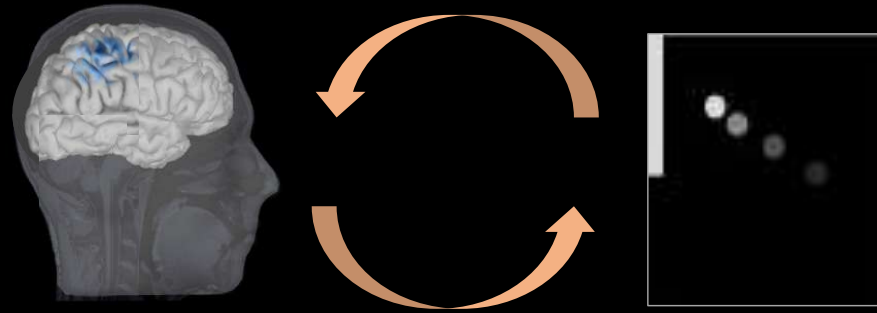


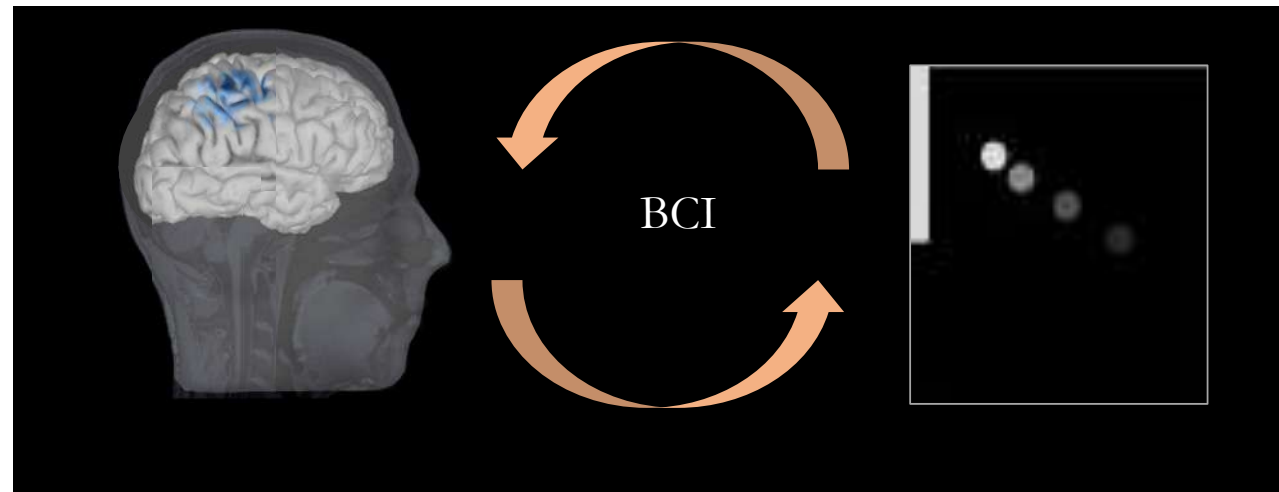
Exploiting brain critical dynamics to inform  
Brain-Computer Interfaces performance



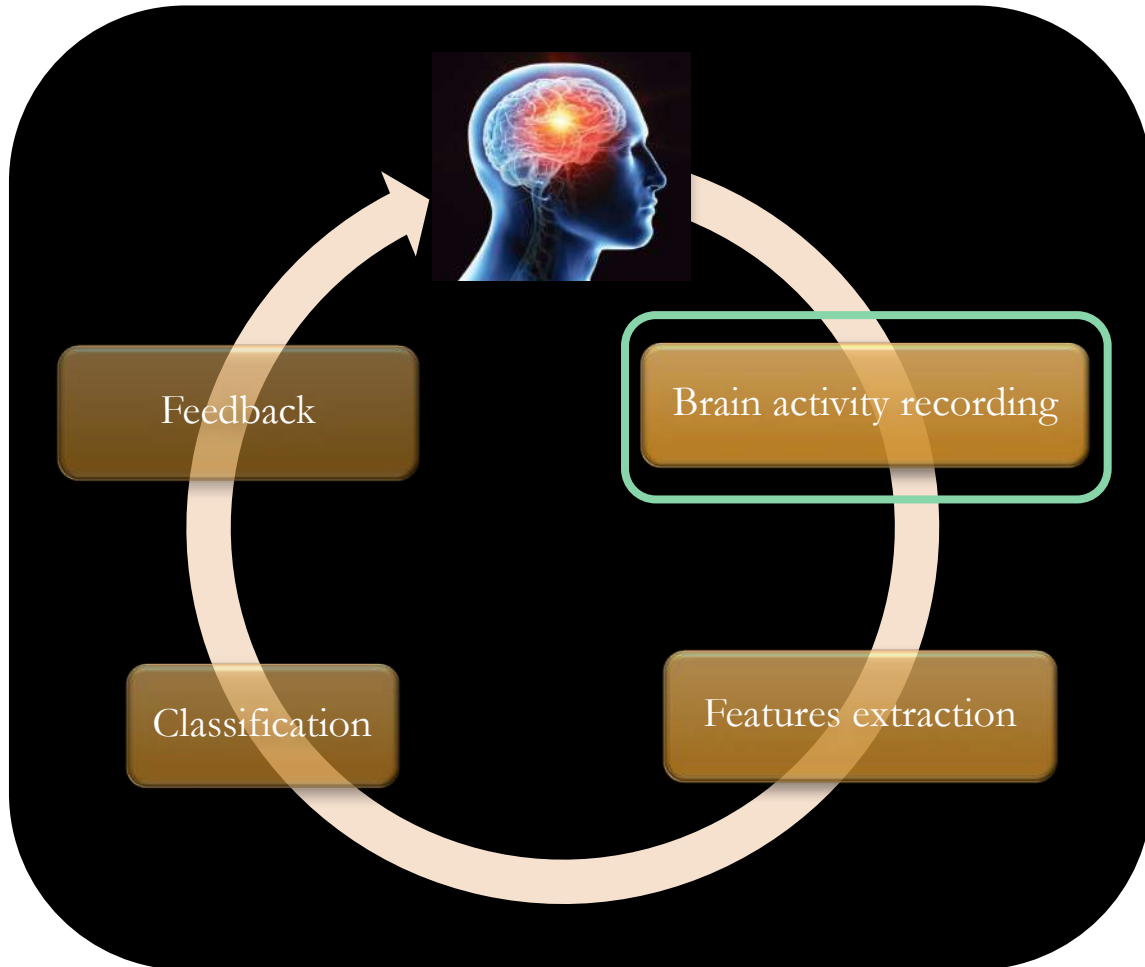
Marie-Constance Corsi\*,  
Paris Brain Institute, France

Pierpaolo Sorrentino\*,  
Institut de Neurosciences des Systèmes, France

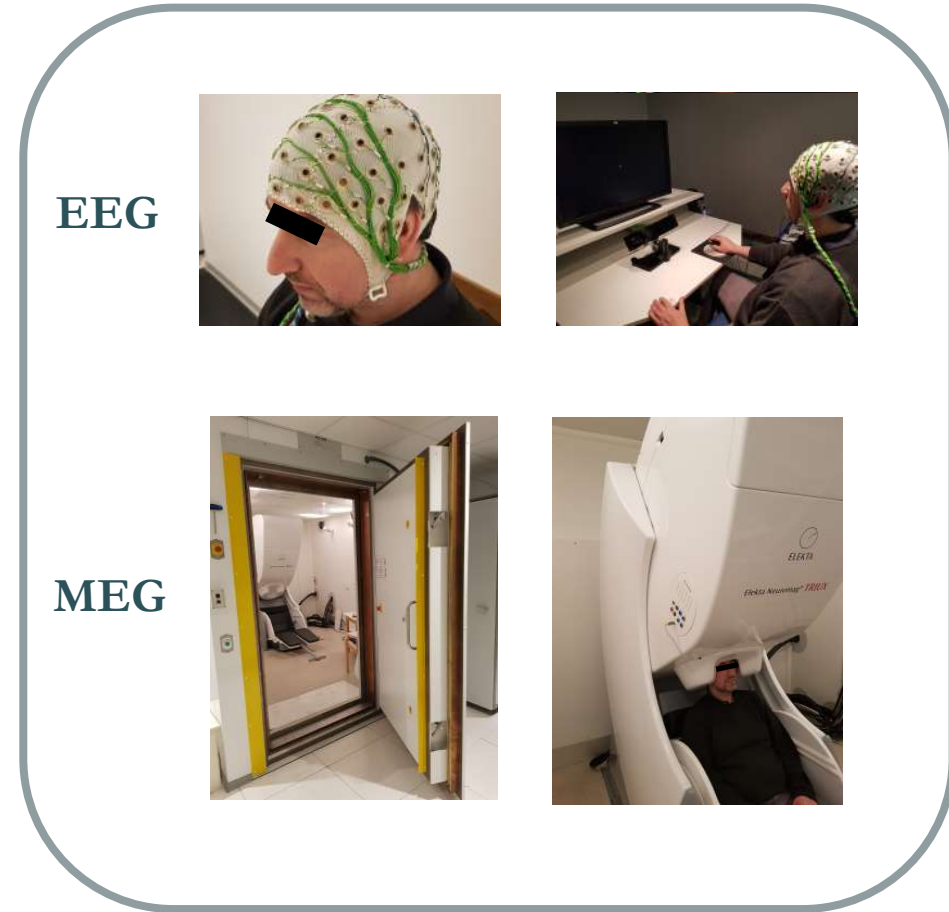
# What is a Brain-Computer Interface (BCI)?



