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**Neurolab - A Space Shuttle Mission
Dedicated to Neuroscience Research**

NASA/NIH Neurolab Collaborations

by

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The National Institutes of Health (NIH) is the nation's steward for biomedical and behavioral research while the National Aeronautics and Space Administration (NASA) is the nation's steward for civilian aeronautical and space research programs. Together, NIH and NASA have the opportunity to conduct biomedical research related to the changes in living organisms associated with spaceflight; research on earth that could benefit from the application or transfer of technologies specifically developed for space-related purposes; and research in space or spacelike environments that could improve knowledge of the normal function of human biologic systems on earth. This collaborative research can ultimately contribute to better health for many Americans as well as safeguard the health of space travelers. Several NIH institutes, centers and divisions have become active partners with NASA, developing research that will be conducted on the 1998 Neurolab space shuttle mission. Those research efforts, which include studies of circadian rhythms, neural plasticity, aging, the effects of microgravity on the vestibular system and on the development of the mammalian nervous system and autonomic control of human blood pressure, will be highlighted.

Neurolab Mission An Example of International Cooperation

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In July 1993, an International Announcement of Opportunity for the SLS₄ mission dedicated to Neurosciences was issued. More than 160 proposals coming from 13 countries were received covering the 5 Neurosciences following fields:

1. Developmental neurobiology
2. Cellular and molecular neurobiology
3. Sensori and motor systems
4. Behavior, cognition and performances
5. Nervous system homeostasis and adaptation

In a first step, a scientific merit evaluation was made by an appropriate peer review group convened by the NIH. The second step consisted in a technical evaluation made by ARC (animal research and biology) and JSC (human physiology).

After these evaluations, 8 scientific teams, involving each one several research groups, were created: the objectives of these were to provide an overview of the experimental objectives of their team integrated protocols: autonomic nervous system, sensory motor and performance, sleep, vestibular, aquatic, adult neuronal plasticity, mammalian development, neurobiology.

At the same time, a preselection and selection of 4 payloads specialists (2 flights and 2 back-up) was made.

All these processes will be discussed, criticized and proposals will be made for the ISSA.

NEUROLAB: AN OVERVIEW OF THE PLANNED SCIENTIFIC INVESTIGATIONS

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Neurolab is a NASA Spacelab mission with multinational participation that is dedicated to research on the nervous system. The nervous systems of all animal species have evolved in a one-g environment and are functionally influenced by the presence of gravity. The environmental stressors encountered during space flight, particularly the absence of gravity, present unique opportunities to gain new insights into basic neurologic functions as well as an enhanced understanding of physiological and behavioral responses mediated by the nervous system. The primary goal of Neurolab is to expand our understanding of how the nervous system develops, functions in and adapts to microgravity space flight.

During the Neurolab flight, the crew will serve as both subjects and operators in carrying out a diverse complement of 26 investigations divided into 8 scientific discipline teams. Four of the teams, with a total of 11 experiments will use the astronauts as subjects and 4 teams with a total of 15 experiments will use non-human subjects. Within the complement of human studies, the Autonomic Nervous System Team will determine the effects of microgravity on autonomic control of the cardiovascular system, as well as the consequences of adaptation by the autonomic nervous system on cardiovascular function after return from space flight. This team will use a number of techniques to apply stressors to the cardiovascular system and will measure a variety of responses to these stressors which are regulated by the autonomic nervous system. The Sensory Motor and Performance Team will investigate the effects of adaptation to the microgravity environment on human perception and motor function. The experiments to be performed by this team range from assessments of adaptive changes in eye-hand coordination to the use of a virtual environment generator to determine how microgravity alters self orientation and the perception of objects. The Sleep Team will evaluate the sleep patterns of crewmembers before, during, and after space flight to identify factors that contribute to sleep disturbances that may be associated with space flight. The influence of the naturally occurring hormone, melatonin, on sleep and performance will be included in these evaluations. Alterations in respiratory function in microgravity and their effects on sleep will also be investigated by this team. The Vestibular Team will investigate the fundamental question of how spatial orientation of the vestibulo-ocular reflex and the optokinetic response are altered in microgravity. These investigations will use a rotating chair to provide stimuli to the inner ear vestibular system. Reflexive eye movements will be measured with an infrared camera system.

