

Wave of the Future

Brain-computer interfaces enable immobilized people to communicate via brain-waves.

BY CATHERINE G. WOLF

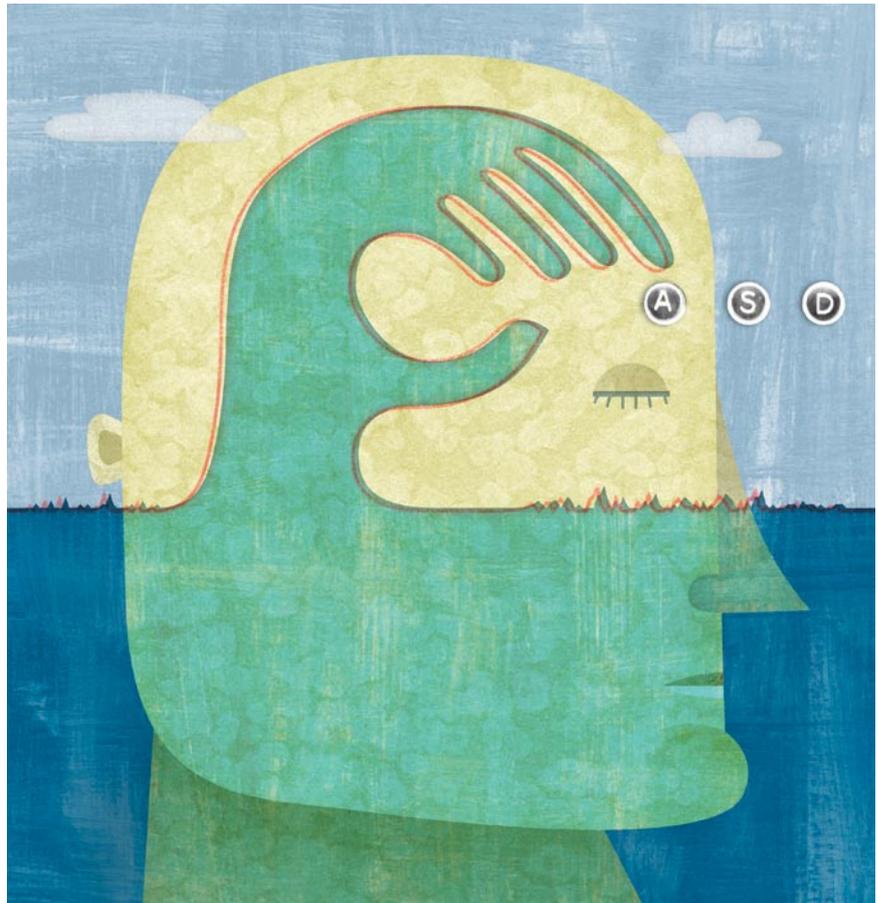
The researchers place a bright red electrode cap on my head, then measure the distance from the bridge of my nose to the first electrode. They squirt electrode gel through the holes in the cap and poke the gel through my thick hair to my scalp. I look at a big screen that displays a matrix of letters, numbers, and symbols. My first task is to type, “The quick brown fox jumps over the lazy dog,” displayed above the matrix. The rows and columns of the matrix flash very quickly in a random pattern. Theresa Vaughan instructs me to count how many times the letter I want flashes.

I stare at the “T” and do my best to count the flashes. Got it! Miraculously, the letter “T” appears. Now the “H.” I concentrate and count. Darn, got the letter below. Oh well, on to the “E.” By the time I get to “jumps,” I am in a Zen-like state and making few errors. At the other end of my dining room table, the researchers are watching my brain waves and adjusting the parameters used to identify the character selected.

TURNING THE COGNITION KEY

It sounds like a scene from *Star Wars*, but it's real. I was using a research prototype called the brain-computer interface, so-called because it uses electrical signals recorded from the brain that are sent to an amplifier and processed by a computer to enable people to communicate. For people with no voluntary movement—such as those with spinal cord injuries, stroke, or (like me) with advanced amyotrophic lateral sclerosis (ALS)—brain-computer interface systems offer the promise to release them from their “locked-in” state and allow them to communicate. (See page 12 for a review of *The Diving Bell and the Butterfly*, a new film about locked-in syndrome.)

It works as follows. Each letter is highlighted in a random but known pattern.



When people pay attention to a particular letter, such as by counting how many times it flashes, certain components of their brain-waves will then react whenever that letter flashes. The amplitude of one or more brain-wave components is matched with the flashing letters. The one with the highest amplitude is selected and displayed on the screen.

The particular brain-computer interface I was using is based on a brain response called P300. Its use in brain-computer interfaces was pioneered by Emanuel Donchin of the University of South Florida in the 1980s. The P300 response occurs about 300 milliseconds after a person has seen something significant. In this case, it was the letter I wanted. The P300 response

is involuntary, but most people get better at controlling its amplitude with practice.

