

Section 2

BIOFEEDBACK & SELF-REGULATION

ABSTRACT

Work with biofeedback in a self-regulation context is detailed through presentation of representative papers. Applications of biofeedback with migraine, hypertension and other disorders are described, as are skills in voluntary control of the physiology found in individuals with special abilities. Philosophical consideration is given to whether biofeedback represents a process of learned voluntary control or merely a conditioning process. The role of volition in biofeedback is examined. Dr. Green points to important ideas underlying biofeedback from ethology, freudian psychodynamics, perception, autogenic training and jungian psychology. The roles of self-reliance and empowerment in health is noted, as is the importance of “health” as a goal, rather than simply “illness treatment.” Finally, Dr. Green discusses the esoteric significance of biofeedback training.

KEYWORDS: Biofeedback, self-regulation

After completing his dissertation in psychophysics, Elmer Green began seeking a suitable setting in which to pursue his interest in *empowering others to take charge of improving their own lives*. Years earlier in a hypnagogic-like dream state, he had seen himself working as a researcher in an institution with a tower building that had a museum in the basement. As he traveled, he sought to discover the location of this building, at first without success. He meditated upon the question, “Where is there an organization in which I would be free to conduct such research, unhindered?”

It was recommended that he contact Gardner Murphy who was Head of the Research Department at the Menninger Foundation. In one of the many synchronicities that have structured his life, a fellow student of Elmer’s from Chicago soon called on behalf of Gardner Murphy who wanted to offer Green a job as Head of the Biomedical Engineering Laboratory at Menninger. Elmer flew to Topeka, Kansas. There, he notes, “When I saw the clock tower, it had a feeling of rightness.”

He was hired to direct the Laboratory and was given at least one fourth of his time to pursue any research he chose. Elmer, his wife Alyce, and their associate Dale Walters soon began research combining autogenic training, a European self-regulation approach, with “biofeedback,” which in 1969 comprised an emergent collection of techniques for developing control of one’s physiology through mental means. While Gardner Murphy was most interested in *muscle* biofeedback for reducing muscle tension, Green and colleagues focused on *autonomic* and *central nervous system* biofeedback. They soon produced and presented the following summary of the state of the art.

As will be seen, even at an early point in their work, they were clearly aware of potentially important scientific, social and political implications concerning empowerment of human beings. Biofeedback, far from being a matter of simple mechanical “conditioning,” was seen as a process usefully understood when placed in the context of a “self,” who was exercising volition and consciousness. This conceptualization was ahead of much thought framing early biofeedback research, and still provides a very contemporary ring to this work.

Note the technical elegance underlying the report below. Also of note: the Greens had a willingness to share procedures, then rare in the field, in service of advancing the new entity of biofeedback. Few laboratories at the time had the capacity to examine comprehensively a variety of biofeedback modalities such as single motor unit firing, and autonomic and electroencephalographic variables. Thousands of articles were mailed to those stimulated by these developments, and hundreds of visitors came to the laboratory and learned how to proceed with their own biofeedback research and practice. [Eds.]

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The following paper originally appeared in: J. Rose, Editor, Progress of Cybernetics, Proceedings of the International Congress of Cybernetics 1969 (Gordon & Breach, London, 1970), pp. 1299-1316. [Eds.]

SELF-REGULATION OF INTERNAL STATES

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SUMMARY

This paper is concerned with the development and use of tools and techniques for investigating states of internal awareness, psychological and physiological, which until recently have been considered unapproachable by scientific means. Experimental subjects have been trained by physiological feedback methods in the voluntary control of normally unconscious physiological functions which represent three major neuroanatomical regions, craniospinal, autonomic, and central. Subjects who have been most successful have demonstrated control by volitional relaxation of striate muscle tension down to the "zero" region, by volitional increase of temperature in the hands as much as 5 degrees C in two minutes, and by volitional increase in percentage of alpha rhythm up to 100% alpha over 10 second epochs, while speaking, with eyes open. The purpose of this physiological training is to enhance and make possible the study of those psychological states which appear as functional concomitants of a passive peripheral nervous system and an "alpha-activated" central nervous system. This on-going project has significant implications for psychology, psychosomatic medicine, psychiatry, education, and research in creativity.

