45. EXPERIMENT M–8, INFLIGHT SLEEP ANALYSIS

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Introduction

The necessity of monitoring the cardiovascular function during space flight has been recognized and implemented since the inception of the manned space-flight program. More recently, attention has been directed to the possibility of monitoring the brain function during space flight.

A cooperative research program at the Baylor University College of Medicine, at the University of California at Los Angeles Medical School, and at the Manned Spacecraft Center has been directed to the following practical and scientific questions:

(1) Can the electrical activity of the brain, as it is revealed in the electroencephalogram (EEG) recorded from the scalp, provide important and useful information concerning such factors as the sleep-wakefulness cycle, degree of alertness, and readiness to perform?

(2) Is it feasible and practical to record the EEG (brain waves), which is an electrical signal measured in microvolts, under the unique and difficult conditions which prevail during space flight?

The special conditions which exist during space flight consist of such factors as—

(a) Possible electrical interference from the many electrical devices near each other aboard the spacecraft.

(b) The necessity for recording during the routine activity of the subjects with attendant artifacts produced by muscle action, movements, sweating, skin resistance changes, and so forth.

(c) The requirement for miniaturization of the necessary instrumentation to a point sufficiently small and light in weight to justify its existence as part of the payload of the space vehicle.

(d) Provision of scalp electrodes and a method of attachment which would permit prolonged artifact-free recordings without producing significant discomfort or irritation to the scalp. (In clinical practice, electrodes are generally not required to remain in place for longer than 1.5 hours.)

(3) What are the minimal number of brain areas and, hence, of channels of electrical data which are necessary to provide EEG information adequate to identify and differentiate all levels of sleep and wakefulness?

(4) Can computer or other forms of automatic analysis be effectively employed to analyze the EEG data in order to yield the required information, thus avoiding the necessity of having EEG experts constantly at hand to read and analyze the records?

(5) Finally, can highly sophisticated techniques of computer analysis reveal important correlations between EEG activity and higher brain functions having to do with such states as vigilance and attention which are not evident on simple visual analysis of the EEG record?

These are the practical problems which are being studied. In addition, the following scientific questions are under investigation:

(1) Possible influences of weightlessness, and so forth, upon brain function and particularly upon the sleep-wakefulness cycle as evidenced by EEG changes.

(2) The application of computer analysis techniques to the analysis of the EEG under various controlled conditions; for example, sensory stimulation, heightened affective states, mental computation, as well as other similar factors.

Objectives

A major part of this research program has already been completed, but the present report is concerned only with the preflight and inflight data obtained in carrying out the specific experiment, Inflight Sleep Analysis, in connection with the Gemini VII flight.

The primary purpose of this experiment was to obtain objective and precise information concerning the number, duration, and depth of sleep periods of one of the members of the crew (Command Pilot Borman).

The importance of precise information concerning the sleep (hence, rest) of the crew, especially during prolonged flights, is obvious. The electroencephalogram is capable of providing this information, as the electrical activity of the brain undergoes clearly established and consistent variations with different levels of sleep. Using the EEG, it is possible to distinguish four levels of sleep ranging from drifting or drowsiness to profound sleep, and a special state sometimes called paradoxical sleep or the rapid eye movement stage of sleep, which is believed by many investigators to be important for the psychoaffective well-being of the individual.

Approach and Technique

Baseline Data

Baseline, multichannel EEG, and other psychophysiological data were recorded on Borman and the backup command pilot, White, at the Laboratory of Space Neurobiology at the Methodist Hospital during all stages of sleep and during the waking state. These recordings were used as a baseline for comparison with recordings made in the altitude chamber runs at St. Louis and finally with the inflight records.

