MSc in Artificial Intelligence and Robotics
MSc in Control Engineering
A.Y. 2019/20

Neuroengineering

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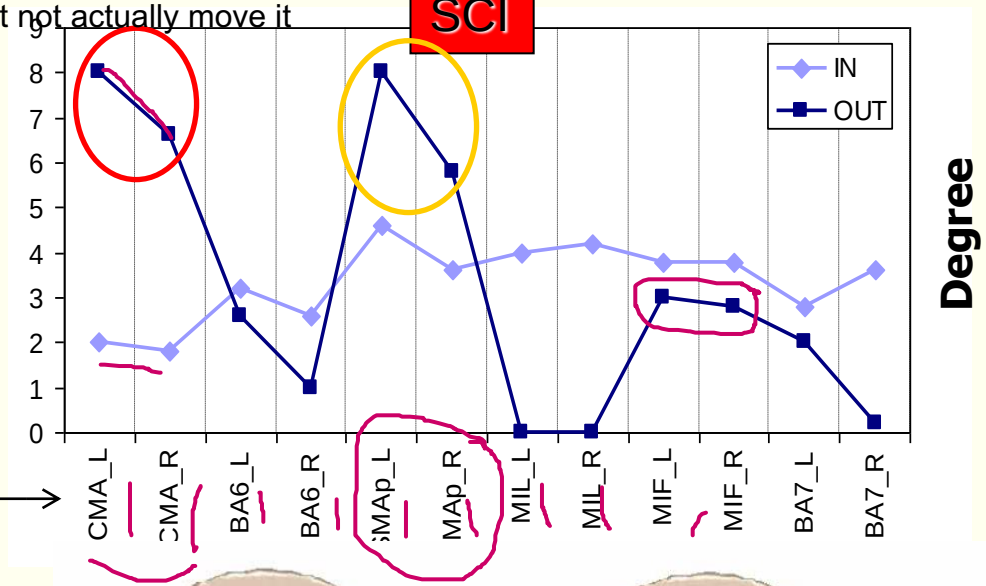
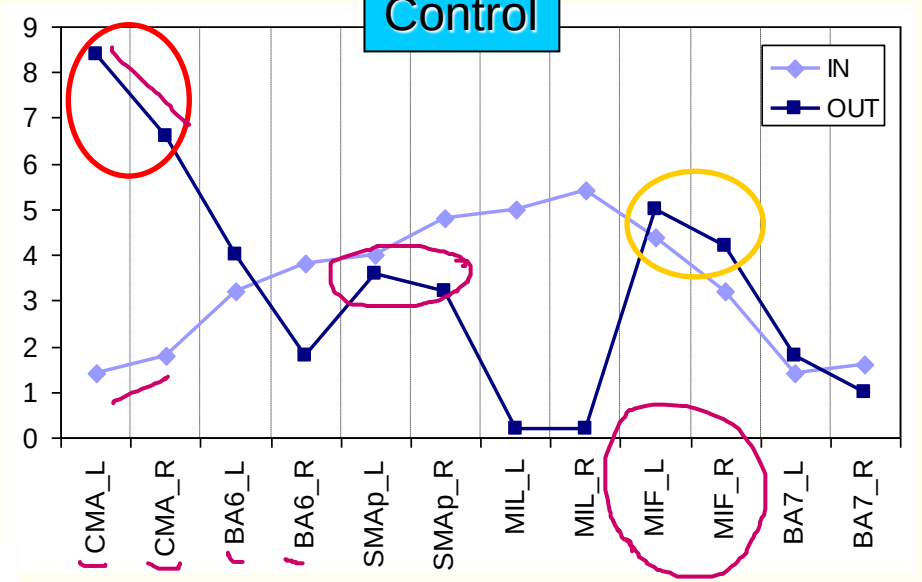
11- APPLICATIONS

Motor execution/attempt

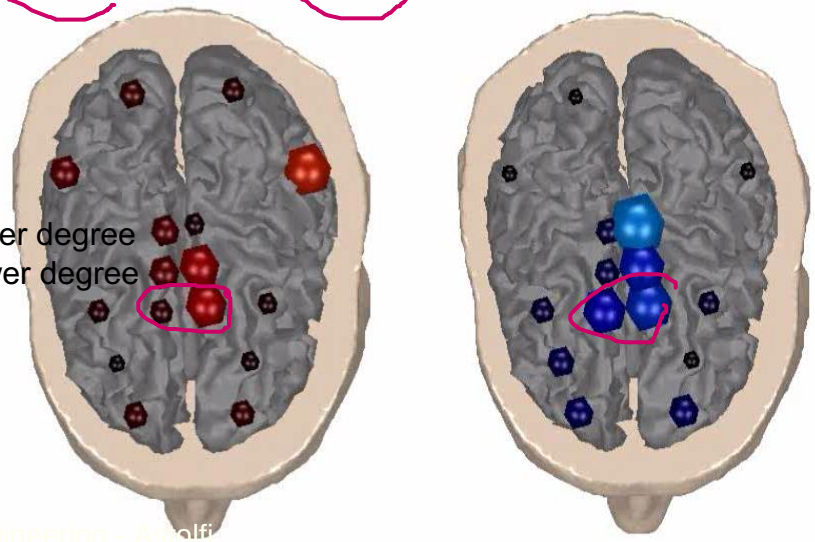
they are able to think to move the feet, but not actually move it





regions of the brain →

3

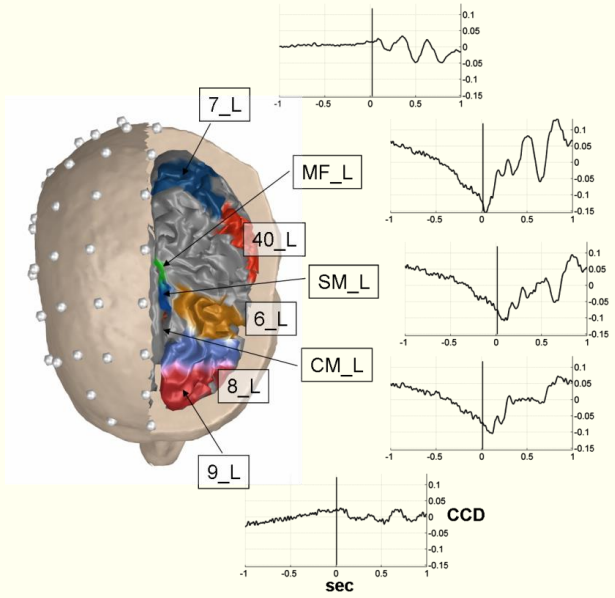


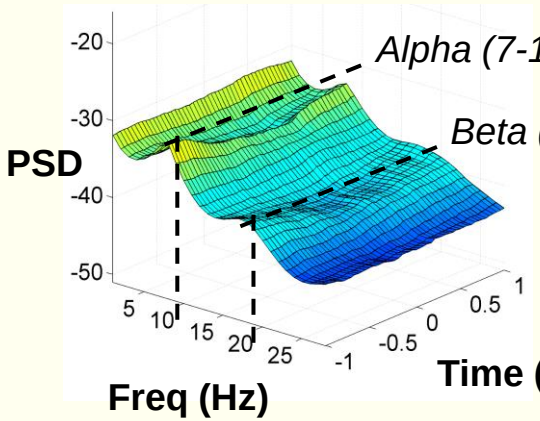
big spheres->higher degree
small sphere->lower degree

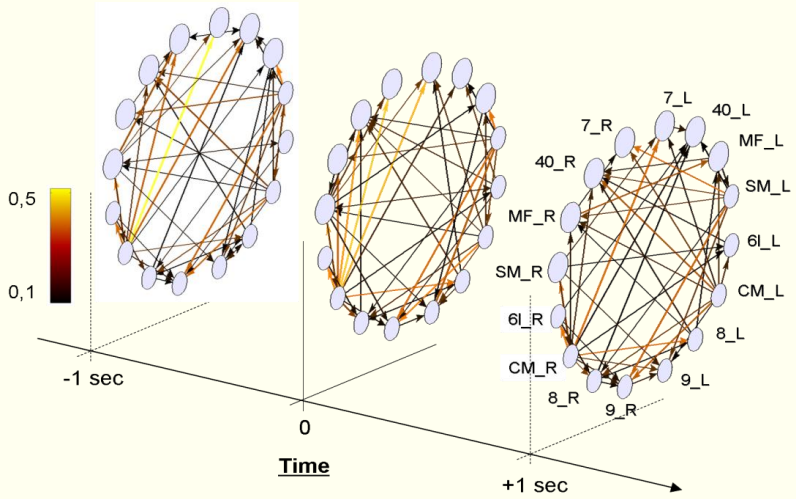
In- and Out-degree from brain regions during a movement execution/attempt by healthy subjects (control) and Spinal Cord Injured patients (SCI)

there is a mechanical lesion interrupting partially or totally the communication between the brain and the periphery, in particular between the brain and everything is below the lesion

