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Apr 1st, 8:00 AM

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ELECTRONIC SLEEP CONTROL IN ASTRONAUTICS

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SUMMARY

Astronautic mission profiles require for the crew, various sleep-wakefulness cycles which are quite different from the normal diurnal rhythm. It has been found that there are means by which certain levels of sleep can be induced electronically without undesirable side effects. The paper describes the efforts made so far in the international scientific community and also the results of his own experiments.

The technique of the so-called "electronic narcosis" which has been used for a number of years is also described in the paper, whereby the differences of the effects of higher and lower frequencies are described.

The paper also discusses the possible hazards of the application of electric currents to the brain.

I. INTRODUCTION

It is of major concern for the systems analyst of space vehicles to establish the criteria of operational integrity of the man-machine system.

One of the great problems in putting the human element into the mechanism is its endogenous cyclic behavior. Among many inherited and acquired periodicities the rest-wakefulness cycle requires prime attention.

It became obvious from task analyses that the terrestrial indoctrination of eight hours of sleep and sixteen hours of wakefulness will not be possible to maintain during certain types of space missions. Yet, this habit is extremely firmly indoctrinated. The acquisition of this behavioral pattern dates back almost to the imprint stage because it was manifest in the mother. The infant has early acknowledged that any interference with this pattern met with the covert or overt hostility in its environment. This early adjustment was reinforced later by the cosmic diurnal cycle and thus developed into the social attitude of day-work and night-rest of most of mankind.

It has been shown in many studies of human efficiency that, depending on the activity, fatigue or boredom will bring about a measurable performance decrement in the relatively short periods of a few hours. The mid-morning and mid-afternoon drop in efficiency brought about the "coffee break" system. Due to the diurnal cycle and the consequent social behavioral pattern, most people would go to sleep during this period of efficiency drop. Some lucky ones, who can afford it, will take a short nap anyhow in the afternoon.

Not only the wakeful state has these fluctuations but, as various studies have demonstrated, also sleep shows periodic phenomena. It should be mentioned here that this problem is even more complex due to the many other parameters which influence sleep and wakefulness.

In astronautics where the two major factors, namely, the diurnal cycle and the social work pattern are not present, it will be much more advantageous to fall into a cycle different from the eight hours to sixteen hours rhythm.

It has been suggested that for prolonged trans-lunar missions a four hours wakefulness, four hours sleep cycle should be adopted. Such a cycle seems proper for the work profile proposed for certain space missions, the details of which are beyond the scope of this paper. The diversity of the duty cycle at various types of missions will, however, require an even more flexible pattern where the astronauts may need varying sleep-wakefulness periods to fit the pattern of the mission. This proposition, however, will meet with difficulties due to the strong habituation of the eight-sixteen hours rhythm.

There is a considerable amount of literature available on the physiology and biophysics of sleep, but relatively little is known on the psychophysical factors of artificially induced sleep. Yet the problem of sleep is quite important in the human factors of astronautics because of the need for maintenance of high

efficiency of the man-machine system.

Sleep is the best long-range remedy for all variants of fatigue which must be reduced to a minimum to avoid performance decrement, for which certain space tasks are quite intolerant.

Besides this recovery from fatigue, sleep may be used for sleep learning or reinforcement of learned information. This latter aspect will become significant in aiding recall of little used data which, however, may be needed suddenly without permitting the necessary time for consulting books or tapes.

II. BIOLOGY OF SLEEP

Although sleep is a most basic bodily function, amazingly little is known of its fundamental mechanism. This, in spite of the virtually thousands of scientific papers dealing with the subject.

Therefore, a brief review is given here presenting some of the more important information

а) Consciousness vs. sleep

Even the terminology of consciousness and sleep is quite confusing. There is no space here, of course, to discuss the semantic subtleties of the difference between consciousness and wakefulness, etc. In rough approximation it can be stated, however, that during consciousness the organism is meaningfully perceiving environmental stimuli and is capable of decision making and able to activate psychomotor functions.

