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AMRL-TDR-62-83

SLEEP AND ALTERED PROPRIOCEPTIVE INPUT AS RELATED TO WEIGHTLESSNESS: WATER IMMERSION STUDIES

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Biomedical Laboratory
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NOTICES

FOREWORD

This report was prepared under Project 7222, "Biophysics of Flight," Task 722201, "Psychophysiology of Flight." The work was done in the Psychophysiological Stress Section, Biophysics Branch, Biomedical Laboratory, 6570th Aerospace Medical Research Laboratories, between October 1961 and February 1962.

ABSTRACT

The "free-floating" condition of immersion is associated with substantial alterations in mechanoreceptive feedback to the central nervous system in a manner similar to the free-floating condition of weightlessness. One area having rather immediate operational application concerns sleep under these conditions. In this study electroencephalographic and electrooculographic recordings were made during sleep of completely immersed, neutrally buoyant subjects. Sleep records were obtained while using both tether and clamshell sleeping facilities and were compared to each subject's normal bedrest sleep records. The results are presented and their possible application to prolonged weightlessness is discussed.

PUBLICATION REVIEW

This technical documentary report has been reviewed and is approved.

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METHODS

The metal tank used for the immersion studies was 9 feet by 7 feet by 7 feet and lined with fiberglas internally for rust protection. The subject entered the tank through the top which remained open. Portholes in the sides permitted continuous visual observation during each experimental procedure. A dry-type rubber suit, modified to adapt to a partial pressure helmet, protected the skin from water contact. The water temperature was maintained at a constant 33° C. A regulator installed in the outflow line of the helmet balanced respiratory pressures. Airflow through the helmet was maintained at 120 liters per minute.

The EEG and EOG electrodes were shallow rubber cups of 5 millimeters inside diameter. Floating wire leads were used so that there was no direct metal-to-skin contact. The electrodes were fixed to the scalp with collodion and filled with electrolyte solution. This established a skin-electrolyte-metal contact, minimizing movement artefact. The sites chosen for electrode application were near the outer canthus of each eye for the electrooculogram and the left occipital and right parietal areas for the electroencephalogram. A final electrode on the forehead established the ground. From a plug in the helmet a shielded cable extended through the air hose outside the tank to an Offner amplifier and recorder. Throughout each experiment, a timer turned on the recorder every 100 seconds for a 10-second period, giving a 10 percent sample of eye movement and brain wave activity. Paper speed was 15 millimeters per second.

Ranging in age from 20 to 31 years, the subjects were healthy males with prior experience in the immersion facility. Each subject reported at 0200 hours after having been awake 20 hours. Electrodes were applied and preparations were made to start monitoring sleep at 0300 hours.

For the bedrest sleep control recording, the subject, wearing his usual nightclothes, slept on a cot in the same room as the immersion facility. The EEG and EOG leads were connected to the plug in the helmet placed near the cot. This allowed the same instrumentation to be used for bedrest and immersion sleep. The weight of the helmet in air made it impractical for it to be worn by the subject during bedrest sleep controls.

The subject during the tethered experiments is shown in figure 1. The tether was located across the groin much like a seat belt. Typically, each subject was supported entirely by water with the exception of the buttocks which lightly touched the top of the sleep platform.

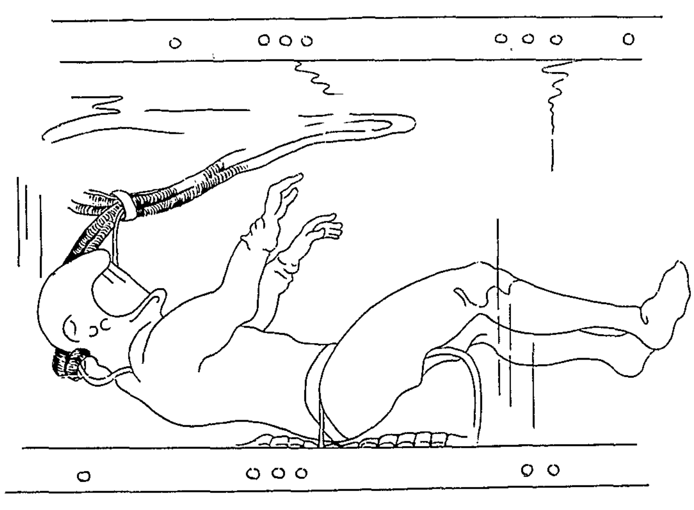

Figure 1. The Usual Appearance of the Subject during the Tethered Experiments Showing the Location of the Tether

