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BCI Research Design

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Abstract

Since computers first captured the imagination of men the possibility to directly interface with computers has been an idea or a dream. It seems that this futuristic capability may not be a very distant possibility as modern technology advances. This report will offer some details of the technology, what is currently possible, what the future may hold, describe the need for further research in BCI, offer a literature review, and discuss research methodologies.

BCI Research Design

The ability to directly interface with computers has been an idea or a dream since computers first captured the imagination of men. It has been an aspect of futuristic life portrayed in books, movies, and other forms of entertainment for many years. As modern technology advances, it seems that this futuristic capability may not be a very distant possibility. Experts are now calling this technology brain computer interface or brain chip interface (BCI). Regardless, the acronym is BCI. Many organizations, universities, and hospitals, have become involved, but also many governments. At present at least two international organizations, including the International Assessment of Brain Computer Interface Research and the World Technology Evaluation Center, have been formed.

Currently, the major focuses of research are advances toward helping paralyzed people with mobility and communication. There are already some technologies available in a limited capacity for these specific needs. This advanced technology is something that up until now has been the subject for sci-fi or futuristic movies but is now actually becoming possible. One might ask oneself, "Now that scientists know (BCI) is possible, how far along current accomplishments are, what the estimated time line for further development is, and can these technologies be applied to teaching/learning?" A highly attention-grabbing, pop-culture orientated question might be, "Are we getting close to a *Matrix* like method of learning?" The answer may be that we are much closer than most people realize. Science fiction is fast becoming reality in modern everyday technology that many are beginning to take for granted.

With highly advanced technology such as BCI, information regarding the specifics of the technological and scientific study is not always readily available. Developers and researchers may be concerned about information leaking before they are ready to reveal their inventions/findings. However, many advanced studies have been published. There are also some

companies assisting in the development, production, and supplying of this technology that offer some interesting information. This report will offer some details of the technology, what is currently possible, what the future may hold, describe the need for further research in BCI, offer a literature review, and discuss research methodologies.

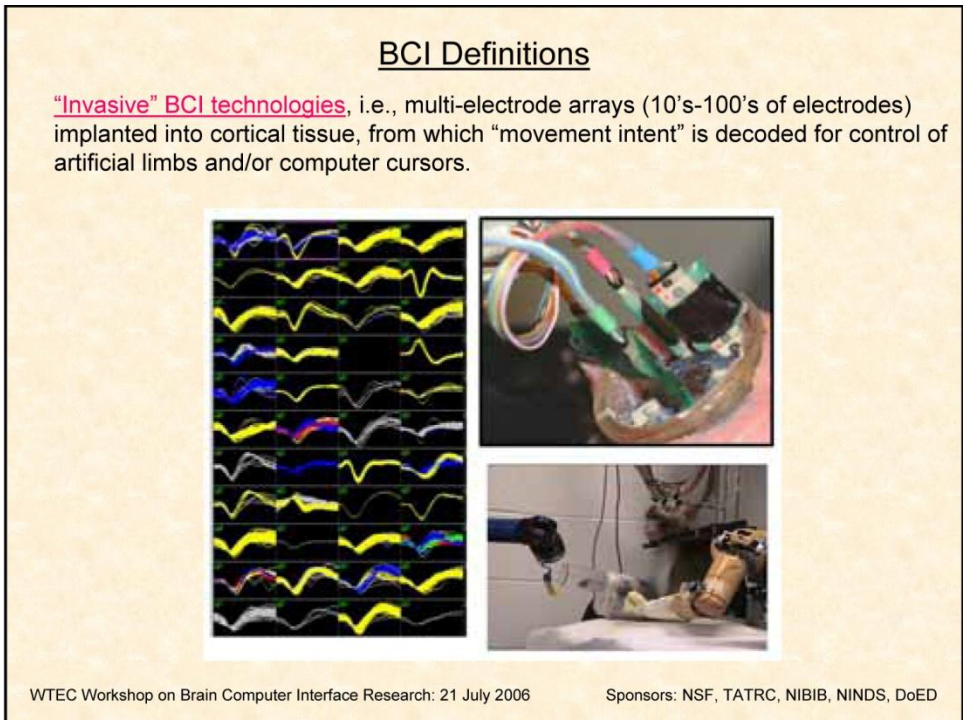
As mentioned, BCI is an extremely highly technical field; therefore, before serious discussion begins it is best to touch upon the basic mechanics of how it works. Current "Brain–computer interfaces (BCIs) are a fundamentally new approach to restoring communication and control to people with severe motor disorders such as amyotrophic lateral sclerosis (ALS), brainstem stroke, spinal cord injury, muscular dystrophies, and cerebral palsy (Wolpaw et al. 2002; Wolpaw & Birbaumer, 2006 for review). All other assistive technology methods depend on the brain's natural output pathways of peripheral nerves and muscles (or peripheral nerves and glands; Wilhelm et al. 2006), and take outputs that the person still retains (e.g. vertical eye movement in a person with a brainstem stroke) and use these to replace missing functions (e.g. using gaze direction to select letters on a computer screen). In contrast, BCIs give the brain entirely new output pathways. They take electrophysiological or other measures of brain activity and from these measures determine the person's wishes. Intent, which is normally achieved by speaking or by another motor action, is instead achieved by producing brain signals that encode the intent so that a computer can translate it into control of a device such as a computer cursor or a neuroprosthesis." (Wolpaw, 2007)

