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

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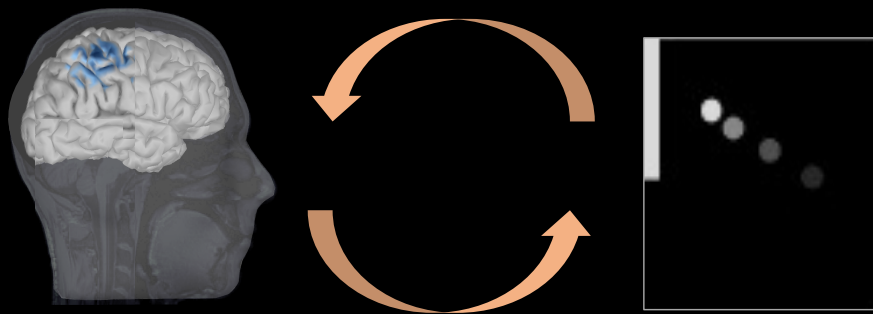
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Using critical dynamics to capture processes underlying Brain-Computer Interface performance



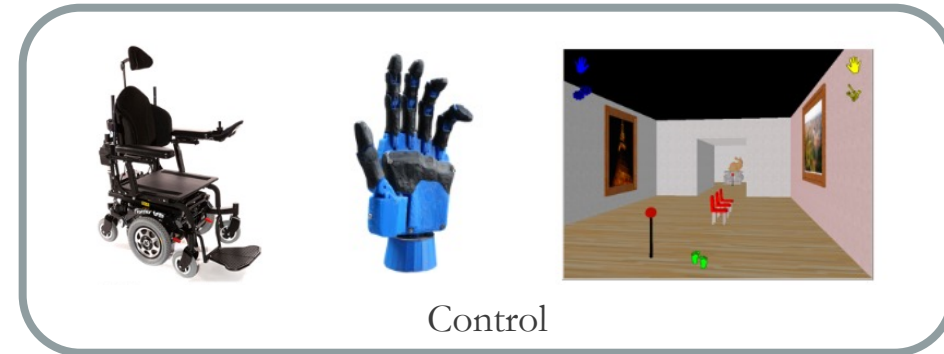
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Inria-Paris Brain Institute, France

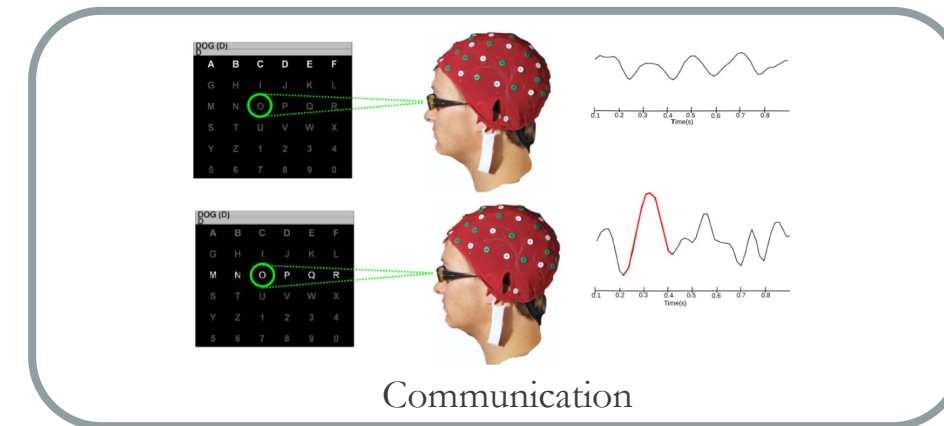
Pierpaolo Sorrentino*,

Institut de Neurosciences des Systèmes, France

What is a Brain-Computer Interface (BCI)?



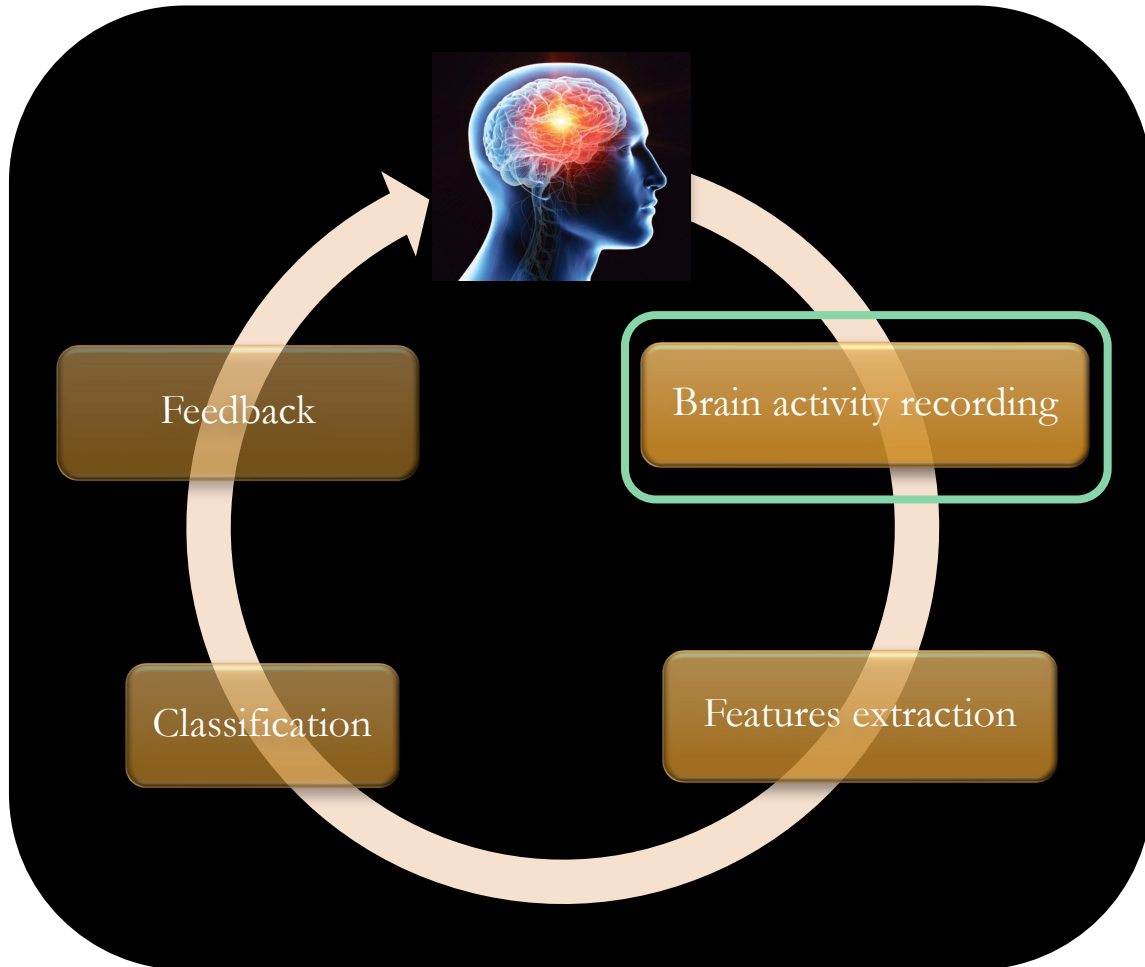
Control



Communication

Adapted from (Lotte et al, 2015)

Behind the magic...

