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The ALS Association

Brain Computer Interface Technology
Overview and Current Status for ALS

The concept of Brain Computer Interface (BCI) technology is a topic of interest for many individuals and the families of individuals who experience significant physical limitations, including those with Amyotrophic Lateral Sclerosis (ALS). This technology is known by many monikers, including Brain Computer Interface (BCI), Brain-Machine Interface (BMI), Direct Brain Interface (DBI), and neuro-brain transmission. Traditional assistive technology and computer input devices depend on small but reliable muscle movements that patients lose as the disease progresses. BCIs detect small changes in brain signals to provide a path of control for devices that does not depend on muscle movement. BCIs do not communicate or interpret thoughts, however, they do detect minute changes in brain signals to enable a path of control that does not depend on muscle movement.

These technology solutions were originally envisioned for assistive technology and more recently for activities such as controlling video games, automating sailboats, robotics, and military tasks. Today, BCIs continue to be researched as assistive technology solutions for those individuals with significant physical disabilities who have a strong desire to communicate with speech and writing, as well as to control their environment and engage in computer-based recreational activities. BCIs are not treatment for the disease; they do not affect a person's health or the progression of ALS in any way. They are an assistive technology that can potentially make a significant difference in the quality of life for people with ALS. Much of this work is largely experimental, based in research laboratories around the country and across the world. The intentions of such technologies are to eventually support "hands-free" keyboard and mouse emulation for use by individuals with significantly limited motor skills and with varying levels of cognitive, linguistic and sensory (e.g., vision and hearing) skills. The research in this area has been ongoing over the past three decades.

In reviewing the literature it is noted that, "Some chose to develop devices that could be steered by brain waves detected outside the head; research more than 30 years ago showed that people can be trained to control these patterns."[1] Past research has included the implantation of electrodes into rhesus monkeys for activities such as controlling robotic arms. Rebecca Zacks notes, [2] "…the electrodes intercept signals from individual neurons in the brain and a specially developed computer algorithm translated these signals into trajectories and velocities for the computer cursor. The researchers' ambitions, however, extend way beyond video-game playing monkeys. Their hope is that their brain-machine-interface system will give patients paralyzed by spinal-cord injuries or neurodegenerative diseases new abilities to interact with the world around them – using nothing more than the power of their thoughts."

Since the publication cited above, researchers, led by Philip Kennedy in 1997, have implanted neurotrophic electrodes into several people with ALS. With these BCI devices, patients were trained to spell with a virtual keyboard, play a virtual piano, move their own hands with functional electrical stimulation, and perform other functional applications. In 2004, John Donoghue was the second researcher to implant humans with chronic recording electrodes, implanting a 100-electrode microwire array into a patient with a spinal cord injury. This work continues toward a clinical trial with the company, Cyberkinetic, and their device, BrainGate.

The March 2003 edition of Communications of the ACM,[3] noted to be the "world's oldest and largest educational and scientific computing society," contained an article by Jose Del R. Millan entitled Adaptive Brain Interfaces. In this article he notes, "…users interact with physical devices through nothing more than the voluntary control of their own mental activity." The work at Miguel Nicolelis' laboratory at Duke University includes experiments with monkeys who learn to reach and grasp virtual objects by controlling a robotic arm using a BCI device.

BCI systems generally consist of a combination of hardware and software that interfaces with the human body via internal and/or external methods. There are many applications of this technology that are being proposed or realized by patients and researchers alike. Many people envision these technologies as useful strategies and interfaces to accompany other inputs (e.g., speech recognition, switch scanning). These solutions are particularly applicable as input alternatives for individuals who are severely physically disabled (e.g., "locked-in") secondary to diagnoses, such as brainstem stroke, ALS, traumatic brain injury, and other severe neuromuscular disorders. Given that many individuals with these diseases and injuries experience a significant impact on their quality of life absent these technologies, the solutions have the potential to improve productivity and extend communication for education, vocation, recreation and leisure activities. It is indisputable that when BCI technology becomes a routine, everyday symptom management device, individuals will likely experience increased independence and improved quality of life.