In recent years scientists in every nation have come to realize that self-regulation is of primary importance if we hope to establish an ordered society. The long-range political implications of a population of self-regulating individuals and the effects on our possessions-oriented society would be salutary, even if not welcomed by everyone. In advertising, for instance, where success depends on setting up strains in the personality which can be relieved (they tell us) only by buying a particular brand of merchandise, people who could regulate their own biological and emotional responses to perceptual stress would be a new, and perhaps difficult-to-manipulate factor. In the domain of social science, it goes without saying that the person with voluntary control of his own behavior (or who at least could curb the excesses of his responses) would not only not be a problem, but would make it easier for others to attain a stable, and yet creative, life.

INTRODUCTION

The title of this paper is "Self-Regulation of Internal States," but a more descriptive title might be "Voluntary control of internal states, psychological and physiological." Although it is not possible to define in an operational way the meaning of the word "voluntary," it goes without saying that all of us have a

feeling of voluntary control, at least part of the time, regardless of the psychophysical and metaphysical implications of that feeling. Few people realize, however, that *that* feeling, or intuition of freedom, has significance in respect to the so-called involuntary nervous system, the autonomic nervous system, nor do they realize that the “psychophysiological principle” when coupled with volition makes it possible to regulate a number of involuntary functions, and at least theoretically to regulate in some degree every physiological function of the body.

The psychophysiological principle affirms that “every change in the physiological state is accompanied by an appropriate change in the mental-emotional state, conscious or unconscious, and conversely, every change in the mental-emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state.” This closed Newtonian-type principle, when coupled with *volition*, which is at present of indeterminate origin, makes possible a psychosomatic self-regulation. Whether volition has origin beyond the physiological matrix, is the essence of the mind-body problem, but this is not of concern in the present paper. It is sufficient that research using feedback techniques has demonstrated that self-regulation of a number of internal states, psychological and physiological, is relatively easy to achieve.¹⁻⁶

For about 200 years, medical doctors serving with the British Army or Civil Service in India sent back reports of a few self-regulating people. The doctors claimed that these unusual individuals, called yogis, could regulate a large number of so-called involuntary physiological processes, such as heart rate, or pain. This unusual degree of control was obtained, they said, through long practice of specific mental, emotional, and physical disciplines.

In some parts of the Western world there was great interest in such reports, and by 1910 in this century, Johannes Schultz (in Germany) had developed a Western system of self-regulation by combining various ideas from his medical research, especially hypnosis, with concepts from yogic methods. Although Freud gave up the use of hypnotism in therapy because its results were too unpredictable, it occurred to Schultz that the major defect with hypnotism might lie in the fact that the patient was not in control of the situation and therefore resisted, in various ways, the doctor’s instructions. Schultz combined

the free will, or volitional aspect of yoga with some of the techniques he had worked with, and eventually developed the therapeutic system to which he gave the name “autogenic training,” that is, self-generated or self-motivated training.⁷ The research which I shall discuss today carries this development one step further and combines the conscious self-regulation aspect of yoga and the psychological method of autogenic training, with a modern technique called physiological feedback. This feedback, of physiological information, generally consists of providing visual or auditory displays which show the subject, or patient, what is happening in certain functions of his body as he attempts to control them.

I do not wish to say much more about autogenic training, but it is worth mentioning that after a patient learns to relax, somewhat in the manner of Jacobson’s *Progressive Relaxation*, he learns to regulate blood flow in various parts of the body.⁸ This is followed by exercises in the control of heart rate, and, if necessary, the patient eventually focuses his control effort (under medical supervision) on the functional correction of psychosomatically sensitive areas, such as the gastrointestinal tract. Gradually, as emotional and physiological harmony is obtained in distraught patients, the therapy moves into the psychological areas important in general psychiatry. In spite of a significant amount of success, autogenic training (though over fifty years old) is almost unknown in the United States, and in the book *Autogenic Training*, by Schultz and Luthe, of 604 references, only 10 are in English.⁷

Although autogenic training has had a measure of success, it is handicapped by the fact that it normally takes a great deal of time for the subject, or patient, to learn how to do it. And this is where feedback techniques come into the picture. In our laboratory and in others throughout the United States, new techniques are being developed for rapid achievement in self-regulation. Before discussing training experiments, electronic devices, and significance, however, I wish to focus attention on the neurological systems which are involved.

