Neuroengineering 2021-2022

Exam of 15 September 2022 – Part II

Solutions

Problem

A study has the aim to investigate the evolution of a **neurodegenerative brain condition** that affects **memory functions**. To this purpose, a neuroelectrical screening is performed in **two sessions**, at three months' distance. The recordings are performed during the execution of **a short term memory task**.

From previous studies, it is already known that the **direction** of the expected connectivity links plays a major role in the task, while no specific role is attributed to different **frequencies**. The memory task is also known to involve a communication between the **frontal** and the **occipito-parietal** (posterior) lobes.

To prevent **learning and habituation effects** during the memory task, the recording sessions are kept **short**.

The **brain functional networks** obtained for the **first session** (at time T_0) and for the **second session** (at time T_1, after three months) are reported in **Fig.1**.

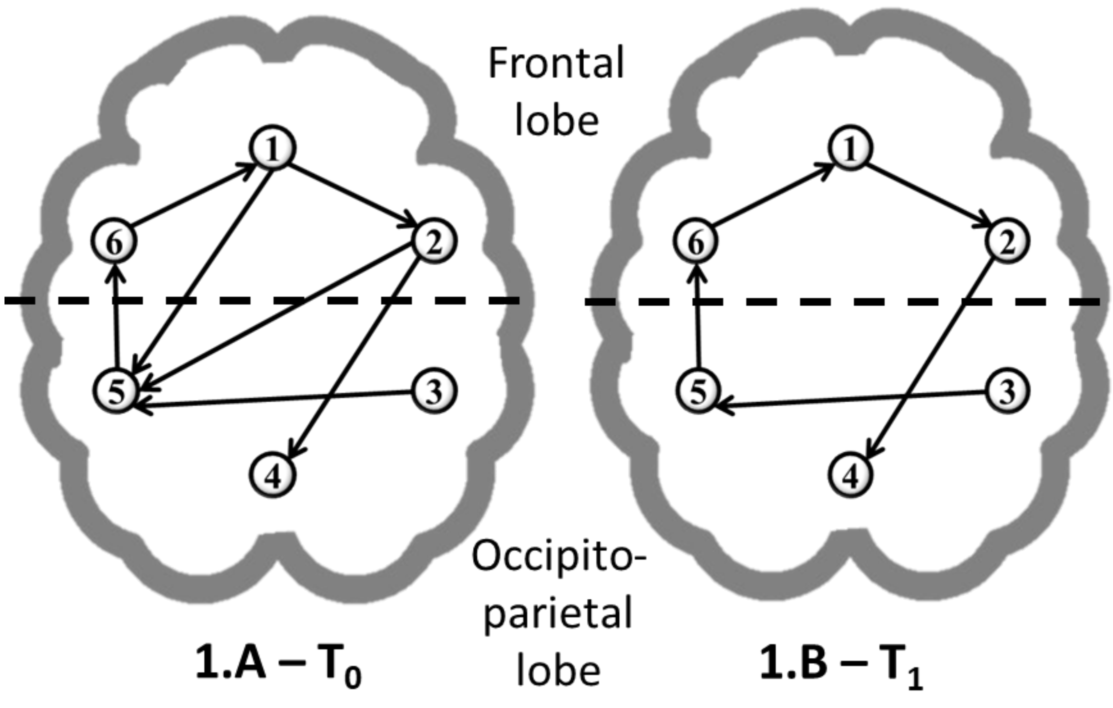


Fig. 1 – Brain Functional Networks obtained at T_0 (first screening session) and at T_1 (after three months). The brain is seen from above, the frontal lobe points to the upper part of the figure.

Questions

A1. Indicate **which connectivity estimator** you would use to perform the **functional connectivity analysis**. Justify your choice, based on the above-mentioned conditions. *(4 points)*

A2. Given the functional connectivity networks obtained for the two sessions, as reported in **Fig.1:**

A2.1. Write down the two **adjacency matrices** (at T_0 and at T_1) and compute the **indegree** and **outdegree** of each node. *(1 point)*

A2.2. Compute the **Global Efficiency** for each of the two graphs *(3 points)*

A2.3. Considering that regions 1, 2 and 6 belong to the frontal lobe and regions 3, 4 and 5 belong to the occipito-parietal lobe, compute the **density of the communications between the two lobes,** defined as the number of links connecting the two lobes divided by the maximum number of links that could exist between them *(2 points)*

A3. Comment on the results obtained at point A2.2 and A2.3. Indicate if the **efficiency of the communications** in the network and the **communication between the two lobes** are **changed** between the two sessions and **how**. (1 *point*)

Solutions

A1.