Electrodes and Recording System

Preliminary studies of 200 control subjects, and specifically of White's and Borman's preflight EEG's, had shown that all of these stages of sleep could be differentiated and identified in records obtained from a single pair of electrodes placed on the scalp—one in the central, and one in the occipital region. It was also found that if these electrodes were placed in the midline of the head, the least possible artifact from muscle activity was attained. As weight and space limitations permitted only one more EEG recording channel, what was essentially a duplicate of the first electrode pair was used but displaced a few centimeters to the left of the midline. Such electrode placements reveal essentially the same information as the midline pair, but this choice was made (rather than obtaining data from another brain area) to provide for the possibility that one or more of the electrodes of one pair might be dislodged or become defective.

The recording system consisted of two miniature transistorized amplifiers, carried by the astronaut in pockets of his underwear, and a small magnetic tape recorder inside the spacecraft. The tape recorder, running at a very slow speed, was capable of recording 100 hours of data continuously.

Preflight Tests

Preliminary tests of the electrode system, amplifiers, and tape recorder under flight conditions were made first in the altitude chamber at McDonnell Aircraft Corp. and subsequently at the Manned Spacecraft Center.

Another dry-run test was made at Cape Kennedy the day before the flight, and recordings were made at the launch pad prior to lift-off.

All of these preflight runs yielded good recordings, clean of all artifact except that engendered by the movements of the subjects themselves.

Inflight Test

Recording of the EEG was to be continuous throughout the first 4 days of the Gemini VII flight. During these 4 days, the command pilot was to keep his helmet on unless marked discomfort or other factors necessitated its removal. The electrode system was, therefore, designed for a helmet-on arrangement.

Results

The events (as determined from the medical recorder data) from 15 minutes before lift-off to the time one of the second electrode pair was dislodged are shown graphically in figure 45–1. A total of 54 hours and 43 minutes of interpretable EEG data was obtained. Most of these data were of excellent quality from the viewpoint of visual interpretation.

EEG channel 1 became noisy after 25 hours and 50 minutes of flight (indicated by point B), and no interpretable data appeared in this channel after 28 hours and 50 minutes (indicated by point C). EEG channel 2 gave good, artifact-free data up to 43 hours and 55 minutes (point D), at which time it became intermittently noisy. No interpretable data were recorded after 54 hours and 28 minutes of flight (point E), at which time the electrodes for this channel were inadvertently dislodged. The sleep periods (shaded areas) will be discussed later in detail. The meals are indicated in the illustration because they represent periods of temporary interruption of the interpretability of the EEG data due to muscle and movement artifacts produced by rhythmic chewing (fig. 45–2).

As indicated in figure 45–1, 8 hours after liftoff, the command pilot closed his eyes and remained quiet for almost 2 hours—8:12:00 to 10:19:00 ground elapsed time (g.e.t.)—without showing signs of drowsiness or sleep. A portion of the record during this period is shown in figure 45–2.

Sleep is very easy to detect in the EEG records. Figures 45–3 and 45–4 show the distinc-

