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PERSONALITY, EDUCATION, AND ELECTRICAL STIMULATION OF THE BRAIN*

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The title of this talk may sound a little strange, or perhaps even alarming. Is there any relation between education, personality, and electrical stimulation of the brain? Is it conceivable that behavior or the psyche can be related to electronics?

Before answering these questions, we should ask one more: what is the main difference between primitive tribesmen still living in the jungle and civilized human beings of the type so well represented by this audience? The essential difference is not the anatomical structure of our brains, but the number and quality of the bits of information which have accumulated in each person through his education, and which form the basis of his individual personality and mental functions.

Education develops the necessary skills for learning, guides behavioral reactions, provides moral values, and transmits the wealth of technical and abstract knowledge accumulated through history. The role of education in establishing the foundations of our personalities has been well substantiated in the past. According to recent ideas, pedagogic technology may be considered a form of sensory stimulation of students, in whom the symbolic meaning of the received auditory and visual information is transformed into coded electrical signals that circulate through the central nervous system, provoking impacts on the functioning structures of the brain. The novelty of this concept is that we now may analyze experimentally part of what happens inside the brain when the bits of information are received by the subject.

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For many years, mental functions have been hidden away in the mysterious black box of cerebral physiology, and the mind has been accepted as a metaphysical entity beyond the reach of inquiring scientists. In recent times, however, we have started to record the activity of the nerve cells, to detect the electrophysiological correlates of learning, to analyze the chemistry of memory, and to photograph the ultramicroscopic changes produced by neuronal impulses. By means of electrical stimulation of the brain, we have been able to block or to induce a wide variety of feelings, emotions, and behavioral reactions in animals and in humans.

Today we can say that science has recovered its mind, which for centuries has been the exclusive property of philosophers. We have begun to identify which areas of the cerebrum are dispensable—or indispensable—for planning the future, for remembering the past, or for behavioral performance in the present. Some mental functions have escaped from the field of speculation and have already entered into the more secure ground of experimental investigation.

This conceptual and methodological revolution will have obvious implications for the ideological development of future generations. Knowledge of the nervous system clarifies many aspects of education. Some of these aspects are: the need for teaching at the pre-kindergarten level, when neuronal plasticity is greater; the possible role of cerebral dominance in reading problems; the importance of multi-sensory education in remedial reading; the existence of brain disturbance in some children with behavioral problems; and the chemical deficiency of nerve cells in some mentally deficient students.

The relationship between education and neurophysiology is not a one-way but a two-way street. Knowledge of the nervous system may show new avenues for the improvement of teaching, and at the same time, education may be decisive in focusing the interest and mental power of our population on conquering and understanding cerebral functions. It is perhaps surprising that most of the intellectual and economic orientation of civilized countries is toward industrial development, construction of roads, organization of cities, harnessing megawatts of electricity, visiting the depths of the sea, and splitting atoms, while only a small proportion of our cerebral and financial resources is devoted to the further understanding and conquering of the one organ, called the brain, which is our power source—allowing

us to think about industry, politics, outer space, atoms, and even about ourselves.

Until recently, this was probably logical because the industrial revolution offered fruitful research areas, and there have been spectacular achievements in the development of machinery and in increasing control over natural forces. In contrast, the study of the psyche has lacked experimental methodology, and has been highly theoretical and speculative. This would account for the tremendous gap between the industrial and the mental revolutions, and our present dangerous situation in which man is far more powerful without being wiser. We are reaching for the moon when we still cannot reach our inner self. We could ask: Are we happier than was Man one or two millenniums ago? Do our children behave better than their ancestors? Have wars disappeared from the earth? Have we diminished human worries, anxieties, and hates, or have we instead increased our consumption of tranquilizers?

Fortunately, the situation is changing. In America and abroad, advances in cerebral surgery, in neurophysiology, and in psycho-pharmacology have demonstrated that a variety of mental functions may be influenced by the knife, by electrical stimulations, and by drugs, and a new era has arrived in the understanding of the functions of the mind. We must hope that in the future more of the best brains will become interested in investigating the tremendously complex mental functions of man. Perhaps, then, personal and international relations may be based on positive values, rather than on coercion and deterrent fears of atomic annihilation. This does not mean that human relations will be molded by electricity or chemistry; it means only that a better knowledge of the intimate substratum of our personality will allow programming of more rational and efficient education. The human brain, like atomic energy, has a great potential power which could be terrifyingly destructive, but it may also be the source of energy which will propel mankind to unforeseen horizons.

