

For Some Patients, the 'Inner Voice' May Soon Be Audible

In a recent study, scientists successfully decoded not only the words people tried to say but the words they merely imagined saying.



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By Carl Zimmer

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For decades, neuroengineers have dreamed of helping people who have been cut off from the world of language.

A disease like amyotrophic lateral sclerosis, or A.L.S., weakens the muscles in the airway. A stroke can kill neurons that normally relay commands for speaking. Perhaps, by implanting electrodes, scientists could instead record the brain’s electric activity and translate that into spoken words.

Now a team of researchers has made an important advance toward that goal. Previously they succeeded in decoding the signals produced when people tried to speak. In the new study, published on Thursday in the journal *Cell*, their computer often made correct guesses when the subjects simply imagined saying words.

Christian Herff, a neuroscientist at Maastricht University in the Netherlands who was not involved in the research, said the result went beyond the merely technological and shed light on the mystery of language. “It’s a fantastic advance,” Dr. Herff said.

The new study is the latest result in a long-running clinical trial, called BrainGate2, that has already seen some remarkable successes. One participant, Casey Harrell, now uses his brain-machine interface to hold conversations with his family and friends.

In 2023, after A.L.S. had made his voice unintelligible, Mr. Harrell agreed to have electrodes implanted in his brain. Surgeons placed four arrays of tiny needles on the left side, in a patch of tissue called the motor cortex. The region becomes active when the brain creates commands for muscles to produce speech.

A computer recorded the electrical activity from the implants as Mr. Harrell attempted to say different words. Over time, with the help of artificial intelligence, the computer accurately predicted almost 6,000 words, with an accuracy of 97.5 percent. It could then synthesize those words using Mr. Harrell's voice, based on recordings made before he developed A.L.S.

But successes like this one raised a troubling question: Could a computer accidentally record more than patients actually wanted to say? Could it eavesdrop on their inner voice?

"We wanted to investigate if there was a risk of the system decoding words that weren't meant to be said aloud," said Erin Kunz, a neuroscientist at Stanford University and an author of the new study. She and her colleagues also wondered if patients might actually prefer using inner speech. They noticed that Mr. Harrell and other participants became fatigued when they tried to speak; could simply imagining a sentence be easier for them, and allow the system to work faster?

"If we could decode that, then that could bypass the physical effort," Dr. Kunz said. "It would be less tiring, so they could use the system for longer."

But it wasn't clear if the researchers could actually decode inner speech. In fact, scientists don't even agree on what "inner speech" is.



Mr. Harrell reads a screen connected to his brain-computer interface. Neuroscientists now wonder if patients might prefer using “inner speech” to attempting to speak out loud. Ian C. Bates for The New York Times

Our brains produce language, picking out words and organizing them into sentences, using a constellation of regions that, together, are the size of a large strawberry.

We can use the signals from the language network to issue commands to our muscles to speak, or use sign language, or type a text message. But many people also have the feeling that they use language to perform the very act of thinking. After all, they can hear their thoughts as an inner voice.

Some researchers have indeed argued that language is essential for thought. But others, pointing to recent studies, maintain that much of our thinking does not involve language at all, and that people who hear an inner voice are just perceiving a kind of sporadic commentary in their heads.

“Many people have no idea what you’re talking about when you say you have an inner voice,” said Evelina Fedorenko, a cognitive neuroscientist at M.I.T. “They’re like, ‘You know, maybe you should go see a doctor if you’re hearing words in your head.’” (Dr. Fedorenko said she has an inner voice, while her husband does not.)

Dr. Kunz and her colleagues decided to investigate the mystery for themselves. The scientists gave participants seven different words, including “kite” and “day,” then compared the brain signals when participants attempted to say the words and when they only imagined saying them.

