Can a Single Cell Recognize Your Face?

by John Horgan
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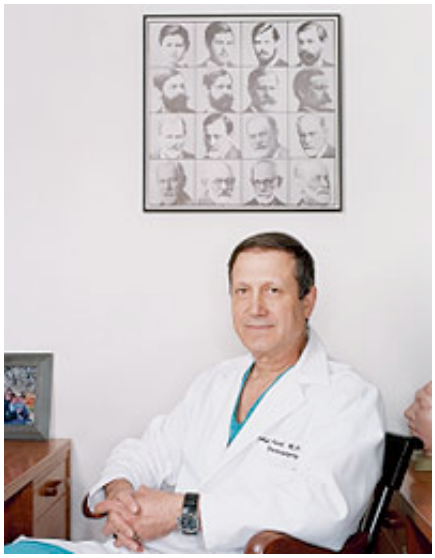

Photographs by Misha Gravenor

NEUROSURGEON: A Freud photo collage adorns Itzhak Fried's office at the UCLA school of medicine. "Freud lacked the scientific tools to study actual physical processes in the brain," Fried says, "so he moved to a more hypothetical realm."

Back in his office, Fried recalled how he ended up overseeing this unusual program. One of his role models was Wilder Penfield, the Canadian surgeon who carried out pioneering operations on epileptics in the 1930s and 1940s. After removing the skullcap of patients, Penfield electrically tickled different spots of their brains with wires and asked them what they felt. Because the brain lacks pain receptors, the patients needed no anesthesia. They reported such sensations as a tingle in the left forefinger, seeing a blue flash, and hearing a low-pitched hum. This procedure not only helped guide Penfield's surgical treatment of each patient but also yielded clues to what different parts of the brain do. "He was really looking at the human mind," Fried said, "but at the same time helping a human being." Fried's method is much more refined than Penfield's. He typically drills a dozen holes in the patient's skull and inserts a dozen hollow macroelectrodes, which can detect large-scale electric waves emanating from a seizure.

Protruding from the end of each macroelectrode are as many as 10 flexible microelectrodes that can detect the pulses of individual neurons. The patient's clinical status dictates the placement of the macroelectrodes. In Danny's case, tests suggested that his seizures originate in his frontal lobes, so Fried inserted most of the macroelectrodes in that region. He embedded one macroelectrode in Danny's hippocampus, a region that

underpins memory and is often implicated in epileptic seizures.

The patient's clinical health and comfort, Fried emphasized, take precedence over research objectives. Even the most carefully planned paradigm must be set aside if the patient becomes bored, tired, frustrated, gets a headache, or just wants to be left alone. Fried carefully screens prospective colleagues to ensure that they treat his patients like human beings rather than laboratory animals. "The person who will not do well," he said, "is an obsessive-compulsive animal physiologist who, if he doesn't control all the variables, falls apart." But Fried also said he believes that "there is a responsibility" to take advantage of these rare chances to learn more about the behavior of individual neurons, which he calls the building blocks of cognition.

NEUROTHEORIST: A quest for hard data led Christof Koch of Caltech to work with Fried. "It's cool to make theories at the biophysical level, which I used to do," he says. "But there are so many things where we have no idea how it works."

Following Penfield's example, Fried occasionally does studies that involve stimulating brain cells with minute electric jolts. In 1998 he and three colleagues discovered that a female patient burst into laughter every time they stimulated a spot at the top of her brain called the supplementary motor area. Her hilarity was not just physiological. The woman felt subjective sensations of "merriment or mirth" and displayed a syndrome known as confabulation: She invented reasons for her hilarity, telling the researchers at one point, "You guys are just so funny . . . standing around."

But most of Fried's findings, which he has described in more than a dozen papers in such leading journals as *Nature*, *Neuron*, and *Proceedings of the National Academy of Sciences*, involve not electrically stimulating neurons but passively listening to their chatter as a patient performs various tasks. In one set of experiments, Fried, Koch, and Gabriel Kreiman, a Caltech grad student, found cells that respond both when a subject looks at an image—of a baseball, say, or a woman's face—and when he closes his eyes and recalls the image in his mind's eye. The results provide convincing evidence that human perception and imagination share neural circuitry.

