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SELF-REGULATION AS AN AID TO HUMAN EFFECTIVENESS

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The goal of this research program is to determine the relevance of physiological processes and internal states for DoD. During this first year of the program, the following universities or research institutes were involved in specific research projects as a part of the overall research program:

University of Pennsylvania	Dr. Martin Orne
Langley Porter Neuropsychiatric Institute	Dr. Joe Kamiya
University of Colorado	Dr. Johann Stoyva
University of Florida	Dr. Wilse Webb
Institute for Behavioral Research	Dr. Edward Taub
Johns Hopkins University	Dr. Alan Harris
University of California, Los Angeles	Dr. Jackson Beatty

In addition to these contractors, contracts have been awarded to:

Michigan University, Ann Arbor	Dr. Leo DiCara
University of Southern California	Dr. Gary Galbraith
University of California, Los Angeles	Dr. Jan Berkhout & Dr. Don Walter
McGill University	Dr. Ronald Melzack

These subcontracts will begin July 1, 1971. This progress report is based upon information presented by the subcontractors at the First Annual Meeting of the subcontractors in San Diego, May 27-28, and from the annual progress reports presented by the individual subcontractors. The overall research project can be divided into four areas. First, that concerned with the self-regulation of brain activity, in particular alpha activity (8-12 Hz EEG activity). This work is being done by Drs. Martin Orne, Joe Kamiya, and Jackson Beatty. The contracts awarded Drs. Gary Galbraith, Jan Berkhout and Don Walter will involve self-regulation of brain activity. Instead of control of alpha activity, these investigators will focus on control of spectral patterns of several frequencies and EEG coherence, relationship of EEG activity from various parts of the head.

The second area is concerned with sleep induction. The work in this area is being done by Drs. Johann Stoyva and Tom Budzynski, University of Colorado, and Dr. Wilse Webb and H. W. Agnew, Jr. at the University of Florida.

The third area involves the study of autoregulation of vasomotor tone and is being done by Dr. Edward Taub at the Institute for Behavioral Research.

The fourth area concerns the use of animal subjects, particularly baboons, to determine the limits of self-regulation, being done by Drs. Alan Harris, Joseph Stephens, and Joe Brady at the Johns Hopkins University School of Medicine. These investigators are also studying the self-regulation of cardiovascular activity, particularly heart rate and its relationship to performance. Dr. Leo DiCara will also do work on self-regulation of heart rate as well as study the possible self-regulation of neuroendocrines. This latter work will be initially done in monkeys.

Dr. Melzack's program at McGill University will be concerned with the ability of a person to reduce the disruptive effect of pain and to determine if there are procedures that the individual can use to minimize pain intensity or the subjective feelings of pain.

During the first year of the contract, all investigators have reported success in training subjects to control the particular physiological variable relevant to their contract. There is little doubt now that man can effectively and reliably control his brain activity, turning on or off a particular frequency of brain activity almost at will. Man can increase his peripheral temperature by as much as 5 to 8 degrees and, upon command, decrease the temperature in the same limb by an equal amount. The cardiovascular system, as reflected by changes in heart rate and blood pressure, has been brought under self-control with increases and decreases of heart rate as high as 20 to 30 beats per minute. It has also been demonstrated that through a process of muscle relaxation, man can overcome problems of sleep and that sleep induction can be achieved in people who have otherwise found it difficult to readily obtain sleep. The first year of this project, thus, has clearly shown that the initial goal of the program, i.e., can man control his internal state, has been successfully met. The remainder of this report will present, in some detail, the major findings relevant to the four areas mentioned above, i.e., brain activity, sleep induction, control of vasomotor tone, and the work being done with animals and humans related to the cardiovascular system.

Alpha

During this year, the investigators in this area have been primarily concerned with investigating appropriate experimental paradigms which permit the evaluation of alpha densities and with the exploration of the effectiveness of various feedback stimuli for maintaining the desired brain activity. Initial approaches have also been made by two of the three investigators to explore the effect of cognitive effort on alpha density and the relationship of alpha activity to performance.

