 DOI:10.3217/978-3-85125-260-6-29

# EEG Correlates of Performance During Long-Term Use of a P300 BCI by Individuals With Amyotrophic Lateral Sclerosis

**Y. Shahriari[1], T. M. Vaughan[2], D. E. Corda[2], D. Zeitlin[3], J. R. Wolpaw[2], D. J. Krusienski[1]**
*[1]Old Dominion University, Norfolk, VA; [2]Wadsworth Center, Albany, NY; [3]Helen Hayes Hospital, West Haverstraw, NY*

Correspondence: Y. Shahriari. E-mail: yshah001@odu.edu

***Abstract.*** People with amyotrophic lateral sclerosis (ALS) are using BCI 24/7, a P300-based brain-computer interface (BCI) system, independently, in their homes, for work and play. At the same time speed and reliability remain important issues for these independent users. This study seeks to correlate the EEG in six frequency bands (0-30 Hz), collected from eight electrode locations, as features in a linear model to predict if a P300-based BCI session will be successful. Data were collected from six home users during a copy-spelling calibration task. These data were divided into sessions with accuracy greater than or less than 70%. The prediction accuracy for session performance using information from the frequency bands was 82.72%. Better understanding of which EEG features are correlated with success could lead to better performance and greater system reliability.

*Keywords:* Brain-Computer Interface, Event-Related Potential, P300 Speller, Amyotrophic Lateral Sclerosis

## 1. Introduction

Studies demonstrating long-term use of a P300-based brain-computer interface (BCI) by individuals with amyotrophic lateral sclerosis (ALS) reveal considerable variation in day-to-day performance [Sellers et al., 2007; Nijboer et al., 2008] not observed in able-bodied subjects [Krusienski et al., 2008]. This may be explained by changes in attention in ALS patients that have been related to frontal lobe pathology [Bathgate et al., 2001]. In a study of 20 ALS patients, nine had some degree of cognitive impairment and five of these met the criteria for behavioral variant frontotemporal dementia (bvFTD) [Lillo et al., 2012]. Symptoms of FTD include changes in sleep patterns, verbal disfluency, decreased attention, working memory, and responses to sensory stimuli. These factors are likely to affect P300 Speller performance. Mak and colleagues examined the relationship of a wide variety of EEG features and found that root-mean-square amplitude, the negative peak amplitude of event-related potentials at five electrode locations, and the power in the theta frequency band for eight electrode locations were correlated with performance [Mak et al., 2012]. The present study undertakes to use an alternate and more direct approach to examine the relationship between EEG spectral features and performance in independent BCI use by six individuals with ALS.

## 2. Methodology

The data are comprised of EEG recorded from six individuals with ALS (4M, 2F; average age 53.4) who used a P300-based BCI independently in their homes for communication and control over months and years [Sellers et al., 2010; Winden et al., 2012]. All six subjects wore an elastic cap (Electro-Cap International) with eight electrodes (Fz, Cz, Pz, Oz, P3, P4, Po7, Po8) [Krusienski et al., 2007]. All locations were referenced to the right mastoid with the left mastoid serving as a ground. The EEG was amplified (g.tec Medical g.USBamp); digitized at 256 Hz; and band-pass filtered at 0.5-30 Hz. All aspects of the experiments were controlled by BCI2000. Subjects performed a brief copy-spelling task for offline calibration several times a week during regular home use of the BCI. This copy-spelling task consisted of spelling 20-40 prescribed characters using either the row-column (RCP) [Donchin et al., 2000] or the checkerboard (CBP) presentation [Townsend et al., 2010]. For consistency, the first 20 characters from each session were included in the analysis. Stimulus flash rate and flash sequence number were optimized for individual subjects and sessions, and they are not considered in the present analysis. All subjects had significant performance variations over sessions as indicated in Table 1.

The offline accuracy on a copy-spelling task (i.e., performance) for each session was determined using stepwise linear discriminant analysis (SWLDA) and five-fold cross validation. Sessions having an accuracy above 70% were labeled successful and sessions below 70% were labeled as unsuccessful [Kübler et al., 2001]. The data for each session was segmented by character and the average power for each segment was computed in six frequency bands:

delta (0-4 Hz), theta (5-8 Hz), alpha1 (9-11 Hz), alpha2 (12-14 Hz), beta1 (15-25 Hz) and beta2 (26-30 Hz) [Mak et al., 2012]. A support vector machine (SVM) classifier with linear kernel function was used to classify the spectral features to predict the session labels. Five-fold cross validation was performed where the features corresponding to 50 randomly-selected characters were used for training and the remaining characters for testing.

