L24

The P300 Based Visual Speller for People with ALS: Insights from Initial Evaluations

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Background & Objective

The overall goal of brain-computer interface (BCI) research is to provide new non-muscular communication and control channels to individuals who are severely disabled. Here we are assessing independent home use of an EEG-based brain-computer interface (BCI) by people with ALS. The majority of the individuals in this study have little or no remaining useful motor control, are not adequately served by conventional augmentative communication devices, have decided to accept mechanical ventilation if needed, and have a supportive environment. Here we seek to identify factors that affect performance and methods to improve classification from the results of 25 evaluations using the P300-based speller.

Methods

Online

- We record 16 channels of EEG using tin electrodes embedded in an elastic cap (Electro-Cap International) following the modified 10-20 system (Sharborough et al., 1992) (Fig. 1). The EEG is sampled at 256 Hz, amplified 20,000X, and bandpass filtered between 0.5-30 Hz.
- Subjects are instructed to attend to one letter (the target) as it flashes in a 6X6 onscreen keyboard, while all letters in the keyboard flash in either rows and columns (Donchin et al., 2000) or in a checkerboard presentation (Townsend, et al., 2010). (Fig. 1).
- Twenty-one letters are presented in five 1.5 to 6 min runs (THE, QUICK, BROWN, FOX, JUMPS).
- Using a standard subset of 8 channels of EEG, (Fig.1 in yellow) we derive classification coefficients (weights) that represent the largest percentage of unique variance between targets and non-targets using a stepwise linear discriminate function (SWLDA) (Krusienski et al., 2008).
- These weights are then applied online for the remaining 4 runs and 14 selections (OVER THE LAZY DOG), and online performance is recorded.

Offline

- Using all 16 channels and the 8-channel subset, we derived classification coefficients from the 21-letter training data and applied them to the 14-letter test set.
- Using all16 channels and all 35 characters, we determined the amplitude, latency, and location of the peak positive target response.
- Using 8 channels, we derived weights from subsets of the training data (5, 10, and 15 characters) and apply them to a 6-character test set.
- Using all 16 channels, the absolute values of the SWLDA coefficients were summed for each channel to assess it's importance.
- Using 16 channels, we derive classification coefficients from four additional 8-channel subsets of the training data and applied them to the test data.

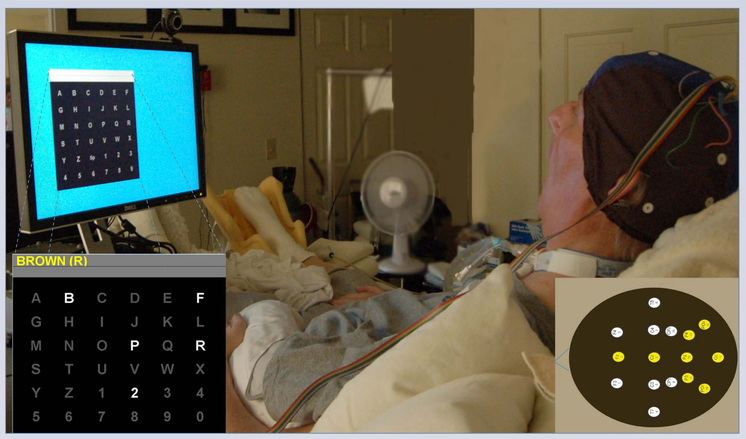


Figure 1. User with ALS performing the calibration task. The 16-channel montage and the 8-channel standard subset (yellow) are displayed in the lower right corner. One stimulus presentation in the checkerboard presentation mode is shown in the lower left corner.

BCI Users	n= 25 (5 F)
Mean Age	56, range 40-72
Mean ALSFRS	5.6, range 0-25
Vent-Dependent	72%, n=18
Nystagmus or Ptosis	32%, n=8

Table 1. BCI User Demographics

Results

Level of Disability

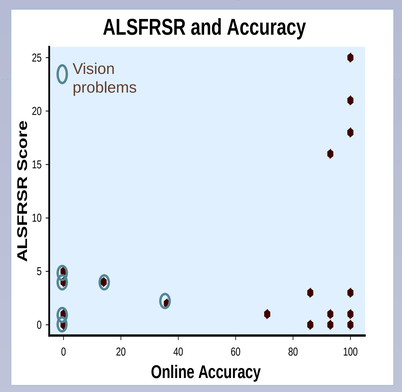


Figure 2. There was no correlation between level of disability (ALSFRSR score) and online accuracy. All those <40% had vision problems.

Number of Channels

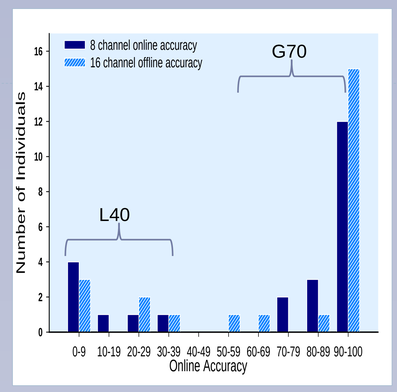


Figure 3. Online accuracy fell into two distinct groups (L40 and G70). There was no significant difference between 8- & 16-channel performance.

Stimulus Presentations

Mean for 8 channels	*G70*	*L40*	
Online No. of Stimuli presented	20.8	14.5	P<0.05
Offline Best Accuracy (8 channel)	95.1%	21.3%	
Offline No. of Stimuli at Best Accuracy	12.4	9.5	

Table 2. There was a significant difference in the number of stimulus repetitions (range 10-30) presented to each group online. Offline data analysis indicate that G70 group performance would have remained high with fewer repetitions.

