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Enhancing Motor Imagery Skills Through Extensive BCI Game Training

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Objective

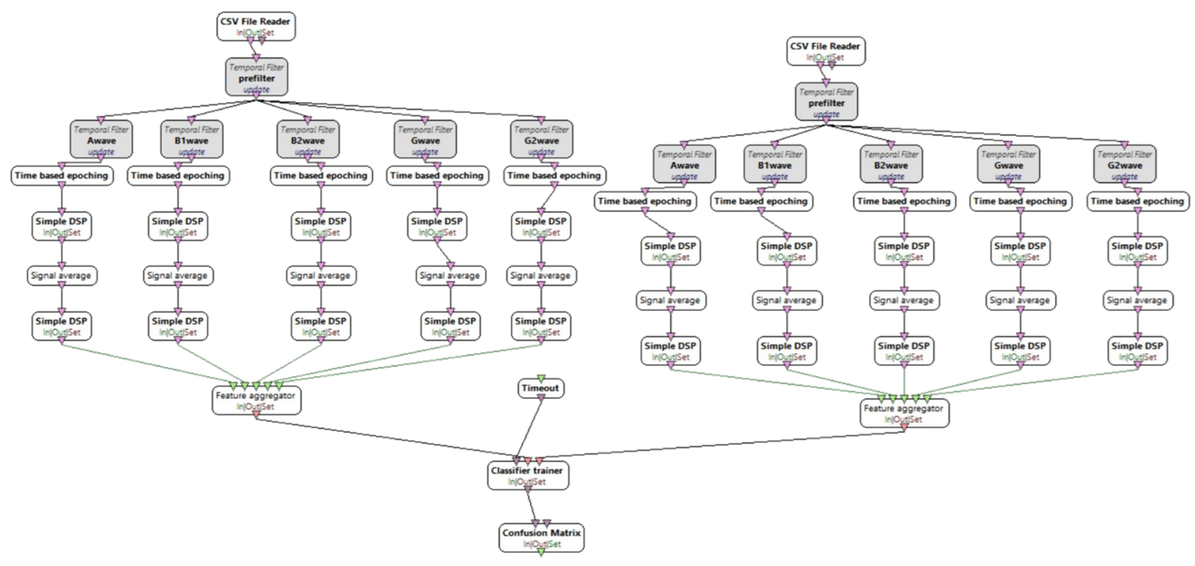
The goal of this study is to investigate whether individuals can enhance their Motor Imagery (MI) skills after extensive training. A 2D game is developed to create an interactive environment for subjects to train. A commercial Electroencephalographic (EEG) headband, Muse 2, is employed to record 2 MI commands: left- and right-hand MI. Subjects participated in 10 sessions, and the results indicate improvement in their performance.