To give some idea of the new orientations in the investigations of cerebral functions which are being developed at different centers around the world, I shall present some experimental evidence obtained in my laboratory at the Yale Medical School. These studies are conducted mainly on monkeys, Macacus rhesus, which are close to the top of the animal scale in brain development. The experimental monkeys carry small sockets on their heads with 12-30 leads which have been inserted into different areas in the depth of the brain. These intracerebral electrodes are so fine that they cause no functional deficit, and as brain tissue is insensitive, the presence of electrodes is not felt. Because these implantations are for life, the monkeys are always ready to receive electrical stimulations or to send out signals of the spontaneous electrical activity of their active brains (see Figure 1). If, in addition, we attach a small radio-receiver to the animal on a belt, the monkey's brain may be excited by remote control, yards or miles away (see Figure 2).

At this moment, I would like to dispel any incipient uneasiness on the part of the audience, who may wonder if we could be surrounded by radio waves which secretly direct our thoughts and desires. I do not believe that a robot-like control of human beings is possible, because our personality depends on the functioning of millions of nerve cells with a multi-complex spatio-temporal integration of so many factors that its duplication by cerebral manipulation is not feasible.

After these words of caution and comfort, let us consider some of the specific functions which *have been* influenced by electrical stimulation of the brain (ESB). The initial discoveries came in the last century, when it was demonstrated that movements could be elicited by electrical stimulation of the cerebral cortex. At that time, experimental methods were very primitive, and the results were elemental. The evoked motor effects were clumsy, purposeless, and abnormal. Modern stimulation techniques now permit a refined control of activities: the eyes, mouth, tongue, or any other area may be induced to move in a special way, and the whole body may be directed to turn, walk, lie down, or rise up at the command of appropriate electrical impulses (see Figure 3). The spontaneous and the evoked movements may be combined, and this interplay suggests that similar mechanisms are activated in each instance. In some cases, the artificially induced movement seemed to be voluntarily directed to some useful purpose. For example, when licking appeared during stimulation of a cortical area, the animal started licking the floor and then began to lick itself, cleaning its fur until cessation of ESB. Many of these movements seemed completely normal and could not be differentiated from the usual spontaneous activities. Often the animals looked like electronic toys with predictable motor reactions, flexing their limbs, yawning, circling, or climbing according to the cerebral point selected for stim-

FIGURE 1: Rhesus monkeys are usually aggressive, and, as shown in the upper control picture, [it] is dangerous to put a hand within reach of their teeth. Caudate nucleus stimulation ... [a]nimal so that it is safe to touch its mouth. As soon ... [a]ggressive again.

