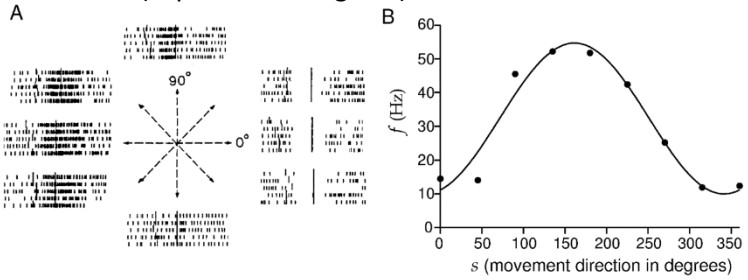
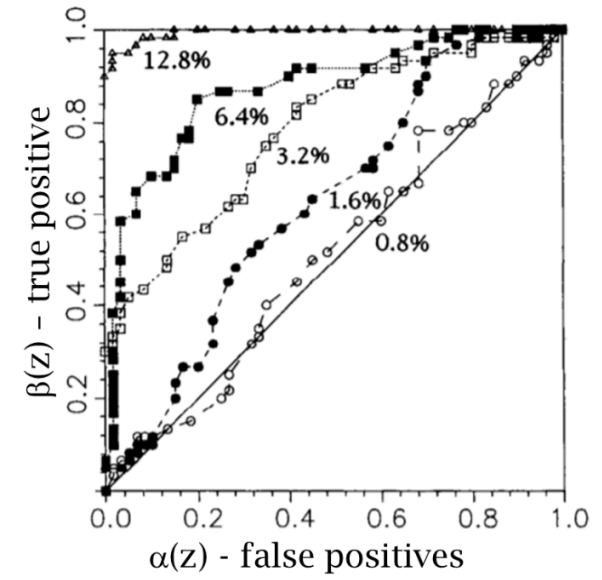
Neuroengineering 2019-2020

Exam 9 February 2021 – Part A

Solutions

Section A.1

	Question	Answer	Points (correct)	Points (wrong)
1	The Na^+ voltage-gated channel is responsible for the absolute refractory period.	T	0.5	-0.25
2	We need to measure the amplitude and duration of an action potential each time it occurs to understand the cell behavior.	F	0.5	-0.25
3	The firing rate of the pre-synaptic neuron influences the amplitude of the resulting action potential in the post-synaptic cell.	F	0.5	-0.25
4	The thalamus is a cortical region.	F	0.5	-0.25
5	sEEG (stereoElectroencephalography) measures the activity in the same regions that are accessible by scalp electroencephalography (EEG).	F	0.5	-0.25
6	The frontal lobe houses the primary motor function.	F	0.5	-0.25
7	To record in vitro measures of the membrane potential over the soma of a single neural cell, you will use extracellular measures.	F	0.5	-0.25
8	One of the main advantages of scalp EEG with respect to other measures of the brain activity is its high temporal resolution.	T	0.5	-0.25
9	The EEG signal is mainly generated by action potentials.	F	0.5	-0.25
10	Given the tuning curve in the figure, obtained for a neuron of the primary motor cortex for different directions *s* of the arm movement (expressed in degrees):  The neural response for a movement direction of 90 degrees is greater than for one of 180 degrees.	F	0.5	-0.25
11	In reference to the previous figure (question 10): if I have many trials recorded for each values of *s* (panel A), I will build a different tuning curve for each of them.	F	0.5	-0.25
12	In reference to the previous figure (question 10): if the measured firing rate is 55Hz, I can «guess» by which movement direction that response was produced.	T	0.5	-0.25
13	In a Poisson process, the probability of an *isi* (inter spike intervals) of 60 ms is lower than that of an *isi* of 20 ms	T	0.5	-0.25

14	The difference between the distribution of *isi* in real data and in simulated data produced by a Poisson generator can be reduced by adding correcting factors to the generator.	T	0.5	-0.25
15	Given the ROC curves in the figure:  The related AUC can assume values between [0,1]	F	0.5	-0.25
16	In reference to the previous figure (question 15): the ideal curve is the one closer to the upper left corner.	T	0.5	-0.25
17	The Ordinary Coherence is an estimator of causality.	F	0.5	-0.25
18	The Partial Directed Coherence (PDC) is based on the spectral matrix *S(f)* obtained by means of the Wiener-Khinchin Theorem	F	0.5	-0.25
19	The Granger Index G_{xy} between two time series *x* and *y* indicates the direction of the interaction between them.	T	0.5	-0.25
20	In a graph, the distance *d(i,j)* between two nodes is given by the shortest path that links them.	T	0.5	-0.25
21	In a graph, given two communities C_1 and C_2, the Divisibility index *D* is directly proportional to the number of connections linking nodes belonging to different communities.	F	0.5	-0.25
22	A random network has high Global Efficiency and low Local Efficiency.	T	0.5	-0.25
TOT			**11**	

Problem A.2

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

A novel approach for the motor rehabilitation of the lower limb is tested in a group of patients with traumatic brain injury (TBI).