However, many challenges and barriers exist with BCI technologies as well as the optimistic opportunities described above. Some of the BCI systems require the end-user to spend many hours practicing and learning to "think" in a manner the systems will recognize. Other systems depend on *evoked responses*; which detect a response in the brain when a stimulus is presented, such as flashing a letter of the alphabet. Both types of systems require the individual to attempt control of involuntary responses (e.g., facial and eye twitches and movements), while also dealing with the primary neurogenic features of their diagnosis (e.g., muscle twitching, spasticity and atrophy). As well, when the individual is "concentrating" so fiercely on regulating brain activity and limiting muscle movements, it can severely impact non-verbal pragmatic language and interactions with those in the immediate environment.

Additional obstacles for some people include the rate of productivity and extended learning curve for familiarizing the brain and body with the BCI system. "Recent tests on college students indicate that [BCI] system can be used to "type" nearly eight characters per minute with 80% accuracy."[4] Such solutions can also be very fatiguing, and are often not useful in the presence of certain visual impairments, since some approaches require visual prompts from the screen. Because some people who are locked-in have limited vision, research in auditory interfaces is an important focus for the BCI community.

For others, the required "equipment" (e.g., a "gel" which may be messy; headgear, such as a headband or helmet) is considered a functional limitation, since it renders him or her dependent on others to "get ready" to communicate. Once the system is set up, there is limited compatibility today to standard application programs (e.g., word processing, email, calendar and address books). Another consideration includes environmental disturbances (e.g., noisy room, ventilator sounds), which may render the equipment less efficient or effective. Some of the BCI products in development and clinical testing require brain implants; others are attached to the scalp. Finally, since the technology is primarily in research stages, most BCI systems are expensive, require the presence of a trained research team to operate, and are not yet available for general patient use.

BCI technology is concurrently in the stages of laboratory research, early clinical experiences and beginning research trials and a few are in commercial production. Current commercial products include, but are not limited to:

1. CyberLink MindMouse, from Brain Actuated Technologies, Inc. - It works by means of a headband with 3 sensors that detect electrical signals on the forehead resulting from subtle facial muscle, eye and brain activity. The headband connects to an interface box, which amplifies and digitizes the signals and transmits them to a computer. The software decodes the signals, eye motions and facial gestures into 10 "BrainFingers" for continuous cursor control, converting them into keystrokes, mouse button clicks and cursor resolution control.
2. MCTOS Mind/Eye/Muscles Switch from Technos America, Ltd LLC – It is described as a simple switch that is controlled by bioelectrical activity measured at the forehead. This hardware can be operated by muscle twitch, eye movement, eye blink, and mental activity.
3. The Interactive Brainwave Visual Analyzer from IBVA Technologies, Inc. – It is described as a Human Computer Interface that reads real time data and provides

wireless transmission to the receiver plugged into the computer of choice (e.g., Mac or Windows).

BCI is an exciting and promising emerging technology that is on the "radar screen" of many researchers in the fields of computer science, cognitive science, visual science, neurology and neuroscience, neurophysiology, psychology, biomedical engineering and rehabilitation. According to BCI pioneer Jonathan Wolpaw of the Wadsworth Center at the New York State Department of Health in Albany, "…it's a very exciting time; a lot of people are getting involved.[5]"

It is important to acknowledge that BCI technology remains largely experimental at this time. It will likely take several more years before the technologies are effective, efficient, accurate, affordable and portable enough to be functional across ages and diagnoses. Dr. Melody Moore of the Georgia State University (GSU) BrainLab "…has tested such technologies on healthy volunteers and more recently has expanded her laboratory's work to include four patients with ALS. Eventually, Moore plans to run multiple applications on a laptop mounted to a "smart" wheelchair, which is under development and will also be controlled by brain waves."[6]

A recent issued of Science[7] relates existing work being conducted by Niels Birbaumer, a researcher at the University of Tubingen, Germany, in which he works with several individuals with ALS and other diagnoses to introduce them to BCI and train them in the use and integration of this new technology. Birbaumer is quoted as saying that his next step is to develop a BCI system that can be operated by a caregiver without ongoing assistance by researchers or technicians.