In general there are three essential aspects of sleep:

- 1) the quality or depth of sleep
- 2) the quantity or duration of sleep
- 3) the rhythm or periodicity of sleep

Maybe the greatest difficulty in sleep research is the measurement of the depth of sleep. A quantitative evaluation of this factor is most pertinent because of the wide spectrum between drowsiness and coma. The physiological and psychological aspects of sleep depend greatly on the state of sleep.

There are a number of measurements proposed for the determination of depth of sleep.

One system uses the numbers 1 to 4 to indicate states of sleep, another uses the letters A to G with intermediates denoted by a + or - sign. Again others refer to slow, rapid or no eye movements which are associated with states of sleep. Fair quantitative information can be provided with good reproducibility, using electroencephalograms, which will be discussed later.

Furthermore, a number of stimulus gradients were applied for depth-of-sleep curves. Auditory, visual, tactile and pain sensations were used with little reliability.

Stupor and hibernation, although these stages can be considered as extremes of sleep, will not be discussed in this paper.

The duration of sleep is strongly dependent on the age of the person. In adults an average of 7.5 hours sleep per 24 hours seems to be a basic human trait because it holds for all races of Homo sapiens, at least for those who live in the temperate zone.

The sleep-wakefulness periodicity is anchored very firmly in the human

physiology. Body temperature changes and other physiological collaterals of sleep do not change readily even after prolonged training. In a test, after many weeks of training, subjects of 12 hours sleep cycle reported no overt discomfort but their body temperature rhythm remained corresponding to the former 8-16 hours cycle. Visceral activities also seem to resist modification of sleep cycles.

Meteorological factors, which have such a profound influence on sleep, are meaningless for astronautics due to the controlled environment of the closed ecological system of the crew compartment. Cosmic cycles may still have bearing on sleep in the space crew compartment but research data on this are incomplete.

b) Anatomy of Sleep

Among many investigators who have contributed to the anatomy of sleep, M. Jouvet is outstanding. According to Jouvet two different neurophysiological systems are controlling sleep. These are:

- 1) the telencephalic activity, which has inhibitory effect on the ascending reticular system and originates in the cortex of the cerebral hemispheres,
- 2) the rhombencephalic phase, which has an inhibitory connection to the limbic system in the midbrain and the reticular cells in the pons. These reticular cells are responsible for the maintenance of alert wakefulness if stimulated from peripheral sense organs.

Of course, since Aristotle, many thinkers and physicians and other related professionals have developed various theories of sleep, none of which were satisfactory, so far.

Some of these theories are relating sleep to the circulation in the brain; others to temporary synaptic disconnects due to amoeboid motion of neuroglia cells. Again, others are advocating that there is an undetected sleep center in the brain which is responsible for the loss of consciousness. The theories of the accumulation of a specific metabolite called "sleep poison" or hypnotoxin as well as the instinct theory of sleep were explored with insufficient results.

The fact of the matter is that the mechanism of sleep is not yet well understood.

c) Physiology of Sleep. Sleep feeding relations.

As indicated before, sleep has a profound influence on many physiological parameters. They are so numerous that only a very few can be mentioned here.

The pH and the blood sugar content of the blood do not change significantly during sleep. There is a slight change in the calcium equilibrium in the body fluids during sleep, but no other noteworthy alteration has been observed during sleep. The pulse-rate, as expected, decreases in the sleeping persons and as an extreme a rate of 45 has been observed. The blood pressure in the body also decreases with drops of 20 to 30 mm Hg, depending on pressure in wakefulness. These figures may account for the anemia in the brain during sleep.

What is interesting is that epinephrin, which causes a strong increase in blood pressure in the wakeful person, fails to do so during sleep.

The symptom of snoring is not considered a pathological condition and does not influence sleep except for those persons who have to share the environs of the snorer. Respiration is altered by sleep but the reports on the details are quite conflicting.

Digestion in its biochemical phase is not much influenced by sleep. Some glandular change has been reported, such as the accumulation of bromine in the anterior lobe of the pituitary gland. The change in body temperature is not considered to be related directly to sleep but to the lack of muscular activity.

d) Psychology of Sleep. Dreaming.