MAJOR PSYCHOPHYSIOLOGICAL CONCEPTS

Figure 2.1, a schematic diagram of the nervous system, is arranged to indicate brain areas associated with conscious functions on the right, and unconscious

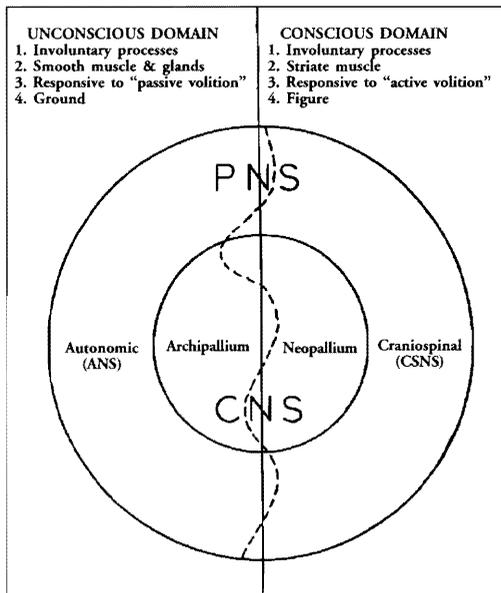


Figure 2.1. Diagram of the major psychophysiological concepts, relating the conscious-unconscious domain to the various sections of the central (CNS) and peripheral (PNS) nervous systems. The solid vertical line separates the nervous system into functional subregions and the dashed line (conceptually visualized to be in continuous undulatory movement) separates the conscious and unconscious areas.

functions on the left. The entire nervous system is contained within the large circle, and the central nervous system (CNS), brain and spinal cord, is represented by the smaller circle. The peripheral nervous system (PNS) is the ring surrounding the central nervous system and is divided by the vertical line into the autonomic *involuntary* nervous system on the left, and the craniospinal *voluntary* nervous system on the right. The central nervous system is divided by the vertical line into the archipallium, the old brain (which man shares with the other vertebrates) and the neopallium, the new brain, whose most significant development is in man (dolphins notwithstanding).

The dashed line is to be visualized as a continuously undulating boundary between conscious and

unconscious processes, as attention shifts from one brain region to another. For instance, after we have learned to drive a car, many of the striate muscular activities upon which so much attention was lavished at first become unconscious, and eventually it is possible, when the mind is preoccupied, to drive through miles of traffic without awareness.

On the other hand, the involuntary nervous system is not necessarily involuntary. If we concentrate attention on our right hand for a few seconds, the blood vessels in it will involuntarily constrict or dilate, depending on our previous conditioning, owing to tensing or relaxing of smooth muscles embedded in blood vessel walls. After training in temperature control, however, many subjects can increase or decrease the volume of blood in the hands at will.

Consciousness of the specific neural pattern involved is not obtained, any more than there is consciousness of the neural network in the voluntary nervous system which causes the arm to move from side to side, but in both cases, autonomic and craniospinal, the desired behaviour is obtained through visualization of the desired event accompanied by volition. The significant difference in controlling these two systems, is that for the voluntary nervous system, *active* volition is used, and for the involuntary nervous system it is necessary to use *passive* volition. It must be admitted that this last, passive volition, sounds like a contradiction in terms. How can anyone have passive volition? It is paradoxical, but after learning to use passive volition it seems quite reasonable, though not easy to put into words. Passive volition might best be described as detached effortless volition.

A RELAXATION EXPERIMENT WITH BIOFEEDBACK

Generally, the control of striate muscle is developed with feedback of information from special sense organs, especially the eyes, and as errors are detected voluntary control is gradually developed, but in one area of striate muscle control there is essentially no perceptual feedback. This is in the reduction of muscle tension down to zero.⁹ If an electromyographic (EMG) electrode is placed on the skin surface, over the dorsal muscle of the forearm, for instance, it will usually detect a continuous firing of motor fibers, even though visible signs of tension may not exist and somatic or muscular feelings of tension may not exist. If the EMG signal is made visible to the subject through external feedback, however, he can learn to turn it off.

