Functional connectivity predicts MI-based BCI learning

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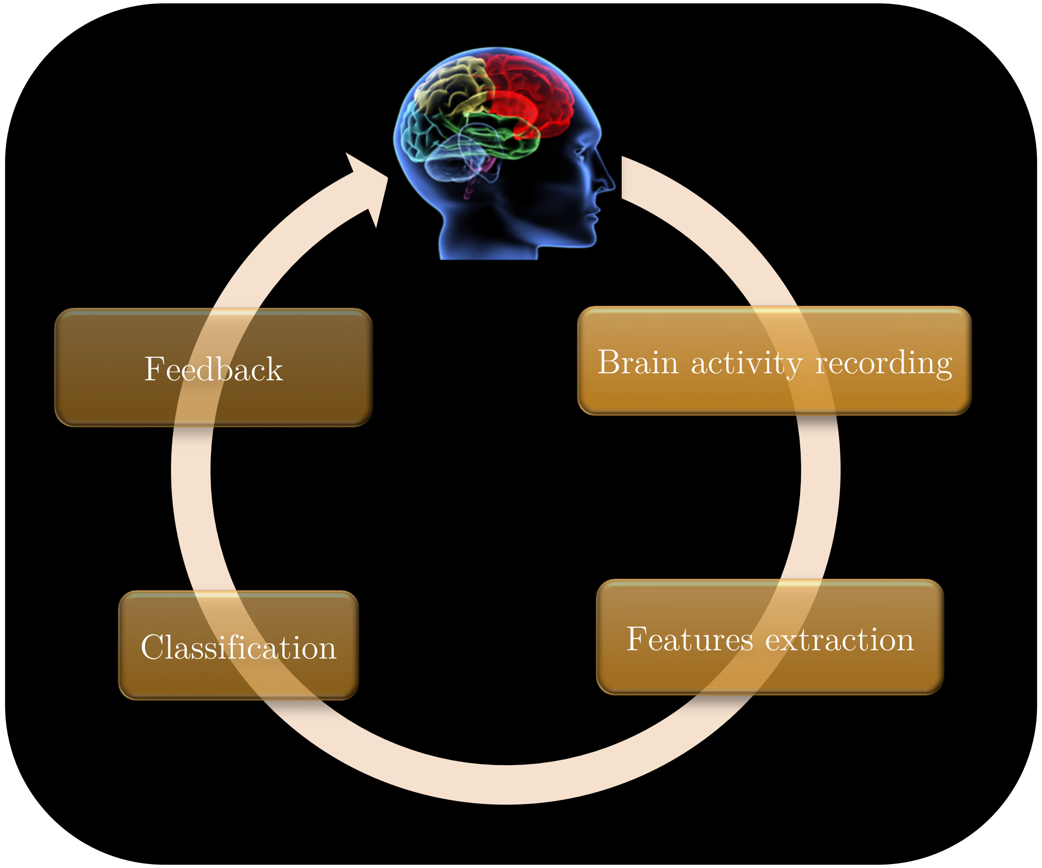
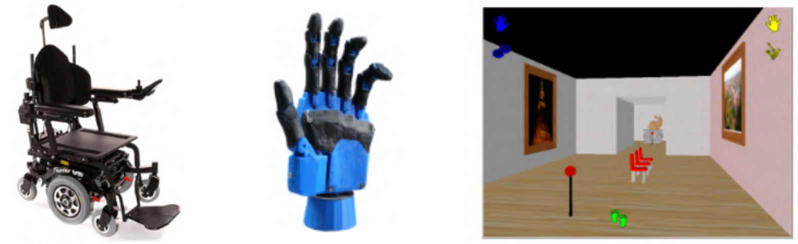
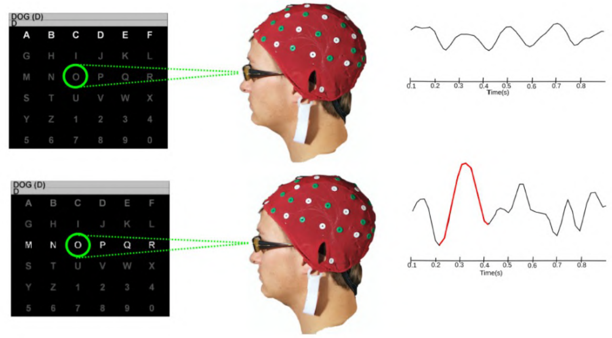
BCI CHALLENGE





