PLUG-AND-PLAY BRAIN-COMPUTER INTERFACE USE BY PEOPLE WITH AMYOTROPHIC LATERAL SCLEROSIS

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INTRODUCTION

Brain-computer interfaces (BCIs) are intended to allow people with paralysis to operate technology without moving. However, BCIs have typically been designed as stand-alone devices without the capability to interface with other technologies. This design limits what BCI technology can provide to the people who need it. While some studies have included BCI operation of commercial technology [1-3], they required custom programming to establish the interface that would not be possible for most clinicians. A BCI that could operate as a plug-and-play replacement for a physical keyboard could serve as a true interface, making any device that can be operated by a standard universal serial bus (USB) keyboard into a BCI-operated device.

The electroencephalography (EEG)-based P300 BCI design[4] is most appropriate for a keyboard replacement device. In this design, a grid of options, typically letters, is presented to the subject on a computer screen. The BCI user pays attention to a desired letter while rows and columns of the grid flash. When the desired letter flashes, this generates a brain signal known as a P300, which can be detected by the BCI after several repetitions of flashes of all the rows and columns. The letter at the intersection of the row and column that produce the P300 is then generated by the BCI.

Plug-and-play capabilities were added to the BCI2000 research and development platform [5] and initial testing performed with people without physical impairments [6]. These tests showed that the accuracy of BCI text generation was not significantly different when the BCI was used in a stand-alone mode, or used to operate two commercially available target devices, a DynaWrite communication device and a laptop computer. However, in the current implementation of the plug-and-play BCI, there is some distance between the BCI screen and the target device screen, which could be an issue for people with physical impairments. Further, BCI performance for people with physical impairments has been shown to be lower than for people without physical impairments [7]. The study presented here tested plug-and-play BCI performance with people with amyotrophic lateral sclerosis (ALS) to determine if BCI character generation accuracy varied based on target device.

METHODS

Subjects with ALS who had some impairment of hand or arm function were recruited from the University of Michigan's Motor Neuron Disease Clinic. Degree of impairment from ALS was measured using the ALS functional rating scale, revised (ALSFRS-R) [8] where a maximum score of 48 indicates no disability

BCI performance testing with different target devices is described in detail in [6]. Briefly, subjects participated in three testing sessions in the University of Michigan Direct Brain Interface laboratory or their homes. The BCI screen was placed about 0.8 meters in front of the subject with the DynaWrite screen below and the laptop screen to the right. The BCI was configured for the individual subject in the first session. The subjects then used the BCI to copy 23-character sentences into each target device (BCI, DynaWrite, laptop), using a backspace selection to correct errors. The order of target devices was counterbalanced across the three sessions to eliminate bias by device order. Time to copy each sentence was limited to 15 minutes.

Accuracy of BCI typing with each target device was compared by calculation of the confidence intervals for the devices to determine 1) if accuracy met the accepted minimal accuracy of 70% [9], and 2) if variations in accuracy occurred based on target device.

RESULTS

Data are reported from 10 subjects with ALS (7 men and 3 women) who completed the 3-session data collection protocol. Age ranged from 45-78 years with mean 62 years. ALSFRS-R scores ranged from 18 to 41 with a mean of 29. For individual subjects, mean accuracy over all devices was in the range 46% to 96% with 6 of 10 subjects having accuracies above 70%. Variations by target device for individual subjects were relatively small (Figure 1). Overall accuracy had a mean of 77% ± 20% (standard deviation). Means and confidence intervals by target device are shown in Table 1.

Table 1: Accuracy means, standard deviations and confidence intervals by target device.

Target Device	Mean	Standard Deviation	Confidence Interval
BCI2000	78%	20%	71% - 85%
DynaWrite	77%	21%	70% - 85%
Laptop	76%	20%	69% - 84%

DISCUSSION

Accuracy of BCI text generation varies only slightly by target device. Confidence intervals are largely above 70% and show only minor differences by target device. Thus, the plug-and-play BCI paradigm seems appropriate for use by people with ALS.

However, the wide range of accuracies for individual subjects and the low accuracy exhibited by some of the subjects is a matter for concern. The mean accuracy was above 90% for 4 subjects and accuracy seems unrelated to more advanced disability, as subject H159 had the lowest ALSFRS-R score of 18 yet a mean accuracy of 83%. However, the variability of results indicates that there are factors unrelated to target device or disease disability as measured by the ALSFRS-R that impact overall BCI performance.

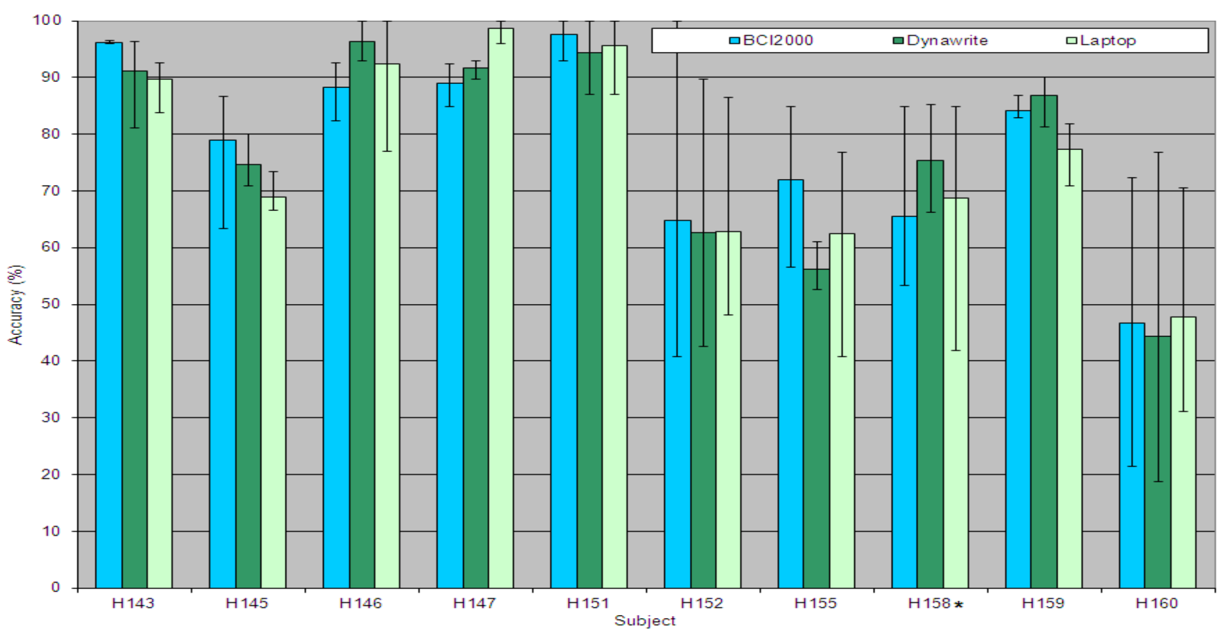

Figure 1: Accuracy of text generation in each environment by subject. Error bars show minimum and maximum accuracy with each device across the three sessions.

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