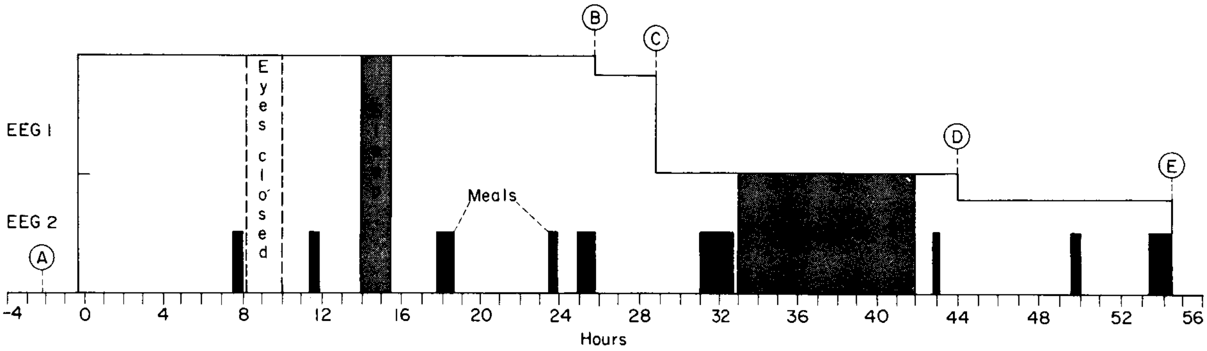
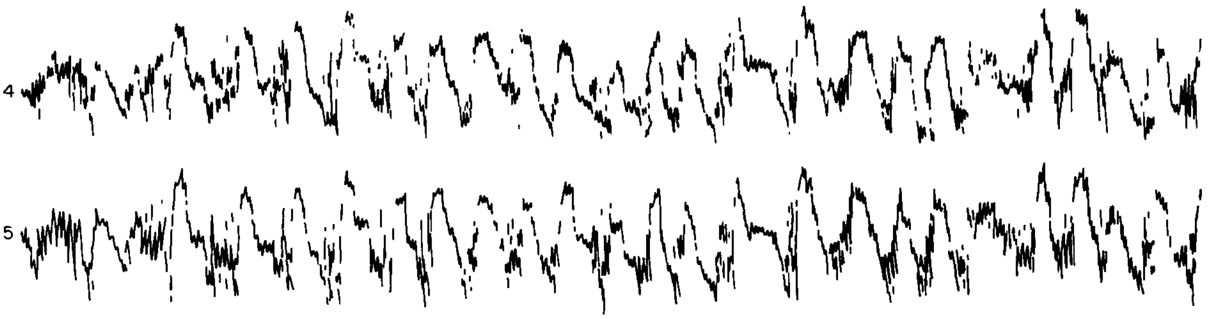
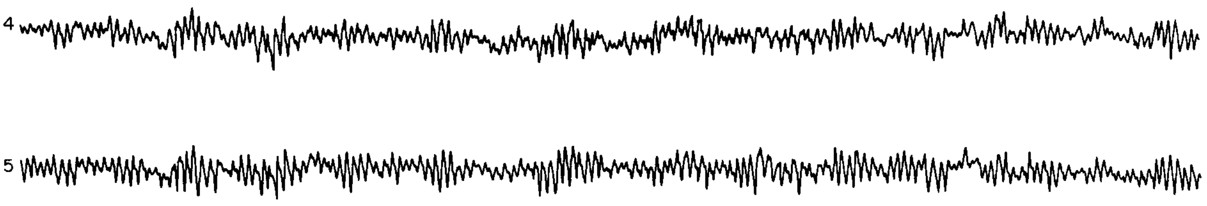


FIGURE 45–1.—EEG data flow.



During meal: 7hrs,49 min



Resting, eyes closed: 8 hrs, 16min

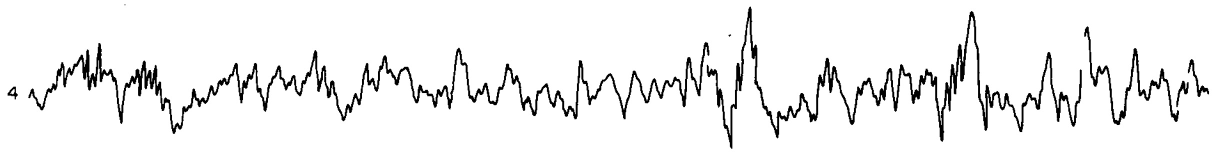
FIGURE 45–2.—EEG recordings taken during rhythmic chewing (upper) and during eyes-closed resting condition (lower).

