A New Graphical User Interface for the P300 Speller Brain-Computer Interface

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1. Introduction

The P300 speller is a type of brain-computer interface (BCI) [1] that enables users to communicate by detecting specific brain signals known as P300 waves. These waves are a type of event-related potential (ERP) [3] that occur approximately 300 milliseconds after a person perceives a significant stimulus. [4] The P300 speller leverages this neural response to allow individuals, particularly those with severe motor disabilities, to spell out words and convey messages without physical movement

In a typical P300 speller setup, the user focuses on a specific character from a grid of letters and symbols displayed on a screen. These characters flash in a random sequence, and when the target character flashes, it elicits the P300 response in the user's brain. The BCI system detects this response, identifies the target character, and translates it into text, allowing the user to spell out words and sentences without any physical movement.

2. Methods

In this adaptation of the P300 speller, several measures are taken to meet the challenges the original model faces.

Rows and columns are instead flashed in a zig-zag shape to decrease the likelihood of selecting an unwanted character. Feedback bars are added underneath each character that tell the user what letter will be selected at the rate that they are going. The speller has two modes, training and testing.

During training, a green circle highlights the target letter, paired with an audio cue, so that less time is wasted trying to navigate the virtual keyboard.

The data is then gathered from the training mode, processed to create a model and then that model is used for the testing mode, where the participant has free range and the model recognizes what the EEG readings look like when a character should be selected.

2.1 Materials

Head Cap

Head cap that can be seen on the bottom right, it has 32 nodes that hold sensors on key points of the head to be able to read the signals

Head Cap Sensors

These sensors, seen on the bottom left, connect to the headcap and deliver readings to the Electroencephalography amplifier

Electroencephalography Amplifier

This device, seen in the center image, produced by Biosemi, records the signals emitted from the brain and compiles it into workable data

Signal electrode gel

This highly conductive gel bridges the gap from the scalp to the sensors, allowing for accurate data reading. Since this is a non-invasive way of reading brain signals, this gel is critical in collecting precise readings

Active electrodes

ActiveTwo EEG Amplifier

EEG caps 32 sensors

2.2 Experimentals protocol

Our BCI is scripted in MATLAB, and uses Psych Toolbox, a library of functions that aid in psychological experiments.

Psych Toolbox provides accurate timing functions so that we are able to present stimuli with efficient timing.

Choosing a letter is set to take have a 5 iterations per character, each iteration having 2 stimulus presentations. A full iteration lasting around 6 seconds.

Triggers are sent from the display computer to the computer analyzing the data right before a letter is flashed to signify a stimulus is being flashed. With the combination of encoded triggers and triggers paired with flashes, we are able to rebuild the experiment with the data.

Using Xdawn filters [7] (to increase the signal to signal + noise ratio), we are able to extract what happened and when, as well as the impact it had on the user. In ERP analysis [8], we section the data into epochs of one second and then detrended them, afterwards we concatenate each epoch to form the timeline.

Detrending the epochs gets rid of overall increases/decreases in the data, making it easier to process and recognize patterns.

