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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

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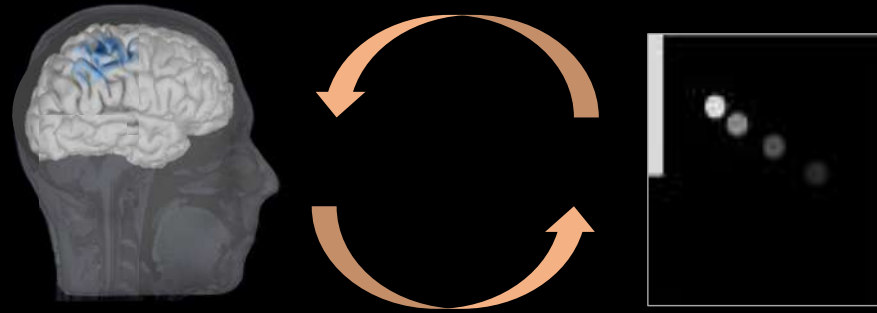
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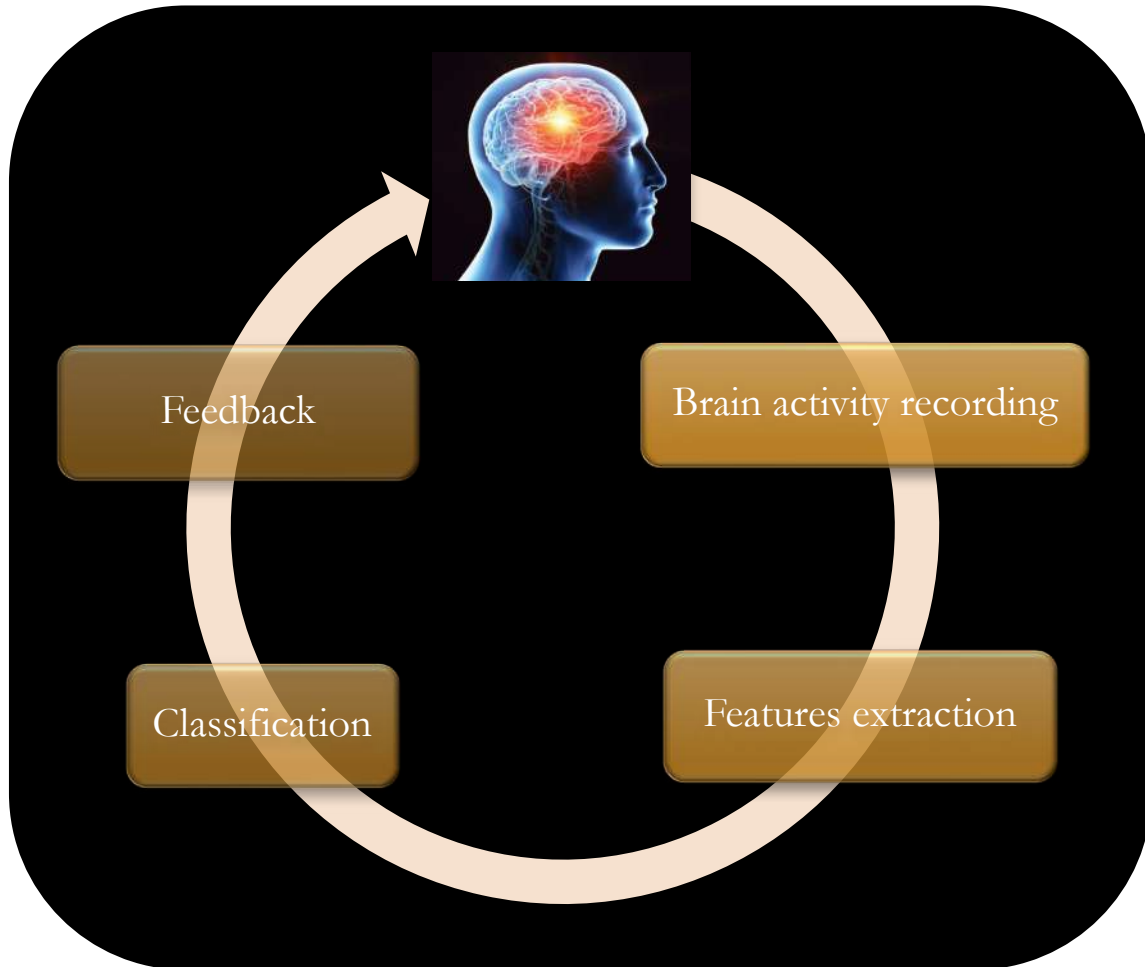
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Exploiting brain critical dynamics to inform
Brain-Computer Interfaces performance

