Exploiting brain critical dynamics to inform Brain-Computer Interfaces performance

Marie-Constance Corsi, Pierpaolo Sorrentino, Denis P Schwartz, Nathalie George, Laurent Hugueville, Ari E Kahn, Sophie Dupont, Danielle S Bassett, Viktor K Jirsa, Fabrizio de Vico Fallani

Brain criticality 2022

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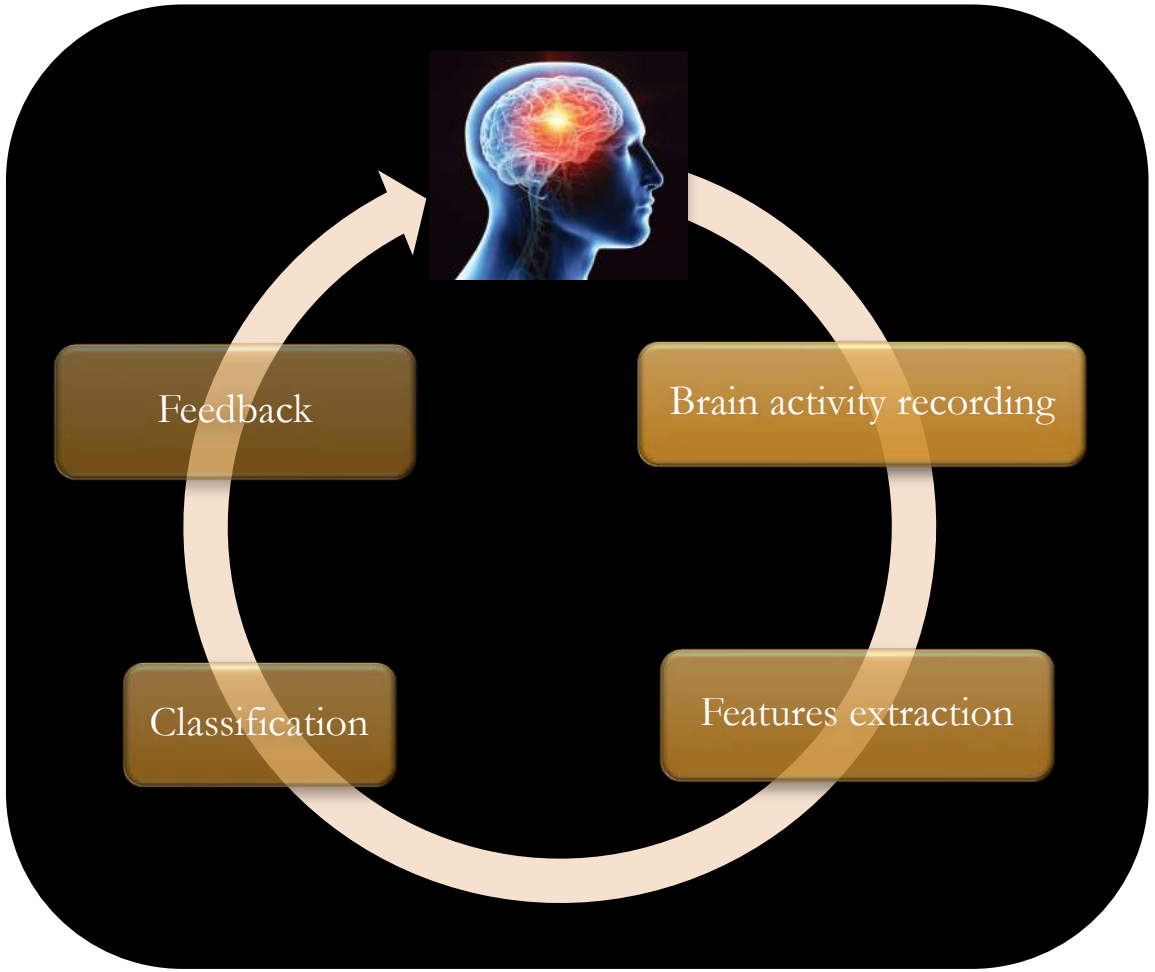
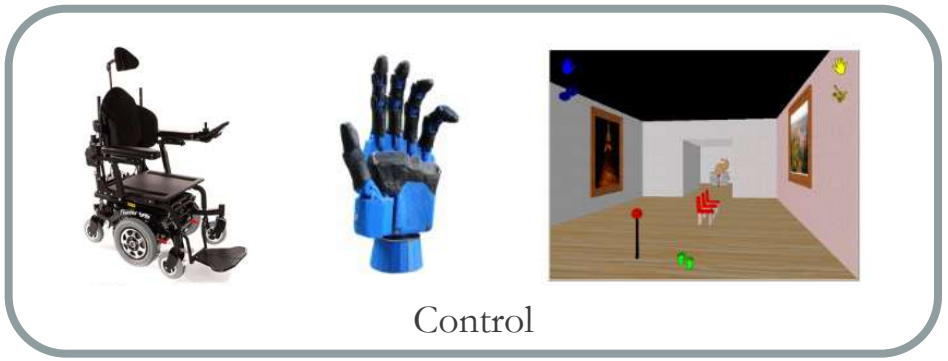
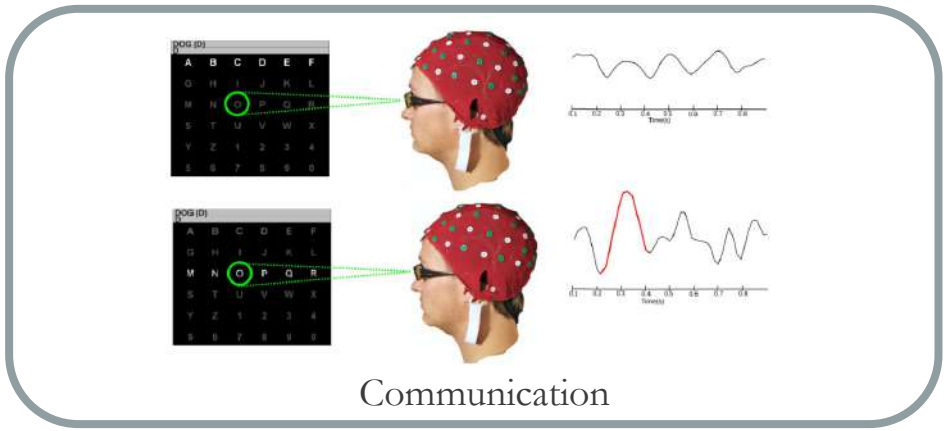
Brain-Computer Interface (BCI) – behind the magic…