Considerable information is now available concerning dreaming. The results are quite far reaching and show that dreaming is a necessary physiological-psychological activity.

During the dreaming phase the blood pressure is generally higher and the variability greater than during other phases of sleep. It is considered, however, that the blood pressure might not be as specific a concomitant of sleep as other factors, rather that it might be due to emotional changes during dreaming.

In a spacecraft, where extensive physical exercise is unlikely, the maintenance of sleep state which is accompanied by rapid eye-movements and which contains the subjective experience of dreaming, is an important factor of life support. It should be mentioned, however, that the correlation of ocular motility in sleep with dreaming is not precisely established and further research is indicated.

The functional integrity of the astronauts is related also to sleep control from a psychiatric point of view. It seems that dreams and hallucinations are brought about by a similar mechanism; thus, psychosis and dreams are related mental processes. From this point of view it is essential to monitor carefully the sleep pattern of the astronauts because sleep disturbances are characteristic for the onset of functional psychosis. It should be pointed out, however, that the EEG and the eye-movement pattern are similar in the normal and the schizophrenic persons; thus, such telemetered information would not give significant indication of schizophrenia occurring in the astronaut.

It was found that dreaming is associated with rapid eye-movements and the corresponding EEG is of low voltage, rapid and without sleep spindles.

Between the dream periods are distinct intervals of cyclic pattern. At these times there are no eye movements and the EEG is entirely different by showing the so-called sleep spindles and about 1 cps delta waves. However, cyclic changes corresponding to dream experiences are not restricted to symptoms occurring in the EEG, but significant changes are manifest in muscle tone, frequency and depth of respiration, skin resistance, blood pressure, etc. These symptoms are easily measured and lend themselves well for telemetry.

The rapid eye movements are not continuous during dreaming but the 4-5 dream experiences per night are normally uninterrupted for longer or shorter times depending on the person's age. For the age limit of 20 to 30 years the total time of dreaming during 7-8 hours of sleep, is one hour and 30 minutes, with amazingly little individual variation, and occurs about every 90 minutes.

For the mental hygiene of the astronauts it seems important that they should have good wholesome dreams every 5-6 hours to avoid "day dreams" or better called "hallucinations." According to theoreticians in this field, dreams are instinctual drive discharge processes in the id, the significance of which has been demonstrated by dream deprivation experiments. They lead to hallucinations. Obviously, the dream-sleep cycles are governed by quite deep-seated

physiological, innate mechanisms. Freud called dreams "safety valves." If these valves are closed the pressure for discharge mounts until the "dreams" occur during wakeful periods. The process of dreaming is called by Jouvet "rombencephalic phase," which seems to be a somewhat cumbersome nomenclature, but has anatomic significance.

It is believed that dreaming is also connected with neuro-humoral secretion. Thus, there might be developed in the future a biochemistry of dreaming but it is likely that the understanding of dreams will need purely psychological interpretation.

There are certain similarities between dreaming and the effects of sensory deprivation. This seems to indicate that dreaming is in fact independent from sleep but is related to the relative absence of environmental stimuli which are essential for wakefulness and the various aspects of adaptive behavior.

Although we cannot enter here into the detailed psychodynamics of sleep, it seems that for the proper functioning of astronauts on long missions we will have to control not only the sleep cycle, but will have to manipulate also the quality and the duration of dreams.

e) Sleep Deprivation

Chronic disturbances in indoctrinated sleep cycles may lead to anomalies of waking experience and behavior. It can easily lead to psychosis.

If muscular activities are excluded it is impossible to deprive a normal person of sleep for longer than two days.

Prolonged sleeplessness causes irritability, irrationality and hallucinations. It causes also marked and increasing performance decrement.

There is a stage or state of mind where the concept of wakefulness becomes transitory to sleep.

f) Psychophysics of Sleep. EEG.

If one is looking at a flickering light, rhythmic signals appear on the EEG which change with the flicker frequency. This indicates that those signals were generated in the visual projection area of the brain.