With respect to the conditions under which alpha density can be increased or decreased, Dr. Martin Orne initially observed that there was no significant increase in alpha density across six days of feedback training, although some learning appeared to take place during the first two or three minutes of feedback on the first day. No further increment, however, was present over the succeeding six days of the experiment, nor did the density of alpha activity during the feedback trials exceed the density seen to occur spontaneously during the rest periods. These studies were carried out in total darkness in order to minimize the very great effects of the visual system on alpha activity. Auditory feedback was used to inform the subject as to the presence of alpha. Although this strategy was effective in terms of helping to clarify the role of external stimuli and cognitive factors, it did not permit subjects to learn how to augment their alpha activity. The failure to observe such learning was particularly striking when these data were compared with previous work in Dr. Orne's laboratory using a visual feedback system where clear-cut evidence of learning was apparent.

To clarify these discrepancies, these subjects were run for an additional two days (a seventh and eighth day), with eyes open, using auditory feedback, but illuminating the room very slightly with a steady dim light. Under these circumstances, trial-to-trial increases in alpha activity were readily observed. Even more striking, alpha densities during the trials were significantly greater than those seen during the resting periods. In order to study the effects of this ambient illumination during the initial stages of feedback training, an additional group of subjects, who had no previous experience with feedback, completed two days with auditory feedback in the dimly lit room. These subjects showed a pattern closely similar to that seen on days 7 and 8 with the original sample. This evidence has strengthened Dr. Orne's feelings concerning the process through which subjects are able to show increments with feedback training. It appears that the process by which subjects overcome the blocking effect of ambient light may be extended to cover other blocking influences which also inhibit alpha. Thus subjects, by self-control, appear to remove the usual inhibitory factors that block the appearance of their basal alpha activity.

Dr. Orne and his staff have also undertaken some studies with the specific aim of determining whether the normally observed alpha blocking effect of cognitive tasks could be modified by feedback training. They have observed that it is possible for subjects to carry out a routine task with little or no decrement in the density of alpha activity. When subjects carry out a task which requires cognitive effort--a task such as counting backward by sevens--a great deal of alpha blocking is observed. This blocking diminishes over time. It would be inappropriate, however, to conclude that the improvement in alpha control is due to alpha training and that the task is performed under constant cognitive stress. Careful analysis of the data indicated to Dr. Orne that subjects not only become accustomed to the task, but that they adopt a strategy of performing the task at a somewhat reduced rate. As they learn the utility of such a strategy, maintaining of alpha densities in the presence of the task is less difficult.

Based upon their basic findings concerning some of the important aspects of alpha training, Dr. Orne and his group feel that they now have sufficient data to advance to the next stage of their contract. During the next year, a technique designed to measure the effects of alpha feedback training for minimizing what might be conceptualized as anxiety, or nonrational components of a subject's response, is being developed. The technique will use a small heating pad in which the temperature increases gradually with time. The subject will have in his hand a switch which he may press to reduce the temperature of the pad by a certain amount. He will be able to maintain the pad at a comfortable temperature simply by pressing the switch at a slow rate. Pilot studies now in progress suggest that subjects characteristically choose a rate of lever pressing considerably in excess of that necessary to maintain the pad below their sensory threshold. If alpha feedback training can lower anxiety, one would expect that it would decrease the rate of lever pressing to the point where it is a function of the temperature in the heating pad rather than being determined, in large part, by anxiety. During the next year, more attention will be focused upon the finding that the effects of alpha feedback on subjective experiences are only partially related to total alpha density and that relative alpha density may serve as a better correlate or monitor of the subjective state. These investigators thus intend to focus more on the relative increase of alpha over the baseline rather than the final total alpha density, both in terms of data collection and in emphasis to subjects.

At UCLA, Dr. Jackson Beatty's initial efforts were directed toward the development and testing of a computer-based paradigm for operant control of alpha and beta (above 13 Hz) brain frequencies. His principal thrust was to develop a modular software system which could serve in both present and future experiments. Emphasis was placed upon both generality and flexibility in these programs. A software package using machine language has been developed and the realtime Fortran version of this system has been completed. After suitable testing, this Fortran program will be made available to other investigators in the project. The Fortran software will run on nearly any computer with a Fortran compiler. Although Dr. Beatty has written this program with particular emphasis on EEG alpha and beta wave activity, the software is sufficiently modular and general to easily process other neuroelectric signals. This computer-based system has been utilized to conduct several experiments. From these studies, Dr. Beatty has drawn the following conclusions:

(1) Naive human subjects can be reliably trained to increase differentially the abundance of occipital EEG waves in the alpha and beta frequency bands in the presence of a discriminative stimulus to inform the subject of the desired EEG activity.