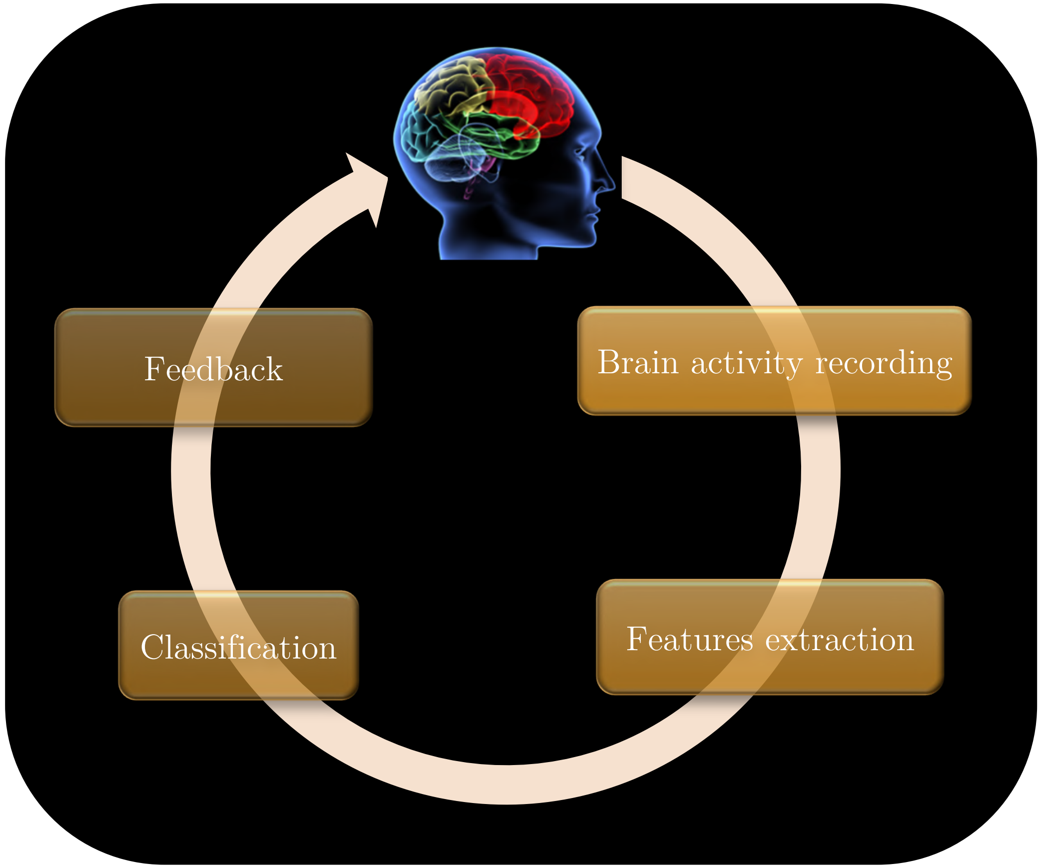
Control

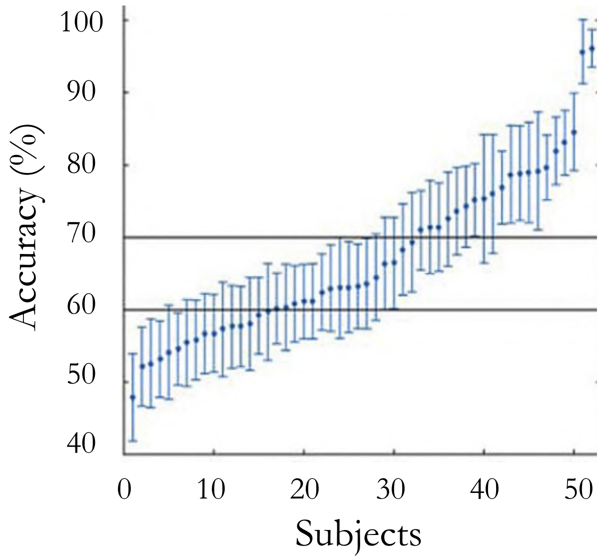


Communication

Adapted from (Lotte et al, 2015)

BCI CHALLENGE





Adapted from (Ahn & Jun, 2015)

Problem : Current BCIs fail to detect the mental intentions in ~30% of users – **BCI inefficiency** (Thompson, 2018)

BCI INEFFICIENCY CHALLENGE

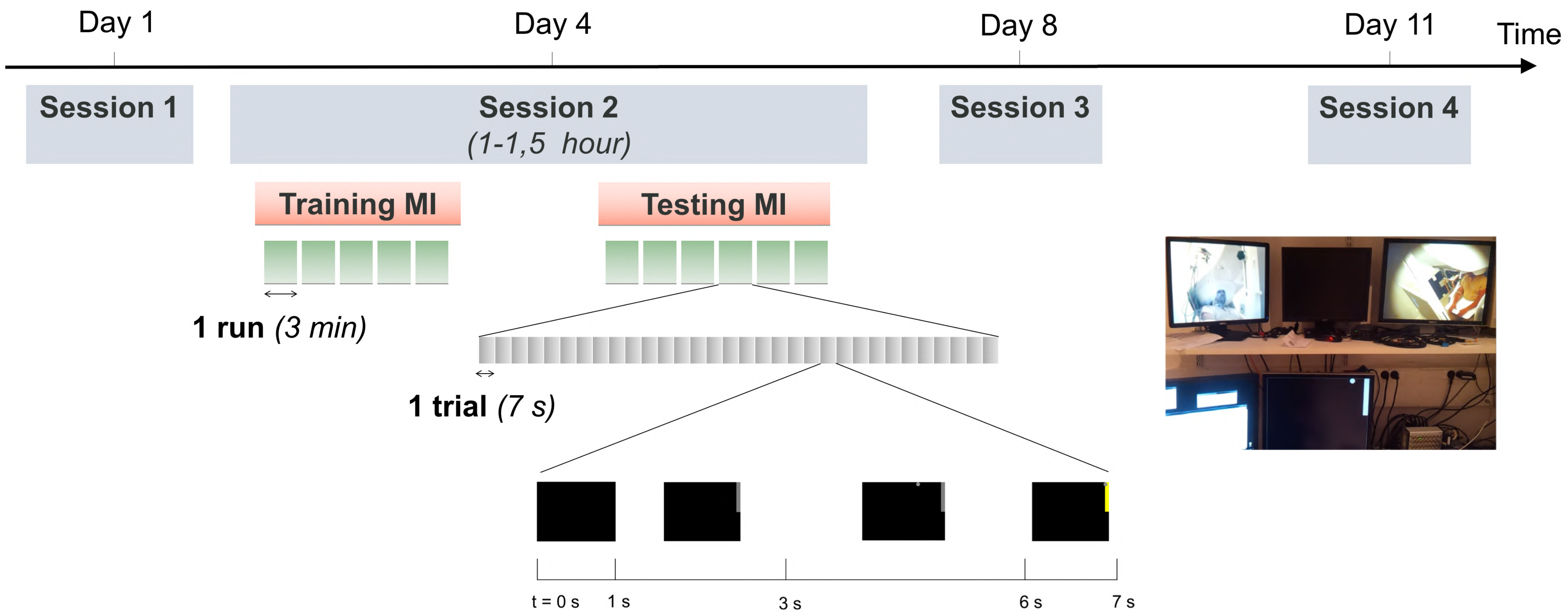
- Machine-centered approaches
  - Signal processing (Vidaurre et al, 2011)
  - Classification algorithms (Lotte et al, 2018)
- User-centered approaches
  - Search for neurophysiological patterns (Blankertz et al, 2010; Ahn et al, 2015)
  - Human factors (Hammer et al, 2012; Jeunet et al, 2015)

