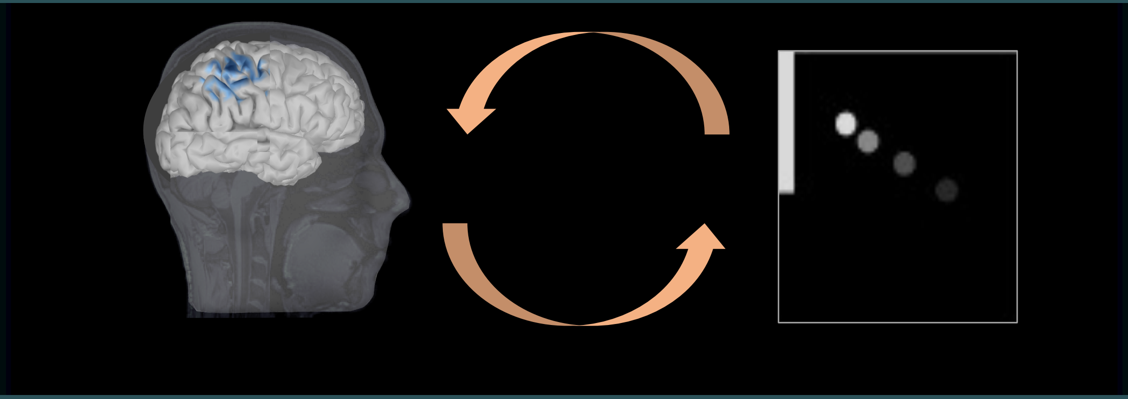
NeuroFrance 2023

Using critical dynamics to capture processes underlying Brain-Computer Interface performance



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Inria-Paris Brain Institute, France

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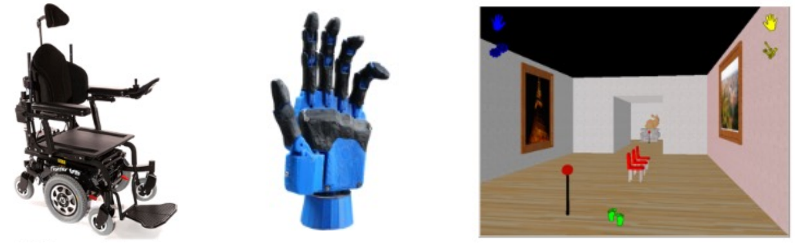
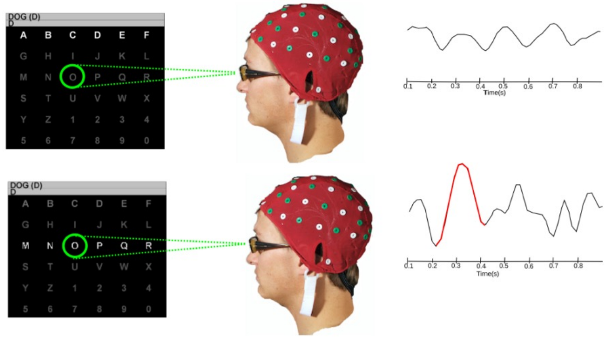
What is a Brain-Computer Interface (BCI)?



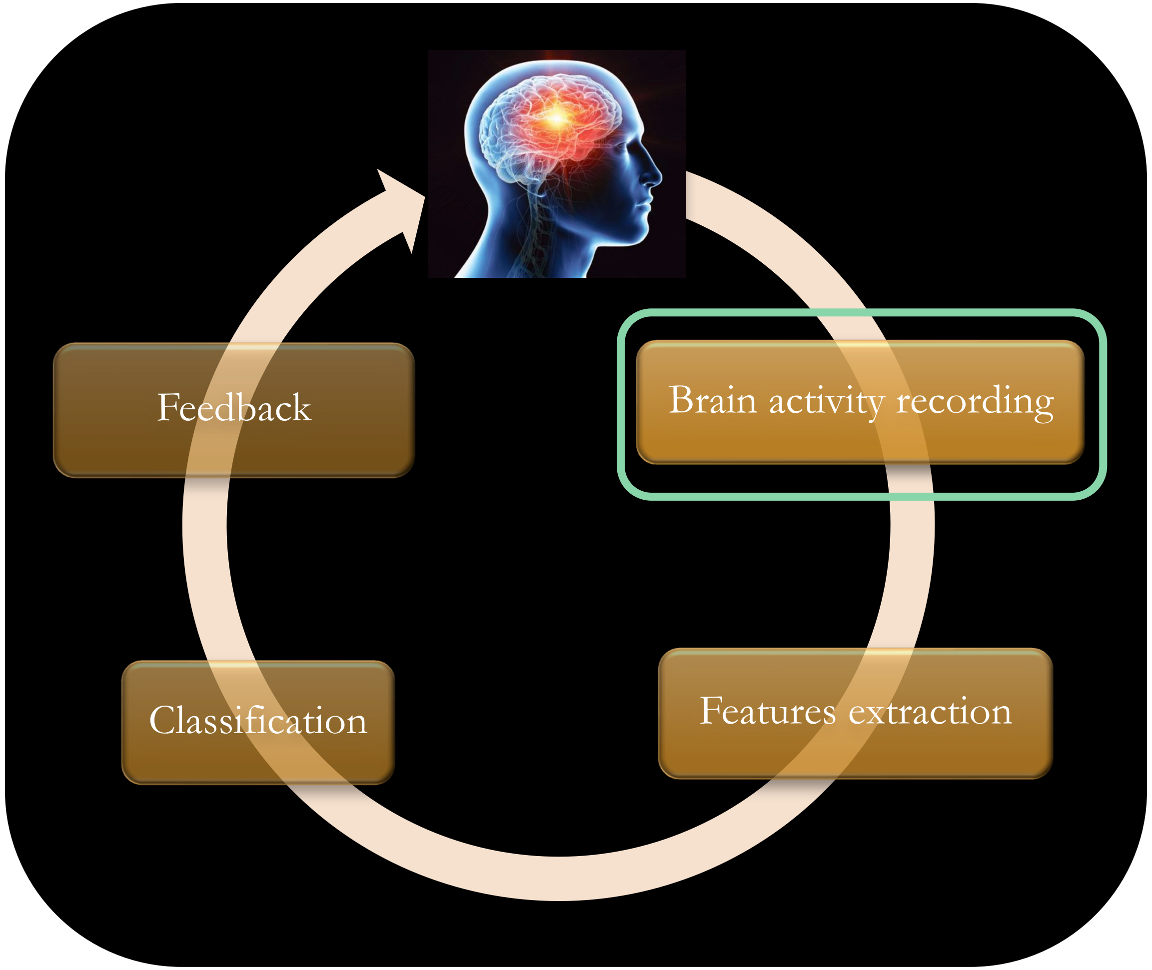
Control



Communication

Adapted from (Lotte et al, 2015)

