the zero gravity condition, the two monkeys will be subjected to rotation and to other vestibular stimulation. The urine will be collected and analyzed under these stimulated vestibular zero G conditions and also during unstimulated zero G conditions.

Purpose: The effect of zero gravity stimulated and unstimulated conditions on labyrinth defective and normal monkeys may yield very significant data not only in EOG, EEG, EKG and GIG feedback but also in urine analysis. For example, a biochemical evaluation of the effects of stress can be made by analyzing the urine for significant changes in amounts of stress hormones such as epinephrine, norepinephrine, 17-hydroxycorticosteroids, uropepsin, and catechal amines. The possible results, based on previous studies done in parabolic flight, are shown in the graph forms which follow. The value for stress hormones are plotted in micrograms per hour and a six hour period of post-stress time is allowed for collection and analysis of all urine without interference from any other test.

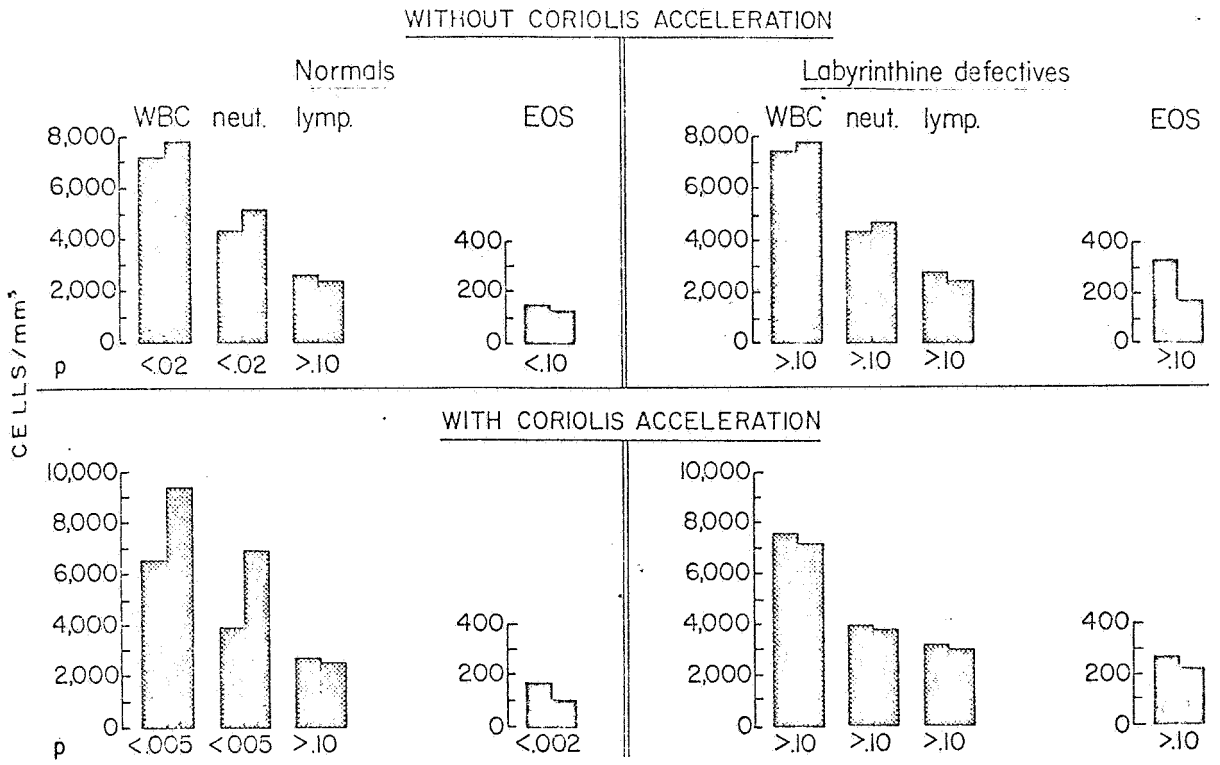

Figure 2.—*Variations in leukocytic elements in the blood after zero-G parabolic flight.*

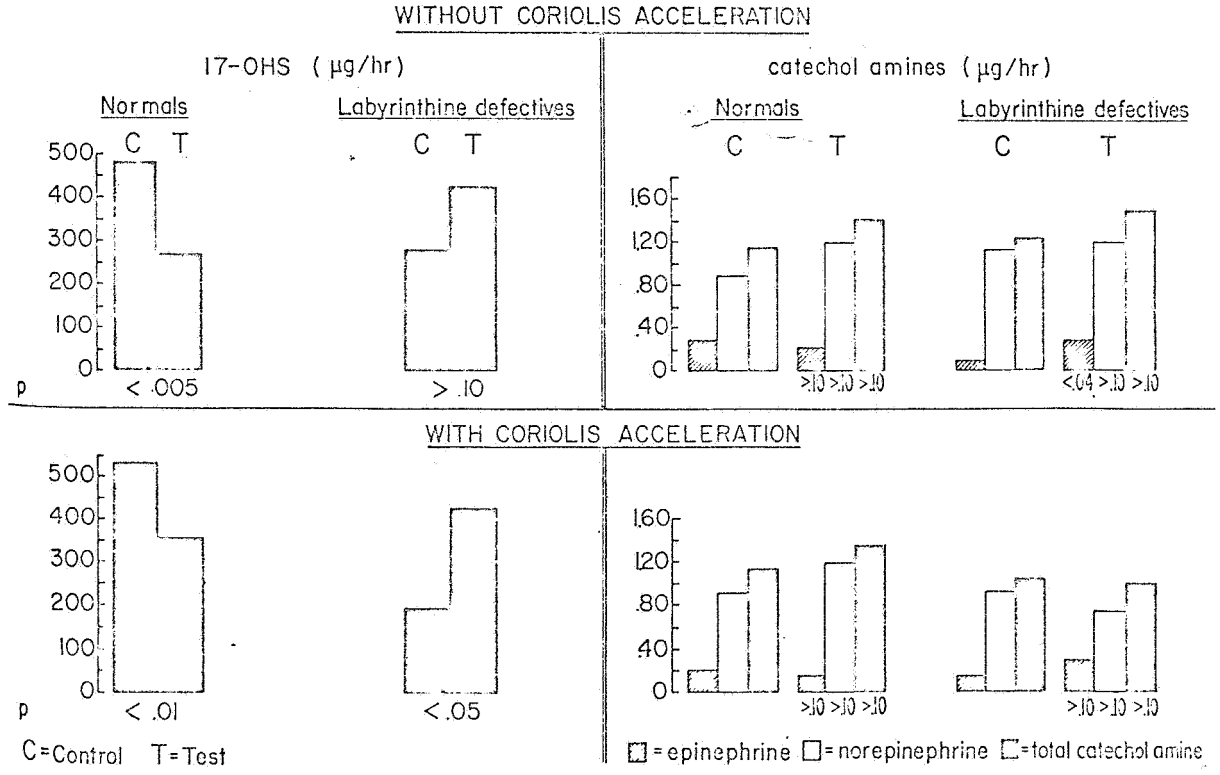

Figure 3.—*Stress hormone excretion rates after zero-G parabolic flight.*

Table 1.—*Statistical Evaluation of Urinary Stress Hormone Levels in Normal and Labyrinthine Defective Subjects After Acrobatic Flight*

