Decoding the Mental States of Focus and Distraction in a Real Life Setting of Tibetan Monastic Deabtes Using EEG and Machine Learning

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Introduction

EEG data are usually collected in the context of a contrived laboratory setting, which makes it challenging to make inferences about the real world. Here we are presenting machine learning methods that can be used to parse more complex and ecologically-valid settings for collecting EEG data. We will focus on the real-life situation of the monastic debate engaged in by Tibetan monks. The mental process we will examine is that of focus and distraction, for which neural correlates are well-known and fairly robust, typically consisting of posterior alpha oscillations [1].

Why Monastic Debate?

Monastic debate is a contemplative debating practice in which there is a large variability in the level of focus, as well as the reported emotions. Debating always involves at least one challenger and one defender. The challenger is standing and free to move while the defender sits for the entire duration of the debate. The debate has a strong formal structure, which is shown in Fig. 1. The goal for the challenger is to make the defender contradict one of the things he has agreed to before. The monastic debate motivate the debaters to improve reasoning abilities and memorization. It may also help them improve emotion regulation as debates can sometimes include teasing and insults to draw the defender out of their concentration and composure. More details about the debate can be found in [2]. In general, this shows that monastic debate is a fertile ground for EEG studies in ecologically valid contexts.

Objectives

We have the following two objectives for this study:

1. Determining whether EEG data can be collected in a real life situation and still render good detection of mental states using machine learning algorithms?
2. Is the classifier trained using machine learning on one set of data general enough to predict the cognitive states in another set of the data, when those data been acquired in different time frames and recording systems?

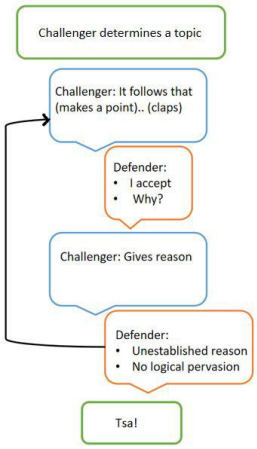

Figure 1: Structure of the debate

Dataset Description

The data consists of the EEG signals recorded from both the debaters simultaneously and the video recordings of the debate. Data has been collected in two sessions, one in 2017 (55 debates) and another in 2019 (46 debates) by two teams and two EEG recording systems (BrainVision actiCAP and Biosemi, respectively). Each debate has been labeled by at least three senior monks after watching the videos using the BORIS ethological observation software [3]. Ratings of focus and distraction were combined using the 'majority wins' rule.

Pre-Processing And Methodology

The EEG data were downsampled from 512 Hz to 256 Hz followed by the application of a band pass filter of 0.5 Hz - 40 Hz to remove low- and high-frequency artifacts. Next, Independent Component Analysis was done to clean the data of muscle and eye artifacts. Daubechies 4 wavelet transform was used to extract brain waves, namely delta (0.5-4 Hz), theta (4-9 Hz), alpha(9-14 Hz), beta (14-28 Hz), and gamma (28-40 Hz) from the pre-processed data. T-tests were used to identify channels and frequency bands that significantly distinguished between focus and distraction episodes identified by the raters. Subsequently, random forest classifiers were used to determine whether focus and distraction states could be detected on a single-trial level, and whether these would generalize across datasets.

Results

Statistical differences between focus and distraction

To check if average differences between the two cognitive states exist, the average raw EEG signals of all the participants for focused and distracted states were plotted along with the difference in the means. Fig. 2 and Fig. 3 show that channels 'FP_1', 'F_8', 'FP_2', 'Cz', 'O_2', 'TP_9', 'T_7', and 'P_7' show significant? differences.

