Brain-Computer Interfaces:

Blurring the Distinction Between Flesh and Metal

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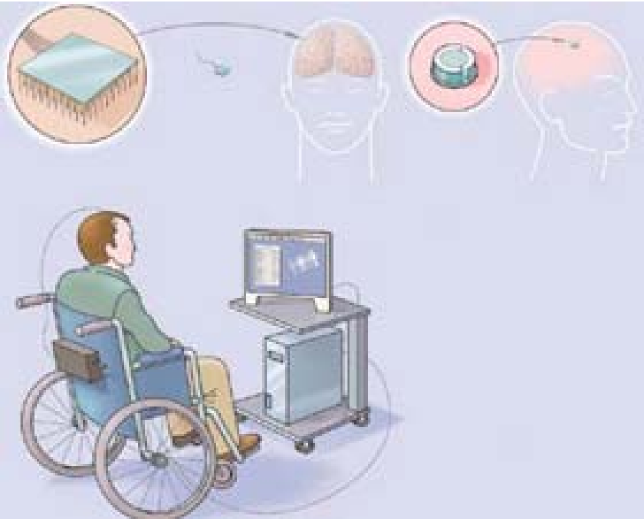
The world of fiction often depicts mad scientists controlling robots with their minds, wreaking havoc and destruction in the lives of many. Although such manifestations of disaster inspire fear in many, the age of the cyborg, or the melding of brain and machine, is here. Dr. Philip Kennedy of Neural Signals, Inc., was the first researcher to implant an electrode into the brain of a quadriplegic, who could then spell out words on a computer by using his thoughts (Kotulak 2004). Such technology is aptly named brain-computer interfacing (BCI). Although much refinement is needed for a wider base of application, the basic mechanisms of brain-computer interfaces have been established and even applied on a small scale. But, in the modern-day age of technology, the question remains: what are the repercussions of the union of the human brain with machine?

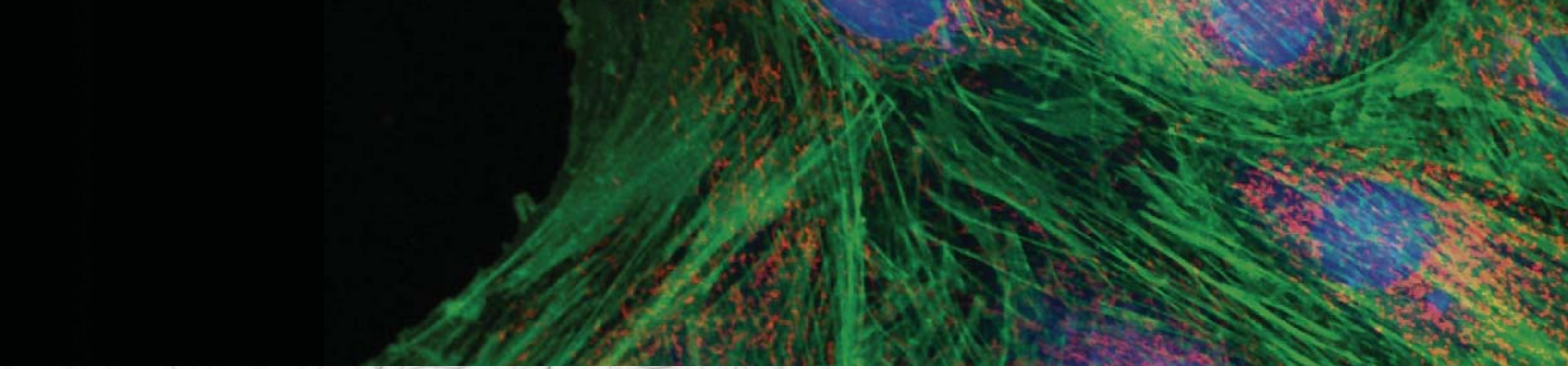


In general, BCI's involve an instrument in association with a brain region of interest and a computer or robot.
http://www.research.va.gov/news/features/brain-comp-interface.cfm