Introduction

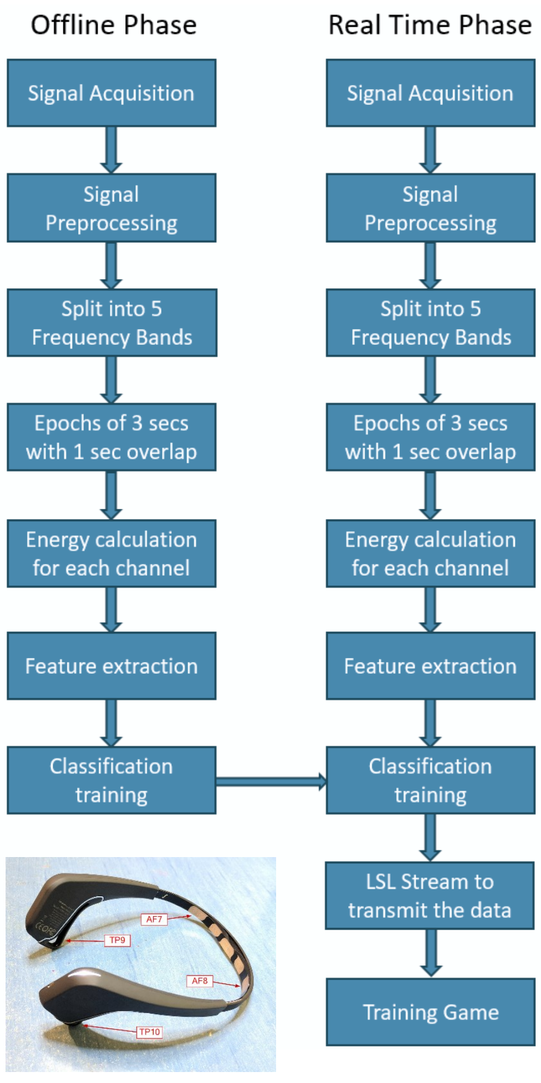
- Brain-Computer Interfaces (BCI) enables direct communication between a human brain and an external device. Through the use of brain signals, thoughts or mental commands, individuals are able to control these devices.
- Motor Imagery (MI) is a cognitive process which involves mentally simulating a motor action without physical execution. It often focuses on hands and feet imagery. MI activates neural pathways similar to physical movement, aiding skill development, motor learning, and rehabilitation and it is often employed in sports and therapy.

Materials and methods

- The proposed study employed a commercial 4-channel (AF7, AF8, TP9, TP10) EEG headband, Muse 2 to acquire the brain signals.
- Through a Lab Streaming Layer (LSL) stream the data are sent to OpenViBE software to be processed and classified.
- To process the raw EEG signals a 4th order Bandpass filter is applied between 8 to 40 Hz. Then the data are split into 5 frequency bands, *alpha* waves (9-12 Hz), low *beta* waves (12-20 Hz), high *beta* waves (20-30 Hz), low *gamma* waves (30-35 Hz), and high *gamma* waves (35-40 Hz).
- The signals are epoched in 3-sec windows with 1-sec overlap which was determined after trial-and-error process.
- The energy of each channel in every epoch is calculated.
- The processed signals are sent to a classifier. Linear Discriminant Analysis (LDA) algorithm is employed to classify the 2 MI mental commands.
- The trained classifier sent every 3 seconds a decision which is translated into a movement of the game avatar.



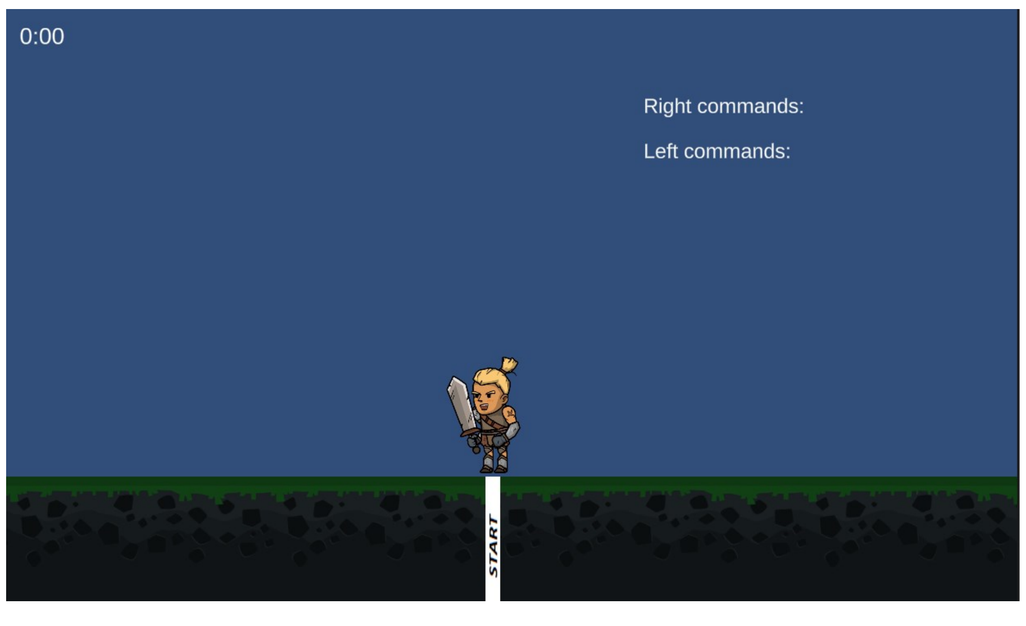
OpenViBE training scenario for the EEG processing and classification.