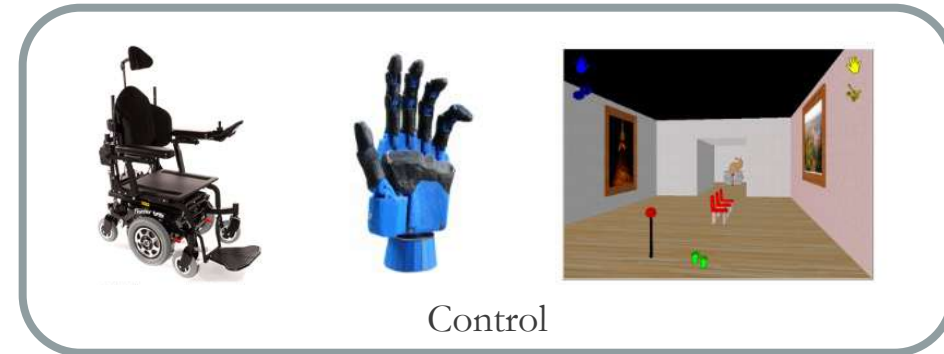


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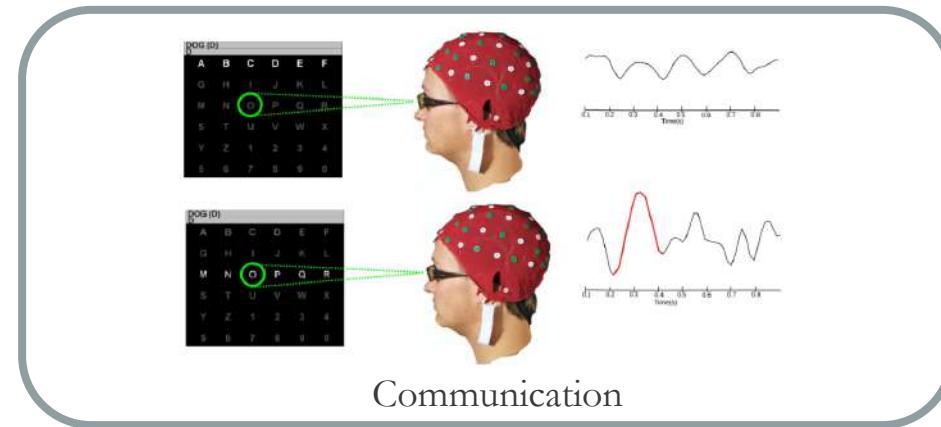
V Jirsa**, F De Vico Fallani**



BCI framework

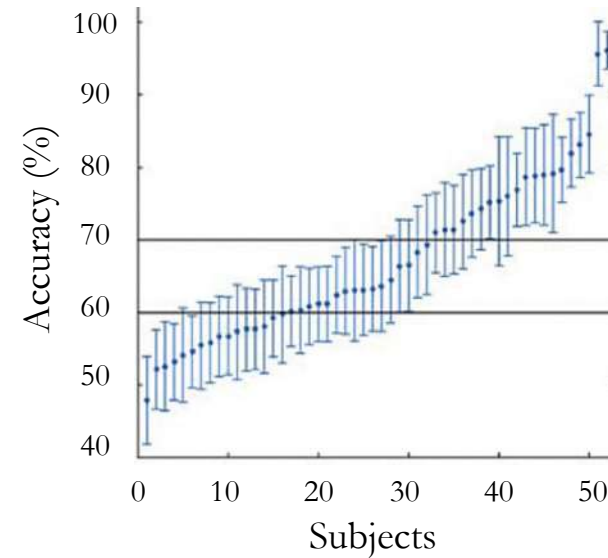
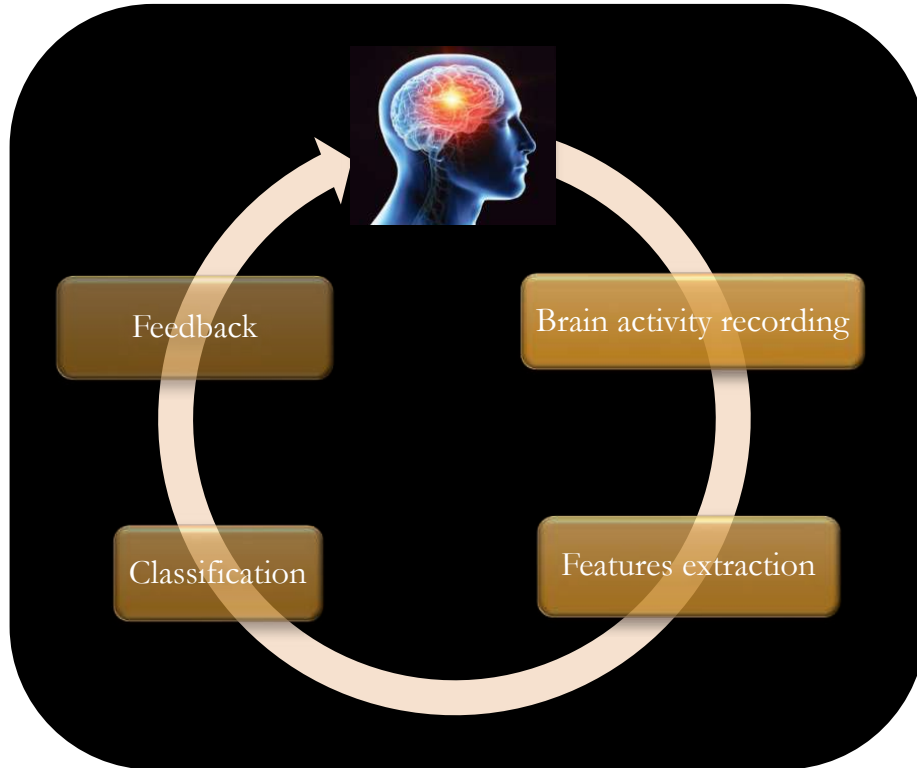