The experiments that have attracted the most attention are those supporting the existence of thinking cells. The possibility of such cells has been debated at least since the 1950s, when researchers found single neurons in the visual cortex of cats and other animals that respond to simple stimuli, such as lines oriented at a certain angle or moving in a specific direction, or light of a particular wavelength. Some theorists wondered whether single neurons might also respond to much more complicated stimuli, such as specific people.

Once known as gnostic cells, after the Greek word for knowledge, they were dubbed grandmother cells in the late 1960s by neuroscientist Jerome Lettvin of MIT. Lettvin originally meant the term as a joke. In one paper, he proposed that mother-smothered neurotics such as Portnoy, the hero of Philip Roth's novel *Portnoy's Complaint*, could be cured of their oedipal disorders by having all the mother cells purged from their brains.

Many neuroscientists were skeptical that a single cell could recognize an inanimate object, let alone a person. Even objects as simple as chairs, trees, or buildings come in an almost infinite variety of forms, and the same object looks different from different perspectives and in different contexts. Then in the early 1970s, experiments on monkeys by Charles Gross of Princeton University turned up cells that respond selectively to hands and faces—not specific faces but faces in general.

No one had conducted tests with humans, however, until the late 1990s, when Fried and his colleagues started reporting how epileptic patients reacted to various images. Some neurons were apparently smart enough to comprehend the highly abstract concept of a nonhuman animal. Their neurons fired when the patient was shown a picture of a tiger, an eagle, an antelope, and a rabbit but not when shown pictures of humans or inanimate objects. Other cells favored images only of food, buildings, or human faces. Some cells responded to all faces, but others were picky, firing for male faces but not female ones, or scowling faces but not smiling ones—or finally, faces of specific individuals.

VISIONARY APPLICATIONS

Pioneering studies of thinking cells by Itzhak Fried and Christof Koch could help advance at least two technological endeavors. One is pattern recognition, particularly artificial vision. Countless researchers, generously funded by military agencies, have tried to develop computer-based vision, with limited success. The Department of Defense is interested in software that can spot missile sites or other items of military interest in satellite images. Since 9/11, moreover, the Department of Homeland Security has funded research on face-recognition programs that can scan crowds in airports or other areas for suspected terrorists. But even the most powerful computers running the latest software programs have difficulty recognizing simple objects when the setting, perspective, distance, or lighting changes. Disregarding the problem of disguises, face-recognition programs can be thrown off by factors such as changes in hair and facial hair, different expressions, and aging. Knowing how brains solve such problems could help software designers.

Studies of thinking cells could also aid efforts to build so-called cognitive prostheses, devices to replace or supplement capacities lost through brain damage. At the University of Southern California, for example, biomedical engineer Ted Berger is building an implantable chip that could augment the signal-processing of memory cells. For now, Berger is basing his design on recordings from live rats and slices of rat hippocampus. Fried and Koch's data could, in principle, help Berger make the leap to clinical trials in humans in years to come. But Fried is doubtful that healthy people will have chips installed in their brains to enhance their cognitive abilities anytime soon: "I think the notion of invading the brain will be too much for the foreseeable future."

—J. H.

One of the first neurons of this type was the so-called Bill Clinton cell, which was buried deep in the amygdala of a female patient. The cell responded to three very different images of the former president: a line drawing of Clinton laughing, a formal painting of him, and a photograph of him mingling with other dignitaries. The cell remained mute when the patient viewed images of other people, including male politicians and celebrities. Fried's group found cells in other volunteers that responded in this same highly selective way to actors, including Jennifer Aniston, Brad Pitt, and Halle Berry.

One reason celebrities have played a prominent role in Fried's experiments is that their photographs are often easier to come by than images of a patient's own relatives. But as part of her dissertation project on biographical memory, Indre Viskontas, the UCLA graduate student, has for several years been showing patients photographs of family members. She is reluctant to reveal details about her results, which have not been published yet. But she confirms that she has found neurons that respond to a particular relative: father, mother, brother, sister, grandfather, and yes, grandmother. The experiments have also found cells that light up when a patient sees an image of himself. Call them narcissism cells.