(2) No prior information about the nature of the psychological concomitants of such activity is needed.

(3) Pretraining alpha abundance predicts only the mean level of alpha output over trials. It does not predict the efficiency of such training nor does it predict anything about beta wave activity.

(4) Significant alterations in EEG spectra may be produced with a relatively short training procedure -- 16.6 minutes under each reinforcement contingency.

(5) Naive subjects show better discriminative enhancement of EEG spectral measures when provided with a feedback signal that indicates success second by second than with reinforcement schedules which provide less information. A continuous reinforcement schedule maintains a higher level of performance than do variable ratio schedules.

(6) While naive subjects show significant spectral shifts with response contingent reinforcement or feedback if appropriate prior information about the psychological concomitants of such spectral changes is provided, feedback is not necessary. Providing subjects with appropriate strategies produces changes similar to those seen in the feedback situation, both in the absolute magnitude of the results as well as the time course of their development.

(7) This result emphasizes the difficulty in ascribing learned changes to the effects of feedback when subjects are not naive, but are informed as to the nature of the task.

(8) The similarities in performance of subjects provided with prior information and subjects given response contingent feedback suggest the following interpretation. Strategies used to modify alpha and beta band brain activity are simple and readily available to naive subjects. Therefore, "feedback only subjects" could be expected to quickly adopt appropriate procedures to maximize reinforcement. Conversely, information about the performance of "information only subjects" is readily available to each subject by his monitoring his own internal state. Subjects know what it feels like to be calm or aroused. Thus, external feedback may be unnecessary.

(9) This finding suggests that the roles of instruction and feedback must be carefully evaluated when designing an applied program of autoregulation. It suggests that under certain conditions elaborate field-based hardware may be minimized or eliminated.

Dr. Beatty feels that the progress made during the first year of his contract will contribute substantially to achieving his objective of examining the possible improvement of human performance on a variety of tasks by training personnel to voluntarily control various CNS states as reflected by their brain activity. During the next year, Dr. Beatty will also include other physiological variables such as autonomic and EMG data. As a first step, an investigation of heart, respiratory, and muscle changes that accompany the EEG training will be studied. These data will provide information about the specificity of EEG effects and could provide clues for further investigation of responses defined across several physiological channels. When stable control of the desired brain state is achieved in each of his subjects, Dr. Beatty will undertake an assessment of the behavioral consequences of these autoregulated states.

At the Langley Porter Neuropsychiatric Institute, Dr. Kamiya and his staff have been exploring the capacity of humans to learn to control their own EEG, the relationship of this EEG alpha training to performance, the relationship of multi-channel EEG activity to cognitive performance, the self-regulation of EEG theta (5-7 Hz) activity, the control of other physiological variables including stomach pH through on-line feedback reinforcement, the abdominal-thoracic respiratory movements and their relationship to levels of consciousness, and work has begun on the computer-controlled EEG feedback training system. The computer work is being done in collaboration with the Stanford Research Institute (SRI).

The effective control of alpha has been repeatedly demonstrated during the past year by subjects in Dr. Kamiya's laboratory. Over four or five training sessions, Dr. Kamiya has noted that the post-session baseline alpha scores are lower than those during the tone feedback scores. This decrease in alpha without reinforcement indicates that even though there is an increase in baseline alpha over training days, this baseline increase is not as large as that seen during the actual feedback sessions. The higher alpha density during the feedback session, when compared to baseline, indicates that the alpha enhancement is due to learning of some sort, but Dr. Kamiya and his staff, at present, are not sure exactly what is being learned.

The studies concerned with the relation of EEG alpha rhythms to performance have focused on the relation between memory and alpha, and the relation of alpha to visual detection of a signal. In the study of memory, subjects were given a list of single words, approximately 4 seconds between each word. Each word was repeated once in the list at varying intervals after the first presentation. The subject's task was to respond "new" or "old" depending on whether he thought the word was presented for the first time or for the second. This permitted a signal detection approach to memory. EEG from the left and right occiput and left and right temporal leads were recorded simultaneously along with the time of presentation of the stimulus and the time of response. The data analysis is underway and will be concerned with these questions: (1) Is the level of alpha prevalent at the time of either the first or second presentation of a word predictive of correct recognition? (2) Is the level of alpha following the first or second presentation predictive of recognition? (3) Is the difference between the alpha level immediately before the stimulus presentation and the level following presentation predictive of recognition? (4) Is there any tendency for "state-specific" recognition? That is, if the individual has high alpha at the time of first presentation, is he more likely to show correct recognition if the word is repeated when he is in a high alpha level than if he is in a changed alpha level upon repetition?

