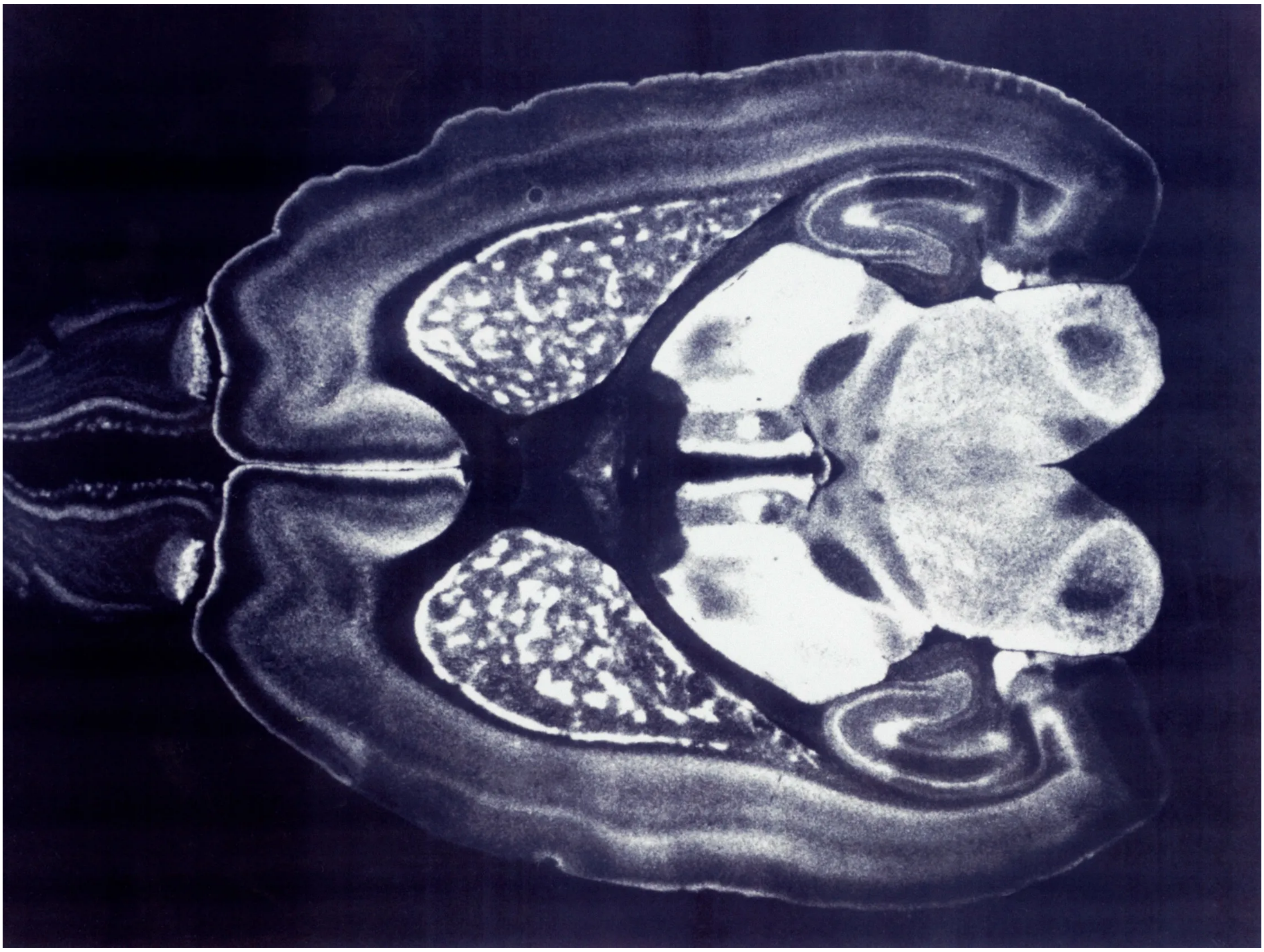
EMILY MULLIN SCIENCE SEP 13, 2021 7:00 AM

'Neurograins' Could be the Next Brain-Computer Interfaces

Dozens of microchips scattered over the cortical surface might allow researchers to listen in on thousands of neurons at the same time.



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A TEAM AT Brown University has developed a system that uses dozens of silicon microchips to record and transmit brain activity to a computer. Dubbed “neurograins,” the chips—each about the size of a grain of salt—are designed to be sprinkled across the brain’s surface or throughout its tissue to collect neural signals from more areas than currently possible with other brain implants.