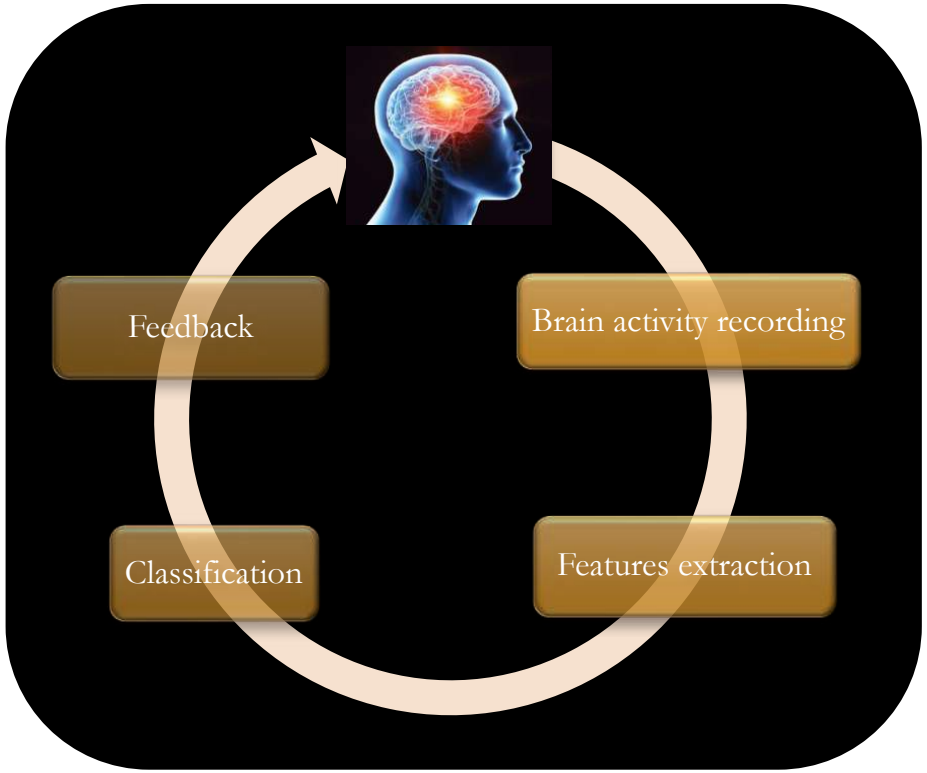
BCI framework

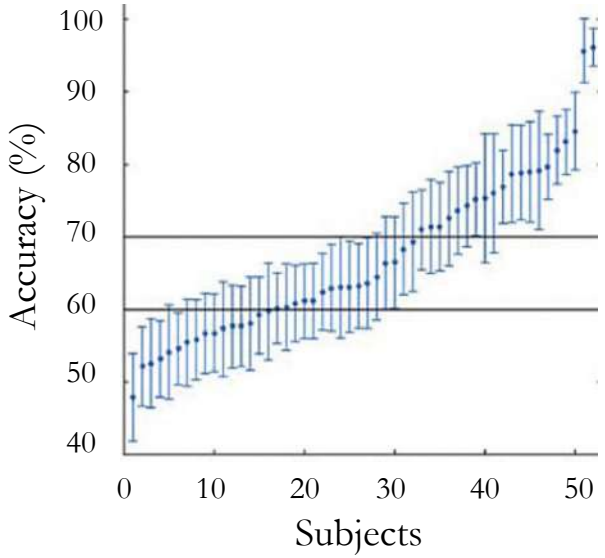




Adapted from (Lotte et al, 2015)