Figure 2.2 is a schematic diagram of such a feedback arrangement by means of which experimental subjects have quickly learned to reduce muscle tension in the forearm down to zero. The signal from an EMG electrode on the forearm is amplified, rectified, and then fed back to the subject by a meter. Instruction to the Subject is to bring the meter needle down to zero. With this arrangement, seven out of twenty-one subjects were able to achieve either zero firing or single motor unit firing in less than twenty minutes of a single session. This is a phenomenal performance which only one subject could do without feedback. He, oddly enough, had practiced yogic meditation for a number of years. Eleven of the twenty-one subjects were able to achieve low

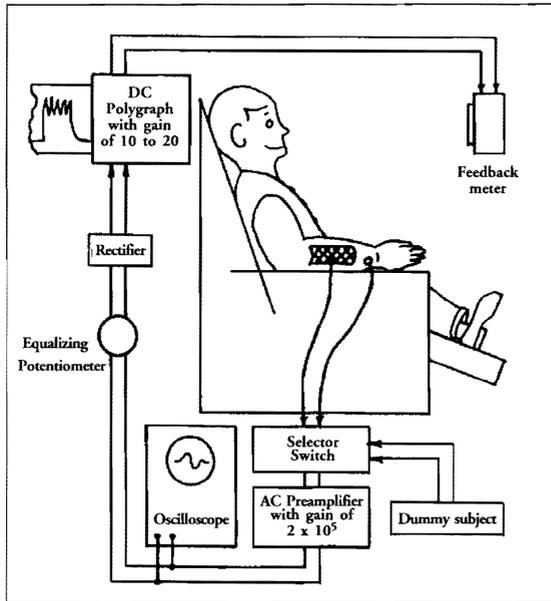


Figure 2.2. Block diagram of E.M.G. feedback system. Viewing distance of the meter is about five feet. The large "active" forearm electrode is referenced to a small disc electrode placed over the bony styloid process. A ground electrode on the subject is sometimes used in order to reduce sixty-cycle noise. The dummy subject is used for calibration of the system. It is an electrical stimulus generator whose biphasic rectangular pulses are rounded off with a choke and capacitor so as to produce trains of triphasic pulses (seven per second, each of twelve milliseconds duration) very similar in appearance to single-motor-unit firing, as shown on the oscilloscope.

learn, with a little practice, to dissociate his right forearm from the rest of his muscular system so that he can tense his left arm, leg muscles, or neck muscles, without causing any significant increase of tension in the right arm.³

TRIPLE TRAINING PROGRAM WITH FEEDBACK

Preliminary experiments with EMG feedback and with autogenic training led to our present project in which college men are being trained in the simulta-

tion levels with feedback but could not reach single-motor unit firing in twenty minutes. Three of the subjects did not seem to succeed at all. They, incidentally, gave evidence of strain due to the experimental setup.

Of the seven subjects who approached zero levels in less than twenty minutes, five reported body-image changes, making such statements as: "My arm feels like a bag of cement," "My arm feels like a ton of lead," "It feels like it is moving away from me," "I had to look at it to see if it was still in the same place," etc. In naive subjects in a proper setting (reclining chair, quiet room, dim lights, etc.), relaxation generally spreads over a large part of the body, but we have found that a normal subject can

neous (1) reduction of muscle tension in the right forearm, (2) increase in temperature in the right hand, and (3) increase in percentage of alpha rhythm in the EEG record. Feedback of muscle tension is from a circuit of the type already described. Temperature feedback is initiated from a thermistor taped to a finger of the right hand. Percentage-of-alpha feedback is achieved by allowing the subject to watch a meter whose scale shows the average percentage over a continuously computed ten-second epoch. That is, the meter continuously tells the subject what his average percentage has been over the preceding ten seconds. More immediate feedback in alpha is obtained, of course, as the average rises or falls in response to the ongoing EEG signal.