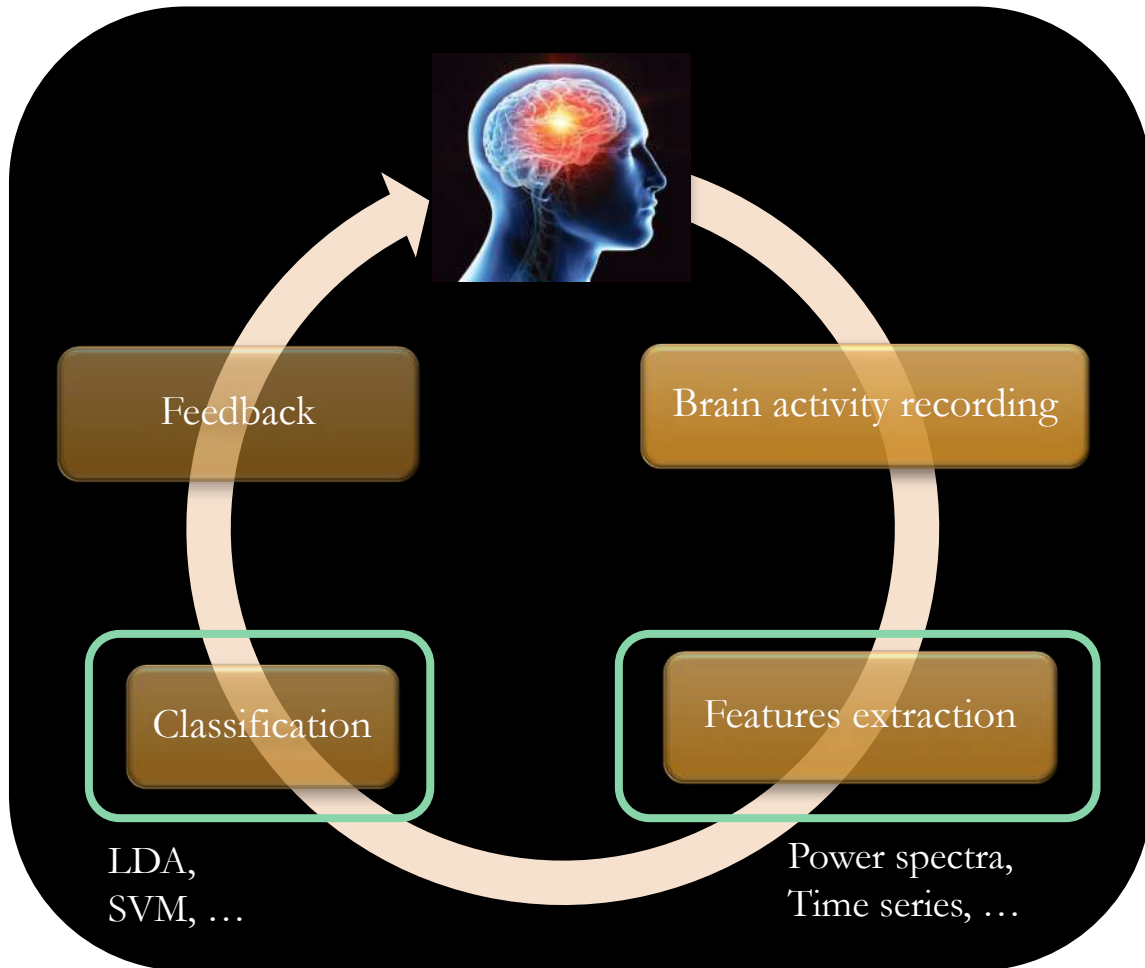
Device that translates brain activity into commands...but how?



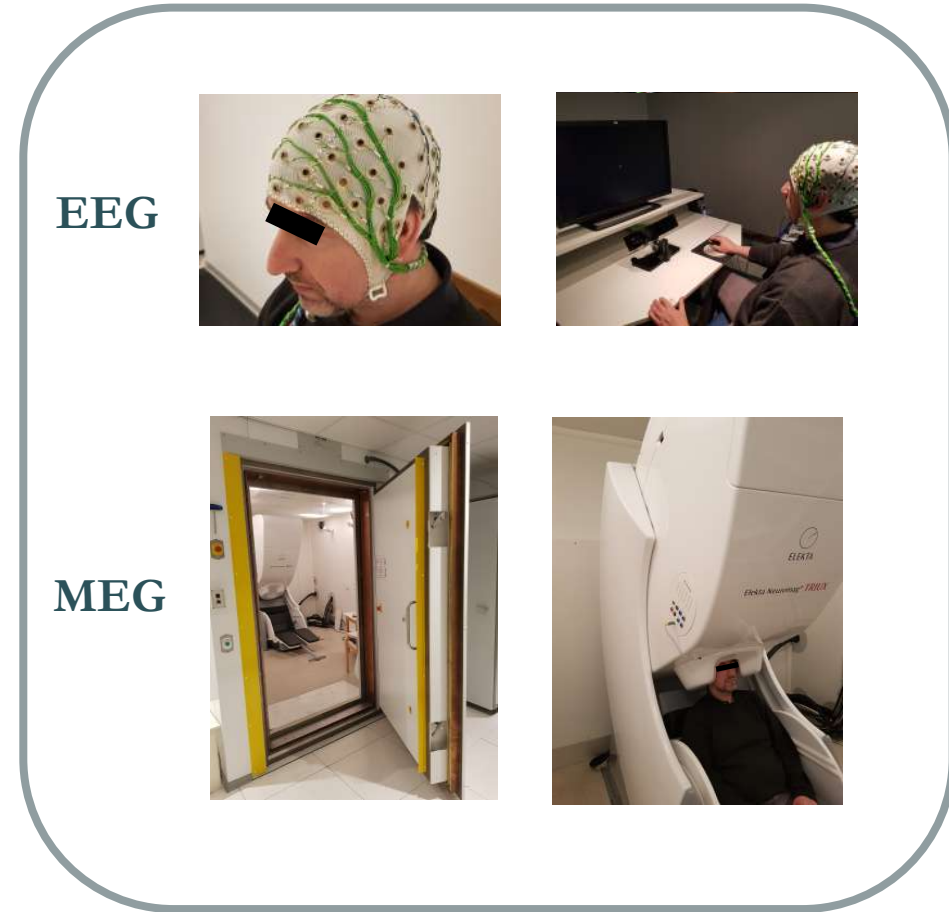
BCI framework



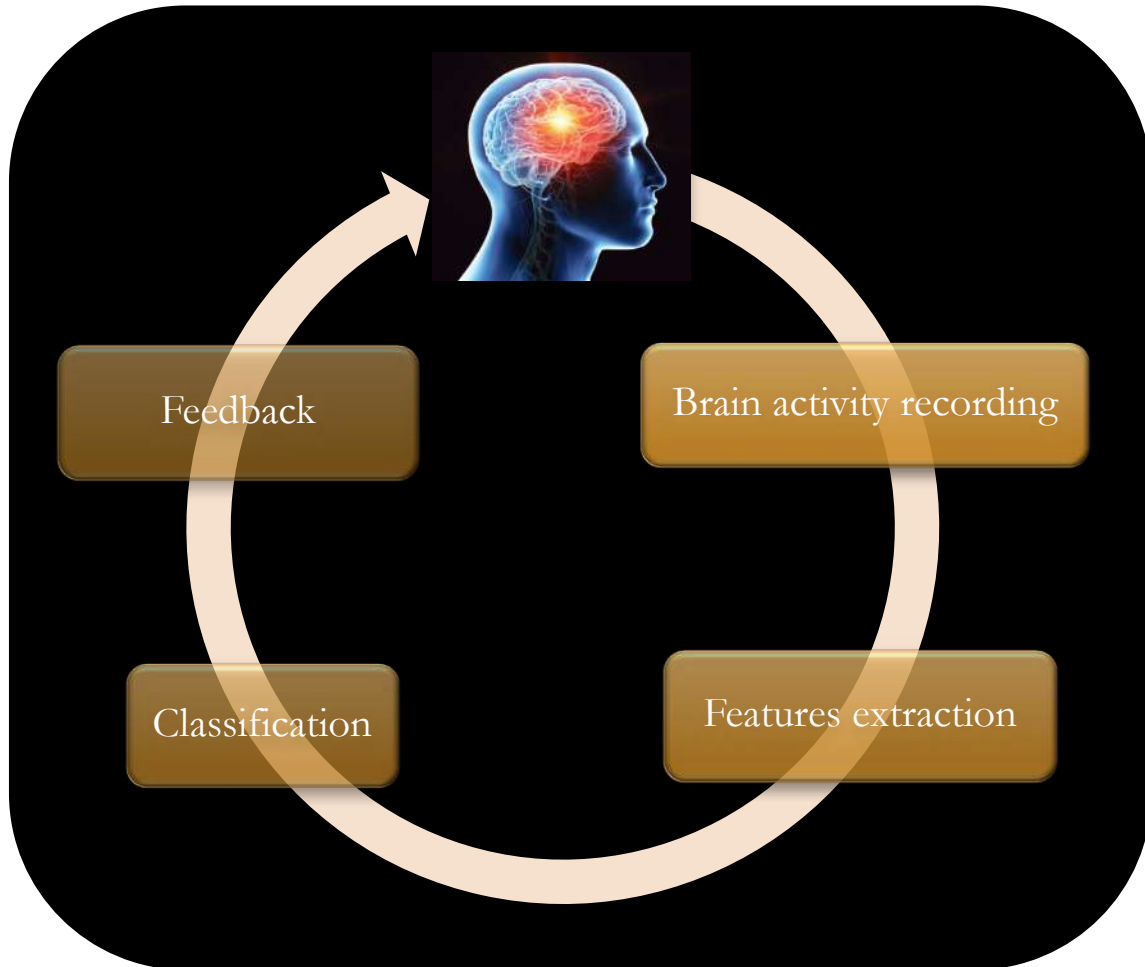
M/EEG facilities at Paris Brain Institute