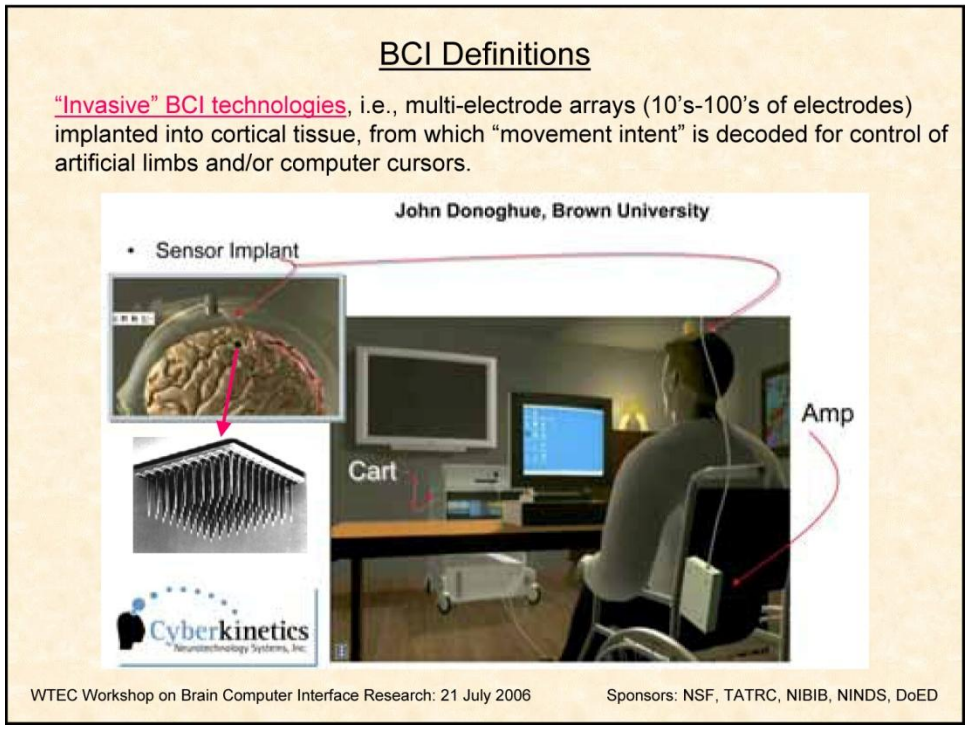
In the U.S. laboratories led by researchers Andrew Schwartz at the University of Pittsburgh, Richard Andersen of Caltech, Miguel Nicolelis of Duke University, and John Donoghue of Brown University have all successfully used a variety of algorithms to record directly from the cortex of monkeys - as a BCI. This design allowed a monkey to navigate a computer cursor on screen, as well as command a robotic arm to perform simple tasks, simply by

