Neuroengineering 2019-2020

Exam of 7 July 2020 – Part II

Solutions

Problem A

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

The aim of an experiment is to study the neuronal basis of the **cooperation** established between **two subjects** during an interactive task in which they have to **jointly control** a cursor on the screen.

EEG recordings:

64-electrodes scalp EEG recordings are acquired **for each subject.** The two EEG systems are synchronized to allow the temporal alignment of the traces. The subjects perform **two tasks**: a **motor collaboration task**, in which they move the cursor on the screen together, and an **individualistic task**, in which each of them controls a cursor on his/her screen by him/herself. **20 trials** are recorded for each task.

Analysis performed:

1. EEG data **preprocessing;**
2. A **connectivity analysis**, to build directed brain functional networks of the two subjects' brain activities during the collaborative and individualistic tasks;
3. A **graph theoretical analysis** to extract the **Density**, the **Global Efficiency**, the **Divisibility** and the **Modularity** of the network;
4. A **classification analysis**, to discriminate the two tasks on the basis of the quantitative indices computed at the previous step.

Questions

A1. *(2 points)* Indicate **which method** you would use to perform the **functional connectivity analysis**. Motivate your choice, indicating the advantages and limitations of the method selected. (Max 5 lines).

A2. *(2 points)* The indices obtained for the two tasks in a pair of subjects are reported in Table A1.

A2.1 Indicate which task is characterized by the **most efficient communication** between the nodes. Justify the answer. (Max 3 lines)

A2.2 Indicate in which task the network can be **divided in two communities**. Justify the answer. (Max 3 lines)

A3. *(1.5 points)* Given the scatter plots obtained for all the subjects, and reported in Fig. A2, indicate which features (pair of indices) you would select to perform the classification study and why. (Max 4 lines)

	Motor collaboration	Individualistic task
Density	0.41	0.38
Global Efficiency	0.31	0.53
Divisibility	0.51	0.97
Modularity	0.15	0.49

Table A1- Graph indices obtained in a pair of subjects for the motor collaboration and individualistic tasks.

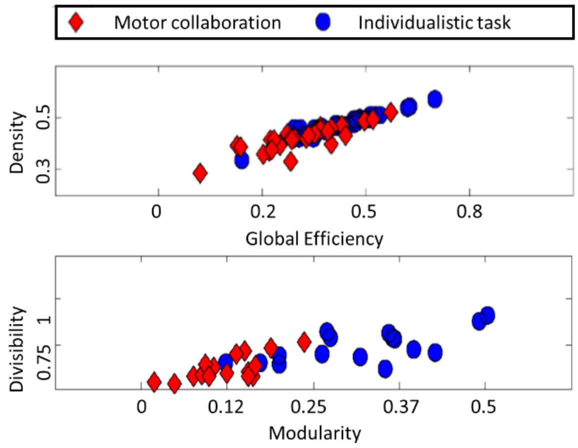


Fig. A2- Scatter plots of the four indices for the two conditions.

Solutions

A1. As stated in the text, the aim of the functional connectivity analysis was to build **directed** brain functional networks of the two subjects' brain activities during the collaborative and individualistic tasks. This implies that a **directed** method should be used, which limits the possible solutions (among the methods addressed by this course) to the Granger Test (GT) and the Partial Directed Coherence (PDC). Since **no specifications** were given about the need for **spectral** or **temporal** domain networks, both methods were acceptable.

A **correct solution** is therefore **either** of the following:

- to indicate **GT** as a possible method;
- to justify the choice with the **advantages** of **directionality** and **robustness to data paucity**;
- to describe the main **limitation** of the method (problem of the hidden source)

OR

- to indicate **PDC** as a possible method;
- to justify the choice with the **advantages** of **directionality** and **accuracy**;
- to describe the main **limitation** of the method (with 64 channels and 20 trials, data may not be sufficient for a robust estimation of the model parameters).

A2.1. The efficiency of communications between the nodes of a network is quantified by the **Global Efficiency (Eg)**. From Table A1, the **individualistic task** is the one showing the higher Eg.

A2.2. The suitability of a network to be divided in communities is quantified by two indices, the **divisibility** and the **modularity**, which capture different and complementary properties of the subnetworks. From Table A1, the task showing higher values of divisibility and modularity is the **individualistic** one.

A2. The scatter plots reported in Fig. A2 show that the pair of indices more suitable as classification features are the **divisibility** and **modularity**, since the other two indices show overlapping distributions for the two tasks.

Problem B

In each trial of an experiment, a pair of auditory stimuli is presented to an experimental subject. The ISI between stimuli in the pair is 500 ms. The ITI is 2000 ms.
The expected amplitude of the evoked components of interest is $V_{peak} \cong 20\mu V$. The standard deviation of the spontaneous EEG activity for this subject is $\sigma_{EEG} \cong 40\mu V$. We wish to obtain an averaged potential with a signal to noise ratio $SNR = \frac{V_{peak}}{\sigma_{noise}} \geq 5$

Questions:

B1. What is the minimum duration of the experiment required to obtain the specified SNR? Explain why. Max 5 lines.

B2. From *Figure B1* identify the latency and amplitude of the P50, N100 and P200 components of the potential evoked by the first stimulus of the pair (bold line). Explain the procedure you followed. Justify in max 10 lines.

