

Neuroengineering 2022-2023

Exam 14 June 2023 (previous modalities)

Part II

How to submit your answers.

Most answers can be typed in the Exam.net editor.

Write the answers in the same sequence as the questions (A1, A2, ... B1, B2, ...) and write the same headers as the test on a separate line just above your answer, e.g.:

```
Problem A
A1
<your answer to question A1 goes here>
A2
<your answer to question A2 goes here>
...
...
```

When graphical elements are required in the answer, the latter can be written on paper and scanned using your mobile phone at the end of the exam.

It should always be possible to use a single sheet of paper for all answers to a specific problem. Anyway, always use separate sheets of paper for problems A and B.

Keep your answers tidy. Messy, hard-to-read answers may penalize your mark.

Your answers should not exceed the length recommended in each question.

Answers significantly longer than requested may reflect poor understanding of the problem, and thus will likely receive a lower mark.

The maximum total score for part II is 11.

Problem A

Carefully read the following scenario and answer the questions listed below.

A novel approach for the **rehabilitation of the upper limb motor function** is tested in a group of **post-stroke patients** with lesions in a single hemisphere of the brain. The duration of the rehabilitative intervention is 4 weeks.

Before and **after** the intervention, the patients are subjected to a **neurophysiological assessment**, with the aim to evaluate the changes in the connectivity occurred as a result of the rehabilitation.

EEG recordings

EEG recordings (36 electrodes) are performed in **two sessions**: one immediately before (**PRE**) and one immediately after (session **POST**) the rehabilitative intervention (Fig. A1). The **task** performed by the patients consists of the **attempt** to move the upper limb controlled by the **lesioned** hemisphere.

Neurophysiological Assessment

The neurophysiological assessment includes the following steps:

- 1- The pre-processing of the EEG traces
- 2- The selection of **8 EEG channels** in the regions above the sensorimotor areas (4 on the left and 4 on the right hemisphere) (Fig. A2)
- 3- The analysis of **brain functional networks** during the task, by means of the **Ordinary Coherence** in the PRE session and of the **Granger Test** in the POST session
- 4- The extraction of a **graph** associated to each network and the computation of the related **indices (degree of each electrode and average degree for each hemisphere)**
- 5- The **statistical comparison** (for the group) of the average degree of each hemisphere in the PRE and POST sessions.

The aim is to extract an **objective index** to be used to **quantify the changes in the brain organization** in terms of **directed causality at specific frequency bands**.

Questions

(type the answer in the exam.net editor unless specified differently).

- A1.** *(2.5 points)* Identify at least one mistake in the procedure described. Indicate what is wrong, why, and propose a solution. *(If you find more mistakes, you can repeat the procedure for each of them. A single mistake correctly identified and commented with the appropriate solution is sufficient to get the full grade).* (Max 10 lines)
- A2.** For a specific subject, the graphs obtained for the PRE and POST sessions are reported in Fig. A3.
- A2.1** Extract the corresponding adjacency matrices *(1 point)* *(write the answer in a single sheet of paper)*
- A2.2** Compute the degree for each node *(0.5 point)* *(write the answer in a single sheet of paper)*
- A2.3** Compute the average degree for each hemisphere *(0.5 point)*
- A2.4** Are there any changes in these indices after the intervention? (Max 3 lines) *(1 point)*



Fig. A1 – Temporal organization of the study

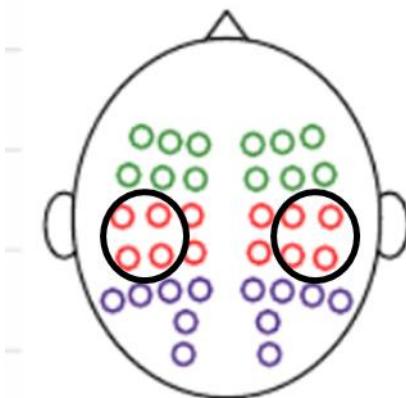


Fig. A2- The electrodes selected for the study (circled)



Fig. A3- Graphs obtained for a specific patient at step 4

Problem B

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 due to a motor imagery exercise.

