ALPHA BRAIN WAVES & BIOFEEDBACK TRAINING

NEW WAYS OF EXTENDING THE INFLUENCE OF THE MIND OVER THE BODY

BY MITCHELL WAITE

HIGH in the Himalayas, the monks of Tibet have practiced a remarkable initiation ritual for thousands of years. On the coldest days of winter, candidates go to spend the night by frozen lakes clad only in their thin orange robes. Symbolic white robes are dipped into the icy water and draped around their naked bodies. The number of robes a candidate can melt in a single night symbolizes the level of his spiritual achievement.

Eastern mystical teachings have a formula that anyone can follow to achieve such spectacular body control: years devoted to meditation, complex visualizations, and sexual continence.

Characteristically, however, Western technology is encroaching on this formerly Eastern monopoly with electronic devices that demand neither sacrifice nor discomfort.

Elmer Green at the Menninger Foundation in Topeka, Kansas, has taught subjects to lower the temperature of their hands ten degrees by using a simple device which indicates body temperature increases by movement of a meter. Subjects were told to move the indicator up-scale and hold it there. Most subjects could, in a small amount of time, learn to influence the temperature of different parts of their bodies by using the information transmitted by the electronic measurement circuit.

Similar to the monks, his subjects were using their minds to generate heat energy at a particular area of their body. Ten degrees is a long way from melting frozen robes but scientists are finding that people can influence all kinds of body processes, hitherto believed beyond the range of conscious control.

Closing the Loop. Traditionally, Western medicine considered certain regulatory func-

Editor's Note: In response to many requests from readers for articles on alpha brain waves, we are presenting two stories. This month, we cover the general principles of biofeedback training as well as the various types of waveforms generated by the brain. Next month, we will have an alpha-wave monitor construction project for those who want to do some experimenting.

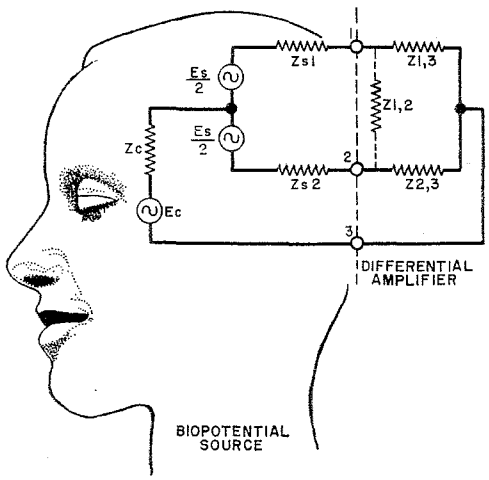
tions of the body such as skin temperature and heart rate as outside the domain of willful control. This assumption seems to have helped shape the self-concept most of us have of being at the mercy of our involuntary nervous system. The self-regulating nervous system is, of course, a necessity, for imagine the effort of controlling all the specialized muscles involved in breathing or digesting. We could, you might say, speed up our heart rate by physical exertion such as fast breathing, but this is not direct control of the autonomic nervous system.

Certain recent experiments have now caused scientists to take a new look at this old assumption. Some visceral organs, it was discovered, could be eventually controlled by the mind if special conditions were first set up. What was needed was a special signal or stimulus, such as sound or light, which would follow the activity of the body function to be controlled. By observing the "feedback" signal, people could actually interact with a particular body function through the monitor. The monitor or biofeedback mechanism serves in a sense as an interpreter between the mind and the so-called "automatic" mind.

The principle is similar to the way you learn to throw a ball. You feel your arm move, see where the ball went and correct your arm movement the next time. In a similar way, an electronic instrument can detect small internal changes in such processes as blood flow or brain-wave patterns of which you may not be consciously aware. By showing you these changes, the device can help you to recognize the cues and learn control. What is even better is that with practice, control can be developed so that the instrument is no longer needed.

The Body Electronic. To understand fully the range of the feedback principle, it is helpful to examine the source of the feedback signal.

