Neuroengineering 2019-2020

Exam 9 June 2020 – 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.

Problem A

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

The aim of a study is to define **quantitative indices** based on the brain activity and connectivity to support the **diagnosis of residual cognitive activity** in patients who, as a consequence of a **traumatic brain injury**, are not able to **communicate** consistently.

EEG recordings

64-electrodes scalp EEG recordings are acquired during **two mental imagery tasks**, in which the subjects are asked to:

- imagine **playing tennis**, i.e. waving a racket with their dominant arm (Task "**tennis")**
- imagine **moving through the rooms** of their home like in a videogame (Task "**spatial navigation**")

Because of the patients' conditions, the duration of the recordings must be kept limited, which results in **short data segments** available.

Definition of brain indices

After the signals pre-processing, **three indices** are defined and computed:

1. **The first index** is based on the detection of the EEG activity generated by a specific brain region for each task:
   a. for the **tennis** task: the **Supplementary Motor Area (SMA**) (Fig. A1)
   b. for the **spatial navigation** task: a small, subcortical region which produces a closed field: the **Parahippocampal Place Area (PPA)** (Fig. A1)
2. **The second index** is based on the **density** of the network built by means of **Partial Directed Coherence** on the 64 EEG channels (N=64 nodes). To reduce the computational time, the index is computed on the upper triangular half of the 64X64 adjacency matrix.
3. **The third index** is based on the **Global Efficiency** computed in a subnetwork of 6 electrodes (N=6 nodes) located over the regions of interest (Fig. A2).

The **goal** is to define brain indices useful to:
- **detect** if the patients are able and willing to perform **both imagery tasks,** as a sign of awareness in support of the diagnosis;
- **distinguish (classify) the two tasks** as a possible binary (Yes/No) communication channel to be used with the patients.

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 subnetwork used for the **third index** are reported in Fig. A2. (unless specified differently, write the answers in a single sheet of paper)

A2.1 Compute the **density** for both tasks *(0.5 points)*

A2.2 Compute the **global efficiency** for both tasks *(2 points)*

A2.3 Given the results obtained at A2.1 and A2.2, which of the two indices would you select as a feature to classify the two tasks? Explain why (Max 3 lines) (type the answer in the exam.net editor) *(0.5 points)*

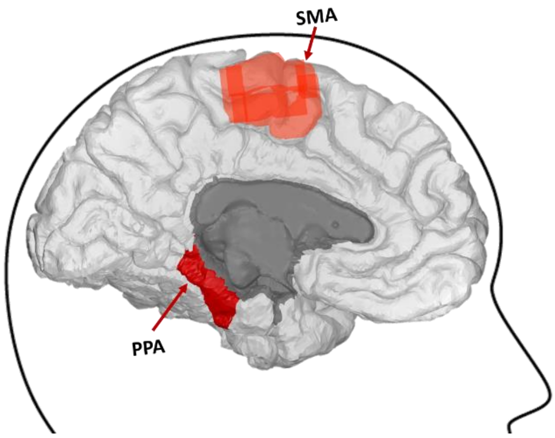
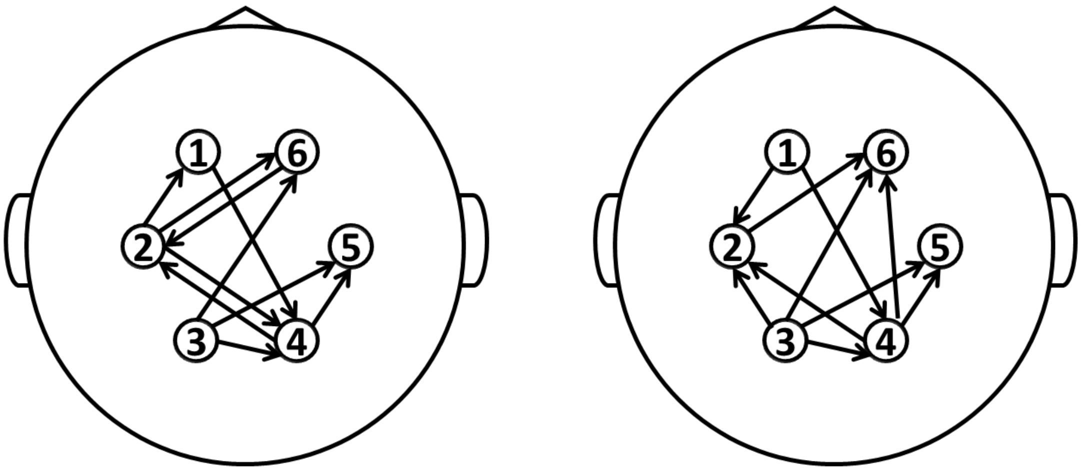


Fig. A1- Brain regions selected for the first index.

Tennis imagery | **Spatial navigation imagery**



A=

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

A=

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

Fig. A2- Graphs (and corresponding adjacency matrices) obtained for the tennis (left) and spatial navigation (right) imagery for a specific patient, and used for the third index

Problem B

An experimenter performs an exploratory study to study ERD/S during a finger tapping task.

Experimental Task.

