

EEG features correlated with performance in P300-based BCI operation: a long-term case study in a home user with amyotrophic lateral sclerosis

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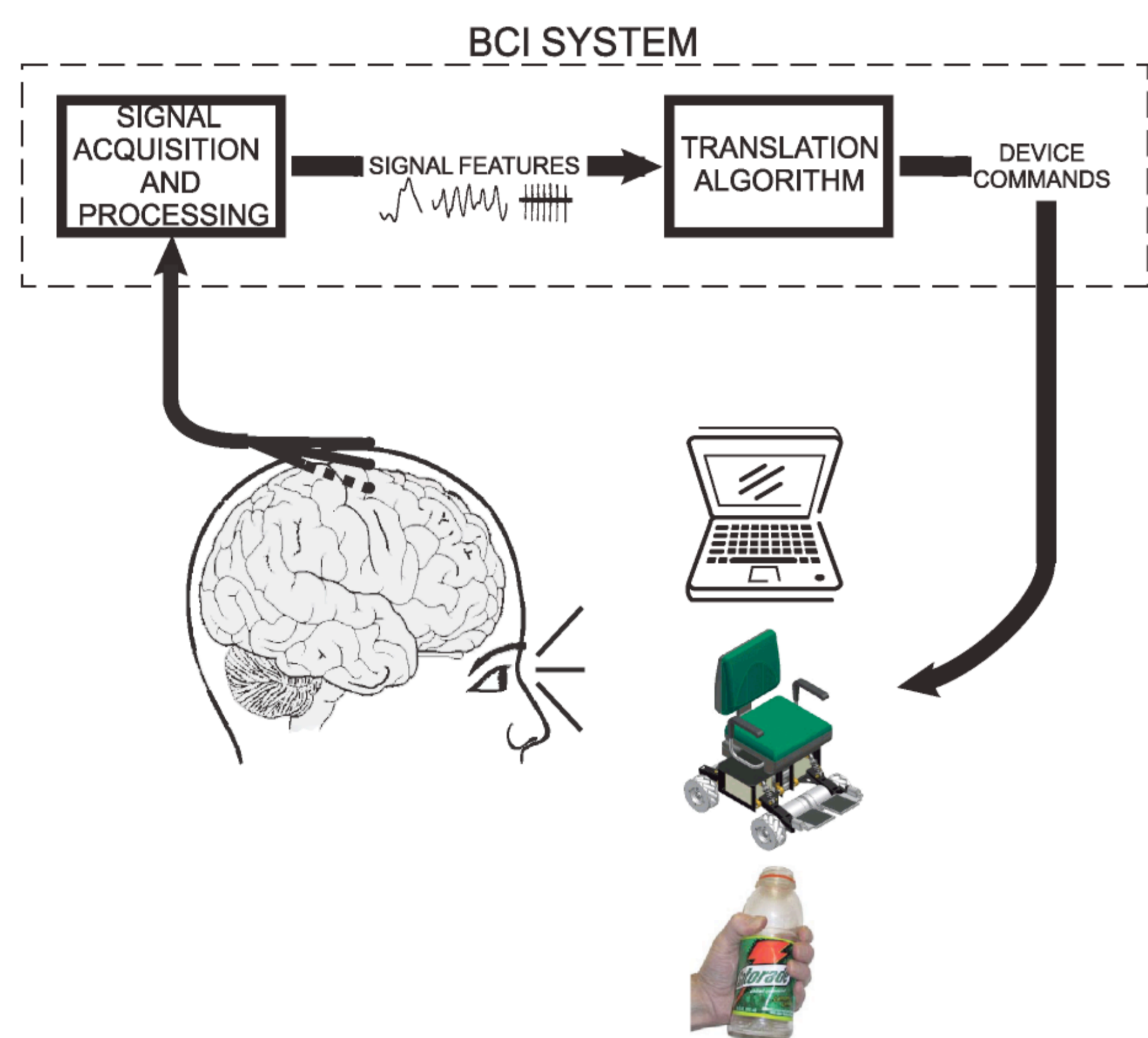
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Introduction

Brain-computer Interface (BCI)

BCI technology can provide patients with severe motor disabilities with a new non-muscular communication and control channels, for conveying messages and commands to the external world (Wolpaw et al, 2002).

