Brain-computer interfaces (BCIs)

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Brain-computer interfaces (BCIs) with a longer history in science fiction (since the 1950s) and in research and animal models (since the 1970s) than practical implants for humans (1990s). A brain-computer interface links a human brain directly to a computer, where neural signals are interpreted and used to perform tasks such as manipulating a mouse. In this way, a paralyzed patient can surf the web or even move a prosthetic arm with their mind alone.

Healthy people can even use non-invasive brain-computer interfaces as another type of computer input device, like a mouse or keyboard, although this technology has yet to be commercialized. Brain-computer interfaces can also send information back into the brain, for instance using electrodes to stimulate the visual cortex to “see” a scene taken by an external video camera, allowing blind patients to possess sight again, albeit far from perfectly.

Several technologies have been successfully used to get basic signals out of the brain and into a computer. These are divided into invasive BCIs, where electrodes are implanted into the gray matter of the brain; partially-invasive BCIs, implanted inside the skull but only resting on the top of the brain; and non-invasive BCIs, involving plastic devices which slip over the head like a shower cap. In general, the more invasive the BCI, the more scar tissue, possible complications, and expense, but the greater resolution of input and output.

Beginning with implants in rats in the early 90s, brain implants were developed which allowed the control of external manipulators or cursors. Monkeys were next to get the implants, and the species continues to be the target of the most sophisticated BCI research today. The big milestone for humans came in 1998, when a patient named Johnny Ray, who suffered “locked-in syndrome” due to a stroke affecting his brain stem, was given an implant, and after several weeks of training, could use it to manipulate a cursor and spell out words. This was a transformative experience for the patient: without the implant, he would remain completely unable to contact the outside world, only able to quietly observe and reflect until death. The BCI opened a channel of communication and immeasurably improved the patient’s quality of life.

In 2002, Jens Naumann, a man who went blind in adulthood, became the first of 16 paying patients to receiver a vision implant from William Dobelle, a pioneer in the field. By this time, the miniaturization of computers and quality cameras made it possible to install the implant without necessitating a hookup to a large mainframe, as had been required for previous attempts in this direction. The implant only offered black-and-white vision at a relatively slow frame rate, but it was enough to allow the patient to slowly drive a car around the research institute’s parking lot. This was the first true commercialization of brain-computer interfaces.

In 2005, the tetraplegic Matt Nagle became the first person to control a prosthetic arm using a brain implant, developed by the company Cyberkinetics Neurotechnology under the product name BrainGate. Cyberkinetics Neurotechnology still seeks to be the first company to bring BCIs to the public in a big way.
A man paralyzed from the neck down has shown he can open email, control a TV and move objects with a robotic arm by thought alone.

The 25-year-old American patient, Matthew Nagle, had a computer-linked implant placed in his brain that enabled him to operate devices just by thinking about it.

Brain-computer interfaces have been demonstrated before, in humans and animals. But this is the biggest step taken so far towards developing "bionic" systems that can restore motor function in people who have lost control of their limbs.

In the 1970s TV series "The Six Million Dollar Man", scientists rebuilt the body of crash victim Steve Austin with bionic prosthetics controlled by his mind. At the time the concept was pure fantasy, but in future thought-controlled replacement limbs could be made real.

The results described today in the journal Nature represent the culmination of decades of work.

However the scientists involved in the research stress that the technology is still in its infancy.

Mr. Nagle, from Massachusetts, whose spinal cord was severed in 2001, received his implant at Rhode Island Hospital in 2004.

Known as the BrainGate Neural Interface System, it consists of an array of electrodes that record neural activity from the motor cortex of the brain.

Signals from the implant are decoded and processed by a computer, allowing them to be translated into movement commands.
First, Mr. Nagle learned to move a computer cursor by focusing his thoughts on the task.

Later, during 57 trial sessions at the New England Sinai Hospital and Rehabilitation Centre in Massachusetts, he greatly expanded his repertoire of thought control.

He was able to open simulated e-mail, draw circular shapes on the computer screen, play a simple video game called "neural Pong", and change the channel and adjust the volume on a television.

Ultimately, he could open and close the fingers of an artificial hand and use a robotic arm to grasp and move objects.

A second patient, aged 55, who had a sensor implanted by surgeons at the University of Chicago in April 2005, was able to move a computer cursor for three months until his implant malfunctioned.

