Neuroengineering 2021-2022

July 21st 2022 – Part II

Even seats

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

A patient needs to undergo **brain surgery** because she has frequent (daily) epileptic seizures that fail to respond to any antiepileptic medications (pharmacoresistant epilepsy). Before the surgery, her **neuroelectrical data** are collected, to monitor the brain functionality involving regions close to the one to be removed.

The aim is to **quantify the role of specific regions** and **the structure of her brain functional network at rest**, to support the surgery, and then **to compare the brain organization after the surgery with the one before it**, to ensure that the brain functioning has reached a physiological behavior.

The region to be removed is subcortical, and so are the ones to be monitored. Their behavior at rest is known to occur in **Theta and Alpha bands**.

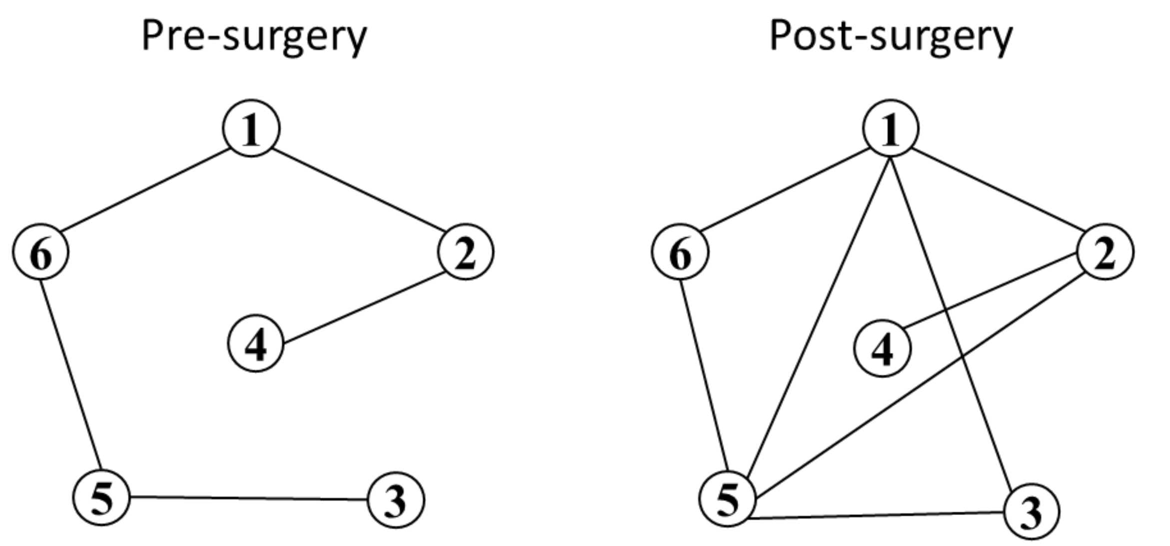

Fig. 1: Graphs obtained for the patient before (Pre) and after (Post) the brain surgery

Questions

A1 – Considering the described scenario, indicate which technique you would use to acquire the brain signals, and **why**. List the pros and cons of your choice. *(2 points)* *(write the answers in the exam.net editor)*
A2 – Indicate which connectivity estimator you would use to perform the network analysis. Justify your choice and indicate the related pros and cons. *(2 points)* *N.B. Do not refer to the graph in Fig.1 to make your choice, nor to justify it.* *(write the answers in the exam.net editor)*
A3 – Assuming that the network analysis returns the two networks reported in **Fig. 1** for PRE and POST surgery, respectively: **A3.1:** Extract the corresponding **Adjacency Matrices** *(0.5 points)* **A3.2:** Compute the **Degree** for each node and the **Average Degree** for each network *(0.5 points)* **A3.3:** Compute the **Density** for each graph *(1 point)* **A3.4:** Compute the **Global Efficiency** for each graph *(3 points)* *(write the answers on paper)*
A4 – Based on the results obtained in A3, describe: **A4.1:** If and how there is a change in the role of specific regions after the surgery, compared to the PRE condition *(1 point)* **A4.2:** If and how there is a change in the brain network organization after the surgery, compared to the PRE condition *(1 point)* *(write the answers in the exam.net editor)*

Solutions

A1: In the context of brain surgery, when invasive procedures are already occurring, we can collect neuroelectrical data invasively, taking advantage of the higher spatial resolution and signal-to-noise ratio of intracranial recordings. Since the brain regions of interest are subcortical, we cannot use Electrocorticography (ECoG), which wouldn't be able to reach the desired target. To this purpose, we can use StereoElectroencephalography (S-EEG).

Pros: High SNR, high spatial resolution, less prone to artifacts, able to reach deep (subcortical) regions.

Cons: Invasiveness, a limited number of regions to be reached (not a whole-brain measure)

A2: The text indicates that the frequency content is relevant, so we should select a frequency-resolved method. We can therefore use either **Ordinary Coherence** or **Partial Directed Coherence** (PDC). Being a multivariate method for the estimation of causality in the Wiener-Granger sense, PDC would return more informative and accurate results, but it requires more data (longer recordings) due to the high number of parameters in the multivariate model. There is no indication about the length of the recordings, so we can either:

a) Assume we can perform long recordings and use PDC
b) Stay on the safe side about the length of the recordings and use OC, which requires a smaller amount of data.

If you choose a):

Pros: Multivariate (=more accurate, reduced hidden source problem), a measure of causality (=directed networks), spectral (as requested);

Cons: If the amount of data recorded is not sufficient, the model estimation will be very inaccurate.

If you choose b):

Pros: Robust to data paucity, spectral (as requested)

Cons: Bivariate (=prone to spurious links due to the hidden source problem, less accurate), undirected (it measures synchronicity, not causality).

A3.1: Adjacency matrices:

A_{PRE}=

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

A3.2. Degree and Average Degree:

A_{PRE}=

						Degree
-	1	0	0	0	1	2
1	-	0	1	0	0	2
0	0	-	0	1	0	1
0	1	0	-	0	0	1
0	0	1	0	-	1	2
1	0	0	0	1	-	2

Average Degree= 10/6= 1,67

A_{POST}=

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

Average Degree= 16/6= 2,67

A3.3. Density:

$k_{PRE} = {}^{L}/_{L_{tot}} = {}^{5}/_{15} = 0{,}33$

$k_{POST} = {}^{L}/_{L_{tot}} = {}^{8}/_{15} = 0{,}53$

A3.4. Global Efficiency:

D_{PRE}=

-	1	3	2	2	1
	-	4	1	3	2
		-	5	1	2
			-	4	3
				-	1
					-

$$E_{gPRE} = \frac{2}{N(N-1)}\sum_{i,j=1,i\neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{15}(5 + \frac{4}{2} + \frac{3}{3} + \frac{2}{4} + \frac{1}{5})=0.58$$

D_{POST}=

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

$$E_{gPOST} = \frac{2}{N(N-1)}\sum_{i,j=1,i\neq j}^{N} \frac{1}{d_{ij}} = \frac{1}{15}(8 + \frac{5}{2} + \frac{2}{3})=0.74$$

A4.1: While in the PRE condition no region has a prevalent role in the network (the degrees are similar), in the POST condition two regions are more involved than the others in the network (those corresponding to node 1 and node 5).

A4.2: After the surgery, the network density and the Global efficiency are increased, which implies that the network organization tends toward a greater integration and a faster exchange of information.