[E = epinephrine; NE = norepinephrine; T = total catechol amines; F = free 17-OH corticosteroids; C = conjugated 17-OH corticosteroids; TC = total 17-OH corticosteroids; TU = total uropepsin; FD = flight day; NF = nonflight day]

Subjects	Mann-Whitney "p" Values											
	Resting (NF) vs. afternoon (NF)			Resting (FD) vs. afternoon (FD)			Resting (NF) vs. resting (FD)			Afternoon (NF) vs. afternoon (FD)		
	Catecholamines											
	E	NE	T	E	NE	T	E	NE	T	E	NE	T
Normal	>.1	>.1	>.1	.005	.005	.005	>.1	>.1	>.1	.05	.05	.05
Lab. Def.	>.1	>.1	>.1	>.1	>.1	>.1	>.1	>.1	>.1	>.1	>.1	>.1
	17-OH corticosteroids											
	F	C	TC	F	C	TC	F	C	TC	F	C	TC
Normal	>.1	>.1	>.1	.01	.005	.005	>.1	>.1	>.1	.10	.02	.02
Lab. Def.	>.1	.05	.04	>.1	.005	.005	>.1	>.1	>.1	>.1	>.1	>.1
	Uropepsin											
	TU			TU			TU			TU		
Normal	>.1			>.1			>.1			>.1		
Lab. Def.	>.1			>.1			>.1			>.1		

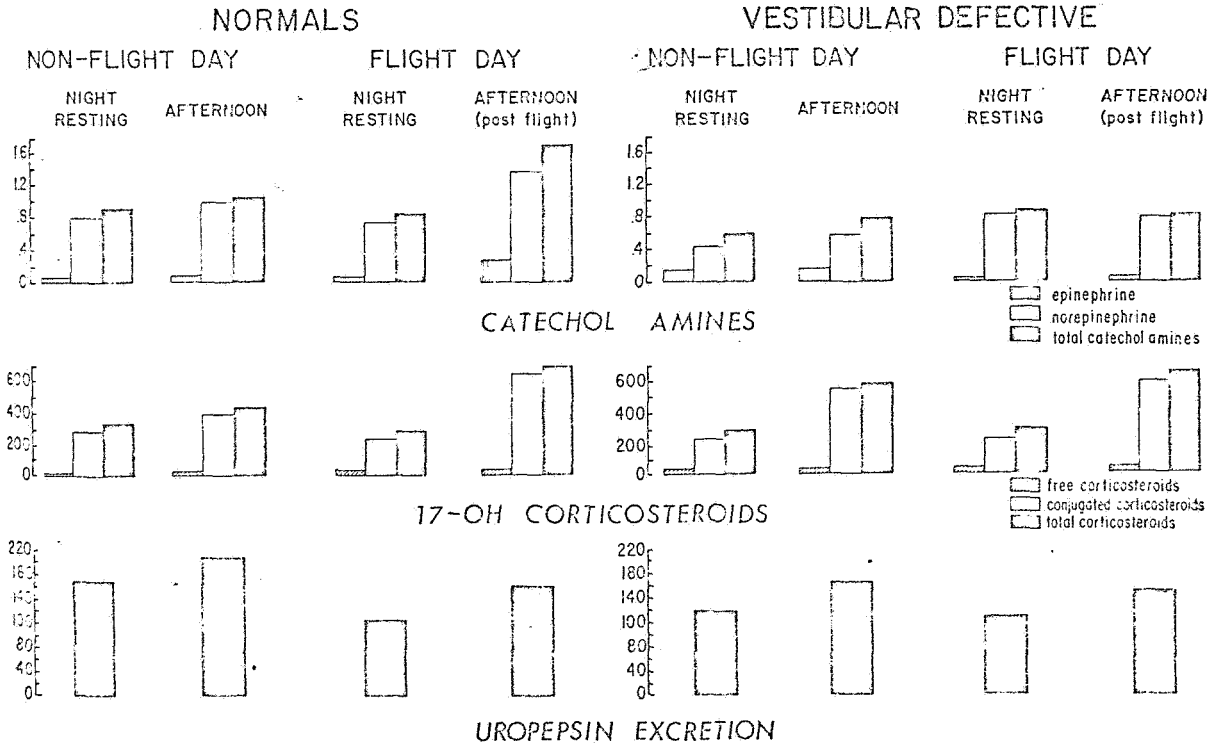

Figure 1.—*Stress hormone excretion after acrobatic flight.*

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Method

Chemical Tests

In order to test for catechol amines and 17-hydroxycorticosteroids, it will first be necessary to hydrolyze the urine at pH 1 to 2. This is necessary since the catechol amines (epinephrine and norepinephrine) may be excreted partly in the free form, partly conjugated with glucuroine acid, and partly as ethereal sulfates. The corticosteroids also may exist as glucuronides.

Hydrolysis may be accomplished in a setup wimilar to that used by Pace and Rho: the urine and aqueous H_2SO_4 are mixed in a small vessel and heated with a resistance coil for a sufficient amount of time.

Preceding hydrolysis, a simple quantitative test for the concentration of 17-hydroxycorticosteroids is to measure their UV absorption (OD) at approximately 235 mμ. This is the wavelength at which the conjugated double load carbonyl group of steroids is expected to absorb.

Following this test, it will be necessary to remove the water from the urine sample. Since it is a very small sample (about 0.5 ml.), it might be feasible to simply boil away the water leaving the steroids and cathechol amines as solid material. This may not be practical in a zero G environment. If not, a system could be devised using $CaSO_4$ or LiOH, both of which are water adsorbants.

Once the water is removed, it will be necessary to make the steroids and amino acids volatile. This can be done by simply adding trifluoroacetic

anhydride t o the sample volatile elements are then passed down a gas chromatography column and their concentrations are then calibrated from the maximum voltage obtained on the chromatograph for each component. It will be necessary to use a column which has a good affinity for hydroxyl groups since epinephrine is a derivative of tyrosine (it differs by having an extra hydroxyl group).

In the telemetry of the gas chromatograph, it will not be necessary to transmit a continuous signal, but only the time at which the voltage of the recorder goes above its ground line. This can be done using a clock in the space capsule.

The creatine, creatinine and Ca^{++} concentrations can be computed by the methods developed by Pace and Rho of JPL and U.C. This procedure will not be detailed here, except to mention that the creatinine concentration is determined by its O.D. at 525 $m\mu$. The creatine concentration is determined by computing the creatinine level of a hydrolyzed creatine-creatinine solution through O.D. and subtracting from this the concentration of creatinine in an unhydrolyzed sample. This is an accurate indication of the creatine level since creatine can be hydrolyzed to creatinine in the presence of a lead catalyst.

