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The potential of neural avalanches to design innovative sensorimotor-based brain-computer interface

Camilla Mannino¹, Pierpaolo Sorrentino^{2,3}, Mario Chavez¹, Marie-Constance Corsi¹

1. Sorbonne Université, Institut du Cerveau – Paris Brain Institute -ICM, CNRS, Inria, Inserm, AP-HP, Hopital de la Pitié Salpêtrière, Paris, France
2. Institut de Neurosciences des Systèmes, Aix-Marseille Université, 13005 Marseille, France
3. University of Sassari, Department of Biomedical Sciences, Viale San Pietro, 07100, Sassari, Italy

INTRODUCTION

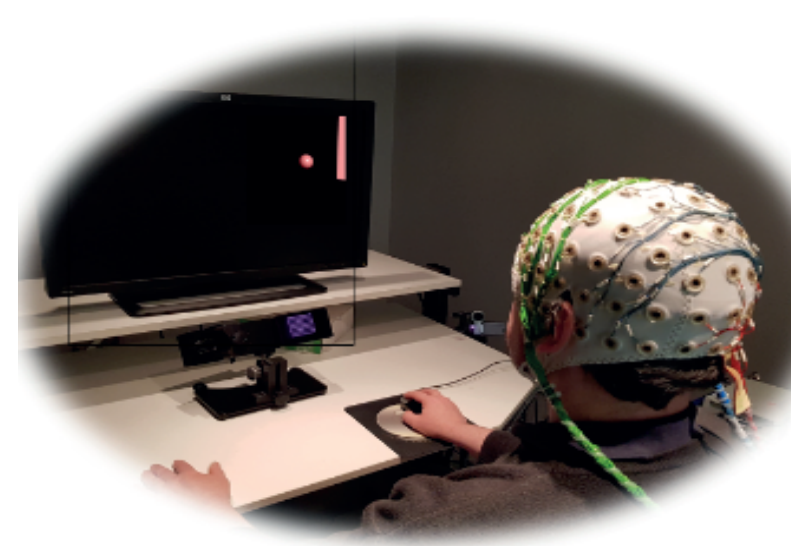
Multiple studies reported that inefficient subjects account for 15%–30% of the experimental population, referred to as the BCI inefficiency.

Among the potential causes of this phenomenon are the features used. Indeed, by relying mostly on local measurements they might not fully capture the brain functioning that also consists in interactions between areas.

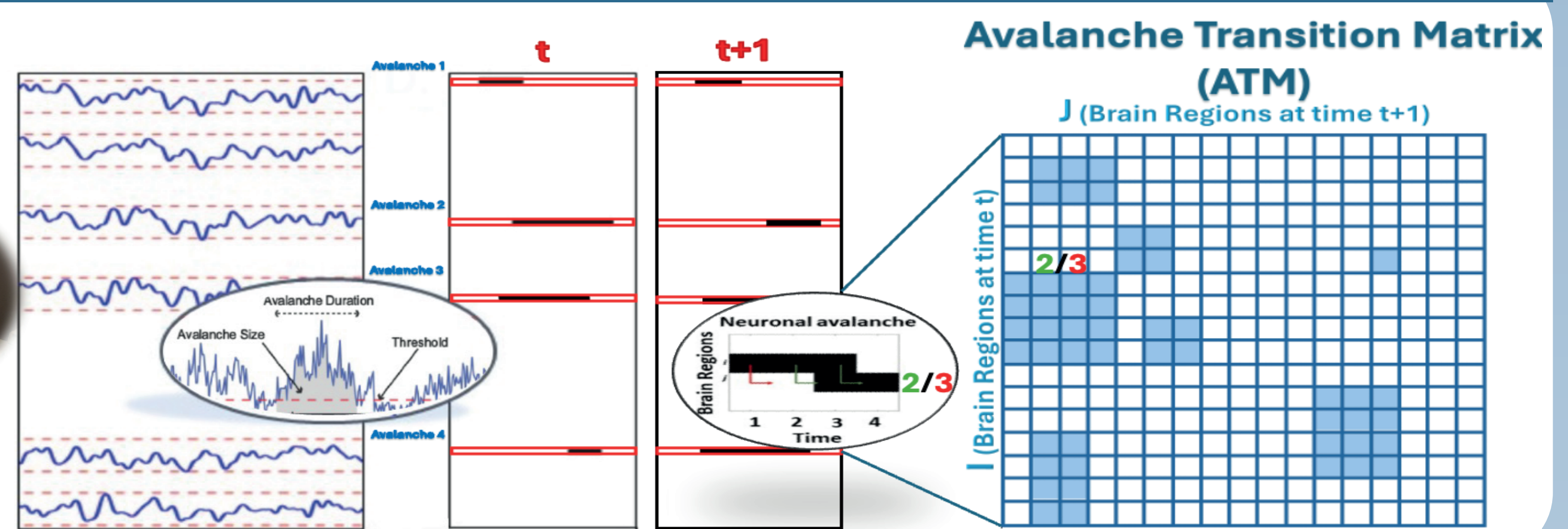
To overcome these limitations in recent researches we proposed to use a metric that captures the dynamic nature of the brain activity: **the neural avalanches**.