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

The neurophysiological measurements are performed in two sessions: one immediately before (PRE) and one immediately after (session POST) the rehabilitative intervention (Fig. A1). During the screening, the patients perform a motor task involving the affected limb.

Questions

A1. The functional connectivity networks obtained for the PRE and POST sessions are reported in Fig. A2. *(write the answers on paper)*
A1.1. Extract the corresponding **adjacency matrices** *(0.5 points)*
A1.2. Compute the **Density** for each graph *(1 point)*
A1.3. Compute the **Global Efficiency** for each graph *(2 points)*

A2. Comment the **changes** (POST vs PRE) in these indices after the intervention. Which index would you chose to quantify the effects of the rehabilitation and why? *(write the answer in the exam.net editor) (1 point)*

A3. If 2 of the 6 regions are subcortical and 4 are cortical, indicate **which technique** for the **acquisition** of **neuroelectrical signals** you would use, and **why**. Motivate the pro and cons of your choice. *(write the answer in the exam.net editor) (1 point)*

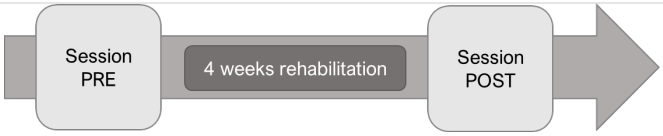


Fig. A1 – Temporal organization of the study

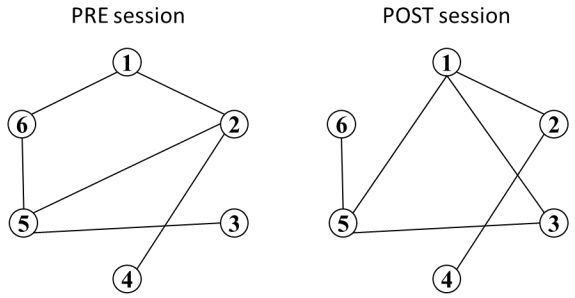


Fig. A2- Brain functional networks PRE and POST rehabilitation

Solutions

A1.1. Adjacency matrices:

A_{PRE}=

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

A_{POST}=

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

A1.2. Density:

PRE:

$N = 6$

$L_{tot} = \frac{N * (N-1)}{2} = 15$

$L = 6$

$k = \frac{L}{L_{tot}} = \frac{6}{15} = 0.4$

$POST$:

$N = 6$

$L_{tot} = \frac{N * (N-1)}{2} = 15$

$L = 6$

$k = \frac{L}{L_{tot}} = \frac{6}{15} = 0.4$

A1.3. Global Efficiency:

D_{PRE}=

-	1	3	2	2	1
	-	2	1	1	2
		-	3	1	2
			-	2	3
				-	1
					-

$$E_{gPRE} = \frac{2}{N(N-1)} \sum_{i,j=1, i \neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{15}(6 + \frac{6}{2} + \frac{3}{3}) = 0.67$$

D_{POST}=

-	1	1	2	1	2
	-	2	1	2	3
		-	3	1	2
			-	3	4
				-	1
					-

$$E_{gPOST} = \frac{2}{N(N-1)} \sum_{i,j=1, i \neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{15}(6 + \frac{5}{2} + \frac{3}{3} + \frac{1}{4}) = 0.65$$

A2. Given the results at point A1, the only index that can be selected to quantify the effects of the rehabilitation (among those here computed) is the Global Efficiency. In fact, the density is unchanged after the intervention. This means that the network has reorganized keeping its number of edges. However, the difference is small, so looking for other indices (especially more physiologically suited ones) would be advisable.

A3. Given the presence of subcortical regions, the accurate acquisition of neuroelectrical signals requires invasive methods (SEEG). *(Clarification: other methods, based on metabolic correlates of the brain activity – see the seminar we had at the end of the course – are also available to detect the activity of subcortical regions).*