Transition to stage I sleep: 33 hrs, 17 min

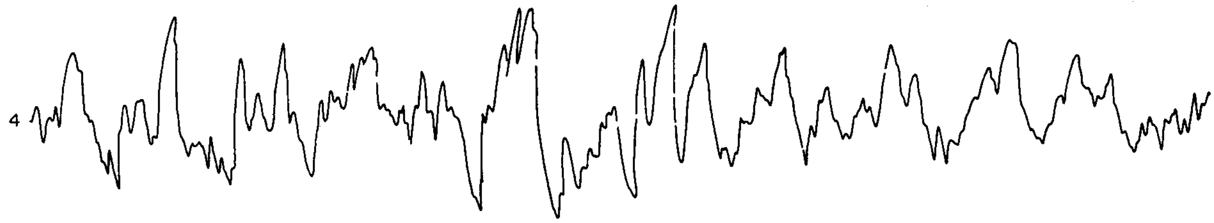
Stage I sleep (continuation of above): 33 hrs, 17 min

Stage 2 sleep: 33 hrs, 24 min

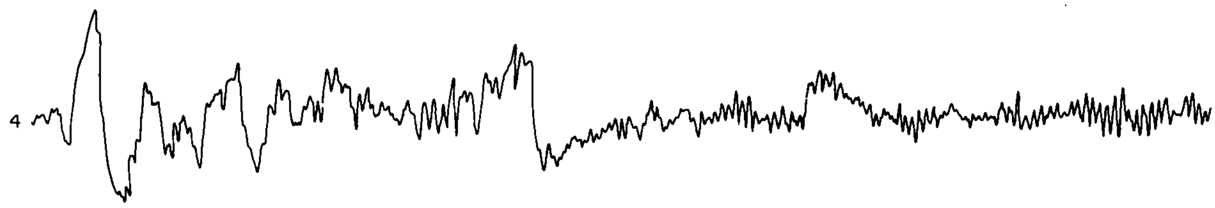
FIGURE 45-3.—EEG recordings showing progression from awake to light sleep.



Stage 3 sleep: 34 hrs, 16 min



Stage 4 sleep: 34 hrs, 44 min



Partial arousal: 36 hrs, 53 min

FIGURE 45-4.—Example of EEG recordings of moderate sleep (stage 3), deep sleep (stage 4), and partial arousal.

tive patterns found at each level of sleep. These illustrations were taken from the second sleep period during flight.

The total sleep periods are graphically represented in figure 45–5. For ease of representation, each period of sleep is divided into 1-minute epochs, and these are illustrated by the vertical lines. The length of this line represents the range of sleep level variation during the minute it represents.

The uppermost level on the vertical axis of the graph (EO) represents the eyes-open, alert-type EEG pattern. The next lower part of the vertical axis marks the eyes-closed, resting pattern (O). Each of the next successive points on the scale represents the four levels of sleep from light to deepest sleep. When, as often happened, more than one EEG stage of sleep occurred in a 1-minute epoch, the vertical line indicating stage of sleep is drawn to show the extent of the alterations of sleep level occurring during this time.

