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P300 Word Speller for Deaf and Dumb Using Brain Computer Interface

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ABSTRACT

A P300 brain-computer interface (BCI) is a paradigm that decodes text characters using event-related potentials (ERPs). In a widely used implementation known as the P300 speller, a subject looks at a display with flashing characters and pays attention to one character to choose it. The item with the strongest ERP is acknowledged as the selection. When cerebral reactions to target and non-target stimuli differ enough, the speller does effectively. While several ways have been put forth to improve the BCI spelling, one that is quite straightforward—reducing the visual field to lessen the contribution from non-target stimuli—has not gotten enough attention in the literature. This concept was previously used in a single-stimulus switch that could give an urgent order, such as stopping a robot.

In order to investigate this strategy further, we conducted a pilot study in which 10 participants wore binocular apertures that limited their field of vision to the center or used a conventional P300 speller. Visual field limitation produced EEG rhythms asynchronous to stimulus periodicity in place of non-target ERPs, as planned. Individual variability was observed in half of the participants with changes in target ERPs. The aperture condition had somewhat higher classification accuracy than the no-aperture condition, but this difference was not statistically significant across the board for the participants in the sample. Throughout the course of four training days, classification accuracy increased for both the aperture and no-aperture conditions, but more for the aperture condition.

While BCI performance was not significantly affected in this investigation, we propose that this approach could be improved upon to speed up BCI operations and lessen user fatigue. Moreover, non-targets might be eliminated algorithmically or using a hybrid interface that makes use of an eye tracker in place of donning an aperture. We also examine the potential for enhancing a P300 speller by the utilization of distinct physiological characteristics seen in central and peripheral vision. Lastly, we propose that basic research on the mechanics of visual processing could make use of the experimental approach that has been suggested.

Keywords: P300 BCI, aperture, central vision, ERP, visual fatigue, visual attention

