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By MAGGIE SCARF
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Brain Researcher José Delgado Asks— 'What Kind of Humans Would We Like to Construct?'

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NEW HAVEN.

"WE are going to talk about love and war and hate," begins the professor, Dr. José M. R. Delgado of the Yale University School of Medicine. The class is an undergraduate course at Yale. Although registration was limited to 15, the seminar room is crowded; every chair around the long table is filled, and some students are sitting on packing cases stored at one end, and some are on extra chairs near the door. "But we shall consider these subjects in a novel way: from the inside of the thinking brain. What is going on there, what is happening *in the nerve cells* while we talk, while we behave, while we feel?"

Delgado, an emotional speaker, pauses. A spare man in his mid-50's, he leans forward on the table, resting his weight on both large hands. His eyes, restless and light in color, rove swiftly around the circle of staring faces. "We have a new way to study behavior, a new methodology which we have developed," he resumes in a voice that is low but as vibrant with promise as a preacher's. There is a stir, almost a sigh from the students; this is what they want to hear about, this "new methodology."

It is E. S. B.: electrical stimulation of the brain. Delgado is one of the leading pioneers in its refinement and development. He is also the impassioned prophet of a new "psychocivilized" society whose members would influence and alter their own mental functions to create a "happier, less destructive and better balanced man."

A few days earlier, just before the start of classes, The New York Times ran a front-page story on Dr. Delgado which was picked up by newspapers across the country. It described his most recent accomplishment: the establishment of direct nonsensory communication between the computer and the brain of a chimp. This study was the latest in a series of experiments involving two-way radio-wave contact with the brains of freely interacting animals. Because it clearly demonstrates that behavior can be influenced by remote radio command, this research has been seen by some as posing an ultimate threat to human freedom and integrity.

THE morning that story appeared, it was raining mildly in New Haven. In Delgado's secretary's office, part of the cluttered wing his staff occupies on the second floor of the Sterling Hall of Medicine, the telephone started ringing early; it kept on and on. In the darkroom next door, Delgado was just finishing the photographing of some E.E.G. recordings, or "brain waves." He bustles back across the hall and into his own office, immaculate as a surgeon in his white laboratory coat. "What do you want me to tell you?" he asks shortly, sitting down at his desk. He runs an irritable hand over his short-cut, curly hair. "I don't want to talk about my wife, my family, my friends. That's not science." He glances, scowling, through the window at the large white square of the School of Public Health building next door, and his expression suddenly clears. He turns back, leans forward over his desk relaxedly in one of the rapid mood changes which one very quickly learns to expect.

"The human race," he says, "is at an evolutionary turning point. We're very close to having the power to construct our own mental functions, through a knowledge of genetics (which I think will be complete within the next 25 years); and through a knowledge of the cerebral mechanisms which underlie our behavior. The question is what sort of humans would we like, ideally, to construct?" He smiles. "Not only our cities are very badly planned; we as human beings are, too. The results in both cases are disastrous.

"I am an optimist," continues Delgado. "I don't accept Lorenz's 'cosmic slip.' I don't think we're con-

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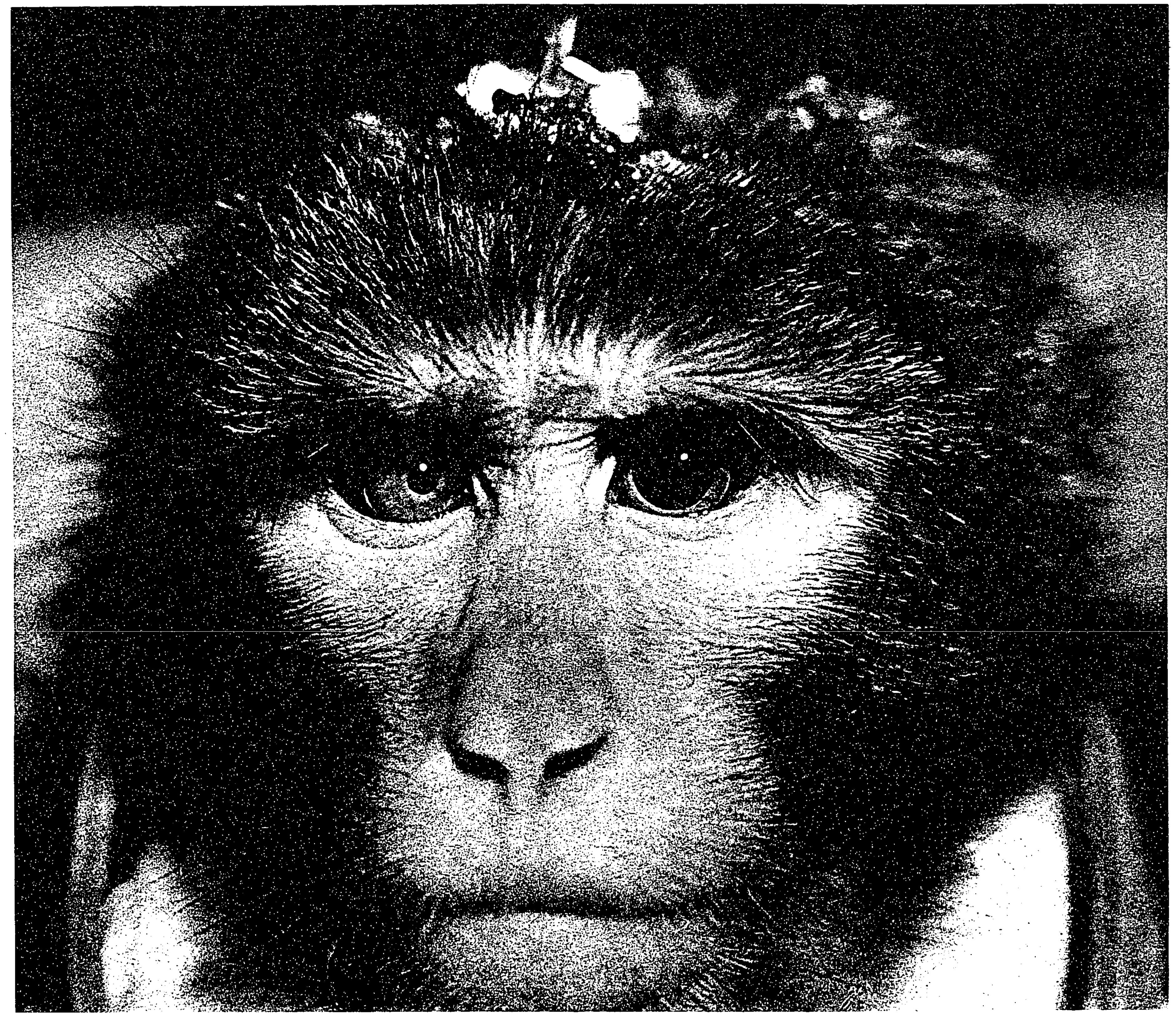
MAGGIE SCARF, a New Haven writer, is currently working on a novel about a social scientist.