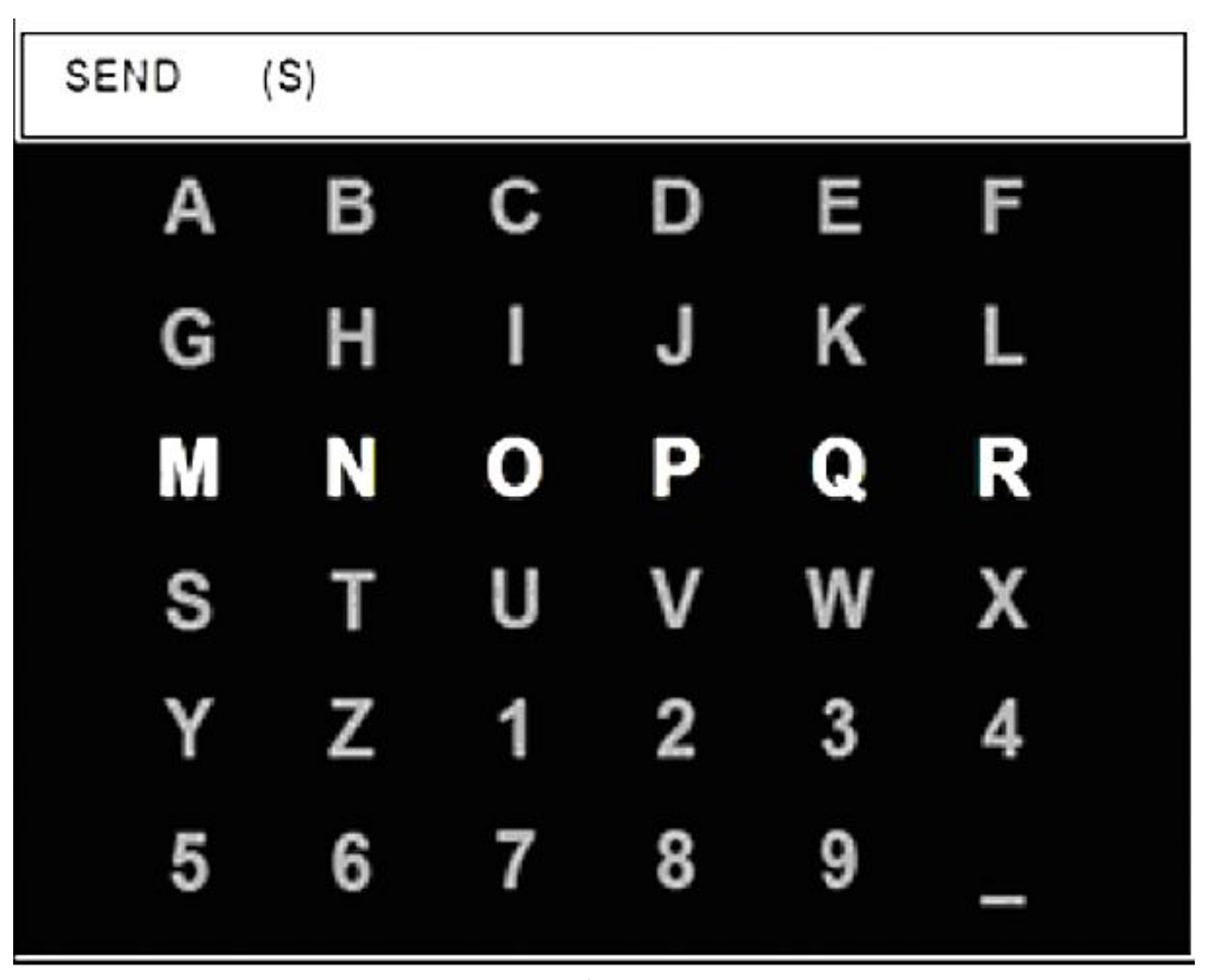


Fig 1. Original State of the art speller. Rows and columns are flashed traditionally, with only the letter flashing [10]

