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REPORT TO THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Research Grant NsG-502

Neurophysiological and Behavioral Studies of Chimpanzees

For the Semi-Annual Period

July 1, 1966 to December 31, 1966

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January 6, 1967

FACILITY FORM 602

N67 18163 (ACCESSION NUMBER)

7 (PAGES)

CR-81667 (NASA CR OR TMX OR AD NUMBER)

1 (THRU)

1 (CODE)

04 (CATEGORY)

ff 653 July 65

GPO PRICE $ _____

CFSTI PRICE(S) $ _____

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

SEMI-ANNUAL REPORT

NsG-502

Considerable progress has been made on the chimpanzee program in the last six months. Computer control of the Matching to Successive Symbols Device (MSSD) described in detail in previous reports is now being established in the new Space Science Center, and training of the chimpanzees on the device has begun. Dr. James McNew joins the staff in January and will be solely concerned with the development of the animal colony and manipulation of the physiological and psychological experiments.

Deatils of work are given below.

A. Development of Data Analysis Techniques

The system programs for the IBM 360-75 provided by the IBM Corporation have been found to be inadequate; thus, further development of data analysis techniques for the chimpanzee program has been impossible during this reporting period. This work will be facilitated on completion of the interfacing of the newly acquired SDS 9300 computer in the Data Processing Laboratory with the IBM 360-75 located in the UCLA Health Science Computing Facility. This link will provide a two-way high-speed (1.2 million 8 bit characters/second) information path between the two computing facilities, permitting introduction of real-time data into analytic programs at HSCF and the return of processed data to the DPL, where it will be made available to the user for graphical display. The interfacing is expected to be completed soon, and along with refinement of the system programs for the IBM 360-75, will permit Dr. D.O. Walter to develop pattern recognition, discriminant analysis, and other data analysis techniques for application to EEG records from the chimpanzee program. However, applications of these techniques have been made to other data in other studies, and they will be described below.

Work has continued on the development of the method of discriminant analysis in which states of the subjects are estimated and discriminated solely on the basis of EEG records. The program has been rewritten to meet the requirements of large studies involving many subjects, many situations, and an unlimited number of parameters to be submitted to the selection procedure. For example, a study is now nearing completion on five astronaut candidates' records in eleven behavioral situations, offering approximately 2100 different parameters for automatic selection of the most useful ones. Methodological improvements, both to reduce computation time and to extend the capabilities of the method, are being pursued.

Along with identifying patterns across a population of individuals, work has been done on the development of pattern recognition techniques in which automated recognition methods have been applied to data from

different individuals in a spectrum of behavioral situations. Using this matrix analysis method, it has been possible to show high accuracy in computer ecognition of basic states of consciousness, from resting states to highly focused attention.

These techniques were used for analyses of EEG data from fifty astronaut candidates, providing the first "library" of normal EEG baseline data from a population of healthy adult males. They are now being extended to a "library" of chimpanzee EEG data. These techniques were also applied to data from other populations, including human subjects performing discrimination tasks, and chimpanzees playing an electronic tic-tac-toe game. In addition to analysis techniques, there has been development and refinement of graphic methods of presenting the results of computer analysis.

An unusual and fascinating application of these display and pattern recognition methods involved complete analysis of 55 hours of EEG data from Astronaut F. Borman in the initial phases of the Gemini GT-7 flight. These display techniques have clearly revealed shifting patterns in EEG records from ground based to flight data. They have exemplified the power of these methods in compressing long record epochs for easy interpretation with retention of all appropriate detail.

In addition to these contributions in fundamental and applied physiology, the Laboratory computing facility has become part of a time-shared console operation, in which macro- and microcommand functions can be exercised over this computer through remote consoles in the investigators laboratory. This aspect of a time-shared computer operation for physiological data analysis represents an extension of the state of the art in the handling of massive amounts of data at high speeds, with data transfer rates up to 500,000 bits per second.

It should be emphasized that utilization of the computer under NASA support has provided us with the means of development of input and output systems including special display devices that are especially suited for the needs of the physiological investigator. In addition, it provides an approach to problems in development of specialized flight monitoring computers, capable of early recognition of undesirable trends in states of alertness, and the appearance of fatigue and inattentive behavior.

B. Study of Learning and Behavior in the Chimpanzee

The four chimpanzees are continuing to receive basic discipline training, as well as being conditioned to accept physical restraint and permit scalp electrode attachment with skin penetration.

