Brain-computer interfaces (BCIs) for communication and control: a mini-review.

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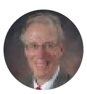

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Brain-Computer Interfaces (BCIs) for Communication and Control

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Categories and Subject Descriptors

J.3 [**Life and Medical Sciences**]: Health; H.1.2 [**Models and Principles**]: User/Machine Systems—*Human information processing*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Input devices and strategies*

General Terms

Design, Experimentation, Human Factors

Keywords

Brain-computer interfaces, augmentative communication and control, neuro-muscular disorders.

1. INTRODUCTION

Brain-computer interface (BCI)) research seeks to develop new augmentative communication and control technology for human patients 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 or local field potentials). 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 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 fundamental principle of BCI operation.

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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 EEG sensorimotor rhythms and can use this control to move a cursor rapidly and accurately in one or two 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 are now going 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 should be able to provide communication and control that is substantially faster and more precise than that currently possible with EEG.

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 120 other labs throughout the world, for research purposes only). Our BCI home system has a simplified electrode cap and can use either sensorimotor rhythms or P300 evoked potentials 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 begun to provide this BCI home system to a selected group of severely disabled users whose current communication methods are extremely limited and/or unreliable. We seek to determine: 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 scientist with ALS who has only eye-movement remaining. He has found the Wadsworth BCI system to be superior to his eye-gaze system. For the past year, he has been using the BCI up to 6-8 hours/day for writing e-mail and for other purposes. We have recently provided two other people similarly disabled by ALS with the Wadsworth BCI home system.

Our goal over the next 2-3 years is to further improve the capability and reliability of the BCI home system, to provide it to an initial user group of 20-30 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 initial clinical validation and subsequent dissemination of new BCI technologies (e.g., ECoG) and applications.

2. ACKNOWLEDGMENTS

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