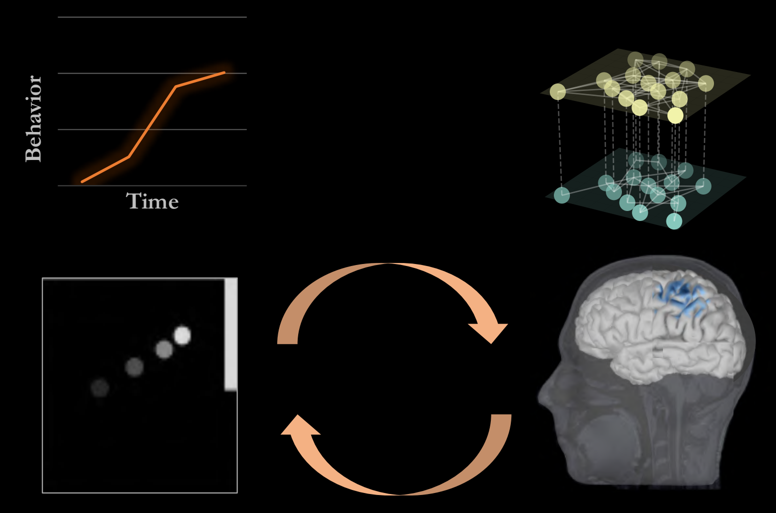
CORE-PERIPHERY MARKERS OF LONGITUDINAL BCI FROM MULTIPLEX BRAIN NETWORKS

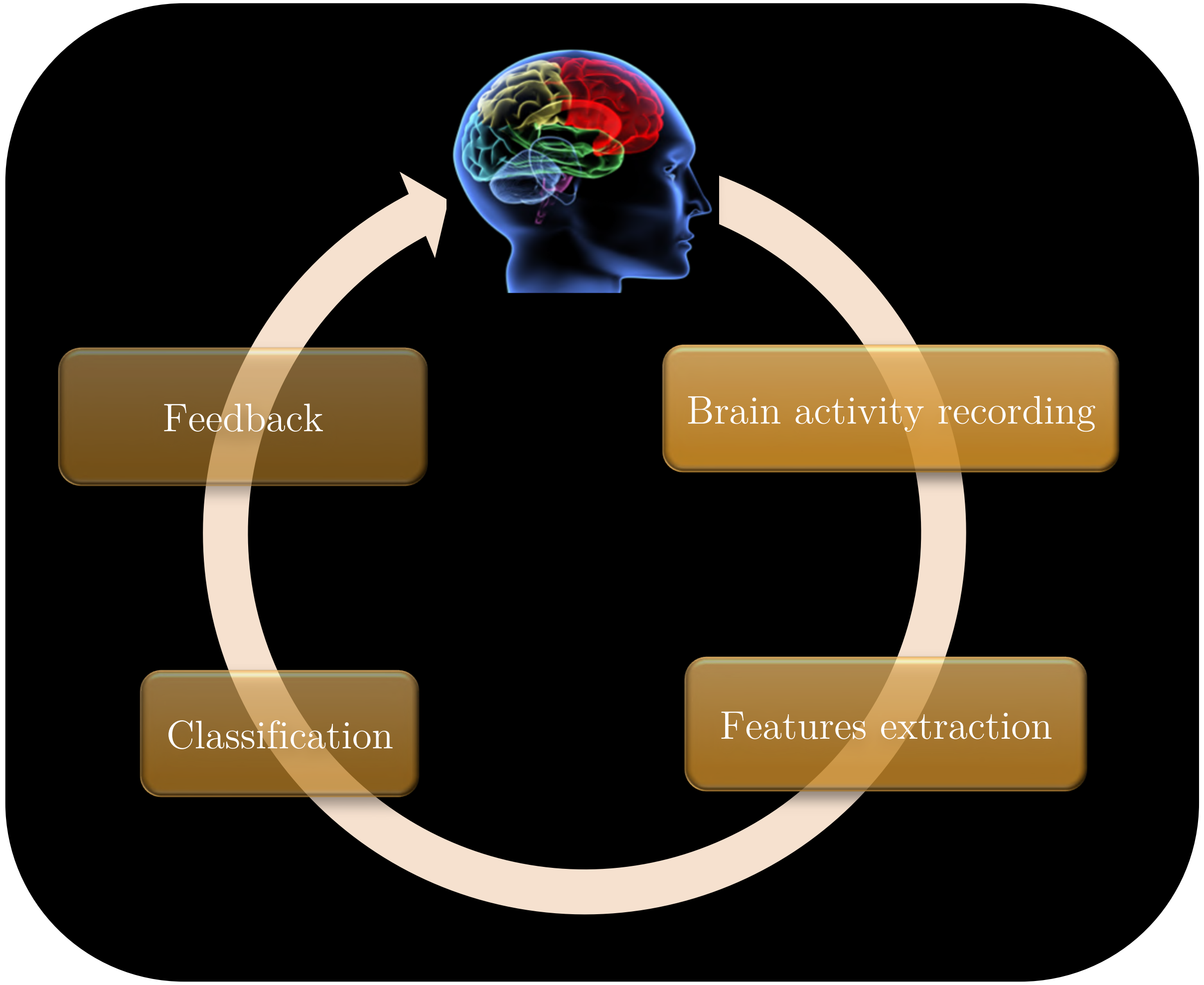


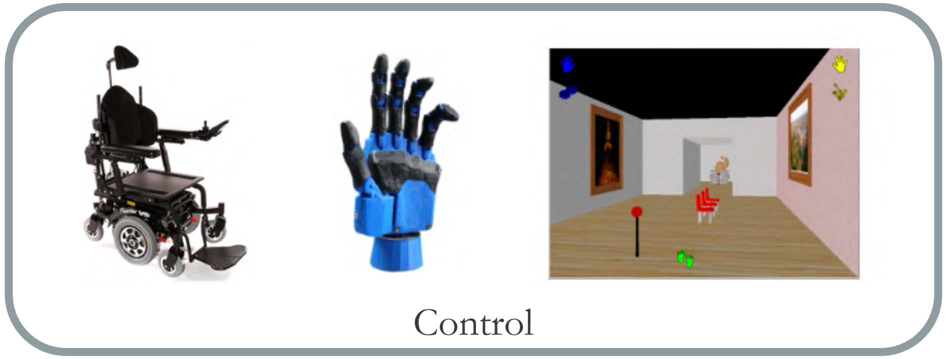
Marie-Constance Corsi

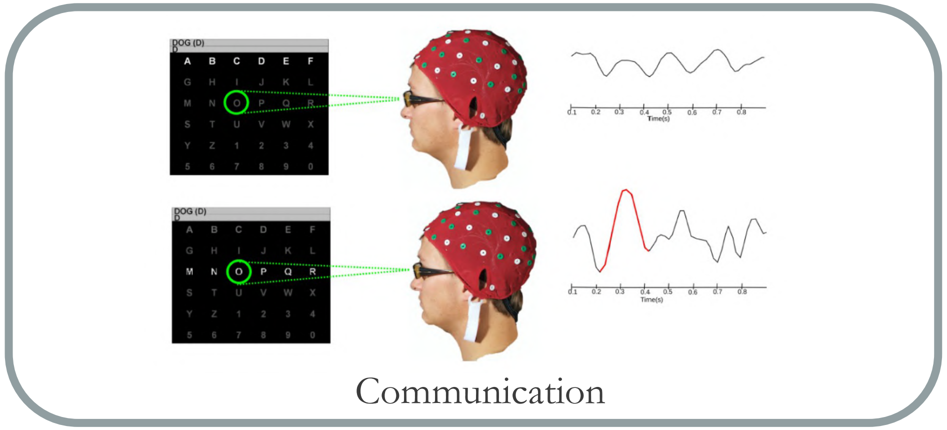
Postdoctoral researcher,

ARAMIS team, Paris Brain Institute

BRAIN-COMPUTER INTERFACE (BCI)