1. Computer control of experimental situation.

The construction of the Matching to Successive Symbols Device (MSSD) is complete, and the computer program has been written to conform to the on-line time-sharing console system attached to the SDS 930 computer. In this system the MSSD program may be initialized by the user from the experimental site via the remote console system, which provides him with 16 analog inputs to the computer, 24 sense lines from the MSSD display panel to the computer, and relay driver output from the computer to the MSSD symbol display circuitry. The investigator also has access to an extensive library of programs resident in the Shared-Laboratory-Interpretive-Processor (SLIP) system.

The MSSD portion of the SLIP system provides both supervisory and executive functions for the experimental situation. When called by the experimenter, the program presents him with a series of questions in order to establish the experimental parameters for the series of trials. These parameters include the number of symbols to be employed (with an option for the user to select specific symbols and symbol order in lieu of an otherwise random selection), symbol "on" time, delay times and digitizing rates, as well as parameters which identify the subject, trial, etc. for bookkeeping purposes. With the performance criteria and experiment strategy thus defined, the executive function of the MSSD program starts digitization of the EEG input to the computer, and provides the MSSD panel switches with the required displays. The supervisory function continuously monitors the panel measuring the correctness of the responses of the subject. The subject's responses are identified as a function of time so that behavioral and physiological relationships may be temporally preserved for analysis purposes.

Since the SDS 930 computer is time-sharing, the experimenter may request displays of any statistical data acquired during a specific trial, or cumulative data from a series of trials without disturbing the continuity of any on-going trial. All physiological and behavioral data are permanently stored on magnetic tape. In addition, the program permits the investigator to alter any experimental parameter at any time he desires.

2. Experimental design.

Under the supervision of Dr. Ralph Berger, the MSSD has been employed under manual control using two symbols with an adult chimpanzee that had been previously trained on the tic-tac-toe procedure described in previous reports. The chimpanzee was able to perform at an accuracy level of about 75% at the end of the training period.

Implantation procedures for the four new young chimpanzees have begun. In two animals cortical and subcortical leads have been

implanted in the brain structures in which discrete changes in EEG accompanying the various behavioral events during learning and performance have been shown to occur in the earlier studies from this laboratory.

Following implantation, the chimpanzees are being 'shaped' to the task under manual control by initially presenting only a single stimulus symbol and subsequently two symbols. When the animals have reached performance criteria when responding to two symbols, experimental control will be shifted to the computer and the number of symbols will be progressively increased until the limit of each animal's capability has been reached. Concurrent EEG recordings will be carried out at all times under both manual shaping and computer control.

C. Developments in Bioinstrumentation

This work is primarily under the direction of Mr. R.T. Kado and Mr. J.R. Zweizig.

1. Development of DC blood flow transducing devices.

Work is continuing on the possibility of chronically implanting a DC blood flow transducer and transmitter, which will provide a means of studying cardiovascular function in space flight. The availability of semiconductor devices with higher gain-bandwidth products at a given power level opens the possibility of a micropower device capable of long-term monitoring.

2. Packaging and miniaturization of a multi-channel biotelemetry system.

Additional biotelemetry units similar to those described in the previous reports have been designed and tested by Mr. Kado and Mr. Zweizig. Smaller VCO and amplifier modules have been built as a result of the availability of smaller capacitors and other components. In addition, there has been a decrease in the required battery power due to lower current requirements in the integrated circuits used in signal conditioning and multiplexing. High-performance linear integrated circuits are used at reduced supply voltages to achieve accepteble performance at reduced power consumption. These integrated components yield not only smaller size but also design and fabrication economies. It is especially important that the battery weight be reduced as this accounts for about one-third of the total weight during a 24-hour recording session.

The frequency-multiplexed IRIG subcarrier system has the advantage of compatibility with standard demodulation equipment of high

quality and proven reliability. It is also possible to record the multiplexed data on a single channel tape recorder for later demultiplexing, thereby reducing the bulk of the receiving and demultiplexing equipment in portable recordings; however, write out is normally made through the discriminators to an electroencephalograph or through a special recorder driven from the discriminator outptus. Further, if biological data are to be transmitted over long distances, the frequency multiplexed data are in a form compatible with telephone line or radio link transmission facilities.

One circularly shaped telemetry unit has been built to fit the crown of an implanted monkey's head. This unit was used successfully by Miss S. Bawin in 24-hour recording sessions on unrestrained animals.

Direct connection of the telemetered outputs to a computer for on-line data analysis has been made by Mr. L. Rovner, thereby providing the investigator immediate access to experimental results.

Work has continued on the development of smaller single-channel telemetry units which can be mounted on the electrode connectors on the animal's head, dsscribed in previous reports. These have been decreased in volume to the point where two channels mount easily on a single electrode connector. As many as three of these have been used simultaneously during a 24-hour recording period, with the animal in his normal living quarters.

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