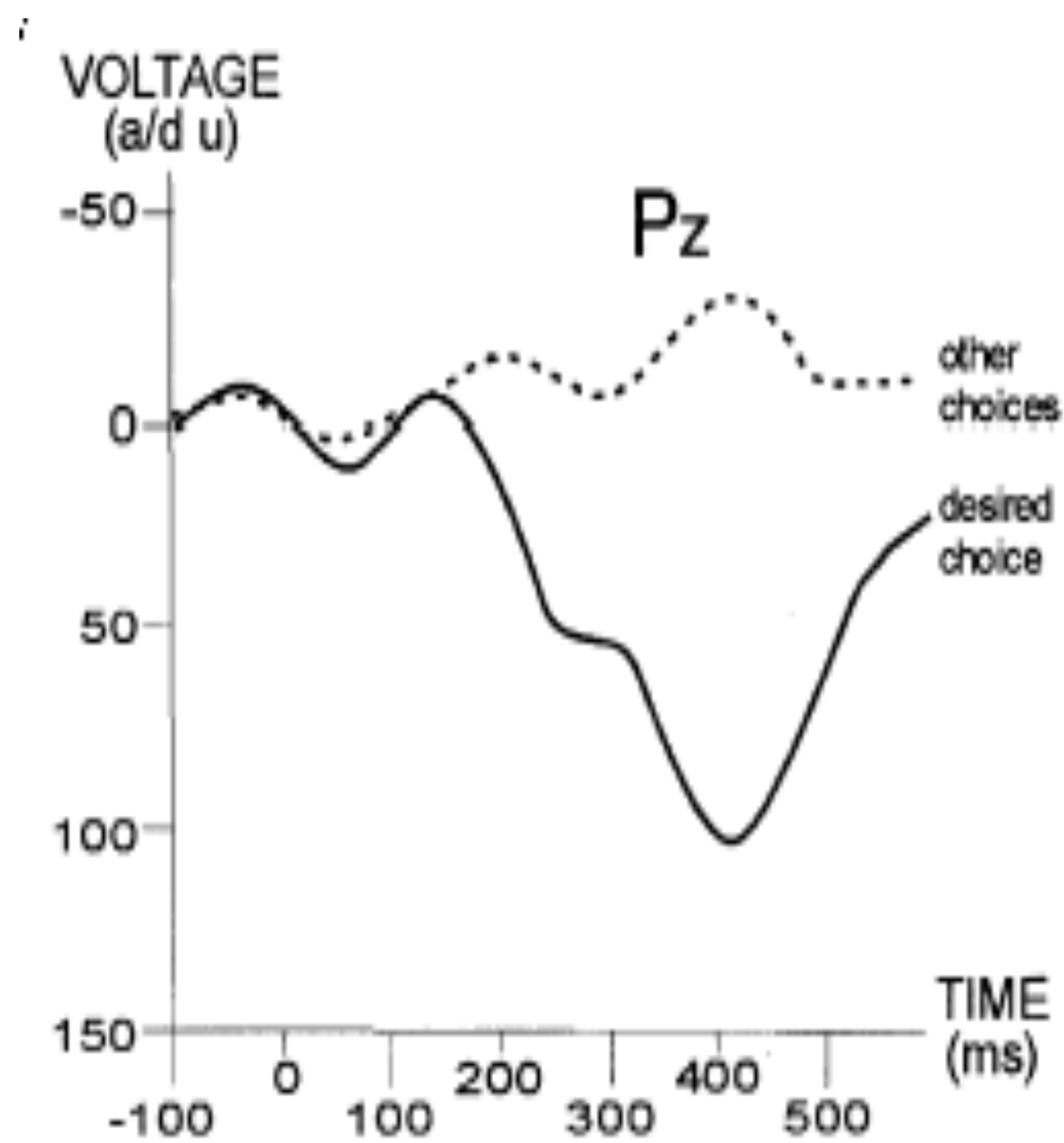
(see below for basic design and operation of BCI system)



P300-based BCI

P300 is a positive wave that occurs about 300ms after the target (i.e. oddball) stimulus.