INTRODUCTION

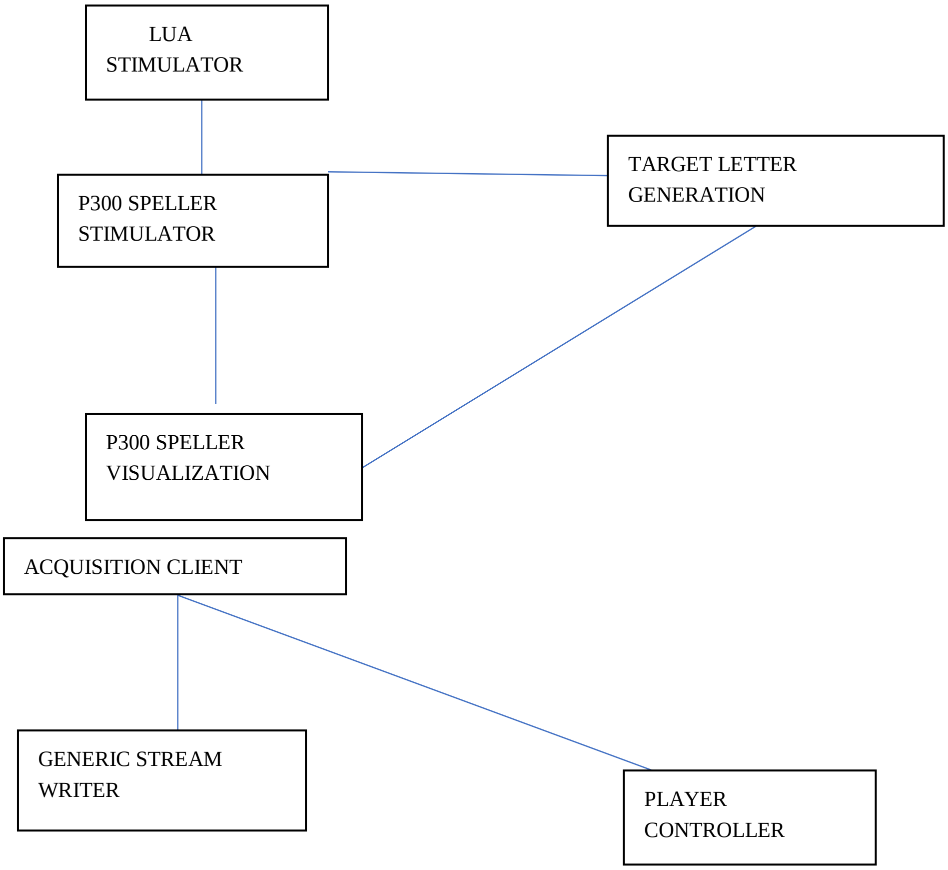
The ability to communicate with other persons, be it through speech, gesturing, or writing, is one of the main factors making the life of any human being enjoyable. Communication is at the basis of human development, makes it possible to express ideas, desires, and feelings, and on a more ordinary level simply allows to cope with daily life. Individuals suffering from the so-called locked-in syndrome do not have the above mentioned communication possibilities. The locked-in syndrome is a condition in which patients are fully conscious and aware of what is happening in their environment but are not able to communicate or move. In fact, the locked-in syndrome is caused by a nearly total loss of control over the voluntary muscles. A disease that is known to lead to the locked-in syndrome is amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease. ALS is a progressive, neurodegenerative disease and is characterized by the death of motor neurons which in turn leads to the loss of control over voluntary muscles. Besides ALS also multiple sclerosis, stroke or other cerebrovascular incidents leading to the infarction or degeneration of parts of the brain can cause the locked-in syndrome. Clearly, the quality of live of persons affected by the locked-in syndrome is strongly diminished by the lack of possibilities to communicate with other persons and by the complete loss of autonomy. A promising means to give back basic communication abilities and a small degree of autonomy to locked-in persons are BCIs. The idea underlying BCIs is to measure electric, magnetic, or other physical manifestations of brain activity and to translate these into commands for a computer or other devices . From a different angle, BCIs can also be seen as a new and exciting means of communication that could be used as well by persons not suffering from disabilities. For example, in the field of multimedia communication and human-computer interaction, BCIs could possibly be used as an additional modality, together with more traditional modalities, such as the auditive and visual modalities. Multimodal communication with the help of a BCI would help to increase the communication bandwidth between man and machine. Beyond communication, other applications of BCI involving multimedia can also be envisioned. For example one can imagine (multiplayer) games in which BCIs are used for control. Another interesting application area might be the visualization, or sonification, i.e. the transformation into sound, of brain activity. Independently of the application in the fields of assistive technology or multimedia, the aim of this paper is to give an introduction to the field of BCI research. In the first part of the paper (Sections II, III, IV) we review neurophysiologic signals that can be used in BCIs, signal processing and machine learning methods for BCIs, and applications for BCIs. In the second part of the paper (Section V) a concrete state-of-the-art BCI system is briefly described. Finally, in the third part of the paper (Section VI) some open problems in BCI research are mentioned

LITERATURE REVIEW

Following the introduction of P300 speller in 1988 by Farwell and Donchin (1988), many studies have strived to improve this method (Fazel-Rezai et al., 2012; Allison et al., 2020; Philip and George, 2020). The speller performance is hindered by the necessity to run many trials to distinguish target and non-target stimuli based on the comparison of the event-related potentials (ERPs) they evoke. Particularly, non-target items that are adjacent to the target attract attention and interfere with the decoding performance (Fazel-Rezai, 2007; Townsend et al., 2010). Several solutions to this problem have been explored, including using flashes of single items instead of flashing rows and columns (Guger et al., 2009), rearranging the spatial configuration of the simultaneously flashing stimuli (Townsend et al., 2010), suppressing the stimuli adjacent to targets (Frye et al., 2011), or all non-targets (Shishkin et al., 2011) during the calibration procedure, and optimizing the characteristics of visual stimuli (Salvaris and Sepulveda, 2009; Jin et al., 2017; Mainsah et al., 2017; Philip and George, 2020). Yet, all these approaches require a considerable amount of distracting stimuli for accurate spelling, which slows the decoding, and causes user fatigue (Boksem et al., 2005; Käthner et al., 2014; Oken et al., 2018).

