Neuroengineering 2022-2023

Exam of 1 February 2024 – Part 2

Solutions

Problem

An experimenter performs an exploratory study to assess the scalp locations and the frequency bands in which her EEG shows a visible modulation of the mu rhythm doe to a motor imagery exercise.

Recording protocol.

The subject is instructed to monitor the cues appearing on a screen, and to imagine a continuous movement of a specific body part whenever the corresponding cue appears on the screen. The cue also included a text describing the target body part, for instance “Right hand” or “Left hand”. Within the recording session, the cue stayed on the screen for 30 seconds, and each body part was shown exactly once.

Data Acquisition.

Using a sampling frequency of 200 $samples/s$, 32 monopolar EEG channels are acquired. With the subject sitting in a comfortable chair, the experimenter applies all required 34 electrodes, injects the conductive gel under each of them, and checks that all contact impedances are at most 5 kOhm.

Data segmentation

Raw data is segmented into trials, each starting when a cue appeared on the screen and ending when the cue disappeared.

Data analysis.

Spectral analysis was used to estimate the spectrum of each EEG channel in a specific condition (e.g. imagined movement of the right hand). For each EEG channel, spectra related to pairs of conditions were then compared (e.g. right vs. left hand).

Unfortunately, the experimenter did not give further details about the spectral analysis.

Results

Among others, the experimenter computed the pair of spectra shown in *Figure 1*, which are referred to the imagination of movement of the left and right hand, respectively. Vertical thin lines in the figure correspond to frequencies at which the spectrum is sampled.

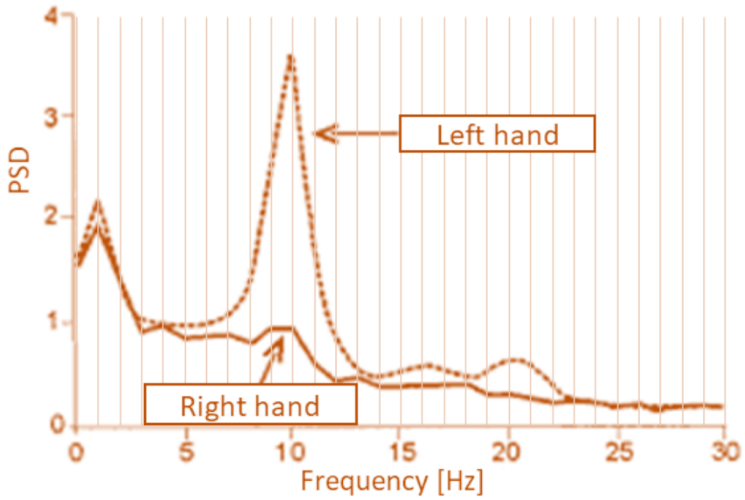

Figure 1. Power Spectral Density of one EEG channel in two conditions (left vs. right hand movement imagination). Vertical thin lines correspond to frequencies at which the spectrum is sampled

Questions

Q1	Did the experimenter apply the correct number of electrodes? Justify in max 2 lines.	1 pt

Yes.

Monopolar recordings require 1 electrode per EEG channel (32), plus 1 for the reference and 1 for the ground.

Q2	How long is a trial (i) in seconds and (ii) in samples?	0.5 pt

30 seconds, as described in the text, equivalent to 30 x 200 = 6000 samples

Q3	Which method would you use to estimate the EEG spectra? Justify in max 2 lines.	2 pts

Averaged periodogram / Welch's spectral estimation.

A direct application of the DFT would yield a spectral resolution of 1/6000 Hertz, which is obviously excessive when the aim is to analyze brain rhythms spanning bandwidths of a few Hertz. The averaged periodogram (or Welch's method) trades off spectral resolution with estimation accuracy, more useful for the purpose of the study.

Q4	Observing the spectrum in *Figure 1*, find out what "window length" was used in the spectral estimation (in samples). Justify in max 4 lines.	2 pts

200 samples.

Spectral lines are 1 Hz apart, thus the length of each window to which the DFT was applied was

$$N = f_s/\Delta f = 200\ Hz\ /\ 1\ Hz = 200\ samples$$

where N is both the number of samples of the time domain signal ($N = f_s \cdot \Delta T$, being ΔT the duration of the trial) and the number of samples of its DFT (spanning the band $[-f_{Nyq}, +f_{Nyq}]$, thus $N \cdot \Delta f = f_s$).

Q5	Do you think that the EEG channel whose spectra is shown in *Figure 1* is C3 or C4? Justify in max 4 lines.	1.5 pts

C3.

The desynchronization of the peak at 10 Hz (alpha band) when a movement of the right hand was imagined shows that the EEG was recorded from the contralateral (left) part of the scalp.