Control



Communication

Adapted from (Lotte et al, 2015)



Adapted from (Ahn & Jun, 2015)

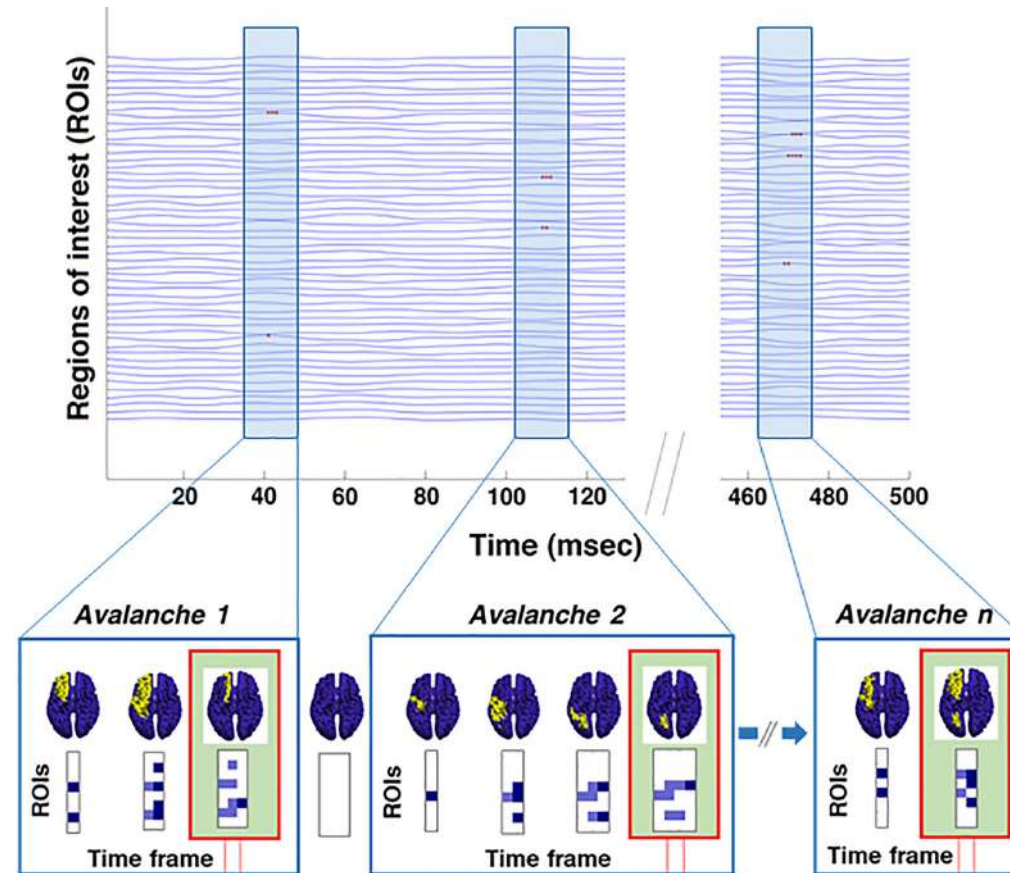
Problem:

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

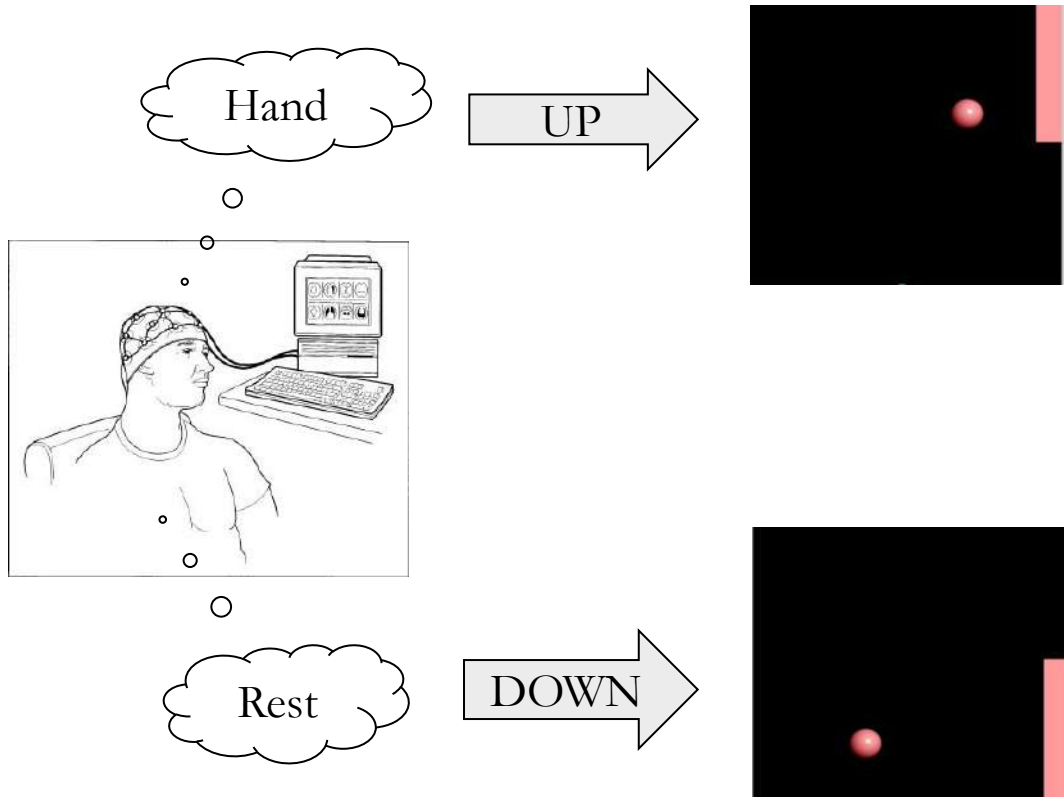
Neuronal avalanches: bursts of enhanced activity observed across neuroimaging modalities