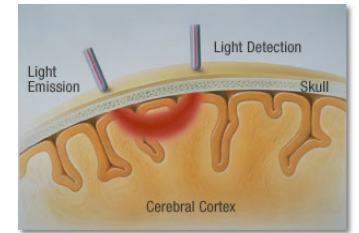


Non-invasive tools

EEG



NIRS



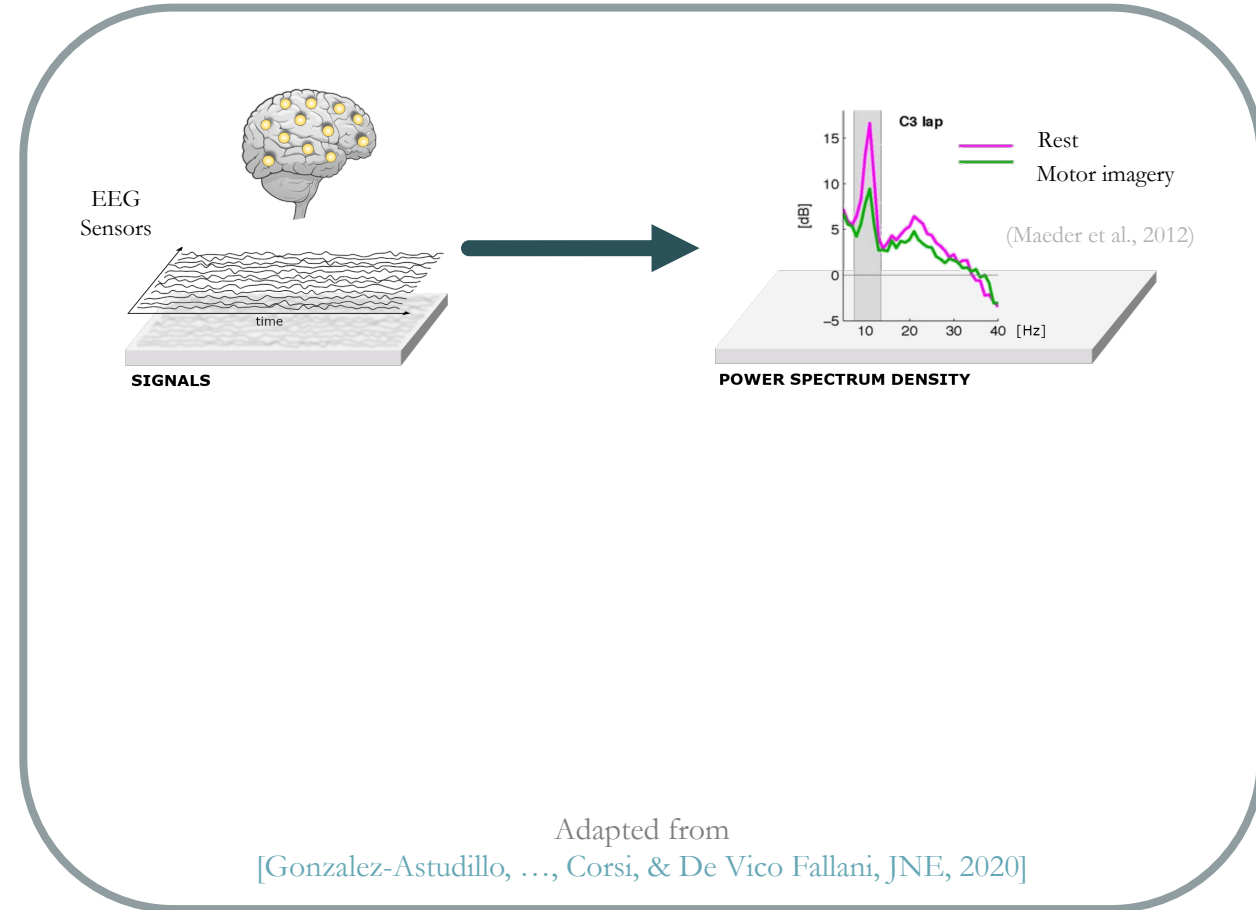
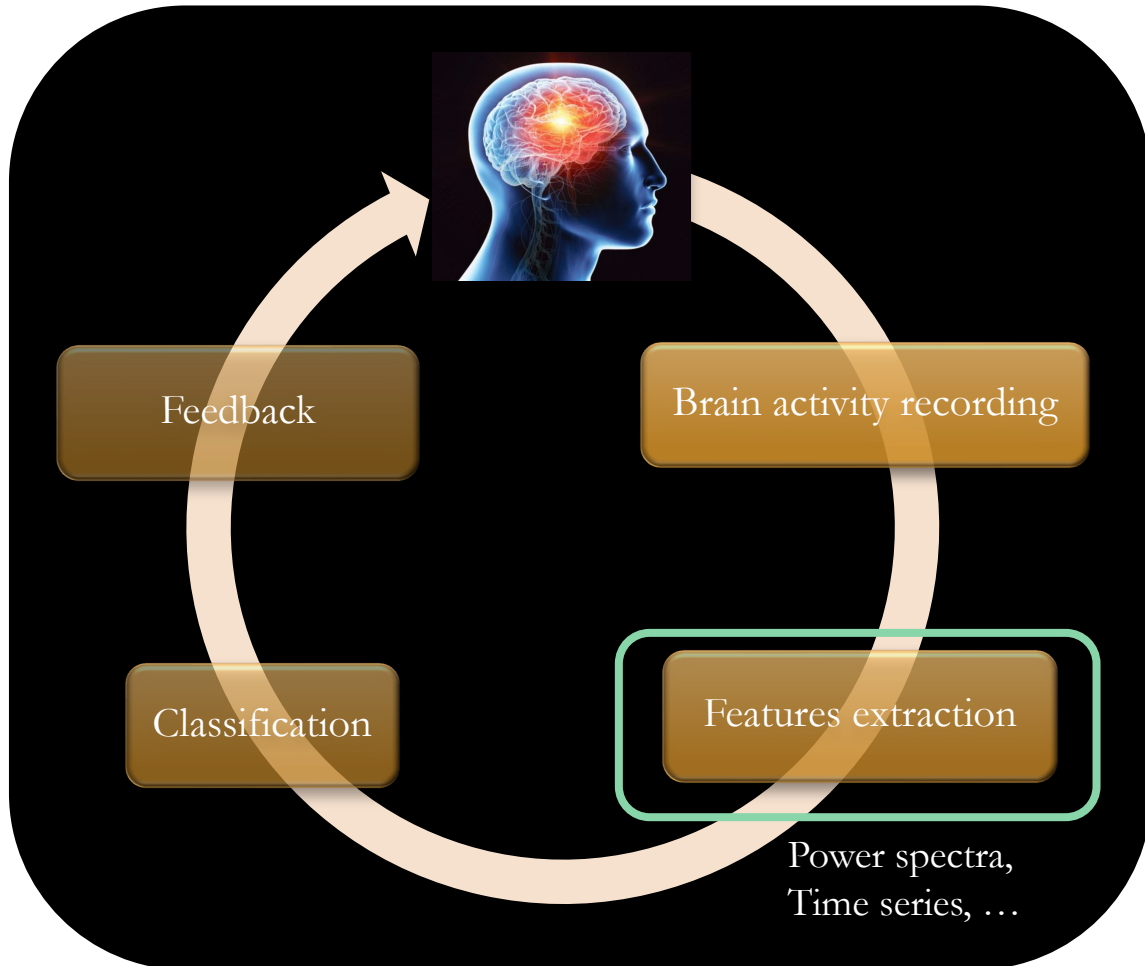
MEG



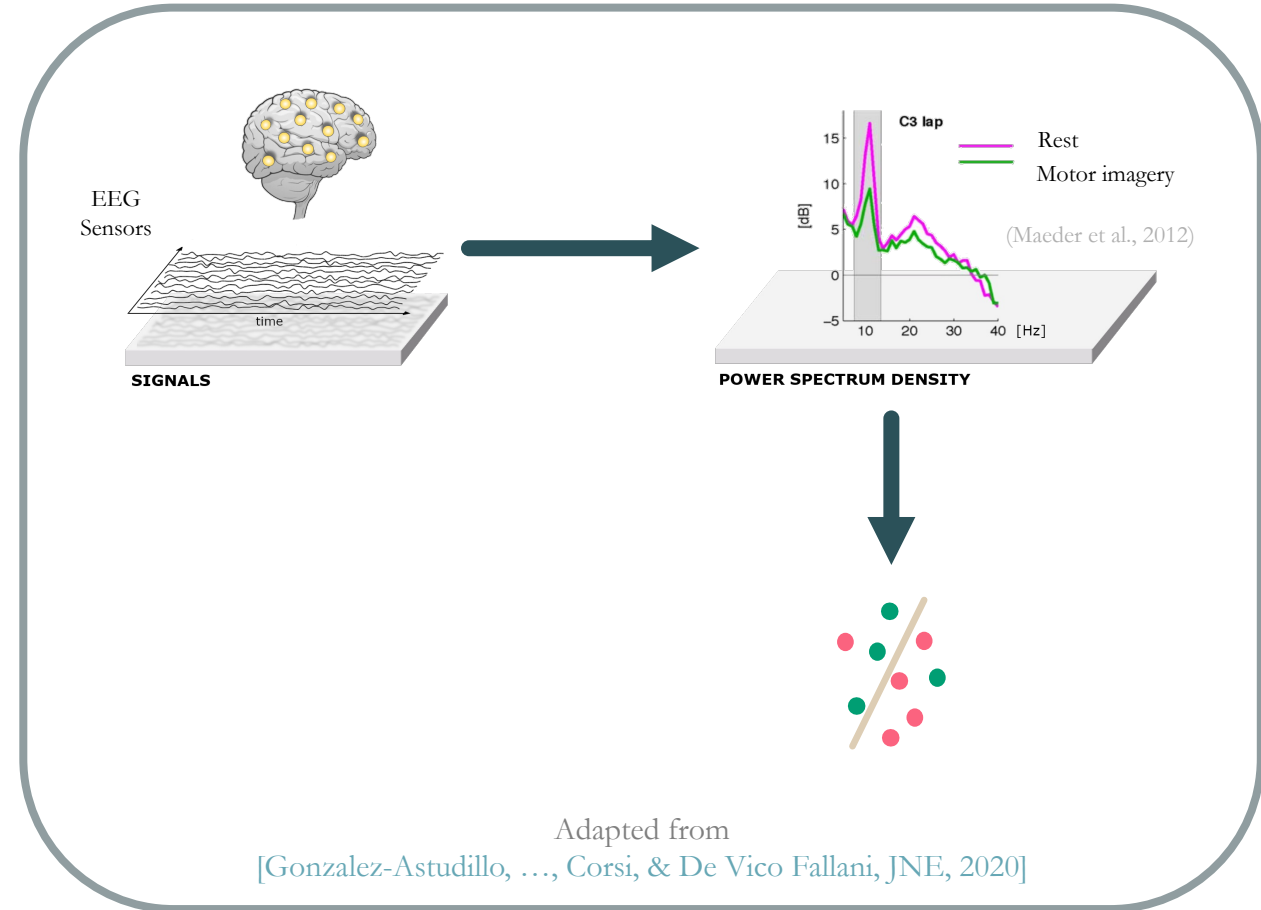
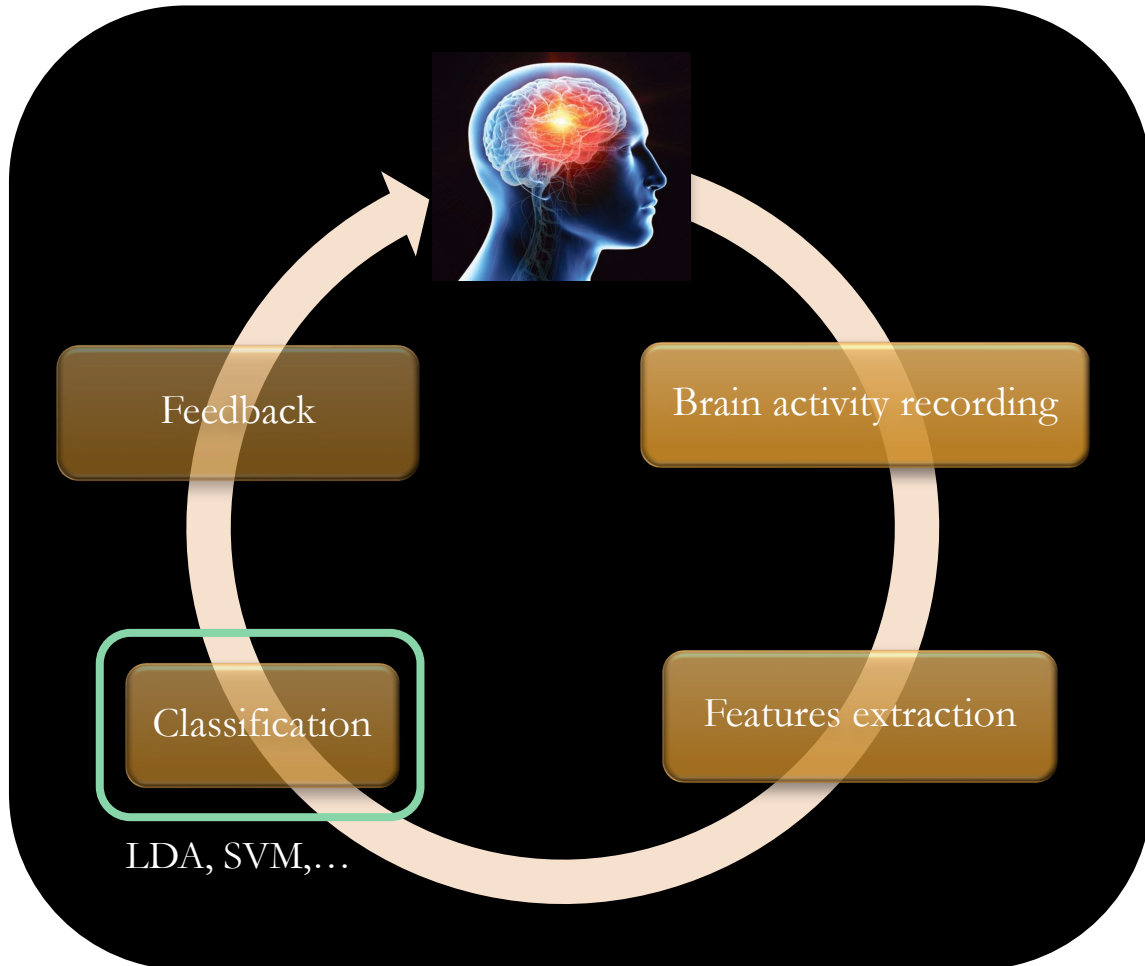
fMRI