During the clamshell sleep studies, the subject was as shown in figure 2. The amount of weight attached to the top netting for adequate pressure sensation was arrived at in preliminary studies by a process of trial and error: 23 pounds of lead distributed along the dependent edge of the net caused pressure sensations very similar to those of bedrest.

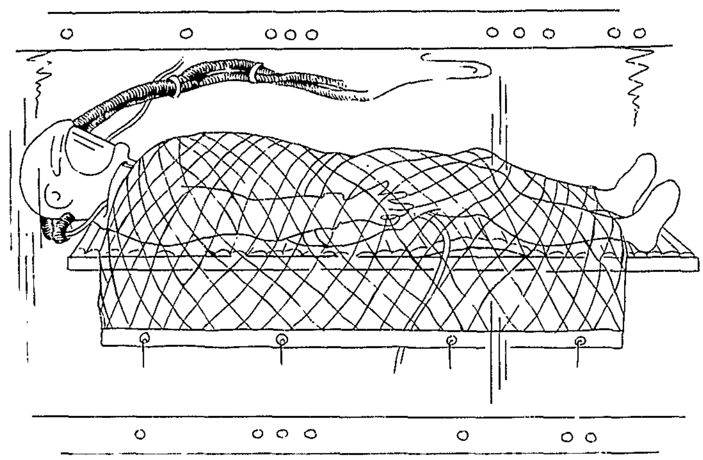

Figure 2. The Usual Appearance of the Subject during the Clamshell Sleep Studies Showing the Posterior Corrugated Supporting Surface and the Anterior Weighted Net

The bottom of the clamshell facility consisted of a corrugated mattress devised to reduce the area in contact with the body to about 50 percent. Therefore, for any given pressure anteriorly, the effect on the tactile and pressure receptor cells of the posterior contact areas should be correspondingly greater giving a subjective feeling of more "weight." Were the posterior supporting surface flat, then, in this free-floating neutrally buoyant situation, pressures above and below would feel equal. With the modification as described, the posterior receptor cells, in theory, should give the sensation of greater pressure more nearly like a bedrest situation.

After 2-1/2 hours of sleep monitoring, the test was terminated and the subject was removed from the water. Prolonging the test duration was impractical because of the diuresis (ref. 4) which necessitated voiding at about this time. Once awake, subjects felt completely rested and could not return to sleep. An interview was held immediately following each test to ascertain dream recall, comfort, sleep gratification, and sleep facility evaluation.

We interpreted the records by the method of Dement and Kleitman (ref. 2). Sample tracings of the various EEG patterns observed are presented in figure 3.

Sample tracings of the EOG during an active period of eye movement with similtaneous recording of right occipital brain wave activity is shown in figure 4. Calibration of the EOG was done before and after each test procedure and consisted of the subject moving his eyes horizontally from one predetermined spot to another so as to cut an arc of 20 degrees.