Brain-Computer Interface (BCI) – current challenges





Adapted from (Ahn & Jun, 2015)

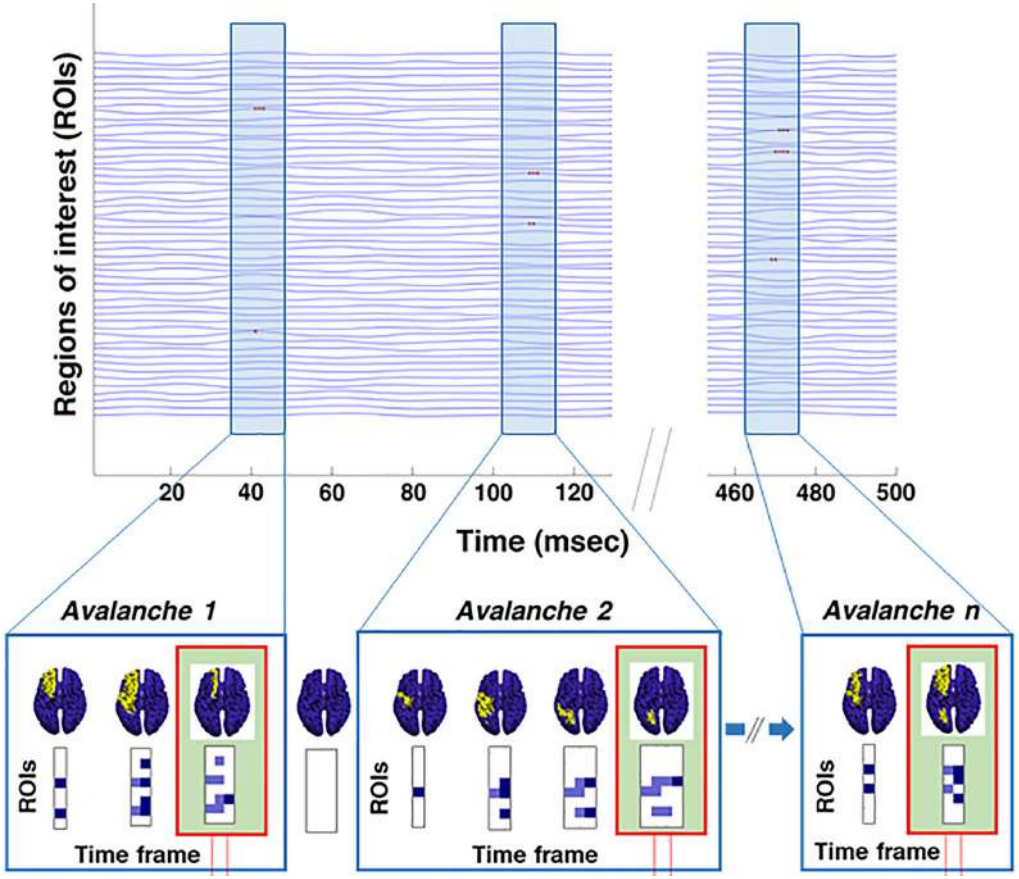
Problem:

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

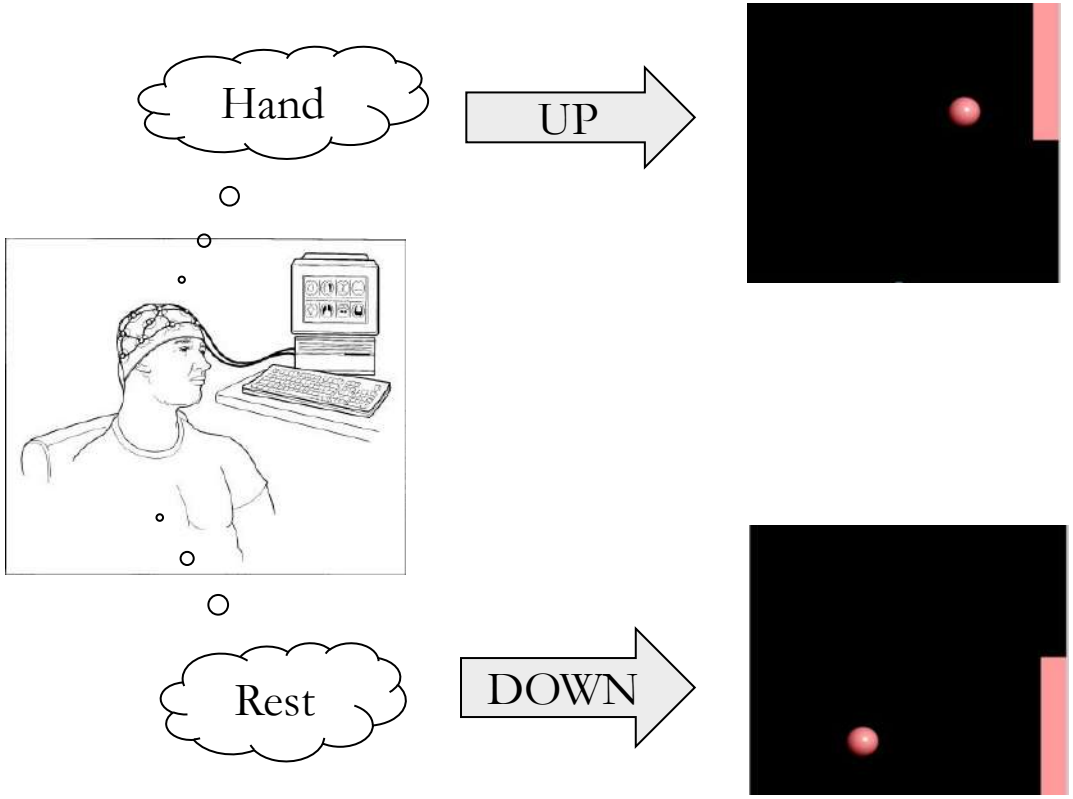


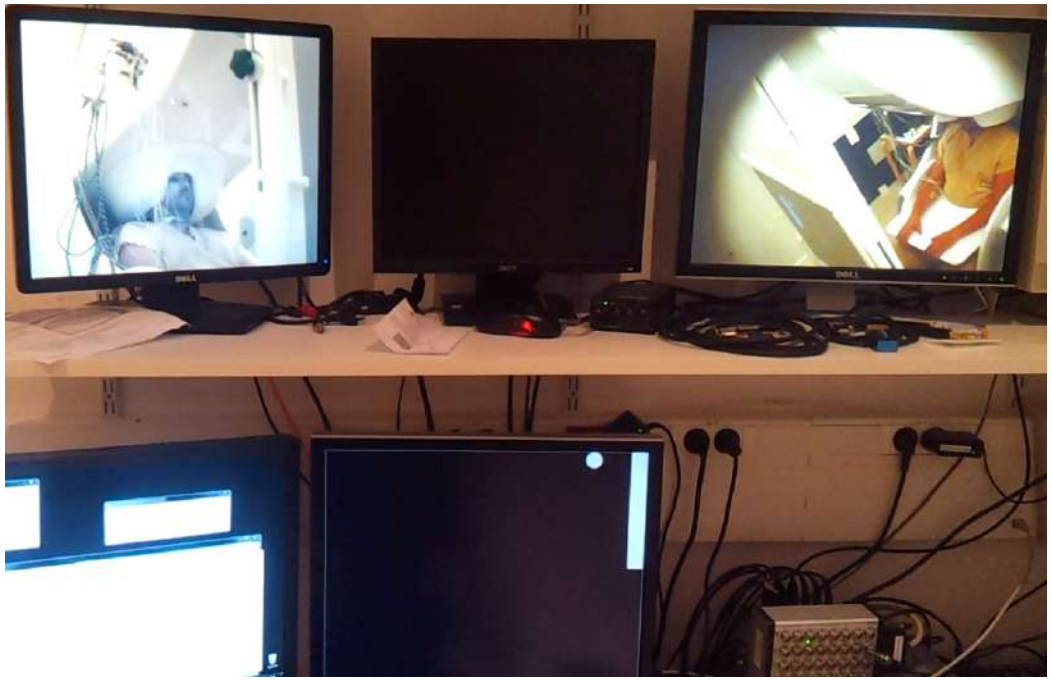
Adapted from [Polverino et al, Neurology, 2022]

Hypothesis:

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

BCI experiment



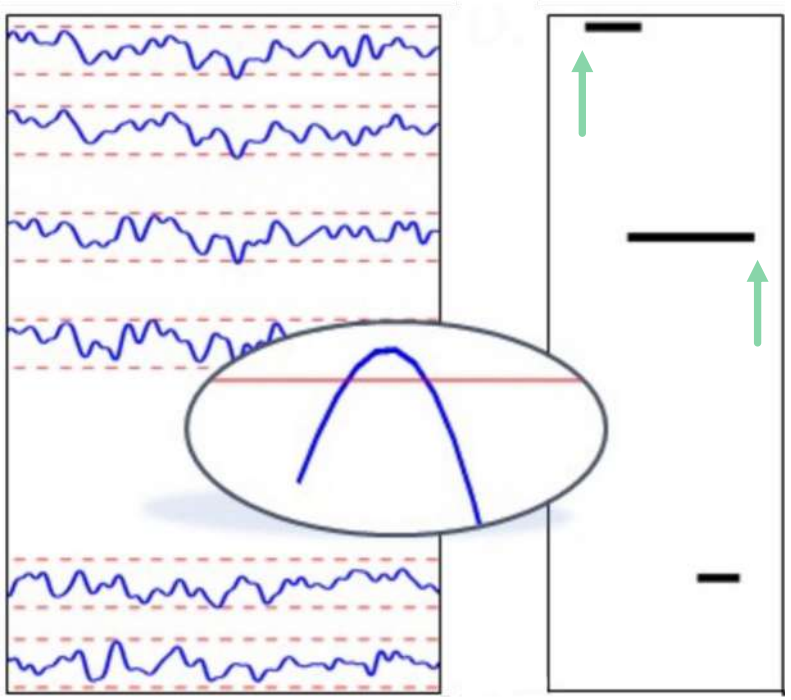


For a complete description of the protocol and the dataset, please refer to [Corsi et al, NeuroImage, 2020]