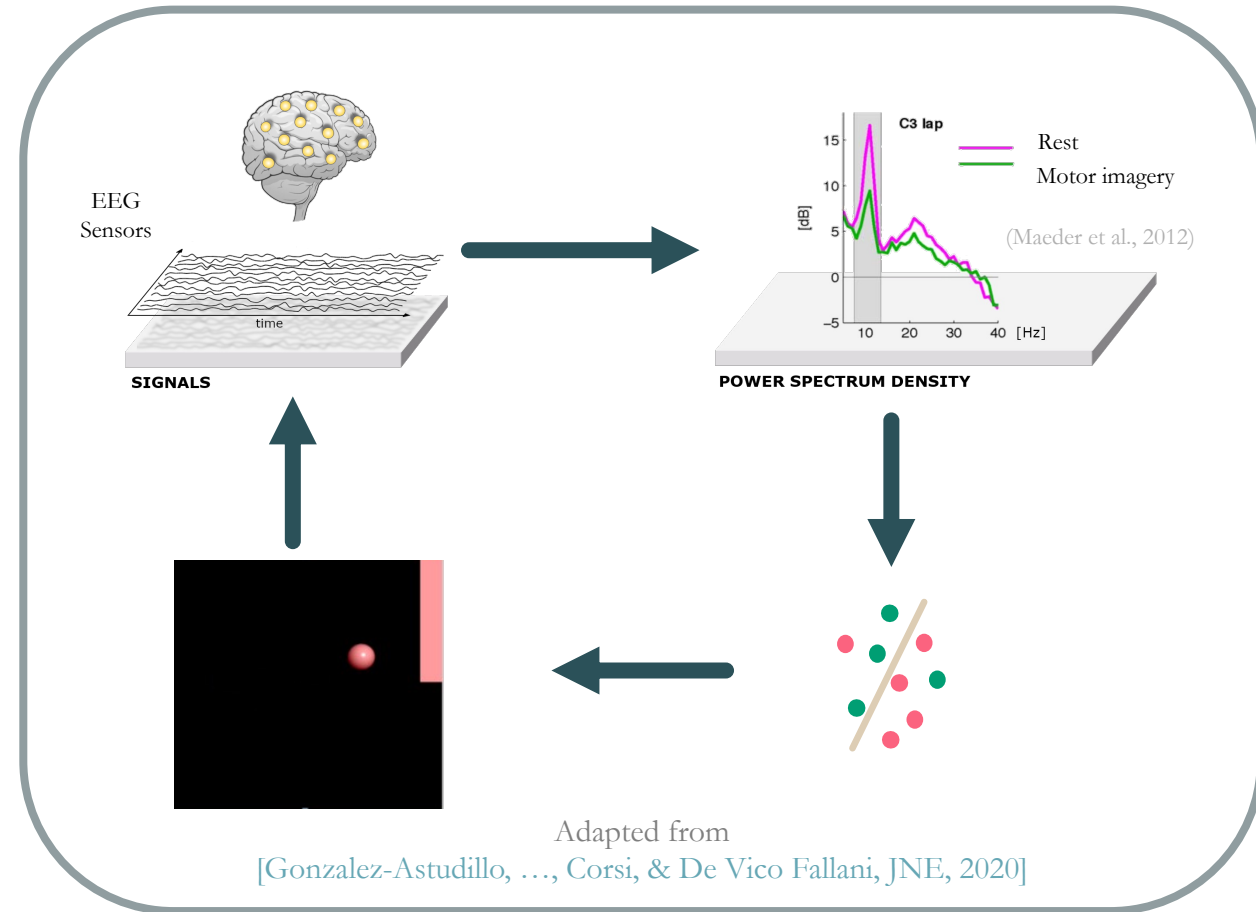
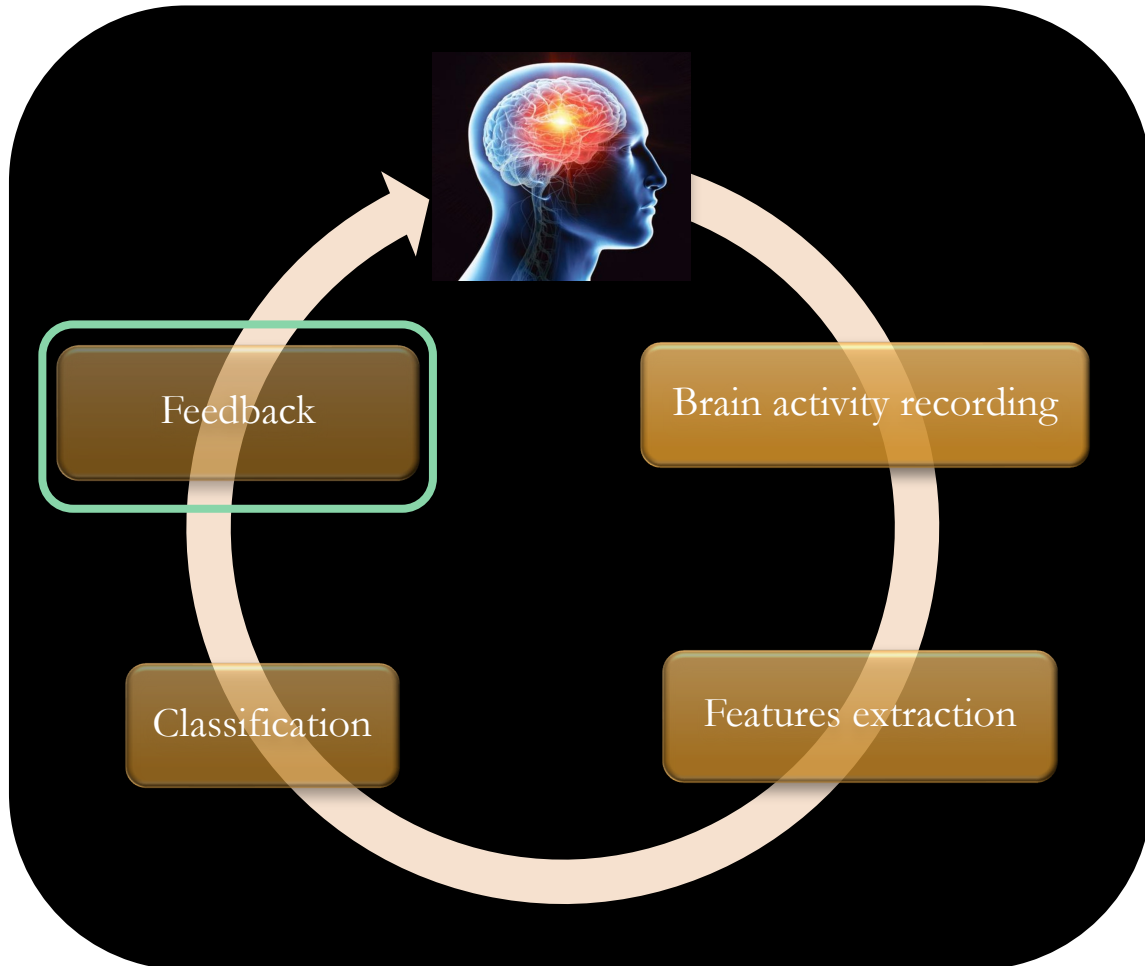
Behind the magic...