The study of visual detection involves presentation of brief exposures of visual stimuli with the goal of determining whether visual detection is related to the presence or absence of alpha. The general design of this study is similar to the memory study. Dr. Kamiya chose this visual detection study because the alpha-nonalpha continuum is often correlated with alertness. One point of view claims that since alpha is a generally more relaxed state than non-alpha, subjects would be less vigilant during the alpha period and would therefore show poorer performance on tasks which place a premium on attentiveness. On the other hand, there is a point of view which maintains that in order to be able to form correct impressions under conditions of low signal strength, a more open state of attention rather than a highly focused one would be helpful. It is hoped that results from these studies will help resolve some of these questions and help decide whether alpha feedback training will be of any value in performance.

Capitalizing on the general knowledge that there is symmetrical localization of the cognitive function in the brain, Drs. Ornstein and Galin have investigated the relationship of brain activity in the hemispheres and, specifically, the relation of EEG activity in the left and right hemispheres to cognitive functions. In general, clinical work has found verbal and mathematical functions in the left hemisphere while spatial relationships appear to be the special province of the right hemisphere. Drs. Ornstein and Galin have carried out a study of EEG asymmetry during the performance of tasks which engage predominantly the left or the right hemispheres. Some of the verbal tests thought to be dependent on the left hemisphere that were used were letter composition, serial arithmetic, reading, verb lists, and sentence completions. For the right hemisphere, the tests were block design, Raven Progressive Matrices, mirror drawing, picture synthesis, reversible figures, seashore tonal memory test, revised Minnesota paper form board test, and sandpaper sorting. A quantitative comparison was made of the EEG activity in each hemisphere during each task. During the left hemisphere tasks, that is those involving verbal skills, the integrated EEG power in the left hemisphere was less than in the right. The lower power reflects greater desynchronization and cortical involvement in the task. During the right hemisphere tasks, i.e., those involving spatial and synthetic abilities, the EEG power in the right hemisphere was less than that in the left. The results of this pilot study have been replicated in another study utilizing 10 subjects. The results of both studies were similar. It thus appears that there are characteristic patterns of activity and inactivity for both the verbal and the spatial cognitive modes. It is reasonable to suppose that more selective inhibition and facilitation of each hemisphere might selectively improve performance depending upon the task. With the aid of feedback from an electrophysiological index reflecting the relative dominance of either the left or right hemisphere, subjects might be able to learn to reduce the interference between hemispheres and thereby improve cognitive performance. Future plans include the use of an EEG asymmetry index to detect the hemispheric differences between individuals in relation to their preferred cognitive mode.

The hypothesis to be investigated is that in any given task, verbal and analytically oriented people, for example lawyers, accountants, computer programmers, will tend to employ the left hemisphere more than the right, and that people who are spatially oriented will tend to employ the right hemisphere more than the left. Subjects will be trained to produce either increased left or right hemisphere EEG activity through use of the PDP-15 computer for on-line computation of simultaneous activity in each hemisphere and for computation of the ratio of EEG activity in one hemisphere to that in the other.

Dr. Kamiya and his staff have also investigated the effectiveness of self-regulation of theta activity in 14 volunteer subjects. They found that their subjects have more difficulty in controlling the theta EEG activity in the 5-7 Hz frequency range than that experienced in the control of alpha activity. Dr. Kamiya and his staff felt that the reason most subjects in their study were unable to learn to increase theta while suppressing alpha was probably due to both the relative brevity of training and the scarcity of alpha-free theta activity in the majority of subjects. The occurrence of the behavior to be learned proved to be so infrequent that rather prolonged conditioning would be required. Further research is planned to explore the effect of longer training.

Dr. Gorman, of Dr. Kamiya's staff, has investigated the ability of subjects to regulate stomach pH through on-line feedback. Twelve subjects were used in this study. Stomach electrodes were placed in the upper stomach and the pH level was measured on a Beckman Model 72 pH meter. The subject was reinforced for either increasing or decreasing his pH during 4 minutes. Subjects were able to learn to control secretory functions of the stomach through feedback training for short periods of time. However, it was felt that the effect of local mechanisms in the stomach on CNS regulation mitigated the degree of this control.