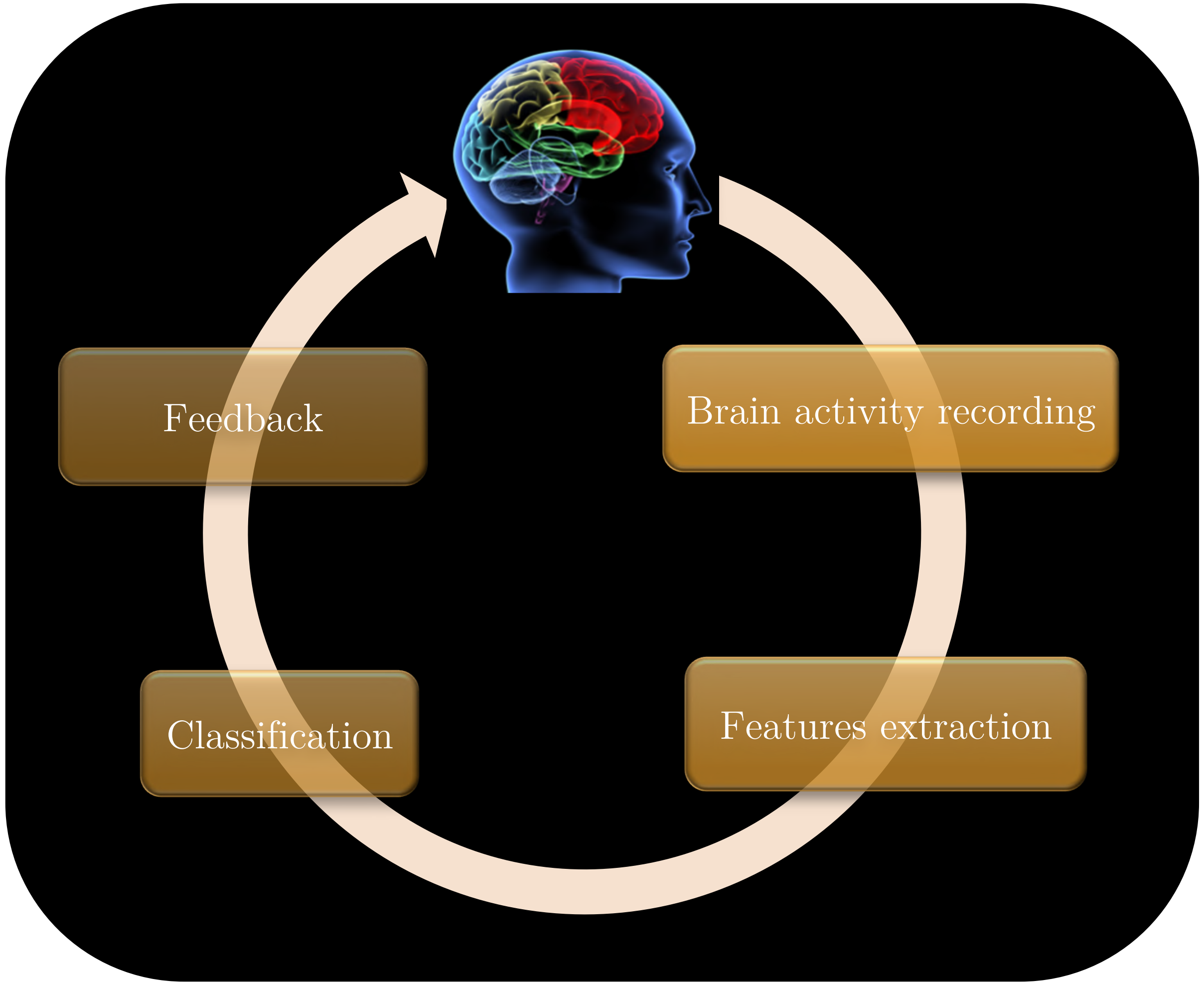


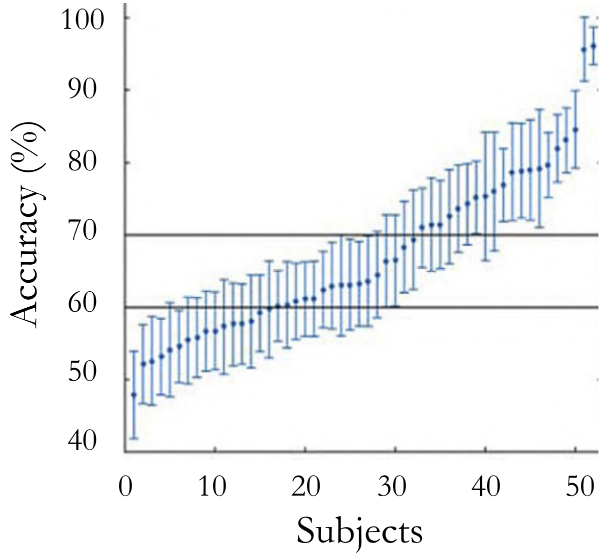




Adapted from (Lotte et al, 2015)

BCI CHALLENGE





Adapted from (Ahn & Jun, 2015)

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

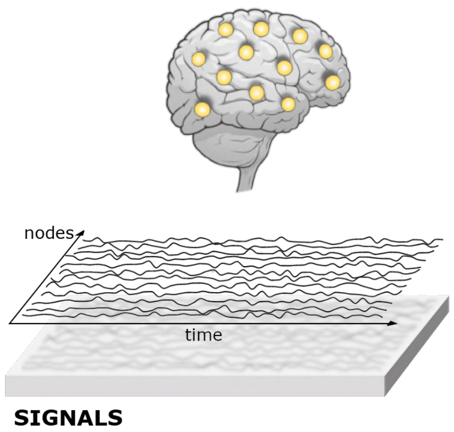
BCI INEFFICIENCY CHALLENGE – STATE-OF-THE-ART

- 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

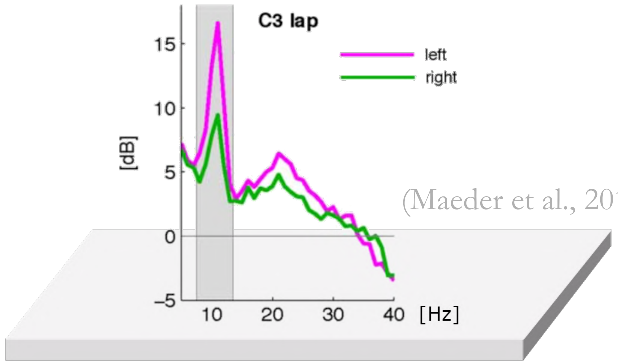
BCI INEFFICIENCY CHALLENGE – NETWORK APPROACH



(Gonzalez-Astudillo et al, 2020)

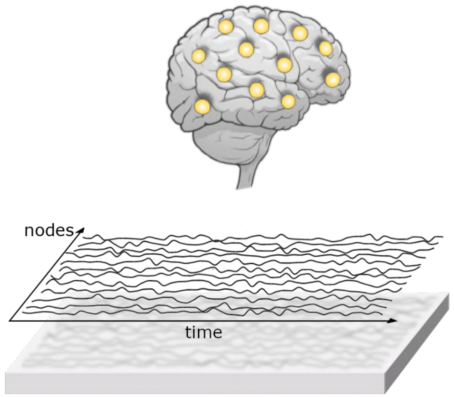
(De Vico Fallani & Bassett, 2019)

BCI INEFFICIENCY CHALLENGE – NETWORK APPROACH



(Maeder et al., 2012)