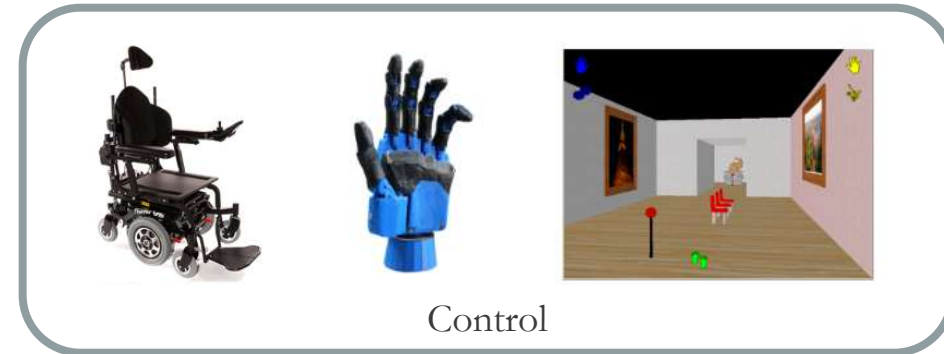
BCI framework



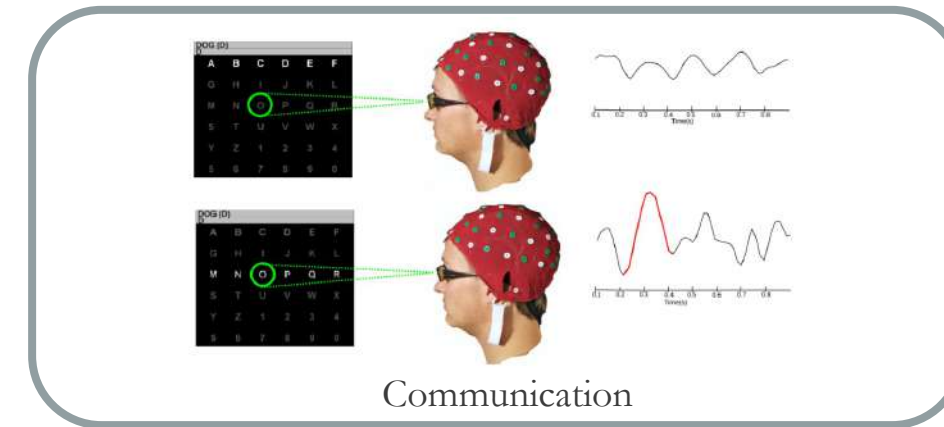
M/EEG facilities at Paris Brain Institute



BCI framework

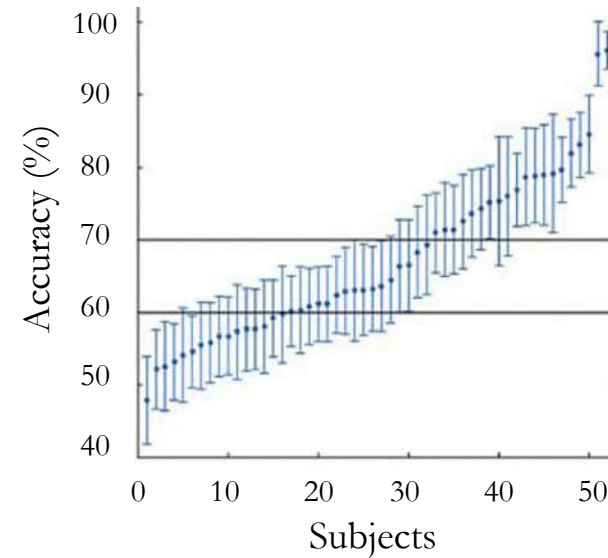
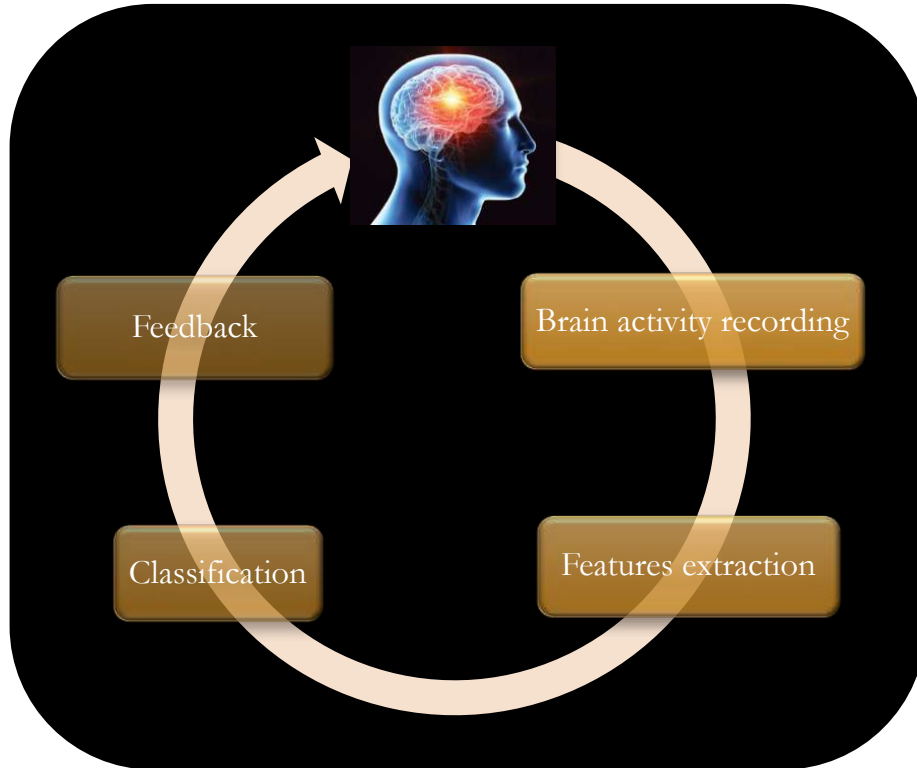


Control



Communication

Adapted from (Lotte et al, 2015)



Adapted from (Ahn & Jun, 2015)

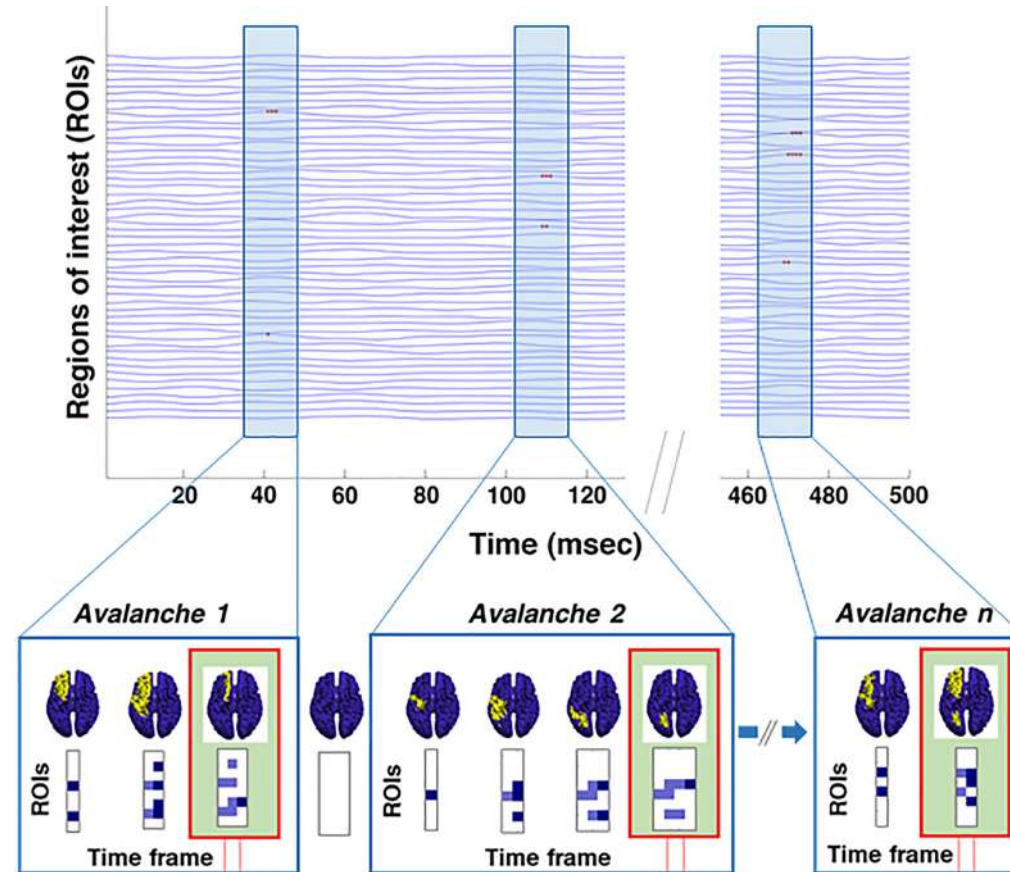
## Problem:

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

⇒ Rely on local measurements of the brain activity

# Capturing fast, non-linear brain dynamics

Neuronal avalanches: bursts of enhanced activity observed across neuroimaging modalities

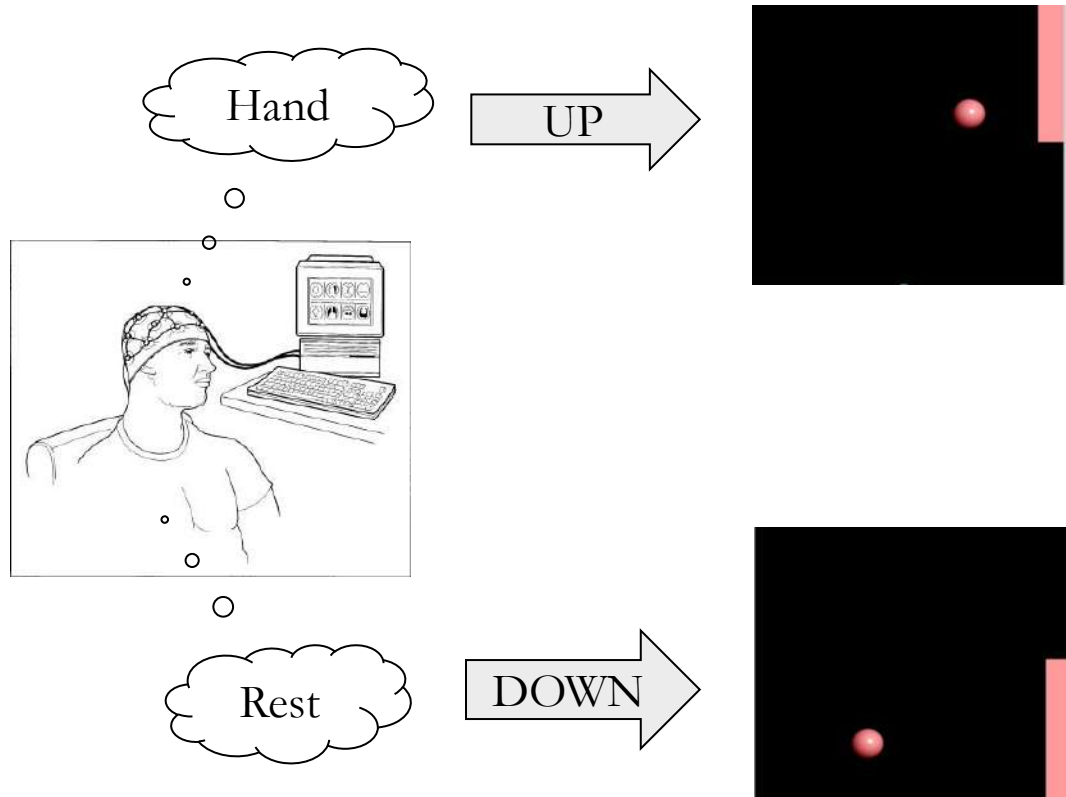


Adapted from [Polverino et al, biorxiv, 2022]

## Hypothesis:

The neuronal avalanches could spread differently according to the task & provide original markers of BCI performance.





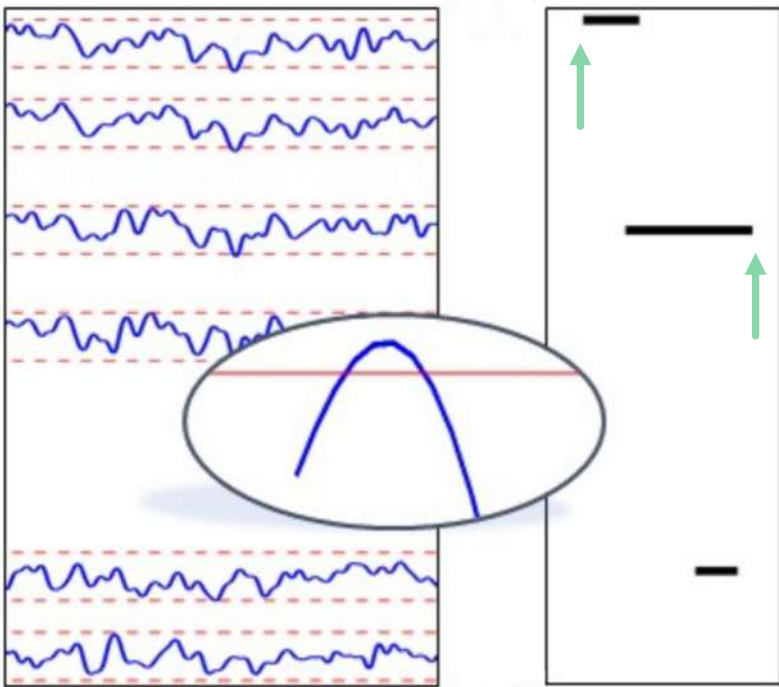
For a complete description of the protocol and the dataset, please refer to [Corsi et al, NeuroImage, 2020]

## Objective:

Tracking the dynamical features related to motor imagery as compared to rest

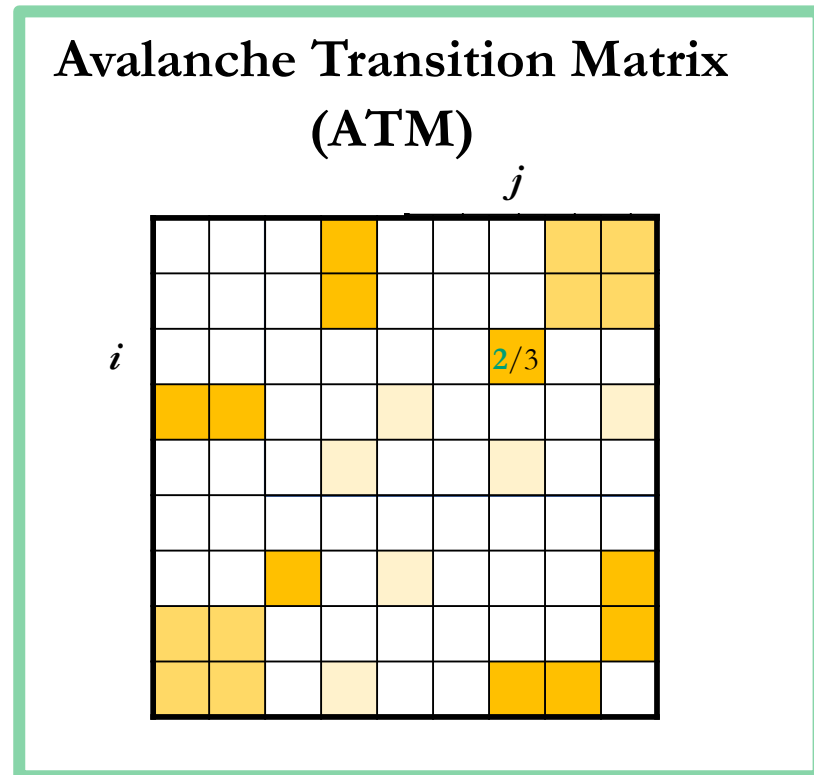
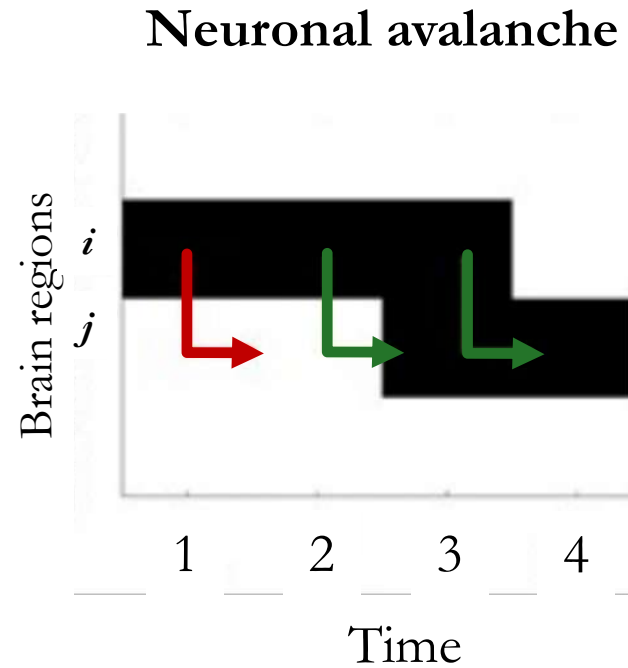
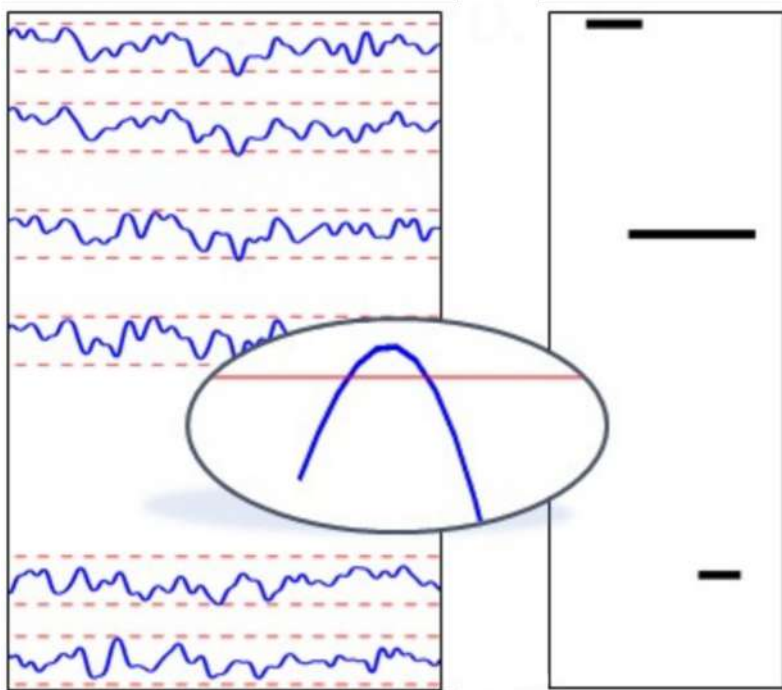