Tracking time-varying brain networks





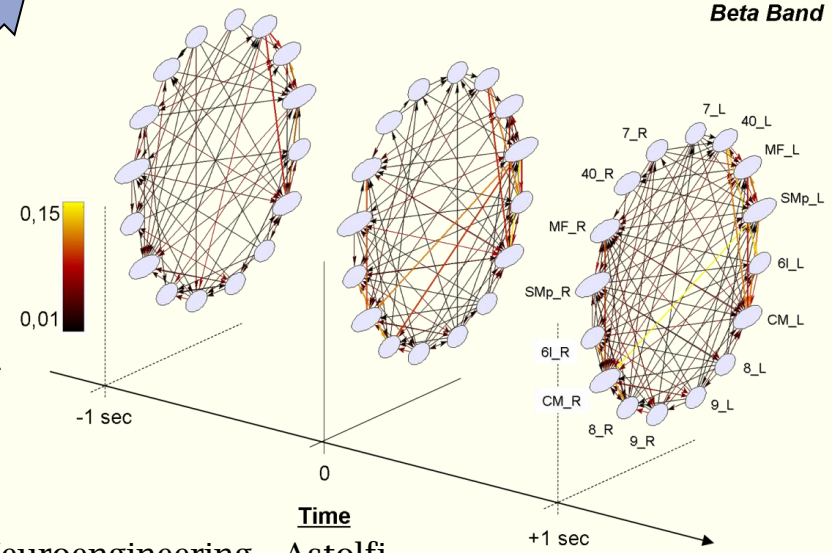


Alpha (7-12 Hz)

we have also the possibility to monitor evolution of brain network

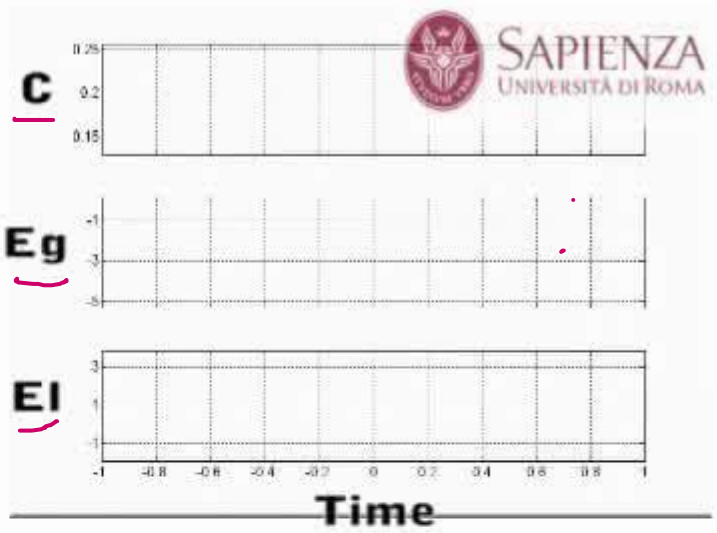
100 networks per second or 100 networks per 100 ms

Beta Band

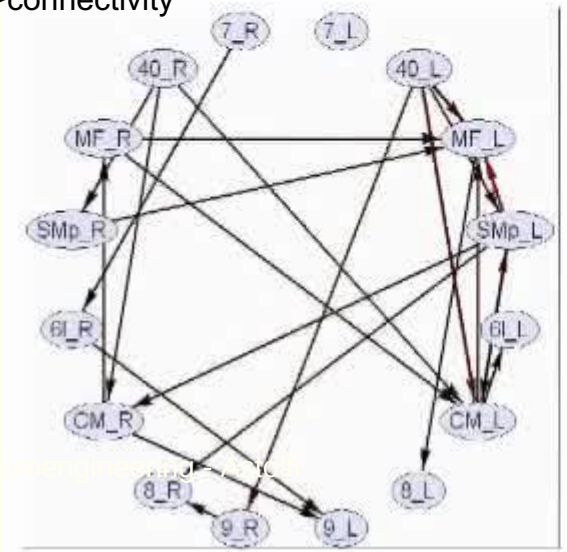


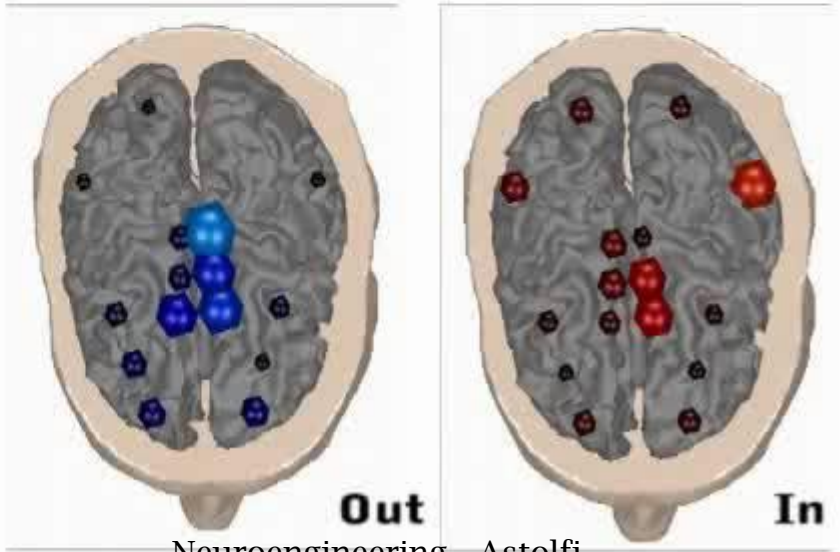
Beta (13-29 Hz)