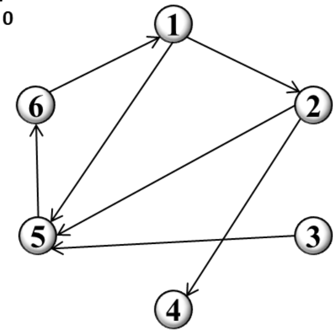
In the text, it is stated that "the direction of the expected connectivity links plays a major role in the task", which excludes the Ordinary Coherence, a measure of synchronization which is undirected.

Among the directed measures (estimating causality in the statistical sense) we have met the Granger Causality Test and the Partial Directed Coherence. While the PDC is spectral and multivariate, and therefore potentially more informative, it does also require an adequate amount of data to allow for an accurate estimation. However, here we learn that "the recording sessions are kept short" so we cannot apply PDC without risking to incur in the problem of data paucity (less data points that parameters to be estimated).

This limits the choice to the GC test. This is a bivariate method, which is robust to data paucity but also lacks of information in the frequency domain (which is, however, not required since "no specific role is attributed to different frequencies"). GC, as all bivariate approaches, exhibits a lower accuracy due to the problem of the hidden source. This is, however, unavoidable when we are in the condition of data paucity.

A2.1

T_0

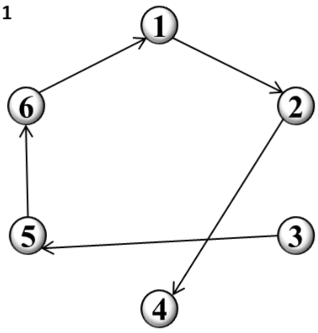


$A_0=$

						In=
-	0	0	0	0	1	1
1	-	0	0	0	0	1
0	0	-	0	0	0	0
0	1	0	-	0	0	1
1	1	1	0	-	0	3
0	0	0	0	1	-	1
Out= 2	2	1	0	1	1	

$N = 6$
$L = 7$

T_1



$A_1=$

						In=
-	0	0	0	0	1	1
1	-	0	0	0	0	1
0	0	-	0	0	0	0
0	1	0	-	0	0	1
0	0	1	0	-	0	1
0	0	0	0	1	-	1
Out= 1	1	1	0	1	1	

$N = 6$
$L = 5$

A2.2

$D_0=$

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

$$E_g = \frac{1}{N(N-1)} \sum_{i,j=1,i\neq j}^{N} \frac{1}{d_{ij}}$$
$$= \frac{1}{6(6-1)}\left(7 + \frac{7}{2} + \frac{4}{3} + \frac{2}{4} + \frac{1}{5}\right) = 0{,}42$$

$D_1=$

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

$$E_g = \frac{1}{N(N-1)} \sum_{i,j=1,i\neq j}^{N} \frac{1}{d_{ij}}$$
$$= \frac{1}{6(6-1)}\left(5 + \frac{4}{2} + \frac{3}{3} + \frac{2}{4} + \frac{1}{5}\right) = 0{,}29$$

A2.3

$$\text{InterLobeDensity}_0 == \frac{4}{N*N} = \frac{4}{18} = 0.22$$

$$\text{InterLobeDensity}_1 = \frac{2}{N*N} = \frac{2}{18} = 0.11$$

A3.

	Global Efficiency	**Inter Lobe Density**
$\mathbf{T_0}$	0.42	0.44
$\mathbf{T_1}$	0.29	0.22

The efficiency of the communications in the network is decreased at T_1 with respect to T_0 as shown by the decrease of the Global Efficiency from 0.42 → 0.29.

As for the communication between the two lobes, at T_1 it is half of what it was at T^0.

This means that the patient's brain has loose part of its capability to exchange information as a whole and particularly between the frontal and the occipito-parietal regions.