Instead of removing the water from the urine sample, it is possible to simply run it as is through the gas chromotograph and simply add extra trifluoroacetic ahydride to react with the water. However, a large water peak would result in the chromatographic process, and this would obscure other peaks. Thus, it is desirable to keep the water content as low as possible.

For all of these tests, it will be necessary to have ground based data, especially for the gas chromatography, so that it can be determined exactly where the basic components of urine will show upon the gas chromatogram.

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The Coriolis Effect

It has been known for a number of years that angular acceleration can cause severely disorienting vestibular and oculo motor effects in man. (Money, K. E., 1965, Vestibular Problems in Rotating Spacecraft, Symposium on The Role of the Vestibular Organs in the Exploration of Space; Jones, G. M., 1965, The Vestibular Contribution to the Stabilization of the Retinal Image, same). The importance of these affects is of primary concern in the possible development of manned rotating space vehicles. Before rotation of a spacecraft is adopted in order to solve the cardiovascular problems of prolonged weightlessness, it should be demonstrated that: (1) the cardiovascular problems at zero gravity are a greater danger to the mission than the vestibular and oculomotor problems are at the proposed rate of rotation, and (2) that the cardio vascular problems cannot be solved in some safer way on a non-rotating vehicle. Our experiment will deal with the latter part of (1) above, asking the question: What are the effects of various magnitudes of extraterrestrial vehicular rotation in inducing nystagmus and the coriolis effect on two experimental monkeys (1 normal, 1 with inactive vestibular apparatus?

Coriolis

Measurements: ENG, GIG, and GSR will be of primary importance.

Procedure: The spacecraft will be rotated slowly about the center of mass at a constant occulation of $2^{o}/sec^{2}$ (similar to the experiment on nystagmus) for 20 sec. Then held at a constant velocity for 2 min. then decellerated at a rate of $2^{o}/sec^{2}$. The animal(s) is then pivoted to a predetermined position (from base-line data) and allowed to experience the coriolis effect.

Should the animal become sick and symptoms of nausea begin, through the GSR and GIG, the ship will start decellerating. A special bag described in the life support system will be used to catch any regurgitated material. Ground base data will have to be established for some tolerance level.

Engineering Considerations

Spacecraft Design

A Gemini-Titan combination is used for the following reasons: two monkeys will be used; there is a great deal of instrumentation, life support, and especially attitude control fuel on board; and because the G-T combination will be relatively off the shelf, in the sense that McDonnell-Douglas will be making them for the MOL project.

The two monkeys are placed back-to-back in the craft as shown (see diagram). Angular acceleration is achieved by use of the yaw attitude control mechanism. The center of mass of the entire spacecraft should be as close as possible to the spinal axes of the monkeys (see diagram). This arrangement is used as a compromise, as the goal is rotation about the individual monkeys spinal axis, or the longitudinal axis of the monkey. This C.M. should not vary as urine is collected and stored liquids (H_2, O_2, N_2, attitude propellant, etc.) are used. To detect any changes in the C.M., a series of accelerometers should be placed at strategic places to be determined in the spacecraft and monitored to calculate the C.M. and to give readings about spacecraft rotational velocity (through integrators) and acceleration. The accelometers should be sensitive enough to detect 0.01 deg/sec^2, or whatever the minimal extraneous acceleration limit is (to be determined by ground base study. This should tie into an automated attitude control mechanism that is computer controlled. The computer should also control the thrusters to gain the desired experimental acceleration and direction. Small thrusters should be used (smaller than on the manned

Gemini flights) to obtain better small acceleration control and to avoid fuel waste due to large blasts of the attitude jets.

No windows should be used since they are unnecessary and because they would interfere with the controlled, 12 hour day, - 12 hour night circadian rhythm that will be strictly adhered to. Further, the doors need not be opened, so they may be well sealed and bolted shut to help with the leakage problem.

The monkeys will be placed as shown, eyeballs sideways (left and right), as has been explained. Since no ground base data is available for this type of support, the feasibility of this method must be studied. [Note: launch and reentry accelerations are in the same direction.] If this method is proved not feasible, the monkeys should be placed in couches that rotate from the eyeballs in launch position to this eyeballs sideways position for experimentation. This would complicate the spacecraft design considerably.

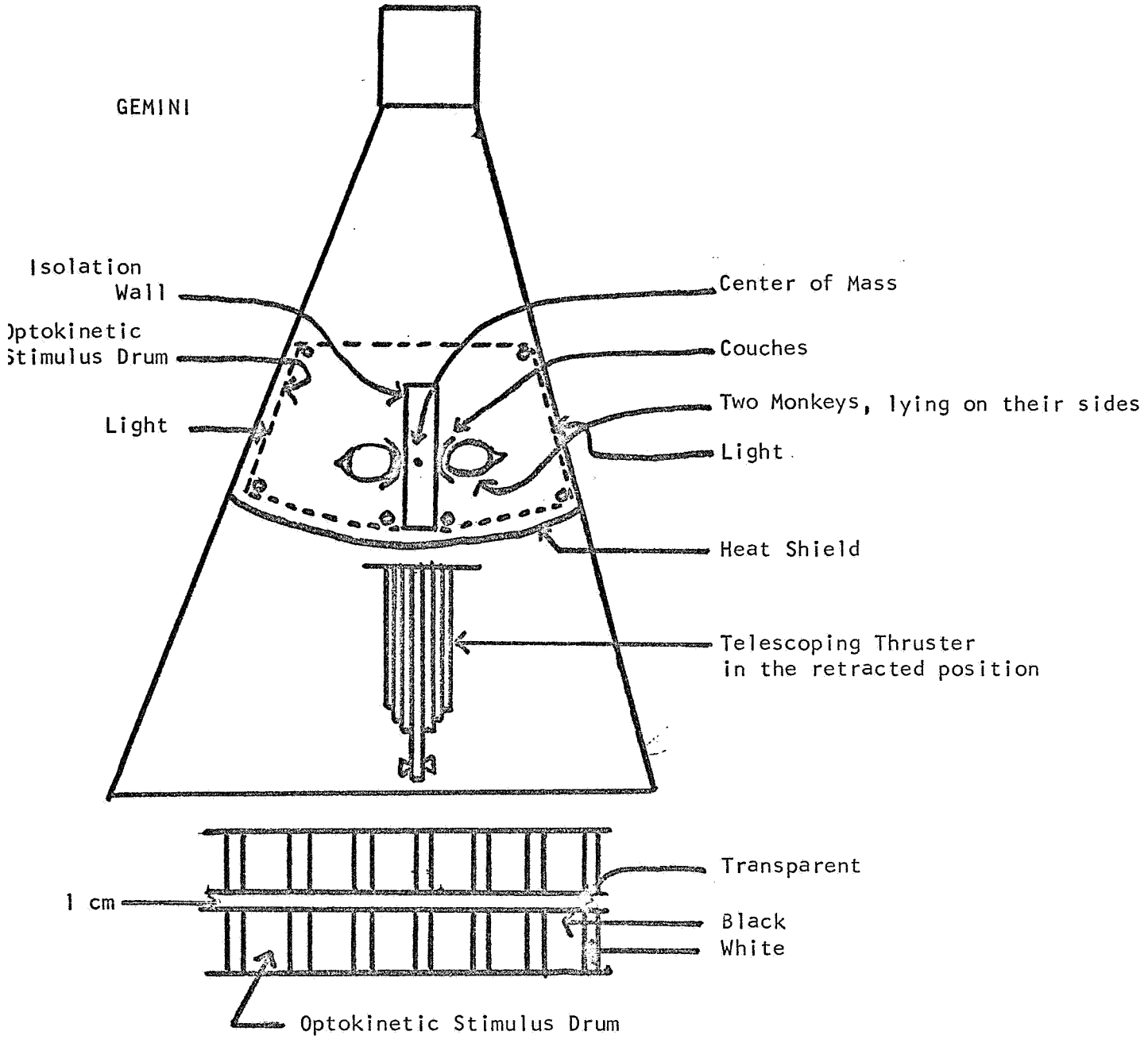
Finally, in order to conserve fuel for attitude control, we apply simple vector analysis:

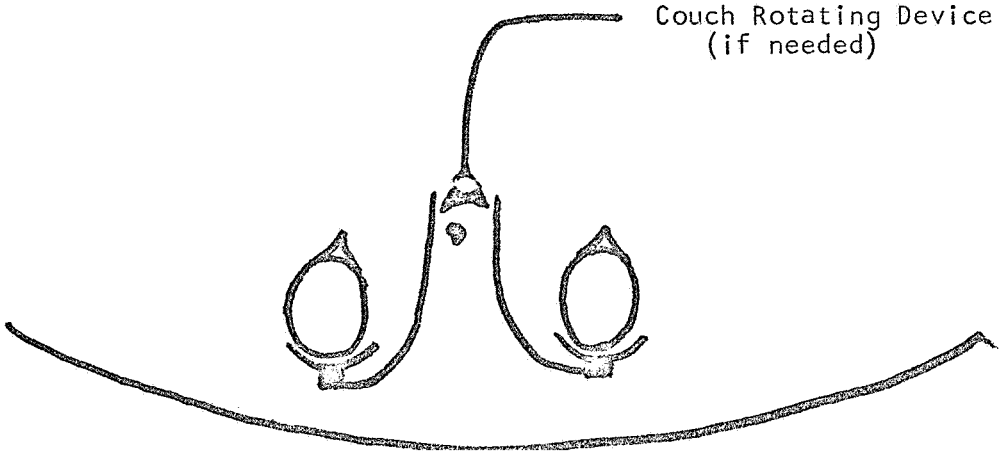
$\vec{N} - I \vec{\alpha}$ where $\vec{N}$ = torque, I = moment of inertia, and $\vec{\alpha}$ = angular acceleration. Now

$$\vec{N} = \vec{r} \times \vec{F}$$

so $$I \vec{\alpha} = \vec{r} \times F$$

or $$\vec{\alpha} = \frac{1}{I}(\vec{r} \times \vec{F}) = \frac{1}{I}(r)\ (F)\ (\sin \theta)$$ where θ is the angle between r and F. Now, for a given α required, we can do several things: decrease I, increase r, increase F, and make $\theta = 90^{\circ}$. We desire to keep F constant or reduce it, so we look at the other three. θ will be equal to 90° if we design the thruster correctly. I will be reduced by concentrating as much mass together as possible to the C.M. point (as shown in the diagram). Also, the thruster radius from the C.M. should be large. For this reason, the thruster could be mounted on a telescoping boom that would extend perpendicular to the axis of rotation.


GEMINI
Isolation Wall
Optokinetic Stimulus Drum
Light
Center of Mass
Couches
Two Monkeys, lying on their sides
Light
Heat Shield
Telescoping Thruster in the retracted position
1 cm
Transparent
Black
White
Optokinetic Stimulus Drum


Couch Rotating Device (if needed)

Life Support

A two-gas atmosphere should be used, even with its problems, because by the time this experiment is flown, this system will either be experimental and in need of testing, or that it will be fairly standard. In any case, we would like to use a 10 psia 30-70%, O_2-N_2 ratio. This pressure and ratio gives a nearly normal partial pressure of O_2.

Much of the rest of the life suppost system will be similar to the present 30-day Biosattelite program in nature, except doubled in capacity. Food and water will be dispensed in the same way, urine will be collected via catheter in the same way, and feces will be stored (hopefully) in the returning space capsule for analysis. Air would be recycled and humidity controlled. Water would probably come from the fuel cell power supply and a storage tank. Temperature and lighting would also be controlled to conform to circadian rhythms. No pressure suit would be used; instead he will be zipped into a couch (see couch design).

Since we will be testing these monkeys relatively severely, they may become nauseated. Base-line data of tolerance limits as well as the symptoms of onset, so that they be monitored and tests terminated if it occurs. Even so, as a backup and because weightlessness may alter symptoms, some form of "burp bag" or vomit trapping device is required. At the onset of any GSR or GIG abnormalities, the monkey would be restrained (see couch design) and then an arm with a plastic bag would swing over or down and fit over the monkey's mouth. It might look very much like the oxygen masks used on commercial aircraft. The act of vomiting should impart enough velocity to be forced into the bag. At the end of the vomiting, the bag would have the end constructed and would then swing back out of the way. Hopefully, it would never be used.

Couch Design

The couches here must be very specialized because they must allow the monkey a certain degree of freedom, yet must completely immobilize him at will (when certain experiments are performed). The monkey will wear a cap similar to Kado's EEG cap except that it will have a nylon strap around the forehead, over the ears to hold the earphones in place, and around the base of the skull in back. Two nylon ropes will be secured at the side of the head and will go through the headrest of the couch. On command, the ropes may be retracted and held firmly by friction brakes, immobilizing the head, yet allowing sufficient head movement when released. Similar devices from corist straps would immobilize the arms, if need be.

The couch must also be able to move the monkey's head in a pre-determined manner for the Coriolis--stress endocrine response test. To see the drive mechanism and details, see the diagram.

Finally, the torsional twisting of the spinal column under vestibular apparatus stimulation is to be measured by four small flat air bags, each with a pressure transducer. Two will be placed at the back of the head (one off to each side) and two similarly by the back in the thoracic region. When restrained, the monkey's head will rest against the bags, producing pressure responses in the transducers. The differential pressure will be sent to the amplifier for telemetering. Under stimulation, the head turns slightly, reducing pressure on one bag and increasing it on the other. This new pressure differential is then monitored.