Time-varying network architecture



black arrows->connectivity



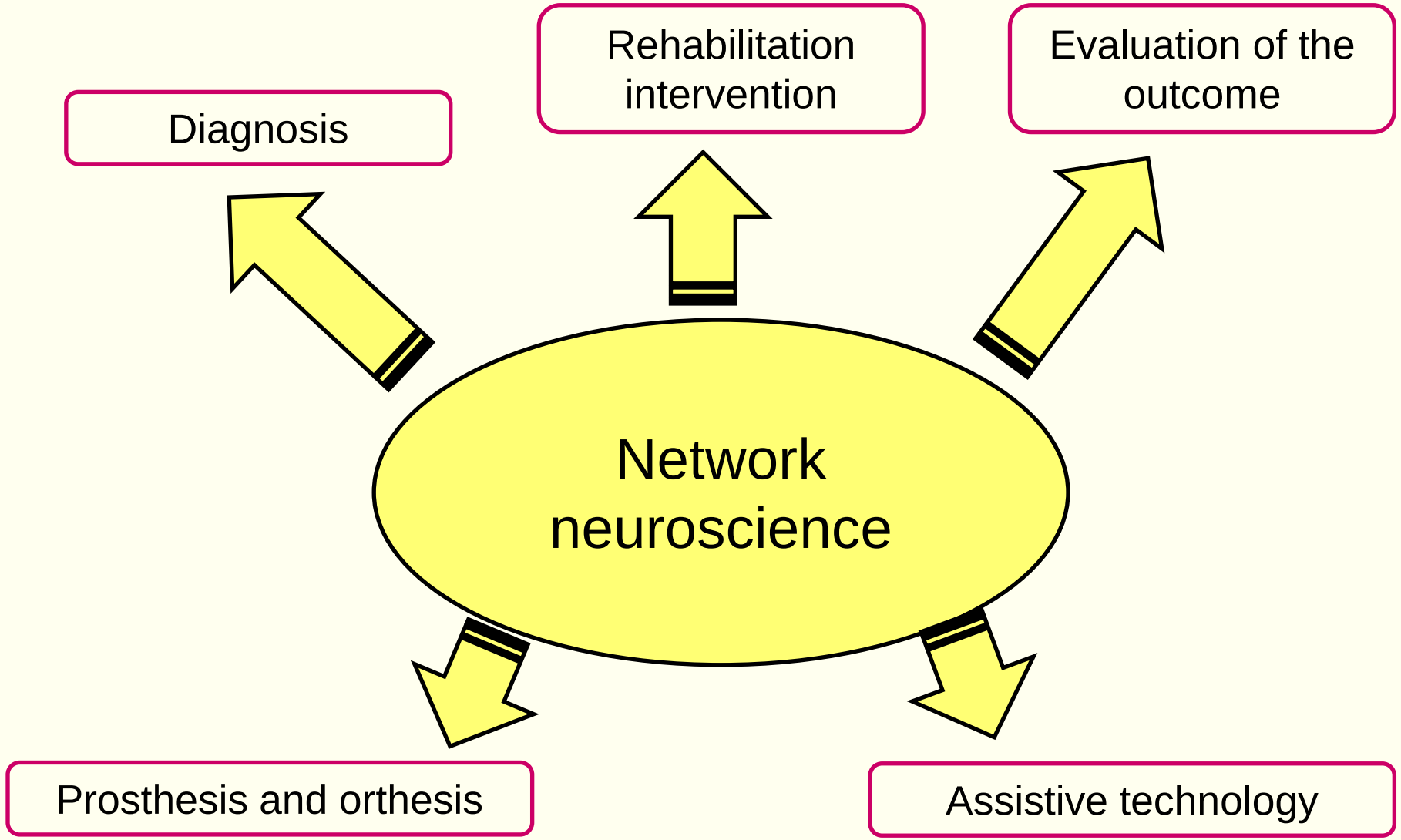


Cortical network

Degree

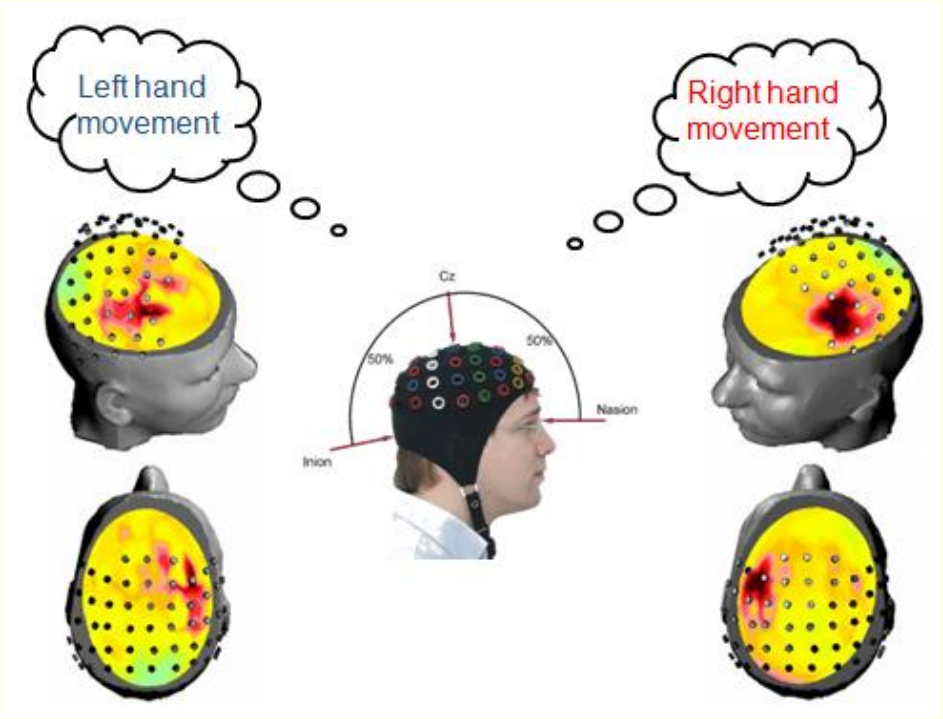
Neurorehabilitation

one of the main field in which neurowngineering can find applications (have an impact on this). The aim is to restore and improve (with respect to what the nature does) some functions losed by cause of pathological events.



Motor Rehabilitation

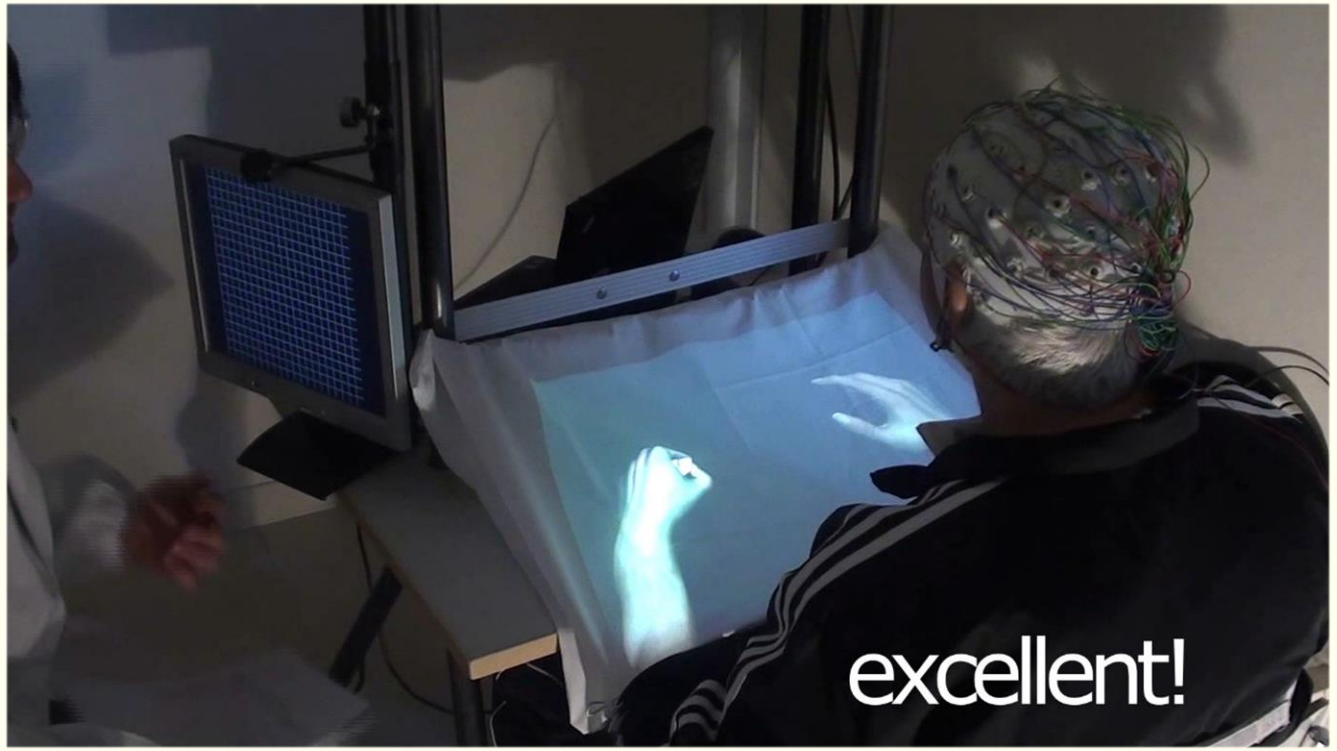
especially of the upper link



brain computer interface

BCI-supported motor imagery training of the upper limb (28 post-stroke patients)

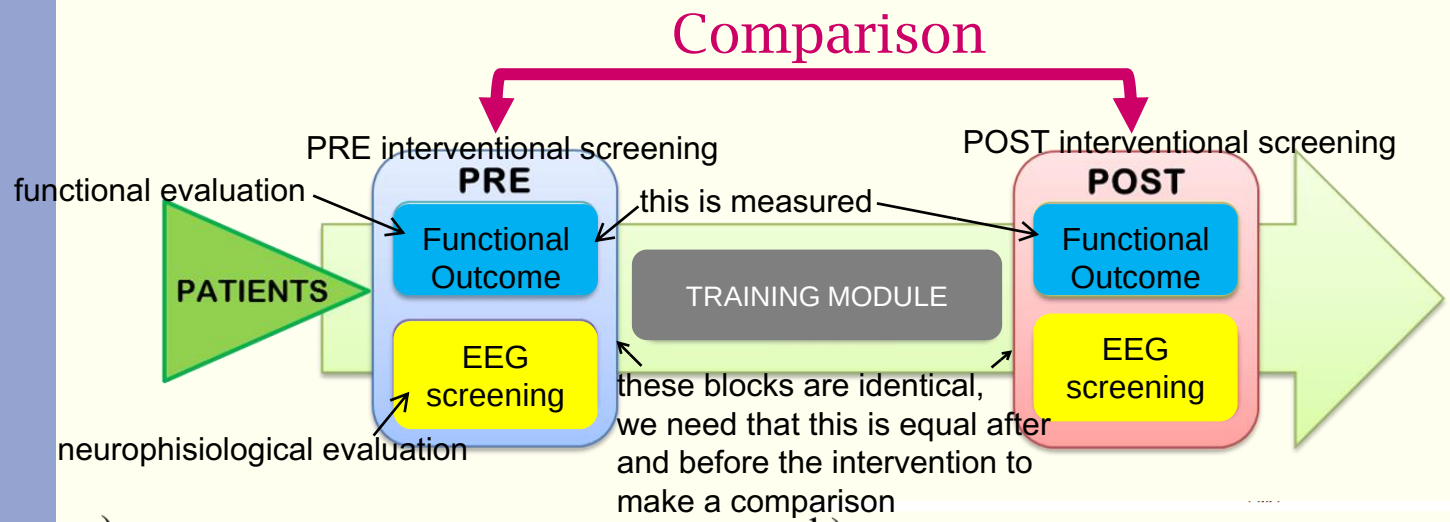
(further details about the online analysis will be provided in prof. Cincotti's classes)



brain plasticity is the capability of the brain to reorganize its structure to deal with changes in the external