Adapted from [Polverino et al, Neurology, 2022]

Hypothesis:

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

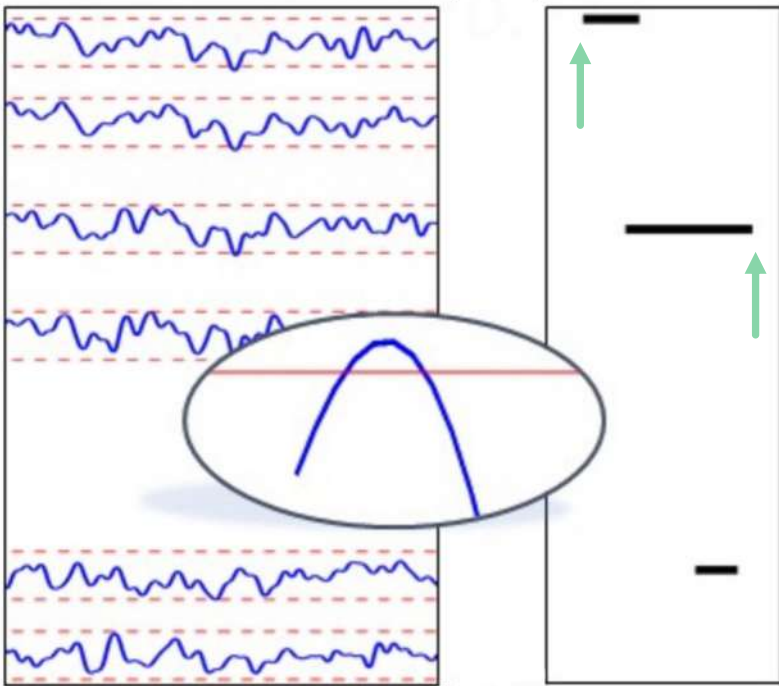


For a complete description of the protocol and the dataset, please refer to [\[Corsi et al, NeuroImage, 2020\]](#)

Objective:

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

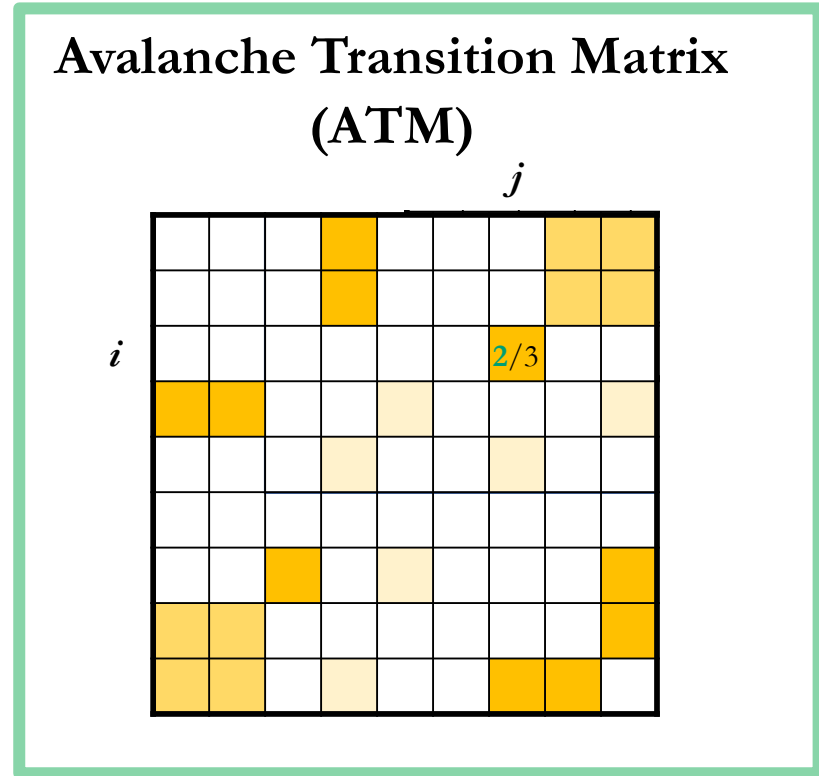
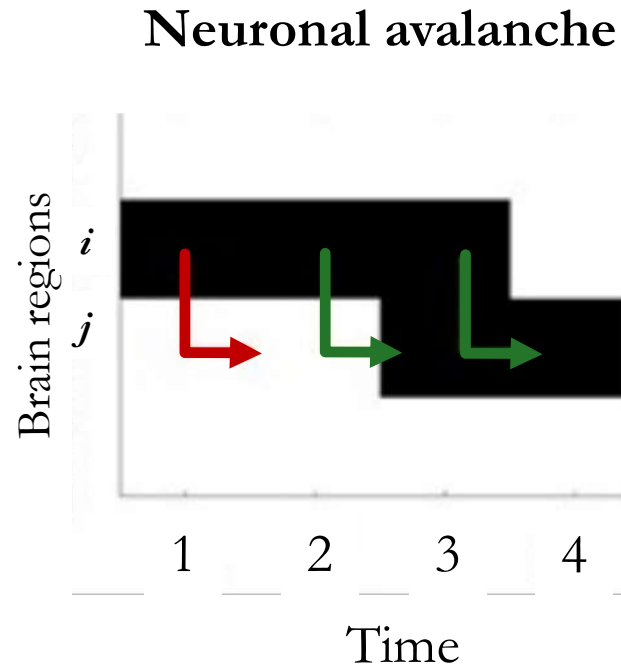
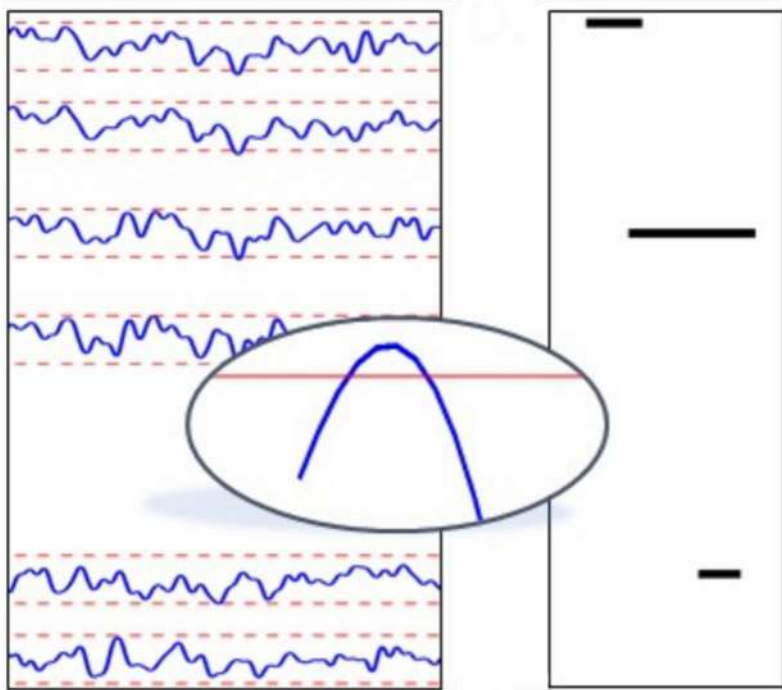
Differences in transition probabilities discriminate mental states



Adapted from [Sorrentino et al, eLife, 2021]