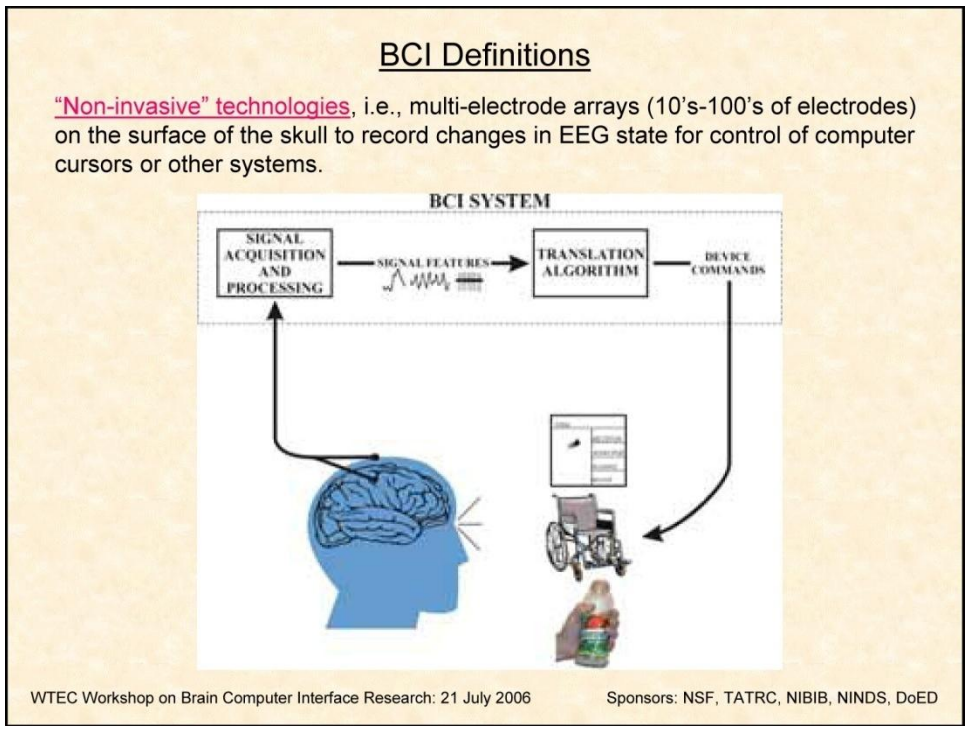
thinking about moving the cursor, without any motor output from the monkey. This technology is now being used and tested on disabled humans. For reasons involving fine temporal resolution, ease of use, portability, and cost of set-up, the most commonly studied potential interface for humans has been electroencephalography (EEG). However, EEG BCI requires immense amounts of user training and is highly vulnerable to outside 'noise'. Scientists of the Fraunhofer Society utilized neural networks to shift the learning phase from the user to the computer and thus recorded noticeable results within thirty minutes of training in 2004. Magnetoencephalography (MEG) and even functional magnetic resonance imaging (fMRI) have also both been used successfully as rudimentary BCIs. Two users being scanned in real-time fMRI were able to play Pong against one another by altering their haemodynamic response through various biofeedback techniques. (Nationmaster, 2009) By developing a new generation of BCIs that can provide communication and control functions to people who have lost muscle control, the Laboratory of Neural Injury and Repair at the Wadsworth Center has addressed the problems of severely disabled people. The system, called the Wadsworth System, allows users to move a computer cursor up/down and left/right, to spell words, and even to control a robotic arm by recording brain waves from the scalp and then decoding them. (Wadsworth Center, 2009) The Wadsworth Center of the New York State Health Department offers an excellent, brief video giving an informative explanation of this BCI technology currently being researched and developed. This video gives an overview of how the Wadsworth System operates, its key features, what tasks a person is able to complete using the system, and the next step in Wadsworth System progress. This remarkable BCI artifact also gives a demonstration of a client using the system. The video file should be viewable for any system as it is offered in Flash, Quick Time, and/or Windows Media formats. The link for this interesting video can be found at http://www.wadsworth.org/bci.