Psycho-motor Response

Dr. Adey's psycho-motor response mechanism to be flown on the 30-day Biosatellite will be retained. The aim is to test the limit of motor response under strong vestibular disturbances. It has application to astronauts in emergency conditions, where they may have to operate under extreme stress and

vestibular stimulation. The monkey will press lights and follow the moving ring so long as he can see them clearly and is able to. This limit will be compared to base-line data (analogies to astronauts can, of course, be made).

Electronic Interface

This part of the communications system exists between the electrodes-implanted, intradermal, etc. and the telemotoring equipment. The number of channels required are:

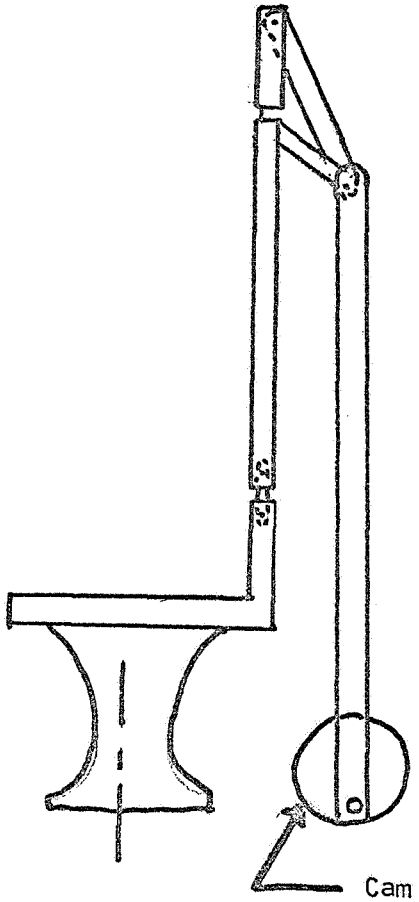
ENG (EOG)	4	channels
EMG	4	"
Blood Pres.	1	"
GSR	1	"
db Level	1	"
Audio Freq.	1	"
EEG	8	"
Brain Temp.	1	"

Other channels will be carrying life support and spacecraft information.

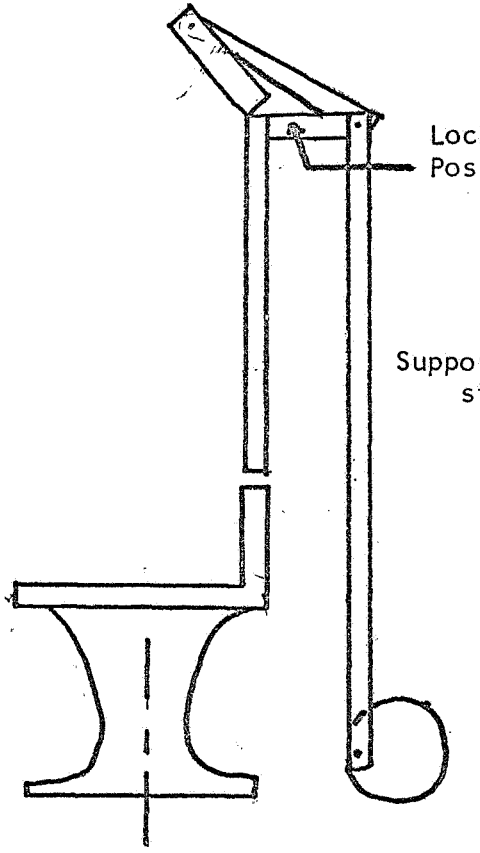
Other considerations:

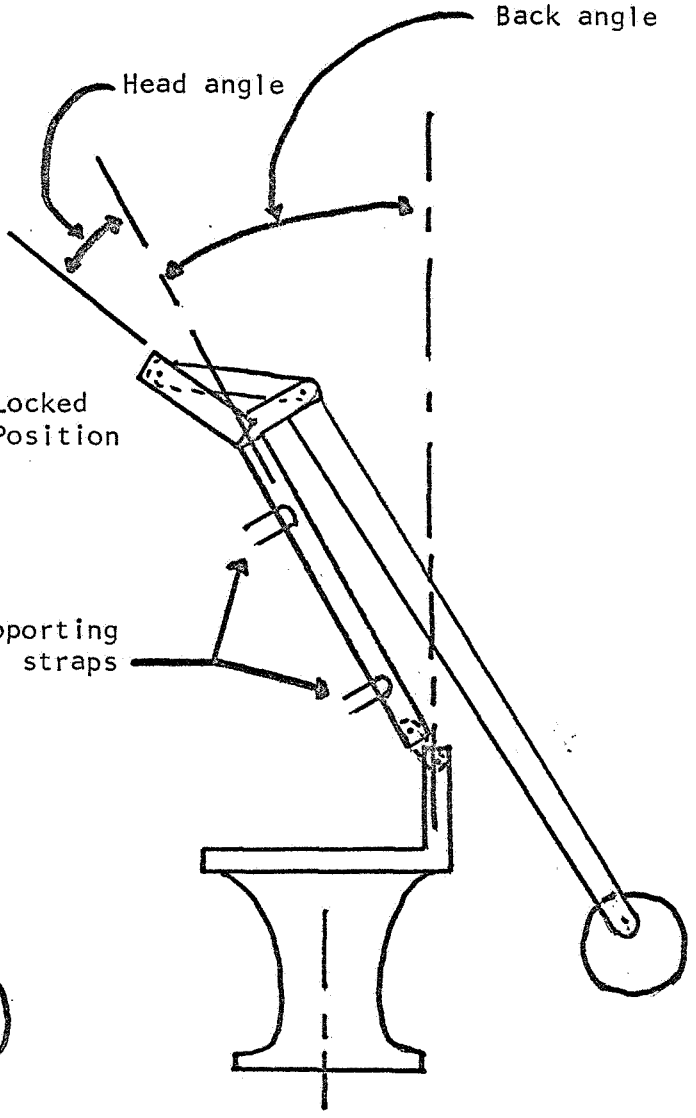
1. If selective monitoring is desired, then sufficient core storage will be available on the spacecraft to accumulated the data after being converted (A/D).
2. A computer will be on board so as to control all the experiments.
3. Two wide angle low resolution cameras will be monitoring the monkeys (possible with zoom lens).
4. An analog to digital (A/D) converters will digitize all signals before transmission.
5. General on board system diagram.

COUCH DESIGN



Chair in Restrained Position





Chair in Full Extended Position

6. A signal generator with a frequency of 100-8000 will be needed for an experiment in conjunction with earphones of similar response.

7. All functions on board will be coordinated with the ground stations via a clock pulse.

8. Strain gages will require a bridge.

Telemetry

Two methods are proposed for communication between the biosatellite and the ground station:

1. Selective monitoring:

   All the information obtained from the animals will be released only when the spacecraft is oriented over a specific ground station. Monitoring of the spacecraft will be a continuous process via either the syncaronous communications satellite or ground stations.

   For sending large amounts of information, it is proposed to use a pulse coded microwave signal, while continuous monitoring will use an FM transmitter.

2. Continuous monitoring:

   All information will be monitored by the ground station via the synchronous communications satellite or alternate ground stations. The transmission will be with an FM transmitter.