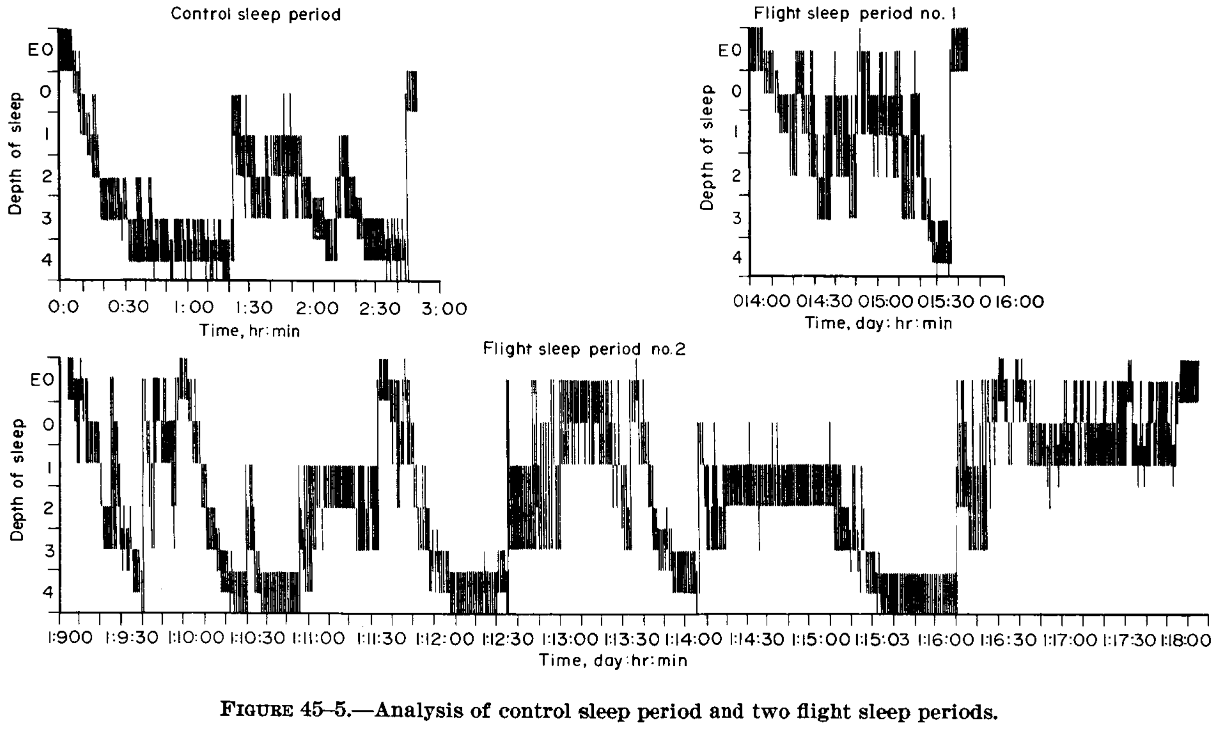
The horizontal axis of these graphs represents the flight time in hours and minutes, translated from the time code on the recording tape.

In addition to the two sleep periods during flight, a similar graphic representation is shown of the control or baseline sleep period made in the laboratory in September 1965. This is shown in order to compare the rate and character of the "falling-to-sleep" pattern, but it cannot be used to compare the cyclic alterations occurring in a full night's sleep because the subject was awakened after 2 hours and 45 minutes. The first part of the characteristic cyclic changes of level can, however, be seen.

The first inflight sleep period shown on the right side of the graph showed marked fluctuations between light sleep and arousal, with occasional brief episodes of stage 3 sleep for the first 80 minutes. At that time stage 4 sleep was reached, but in less than 15 minutes abrupt arousal and termination of sleep occurred.

On the second day, at 33 hours and 10 minutes after lift-off, the command pilot again closed his eyes and showed immediate evidence of drowsiness. Within 34 minutes he was in the deepest level of sleep (stage 4).

During this prolonged period of sleep, there were cyclic alterations in level similar to those which occur during a full night of sleep under normal conditions. Such cyclic changes are usually irregular and aperiodic, as shown in figure 45–6, which is taken from a normal control series studied by Dement and Kleitman. Generally, each successive swing toward deeper



Control sleep period

Flight sleep period no. 1

Flight sleep period no.2

Figure 45–5.—Analysis of control sleep period and two flight sleep periods.

sleep, after the first period of stage 4 has been obtained, only reaches successively lighter levels; but, in Borman's second night of sleep, stage 4 was reached and maintained for 20 minutes or more at three different times after the first episode. It is interesting to speculate as to whether this increase in the number of stage 4 periods reflected an effect of deprivation of sleep during the first 24 hours.

After approximately 7 hours of sleep, a partial arousal from stage 4 sleep occurred, and, after a brief period (12 minutes) of fluctuating between stages 2 and 3, Borman remained in a state fluctuating between drowsiness and stage 1 sleep until finally fully roused about 1.5 hours later. Whether any periods of the so-called "paradoxical" sleep, rapid eye movement sleep, or dreaming sleep occurred during this oscitant period cannot be determined with certainty from our records because of the absence of eye movement records and because paradoxical sleep is generally very similar in its character to ordinary stage 1 sleep. However, two periods of a pattern which resemble an admixture of certain characteristics of stage 1 and stage 2 sleep, and which resemble some of the activity which this group and other investigators have observed in paradoxical sleep, were recorded for relatively long periods in the second day's sleep (at 11:05 G.m.t. and 14:20 G.m.t.). Typical examples of this activity (which consists of runs of 3 per second "saw-tooth" waves, runs of low-voltage theta and alpha activity, low-voltage beta activity without spindles, and occasional slow transients with a time course of about 1 second are shown in figure 45–7.

