Towards Two-Dimensional Cursor Control Using Electrocorticographic Signals

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Since the discovery about 70 years ago that brain signals can be detected in humans with appropriate equipment, people have theorized that these signals might be used to decipher intentions, so that a person could control devices directly by means of brain activity. This idea has appeared often in popular fiction and fantasy such as the book (and subsequent movie) "Firefox" in which an airplane is controlled in part by the pilot's brain waves. Over the past 20 years, many studies have demonstrated that direct brain control is no longer merely speculation and that it might serve useful functions. Although we cannot yet fly airplanes with brain control, and are unlikely to do so anytime soon, studies have shown that brain signals can allow people with severe disabilities to communicate without using muscles. These devices, which record signals from the brain and translate them into control of an output device, are called Brain-Computer Interfaces or BCIs.

BCI systems can provide communication for people who are totally paralyzed and cannot communicate in any way using conventional methods. While previous studies have shown the potential benefit of BCI systems, current techniques, which use either scalp recording of EEG or intracortical recordings of neuronal action potentials, have drawbacks that have thus far delayed their widespread application outside the laboratory. EEG has low spatial resolution (Freeman, Holmes, Burke, & Vanhatalo, 2003; Srinivasan, Nunez, & Silberstein, 1998), while intracortical recordings have limited long-term stability. An intermediate BCI methodology, using electrocorticographic activity (ECoG) recorded from the cortical surface, could be a powerful and practical alternative to these two extremes. ECoG has higher spatial resolution than EEG (i.e., millimeters vs. centimeters (Freeman et al., 2003), broader bandwidth (i.e., 0-200 Hz vs. 0-40 Hz), higher amplitude (i.e., 50-100 μV maximum vs. 10-20 μV), and far less vulnerability to artifacts such as electromyographic activity produced by muscle contractions (Srinivasan et al., 1998). At the same time, because ECoG is recorded by electrode arrays on the surface of the brain and thus does not require electrodes that penetrate into cortex, it entails less clinical risk and is likely to have greater long-term stability than single-neuron recording. Recent work shows that people can quickly learn to use ECoG signals to control cursor movement in one dimension (Leuthardt, Schalk, Wolpaw J.R., Ojemann, & Moran, 2004). We are currently exploring the use of ECoG for two-dimensional movement control.

The initial subject was a patient with intractable epilepsy who underwent temporary placement of intracranial electrode arrays to localize seizure foci prior to surgical resection. The patient had no prior training on a BCI system. The patient first performed a set of motor and imagery tasks while 32 ECoG channels were digitized and stored with BCI2000 software (Schalk, McFarland, Hinterberger, Birbaumer, & Wolpaw, 2004). An initial evaluation found strong correlations between the tasks and specific ECoG spectral bands. The patient then used actual or imagined actions (e.g., imagined shoulder or finger movement) to control these features so as to move a cursor in two dimensions from the middle of a computer screen to a target occupying one of the four edges of the screen.

The results show that the patient was able to use movement imagery to accurately control a cursor on a computer screen in two dimensions after only minutes of training. If these results are confirmed by further studies, these results significantly increase the possibility that brain-controlled communication devices can be developed that give back to severely paralyzed patients one of humanity's most basic needs: the capacity to communicate with others and to control their environment.

Reference List

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