⇒Neural mechanisms underlying BCI learning **poorly understood**

⇒The **interconnected** nature of the brain functioning not considered

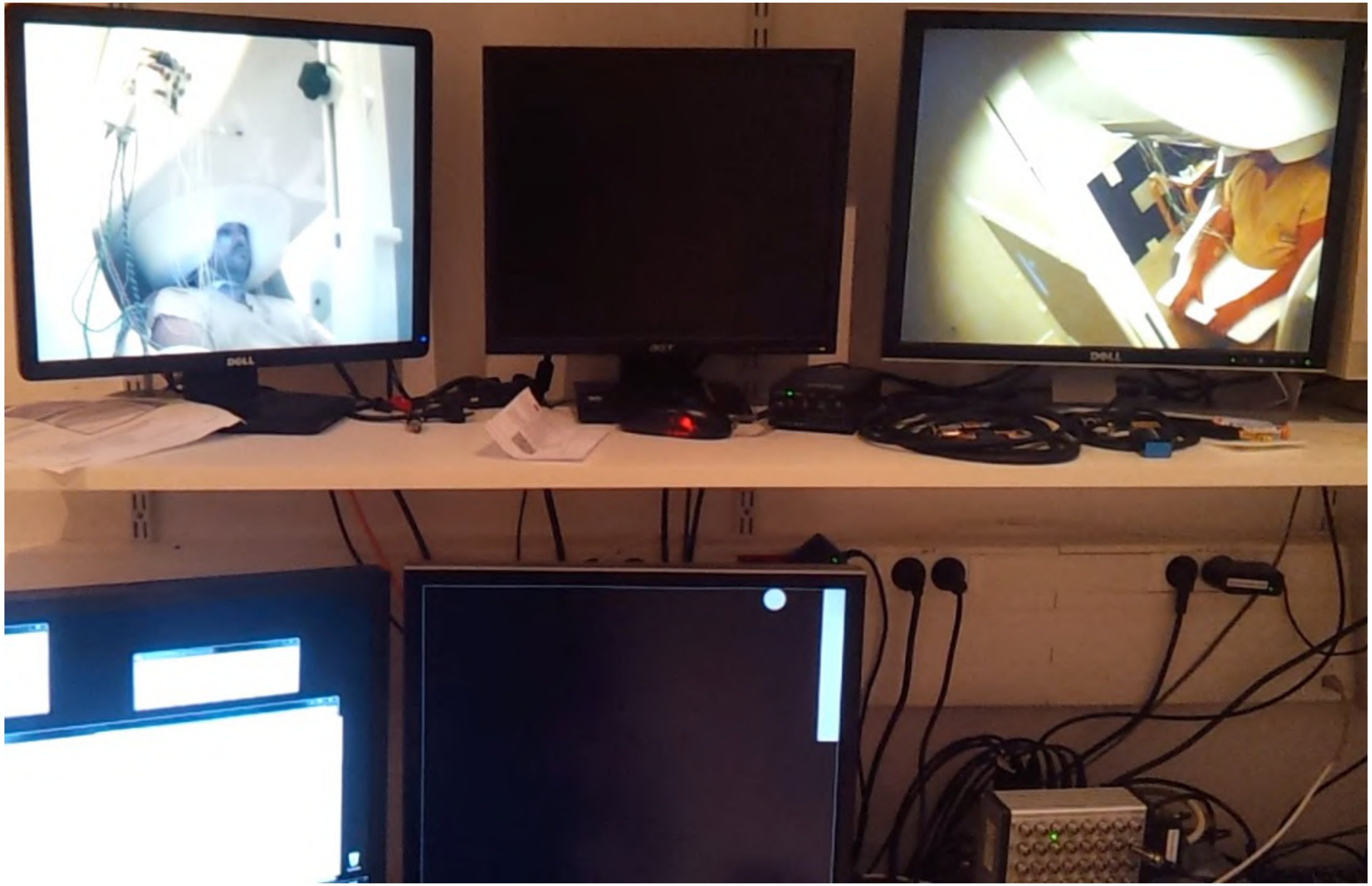
Hypothesis : BCI training associated with a dynamic recruitment of a larger network – **Potential markers of BCI performance**

PROTOCOL

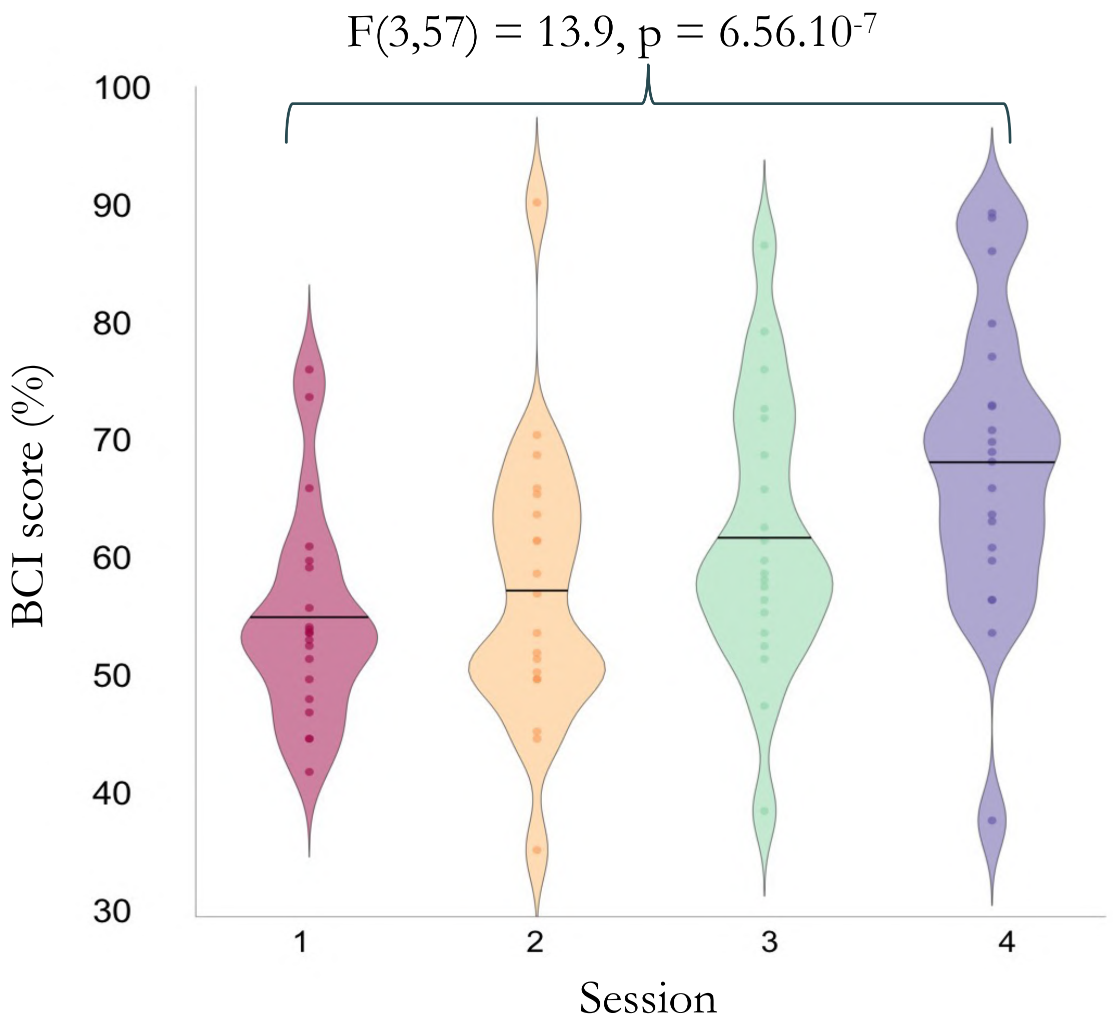


Day 1
Day 4
Day 8
Day 11
Time
Session 1
Session 2
(1-1,5 hour)
Session 3
Session 4
Training MI
Testing MI
1 run (3 min)
1 trial (7 s)
t = 0 s
1 s
3 s
6 s
7 s