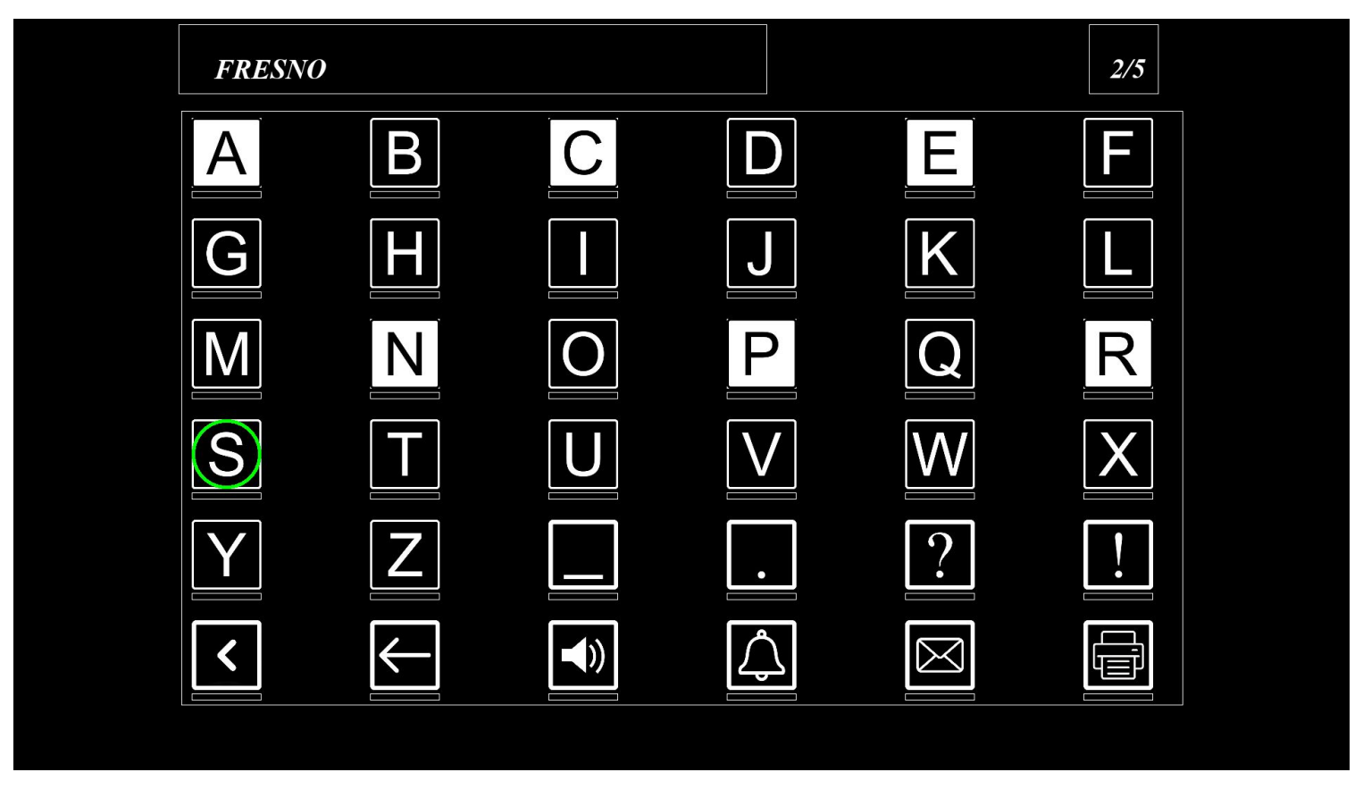
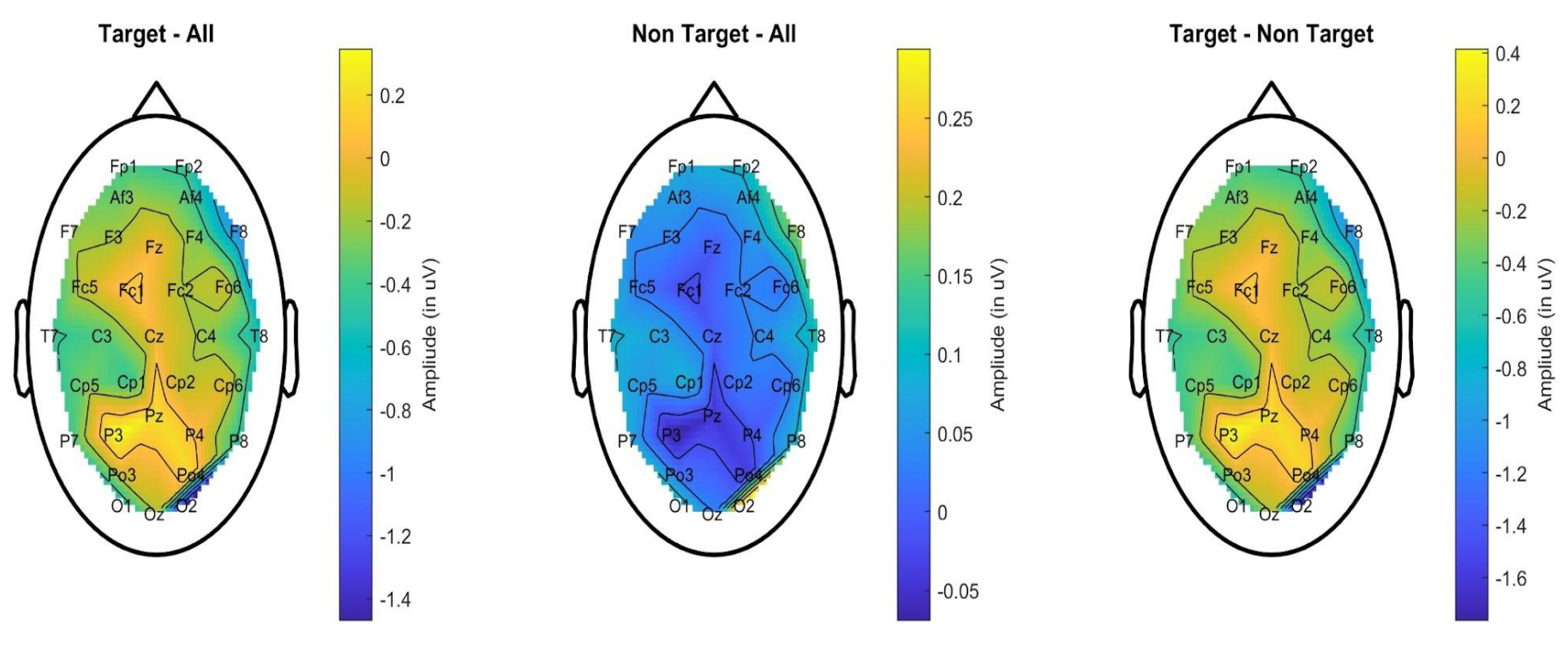