(see below target response (P300) and non-target response recorded from location Pz)



An EEG-based BCI system that detects the P300 event-related potential and classifies the signal can allow users to select items from a matrix consisting of letters, numbers, and function calls (Donchin et al, 2000).

Clinical application of P300-based BCI

Our laboratory seeks to realize independent home-use of P300-based BCI by severely disabled individuals. User performance varies over days and / or sessions. This variation is largely unexplained. In an earlier study (Mak et al, 2009), we found that P300-based BCI performance (i.e., accuracy) correlated with the test data but not with classifier training data.

Objective

The present study set out to identify EEG features that correlate with P300-based BCI performance in the first long-term home user a man severely disabled by amyotrophic lateral sclerosis (ALS).

Methods

Subjects

Our first Home-user (H1).
51 year-old research scientist with amyotrophic lateral sclerosis (ALS).

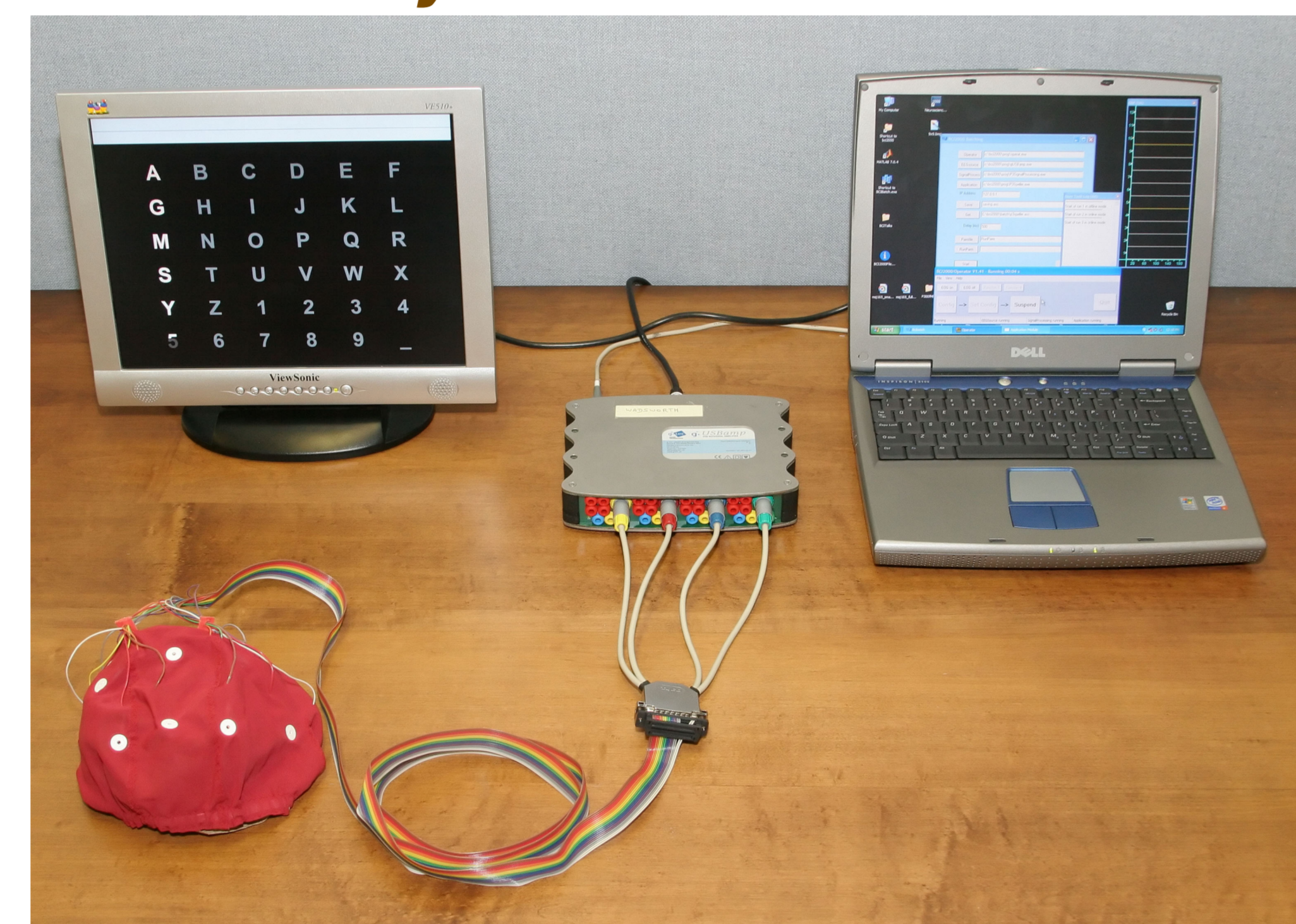
Condition

Only remaining muscle control consists of weak eye-movements.

BCI usage