PROTOCOL

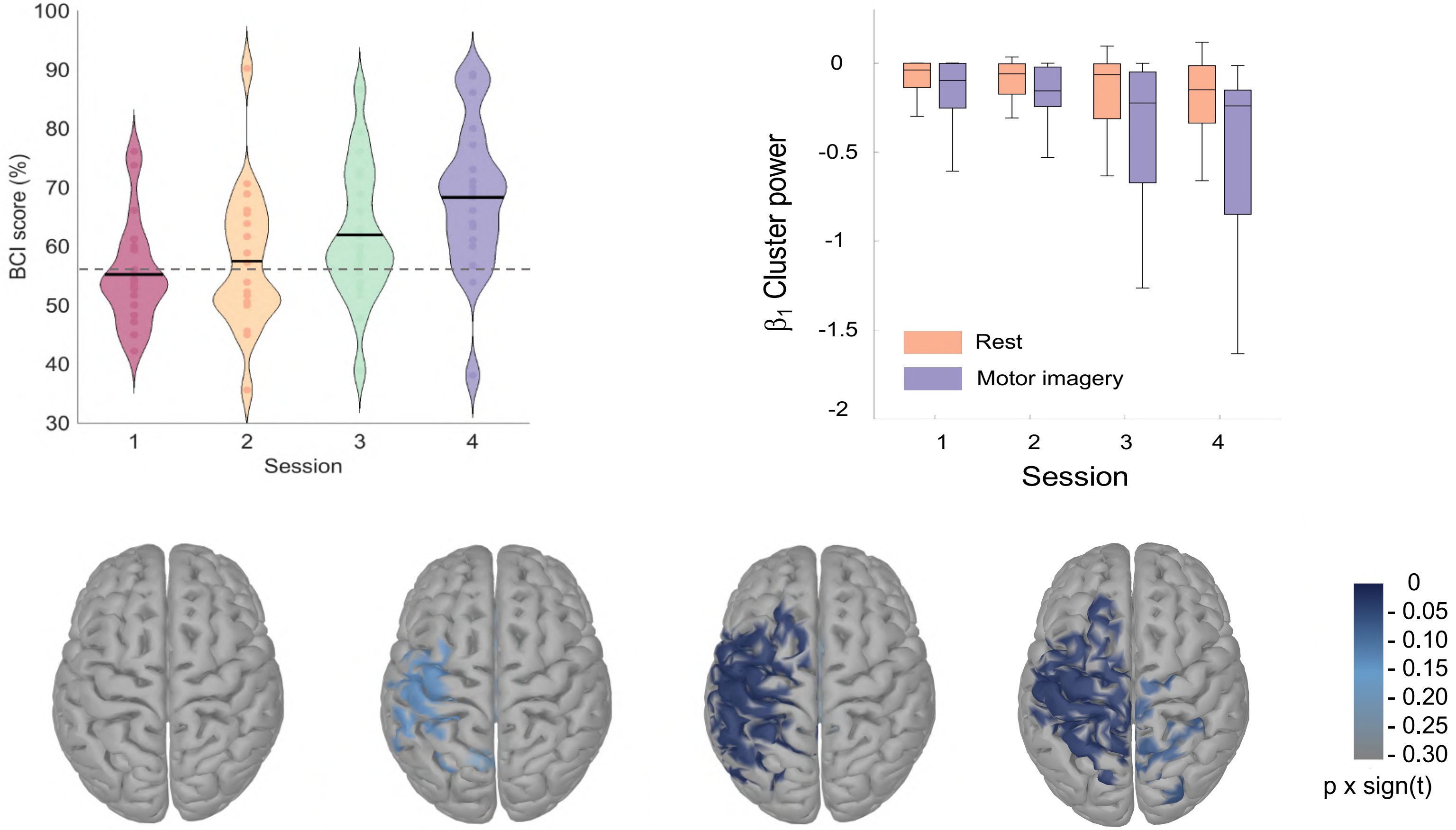


BEHAVIORAL RESULTS – CHANGES OVER SESSIONS



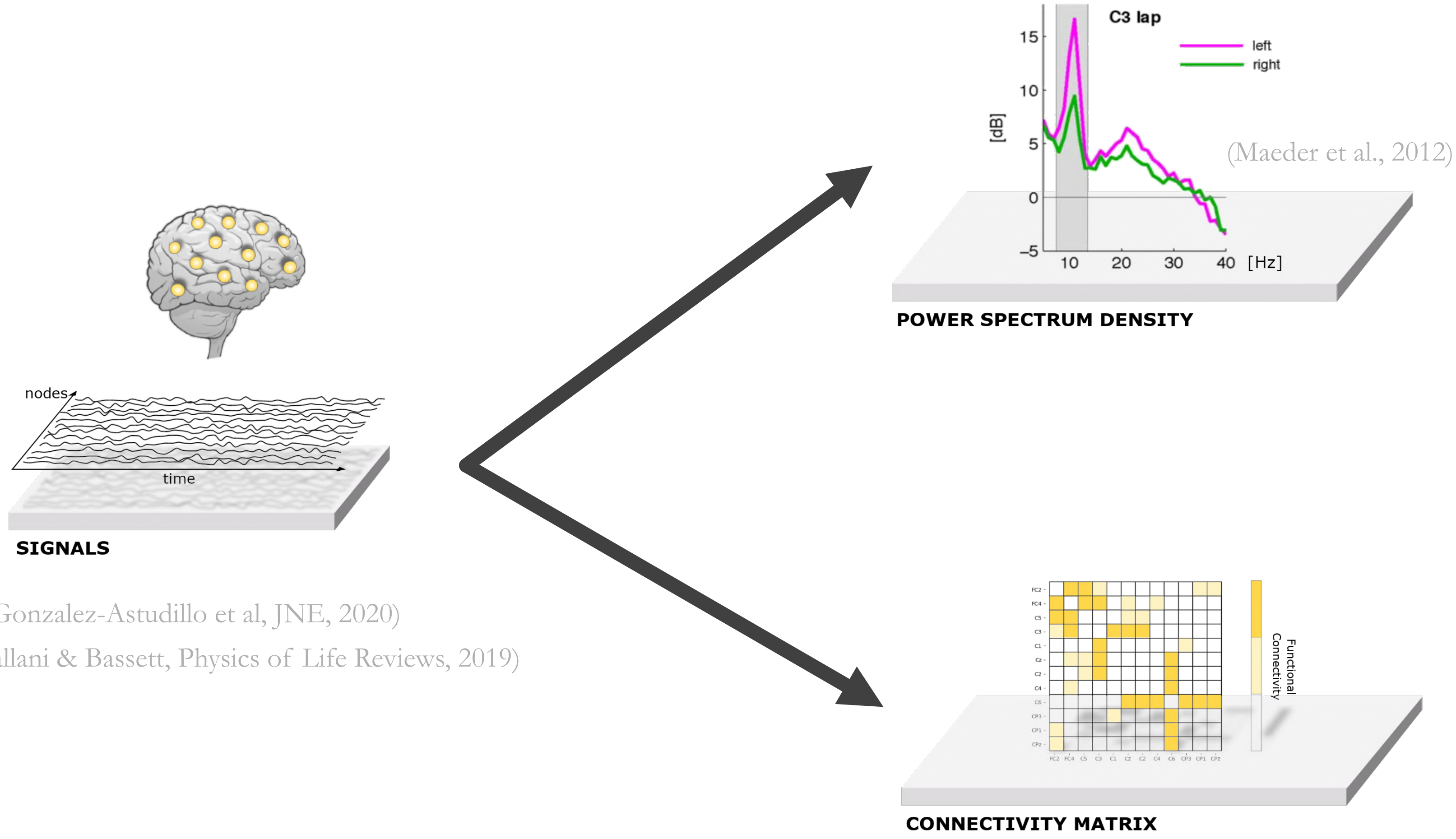
(Corsi et al, NeuroImage, 2020)

