

The work of Jose Delgado, a pioneering star



The Forgotten Era of **BRAIN**

By John Horgan

in brain-stimulation research four decades ago, goes largely unacknowledged today. What happened?

In the early 1970s Jose Manuel Rodriguez Delgado, a professor of physiology at Yale University, was among the world's most acclaimed—and controversial—neuroscientists. In 1970 the *New York Times Magazine* hailed him in a cover story as the “impassioned prophet of a new ‘psychocivilized society’ whose members would influence and alter their own mental functions.” The article added, though, that some of Delgado’s Yale colleagues saw “frightening potentials” in his work.

Delgado, after all, had pioneered that most unnerving of technologies, the brain chip—an electronic device that can manipulate the mind by receiving signals from and transmitting them to neurons. Long the McGuffins of science fiction, from *The Terminal Man* to *The Matrix*, brain chips are now being used or tested as treatments for epilepsy, Parkinson’s disease, paralysis, blindness and other disorders. Decades ago Delgado carried out experiments that were more dramatic in some respects than anything being done today.



CHIPS

ELECTRICAL BRAIN-STIMULATION DEVICES [opposite page], invented by Jose Delgado for his research into behavior and motor control, were implanted into apes, monkeys [shown above], bulls, cats and humans. Electrodes could remain implanted for more than two years without complications.

He implanted radio-equipped electrode arrays, which he called “stimocivers,” in cats, monkeys, chimpanzees, gibbons, bulls and even humans, and he showed that he could control subjects’ minds and bodies with the push of a button.

Yet after Delgado moved to Spain in 1974, his reputation in the U.S. faded, not only from public memory but from the minds and citation lists of other scientists. He described his results in more than 500 peer-reviewed papers and in a widely reviewed 1969 book, but these are seldom cited by modern researchers. In fact, some familiar with his early work assume he died. But Delgado, who recently moved with his wife, Caroline, from Spain to San Diego, Calif., is very much alive and well, and he has a unique perspective on modern efforts to treat various disorders by stimulating specific areas of the brain.

When Lobotomies Were the Rage

BORN IN 1915 in Ronda, Spain, Delgado went on to earn a medical degree from the University of Madrid in the 1930s. Although he has long been dogged by rumors that he supported the fascist regime of Francisco Franco, he actually served in the medical corps of the Republican Army (which opposed Franco during Spain’s civil war) while he was a medical student. After Franco crushed the Republicans, Delgado was detained in a concentration camp for five months before resuming his studies.

He originally intended to become an eye doctor, like his father. But a stint in

a physiology laboratory—plus exposure to the writings of the great Spanish neuroscientist Santiago Ramón y Cajal—left him entranced by “the many mysteries of the brain. How little was known then. How little is known now!” Delgado was particularly intrigued by the experiments of Swiss physiologist Walter Rudolf Hess. Beginning in the 1920s, Hess had demonstrated that he could elicit behaviors such as rage, hunger and sleepiness in cats by electrically stimulating different spots in their brains with wires.

In 1946 Delgado won a yearlong fellowship at Yale. In 1950 he accepted a position in its department of physiology, then headed by John Fulton, who played a crucial role in the history of psychiatry. In a 1935 lecture in London, Fulton had reported that a violent, “neurotic” chimpanzee named Becky had become calm and compliant after surgical destruction of her prefrontal lobes. In the audience was Portuguese psychiatrist Egas Moniz, who started performing lobotomies on psychotic patients and claimed excellent results. After Moniz won a Nobel Prize in 1949, lobotomies became an increasingly popular treatment for mental illness.

Initially disturbed that his method of pacifying a chimpanzee had been applied to humans, Fulton later became a cautious proponent of psychosurgery. Delgado disagreed with his mentor’s stance. “I thought Fulton and Moniz’s idea of destroying the brain was absolutely horrendous,” Delgado recalls. He felt it would be “far more conservative” to treat mental illness by applying the elec-

trical stimulation methods pioneered by Hess—who shared the 1949 prize with Moniz. “My idea was to *avoid* lobotomy,” Delgado says, “with the help of electrodes implanted in the brain.”