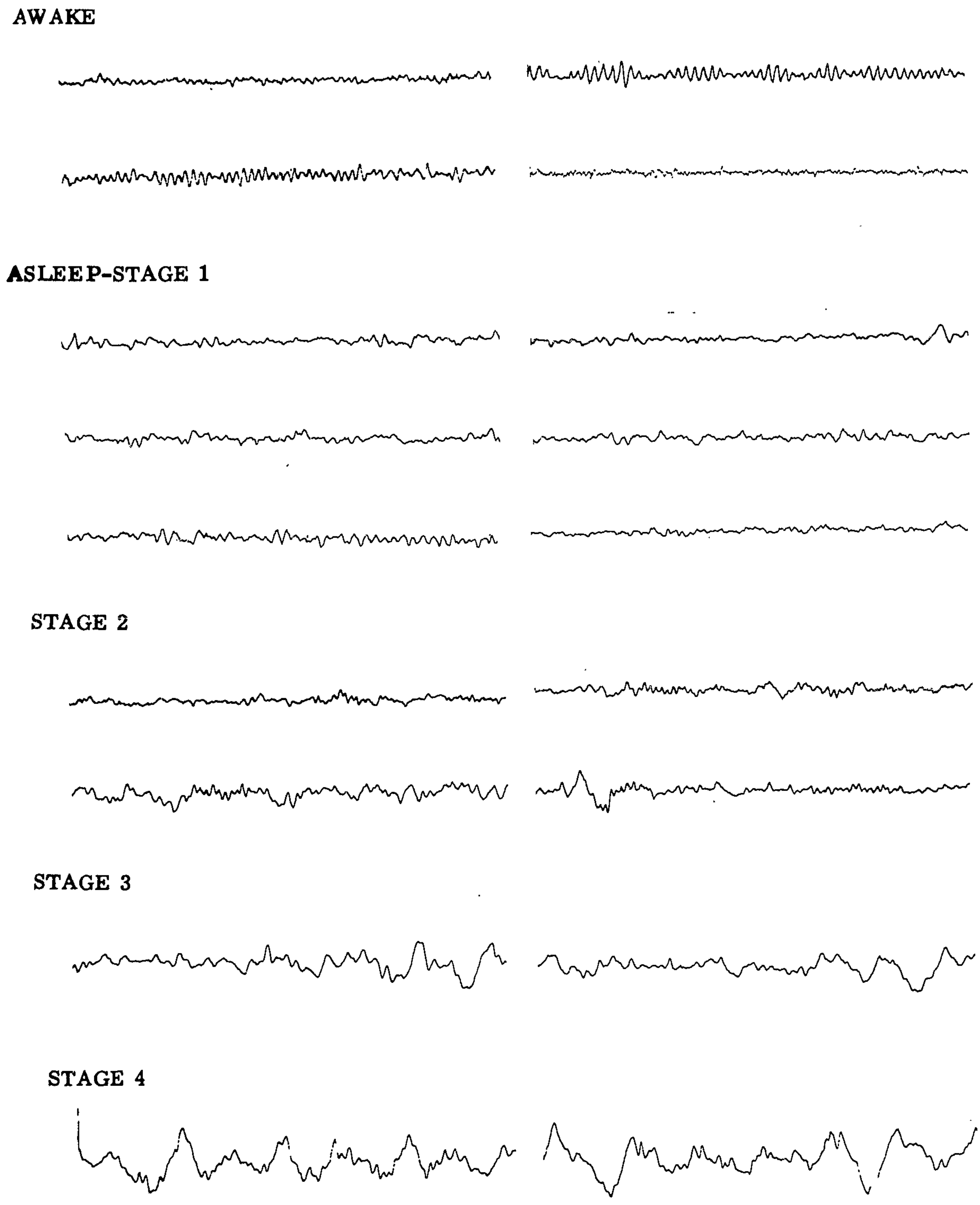

Figure 3. Sample Tracings of the Various Electroencephalogram Patterns Observed during the Sleep Experiments Illustrating the Classification into Awake and Asleep Stages 1-4