REINFORCEMENT OF MOTOR-RELATED ACTIVITY



(Corsi et al, NeuroImage, 2020)

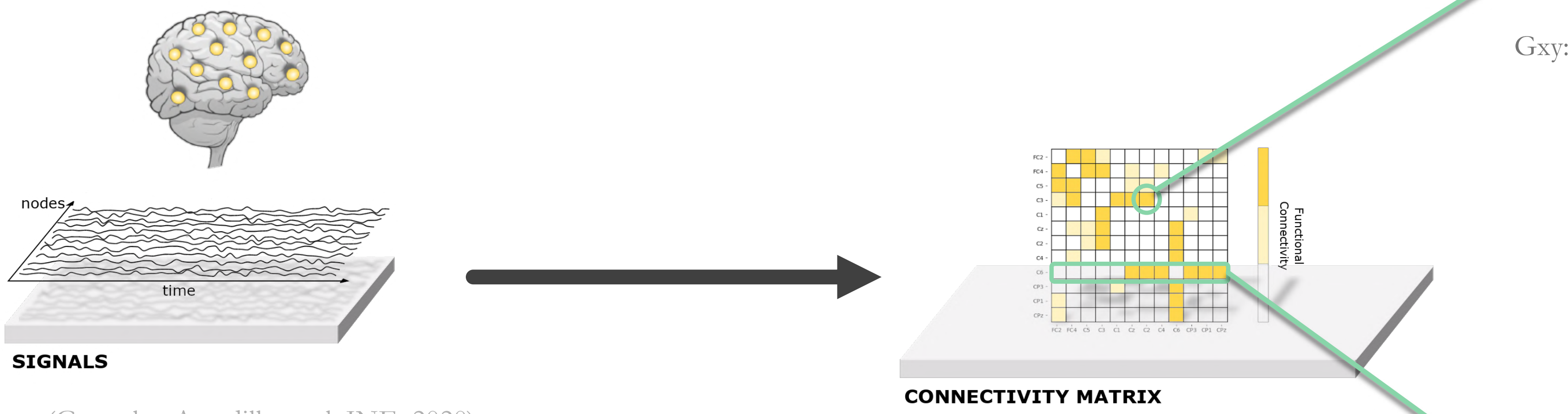
FUNCTIONAL CONNECTIVITY



(Gonzalez-Astudillo et al, JNE, 2020)

(De Vico Fallani & Bassett, Physics of Life Reviews, 2019)

FUNCTIONAL CONNECTIVITY



(Gonzalez-Astudillo et al, JNE, 2020)

(De Vico Fallani & Bassett, Physics of Life Reviews, 2019)

Imaginary coherence

(Nolte et al, 2004; Sekihara et al, 2011)

$$IC_{x,y} = \mathrm{Im}\left(\frac{G_{xy}}{\sqrt{G_{xx}.\,G_{yy}}}\right)$$

Gxy: cross-spectral density between ROIs x and y;

