ECE-374N/385J

Neural Engineering - Spring **2024**

ECE Department, The University of Texas at Austin

HW-III
Longitudinal MI Training and Plasticity

Out: Wednesday, **11 March 2024** *Due: Wednesday,* **15 April 2024**

*Note-1: Please start early! We will hold a QA session next Wednesday in which you can ask questions *after* you have started on your HW and tried as many questions as possible.*

Note-2: Group discussions with your classmates are encouraged, but you have to submit your own individual work! Make sure to analyze the results you report and to suggest ways of improvement to the applied methods!

1 Overview

In this HW, you will analyze the neuro-plastic effects of longitudinal MI training for two healthy subjects. Throughout the training protocol, each of the subjects completed 7 sessions with 32-channel EEG recordings: one offline session that is used to build a subject-specific MI decoder, and six online sessions for visual-feedback-based MI training on consecutive days. You will analyze EEG signals recorded while the subjects perform motor imagery of left versus right hand movements on several BCI sessions to track changes in neural activity that may be indicative of neuroplasticity.

The BCI protocol used for this experiment is depicted in Fig. 1. Power spectral density features were extracted in real-time and are used to classify periods of MI task execution into either of the two classes: Left- or Right-Hand movement. The decoder used in online session is trained on subject-specific features extracted from the MI task execution periods of an initial offline session.
The objective of this HW is to track the changes in BCI performance metrics and the evidence of plastic changes over multiple training sessions.

1.1 Data Description

Each of the seven sessions completed by the subjects (1 offline and 6 online) includes 3 recording runs: a run contains 20 trials split equally between the two tasks: Left Hand and Right Hand (RH) MI.

You will be provided with a data file that contains the following for each subject:

subj.offline.run(r).eeg: (#*samples* × #*sensors*) contains 32-channel EEG data of *run-r*

subj.offline.run(r).header: contains the header of *run-r*

- subj.offline.run(r).fs: sampling rate
- subj.offline.run(r).chLabels: labels of the 32 EEG electrodes as distributed according to the 10/20 standard electrode placement
- subj.offline.run(r).header.EVENT.TYP: triggers marking the events of a trial
- subj.offline.run(r).header.EVENT.POS: position in samples of each of the logged triggers
- subj.online(s).run(r).eeg: (#*samples* × #*sensors*) contains 32-ch EEG of *session-s, run-r*
- subj.online(s).run(r).header: contains the header of *session-s, run-r* with similar structure to the one in offline sessions

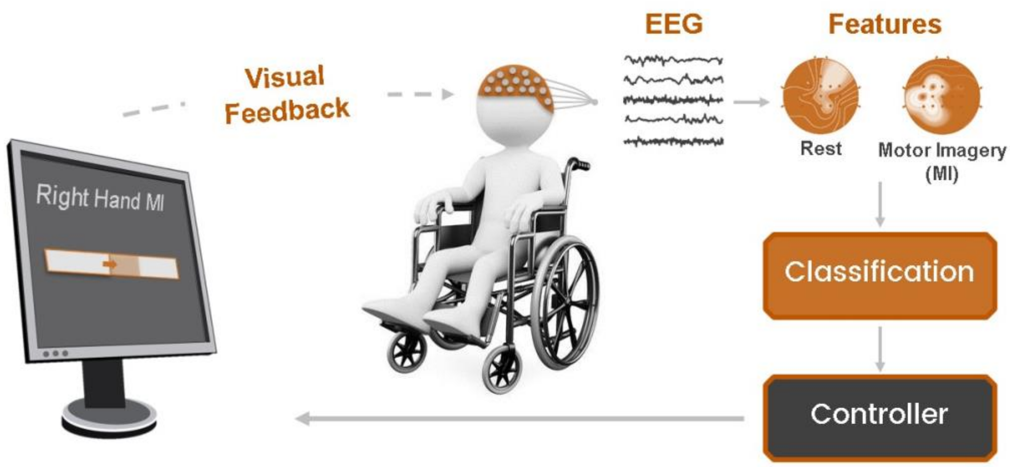

Figure 1: Positioning of EMG electrodes on the forearm.