How Brain-Computer Interfaces Function

To maximize the effectiveness of BCIs, the brain has been studied through functional magnetic resonance imaging (MRI) in order to correlate brain region with bodily function. fMRI uses radio waves and an extremely powerful magnetic field to depict regions of the brain where blood vessels are expanding, chemical reactions are occurring, or extra oxygen is being delivered, all of which are activities associated with a brain functioning normally (University of Washington School of Medicine 2007). For example, it has been determined that the motor cortex is the area of the brain responsible for bodily movement. Thus, in paralyzed individuals, commands from the brain are read by a variety of instruments, ranging from an implant surgically placed inside the motor cortex (invasive) to electrodes placed on the scalp (non-invasive). Commands from the brain are read by these instruments so that when a patient thinks about performing a movement, the instrument picks up the electrical signal, amplifies it, and then transmits it to an attached computer or robotic element (Gupta 2002). For example, researchers led by John Donoghue of Brown University implanted electrodes into the motor cortex of a patient whose spinal cord was permanently damaged, allowing him to open his e-mail, control a television, and move objects with a robotic arm, all simply by thinking about the actions (Nature 2006).

It is important to realize that BCIs work due to the natural organization of the human brain, which is a complex system of neurons. Neurons are interconnected through dendrites and axons, which transmit electrical pulses generated by the movement of ions across neuronal membranes.



Paths that the signals take are insulated by a fatty substance called myelin, but some of this electrical signal may escape. Researchers have developed BCIs to detect such signals. Invasive BCIs provide the best quality of signals, since the implant is placed directly into the brain. Unfortunately, scar tissue may form in the brain due to the surgery required for the implantation, which can disrupt signal reception. The invasive technique also runs the risk of infection and is bulky, and thus not easily portable; it is hoped that wireless signal transmission will address the latter issue (Nature 2006). Partially invasive BCIs, in which some components of the BCI are implanted on the external surface of the brain and the rest outside the brain, provide high resolution signals without the risk of scarring; however, the signals detected by non-invasive BCIs can be distorted by bone tissue. Less invasive techniques also require months of training to use, while the patient described above was able to effectively control his implant within minutes of practice (Singha 2008).

> ***"...the brain is no longer a separate entity from the machine..."***

RECREATIONAL, TECHNOLOGICAL, AND MEDICAL APPLICATIONS OF BRAIN-COMPUTER INTERFACES

Early research used monkeys with implanted electrodes to test simple video games. The monkeys were able to control a joystick to chase a green dot on a computer screen with their cursors, which were controlled by the BCIs in their brain (Murphy 2003). Mathematical models were used to extract parameters such as hand position, velocity, gripping force, and the like. By practicing, the monkeys were observed to improve model predictions and performance. It was found that, over time, several cortical areas were functionally reorganized to accommodate the BCI (Carmena 2003). Recently, such technology has been applied to humans as well: approximately two years ago, a team of neurosurgeons, neurologists, and engineers at Washington University developed a BCI that allowed a 14-year-old boy to play video games not with his hands, but exclusively with his brain. The epileptic teenager is the first to play a 2D video game through a BCI (University of Washington School of Medicine).

On the other side of the spectrum, a Florida scientist developed a brain through 25,000 neurons extracted from a rat's brain, arranged in sixty electrodes in a Petri dish. The brain cells reconnected themselves and could be used to fly aircraft. The brain, when connected to a jet flight stimulator, was able to establish a two-way connection with the stimulator, in a manner not different from the connections forged between the brain and the body. The brain was then able to

Lindsay Block, born without the lower part of her left arm, was the first recipient of a bionic arm.
http://minnesota.publicradio.org/display/web/2008/06/05/midmorning2/

receive and interpret signals regarding flight conditions and then eventually learned to control the flight of the jet (CNN 2004). The signals indicated whether the stimulator was experiencing stable conditions or hurricanes, and the brain was able to determine the correct path of flight and then transmit this information to the airplane controls (Biever 2004). This example indicates that BCIs could, in the future, have a wide range of technological applications.