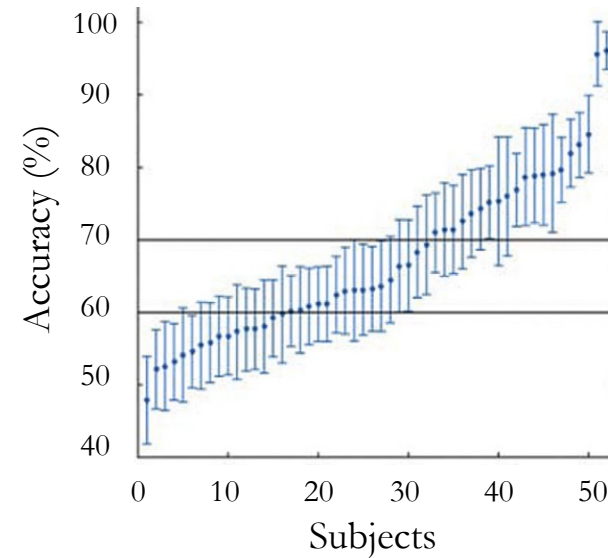
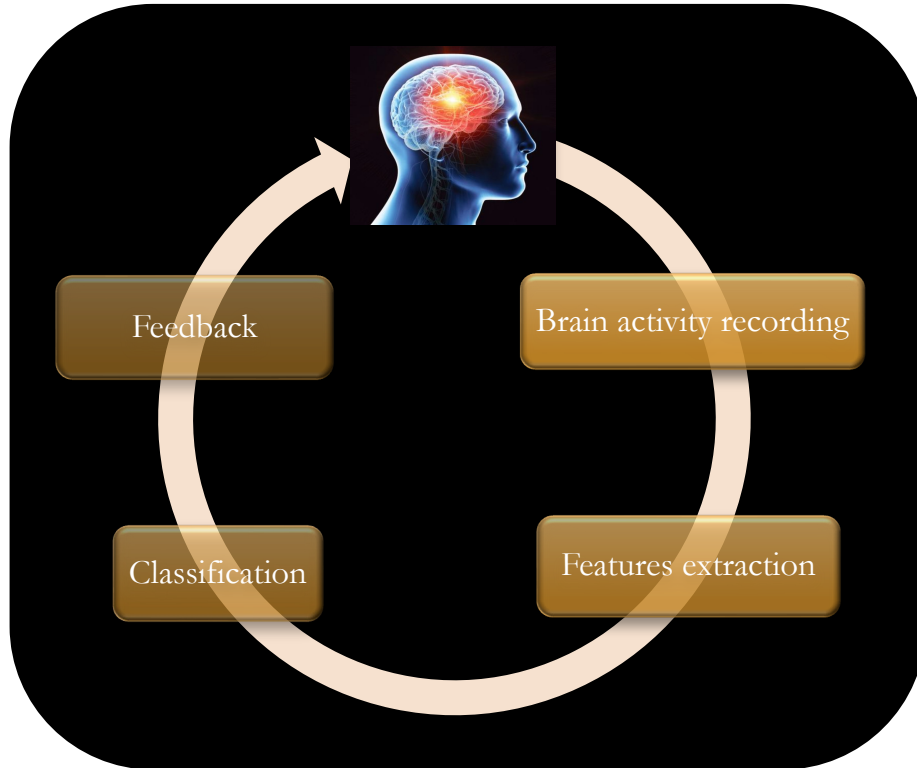


Behind the magic...



Behind the magic...





Adapted from (Ahn & Jun, 2015)

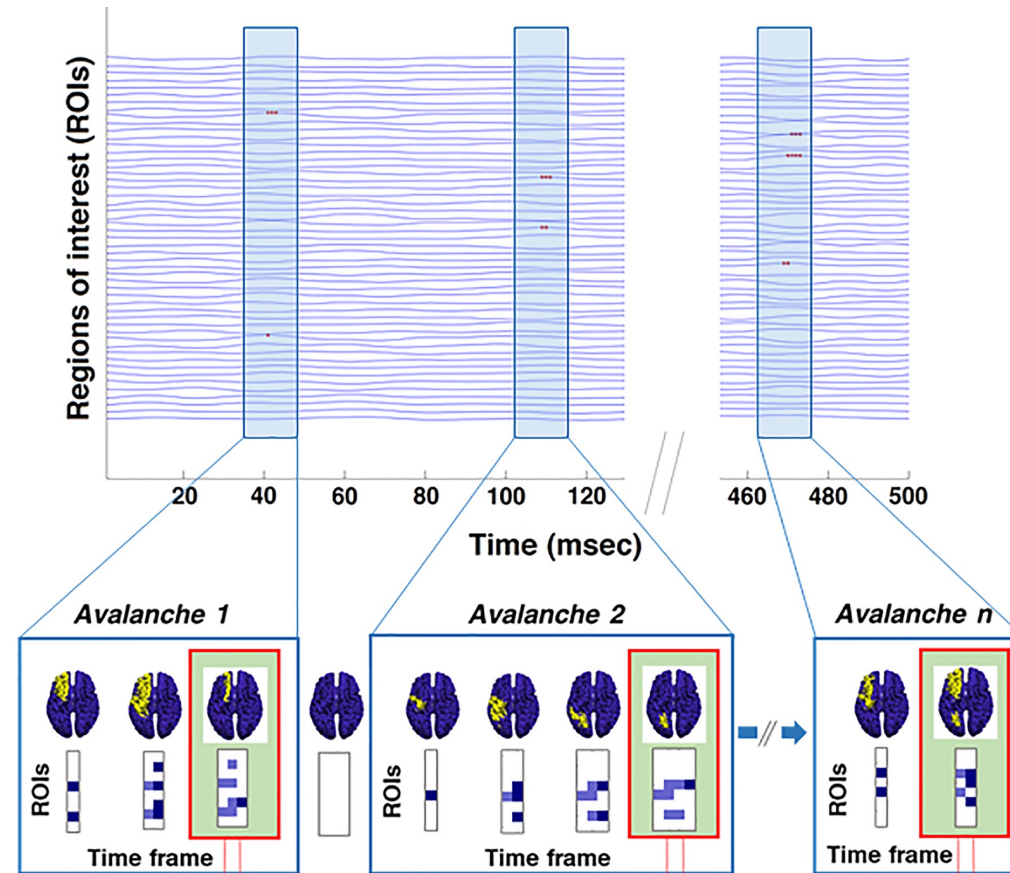
Problem:

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

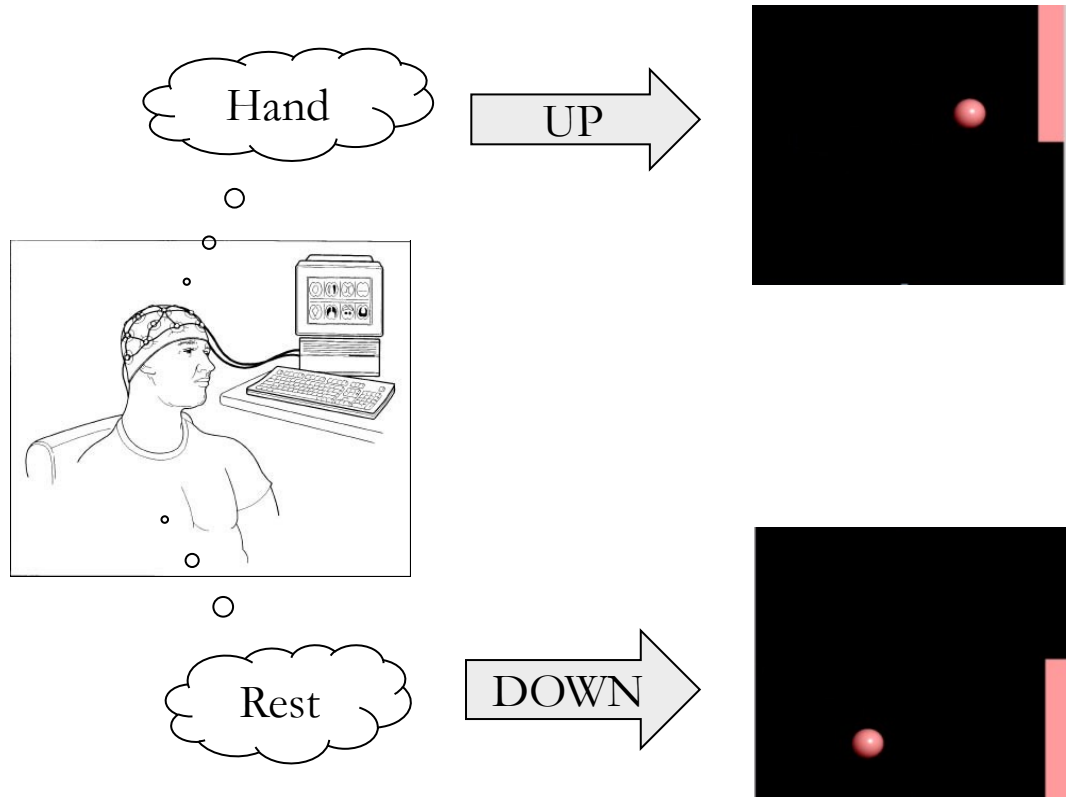
Neuronal avalanches: bursts of enhanced activity observed across neuroimaging modalities



Adapted from [Polverino et al, Neurology, 2022]

Hypothesis:

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

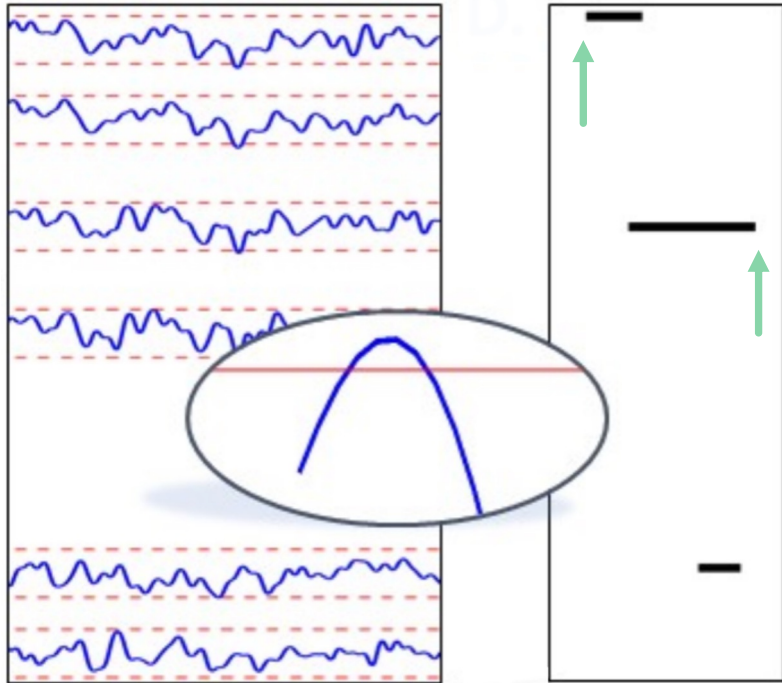


For a complete description of the protocol and the dataset, please refer to [\[Corsi et al, NeuroImage, 2020\]](#)

Objective:

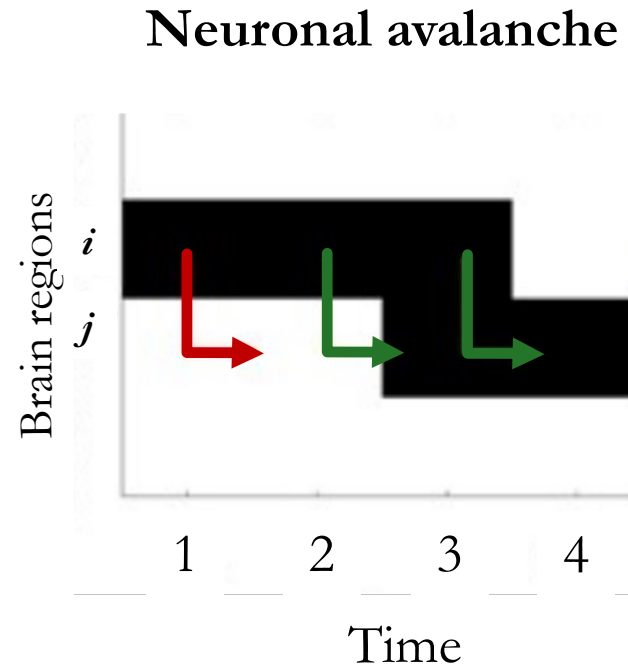
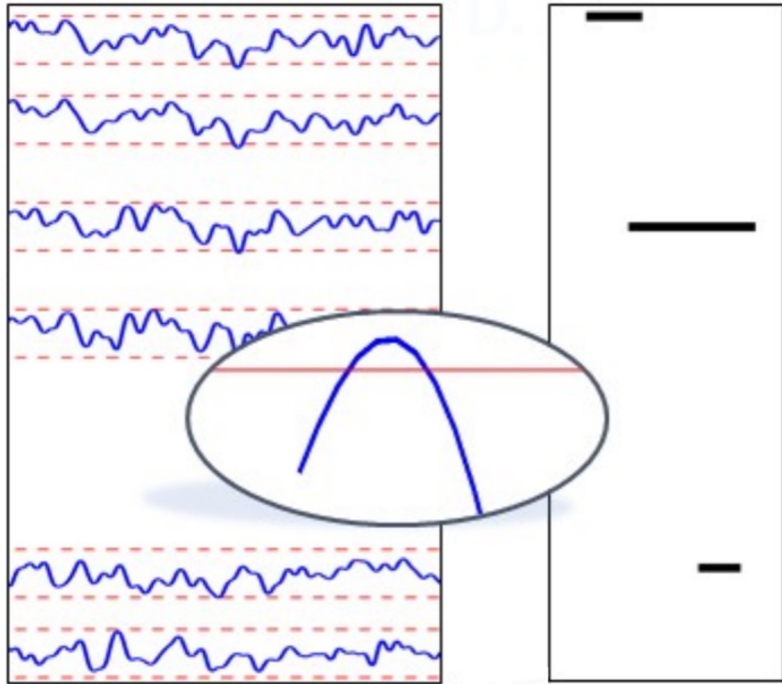
Tracking the dynamical features related to motor imagery as compared to rest

Differences in transition probabilities discriminate mental states

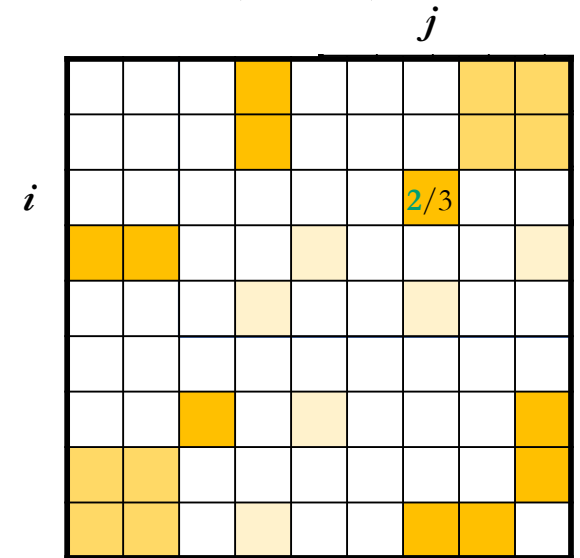


Adapted from [Sorrentino et al, eLife, 2021]





Avalanche Transition Matrix (ATM)

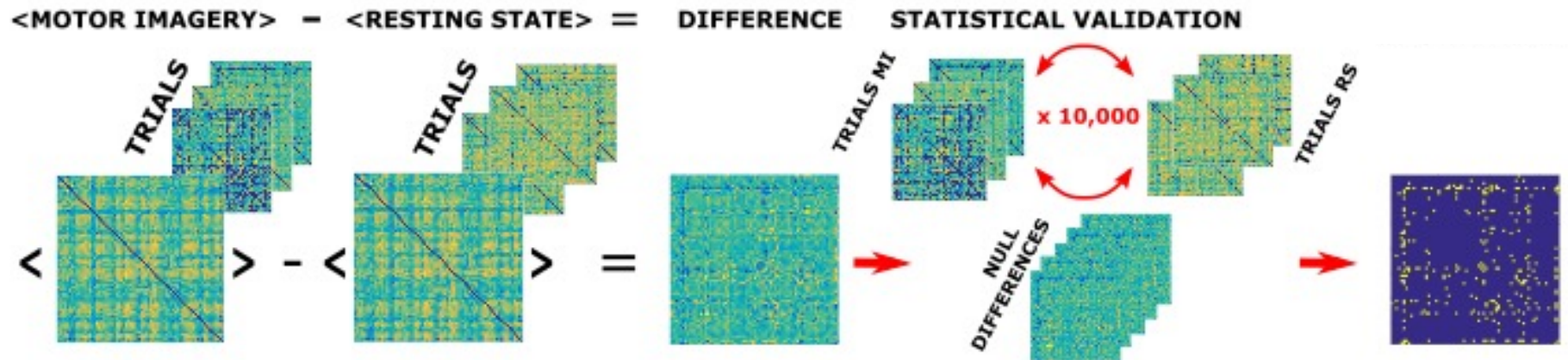


Adapted from [Sorrentino et al, eLife, 2021]