Professor John Donoghue, who led the research and heads the brain science program at Brown University in Rhode Island, said: "The results hold promise to one day be able to activate limb muscles with these brain signals, effectively restoring brain-to-muscle control via a physical nervous system."

Prof Donoghue is chief scientific officer at Cyberkinetics Neurotechnology Systems Inc, based in Foxborough, Massachusetts, which developed the implant.

Previous attempts at linking brains to computers have only had limited success, such as getting patients to move a cursor to the left and right. Experiments have also been conducted with less invasive techniques using sensors attached to the scalp, but these take months of training to use.

Mr Nagle adapted to the BrainGate system in minutes, and was able to talk while using it.

The implant consists of a pill-sized sensor measuring just four millimeters across containing 100 tiny electrodes, each thinner than a human hair.

It is placed on the surface of the motor cortex, the area of the brain responsible for voluntary movement. The hair-like electrodes penetrate about one millimeter into the brain, where they pick up electrical signals from nearby neurons. These are transmitted through thin gold wires to a titanium pedestal protruding about an inch above the patient's scalp. A cable connects the pedestal to the computer.

In future it is hoped that "wi-fi" systems will avoid the problem of having to use invasive and bulky wires and cables.

The patient learns how to operate devices simply by imagining a particular task being carried out.

Dr Richard Penn, the University of Chicago neurosurgeon who implanted the sensor in the second patient, said: "This is the strangest, most interesting surgery I've ever done. Not the technical stuff, but the data that we get from the neurons firing in different patterns when you're thinking in different ways. And seeing it is only the beginning."

Experts had not been certain that the brain's limb-control signals could still be found years after a paralyzing spinal injury.
But such doubts were put to rest by the success with Mr. Nagle, who was injured three years before his surgery.

"We're finding that, even years after spinal cord injury, the same signals that originally controlled a limb are available and can be utilized," said Dr Leigh Hochberg, a neurologist from Massachusetts General Hospital, who was a member of the research team.

Major technical obstacles remain, such as the great variation in individual responses to the implants, and a tendency for the sensors to become less efficient over time.

To restore limb function in any meaningful way scientists must also work out how the body tells the brain where its limbs are positioned in space. This is done through a little-understood sense called "proprioception".

However, enormous challenges have already been overcome - in particular, being able to "listen" to large groups of brain cells firing together between 20 and 200 times a second.

A second team of scientists whose work with monkeys was also published in Nature today has made headway speeding up the interface between brain and machine.

Dr Krishna Shenoy, from Stanford University in California, and colleagues, showed that it is possible to communicate information at a rate equal to typing 15 words per minute on a keyboard.

== Brain implant lets man control computer by thought ==

By Aisling Irwin, Science Correspondent

A MAN has been able to control a computer by thought alone after receiving an electronic implant that fused with his brain cells.

The most immediate application of this marriage of man and machine would be for people who are totally paralyzed, enabling them to express their thoughts or even control artificial limbs. The American surgeons involved say it is the first time that such a connection has been made directly in the brain, rather than with nerves in the spine or limbs.

"If you can run a computer you can talk to the world," said Dr Roy Bakay, of Emory University in Atlanta, Georgia, whose team developed the implants. He told a meeting of brain surgeons that he had performed two of the operations in which he persuaded the patients' brain cells to grow into his implant, linking up with its electronics.
One of the patients, a 53-year-old man known only as JR, was almost totally paralyzed by a stroke. He is dependent on a ventilator and cannot speak, although he is fully alert and intelligent and knows everything that is going on around him. Once he received the implant he could control a cursor on a computer screen and point at different icons, triggering a computer voice to make comments such as "I'm thirsty".

Now that JR, who is in the Atlanta Veterans Affairs Medical Centre in Georgia, can select phrases, his favorite is: "See you later. Nice talking with you." The first volunteer, a woman suffering from a neuro-degenerative disease, was given the implants 18 months ago and has since died.

Dr Bakay said: "The trick is teaching the patient to control the strength and pattern of the electric impulses being produced in the brain. After some training they are able to 'will' a cursor to move and then stop on a specific point on the computer screen. If you can move the cursor you can stop on certain icons, send e-mail, turn a light on or off and interact with the environment.

"Our hope is that soon we will be able to get to the point that we can connect the neural signals to a muscle stimulator in the patient's paralyzed limb and have them move that limb using the same principle that they use to move the cursor."

Dr Bakay told the Congress of Neurological Surgeons in Seattle that the implants consisted of two hollow glass cones, each no bigger than the tip of a ballpoint pen.