One key to Delgado’s scientific success was his skill as an inventor; a Yale colleague once called him a “technological wizard.” In his early experiments, wires ran from implanted electrodes out through the skull and skin to bulky electronic devices that recorded data and delivered electrical pulses. This setup restricted subjects’ movements and left them prone to infections. Hence, Delgado designed radio-equipped stimocivers as small as half-dollars that could be fully implanted in subjects. His other inventions included an early version of the cardiac pacemaker and implantable “chemitrodes” that could release precise amounts of drugs directly into specific areas of the brain.

In 1952 Delgado co-authored the first peer-reviewed paper describing long-term implantation of electrodes in humans, narrowly beating a report by Robert Heath of Tulane University. Over the next two decades Delgado implanted electrodes in some 25 human subjects, most of them schizophrenics and epileptics, at a now defunct mental hospital in Rhode Island. He operated, he says, only on desperately ill patients whose disorders had resisted all previous treatments. Early on, his placement of electrodes in humans was guided by animal experiments, studies of brain-damaged people and the work of Canadian neurosurgeon Wilder Penfield; beginning in the 1930s, Penfield stimulated epileptics’ brains with electrodes before surgery to determine where he should operate.

Taming a Fighting Bull

DELGADO SHOWED that stimulation of the motor cortex could elicit specific physical reactions, such as movement of the limbs. One patient clenched his fist when stimulated, even when he tried to resist. “I guess, doctor, that your electricity is stronger than my will,” the patient commented. Another subject, turning his head from side to side in response to stimulation, insisted he was doing so vol-

Overview/Brain Implants

- Jose M. R. Delgado, a pioneer in brain-implant technology, is perhaps most famous for halting a charging bull by merely pressing a button on a device that sent signals to the animal’s brain.
- In the early 1970s Delgado went from being acclaimed to being criticized. In 1974 he moved from the U.S. to Spain and then gradually faded from public consciousness and the citation lists of neuroscientists.
- His accomplishments, however, helped to pave the way for modern brain-implant technology, which is enjoying a resurgence today and is improving life for patients with epilepsy and such movement disorders as Parkinson’s and dystonia.
- Delgado, now 90, recently returned to the U.S., complete with strong opinions on the promise and perils of the ongoing work.



untarily, explaining, “I am looking for my slippers.”

By stimulating different regions of the limbic system, which regulates emotion, Delgado could also induce fear, rage, lust, hilarity, garrulousness and other reactions, some of them startling in their intensity. In one experiment, Delgado and two collaborators at Harvard University stimulated the temporal lobe of a 21-year-old epileptic woman while she was calmly playing a guitar; in response, she flew into a rage and smashed her guitar against a wall, narrowly missing a researcher’s head.

Perhaps the most medically promising finding was that stimulation of a limbic region called the septum could trigger euphoria, strong enough in some cases to counteract depression and even physical pain. Delgado limited his human research, however, because the therapeutic benefits of implants were unreliable; re-

sults varied widely from patient to patient and could be unpredictable even in the same subject. In fact, Delgado recalls turning away more patients than he treated, including a young woman who was sexually promiscuous and prone to violence and had repeatedly been confined in jails and mental hospitals. Although both the woman and her parents begged Delgado to implant electrodes in her, he refused, feeling that electrical stimulation was too primitive for a case involving no discernible neurological disorder.

Delgado did much more extensive research on monkeys and other animals, often focusing on neural regions that elicit and inhibit aggression. In one demonstration, which explored the effects of stimulation on social hierarchy, he implanted a stimoceiver in a macaque bully. He then installed a lever in the cage that, when pressed, pacified the bully by causing the stimoceiver to stimulate the mon-

CAROLINE DELGADO, shown monitoring encephalographic readings from a monkey, has assisted her husband since their meeting at Yale University in the 1950s.

key’s caudate nucleus, a brain region involved in controlling voluntary movements. A female in the cage soon discovered the lever’s power and yanked it whenever the male threatened her. Delgado, who never shied from anthropomorphic interpretations, wrote, “The old dream of an individual overpowering the strength of a dictator by remote control has been fulfilled, at least in our monkey colonies.”