In this perspective, we discuss a rather straightforward way to reduce the interference from non-target stimuli by the restriction of user sight to only the central visual field. Since the contribution from non-targets is blocked, the response to target stimulus could become cleaner and easier to detect. Previously, somewhat similar ideas were implemented in single-target brain-computer interfaces (BCIs) for generating an urgent command like braking a neurally-controlled wheelchair (Rebsamen et al., 2010) or stopping a robot (Fedorova et al., 2014). In these implementations, the speed of operation increased because the decoding was reduced to detecting the presence or absence of a single target stimulus. Here we tackled a different approach, where non-targets were effectively removed while the BCI was used for spelling instead of issuing a single command. We have conducted a pilot experiment where visual field reduction was accomplished by wearing a binocular aperture. When looking at the screen through the aperture, subjects were able to perform the same spelling task as they executed with the traditional P300-speller.

PROPOSED MODEL



SOFTWARE DESCRIPTION:

Open ViBE:

The project in a whole is based on a software, the "Open Vibe".

OpenViBE is a software platform dedicated to designing, testing and using brain-computer interfaces.

OpenViBE is a software for real-time neurosciences (that is, for real-time processing of brain signals). It can be used to acquire, filter, process, classify and visualize brain signals in real time. Since v2.2.0, OpenViBE also includes a tool for offline or batch analysis of large datasets.

OpenViBE is free and open source software. It works on Windows and Linux operating systems.

APPLICATIONS:

The main OpenViBE application fields are medical (assistance to disabled people, real-time biofeedback, neurofeedback, real-time diagnosis), multimedia (virtual reality, video games), robotics and all other application fields related to brain-computer interfaces and real-time neurosciences.

OpenViBE users can either be programmers or people not familiar with programming. This includes medical doctors, video game developers, researchers in signal-processing or robotics, etc.

FEATURES:

OpenViBE can use a vast selection of hardware EEG devices. You should assure yourself that the device you are using is compatible.

OpenViBE is a multi-platform software. It works on Windows and Linux operating systems. For best performance use one of the officially supported Windows versions or Linux distributions.

OpenViBE has many capabilities such as signal processing algorithms, machine learning functions and scripting support. It comes with several example applications and scenarios to illustrate their use.

SOFTWARE FEATURES USED:

LUA STIMULATOR:

Scripts are very simple programming languages. They are usually easy to understand, fast to write and reasonably fast to execute. They are used for high level operations and do not need compilation. There are a number of scripting languages around.

Lua is one of those scripting languages. It is know for its execution speed and it's ease of use. It can be used on a large number of platforms. For all those reasons, Lua is widelyused in the video game industry.

This box has a variable number of inputs and outputs. The author is able to add as many of them as necessary. The box automatically decodes the incoming streams and automatically encodes the outgoing streams, leaving the interesting part to the script : doing something with input stimulations and produce output stimulations.

PROPOSED SYSTEM

P3000 SPELLER:

P300 is a well-known pattern in the brainwaves, a positive peak that occurs 300 ms after a relatively rare but expected event.

The Speller application flashes randomly a grid of letter, and the user is instructed to focus on the letter (s)he wants to spell out.

After some repetitions, a vote determines which letter the BCI system selects.

AQUISITION.CLIENT:

To use the P300 speller, first have the headset set up on the subject with a proper electrode configuration. Then, run the Acquisition Server and start the data acquisition. With the P300 as implemented by these scenarios, it may be beneficial to **disable the drift correction** in the acquisition server settings.

P300 SPELLER STIMULATOR:

This block consists of features that discloses the nth label to be monitored, number flashes to be executed, number of rows, number of columns, flash duration and number of trials.

TARGET LETTER GENERATION:

It consists of panels that help the user to give the required word to be displayed and the required second to display the letters.

P300 SPELLER VISUALIZATION:

This panel consists of what the required background or flash colour is to be displayed, the number of columns or rows, the font size required etc.