# Differences in transition probabilities discriminate mental states



Adapted from [Sorrentino et al, eLife, 2021]

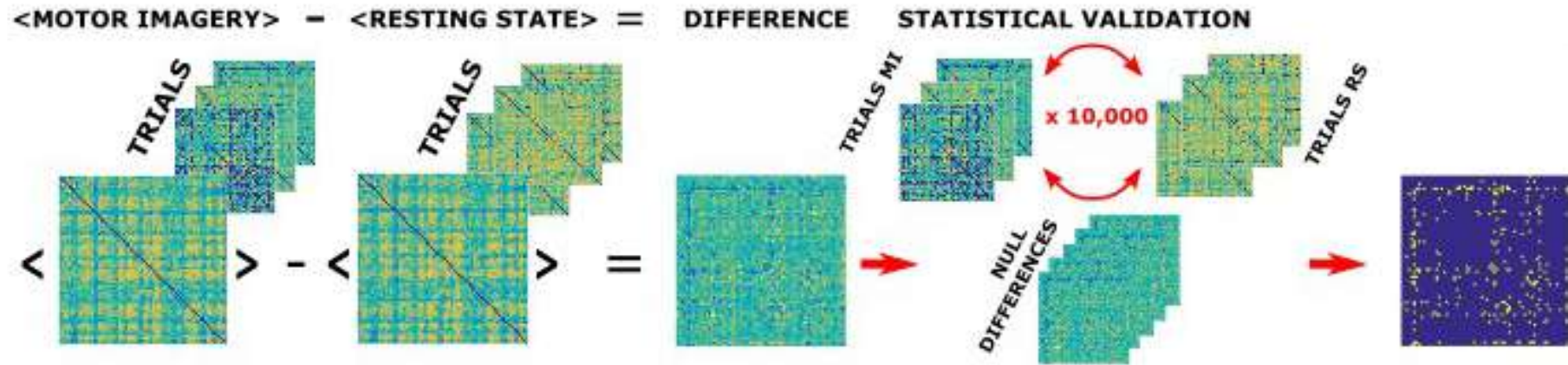




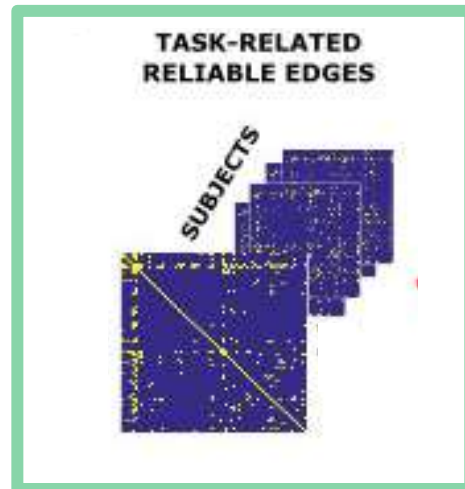
Adapted from [Sorrentino et al, eLife, 2021]