Table 1 and Fig. 2 below detail the description of the used triggers within a trial as well as the trial structure for offline and online session. Note that in offline sessions, a task period ends after a fixed period of 5s while in an online session, it can end in three different ways:

- **Hit**: a correct BCI command has been delivered after accumulating enough evidence for the cued MI task
- **Miss**: a wrong BCI command has been delivered after accumulating enough evidence for the MI task opposite to the one cued in the trial
- **Timeout**: the decoder couldn't accumulate enough evidence for either of the classes within 7s

Table 1: Details of the trigger labels in a task

Trigger	EVENT.TYP	Description
Run Start/End	32766	marks the start and end of a run
Trial Start	1000	Start of a new trial - beginning of inter-trial rest period of 2-2.5s
Fixation	768	Fixation Cue presented for 2s
Task Cue	769/770	Task cue presented for 2s in Left Hand and Right Hand MI tasks respectively
Task Start	7691/7701	Task execution starts in Left Hand and Right Hand MI tasks respectively
Task End - Timeouts/Misses	7692/7702	Task execution ends in Left Hand and Right Hand MI tasks respectively after 5s in offline session and after a timeout of 7 seconds or a wrong command delivery for online sessions
Task End - Hits	7693/7703	Task execution ends successfully in Left Hand and Right Hand MI tasks respectively after a correct command delivery for online sessions (this cue is not present in offline sessions)

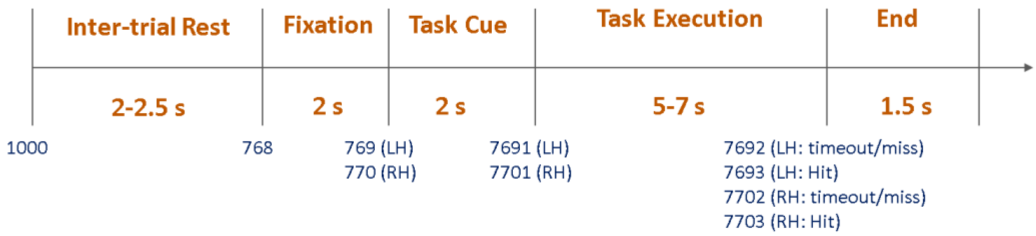

Figure 2: Triggers in a single trial.

2 Tasks

2.1 BCI Command Delivery

1. Using the trigger labels of the header files, determine the command delivery accuracy and the percentage of timeouts. Perform this operation for each of the runs in each of the online sessions and for the two subjects. On the same figure, plot the accuracy over the session (averaged across runs) for each subject. **[0.5pt]**

2. Perform statistical analysis for the trend in the command delivery accuracy over sessions at the group level (both subjects together) and at the subject level (each subject independently). Perform a similar analysis for the percentage of timeouts. Do you observe a statistically significant trend? Comment on the results! **[1.5pt]**

3. Perform appropriate statistical testing to compare the accuracy values at any given online session to the values in the first online session. Is there a session at which statistical significance emerges and is it sustained for subsequent sessions? Perform similar analysis for the percentages of timeouts. Comment on your results! **[1.5pt]**

2.2 Discriminability of Features

1. For all sessions of both subjects, extract power spectral density (PSD) features from task periods using the *pwelch* method for all 32 channels and for frequency components in the range [4-30] Hz with a resolution of 2Hz. Note: you should obtain 448 features. **[1pt]**

2. Compute the Fisher Score, Equation (1), of each of the extracted features in each of the sessions for the two subjects. **For Subject-2 only**, find the top 10 features (what channel/band combination do they correspond to) and comment on the stability of the features across different sessions for each subject. **[1pt]**

$$fisherscore = \frac{|\mu_{class-1} - \mu_{class-2}|}{\sqrt{\sigma^2_{class-1} - \sigma^2_{class-2}}} \tag{1}$$

3. In each session, sum the fisher scores for all the bands per EEG channel, and show the topoplots of the summed fisher scores across sessions. Do this for each subject independently. Comment on the change in discriminability over sessions and their physiological relevance. **[1pt]**

4. For each subject, find the channel/band feature that has the highest fisher score on the last online session, and track the fisher score of that feature across all online sessions. Perform statistical analysis for the trend in discriminability across sessions at the subject level. Perform statistical

analysis to compare session-1 to session-6 values at the group level. Comment on the results! If the results are not as you expect them to be, elaborate on any potential limitations to this analysis. **[2pt]**

5. **Only for Subject-2**, find the top 10 features on the last online session and correlate the discriminability of those features across sessions to the average command-delivery accuracy across sessions (from 2.1). Are there features whose discriminability show statistically significant correlation with accuracy. Discuss the physiological relevance of the results. **[1.5pt]**