6-8 hours per day i) to communicate via email with family and friends, ii) to supervise his medical research laboratory for environmental control.

BCI HomeSystem



Data analysis

EEG recorded from Fz, Cz, P3, Pz, P4, PO7, Oz, PO8 (see montage figures on the right).
155 copy-spelling runs over 12 months were analyzed.
18 letters per run.
Mean accuracy = 79(+/- 12)% (chance accuracy = 1.4%)

Temporal and Spectral features were extracted from each of the eight channels used online:

Frequency-domain features from background EEG:
1. Delta power (0.5 - 4 Hz)
2. Theta power (4.5 - 8 Hz)
3. Apha1 power (8.5 - 11 Hz)
4. Apha2 power (11.5 - 14 Hz)
5. Beta1 power (14.5 - 25 Hz)
6. Beta2 power (25.5 - 35 Hz)
7. Gama power (> 35.5 Hz)
Time-domain features from ERPs of target responses:
1. Peak amplitude
2. Latency of Positive peak
3. Negative peak amplitude
4. Latency of negative peak
Feature matrix (155 runs x 11 features x 8 channels).

Statistical prediction model

The feature matrix was processed by Stepwise multivariate linear regression analysis to build prediction model for P3speller online performance.
Only components significantly improve performance predicability were kept in the model.

