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Jose Delgado's "Physical Control of the Mind"

Medical Applications

The discovery of new therapies has been - and still is - a more pressing need in cerebral disorders than in other fields of medicine because of their greater consequences for the mental and somatic well-being of patients. Unfortunately, advances in this area have been relatively slow, partly because of the intrinsic complexity of the problems involved, and partly because of a traditional fear and reluctance to disturb or deal directly with the material substratum of mental activities. At the beginning of the century, the public was generally hostile to surgery and considered it almost obscene for a surgeon to look into the most intimate depths of the body (185). With cultural and scientific advances this prejudice has slowly receded, and the study of the human body is now recognized as essential for the advance of medicine. Sexual taboos have diminished, and even the scientific investigation of the phases and details of human intercourse has at last been undertaken. All of the organs of the body, including the heart, genitals, and brain, have been accepted as suitable subjects for research.

Implantation of electrodes inside the human brain is like installing a magic window to reveal the bursts of cellular discharges during functional activation of specific structures. The meaning of these bursts is often difficult to decipher, but some correlations between electrical patterns and behavioral effects have already been firmly established. The electrical line of communication has also been used to send simple messages to

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the depth of the brain in order to arouse dormant functions or to appease excessive neuronal firing. A new method was thus found to impose therapeutic order upon disorderly activity.

In spite of the tremendous potential offered by the direct access to the brain, medical applications were received with suspicion and strong criticism and have progressed rather slowly. The growing acceptance of even experimental surgical interventions in most organs including the human heart is in sharp contrast with the generally cold reception to the implantation of wires in the human brain, even though this procedure has been used in animals for forty years and has proved to be safe. The reasons are to a great extent related to the persistence of old taboos, in scientists as well as in laymen, and to the more logical fear of opening some Pandora's box.

As experience overcomes opposition, cerebral explorations are being extended to different hospitals around the world, as shown by several recent symposia (159, 182, 216).

Diagnosis

The spontaneous electrical activity of the brain (electroencephalogram or EEG) can be recorded by means of surface electrodes attached by conductive paste to the outside of the scalp. This is a standard procedure used for diagnostic purposes in several cerebral illnesses, such as epilepsy, which is characterized by episodes of increased amplitude and synchronization of neuronal activity which can be recorded and identified. Strong electrical disturbances may, however, he present in structures located in the depth of the brain which cannot be detected by scalp EEG (57), and in this case the use of intracerebral electrodes may provide essential diagnostic information. For example, psychomotor epilepsy has been alleviated by surgical removal of the tip of the temporal lobe where seizure activity originated, and in these cases it is imperative to identify the source of the fits and especially to decide whether they are unilateral or present on both sides of the brain. In spite of some

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controversial problems about the location, multiplicity, and migration of epileptic foci, there is general agreement that depth recordings through implanted electrodes can give valuable data unobtainable by any other means.

The expected correlations between scalp EEG and mental disturbances have failed to materialize in experimental studies, although some mentally ill patients have exhibited electrical abnormalities. Depth recordings have also failed to provide decisive information about these patients, and for example, the suggestion that septa] spikes might be typical of schizophrenia (98) has not been confirmed (57). The absence of significant data must be attributed to the lack of refinement of present methodology Disturbed functions must have a background of altered neuronal physiology which should be detectable if more knowledge of the mechanisms involved and more sophisticated techniques were available. One step in this direction is the analysis of electrical activity by means of auto-correlation and cross-correlation (23) in order to recognize periodicity of patterns among the noise of other signals. Computer analysis of power and spectral analysis of frequencies are also new tools which will increase the future scientific and diagnostic usefulness of electrical recordings. Depth recordings may also be used for localization of tumors inside the unopened skull to detect abnormally slow potential shifts from the tissue surrounding the neoplasm and the lack of spontaneous waves within the mass of tumoral cells.