Within the highly integrated complement of non-human studies, the Adult Neuronal Plasticity Team will study neural and physiological changes that occur during space flight to determine the adaptive responses of the adult rodent's central nervous system to microgravity. The primary focus of this team will be assessments of neural plasticity of the vestibular system and related spatial and motor integration processes. Investigators on this team will also use behavioral and histochemical techniques to assess the effects of microgravity on the ability of rodents to maintain circadian rhythms and homeostatic regulation. The Aquatic Team will carry out two experiments, each using different aquatic species housed in separate facilities. This team will investigate the

effects of microgravity on the development and activation of gravity-sensing organs in the vestibular systems of saltwater and freshwater animals. The Mammalian Development Team will study the effects of space flight on the normal development of the central nervous system. The series of experiments to be conducted by this team will involve the use of anatomical, physiological, molecular, and biochemical techniques to assess the processes essential for normal development of the central nervous system and motor systems. The Neurobiology Team will study the effects of microgravity on the development of gravity receptors in an invertebrate, the cricket.

Elements of the knowledge acquired from the Neurolab mission will be applicable to enhancing the well being and performance of future long duration space travelers. Additionally, the new information to be gained will contribute to our understanding of normal and pathological functioning of the nervous system and may be applied by the medical community to enhance the health of humans on Earth. The cooperative nature of the mission, involving multiple domestic and international agencies, will serve as a model for the scientific collaboration and agency cooperation that will be necessary to carry out high-quality neuroscience and biomedical research on the International Space Station.

ABSTRACT

EDEN : A payload for NEUROLAB, dedicated to Neuro Vestibular Research

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INTRODUCTION

The major aim of the ATLAS experiment (Adaptation To Linear Acceleration in Space), to be performed on-board the Neurolab mission in early 1998, is to investigate the basic question of how spatial orientation of the vestibulo-ocular reflex and optokinetic response are altered in microgravity. The investigators proposing this research (1) aim to improve understanding of the contribution of spatial orientation to oculomotor and postural function on earth, and to determine the oculomotor and perceptual consequences of plastically modifying and adapting this orientation by adaptation to microgravity.

To achieve this purpose, they will use the "Visual and Vestibular Investigation System" (VVIS). This facility is currently under development by AEROSPATIALE, as part of the contribution of ESA to the Neurolab mission (ESA Programme EDEN : ESA Developed Elements for Neurolab).

VVIS REQUIREMENTS

The ATLAS experiment will stimulate the vestibular and visual systems of human subjects and record and analyse the effects of these stimuli with three-dimensional measurements of eye movements.

The VVIS facility provides these functions through the simultaneous use of three main units which are accurately synchronised and managed through a central computer :

- An Off-Axis Rotator, that can apply inertial accelerations of 0.5g or 1g, to a subject seated in yaw and roll positions.
- An Eyes Stimulation System, that can present an optokinetic stimulus or a smooth pursuit stimulus to a subject. The stimuli are binocular and cover a large field of view in all directions (more than $\pm 40^\circ$).
- An Eye Movement Recording System, which will measure the horizontal, vertical and torsional components of movements of both eyes simultaneously. Real-time measurements at 60 Hz can be made, but the final accuracy will be reached through post-flight analysis of the video recorded images.

DISCUSSION

For the first time, the VVIS will enable application of well-controlled linear accelerations to the vestibular system combined with wide-field, binocular eye movement recordings. This will be achieved through the use of new technology and through the development of the specific pieces of equipment which are described and discussed in this paper, together with the experiments presentation. Possible use to prepare next neurophysiology science works for the future International Space Station will be proposed as a conclusion.

