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► **To cite this version:**

Pierre-Baptiste Mathieu de Carvalho, Lorraine Charles, Elena Parsy, Lorraine Raquel Lindquist, Laurent Bougrain. A Hybrid BCI based on SSVEP and Gaze Direction Recognition: Towards a Speller for Patients with Amyotrophic Lateral Sclerosis. CORTICO 2024, May 2024, Nancy, France. hal-04630176

HAL Id: hal-04630176

<https://hal.science/hal-04630176>

Submitted on 1 Jul 2024

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A Hybrid BCI based on SSVEP and Gaze Direction Recognition: Towards a Speller for Patients with Amyotrophic Lateral Sclerosis

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Motivations

Amyotrophic lateral sclerosis (ALS) is an incurable neurodegenerative disease involving motor neurons. One of the most disabling symptoms is difficulty in communicating due to dysarthria and progressive loss of movement. To tackle this issue, we are designing an affordable solution suitable for patients.

Approach: a hybrid BCI that exploits SSVEP and eye-tracking through the laptop's webcam could help ALS sufferers communicate effectively in their day-to-day life.

Material

Since, eyes' muscles are minimally affected by the pathology, the solution we are developing is a hybrid BCI that exploits SSVEP and eye-tracking [1,2]. This system requires a simple laptop with a webcam, a low-cost OpenBCI electroencephalographic system composed of a Cyton card and seven passive electrodes (fig. 1,2). The OpenVibe software sends triggers via LSL to a PsychoPy program which displays a virtual keyboard on the patient's screen.

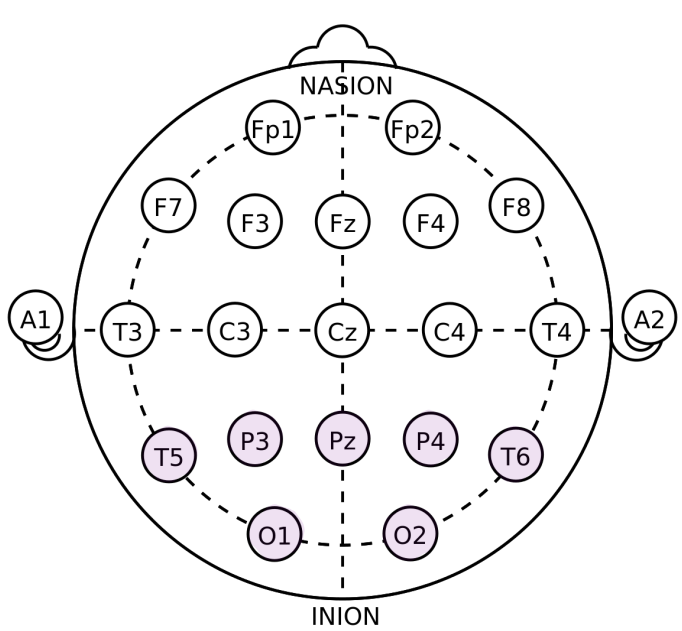


Fig. 1: Electrode layout of the OpenBCI's cap.

Fig. 2: Experimental setup. After selecting a sub-group of letters with the gaze direction (currently this step is performed with the mouse), the letters in the sub-group are flashed at different frequencies.

Methods

Letters of the alphabet and essential punctuation marks to communication [3] are distributed in several zones on a visual interface (fig. 1). When the patient's gaze rest on a zone, the signs in this zone are spread in the screen (fig. 3) and flash at different frequencies. By observing the electroencephalograms recorded by the electrodes, the system determines the character chosen by the patient, therefore allowing them to construct words and sentences.

Various conditions are tested:

- two EEG amplifiers (OpenBCI, BioSemi Active II);
- two display layout (horizontal or squared);
- three sets of frequencies (6,9,15,21, 6,10,14,22 and 6,10,12,15).

Frequencies are filtered with a 4-degree butterworth between $[f-0.25; f+0.25]$.

A regularized Common Spatial Pattern algorithm and a regularized Linear Discriminant Analysis are trained to discriminate the frequencies.



Fig. 3: Two display layouts tested. Target letter during the learning phase stays red for one second at the beginning of each trail.

Results

Amplifier	Letter Layout	Frequencies (Hz)	1st Harmonic	Mean Training Accuracy	Mean Test Accuracy
BioSemi	Linear	6; 9; 15; 21	Yes	56.85 %	18.8%
	Square			57.65%	21.9%
	Square	6; 10; 12; 15	No	62.13%	28.1%
OpenBCI	Linear	6; 10; 14; 22	Yes	57.96%**	25%**
	Square			51.40%**	28.15%**
	Linear	6; 9; 15; 21	Yes	46.86%	21.9%
	Square			58.41%	28.1%
	Lineare	6; 10; 12; 15	No	53.46%	15.6%
	Square			57.31%**	29.7%**

Table 1: Average (N=1) accuracies for SSVEP recognition. (**N=2).

Discussion

SSVEP recognition accuracies are lower than expected. One possible explanation could be that the frequencies chosen for SSVEP are not divisors of the screen's refresh rate. However, the performance of the set of frequencies containing only divisors of the refresh frequency does not show significantly better performance.

Another explanation could be the electrode locations available on the OpenBCI cap, which cover little of the occipital lobe (with only O1 and O2). Another potential explanation may lie in the short duration of training. Although a shorter training duration was chosen to prevent fatigue, this duration may be insufficient in view of the results obtained.

Experimental conditions were not optimal, as there was a potentially distracting activity in the room, which may have affected test performance. Finally, testing this device on a larger population could provide more robust data before specifically targeting the ALS patient.

Conclusion & Future work

The OpenBCI system with passive wet electrodes offers competitive accuracy compare with the BioSemi system with active wet electrodes. Frequencies used for SSVEP do not need to be divisors of the screen refresh rate.

SSVEP recognition rate should be improved. Eye tracking could enable hybridization to improve letter recognition.

Gaze recognition via webcam or Tobii nano will be tested.

Finally, our solution has only been tested on a few healthy subjects. So, we will be introducing it to ALS patients.

[1] Thillier C., Parsy E., Charles L., Mathieu De Carvalho P.-B. (2024). Conception d'une interface cerveau-ordinateur pour contribuer à la communication de patients atteints d'une sclérose latérale amyotrophique". master's report. IDMC - Univeristé de Lorraine. <hal-04521816>

[2] Wang, J., Xu, S., Dai, Y., and Gao, S. (2023). An Eye Tracking and Brain-Computer Interface-Based Human-Environment Interactive System for Amyotrophic Lateral Sclerosis Patients. IEEE Sensors Journal, 23(20) :24095-24106. Conference Name : IEEE Sensors Journal.

[3] Maslova, O., Komarova, Y., Shusharina, N., Kolsanov, A., Zakharov, A., Garina, E., and Pyatin, V. (2023). Non-invasive EEG-based BCI spellers from the beginning to today : a mini-review. Frontiers in Human Neuroscience, 17.