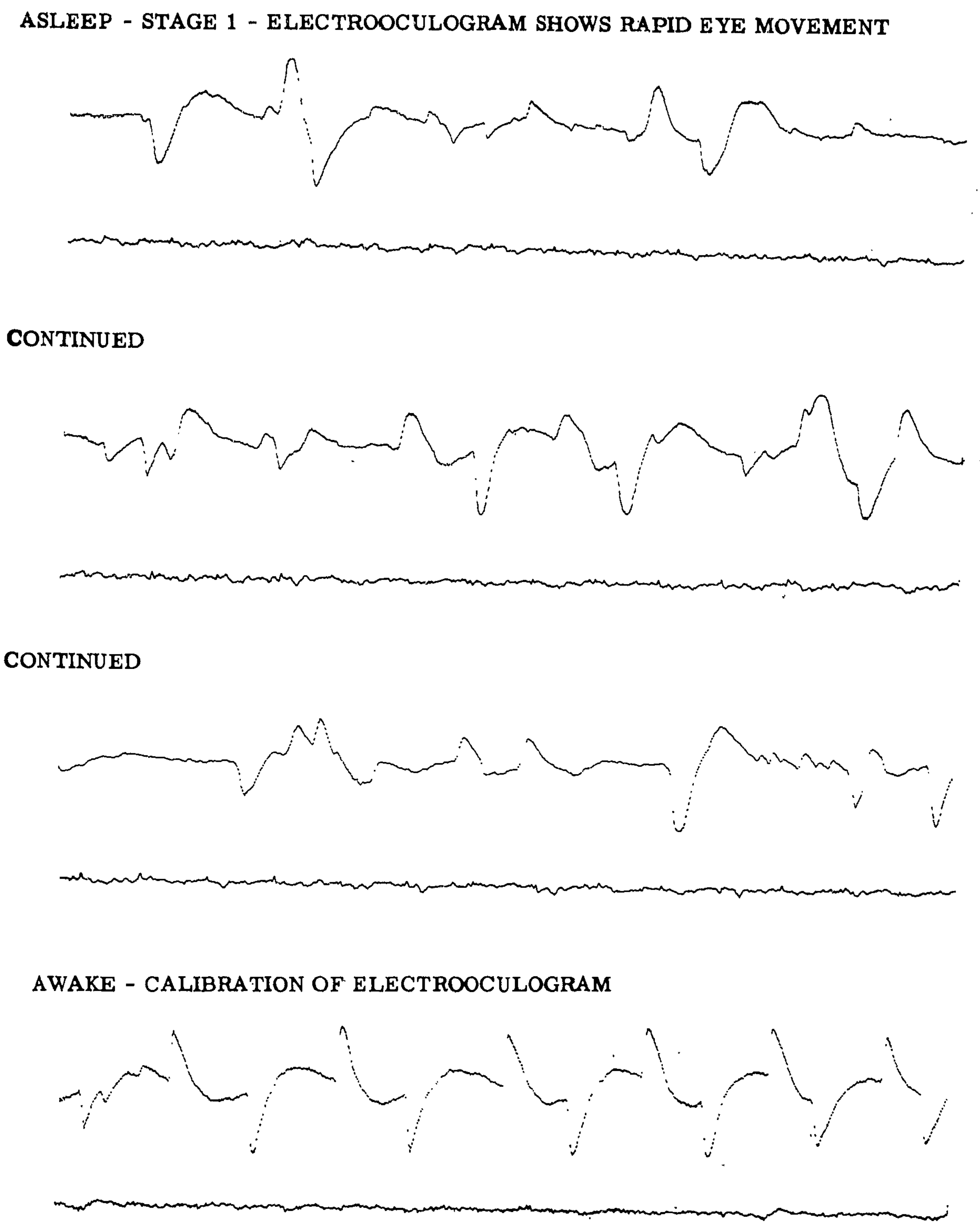

Figure 4. Sample Tracings of the Electrooculogram during an Active Period of Eye Movement with Simultaneous Recording of Right Occipital Brain Wave Activity (Subject V)

RESULTS

Depth of sleep (EEG) versus time data for each of the 5 subjects during the bedrest, tether, and clamshell sleep experiments is presented in figure 5.