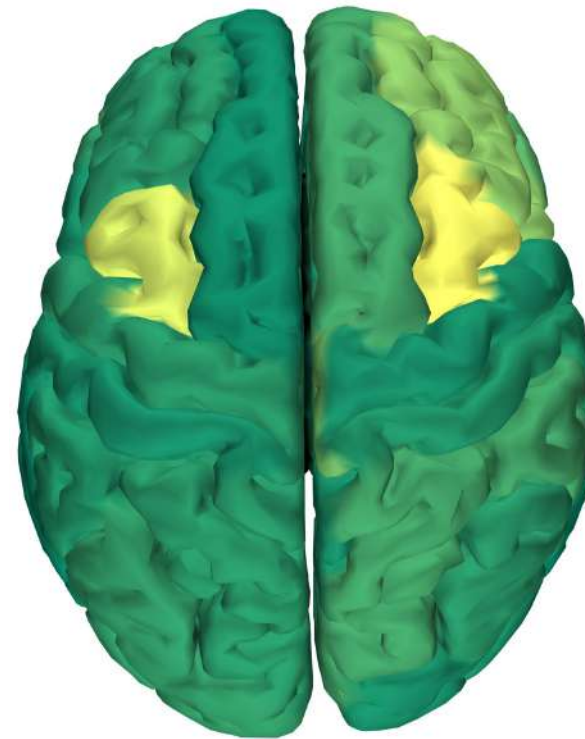
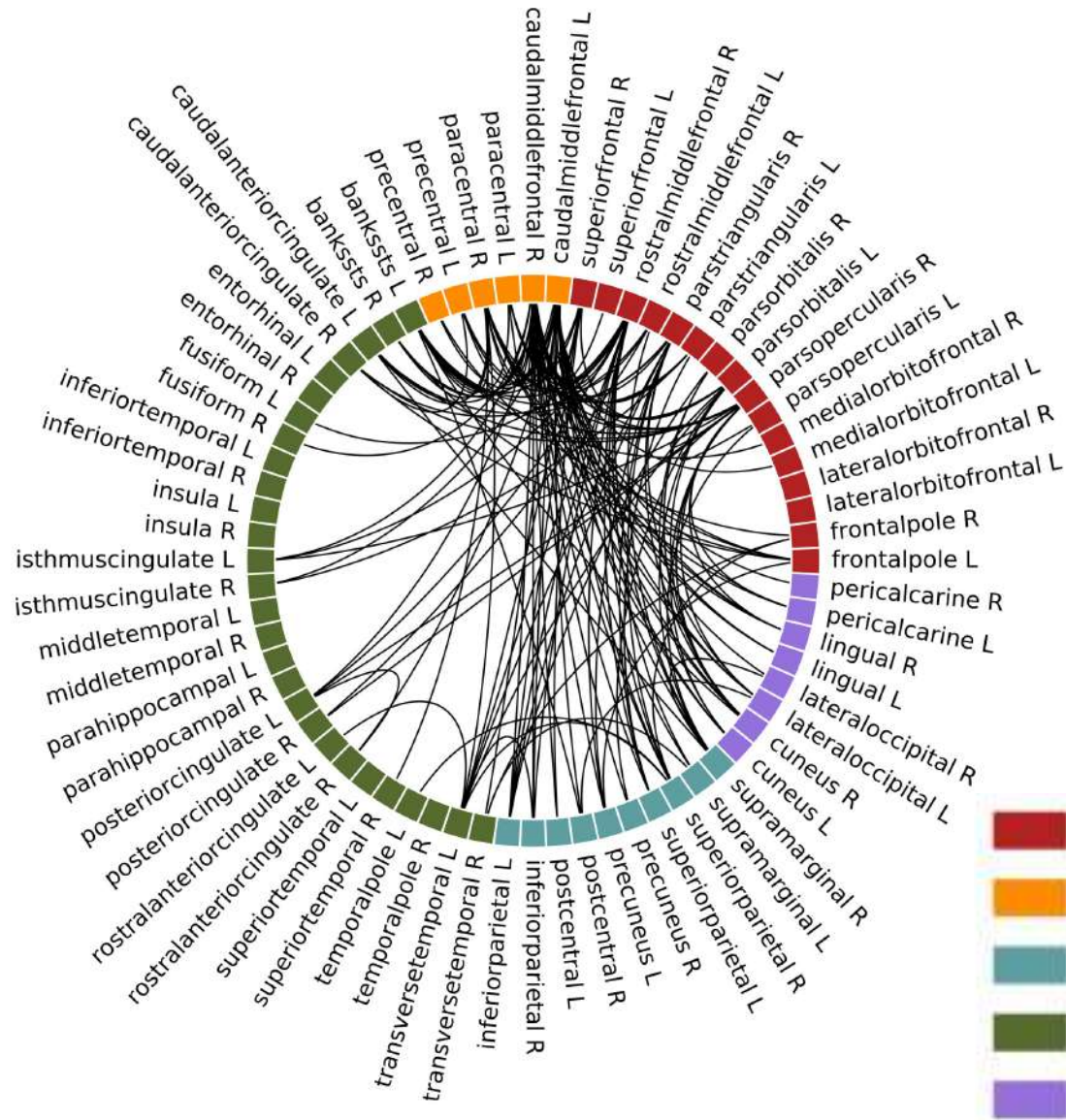
Differences in transition probabilities discriminate mental states



Adapted from [Sorrentino et al, eLife, 2021]