As it turned out, imagining a word produced a pattern of activity similar to that of trying to say it, but the signal was weaker. The computer did a pretty good job of predicting which of the seven words the participants were thinking. For Mr. Harrell, it didn’t do much better than a random guesses would have, but for another participant it picked the right word more than 70 percent of the time.

The researchers put the computer through more training, this time specifically on inner speech. Its performance improved significantly, including on Mr. Harrell. Now when the participants imagined saying entire sentences, such as “I don’t know how long you’ve been here,” the computer could accurately decode most or all of the words.

Dr. Herff, who has done his own studies on inner speech, was surprised that the experiment succeeded. Before, he would have said that inner speech is fundamentally different from the motor cortex signals that produce actual speech. “But in this study, they show that, for some people, it really isn’t that different,” he said.

Dr. Kunz emphasized that the computer’s current performance involving inner speech would not be good enough to let people hold conversations. “The results are an initial proof of concept more than anything,” she said.

But she is optimistic that decoding inner speech could become the new standard for brain-computer interfaces. In more recent trials, the results of which have yet to be published, she and her colleagues have improved the computer’s accuracy

and speed. “We haven’t hit the ceiling yet,” she said.

As for mental privacy, Dr. Kunz and her colleagues found some reason for concern: On occasion, the researchers were able to detect words that the participants weren’t imagining out loud.

In one trial, the participants were shown a screen full of 100 pink and green rectangles and circles. They then had to determine the number of shapes of one particular color — green circles, for instance. As the participants worked on the problem, the computer sometimes decoded the word for a number. In effect, the participants were silently counting the shapes, and the computer was hearing them.

“These experiments are the most exciting to me,” Dr. Herff said, because they suggest that language may play a role in many different forms of thought beyond just communicating. “Some people really seem to think this way,” he said.

Dr. Kunz and her colleagues explored ways to prevent the computer from eavesdropping on private thoughts. They came up with two possible solutions.

One would be to only decode attempted speech, while blocking inner speech. The new study suggests this strategy could work. Even though the two kinds of thought are similar, they are different enough that a computer can learn to tell them apart. In one trial, the participants mixed sentences in their minds of both attempted and imagined speech. The computer was able to ignore the imagined speech.

For people who would prefer to communicate with inner speech, Dr. Kunz and her colleagues came up with a second strategy: an inner password to turn the decoding on and off. The password would have to be a long, unusual phrase, they decided, so they chose “Chitty Chitty Bang Bang,” the name of a 1964 novel by Ian Fleming as well as a 1968 movie starring Dick van Dyke.



For people who might prefer to use inner speech to talk, Dr. Kunz and her colleagues came up with a strategy to turn computer decoding on and off with an internal password. They chose “Chitty Chitty Bang Bang,” the name of the 1964 novel by Ian Fleming and 1968 movie starring Dick van Dyke. Silver Screen Collection/Getty Images

One of the participants, a 68-year-old woman with A.L.S., imagined saying “Chitty Chitty Bang Bang” along with an assortment of other words. The computer eventually learned to recognize the password with a 98.75 percent accuracy — and decoded her inner speech only after detecting the password.

“This study represents a step in the right direction, ethically speaking,” said Cohen Marcus Lionel Brown, a bioethicist at the University of Wollongong in Australia. “If implemented faithfully, it would give patients even greater power to decide what information they share and when.”

Dr. Fedorenko, who was not involved in the new study, called it a “methodological tour de force.” But she questioned whether an implant could eavesdrop on many of our thoughts. Unlike Dr. Herff, she doesn’t see a role for language in much of our

thinking.

Although the BrainGate2 computer successfully decoded words that patients consciously imagined saying, Dr. Fedorenko noted, it performed much worse when people responded to open-ended commands. For example, in some trials, the participants were asked to think about their favorite hobby when they were children.

“What they’re recording is mostly garbage,” she said. “I think a lot of spontaneous thought is just not well-formed linguistic sentences.”

Carl Zimmer covers news about science for The Times and writes the Origins column.