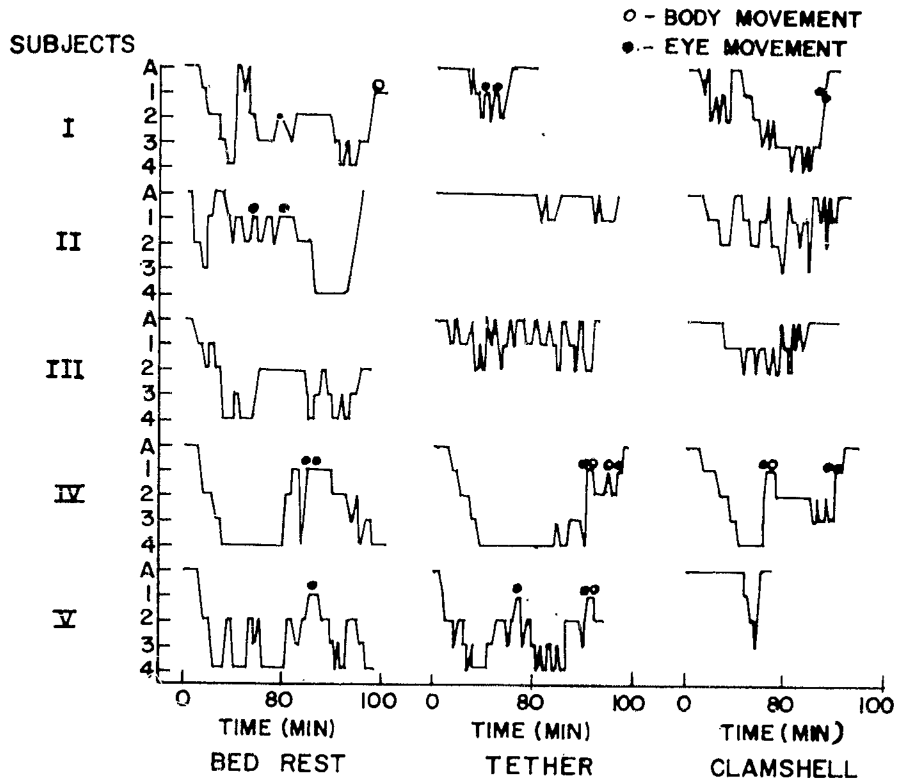

Figure 5. Depth of Sleep (by electroencephalograph records) versus Time for Each of the 5 Subjects during the Bedrest, Tether, and Clamshell Sleep Experiments

Periods of eye movement activity (by the electrooculograph) and body movement as observed and recorded by the monitor are also shown.

Subject I

Subject I promptly went to sleep during his bedrest control and rapidly progressed down in depth to stages 3 and 4. (See reference 2 for explanation of stages of sleep.) He tended to "lighten" or cycle every 45 minutes.

> This subject's characteristic awake tracings from the occipital area showed low-voltage, 20-25 cycles per second (cps) beta activity. Stage 1 sleep was associated with disappearance of the beta activity and appearance of 5-6 cps low-voltage waves. Stage 2 was quite characteristic in this subject with prominent 13 cps spindles superimposed on 3-4 cps low-voltage waves. Stages 3 and 4 showed the usual 1-2 cps high-voltage waves.

During his tether sleep study, he had considerable delay in the onset of sleep and the depth oscillated between stages 1 and 2, never going into deeper stages. After a brief sleep period (see figure 5) he awoke feeling completely rested and was unable to go back to sleep. In the clamshell sleep study, this subject promptly went to sleep and, with the exception of a brief period of awakening for a drink of water, he showed deeper sleep than during his tether test, maintaining stage 3 and occasionally dropping into stage 4.

Subjective Impressions Concerning the Clamshell Test:

"All sensory cues seemed to indicate normal restful sleep environment and I had no trouble going to sleep. The feeling was very similar to being in bed with a lot of covers."

Subject II

Subject II promptly went to sleep during his bedrest study and demonstrated a tendency to hold at stages 1 and 2 sleep before dropping down into stage 4. "Lightening" occurred after approximately 100 minutes of sleep.

> This subject's characteristic awake tracings from the occipital area showed prominent 9 cps alpha activity. Stage 1 sleep was associated with the disappearance of the alpha and the appearance of 4-6 cps low-voltage waves. Fourteen cps spindles superimposed on 3-4 cps low-voltage waves with occasional 1-2 cps high-voltage waves occurred in stage 2. The usual patterns of 1-2 cps high-voltage slow waves indicated stages 3 and 4.

Almost no sleep occurred during this subject's tether study. Only rarely did he drop down to stage 1 for brief periods. The clamshell facility tended to promote prompt and deeper sleep with a considerable duration (see figure 5) spent at stages 2 and 3. However, this subject demonstrated a tendency to rather frequent "lightenings" with a cycle from 25 to 30 minutes.

Subjective Impressions Concerning the Tether Test:

"In spite of being sleep deprived, I felt little desire to sleep during the test. Noted considerable daydream activity. Felt rested upon emersion despite minimal sleep."

