

EMILY MULLIN SCIENCE AUG 17, 2022 7:00 AM

## This Man Set the Record for Wearing a Brain-Computer Interface

Implanted devices let people control computers and prosthetic limbs with their minds. But nobody knows how long they'll last—and when they'll need upgrades.



Nathan Copeland started using a brain-computer interface in 2015 as part of a research study. COURTESY OF THE UNIVERSITY OF PITTSBURGH

**NATHAN COPELAND CONSIDERS** himself a cyborg. The 36-year-old has lived with a brain-computer interface for more than seven years and three months. As of today—August 17—that's the longest anyone has had an implant like this. Four electrode arrays, each the size of a pencil eraser, translate his neural impulses into commands that allow him to control external devices: a computer, video games, and a robotic arm he can move with just his thoughts.

## Content

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A car accident in 2004 left Copeland paralyzed from the chest down, unable to move or feel his limbs. In 2014, he joined a study at the University of Pittsburgh for people with major spinal cord injuries to see whether a brain-computer interface, or BCI, could restore some of the functionality he'd lost. He didn't hesitate to sign up, even though it would require brain surgery—and nobody knew how long the device would keep working. "When I started, they said, 'Oh, it'll probably last five years.' And that five years was based on monkey data, because no human had ever done it," he says.

That Copeland's implant is still working—and hasn't caused any major side effects or complications—is promising for the field. It's a sign that the devices, which have been in development since the 1960s but are still experimental, are moving closer to commercial reality for patients with severe disabilities. "It feels like it's on the borderline of being practical," says Jane Huggins, director of the University of Michigan Direct Brain Interface Laboratory, who's not affiliated with the Pittsburgh study.

Nathan Copeland controls a tablet using just his thoughts. COURTESY OF UNIVERSITY OF PITTSBURGH

But questions still remain about the long-term durability of the implanted arrays—how much their performance will erode over time, and whether they could be upgraded. "It would be utterly maddening to have function restored for years, then lose it again. And that is always a concern with implanted devices that may require service," Huggins says.

Copeland had four arrays surgically installed in 2015, two in the part of the brain that controls motor functions and the other two in the region responsible for processing sensory information. Called Utah arrays, they are made of hard silicon and look a bit like the bristly part of a hairbrush. A standard array is a square grid with 100 tiny needles, each about a millimeter long and coated with conductive metal. Because neurons produce electrical fields when they communicate with one another, scientists are able to use these arrays to capture and record activity from hundreds of nearby neurons.

To build a brain-computer interface, researchers have to translate those neural signals into digital commands that let the wearer drive a prosthetic limb or a computer. The system Copeland uses involves an implanted array, a cable that runs from a nickel-sized pedestal on his head to an external device that amplifies his neural signals, and a computer

that runs software to decode those signals.

Richard Normann first conceived of the Utah array in the 1980s as a professor of bioengineering at the University of Utah, where he was interested in finding a way to restore vision. It's since become the gold standard for brain-computer interface studies. "The whole field is built on the Utah array," says Matt Angle, CEO of Paradromics, a Texas-based BCI company. "The fact that we've gone so long on a device that was designed in the '80s and '90s speaks to how much ahead of its time it was."

A close-up of a Utah array. COURTESY OF BLACKROCK NEUROTECH

The Utah array is a 4.2 millimeter square grid with 100 silicon electrodes. COURTESY OF BLACKROCK NEUROTECH

In 2004, [Matt Nagle](#) became the first paralyzed person to be implanted with a Utah array; it allowed him to move a computer cursor, operate a TV, check email, and make a prosthetic hand open and close. Nagle's implant was removed after a year, following the protocol of the study he was participating in. Now there are more than 30 study participants around the world wearing implanted BCIs. Ian Burkhart previously held the record for the longest BCI

implant, until he had his removed in 2021 when his research study ended.

With so few people outfitted with these devices, their longevity is still unknown. So far, the Utah array has lasted up to 10 years in monkeys. In Copeland's case, his arrays are still working, but not as well as in the first year or so after being implanted, says Robert Gaunt, a biomedical engineer at the University of Pittsburgh and a member of

Copeland's research team. "The body is a very difficult place to put electronics and engineered systems into," Gaunt says. "It's an aggressive environment, and the body is always trying to get rid of these things."

Implanted arrays can provoke an immune response in the neural tissue that surrounds the electrodes—the spiky probes that stick into the brain. Studies have shown that this inflammation can lead to decreased signal quality. And scar tissue can form around brain implants, which also affects their ability to pick up signals from nearby neurons. The less information that a BCI can interpret from neurons, the less effective it is at carrying out its intended functions.

One way scientists are trying to make implants last longer is by experimenting with different kinds of materials. The Utah array is insulated with parylene, a protective polymer coating used in the medical device industry for its stability and low permeability to moisture. But it can corrode and crack over time, and other materials may prove to be more durable.

Florian Solzbacher, co-founder and chairman of Blackrock Neurotech, which manufactures the Utah arrays, says the company is testing one that's coated with a combination of parylene and silicon carbide, which has been around for more than 100 years as an industrial material. "We've seen lifetimes on the benchtop that can reach up to 30 years, and we've got some preliminary data in animals right now," he says. But the company has yet to implant it in people, so the real test will be how human tissue reacts to the new formulation.

Making electrodes more flexible could also help reduce scarring. Angle's company Paradromics is developing an implant similar to the Utah array, but with thinner electrodes intended to be less disruptive to tissue.

Some researchers are trying out softer materials that may be able to better integrate into the brain than the rigid Utah array. One group, at the Massachusetts Institute of Technology, is experimenting with hydrogel coatings designed to have an elasticity very similar to that of the brain. Scientists at the University of Pennsylvania are also growing "living" electrodes, hairlike microtissues made of neurons and nerve fibers grown from stem cells.

But these approaches have downsides, too. "You can get a rigid thing into a soft thing. But if you're trying to put a very soft thing into another soft thing, that's very hard," Gaunt says.

Another approach is to make the implants smaller, and therefore less invasive. For instance, researchers are testing neurograins, tiny chips the size of a grain of sand that could hypothetically be sprinkled across the cortical surface. But no one has tried dispersing them on a human brain; the system has only been tested in rodents that had their skulls removed.

Some research participants have had their Utah arrays taken out and replaced, but multiple surgeries aren't ideal, because each one carries a risk of infection or bleeding at the implant site. Gaunt says surgeons probably wouldn't place a new implant in the exact same place as an old one, especially if there's scarring in that area. But making sure that a replacement is put in the right spot is important because implants in the wrong place could impair the function of the BCI.

Gaunt says it would be better for the external BCI components—the processors or software, for instance—to be upgradable, so that patients wouldn't have to undergo multiple surgeries.




Nathan Copeland plays a game using his brain-computer interface. COURTESY OF UNIVERSITY OF PITTSBURGH

But in fact, an external part of most BCI systems is actually one of the biggest risks for brain implants. The pedestal that sits atop the skull can cause infection, but its presence is necessary to connect the implanted array to the external computer. For now, Copeland and other research participants have to get plugged into the system via their head pedestals to use their BCIs. (Researchers are working on getting rid of the cables.) For Copeland, it's a mild annoyance in exchange for getting to do the things he can do with his BCI—although he hopes future systems will be wireless and give paralyzed people an even broader range of abilities.

Given the unknowns of BCI longevity, Copeland knows his implant could stop working some day. But he tries not to worry about it. “I’m super chill about most things. I just go with the flow,” he says. That said, he wouldn’t turn down an upgrade: “In five or 10 years, if there is something that would have significant improvements, I would do the surgery again and just go for it.”

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