Objective:

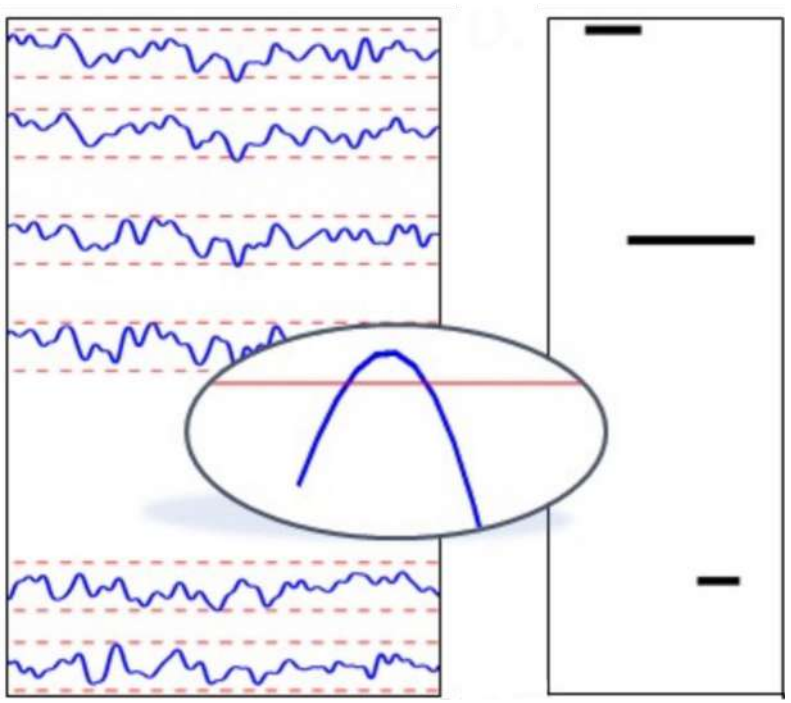
Tracking the dynamical features related to motor imagery as compared to rest

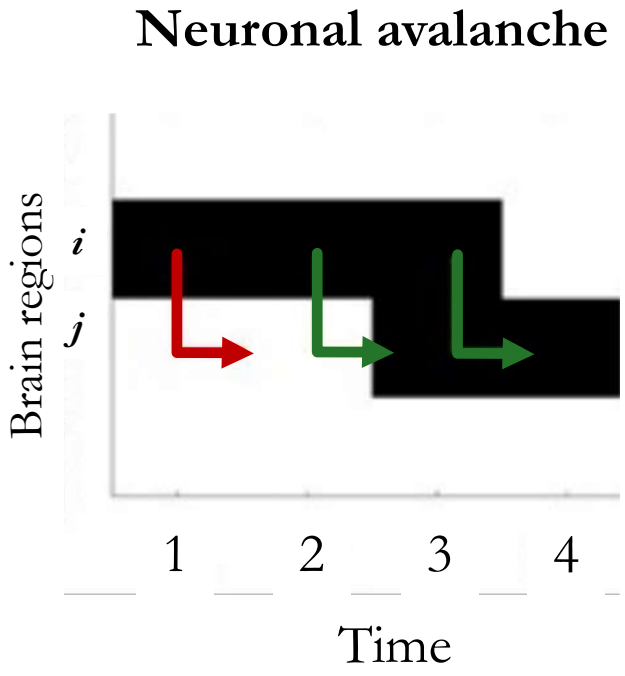
Differences in transition probabilities discriminate mental states