Subjective Impressions Concerning the Clamshell Test:

"Clamshell technique is very comfortable, affording good pressure sensation top and bottom much like a regular bed with lots of blankets."

Subject III

Subject III promptly went to sleep during the control study and rapidly progressed down to stage 4. Sleep cycles occurred at approximately 60-minute intervals.

> This subject's characteristic awake tracings showed prominent 9-10 cps alpha activity. Disappearance of the alpha and appearance of 4-6 cps low-voltage waves indicated stage 1 sleep. Stage 2 was associated with 14 cps spindles superimposed on 3-4 cps low-voltage waves with occasional 1-2 cps high-voltage waves. Stages 3 and 4 showed usual pattern of 1-2 cps high-voltage waves.

At no time during his tether study was sleep deeper than stage 2. Although sleep promptly occurred, he characteristically showed rapid oscillations from awake through sleep stage 1, occasionally to stage 2, then back to awake. The clamshell facility promoted better sleep stability but it did not enable this subject to obtain deep sleep and seemed to offer fewer objective advantages than in subjects I and II.

Subjective Impressions Concerning the Tether Test:

"I feel rested on leaving the tank as after a good nap. No drugged or groggy feeling. Felt not particularly sleepy in the tank. Content to doze."

Subjective Impressions Concerning the Clamshell Test:

"Initial comfort excellent with moderate pressure anteriorly from the netting with only the barest pressure below but altogether very secure. Felt that if I was going to sleep I could do it here as well as in bed."

Subject IV

Subject IV promptly fell asleep in the control study and rapidly progressed to stage 4 where he remained except for a 50-minute period of "lightening" which occurred 90 minutes after the onset of sleep.

> This subject characteristically demonstrated 12 cps rather low-voltage alpha activity while awake. The disappearance of this alpha and appearance of 5-6 cps low-voltage waves indicated stage 1 sleep. Prominent 12 cps spindles superimposed on 4 cps low-voltage waves indicated stage 2. The usual 1-2 cps high-voltage patterns were seen in stages 3 and 4.

In contrast to the previous three subjects, this subject promptly went to sleep during his tether test and rapidly progressed to stage 4 very much like his control pattern. He remained deeply asleep until approximately 120 minutes at which time "lightening" occurred. In the clamshell technique, his sleep again resembled his control pattern with somewhat less time spent in deep sleep and with slightly shorter sleep cycles.

Subjective Impressions Concerning the Tether Test:

"When I first got on the cot it seemed as though I wouldn't stay down. After a few minutes I was able to let my whole body relax and found I could stay down very easily. As I breathed my body would rise and fall slightly. Soon I became very drowsy."

Subjective Impressions Concerning the Clamshell Test:

"This time it felt very much like a bed. The net over me felt very much like covers. I did not like the 'cover,' however, as I have a phobia to anything restricting the movements of my arms or legs."

Subject V

Subject V promptly went to sleep during his control study and rapidly progressed to stage 4. He tended to oscillate between stages 2 and 4 and showed a "lightening" to stage 1 for a brief period about 90 minutes after the onset of sleep.

> This subject's normal awake occipital EEG recordings are characterized by the presence of 18-22 cps low-voltage beta activity. Disappearance of the beta waves and appearance of 4-6 cps low-voltage waves indicated stage 1 sleep. Well-developed 14 cps spindles superimposed on 3-4 cps low-voltage waves with an occasional 1-2 cps high-voltage wave indicated stage 2. Stages 3 and 4 were characterized by the usual pattern of 1-2 cps high-voltage waves.

Like subject IV, this subject promptly went to sleep during his tether test and rapidly progressed to stage 4. He "lightened" to stage 2 on two occasions with a sleep cycle of approximately 80 minutes. In contrast, during the clamshell experiment, the onset of sleep was delayed considerably and for only a relatively brief time was he able to sleep. Most of this was in stage 2 with a brief progression to stage 3 noted on one occasion.

Subjective Impressions Concerning the Tether Test:

"At first felt somewhat unstable. Felt as if I wanted to sleep on my side. Much more comfortable than a regular bed, and easier to doze off."