POWER SPECTRUM DENSITY

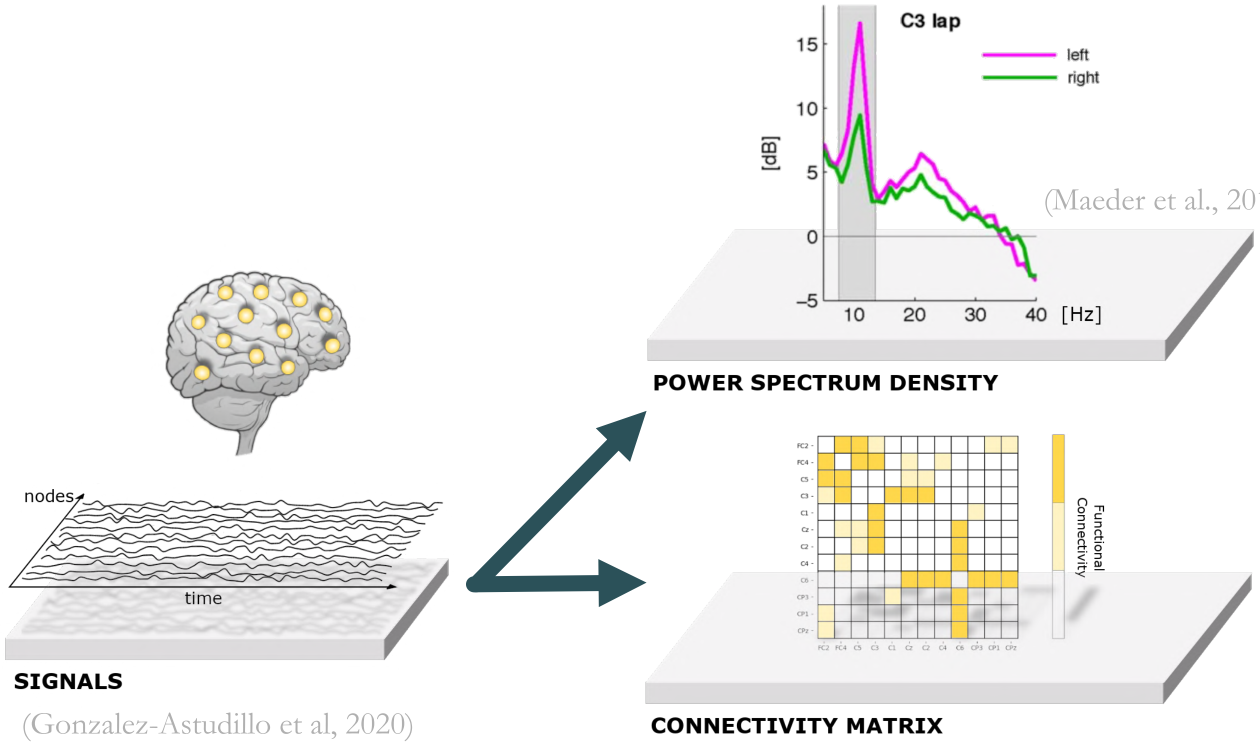


SIGNALS

(Gonzalez-Astudillo et al, 2020)

(De Vico Fallani & Bassett, 2019)

BCI INEFFICIENCY CHALLENGE – NETWORK APPROACH

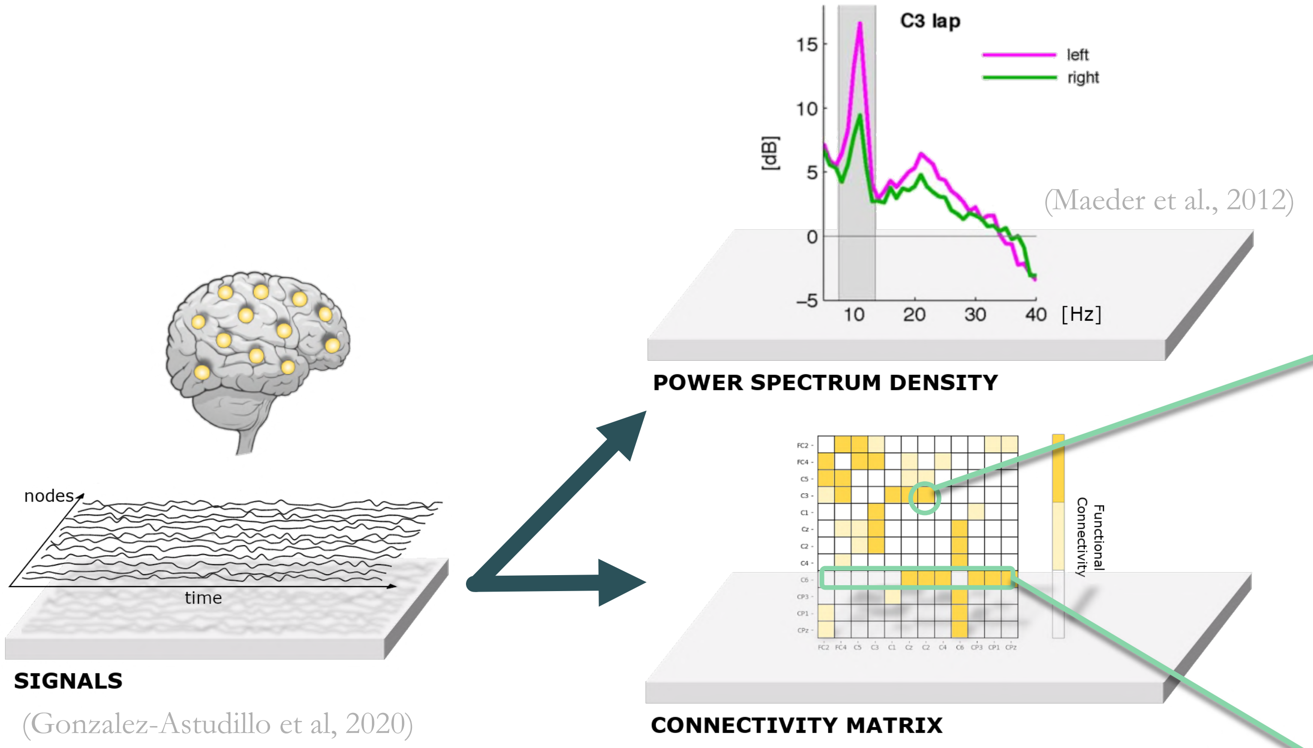


(Maeder et al., 2012)

(Gonzalez-Astudillo et al, 2020)

(De Vico Fallani & Bassett, 2019)

BCI INEFFICIENCY CHALLENGE – NETWORK APPROACH



(Gonzalez-Astudillo et al, 2020)

(De Vico Fallani & Bassett, 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