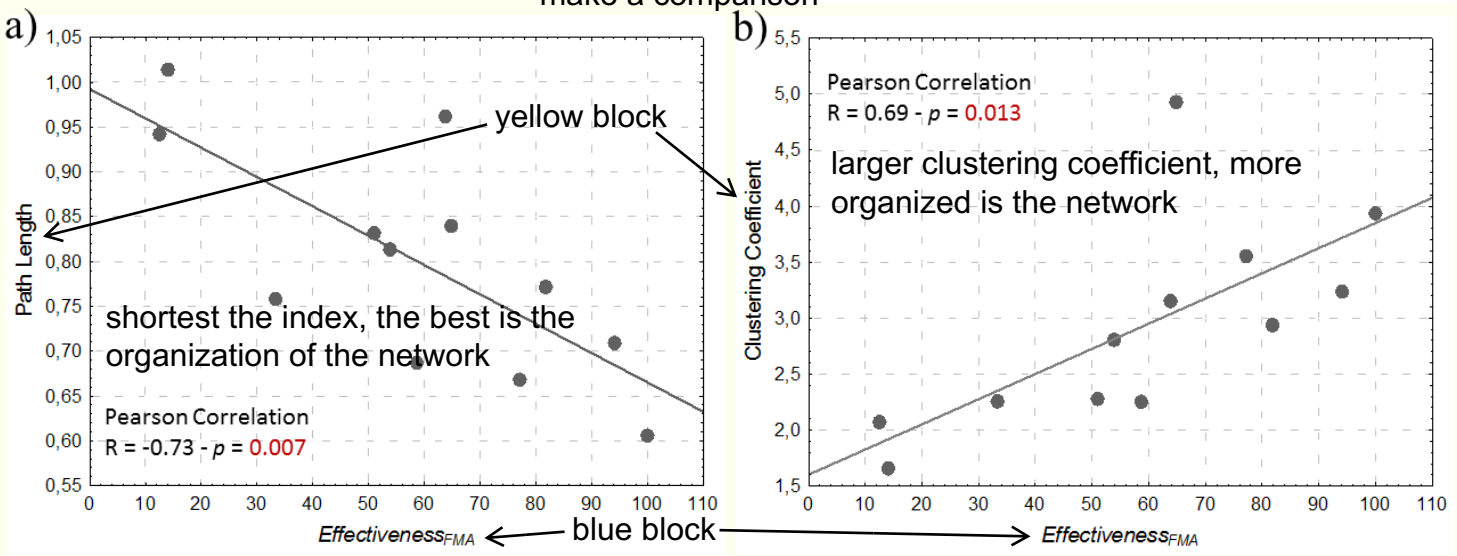
Evaluation of brain plasticity after stroke

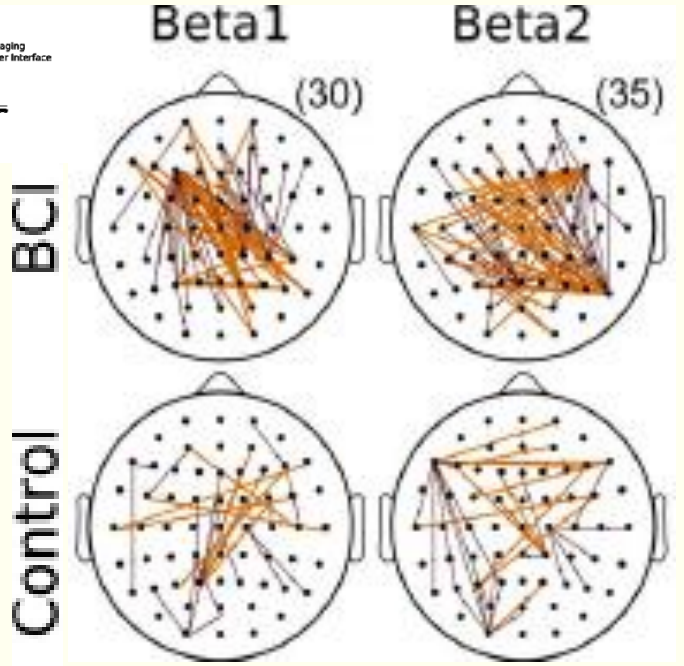
we need to know if it has provided some results or not. We need to test its efficacy



Increase in inter-hemispheric connectivity in the BCI group

Correlation between graph indices and functional outcome





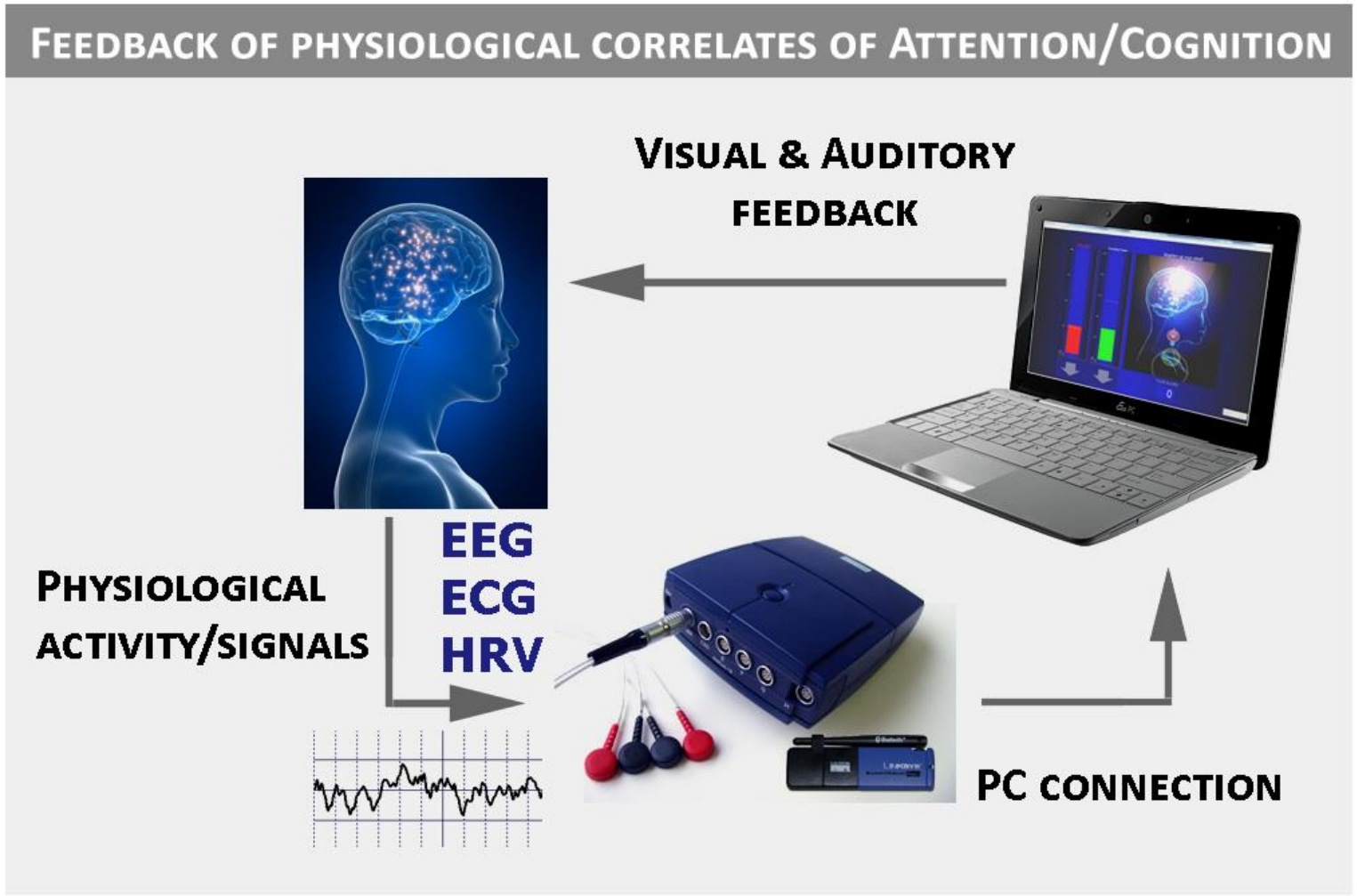
Pichiorri et al, Annals of Neurology, 2015