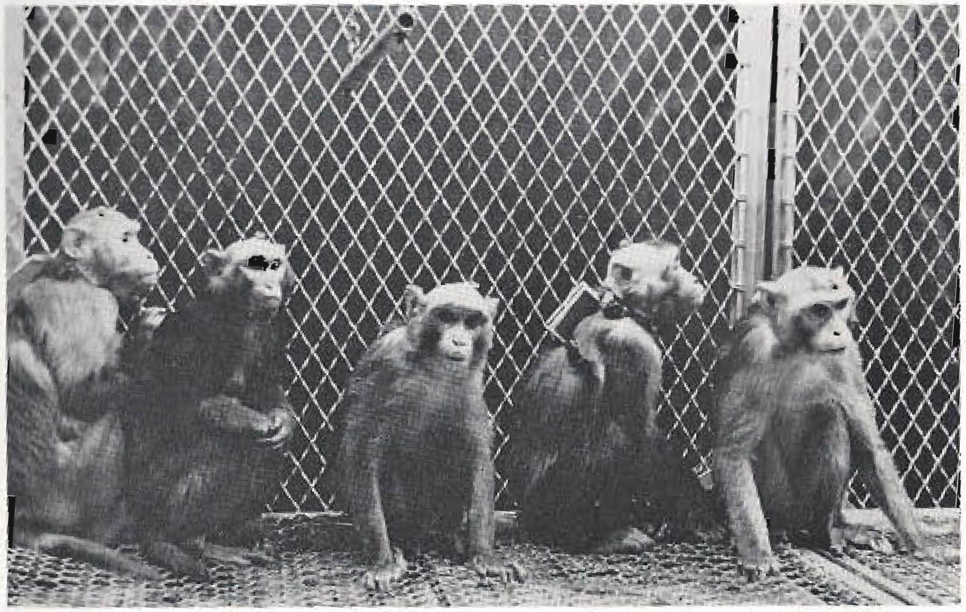

FIGURE 2: Monkey colony with animals equipped with receivers for radio stimulation of the brain. Individual and social behavior may be influenced by remote control.

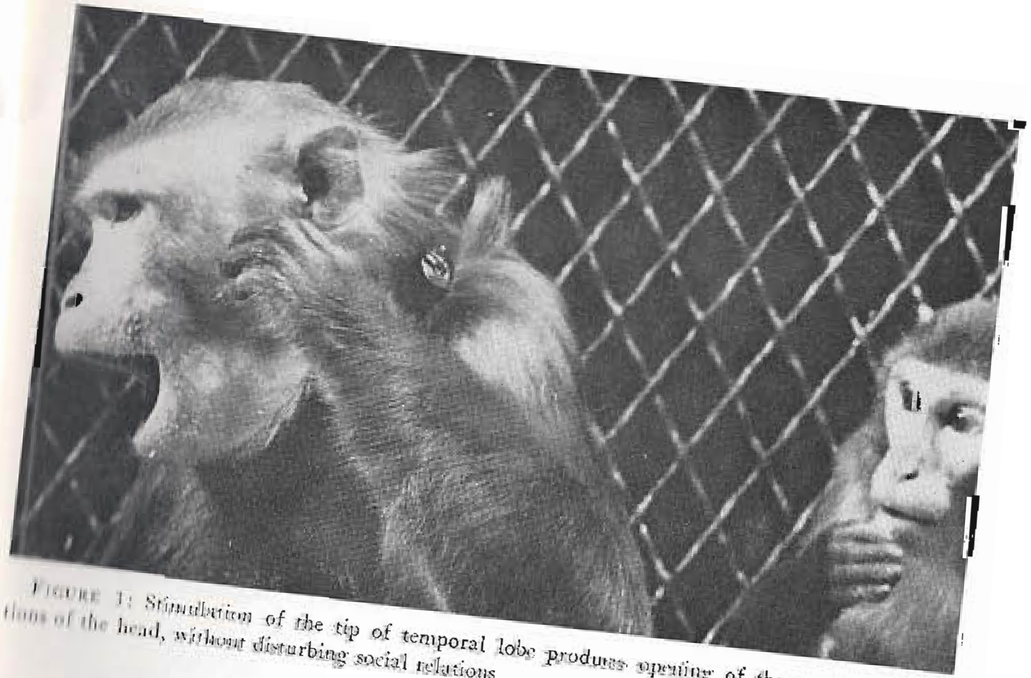

FIGURE 1: Stimulation of the tip of temporal lobe produces opening of the mouth and rotations of the head, without disturbing social relations.