Muse 2 headband.

Game Design

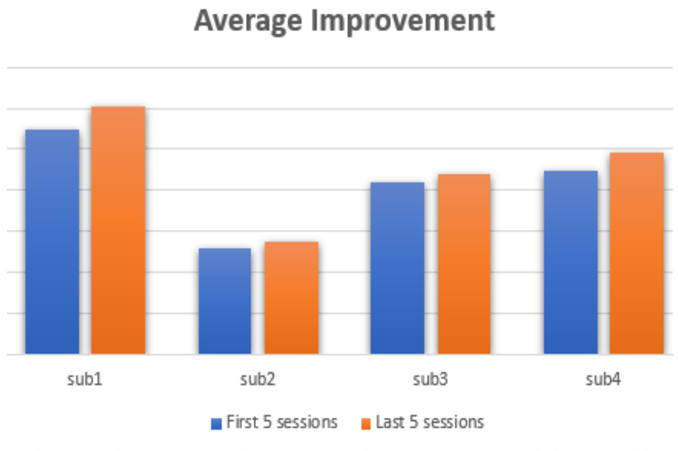
- The game is developed on Unity Engine. It is a 2D game where the in-game avatar can only move left or right.
- Through an LSL stream the classification results are sent in Unity and the avatar moves according to the decision.
- Every 3 seconds a new command is given to the avatar.



A snapshot from the 2D game.

Results

- To assess the proposed study, 4 healthy participants (2 males and 2 females) took part in the experiment. None of them had any previous experience with BCI experiments and all of them are both physical and mentally healthy with normal or corrected to normal vision.
- An experienced researcher instructed them to sit in a chair and minimize their movements to perform 2 separate EEG recordings. For the first recording, subjects had to perform left-hand MI commands and for the second, they had to perform right-hand MI commands. The duration of each recording is 5 minutes.
- To assess whether individuals can enhance their proficiency in utilizing mental commands for MI, they participated in a series of 10 sessions. In each session, subjects must complete 12 runs of playing the game. In each run, the participants are instructed by the researcher what command (left or right) they must execute. In each session 6 runs are for the left MI commands and the other 6 for the right. A run is considered completed when the subject have successfully executed 2 consecutive correct mental commands.
- Before the start of each session, participants' EEG recordings are taken for the two mental commands related to motor imagery. This process yields a total of 80 EEG recordings (20 per participant). The combined duration of all the recordings amounts to 6.66 hours.
- The average classification results for each subject in the 10 sessions are presented in the table.



The graph presents the average improvement of the 4 subjects. The first 5 sessions are compared with the last 5 sessions.

Subj.	AVG left Accuracy	AVG right Accuracy	AVG Accuracy
1	99.48%	98.14%	98.74%
2	98.15%	97.21%	97.64%
3	97.83%	96.80%	97.31%
4	96.07%	99.15%	97.70%

The average classification results for the 10 sessions are presented.

- To assess whether subjects improved their proficiency in executing hand MI commands, the number of commands carried out in each run is calculated. The baseline minimum number of commands in each run is set at 2, indicating a perfect run. After completing each session, a comparison is made between the number of commands executed in each run to evaluate whether subjects demonstrated improvement.
- Every participant demonstrated improved performance in their final sessions when compared to their initial ones.

Conclusion

✓ Subjects can enhance their ability to perform MI mental commands.

Acknowledgements

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