Delgado’s most famous experiment took place in 1963 at a bull-breeding ranch in Cordoba, Spain. After inserting stimoceivers into the brains of several “fighting bulls,” he stood in a bullring with one bull at a time and, by pressing buttons on a handheld transmitter, controlled each animal’s actions. In one in-



CAT LIFTED ITS HIND LEG in response to stimulation by an electrode implanted in its brain. The cat, Delgado says, displayed no discomfort in this experiment done in the early 1950s.

other disorders characterized by specific brain signals.

Delgado's research was supported not only by civilian agencies but also by military ones such as the Office of Naval Research (but never, Delgado insists, by the Central Intelligence Agency, as some conspiracy theorists have charged). Delgado, who calls himself a pacifist, says that his Pentagon sponsors viewed his work as basic research and never steered him toward military applications. He has always dismissed speculation that implants could create cyborg soldiers who kill on command, like the brainwashed assassin in the novel and film versions of *The Manchurian Candidate*. (The assassin was controlled by psychological methods in the original 1962 film and by a brain chip in the 2004 remake.) Brain stimulation may "increase or decrease aggressive behavior," he asserts, but it cannot "direct aggressive behavior to any specific target."

Envisioning a "Psychocivilized Society"

IN 1969 DELGADO described brain-stimulation research and discussed its implications in *Physical Control of the Mind: Toward a Psychocivilized Society*, which was illustrated with photographs of monkeys, cats, a bull and two young women whose turbans concealed

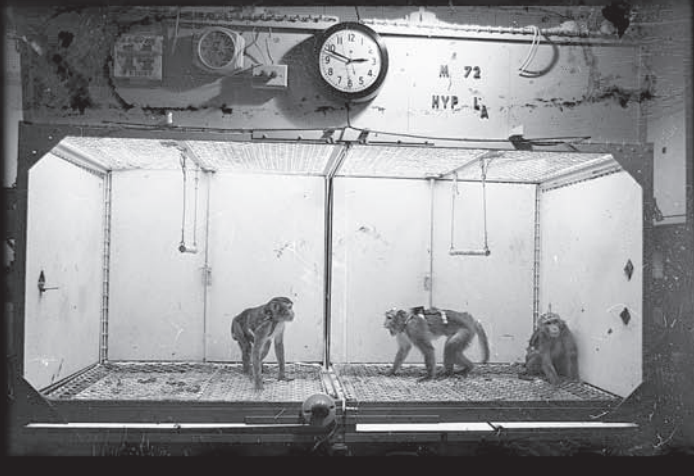
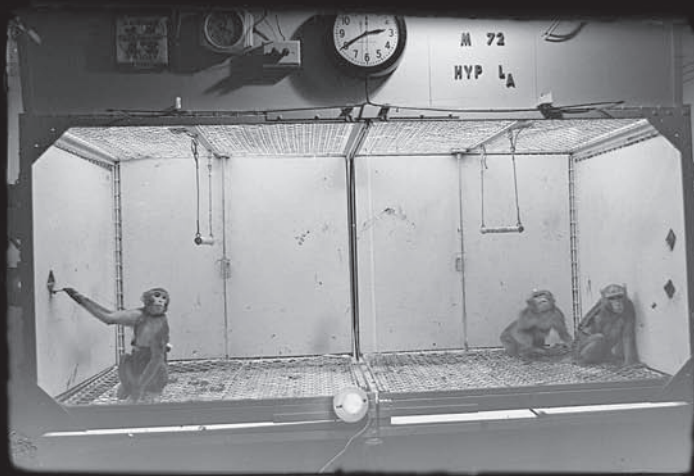
stance, captured in a dramatic photograph, Delgado forced a charging bull to skid to a halt only a few feet away from him by stimulating its caudate nucleus. The *New York Times* published a front-page story on the event, calling it "the most spectacular demonstration ever performed of the deliberate modification of animal behavior through external control of the brain." Other articles hailed Delgado's transformation of an aggressive beast into a real-life version of Ferdinand the bull, the gentle hero of a popular children's story.