Since precise control will be needed for the on-board experiments, continuous monitoring of the spacecraft is essential. Some of the information that will be continuously monitored will be: (1) position, (2) rotation, (3) life support components, and (4) TV monitors.

On board the spacecraft will be a command receiver which will be in continuous communication with the ground.

A General Ground Station:

Power Supply

The D.C. power for the equipment will be supplied by the fuel cell in the adapter stage. A storage battery will be used for re-entry and emergency purposes.

Animals

The monkey used will be the macaque (pigtail) similarly implanted as in the 30-day Biosatallite.

Urine Analysis

The urine analysis will be similar in technique to that developed by JPL. The range of analysis to include epinephrine, etc., is within present technology. The catheter used will be a 15 Fr inserted personally into the bladder. This technique was developed by USC.

Sampling Problems

In order to accommodate all experiments during the flight, it may be necessary to perform them every second day, rather than performing them every day as is presently planned. This problem arises because there are 13 major tests being performed on the monkeys, the duration of which ranges from one to six hours.

In order to avoid inducing a circadian rhythm by giving tests at the same time each day, testing periods for each experiment for each day will be assigned randomly. Subsequent analysis of the data using spectral analysis and then analysis of covariance should detect any significant results.

Data Analysis

Techniques of data analysis which might be employed include:

1. Pearsonnian r.
2. Point biserial correlation.
3. Spectral analysis.

4. Profit analysis.
5. Multivariate non-linear regression analysis.
6. Factor analysis, followed by rotation to simple structure or by varimax rotation.
7. Analysis of variance.
8. Analysis of discriminant functions.
9. Autocorrelation (autocovariance)

Hopefully the experiments can be performed at the desired rates and replications so that ANOVA can be used. Factor analysis with rotation may also prove valuable. The data will probably have to first be reduced via frequency analysis, etc. Of course, it is possible we won't be able to venture beyond frequency analysis to more esoteric techniques. In any event, there are numerous methods of analyzing data from the experiments in order to obtain maximum information.

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for

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GROUP PROPOSAL

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INTRODUCTION

Disorientation may be an important response of higher animals to weightlessness. The dependence of such disorientation on changes in vestibular function is an unsolved problem, but it is known that weightlessness may directly and indirectly influence stimulation in the vestibular apparatus.

Previous short-duration experiments with mice (Henry, 1952) and water turtles (von Beck, 1954) suggest that surgical removal of the labyrinth may improve an animal's capacity to orient itself in the weightless state. However, similar, longer-duration investigations have not been reported.

The present proposal is designed to investigate the possibility that elimination of vestibular response improves the performance of a primate living for 30 days in an orbiting space craft.

Elimination of vestibular response is to be accomplished by local anesthesia and the monkey's performance is to be tested by psychomotor tasks involving head movement and eye-to-hand coordination. Although not a primary objective in the experiment, it should also be possible to obtain valuable information about the action of anesthetics in space.

EXPERIMENTAL DESIGN

In order to analyze the experimental animals vestibular stability, the test panel is designed to insure movement of the animal's head during his performance of the tests. The tests consist of two separate tasks. In order to accommodate these tasks, the panel is composed of two independent systems shown in figure 1. The first part (TEST A) consists of five buttons, which can be individually lit at different places on the panel; one in each corner and one in the center. Each button is surrounded by three concentric bands of progressively larger radii and divided into quadrants. During the test, one button will be lit at random and remain lit for one second. The primate will be given a total of three seconds from the time the button is lit to respond by pushing the button. Eight seconds after the first light, another button will be lit, and the animal will again have three seconds to make the correct response. The process will then be repeated for a third time. It will be necessary for the animal to push all three buttons within the specified times in order to receive a food pellet reward. The entire procedure would be repeated at one minute intervals during the testing periods. If the target button is spatially missed during the tests, the mistakes can be analyzed by recording which area of the quadrants, surrounding the button, was depressed. In this manner, possible trends in the animals errors can be detected, and his degree of disorientation can be measured.

The second test (TEST B) consists of two concentric disks of equal radius situated one above the other and located in the center of the panel. The lower disk has a button positioned near its rim; the upper disc, made of clear plastic, has a hole in a corresponding position. The two disks will be rotated at different velocities so that the button below coincides with the hole on top at regular intervals and at different positions. The

primate has to follow the movement of the disks and depress the button through the hole when the two coincide. After two successive correct responses the animal receives a food pellet.

The test panel itself will be slightly concave so that all points will be within approximately equal reach of the primate. A camera will be located in the upper central portion of the panel to photograph the subject at intermittent periods during the test.

The tests will be given for one hour periods, two times a day. The testing sequence will be as follows: fifteen minutes of Test A, a ten minute pause, ten minutes of Test B, another ten minute pause, and a second fifteen minute interval of Test A. The period of the tests will be variable in order to limit the number of food pellets to a maximum of twenty per period, with the option of supplying an additional twenty pellets per day by ground control if the subject is incapable of earning his minimum food requirements.

In order to obtain as reliable and thorough an index as possible of the primate's physical condition, several different physiological parameters will be monitored throughout the thirty day test. These include the EEG to follow the animal's pattern of alertness, EOG to detect the presence and extent of nystagmus, EKG and blood pressure, ZPG and deep body temperature. Body surface temperature and GSR will also be measured to give an indication of the subject's disorientation. Along with an EMG from the neck to record head movements, the primate's legs will also be monitored with EMGs to detect any involuntary leg movement which might reflect disorientation since reflex action is associated with otolith stimulation in maintaining balance.

To establish base line data, a series of ground control experiments will be conducted. During these preliminary studies the effects of the

anesthetic will be carefully evaluated in order to perfect surgical and application procedures. To allow for the possibility of slightly different effects of the anesthetic in space, a system will be provided which will allow either the dosage or the time of application of the drug to be varied by a command from the ground. Besides the pre-flight simulated orbits, a ground control will also be run, during the actual flight, in real time in order to simulate as nearly as possible all of the environmental parameters within the capsule.

DISRUPTION OF VESTIBULAR FUNCTION

The problem is to provide in-flight blockage of vestibular signals from the eighth cranial nerve in a primate. This blockage should be for periods of predetermined duration varying from 90 minutes to 10 days. This nerve block must be repeatable throughout the thirty day flight, without causing nerve damage. The activity of the nerve in flight must also be monitored electrically.