Dr. José M. R. Delgado, in his lab at the Yale School of Medicine. A pioneer in E.S.B.—electrical stimulation of the brain—he hopes his experiments with animals (such as the gibbon in his arms) will one day help to construct "happier, less destructive, better balanced" men. But because his research shows that behavior can be influenced by remote control, some see it as a threat to human freedom.



The pupil of this monkey's left eye dilates in response to stimulation from electrodes planted in the hypothalamic region of his brain. By varying the intensity of the E.S.B., Delgado can adjust the pupil's size "as easily as a camera lens."

The "torero" at left is Delgado, during a bold experiment in Spain some years ago. With him in the ring is a bull bred for fierceness—but implanted with electrodes in its brain. As the animal charged (first picture), Delgado pressed a button on the radio transmitter in his hand—activating an inhibitory area of the brain—and the bull braked to a halt (second picture).

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demned by our natural fate to violence and self-destruction. My thesis is that just as we've evolved in our understanding of material forces, so we can — through a combination of new technology and of intelligence — evolve in our understanding of the mind.

"Man once used his intelligence to achieve ecological liberation, so that he no longer had to be wet when it rained, or cold when the sun was hidden, or killed because predators were hungry. He can achieve mental liberation also. Through an understanding of the brain, the brain itself may act to reshape its own structures and functions intelligently. That we bring this about is most essential for the future of mankind."

Delgado glances at his watch: "Come, I will show you around; I must hurry; I'm leaving for Zurich in two days." He looks impatient and harried again.

We go across the hall, through the secretary's office, into a large room full of equipment. Here, the two electronics engineers on Delgado's staff are at work. "How are you coming along?" asks Delgado, falling into a rapid conversation about equipment that will be needed for an experiment going on in Bermuda, for a motion-recording study to be carried out in a psychiatric ward, for a monkey-colony investigation going on upstairs; also, he checks over drawings of an improved transdermal (under the skin) brain stimulator. The noise of the phone and the secretary's voice provide a constant backdrop: "Dr. Delgado?" she asks, hurrying in suddenly. "How would you like to be on television?"

"What?" he says distractedly, in his rapid Spanish accent. "I wouldn't like it at all."

"How would you like to be on the David Frost show?"

"What's that?" He taps his foot impatiently. She seems uncomfortable: "He doesn't know," she says, looking at the two engineers helplessly. But they both shake their heads and shrug; they don't know either. "What shall I say?" she asks.

"Say no," Delgado answers curtly, but then, more gently, adds: "Tell them I'm going to Zurich. Tell them to call me some other time. I'm sorry."

On the way up to the fourth-floor laboratory, he stops in his office to pick up a small plastic box which at first sight looks empty. "Here is something that's going to be fantastic, really exciting," he says, holding it up like a conjuror. "But I can't tell you what it is; it's too early, it wouldn't be scientific."

Wouldn't he be willing to explain what it is privately? He hesitates: "All right . . . " But then he hurries off, at a pace only a little short of a run. Staring at the box in his hand, I see that it does contain something — two tiny chemitrodes, that is, arrays of electrodes and fine chemical tubes that can be inserted into the brain. "When we know the mechanisms by which the brain operates," resumes Delgado, "then we will be able to control our reality. The predicament of mankind is not too different from that of the dinosaurs, who flourished on earth for some 30 million years. They had very little intelligence; and 40 tons of flesh and bones. When the environment began to change, they lacked the intelligence to understand their situation, to adapt. Their fate—extinction."

"We, too, have developed disproportionate muscles and bones: missiles, guns, biological warfare. Our brains are *not developed accordingly*; they must become so or our own fate will be the same." We pass through a wide corridor. On either side are shining steel machines with bright plastic, electric leads coming out of them; it looks as cheery as a nursery school. In one room a monkey is calmly sitting in a plastic chair while his brain waves are recorded. He throws us a curious glance as we go by.