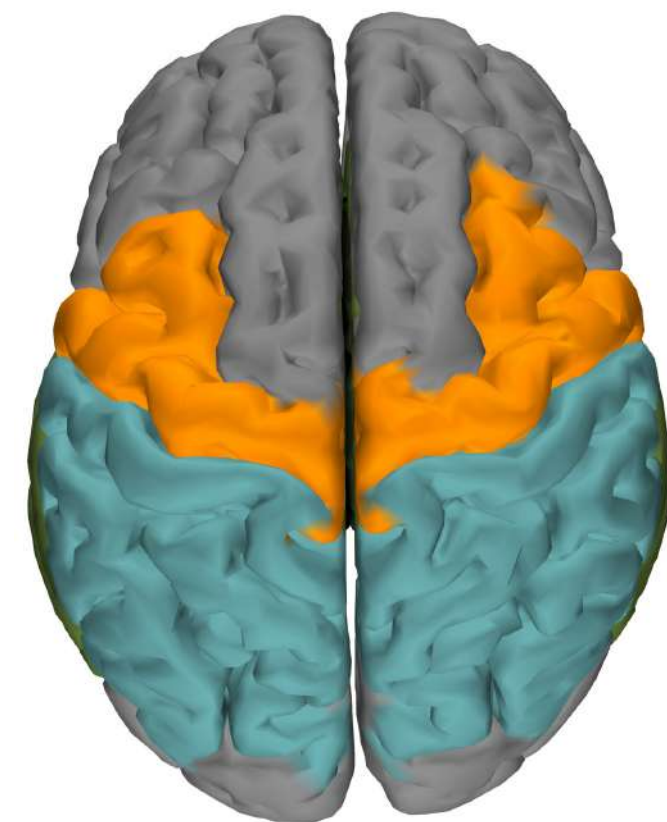
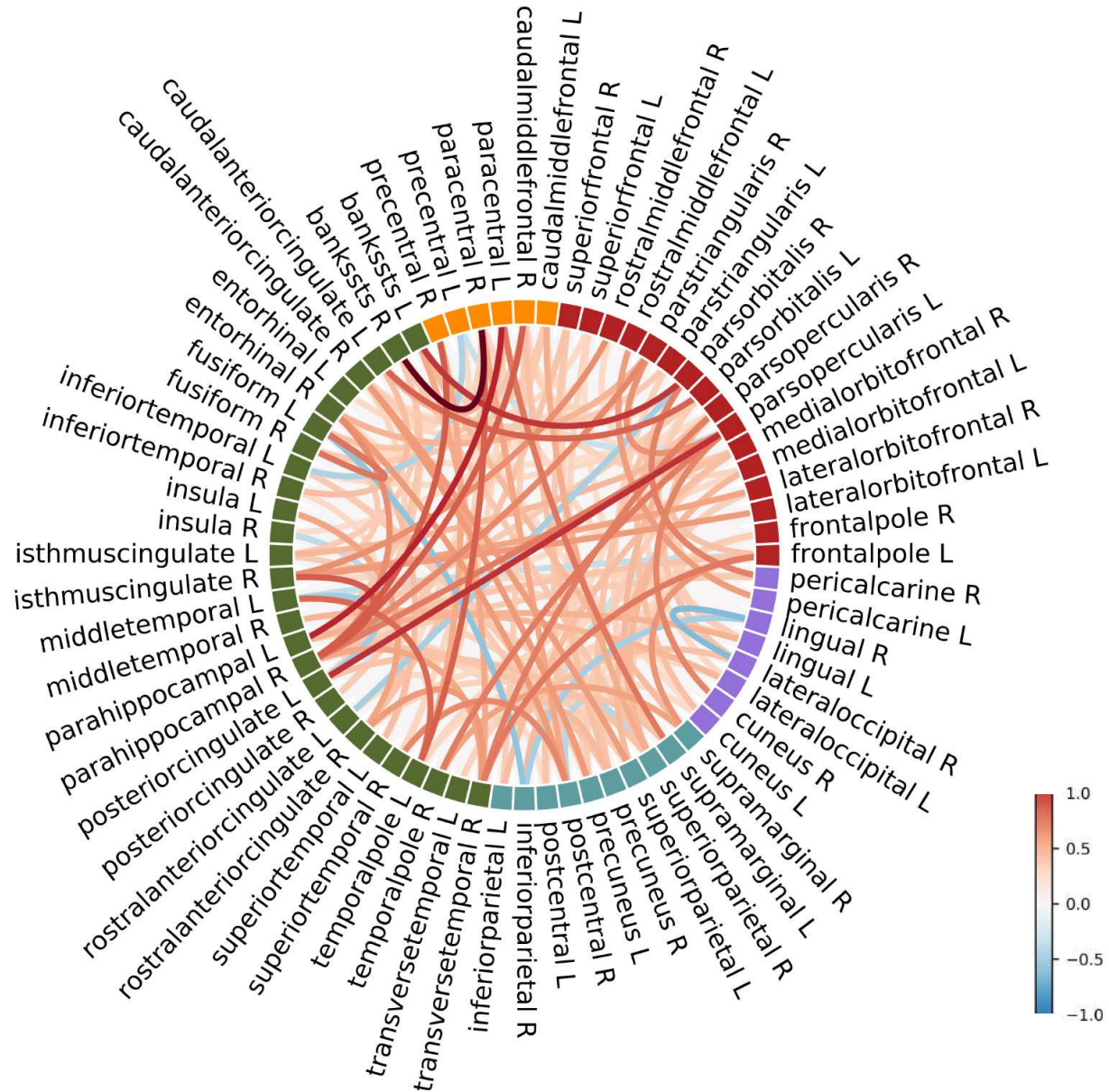