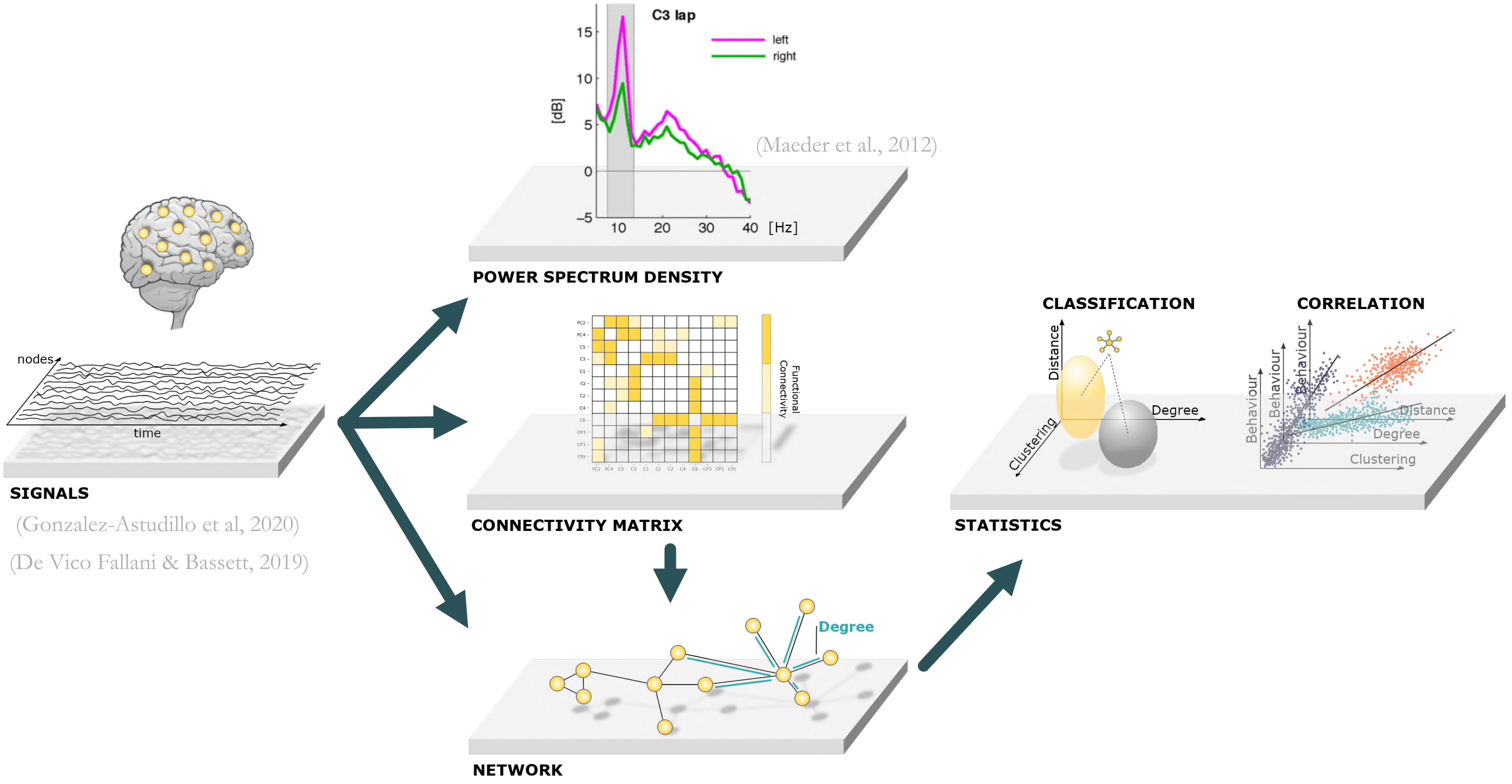
Node strength

For a given ROI x, and a condition j

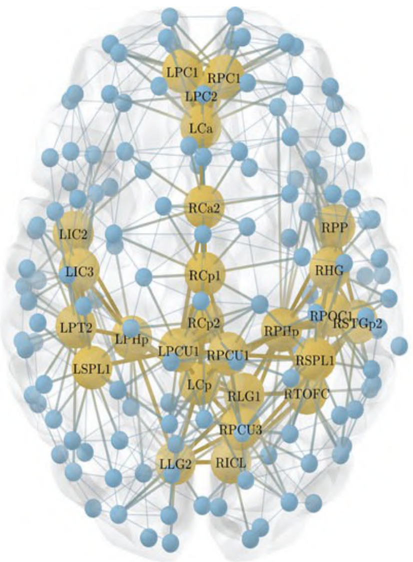
$$N_{x,j} = \sum_{i\in\{ROI\}} IC_{x,j,i}$$

Task-related node strength as marker of **BCI performance & learning rate** (Corsi et al, 2020)

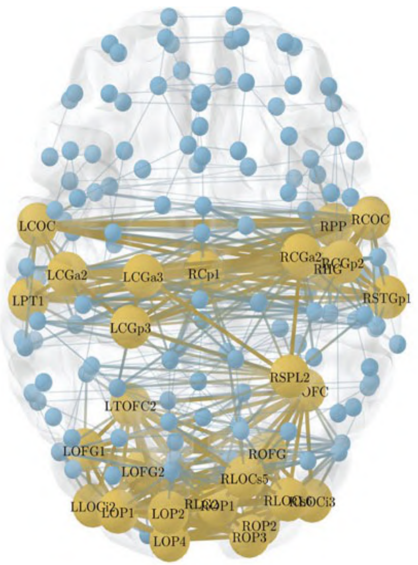
BCI INEFFICIENCY CHALLENGE – NETWORK APPROACH



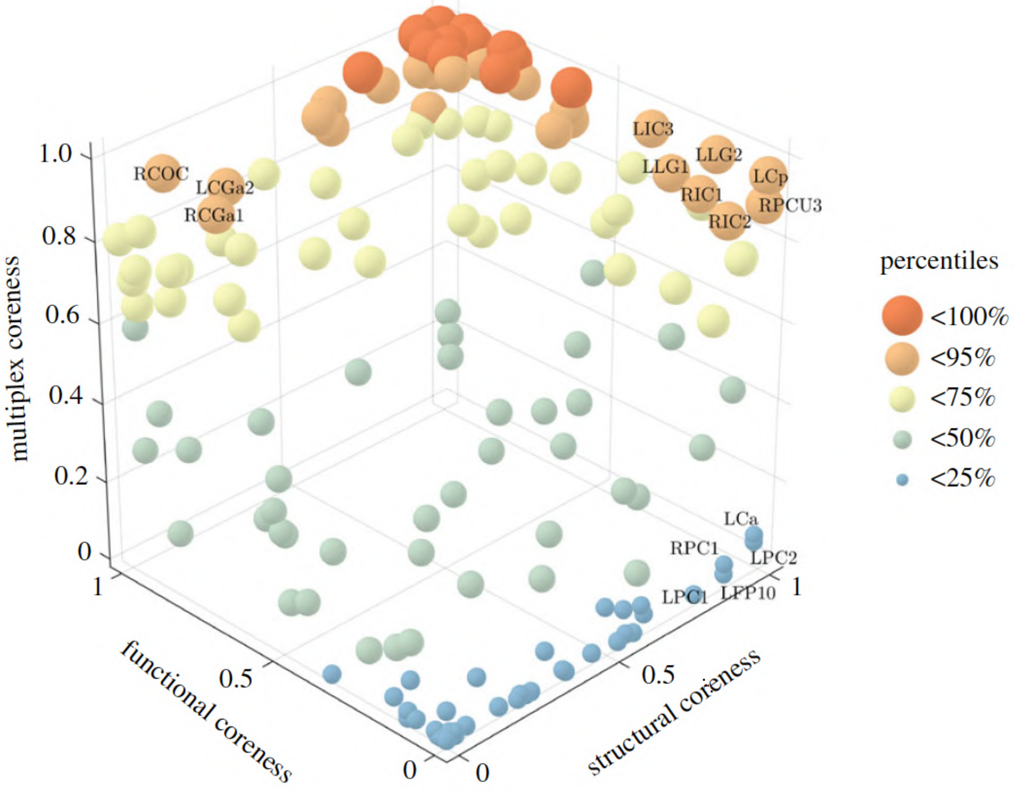
TRACKING BCI TRAINING – MULTILAYER CORE-PERIPHERY



