Project 4

Experimental paradigm

The paradigm, called inner speech, raises the possibility of executing an order just by thinking about it, allowing a “natural” way of controlling external devices. A ten-participant EEG dataset, recorded with an acquisition system of 136 channels, is presented. The device setup for the experiment is shown in Fig.1,

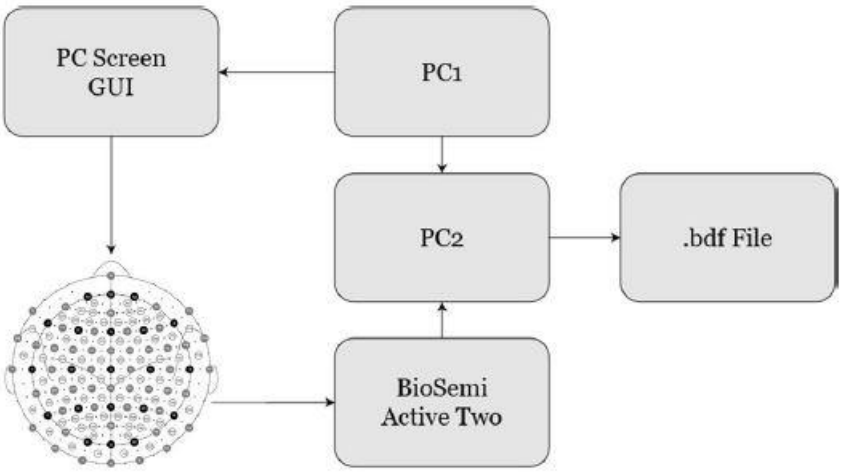

Fig. 1: Experiment setup. Both computers, PC1 and PC2, were located outside the acquisition room. PC1 runs the stimulation protocol while communicating to PC2 every cue displayed. PC2 received the sampled EEG data from the acquisition system and tagged the events with the information received from PC1. At the end of the recording, a.bdf file was created and saved.

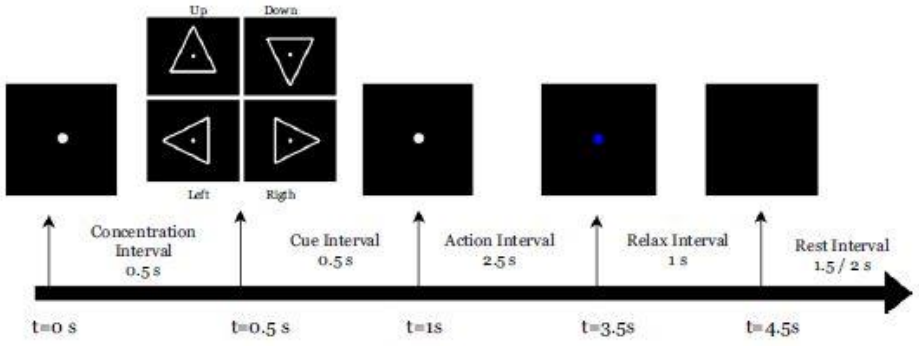

Fig. 2: Trial workflow. The screen presented to the participant in each time interval was plotted on the top arrow of the figure. Relative and global time were plotted above and below the arrow, respectively.

The study was conducted in an electrically shielded room. The participants were seated in a comfortable chair in front of a computer screen where the visual cues were presented. In order to familiarize the participant with the experimental procedure and the room environment, all steps of the experiment were explained, while the EEG

headcap and the external electrodes were placed. The setup process took approximately 45 minutes, as shown in Fig.1. Each individual participated in one single recording day comprising three consecutive sessions, as shown in Fig.2. A self-selected break period between sessions, to prevent boredom and fatigue, was given (inter-session break).

Event ID	Description
1	Start of protocol
12	End of protocol
13	Start of baseline
14	End of baseline
15	Start of run
16	End of run
17	Cognitive control - question posing
21	Start of pronounced speech run
22	Start of inner speech run
23	Start of Visualized condition run
31	"Arriba/Up" trial - start of cue interval
32	"Abajo/Down" trial - start of cue interval
33	"Derecha/Right" trial - start of cue interval
34	"Izquierda/Left" trial - start of cue interval
42	Start of concentration interval
44	Start of action interval
45	Start of relax interval
46	Start of rest interval
51	Start of inter runs rest interval
61	Answer to cognitive control: "Arriba/Up"
62	Answer to cognitive control: "Abajo/Down"
63	Answer to cognitive control: "Derecha/Right"
64	Answer to cognitive control: "Izquierda/Left"

Fig. 3:. Raw data event tags number and meanings.

At the beginning of each session, a fifteen-second baseline was recorded where the participant was instructed to relax and stay as still as possible. Within each session, five stimulation runs were presented. Those runs correspond to the different proposed conditions: pronounced speech, inner speech and visualized condition. At the beginning of each run, the condition was announced in the computer screen for a period of 3 seconds. In all cases, the order of the runs was: one pronounced speech, two inner speech and two visualized conditions. A one minute break between runs was given (inter-run break). The classes were specifically selected considering a natural BCI control application with the Spanish words: "arriba", "abajo", "derecha", "izquierda" (i.e."up", "down", "right", "left", respectively). The trial's class (word) was randomly presented. Each participant had 200 trials in both the first and the second sessions. Nevertheless, depending on the willingness and tiredness, not all

participants performed the same number of trials in the third session. Fig. 2 describes the composition of each trial, together with the relative and cumulative times.

Please take note that the data you have received is pre-segmented. Each '.mat' file includes a structured file named 'data.' Within this 'data' structure, you will find a field labeled 'trial' containing 200 segmented EEG data epochs. Another field, 'trialinfo,' contains class labels for each epoch, and the 'classLabel' field contains the actual label information. The 'fsample' field specifies the sampling frequency of the recorded EEG signals, while the 'label' field contains the labels for all EEG channels. The initial 40 trials correspond to pronounced speech, the subsequent 80 trials correspond to inner speech, and the final 80 trials are associated with the visualized condition. It's important to note that the data has already been subjected to bandpass filtering in the range of 0.5 to 100 Hz, and a notch filter has been applied at 50 Hz.

Project Objective

The goal of this project is to create a classification model using deep learning techniques for the purpose of categorizing various inner speech tasks. Participants have the flexibility to define appropriate classification challenges, which could involve subject-specific or cross-subject classification. Participants can employ various signal processing methods and deep learning models, including CNN, GNN, Transformer, and LSTM, to achieve the desired classification accuracy. Upon project completion, participants should be prepared to present and elucidate their work, including their developed model, through appropriate feature visualization and statistical tests.

Reference: Nieto, N., Peterson, V., Rufiner, H.L. *et al.* Thinking out loud, an open-access EEG-based BCI dataset for inner speech recognition. *Sci Data* **9**, 52 (2022). https://doi.org/10.1038/s41597-022-01147-2