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Final Report on NASA Research Grant NsG-203-62, concerning Research Performed in Space Biology Laboratory, Brain Research Institute, University of California, Los Angeles.

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This report details work performed under this grant in the period January 1, 1962 to December 31, 1962. Although most of the research areas remain active under alternate support, each facet of these programs is presented with an aspect of completeness for the purposes of this report. It will be obvious that the nature of the majority of these studies will necessitate vigorous pursuit in continuing programs over the next three to five years.

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a. Chimpanzee Program.

A stereotaxic atlas of the chimpanzee's brain has now been completed, and is in the hands of the publishers. This atlas will allow the routine placement of surface and deep brain recording probes in any desired region of the immature chimpanzee's brain. The atlas is largely the work of Dr. M. R. DeLucchi, and has involved extensive histological sectionning of these brains in a variety of planes, and with a variety of staining techniques. The accuracy of the atlas has been confirmed in a series of three animals in which stereotaxic placements have been made on the basis of the preliminary atlas. It is considered that the forthcoming publication will provide a highly useful tool for the increasing number of physiological and psychological studies now in progress on the chimpanzee. Publication of the atlas has been undertaken by the University of California Press, and it is anticipated that the volume will appear in approximately nine months.

Much effort has been expended in the correlation of surface and deep brain electroencephalographic records in the implanted chimpanzee with states of sleep, fatigue, wakefulness, alerting and emotional arousal. Particular attention has been directed to the evaluation of sleep states in these animals, with comparison of surface and deep records with those from similar deep electrode placements in man. This study appears to materially enhance the value of the EEG as a potential monitor of behavioral states of man and the chimpanzee in the space environment. Work completed by December 31, 1962 has been prepared for publication by Dr. J. S. Rhodes and is now in press.

havioral training of the chimpanzees in a variety of test performs initiated under this program, and is, in fact, still being ly pursued under alternate support. These task performances are nied by EEG recording, and the significance of these stimultaneous ve records in evaluation of behavioral states is now under review.

Studies of centrifugal and vibrational stresses on brain electrical activity and concomitant behavioral performance.

cords from deep brain structures during centrifuging on the human

centrifuge facility at the University of Southern California were performed in various planes, including those producing depletion of the cerebral circulation and associated unconsciousness. It was found that at the onset of cerebral anoxia, and during the period of reestablishment of the cerebral circulation, there was a high incidence of electrical seizure discharge, associated with frank epileptiform convulsions in some cases. These seizure discharges were initiated in deep structures of the temporal lobe and spread progressively to diencephalic structures, and thence to cortical areas.

Extensive examination of the effects of vibration over a spectrum of frequencies from 5 to 40 cycles per second indicated a "driving" of brain wave rhythms in the monkey, particularly in the range 11 to 15 cycles per second. Peak accelerations of 2G were used. It was found that this driving at the shaking frequency was abolished or essentially eliminated by barbiturate anesthesia and disappeared after death. It is thus suggested that the phenomenon is a true physiological event, not related to electromechanical artifacts in the recording or electrode systems, nor does it arise from photic stimulation, since the intracerebral distribution of the evoked trains during shaking is different from that in photic stimulation, and the phenomenon persists during shaking of the blindfolded animal. These studies have recently been published in extenso, including evidence of defective behavioral task performance during periods of brain wave rhythmic driving, but without effects during shaking not associated with distorted brain wave rhythm patterns. It appears from these studies that the essential receptors may not necessarily be those in the inner ear mechanisms, but may involve thoraco-abdominal mechanoreceptors.

c. Studies in monkeys of brain wave patterns during exposure to cosmis rays at high altitudes.

A series of ten monkeys were implanted with cortical screw electrodes at Armed Forces Institute of Pathology, Washington, D.C. in behalf of NASA Ames Research Center, preparatory to a series of balloon flights planned from Goose Bay, Labrador in July 1962. A series of 32 EEG recording amplifiers were designed and constructed in miniaturized modules for these flights in the short span of 6 weeks. Unfortunately, seven of the ten animals were lost prior to flight through concomitant cardiovascular surgical procedures performed by others.

Despite the limited data yield from these flights, an earnest attempt has been made to evaluate the available records for evidence of sudden or slow changes which might be attributable to irradiation. This laboratory has already extensively investigated threshold phenomena in brain electrical activity following acutely on irradiation. We have been unable to discern any pathological changes in the records from two animals exposed to cosmic rays at 100,000 feet for 24 hours. The records do give, however, a valuable baseline for estimations of general behavioral

states in these animals throughout the period of recording, including drowsiness, sleep, wakefulness and extreme alertness.

d. Development of EEG amplifiers for manned space flight.

Much evidence has accumulated indicating the desirability of monitoring central nervous functions in man as directly as possible, and on a continuing and non-interference basis, in the space environment. Work undertaken under this grant has resulted in a series of microminiature EEG amplifiers, suitable either for adhesive fixation to the scalp as an integrated electrode-amplifier, or for insertion into the helmet-liner and connection to the scalp with a short input lead.

The latter technique has been developed to a virtually complete EEG sensing and amplifying system incorporated within the astronaut helmet. This system has been developed to the point of providing satisfactory EEG recordings over many hours on the basis of sponge contact with the scalp, and without any adhesive contact or skin abrasion. This method has involved elimination of contact potential between the metallic electrode surface and the electrode paste or sweating scalp. It uses a half-cell system of semi permeable membranes to achieve zero contact potential. In consequence, there are minimal problems from sliding contact between the scalp and sponge electrodes integral with the helmet-liner, and minimal artifacts as the subject moves his head inside the helmet. This novel system also has the unique advantage of suffering no defects from scalp sweating, an inevitable concomitant of certain periods of capsule flight.

This system is currently being evaluated in jet fighter pilots under flight conditions, and in freeway drivers. It is hoped to secure alternate support to permit satisfactory completion of an apparently important development.

e. Automatic reduction and computer analysis of EEG data.

The value of the EEG as a monitor of behavioral states can be enormously enhanced by the use of computer analyses, including auto- and cross-correlation techniques, and auto- and cross-spectral analyses, with calculations of complex transfer functions on a stochastic basis. These techniques have been substantially pioneered in this laboratory in their application to EEG data. These studies have disclosed subtle changes in brain wave patterns relating to correctness or incorrectness of decision making processes, as well as clearly delineating broad changes in spectral characteristics associated with sleep, wakefulness, fatigue, and directed attention.

These studies appear to have both fundamental and applied significance. On the one hand they have permitted the consideration of fundamentally new ways in which information is handled and stored in brain systems, involving consideration of slow electrical brain wave processes as the basis of information transaction and storage, with random or probabilistic modes of operation within relatively large domains of

cortical tissue. On the other hand, these studies have provided a baseline of analytic procedures and data well suited to the evaluation of EEG records from man in the varied conditions of space flight. They have exemplified the reliability of computed criteria in evaluation of EEG data, and its usefulness as a monitor of psychophysiological states.

These studies have been performed in part in the Data Processing Laboratory of the Space Biology Laboratory, which has been equipped with a CDC-160A general purpose computer and analog-digital conversion facilities. Additional more complex computations have been performed on the IBM 7090 computer at the Campus Computing Facility. The establishment and maintenance of the Data Processing Laboratory resulted partly from this grant, and continuing support for 1963 has been provided from other NASA sources. It is submitted that the vital role of this laboratory in the development of brain wave monitoring in manned space flight makes continued support of such activities of singular importance.

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