I did about 45 minutes more of “copy spelling” while the researchers from the Wadsworth Center in Albany—Theresa Vaughan, Eric Sellers, Ph.D., and Dennis McFarland, Ph.D.—adjusted parameters. Then I was ready to type on my own. I like to write poetry, so one of the first things I typed was a two-line rhyme:

*I'm typing with my mind—
What a wonderful find.*

It was much slower than the scanning keyboard I normally use (See “Talking Technology,” July/Aug 2007), but since it required no movement, it wasn't tiring. On the first of five visits, I used the system for

five hours. I expect my own system this fall. You can be sure when I become unable to use my onscreen scanning keyboard, I will use it full time.

**I'm typing
with my
mind! It's
magic!**

THE STORY OF BCI

There are about 100 groups working on brain-computer interface systems worldwide, according to Vaughan. But the Wadsworth Center and a group at the University of Tuebingen in Germany that works with the Wadsworth Center are the only groups with systems advanced enough to allow home users to participate. The first user for the Wadsworth system was Scott Mackler, M.D., Ph.D., a scientist at the University of Pennsylvania who has ALS. He started using it in February 2006. "I couldn't run my lab without BCI. It was easy to learn," he said in an e-mail written with the Wadsworth brain-computer interface system. Now two more people with ALS in the U.S. and two in Germany are using the system on a daily basis in their homes. Working with Debra Zeitlin, a speech therapist at Helen Hayes Hospital in New York, the Wadsworth team plans to add five more users. The researchers transfer data from the users over the Internet and make visits when necessary.

One of the early research subjects was the late Wayne Wickelgren, Ph.D., a scientist at New York's Columbia University who had ALS. "For people whose cognition is still intact although their motor systems are gone or going, I would think it could work extremely well indeed. Some communication is a great deal better than none," says his wife, Norma Graham, Ph.D., professor of psychology at Columbia.

According to Jonathan Wolpaw, M.D., director of the Wadsworth Center brain-computer interface project, some of the practical challenges for a home system are "to develop more robust, comfortable, convenient, and cosmetic electrode

caps, to substantially reduce the amount of technical support needed for reliable BCI operation in a user's home, and to establish and maintain a viable organization—perhaps a non-profit entity—that can make the home BCI system widely available to those users who need it most."

Indeed, on their first visit to my home, the Wadsworth researchers used a 16-channel electrode cap and an amplifier costing thousands of dollars. On a subsequent visit, they tried eight channels and a less expensive amplifier with much poorer results. But that is typical of cutting-edge research.

FROM THOUGHT TO ACTION

The BrainGate by Cyberkinetics takes a different approach. An array of 100 tiny electrodes, about the size of a baby aspirin, is implanted on the surface of the motor cortex. The motor cortex is the part of the brain that controls movement. In people with spinal cord injuries, brainstem stroke, or neuromuscular diseases such as ALS, the motor cortex is disconnected

from the nerves in the limbs responsible for movement, explains Leigh Hochberg, M.D., Ph.D., of Brown University, the Veterans Health Administration (VA), and Harvard Medical School, one of the principal BrainGate researchers. The patient imagines moving a mouse, for example, and with the aid of computer processing, thoughts are turned into action, such as moving a computer cursor.

The BrainGate senses the neuronal signals from the motor cortex when the patient thinks of moving a limb. The array of electrodes is connected to a pedestal that protrudes above the scalp. The pedestal is connected by cables that go to a computer that interprets the signals from the motor cortex. Cyberkinetics hopes that one day, with the BrainGate and an appropriate device in a limb, patients will be able to bridge the disconnect between motor cortex and peripheral nerves and move their own limbs. Here is a technology that actually enhances our humanity. NN

Catherine G. Wolf has been living with amyotrophic lateral sclerosis since 1997 and is a frequent contributor to Neurology Now.

BRAIN-COMPUTER INTERFACE TRIALS

► **BRAINGATE:** Two safety and feasibility studies are now being conducted in Boston, Providence, and Chicago. One is for people with motor neuron diseases such as ALS. The other is for people with spinal cord injuries, brainstem stroke, or muscular dystrophy. For more on BrainGate and the clinical trials, visit cyberkineticsinc.com or email braingateinfo@cyberkineticsinc.com. In addition to Hochberg, key members of the BrainGate team include John Donoghue, M.D., Michael Black, Ph.D., Arto Nurmikko, Ph.D., and Gerhard Friehe, M.D. The research is funded by divisions of the National Institutes of Health (NIH), the VA, and Cyberkinetics Neurotechnology Inc.

► **WADSWORTH BCI:** The Wadsworth Center is part of the New York State Department of Health. Additional funding is provided by divisions of the NIH and private foundations. For more information about the Wadsworth brain-computer interface research, go to bciresearch.org.