Cognitive rehabilitation

attention, inhibition, memory, decision making…..

this is a home based setting, not clinical setting

Home-based systems

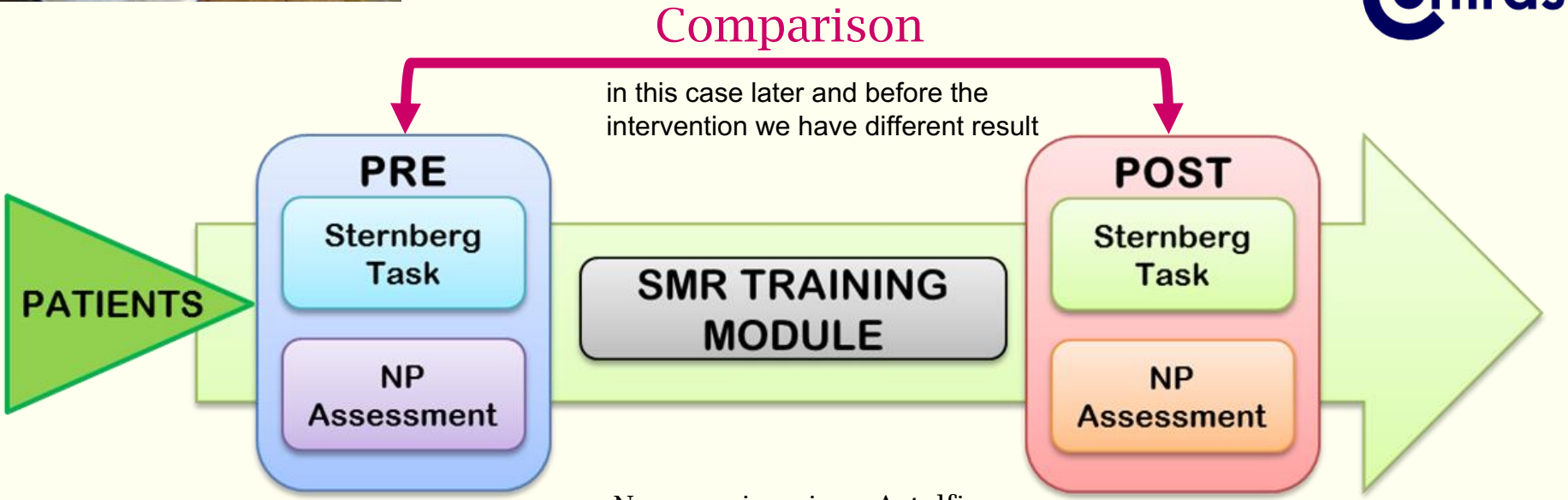


Contrast Remote Control Cognitive Training

Neurofeedback-based cognitive rehabilitation

- EEG-based neurofeedback (with 3 electrodes)
- Sensorimotor rythms
- Post-stroke cognitive rehabilitation (memory functions)

Contrast Remote Control Cognitive Training



Graph Theory

Global Indices

Global Efficiency

$$E_g = \frac{1}{N(N-1)} \sum_{i \neq j} \frac{1}{d_{ij}}$$

remember that this is always a global property of the network

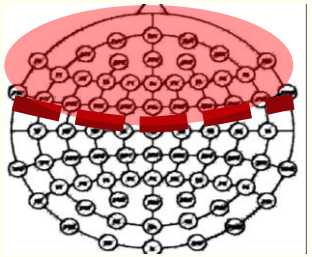
Local Efficiency

$$E_l = \frac{1}{N} \sum_{i=1}^{N} E_g(G_i)$$

Local Indices

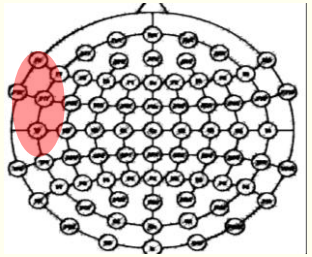
Anterior Density

$$d_{Ant} = \frac{\sum_{i=1}^{N_1} \sum_{j=1}^{N_1} G_{ij}}{N(N-1)}$$



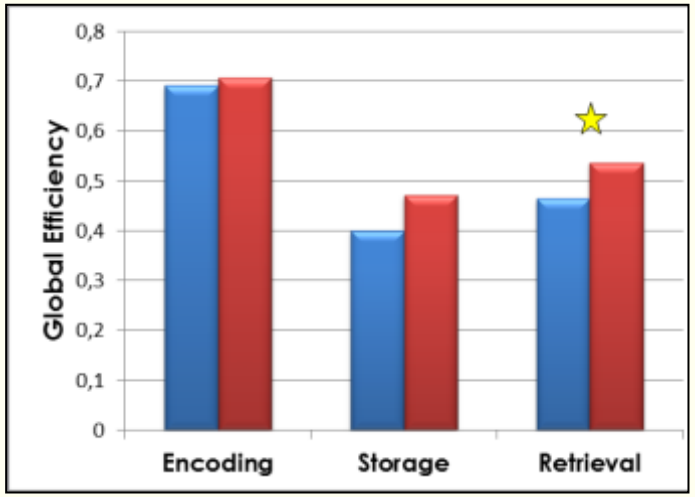
Left temporal degree

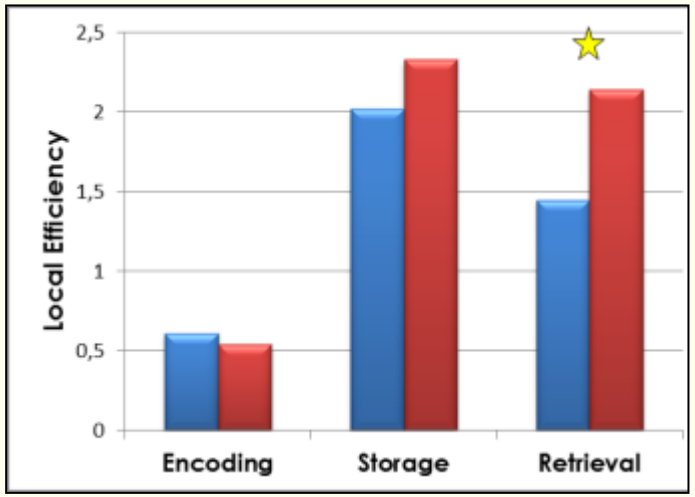
$$k_l = \sum_{\substack{i \in N \\ i \neq l}} G_{ij} + \sum_{\substack{j \in N \\ j \neq l}} G_{ij}$$