METHOD

Motor Imagery BCI Re-grasp protocol



20 Subjects EEG data



RESULTS

CLASSIFICATION PERFORMANCE

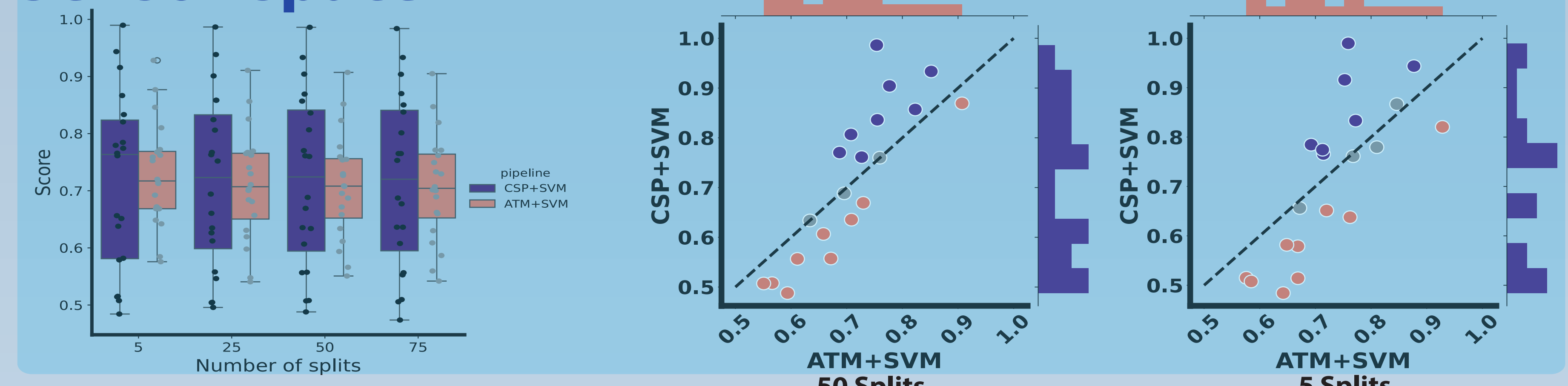
Performance was robust across splits for both CSP+SVM and ATM+SVM pipelines (one-way ANOVA $p > 0.05$), and we observed a **higher accuracy score** for most of the subjects with **5 splits** both in sensor and source space.

In **sensor-space CSP+SVM pipeline** led to a **larger number of subjects** with a performance **below the chance level**, set to 58% here (6 subjects) with respect to ATM+SVM (1 subject).

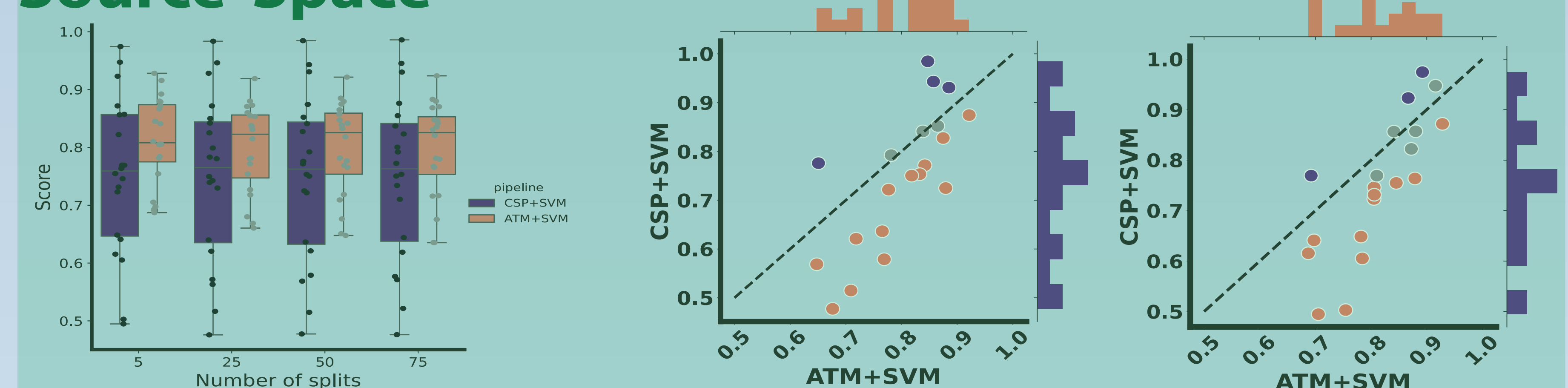
EEG source-reconstructed data, ATM+SVM demonstrated superior performance in 12 subjects, whereas the opposite was observed in 3 subjects with CSP+SVM

Larger inter-subject variability in the case of **CSP+SVM** than **ATM+SVM** with a standard deviation of respectively 15.55% and 9.14%.