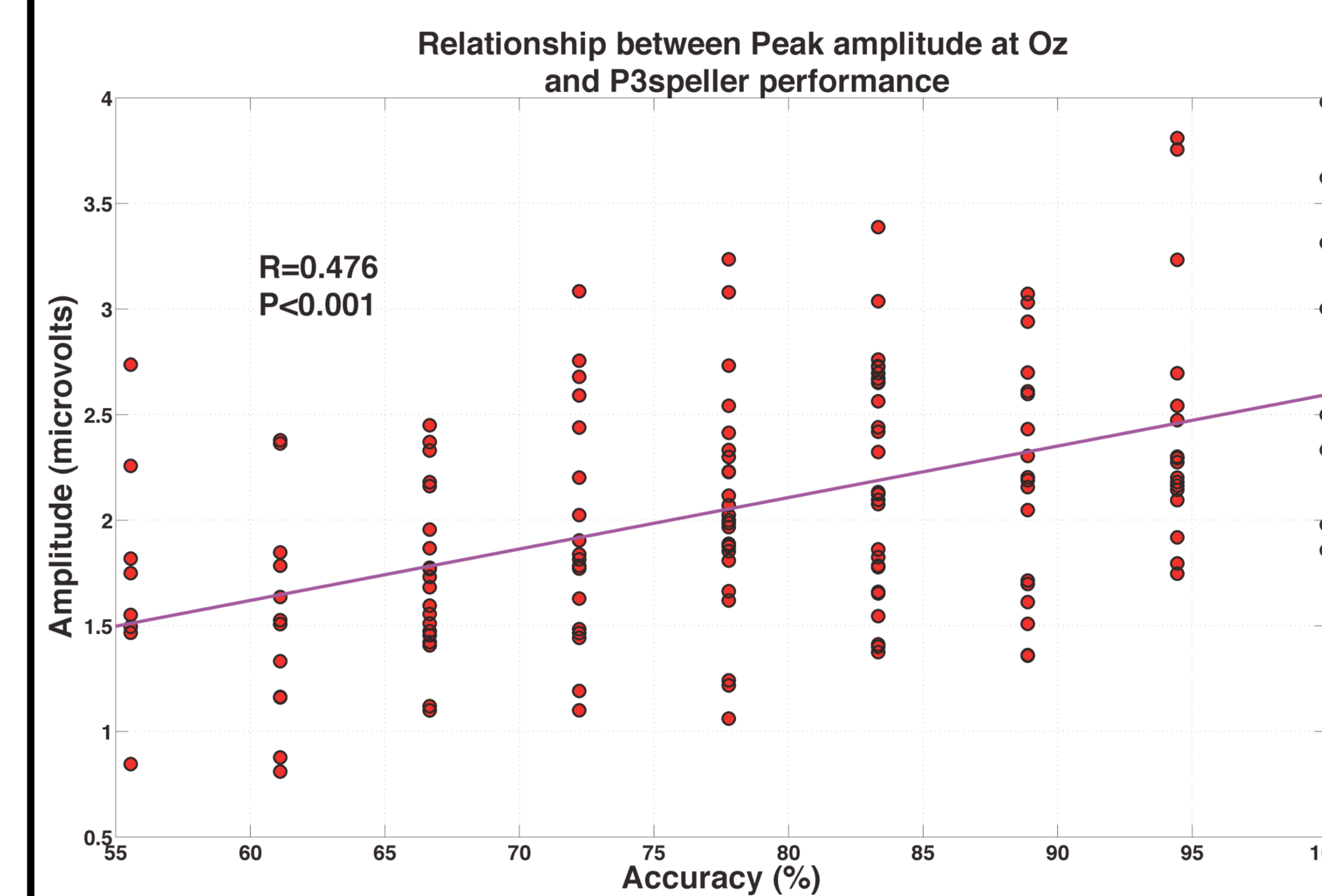
Results

Statistical prediction model

Successfully predicts P300 speller online performance of H1 ($R = 0.579$; $P < 0.001$).
Components selected by the model: 1) Peak amplitude of Target response at Oz, 2) Theta power at Cz.