Newer research is relying on implanted BCIs which may be too invasive for some, or medically contra-indicated for others. Some of this research is being pioneered by Philip Kennedy of Neural Signals in Atlanta, Georgia. Birbaumer notes that "implantation of electrodes will ultimately be the only way to go with these BCIs, but notes "none of his patients are keen."[8] At the same time, it can be noted that in his keynote address at the CSUN 18th Annual International Conference, "Technology and Persons with Disabilities," held in Los Angeles, March 17-22, 2003, Ray Kurzweil, a leading inventor of our times, stated emphatically that the size and use of technologies has and will continue to improve at exponential rates. So much so, that people will be "wearing computers in seven years." This proclamation bodes well for individuals awaiting brain computer interface technology.

More and more research is being published on this topic. Laura Spinney[9] quotes John Donoghue from Brown University, whose group has published its results from trials of implantations in monkeys and, more recently, in humans. "…to create speech from a speech area in the brain might be difficult … but one could imagine a way that you would type out the words and then have the computer produce speech." He also notes that eventually the aim is to read the activity of the brain's language areas and turn that directly into speech.

Several scientific and technical conferences and meetings have been held in recent years to advance the knowledge base for BCI and spur further research and development. The NIH sponsored the Human Brain Project Conference[10] with a goal of "creating a system of databases, analytical tools, computational models to manage, integrate and explore data on the structure and function of the brain. The objectives of the conference were to bring together persons working in the field of "neuroinformatics" to present and exchange ideas, new tools and new strategies and to make investigators aware of new opportunities in this area. A second conference held July 2003, covered aspects of neurotechnology in the 1st International Conference on Medical Implants. This meeting focused on scientific, engineering, clinical, regulatory, and commercial aspects of medical implants, and has assembled an impressive international advisory committee[11]. The flagship conference for this highly specialized field will be held in June 2005 in New York. This third International Brain-Computer Interface Meeting will include most of the active BCI researchers and the content will focus exclusively on BCI issues.

While significant research and beta-testing is ongoing, a multiplicity of resources is currently available for the professional and layperson in the arena of BCI. Such resources include, but are not limited to, coursework (e.g., Topics in Brain Computer Interfaces, Brown University), numerous online and paper-based publications, a flooding of new research funded by various private and public sources and being conducted across the country and around the world. Funding sources for BCI research include the National Institutes of Health, Massachusetts Institute of Technology, and the National Science Foundation. Research in the field is being conducted at several academic and biotechnical organizations including the University of Rochester; Duke University, Neil Squire Foundation, Georgia State University, Wadsworth Center at the New York State Department of Health, Defense Advanced Research Projects Agency (DARPA) and Brown University. Additional resources include newsgroups, national and international meetings/conferences and websites.

In general, most researchers, rehabilitation specialists and others agree that the BCI field for ALS continues to develop, and with exponential improvements in some cases. There are some exciting individual anecdotes regarding the use, efficiency and effectiveness of a range of BCI technologies. At this time, there are a number of funders, research laboratories, start-up and mainstream companies, and individuals and the families of individuals with ALS that are very excited about the current and future impact of these technologies. Despite the wealth of interest and solid work in this field, it has to be said that overall the field is still in the research and development phase. Although clinical trials of devices are on the near horizon, the field has more work to accomplish before the technology is readily available and is a proven intervention for people with ALS. With the generosity, dedication and involvement of people with ALS and their families, the clinical studies to test the practicality and effectiveness of services will help immeasurably to move the field forward.

Written by Patricia R. Ourand, MS, CCC-SLP, October 2004
Reviewed and Updated by Melody Moore, PhD, February, 2005

(Footnotes)

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