Abstract

While using a brain-computer interface (BCI), users can learn to self-modulate brain activity to perform a simple computer activity, such as spelling, answering yes or no questions, or moving a cursor on a computer monitor. Recent research has shown that recording from electrocorticogram (ECoG) can provide increased accuracy in these tasks when compared to using an electroencephalogram (EEG). Our research goals include 1) exploring and extending the feasibility of using human electrocorticogram (ECoG) to control several BCI-tasks, and 2) using both motor and sensory modalities for different aspects of control. Patients who are in epilepsy surgery programs and have subdural electrodes implanted for clinical monitoring purposes unrelated to this project participated in this research. For purposes of monitoring their epilepsy, patients typically had electrode grids (64-66 channels) located over the temporal lobe and extending superiorly above the Sylvian fissure. These areas often include auditory centers and facial motor centers near the Sylvian fissure. The BCi2000 software [2] was used for all experiments.

Offline analysis was performed with a battery of motor/sensory/auditory tasks (i.e., screening) that determined which coordinates of the signal the user could most easily modulate. This determined the locations and frequencies that changed with the task compared to rest. To measure and characterize responses to auditory imagery, patients were asked to imagine hearing a variety of common salient environmental sounds, such as a phone ringing, car horn, or the voice of a child in response to a visual cue-target on a monitor. To measure and characterize responses to motor imagery, patients were asked to imagine facial movements.

Online testing gives patients feedback of important brain signal characteristics, allowing voluntary modulation of brain activity to move a cursor to a target on the computer screen. The two modalities (motor and auditory) were each used independently to control movement in the horizontal direction. Once sufficient accuracy is achieved for each modality, the patients were provided with the task of controlling motor and auditory responses simultaneously for cursor control in two dimensions. For example, the auditory component could control vertical cursor movement, and the motor component could control horizontal cursor movement.

Using two control modalities simultaneously provides a unique opportunity to compare brain plasticity of sensory and motor areas. While motor control is often easier and less abstract for the user to modulate and control, it is believed that some sensory areas may be more plastic, potentially adapting to new tasks more quickly and efficiently than motor areas. On the basis of this preliminary data we have observed that bilateral motor and sensory areas are modulated during online task performance.

Methods

We used a multimodal BCI developed at the Wadsworth Center. This BCI system consists of four modules: 1) Data acquisition, 2) signal processing, 3) parameter control, and 4) System parameter controller. Each is interchangeable so that any conceivable design can be implemented without changing the entire system.

ECoG Grid and Screening

UWP15 Results

The first task presented for the user was one-dimensional control of a cursor. Using the data obtained from the screening process, electrodes were assigned a weight and preferred direction. The power content of the signal in the range of 12-15 Hz is measured continuously, and the magnitude is translated into up and down motion of the cursor. The cursor moves at a constant rate from the left side of a computer monitor, and the goal for the patient is to direct it up or down to one of a number of targets.

Day 1: 2 Targets

The patient was able to obtain an accuracy of 100% on the first day of testing for a two-target task after 92.2% runs, each run consisting of 2-8 trials. The overall accuracy was 68.2% (n=18). On the second day of testing, the patient was presented with three targets. The overall accuracy was 56.1% (n=68). We believe that the lower accuracy is due to low system gain, which means that the patient must provide more activity to accomplish a task.

Day 2: 3 Targets

UWP42 Results

After some initial difficulty, a second patient, UWP42, was able to hit 2 targets with little difficulty by the last run (100% accuracy, n=10). In this case, we progressively increased the number of targets up to 6, only missing 1 target out of 50. Day 3 produced varied results due to increased cursor rate and varying the gain of the channels. On day 4 the number of targets was kept at 8, and an accuracy of 94.3% was achieved.

User Task

Brain Control

Future Directions

Comparison of 1D joystick control and brain control cursor movement. UWP42 achieved comparable results in the cursor task using brain control and joystick control. The accuracy for brain control was 86.6% (n = 104), and the accuracy for joystick control was 50.2% (n = 127). Variables such as gain and speed were changed to measure reaction characteristics.

Brain Control

Future Directions

Comparison of 1D joystick control and brain control cursor movement. UWP42 achieved comparable results in the cursor task using brain control and joystick control. The accuracy for brain control was 86.6% (n = 104), and the accuracy for joystick control was 50.2% (n = 127). Variables such as gain and speed were changed to measure reaction characteristics.

Conclusions

Two patients were able to achieve good to superior results using 2 different control strategies. UWP15 learned to modulate both motor and sensory brain signals for cursor control, which could be extended to a 2D “move cursor” task. UWP42 used a different approach. By increasing the power content at all frequencies, UWP42 achieved comparable control of the 1D cursor task, which can be expanded to many other BCI areas. However, it remains unclear if this approach can be expanded to a multi-dimensional task.

References


The authors would like to acknowledge Hans Baeken, Michael Newton, and Tom Pearce for their contributions to this project.