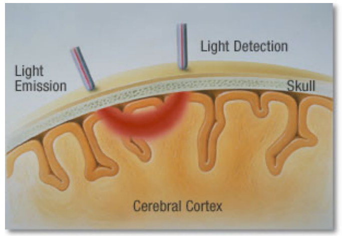
Behind the magic…



Non-invasive tools

EEG

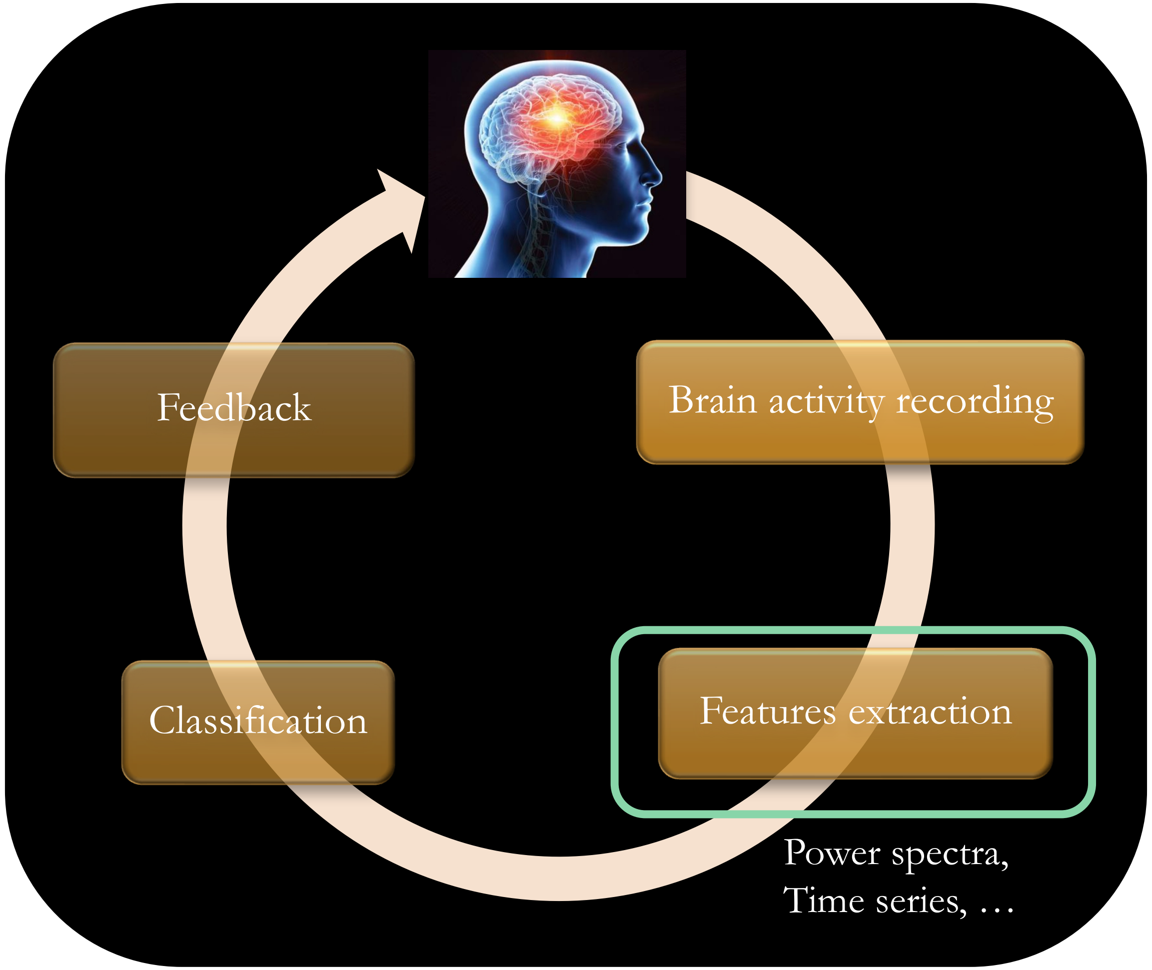
NIRS

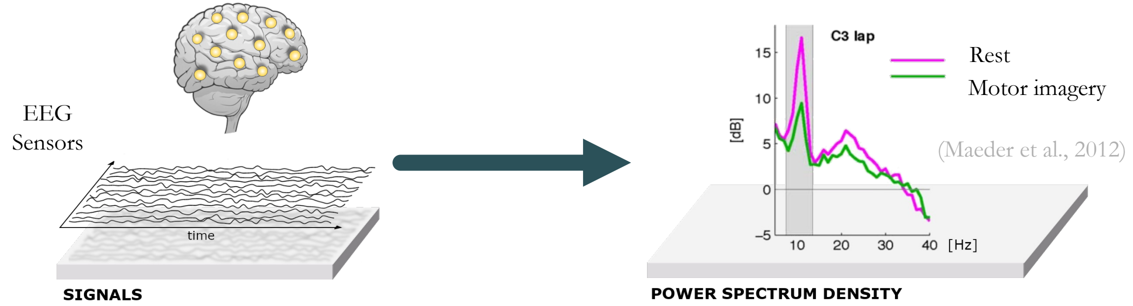


MEG

fMRI

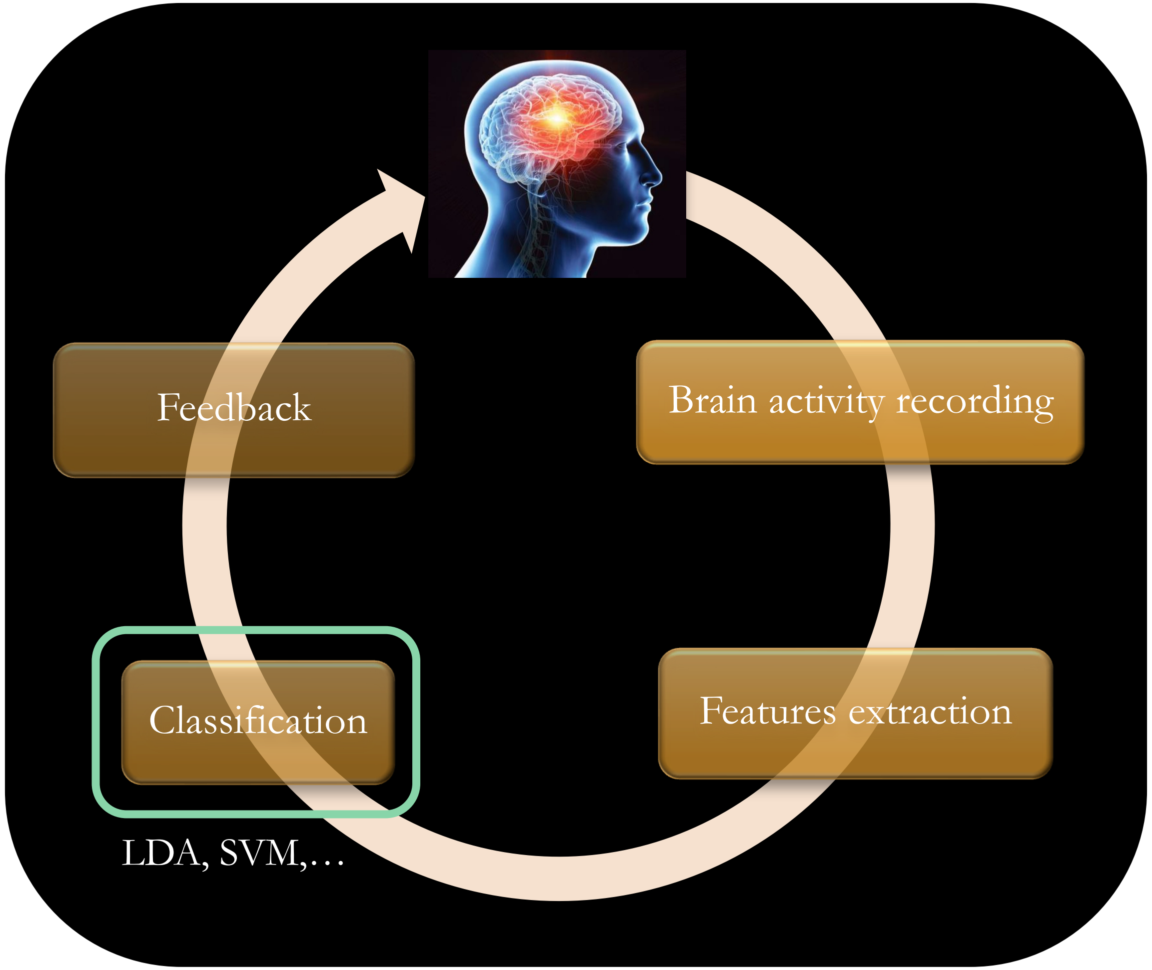
Behind the magic…

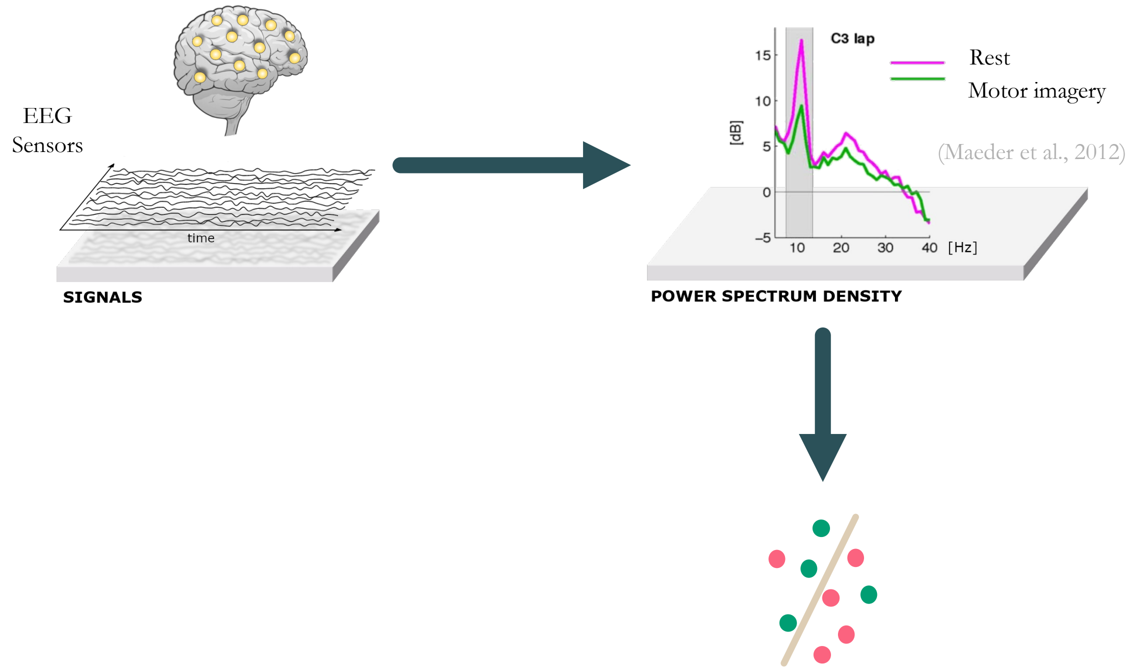




Adapted from
[Gonzalez-Astudillo, …, Corsi, & De Vico Fallani, JNE, 2020]