In this same area of research, i.e., that concerning the control of physiological parameters other than brain activity, respiratory excursions and EEG activity were observed during the onset of sleep. Amplitudes of the respiratory movement showed progressive changes. Abdominal-dominant breathing was associated with relaxed wakefulness while thoracic movements were equal to abdominal movements with drowsiness. With sleep onset, thoracic-dominant breathing was noted. During drowsiness, the presence or absence of alpha activity was highly correlated with the amplitude of abdominal movements.

During this year, the PDP-15 computer was received and installed. The computer has been functioning for spectral and other routine EEG programs. Programs are currently being written so that the PDP-15 can be used on-line for the control of the feedback stimulus and for on-line analysis of the physiological variables. Electrophysiological data are also being recorded on FM tape for further analysis by the Stanford Research Institute. SRI has been working to develop software for on-line interactive graphic manipulation and display of time series data. These programs will be available to analyze the data collected.

In summary, the results obtained in the control of brain activity leave little doubt that subjects can be trained to regulate alpha activity. Dr. Orne's observation that subjects appear unable to increase their alpha obtained in an eyes-closed resting condition over that obtained in a darkened room suggests that one of the factors in alpha training is the subject's ability to learn to reduce the usual inhibitions that would lower alpha activity. Thus, the subject probably learns to maintain a maximum alpha state through the control of what would otherwise be alpha inhibiting internal or external events. The question is increasingly raised over whether it is the total amount of alpha activity that is relevant or whether the crucial variable is the relative increase in alpha over that generally present. It appears that the relative measure of alpha is more important and probably more accurately reflects the subject's ability to control the alpha inhibiting processes. Subjects can learn to accomplish the task of alpha control very quickly and maintain this alpha state without feedback. This ability, as Dr. Beatty pointed out, indicates that expensive electronic feedback equipment may not be necessary for field operations. The crucial question yet to be explored by the contractors in this area is the relation of these alpha states to performance. Plans have been made to attack this problem directly during the next year of the contract as well as continuing studies concerning the relationship of alpha states to other physiological measures.

Sleep

The second major area being supported by this project concerns the biofeedback training in the self-induction of sleep and in the control of sleep. The aim of the contract awarded to Drs. Stoyva and Budzynski is the use of biofeedback induced relaxation as a way of voluntarily achieving low arousal states and sleep. During the first year of the project, they have examined the best ways of attaining low arousal states and, during the subsequent years, will explore the properties of such voluntarily induced low arousal states and their ability to moderate the subject's response to stress. Specific questions being investigated are, (1) Can biofeedback training and profound muscle relaxation be of assistance in helping the individual to achieve drowsy and/or sleep states at will? (2) Can such training in attaining states of profound relaxation and low arousal be useful in moderating the individual's reaction to external stresses? (3) Can training in profound relaxation assist the individual in his ability to return quickly to moderate levels of arousal after the passing of a dangerous or stressful episode which has produced a high arousal condition? and (4) Can the benefits of such training be detected and enhance performance?

During the past year, the main focus of the work by Drs. Stoyva and Budzynski has been the exploration of the most efficient means of teaching the individual to voluntarily produce deep relaxation and drowsy sleeplike states. Their experiments have centered on whether relaxation produced by EMG feedback training of one muscle will generalize to other bodily muscle groups and to other bodily systems. The investigators have sampled from three major bodily systems: the striate musculature, the central nervous system, and the autonomic nervous system. The essential question was whether feedback training for deep relaxation of one muscle, such as the frontalis, can (a) be detected in lowered levels of muscle activity at other muscle sites, (b) whether there is evidence of drowsiness as indicated by EEG criteria, and (c) whether there is evidence of slowing of autonomic functions.

The core instrumentation system has been developed for this work. This system allows feedback of EMG activity, simultaneous recording of alpha and theta activity, and, in addition, it provides trial by trial quantification of the physiological parameters in which the investigators are interested. A major advantage of this system is that much of the data reduction is accomplished during the course of actually running the subjects.