Technologies are also being developed at the University of California Los Angeles, (UCLA) that will improve brain-computer interfaces on multiple levels. Novel micro-machined, multi-electrode probes have been developed and are being used for deep-brain-computer-interface (DBCI) research. Head-stage integration is being advanced by combining amplification, filtering, signal processing, computing, and wireless communications all into a highly mobile 25 millimeter diameter system. These and related technologies are being used, with operant conditioning, to study methods for creating high reliability and high-quality BCI-based control signals. (Judy *et. al*., 2005)

The following explanatory graphics were garnered from a presentation by the World Technology Evaluation Center (WETC) to offer greater detailing in current BCI connectivity:




BCI Definitions
"Invasive" BCI technologies, i.e., multi-electrode arrays (10's-100's of electrodes) implanted into cortical tissue, from which "movement intent" is decoded for control of artificial limbs and/or computer cursors.
John Donoghue, Brown University
Sensor Implant
Cart
Amp
Cyberkinetics
WTEC Workshop on Brain Computer Interface Research: 21 July 2006
Sponsors: NSF, TATRC, NIBIB, NINDS, DoED


BCI Definitions
"Non-invasive" technologies, i.e., multi-electrode arrays (10's-100's of electrodes) on the surface of the skull to record changes in EEG state for control of computer cursors or other systems.
BCI SYSTEM
SIGNAL ACQUISITION AND PROCESSING
SIGNAL FEATURES
TRANSLATION ALGORITHM
DEVICE COMMANDS
WTEC Workshop on Brain Computer Interface Research: 21 July 2006
Sponsors: NSF, TATRC, NIBIB, NINDS, DoED

(WETC, 2006)

According to the WETC, there has been increasing interest since the 1970s among agencies of the U.S. Federal government, such as National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), Air Force Office of Scientific Research (AFOSR), U.S. Army, National Institute of Standards and Technology (NIST), and National Institutes of Health (NIH), and state agencies, as well as universities and private industry in improving human-computer interaction and developing a BCI system. The WETC maintains that specific technological advances in areas of computational technology, component miniaturization, biocompatibility of materials, and sensor technology will lead to much improved brain-computer interfaces within an estimated five years. Future achievements are expected to advance the performance and functions of BCIs, with focus on producing feasible, practical, and affordable communication and mobility alternatives for severely disabled people worldwide. While this may be the focus of current development, the many potential applications that advanced BCI technology offers could radically change modern everyday life. Computers are so integrated into modern society that most are completely overlooked or taken for granted. With advanced BCI technology accessing any computer function could become as simple as putting on a headset or simply standing close enough to a computer with specialized sensors. This possibility opens up many sweeping transformations that could be classified as revolutionary. People would no longer need keyboards or mice to operate a computer. Machinery would likely be operated in completely different ways than that of today. General traffic of both automotive and flight navigation would certainly be altered. Cars may not even have manual controls in the future, but only a type of headset or earpiece for BCI operation. Even home life could be much different with BCI controlled lighting, entertainment systems, security, and various other functions. If information transferability becomes as easy as connectivity and control, even more possibilities become promising. Just as the Industrial

Revolution changed the world in the 1800s, advanced BCI technology could alter the methods of basic functionality of every aspect of modern life; including the home, entertainment, educational, and work environments.

