Neuroengineering 2022-2023

Exam 14 June 2023
(previous modalities)

Part II

Problem A

A1. *1st mistake:* to use a different connectivity estimator for the PRE and POST sessions. Any changes resulting from the subsequent analysis may be due to the different meaning of the networks and not to the effect of the rehabilitation. Moreover, the networks obtained will have different properties (directed/undirected, frequency-resolved, or not)
Solution: to adopt exactly the same procedure for the analysis of the PRE and POST data.

2nd mistake: the aim is to extract an index of **directed** causality at specific **frequency bands**, yet the two methods used are (i) a measure of synchronization and not causality (Ordinary Coherence); (ii) a measure defined in the time, not in the frequency, domain.
Solution: to use a spectral, directed measure of causality: e.g., the Partial Directed Coherence.

(*Additional:* to use a single group for the test of a novel therapeutic approach. Patients should be randomly assigned to a control group performing the usual treatment and to the experimental group performing the proposed new approach, and results obtained for the two groups should be compared).

A2. Solution:

a. Adjacency matrices:

PRE session

A=

--	1	1	0	1	0	0	0
1	--	0	1	0	0	0	1
1	0	--	1	0	0	0	0
0	1	1	--	1	1	0	1
1	0	0	1	--	0	0	0
0	0	0	1	0	--	0	1
0	0	0	0	0	0	--	1
0	1	0	1	0	1	1	--

POST session

A=

--	1	1	0	1	0	1	0
1	--	0	1	0	1	0	0
1	0	--	1	1	0	1	0
0	1	1	--	1	1	0	1
1	0	1	1	--	0	1	0
0	1	0	1	0	--	0	1
1	0	1	0	1	0	--	1
0	0	0	1	0	1	1	--

b. Degree for each node:

PRE session

A=

								Degree
--	1	1	0	1	0	0	0	3
1	--	0	1	0	0	0	1	3
1	0	--	1	0	0	0	0	2
0	1	1	--	1	1	0	1	5
1	0	0	1	--	0	0	0	2
0	0	0	1	0	--	0	1	2
0	0	0	0	0	0	--	1	1
0	1	0	1	0	1	1	--	4

POST session

A=

								Degree
--	1	1	0	1	0	1	0	4
1	--	0	1	0	1	0	0	3
1	0	--	1	1	0	1	0	4
0	1	1	--	1	1	0	1	5
1	0	1	1	--	0	1	0	4
0	1	0	1	0	--	0	1	3
1	0	1	0	1	0	--	1	4
0	0	0	1	0	1	1	--	3

c. Average degree for each hemisphere:

PRE:

Average degree of the left hemisphere: (3+5+2+4)/4= **3.5**
Average degree of the right hemisphere: (3+2+2+1)/4= **2**

POST:

Average degree of the left hemisphere: (3+5+3+3)/4= **3.5**
Average degree of the right hemisphere: (4+4+4+4)/4= **4**

d. Yes, the right (lesioned) hemisphere has increased its average degree (meaning a greater involvement in the network subtending the arm movement attempt), while the left (unaffected) hemisphere shows no changes in the index.

Problem B

Question B1.
Mistake 1 - Too few electrodes.
Each EEG channel requires *active* and a *reference* electrode (see diagram of the differential amplifier). In monopolar recordings the reference electrode is common to all channels, so we need to add one extra reference electrode. Moreover, each stage of a differential amplifier uses for its electronics the ground potential of the equipment, which must be connected to the subject, so we need to add a ground electrode too.

Mistake 2 – contact impedance should be low.
Rather than checking if the impedance is "at least" some value, he should make sure that it is at most some value. This value is conventionally set at 5 kOhm, even though higher thresholds are acceptable with modern equipment, as far as impedances are balanced across electrodes.

Mistake 3 (trickier) – fail to monitor the recording.
An experimenter must ensure the quality of the recorded data, and react in case of an event that degrades the signal such as the presence of avoidable artifacts or the subject failing to follow the instructions.
Thus, he should have been in the room monitoring the EEG traces and the subject for the whole duration of the experiment.

Question B2
Mistake 1 – Trial (a) does not contain sweat artifacts.
Sweating artifacts produce very slow (below 0.5 Hz) and very large (even more than 1 mV) drifts of the EEG traces. Panel (a) in Figure 1 shows none of these features. Rather, starting at t=0.5s a positive bell shaped artifact appears mostly on frontal channels, lasting a few hundred milliseconds. It is safe to state that this is a blink artifact.

Mistake 2 – Too many trials were rejected.
Artifact rejection should aim at maximizing the amount of "clean" data available for successive analyses. Since electrode popping artifacts only occurred on one channel (O1), the experimenter should have saved more than half of the dataset (55 trials) by rejecting the defective channel only. [Moreover, O1 is unlikely to be indispensable for the purposes of the experiment, since it is quite distant from the cortical motor areas.]

Mistake 3 (trickier) – artifacts could have been filtered away rather than rejected.
You usually do not reject EEG data because they contain powerline artifacts, rather you want to use a notch filter.

Question B3
200 samples.
In fact, since frequency bins in the figure are 1 Hz apart and since $\Delta f = 1/T_{max}$, the window length must be 1s. Since the sampling frequency is 200 Hz, we have the answer.

Question B4
C3.
In fact, we see that the mu rhythm desynchronizes when the right hand movement is imagined, so it must be recorded on the left hemisphere.