It is significant that the flicker is generally accompanied by sensation of motion and patterns.

The action potential which is concomitant with every biophysical or dynamic activity of every cell is manifest also in brain function.

The best understood pattern of electroencephalograms is that of sleep. It enables us to clearly distinguish between the various stages or levels of sleep and arousal.

The various typical patterns of the EEG are designated mostly by the Greek letters alpha, beta, gamma, delta and epsilon. The alpha pattern, which appear also by slight drowsiness, is 9-12 cps with about 60 microvolt amplitude. Beta rhythm is of low voltage, where the alpha pattern is replaced by small undulations and indicates definite sleep. Gamma rhythm is characterized by the so-called sleep spindles and wave trains of 14-15 cps with 20-40 microvolt amplitudes. These are superimposed on irregular slower waves. Delta is the designation of high amplitude (300 microvolt) very slow 1 cps waves with irregular sleep spindles. The Epsilon stage shows random pattern with even slower Delta waves of 5-20 sec intervals. This stage is characterized also by the complete absence of sleep spindles.

The total picture is, however, not as simple as indicated here and large amounts of literature are available for the interpretation of further and complex details.

III. SLEEP CONTROL

The human mechanism has an apparent shortcoming as compared with a bionic device, namely that it cannot be switched "on" or "off" as needed. Of course, there are bodily activities such as recovery from fatigue, etc. which require the proper functioning of the body during a non-conscious period. This occurs, however, at a lower metabolic rate, although it can be said that during dreaming sleep we are more intensely alive than in the conscious or waking existence.

But there are a number of ways which permit a certain limited control of sleep. They are briefly mentioned below.

a) Training and Indoctrination

It is possible that by prolonged training most individuals will acquire a four-four hours rhythm. It must be expected, however, that such terrestrial training may initiate neuroses, because the forced rhythmic behavior may not coincide with the long established physiological "clock" mechanism. This condition will be further aggravated by the weak environmental signals which will reach the person even in his confinement and which tend to reenforce the deeply embedded original pattern. The astronaut will be especially susceptible to these weak signals as a consequence of the stress of sensory deprivation caused by the confinement in the space compartment. Of course, the simulation of certain nocturnal noise, to which the urban population is acclimated, may be used to override the weak diurnal noises. However, this method may not be sufficient to provide sleep.

b) Drugs

The use of hypnotics must be discarded because our present inventory does not contain a compound or mixture which would initiate sleep rapidly nor does the compound have a well defined four hours of duration and permit a quick arousal without any after-effects.

There are two distinct types of drugs, the hypnotica which facilitate sleep and narcotica, which cause in many people irresistible and deep stupor. However, hypnotica, if administered in larger quantities will cause a state called narcosis, or, if the product is applied through respiration, anesthesia.

c) Hypnosis. Post-hypnotic Suggestion.

This method cannot be recommended because of the limited duration of its effect. It is thinkable that a combined post-hypnotic and auto-suggestion technique which would utilize an artificial clue, such as a tape recording, may work for a longer time but this method has not been demonstrated to be reliable enough.

Beyond the aforementioned practical space applications, it is significant that the below mentioned technique of electronically induced sleep could contribute to our understanding of the various hypnotic states. From a few experiments it seems also that this technique will have therapeutic values inasmuch as those neurotic patients who resist hypnotherapy could be brought into a state of consciousness where their excitation and hostility is reduced

enough to make them responsive to hypnosis.

d) Visual and Audio Stimuli

It is a well known fact that certain rhythmic photic stimuli or monotonous audio signals have the tendency of hypnotic sleep induction.

The effects of flickering light has been under study for about 200 years and it has brought us quite close to being able to disrupt consciousness and thus manipulate the onset of sleep. Previous reports have indicated that the limit of the results was a slight hypnotic effect with drowsiness and occasionally with unpleasant side effects. The impairment of cognition by flickering light has also been described.

e) Electrical Current

Japanese and Russian reports, together with the research of the present writer, which he has performed in the past years, suggest that the solution to the problem of sleep control of the astronauts may lie in the area of cyclic electronic stimulation of a so far unknown resonance area in the brain, which reduces cognition and willful activities.