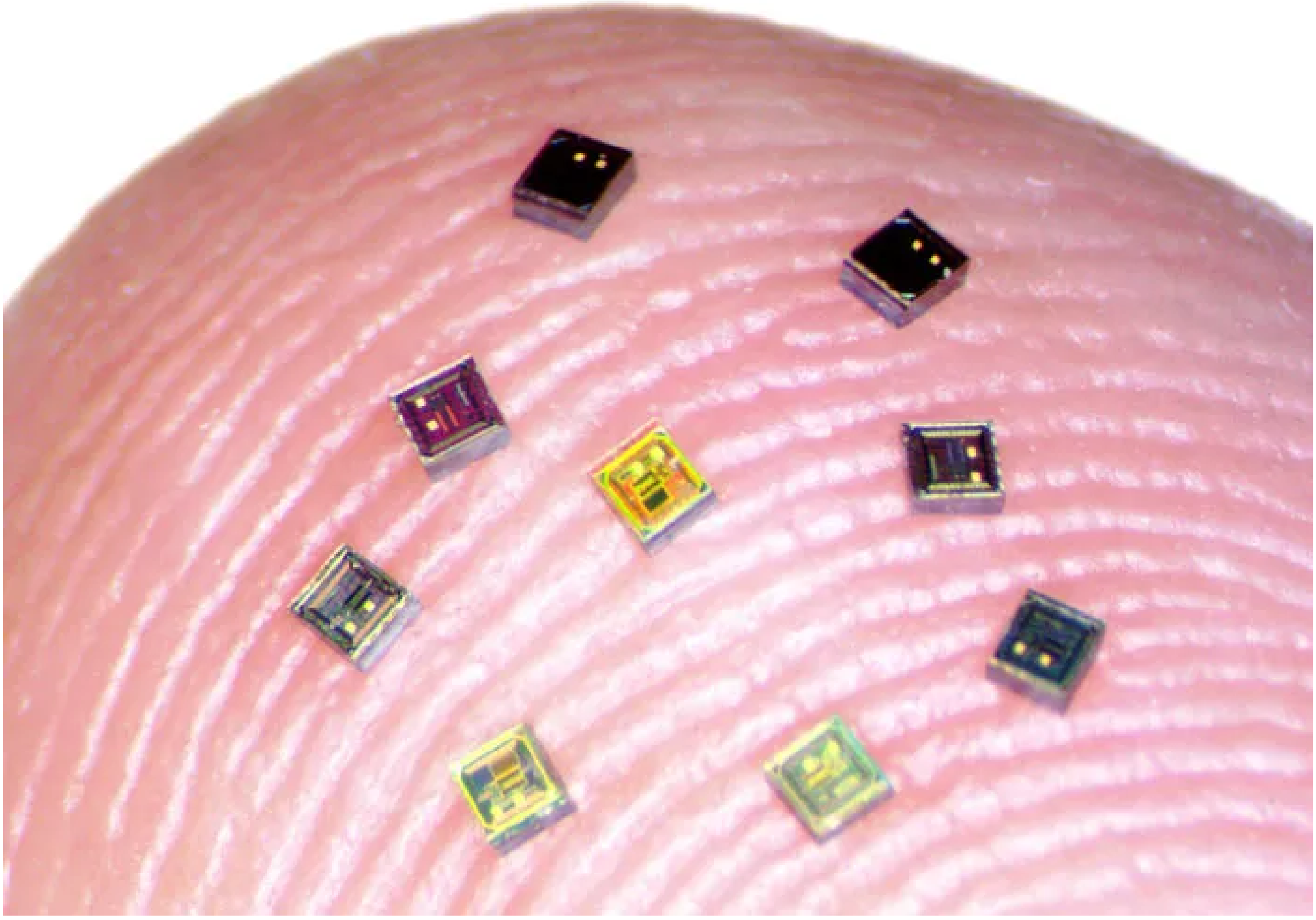
“Each grain has enough micro-electronics stuffed into it so that, when embedded in neural tissue, it can listen to neuronal activity on the one hand, and then can also transmit it as a tiny little radio to the outside world,” says lead author Arto Nurmikko, a neuroengineer at Brown who led the development of the neurograins. The system, known as a brain-computer interface, is described in a paper published August 12 in *Nature Electronics*.

Alongside other Brown researchers, as well as collaborators from Baylor University, the University of California at San Diego, and Qualcomm, Nurmikko began working on the neurograins four years ago with initial funding from the Defense Advanced Research Projects Agency. So far, the researchers have only tested the neurograins in rodents, but they hope their prototype will lay the groundwork for human studies. In addition to recording brain activity, the neurograins can also stimulate neurons with tiny electrical pulses, making them an intriguing avenue to explore for treating brain disorders like epilepsy and Parkinson’s or restoring brain function lost to injury.