Structural core

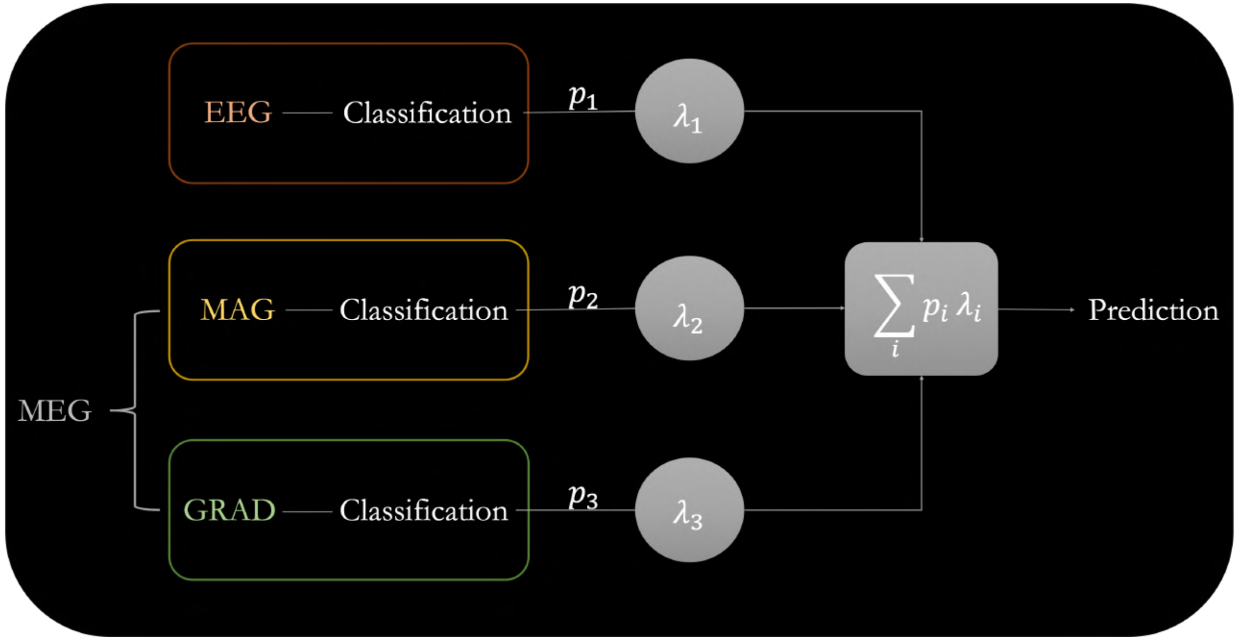


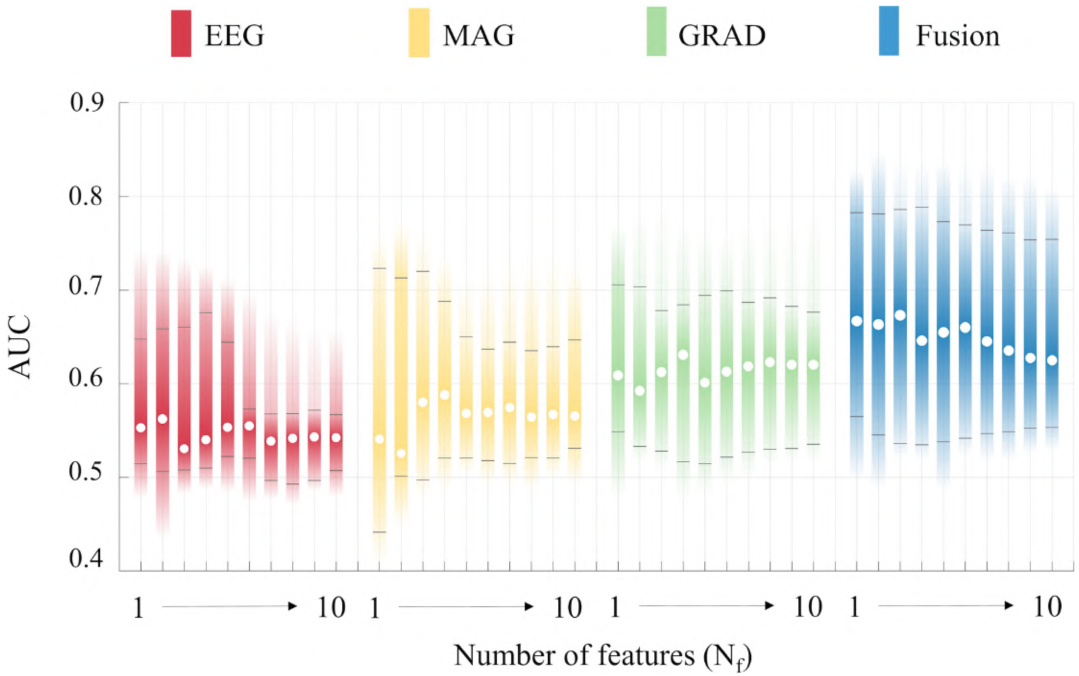
Functional core



Adapted from (Battiston et al, 2018)

TRACKING BCI TRAINING – MULTIMODAL APPROACH

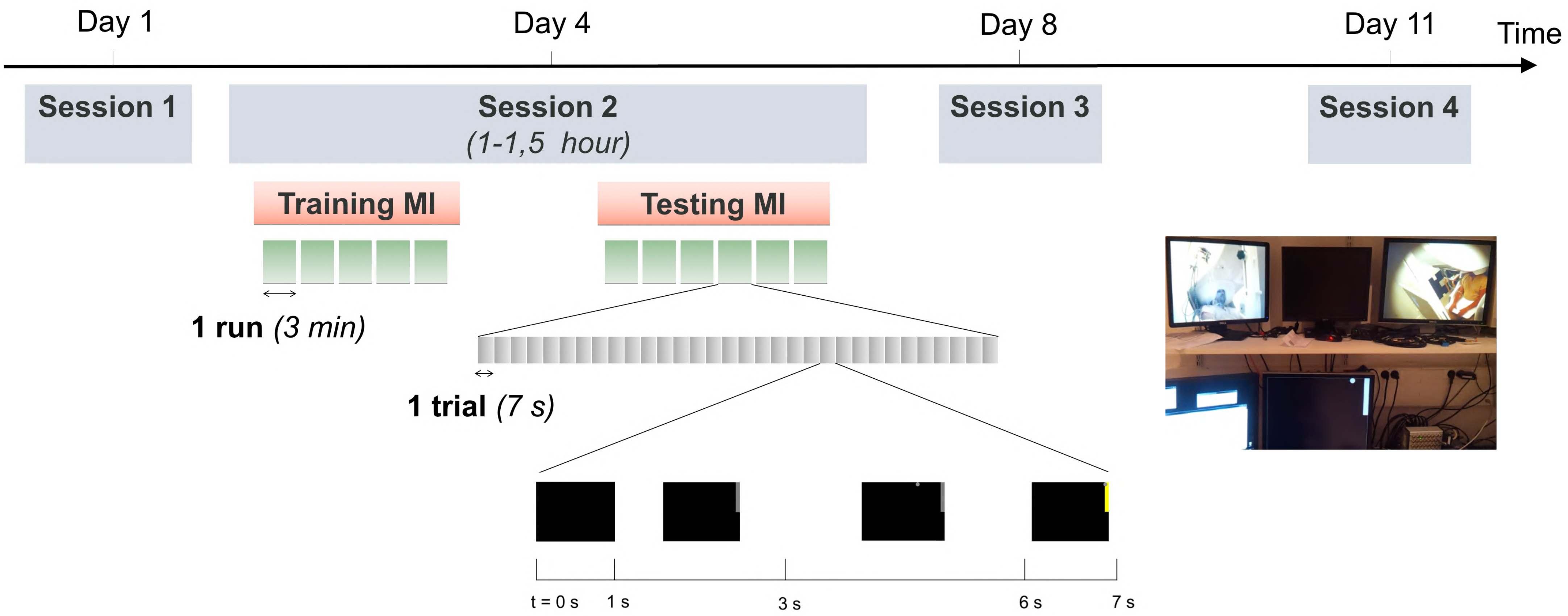




Adapted from (Corsi et al et al, 2018)