It is known from research here and abroad that electrical stimuli of a certain frequency, if applied to the brain, will cause drowsiness or sleep.

The electrical influence of consciousness can be subdivided into three distinctly different types:

- 1) electroshock
- 2) electronarcosis
- 3) electrosleep

Electroshock was used extensively in certain mental diseases such as schizophrenia and sometimes to supplement prefrontal lobotomy. Lately, it is applied less frequently. The effect of the relatively high current density causing artificially a seizure, with temporary blocking of respiration.

This type is applied primarily only to psychotic patients and does not concern us here.

Electronarcosis, also called electroanesthesia, is a modified, subseizure electronically induced loss of consciousness, without drastic effect on respiration. However, convulsions are frequent and the application of muscle relaxants is indicated. Sometimes the extreme rise of blood pressure puts this technique into expert hands. In spite of this, electronarcosis has definitely a place an astronautics.

Although the character traits of astronauts are as carefully determined as possible, under many months or years of lasting space-stress some psychosis may occur. Since the reaction to deprivation, of which there will be many in space, is the defense of a break with reality, psychotic persons will be greatly prone to hallucinations and delusions.

Many reports indicate that electronarcosis can be successfully applied to alleviate such conditions.

Since electronarcosis has a hypnotic effect to the reflexless stage it can easier be applied in case of medical emergency than inhalation anesthesia or drugs which could be in short supply in space, but electricity will be always available.

Over 60 years ago electronarcosis was successfully applied by Leduc at the beginning of the century, on rabbits.

The applied frequencies vary from 60 to 700 cps and the current is reported between 5 and 250 milliamps. Thousands of narcoses were administered, to men and animals, in this fashion.

Good results were obtained with 700 cps sine wave signals with 12-50 volts and 50 to 100 milliamps. The electrodes were placed on the temple. The equipment consists of an oscillator, an inverter and a push-pull amplifier.

Electrosleep produces a shallower state of sleep, which persists for some time after the current is cut off.

There is some uncertainty whether by applying such weak signals sleep is due to the current or suggestion. Whatever the underlying mechanism may be, the hypnotic effect of 9-14 cps sine wave signals on many test persons has been established.

IV. ELECTRONIC TECHNIQUES

a) Applications Published

In a critical review of the available literature it became evident that electrical signals fed into the brain through skin electrodes, have a most confused pathway due to the very noisy electrical environment. This situation is amplified by the characteristics of the low frequencies used for stimulation which have a diffused propagation under the dielectric of the brain.

Therefore, it occurred to the present writer that the signals should be channeled through the established pathways of afferent neurons. Here evolutionary and homeostatic mechanisms provide a noise-free input.

Japanese and Russian reports, together with the research of the present writer, which he has performed in the past years, indicate that the solution of the problem of sleep control of the astronauts lies in this area.

The writer has investigated this problem and brought about preliminary results which have demonstrated the feasibility of his approach. The applied equipment and a clinical and statistical evaluation, however, need further research and development. The hypothesis was that if one can generate a rhythmic stimulation of the optic nerve, the frequency of which coincides with the alpha rhythm of the person's EEG, then by presently undefinable resonance the "sleep center," or the rhombencephalic reticular fibers will adopt the periodicity and as a consequence sleep will occur, provided the noise in the brain is below a certain arousal value. Research has been performed mainly on animals. Some of the information available on humans is mentioned here.

Japan's National Railway Labor Medical Laboratory reports that 10 cps and 100 microamperes applied to insomniacs eye-lids will put them to sleep within seconds.

Gilyarovskiy in the USSR applies a pulsing dc current in the frequency band of 1 - 20 cps, with square wave pulses of 0.2 m sec duration.

Vransky in Bulgaria applied 0.5 - 2.5 volt and 0.2 - 1.5 mamp in form of ac current.

In the USA research is in progress in New York, Chicago and other places, with a broad spectrum of experiments.

b) Experiments of Present Writer.