The team implanted the system in a rat, performing a craniotomy to place 48 of the neurograins on the cerebral cortex—the outer layer of the brain—arranging the microchips to cover most of the motor and sensory areas. A thin, thumbprint-sized patch that attached to the scalp acted as the external communications hub, receiving signals from the neurograins like a miniature cell phone tower, processing them, and charging the chips wirelessly.

The researchers tested out the system while the animal was under anesthesia and found that the neurograins were able to record spontaneous cortical activity in the unconscious rat. However, the quality of the signals wasn’t as good as those acquired by commercial chips used in most brain-computer interface research.

These interfaces have been in development since the 1970s, and in recent years have allowed a small number of paralyzed patients to control tablet devices, type on a computer at increasingly faster speeds, or move a robotic limb or on-screen cursor just by thinking about it.



Several of the silicon microchips known as "neurograins." COURTESY OF BROWN UNIVERSITY

For people with brain and spinal injuries, these systems could eventually restore communication and movement, allowing them to live more independently. But currently, they're not all that practical. Most require clunky set-ups and can't be used outside of a research lab. People outfitted with brain implants are also limited in the types of actions they can perform because of the relatively small number of neurons the implants can record from at once. The most common brain chip used, the Utah array, is a bed of 100 silicon needles, each with an electrode at the tip that sticks into the brain tissue. One of these arrays is about the size of Abraham Lincoln's face on a US penny and can record activity from a few hundred surrounding neurons.

But many of the brain functions that researchers are interested in—like memory, language, and decision making—involve networks of neurons that are widely distributed throughout the brain. "To understand how these functions really work, you need to study them at the systems level," says Chantel Prat, an associate professor of psychology at the University of Washington who is not involved in the neurograins project. Her work involves non-invasive brain-computer interfaces that are worn on the head rather than implanted.

The ability to record from many more neurons could enable much finer motor control and expand what's currently possible with brain-controlled devices. Researchers could also use them in animals to learn how different brain regions speak to each other. "When it comes to how brains work, the whole really is more important than the sum of the parts," she says.

Florian Solzbacher, co-founder and president of Blackrock Neurotech, the company that manufactures the Utah array, says a distributed neural implant system might not be necessary for many near-term uses, like enabling basic motor functions or the use of a computer. However, more futuristic applications, like restoring memory or cognition, would almost certainly require a more complicated set-up. "Obviously, the Holy Grail would be a technology that could record from as many neurons as possible throughout the entire brain, the surface and the depth," he says. "Do you need that in its entire complexity right now? Probably not. But in terms of understanding the brain and looking at future applications, the more information we have, the better."

Smaller sensors could also mean less damage to the brain, he continues. Current arrays, even though already tiny, can cause inflammation and scarring around the implant site. "Typically, the smaller you make something, the less likely it is to be detected by the immune system as a foreign object," says Solzbacher, who wasn't involved in the Brown study. When the body detects a foreign object like a splinter, it tries to either dissolve and destroy it, or encapsulate it with scar tissue.

But while smaller may be better, it isn't necessarily foolproof, Solzbacher cautions. Even miniscule implants could trigger an immune response, so the neurograins will also need to be made of biocompatible materials. A major hurdle with developing brain implants has been trying to minimize harm while building a long-lasting implant, to avoid the risk of replacement surgeries. Current arrays last around six years, but many stop working much sooner because of scar tissue. If neurograins are the answer, there's still the question of how to get them in the brain. In their rodent experiment, the Brown researchers removed a large portion of the rat's skull, which, for obvious reasons, wouldn't be ideal in humans. Current implanted arrays require drilling a hole into a patient's head, but the Brown team wants to avoid invasive brain surgery entirely. To do that, they're developing a technique to insert the neurograins involving thin needles that would be threaded into the skull with a special device. (Neuralink is pursuing a similar "sewing machine"-like robot for delivering its coin-shaped brain implant.)

The safety and longevity of the microchips will need to be tested in awake and freely-moving rodents, which the Brown team plans to do next. Then, they'll move on to studies in monkeys. Ultimately, Nurmikko envisions that the rat set-up could be scaled up to 770 neurograins, covering the surface area of a human brain.

With so much neural data being collected by all these chips, decoding what all these signals mean will be a challenge. The Brown team wants to be able to record from thousands—and eventually, hundreds of thousands—of neurons. All those brain signals will need to be decoded and translated into commands to be relayed to the external devices that will carry out the user's desired actions. That will require a much more sophisticated parsing of neural information than today's simpler systems can provide.

In the meantime, Nurmikko's team wants to see if they can make the neurograins even smaller, so that putting hundreds of them in the brain would cause minimal damage. That, Nurmikko says, is a microelectronics problem. "You're doing this *Honey, I Shrunk the Kids* kind of thing," he says. "But the chip comes back and it may not quite do what you want it to do and then you have to reiterate. That's the blood, sweat, and tears part of this journey."