Pilot subjects were wired up for a training session to take measures of skin resistance, skin potential, photoplethysmographic response in one finger, temperature of the adjacent finger, eye movement (EOG) (not visible), right forearm EMG, and left and right occipital EEG, referenced to the vertex. A respiration gauge in the psychophysiological research jacket was constructed for reducing "the electric chair effect" in this type of experiment. The individual signal wires were plugged into sleeve and collar pin-blocks molded of silicone rubber. Fine shielded cables sewn into the jacket lead to a thirty-six-pin miniature connector (in the hem) which was snap-attached to a flexible cable, carrying the various signals to the main control room fifteen feet away.

The meters and their arrangement for this triple training program were observed by the experimenter, who was able to switch on any of the feedback meters which gave the subject, in a reclining chair, information about forearm muscle tension, finger temperature, and percentage of alpha. The behaviour of these three physiological variables was shown by three bars of light on a black panel in front of the subject, each bar, becoming taller or shorter in correspondence with the behaviour.

A training sequence involves eight sessions, two per week, each of about two and one-half hour's duration, including forty minutes for wiring. The time of only six sessions is devoted to training, however, since a number of psychological tests are given to each subject, mainly to determine his inward-outward orientation, which is hypothesized to be significantly related to his success in voluntary control of internal states. The tests include (1) the *Eysenck personality inventory*, for determination of extroversion-introversion, (2) the *James I-E*

scale, for determining internal versus external control of behaviour, (3) the *rod and frame test*, for determination of field dependence or independence, (4) the flexibility scale, Fx of the *California personality inventory*, (5) the *Thurstone concealed figures test*, for estimating flexibility of closure, (6) a *visual autokinetic test*, for determining ego closeness (to the environment), (7) an *afterimage test*, which seems to be related to internal awareness, and (8) a *recall test*, for determining relationship between recall and percentage of alpha.¹⁰ The last two tests are of our own construction.

A typical training session has several distinct phases. After the subject is comfortably seated he closes his eyes and relaxes for three or four minutes while various recording machines are adjusted. Then the EMG signal is calibrated by having the subject squeeze a hand dynamometer to produce a one-kilogram force while the recorder and feedback circuit is adjusted. In this way, all Subjects produce an equal EMG response for equal tension regardless of the exact electrode placement, skin thickness, etc. Training typically consists of the following phases.

1. Relax with eyes closed, no feedback, for three minutes.
2. Relax with eyes open, no feedback for four minutes
3. Maintain relaxation and visualize warmth with eyes open, no feedback for four minutes.
4. Maintain relaxation and warmth, and establish a quiet inner-focused and alert state of mind, no feedback, for four minutes.
5. Training with *muscle tension* feedback meter; three minutes with autogenic phrases for relaxation initiated by the experimenter, followed by four minutes of practice without phrases. Relaxation phrases, of which about eight are used, follow a typical pattern. Three such phrases are: "I feel quite quiet." "My feet are heavy." "My ankles, my knees, my hips, feel heavy and relaxed."
6. Training with muscle tension and *warmth* meters; three minutes with several autogenic phrases for warmth initiated by the experimenter, followed by four minutes of practice without phrases. A typical warmth phrase often emphasizes both relaxation and warmth. For instance: "My hands are heavy and warm."

7. Training with muscle tension, warmth, and *percentage-of-alpha* feedback meters; three minutes with autogenic phrases for alpha enhancement initiated by the experimenter, followed by four minutes of practice without phrases. For control of percentage of alpha we have devised autogenic-like phrases that focus attention inward, away from the outside world, and emphasize the quiet, but alert mind, as in the practice of Raja Yoga.
8. Twenty minutes of free practice with three meters.
9. With feedback meters switched on, subject attempts to maintain peripheral nervous system passivation and central nervous system alpha-activation during discussion and interview, about twelve minutes.

For five experimental subjects whose training records have been almost completely evaluated, it was found that relaxation results were essentially the same as those reported above for the seven out of twenty-one subjects who achieved unusually low tension levels in a single session. It should be noted that as attention shifts to warmth control and alpha control in the first two or three training sessions, subjects find that deep relaxation is difficult to maintain. In later sessions, control of relaxation improves. Zero levels were not observed in any of the five subjects, but all reached very low levels of tension and, when interviewed, reported significant body-image changes, including one comment: "I felt I was floating above the chair."