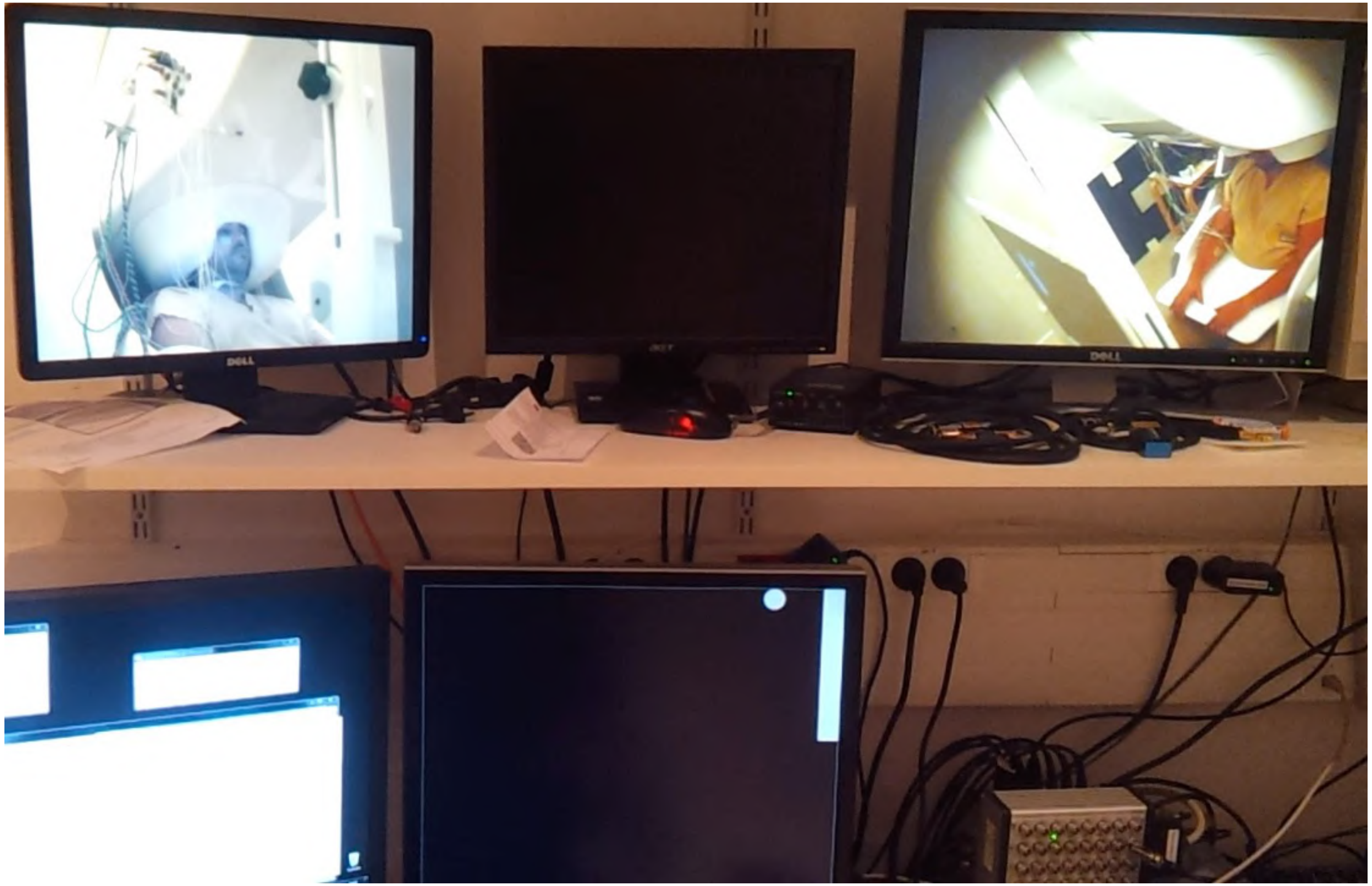
Hypothesis : Integrating M/EEG enables a better description of the core-periphery changes during BCI training

PROTOCOL



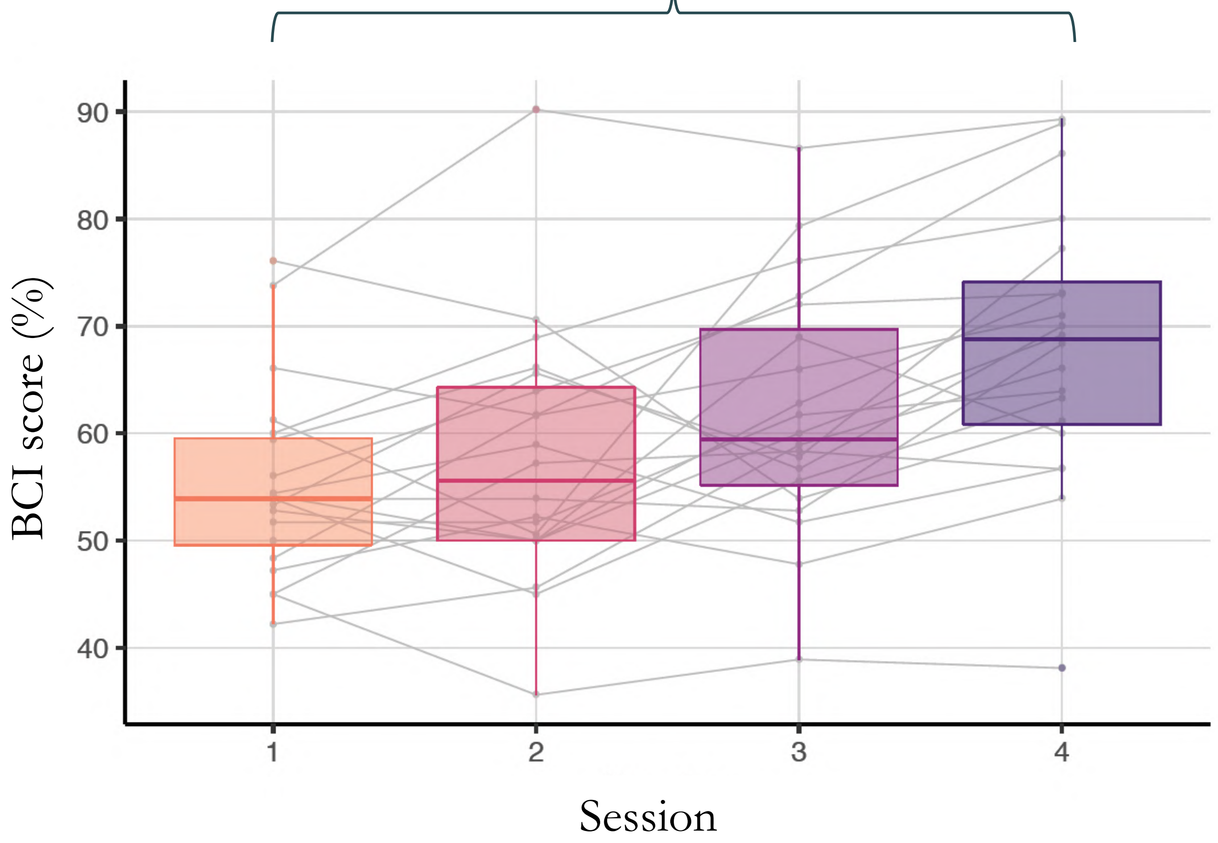
Day 1
Day 4
Day 8
Day 11
Time
Session 1
Session 2
(1-1,5 hour)
Session 3
Session 4
Training MI
Testing MI
1 run (3 min)
1 trial (7 s)
t = 0 s
1 s
3 s
6 s
7 s