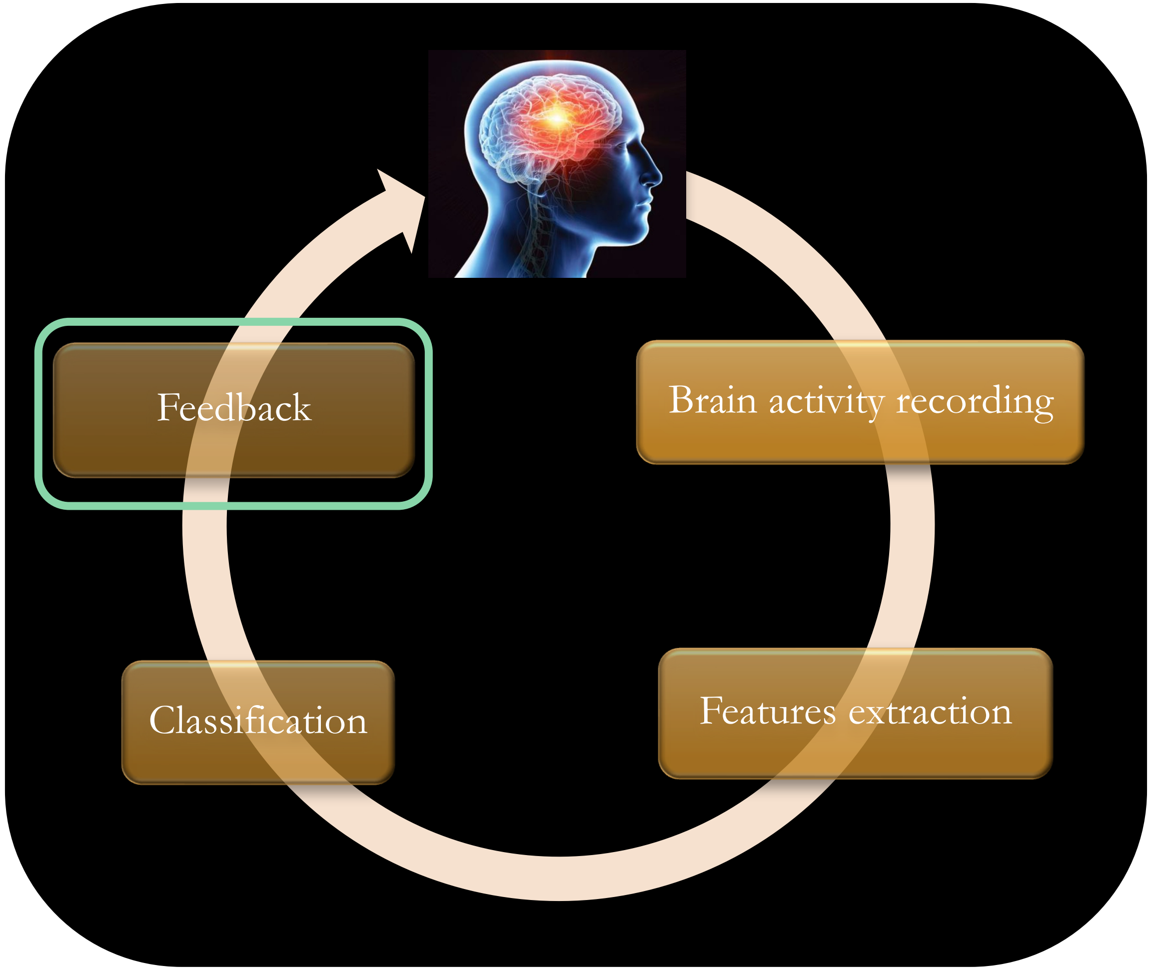
Behind the magic…

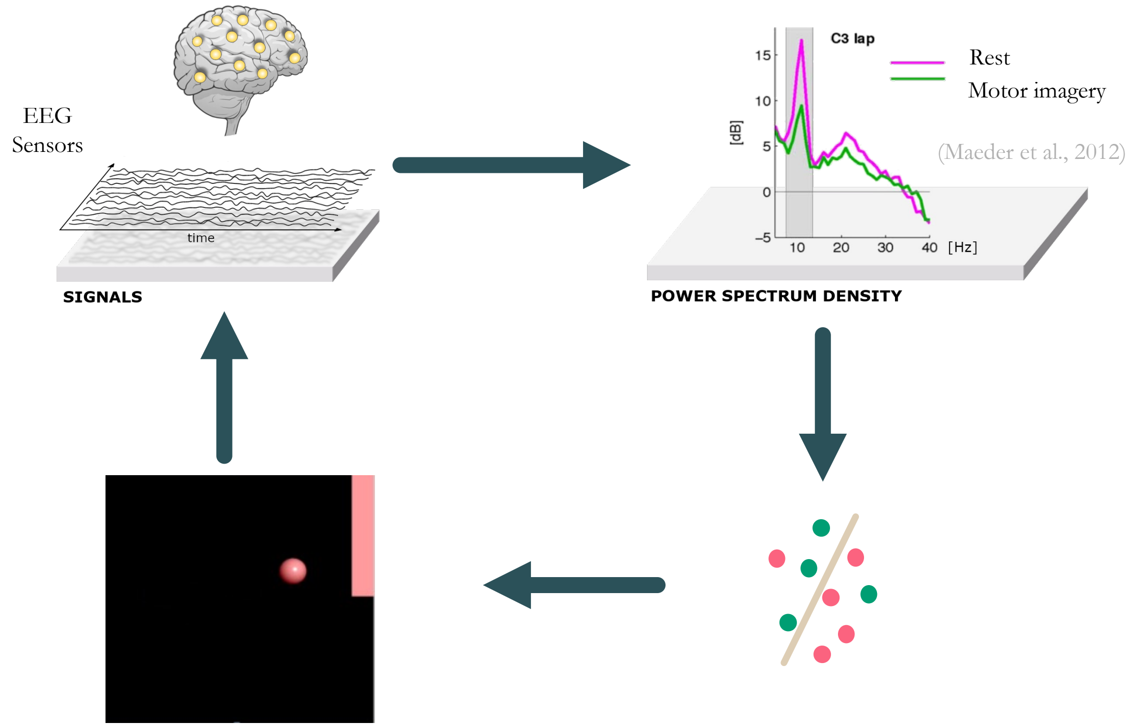




Adapted from
[Gonzalez-Astudillo, …, Corsi, & De Vico Fallani, JNE, 2020]

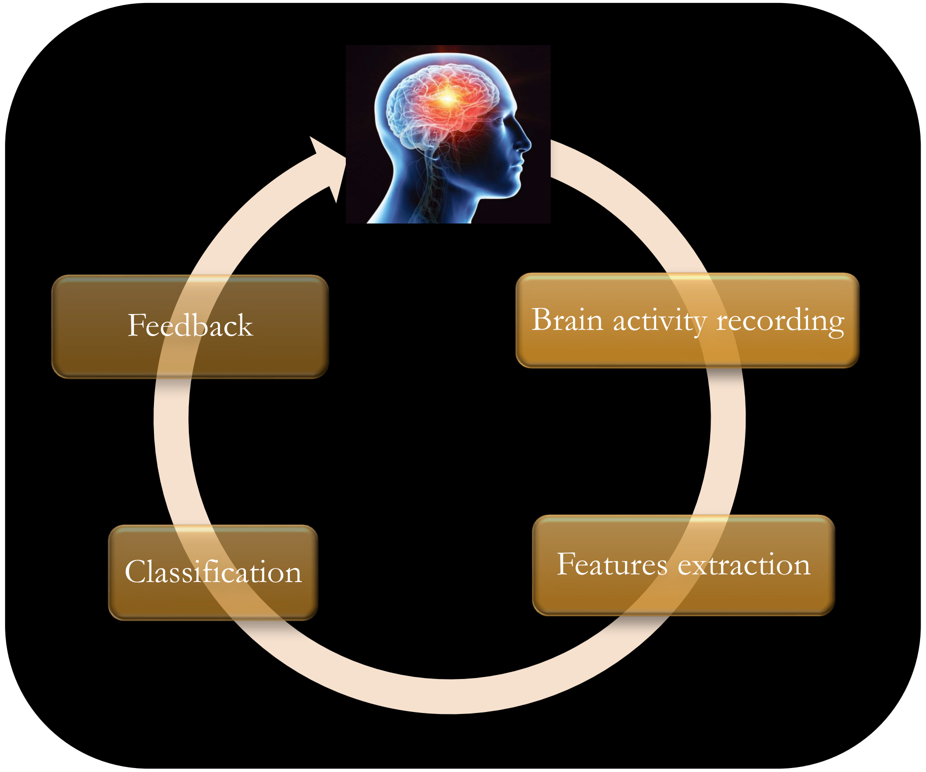
Behind the magic…

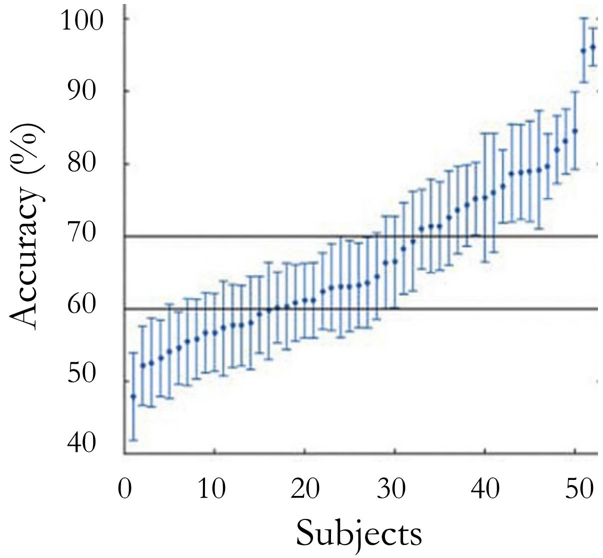




Adapted from
[Gonzalez-Astudillo, …, Corsi, & De Vico Fallani, JNE, 2020]

Brain-Computer Interface (BCI) – current challenges





Adapted from (Ahn & Jun, 2015)

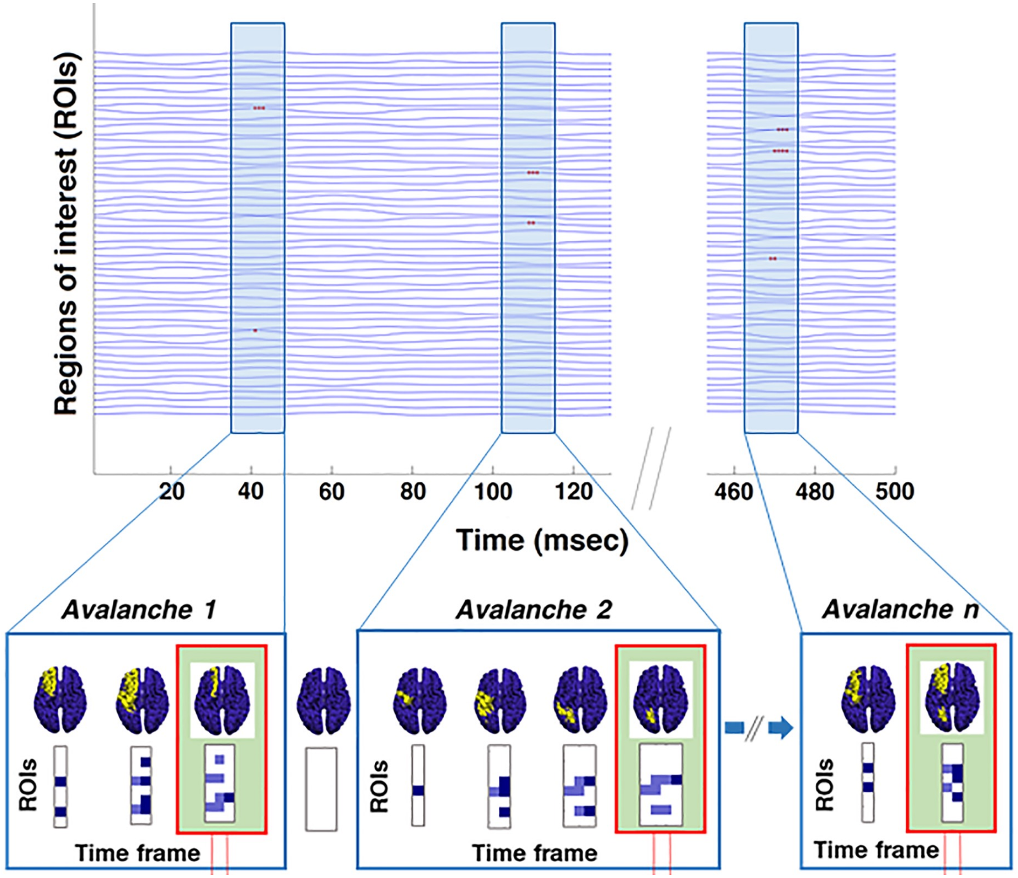
Problem:

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

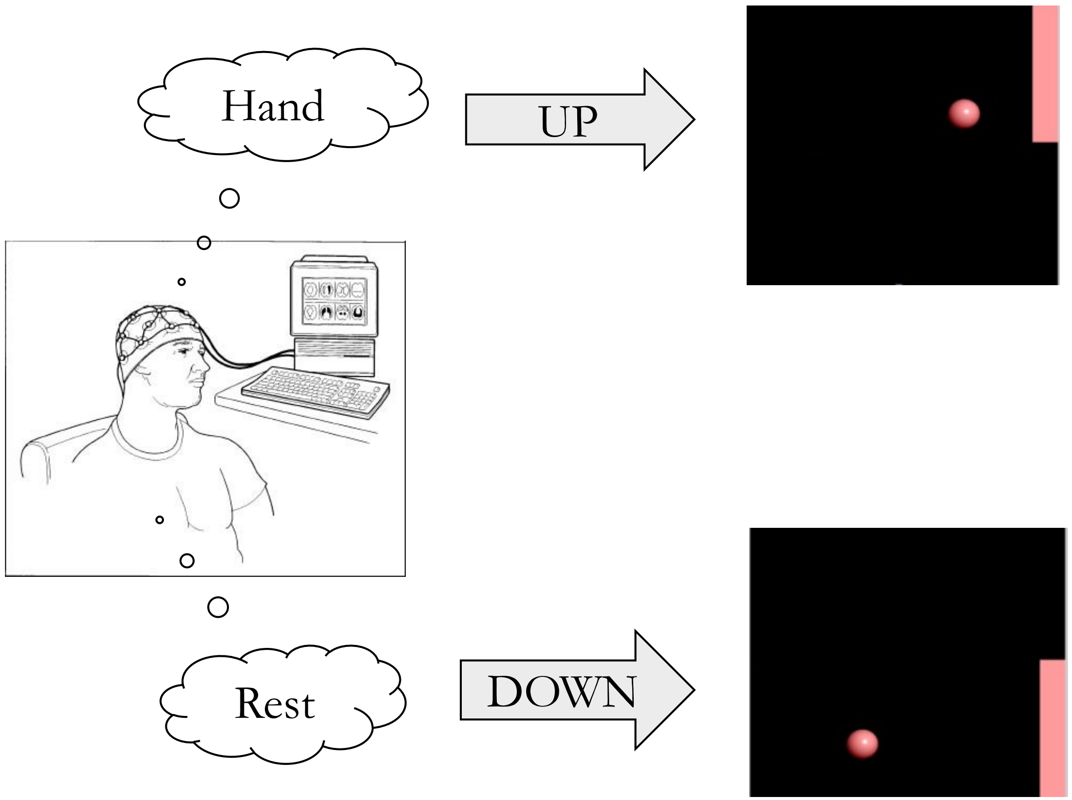


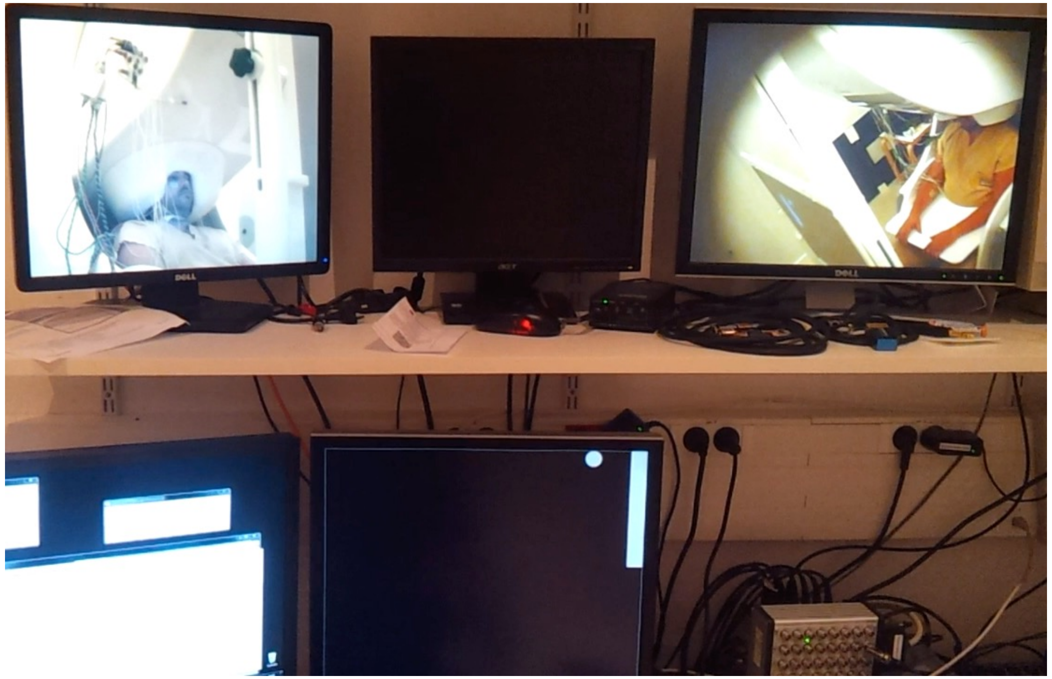
Adapted from [Polverino et al, Neurology, 2022]

Hypothesis:

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

BCI experiment



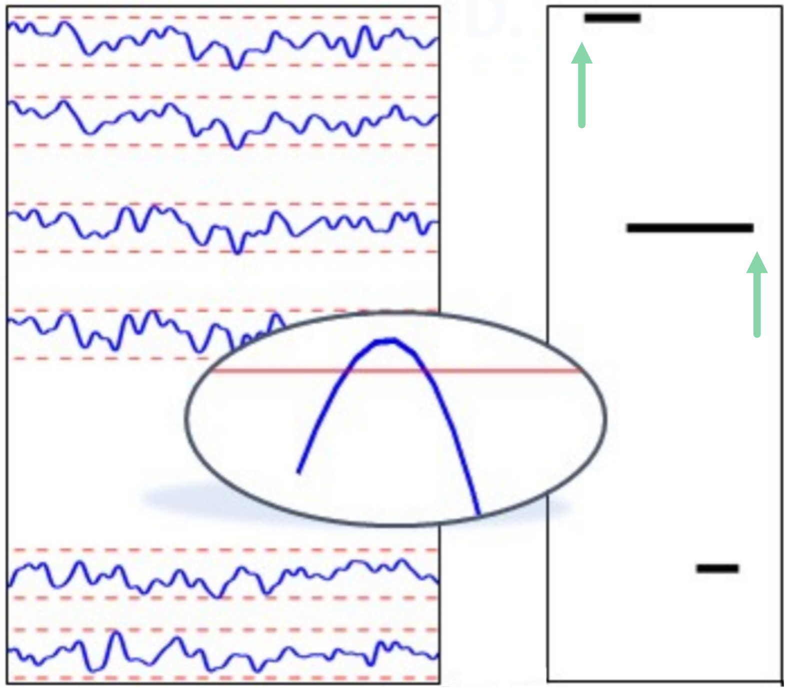


For a complete description of the protocol and the dataset, please refer to [Corsi et al, NeuroImage, 2020]

Objective:

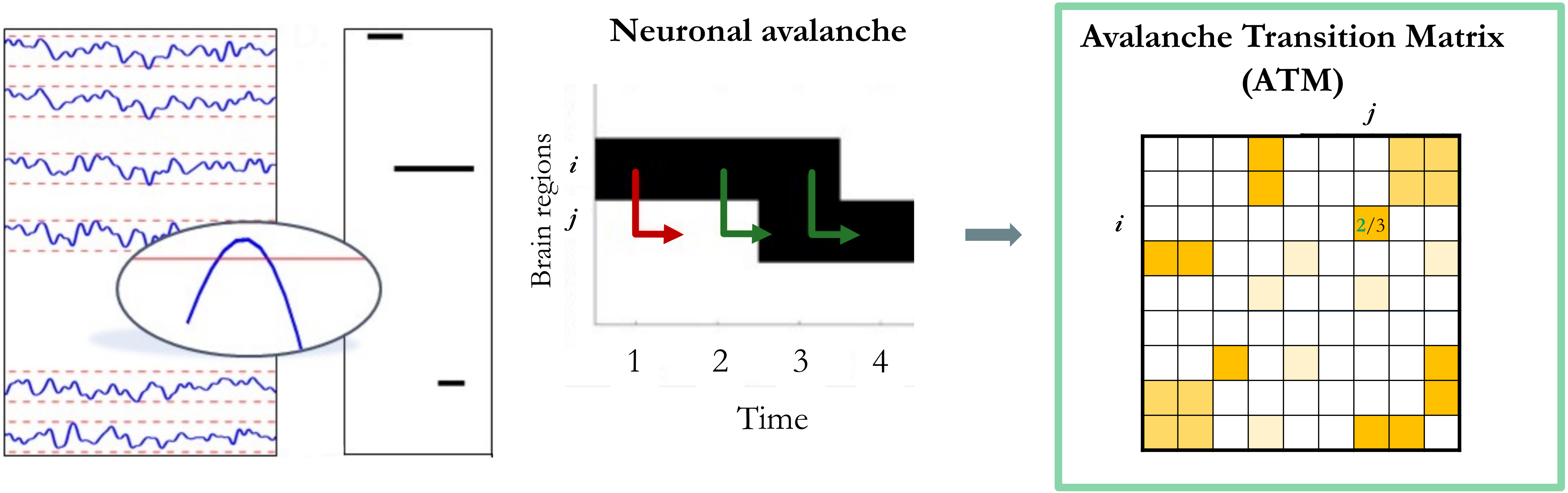
Tracking the dynamical features related to motor imagery as compared to rest

Differences in transition probabilities discriminate mental states



Adapted from [Sorrentino et al, eLife, 2021]

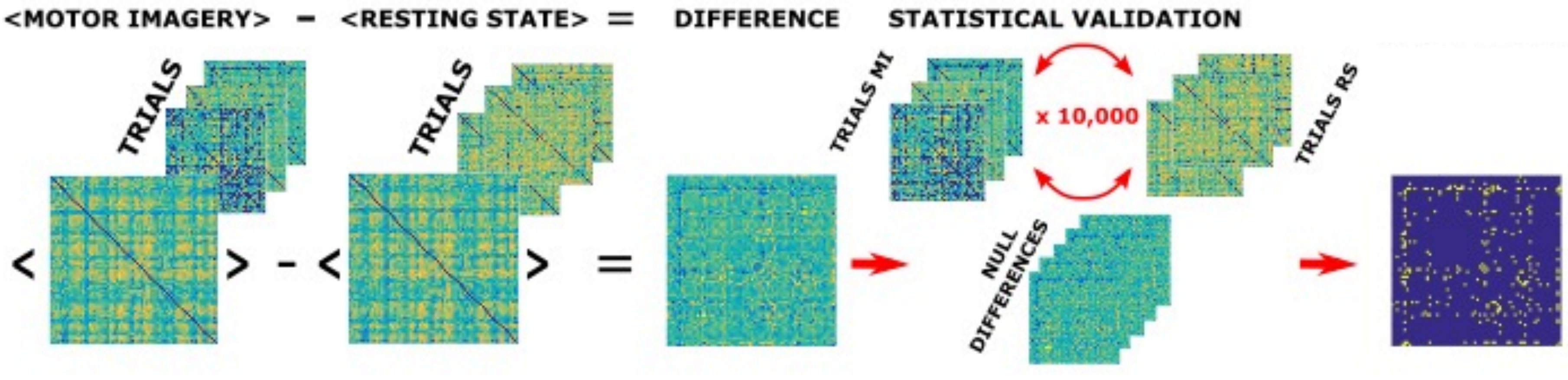
Differences in transition probabilities discriminate mental states



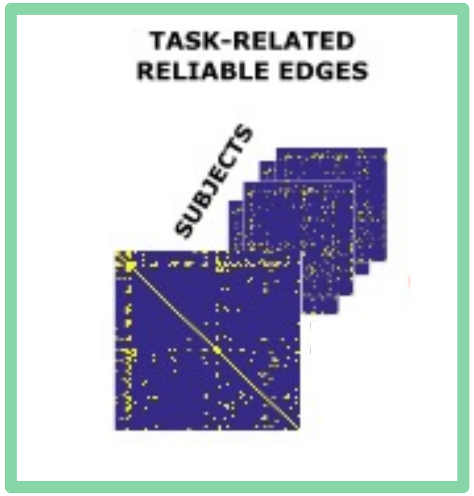
Adapted from [Sorrentino et al, eLife, 2021]

