EE-379K/385V

Neural Engineering - Spring 2021

ECE Department, The University of Texas at Austin

Term Project
FES - TMS - EMG - EEG

Out: Wednesday, March 7, 2021

Note-1: Please start exploring the data early!

1 Project Option-II

In this option, you will be provided with data collected from two subjects who completed the following experiment over three sessions with multiple runs per session:

1.1 Session-1

EEG and EMG signals were recorded as subjects performed MI of the hand flexion and hand extension tasks. At some point during each task period, transcranial magnetic stimulation (TMS) was applied once on the contra-lateral hemisphere.

- **EEG**: recorded from 32 channels distributed over the scalp according to the 10/20 standard electrode positioning.
- **EMG**: recorded from 4 electrodes placed on the proximal and distal parts of the flexor carpi radialis and the extensor digitorum muscles as in HW-II.
- **TMS**: single pulse stimulation over the contra-lateral motor area.

1.2 Session-2

Subjects did motor imagery of the hand flexion and hand extension tasks while receiving FES-based proprioceptive feedback.

- **EEG**: recorded from 32 channels distributed over the scalp according to the 10/20 standard electrode positioning.
- **FES**: stimulation was applied at sensory threshold - without evoking any contraction - on the proximal and distal parts of the extensor digitorum muscle while doing MI of hand extension and on the proximal and idstal parts of the flexor muscles while doing MI of hand flexion.

1.3 Session-3

Same as Session-1: EEG and EMG signals were recorded as subjects performed MI of the hand flexion and hand extension tasks. At some point during each task period, transcranial magnetic stimulation (TMS) was applied once on the contra-lateral hemisphere.

2 Hypothesis (High Level)

Delivery of st-FES feedback during MI training will have an effect on EEG activity and on the EMG activity elicited by TMS during motor imagery of fine hand movements: flexion/extension.

3 Objectives

- Elaborate on the high level hypothesis concerning the effects of st-FES feedback during BCI training on the effects of FES feedback during BCI training on the changes in MI correlates and motor evoked potentials (MEPs) - elicited by the TMS - for each of the tasks and for the "No MI" case.
- Analyze the EEG and EMG activity for the "No MI" and "MI" runs of the first and last sessions. For the "MI" sessions, analyze the signals for both MI tasks: hand flexion and hand extension.
- Provide evidence based on your reviewed and proposed methods to probe your hypotheses and discuss possible physiological explanations for your results.
- Will you need to formulate a new hypothesis based on the results?

4 Experimental Details

- **EMG placement:** The emg electrodes where placed as depicted in Fig. 1 on the flexor carpi radialis and extensor digitorum muscles.

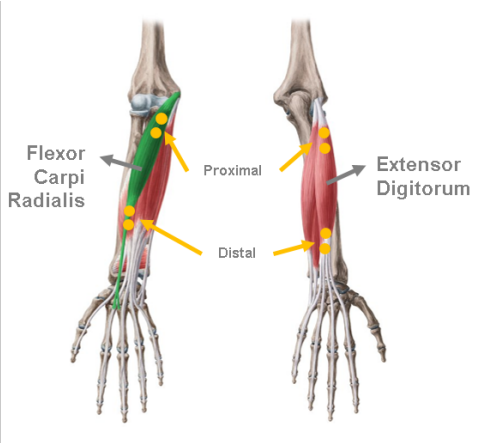

Figure 1: Trial organization with trigger labels.

- **Force**: Subjects controlled their force while executing the movement through feedback from a pressure sensor.
- **FES-based BCI training**: Motor Imagery sessions with FES-feedback were conducted as follows:
  - **Offline run**: Includes 10 trials of motor imagery for each of flexion and extension. The trials were guided by a moving bar independent of the subjects' brain activity.
  - **Decoder**: The data from the offline run was used to build a decoder to classify the MI tasks from EEG signals.
  - **Online runs**: The decoder from the offline run was used to control sensory-threshold FES feedback while the subject performed MI tasks. When the subject was performing flexion, the feedback was provided on the flexor muscle, and it propagated from the proximal to the distal part of the muscle based on the accumulated decoder confidence - same thing was done for extension. A total of 4 runs with 20 trials of each task were completed.
  - **FES parameters**: st-FES stimulation was delivered at 30 Hz with an average amplitude of 5 $\pm$1 mA and a pulse width of 250 μs.