Delgado turns into a room at the left, the laboratory of his new young assistant, freshly arrived from Germany. They sit down together and the older man begins a careful explanation of how the chemitrodes are to be mounted. When he is finished, the new researcher blushes and stammers: "Please, I'm still not understanding too well . . . the English. Won't you repeat?" Delgado, very patiently, goes over the instructions. Then he stands up and excuses himself for a moment.

While he is gone, I ask the assistant what the new experiment will be. He explains, haltingly, that they are going to infuse a radioactive substance through the monkey's brain very slowly—"Stop, don't say anything!" cries Delgado, rushing back into the laboratory. "You mustn't tell her, she's dangerous. She's a journalist!"

"What, what?" demands the assistant, jumping back frightened. And suddenly, inexplicably, the three of us burst out laughing.

In a small corridor off the end of the main hallway are the animal cages, full of rhesus monkeys and gibbons right now. Delgado goes into one room, opening the cage of a female rhesus named Linda (after his 8-year-old daughter). "Hello, hello, Linda," he says softly to the monkey, who scampers up on to the wire-mesh ceiling. "It's O.K., it's O.K., come down." He takes a piece of apple, holds it out to her. Linda comes down, grabs the apple; a moment later she throws it at Delgado. He laughs: "That's not nice Linda, come down." She consents at last, comes swiftly to sit in Delgado's arms and throws her own around his neck.

He parts the hair on her shoulder, revealing an almost invisible transdermal brain stimulator. "Linda has been wearing this for over a year now; it's very important in its implication for humans. One of the real difficulties with humans is the cosmetic one. This transdermal can be placed below the skin and sealed forever, so that there are no unsightly plugs or equipment showing. We're working now on another one that would be even smaller."

Delgado strokes Linda's fur, then he looks up: "I have a great respect for the human brain," he remarks with the air of a man who has had to reiterate the statement often. "It distressed me greatly when I first came to this country in the early fifties to see so many patients without frontal lobes. Of course, much psychosurgery has now been replaced by drug treatment, but there are still people with dangerous seizures which simply do not respond to medication. In these cases, rather extensive portions of the temporal lobe may be removed —and since brain tissue doesn't regenerate, those functions which are lost are lost.

"Intracerebral electrodes offer a more conservative approach. Instead of cutting down through cerebral tissue, we insert very fine stainless steel wires. Then we can record the activity of various brain areas; in this way it becomes possible to locate the disturbances with a good degree of precision. After that, damaged areas can be treated by cauterization, or by E.S.B. in a brain area which inhibits on-going activity. Or still another possibility would be inducing electrical excitement in a competing area. For instance, there is one epileptic patient who uses a self-stimulator each time he feels a seizure coming on. By activating another part of the brain, he stops the discharge from spreading; the fit never develops."

In the past several years, electrode implantation has been used in the diagnosis and treatment of involuntary movements and intractable pain, as well as in epilepsy, some cases of schizophrenia and of excessive anxiety. Delgado was one of a small group of brain researchers to pioneer their clinical application. Implantation of electrodes, although carried out only as an alternative to destructive surgery, is "like installing a magic window through which one may look at the activity of the conscious, behaving brain.

"We are," says Delgado, "only in the initial stages of our understanding of E.S.B., but we know that it can delay a heartbeat, move a finger, bring a word to memory, evoke a sensation."

Brain stimulation in humans has elicited diverse and curious responses. It has stirred long hallucinations, such as hearing a piece of music being played from beginning to end; it has produced peculiar illusions of *déjà vu* — the intense feeling that the present moment has been experienced in the past. Patients have also described the vivid "reliving" of moments from their past, far more immediate than mere recollection. All the sensations of the former experience seem to spring to life—cars passing in the street outside, the sounds of children playing, words said and forgotten long ago.

"There are basic mechanisms inside the brain, I believe," says Delgado, "that are responsible for all mental activities, including emotion. I think we are now on the threshold of understanding them. We must do so—and soon—if the precarious race between unchained atoms and intelligent brains is to be won."

JOSE MANUEL RODRIGUEZ DELGADO was born in Ronda, Spain, in 1915. The town, which stands high on a rocky cliff to the southwest of Granada, was one of the last strongholds of the Moors. Dr.

Delgado is the son of Rafael Rodriguez Amerigo; on the paternal side he is directly descended from Amerigo Vespucci. (The name Delgado is his mother's maiden name: in Spain, where lineage is of paramount importance, a child takes the names of both grandparents as surname. Thus, Delgado's last name there is Rodriguez Delgado.)

José, the second of three boys (his older brother is a staff member of the United Nations), went directly from high school to the University of Madrid, taking his degree in medicine just before the outbreak of the Spanish Civil War. In 1938 he was drafted and joined the Spanish Republicans. "I fought with them until the triumph

"Not until the advent of computers could researchers sort out the signals from the various structures and areas of the brain."

of France, then I was thrown in a concentration camp. Those few months had a great effect upon me; they shaped me."

In what way?

"Oh, well," he shrugs slightly, his brows beetling in annoyance; he dislikes direct questions. "That all has nothing to do with my work." After his release in 1939, Delgado returned to the University of Madrid to take his M.D. once again (the old one was no longer valid). Then he lingered to take a Ph.D. in science at the Cajal Institute in Madrid. In 1950, he was invited to Yale by the famed neurophysiologist John Fulton. "And I never have left here," he concludes in a pleased voice.