Subjective Impressions Concerning the Clamshell Test:

"Clamshell felt good, like a bed with a heavy comforter but arms felt pinned. As time passed I got the feeling of insecurity. I tried to think in terms of everything was normal and tried my hardest to go to sleep. The netting seemed to be the biggest complaint as I felt it to be a real burden. I'm not the least bit sleepy now that I'm out."

EEG and EOG Recordings

In all subjects, the EEG characteristics during both the tether and clamshell sleep experiments showed no apparent deviation from control patterns.

The EOG recordings of eye movement activity and body movements as observed and recorded by the monitor are presented in figure 5. The results are in agreement with work of Dement and Kleitman (ref. 2) who found that body movement and rapid eye movements characteristically occur only during periods where "lightening" to stage 1 has occurred and appear to yield objective evidence for the presence of dreaming. The results observed in subject IV are particularly revealing in this regard and present evidence that this relationship of eye and body movements and stage 1 sleep persists in this unusual free-floating environment of water immersion.

DISCUSSION

Although it remains to be established how much correlation exists between the "free-floating" condition of immersion and the free-floating condition of weightlessness, both are associated with substantial decreases in mechanoreceptive feedback to the central nervous system. The subjects with experience both in the 0-G aircraft and in our immersion facility observed a subjective similarity of the two situations, particularly with eyes closed. Although orientational information of vestibular origin is present while the subject is immersed, surprisingly few clues are afforded. Information concerning slowly changing body position is usually derived either from contact with the sides of the tank or by slight changes in the helmet airflow as the regulator adjusts for differences in depth.

The results of this study suggest that considerable individual variation exists in the ability to sleep under conditions of reduced mechanoreceptive input. Three of the subjects demonstrated a relative decrease in the ability to sleep while neutrally buoyant during the tether test. This was evidenced by delay in the onset of sleep, very light depth of sleep, and frequent oscillations from awake through stage 1 sleep to stage 2, then back to either stage 1 or awake. The remaining two subjects were able to sleep promptly while free floating and progressed rapidly to deep sleep in patterns indistinguishable from their control bedrest sleep.

A wide range of individual variation in free-floating sleep patterns was expected. This variation is probably intimately related to the personality structure of the individuals. It may be a reflection of those subtle genetic and environmental influences which have contributed to the process of personality development. This was aptly inferred by Simons (ref. 8) in his use of the term "mental set" of an individual to explain why the sudden transposition to the weightless state might be regarded as a pleasant sensation of floating by some subjects and as an unpleasant sensation of falling by others, accompanied by those reflex actions usually associated with a falling reaction.

The two subjects (subjects IV and V) who experienced no difficulty in obtaining deep, essentially normal sleep during the tethered studies demonstrated considerable intolerance to the clamshell technique. In both cases, although they initially reported this technique as comfortable, a claustrophobia type of reaction later became manifest with strong urges to move the extremities from under the confines of the net and to move about. Both reported great relief at termination. Inquiry into the past histories of these subjects revealed evidence of chronic patterns of intolerance to restriction. Subject IV reported a sibling who would manifest a near hysterical reaction when her arms or hands were forcibly restrained, even by a relative or close friend.

Essentially none of this intolerance to the clamshell sleep facility was experienced by the three subjects who had been able to obtain only brief, intermittent periods of light sleep during the tethered sleep studies. They uniformly described their sensations as being on a soft mattress with a lot of blankets or with several comforters. Although subject III reported an awareness of restriction and on one occasion removed his arm from under the netting letting it hang over him, there was not nearly the degree of intolerance reported by subjects IV and V.

Each subject was questioned concerning his subjective evaluation of the clamshell device, particularly with regard to any advantage from the posterior corrugations. All subjects agreed that awareness, if any, of increased pressure posteriorly was minimal, and that generally the pressure sensation above and below seemed equal. This modification of the posterior supporting area to a corrugated rather than flat surface none the less seems sound in theory and deserving of more consideration.

