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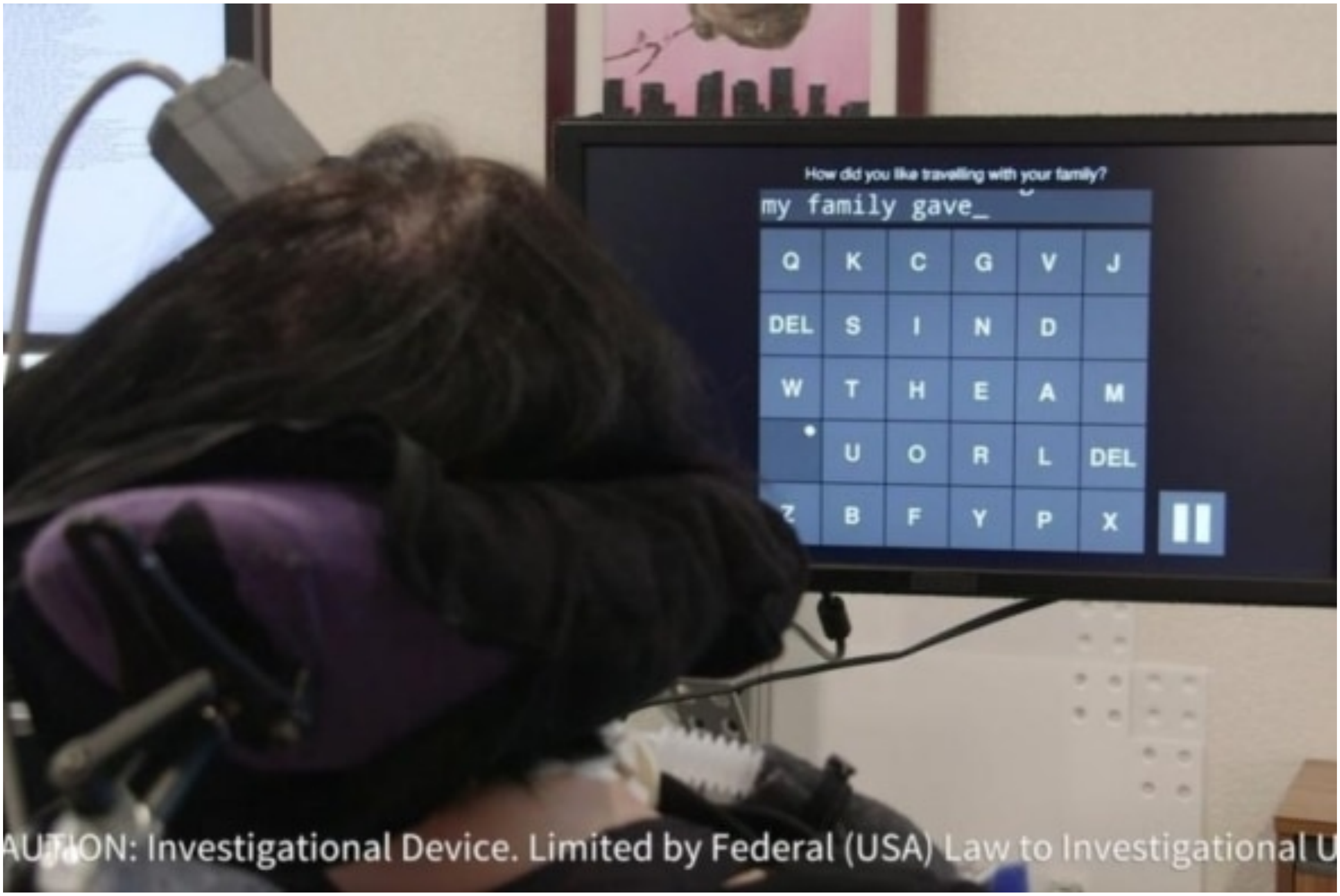
Brain–Computer Interface Allows Speediest Typing to Date

A new interface system allowed three paralyzed individuals to type words up to four times faster than the speed that had been demonstrated in earlier studies

By Simon Makin on February 21, 2017



A participant enrolled by Stanford University in the BrainGate clinical trial uses the brain-computer interface to type by controlling a computer cursor with her thoughts. *Credit: Courtesy Stanford University*

Ten years ago Dennis Degray's life changed forever when he slipped and fell while taking out the trash in the rain. He landed on his chin, causing a severe spinal cord injury that left him paralyzed below the neck. Now he's the star participant in an investigative trial of a system that aims to help people with paralysis type words using only their thoughts.

The promise of brain–computer interfaces (BCIs) for restoring function to people with disabilities has driven researchers for decades, yet few devices are ready for widespread practical use. Several obstacles exist, depending on the application. For typing, however, one important barrier has been reaching speeds sufficient to justify adopting the technology, which usually involves surgery. A study published Tuesday in *eLife* reports the results of a system that enabled three participants—Degray and two people with amyotrophic lateral sclerosis (ALS, or Lou Gehrig's disease, a neurodegenerative disease that causes progressive paralysis)—to type at the fastest speeds yet achieved using a BCI—speeds that bring the technology within reach of being practically useful. “We're approaching half of what, for example, I could probably type on a cell phone,” says neurosurgeon and co-senior author, Jaimie Henderson of Stanford University.