# Differences in transition probabilities discriminate mental states

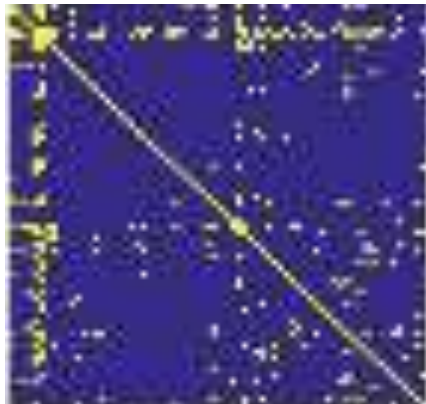


Subject-level

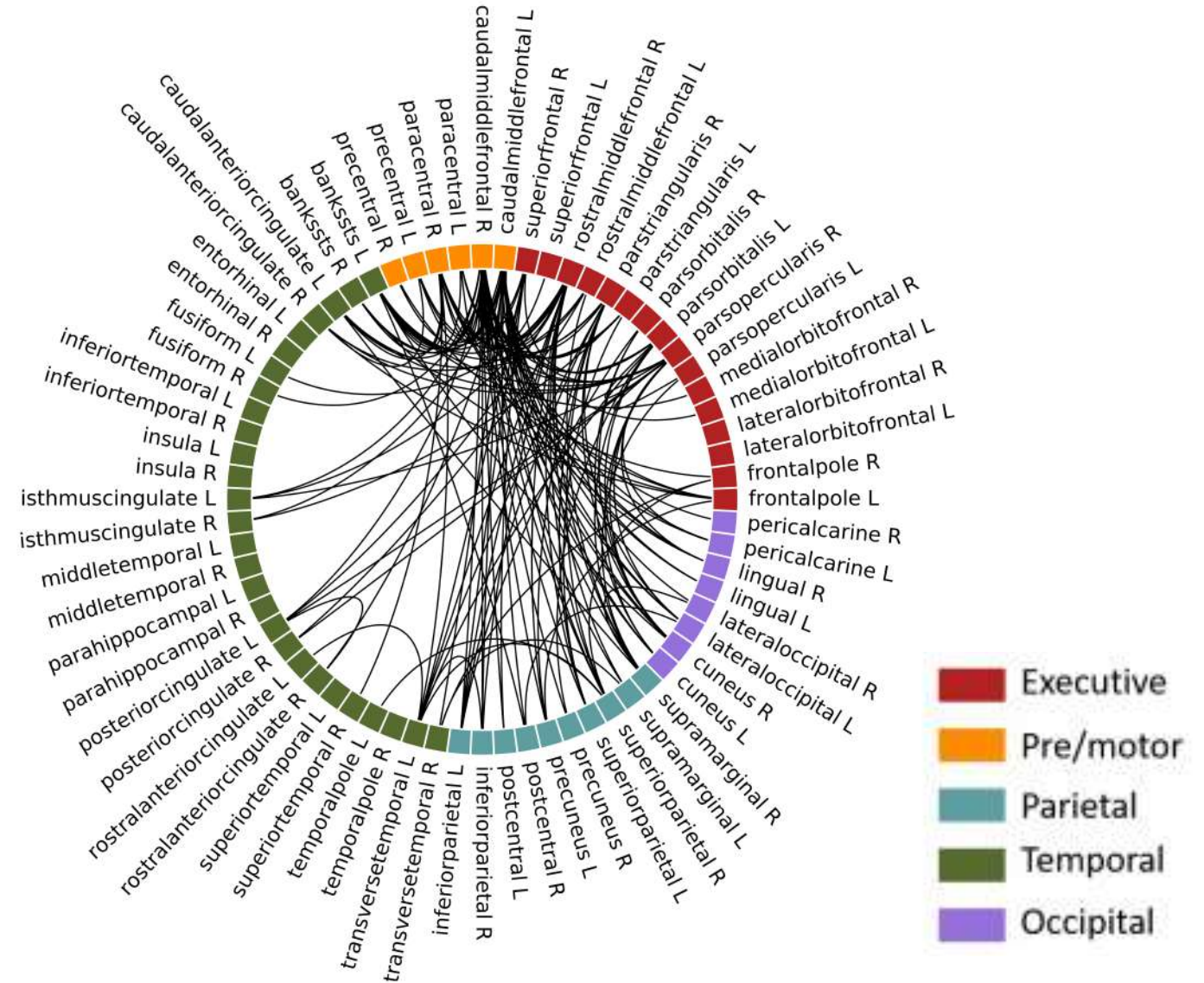


Group-level

# Differences in transition probabilities discriminate mental states



||

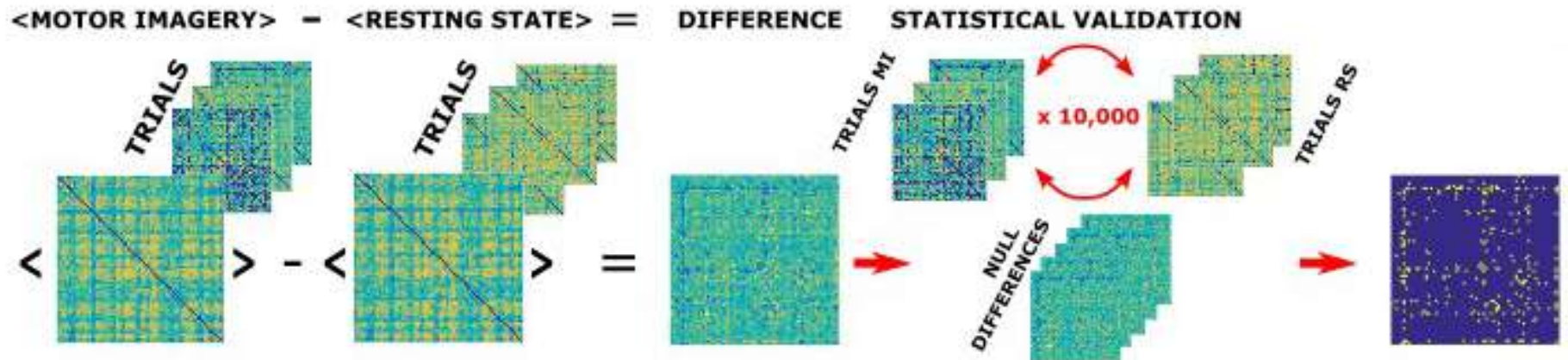


Task-related differences are in edges hinging on pre/motor areas (in most subjects)

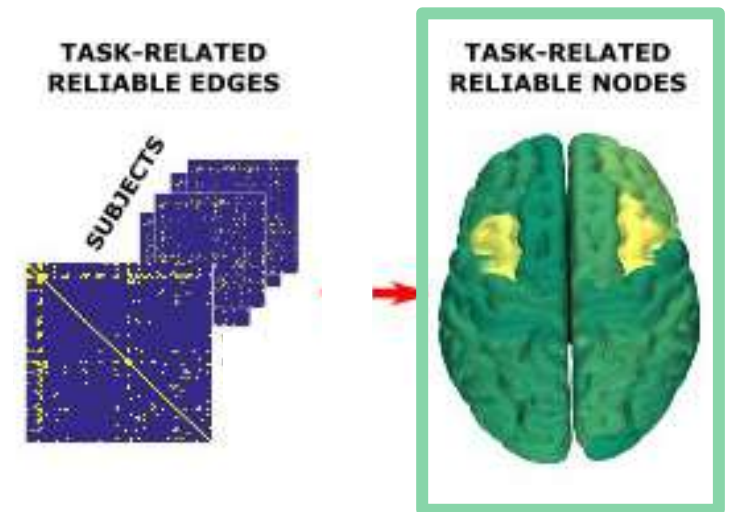


# Differences in transition probabilities discriminate mental states

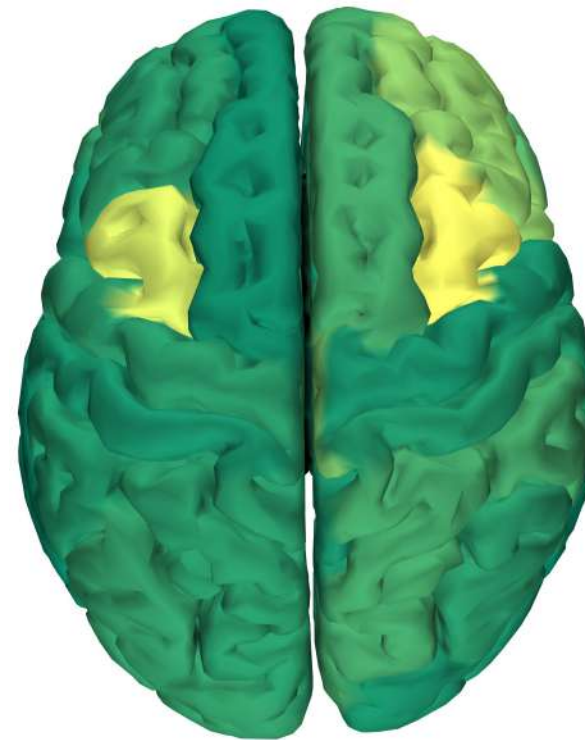
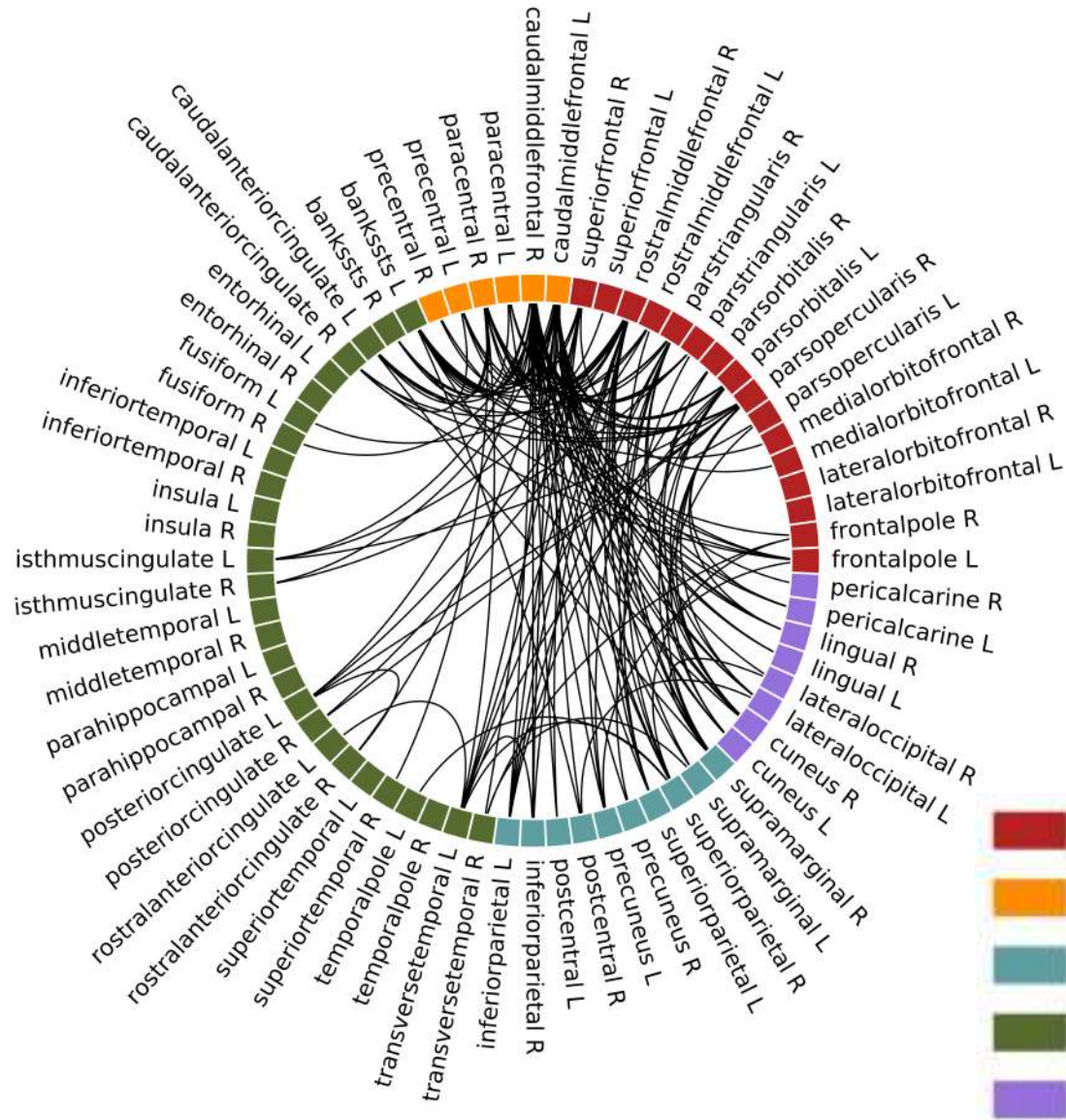
Subject-level