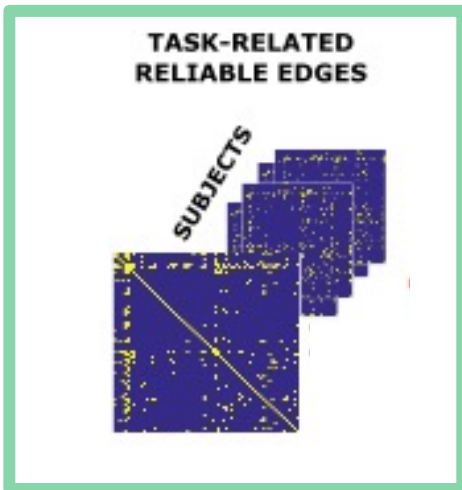


Differences in transition probabilities discriminate mental states

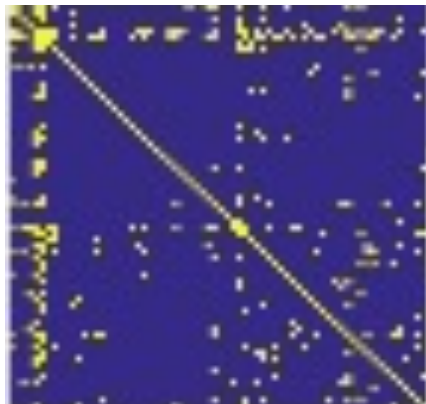
Subject-level



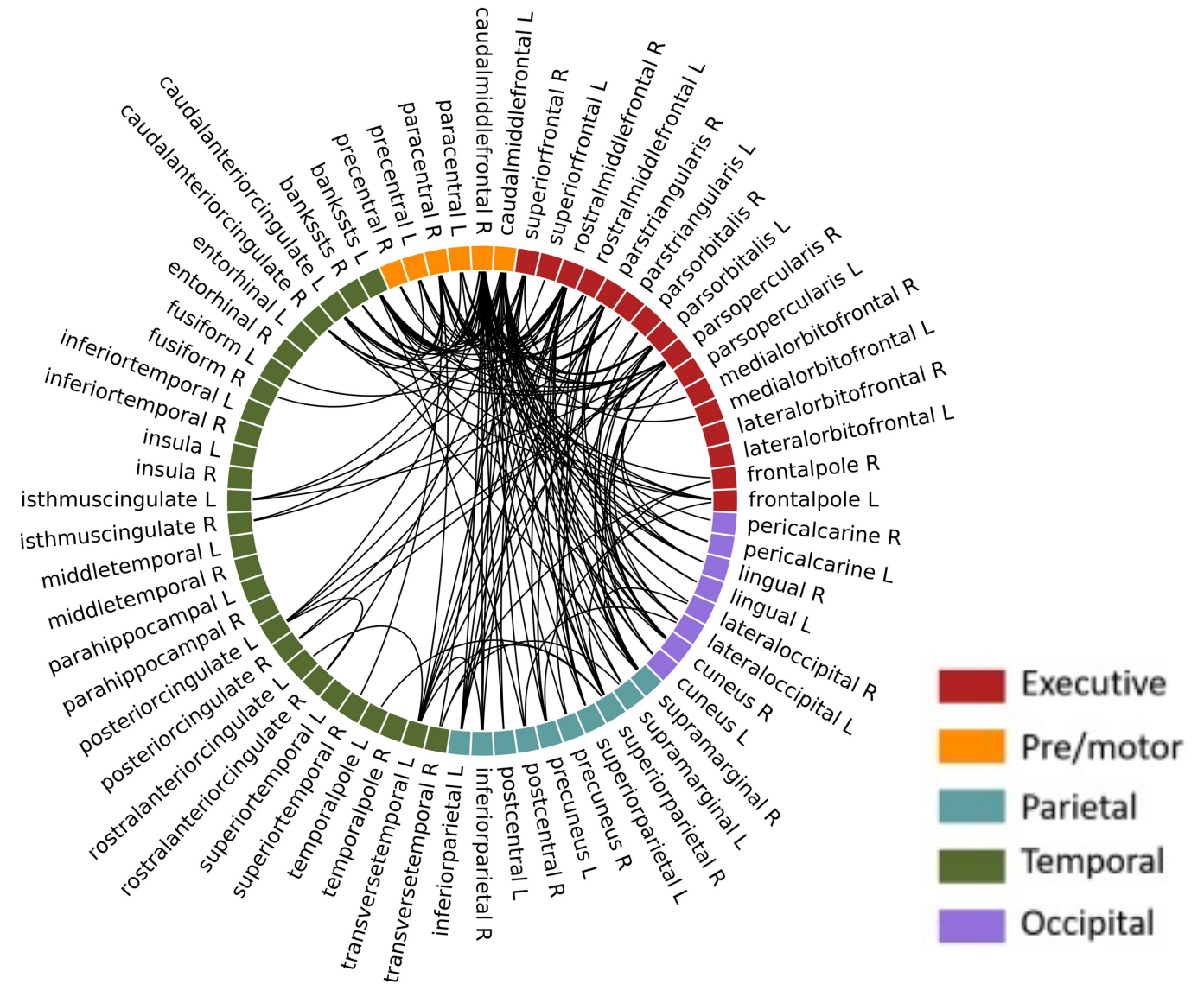
Group-level



Differences in transition probabilities discriminate mental states



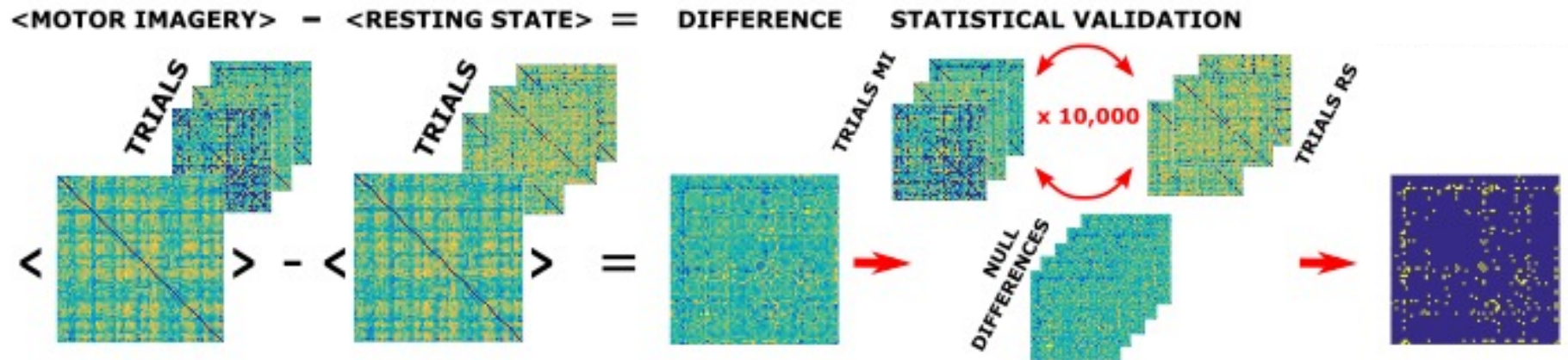
||



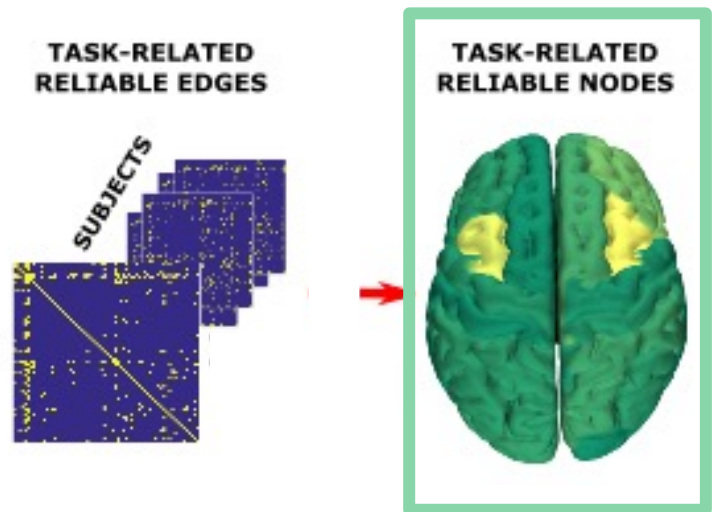
Task-related differences are in edges hinging on pre/motor areas (in most subjects)

Differences in transition probabilities discriminate mental states

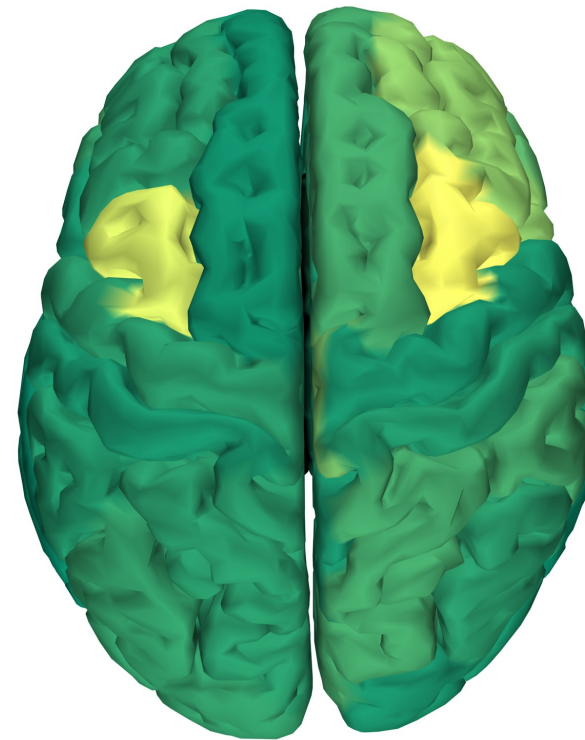
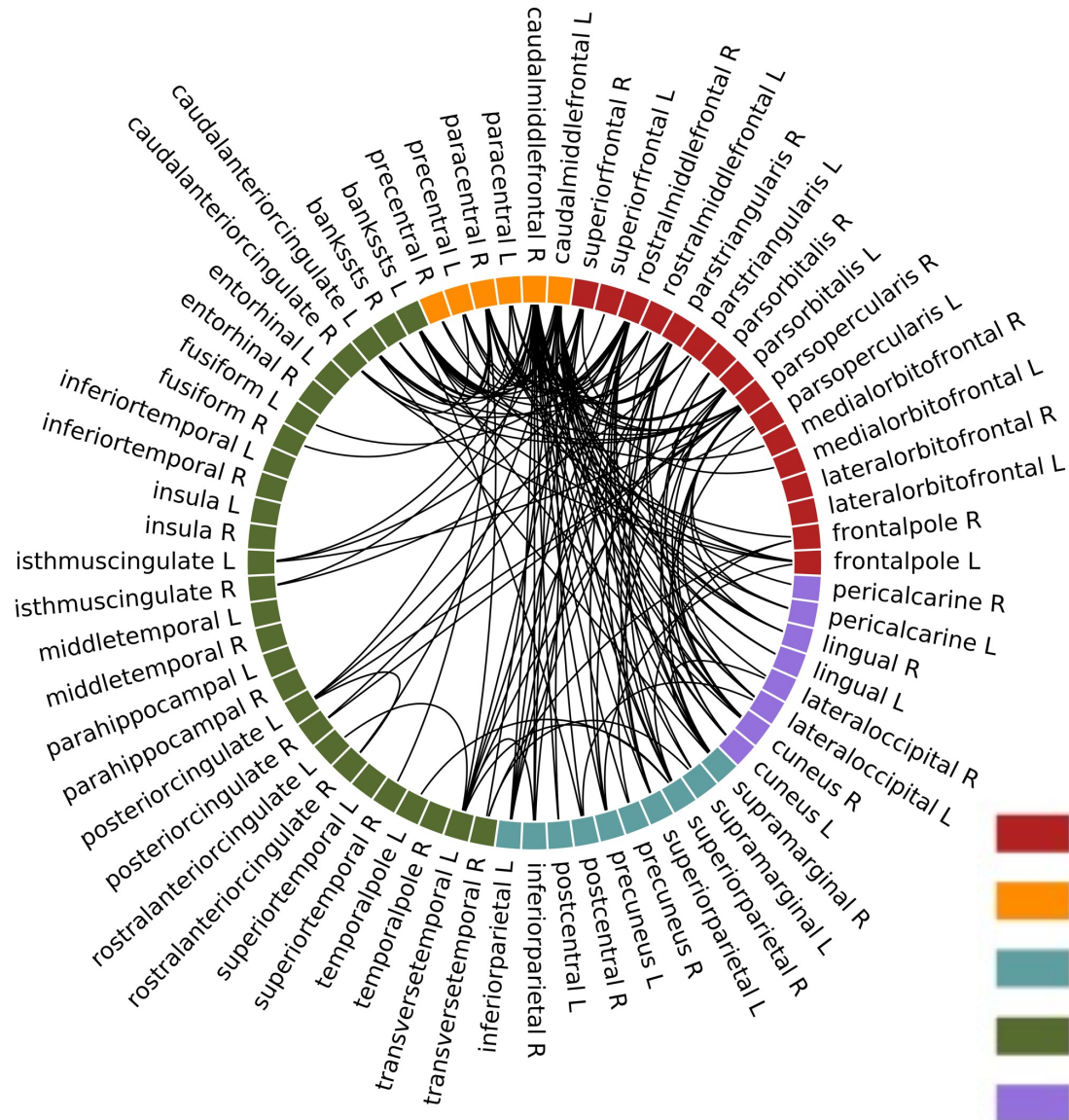
Subject-level

