P300 Matrix Speller: Rate, Accuracy, and Effects of Practice

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Introduction

- Brain computer interface (BCI) is technology that uses noninvasive electroencephalography (EEG) to record the neural activity of the brain and convert it into alternative outputs to run electronic devices requiring no motor output. [1]
- One population of people who can benefit from BCI is people with severe motor disabilities who experience "locked-in syndrome" and have limited communication.[2]

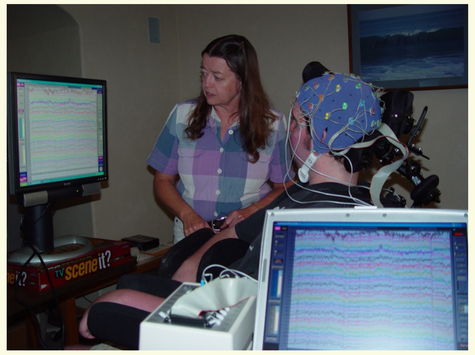


Figure 1:BCI technology can enhance quality of life for people with motor disabilities. Dr. Patti Davies of the Brainwaves Research Lab collecting EEG data from a client with a motor impairment.

Purpose

- Provide a basis for analyzing performance of the P300 speller module of the BCI2000 software across multiple sessions.
- Assess usability of the P300 speller module of the BCI2000 software.

Research Question

- What are the effects of practice on spelling accuracy for the P300 speller module of the BCI2000 software?

Hypothesis

- Spelling accuracy will increase with practice.

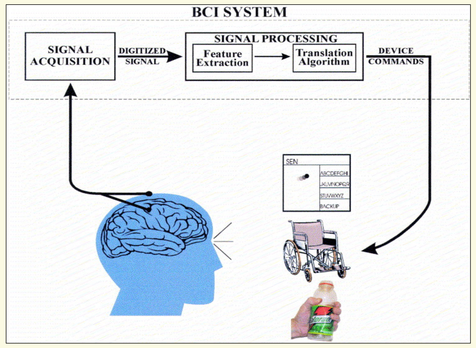


Figure 2: General diagram of a BCI system.

Technology and Software

BCI2000 System:

- The BCI2000 is a general purpose software available as a standard platform to facilitate BCI research.3
- This study utilized the BCI2000 in combination with the Biosemi ActiveTwo EEG system.

P300 Speller

- This study utilized a copy spelling function where the word or phrase to be spelled was displayed at the top of the screen. Spelling results were displayed directly below. See Figure 3.
- Contained a 6x6 matrix whose rows and columns flashed randomly at rapid rates. See Figure 3.
- Each row/column is illuminated for 125ms with a 125ms ISI.
- Rate is held constant across all trials at 1.33 characters per minute.

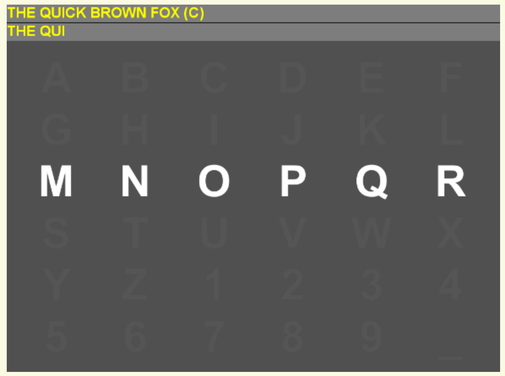
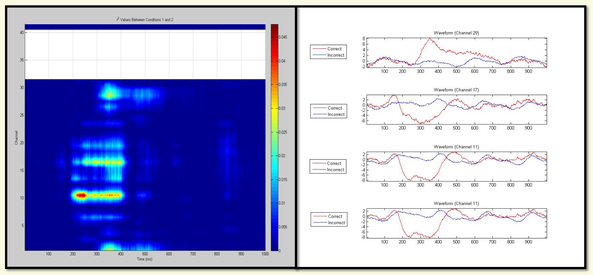


Figure 3: P300 speller with 6x6 matrix showing one of the rows illuminated.

Biosemi ActiveTwo: Electrophysiological Measurements

- 32 scalp sites, 2 bipolar eye monitors
- Recorded at 1024 Hz sample rate



Figures 4 and 5: RMS (left) and ERP (right) plots of a participant's calibration data.