The subject is instructed to monitor the cues on a screen, and to imagine a continuous movement of her left/right hand whenever the corresponding cue appears on the screen. Each cue stays on the screen for 10 seconds.

Data Acquisition.

Using a sampling frequency of 200 Hz, 16 monopolar EEG channels are acquired. With the subject sitting in a comfortable chair, the experimenter applies 16 electrodes, injects the conductive gel under each of them, and checks that all contact impedances are at least 50 kOhm.

The experimenter starts the recording and then leaves the recording room to deal with another experiment. When he returns after the experiment time is over, he unmouts the EEG cap and dismisses the subject. Finally, he checks the quality of the raw EEG traces.

Segmentation

Raw data is segmented into 10 seconds long trials, using the beginning of each imagined movement as event. 50 trials are available for each of the two imagined movement type.

Artifact rejection.

When the experimenter inspects the raw recordings, he finds out that channel O1 shows clear signs of electrode popping artifacts in 55 trials out of 100. He discards these trials and proceeds with the inspection of the remaining 45. Among others he discards the four trials shown in [Figure B1](#), having detected that they contain: sweating (a), EOG (b), EMG (c), and powerline (d) artifacts.

Data analysis.

To compare the spectra of the EEG signal in the two condition, he chooses to use the Welch's algorithm for PSD estimation.

Among others, he obtains the pair of spectra shown in [Figure B2](#), which are referred to a specific EEG channel during the left and right hand movement imagination, respectively. Vertical thin lines in the figure correspond to frequencies at which the spectrum is sampled.

Questions:

(type all answers in the exam.net editor)

- B1. [\(2 points\)](#) Report at least one mistake in the data acquisition procedure. Describe what was done wrong, argument why it was wrong, and propose your solution.

(If you find more mistakes, only give a full answer for the most severe one, and then briefly report what else was wrong and why – one extra line per mistake.)

Max 10 lines.

- B2. [\(2 points\)](#) Report at least one mistake in the artifact rejection procedure. Describe what was done wrong, argument why it was wrong, and propose your solution.

(If you find more mistakes, only give a full answer for the most severe one, and then briefly report what else was wrong and why – one extra line per mistake.)

Max 10 lines.

- B3. [\(1.5 points\)](#) Observing the spectrum in [Figure B2](#), find out what “window length” (i.e. the length of the epochs into which the signal is chopped) was used in the Welch's algorithm. Express this value in number of samples.

Justify in one line.

- B4. [\(1 point\)](#) Do you think that the EEG channel whose spectra is shown in [Figure B2](#) is C3 or C4?
Justify in one line.