The subject is instructed to perform a brisk movement of her right index finger approximately every 2 seconds. She has time to practice so that the experimenter can train her on how to keep the right timing. The experimental session is broken down into 4 runs separated by a short break. Each recording run lasts 60 seconds. The experimenter is quite satisfied that he could plan an experiment using such a small amount of the subject's time.

Data Acquisition.

Four separate biosignal amplifiers (A-D) are available in the lab, each with 8 channels. Three of them (A-C, 24 channels) are used to acquire EEG from the scalp, in monopolar configuration. The last one (D) is used to acquire 1 EMG channel from the arm in bipolar configuration, to monitor the finger's movements.

Electrodes are plugged into the EEG amplifiers with the following mapping:

- frontal+frontopolar channels → A
- central+temporal channels → B
- parietal+occipital channels → C

The sampling frequency is 500 Hz.

Data Inspection.

When the experimenter inspects the data, he recognizes that the connectors between amplifiers A-D and the acquisition PC must have been misplaced. In fact, four selected channels, one from each amplifier, show the traces in *Figure B1*.

Segmentation

Data from the EMG channel is processed to detect the onset of the muscular contraction in each repetition of the movement. These events are used to segment 118 trials, starting at the EMG onset and lasting 4 seconds (2000 samples).

Data analysis.

For each channel, the following procedure is followed to estimate the ERD/S:

(i) Trials are averaged
(ii) A FIR bandpass filter with cutoff frequencies at 8 and 11 Hz is applied
(iii) The square of each sample is computed
(iv) The signal is resampled, computing averages of the 50 samples contained in each of the 400 contiguous blocks spanning the whole signal.

Questions:

(type all answers in the exam.net editor)

B1. *(1 point)* How many electrodes are required to perform this experiment? Explain why.
Start your answer typing the number of electrodes
Max 5 lines.

B2. *(2 points)* Match the correct amplifier (A-D) to the signals shown *Figure B1*, panels (a-d).
Start your answer with a line reporting the correct pairs, such as: "A-d, B-c, C-b, D-a"
Justify in max 10 lines.

B3. *(2.5 points)* Report at least two mistakes in the 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 two of them, and then briefly report what else was wrong and why – one extra line per mistake.
Max 20 lines.

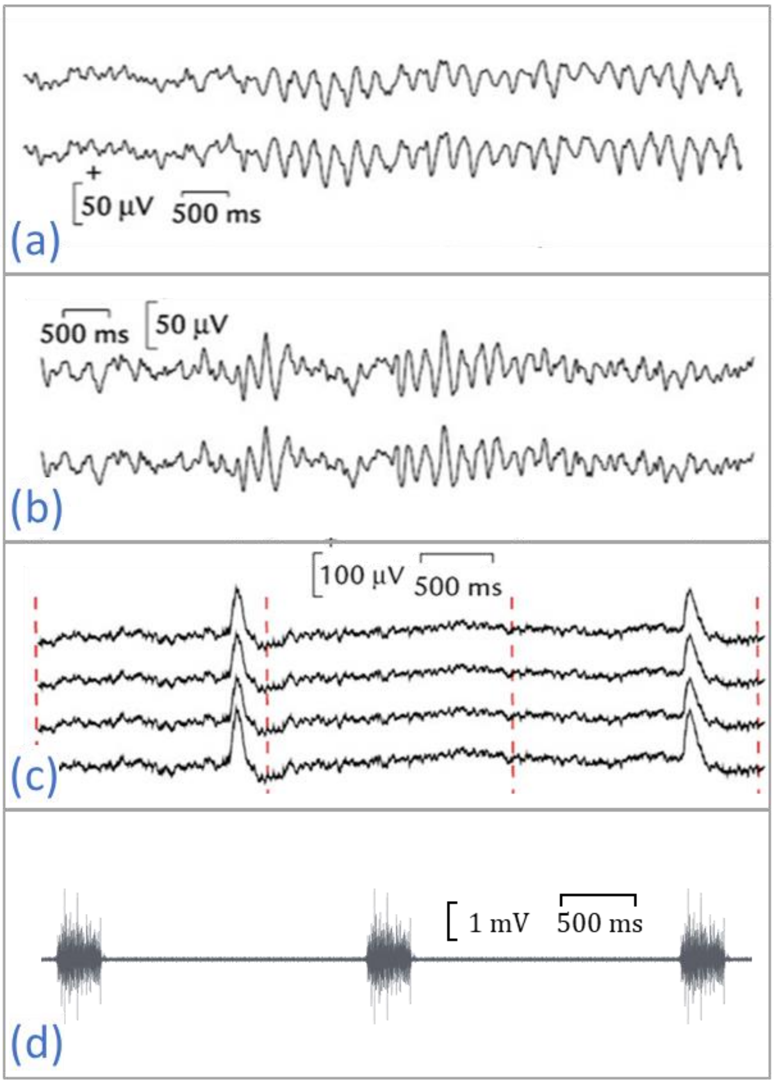


Figure B1. Example waveforms acquired during the experiment. Each panel (a-d) shows a subset of the channels acquired by each of the four biosignal amplifiers. Panels do not seem to appear in the same order as the amplifiers.