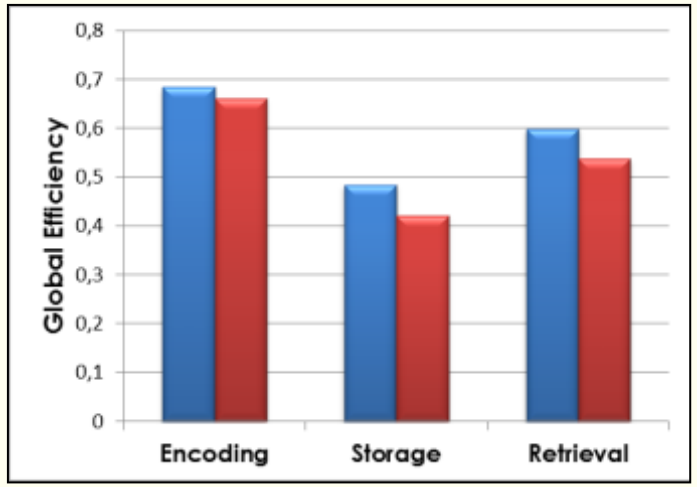
Global Indices

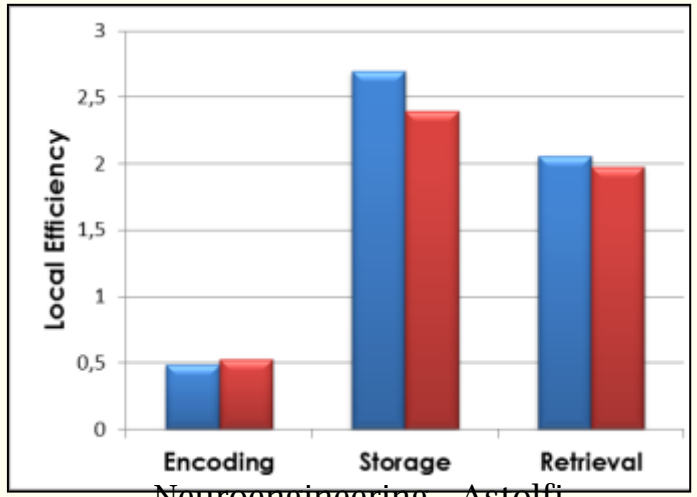
RESPONDERS

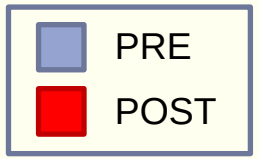




NON-RESPONDERS





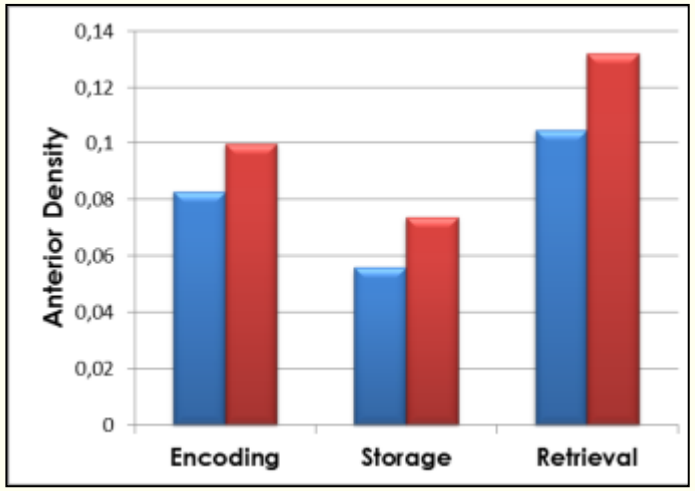


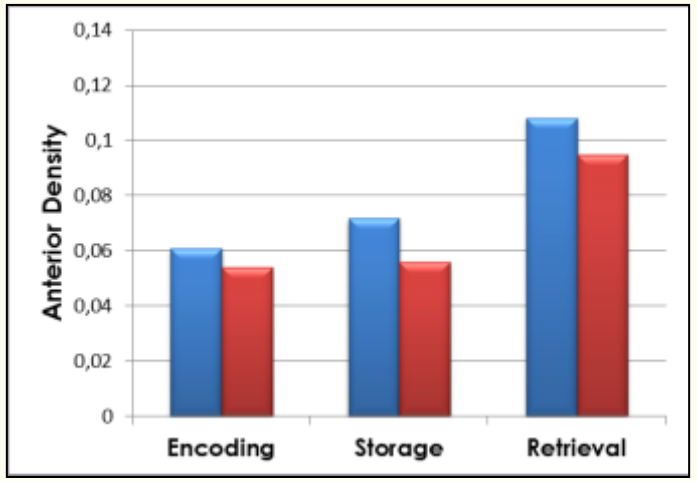
the result of therapy is strongly dependent on the specific patient