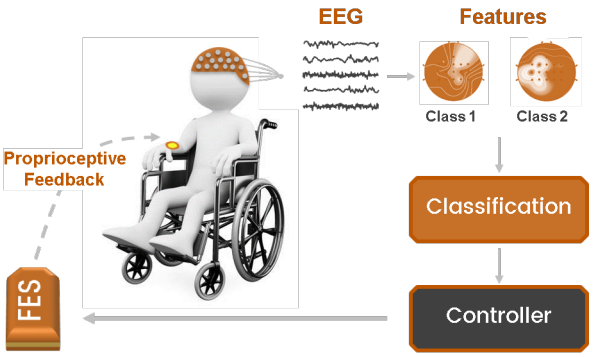

Figure 2: MI training with FES feedback.

- **TMS**: TMS was applied over the motor area contra-lateral to the non-dominant hand of the subject while recording EMG and EEG signals. The amplitude of stimulation was tuned to consistently generate observable motor-evoked potentials (MEPs) in all EMG electrodes. The TMS stimulation runs were conducted as follows:
  - **No MI**: 80 stimulations were applied while the subject was resting
  - **MI**: 60 stimulations - split into 3 runs - were applied while the subject was performing extension or flexion MI (30 trials per task). The stimulation pulse was triggered at a random instance within the task period.

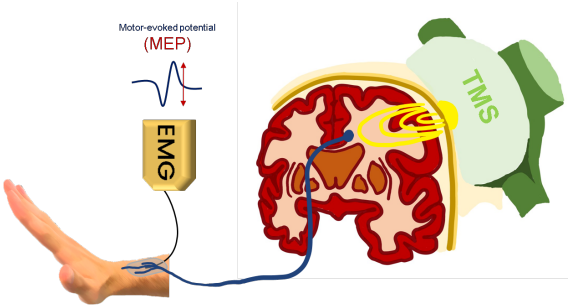

Figure 3: Illustration of the TMS session.

5 Data Description

Data is provided for the first and third sessions only. Each session includes the following:

- **Handedness**: Subjects were instructed to use their non-dominant hand for MI and motor execution. Both subjects were right handed (used the left hand).
- **Runs**: One run of "No MI" (with 80 trials) and three runs of "MI" (60 trials split between extension and flexion)were completed.
- **Trial - No MI**: In each trial, the task period ends with a TMS pulse as depicted in Fig. 4. In emg data, the pulse is logged with a trigger while in eeg data the pulse location can be found through the high-voltage artifact elicited upon stimulation.
- **Trial - MI**: The trial organization with the associated trigger labels is depicted in Fig. 5.

Figure 4: Trial organization with trigger labels for the "No MI" case.

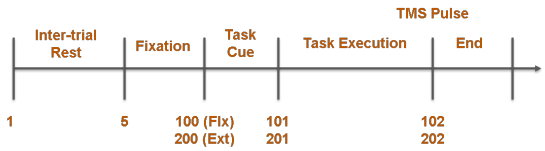

Figure 5: Trial organization with trigger labels for the "MI" case.

5.1 Data Structure

The variable **subjectData** contains the following:

- **subject1Pre.noMI.eeg**:(# samples x 32 channels) contains eeg data of the "No MI" run in the first session for subject 1.
- **subject1Pre.noMI.emg**:(# samples x 4 channels) contains emg data of the "No MI" run in the first session for subject 1.
- **subject1Pre.noMI.hdr**: header info of the "No MI" run in the first session for subject 1:
  - .fs: sampling rate
  - .triggers: trigger values during the task
  - .eegLabel: labels of the 32 eeg channels
  - .emgLabel: labels of the 4 emg channels
- **subject1Pre.MI(i).eeg**:(# samples x 32 channels) contains eeg data of the i^{th} "MI" run in the first session for subject 1.
- **subject1Pre.MI(i).emg**:(# samples x 4 channels) contains emg data of the i^{th} "MI" run in the first session for subject 1.
- **subject1Pre.MI(i).hdr**: header info of the i^{th} "MI" run in the first session for subject 1:
  - .fs: sampling rate
  - .triggers: trigger values during the task
  - .eegLabel: labels of the 32 eeg channels
  - .emgLabel: labels of the 4 emg channels
- **Post Sessions**: Same structure applies to "subject1Post" variable
- **Subject 2**: Same structure applies to "subject1Pre" and "subject1Post" variables
- **Note**: $i \in \{1, 2, 3\}$