ERP Characteristics

Mean	G70 (n=17)	L40 (n=8)	
Online accuracy	92.5	11.2	
Visual problem	0	8	
ERP Latency (ms)	278	328	P>0.05
Amplitude (μv)	3.36	1.62	P<0.05
Location	Central	Parietal	P<0.05
ALSFRSR	6.6	5.0	P>0.05

Table 3. The G70 and L40 groups differed significantly in the amplitude and location of the target response's positive peak.

Character Set and Accuracy

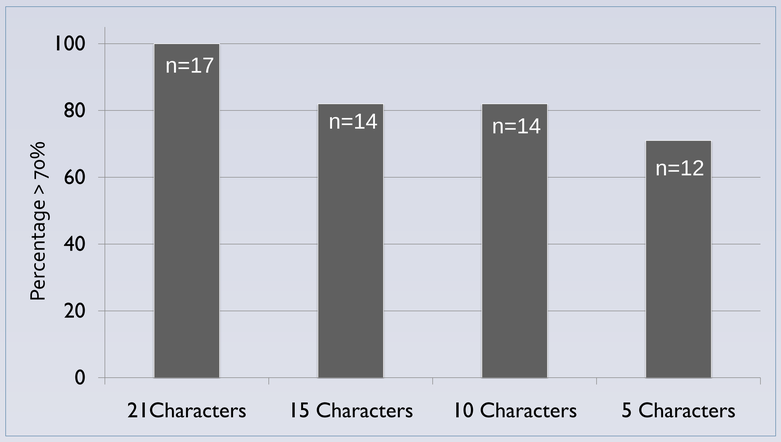
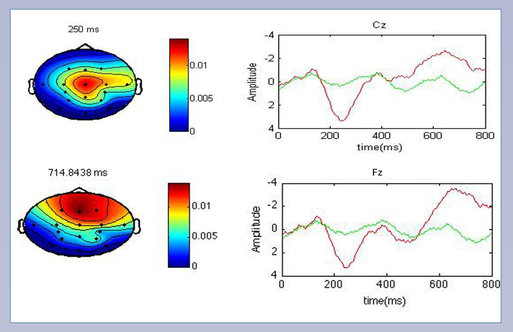


Figure 4. Using fewer selections to develop weights for the G70 group reduced the number of people for which offline classification was 70% or higher.

Electrode Location and Accuracy

Figure 5 . Variance topographies (r^2) and ERP waveforms for six G70 subjects at Cz (top) and Fz (bottom). Target responses (red) have a positive peak (P300) at Cz and a later negative peak at Fz.



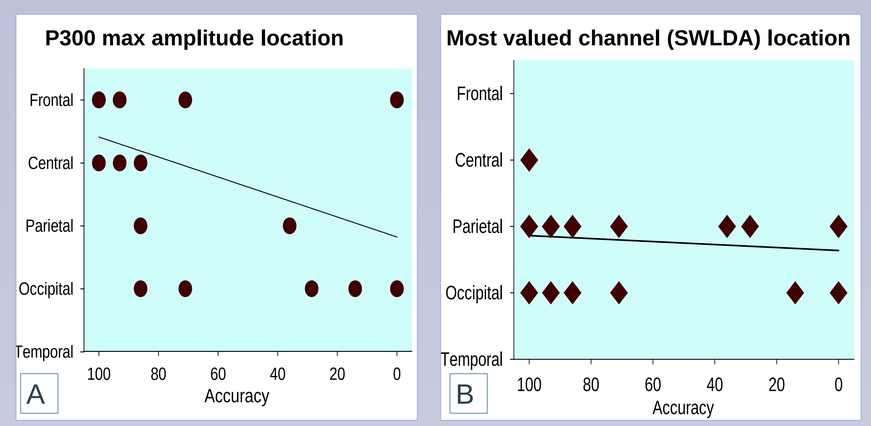


Figure 6. *A:* The location of the positive peak amplitude tends to be more frontal in users with greater accuracy. *B:* The most common location of the most valued channels by SWDLA is parietal.

Montage	A: Standard	B: Frontal - Central	C: Frontal-Parietal	D: Central Parietal	E: Parietal
Average Accuracy	95.1%	75.8%	83.9%	75.0%	88.5%
		P<0.05	P>0.05	P<0.05	P>0.05

Table 4. Offline analysis with 5 different 8-channel montages revealed a significant difference in predicted performance when fewer parietal channels were used (B and D). On average, no montage performed better than the standard, but 5 subjects could have performed similarly with fewer repetitions by using set D or E.

Conclusions

1) Most people with late-stage ALS, including those who are nearly locked-in, can use a visual P300-based BCI with the current design. Using 8 EEG channels and fewer online stimulus repetitions could shorten the initial evaluation.
2) Those who cannot use the BCI speller typically have nystagmus or ptosis. ERP-based BCIs that use auditory, somatosensory, or alternative visual stimuli might help those in this group.
3) Individualized montages might produce the best long-term performance in some users.
4) Frontal peaks (Fz and Cz) in the target response correlate with better performance, while the parietal and occipital (Pz and Oz) responses are usually most valuable for the SWLDA classification.

Supported by: NIH (HD30146(NCMRR, NICHD); EB00856 (NIBIB & NINDS); James S. McDonnell Foundation; NEC Foundation; Altran Foundation; ALS Hope Foundation; Brain Communication Foundation