PROTOCOL



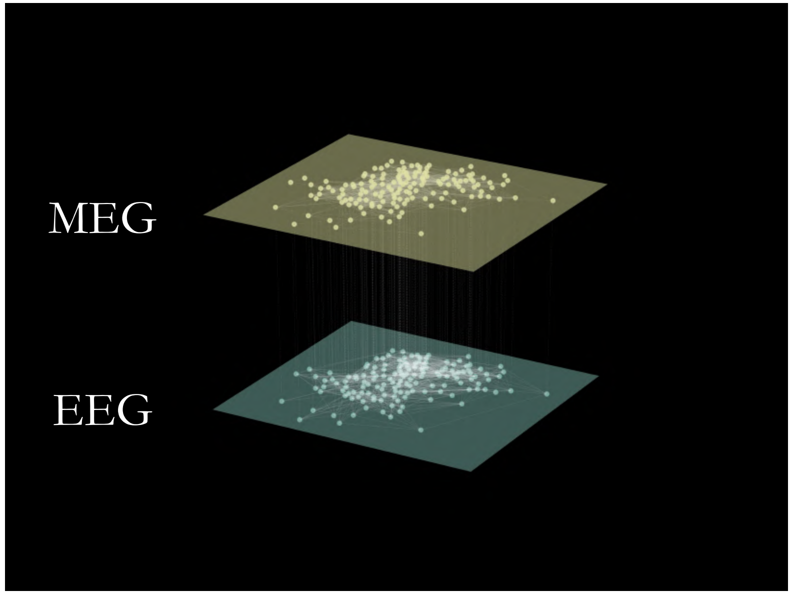
BEHAVIORAL RESULTS – CHANGES OVER SESSIONS

$F(3,57) = 13.9, p = 6.56.10^{-7}$



(Corsi et al, 2021)

MULTIPLEX CORE-PERIPHERY



Multiplex coreness of node 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:

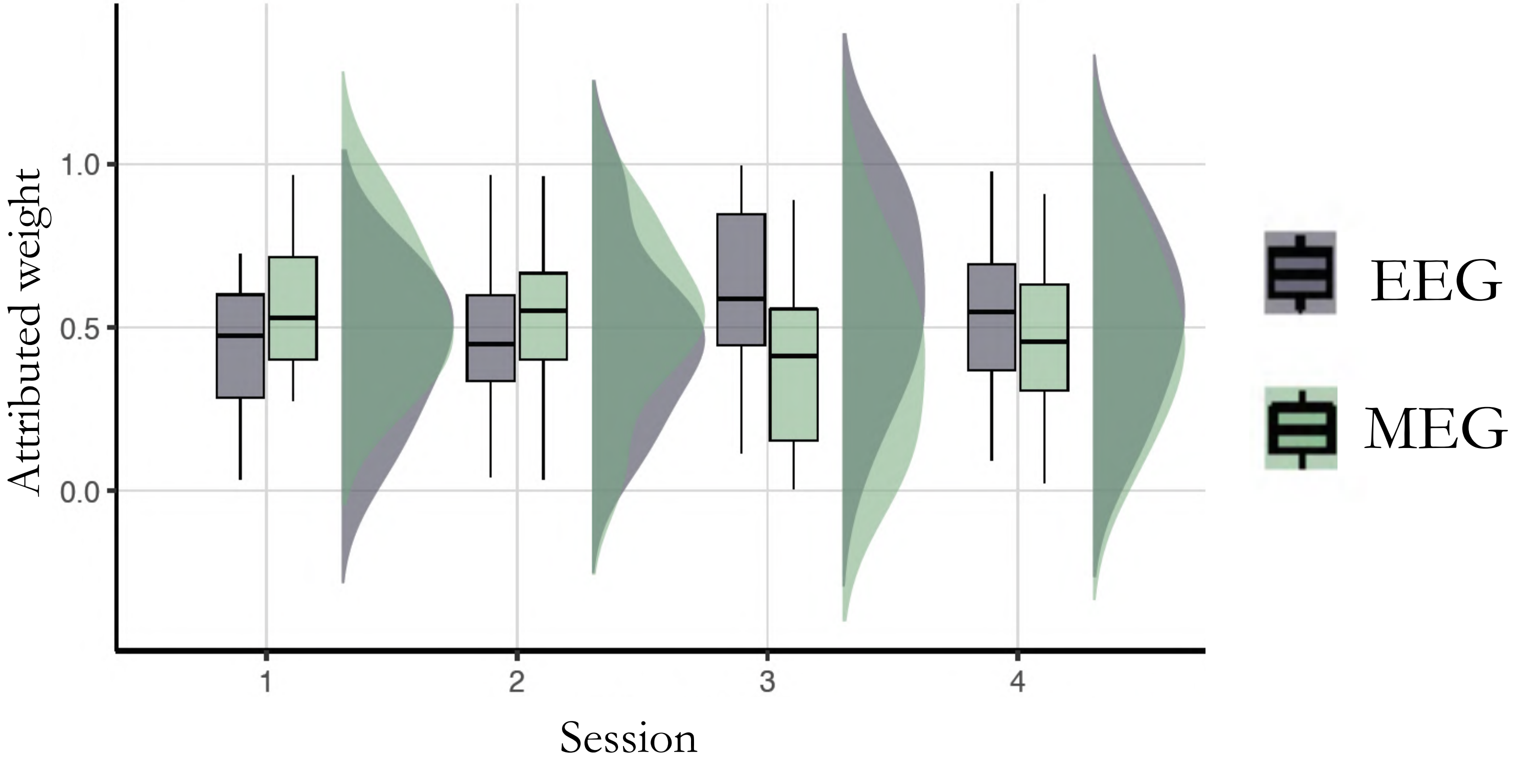
$$(s^{cond})^2 = \sum_{i \in \{1 \ldots N\}} (\langle C_i^{cond}(c)\rangle - \langle C^{cond}(c)\rangle)^2$$

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

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

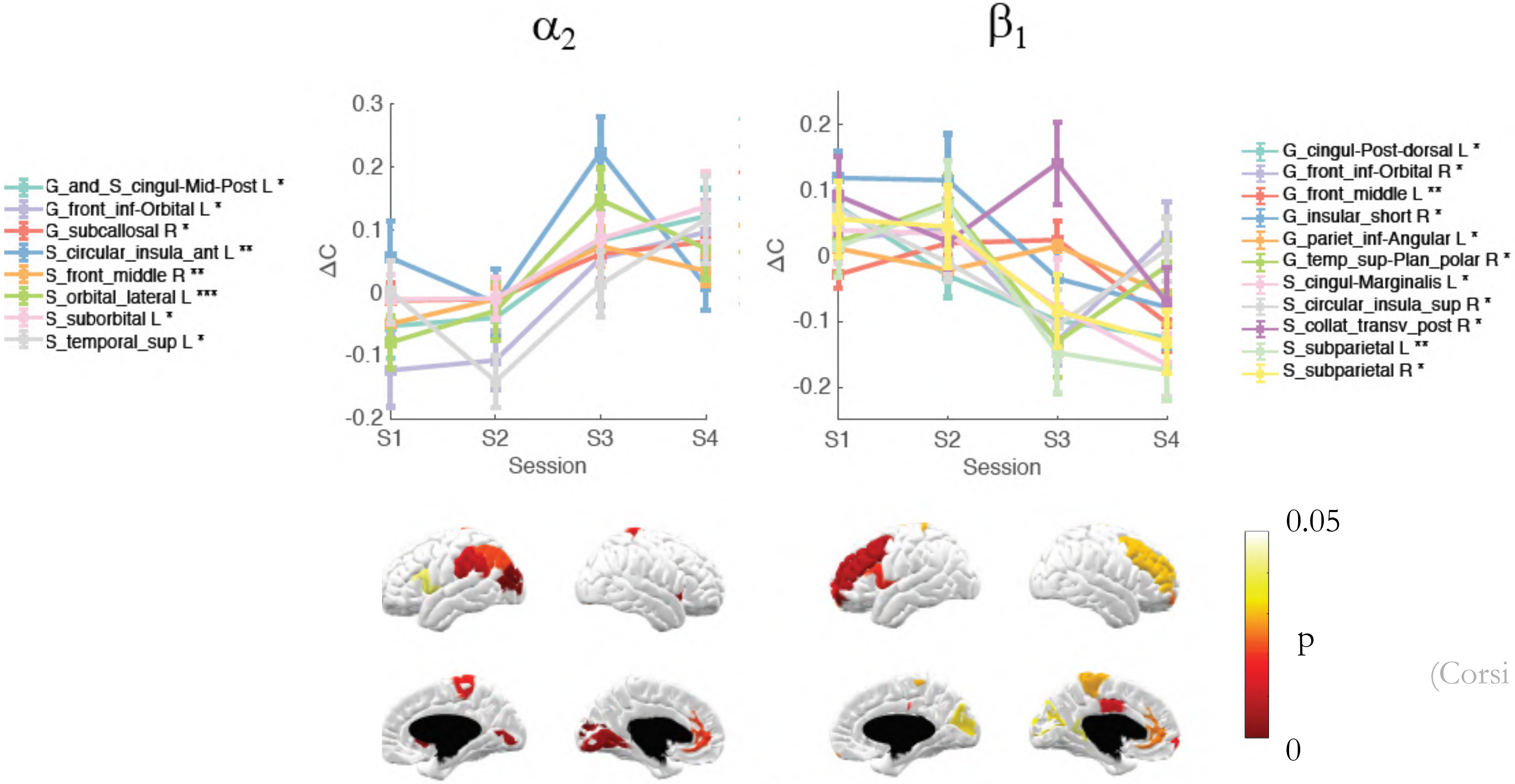
(Corsi et al, 2021)