The aspect most significant to this author is education. If students were able to directly interface with computer data and implant it into their long term memories, the need for traditional schools would become obsolete except to those that were too poor to afford access to the technology or disabled in a way that made BCI dangerous or nonviable. It is not the nature of man to stagnate when it comes to progress. It is no longer a question of whether this technology will become possible, but rather when it will become mainstream. Just as the Internet changed the face of common knowledge so will the eventuality of advanced BCI technology. The existence of seemingly instantaneous information and knowledge available and gained by high-speed Internet access could actually be instantaneous and immediate with BCI advancement. If a person could simply plug into a computer and have knowledge downloaded into their brain, learning and teaching would be radically changed. The knowledge standard for educational requirements or employment positions would most likely become more stringent. It is mind boggling to imagine how much information a human brain could hold, how much might be too much, and what would happen to an individual who tried to push the envelope. Personality and/or memory enhancement or modification may become available. Corporate renting of brain space for the transfer of extremely sensitive information could even become an issue. The effective, efficient functionality of instantaneous connectivity, transferability, and control of BCI technology could truly transform the modern world in ways only imaginable now.

With these ideas in mind, research possibilities should be explored. Thorough research consists of proper organization, knowledge and application of significant research methodologies, and an understanding of research tools and formalities. These aspects are as

important to the presentation of the research as the collecting of related data. Below is an online of these aspects of proper research.

Methodology is important to research of all forms. Clear-cut methodologies provide thorough, organized, systematic processes to answer questions or solve problems. Proper use ensures that all the bases have been covered so that nothing might have been over looked that might affect the outcome and make the study invalid. The following content pertains to a methodology of proposed research project on BCI. It will address several the following methodology questions:

- What is the research interest?
- What methods will be tried?
- How will the process be documented?
- How will the findings be proven valid and credible?
- How will the data be interpreted?
- How will the process and outcome be presented?
- How will this research make life better and what will its future hold? (Holly, Arhar, & Kasten, 2005, p. 186)

The interest of this research is brain computer interfacing (BCI). The question to be answered as stated in the introduction would be, "Now that scientists know brain computer interface (BCI) is possible, how far along are current accomplishments, what is the estimated time line for further development, and can these technologies be applied to teaching/learning?" This question involves cutting edge technology and its relation to learning/teaching.

Because this is a very highly technical, experimental, advanced technology; information may only be sought through specific means and sources. Sources might include: scientific

research databases, research developers or participants, and related vested interested parties. Information regarding the specifics of higher technological and scientific study is not always readily available. The related parties may be concerned about sensitive information leaking before they are ready to reveal their inventions/findings.

The research process should be documented in each stage in the form of written documentation. Actual observation might be an option through the use of Internet or special permission acquired through interaction with researchers or developers. Testimonies from subjects who have actually tested or operated BCI equipment would be highly valuable.

Research sources are an extremely important fundamental base of research. Proper sources provide credibility to the statements being made, examples being given, or theories or opinions being presented. Sound sources could be information from experts, scientists, and other recognizably credible sources. This information type instills more confidence by the reader in the author(s) that the subject being presented is accurate or at least a shared educated opinion or theory. Finding proper, credible references can sometimes be a challenge, but the end results are worth the effort. The literature review process for selecting appropriate, relevant sources has significant value. Author credentials, language, and references are things that should be considered when choosing appropriate reference sources. When possible relevant authentic study results should be found and used as references. Related reports from upper administrative or highly educated professionals, such as doctors, are generally also very good for references sources.

For those living in less technologically advanced areas, physical library resources may leave much to be desired for current information; so most research could be conducted online. The source search could involve online libraries, databases, and search engines. Many of these

online tools offer an option of searching only for scholarly journals. While not all sources are ideal scholarly sources, most will offer valid, credible information.