In respect to warmth, subjects succeeded to an encouraging, though not remarkable, degree. The average voluntary increase in temperature of the finger for the group was about one and one-half degrees centigrade after three or four training sessions. One pilot subject (not a member of the three variable training group) when working only with the temperature meter, is able to produce a change in hand temperature of 5 degrees C in two and one-half minutes, after being requested to increase the meter reading. Training experiences have convinced us that for warmth control, practice at home for fifteen to twenty minutes per day during the one-month training period, using autogenic-type phrases and visualizations, will enhance the efficacy of the feedback sessions in the laboratory and will, of course, make it possible for the skill that is developed to be more easily applied in normal life. Warmth control does not seem to have any unusual body-image effects, but rather is accompanied by a feeling of tranquil well-being.

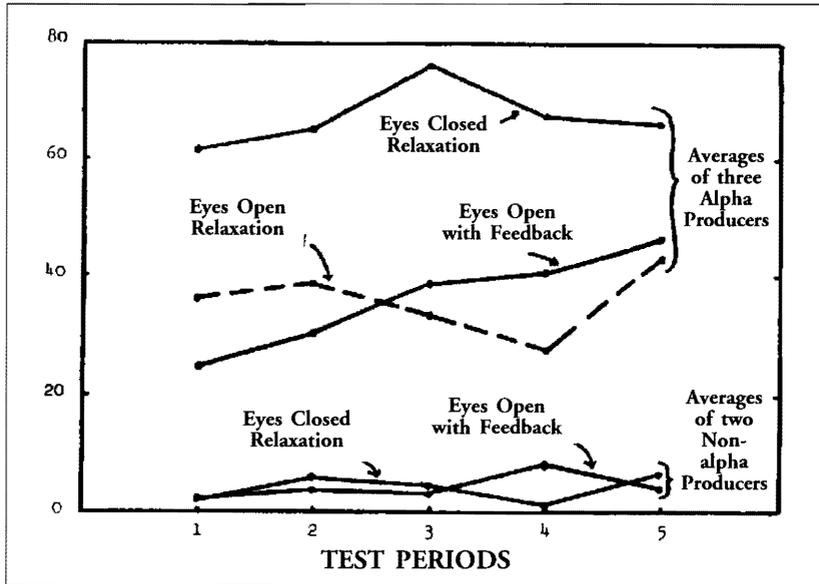


Figure 2.3. Average percentages of alpha rhythm under various conditions of eyes-open, eyes-closed, with and without feedback. Point 5 of the dashed line was raised unusually high by one subject who produced 79% alpha.

Average percentages of alpha for subjects on whom data reduction is complete, are shown in Figure 2.3. The two upper solid lines show the average results of three alpha-producing subjects, with closed eyes, and with open eyes, using feedback. The two lower solid lines show the average results of two non-alpha-producing subjects (less than 10% alpha), also with closed eyes and with open eyes (feedback). The dashed line shows the average results of the three alpha-producing subjects during relaxation without feedback, but with their eyes open. Visual examination of the records of additional subjects suggests that the increase in percentage-of-alpha in the eyes-open feedback situation is not a chance occurrence for alpha producers, but we are not yet prepared to offer statistical evidence. It will be noted that the two "non-alpha" producers give a slight indication of an increase in percentage of alpha with training. If this tendency is borne out with additional subjects, a future experiment may seek to determine the extent to which the percentage curve of non-alpha subjects can be raised.

An especially interesting finding was that in the *delayed* recall test of prose stories, the subjects who produced the highest percentages of alpha rhythm in their EEG patterns while they were recalling and speaking, remembered the most material, but since we have completed data reduction for so few subjects we have no feeling of certainty about the significance of this finding. An important observation is that every subject who learned to produce a relatively high percentage of alpha rhythm with open eyes and while being interviewed by the experimenter, was a natural high-level alpha producer with closed eyes.