Each cone contained a tiny electrode. The doctors also inserted a natural human substance that encourages nerves to grow, which they extracted from the man's knee. They inserted the cones into the patient's motor cortex, the region of the brain that controls movement.

Once the cones were inserted, the growth factor substances encouraged the man's brain cells to grow. Over several months they spread into the cones and attached themselves to the electrodes.

When the patient learned to think in the correct way, he could routinely trigger the electrode to send a signal to a small transmitter-receiver placed just inside the skull. This transmitted to an amplifier worn outside the skull in a cap, which boosted the signal and sent it to the computer. Controlling the cursor soon became second nature, said Dr Bakay. But he added that it might take several more years before the implants could be used to give more complex commands.
To reach this stage had taken eight years, according to New Scientist magazine. Prof Kevin Warwick, a cybernetics expert at Reading University, said: "If they have actually gone into the brain and picked up signals with electrodes that is very new. It is another very exciting step." He said that one of the major obstacles to the production of such a cyber-human had been the moral issue of tampering with the brain of a healthy person.

John Cavanagh, of the International Spinal Research Trust in Cheshunt, Herts, said: "If these implants can be developed then they could do an enormous amount to alleviate many illnesses." The team has been given funding to continue research with three more patients.

Brain implant turn thoughts to words

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Author: Jim Giles, New Scientist, San Francisco
Related Link

FORTY-ONE neurons is a drop in the ocean compared with the hundred billion or so cells that are present in our brains. But those few neurons could help Eric Ramsey talk again.

It is eight years since a car accident left Ramsey “locked-in” - aware but paralyzed and unable to communicate other than through eye movements. By listening in on a tiny population of cells in his brain, neuroscientists hope to give him back his “voice” - a first for someone with his problems.

Ramsey had a wireless electrode implanted 6 millimeters or so below the surface of his brain in 2004 (see Diagram). The electrode records the electronic pulses sent by 41 neurons that surround it in an
area of the brain involved in generating speech. By analyzing the signals created when Ramsey imagines speaking, the team has developed software that may one day turn his thoughts into speech.

For now, the team is focusing on the building blocks of words. In a series of experiments over the last few years, Ramsey has imagined saying three vowel sounds: “oh”, “ee” and “oo”. By watching his brain activity, the researchers have been able to identify distinct patterns associated with the different sounds. Although the data is still being analyzed, they believe that they can correctly identify the sound Ramsey is imagining around 80 per cent of the time, says Jonathan Brumberg of Boston University, who presented the results at the Society for Neuroscience meeting in San Diego, California, on 5 November.

Over the coming weeks, a computer will begin analyzing and translating Ramsay’s thoughts into sounds that he will hear immediately - giving him feedback in real time. That should allow him to tune his thoughts so that he can consistently produce the vowel he wants. “That will be really exciting,” says Joe Wright of Neural Signals, a company based in Duluth, Georgia, that has helped develop the technology Ramsey is using. “We hope it will be a breakthrough.”

After that, the researchers will extend the range of sounds to other vowels and also consonants, with the ultimate aim of enabling Ramsey to hold conversations. The electrode is implanted in an area of brain that generates the movements of the tongue and mouth when speech is being generated. Since no one else has attempted this before, they acknowledge that there is a long way to go. “Conversation is what we’re hoping for, but we’re pretty far from that,” says Wright.

Ramsey is an ideal person to put this treatment to the test, since he was just 19 at the time of the accident, has a normal life expectancy and is capable of participating in several sessions a week. Previous studies have usually involved people who are locked-in as a result of a terminal illness such as amyotrophic lateral sclerosis, a handful of whom have had electrodes implanted to help them move cursors on a computer screen, for example.

Progress with such volunteers has been steady, says Dawn Taylor, a biomedical engineer at Case Western Reserve University in Cleveland, Ohio, and they can move cursors with a skill approaching that of an able-bodied person.

Instructor’s Notes:

There are four different papers in this posting. Read all of them. Then write your essay.

Remember that all essays are a MINIMUM of 5 paragraphs. Each Paragraph must have 5 sentences (of which 4 of those sentences must be in your own words). One direct quote with a page reference is required. Direct Quotes require Quotation Marks!!! The quote, no matter how many sentences, only counts as ONE sentence in a paragraph. Why? Because this is your work and at least four sentences in each paragraph must be in YOUR words. I count sentences so YOU should TOO!