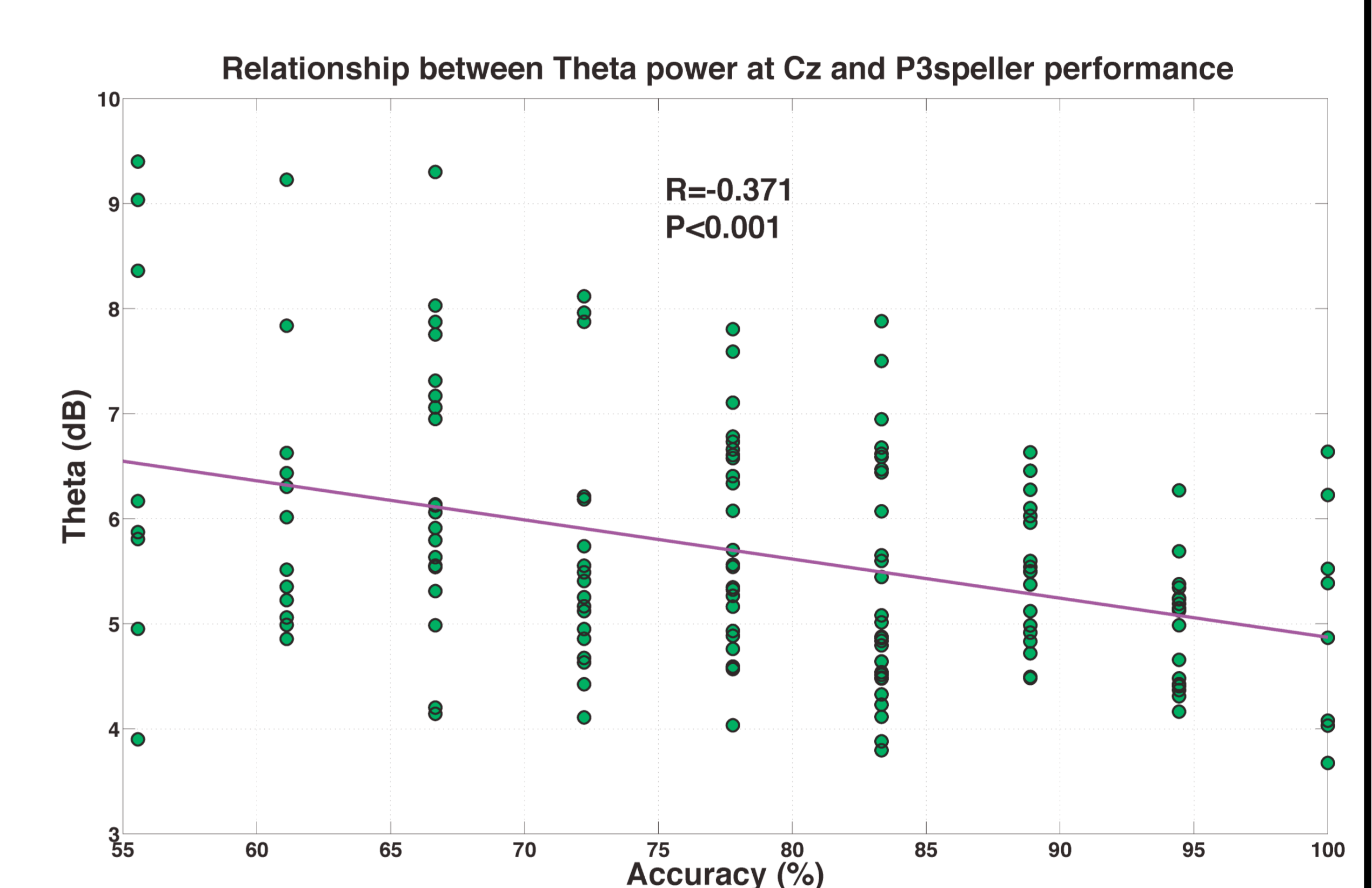
Peak amplitude at Oz

Oz - Positively related to P3speller performance