Differences in transition probabilities discriminate mental states



Reliable differences across subjects – Node-level

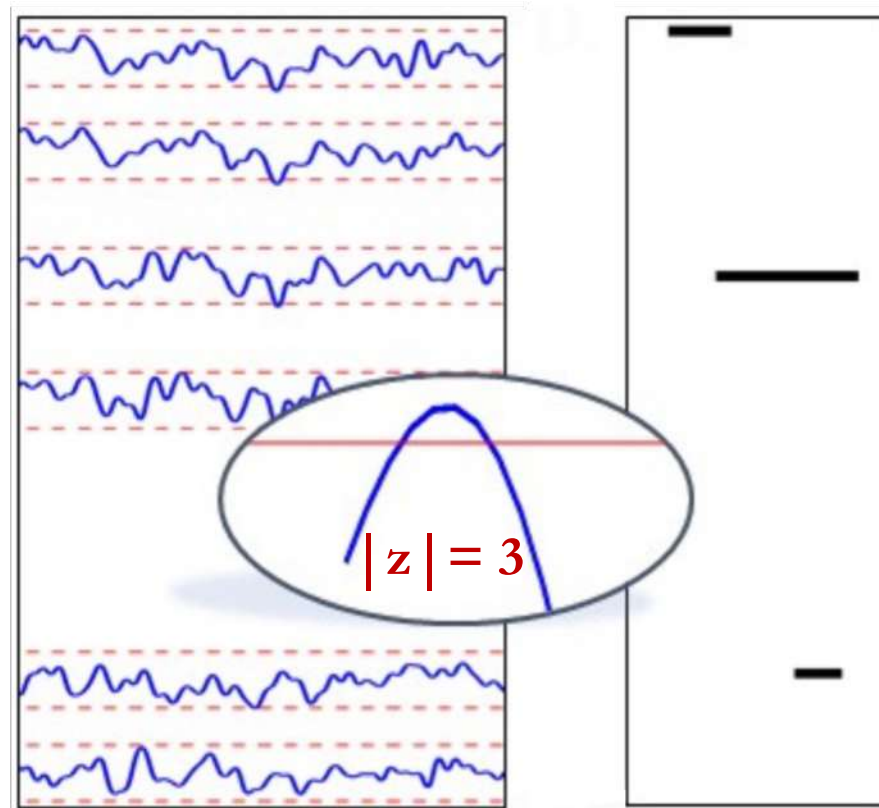
Differences in transition probabilities relate to BCI scores



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

Reliable functional information of task performance retrieval

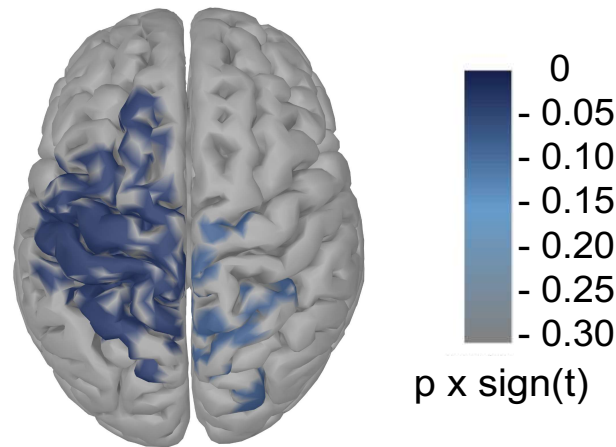
- Meaningful information communication among regions on the large-scale & aperiodic and scale-free perturbation



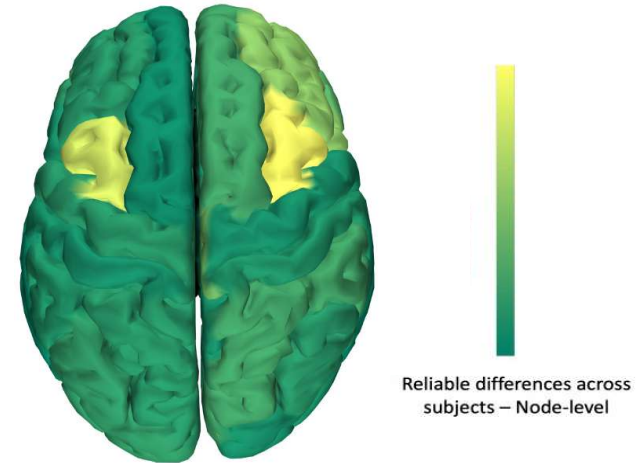
⇒ Focusing on higher-order perturbations to capture functionally-relevant processes & reliable information

Reliable functional information of task performance retrieval

- 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

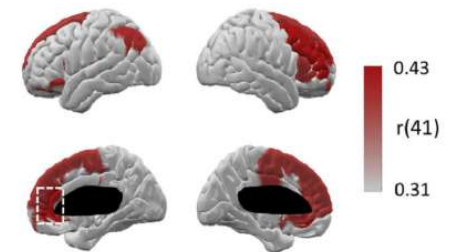
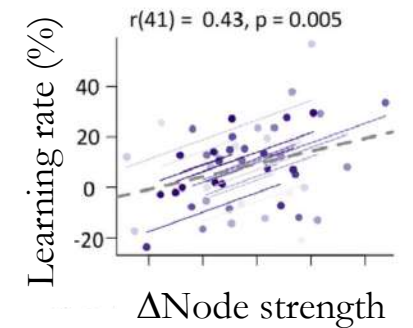
Reliable functional information of task performance retrieval

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

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

} Replicability?
} Online implementation?



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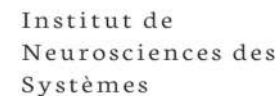
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Pierpaolo Sorrentino,
Viktor Jirsa (PI)



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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