The work currently underway is continuing to focus on muscle relaxation and the generalization of relaxation from one muscle group to another. The following measurements are being sampled on male volunteers: frontalis EMG, forearm EMG, heart rate, respiration, amount of alpha, and amount of theta. Each subject is being run for a total of ten laboratory sessions. This includes three baseline sessions, five training sessions, and two post-baseline sessions. Based on their preliminary observations of the experiments now in progress, the investigators have noted that when the frontalis EMG activity goes down, there is an increase in the amount of theta frequencies in the EEG. This inverse relationship between frontalis EMG levels and the amount of theta does not appear to hold, however, for the forearm EMG levels and theta. This observation strengthened the investigators' belief that deep levels of relaxation of the facial muscles are especially associated with low arousal and drowsy states and may be useful in inducing such states. In a pilot study using three individuals with persistent sleep onset insomnia, the investigators have achieved positive results in that each of the three subjects have been able to significantly reduce sleep onset time. These preliminary results indicate that the incidence of sleep onset insomnia is decreased by EMG muscle relaxation training and the results are consistent with other work published in the field.

The relationship or generalization of relaxation of frontalis muscles to the autonomic nervous system, particularly heart rate, appears to be more complex and the moderate amount of relaxation training used so far does not appear to be sufficient to regularly produce a decrease in heart rate.

Dr. Webb and his group at the University of Florida have been concerned with the control of sleep. Their primary goal is to control sleep onset by exogenous stimulation. Attention will be given to the role of stimulus events in the determination of the onset of sleep. Attempts will be made to investigate the interference role of stimulation which results in activation or elicitation of incompatible sleep responses. Conversely, the absence of stimulation occasionally appears as an important factor in sleep onset. Monotonous stimulation has also been referred to as a sleep inducer. Both the absence of stimulation and the monotonous repetitious stimuli will be investigated in the control of sleep.

During the first year of this work, Dr. Webb and his group have been concerned with the effect of acute sleep deprivation upon performance. The purpose of this study was to determine if resting awake in bed would attenuate some of the effects of sleep loss. In one condition, the subjects stayed awake but were lying prone on the bed. The EEG and body temperature were monitored constantly during the study. The subjects were asked to perform the following tasks: the Wilkinson Addition Task, Wilkinson Vigilance Task, Williams Word Memory, a mental addition task, and a serial counting task. The results suggest that there may be an order effect in this experiment since the acute deprivation with exercise always preceded acute deprivation with rest. To counteract this effect, four more subjects must be studied with deprivation with rest preceding deprivation with exercise. At this point, Dr. Webb and his group are unable to state whether bed rest attenuates the effects of sleep deprivation because of the order effect problem.

A second study during the past year concerned the effect of chronic sleep restriction on behavior and performance. Four pairs of subjects were selected under the condition of chronically restricting their sleep to 5-1/2 hours per day. The performance tasks again included the Wilkinson Vigilance Task, Wilkinson Addition Task, Williams Word Memory, a mental addition task (plus seven), plus the Zung Depression Scale, and the Gough Adjective Check List. Seven subjects completed the study; that is, for the eight-week period, they reduced their normal sleep of from 7-1/2 to 8 hours, to 5-1/2 hours of sleep in a 24-hour period. One subject disqualified himself after the first four weeks as he was finding it difficult to remain awake. Except for this one subject, the remaining seven subjects reported that it was not difficult to maintain a 5-1/2 hour day sleep schedule. Their major complaint was that the addition of 2-1/2 hours of wakefulness presented them with time that was difficult to fill. Additionally, the behavioral and performance measures showed no systematic declines as a function of the restricted sleep regime. The EEG records from this study are currently being scored for stages of sleep. This task is 75% complete.

During this past year, Dr. Webb has worked toward the establishment of a reliable criteria of sleep onset. Existing sleep data in his laboratory were examined in an effort to extract information on sleep latency, and 24 subjects have been run in a study conducted to determine standard conditions for measuring sleep latency. The criteria for sleep onset does not appear to be a problem. Three sleep criteria were used, i.e., epochs which contained less than 30 seconds of alpha (stage 1); onset of the first 5 minutes containing no alpha at all; and the onset of the first spindle. There was 99% agreement between scorers on each of the three criteria.

During the second year of the contract, Dr. Webb and his staff will do a second study to control the order effect of the sleep loss study and will concentrate upon techniques for the effective control of stimuli as related to sleep onset.