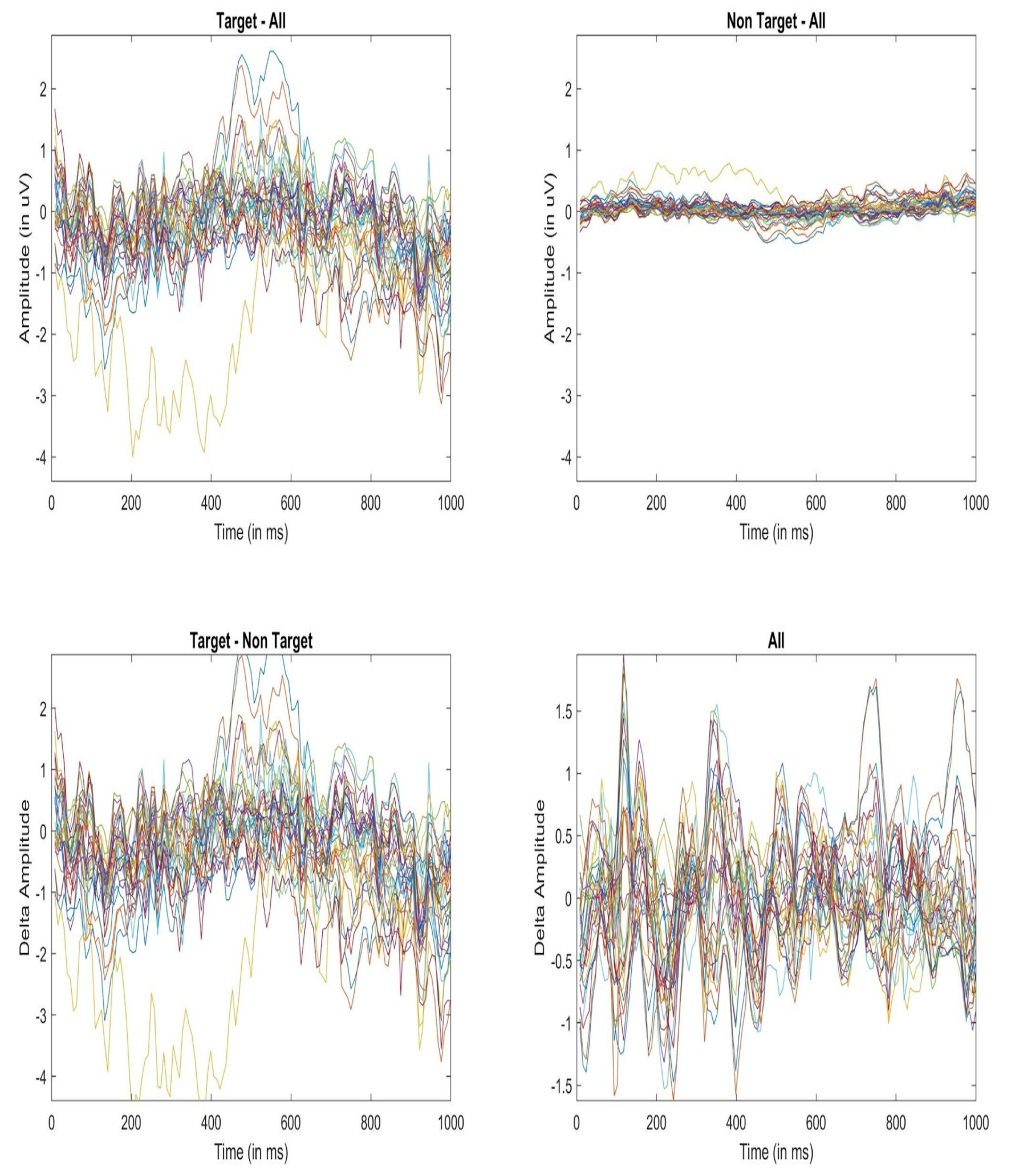