In the exploratory experiments, of which this is a brief report, 52 persons

were used, 18 females and 34 males, who were in the age bracket of 17-22 years. A few of the experiments were repeated with the same person on several days. The persons were subjected to the experiment after receiving explanation of the purpose and technique. In cases where the subject showed anxiety, which was frequent, the electrodes were applied and the effect was demonstrated. The electrodes were then removed and the subject was left alone on the reclined chair while the experimenter busied himself with other work. Within five to ten minutes the subjects themselves requested continuation of the experiment. From then on the experimenter did not communicate with the subject to avoid hypnotic suggestion.

In many cases the subjects selected the "most pleasant" frequency and the "best" current by themselves adjusting the signal generator. This activity must have preconditioned the subject because in these cases the hypnotic effect seemed to occur sooner than in cases where the frequency was pre-set.

Based on the declared results of the advertised "heart-beat comforter" for babies, it was considered to explore whether a monotonous audio stimulus is synergistic to the effect of photic stimulation. Therefore, the heart sound was chosen and a tape recording was made from an audiocardiograph. The tape was edited to remove the sound of arrhythmias and the peristaltic noise. Without exception the subjects considered the sound of the recording as distractive and it interfered with the effects of photic stimulation. It seems possible, however, that other less complex audio signals than the heart sound could be effectively used if applied at the low frequencies of 1 - 2 cps. This is indicated by the experiment by which a small relay or solenoid was strapped on the vertebral column of a rabbit in the sacroiliac region and made to tap the vertebra at set frequencies. The results were inconclusive because the problem could not be explored with statistically satisfactory data in the available time. In some cases the animal went to sleep; in others it acquired catatonic posture or showed almost epileptoid behavior. In other instances when the animal was stimulated at other parts of the backbone there seemed to be no effect. In these experiments it is uncertain, of course, if the stimulus is primarily tactile or audio.

The use of weak audio signals which are pleasurable but subconsciously associated with the person's individual environment at the time of going to sleep, has been considered.

The photic stimulus was generated by a signal generator with variable frequency. The frequency was selected by the subjects who were permitted to scan between 1 cps up to the frequency of flicker fusion. All subjects tested so far have chosen a frequency between 10 and 14 cps. It is thinkable that the hedonic value of their choice in frequency may have significance in some aspects of hypnotherapy.

The electrodes were made in the shape of eyeglasses with the glass replaced by a metal screen which was covered with a thick pad of gauze. When used, the pads were moistened with saline solution. To the ends of the temple of the eyeglass frame was fastened a rubber band which assured proper fit and contact to the eyelids. The connection from the electrodes to the signal generator was made with alligator clamps on a shielded cable.

The input signal was sinusoidal and was applied across the eyeballs. Depending on the skin resistance, the current was 20 to 50 ma. It is thought

that such a low frequency current probably travels within the sclera to the optic nerve. This is fortunate for the protection of the retina at prolonged exposure. Higher currents in the 200-300 ma range may propagate partially in the choroid, the effect of which must be ophthalmologically tested. In all experiments performed not one subject showed even the slightest temporary aftereffects in spite of several repetitions. Presumptive data indicates a broad margin of safety for this technique.

The observation of the depth of sleep by the eye movement was not possible because the electrodes covered the eyes. Therefore, the onset of sleep was measured in many cases by a light touch of the underarm hairs with a camel-hair brush and instructing the subject to report with a slight motion of the index finger. The tactile stimulus was applied at random intervals of about once a minute until the report failed. Sleep occurred in most of the cases within five to eight minutes. By repeating the experiment on different days with the same person there was at first a decrease in the time, but by further repetition an increase was observed in the time required for the effect.

The room was a quiet environment (10-15 db) but was not fully soundproofed to avoid possible effects of sensory deprivation.

From these preliminary experiments it seems to be evident that a sinusoidal wave pattern in the low frequencies applied as photic stimuli produce in most cases a hypnotic state. The frequency range was 10-14 cps; thus, the effect is not identical with electronarcosis, which operates at much higher frequency and higher current.