A tentative summary of our *physiological* findings with about sixty subjects over a period of three years in both feedback and autogenic training studies, indicates that (1) relaxation of muscle tension down to extremely low levels is quite easy to learn with feedback of EMG signals, but not nearly so easy with autogenic phrases alone, (2) control of warmth is aided by feedback and in some cases phenomenally, but does not generally become easy with just a few practice sessions, and (3) increase in percentage of alpha rhythm with eyes open, and while talking to the experimenter, is easy to learn by feedback methods for those subjects who normally have a high percentage of alpha rhythm (above 30% when their eyes are closed), but is not easy for subjects who do not normally produce alpha rhythm with closed eyes.

A tentative summary of our *psychological* findings are (1) body-image changes, reaching a feeling of disembodiment in some subjects, seem to be associated with very low levels of muscle tension, (2) a general feeling of tranquility is usually reported in conjunction with significant increases in hand temperature, but an accompanying drowsiness tends to interfere with the alert inner-focused state which is associated with the production of alpha rhythm, (3) a poised non-drowsy reverie is generally associated with a high percentage of alpha, and appears to facilitate recall processes, and in addition, (4) hypnagogic, awake, dream-like images have been observed by a number of pilot subjects in conjunction with periods of theta rhythm and low-frequency alpha waves.

With the above findings in mind, we are selecting the most talented of our alpha rhythm producers for more advanced experimentation in alpha frequency lowering and conscious theta wave production. In connection with this we will test several methods of bringing the subjects to focused awareness during

these physiological conditions in order to study the associated states and contents of consciousness.

The main goals of our research, it should be mentioned, are related only indirectly to the peripheral nervous system, and are focused mainly toward voluntary control of the central nervous system so that subjects can experience, and we can study, the states of awareness which are associated with the conscious control of alpha and theta rhythms in the brain. The reason for working at first with the peripheral nervous system, is because it is relatively easy to learn the rudiments of passive volition therein. Central control is not easily attained, and very few people can, without previous practice in passive volition, significantly lower the frequency of their basic alpha rhythm, or consciously increase the percentage of theta rhythm in their EEG pattern. The last two items, lowering of alpha frequency and increase in percentage of theta, are associated with a developing awareness of normally unconscious processes.^{11,12} In this connection, it is interesting to note that pilot work, with three subjects who have practiced meditation, indicates that effort toward the voluntary control of internal states, if persisted in, is accompanied by extensions of perception, and appears to lead to what some people have called “altered states of consciousness”.

Feedback in frequency of alpha and percentage of theta is obtained by switching on a fourth and a fifth bar of light on the subject's feedback panel. The fourth bar of light is arranged so that a change in the frequency of alpha from 12 Hz to 8 Hz causes the bar to rise from the bottom to the top. The fifth bar rises to the top when the subject produces continuous theta waves for a ten-second period. One pilot subject could essentially do this, and could communicate verbally during trains of theta.

AUDITORY FEEDBACK

In addition to the visual display of EEG data, we are beginning pilot studies in which auditory feedback of delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), and beta information (13-26 Hz) is used. For this we have constructed a stereo-audio feedback system in which the frequencies in each EEG band are multiplied by 200. Separate banks of EEG filters for signals from the left and right occiputs control both frequencies and amplitudes of audio oscillators,

whose signals when recombined, give a pleasant modernistic biological music, which we call “the music of the hemispheres.” Just below the experimenter’s hand in are eight switches which individually control the auditory feedback to the two ears in each of the four EEG bands. When training with auditory feedback, the subject and experimenter will both wear stereo headphones.

Although auditory feedback is expected to be useful in training subjects in awareness of internal states associated with alpha and theta bands, especially in early stages of training, it seems to be so internalized that the subject cannot easily verbalize. We are hypothesizing, therefore, that a visual tie-in will be useful in attempting to enhance both consciousness and the ability to communicate while in the alpha-theta border region. As already mentioned, each auditory component of the stereo system can be presented singly to the appropriate ear, but in addition a monaural arrangement makes it possible to provide both ears with feedback of any component or combination of components from either left or right occiput. Thus, visual and auditory feedback can be used together.