Differences in transition probabilities discriminate mental states

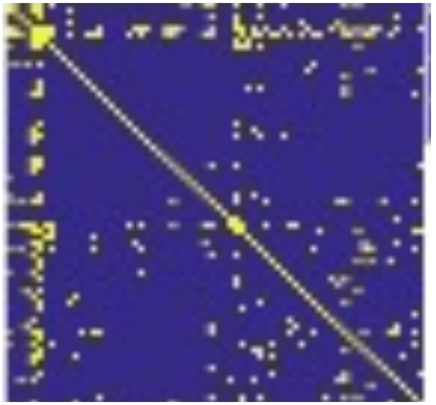
Subject-level



Group-level



Differences in transition probabilities discriminate mental states



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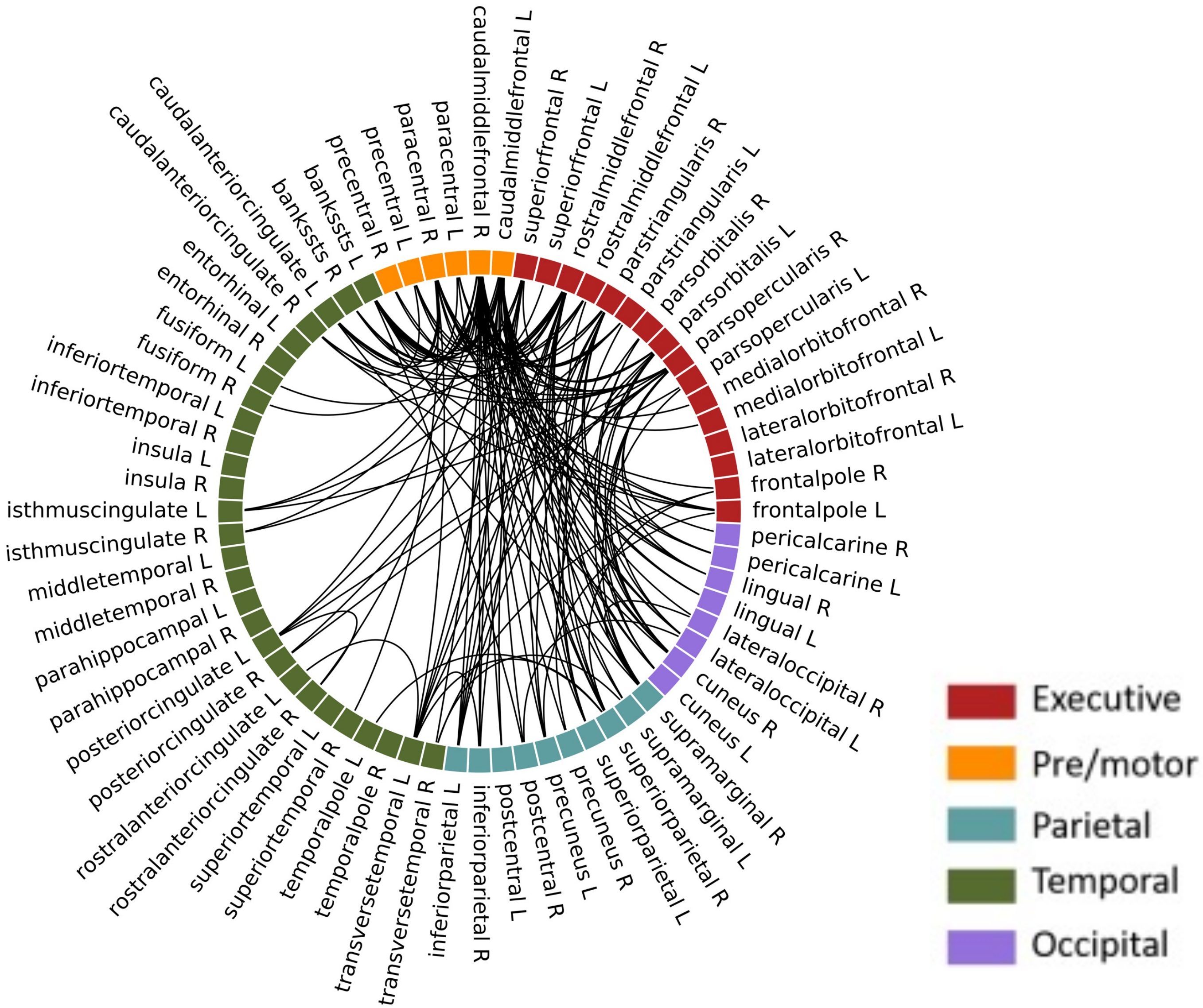
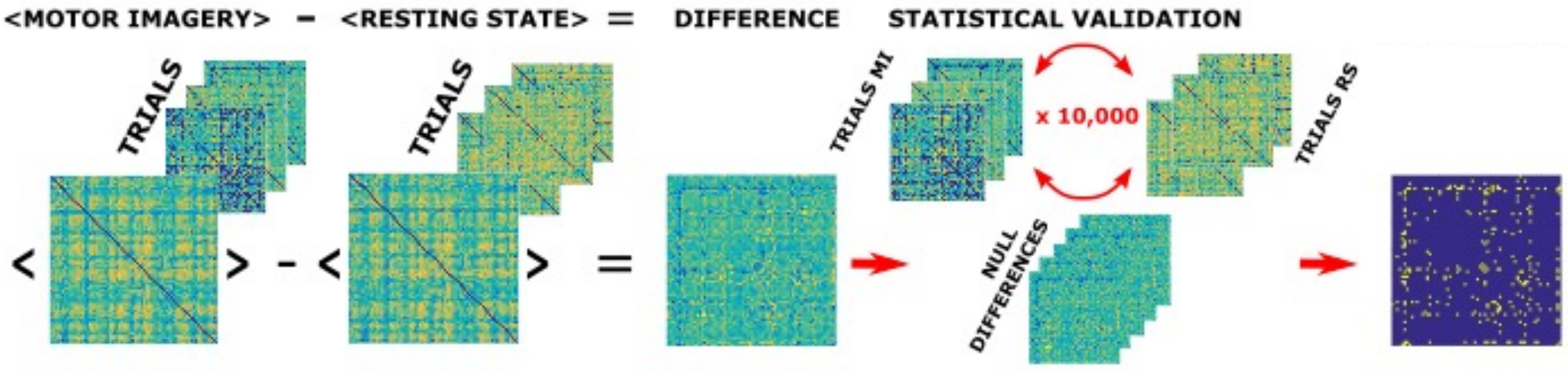


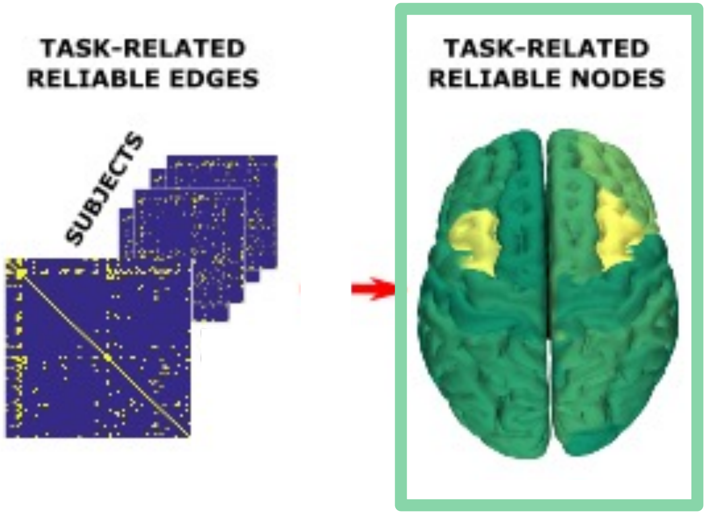
Task-related differences are in edges hinging on pre/motor areas (in most subjects)