The mechanism of the onset of sleep seems to respond better to the sine wave pattern than to square waves or to signals with extremely short duration, as was used by Russian investigators.

It seems also that the conscious level of the subject was about A- on the Simon-Emmons scale, although the favored frequency of about 14 cps corresponds to the sleep level C on the same scale, which indicates the appearance of sleep spindles.

The plans call for further experiments with larger numbers of subjects, better controlled conditions and EEG, as well as biochemical and physiological monitoring, such as eosinophil count, lactic acid production, etc. The spectrum of frequency will be also extended to five seconds or even fifteen seconds per cycle to explore a possible hypothalamic resonance effect in the delta activity range.

It is expected that, from the presently available laboratory equipment, a prototype will be developed which can be applied to sleep control in the space crew compartment.

Such a device must be:

- 1) applicable and effective to the majority of astronauts
- 2) proven harmless
- 3) free of side effects
- 4) highly reliable and maintainable
- 5) insensitive to acceleration
- 6) insensitive to nuclear radiation
- 7) light weight and small

Good progress has been made in the R&D of such a design.

Acknowledgment: I wish to acknowledge the conscientious efforts and achievements of my student assistant, Mr. Ernest Lado, Jr., who diligently helped me in these experiments.

V. CONCLUSION AND FUTURE DEVELOPMENTS

Man spends about one-third of his lifetime sleeping. This in itself indicates the significance of this state for the physiological and psychological homeostasis of a normal person.

Unfortunately, the sleep-pattern of man does not match always the requirement of our modern and sophisticated socio-technocratic life. Therefore, recently it became necessary to study the mechanism of sleep. The aim of such investigation is, besides the scientific information, the desire to manipulate sleep.

What is known is, in essence, the fact that monotonous repetition of audio or visual stimuli has frequently induced sleep in a number of subjects. This effect has a number of dependent variables, such as frequency spectrum, environmental factors and variables of certain mental states.

In addition to the condition of insomnia, this problem received impetus by the design of the work profile of long-range space missions. Here the rest-work cycle is radically different from the terrestrial nocturnal-diurnal human pattern. Because of the - some times - highly taxing performance requirements it is imperative that the astronaut should fall into restful sleep at any regular or irregular intervals. Of course, drugs which cause drowsiness or other side effects are out of the question.

It has been confirmed by the writer that sinusoidal electrical stimuli of the optic nerve in the 9 to 12 cps range will bring about sleep in most subjects within minutes. The current applied is below the sensory threshold of the skin and the homeostatic effect is fair provided arousal threshold is not exceeded. In other words, the effect shows stability against overriding stimuli. The created flicker seems to dominate, if applied long enough, even over otherwise strong arousing audio stimuli such as soft jazz music.

The biophysical or psychophysical problem of sleep control has a broad spectrum for experimentation. Large numbers of individual experiments have to be carried out for statistical evaluation of the results. They will demonstrate the considerations which are needed if one deals with a single factor of a complex system.

It does not seem far fetched to expect that within a relatively short time man will develop equipment which may be pre-set to alter the biological clock of sleep.

The time might even come when implanted bionic will control sleep and wakefulness. They could be governed by biophysical or biochemical symptoms of fatigue; thus would eliminate the over-taxing of our physiology and prevent the exposing of our psyche to undue stress. Such a condition will significantly increase the life expectancy of mankind. We could live 150 or 200 years, taking even into consideration the lack of regeneration of our cardiac tissue.

Of course, when such time comes, our activity pattern will be greatly changed. You may feel a prickle on your skin above the implanted bionic device. This could signify: "You are working too hard, better go to bed because in five minutes I will make you sleep." On the other hand, after two hours it might wake you up and if

you choose to stay in bed it will sense the reduced rate of respiration and circulation and will deliver continuous mild electric shocks which signify:

"You are lazy. I know you are well rested. Get up and do whatever you want to do."

And this, ladies and gentlemen, is not any more science fiction. It seems that a good old standby, the alarm clock, is going out of fashion.



Figure. 1