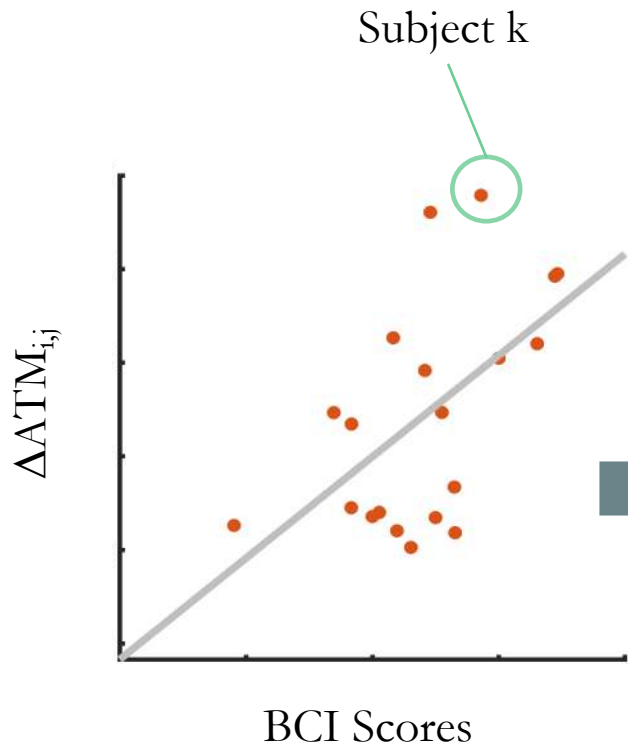
Group-level



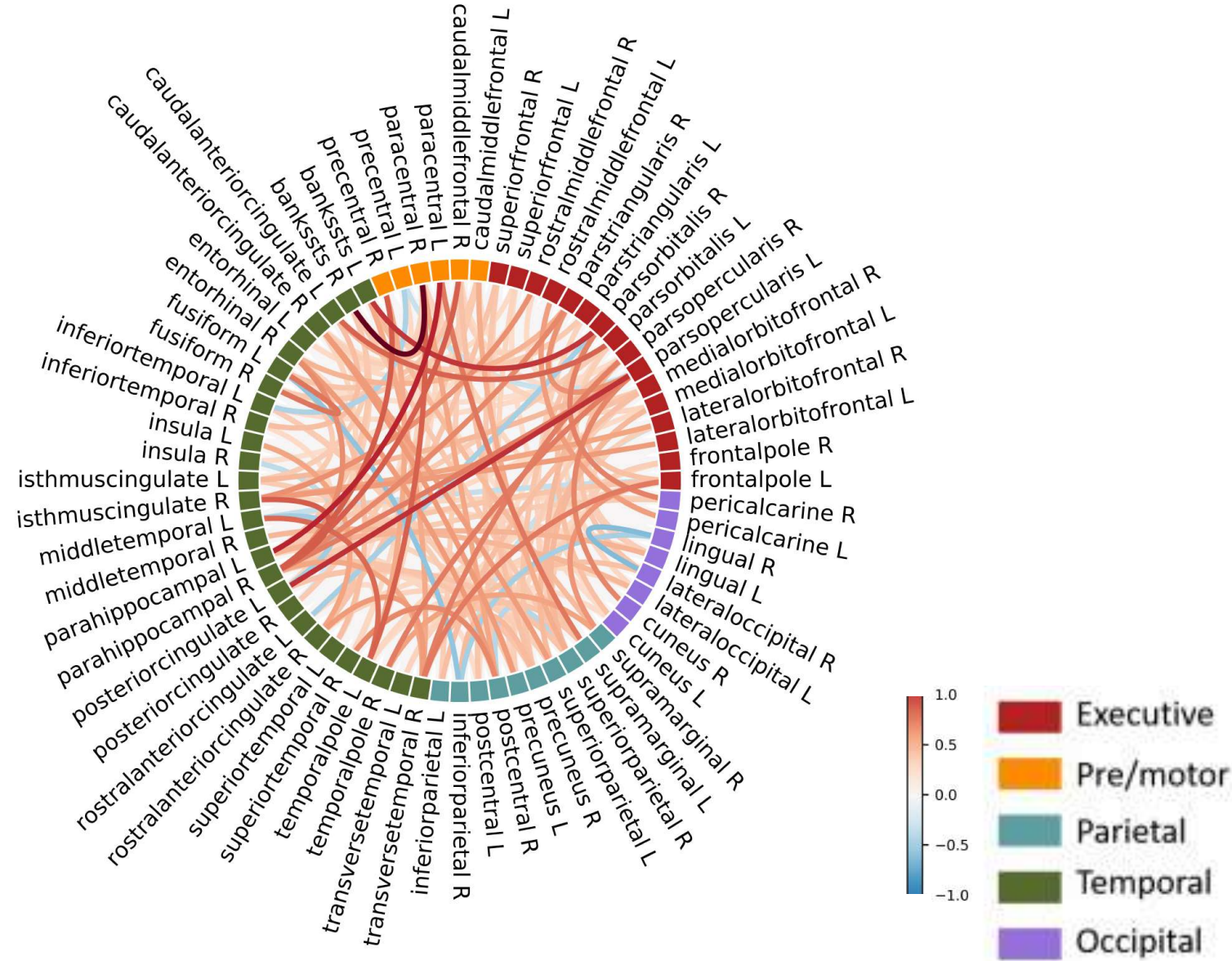
# Differences in transition probabilities discriminate mental states