Study Design

Participants

- 7 neurotypical adults (ages >18)
  - Male: 2, Female: 5
  - Average age: 26.29 years (SD= 10.21)

Procedure

- Participants were asked to make 5 visits to the lab within one week at about the same time each day.
- Participants were instructed to count the number of times each target letter flashed for each word or phrase presented.
- The first part of the session involved spelling the same 4 words each day, "THE, QUICK, BROWN, FOX." These words were used to train the classifier. See Figure 6.
- The second part of each session involved spelling words and phrases in real time. The pre and post tests used the same two phrases. The practice sessions used words of increasing complexity. See Figure 6.
- The number of characters was held constant across all sessions.

Session #	Session Type	Character Type	Word/Phrase	Total # of Characters
0	Each Session	Training	THE, QUICK, BROWN, FOX	16
1	Pre-test	Phrases	A-LONG-TIME-AGO, BE-QUIET-PLEASE	30
2	Practice 1	2-3 letter words	OF, TO, LAY, AND, IN, WAS, ARE, OR, MY, ON, BUT, NOT	30
3	Practice 2	4-5 letter words	LIKE, EACH, MORE, OTHER, FROM, MAKE, ABOUT	30
4	Practice 3	Phrases	IT-IS-HIS-RADIO, ONE-CAR-FOR-YOU	30
5	Post-test	Phrases	A-LONG-TIME-AGO, BE-QUIET-PLEASE	30

Figure 6: Summary of study design

Calibration

- A linear discriminant analysis (LDA) classified the participant's brain response to each flash as either a target or a non-target letter.
- RMS plots of these data indicated the power (brain activity intensity) across times (in ms) and channels (2 to 4 of the highest activity points were selected). See Figure 4.
- Event-related potential (ERP) plots of these data illustrated the discrimination between target and non-target letters for the channels selected from the RMS plots. See Figure 5.

Participants	Day 1 %	Day 2 %	Day 3 %	Day 4 %	Day 5 %
V001	10%	87%	83%	100%	73%
V002	43.33%	36.66%	50%	57%	27%
V003	36.67%	43.33%	33%	23.33%	36.67%
V004	93%	43.3%	43.3%	56.67%	80%
V005	80%	93%	70%	93%	93.33%
V006	77%	47%	33%	47%	63%
V007	17%	83%	47%	90%	97%
V008	87%	37%	30%	47%	40%
V009	90%	83%	93%	90%	100%
Averages	**59%**	**61%**	**54%**	**67%**	**68%**

Figure 7: Percentage correct (for all participants across all days) and averages by day.

Results

- Between days 1 and 5, 4 participants' accuracy improved, 4 participants' accuracy declined, 1 participants' accuracy stayed the same. See Figure 7.
- Accuracy improved 16% from both session 1 to 4 and from sessions 1 to 5.
- The targets showed increases in the N200 amplitude 240-360ms at parietal sites in the initial sessions and P300 amplitude changes from 350-460ms at frontal sites.
- Participants' average usability rating for the P300 speller was 6.9 out of 10 with 0="not usable" and 10="definitely usable."

Discussion

- The mean performance improved from session 1 to session 4 and from session 1 to session 5, but not significantly so.
- The N200 component was consistently used by the classifier to distinguish target and non-target letters indicating that the system does not exclusively use the P300 component for real-time analysis as the literature indicates.
- The presence of the P300 component at frontal sites indicates later sessions may involve more executive processing in comparison to initial sessions.
- This study provides a basis for analyzing BCI performance across sessions and may yield strategies for improving BCI systems for clients.
- With the data collected from this study more effective techniques may be developed to train clients on the BCI2000 system.
- This study will advance our knowledge in the application of BCI and allow us to begin to translate these results into the home of persons with severe motor impairments.

References

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2. Anderson, C., Davies, P. L., Gavin, W.J. (2011) Removing Barriers to the Practical Use of Non-Invasive Brain-Computer Interfaces. Abstract for Grant Proposal to NSF. Colorado State University. Fort Collins, CO.
3. Schalk G, Mellinger J. (2010). A practical guide to brain-computer interfacing with BCI2000: General-purpose software for brain-computer interface research, data acquisition, stimulus presentation, and brain monitoring. London: Springer.

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