In 1956, Delgado, in his early 40's, met Caroline Stoddard, the pretty, 22-year-old daughter of a Yale administrator; they were married within the year. They now have two children: Linda, 8, and José Carlos, 11. After 14 years of marriage, Caroline Delgado is quietly and passionately devoted to her husband's work, perhaps even a bit awed by it. (She sometimes refers to him, in a voice innocent of irony, as "the great Delgado.") "I go in to the lab with José pretty much every morning," she says cheerfully. She generally works in the same office, editing and typing papers. Does she mind the work? "Oh, no, I love it! It's nice being with someone who's always optimistic. And then it's a continuing circus; it's fun to see what's coming next. The brain is a relatively new field—there's a tremendous feeling of excitement."

THE human brain—that most delicate, complex organ, the organ of selection and imagination—is a mass of about 10 billion neurons, or nerve cells, which are almost continually receiving, transmitting, and discharging electrical impulses. In the early nineteen-twenties, Hans Berger, a German psychiatrist, first recorded the electrical activity of the human brain. Berger's electroencephalograms (E.E.G.'s) were made by attaching electrodes to the outside of the scalp. They could convey only the crudest information, for the signals emanating from the "black box" of the brain were bewildering and manifold: It was like opening the door on a cocktail party where many conversations were going on at once. Some of the voices were persistent, some started and stopped; there was a great deal of background racket. Not for many years—and not until the advent of electronic computers—were researchers able to sort out the signals coming from various structures and areas of the brain.

Shortly after Berger first recorded brain waves, the Swiss neurophysiologist W. R. Hess implanted very fine, stainless-steel electrodes deep within the brain of a cat. The cat, once recovered from the anesthesia, could not feel the wires at all. For the brain, the most exquisite of sensory interpreters, actually has no receptors or nerve endings in its own tissue; it feels nothing. Hess introduced a mild electrical impulse, stimulating the central gray matter, and the cat suddenly behaved "as if threatened by a dog." Evidently, nerve cells associated with emotions of rage had been activated. "It spits, snorts or growls," wrote Hess, ". . . its pupils widen . . . its ears lie back, or move back and forth to frighten the non-existing enemy."

Hess's experiment raised some excited speculations. It was known that certain areas of the brain controlled specific functions such as speech, sight, the flexing of arm and leg muscles. But emotions were not thought to be represented specifically—was it possible that there *were* areas or "centers" in the brain which corresponded to the different emotional states? E.S.B. seemed to offer a way to study the mechanisms of emotions experimentally, and yet, says Delgado: "When I came to this country some 20 years after Hess's early work, there were very few people—practically no one—working with brain stimulation."

Delgado had learned E.S.B. techniques while still in Spain, "mainly from reading about Hess's experiments. I was self-taught." Electrode implantation does not entail a large opening in the skull. Only a small burr hole is drilled, through which micromanipulators guide the electrode shafts — assemblies of very fine wires insulated with Teflon and scraped bare at the tips to permit the passage of current—down to their desired locations in the brain. The electrodes can be placed quite precisely with the aid of special (stereotaxic) maps of the brain and measuring instruments. Once they are in, the ends of the wires are soldered to a small exterior socket anchored to the skull.

After anesthesia wears off, plugging into the fully awake brain of cat, monkey or man is as simple as putting a lamp plug in a wall socket. There is no "awareness" of the electrodes, no ensuing damage to brain tissue. "There are chimps in our laboratory," Delgado says, "who have had up to 100 contacts implanted for more than four years; there seems to be no limit to how long they may safely be left in."

DELGADO'S early work at Yale was done with cats, and then increasingly with the far more intelligent and interesting monkey. Under the influence of E.S.B., the animals performed like electrical toys. "By pushing the right 'button' we could make a monkey open or shut his eyes, turn his head, move his tongue, flex his limbs. He could be made to yawn, sneeze, hop." During one experiment, a cat began the motions of licking each time it was stimulated at a certain point in the cortex. If the animal happened to be sleeping, it licked in its sleep; if awake, however, the cat looked around for a milk bowl to lap at; if there was no bowl, it began licking its own fur. "The cat seemed determined," smiles Delgado, "to make sense out of what he was doing."

E.S.B. can evoke not only simple but complicated behaviors which may be performed in sequence. One monkey, Ludy, each time she was stimulated in the red nucleus (in the posterior part of the brain) would stop what she was doing; change expression, turn her head to the right; stand up on two feet and circle to the right; climb a pole and then descend again; growl, threaten and often attack another monkey; then change attitude and approach the rest of the group in a friendly way. This "automatism" was repeated in the same order each time—through 20,000 stimulations!

"Interestingly enough," remarks Delgado, "when Ludy was stimulated at another point in the red nucleus only 3 millimeters away, she simply yawned."

Stimulation of certain brain areas has caused animals to increase the amount of food they eat by as much as 1,000 per cent, while E.S.B. at hunger-inhibiting points will make starving monkeys and cats turn away from food. The tickling of a few electric volts can send a monkey into a deep sleep, or snap him awake. "By brain stimulations in the hypothalamic region we can adjust the size of a monkey's eye pupil, making it larger or smaller as easily as you would the lens of a camera," Delgado adds.

“Plugging into the fully awake brain of a cat, monkey or man is simple. There is no 'awareness' of the electrodes, or damage to brain tissue.”

Sometimes it may happen that the voluntary impulse of an animal opposes an electrically evoked movement such as raising of a foreleg; in that case, the movement might not occur. "But," Delgado says, "by increasing the intensity of stimulation it is always possible to get the animal to respond as 'directed.'"