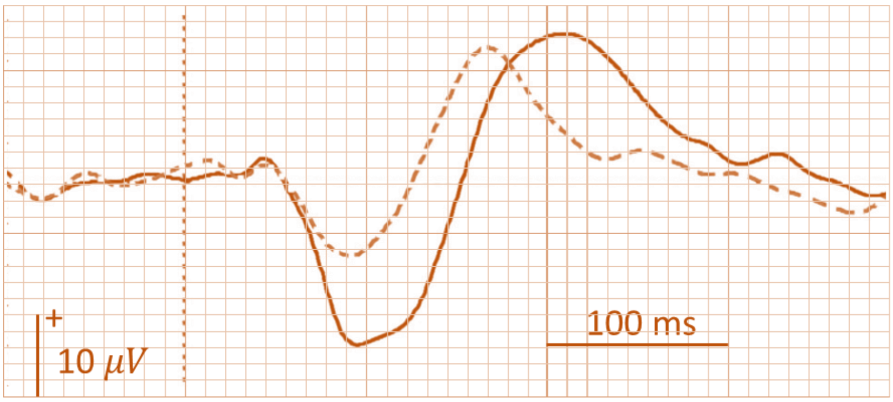


Figure B1. The averaged potential on channel Cz response showing the three main components: P50, N100, and P200. The bold line indicates the response to the first stimulus in a pair of rapidly presented stimuli (with 500 ms between stimuli). The dashed line represents the response to the second stimulus of the pair. The vertical dotted line represents the zerotime, i.e. the time of the event (first or second auditory stimulus).

Question B1.
I considered correct one of the following two solutions:
3’20” (solution 1) or
4‘10” (solution 2)

Common part
Given the requested boundary on SNR:

$$SNR = \frac{V_{peak}}{\sigma_{noise}} \geq 5 \quad \Rightarrow \quad \sigma_{noise} \leq \frac{V_{peak}}{5} = 4\ \mu V$$

Since averaging reduces the amplitude of uncorrelated noise by a factor $\sqrt{N}$:

$$\sigma_{noise} = \frac{\sigma_{EEG}}{\sqrt{N}} \quad \Rightarrow \quad N \geq \left(\frac{\sigma_{EEG}}{\sigma_{noise}}\right)^2 = 100$$

Solution 1.
the Intertrial Interval (ITI) is defined as the duration of time between the onset of one trial and the onset of the next trial ([1]). Thus, the total duration of one trial equals the ITI (2 s).

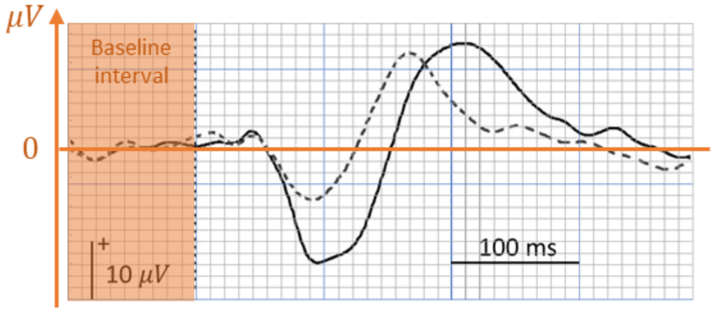
The minimum duration T_{min} of the experiment should be:
$T_{min} \geq N \cdot ITI = 100 \cdot 2000\ ms\ =\ 200\ s.$

Solution 2.
the Intertrial Interval (ITI) is defined as the duration of time between the end of one trial and the beginning of the next trial ([2]). Thus, the total duration of the trial includes the ITI and the SOA, plus the duration of the two stimuli, plus any time before the first stimulus and after the second stimulus.

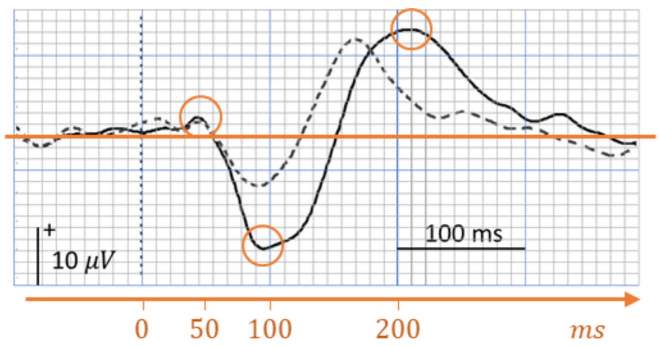
The minimum duration T_{min} of the experiment should be:
$T_{min} > N \cdot (ITI + ISI) = 100 \cdot 2500\ ms\ =\ 250\ s.$

Question B2
P50: 40-45 ms, ~3 uV;
N100: ~95 ms, ~-20 uV;
P200: ~210 ms ~18 uV;

First off, we must choose a baseline epoch. A reasonable choice is to use the interval between -100ms and 0 ms (see figure). All potentials will be measured with respect to the average value of this period.



Then we identify:
- P50: a positive peak approximately 50 ms after the event
- N100: a negative peak peak approximately 100 ms after the event
- P200: a positive peak approximately 200 ms after the event



[1] This is a solution that many used in their solution. I checked several sources, and I found that this definition is sometimes used.
[2] This is the definition I gave in my lecture.

Finally, we measure the amplitude and latency of the peaks (squares are $2\mu V$ high and $\sim 10ms$ wide):