Theta at Cz

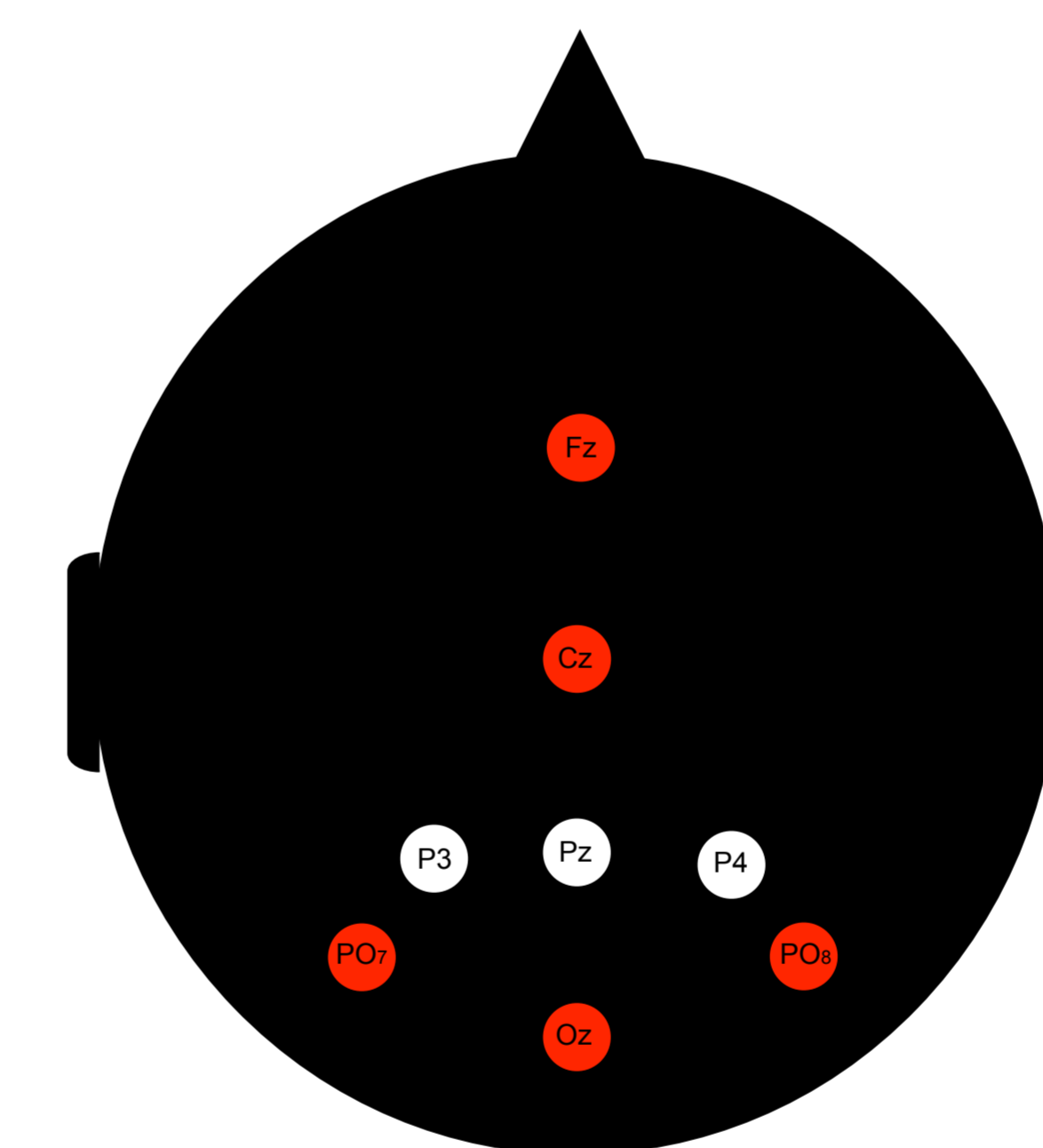
Cz - Negatively related to P3speller performance