In terms of scientific significance, Delgado believes his experiment on a female chimpanzee named Paddy deserved more attention. Delgado programmed

Paddy's stimoceiver to detect distinctive signals, called spindles, spontaneously emitted by her amygdala. Whenever the stimoceiver detected a spindle, it stimulated the central gray region of Paddy's brain, producing an "aversive reaction"—that is, a painful or unpleasant sensation. After two hours of this negative feedback, Paddy's amygdala produced 50 percent fewer spindles; the frequency dropped by 99 percent within six days. Paddy was not exactly a picture of health: she became "quieter, less attentive and less motivated during behavioral testing," Delgado wrote. He nonetheless speculated that this "automatic learning" technique could be used to quell epileptic seizures, panic attacks or

FIGHTING BULL with a stimoceiver in its brain (*below*) charged Delgado in a Spanish bullring in 1963 (*middle two photographs*) and then stopped and turned in response to a radio signal from Delgado (*far right*). Critics contended that the stimulation did not quell the bull's aggressive instinct, as Delgado suggested, but rather forced it to turn to the left. Delgado, who grew up in Ronda, Spain, a bastion of bullfighting, admits he felt "frightened" just before his signal made the bull abandon the chase.





stimoceivers. (Female patients “have shown their feminine adaptability to circumstance,” Delgado remarked, “by wearing attractive hats or wigs to conceal their electrical headgear.”) Spelling out the limitations of brain stimulation, Delgado downplayed “Orwellian possibilities” in which evil scientists enslave people by implanting electrodes in their brains.

Yet some of his rhetoric had an alarmingly evangelical tone. Neurotechnology, he declared, was on the verge of “conquering the mind” and creating “a less cruel, happier, and better man.” In a review in *Scientific American*, the late physicist Philip Morrison called *Physical Control* “a thoughtful, up-to-date account” of electrical stimulation experiments but added that its implications were “somehow ominous.”

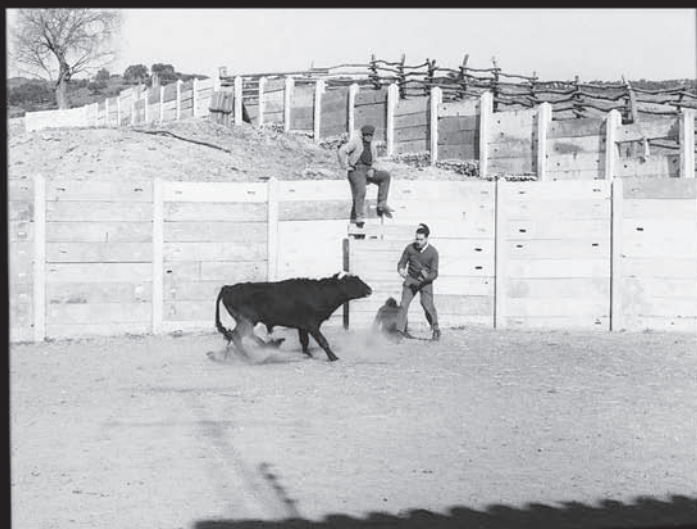
In 1970 Delgado’s field was engulfed in a scandal triggered by Frank Ervin and Vernon Mark, two researchers at Harvard Medical School with whom

Delgado briefly collaborated. (One of Ervin’s students was Michael Crichton, who wrote *The Terminal Man*. The best-seller, about a bionic experiment gone awry, was inspired by the research of Ervin, Mark and Delgado.) In their book, *Violence and the Brain*, Ervin and Mark suggested that brain stimulation or psychosurgery might quell the violent tendencies of blacks rioting in inner cities. In 1972 Heath, the Tulane psychiatrist, raised more questions about brain-implant research when he reported that he had tried to change the sexual orientation of a male homosexual by stimulating his septal region while he had intercourse with a female prostitute.