Similarly, human beings are unable to resist motor responses elicited by E.S.B.: Delgado describes a patient under treatment for psychomotor epilepsy who slowly clenched his hand into a fist each time he was stimulated through an electrode in the left parietal cortex. When asked to try to keep his fingers extended through the next stimulation, the man simply could not do it. "I guess, doctor," he commented ruefully, "that your electricity is stronger than my will."

ONE fascinating question, debated since the time of Hess, was whether the rage which could be induced in cats

"'The old dream of an individual overpowering a dictator by remote control has come true,' laughs Delgado. 'At least in our monkey colonies.'"

by E.S.B. was truly experienced by them emotionally. Were the hissing and spitting mere motor responses—or did the cat actually feel all the noxious sensations which accompany anger and fear? In 1954, Delgado, working with Warren Roberts and Neal Miller, the well-known psychologist, demonstrated that E.S.B. in certain brain areas which produce rage responses could act as a powerful punishment. Hungry cats who received E.S.B. at these points each time they began to eat quickly learned to avoid food. But cats being stimulated in other cerebral areas—though they might rear back from the bowl momentarily—never were motivated to learn to refuse food: they returned to eating as soon as the stimulation was over.

"The implication," explains Delgado, "was that there were places in the brain which corresponded to negative emotional states, to the cerebral perception of pain. If that were so, we could understand the mechanisms of suffering and block them at their source." Shortly after this experiment, doctors started to use brain stimulation for the relief of intractable pain.

A few months after the Delgado-Roberts-Miller study was published, a young Canadian, James Olds, began wondering . . . If there were "pain centers" in the brain, were there also areas devoted to the perception of pleasure? Olds, working at McGill University, implanted electrodes in the brains of a group of rats: He meant to probe an area just below the one that the Yale group had been studying, but in one rat an electrode went astray, landing a good deal above its target—it was an inspired mistake. For, as Olds soon realized, the rat found the stimulation rewarding; in fact it kept continually and dedicatedly returning for more.

Olds's subsequent large-scale studies of rats with electrodes in this "pleasureful area" found that they preferred E.S.B. above all else—including water, sex and food. Even when famished, they would run toward a stimulating lever faster than they would run toward food. They would remove obstacles, run mazes and even cross electrified grids in order to press the wonderful lever that provided self-stimulation. Sometimes ravenously hungry rats, ignoring nearby food, would stimulate themselves up to 5,000 times an hour—persisting with manic singleness of purpose for more than a day running, until they keeled over on the floor in a faint!

Olds thought that the pleasure areas must contain nerve cells that would be excited by satisfaction of the basic drives—such as hunger and sex—but that somehow E.S.B. of them was even better. In a subsequent experiment he demonstrated that the delights of E.S.B. in certain brain areas could be abolished by castration; they could then be restored by injections of the sex hormone, testosterone.

DELGADO, among others, later confirmed the existence of "reward areas" in the brain of the monkey. "In humans also, during diagnostic procedures, states of arousal and pleasure have been evoked. We have seen this in our own experience. One patient of ours was a rather reserved 30-year-old woman suffering from psychomotor epilepsy; she had electrodes implanted in her right temporal lobe. E.S.B. at one cerebral point made her suddenly confess her passionate regard for the therapist—whom she'd never seen before. She grabbed his hands and kissed them and told him how grateful she was for what he was doing for her.

"When stimulation was over, she was as poised and distant as ever; she remained so during E.S.B. through all other electrodes. But," one of Delgado's eyebrows rises slightly, "the same thing happened when she was stimulated at the same point on another day."

There have been several studies of humans with implanted electrodes. One carried out by Dr. C. Sem-Jacobsen in Norway with a group of patients suffering from schizophrenia and Parkinson's disease describes E.S.B. at different cerebral points as producing moods which ranged from "feeling good," to "slight euphoria," to where

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"the euphoria was beyond normal limits" and the patients laughed hilariously. During another study, a man being treated for narcolepsia (irresistible sleep attacks) was given a small self-stimulator. He kept pushing one particular button which, he declared, made him feel as if he were building up to a sexual climax.

"Pleasure is not in the skin being caressed or in a full stomach," remarks Delgado. "It is somewhere inside the cranial vault."

And so, also, are anxiety, fear, aggression. Early in the sixties, Delgado wanted to study problems of aggression —and its inhibition—among rhesus monkey colonies in which some members were receiving E.S.B. which increased or decreased levels of hostility. But there were practical problems: the monkeys tended to become curious about trailing wires, and their destructive capabilities were legendary. Most researchers had to keep them separated and restrained in little plastic chairs.

The nineteen-fifties, however, had brought advances in electronic technology and miniaturization of components. Delgado, who is, in the words of a colleague, "a kind of 19th-century mad inventor, a real technological wizard," developed an instrument called a stimoceiver. This was, as its name implies, both a brain stimulator and brain wave receiver; it could send stimulations by remote radio command on three channels and receive E.E.G. recordings on three channels. Weighing roughly just over an ounce, the stimoceiver was easily anchored to the animal's skull: it was monkey-proof.

A series of experiments was now carried out with monkeys who were freed of wires, interacting spontaneously and receiving E.S.B. by remote radio command. They demonstrated that while stimulation could increase the level of hostility experienced by an animal, whether or not he expressed his hostility against another monkey depended upon the social situation. Monkeys form hierarchical societies. If rage and aggression were evoked in a monkey at the bottom of the social scale, no threats would be directed against other monkeys. If, however, the animal were moved into another colony in which he held a higher rank, he would threaten or attack the animals below him. When the "boss monkey" of a colony was stimulated, his attacks were also carefully determined by the social situation: he attacked the male just below him in rank, never his favorite girl friend.