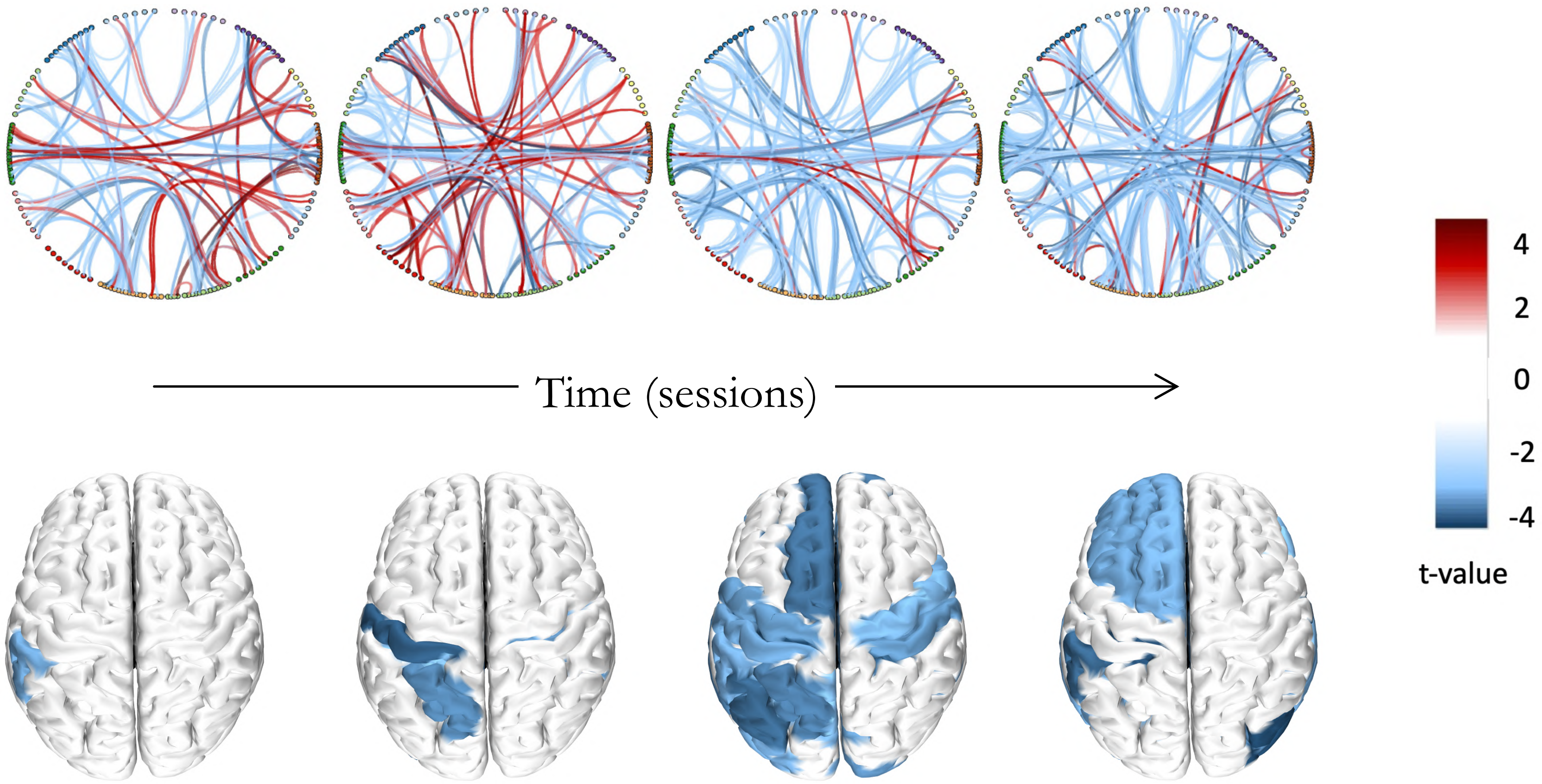
Gxx: autospectral density of ROI x

Node strength

For a given ROI x, and a condition j

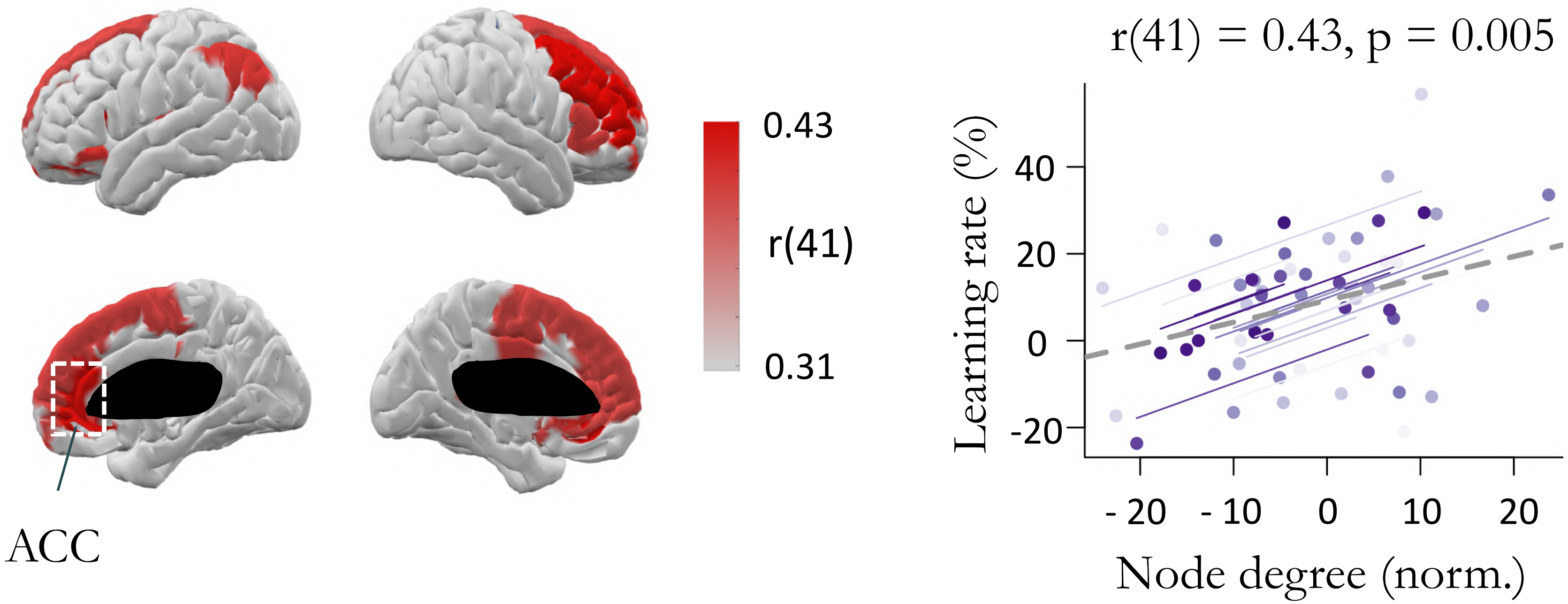
$$N_{x,j} = \sum_{i \in \{ROI\}} IC_{x,j,i}$$

FUNCTIONAL DISCONNECTION OF ASSOCIATIVE AREAS



(Corsi et al, NeuroImage, 2020)

NODE STRENGTH PREDICTS BCI LEARNING RATE



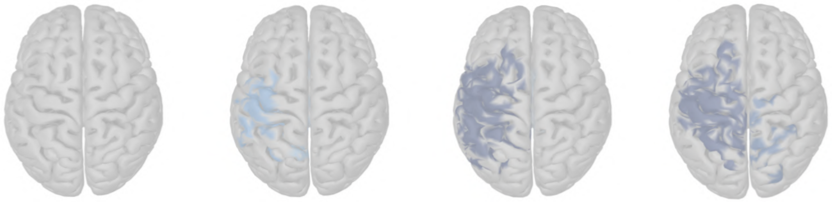
The *reserve* effect

Higher connectivity → higher **potential** to disconnect (learning)

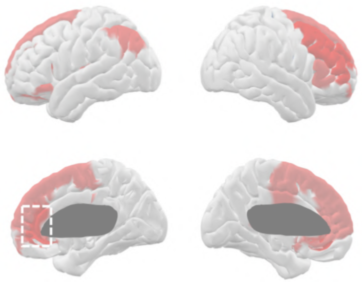
(Corsi et al, NeuroImage, 2020)

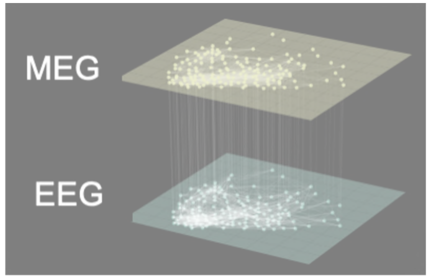
TAKE HOME MESSAGES

- Cortical changes & dynamic reorganization during BCI training
  - Increase of desynchronization & focus on BCI-targeted areas
  - Decrease of connectivity in associative & attentional areas



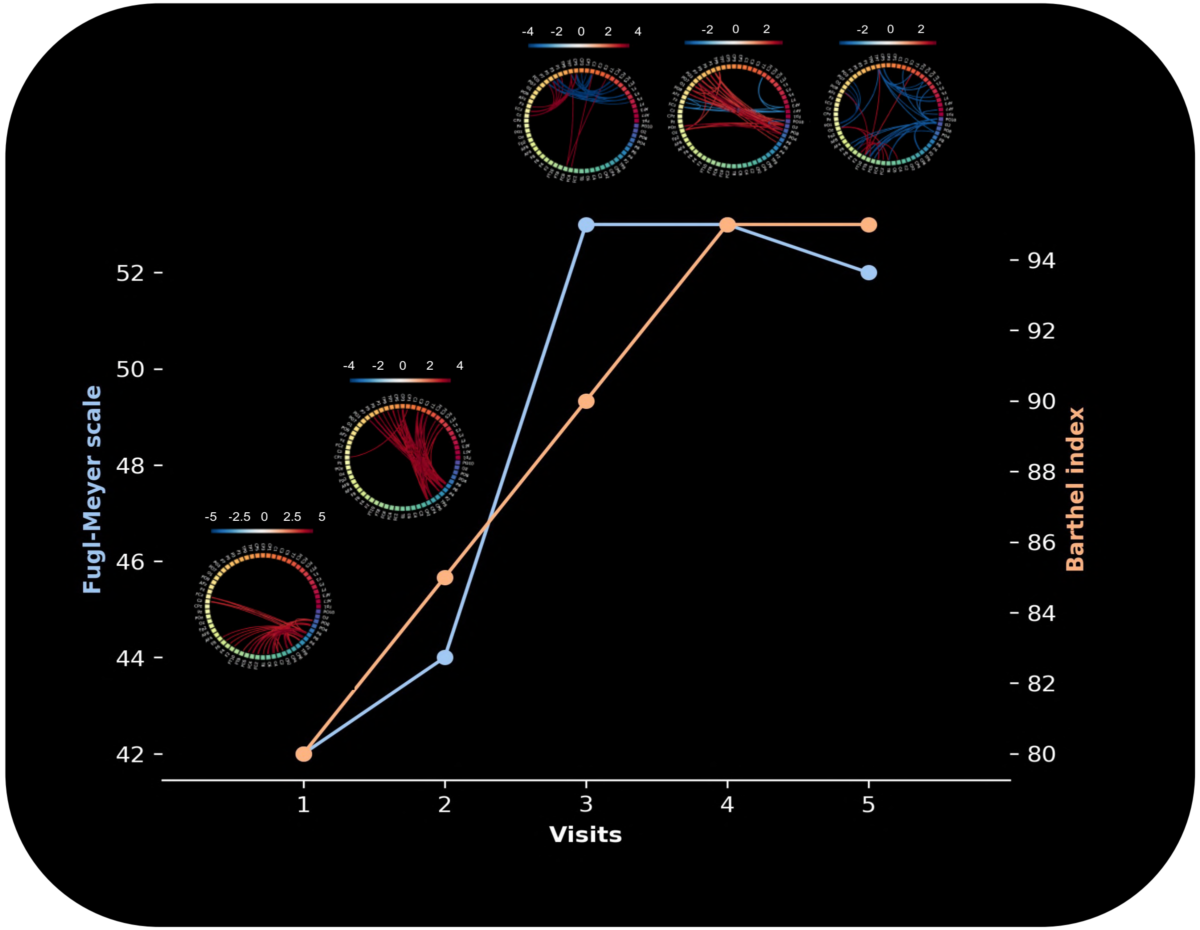
- Neurophysiological predictors of BCI performance
  - Activations: relative power
  - Functional connectivity: relative node strength
  - Brain networks: multimodal network properties integration