The fiercest opponent of brain implants was psychiatrist Peter Breggin (who in recent decades has focused on the dangers of psychiatric drugs). In testimony submitted into the Congressional Record in 1972, Breggin lumped Delgado, Ervin, Mark and Heath together with advocates of lobotomies and

FEMALE MACAQUE (far left in first photograph) learned that by pulling a lever in the cage she could escape encounters with an alpha male. The lever sent a signal to a stimoceiver in his brain, pacifying him. The alpha male is in the pacified state at the far right in the left image and has become aggressive in the other shot. Delgado carried out many investigations, such as this one in the early 1960s, into the effects of brain stimulation on social interactions.

accused them of trying to create “a society in which everyone who deviates from the norm” will be “surgically mutilated.” Quoting liberally from *Physical Control*, Breggin singled out Delgado as “the great apologist for technologic totalitarianism.” In his 1973 book *Brain Control*, Elliot Valenstein, a neurophysiologist at the University of Michigan at Ann Arbor, presented a detailed scientific critique of brain-implant research by Delgado and others, contending that the results of stimulation were much less precise and therapeutically beneficial than proponents often suggested. (Delgado notes that in his own writings he made



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many of the same points as Valenstein.)

Meanwhile strangers started accusing Delgado of having secretly implanted stimoceivers in their brains. One woman who made this claim sued Delgado and Yale University for \$1 million, although he had never met her. In the midst of this brouhaha, Villar Palasi, the Spanish minister of health, asked Delgado to help organize a new medical school at the Autonomous University in Madrid, and he accepted, moving with his wife and two children to Spain in 1974. He insists that he was not fleeing the disputes surround-

ing his research; the minister's offer was just too good to refuse. "I said, 'Could I have the facilities I have at Yale?' And he said, 'Oh, no, much better!'"

In Spain, Delgado shifted his focus to noninvasive methods of affecting the brain, which he hoped would be more medically acceptable than implants. Anticipating modern techniques such as transcranial magnetic stimulation, he invented a halolike device and a helmet that could deliver electromagnetic pulses to specific neural regions. Testing the gadgets on both animals and human volunteers—including himself and his daughter, Linda—Delgado discovered that he could induce drowsiness, alertness and other states; he also had some success treating tremors in Parkinson's patients.

Delgado still could not entirely escape controversy. In the mid-1980s an article in the magazine *Omni* and documentaries by the BBC and CNN cited

Delgado's work as circumstantial evidence that the U.S. and Soviet Union might have secretly developed methods for remotely modifying people's thoughts. Noting that the power and precision of electromagnetic pulses decline rapidly with distance, Delgado dismisses these mind-control claims as "science fiction."

Except for these flashes of publicity, however, Delgado's work no longer received the attention it once had. Although he continued publishing articles—especially on the effects of electromagnetic radiation on cognition, behavior and embryonic growth—many appeared only in Spanish journals. Moreover, brain-stimulation studies back in the U.S. bogged down in ethical controversies, grants dried up, and researchers drifted to other fields, notably psychopharmacology, which seemed to be a much safer, more effective way to treat brain disorders

Brain Implants Today

When Jose Delgado and a few other intrepid scientists first began exploring the effects of implanting electrodes in the brain half a century ago, they could not foresee how many people would one day benefit from this line of research. By far the most successful form of implant, or "neural prosthesis," is the artificial cochlea. More than 70,000 people have been equipped with these devices, which restore at least rudimentary hearing by feeding signals from an external microphone to the auditory nerve. Brain stimulators have been implanted in more than 30,000 people suffering from Parkinson's disease and other movement disorders (including 17-year-old Kari Weiner, shown at the right). Roughly the same number of epileptics are being treated with devices that stimulate the vagus nerve in the neck.

Work on other prostheses is proceeding more slowly. Clinical trials are now under way to test brain and vagus nerve stimulation for treating disorders such as depression, obsessive-compulsive disorder, panic attacks and chronic pain. Artificial retinas—light-sensitive chips that mimic the eye's signal-processing ability and stimulate the optic nerve or visual cortex—have been tested in a handful of blind subjects, but they usually "see" nothing more than phosphenes, or bright spots.

Several groups have recently shown that monkeys can control computers and robotic arms "merely by thinking," as media accounts invariably put it—not telekinetically but via implanted electrodes picking up neural signals. The potential for empowering the paralyzed is obvious, but so far few



KARI WEINER was confined to a wheelchair (left) for seven years by dystonia, a condition that causes uncontrollable muscle spasms. Now (right) she walks without assistance, thanks to battery-powered electrodes that were implanted in her brain when she was 13—and to surgeries that then repaired her twisted muscles and lengthened her tendons.

experiments with humans have been carried out, with limited success. Chips that might restore the memory of those afflicted with Alzheimer's disease or other disorders are still a year or two away from testing in rats.