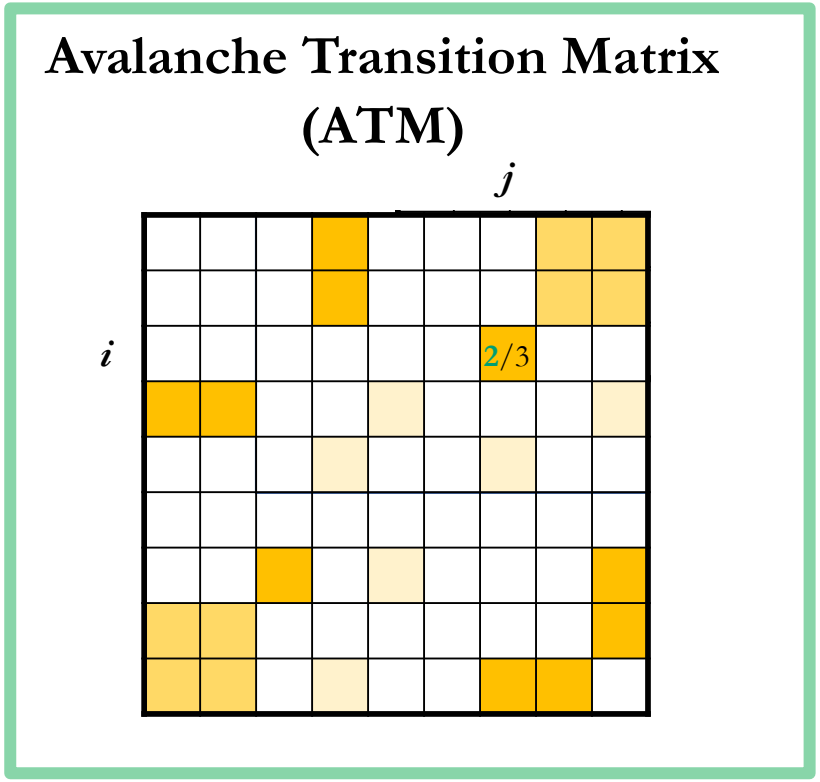


Adapted from [Sorrentino et al, eLife, 2021]