## 3. Results

Table 1 shows the session parameters and performance predictions for each subject. The accuracy is the result of the five-fold cross validation for predicting successful (> 70%) or unsuccessful sessions (< 70%) using the spectral features. The sensitivity and specificity are included to indicate that the classification results are not biased due to an imbalance of successful and unsuccessful sessions.

***Table 1.*** *Session information and prediction results.*

| **Subject** | **A** | **B** | **C** | **D** | **E** | **F** | **Average** |
|---|---|---|---|---|---|---|---|
| *Presentation* | CBP | CBP | CBP | RCP | RCP | RCP | |
| *No. Sessions Evaluated* | 32 | 6 | 14 | 11 | 38 | 31 | |
| *No. Session. > 70%* | 8 | 4 | 10 | 4 | 17 | 21 | |
| *Range of Session Accuracies (%)* | 4-87 | 38-90 | 37-98 | 2-90 | 8-95 | 33-96 | |
| *Duration of BCI Use (months)* | 13 | 1.5 | 19 | 4 | 7 | 6 | |
| **Session success vs unsuccess prediction** | | | | | | | |
| *Accuracy (%)* | 72.04 | 97.19 | 91.39 | 98.87 | 69.85 | 67.02 | **82.72** |
| *Sensitivity (%)* | 73.61 | 97.43 | 86.14 | 99.18 | 74.17 | 61.77 | **82.05** |
| *Specificity (%)* | 67.51 | 97.21 | 93.68 | 98.45 | 64.55 | 69.92 | **81.88** |

## 4. Discussion

These results indicate that simple spectral features can be used to reliably predict P300 Speller performance for a given session. An analysis of the individual features indicated that the theta and alpha1 frequencies have the highest correlation with session performance for most subjects. However, locations of the highly-correlated features did not generalize across subjects. Better understanding of the mechanism of successful BCI use may lead to improved classification, and thus, better more reliable performance. Further this approach might provide BCI users about their BCI readiness on a given day. Such information may save time and effort, and help the user avoid frustration.

### References

Bathgate D, Snowden JS, Varma A, Blackshaw A, Neary D. Behaviour in frontotemporal dementia, Alzheimer's disease and vascular dementia. *Acta Neurol Scand*, 103(6):367-378, 2001.

Donchin E, Spencer KM, Wijesinghe R. The Mental Prosthesis: Assessing the Speed of a P300-Based Brain–Computer Interface. *IEEE Trans Rehabil Eng,* 8(2), 2000.

Krusienski DJ, Sellers EW, McFarland DJ, Vaughan TM, Wolpaw JR. Toward enhanced P300 speller performance. *Neurosci Meth*, 167:15-21, 2007.

Kübler A, Kotchoubey B, Kaiser J, Wolpaw JR, Birbaumer N. Brain-computer communication: unlock the locked-in. *Psychol Bull*, 127:358-375, 2001.

Lillo P, Savage S, Mioshi E, Kiernan MC, Hodges JR. Amyotrophic lateral sclerosis and frontotemporal dementia: A behavioural and cognitive continuum. *Amyotroph Lateral Sc*, 13(1):102-109, 2012.

Mak JN, McFarland DJ, Vaughan TM, McCane LM, Sellers EW, Wolpaw JR. EEG correlates of P300-based brain-computer interface (BCI) performance in people with amyotrophic lateral sclerosis. *J Neural Eng*, 2012.

Nijboer F, Sellers EW, Mellinger J, Jordan MA, Matuz T, Furdea A, Halder S, Mochty U, Krusienski DJ, Vaughan TM, Wolpaw JR, Birbaumer N, Kübler A. A P300-based brain-computer interface for people with amyotrophic lateral sclerosis. *Clin Neurophysiol*, 119(8):1909-1916, 2008.

Sellers EW, Vaughan TM, Wolpaw JR. A brain-computer interface for long-term independent home use. *Amyotroph Lateral Sc*, 11(5):449-455, 2010.

Townsend G, LaPallo BK, Boulay C, Krusienski DJ, Frye GE, Hauser CK, Schwartz NE, Vaughan TM, Wolpaw JR, Sellers EW. A novel P300-based brain-computer interface stimulus presentation paradigm: moving beyond rows and columns. *Clin Neurophysiol,* 121:1109-1120, 2010.

Winden S, Carmack CS, Corda DE, McFarland DJ, Zeitlin DJ, Tenteramano L, Vaughan TM, Wolpaw JR. BCI-360: Full-service support for independent home-based BCI use and for translational studies. *Society for Neuroscience Annual Meeting*, 2012.