(Corsi et al, 2021)

STROKE – SEARCH FOR ALTERNATIVE FEATURES



Neurophysiological patterns of stroke recovery over 1 year (ongoing project w/ AP-HP)

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Thank you for your attention !

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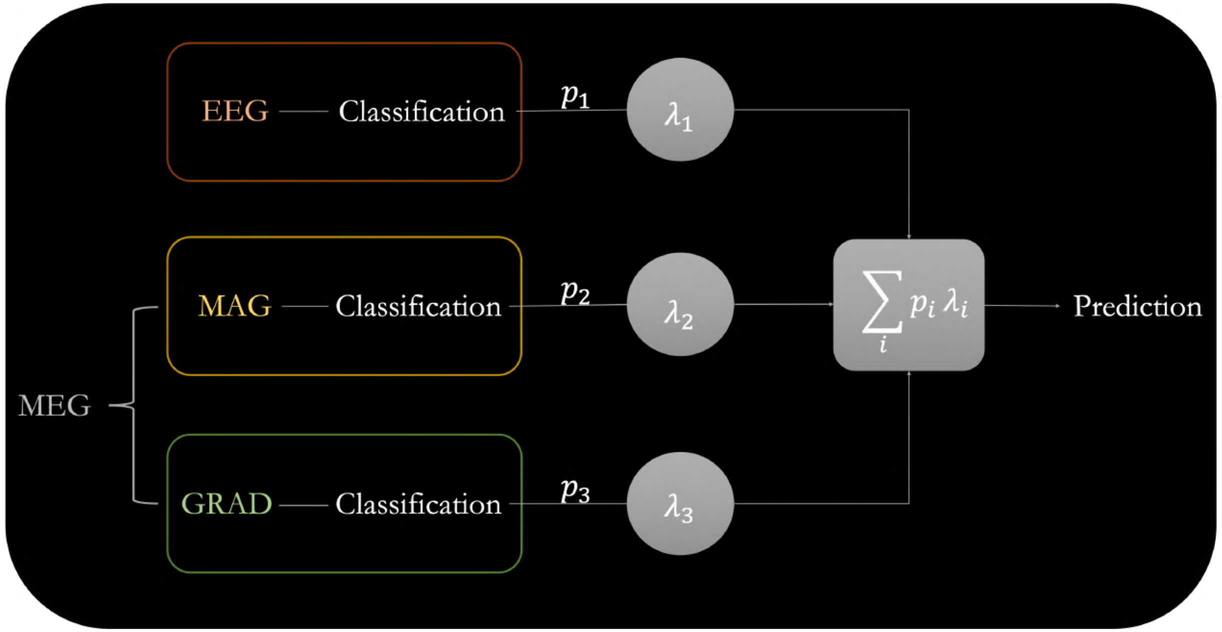
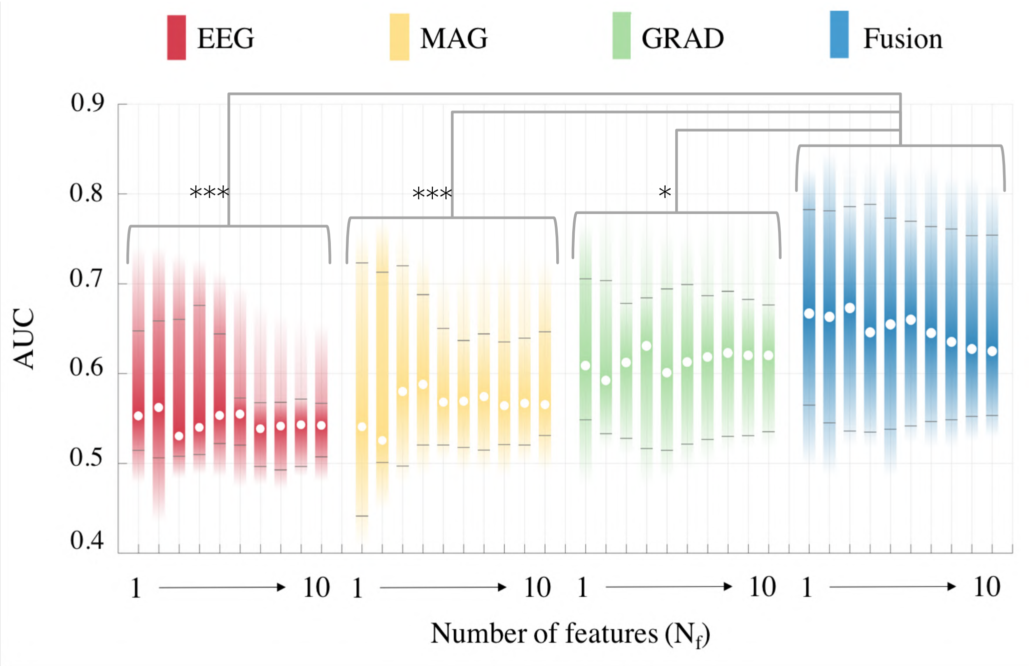
MConstanceCorsi