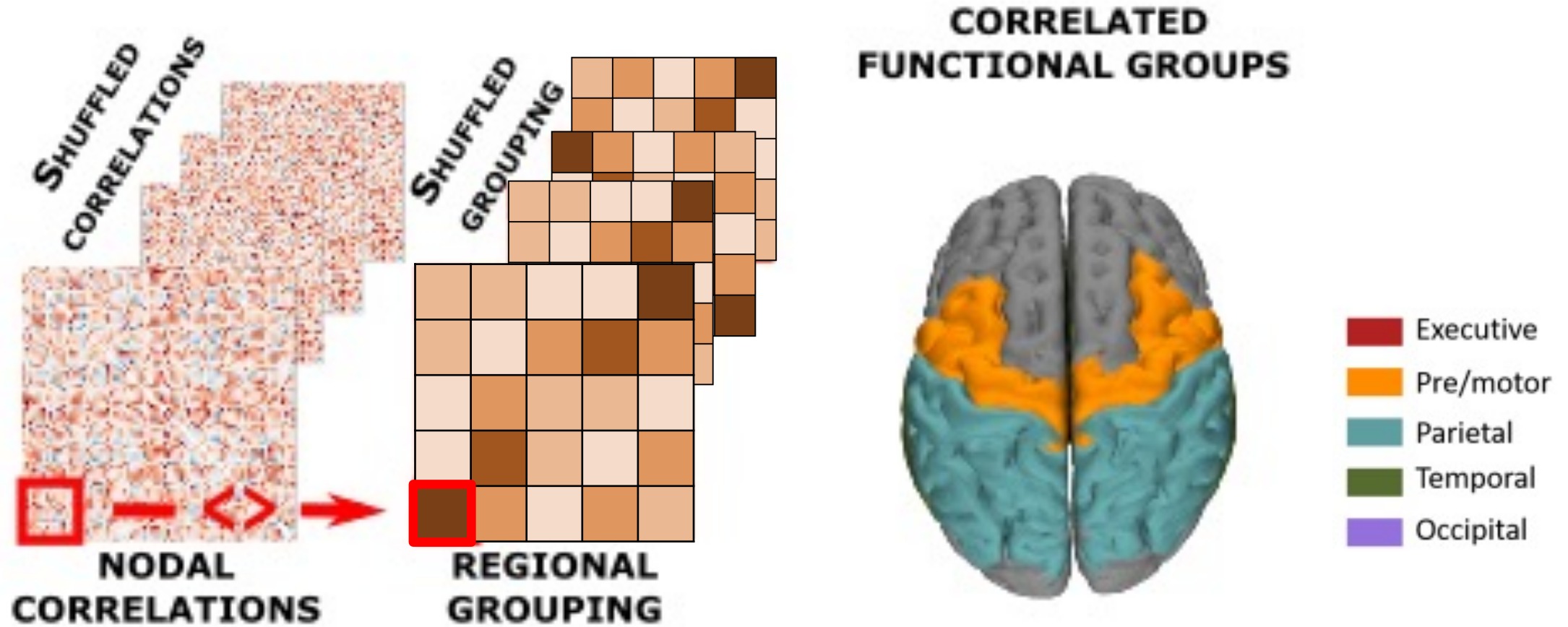


Group-level

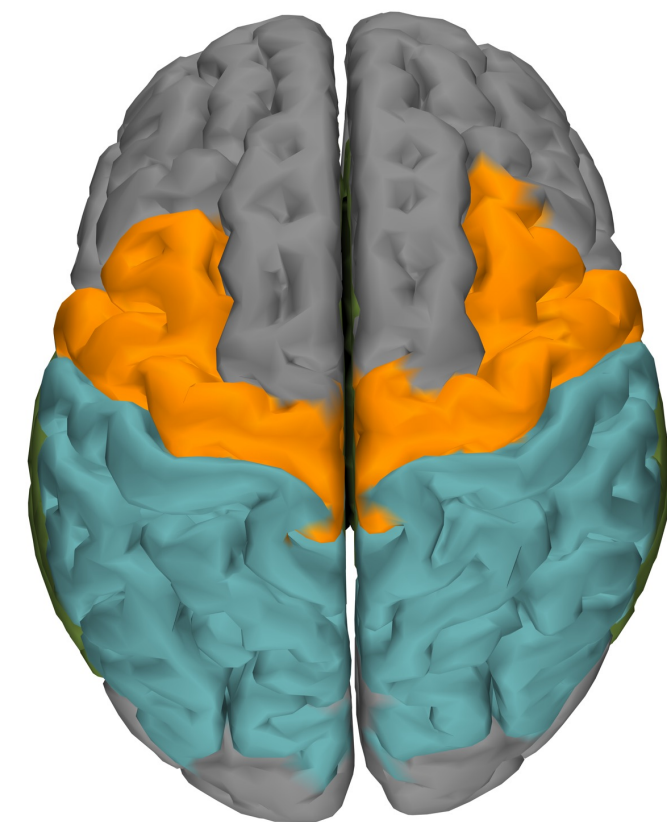
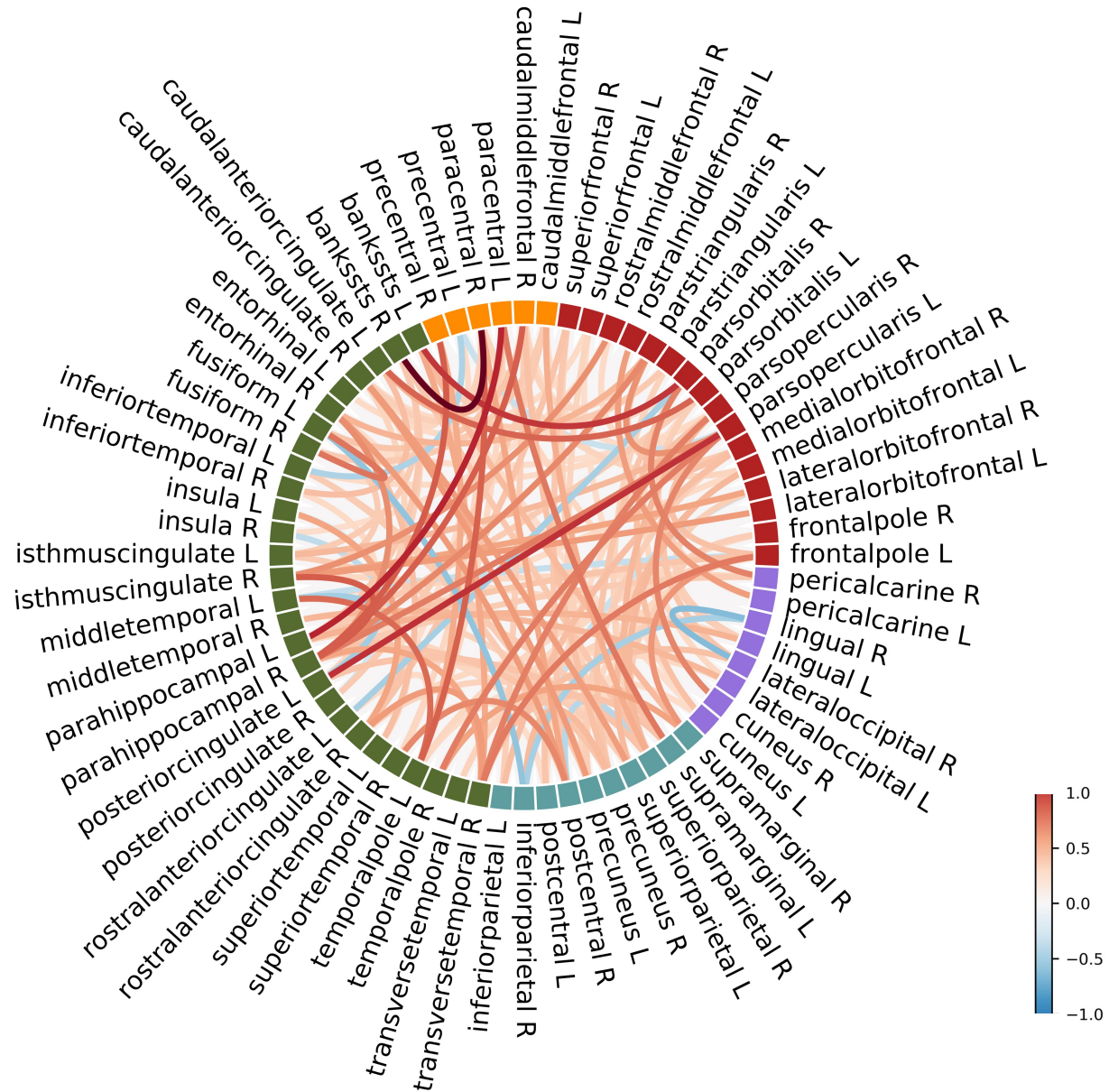


Differences in transition probabilities discriminate mental states



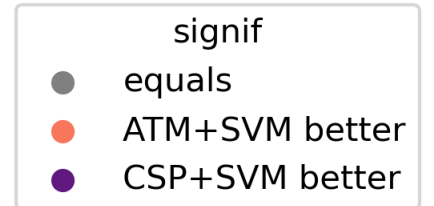
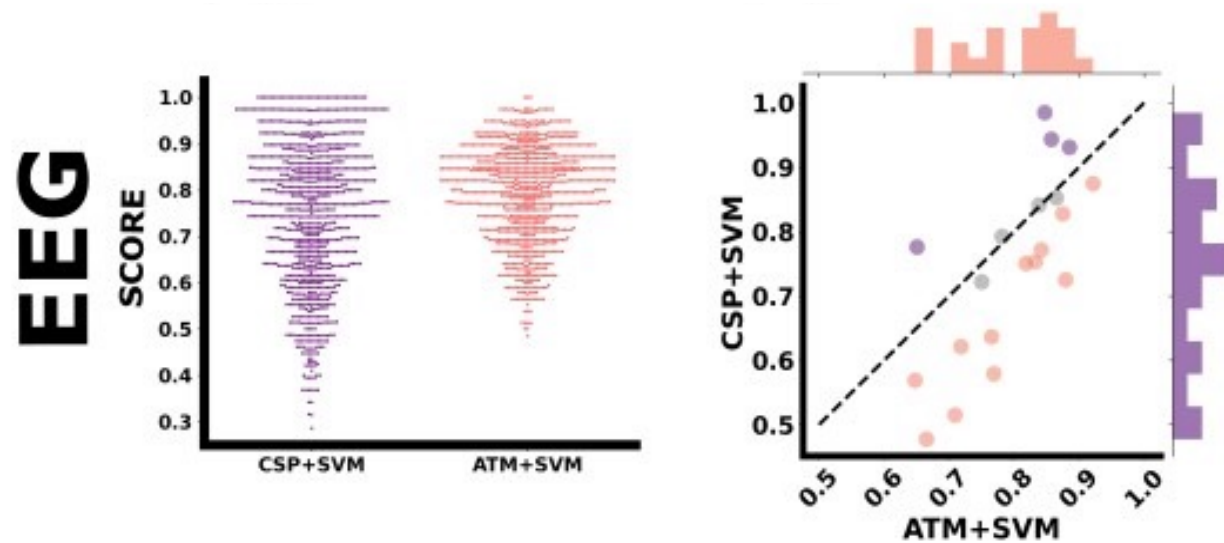
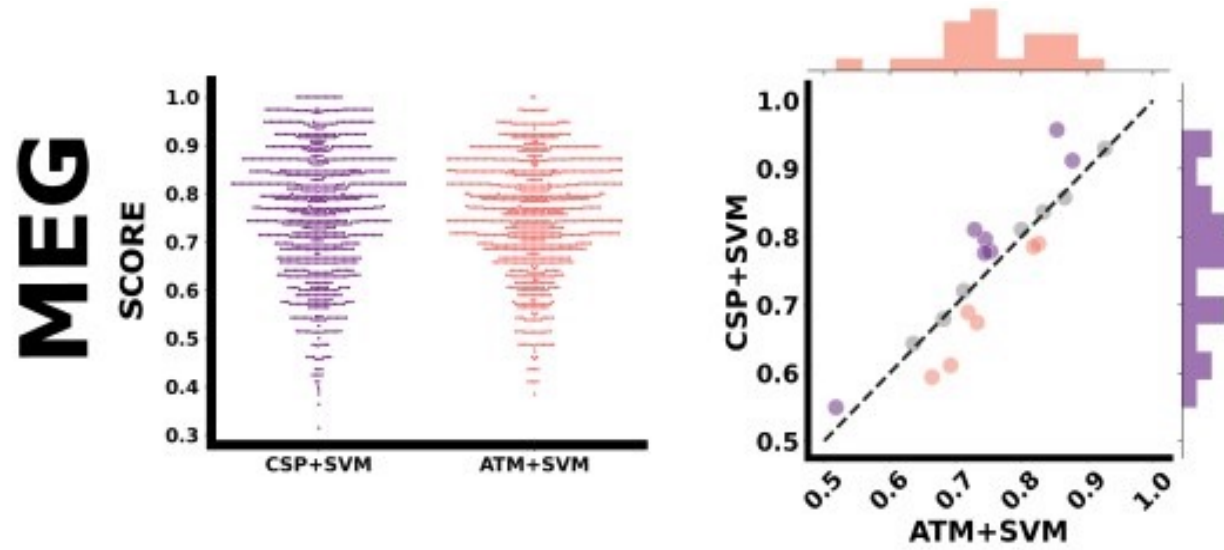