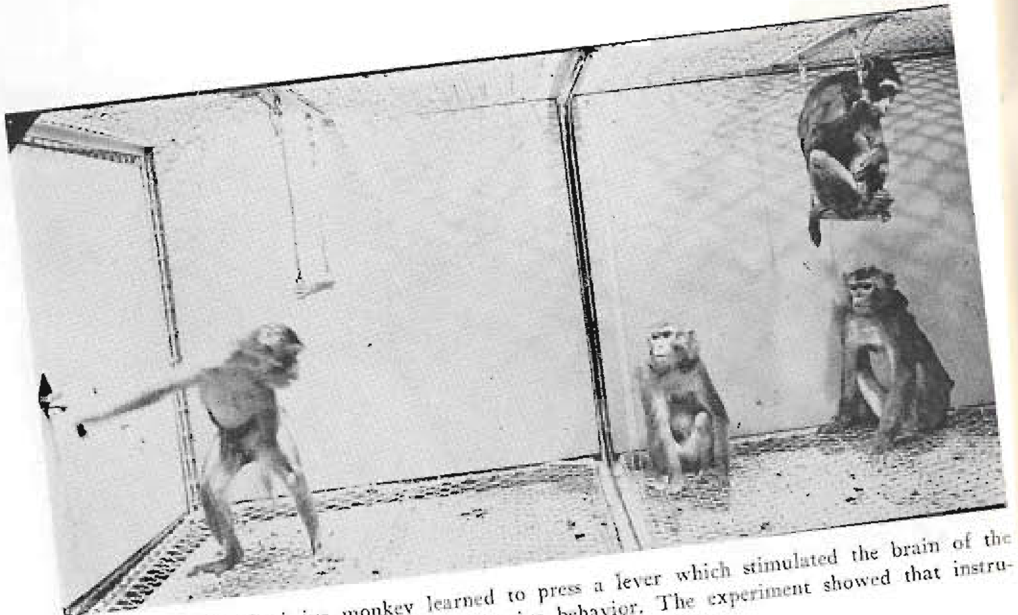

FIGURE 4: A submissive monkey learned to press a lever which stimulated the brain of the boss monkey by radio, inhibiting his aggressive behavior. The experiment showed that instrumental control of animal behavior can be taught in monkey societies.

ulation. These experiments were not uncomfortable for the animals; they seemed to enjoy their period of forced mobility and would come to the experimental stage where they were repeatedly stimulated on different days without any signs of fear or anxiety. Excitation of the motor cortex produced, in general, relatively simple motility, while more elaborated responses appeared when other areas were investigated.

Stimulation of the thalamus (located approximately in the center of the brain) produced a complex sequence of movements. The monkey walked to one side of the cage, came back to the other side, climbed to the back corner, and then descended to the floor. This complete pattern could be evoked as many times as the animal was stimulated (in some experiments, 60 times in one hour), with well-organized movements. The animal would change his walking path if another monkey were in the way, would avoid the proximity of the aggressive boss of the colony, and would stop and run away if a human observer threatened the group. This evoked activity was not the blind contraction of a group of muscles, but the flexible performance of a series of acts which could be modified according to changing circumstances. The effect was as if the ESB were influencing the cerebral mechanisms which usually direct the voluntary activities of the monkey. The idea of a possible "electrical stimulation of the will" is an intriguing working theory which is being investigated at the present time.

One of the most spectacular effects induced by ESB has been the arousal of social aggressiveness. In a colony of rhesus monkeys, the social hierarchy is usually clear. One of the animals establishes himself as the boss of the group and is highly respected by the others. The boss usually occupies more than half of the living quarters, while the rest of the colony crowds to one side. He is the first to eat when food is provided, he will select any female he wishes, and he will punish insubordination by immediately threatening and chasing the transgressor. Life, however, is usually peaceful in this dictatorial society because each member knows his status and does not try to change it. In these colonies, ESB has been able to alter the simian peaceful coexistence. In one of our experiments, as soon as a specific point of the boss's brain was radio-stimulated (nucleus postero-ventralis), the animal interrupted his peaceful activities of grooming and picking and general guard duty, adopted a threatening posture on all fours, and showed his teeth; there was piloerection, his tail became rigid, and he launched well-directed attacks against the rest of the group, especially against the other male, who was his main competitor and enemy. He would not attack the nice little female, who was his favorite "monkey friend." These attacks were repeated whenever the same point was stimulated, and they subsided a few seconds after cessation of stimulation. The opposite results have also been obtained by excitation of inhibitory areas of the brain, located in the caudate-septal region, just behind the frontal lobes. Radio stimulation of this region produced a subtle change in the expression of the boss monkey, which human observers would not have been able to evaluate, but which was apparently very noticeable and significant to the other monkeys, who shed their inhibitions and their fear and respect for the boss and approached him and walked freely around him while he was under stimulation.

If the investigators were able to diminish the aggressiveness and dominance of the authoritarian chief, could the subordinate monkeys learn to do it themselves, if adequate means were provided? To test this possibility, a radio transmitter was connected to a lever placed inside the colony cage. When the lever was pressed, a transmitter was activated which radio stimulated the inhibitory area of the boss, arresting his aggressive behavior. After several days, the monkey who was most often harassed by the chief had learned to press the magic lever which controlled the boss's hostility (see Figure 4), proving that a monkey may be educated to direct the behavior of a powerful dictator by using artificial instrumental means.