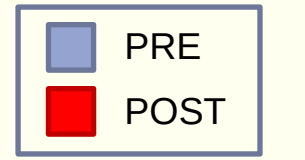
Local Indices

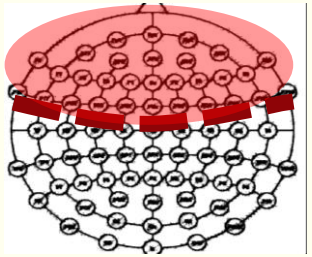
RESPONDERS

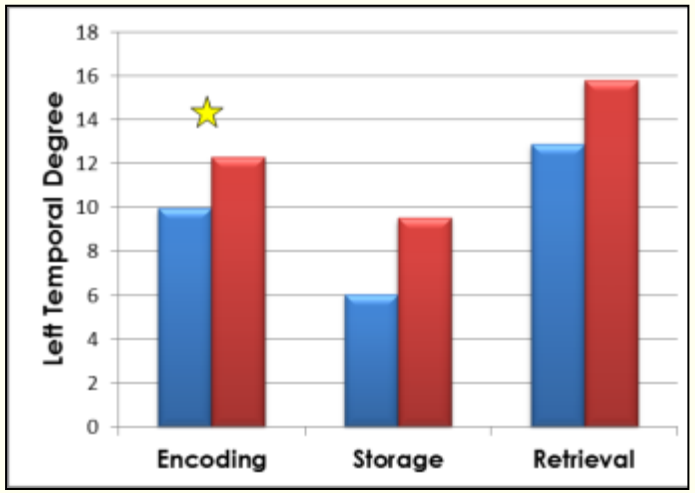
NON- RESPONDERS

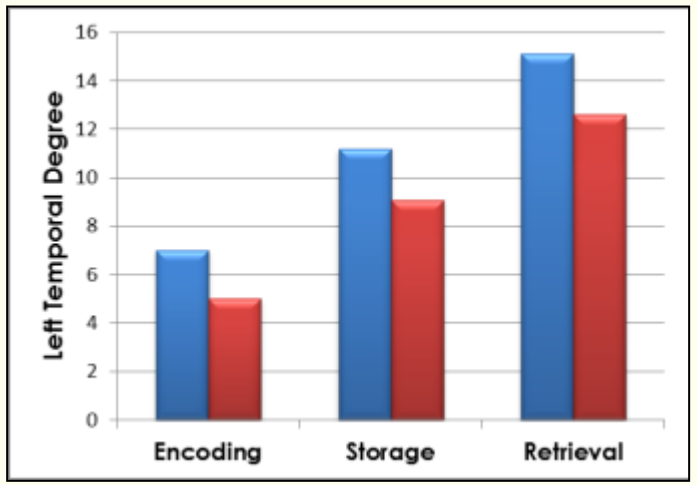


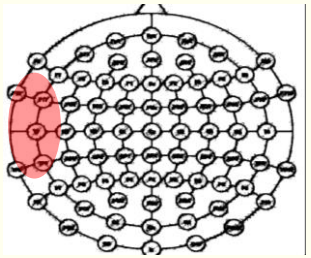








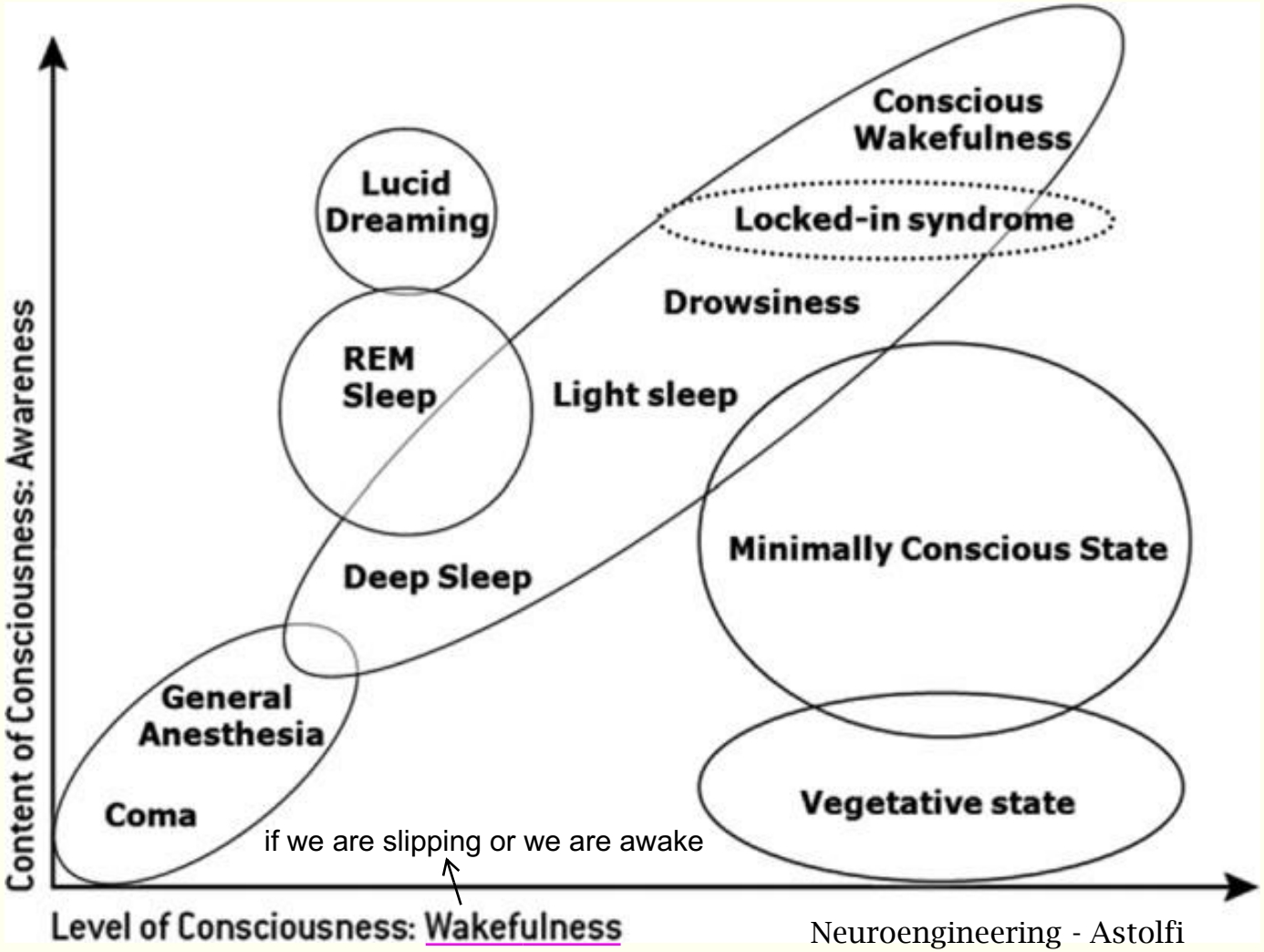




summation of 2 conditions of the subject: awareness and wakefulness

Disorders of Consciousness (Gosseries et al. 2011)

- Consciousness: arousal + awareness



Vegetative State → no consciousness?

BREVIA

Detecting Awareness in the Vegetative State

Adrian M. Owen,[1*] Martin R. Coleman,[2] Melanie Boly,[3] Matthew H. Davis,[1] Steven Laureys,[3] John D. Pickard[2]

The vegetative state is one of the least understood and most ethically troublesome conditions in modern medicine. The term describes a unique disorder in which patients who emerge from coma appear to be awake but show no signs of awareness. Although the diagnosis depends crucially on there being no reproducible evidence of purposeful behavior in response to external stimulation (*1*), recent functional neuroimaging studies have suggested that

from a *beam* in the *ceiling*") produced an additional significant response in a left inferior frontal region, similar to that observed for normal volunteers. This increased activity for ambiguous sentences reflects the operation of semantic processes that are critical for speech comprehension.

An appropriate neural response to the meaning of spoken sentences, although suggestive, is not unequivocal evidence that a person is consciously aware. For example, many studies of

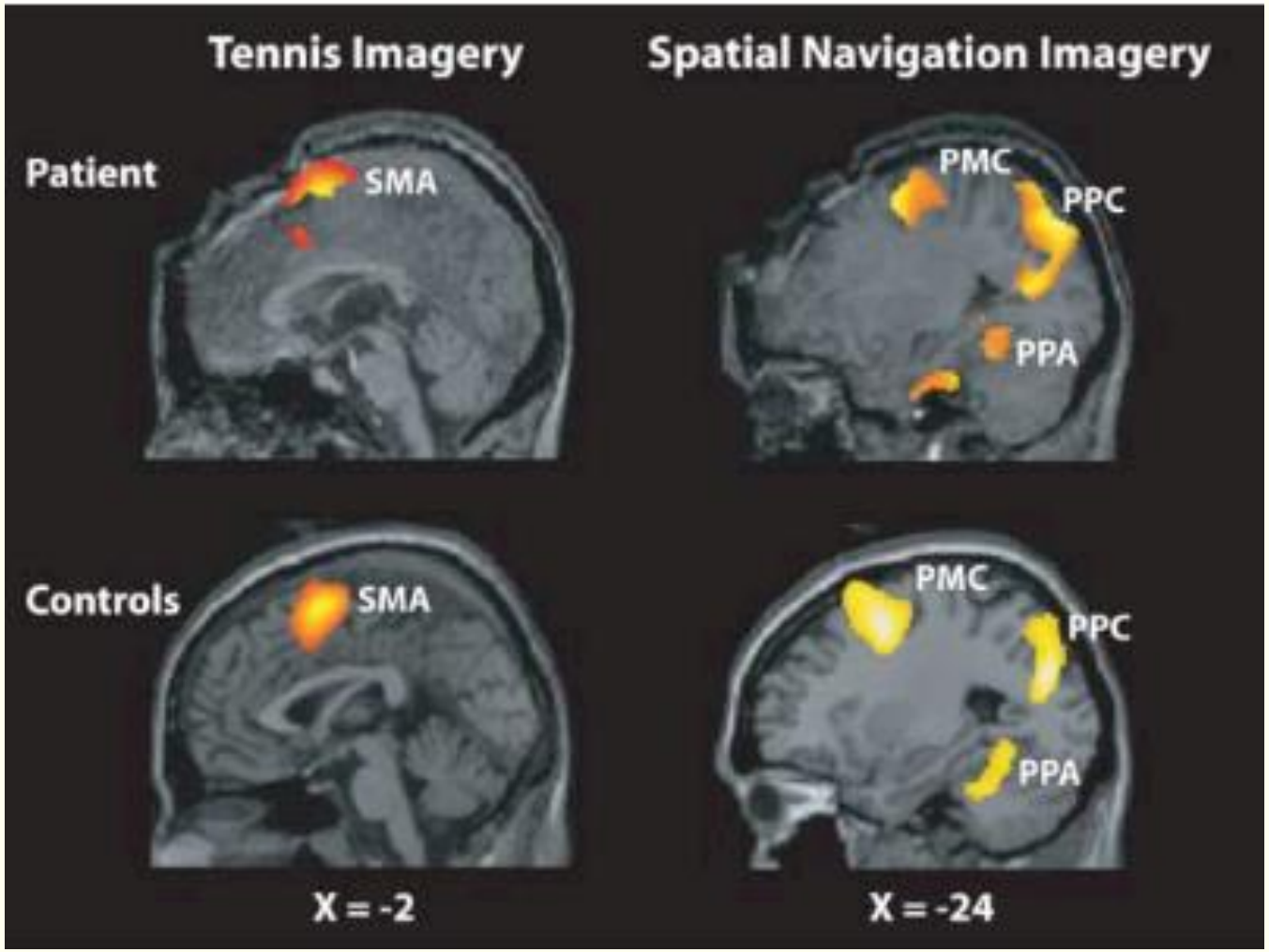
imagine playing tennis, significant activity was observed in the supplementary motor area (Fig. 1). In contrast, when she was asked to imagine walking through her home, significant activity was observed in the parahippocampal gyrus, the posterior parietal cortex, and the lateral premotor cortex (Fig. 1). Her neural responses were indistinguishable from those observed in healthy volunteers (fig. S2) performing the same imagery tasks in the scanner (SOM text).

These results confirm that, despite fulfilling the clinical criteria for a diagnosis of vegetative state, this patient retained the ability to understand spoken commands and to respond to them through her brain activity, rather than through speech or movement. Moreover, her decision to cooperate with the authors by imagining particular tasks when asked to do so represents a clear act of intention, which confirmed beyond any doubt that she was consciously aware of herself and her surroundings. Of course, negative find-

Owen et al, Science 2006

Detecting awareness from the brain activity

- Activity in the Supplementary Motor Area (SMA) during the playing tennis imagery
- Activity in the parahppocampal Place Area (PPA), in the Posterior Parietal Cortex (PPC) and in the Premotor Cortex (PMC) during the spatial navigation imagery
- A patient with three independent diagnosis of Vegetative State (according to behavioural scales)