SIGNAL HANDLING AND RECORDING

Feedback of physiological information involves a number of real-time signal handling steps, and in order to present percentage and frequency of EEG data, we have had to construct small single-purpose computers. Computing for on-line feedback of physiological variables and for automatic data reduction is an essential feature of a voluntary controls project. Immediate knowledge is needed by the experimenters concerning a subject’s performance in order to efficiently modify various training procedures, especially in the early phases of research. The most important physiological signals are recorded, raw, on the tape machine in the background for back-up in case of polygraph malfunction. Recorded information includes (1) the various physiological signals already mentioned, (2) heart rate, which is obtained from the photoplethysmograph signal, (3) percentages of delta, theta, alpha, and beta waves, from either right or left occiputs whichever is selected, (4) event markers which show the presence of EEG signals meeting specific criteria for amplitude, frequency, and duration, in each of the Four EEG bands, for either left or right

occiput, (5) Continuous tachometer-like readout of frequencies in each of the four EEG bands, for left or right occiput, (6) event markers controlled by a voice-sensitive relay, to indicate the exact times of the subject's verbalizations, and (7) event markers controlled by the experimenter to indicate specific phases of the training program. Our greatest single hardware difficulty at present is with in obsolete six-channel polygraph, on which are recorded those data whose loss will least seriously jeopardize our work.

SIGNIFICANCE

If a successful training procedure develops out of this combined physiological and psychological research with feedback techniques, it is anticipated that it will be of significance in the fields of psychology, psychosomatic medicine, psychiatry, education, and research in creativity.

1. Psychology has long suffered, at least in the United States, from the exclusion of "attention" and "consciousness" because these words could not be operationally defined. Now it is hoped to help reinstate these once abandoned concepts through the use of feedback techniques, and even more, reintroduce volition into experimental psychology. Volition has been largely ignored in the United States for seventy years, since the days of William James. Johannes Schultz, be it noted, is a German, and Roberto Assagioli, the author of *Psychosynthesis*, in which volition is of great significance, is an Italian. Carl Jung, of course, was a Swiss.¹²
2. Psychosomatic medicine is an obvious area for application of feedback techniques. In the last ten months, for instance, several of our subjects have reduced or eliminated chronic headaches through the use of autogenic phrases and a portable temperature feedback device which they were able to work with at home for two weeks. One of these subjects has stopped using medication and has been free from headaches for over six months. She also taught herself to increase the temperature of her feet at night, and was able to alleviate a long-standing insomnia problem.

In appropriate situations, starvation and absorption of tumors through blood flow control would be an interesting psychosomatic area in which to work. The elimination of warts through hypnosis, a well-established fact, is possibly a function of blood flow control.

3. Psychiatrists will be able to develop in many patients a deep reverie in a short period of time through the use of feedback techniques for deep relaxation, and if they use EEG feedback during interviews with selected cases, as we have done with each experimental subject, an increased amount of normally unconsciousness material of analytic value should be recoverable.
4. Education has need of a method for teaching control of attention, but until now no way of gauging central processes was available. The control of attention can be learned through EEG feedback techniques, and if it should prove to be a fact that better recall is associated with higher percentages of alpha rhythm, then it may be feasible to teach students how to put themselves into that psychophysiological state which facilitates recall. The pain of an education could be lessened, and mental blocks during examinations, for instance, could perhaps be avoided.
5. Creativity is one of the fascinating areas of modern research and it is interesting to note that the psychological state associated with hypnagogic like imagery has been reported by many outstanding thinkers as the condition in which their most valuable ideas came to them. To describe this state, they have used such phrases as "the fringe of consciousness," "the off-conscious," "the transliminal mind," "the threshold of consciousness," and "reverie." Feedback of EEG signals certainly has bearing in this area, and it is not difficult to imagine a research program in creativity in which brainwave feedback is used for voluntary induction of that psychophysiological state, in the alpha-theta border region, which is associated with such descriptive statements.

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ACKNOWLEDGEMENTS: This study was supported in large part by Grant MH 14439, National Institute of Mental Health. "We thank Mr. Rex Hartzell and the personnel of the Biomedical Electronics Laboratory for their great assistance in the design, construction, and maintenance of feedback apparatus.

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