The Myth of Mind Control

Will anyone ever decode the human brain?

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The mutability of the neural code is not necessarily bad news for neural-prosthesis designers. In fact, the brain's capacity for inventing new information-processing schemes is thought to explain the success of artificial cochleas, which have been implanted in more than 50,000 hearing-impaired people. Commercial versions typically employ an array of electrodes, each of which channels electrical signals corresponding to different pitches toward the auditory nerve. Like an old telephone party line, the electrodes can stimulate not just a single neuron but many simultaneously.

When cochlear implants were introduced in the mid-1980s, many neuroscientists expected them to work poorly, given their crude design. But the devices work well enough for some deaf people to converse over the telephone, particularly after a break-in period during which channel settings are adjusted to provide the best reception. Patients' brains somehow figure out how to make the most out of the strange signals.

There are surely limits to the brain's ability to make up for scientists' ignorance, as the poor performance of other neural prostheses suggests. Artificial retinas, light-sensitive chips that mimic the eye's signal-processing ability and stimulate the optical nerve or visual cortex, have been tested in a handful of blind subjects who usually "see" nothing more than phosphenes, or flashes of light. And like Schwartz's monkeys, a few paralyzed humans have learned to transmit commands to computers via chips embedded in their brains, but the prostheses are still slow and unreliable.

Nevertheless, the surprising effectiveness of artificial cochleas—together with other evidence of the brain's adaptability and opportunism—has fueled optimism over the prospects for brain-machine interfaces. "This is very relevant to why we think we're going to be successful," says **Ted Berger of the University of Southern California in Los Angeles**, who is leading a project to create implantable brain chips that can restore or enhance memory. "We don't need a perfectly accurate model of a memory cell," he says. "We probably just have to be close, and the rest of the brain will adapt around it."

Thus far, Berger's experiments have been confined to slices of rat brain in Petri dishes. For more than a decade, he has embedded electrodes in slices of hippocampus—which plays a role in learning and memory—and recorded neurons' responses to a wide range of electrical stimuli. His observations have made him a firm believer in temporal codes; hippocampal cells seem to be exquisitely sensitive not only to the rate but also to the timing of incoming pulses. "The evidence for temporal coding is indisputable," Berger says. Within three years, he hopes to have chips that mimic the signal- processing properties of hippocampal tissue ready for testing in live rats.

Berger boldly predicts that someday chips like his might restore memory capacity to stroke victims or help soldiers instantly learn complex fighting procedures, like the characters in The Matrix. But in some respects Berger is quite modest. He acknowledges that his memory chips could not be used to identify and manipulate specific memories. His chips can simulate "how neurons in a particular part of the brain change inputs into outputs. That's very different from saying that I can identify a memory of your grandmother in a particular series of impulses." To achieve this sort of mind reading, scientists must compile a "dictionary" for translating specific neural patterns into specific memories, perceptions, and thoughts. "I don't know that it's not possible," Berger says. "It's certainly not possible with what we know at the moment."

“Don’t count on it in the 21st century, or even in the 22nd,” says Bruce McNaughton of the University of Arizona. With arrays of as many as 50 electrodes, McNaughton has monitored neurons in the hippocampus of rats as they run through a maze. Once a rat learns to navigate a maze, its neurons discharge in the same patterns whenever it runs the maze. Remarkably, when the rat sleeps after a hard day of maze running, the same firing pattern often unfolds; the rat is presumably dreaming of the maze. This pattern could be said to represent—at least partially—the rat’s memory of the maze.

McNaughton emphasizes that the same maze generates a different firing pattern in different rats; even in the same rat, the pattern changes if the maze is moved to a different room. He thus doubts whether science can compile a dictionary for decoding the neural signals corresponding to human memories, which are surely more complex, variable, and context sensitive than those of rats. At best, McNaughton suggests, one might construct a dictionary for a single person by monitoring the output of all her neurons for years while recording all her behavior and her self-described thoughts. Even then, the dictionary would be imperfect at best, and it would have to be constantly revised to account for the individual’s ongoing experiences. This dictionary would not work for anyone else.

Delgado hinted at the problem more than 30 years ago in *Physical Control of the Mind* when he raised the knotty question of meaning. With new and improved stimoceivers and a better understanding of the neural code, he said, scientists might determine what we are perceiving—a piece of music, say—based on our neural output. But no conceivable technology will be subtle enough to discern all the memories, emotions, and meanings aroused in us by our perceptions, because these emerge from “the experiential history of each individual.” You hear a stale pop tune, I hear my wedding song.

This is one point on which many neuroscientists agree: The uniqueness of each individual represents a fundamental barrier to science’s attempts to understand and control the mind. Although all humans share a “universal mode of operation,” says Freeman, even identical twins have divergent life histories and hence unique memories, perceptions, and predilections. The patterns of neural activity underpinning our selves keep changing throughout our lives as we learn to play checkers, read *Thus Spake Zarathustra*, fall in love, lose a job, win the lottery, get divorced, take Prozac.

Freeman thinks the prospects are good for developing relatively simple neural prostheses, such as devices that improve vision in the blind or that let paralyzed people send simple commands to a computer. But he suspects that our brains’ complexity and diversity rule out more ambitious projects, such as mind reading. If artificial-intelligence engineers ever succeed in building a truly intelligent machine based on a neural coding scheme similar to ours, “we won’t be able to read its mind either,” Freeman says. We and even our cyborg descendants will always be “beyond Big Brother, and I’m very grateful for that.”