In addition to knowledge derived from the study of spontaneous brain waves, other valuable information may be obtained by recording the alterations evoked in intracerebral electrical activity following application of sensory stimulation or ESB. Presentation of flashes of light with a stroboscope, or of auditory clicks, activates the corresponding cerebral analyzers and may unveil areas of excessive reactivity. Epileptic patients are especially sensitive to repeated flashes and may respond with an activation of dormant electrical abnormalities or even with a convulsive seizure. Administration of single or repeated

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electrical shocks may also help in the localization of malfunctioning neuronal fields. Systemic administration of drugs which increase or decrease brain excitability (such as metrazol or phenobarbital) can be used in conjunction with evoked potentials in order to test the specific pharmacological sensitivity of a patient, thus orienting his medical or postsurgical therapy.

Electrical stimulation of the brain during surgical interventions, or during therapeutical destruction of limited cerebral areas, is necessary in order to test local excitability and determine the functional localization of areas which must be spared. This is particularly important during the surgical treatment of Parkinson's disease, which requires freezing of cerebral tissue around the pallidum or thalamus, close to motor pathways in the internal capsule. Identification of these pathways is imperative in order to avoid their accidental destruction and the subsequent permanent motor paralysis of the patient.

Therapy

The cerebral tissue around the electrode contact may be destroyed by electrocoagulation, passing a suitable amount of direct current. The main advantages of using implanted electrodes for this purpose, instead of open brain surgery, are that careful functional explorations are possible before and after the brain lesion is placed and, more importantly, that coagulation can be controlled and repeated if necessary over a period of days or weeks, according to the therapeutic results obtained. The procedure has been used for therapy of involuntary movements, intractable pain, focal epilepsy, and several mental disturbances including anxiety, fear, compulsive obsessions, and aggressive behavior. Some investigators report a remarkable therapeutic success in obsessive patients; others are more skeptical about the usefulness of depth electrodes and electrocoagulations in treating mental illness.

Electrical stimulation of specific structures has been used as a therapeutic procedure, and beneficial effects have been ob-

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tained in schizophrenic patients by repeated excitation of the septum and other areas which produce pleasurable sensations (99, 201, 233). In other cases of intractable pain, considerable improvement has also been reported, and some patients have been allowed to stimulate their own brains repeatedly by means of portable stimulators. In one patient, spontaneous bursts of aggressive behavior were diminished by brief periods of repeated stimulation of the amygdaloid nucleus (60).

One of the promising medical applications of ESB is the programing of long-term stimulations. Animal studies have shown that repeated excitations of determined cerebral structures produced lasting effects and that intermittent stimulations could be continued indefinitely. Some results in man have also been confirmatory. It should be emphasized that brain lesions represent an irreversible destruction while brain stimulations are far More physiological and conservative and do not rule out placing of lesions if necessary. One example may clarify the potential of this procedure. Nashold (160) has described the case of one patient, suffering from very severe intention tremor associated with multiple sclerosis, in whom stimulation of the dentate nucleus of the cerebellum produced an inhibition of the tremor with marked ipsilateral improvement of voluntary motility. The speculation was that a cerebral pacemaker could be activated by the patient himself when he desired to perform voluntary movements.

Many other possible applications could be explored including the treatment of anorexia nervosa by stimulation of the feeding centers of the lateral hypothalamus, the induction of sleep in cases of insomnia by excitation of the center median or of the caudate nucleus, the regulation of circulating AC'FH by activation of the posterior hypothalamus, and the increase of patients' communication for psychotherapeutic purposes by excitation of the temporal lobe.

A two-way radio communication system could be established between the brain of a subject and a computer. Certain types of neuronal activity related to behavioral disturbances such as

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anxiety, depression, or rage could be recognized in order to trigger stimulation of specific inhibitory structures. The delivery of brain stimulation on demand to correct cerebral dysfunctions represents a new approach to therapeutic feedback. While it is speculative, it is within the realm of possibility according to present knowledge and projected methodology.