GENERIC STREAM READER:

This box is able to dump any **OpenViBE** stream into a binary file. In the cacse where this boxwould have multiple inputs, the streams would be multiplexed in the file. Such file can be read back with the **Generic stream reader**

It consists of inputs, file name and the required compression to be modified.

PLAYER CONTROLLER:

It helps the experiment to start or stop the output.

DETAILED METHODOLOGY:

The patient details are acquired from the acquired server client. The details are inserted through the Lua Stimulator and further it is sent through the speller stimulator. Further more the details are sent towards the target speller generation through which the targeted word can be spelt letter by letter. Later the speller visualization represents the number of flashes or the number of rows or columns to be printed.

The experiment is planned to be proceeded by selecting the electrodes to be pasted on the brain. The required letters are to be concentrated by the patient through which the concentrated letters are displayed by sending the brain waves to the blocks.Here the patient details are given in a readymade format as of the real patient. A visual display is selected for presenting the speller matrix (e.g., a computer screen matrix).Determine the layout of the speller matrix, including the number of rows and columns and the arrangement of characters.

Choose the stimuli presentation method (e.g., flashing or highlighting characters) and the timing parameters (e.g., stimulus duration, inter-stimulus interval).Place electrodes on the scalp according to the international 10-20 system, with specific locations for recording the P300 signal (e.g., Pz, Cz, and Oz).Use a reference electrode (e.g., on the earlobe or mastoid) and a ground electrode (e.g., on the forehead or mastoid).

Use an EEG amplifier to acquire EEG signals from the scalp electrodes. Apply bandpass filtering (e.g., 0.1-30 Hz) to remove noise and artifacts. Sample the EEG signals at a sufficient rate (e.g., 250-1000 Hz) for accurate signal processing. Present the speller matrix on the visual display. Use a software program to control the presentation of stimuli based on the selected layout and timing parameters. Ensure that the stimuli presentation is synchronized with the EEG recording. Record EEG signals while the user focuses on a specific character or item in the speller matrix. Average the EEG signals across trials to enhance the signal-to-noise ratio.

Use signal processing techniques (e.g., filtering, artifact rejection) to extract the P300 signal from the EEG data.Use machine learning algorithms (e.g., support vector machines, linear discriminant analysis) to classify the extracted P300 signals. Train the classifier using labeled EEG data from calibration sessions. Use the trained classifier to decode the user's intended selection based on the P300 signals. Provide feedback to the user (e.g., highlighting the selected character) based on the decoded selection. Use the decoded selection to control external devices (e.g., text-to-speech synthesizers, prosthetic limbs) according to the user's intentions.

Evaluate the performance of the P300 speller stimulator in terms of accuracy, speed, and user satisfaction.Optimize the stimulator parameters (e.g., stimulus timing, electrode placement) based on user feedback and performance metrics.Conduct clinical trials to assess the effectiveness and usability of the P300 speller stimulator in real-world settings.Validate the stimulator's performance against established benchmarks and criteria for BCI systems. The P300 speller is a device that allows individuals to communicate by selecting characters or commands on a screen using only their brain activity. It relies on the P300 event-related potential, a positive spike in the brain's electrical activity that occurs around 300 milliseconds after a person is presented with a stimulus they are paying attention to. Here's a detailed methodology on how the P300 speller typically work

The user is comfortably seated in front of a computer screen displaying a grid of characters (letters, numbers, symbols) or commands (like "yes" and "no").Electrodes are placed on the user's scalp to measure the electrical activity of the brain. Common placements include positions Pz, Cz, and Oz according to the international 10-20 EEG system.EEG signals are recorded from the electrodes. These signals are typically amplified, filtered, and digitized for further processing.The speller presents a series of flashes (stimuli) highlighting rows and columns of the character grid in a random sequence. Each flash elicits a P300 response if the user's brain recognizes the target character.The EEG signals are analyzed to extract features that represent the brain's response to each stimulus.

