Neural Markers of Student Confusion

Exploring Patterns of EEG Bands Correlated with Levels of Confusion

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Motivation

Accurately identifying the general level of student confusion is a crucial task for educators. The ability to do so enables instructors to personalize the pace and delivery of content for different classrooms, ensuring that the maximum amount of students can understand and learn the concepts. Current solutions are volatile, relying on students to actively request help and on teachers to actively guess at and sense the confusion levels in the classroom. Both of these methods are not rigorous and may result in a subset of students who do not understand the concepts being taught, leading to poor academic performance.

Neural activity in different bands (i.e., delta, theta, alpha, beta, low gamma, high gamma) has been shown to correlate with a variety of cognitive and behavioral events. Preliminary work has demonstrated that the power within the delta to low gamma bands may be correlated with confusion levels [1]. If the neural activity in different bands can rigorously be demonstrated to correlate with confusion levels, then it can be utilized to design robust systems that monitor confusion levels in students. These systems could then be deployed in classrooms to provide quantitative metrics of student confusion levels, enabling instructors to easily provide feedback and students to gain the maximal learning experience.

Approach

The dataset includes 12,000 data points of different bands of EEG data recorded from the frontal cortex of ten subjects as they watched ten short videos on confusing and straightforward topics [2]. 120 data points make up a single recording (i.e., a unique subject ID + video ID pair). Subjects noted their confusion levels on an ascending scale of one to seven after the recording. Demographic information on the ten subjects is also available.

The team plans to plot the correlation of data points from different bands with confusion levels to identify interesting positive and negative relationships. Measuring the R-value of these plots would also provide information on the predictive power of each band. It would also be informative to plot the relationship of different bands against each other over time. Finally, it would be interesting to identify the influence of any demographic information on the subject's confusion levels and on the activation in different bands. Through these visualizations, the project should provide an intuitive understanding of the correlation of different bands with student confusion levels.

Milestones

Preliminary Design: The preliminary version of the dashboard will include the core information that this project is intended to convey (i.e., correlates of student confusion). The dashboard will primarily include scatter plots of different bands and levels of student confusion to assess the relationships between band value and confusion. Relationships between demographic information and confusion levels will also be included.

Final Design: The final design will include more granular detail, including the ability to filter the scatterplots to look at the variation of EEG bands for individual students across confusion levels. It will also include heatmaps encoding the relationship between two bands, with color encoding the level of confusion. Finally, the dashboard will include a bar chart to show the correlation of features with confusion levels, using bar height to encode the feature's R-value.

A comparison of the performances of different machine learning algorithms in predicting student confusion from EEG bands will also be presented if time permits.

Approach: We will first begin by creating the charts described in the preliminary design. While analyzing the results, we will perform a literature review to identify previously documented neural correlates of grip force as well as the neurophysiological underpinnings for the resulting relationships.

Extensions

Beyond the scope of this course, the project can be extended in the following ways:

1) Compare the relationship between metrics of reconstructed EEG signals (i.e., fractal dimensionality, area under the curve, etc.) with confusion level [3]
    a) More nuance and resolution than simple amplitude
2) Analyze data on more participants
    a) The sample size of ten is relatively small from which to draw robust conclusions
3) Design an experimental setup such that the technology on which the one-minute videos were shown does not interfere with the impedance of the EEG

a) The proximity of technology is a leading cause of noise in EEG, and improper cleaning can lead to erroneous results

Tools

Tableau will be used for data visualization. MATLAB will be used for data cleaning and signal reconstruction.

References

[1] T. Xu, J. Wang, G. Zhang, L. Zhang, and Y. Zhou, “Confused or not: decoding brain activity and recognizing confusion in reasoning learning using EEG,” *Journal of Neural Engineering*, vol. 20, no. 2, Mar. 2023, doi: https://doi.org/10.1088/1741-2552/acbfe0.

[2] “Confused student EEG brainwave data,” *www.kaggle.com*. https://www.kaggle.com/datasets/wanghaohan/confused-eeg (accessed Mar. 19, 2024).

[3] J. Z. Liu, Q. Yang, Bra. Yao, R. W. Brown, and G. H. Yue, “Linear correlation between fractal dimension of EEG signal and handgrip force,” *Biological Cybernetics*, vol. 93, no. 2, pp. 131–140, Jul. 2005, doi: https://doi.org/10.1007/s00422-005-0561-3.