Two possible approaches are as follows:

(1) A thin cannula could be surgically implanted bilaterally on or near the nerve, the vestibular ganglion, or perhaps somewhere within the vestibular apparatus itself. An anesthetic agent could be introduced through this cannula at desired intervals. When the cannula is not being used for anesthesia it could be kept open by filling it with an isotonic or heparinized saline solution. When the command from the ground is given to anesthetize the nerve, an on-board, programmed sequence of events could be activated. This sequence would include (a) withdrawal of the small volume of saline in the cannula, (b) shifting valves to allow the anesthetic agent to enter the cannula, (c) forcing a known, predetermined amount of anesthetic agent into the cannula, (d) reversing the valves, and (e) forcing saline down the cannula again. Prolonged anesthesia could be achieved by

repeating event (c) when needed. The exact anesthetic agent and the exact dosage would, of course, have to be selected on the basis of ground lab experiments. Three good candidates appear to be (1) chloroprocaine and (2) Lidocaine for short term anesthesia, and (3) Tetracaine for anesthesia of longer duration. The nerve activity could be monitored by an electrode implanted in or near the nerve. In-flight drug dosage could be determined by observing changes in the electrical activity of the nerve.

(2) A cryoprobe could be surgically implanted bilaterally in or near the nerve. This probe could be controlled from the ground to provide temperatures low enough to altenuate the function of the nerve without damaging it. The collant could be alcohol, cooled by liquid hydrogen or oxygen, which would circulate inside the probe. The cooling process would have to be automatically controlled in order not to freeze the alcohol. The nerve activity could, again, be monitored by an electrode placed in or near the nerve.

In both of the above techniques it may be advantageous to eliminate the hearing ability of the primate by removal of the ossicular chain, a few months before the flight, possibly during the initial surgery. The predicted advantage of this operation is due to the fact that during the anesthesia, designed to block vestibular input, the primate would also experience a loss of hearing, if hearing had not been destroyed earlier. This sudden loss of hearing could affect the primate's performance.

Another possible problem would be the danger of accidental anesthetization of the seventh nerve. This might be especially critical during prolonged anesthesia. This problem could be solved by ground studies to determine the best location for the cannula or cryoprobe and then carefully monitoring the amount of anesthesia given or the temperature of tissues surrounding the eighth nerve.

Due to the fact that both divisions of the eighth nerve contain vestibular fibres, the entire nerve will have to be blocked rather than either single division. Later experiments could be done to determine the effectiveness of anesthetizing the superior division only, which might help eliminate disorientation in weightlessness, while allowing the nerve fibres to the cochlea, the ampulla of the inferior semicircular ducts, and the saccule to remain functional.

Control at the surgical stage of the experiment could be provided by sham operated animals.

TABLE I

Schedule for administration of anesthetic to 8th cranial nerve.

DAY	ANESTHESIA
1	0 (none)
2	0
3	morning only
4-8	0
9	morning only
10	0
11	morning only
12	0
13-22	continuously
23-30	0

*Two task periods per day: 9:00 a.m. and 4:00 p.m.
This schedule will be modified by real time data as seen fit.

LIFE SUPPORT SUBSYSTEM

The function of the life support subsystem will be to provide a comfortable habitual capsule environment comparable to that maintained in Biosatellite III. This provision calls for control of oxygen, nitrogen, carbon dioxide, toxic gases, pressure, temperature, humidity and particulate matter. The design of the control system itself will follow as closely as possible to the specifications of the Biosatellite III subsystem, (See Biosatellite Proposal, 2nd revision, Spec. A3824). The primate will be maintained on

a light cycle consisting of 12 hours of white light and 12 hours of red light (obtained with a Wratten 70 filter). Water will be derived from the hydrogen-oxygen fuel cell, and the quantity dispenced will be metered. Food will consist of dry pellets, and food dispensation will be controlled by psychomotor tests and the psychomotor programmer. In emergencies, both food and water can be controlled by ground command. Urine will be collected and samples transmitted to the adapter section will be analyzed at desired time intervals. Feces will be collected and stored in a container attached to the primate and will be dried out by air flow through the container. Air in the capsule will be filtered through a 100 micron or smaller filter to control particulate matter, and air circulation will be maintained so that the flow is directed away from the primate's face. Oxygen will be replenished from a supply stored in compressed form in containers in the spacecraft.

INSTRUMENTATION

The spacecraft specifications for dimensions, power requirements, and instrumentation, as well as launch vehicle specifications and launch control, in flight ground control, and recovery operations, will be nearly identical with those planned for the Biosatellite III, as listed in the NASA/ARC publication (A-62? Revision 2, dated January 1, 1968.) The parameters pertinent to the maintenance and operation of this proposed experiment are as follows:

Acceleration loads must remain less than 20 g's during re-entry, and 60 g's during landing. The flight will be of thirty day duration, with capability of manual call-down during any radio contact period prior to scheduled re-entry in the event of emergency needs. Measurement will be made and records kept of the following physiological parameters of the experimental primate: electroencephalogram (EEG), electrocardiogram (ECG), blood pressure, deep body temperature, skin temperature, respiration,

electromyogram (EMG), electro-oculogram (EOG), galvanic skin response (GSR), and electrical impulses from the eighth cranial nerve. Also, as in the 30 day Biosatellite III, pre- and post-flight, X-rays will be taken. The psychomotor testing apparatus to be used in this experiment is described elsewhere in this paper, and has capsule volume requirements greater than the device to be used on Biosatellite III; this will require a moderate reallocation of capsule volume.

As in the BIOS III flight, the primate will have implanted sensors and will be restrained in a couch which is compatible with the efficient performance, by the primate, of given tasks. The capsule will be equipped with radiation dosimeters, two movie cameras (to be actuated both by the psychomotor tester and by ground control), and with a timepiece which will provide a time record on film for correlation with tape data. The day-night cycles and lighting system will be arranged as in BIOS III, and one camera will be situated so that it monitors head and eye movements, while the other monitors hand and arm movement and the task device face as the primate performs its tasks.

Parameters which will determine the operating condition of the capsule as well as of the primate will be telemetered in real time data transmission during ground station acquisition. These parameters will include spacecraft temperatures, pressures, cabin atmosphere composition, vibration and acceleration, the primate's electrocardiogram and electroencephalogram, and its record of "correct" responses in its psychomotor task.

The command sequencing signals (using the same format as that for BIOS III) will also be radioed to the satellite during the acquisition phases. These signals will activate and deactivate emergency food and water dispensing, urine analysis system operation, psychomotor testing, camera operation, tape recorder operation, satellite attitude controls,

and anesthetic dosage and volume control to the eighth cranial nerve of the primate.

The on-board tape recorder will provide seven channels of information to be recorded during acquisition phases (with a 73 hr. total recording time limit), for post-flight retrieval and analysis. In addition, the tape will store two hours of pre-launch data, and three hours of data from lift-off through launch phase. As in the BIOS III, recording plan, there will be two EEG channels, one each of EOG, and blood pressure, AND ECG, a timing channel, and a commutated information channel. The commutated channel will be used to monitor all other sensor outputs in a discontinuous pre-programmed sampling pattern. This channel will contain records of audio noise, ECG, EEG, blood pressure, EOG, EMG, skin temperature, respiration rate, deep body temperature, GSR, and the psychomotor performance outputs. The remaining observation spaces on the commutated channel will monitor various capsule operating parameters.