This study was not designed to provide quantitative sleep information of the nature reported by McKenzie, Hartman, and Graveline (ref. 6). In that study, the subject slept longer and demonstrated a wider range of sleep depth the first day of immersion than any of the succeeding ones. This observation is corroborated in part by the immersion studies of Beckman et al. (ref. 1), who reported that some of their subjects promptly fell asleep after being immersed. EEG tracings revealed that in at least one of their subjects deep sleep occurred. Some subjects slept 4 or 5 hours while immersed. Graybiel and Clark (ref. 5), who pioneered the use of water immersion studies as having possible application to prolonged weightlessness research, also reported that one of their subjects routinely slept during much of his immersed periods. They stressed the importance of individual differences in this regard and pointed out the possible requirement for selection devices or for indoctrination with respect to sleep.

During his post-orbital flight debriefing as reported in Pravda (ref. 7), Cosmonaut Gherman Titov on one occasion said, "To remain in my chair, I tied myself up with special belts. Once I awoke because of some strange position of my body. I saw my hands raised and hanging in mid-air. I put them under the belts." This statement suggests that the system used by Titov was more than a simple tether system and in principle was probably more like our clamshell device with the "special belts" affording pressure sensation and restriction. The observations of Graybiel and Clark (ref. 5) are particularly relevant here. They commented upon the desire of the immersed subjects to maintain contact with the webbing or edge of the tank especially with regard to the arms which tended to float free unless the hands were slipped between the mesh of the webbing. Our own study presents additional evidence confirming this observation. Although we have demonstrated that some subjects are able to obtain deep sleep with the extremities and trunk essentially free floating, all subjects found the clamshell technique with the weighted top netting to be much more comforting and sleep promoting initially. Possibly much of the late intolerance noted by some subjects to the restriction of the netting might not have occurred had the amount of pressure of the top net been subject to their control. A device of this nature should be so engineered that the degree of pressure is variable over a considerable range upon demand of the occupant.

From an operational point of view, a rather urgent requirement exists for information as to whether sleep will be significantly affected in weightlessness and whether special sleep facilities may be required to promote sleep. At this time we must say that we still do not know. We are accumulating information which suggests that a good deal of individual variation may be expected. Some individuals may have the capacity for essentially unaltered sleep patterns with only a minimum of restriction such as a tether. Other individuals may require special facilities of the clamshell type to promote sleep. If a clamshell system appears necessary, we must consider the general design and optimum pressure range. We still have no information regarding how much sleep to expect under weightlessness conditions, but it may be reduced (ref. 6). Again this may be an individual matter. If, from a human engineering viewpoint, it is necessary to program and design for sleeping facilities before more definite information is available, then it seems logical to advise that clamshell-type sleep facilities be made available with the understanding that some crew members may find them unnecessary. No information exists concerning the possibility of adaptation of the initial sleep pattern during prolonged weightlessness.

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Unclassified report

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II. Biomedical Laboratory
III. Graveline, D.E., Capt, USAF, MC, and McCally, M., Capt, USAF, MC
IV. In ASTIA collection
V. Aval fr OTS: $.50

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III. Graveline, D.E., Capt, USAF, MC,and McCally, M., Capt, USAF, MC
IV. In ASTIA collection
V. Aval fr OTS: $.50

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Aerospace Medical Division, 6570th Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio
Rpt. No. AMRL-TDR-62-83. SLEEP AND ALTERED PROPRIOCEPTIVE INPUT AS RELATED TO WEIGHTLESSNESS: WATER IMMERSION STUDIES. Final report, Aug 62, iii + 12 pp. incl. illus., 8 refs.
Unclassified report

The "free-floating" condition of immersion is associated with substantial alterations in mechanoreceptive feedback to the central nervous system in a manner similar to the free-floating condition of weightlessness.

(over)

UNCLASSIFIED

1. Weightlessness
2. Sleep
3. Proprioception
I. AFSC Project 7222, Task 722201
II. Biomedical Laboratory
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One area having rather immediate operational application concerns sleep under these conditions. In this study electroencephalographic and electrooculographic recordings were made during sleep of completely immersed, neutrally buoyant subjects. Sleep records were obtained while using both tether and clamshell sleeping facilities and were compared to each subject's normal bedrest sleep records. The results are presented and their possible application to prolonged weightlessness is discussed.

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