Viskontas is wary of overinterpreting these results or others emerging from the UCLA program. She does not believe, for example, that they support the most extreme version of the grandmother-cell hypothesis, in which cells are exclusively and permanently assigned to one person, place, or thing. The past few decades, she adds,

have revealed that brain cells are versatile, or plastic, changing their roles in response to new experiences. The UCLA experiments may not be detecting long-term memory but rather so-called working memory, in which cells are temporarily assigned to the job of representing Grandma, Jennifer Aniston, or Rocky only as a result of the stimulation provided by the experiment.

Koch isn't so sure. It would make sense, he argues, for our brains to dedicate some cells to people or other things frequently in our thoughts. The larger significance of the UCLA experiments, he says, is that neuroscientists may have to change their view of neurons as simple switches, transistors, or pixels. Each neuron may be more like a sophisticated computer. After all, individual neurons can receive input from more than one hundred thousand other cells, some of which inhibit rather than encourage the neuron's firing. The neuron may in turn encourage or suppress firing by some of those same cells in complex positive- or negative-feedback loops.

What excites Koch most about the thinking-cell results is the possibility that they may illuminate a fundamental component of cognition. Our comprehension of the world, he says, requires that we ignore much of the data flooding in through our senses. When we turn on a TV or reminisce about a movie, our brains somehow instantly compress raw sensory data into meaningful concepts and categories. This feat may be accomplished at least in part, Koch says, by cells that represent not just this or that particular image of Rocky but "the platonic ideal of Rocky."

Quiroga notes that a short story by a fellow Argentine, Jorge Luis Borges, spelled out what would happen to us if we lacked this capacity for compression. "Funes, the Memorious" tells the tale of a youth who, after falling from a horse and striking his head, becomes gifted, or cursed, with photographic recall of every minute experience. He is so overwhelmed by the infinitude of his perceptions that he retreats into a darkened room. "To think is to forget a difference, to generalize, to abstract," Borges writes. "In the overly replete world of Funes there were nothing but details." Unlike Danny, Funes had lost the capacity to perceive the platonic ideal of Rocky.

In Danny's hospital room, weighty philosophical issues yield to more practical concerns, like getting a tray on rollers properly positioned over his lap. "I'm not an engineer, just a scientist," Quiroga says apologetically as he struggles with the balky tray. He eventually succeeds with the help of Emily Ho, who is an engineer and the team's chief troubleshooter.

As other researchers come and go, Ho remains in Danny's room, manning the test equipment. When the readouts from Danny's microwires go haywire, Ho checks lights and other appliances that might cause electrical interference. Within minutes she traces the problem to the remote control that Danny uses to make his bed go up and down. After she unplugs it, the readouts return to normal.

The atmosphere in the room is surprisingly cheery. One reason is the frequent presence of Danny's father, Bill, owner of a carpeting business. Silence reigns during experiments so that Danny doesn't get distracted, but between sessions Bill teases both the researchers and his son. At one point, Ho, watching signals from Danny's neurons scroll across a computer screen, tells him that he's got "great brain cells."

"Are you kidding?" Bill exclaims. "He's got lousy brain cells!"

Danny grins, even more so later after his father fumbles a Styrofoam container of Chinese food, sending chicken chunks skidding across the floor. "Who's got the lousy cells?" Danny chortles.

Bill turns serious when asked why he and his wife agreed to let their son participate in these studies. "It's a duty," Bill says. Danny, Bill points out, has benefited because many other patients before him volunteered to be subjects for research. In the future, people suffering from epilepsy or other brain disorders may benefit from what the UCLA team learns from Danny.

For his part, Danny says he enjoys hanging out with scientists and doing experiments—"as long as there's no math.

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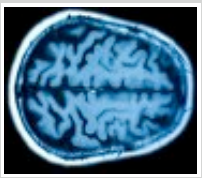

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