The researchers measured performance using three tasks. To demonstrate performance in the most natural scenario possible, one participant was assessed in a “free typing” task, where she just answered questions using the device. But typing speeds are conventionally measured using copy typing, which involves typing out set phrases, so all three participants were also assessed this way. The woman who performed the free-typing task achieved faster than six words-per-minute, the other ALS patient managed nearly three and Degray achieved almost eight. The group reported comparable results in a *Nature Medicine* studyin 2015 but these were achieved using software that exploited the statistics of English to predict subsequent letters. No such software was employed in this study.

The drawback of copy typing is performance can vary with the specific phrases and keyboard layouts used. To get a measure independent of any of these factors, the third task involved selecting squares on a six by six grid as they lit up randomly. This gets closer to quantifying the maximum speed the system can output information, and is easily converted into a digital “bits per second” measure. The team used this range of tasks, without predictive software, because one of the study’s central aims was to develop standardized measures. “We need to establish measures so that—in spite of potential variability between people, methods and researchers—we can really say, ‘clearly this new advance led to higher performance,’ because we have systematic ways of comparing that,” says co-lead author Chethan Pandarinath, then a postdoctoral fellow at Stanford. “It's critical for moving this technology forward.”

The two ALS patients achieved 2.2 and 1.4 bits per second, respectively, more than doubling previous records (held by these same participants in a previous study from this group). Degray achieved 3.7 bits per second, which is four times faster than the previous best speed. “This is a pretty large leap in performance in comparison to previous clinical studies of BCIs,” Pandarinath says.

Other researchers agree these are state-of-the-art results. “This is the fastest typing anyone has shown with a BCI," says biomedical engineer Jennifer Collinger, of the University of Pittsburgh, who was not involved in the study. "It's on par with technologies like eye-trackers, but there are groups those technologies don't work for such as people who are "locked-in." These speeds also approach what ALS patients questioned in a survey said they would want from a BCI device. "You're getting to the point where performance is good enough that users would actually want to have it," Collinger says.

Participants had either one or two tiny (one-sixth-inch) electrode arrays implanted on the surfaces of their brains. These "intracortical" implants contain 96 microelectrodes that penetrate one to 1.5 millimeters into parts of the motor cortex that control arm movements. Two of the surgeries were performed by Henderson, who co-directs Stanford's Neural Prosthetics Translational Laboratory with the study's senior co-author, bioengineer Krishna Shenoy. The neural signals recorded by the electrodes are transmitted via a cable to a computer where algorithms developed in Shenoy's lab decode the participant's intentions and translate the signals into movements of a computer cursor. The Stanford team is part of a multi-institute consortium called BrainGate, which includes Massachusetts General Hospital and Brown University, among others.

Other methods of interfacing with the brain via electrodes include those put on the scalp for electroencephalography (EEG) and ones placed under the skull on the brain's surface, known as electrocorticography (ECoG). The advantage of intracortical implants is they can pick out activity from single cells whereas the other methods capture the average activity of thousands of neurons. "This performance is 10 times better than anything you would get from EEG or ECoG, [which don't] contain enough information to do this kind of task at this level," says neurobiologist Andrew Schwartz, at Pitt, who was not involved in the study. Movement and scarring reduces signal quality over roughly the first two years after implantation, but what remains is still useful—"much better than you get with any other technique," he says.

The biggest drawback, currently, is having wires coming out of people's heads and attached to cables, which is cumbersome and carries risks. "The future is making these devices wireless," Pandarinath says. "We're not there yet with people but we're probably closer to five than 10 years away, and that's a critical step [toward] a device that you could send somebody home with and be less worried about potential risks like infection." The devices would need wireless power but several groups are already working on this. "Most of the technology is basically there," Schwartz says. "You can do that inductively using coils—like wirelessly charging your cell phone in a cradle with coils on either side."

The team attributes the improvements to better systems engineering and decoding algorithms. “Performing repeated computations rapidly is critical in a real-time control system,” Pandarinath says. The researchers published a study last year, led by Stanford bioengineer Paul Nuyujukian. In it they trained two macaque monkeys to perform a similar task to the grid exercise used in this study. The animals typed sentences by selecting characters on a screen as they changed color (although they wouldn’t have understood what the words meant). When the team added a separate algorithm to detect the monkeys’ intention to stop, their best speed increased by two words per minute.

This “discrete click decoder” was also used in the current study. “We've basically created a ‘point and click’ interface here, like a mouse. That’s a good interface for things like modern smartphones or tablets,” Pandarinath says, “which would open a whole new realm of function beyond communication: surfing the Web, playing music, all sorts of things able-bodied people take for granted.”

The Stanford team is already investigating wireless technology, and has ambitious long-term goals for the project. “The vision we hope to achieve someday would be to be able to plug a wireless receiver into any computer and use it using your brain,” Henderson says. “One of our main goals is to allow 24 hours a day, seven days a week, 365 days a year control of a standard computer interface using only brain signals.”

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Simon J. Makin is an auditory perception researcher turned science writer and journalist. Originally from Liverpool in the north of England, he has a bachelor's in engineering, a master's in speech and hearing sciences, and a Ph.D in computational auditory modeling from the University of Sheffield. He spent several years working as a research fellow in the psychology department at the University of Reading, before recently branching out and retraining in journalism.

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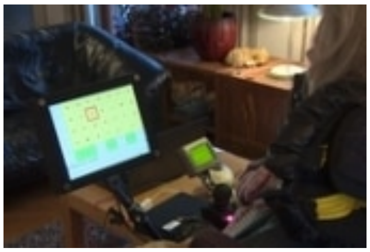

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