ATTRIBUTED WEIGHTS – CHANGES OVER SESSIONS



(Corsi et al, 2021)

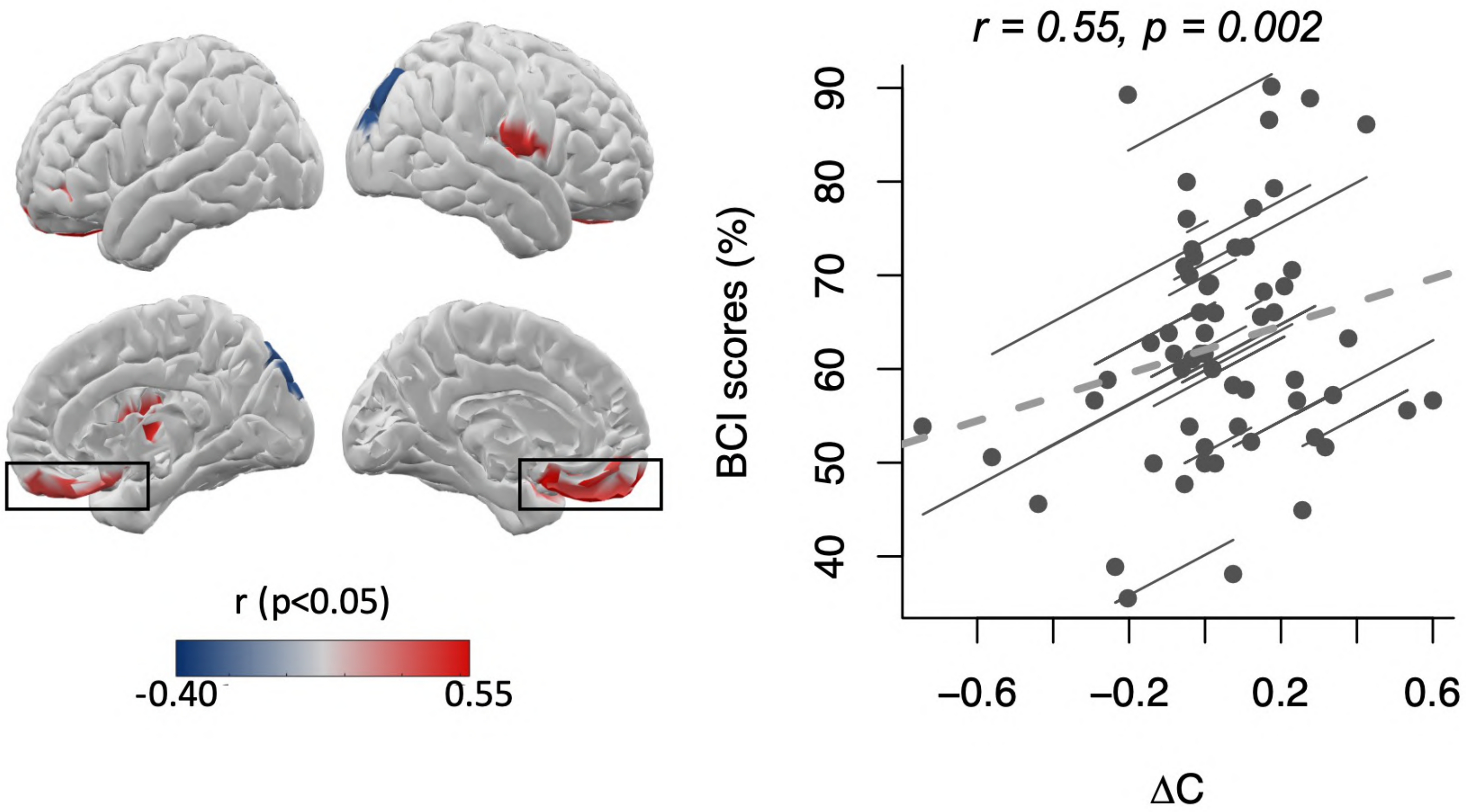
TASK-RELATED CORENESS – CHANGES OVER SESSIONS



(Corsi et al, 2021)

Opposite trends in the integration between alpha and beta bands

MULTIPLEX CORENESS ASSOCIATED WITH BCI PERFORMANCE

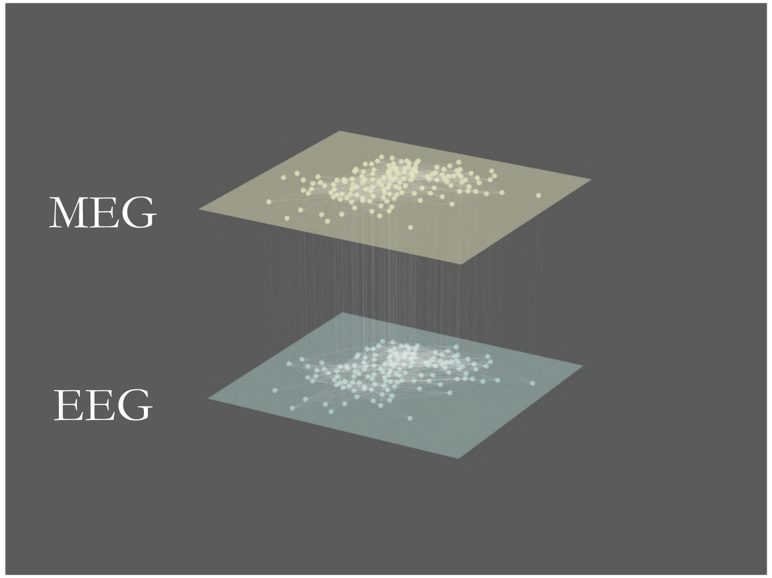


(Corsi et al, 2021)

TAKE HOME MESSAGES

- Dynamic reorganization during BCI training
  - α band: increase in the integration of somatosensory areas
  - β band: decrease of the integration of visual processing and working memory

- Neurophysiological predictors of BCI performance
  - Task-related multiplex coreness
  - Correlation with future BCI scores – α band
    - Positively in somatosensory and decision-making areas
    - Negatively in associated areas



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Jennifer Stiso,

Arnold Campbell,

Danielle S. Bassett (PI)

Thank you for your attention !

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