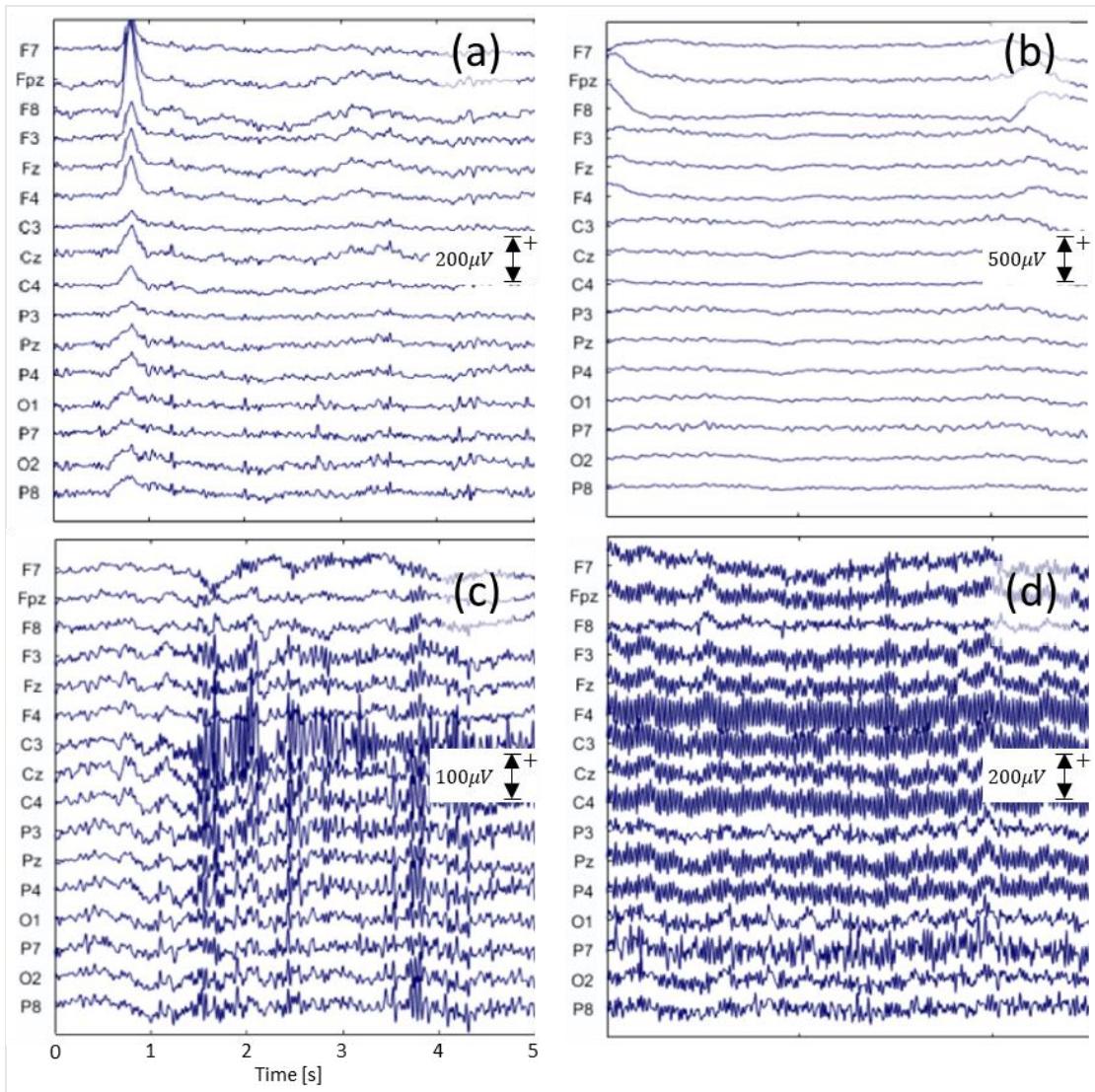


Figure B1. Four of the discarded trials shown in Figure B1, in which the experimenter recognized: sweating (a), EOG (b), EMG (c), and powerline (d) artifacts. Only the first five seconds of each trial are shown.

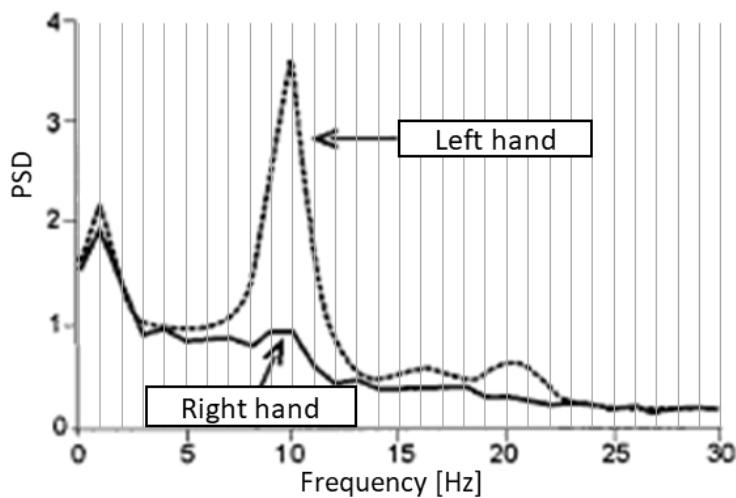


Figure B2. Power Spectral Density of one EEG channel in two conditions (left vs. right hand movement imagination). Vertical thin lines in the figure correspond to frequencies at which the spectrum is sampled