Bio-potentials, tiny voltages present in all living organisms, are caused in man by the activity of nervous system sensors, muscles, or nerves. All bio-potentials originate at the cellular level, but the measurement of any one signal is related to a specific physiological subsystem. Thus, the electrocardiogram (EKG) is a recording of the electrical activity of the heart, the electroencephalogram (EEG) of the voltages in the brain, the electromyogram (EMG) of the activity of the muscles.



Z1,2=COMMON MODE INPUT IMPEDANCE
Ec=COMMON MODE SIGNAL GENERATOR
Zs1, Zs2=IMPEDANCE BETWEEN ELECTRODE AND BRAIN
$\frac{Zs1}{Zs2}$ CAN VARY FROM ONE TO OVER ONE HUNDRED

Fig. 1. Schematic of brain shows how unbalancing of source impedances (Zs1 and Zs2) can affect the common mode rejection of differential circuit. Common mode generator includes all unwanted signals such as electrode potentials, power line interference, noise from extraneous body signals, etc. Unfortunately, these signals are not always common mode and show up at differential amplifier output, distorting the real brain-wave signal. Ignoring the loading effect of Z1,2, and if Z1,3 equals Z2,3, and both Zs1 and Zs2 are much less the Z1,3 and Z2,3, the CMR limit (greatest reduction to a common mode signal) is 20 times the log to base 10 of Z1,3 divided by the difference between Zs1 and Zs2. Thus, if Z1,3 is 100,000 ohms and electrode impedance ratio is 100, the CMR limit is 60 dB. Source and input impedance of circuit determine actual rejection. A circuit with these values produces 1 mV of common mode output noise for every 1 volt on the input.

Detecting the brain-wave biopotentials is greatly complicated by the minute signal voltages, high level of external interference (noise and hum) and high impedance values of the body. For example, the magnitudes of the signals measured on the scalp typically vary from ten to a hundred millionths of a volt (10-100 microvolts) peak-to-peak. To top it off, in residential areas, stray 60-cycle fields from power lines surround the body. Such fields may reach values of 10 volts, or a million times stronger

than the brain-wave signal! It is this interference problem which has been a stumbling block of experimentalists for so long.

Recent advances in semiconductor technology have allowed the construction of miniature feedback devices which overcome these basic problems. The large fields can be screened out by a differential amplifier, which rejects any extraneous voltage *common to two inputs* while boosting the small difference signal *between the two inputs.* (See Fig. 1.)

Because of the typically high impedance levels of the head (1,000 to 10,000 ohms) the differential amplifier cannot load the signal source and therefore requires a very high input impedance, typically 0.1 to 100 million ohms. The amplifier also must not, while amplifying, contribute any spurious signals to the original biopotential. All these factors add up to a high-gain, low-noise, high-input-impedance differential amplifier commonly referred to in electronics as an instrumentation amplifier. Medical equipment reflects this high quality with typical prices for a multi-channel EEG amplifier and recorder of $1000 to $10,000. Less expensive devices sacrifice the unnecessary electronics involved in medical equipment while retaining just enough information for feedback recognition.

The second step in a biofeedback system is utilization of the amplified biopotential signal. Optimally, a second signal source which falls into the range of one of the five senses is varied (modulated) by the amplified biopotential signal. For example, a tone which is easily sensed by the ears is made to vary in volume by the amplified biopotentials of the brain. The user of the feedback device makes a mental effort to alter the intensity of the sound. (See Fig. 2.)

This last step, altering the sound, completes the biofeedback loop. With routine practice a user develops control over the sound pattern and thus is actually altering an organ's functioning. It is still however, a subtle effect, difficult to describe to other people, and some never completely master it.

Although biofeedback training has similarities to conditioning, it does not offer an explicit reward for the correct response. The only reward is what comes from eventual mastering of the process.