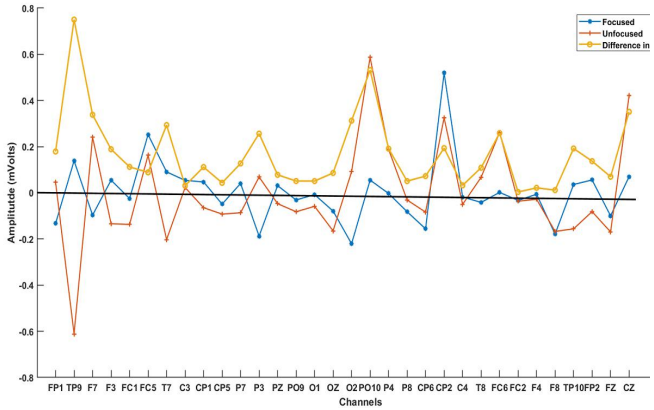

Figure 2: Raw EEG signals as a function of channel for 2017 dataset with focused (blue), distracted (orange) and their difference (yellow).

In addition to the raw EEG data, t-tests showed significant differences between focus and distraction in the delta band for the 2017 dataset, and in delta, theta alpha, and beta, bands for the 2019 dataset.

Machine Learning

To examine whether these differences could be observed on a single-trial level, we used a random forest classifier. Our random forest classifier consisted of 20 decision trees with maximum depth of each tree of 40 for the 2017 dataset. The accuracy obtained is shown in Fig. 4. The accuracy obtained is shown in Fig. 4. An accuracy of 79%, 97%, 93%, 99%, 88% and 99% was obtained for 2019 dataset in the raw, alpha, beta, delta, gamma and theta waves respectively using a single decision tree.

Conclusion and Future Work

Our results show that focus and distraction can be distinguished in EEG data collected in real life scenarios using statistical analysis and machine learning. In the future we will focus on determining if more subtle states like emotions can be detected and classified using this dataset as well.

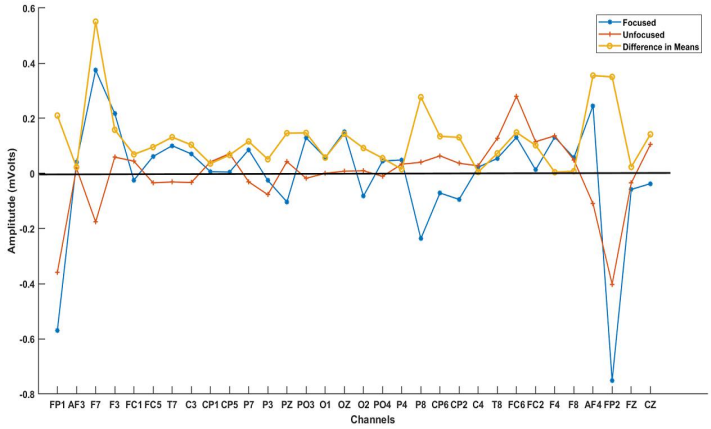

Figure 3: Raw EEG signals as a function of channel for the 2019 dataset with focused (blue), distracted (orange) and their difference (yellow).

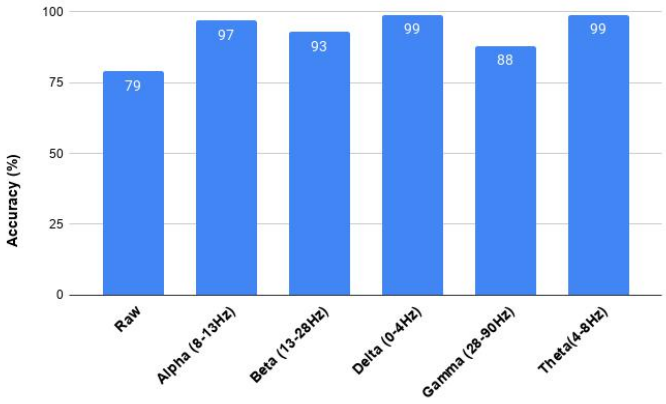

Figure 4: Accuracy obtained for 2017 dataset

References

Jin, C. Y., Borst, J. P., & van Vugt, M. K. (2019). Predicting task-general mind-wandering with EEG. *Cognitive, Affective, & Behavioral Neuroscience*, *19*(4), 1059-1073.

van Vugt, M. K., Pollock, J., Johnson, B., Gyatso, K., Norbu, N., Lodroe, T., & Lobsang, J. (2020). Inter-brain synchronization in the practice of Tibetan monastic debate. *Mindfulness*, 1-15.

http://www.boris.unito.it/pages/download.html