Differences in transition probabilities discriminate mental states

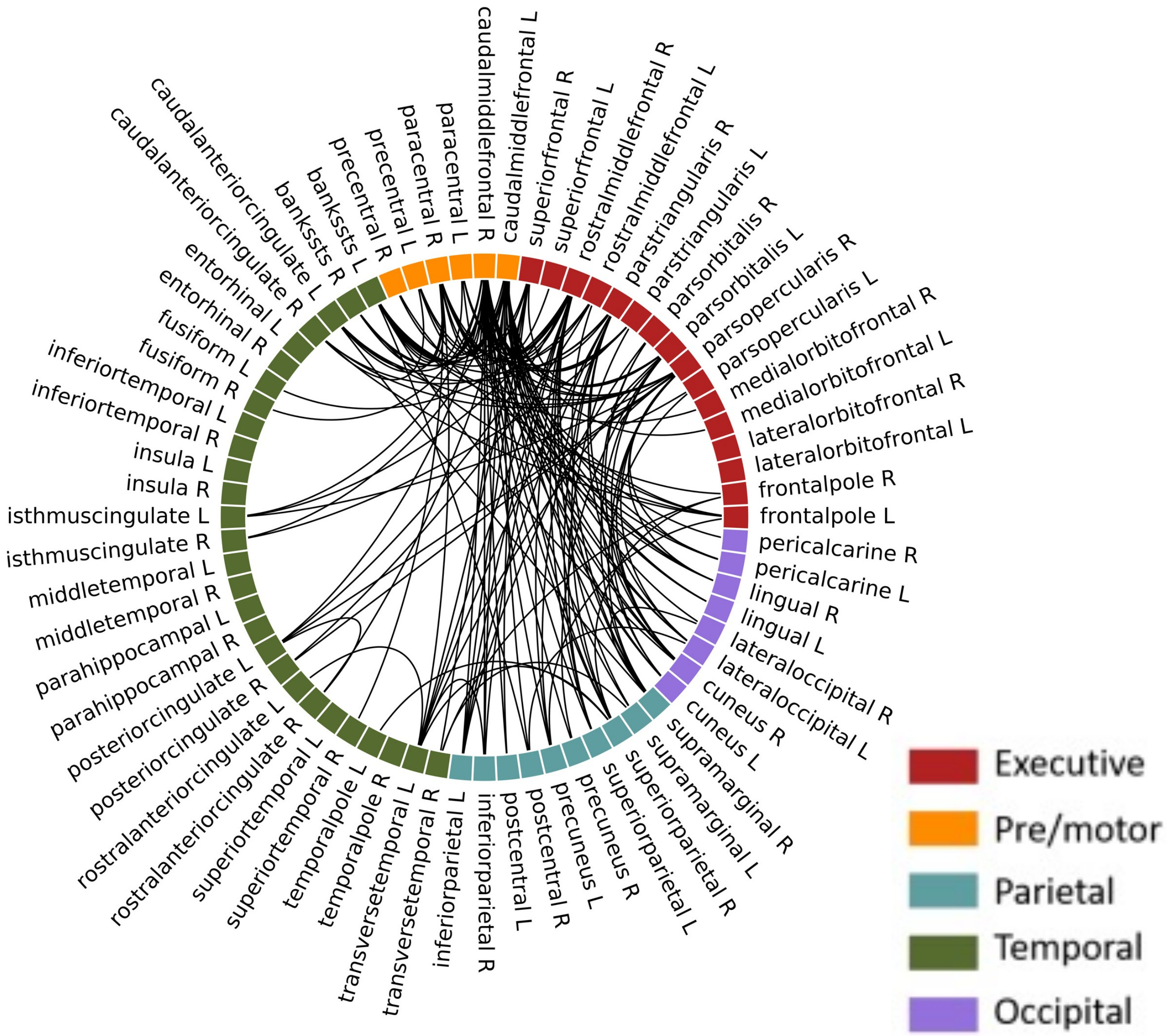
Subject-level

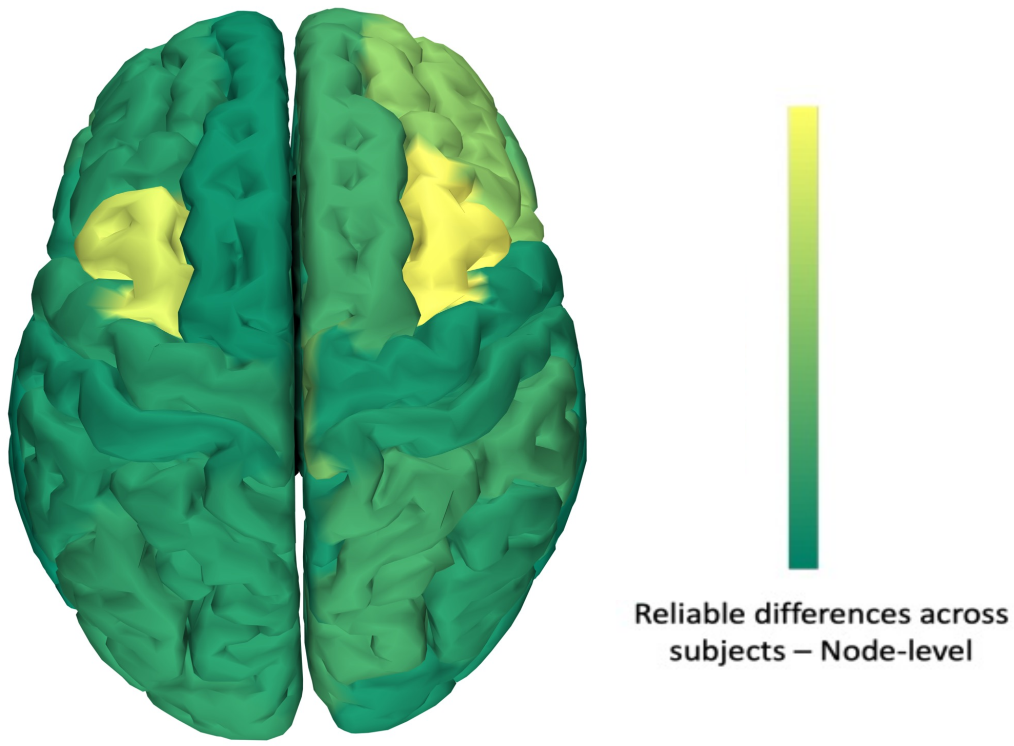


Group-level

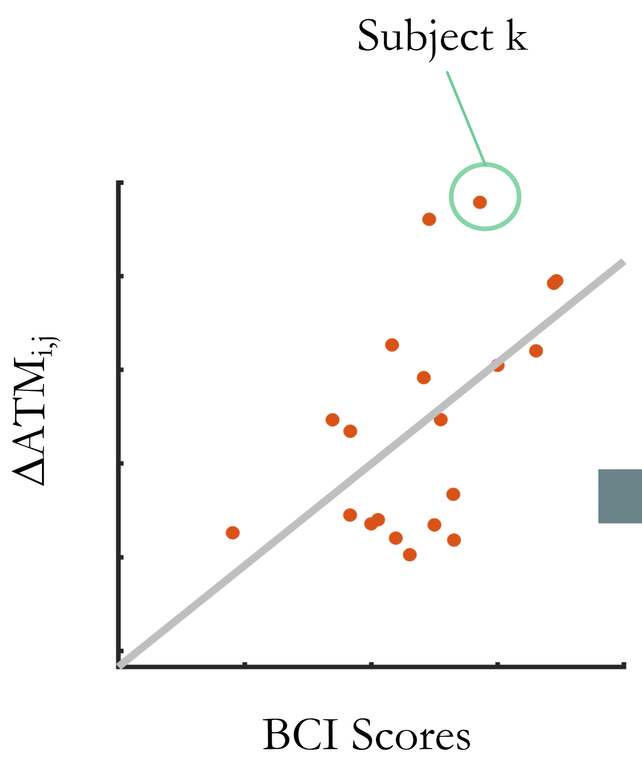


Differences in transition probabilities discriminate mental states

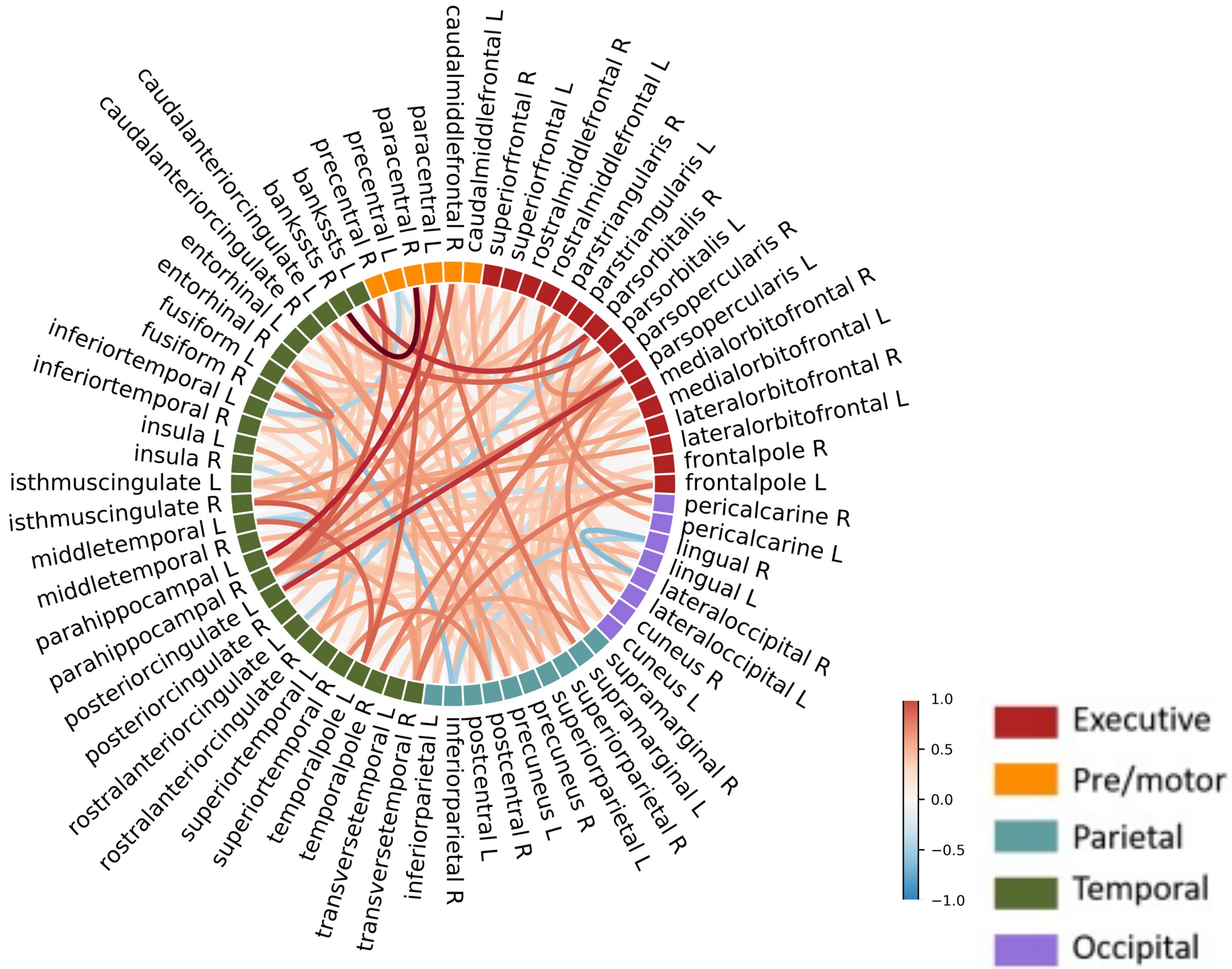




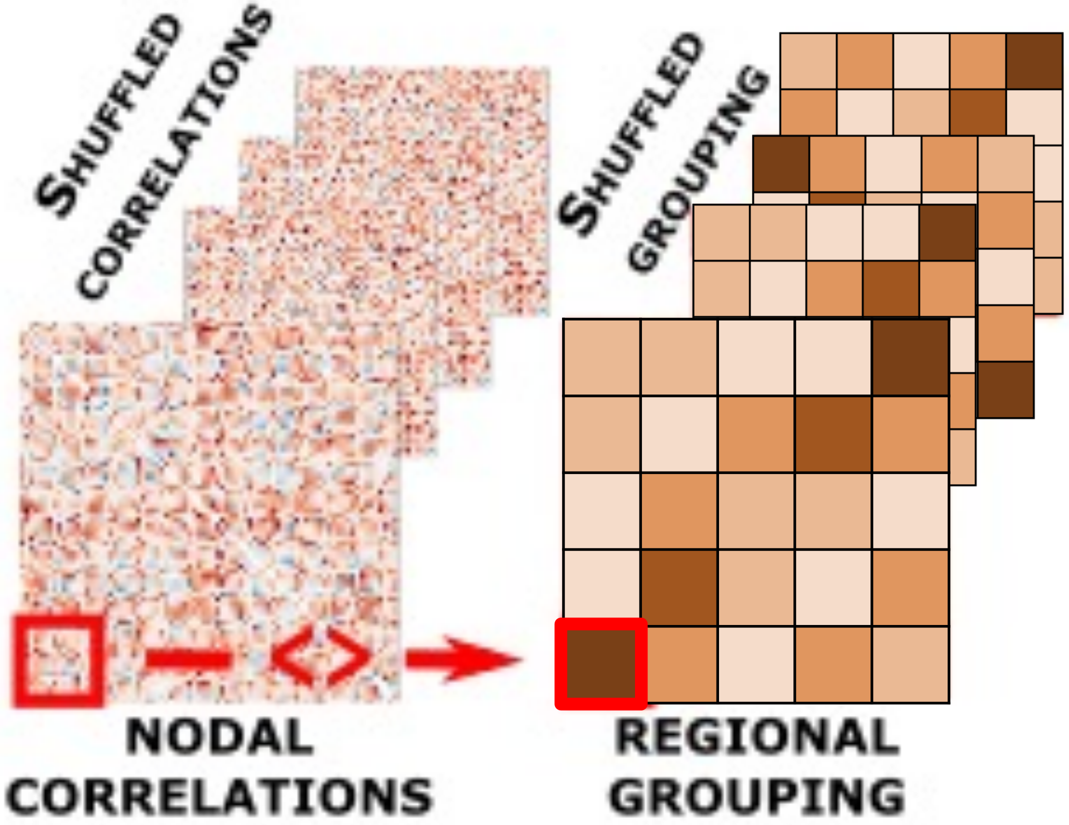
Differences in transition probabilities relate to BCI scores