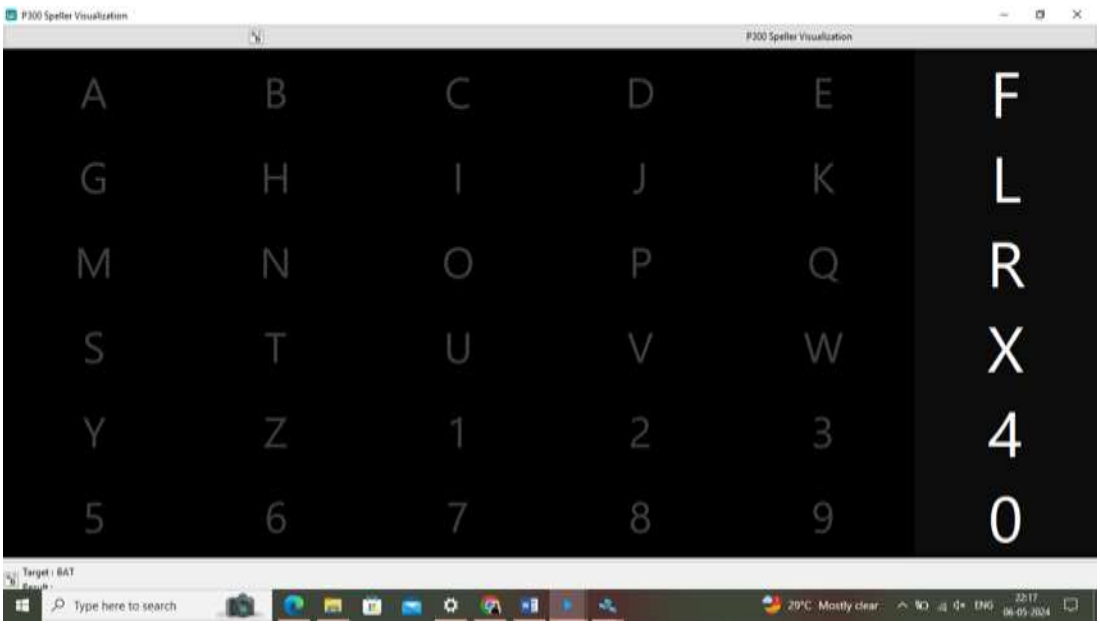
Since the P300 response is a relatively small signal compared to background brain activity, multiple repetitions of the same stimulus are averaged to enhance the signal-to-noise ratio.Machine learning algorithms, such as linear discriminant analysis (LDA) or support vector machines (SVM), are often used to classify the extracted features into target and non-target categories.Based on the classification results, the system determines which character or command the user is selecting. This information is then used to compose messages or control external devices.The speller provides visual or auditory feedback to the user, confirming the selection made by the system. This feedback loop helps the user correct any errors in the selection process.

Some P300 spellers employ adaptive algorithms to improve accuracy over time. These algorithms adjust the speller's parameters based on the user's performance to optimize the spelling process.Users may undergo a calibration phase where they are asked to spell out known words or phrases. This helps the system adapt to the user's unique brain signals and improve spelling accuracy.

P300 spellers are used primarily as assistive communication devices for individuals with severe motor disabilities, such as locked-in syndrome or advanced ALS. They can also be used in other applications, such as brain-computer interfaces for gaming or controlling devices.

RESULTS AND DISCUSSIONS:

The letters in the slide begins to flash as of required. The patient concentrates on the required letter as he needs. The concentrated letter appears with the constratic colored background. After the flashes were came to rest the targeted letter appears and the required result is obtained.



DISADVANTAGES

Though the above mentioned work has a vast advantages over the field , it is also in the position to overcome a very few drawbacks such as

- Time consuming
- Words are limited

- Always requires a wifi connection for data transmission where it's irregular connection may affect the messages to be passed to the doctors.

FUTURE WORK

It is sure that our future trends on developing this idea will definitely vercome the above mentioned disadvantages over this approach. The future work on this idea will be implemented with furthermore advancement in technologies, devices used also as if in analyzing various parameters of the body in form of hardware.

CONCLUSION

The development here allowed the therapists to do various recording of the brain's waveforms and automatically deliver the signals throughout the blocks as mentioned. It almost reduced the manual errors and and helps the deaf dump to provide a support for their dsability

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