Clinical Research. Currently, biofeedback research is being carried on by over 150 different laboratories. A Biofeedback Society has been formed which brings together experimental research and integrates it with current psychological knowledge. The mainstream of activity covers five basic areas of body control: (1) muscle tension (EMG), (2) blood flow and blood pressure, (3) heart rate (EKG), (4) body temperature, and (5) brain waves (EEG).

For example, psychologists at the University of Colorado Medical Center in Denver have employed feedback therapy to cure patients who have suffered from muscle tension headaches for an average of nine years.

Patients lie down in a comfortable position with small surface electrodes taped to their foreheads. They then listen to a tone from a pair of headphones. As the muscle contraction of the forehead increases (increased muscle tension) the pitch of the tone goes higher. The people are told to try to lower the tone. Within twenty minutes the tone drops and they have halved the original muscle tension!

What are these people doing that they hadn't already tried? Most found that any direct effort to relax resulted in a higher pitch tone (increased muscle tension). Only by "letting go" could they relax the forehead muscles. It appears that by not concentrating on the headache, other processes of the brain come into play, processes that are unfamiliar and difficult to explain.

At the Menninger Foundation in Topeka, Kansas, researchers have helped patients to stop their migraine headaches by monitoring the blood flow as it went up the main artery to the face. They trained these people to reduce the arterial swelling by reducing the blood flow through it. Rather than trying directly to stop the headache, they learned, through biofeedback, to steer around it much as a pilot does when he is flying blind.

But even more incredible is the new information coming from heart rate control research. At the University of Wisconsin in Madison, subjects were taught to "drive" their own hearts much like the driving skill booths at penny arcades. Subjects would watch a light which moved left or right as the time between heartbeats changed. Trained subjects could eventually keep the light in the middle and thus keep the time between heartbeats a constant 10%. This didn't mean necessarily that they were directing the autonomic nervous system. As

mentioned earlier, the heart can be influenced by the breathing process. However, this was later ruled out when subjects showed they could learn to control breathing and heart rate independently.

At the Gerontology Research Center in Baltimore, Dr. Bernard T. Engel and his colleagues have trained eight persons to control potentially lethal irregularities in heart rhythm. The subjects were trained to slow their heartbeats by concentrating intensely when a red light appeared and to speed up the heart rate in the presence of a green light. Ultimately, they learned to maintain a safe mid-pace indicated by a steady yellow light. Eventually, three of the patients acquired the ability to stabilize their rhythms at the first sign of an oncoming attach of arrhythmia with their own feedback cues.

Map of Consciousness. Perhaps the most exciting aspect of biofeedback is its contribution to mapping altered states of consciousness.

Dr. Joe Kamiya at the Langley Porter Neuropsychiatric Institute in San Francisco has spent a decade studying the effect of *alpha* brain-wave training. He was particularly interested in whether normal subjects could discriminate alpha from non-alpha. Dr. Kamiya used a feedback program which produced a score every time the person indicated verbally which state he was in; alpha or non-alpha. After two weeks of training, 70 percent of the subjects could differentiate alpha and non-alpha. What was the alpha experience of Dr. Kamiya's subjects?

The replies were mostly diverse and inarticulate. This is almost to be expected—the English language has few words to describe different conscious states. Alpha has been described as "a range of mildly pleasurable reveries and body feelings often called relaxed awareness."

As for the other brain-wave states, each frequency band has associated with it certain behavior traits. (See Table.) The theta band (3.5 to 7.5 Hz) occurs during uncertainty, day dreaming, and problem solving. Worry, anger, fear, and tension are characteristic of the beta band, 13 to 28 Hz. Between theta and beta lie the alpha rhythms. These frequencies, 7.5 to 13 Hz, have drawn special attention since they are most often produced during states of meditation and relaxation.

Alpha is difficult to describe. It is a non-thinking and non-emotional condition; a detachment from the usual reality. There is an opening of awareness and an enhanced ability to be still. Researchers call it a mode of de-automization, a reduction in the cortical activity of the brain.

This partly explains why alpha-wave feedback is being so widely discussed. It is because the alpha wave and its positive mental character can be turned on and sustained by using a biofeedback device.