Thus, while E.S.B. could

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arouse aggressions in peaceful simian societies, these feelings were always expressed in socially intelligent ways. In one study a small female named Elsa learned to press a lever which activated a radio stimulator and inhibited the aggressiveness of the powerful, mean-tempered boss of the colony. "The old dream of an individual overpowering the strength of a dictator by remote control has come true," laughs Delgado. "At least, in our monkey colonies."

TWO years after developing the stimoceiver he and his invention made world headlines when Delgado took part in a "bullfight" in Spain. Climbing into the ring at a farm near Cordova, this matador in sweater and slacks faced a brave bull—one of a species genetically bred for fierceness.

Delgado, standing in the sun, waved a heavy red cape in the air. The bull lowered his head and charged through the dust. But, as the animal bore down on him, Delgado pressed a small button on the radio transmitter in his hand: the bull braked to a halt.

When the professor pressed another button, the bull turned away and trotted docilely toward the high wooden barrier. The bull had, of course, had electrodes implanted shortly before. The radio stimulation had activated an inhibitory area deep in the bull's brain, thus halting it in mid-charge.

This disquieting demonstration of the power of brain stimulation aroused a flurry of speculation about the possibilities of remote-controlled behavior. "Since that time," Delgado says ruefully, "I've received mail each year from people who think I'm controlling their thoughts."

Crank letters are not likely to stop arriving after Delgado's recent announcement that he has established two-way, nonsensory communication between the brain and the computer. In the experiment a young chimp named Paddy (after an Irish research assistant) was equipped with 100 electrodes implanted in his brain and wired to a socket on top of his skull. Mounted over the socket was a stimoceiver, its tiny components encased in a Teflon box not much bigger than a cigarette lighter.

Paddy, in the company of three other chimpanzees, was left to roam about an artificial, moat-surrounded island at Holloman Air Force Base in New Mexico. As he ran, ate, sat and played, his brain waves and other activities were monitored 24 hours a day. During early testing, it was found that E.S.B. in the central gray—the emotionally "negative" area explored by Hess and then Delgado—was obnoxious and disturbing for Paddy.

In the meanwhile, a computer standing nearby was programed to receive radio signals which were broadcasts of electrical activity from the chimp's brain and to respond to certain waves called "spindles." The spindles, coming from the amygdala, a structure deep in the temporal lobe, are correlated with aggressiveness and excitement; they occur spontaneously about 1,000 times an hour in the brain waves from the amygdala. In response to each spindle, the computer was instructed to deliver a radio stimulation to Paddy's central gray.

When the experiment began, each spindle produced by the amygdala was followed immediately by the punishing E.S.B. in the emotionally negative area—it was similar to the slapping of a child's hand each time he touches a forbidden object. Within two hours, spindling had diminished by 50 per cent. A few days later, there were practically no spindles at all. One part of the brain (the central gray) had "talked to" the other: it had forced the amygdala to change its normally occurring electrical activity! Paddy's behavior changed also. He was less aggressive, his appetite waned, he sat around lazily with visitors or with the other chimps. "In this case, we were able to get one area of the brain to communicate with the other," Delgado says. "Soon, with the aid of the computer, we may have direct contact between two different brains —without the participation of the senses."

PADDY'S changed behavior persisted for two weeks following the experiment. Then the amygdala resumed its spindling and the chimp returned to normal. "One of the implications of this study," explains Delgado, "is that unwanted patterns of brain activity—for instance those correlated with assaultive or antisocial activity—could be recognized by the computer before they ever reached consciousness in order to trigger pacification of the subject.

"Another speculation is that the onset of epileptic attacks could be recognized and avoided by feedback." (Feedback occurs when the activities of an organism or machine are modified continuously by the interaction between its signals or output and the environment; thus, E.S.B. in the central gray made the amygdala suppress its spindling in much the same way that warmth rising in a room causes a thermostat to shut off the supply of heat.)

Delgado looks forward to a time "not very far in the future" when cerebral pacemakers, operating in much the same way that cardiac pacemakers now do, will treat illnesses such as Parkinson's disease, anxiety, fear, obsessions, violent behavior, by direct stimulation of the brain. The premise is that each of these illnesses has its own characteristic pattern of electrical activity. In the case of an epileptic, these would be the high voltage slow waves which represent the simultaneous "explosion" of groups of neurons. Long before the first muscle twitch of an epileptic fit is seen, the brain waves show this typical pattern. If they were being monitored by a computer, the machine could respond immediately by triggering radio stimulation to brain areas that would inhibit and contain the seizure.

NO-DOZE—A monkey named Ludy yawns in response to a radio signal to the brain. But another signal just 3 millimeters away made Ludy growl.

This would all take place below the level of perception, without the person's conscious awareness. For instance, a man walking down a street, equipped with a subcutaneous stimulator, could avoid an epileptic seizure through interaction with a computer miles away—and never know it. Or, as seems quite feasible technologically, a minicomputer programed to respond to a specific type of electrical activity could be worn on the person's body. Thus, the "go-between" connecting two areas of the same brain might be situated either in the middle of a medical center or the middle of a shirt pocket.

Certain types of uncontrollably assaultive behavior might be treated without the computer, using carefully programed stimulation in inhibitory brain areas. According to Delgado, these could, over a period of time, cause a mellowing of aggressive reactions.