As described previously, physically challenged individuals have also successfully used BCIs in order to regain the simple motor functions they had lost. In a more drastic case, the Rehabilitation Institute of Chicago worked with Jesse Sullivan, who lost both arms in job-related accident. They successfully fitted him with bionic arms, giving him a new sense of independence, and now, with practice, he does not have to think too hard about performing an activity (Kotulak 2004).

A Behind the Ear Cochlear Implant.
www.hearingloss-wa.org/cochlear_implants.htm

Another application for the impaired is the cochlear implant, one of the oldest BCIs available. Some individuals suffer from hearing loss even though their auditory nerves are functioning normally. A cochlear implant can help them regain their auditory reception by bypassing defected regions of the ear, (which cannot transmit sound waves to the auditory nerves), and transmitting electrical signals directly to the auditory nerves. A similar device has been developed to help the visually impaired, though the visual processing system of the brain is much more complex than the auditory. The electrodes are implanted in the visual cortex, the region of the brain responsible for processing visual information. A pair of glasses with small cameras is connected to both a computer and to the implants. Jens Naumann received such visual implants; previously blind, he can now be seen navigating his way around subways (Singha 2008, CBC 2003).

As for the future, Neural Signal is working on developing a BCI that will restore speech. An implant would pick up signals from Broca's area, the region of the brain responsible for speech production, and would transmit them to a computer and speaker. The system would recognize the thirty-nine phonemes in the English language and reconstruct speech. NASA is working on a similar BCI that would read electrical signals from nerves in the mouth and throat, instead of the brain. (Singha 2008). But, the possibilities are literally endless, as BCIs could potentially be used to control all actions, including day-to-day tasks, through thought.

Ethical Considerations of Brain-Computer Interfaces

The mechanics of BCIs have largely been established. Now, researchers are working on refining the technology to increase its range of applications. BCIs represent only one example of direct human-machine interaction, but what are the repercussions of such a union?

One concern is that the technology may become excessively commercialized. It may be purchased by those who can afford it as a means of convenience, rather than utilized by disabled individuals in order to augment the quality of their lives. Even if used medically, the price tag is staggering – Jens Naumann paid $80,000 for his bionic eyes (CBC 2003). The question then arises: will BCIs be used to further increase the gap between the wealthy and the poor? Will BCIs become another amenity that only a select few individuals can afford? If so, will BCIs be used to artificially expand the capacity of the mind? Like the debates surrounding so-called "smart drugs" (medications to enhance one's cognitive abilities) and genetic engineering, BCIs could very well provide an unfair advantage to those who can incorporate them into their lives. They could become a means of evolution, comparable to genetic mutations. But, genetic mutations are natural and, for the most part, involuntary, whereas the use of this new technology is completely intentional. Ellen McGee, associate of bioethics at the Long Island Center of Ethics, even says that "if at some point in the future we're able to upload our memories onto a chip . . . then if that chip were implanted in my clone, I could achieve a kind of immortality" (Shalhoup). The thought of a tyrant such as Adolf Hitler gaining access to such technology is unbelievably frightening. On a similar note, criminals could adapt their BCIs to control the robots and technological property of other individuals (Adams).

Furthermore, individuals using the technology for medical reasons might become completely dependent on the machinery, so that their lives will be tethered to human-made technology that is, unfortunately, not infallible. Just like computers and other medical technology occasionally malfunction, BCIs could also experience glitches, although of a much more fatal nature, since the brain is no longer a separate entity from the machine it is functioning with. Perhaps the main concern here is that more extensive research needs to be done regarding the effects of such malfunctions.

In the end, perhaps like most technologies, BCIs must be used with discretion, but since we are venturing into new territory, we must be prepared for new problems. BCIs may function through invasive to noninvasive means and be applied to vastly different fields of study. But, understanding the mechanisms behind this new technology is not enough in order to ethically evaluate it.

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