In general,

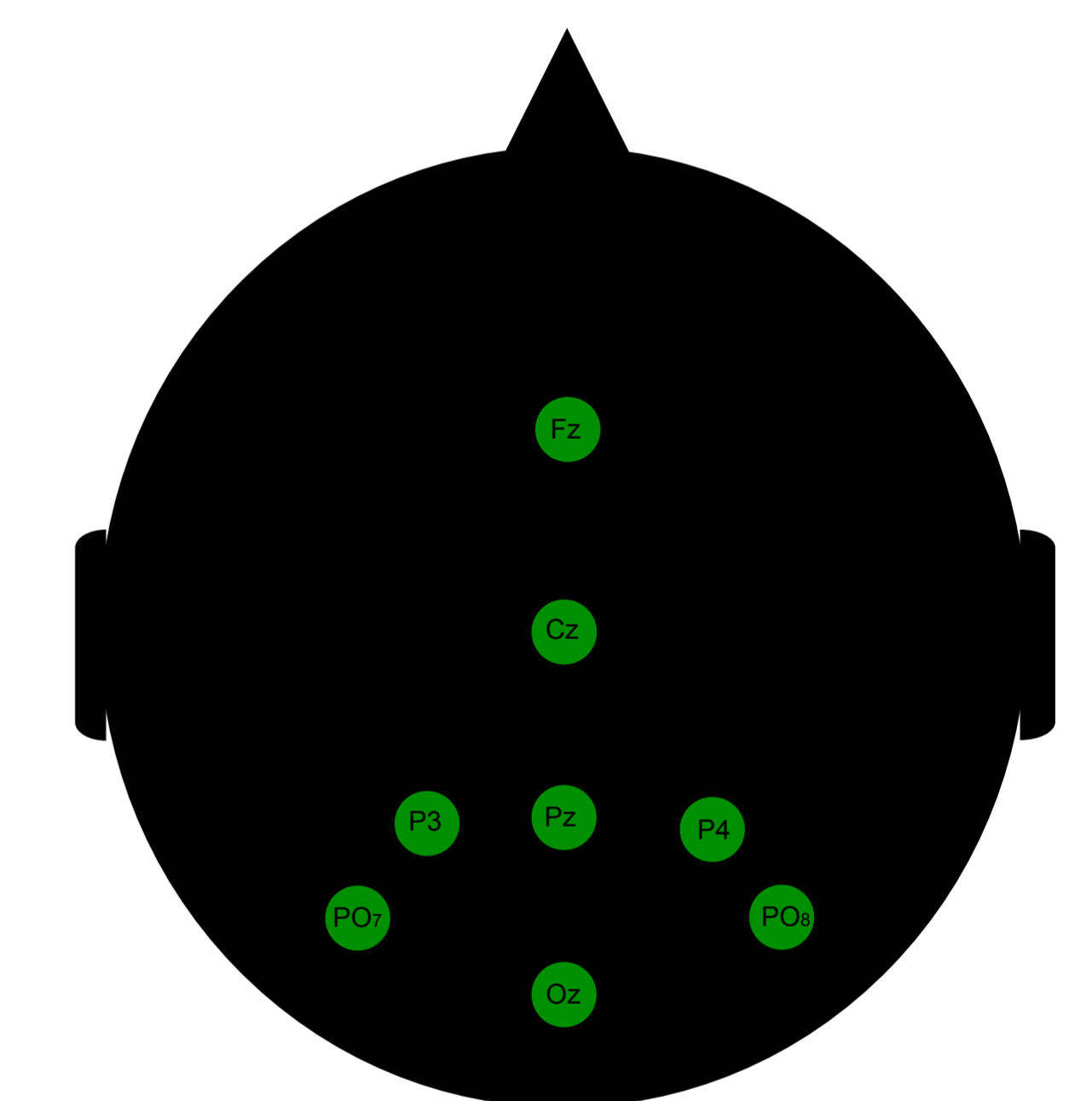
Peak amplitude of Target response

Positively related to P3speller performance ($P < 0.05$).
Significant correlated channels are highlighted in RED.



Theta power

Negatively related to P3speller performance ($P < 0.05$).
Significant correlated channels are highlighted in GREEN.



Conclusion

The results suggest that P300-based BCI performance might be improved by:

- Using Theta power to assess online reliability of concurrent responses
- Modifying stimulus presentation parameters (e.g., matrix size, matrix intensity stimulus rate, etc.) so as to increase the amplitude of the target response and/or minimize theta activity
- Developing user training methods that increase the amplitude of the target response and/or minimize theta activity

Such user-specific improvements might substantially increase the capacity and reliability of P300-based BCI systems for long-term home use by people with severe disabilities.

Further work is needed to assess the generalizability of these predictors to other home user.

Acknowledgments

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