Circumvention of Damaged Sensory Inputs

The miracle of giving light to the blind and sound to the deaf has been made possible by implantation of electrodes, demonstrating the technical possibility of circumventing damaged sensory receptors by direct electrical stimulation of the nervous system,

Brindley and I.ewin (24) have described the case of a 52-year old woman, totally blind after suffering bilateral glaucoma, in whom an array of eighty small receiving coils were implanted subcutaneously above the skull, terminating in eighty platinum electrodes encased in a sheet of silicone rubber placed in direct contact with the visual cortex of the right occipital lobe. Each receiving coil was tuned to a frequency of 6 or 9-5 megahertz and could be activated by pressing a transmitting coil against the scalp. With this type of transdermal stimulation, a visual sensation was perceived by the patient in the left half of her visual field as a very small spot of white light or sometimes as a duplet or a cluster of points. The effects produced by stimulation of contacts 2.4 millimeters apart were easily distinguished, and simultaneous excitation of several electrodes evoked the perception of predictable simple visual patterns. The investigators suppose that by implanting six hundred tiny electrodes it would be possible for blind patients to discriminate visual patterns; they could also achieve a normal reading speed by using electrical signals from an automatic

Using a different approach, the Mexican investigator del Campo (26) has designed air instrument called an "amaroscope," consisting of photoelectric cells, to transform luminous images

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into electrical impulses which are modulated and fed through electrodes placed over the skin above the eyes to stimulate the supraorbital branches of the trigeminal nerve. Impulses are thus carried to the reticular system and the cerebral cortex. The instrument is not too sophisticated and its neurophysiological principles are controversial, but its experimental testing in more than too persons has proved that visual perceptions may be electrically produced in blind patients, even in some who have no eyes at all.

Auditory sensations have also been produced in a deaf person by electrical stimulation of the auditory nerve through permanently implanted electrodes. Simmons et al. (208) studied a 60-year-old male who had been totally deaf in his right ear for several years and nearly deaf in the left for several months. Under local anesthesia, a cluster of six electrodes was implanted on the right auditory nerve with a connector anchored to the skull just beneath the right ear. Two weeks after surgery, electrical stimuli were able to produce perception of different kinds of auditory sensations. Pitch varied with the point stimulated and also depended on the electrical parameters used. For example, 3 to 4 pulses per second were heard as "clicks," to per second as "telephone ringing," 30 per second as "bee buzz," and 100 to 300 per second could not be discriminated. Loudness was related to amplitude of stimulation and to pulse duration, and was less affected by its frequency.

To evaluate these studies we must understand that the refinement of the senses cannot be duplicated by electronic means because receptors are not passive transducers of energy but active modulators and discriminators of impulses. The reciprocal feedback between peripheral and central neurons and the processes of filtering and cross-correlation of information which takes place during afferent transmission of impulses are absent in the instrumental reception of inputs. It is doubtful that refined perceptions comparable to physiological ones can be provided by electronic means, but the perception of sensations - even if crude - when hope had been lost is certainly encouraging and demands the continuation of research efforts,

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Brain Viability

The clinical distinction between life and death was not too difficult to establish in the past. When respiration and palpitations of the heart had ceased, a person was pronounced dead, and there was little that a doctor could do. It is true that in some extraordinary cases the signs of death were only apparent, and a few patients have revived spontaneously, creating quite a shock for their doctors, relatives, and for themselves, but these fantastic stories are the very rare exceptions.

A new situation has been created in recent years because medical technology has often taken the determination of human death away from natural causality. Respiratory arrest is no longer fatal, and many poliomyelitic victims have survived with the help of iron lungs; cardiac block does not necessarily signal the end of life because heart beats may be artificially controlled by pacemakers; kidney failure will not poison the patient if dialysis machines are available to clean his blood. To the growing collection of ingenious electromechanical instruments a new methodology has recently been added: the cross-circulation between a sick human being and a healthy baboon in order to clear the human blood. This procedure was first tested in December, 1967, by Dr. Hume at the Virginia Medical College Hospital to treat a woman patient in deep hepatic coma with jaundice and edema. A 35-pound baboon was anesthetized, cooled, and its blood completely washed out with Ringer solution and replaced with human blood matched to the patient's. Then a cross-circulation was established from the ape's leg to the patient's arm, In twelve hours the patient had excreted about 5 liters of fluid through the baboon's kidney and regained consciousness. Twenty-two days later the patient went home, and the baboon was alive and healthy. A similar procedure was successfully used later in other cases (21).

