EE-379K/385V

Neural Engineering - Spring 2022

ECE Department, The University of Texas at Austin

Term Project
FES - TESS - EMG

Out: Wednesday, April 06, 2022

Note-1: Please start exploring the data early!

1 Project Overview

You will be provided with data collected from two subjects who completed the following experiment over two days:

1.1 Day-1

Session-1 - Offline Motor Imagery with EEG recordings
Subjects did motor imagery (MI) of one of the two tasks: right hand extension or left hand extension while EEG was recorded.

1.2 Day-2

Session-1 - Online Motor Imagery with EEG recordings
Subjects completed multiple recording runs while performing one of two tasks: Right Hand Extension or Left Hand Extension. During MI, they received EEG-based visual feedback in closed-loop manner.

Session-2 - TESS + FES Stimulation while doing MI
Subjects received continuous transcutaneous electrical spinal stimulation (TESS) for 20 minutes between the C5-C6 vertebrae. During TESS, subjects performed MI of left and right hand extension while receiving FES-based proprioceptive feedback.

Session-3 - Online Motor Imagery with EEG recordings
Subjects completed multiple recording runs while performing one of two tasks: Right Hand Extension or Left Hand Extension. During MI, they received EEG-based visual feedback in closed-loop manner.

- **EEG**: recorded from 32 channels distributed over the scalp according to the 10/20 standard electrode positioning.
- **TESS**: stimulation was applied over the cervical vertebrae C5-C6 without evoking any muscular contractions.
- **FES**: stimulation was applied at sensory threshold - without evoking any contraction - on the proximal and distal parts of the extensor digitorum muscle of the right or left arm while doing MI of the corresponding movement.

2 Hypothesis (High Level)

Pairing the TESS with FES on the peripheral muscle while performing MI will have an effect on EEG activity corresponding to the motor imagery of right versus left hand extension.

3 Objectives

- Elaborate on the high level hypothesis concerning the cortical effects of pairing TESS with FES and on the changes in MI correlates for each of the tasks following the stimulation session.
- Analyze the EEG activity during the two task periods (left and right hand extension MI) before and after the TESS-FES session
- Provide evidence based on your reviewed and proposed methods to probe your hypotheses and discuss possible physiological explanations for your results.
- What conclusions or aspects of your hypothesis have been answered by the results? Would you formulate a new hypothesis that requires more recordings?

4 Experimental Details

- **FES-based BCI training**: Motor Imagery sessions with FES-feedback were conducted as follows:
  - **Offline runs - Day 1**: Includes 20 trials split into the tasks of: Left versus Right hand extension MI. MI trials were guided by visual feedback independent of the subjects' brain activity.
  - **Offline run with TESS - Day 2**: Includes around 60 trials (over 20 minutes) split into the tasks of: Left versus Right hand extension MI. MI trials were guided by a sensory stimulation independent of the subjects' brain activity - no visual feedback was provided. During the entire 20 minutes, TESS was continuously applied over C5-C6.
  - **Decoder**: The data from the offline runs on Day-1 was used to build a decoder to classify the MI tasks from EEG signals in both online sessions of Day-2.
  - **Online runs - Day 2**: The decoder from the offline run of Day-1 was used to provide visual-based feedback while the subject performed the two MI tasks (no stimulation in these runs). A total of 4 runs with 20 trials were completed.
  - **FES parameters**: st-FES stimulation was delivered at 30 Hz with an average amplitude of 5 ± 1 mA and a pulse width of 250 μs.
  - **TESS parameters**: Stimulation was applied at 30Hz pulses with a 5kHz carrier frequency on the C5/C6 location.The current intensity was adjusted to the comfort of the subject between 20-30mA.

Figure 1: MI training with FES feedback.

5 Data Description

Each session includes the following:

- **Handedness**: Both subjects were right handed.
- **Runs**: Offline sessions consisted of 4 runs with 20 trials each while online sessions (pre and post stimulation) consisted of 3 runs with 20 trials each.
- **Trials**: The trail structure is depicted in Fig 2. For offline sessions, the trial always ends with the timeout triggers, but for the online session, a trial can either end by a Hit (accumulated evidence crossed a pre-defined threshold for the correct class), a Miss (accumulated evidence crossed a pre-defined threshold for the wrong class), or a timeout (7s passed without accumulating enough evidence for either classes).

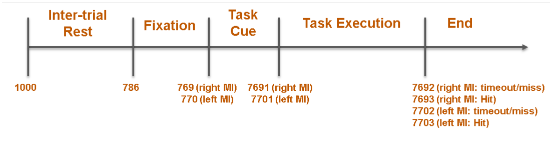

Figure 2: Trial organization with trigger labels.

5.1 Data Structure

The variable **subjectData** contains the following: **Note**: $s \in \{1, 2\}$ and $i \in \{1, 2\}$

- **subjectData(s).preON(i).eeg**:(# samples x 32 channels) contains eeg data of the i^{th} run in Day-2 first online session for subject s.
- **subjectData(s).preON(i).header**: header info of the i^{th} run in Day-2 first online session for subject s.
  - .fs: sampling rate
  - .eegLabels: labels of the 32 eeg channels
  - .eegLocs: locations of the 32 channels on the scalp
  - .triggers.TYP: event triggers during the trial
  - .triggers.POS: position in samples of each trigger
- **subjectData(s).postON(i).eeg**:(# samples x 32 channels) contains eeg data of the i^{th} run in Day-2 second online session for subject s.
- **subjectData(s).postON(i).header**: header info of the i^{th} run in Day-2 second online session for subject s.
  - .fs: sampling rate
  - .eegLabels: labels of the 32 eeg channels
  - .eegLocs: locations of the 32 channels on the scalp
  - .triggers.TYP: event triggers during the trial
  - .triggers.POS: position in samples of each trigger