EXPECTED RESULTS

If the hypothesis is correct that in a weightless environment vestibular function lowers the capacity for well oriented, coordinated activity, then the prediction is that anesthesia of the 8th cranial nerve will improve the primate's performance on the psychomotor tests as well as his general performance in the space craft.

On the other hand, if the results indicate that the anesthesia lowers the primate's performance, it would appear that vestibular function effectively enhances the primate's capacity to perform effectively in the weightless state. Further experimentation would be desireable to support such a conclusion. Conceivably the anesthesia will not influence the primate's performance level one way or the other.

Very likely, as the primate becomes habituated to the weightless environment, in the course of the thirty-day test period, the effect of the anesthesia will change. If the initial hypothesis is correct, one may predict that as the primate habituates and his overall performance improves, the improvement due to the anesthetic will decline.

SYSTEMS APPROACH

An alternate approach toward a hypothesis of experimental results can be made by expressing the sensory information processing pathways in the primate's brain as a block diagram circuit. As shown below, the applied anesthetic will alter the normal inputs and outputs, affecting the animal's performance. Predictions can thus be made on the basis of input and output variations, and these predictions may be parallel with those drawn by an intuitive approach.

In the weightless environment, the vestibular system is sending scattered "noise" signals to the reticular formation, and through the feedback loops, this noise input is spread throughout the circuit. The anesthetic essentially blocks out the noise pathway and restabilizes the system inputs and outputs.

This hypothetical result thus closely agrees with the previous hypothesis, since physical responses can now be inferred using the same logic as shown previously.

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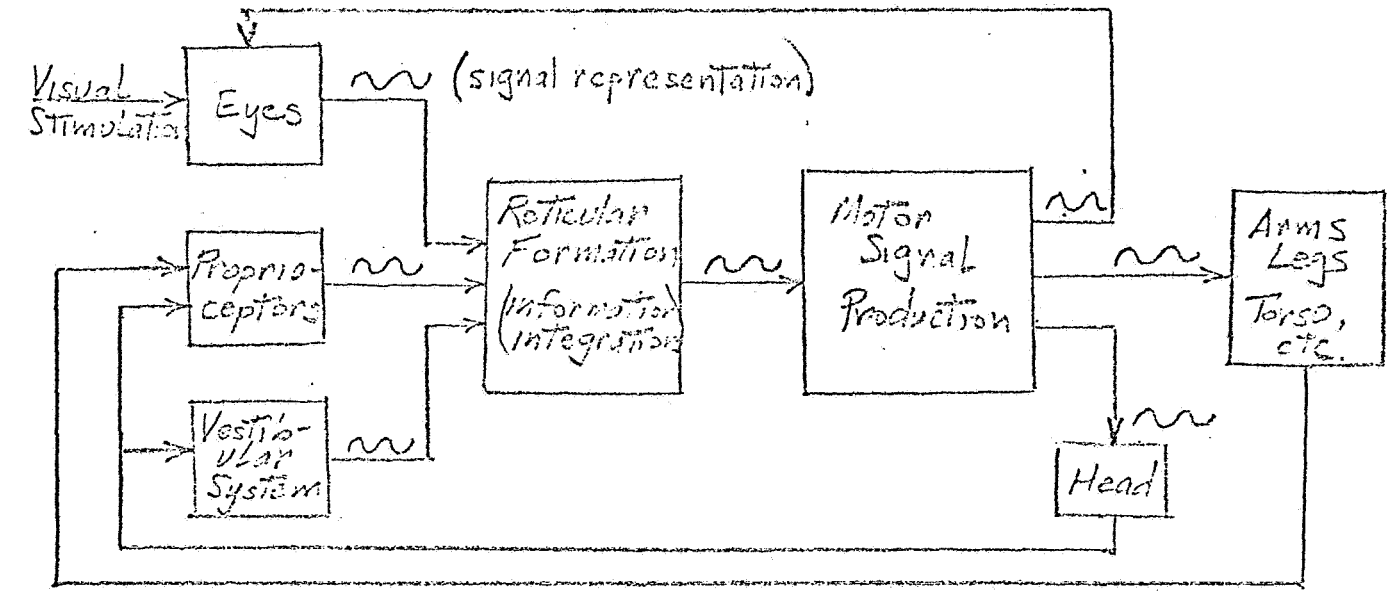
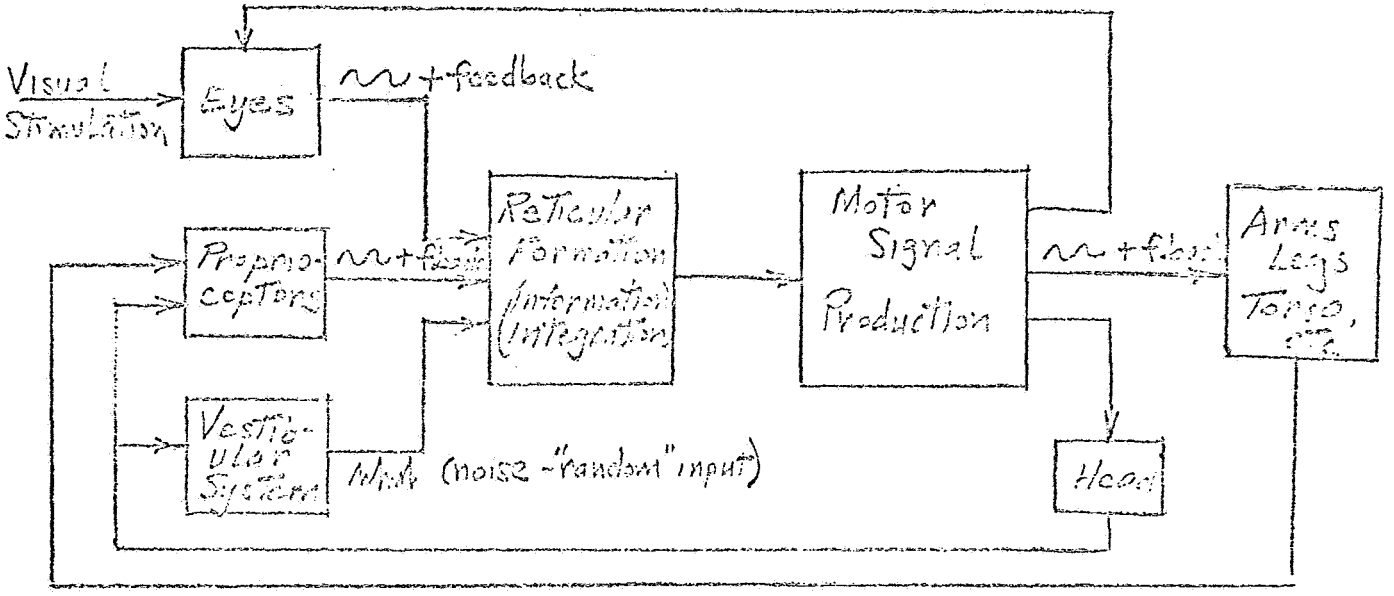


Unaltered O-G Environment



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