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CNRS - Cerveau et Cognition, Université Paul Sabatier - Toulouse - France
Experiment : Visual-Otolithic Interactions in Microgravity

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Experiment : Spatial Orientation of the Vestibulo-ocular Reflex and Velocity storage

Neurolab Experiments on the Role of Visual Cues in Microgravity Spatial Orientation

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Working in space, astronauts often move in 3 dimensions, and view the spacecraft interior and each other from a variety of different body orientations. The “down” cue is absent to the body’s gravity receptors, such as the otolith organs of the inner ear and muscle and joint receptors. Crew members are therefore reliant on vision to maintain their orientation. Many report occasional difficulty their spatial orientation due to the inherent ambiguities in visual cues available in certain situations. Most experience striking but labile “visual orientation illusions”, which can trigger space sickness in some individuals, and to cause disorientation and a variety of space human factors problems. The goal of our Neurolab experiment is to study how humans perceive their own orientation and that of surrounding objects, and the interdependence of self-and object-orientation perception in microgravity, using quantitative methods. Previous Spacelab experiments studied illusory self rotation (“circular-vection”), but did not explore the role of scene content on the perception of “down”, illusory self-translation (“linear-vection”), or the effect of perceived orientation on object recognition and interpretation of shading gradients, which are the focus of our specific experiments. To provide controlled visual stimuli, we use NASA’s “Virtual Environment Generator” (VEG): Our astronaut subjects wear a wide field of view head mounted display to view color stereo scenes rendered by a 3D graphics computer. The VEG is equipped with an optical head tracker, so the scene appears stable when the head moves. In some portions of our experiment, our subjects also wear a constant force spring harness to provide artificial “down” cues to their muscle and joint receptors. Our findings will help NASA human factors engineers design the next generation of spacecraft; suggest new types of preflight training techniques which could reduce the incidence of disorientation and in flight space sickness; and better understand the relative role of vision in human spatial orientation not only in space but also in our daily lives on Earth.

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The Role of Space in the Exploration of the Mammalian Vestibular System

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Results of two spaceflight experiments are revealing the importance of space research in exploring gravity sensor organization, adaptability to altered-G, and function. Gravity sensors respond to gravitational and translational linear accelerations acting on the head. In space, the bias of gravitational acceleration is virtually absent but translational accelerations are still effective. The hypothesis tested by the research presented here is that the synapses of the rat gravity sensing cells (hair cells) will be modified during adaptation to the space environment. The rat utricular gravity sensor is used as the model system. Ultrastructural and statistical studies employed 50-100 serial sections in which the organization of the sensor was reconstructed in 3-D, changes in voltage were simulated, and ribbon synapses in hair cells were counted and analyzed. The results were as follows. 1) Ground-based research showed that peripheral gravity sensors have a dual circuit organization that includes local feedback as well as feedforward microcircuitry. The sensors are comparable in organization to retina, olfactory system, cerebellum and cerebral cortex. Of the two types of hair cells, type I cells are inserted into direct circuits and type II cells into local circuits. 2) Synaptic ribbons doubled in number in type II cells in microgravity and changes in ribbon morphology and distribution also occurred. Type I cells were only subtly affected. 3) Computer simulations demonstrated that the morphology of neuronal endings is related to their output. Interpretations of the findings are: 1) Gravity sensor morphology indicates that the preprocessing of acceleratory information occurs at the gravity sensor level. Local circuits shape the final output which induces behavioral responses. Thus, adaptation to microgravity should largely occur in local circuits, which it does, 2) Type II hair cells appear to be sensitive to gravity and type I cells to translational accelerations. The continuum of mix type I and type II hair cells in receptive fields of gravity sensors could be related to the continuum of physiological responses. 3) Simulations of voltage changes in single neuronal endings indicate that morphology affects discharge frequency and latency. Changing the direction of input alters output in multicalyx endings. Distal spread of voltage from the spike initiating zone briefly shuts off synaptic input. This mechanism could be essential to sense gravity, a continuous stimulus that neuronal systems learn to ignore. Thus, space exploration has made significant contributions to our understanding of gravity sensor organization and adaptive capabilities. We now need correlated physiological and behavioral studies, and a better understanding of the molecular mechanisms involved in inducing synaptic changes. Thus, space research will continue to play a major role in the exploration of the vestibular system, particularly as the era of the space station arrives and prolonged exposure to microgravity becomes a reality.