Differences in transition probabilities relate to BCI scores



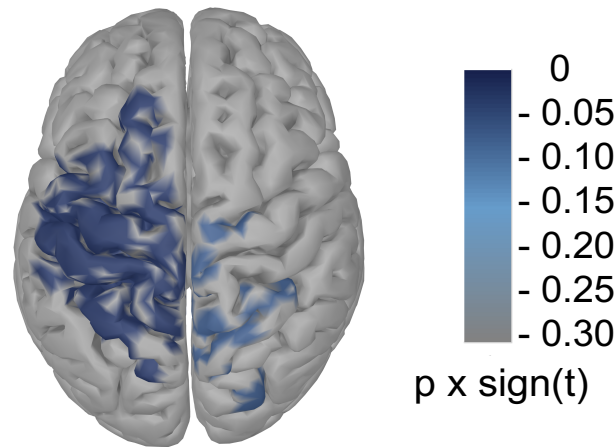
- Executive
- Pre/motor
- Parietal
- Temporal
- Occipital

Transition probabilities as alternative features for BCI

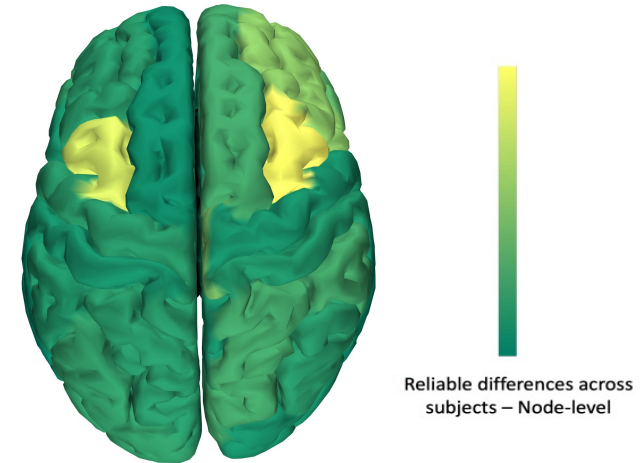


Reliable functional information of task performance retrieval

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



Power spectra
significant at **group** level

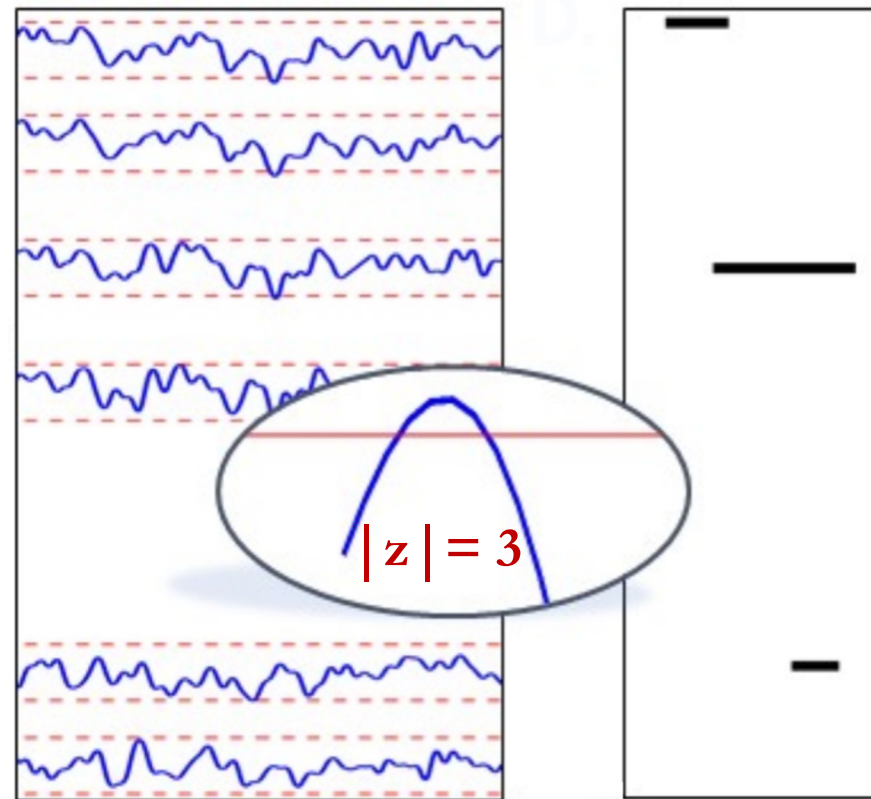


Neuronal avalanches
significant at **individual** level

⇒ 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

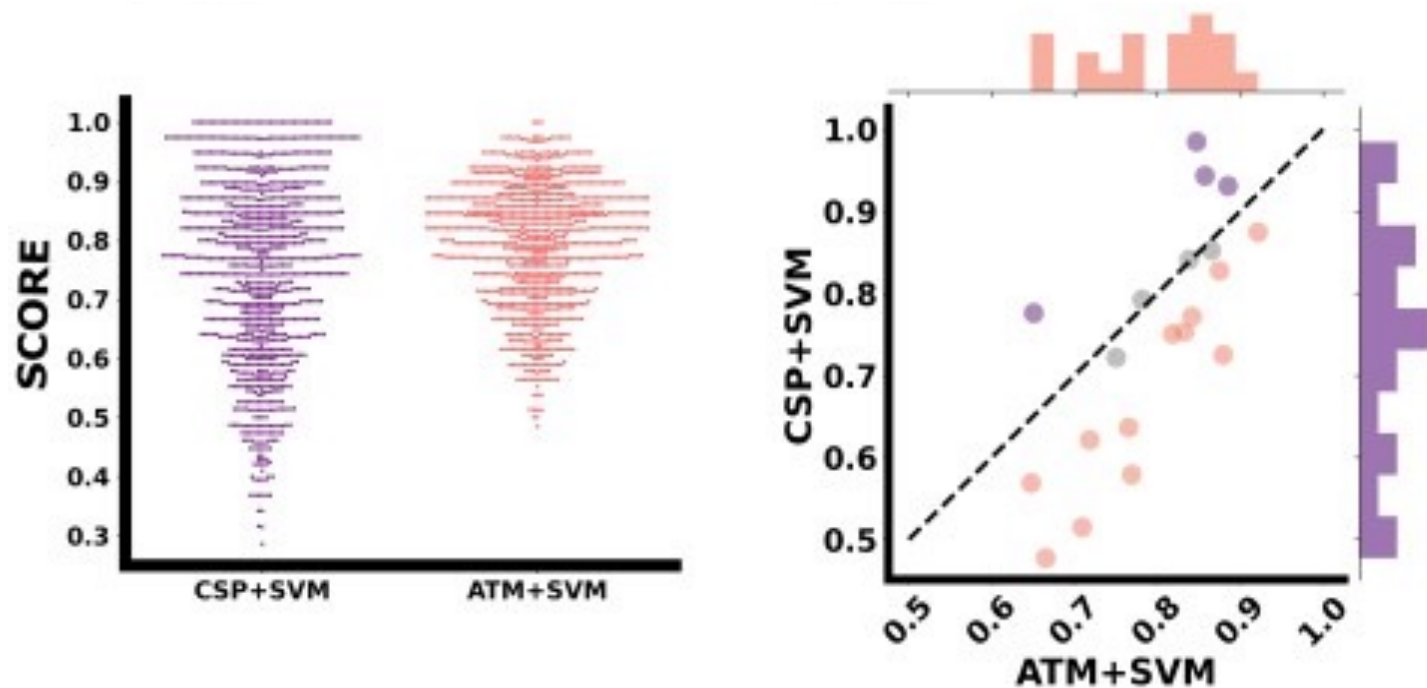


⇒ Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information

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



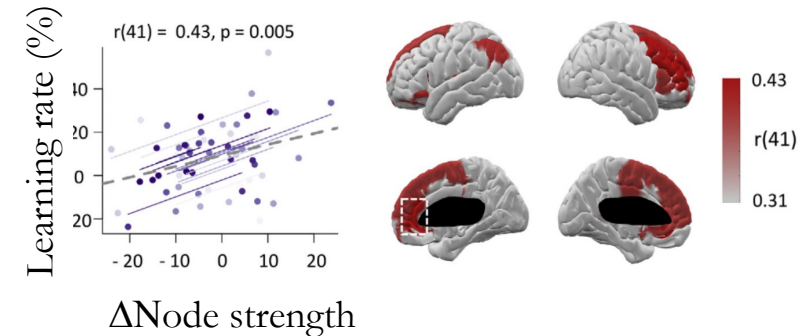
Reliable functional information of task performance retrieval

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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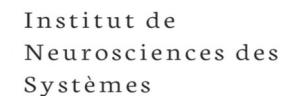
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Interested in this study?

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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