Neuroengineering 2020-2021

June 18th, 2021 – Part II

Solutions

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

A study aims to define objective measures of the **brain networks' structure** to be used in support of the diagnosis of a **disorder of consciousness (DoC)**. A group of patients with a diagnosis of **Minimally Conscious State (MCS)** or **Unresponsive Wakefulness Syndrome (UWS, previously known as Vegetative State)** undergo a **64-channels scalp EEG** screening during the **resting state**.

To avoid stress and fatigue to the patients, **a limited amount of trials** is collected.

Hypothesis: it is known that the peculiar brain organization for these patients is coded at **specific frequency bands** (Delta, Theta).

The goal of the study is to **compare the properties** of the brain networks of patients belonging to the two groups, to define new indices to be used in support of the **correct diagnosis** of the patients' conditions.

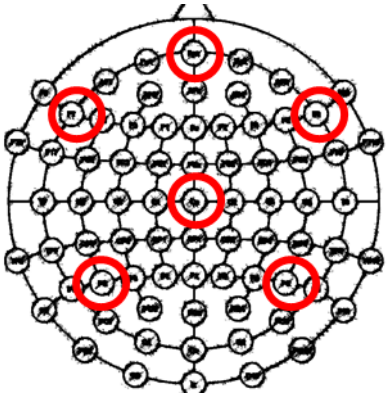

Fig. 1: The **electrodes selected** for the study (circled)

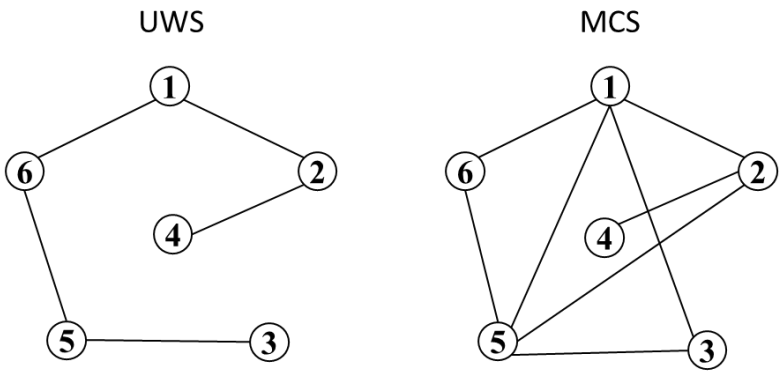

Fig. 2: Graphs obtained for patients with **Unresponsive Wakeful Syndrome (left)** and **Minimally Conscious State (right)**

Questions

Q1 – Considering the limited amount of trials available and the study's hypothesis, indicate **which connectivity estimator** you would use to perform the **network analysis**.
Motivate your choice. *(4 points)*

(write the answers in the exam.net editor)

Q2 – Assuming that the network analysis is performed on the **subset of electrodes** reported in **Fig. 1**, and that it returns the two networks reported in **Fig. 2** for UWS and MCS patients, respectively:

Q2.1: Extract the corresponding **adjacency matrices** *(1 point)*
Q2.2: Compute the **Degree** for each node and the **Average Degree** for each network *(1 point)*
Q2.3: Compute the **Density** for each graph *(1 point)*
Q2.4: Compute the **Global Efficiency** for each graph *(2 points)*

(write the answers on paper)

Q3 – The Average Degree, the Density and the Global Efficiency computed for each patient are later used to classify them in two groups. The rate of correct classifications (in terms of **true positives** and **false positives**) is reported in a **ROC curve** for each index, with:

- AUC = 0.6 for the Average Degree
- AUC = 0.6 for the Density
- AUC = 0.95 for the Global Efficiency

Indicate which of the three indices you would select as a measure to support the diagnosis of MCS/UWS and **why**. *(2 points)*

(write the answers in the exam.net editor)

Solutions

Q1: Given the **limited amount of trials**, we need to select a **bivariate method** (PDC would require more data). Granger Causality Test is a bivariate method, and it provides an estimation of causality (directed influence), but it is not spectral, and according to the hypothesis important information **is coded in the frequency domain**.

We can therefore choose the **<u>Ordinary Coherence</u>**, with the following advantages:

- **robustness to data paucity**
- **spectral content**

On the other hand, the limitations of this method include:

- the lack of **directionality**
- the problem of the **hidden source**

Q2.1: Adjacency matrices:

A_{UWS}=

-	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_{MCS}=

-	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	-

Q2.2. Degree and Average Degree:

A_{UWS}=

						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_{MCS}=

						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

Q2.3. Density:

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

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

Q2.4. Global Efficiency:

D_{UWS}=

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

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

D_{MCS}=

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

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

Q3: The Global Efficiency shows the highest AUC, which is associated to better performances both in terms of true positives and in terms of false positives.