Differences in transition probabilities discriminate mental states







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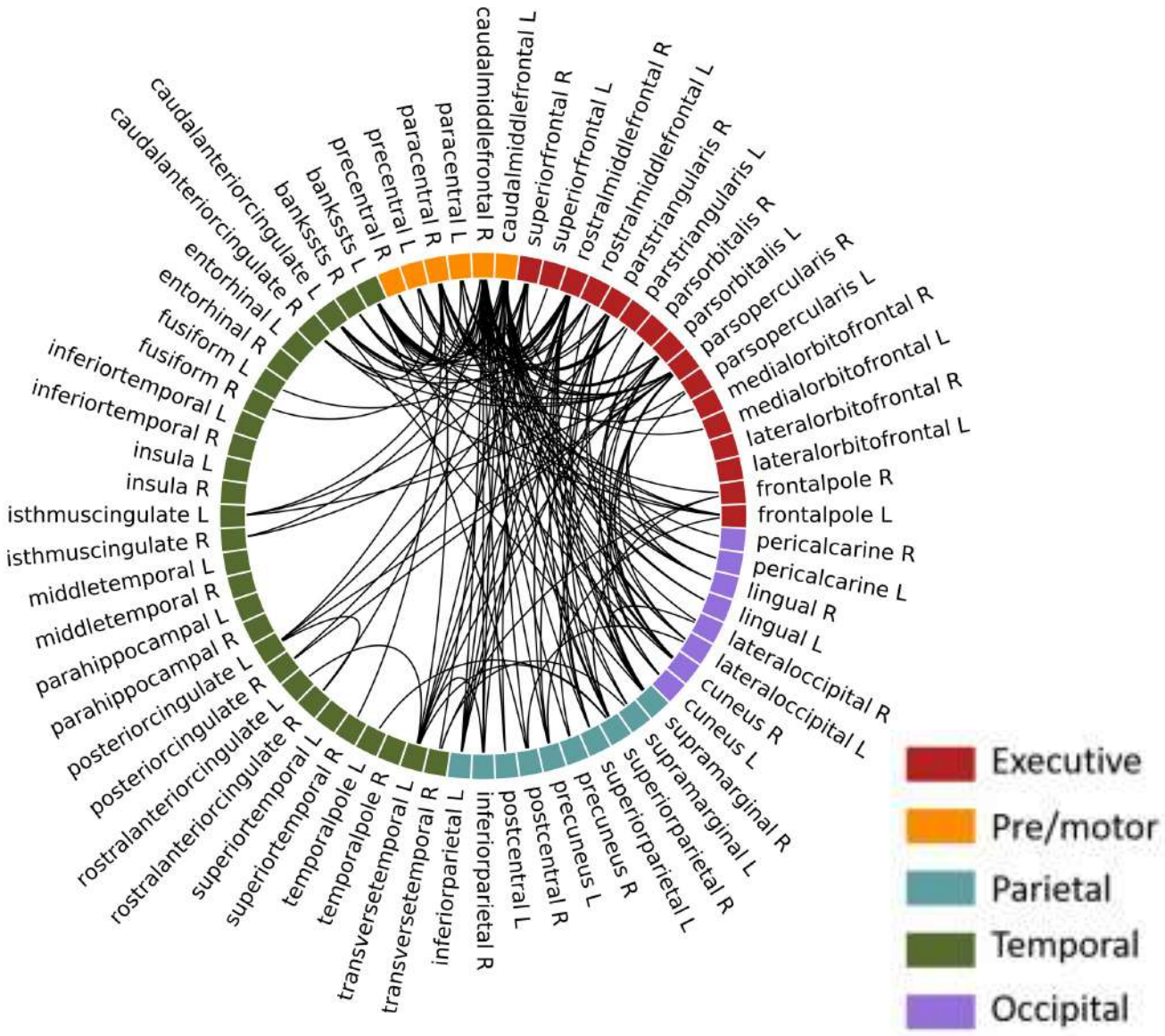
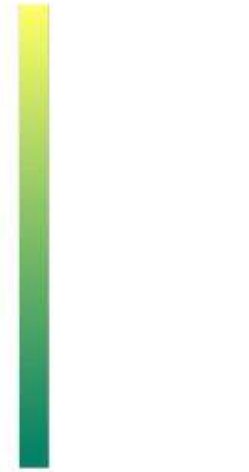
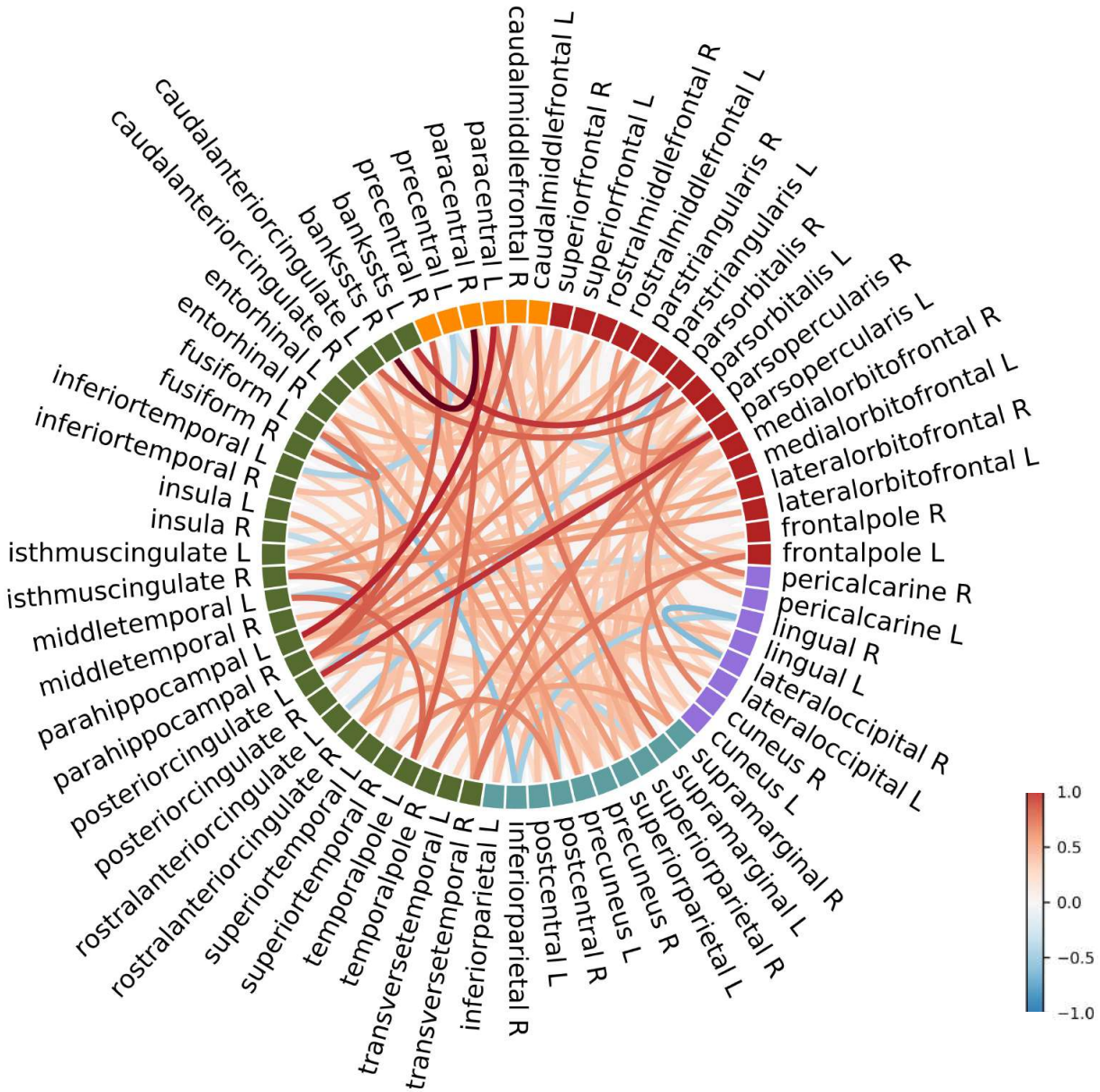
Differences in transition probabilities discriminate mental states