TYPICAL BRAIN-WAVE DETAILS

Name of Brain Wave	Magnitude (V x 10^{-6})	Frequency (Hz)	Associated Mental State*	Percent Produced Per Day
Alpha	10 to 100	7.5 to 13	Tranquility, relaxation, heightened awareness.	10
Theta	50 to 200	3.5 to 7.5	Uncertainty, problem solving, future planning, switching thoughts, day dreaming.	25
Delta	10 to 50	0.2 to 3.5	Deep sleep, trance state, non-REM type of sleep.	10
Beta	10 to 50	13 to 28	Worry, anger, fear, attention, tension, hunger, surprise.	35
?	0.01 to 0.1	Vhf to Uhf	**	?

*These descriptors are from a Clyde Mood Adjective checklist following one 60-minute feedback session with the eyes open.
**This last band is a recent Russian discovery. It could be revolutionary in the brain-wave field. In terms of just information content, these signals could contain over a billion times more data than the slower brain waves produce.

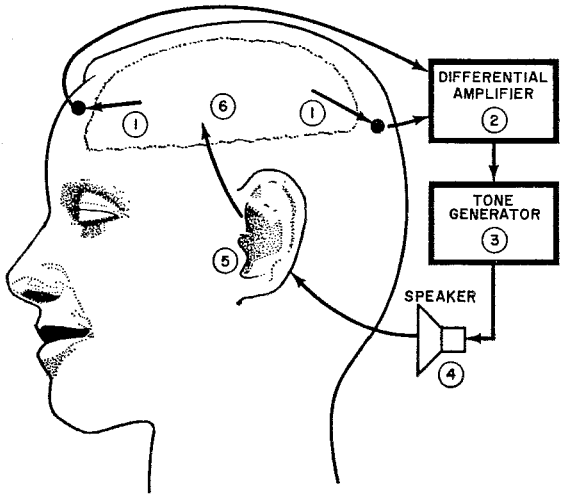


Fig. 2. Brain-wave signals originating in the brain (1) pass through cerebral fluids and reach the surface electrodes. Electrode cream is used on electrodes to help lower resistance to the scalp. From electrodes, the signals flow into the special differential amplifier where interference is reduced and signal level is raised. The amplified signal is used to control (turn on and off) a tone (3) which drives a speaker (4). Sounds leaving the speaker are following the brain-wave signal (the brain-wave frequency is well below the threshold of human hearing) so a sound is perceived each time the brain-wave signal reaches a peak. These peaks occur at a smooth stacatto rate which the hearing integrates as the alpha wave if it is a 10-Hz rate or the theta wave if it is 4 Hz. Signals from speaker return to the ear (5) and then back to brain (6).

Kamiya and researchers like him seem to feel that this is one way of reducing tension and increasing awareness by dealing with it in an internal and self-motivated way. It may be possible, says Kamiya, to use the descriptors of biopotential signals (frequency, magnitude, direction, origin) to discover how to reproduce altered states of awareness.

Already various groups are following brain-wave biofeedback research and presenting it to the public in more palatable form. Some of the interest is in providing verbal instruction and exercises in producing the desired brain-wave states. There is some skepticism voiced that these different groups have over-inflated claims and they are using mass suggestion. However, no one has tested the brain waves of these people or how they control them so it is still to be proved. The brain waves of people with ESP powers have been studied and they show a definite abundance of the alpha wave just prior to the ESP experience.

Some companies are producing brain-wave monitors which allow anyone to safely experiment in feedback training. The Xerox Corporation is exploring the feasibility of brain-wave training in helping employees relax and get their strength back after hard business meetings.

Besides mapping consciousness, brain-wave research is giving science more insight into different philosophies and their objective biophysical correlations.