Fig 2. Adaptive Speller. Taken in training mode, it flashes in the zig-zag shape to reduce the probability of an inadvertent reaction to an unwanted letter.

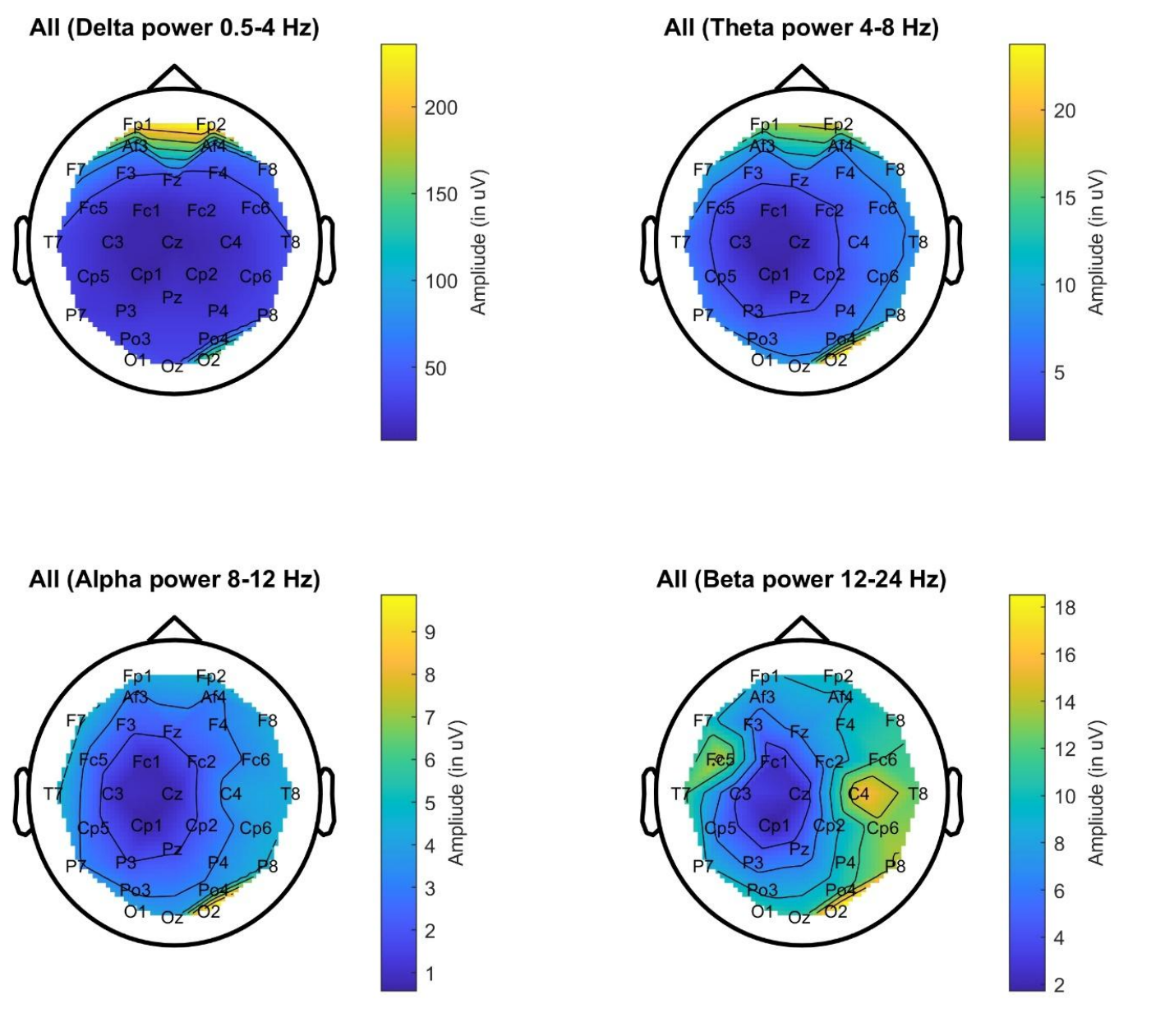
3. Results



When presented with a target, the participant shows more activation in the parietal lobe, which is responsible to sensory. In non-targets, the parietal shows significantly less activity.

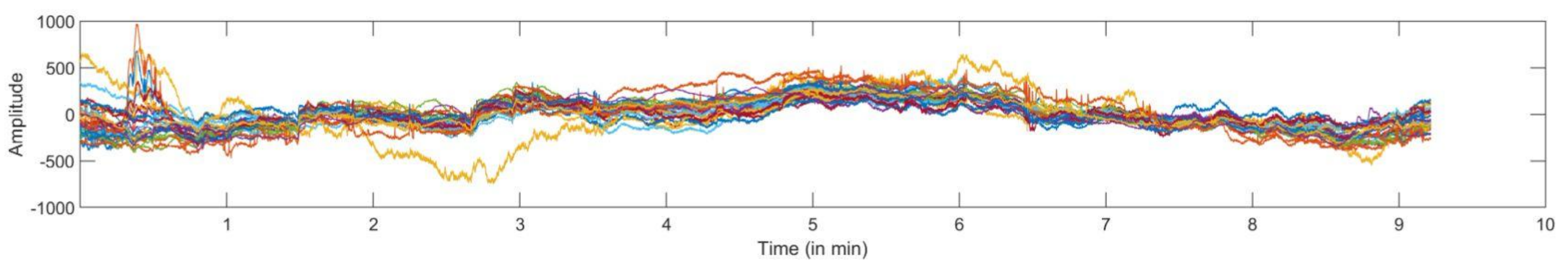


We subtract the target and non-target values from all to distinguish the raw values from each stimulus type. In the target graph, we can see the wave in response to the stimulus and little to no reaction in non-targets.



Beta waves were the most prevalent in this experiment, which with alertness and engagement.[6]

Raw signals from the duration of the experiment where 20 characters were spelled out using the adaptive speller. Without mistakes, a participant is able to spell around 2 characters per minute with 5 repetitions.



4.Discussion and Conclusion

In running the adaptive speller, the distinction between targets and non-targets that the algorithm is able to pick up shows that the new pattern of flashes that the adaptive speller integrates is effective.

The added feedback allows the user to change what they are doing to achieve a desired outcome during an iteration, so they won't have to spend an additional iteration to fix a possible mistake.

The main issue that arises is the speed. This experiment used 5 repetitions per character, giving us a spelling rate of 2 characters per minute, however reducing the number of repetitions will increase the speed, shaving off 6*(number of characters) in seconds. Using 4 repetitions for the same experiment of 20 characters would shave off about 2 minutes total.

The model trained using the training data has a score of near perfect accuracy. This is crucial, since the model is able to accurately tell what the user is trying to select, it doesn't leave any room for any computational or technical difficulties in selection the desired character. We plan on testing the paradigm online, and testing it with participants with disabilities.

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Acknowledgements

I would like to thank the U.S. Department of Education for funding my research interests, as well as the Finish in Five Program and team that give us the opportunity to get an early start on our research.

Funding Agency:
U.S. Department of Education
Official Name of the Grant:
Title V Promoting Postbaccalaurea
Opportunities for Hispanic
Americans
Project Title Finish in Five
PR Award Number: P031M210039