Cardiovascular

The third area of research in the self-regulation project is that being done by Drs. Harris, Stephens, and Brady at Johns Hopkins University concerned with cardiovascular self-control in the laboratory primate and in humans. The purpose of the research, utilizing laboratory primates, is to explore the optimal conditions and limits of cardiovascular self-control. During the past year, a study was conducted in which large increases of diastolic blood pressure, 50-60 mm Hg, were required in order to secure food and avoid electrical shock. If the diastolic blood pressure fell below 125 mm Hg for specified periods of time, the animals received shocks. Pressures above 125 mm Hg were reinforced with food. The specified duration of this large magnitude change was systematically increased until adequate performance could not be maintained and the animals received frequent shocks and earned inadequate daily food rations. This breakdown in performance was related to the daily work schedule.

Currently, two baboons are being trained to raise their diastolic blood pressure and maintain an elevated pressure for periods of 12 hours at a time. They are being run daily on a 12-hour "on," 12-hour "off" cycle. When the pressure is above the set criterion, a white light is on and a white clock accumulates the time. Similarly, a red light is on and time on a red clock is accumulated when blood pressure is below the set criterion. The subject receives food for maintaining the blood pressure at the desired increased level and, similarly, the animal receives an unpleasant electric shock when the blood pressure falls below the stated level for a set period of time. Initially, the investigators are attempting to maintain a modest elevation over most of the 12-hour "on" period. When the animal adjusts to this new pressure level (that is, receive fewer shocks and sufficient daily food ration), the diastolic blood pressure criterion will again be raised 3-5 mm Hg. The research plan is to gradually, over a 2 to 3 month period, reach 35-40 mm Hg elevations which can be sustained for 12 hours a day on a chronic basis. During the 12-hour "off" period, there will be no blood pressure requirements, no shock, and no food. This "rest" period will allow obtaining comparison pressures and heart rate levels to determine contrast or induction effects from the 12-hour "on" period. Two additional animals are being trained to lower diastolic blood pressure. In this experiment, food and shock avoidance are contingent upon prescribed reductions in diastolic blood pressure levels. In this study, there is also a 12-hour "on," 12-hour "off" daily cycle. Initial results with these animals suggest that lowering of diastolic blood pressure may be more difficult to obtain than raising. Preparations are also underway for the next phase of the project which is to examine the interactions of autonomic self-control with ongoing concurrent performance measure. Based upon the results of their first year's work, the investigators feel that they have demonstrated that blood pressure changes are highly susceptible to both operant shaping and stimulus control procedures and that these results extend the range of instrumental conditioning effects upon the cardiovascular system.

A laboratory for human heart rate and blood pressure conditioning has been established in the Phipps Psychiatric Building of the Johns Hopkins University Medical Center. These laboratory facilities include a soundproof, temperature and humidity controlled subject testing room, and an adjoining control room housing an Offner Type R polygraph, strip chart recorders, and associated programming circuitry. All the subjects in these studies are volunteers, usually students in their early twenties. Only those in excellent health are accepted and they are told the general nature of the research in which they are to participate. In addition, prior to experimentation, the subjects are given three psychological tests (MMPI, 16PF, and the Sensation Seeking Test), the data from which will be used in subsequent analyses to determine the extent of correlation between "personality" types and susceptibility to autonomic self-conditioning procedures. Prior to testing, the subject is given a "briefing" on the nature of the experiment, asked to breathe "normally," and to refrain from making excessive muscular movements or contractions. He is then placed in a reclining position on a couch in the testing room and connected to electrodes which provide an EKG, respiration, and palmar skin potential. Visual feedback displays consisting of an arrow meter, digital meter, colored lights, and cumulative counters, provide the subject with information concerning (a) his immediate heart rate, (b) the "desired" or criterion heart rate, (c) the direction of the required heart rate change, and (d) his success in achieving the criterion level. An auditory feedback system provides a beat by beat tone whose frequency changes in direct proportion to the subject's heart rate. The specified motivation for all subjects is money, which they earn by their performance during experimental sessions. Usually, subjects receive 1/2 cent for every second that their heart rate meets the prescribed criterion level. Baseline heart rates are taken for 20-30 minutes before and after each experimental session. The current procedures are of two basic types. In one, subjects are instructed to change their heart rates either up or down for periods of 10-15 minutes at a time. Then, bi-directional changes are produced within a single session by alternating increase and decrease periods, with short "rest" periods in between. These conditioning sessions are usually 60-90 minutes in duration followed by a 20-30 minute post-session baseline determination. In the other type procedure, the subject is required to change heart rate in just one direction and maintain that change for the entire session. To date, these sessions have been run up to one hour's duration. At the end of all experimental sessions, the subjects are asked about their "sensations" during the session, and about the methods or strategies they employed to control their heart rate.