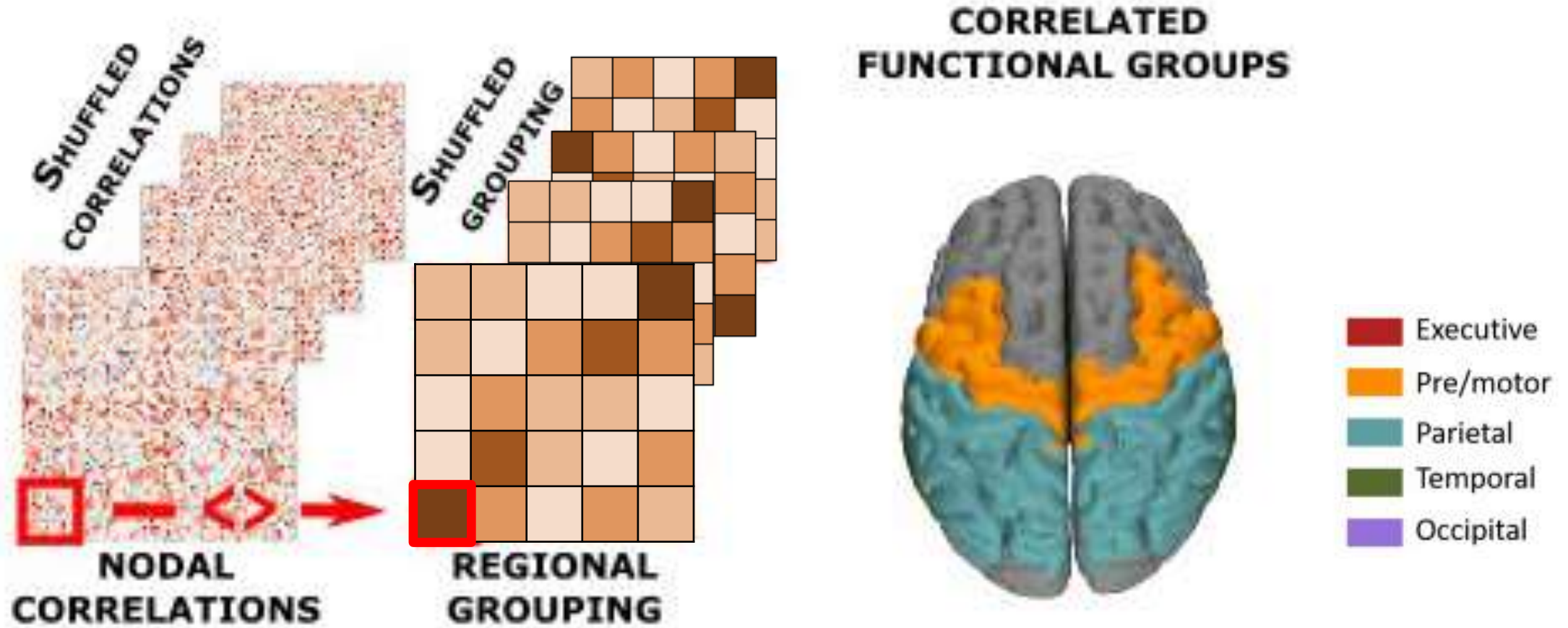




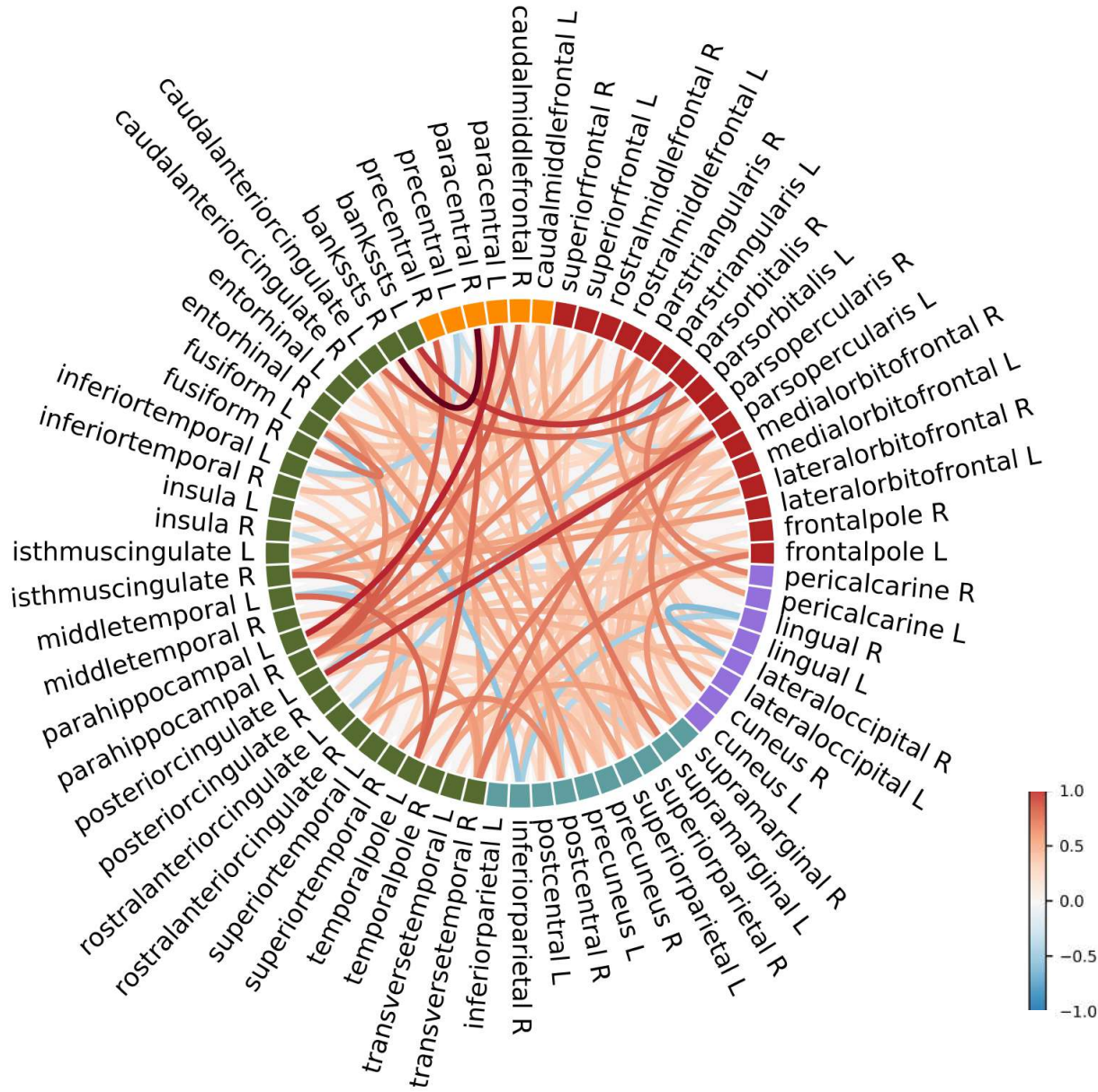
Edge-wise correlation







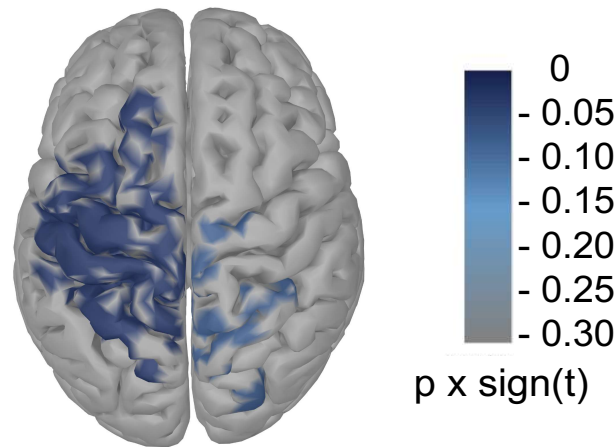
# Differences in transition probabilities relate to BCI scores



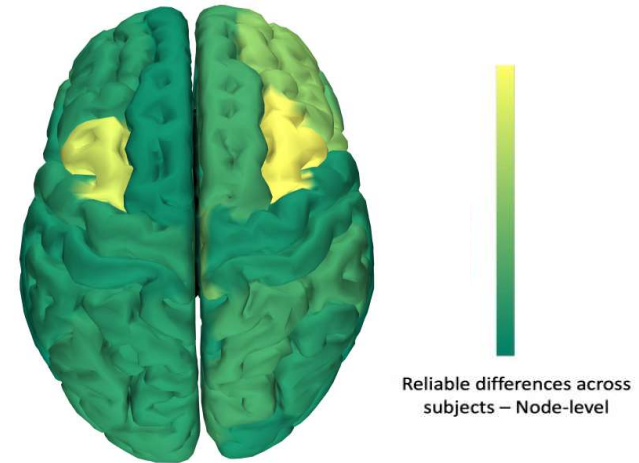
- Executive
- Pre/motor
- Parietal
- Temporal
- Occipital

## Reliable functional information of task performance retrieval

- Meaningful information communication among regions on the large-scale & aperiodic and scale-free perturbation
- Building innovative BCI protocols



Power spectra  
significant at **group** level

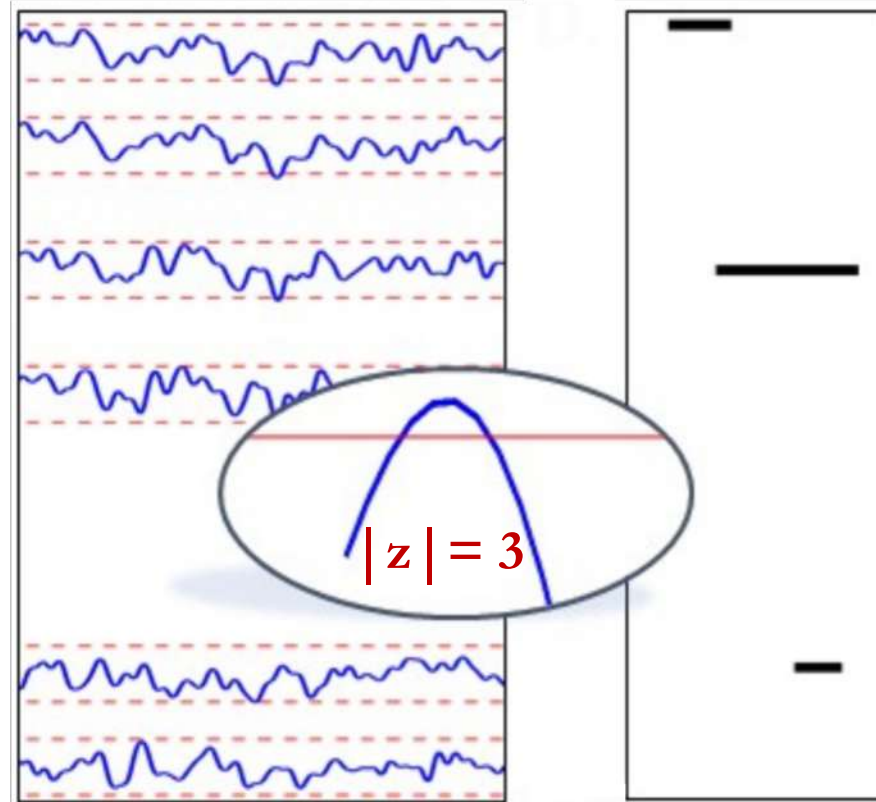


Neuronal avalanches  
significant at **individual** level

⇒ Tracking changes in perturbation spreading while performing different tasks via the avalanches transition matrices

## Reliable functional information of task performance retrieval

- Meaningful information communication among regions on the large-scale & aperiodic and scale-free perturbation
- Building innovative BCI protocols



⇒ Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information

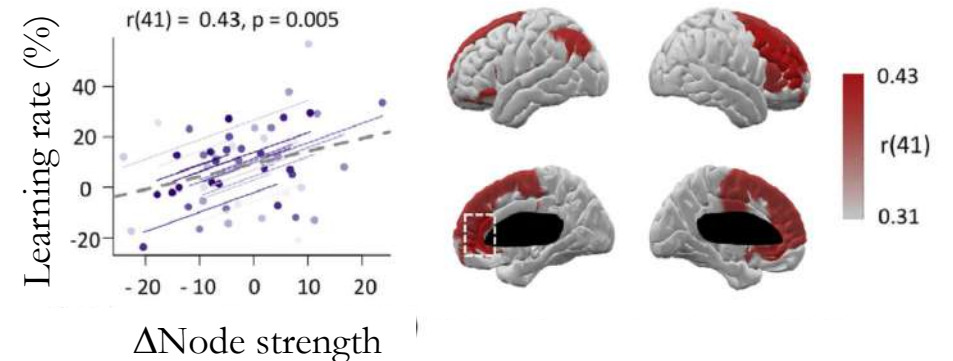


## Reliable functional information of task performance retrieval

- Meaningful information communication among regions on the large-scale & aperiodic and scale-free perturbation
- Building innovative BCI protocols
  - Tracking changes in perturbation spreading while performing different tasks
  - Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information

## Markers of BCI performance

- Current predictors of BCI
  - Local measurements – power spectra (Ahn et al, 2015) → replicability issues
  - Time-averaged brain interactions (Sugata et al, 2014) & Brain networks metrics [Gonzalez-Astudillo et al, JNE, 2020] → online implementation?
    - node strength & learning process [Corsi et al, NeuroImage 2020] ]
    - core-periphery properties & multimodal integration [Corsi et al, JNE 2021]
- Spreading of neuronal avalanches
  - Patterns behaviorally meaningful (Chialvo et al, 2010)
  - Computational fast marker



## Paris Brain Institute

Mario Chavez,  
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Laurent Hugueville,  
Christophe Gitton  
Sophie Dupont,  
Juliana Gonzalez-Astudillo,  
Fabrizio De Vico Fallani (PI)



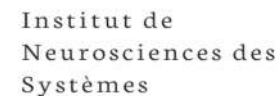
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## Interested in this study?

Scan the QR code to get access to the associated preprint!



[mccorsi/NeuronalAvalanches4BCI](https://github.com/mccorsi/NeuronalAvalanches4BCI)

## Thank you for your attention!



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