In regards to the validity and credibility of the research findings; the researcher has maintained the following guidelines:

- The source must be acceptable for scholarly documentation.
- The source must be a primary source.
- The source must be from a credible organization, such as a university or well-known higher technology producing company.

The researcher feels with these standards in practice, it is unlikely that misinformation will be found and utilized in the final project.

Below is a short literature review of credible sources on BCI research and technology:

- *Brain–Computer Interfaces As New Brain Output Pathways* by Jonathan R. Wolpaw of the Wadsworth Center, Laboratory of Nervous System Disorders, New York State Department of Health and State University of New York. This is a very comprehensive look at BCI technology by one of the nations leading researchers in the field.
- *International Assessment of Brain-Computer Interface Research* by the WTEC. This is a look at BCI technology on a global level.
- *The Third International Meeting on Brain-Computer Interface Technology: Making A Difference* by T.M. Vaughan and J.R. Wolpaw. This is a briefing on the latest international meeting of experts and dignitaries associated with BCI research and technology.

- *Brain–Computer Interface Research: Coming of Age* by Niels Birbaumer of the Human Cortical Physiology Unit, National Institutes of Health, USA; Institute of Medical Psychology and Behavioral Neurobiology; University of Tuebingen, Germany; and the Center for Cognitive Neuroscience, University of Trento, Italy.

These example sources are sources that have in fact been utilized for this report. After a researcher finds credible sources it is up to him/her which data to make use of and how it will be interpreted and presented.

Initial information should be interpreted by analyzing, synthesizing, and theorizing the data gathered. Analyzing should occur at the time each element of BCI is presented. Relation between the chosen elements should then be shown to exhibit the synthesizing component of the methodology. The researcher should then theorize or make assertions about BCI technology, accomplishments, and possible future directions or goals.

The findings for a research project must be presented in a formal format if it is to be taken seriously. Whether the research is for the benefit of scholarly pursuit or career orientated, research must be presented in a manner best suited to its purpose. For scholarly gains this generally means in formal American Psychological Association (APA) or Modern Language Association (MLA) format, dependent upon the requirements of the instructor or review board. For career goals it can be more ambiguous. The researcher may be presenting information to superiors or preparing a statement to be released to press or the general public. Whatever the end purpose, the researcher needs to be prepared with a thorough, organized, properly prepared and presented report. While this may have different meanings in different situations, it is a vital part of research. Research is wasted time and effort and useless if it does not suit its intended audience. Therefore the researcher must complete a study of organizational and presentation methods to best fit the intended audience and present the findings in an appropriate manner

In reference to the last methodology question, how the research will make life better, as mentioned BCI is already being used to enhance the lives of specific handicapped individuals. It is the hope of many doctors and scientists to be able to possibly correct many types of severe disabilities, especially those who are "locked" in nonfunctioning bodies. These are individuals who have no mind brain damage, but who have no or limited control over their bodies are unable to move, talk, or communicate. By making BCI technology more widely known, more assistance may come to researchers and developers, allowing them to conduct further research and have better opportunities to achieve the desired goals. In theory, BCI technology has limitless possibilities. While the focus of BCI development currently has to do with assisting the severely handicapped, many current and future technologies could be radically altered. With true instantaneous connectivity, transferability, and control many fantastic prospects could arise. It would certainly change the modern advanced world drastically.

Up until now this advanced technology is something that has only been the subject for sci-fi or futuristic movies but is now becoming possible. “Now that scientists know (BCI) is possible, how far along current accomplishments are, what the estimated time line for further development is, and can these technologies be applied to teaching/learning?” is a BCI question one might ask oneself. “Are we getting close to a Matrix like method of learning?” is a question even the most mundane public may relate to. We are much closer than most people realize may be the answer. Everyday technology that many are beginning to take for granted was formerly only science fiction that has become reality in modern society. This report has offered some details of BCI technology, what is currently possible, what the future may hold, expressed the need for further research in BCI, offered a literature review, and discussed necessary research methodologies on the subject.

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