WHAT is the choice? Does it lie on the one hand between spiraling violence and continuous outbreaks of aggression and war, and, on the other hand, the development of a race of electrical toys whose every antisocial impulse could be neatly nipped by the computer before it ever became realized in the form of behavior? In his intriguing, troubling book, "Physical Control of the Mind," Delgado carefully explores the implications of E.S.B.:

"The possibility of scientific annihilation of personal identity, or even worse, its purposeful control, has sometimes been considered a future threat more awful than atomic holocaust," he writes. "The prospect of any degree of physical control of the mind provokes a variety of objections: theological objections because it affects free will, moral objections because it affects individual responsibility, ethical objections because it may block self-defense mechanisms, philosophical objections because it threatens personal identity."

However: ". . . it is not knowledge itself but its improper use which should be regulated. A knife is neither good nor bad; but it may be used by a surgeon or an assassin . . . Psychoanalysis, the use of drugs . . . insulin or electroshock . . . are all aimed at influencing the abnormal personality of the patient in order to change his undesirable mental characteristics."

Patients on drugs, he points out, are being controlled. Their behavior is modified, their systems are flooded and sometimes there are deleterious side effects; also, they are made lethargic and stupid. "And why? Because one little

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group of neurons keep misfiring. Is it destroying that patient's personal freedom to offer him precise, on-demand medication affecting only the area involved, so that none of his other mental processes are altered?

"Suppose that the onset of epileptic attacks could be recognized by the computer and avoided by feedback: would that threaten identity? Or if you think of patients displaying assaultive behavior due to abnormalities in brain functioning: do we preserve their individual integrity by keeping them locked up in wards for the criminally insane?"

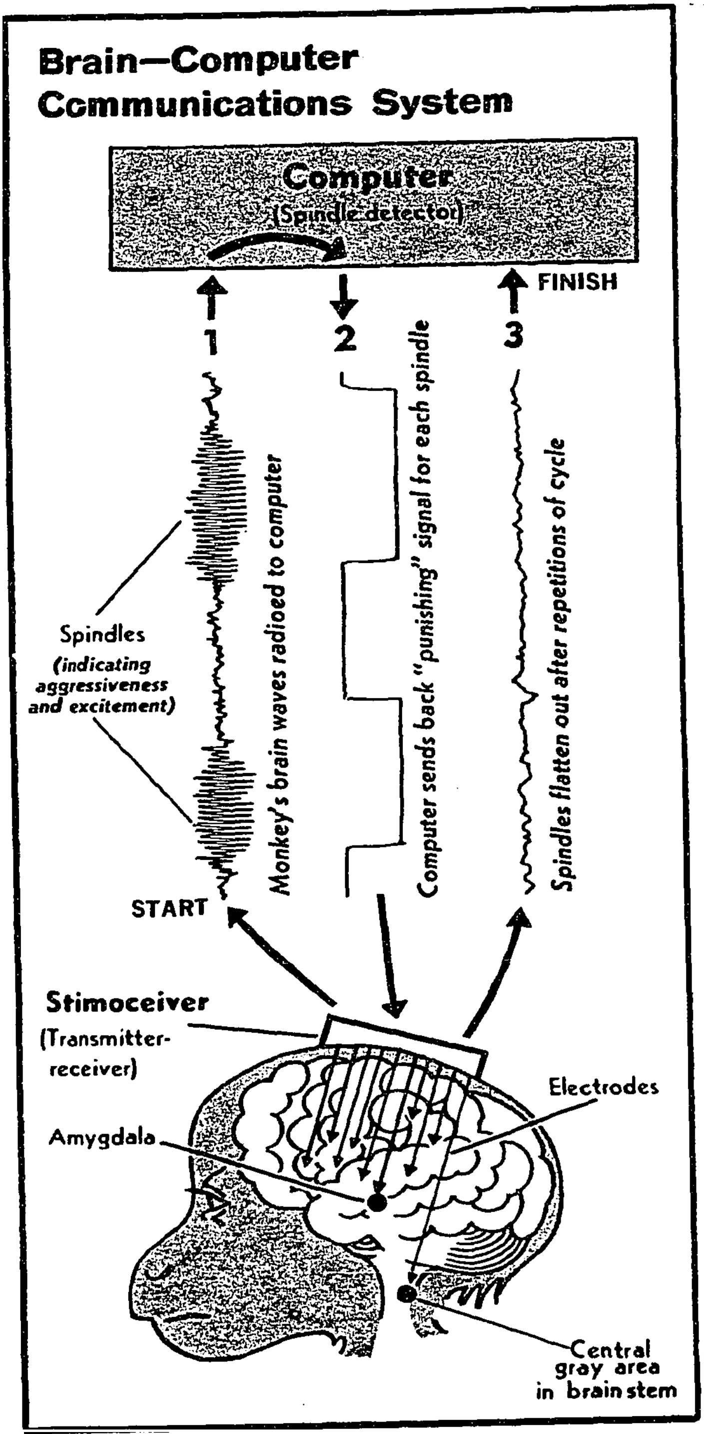
E.S.B. is actually a rather crude technique based on the delivery of a monotonous train of messageless electrical pulses. Like the button which launches a rocket, it sets off a train of programed events: biochemical, thermal, enzymatic, electrical. "Nothing which is not already in the brain can be put there by E.S.B.," Delgado says. It cannot be used as a teaching tool [to impart knowledge]. Since it doesn't carry specific thoughts it can certainly *not* be used to implant ideas or to order people about like robots —you couldn't use it to direct a person down to the mailbox to get the mail."