Recently, in order to determine the interactions between "voluntary" heart rate control and a concurrent performance, subjects have been required to report (i.e., press a thumb switch) the occurrence of a 0.5 sec. tone which is programmed to occur every

50" on the average (range 15" - 95"), during the course of an experimental session. This simple reaction time paradigm becomes a more complex counting task when subjects are instructed to report only every 3rd, 8th, or nth occurrence of the tone. Accuracy scores and individual response latencies are obtained during all experimental phases, including pre-session baseline, induced heart rate increases, induced heart rate decreases, rest periods, and post-session baselines. Preliminary results from a small group of subjects suggest that humans can learn to control their own heart rate and maintain this control while concurrently performing a simple signal detection task.

Vasomotor

The final and fourth area of study supported during the past year has been that concerned with autoregulation of vasomotor tone and peripheral vascular beds, as reflected by changes in skin temperature. The principal investigator is Dr. Edward Taub at the Institute for Behavioral Research. During the past year, Dr. Taub has developed techniques enabling humans to establish voluntary control of their own skin temperatures when provided with immediate feedback information concerning variations in local skin temperature. Two subjects have been identified, who have described an extraordinary capacity in this regard. After training with increasing or decreasing light intensity as the feedback stimulus, both subjects were able to change the skin temperature on the back of one hand 4-8°F. within minutes, return to baseline values upon command, and then change their skin temperature 4-8°F. in the opposite direction with equal speed. After the preliminary phase of training, these responses were uncorrelated with temperature changes in the other hand, or under the other armpit, nor were they related to muscular tension (EMG) in the same forearm. The subject who received the most training was able to control her skin temperature as well without feedback as with feedback. As with alpha training, this capacity for self-regulation without feedback is particularly significant with respect to possible use in field or clinical situations. Dr. Taub is proceeding with his work in an effort to determine the nature of the characteristics, abilities, and methods that contribute to the impressive performance of these two subjects.

In his study, Dr. Taub has the subjects seated in a sound-insulated room with dim illumination. One thermistor probe is placed on the dorsum of the dominant hand while another thermistor probe is placed at another location, usually the dorsum of the other hand. A feedback light, located at eye-level and in front of the subject, can vary in intensity directly with the change in skin temperature in the dominant hand. The subject is given baseline days during which he simply sits quietly and is asked to stay awake while skin temperature is monitored over a period of approximately 45 minutes. Various control procedures are then taken to make sure that movements, flexing the arm, tensing the hands, etc. do not contribute to the changes in skin temperature. A series of training sessions then begins in which the subject is asked to either raise or lower the temperature in one hand. The experimental sequence is carried out over four consecutive days. Dr. Taub has noted marked individual differences in each subject's ability to control skin temperature, and it is hoped that through extensive study of the two subjects, which were able to efficiently and rapidly control their skin temperature, information will be obtained which will be useful in training other subjects to also control skin temperature.

During the next year, Dr. Taub will investigate whether skin temperature is, in fact, a sufficient indicator of peripheral blood flow. Measurements will be made of blood flow by use of a reflectance photoplethysmograph. This measure of blood flow will give some indication of whether the autoregulatory control of skin temperature that Dr. Taub has been able to demonstrate has, in fact, been due to changes in blood flow, as Dr. Taub has contended. During the next year, EEG activity and muscle activity will also be recorded and related to changes in skin temperature.

Renewal contracts and the four new contracts to begin July 1, 1971, are being negotiated. There have been no major administrative problems in the administration of this contract.

PUBLICATIONS SUPPORTED BY THIS CONTRACT

Beatty, Jackson. Effects of initial alpha wave abundance and operant training procedures on occipital alpha and beta wave activity. Psychonomic Science, 1971, 23, 197-199.

Beatty, Jackson. Control of occipital EEG activity: Effects of the schedule of reinforcement. To be submitted for publication.

Beatty, Jackson. Control of occipital EEG activity: Similar effects of feedback signals and prior information. Submitted for publication.

Harris, A. H., Findley, J. D., & Brady, J. V. Instrumental conditioning of blood pressure elevations in the baboon. Submitted for publication.

Paskewitz, D. A., & Orne, M. T. Cognitive effects during alpha feedback training. Submitted for publication.

Webb, W. B., & Agnew, H. W. A normative study of the latency of sleep in humans. Psychonomic Science. In press.