The classical experiments that started this exploration were set up to record the brain waves of both students and masters of Yoga and Zen. Kasamatsu and Hirai in 1966 found a highly positive correlation between the EEG pattern and the number of years of Zen meditation. They reported as the years of study of Zen increased: (1) the brain-wave rhythm which was predominately alpha lowered in frequency toward theta by up to three hertz; (2) the percentage of alpha in the occipital areas (back of the head) decreased while alpha activity in the frontal (front of the head) increased; (3) there was an increase in average brain-wave amplitude; (4) there was alpha activity with the eyes open (something that is particularly rare in most people's EEG's); and (5) when an external

stimulus (such as a loud click) was delivered, the alpha activity of the Zen student was blocked for constant 2-to-3-second periods. Normal subjects, that is those with non-Eastern type philosophies, block alpha but the blocking interval decreases as the external stimulus occurs more often.

When Anand, et al., studied the brain waves of Yoga masters, they found "increased alpha activity (magnitude and percent occurance) and absolutely *no* blocking on an external stimulus"!

How can the difference in alpha blocking between the Zen, Yoga, and non-meditator be explained? In the case of the normal subjects (non-meditators) the more the stimulus occurs, the less interference there is in alpha production. The subject adapts to the stimulus and eventually does not hear it. On the other hand, the Yoga student (no alpha blocking) apparently is totally screening out stimuli from the outside world while the Zen meditator (constant alpha blocking interval) is reacting to every stimuli in an equal manner.

For psychology and philosophy, these results help to organize a division between subjective reporting of conscious states according to a particular world view and their measureable physiological correlates. The follower of Buddhism (who uses Yoga as an exercise) believes the sensory world to be illusory and attempts to withdraw from it. The practicer of Zen, however, believes the world is not illusion and tries to remain awake and fully sensitive to it. From the point of view of the average subjects, the world is simply related to him in a self-centered manner. He explores the stimulus with a "What's in it for me" attitude and, if satisfied it offers nothing, stops paying attention to it.

Biofeedback in the Future. Interpreting brain-wave patterns is helping scientists understand the general activity level of moods, feelings and mental attitudes. To understand the actual mechanisms of thinking and reasoning a closer look at the brain is needed. However the countless chemical reactions of the brain occur at such high speeds and low magnitudes that direct observation reveals little.

Nevertheless, Derek Fender, professor of biology and applied science, and his graduate assistant Robert Kavanagh, have found some beginning answers to how the brain works. They have constructed a machine which records brain waves from many areas of the scalp and sends them into a specially programmed computer. From there the brain waves are analyzed and displayed on a cathode ray tube. The result is a picture of the brain waves—a contour map of the peaks and troughs of electrical activity as "seen" through the top of the subject's head.

Each picture is photographed and used to make a movie. Two movies have been made, each a minute long, representing the brain-wave activity in a quarter of a second —but slowed down 250 times.

By studying various subjects, Fender and Kavanagh have discovered a simultaneous sound and light-flash stimulus causes activity in three distinct locations of the brain. One area analyzes visual images, the second sound patterns, and the third seems to decide if the sound and light come from the same place. They have discovered these locations by increasing the number of electrode positions to 49 and plotting the locus of the neuron emissions with the powerful computer program. The computer gives an accurate reading of exact positions of the brain-wave sources rather than just the frequency and magnitude. By studying these brain-wave movies, scientists are bridging the gap between single neuron firing and the functioning of groups of neurons working together.

During this project Fender discovered that the best subjects for his brain-wave studies were waitresses. Most people either produced fast surface level beta waves or just went to sleep. Waitresses however were just right. They were quick-minded so they didn't fall asleep and industrious enough to concentrate on the light-flash stimulus. And they weren't too nosy about what was going on or too preoccupied with some other problem.

As computers become more powerful with faster and larger memories, Fender's programs might reveal creative brain-wave patterns and possibly provide a means of utilizing biofeedback to stimulate these types of thinking.

As biofeedback techniques become more effective, we might begin to see their use in therapeutic techniques. Ancient teachings have constantly pointed to using the mind to prevent disease and eliminate infection. We may one day see doctors prescribing biofeedback methods instead of pills. ◈