A wide variety of effects have been evoked by ESB, including changes in food intake, in respiration, in heart rate, in hormonal release, and other behavioral manifestations such as rage, fear, and pleasure. Some of these effects seemed to have all the characteristics of true emotions because they could be used to establish conditioned responses, to motivate trial and error learning, and to induce the performance of instrumental responses.

All these experimental results certainly demonstrated that ESB may influence and control many behavioral manifestations. These experiments have been made on monkeys, it is true, but much of the research carried out on the brains of animals, especially in monkeys, may be applied to human beings. It is also true that animal studies

cannot throw light on the most important mental functions which are highly developed only in man.

Fortunately, experimental data on human ESB have also begun to accumulate from patients in whom it was necessary, for therapeutical purposes, to explore the cerebral cortex or to implant very fine electrodes inside the brain. Some of these patients have undergone testing for weeks and months, and lead a nearly normal life while 10, 20, or even more fine wires are present, in different cerebral areas and ready for stimulations from outside the scalp. In our studies, spontaneous conversations of the patients with the therapist were tape recorded, while, from time to time, different intracerebral points were electrically stimulated. Later, the entire conversations were transcribed and their ideological and emotional content were analyzed by independent investigators to determine possible changes induced by ESB and to evaluate the statistical significance. Results demonstrated that both subtle and spectacular changes in mental activity can be induced by ESB. For example, in one patient, who, during control interviews, spoke a mean of 8½ words per minute, stimulation of the second temporal convolution increased his conversation up to 44 words per minute. This effect was highly reliable ($P = 0.01$). During the same period, the number of friendly remarks increased 9 times above control periods ($P = 0.02$). In other cases, blocking of the thinking process has been produced by excitation of anatomical structures in the vicinity of the frontal lobes. The persons were oriented, able to obey the doctor's orders, but they could not respond to questions or even pronounce a single word. "I could not coordinate my thoughts," one explained. "My head felt as if I had drunk a lot of beer." And another said, "I don't know why, but I could not speak." These were the manifestations of several patients when asked why they had suddenly stopped talking.

A variety of other mental phenomena has been produced in human beings by ESB: vivid recollection of the past; sensations of fear and threats of unknown danger; feelings of pleasure and happiness, accompanied by giggling, laughter, and humorous comments; perception of words and phrases; sensations that the present had already been experienced in the past; and hearing of pleasant melodies.

All of these findings are of great scientific interest and may possibly lead to new medical orientations in the difficult treatments of mental illnesses, but their value is even greater because they represent the proof that behavior and mental functions can be influenced by physical means and, therefore, bring the study of the mind to the domain of experimental sciences. This approach, however, does not prejudge the possible existence of other aspects of mental functions related to psychological, spiritual, or even religious conceptions of man. To the contrary, it recognizes that in the same way that light is simultaneously corpuscle and wave, and atoms are both matter and energy, mental functions may also have multidimensional characteristics which will not be revealed by a single type of methodology and may require different physical and intellectual tools to be understood. The mind of the scientist must be kept open to possible philosophical interpretations while he continues his investigations.

Motor performance, emotions, and ideas are related to electrical flashes of the cerebral neurons which we can now detect, measure, and analyze. Science has very recently developed new and powerful tools for the investigation of the conscious brain, and these tools are waiting for the many brains of new students who will use them to full advantage. We are in a precarious race between the acquisition of many megatons of destructive power and the development of intelligent human beings who will make intelligent use of the formidable forces at our disposal. The brain scientists may help the educators, but they need the educators' help.

I would like to close by asking your cooperation in spreading the message to your students that the mind is no longer considered an obscure metaphysical entity, but a concrete experimental reality with functions which may be evoked, inhibited, recorded, and analyzed. We need more students and more effort in mental research because these investigations may clarify the basis of human behavior and will probably bring more happiness to human beings than the advances in the physical sciences. Indeed, knowledge of the human mind may be decisive for our pursuit of happiness and for the very existence of mankind.

Additional Suggested Reading

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