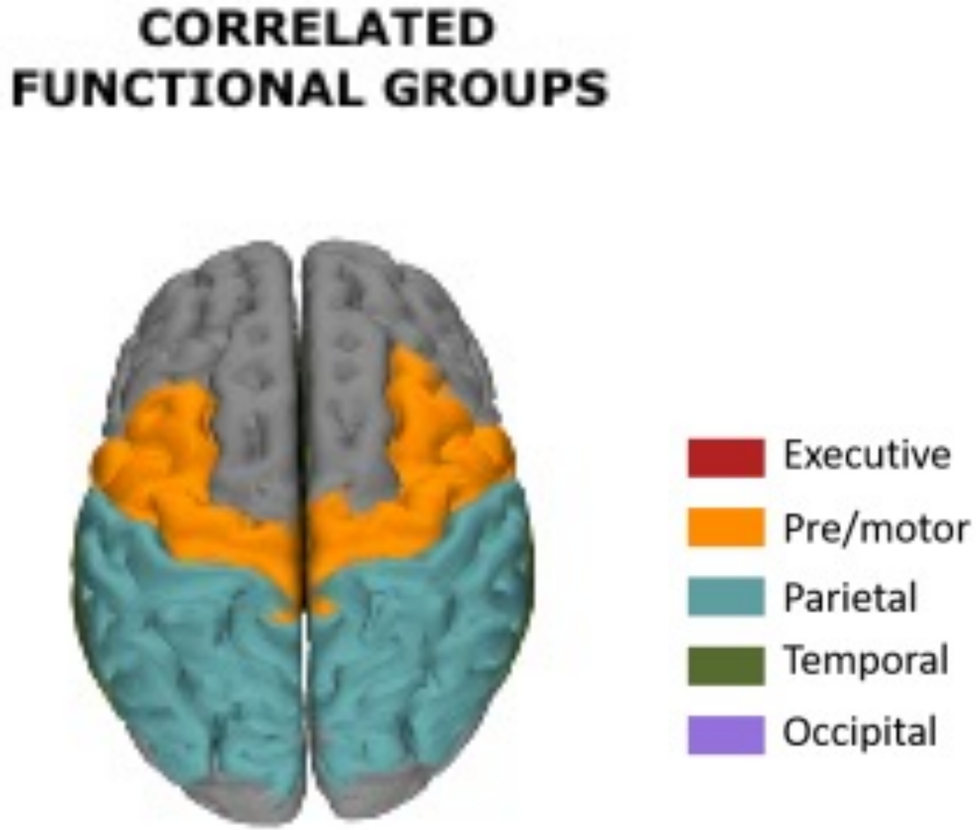


Edge-wise correlation

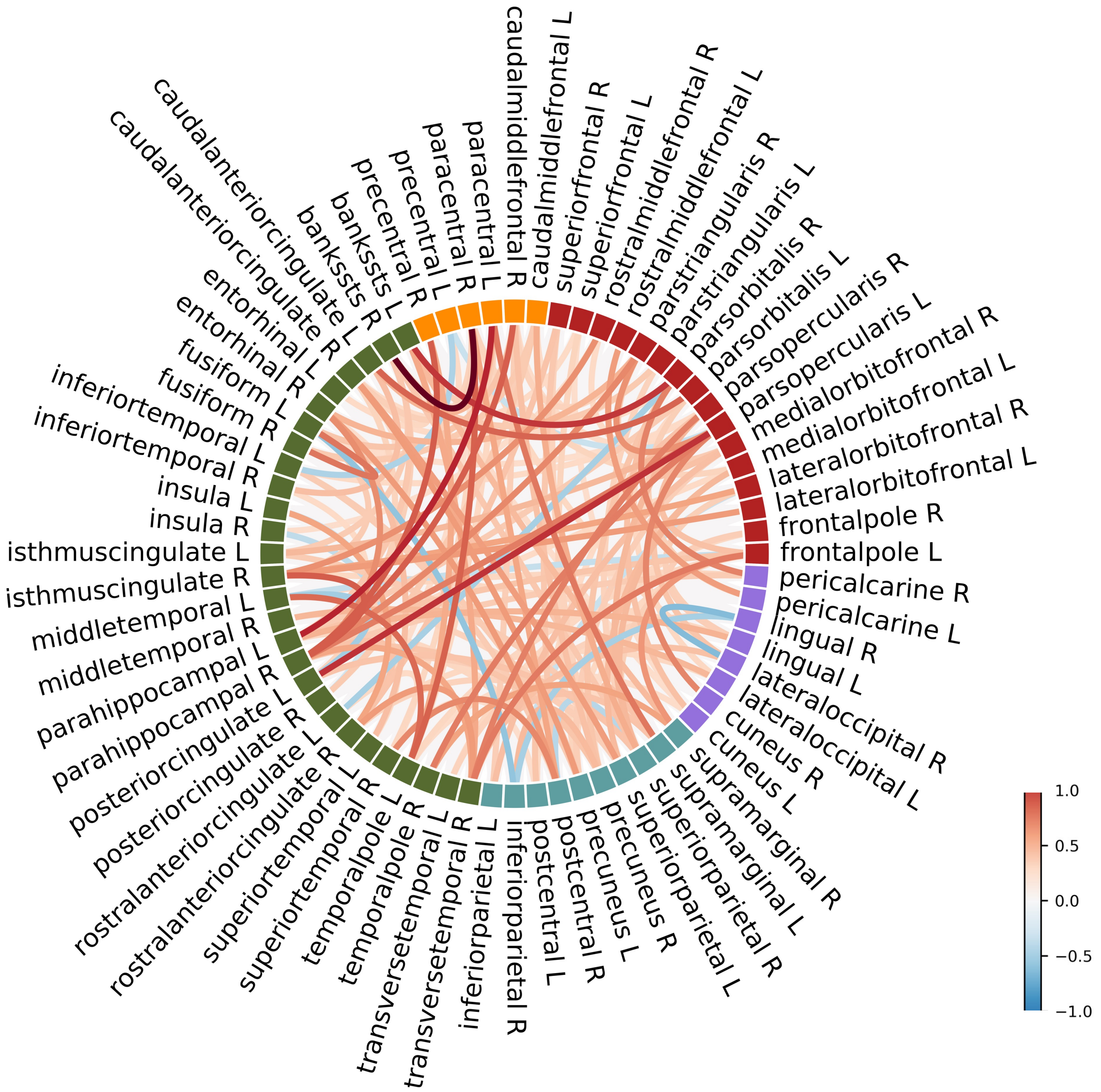


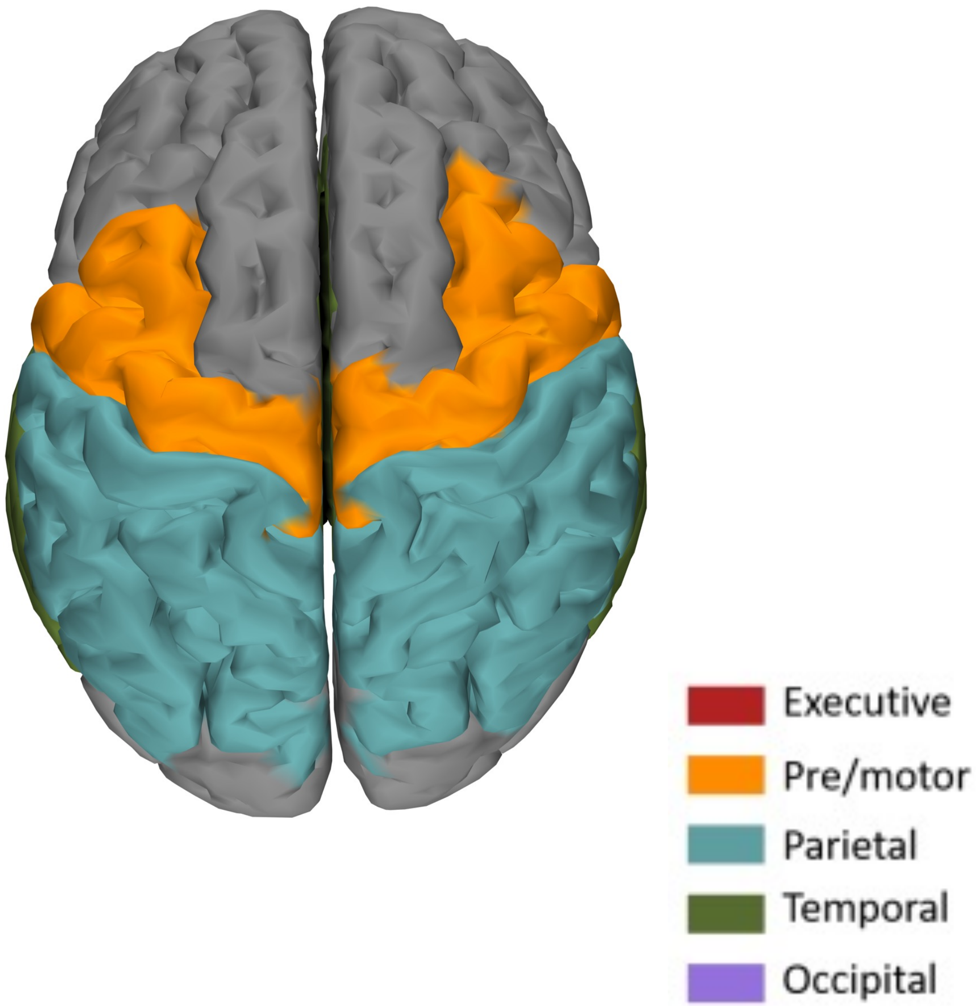
Differences in transition probabilities relate to BCI scores