Reliable differences across subjects – Node-level

Differences in transition probabilities relate to BCI scores

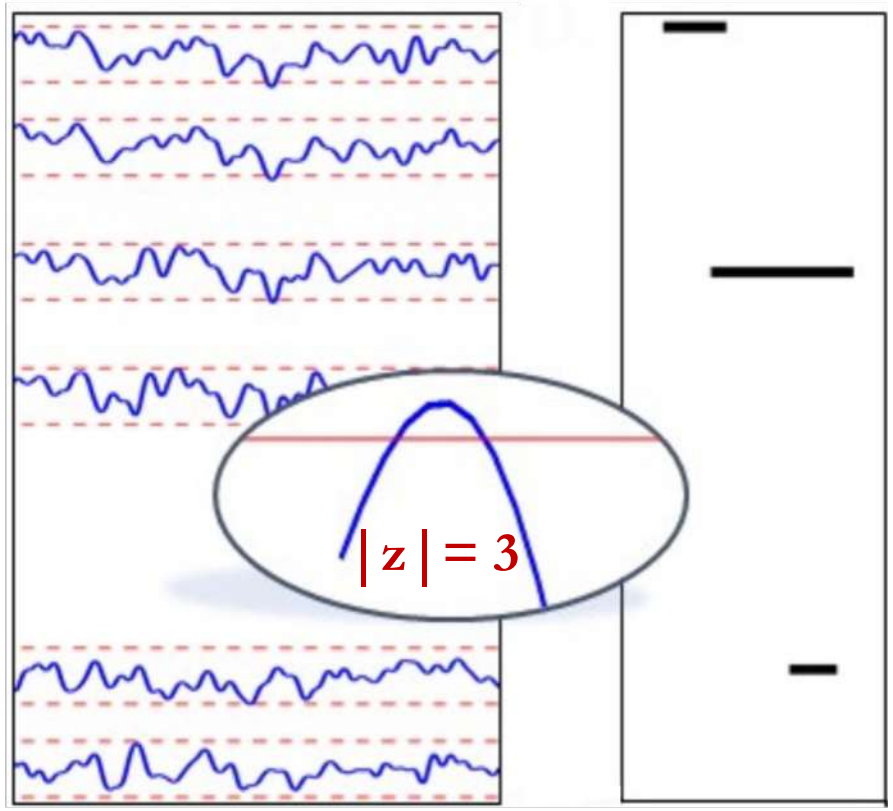


Executive
Pre/motor
Parietal
Temporal
Occipital

Discussion

Reliable functional information of task performance retrieval

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

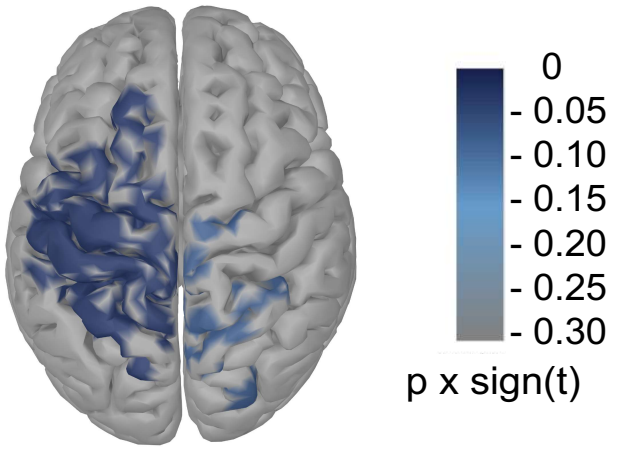


⇒ **Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information**

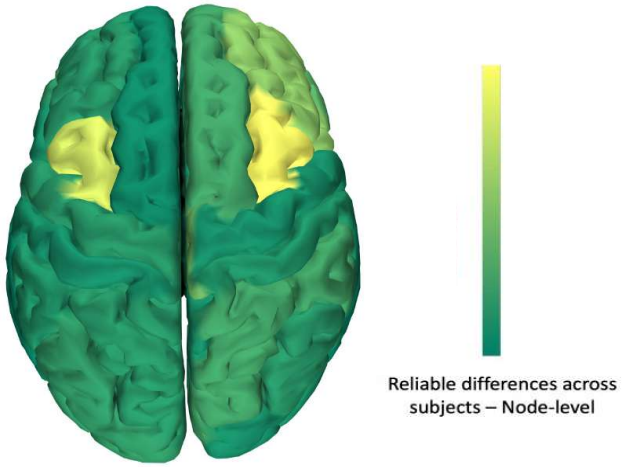
Discussion

Reliable functional information of task performance retrieval

- 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**

Discussion

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

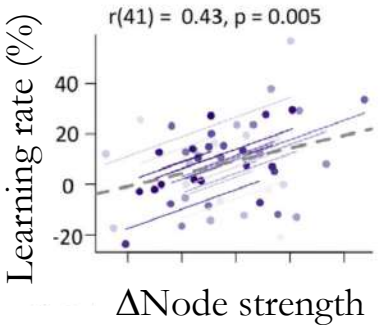
Markers of BCI performance

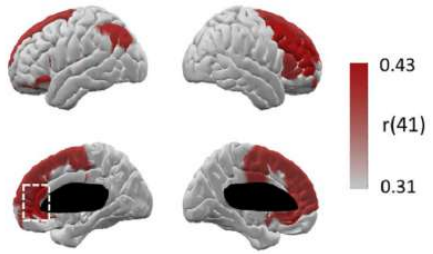
- Current predictors of BCI
  - Local measurements – power spectra (Ahn et al, 2015)
  - Time-averaged interactions (Sugata et al, 2014)
  - Brain networks metrics [Corsi et al, NeuroImage 2020; Corsi et al, JNE 2021]

Replicability?

Online implementation?

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





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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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