M/EEG INTEGRATION TO IMPROVE BCI ACCURACY

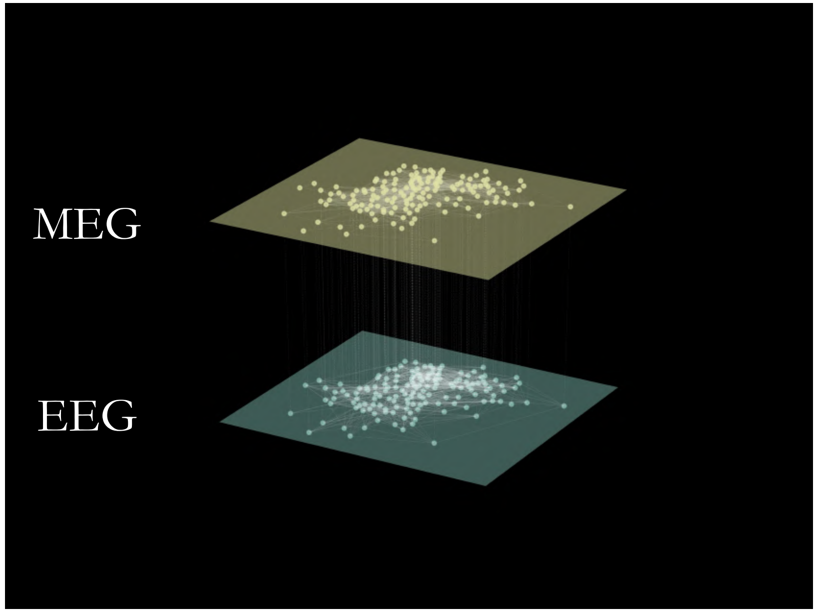




M/EEG integration improves accuracy → **subject's specificity** taken into account

(Corsi et al, IJNS, 2018)

MULTIPLEX CORE-PERIPHERY PREDICTS BCI PERFORMANCE



Multiplex coreness of node (ROI) i – C_i

$$C_i = \frac{1}{N-1} \sum_{k=1}^{N-1} \delta_i^k\, ; \quad \delta_i^k = 1, \text{ if nodes } i \text{ in the core, 0 otherwise}$$

Optimization of the contribution c of each layer/modality

$$F(c) = \frac{(\langle C^{MI}(c)\rangle - \langle C^{Rest}(c)\rangle)^2}{(s^{MI})^2 + (s^{Rest})^2}$$

Where:

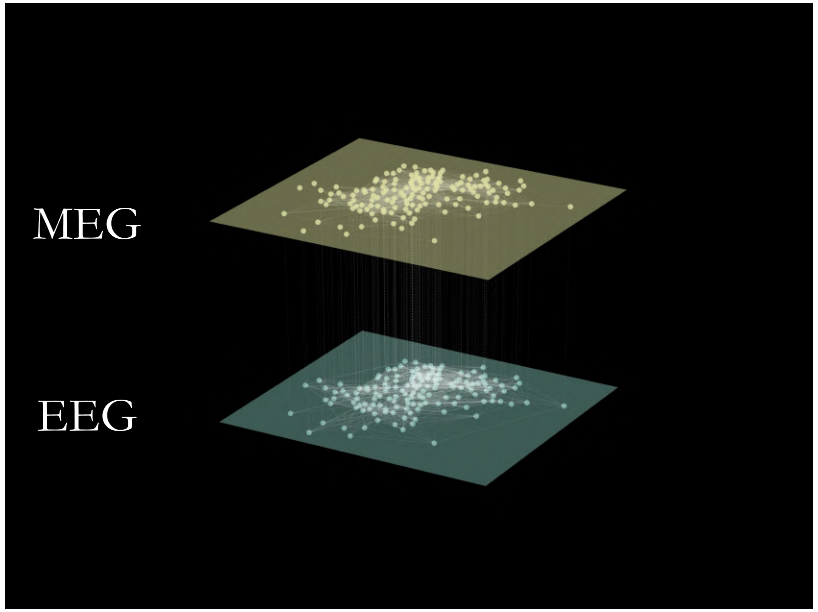
$$(s^{cond})^2 = \sum_{i \in \{1 \ldots N\}} (\langle C_i^{cond}(c)\rangle - \langle C^{cond}(c)\rangle)^2$$

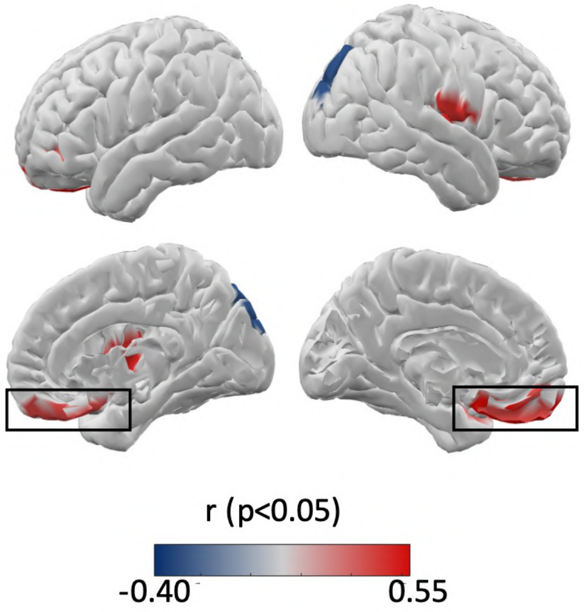
$\langle C^{cond}(c)\rangle$, averaged coreness over the nodes *i*

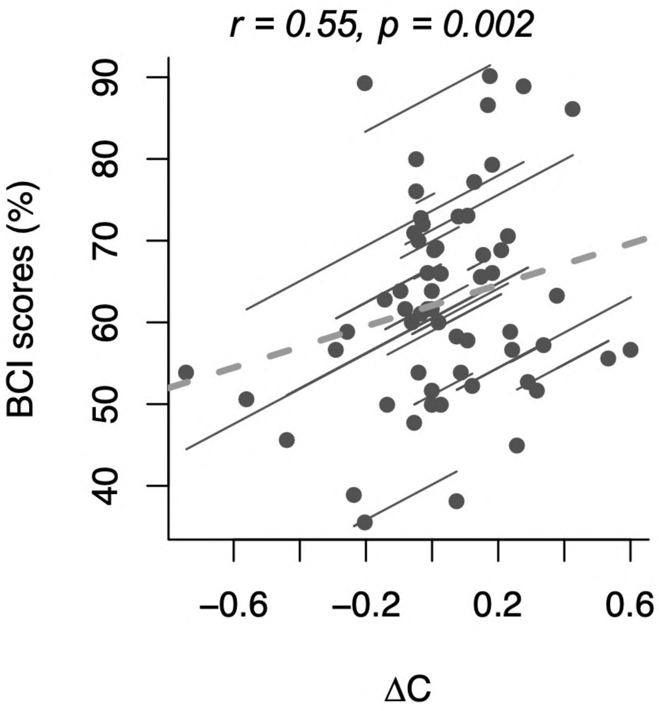
C_i^{cond}, coreness computed in node *i*, condition *cond*

(Corsi et al, JNE, 2021)

MULTIPLEX CORE-PERIPHERY PREDICTS BCI PERFORMANCE







(Corsi et al, JNE, 2021)