Brain-Computer Interface (BCI) Research and Development at the Wadsworth Center

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Abstract

Brain-computer interface (BCI) research and development is providing nonmuscular communication and control technology for people who cannot use conventional assistive communication devices, all of which require some muscular control. BCI work at the Wadsworth Center is focused both on improving the capabilities of this new technology and on implementing and validating its clinical applications.

1 Introduction

Brain-computer interface (BCI) research seeks to develop new augmentative communication and control technology for people with severe neuromuscular disorders, such as amyotrophic lateral sclerosis (ALS), brainstem stroke, and spinal cord injury. The goal is to give these users, who may be totally paralyzed ("locked in"), basic communication and control capabilities so that they can express their desires to caregivers or even operate word processing programs or neuroprostheses. Current BCIs determine the intent of the user from scalp-recorded electrical brain signals (EEG), or from electrodes surgically implanted on the cortical surface (ECoG) or within the brain (neuronal action potentials (spikes) or local field potentials (LFPs)). These signals are translated in real time into commands that operate a computer display or other device. Successful operation requires that the user encode commands in these signals and that the BCI derive the user’s commands from the signals. Thus, the user and the BCI system need to adapt to each other initially and continually to ensure stable performance. This dependence on the mutual adaptation of user to system and system to user is a key principle of BCI operation.

2 BCI Research at Wadsworth

2.1 Laboratory Studies

BCI research at the Wadsworth Center focuses on non-invasive EEG-based BCI methods and on moderately invasive ECoG-based methods. We have shown that patients with motor disabilities can learn to control amplitudes of sensorimotor rhythms in scalp-recorded EEG and can use this control to move a cursor rapidly and accurately in one, two, or three dimensions. Current EEG-based multidimensional control is comparable in speed and accuracy to that reported using implanted electrodes (e.g., compare the videos at the first two web sites listed below). We have gone on to develop sequential “reach and grasp” movement control. Parallel studies are underway using ECoG signals recorded from people implanted temporarily with electrode arrays on the cortical surface prior to epilepsy surgery. Initial studies suggest that ECoG may be able to provide communication and control that is faster and more precise than that currently possible with EEG.

2.2 Clinical Studies

At the same time, we are engaged in an effort to demonstrate that a simplified EEG-based BCI system can function reliably in the homes of patients with severe disabilities, can provide them with communication functions that are useful to them in their daily lives, and can do so without requiring excessive ongoing technical support. This simplified BCI system uses our standard general-purpose BCI software platform, BCI2000 (which we have provided to more than 225 other labs throughout the world, for research purposes only). Our BCI home system has a simplified EEG electrode cap and can use either P300 evoked potentials or sensorimotor rhythms as the EEG signal features that provide control. It uses a highly flexible, sequential menu-based format that can be configured for the needs and capacities of each user (e.g., for word-processing, environmental control, entertainment access, e-mail, etc.).

We have provided this BCI home system to a small group of severely disabled users with late-stage ALS for whom conventional assistive communication devices are no longer effective. We are seeking to learn: to what extent they use the BCI system in their daily
lives; to what extent we can minimize the need for ongoing technical support; and to what extent the BCI system improves quality of life for these users and their families and caregivers. The first user is a highly productive NIH-funded scientist with ALS who has only weak eye-movement remaining. He has found the Wadsworth BCI system to be superior to his eye-gaze system. For the past two years, he has been using the BCI up to 6-8 hours/day for e-mail, environmental control, and other purposes. He recently used the BCI to help produce a successful renewal application for his NIH research grant.

Our goal over the next two years is to further improve the capability and reliability of the BCI home system, to provide it to a larger user group of 25-30 people with severe disabilities, and to show that it is useful to them and improves their quality of life. We intend to develop a network of clinical sites, each of which will manage the BCI use of its own patients with assistance from the Wadsworth BCI group as needed. Over the next 5 years, we hope to make BCI technology widely available to those with severe disabilities and to establish a framework that will serve as a pipeline for the clinical validation and subsequent dissemination of new BCI technologies (e.g., ECoG) and applications. New colleagues at Wharton School of Business of the University of Pennsylvania are in the process of establishing a self-sustaining nonprofit foundation to disseminate and support the Wadsworth BCI home system for use by people with ALS and other devastating neuromuscular disorders.

2.3 Support

BCI research at the Wadsworth Center receives or has received support from the National Institutes of Health (NIBIB, NICHD, NINDS), the James S. McDonnell Foundation, the ALS Hope Foundation, The NEC Foundation, and the Altran Foundation.

3 Representative References

3.1 Articles


3.2 Web Sites

http://www.bciresearch.org/html/2d_control_8tn.html
http://www.nature.com/nature/journal/v442/n7099/supinfo/nature04970.html (video 1)
http://www.bci2000.org
http://www.nibib.nih.gov/HealthEdu/eAdvances/28Nov06