Brain stimulation does offer, however, an experimental method for the study of the neurophysiological basis of behavior. "True freedom," insists Delgado, "will come from an understanding of how the brain works; then we will be able to control our reality." A high-priority national goal ought to be an intensive study of cerebral processes for the purpose of establishing an educational system based on that knowledge: "We must first start with the realization that the mind, to all intents and purposes, does not exist at birth; in some brain areas as many as 80 to 90 per cent of the neurons don't form until afterwards. Personal identity is not something we are born with. It is a combination of genetic bias, the sensory information we receive, our educational and cultural inheritance. In other words, the mind is not revealed as the child matures; it is constructed."

Genetic determination is like the blueprint of a beautiful house, Delgado contends: "But the house itself is not there; you can't sleep in a blueprint. The kind of building you eventually have will depend on the choice of which bricks, which wood, which glass are used—just as the virgin brain will be shaped by what is given to it from the environment. Now in order to give this newborn brain the best possible building materials, there are questions to which we need answers: What is the chronology of imprinting? At what ages are certain patterns fixed? What are the true sources of pleasure and accomplishment?—this question has not only a psychological but a neurophysiological component, since we know that pleasure is localized in certain areas of the brain."

Most important, according to Delgado, is the need to develop an educational system that is based on knowledge of our biological realities, an education that would attempt to: first, establish good "automatisms" in the child, and, second, as he matures, permit his thinking capability to evolve without being subjected to unknown forces and impulses which may overpower his rational intelligence.

Like many another prophet,



BRAINWASH?—A diagram of Delgado's famous experiment with Paddy. With the aid of 100 electrodes in its brain, the chimp's brainwaves were broadcast (1) to a computer that was programed to react to "spindles"—i.e., widely fluctuating waves that occur about 1,000 times an hour and are associated with aggressiveness. For each spindle, the computer radioed back a punishing signal to Paddy's "central gray" (2). The brain was thus conditioned to stop spindling (3) and the chimp became docile.

Delgado is not always seen as such in his own country. Aside from the fantasy and fears aroused by his experiments, there are criticisms of the public stance he has adopted, as well as of his techniques and method. "There's something idiosyncratic about the way he works," remarks one Yale colleague. "He doesn't follow the ordinary rules. I mean one mustn't confuse technological elegance with methodological rigor: there must be the slow dogged part, the careful checking of observations, the randomization of experiments, the estimate of the probability that your findings weren't just due to chance . . .

"Delgado doesn't seem to have the patience to fool around with that. If he stimulates a monkey's brain and gets an expected reaction he gets bored. He gets a lot of things started, and then leaves other people to clean up after him. But let's face it, technologically the man's incredible; he's a real genius in a practical way — a sort of Thomas Edison of the brain."

Questions about the brain, says a young neurophysiologist, are extremely complex: "People like Delgado can talk about breakthroughs in this and that, but progress in knowledge is slow. It may be several centuries before we have any real understanding of what is going on . . . And besides there are different schools of thought. Some neurophysiologists think it's a waste of time to study groups of neurons and over-all behavior — that we'll learn more by figuring out what's happening in a single nerve cell. To a man with this approach, trying to understand the workings of the brain through gross stimulation appears silly—like using a hand lens to try and unlock the mysteries of the fine structure of a virus."

Nevertheless, if not the dogmatic experimentalist, Delgado, according to his research associates, more than makes up for it: "He's an inventor in the purest sense. You can't fault his creativity," says Dan Snyder, a Ph.D. in physiological psychology who has worked with Delgado for the past several years. "The man drops gems of ideas in his casual conversations the way some people shed bacteria. That's part of the problem: he hasn't time to beat an experiment to death because he's got so many good ideas that he more or less has to be in 10 places at once."

"The truth is," adds Snyder, "he's opened up enough research potentials to keep several laboratories busy for a lifetime."

Speculations about the future implications of E.S.B. —medical and social—are still various and vague. According to Dr. Morton Reiser, chairman of the Yale department of psychiatry (in which Delgado holds his appointment as professor of physiology), there are "probably some frightening potentials" in Delgado's work. "If you can use computer technology to send an unmanned space satellite to the moon, then it doesn't seem utterly impossible that one day our computers will be sophisticated enough to be used to put thoughts into people's heads." He pauses doubtfully. "At any rate, one could possibly exert some influence on gross emotional behavior. Suppose, for instance, there were someone with uncontrollable rage reactions which were due to something detectable in the nervous system. The computer could send back a stimulus to inhibit that response. I don't think *that's* science fiction. . . ."

Professor David Hamburg, chairman of the psychiatry department at Stanford and an expert on brain and behavior, says: "The stronger our scientific base, the better our position for making rational choices. Brain stimulation could lead to the relief of much human suffering, to new treatments for mental and neurological disorders; it could possibly help to solve some human problems and it may ultimately affect man's understanding and conception of himself.

"Of course," adds Hamburg, "the utilization of knowledge always presents certain problems. Any increase in understanding can be used in ways that are harmful or helpful. As with atomic research, as with our investigation into the chemistry of behavior, E.S.B. does open up possibilities for exploitation and harm. Any new technique for understanding how the brain mediates behavior could affect our lives for better or worse."

Certainly, mistrust and doubt are aroused on many sides by the suggestion that thought process can be rerouted and the mind physically controlled. According to one psychoanalyst, "The danger of this being abused is, I think, tremendous."

"I suppose," remarks Delgado, aware of the controversy his work inevitably stirs, "that to primitive man the idea of diverting the course of a river would have seemed irreligious." ■