DOI:10.3217/978-3-85125-260-6-7

Just a Switch: Timing Characteristics of ECoG-Based Assistive Technology Control

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Abstract. In the development of an implantable ECoG-based BCI system, we have investigated the possibilities of generating quick shifts between high and low levels of brain activity ("brain clicks") using voluntarily modulated brain activity. We conclude that it is possible to produce ECoG-based 'clicks' using both motor execution and covert serial subtraction. These 'clicks' can serve as an input for commercially available assistive technology devices, potentially making communication, as well as environmental control, available for locked in patients.

Keywords: BCI, ECoG, assistive technology, subdural, switch, working memory, sensorimotor

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1. Introduction

For most paralyzed patients, there is a variety of commercially available assistive technology available, ranging from devices that turn book pages and robotic arms to dynamic systems that facilitate communication and environmental control, and which can be controlled in a number of ways. For patients with the highest level of paralysis (locked-in syndrome), however, these devices are, so far, less usable because most of them need some form of goal-directed muscle activity to be operated. Brain computer interfaces (BCIs) promise control over devices using brain activity only, thereby potentially improving greatly the communicative abilities, quality of life and independence of this population. The possibilities offered to locked-in patients by a BCI can be maximized if one would make use of the existing commercially available systems, which are the result of years of development and optimization by dedicated people, guided by the wishes of end users. One of the most basic approaches to control an assistive technology device such as a dynamic system is a button press or mouse click. Generating these clicks by brain activity only requires that the user is able to quickly switch on and off the activity in a certain brain area. In the development of an implantable ECoG-based BCI system, we have investigated the possibilities of generating these "brain clicks" using voluntarily modulated brain activity.

2. Material and Methods

Subjects were epilepsy patients who were implanted with subdural ECoG electrodes for diagnostic purposes. Each patient performed a localizer task (movement/rest or covert serial subtraction/rest) with both fMRI and ECoG to select electrodes on motor areas or the dorsolateral prefrontal cortex to be used for the tests. An electrode showing a large response in the 65-95 Hz frequency range during this task was selected for further use. Subsequently, patients performed a second localizer task with shorter intervals of activity and rest. Patients were instructed to respond as quickly as possible to the different conditions. The signal of the preselected electrode was used to estimate an upper and lower threshold for brain activity.

In the Click Target Task, a blue target square was present on the screen (20 trials), for a maximum of 8 s. Patients were instructed to generate the relevant brain activity as quickly as possible once they saw the target. As soon as the patient elicited a switch event, the target changed color and disappeared. The intertrial interval was variable, 3-9 s. A switch was defined as the brain activity crossing the upper threshold as determined by the second localizer task. This task was performed by three patients (Pat1, Pat2, Pat3).

In the Assistive Device Control Task crossing the threshold was translated into a short closing of a relay, simulating a button press. Patients were presented with a commercially available communication device running scanning software, which showed a keyboard on a screen. Lines of characters were highlighted consecutively. When a line was highlighted, it could be selected by activating the switch. Then the individual characters of the row are highlighted for selection. By this method each character of the alphabet can be selected by two activations of the switch. Patients were asked to spell the word ‘UMC Utrecht’. Two patients performed this task (Patients 1 and 4 (Pat1, Pat4)). Both patients had a (slightly different) 6x8 matrix of characters, which included the complete alphabet, a space, a backspace, a clear all button, and a number of blank items.

3. Results

Three patients performed the Click Target Task. Pat1 used executed movement of the right hand, and Pat2 and 3 used covert serial subtraction. All patients performed well during the Click Target Task, with 90% or more of the targets ‘clicked away’ within the maximum trial time of 8 s. For the patient using executed hand movement (Pat1), the average time needed to generate the switch event was 1.3 s (range 0.8-4.6 s), with 2 false alarms (i.e. switch events generated during the intertrial interval). Pat2 and 3 each performed the Click Target Task 3 times using serial subtraction. The average time they needed to generate the switch events was variable, but was between 2 and 3 s for each session (range of all trials of both patients 0.2-7.7 s).

Two patients (Pat1, Pat4) performed the Assistive Device Control Task using executed movement of the right hand (Pat1) or the tongue (Pat4). The scanning software was set such that the interval between two highlighted selections was 2.1 s. Both patients needed ~4 min to spell the words ‘UMC Utrecht’, with a mean time per character of 20.6 ± 7.8 s, and 22.8 ± 7.8 s, respectively. Pat1 had three misses, which required the system to perform another cycle of scanning before a second attempt to select the character could be made. Pat2 had two misses and two false alarms, which did not result in an incorrectly selected character.

4. Discussion

The data from this study reveal that subjects are able to voluntarily produce quick alternations between high and low levels of brain activity using both motor execution and covert serial subtraction, without a lot of practice. Moreover, these voluntarily generated ‘brain clicks’ can be used as a control signal for a commercially available assistive technology device running scanning software.

Not surprisingly, the speed with which switch selections were made in the Click Target Task was faster for motor execution than for covert serial subtraction. Even with serial subtraction, however, switch events were made in 3 s or less, which would allow 20 selections per min. In an actual scanning environment, it was possible to spell words with a speed of about 3 characters per min using ‘brain clicks’ based on motor execution. This value is comparable to several custom spellers: an EEG switch based Hex-O-Spell [Williamson et al., 2009] (2.5-7 characters per min) and ECoG studies with a P300 speller [Krusienski and Shih, 2010] (2.3-4.4 characters per min). [Brunner et al., 2011] report 17 characters per min with one patient. Importantly, the spelling speed in our setup may be increased by optimizing parameters, and practice.

We conclude that it is possible to voluntarily generate ECoG-based ‘clicks’, which can serve as an input for commercially available assistive technology devices, potentially making communication, as well as environmental control, available for locked in patients.

Acknowledgements

We would like to thank the subjects of our study for their effort. We also thank Cyrille Ferrier, Frans Leijten, Tineke Gebbink, Peter Gosselaar, Peter van Rijen and the Clinical Neurophysiology Team for their contributions. This research is supported by the Dutch Technology Foundation STW, applied science division of NWO and the Technology Program of the Ministery of Economic Affairs, and the University of Utrecht, grant UGT7685.

References

Brunner P, Ritaccio AL, Emrich JF, Bischof H, Schalk G. Rapid Communication with a “P300” Matrix Speller Using Electrocorticographic Signals (ECoG). *Front Neurosci*, 5:5, 2011.

Krusienski DJ, Shih JJ. Control of a visual keyboard using an electrocorticographic brain-computer interface. *Neurorehabil Neural Repair*, 25:323-331, 2011.

Williamson J, Murray-Smith R, Blankertz B, Krauledat M, Müller K-R. Designing for uncertain, asymmetric control: Interaction design for brain-computer interfaces. *Int J Hum Comput Stud*, 67:827-841, 2009.