Owen et al, Science, 2006

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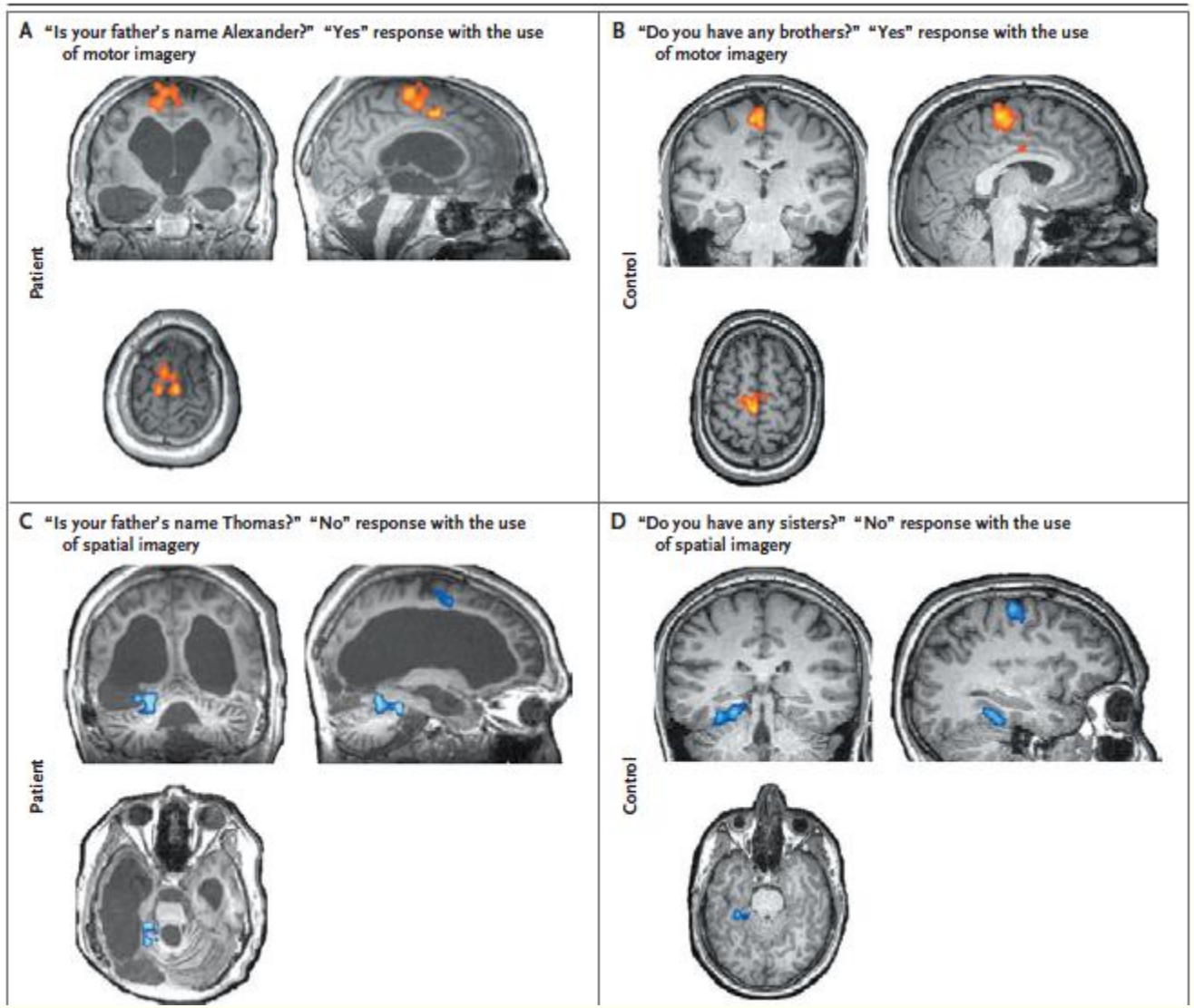
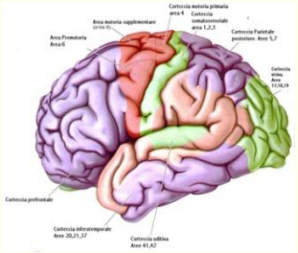
Owen et al, Science 2006

Brain decoding to detect the patients' intentions



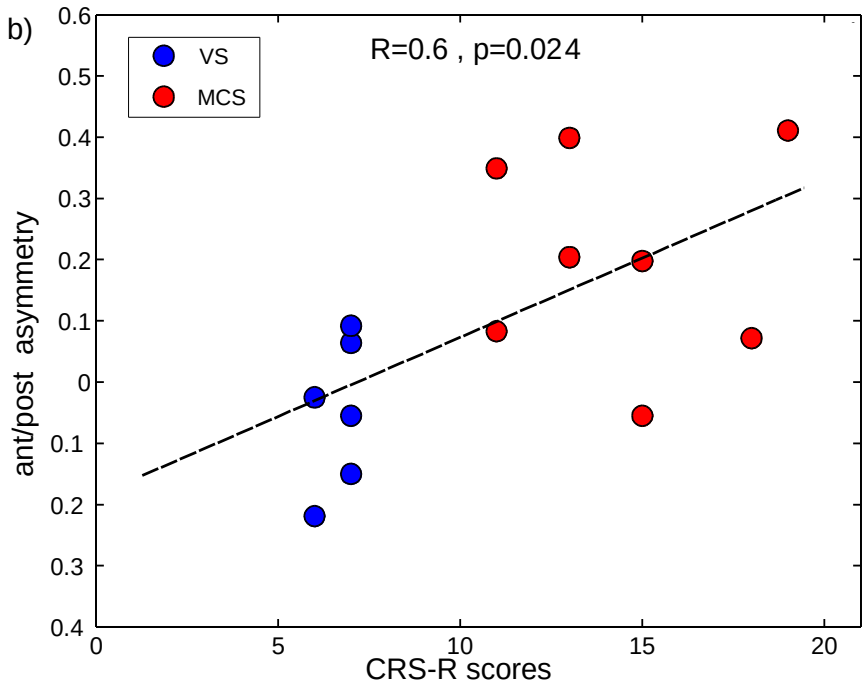
- 5 patients out of 56 showed a brain activity similar to healthy controls
- One of them was able to communicate through the voluntary modulation of his mental states

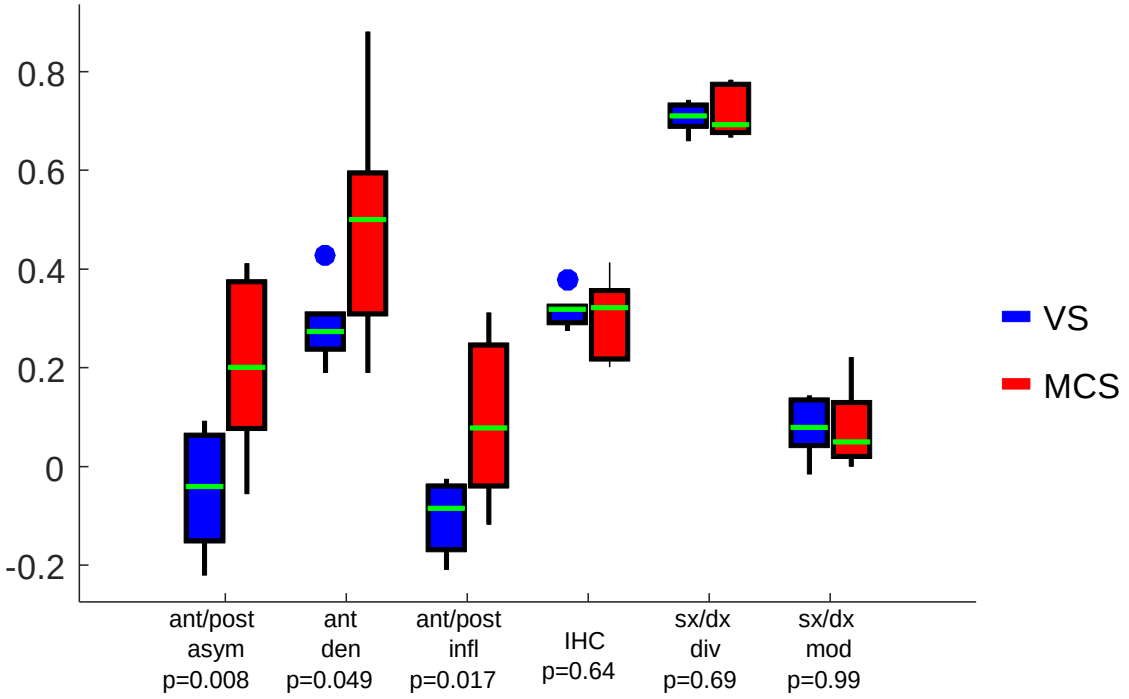


Monti et al, New England Journal of Medicine, 2010

Support to the diagnosis of DoC

- 40% misdiagnosis estimated
- Classification of patients in different clinical conditions (Vegetative State – VS, Minimally Conscious State-MCS) by graph indices computed from resting state EEG networks





IEEE Transactions on Biomedical Engineering, 2016
Frontiers in Human Neuroscience, 2018