Today the lives of many patients do not depend completely on the well-being of their own organic functions but on the availability of apes, organ donors, the voltage of a battery, in-

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tegrity of electronic circuits, proper management of pumps, and teamwork of doctors and technicians. In certain cases death can be delayed for weeks or months, and current technology has placed upon doctors the tremendous responsibility, the nearly deific power, of deciding the duration of patients' survival. A heated controversy, reaching the public and the British' Parliament, was created by the recent disclosure that in London's Neasden Hospital the records of patients over sixty-five years of age and suffering from malignant rumors or other serious chronic diseases were marked "NTBR" ("not to be resuscitated") in case of cardiac arrest. Artificial prolongation of human life is time consuming and expensive in terms of instrumentation and personnel, and it imposes added stress on tire patients and their families. Because resources are limited, it is materially impossible to attempt to resuscitate all the patients who die every day, and it is necessary to select those who have the best chance of prolonged and useful survival. Why should life be maintained in unconscious patients with irreversible brain damage and no hope of recovery?

This dramatic decision between individual life and death illustrates both man's recently acquired power and the necessity to use it with intelligence and compassion. To make the situation even more complex, the recent development of organ transplantation is creating a literally "vital" conflict of interests because a person kept alive artificially owns many good working organs-including kidneys, pancreas, heart, and bones -that are needed by other dying patients.

Death, personality, and biological human rights must be redefined in view of these new scientific advances. Possessions to be disposed of after death include not only real estate, stocks, and furniture, but teeth, corneas, and hearts as well. This prospect involves many ethical and legal questions and sounds altogether gruesome and uncomfortable, but that is only because it is unfamiliar. Giving blood to be transfused, skin to be grafted, spermatozoas for artificial insemination, and kidneys to be transplanted are more acceptable practices because they do not

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depend on the death of the donor; but when death cannot be avoided, the idea of the transfer and survival of some organs should be considered reasonable.

The possibility of piecemeal survival of functions and organs introduces the basic question of what part of the organism to identify with human personality. There is general agreement that the organ most fundamental to individual identity is not the stomach, the liver, or even the heart, but the brain. In the necessary redefinition of death it has been proposed that in difficult cases when circulation, digestion, metabolic exchange, and other functions are still active, the decisive information about whether a person should be considered alive-entailing the decision to continue or to withdraw artificial support for survival-must come from the viability of the brain. In some hospitals the ultimate arbiter of death is the EEG machine, and at the Massachussetts General Hospital, Dr. Robert Schwab has proposed that death should be determined by flat lines on all EEG leads for twenty minutes of continuous recordings and lack of response to sensory and mechanical stimuli. In the absence of EEG activity tested twenty-four and forty-eight hours later, death is presumed to have occurred even if (as happens in rare cases) the heart is still beating normally.

In the near future it will be necessary to examine this question in greater detail in order to determine the parts of the brain considered essential for the survival of human personality. We already know that portions of the brain may be destroyed or taken away with negligible or only moderate psychic changes. Destruction of the motor cortex produces paralysis; ablation o f the temporal lobe may affect recent memory; and destruction of the frontal lobes may modify foresight and affective reactions, but in all these cases the patient's behavior is recognized as human. Destruction of the hypothalamus or reticular formation, however, may induce permanent loss of consciousness, and in this case it is questionable whether personal identity persists. The possible piecemeal survival of psychological functions will make the definition of man more difficult and will perhaps in-

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crease the present problem of deciding what human life is. From the examination of these questions, however, a deeper understanding of the essential qualities of a human being - and of the direction of their evolution with intelligent purpose - will emerge.

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