The potential market for neural prostheses is enormous. An estimated 10 million Americans grapple with major depression; 4.5 million suffer from memory loss caused by Alzheimer's disease; more than two million have been paralyzed by spinal cord injuries, amyotrophic lateral sclerosis and strokes; and more than a million are legally blind.

—J.H.

DELGADO, holding two of his brain implants in a photograph taken in August, once wrote that humanity should shift its mission from the ancient dictum “Know thyself” to “Construct thyself.”

than brain stimulation or surgery. Only in the past decade has brain-implant research revived, spurred by advances in computation, electrodes, microelectronics and brain-scanning technologies—and by a growing recognition of the limits of drugs for treating mental illness.

Delgado, who stopped doing research in the early 1990s but still follows the field of brain stimulation, believes modern investigators fail to cite his studies not because he was so controversial but simply out of ignorance; after all, most modern databases do not include publications from his heyday in the 1950s and 1960s. He is thrilled by the resurgence of research on brain stimulation, because he still believes in its potential to liberate us from psychiatric diseases and our innate aggression. “In the near future,” he says, “I think we will be able to help many human beings, especially with the noninvasive methods.”

Delgado’s successors have faced some of the same questions that he did about possible abuses of neurotechnology. Some pundits have expressed concern that brain chips could allow a “controlling organization” to “hack into the wetware between our ears,” as *New York Times* columnist William Safire put it. An editorial in *Nature* recently expressed concern that officials in the Defense Advanced Research Projects Agency, a major funder of brain-implant research, have openly considered implanting brain chips in soldiers to boost their cognitive capacities. Meanwhile some techno-enthusiasts, such as British computer scientist Kevin Warwick, contend that the risks of brain chips are far outweighed by the potential benefits, which will include instantly “downloading” new languages or other skills, controlling computers and other devices with our thoughts, and communicating telepathically with one another.

Delgado predicts that neurotechnologies may never advance as far as many people fear or hope. The applications envisioned by Warwick and others, Del-



gado points out, require knowing how complex information is encoded in the brain, a goal that neuroscientists are far from achieving. Moreover, learning quantum mechanics or a new language involves “slowly changing connections which are already there,” Delgado says. “I don’t think you can do that suddenly.” Brain stimulation, he adds, can only modify skills and capacities that we already possess.

But Delgado looks askance at the suggestion of the White House Council on Bioethics and others that some scientific goals—particularly those that involve altering human nature—should not even be pursued. To be sure, he says,

technology “has two sides, for good and for bad,” and we should do what we can to “avoid the adverse consequences.” We should try to prevent potentially destructive technologies from being abused by authoritarian governments to gain more power or by terrorists to wreak destruction. But human nature, Delgado asserts, echoing one of the themes of *Physical Control*, is not static but “dynamic,” constantly changing as a result of our compulsive self-exploration. “Can you avoid knowledge?” Delgado asks. “You cannot! Can you avoid technology? You cannot! Things are going to go ahead in spite of ethics, in spite of your personal beliefs, in spite of everything.”

MORE TO EXPLORE

Brain Control: A Critical Examination of Brain Stimulation and Psychosurgery. Elliot S. Valenstein. John Wiley and Sons, 1973. [A contemporaneous scientific critique of the work of Delgado and other neuroscientists.]

Controlling Robots with the Mind. Miguel A. L. Nicolelis and John K. Chapin in *Scientific American*, Vol. 287, No. 4, pages 46–53; October 2002.

Rebuilt: How Becoming Part Computer Made Me More Human. Michael Chorost. Houghton Mifflin, 2005. [A personal story on the pros and cons of brain implants.]

The President’s Council on Bioethics Web site is at www.bioethics.gov

An overview of modern brain stimulation can be found at www.bioethics.gov/transcripts/june04/session6.html

Other Web sites extol the utopian possibilities of brain stimulation, www.wireheading.com, or deplore it as a government mind-control plot, www.mindjustice.org/