Conclusions

This experiment has clearly demonstrated the feasibility of recording the EEG during space flight. Refinement of technique and the development of more comfortable and efficient electrode systems will soon permit recording throughout prolonged space flights.

The precise information which the EEG can afford concerning the duration, depth, and number of sleep periods suggests that EEG monitoring should be considered for routine use in the prolonged space flights contemplated in the Apollo and other programs.

The importance of such information in the direction and execution of the flight, both to the medical monitors on the ground and to the crew, is evident.

In the meantime, EEG studies presently planned in the Gemini and Apollo programs, correlated in time with activity and events aboard the space vehicle, should provide important information for the formulation of future flight plans in relationship to scheduling of sleep periods.

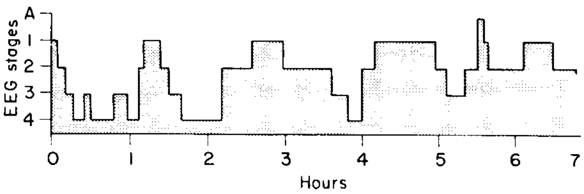


FIGURE 45–6.—Graph of cyclic variations during spontaneous sleep.

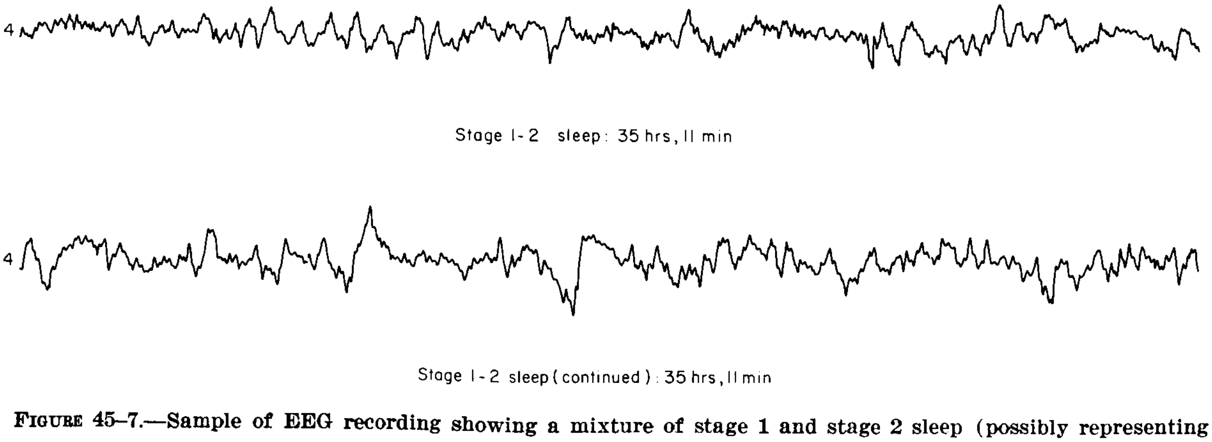


FIGURE 45–7.—Sample of EEG recording showing a mixture of stage 1 and stage 2 sleep (possibly representing "paradoxical" sleep phase).

The analysis of sleep by EEG is a very elementary exercise at the present state of the art. The possibility that monitoring electrical brain activity may yield important information concerning higher brain functions during flight has yet to be fully explored. It is to be hoped that the full exploration of the potentiality of electroencephalography as an analytic tool in brain function can be realized through the intense efforts catalyzed by the space program.