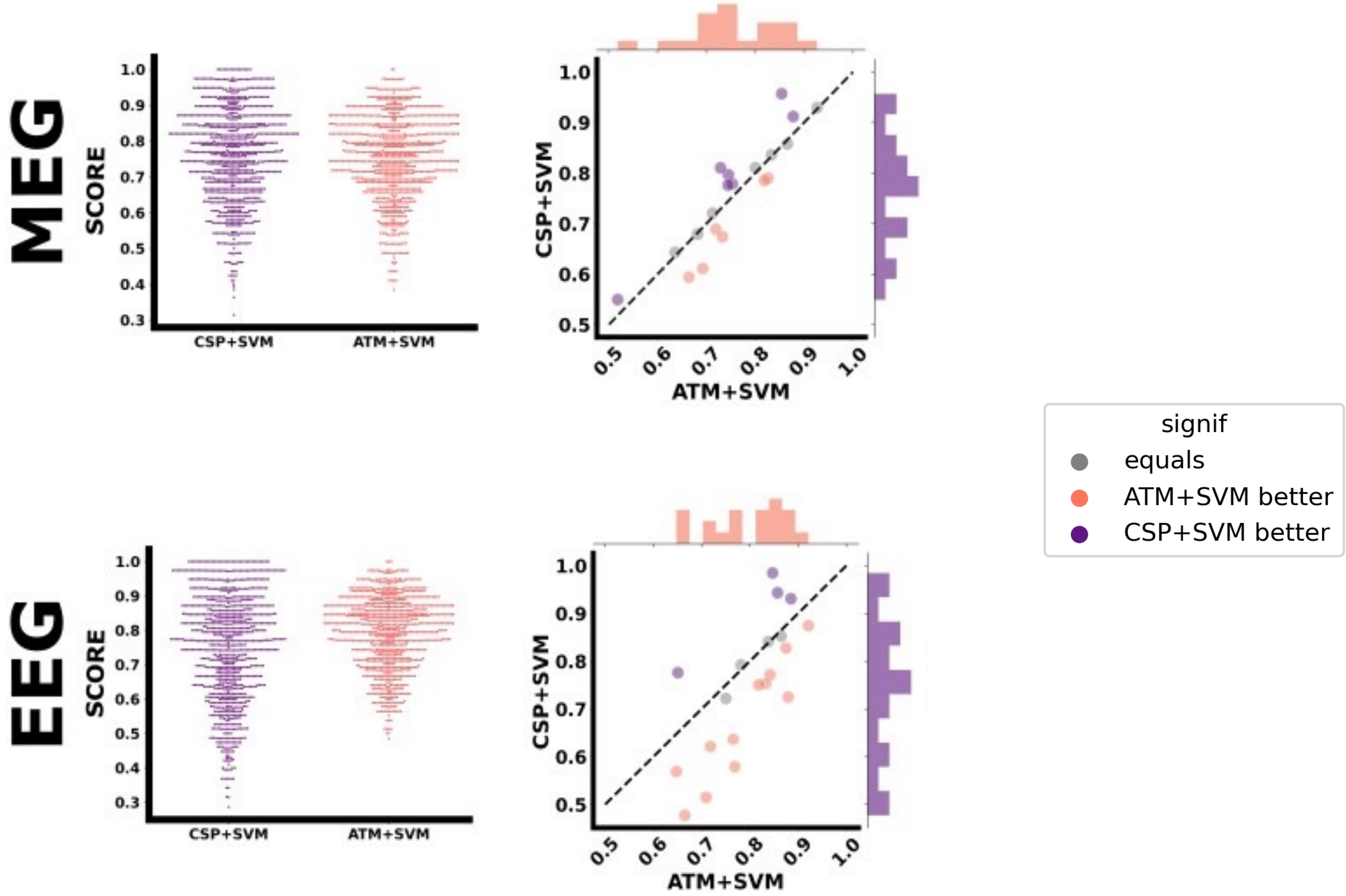


Differences in transition probabilities relate to BCI scores



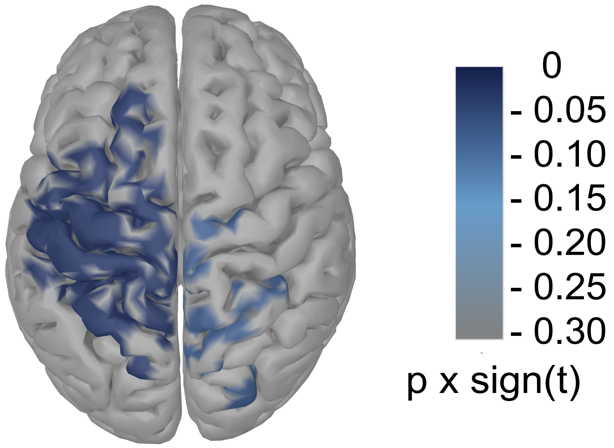


Transition probabilities as alternative features for BCI

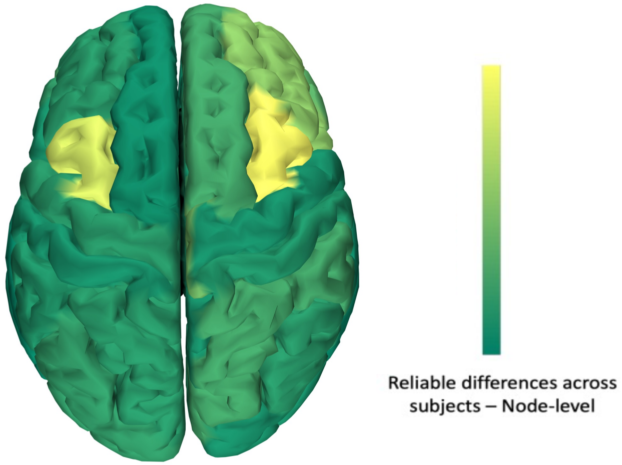


Reliable functional information of task performance retrieval

- Meaningful information communication among regions on the large-scale & aperiodic and scale-free perturbation



Power spectra
significant at **group** level

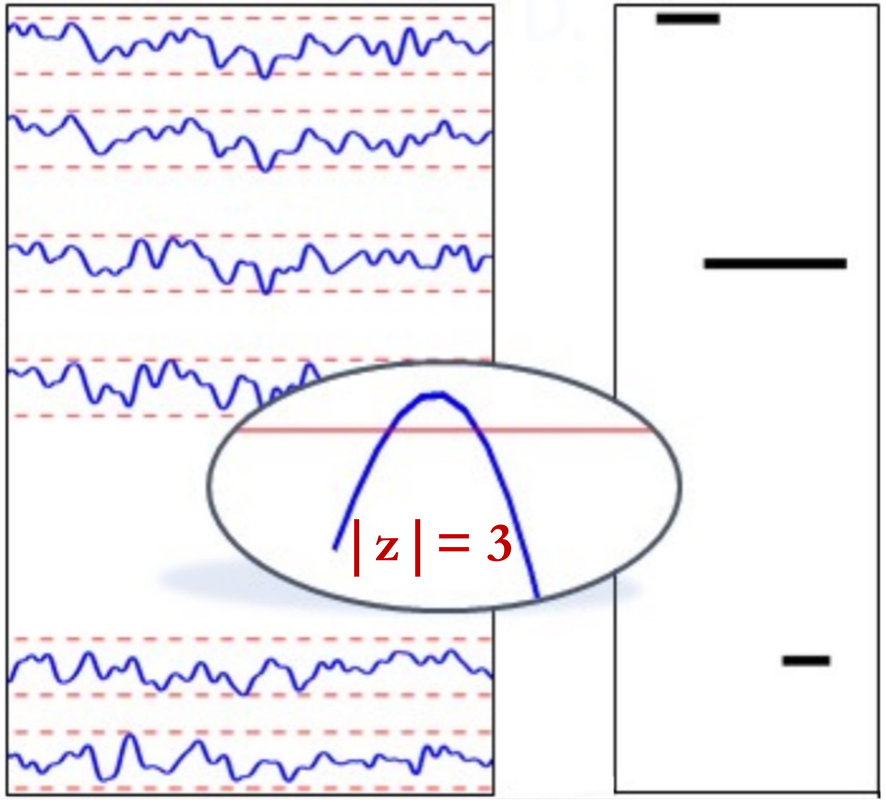


Neuronal avalanches
significant at **individual** level

⇒ **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



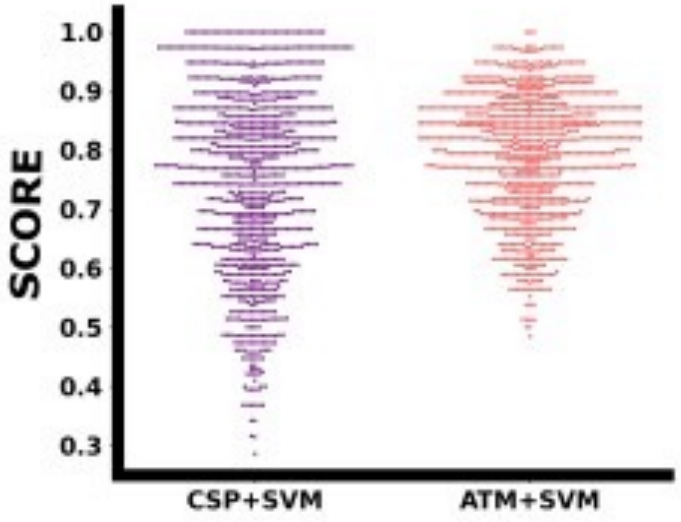
⇒ **Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information**

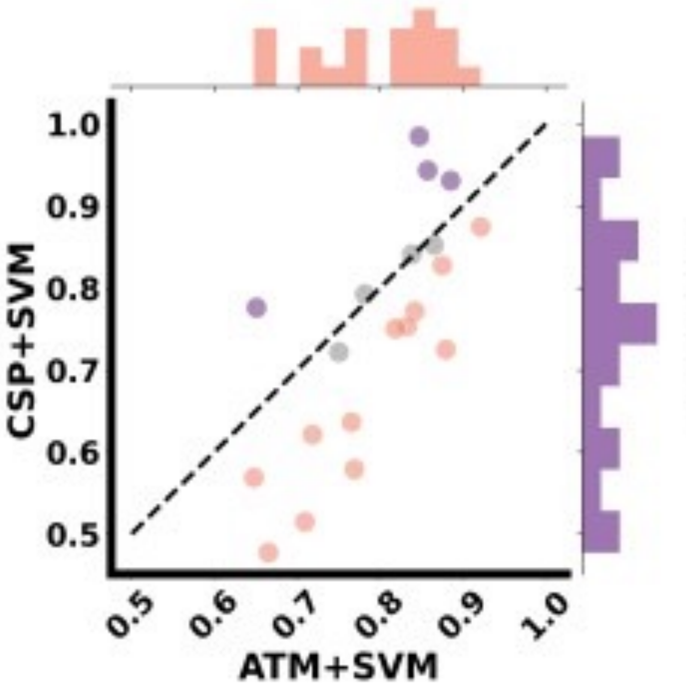
Discussion

Reliable functional information of task performance retrieval

Building innovative BCI protocols based on ATMs

- Outperforms the benchmark in EEG – gold standard in BCI → one step closer to the implementation
- Need to further investigate more suited classification methods





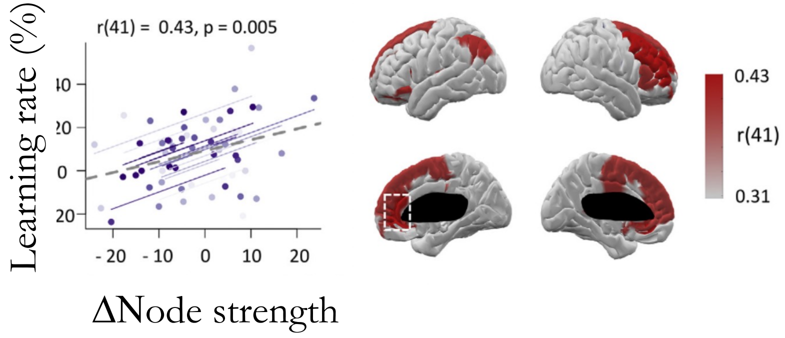
Discussion

Reliable functional information of task performance retrieval

Building innovative BCI protocols based on ATMs

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]
- Spreading of neuronal avalanches
  - Patterns behaviorally meaningful (Chialvo et al, 2010)
  - Computational fast marker



Node strength [Corsi et al, NeuroImage 2020]]
Multimodal core-periphery properties [Corsi et al, JNE 2021]

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Inria informatics mathematics

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Interested in this study?

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

mccorsi/NeuronalAvalanches4BCI

Thank you for your attention!

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