Sensor-space



Source-Space

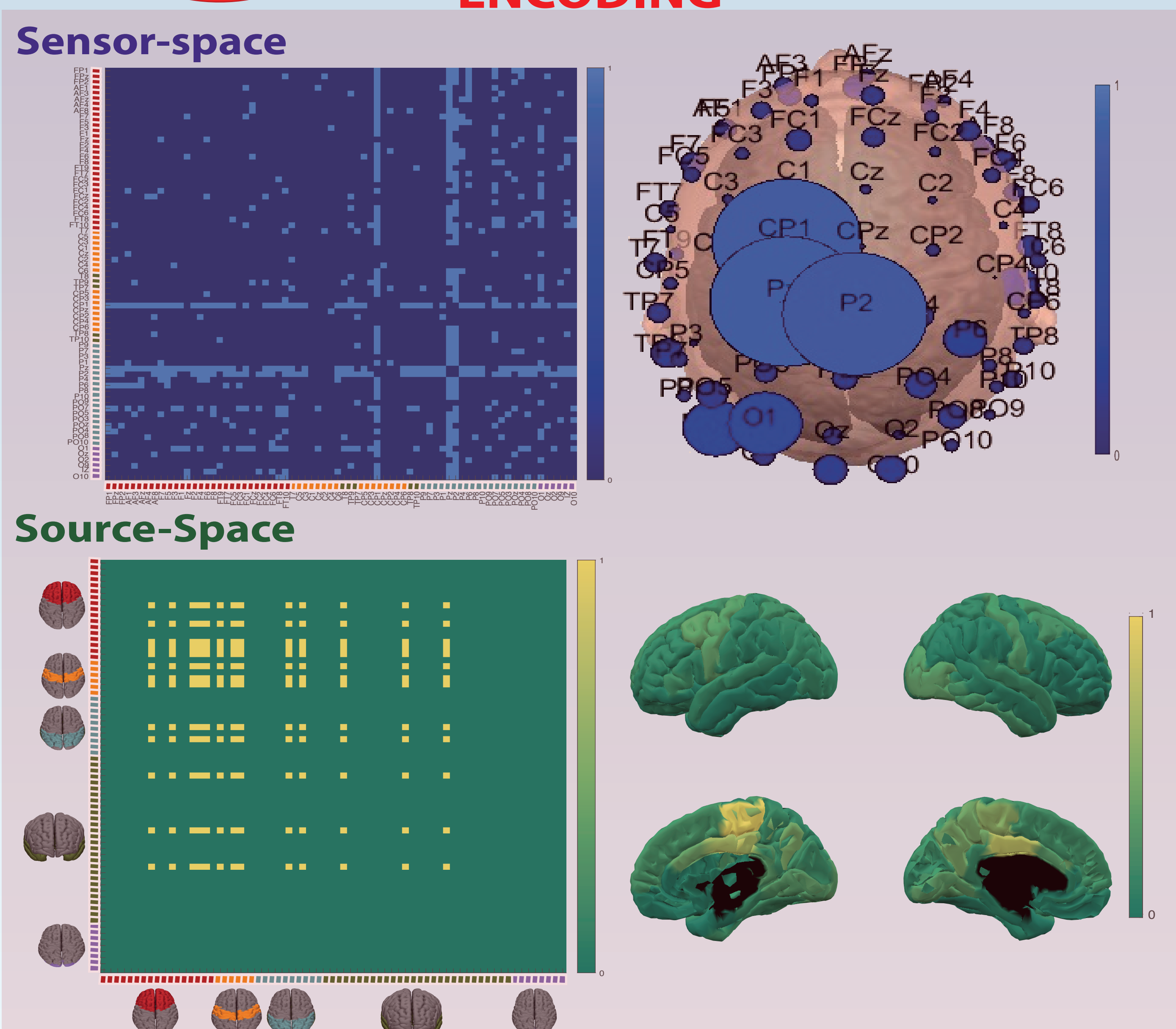


What we can observe directly from the data

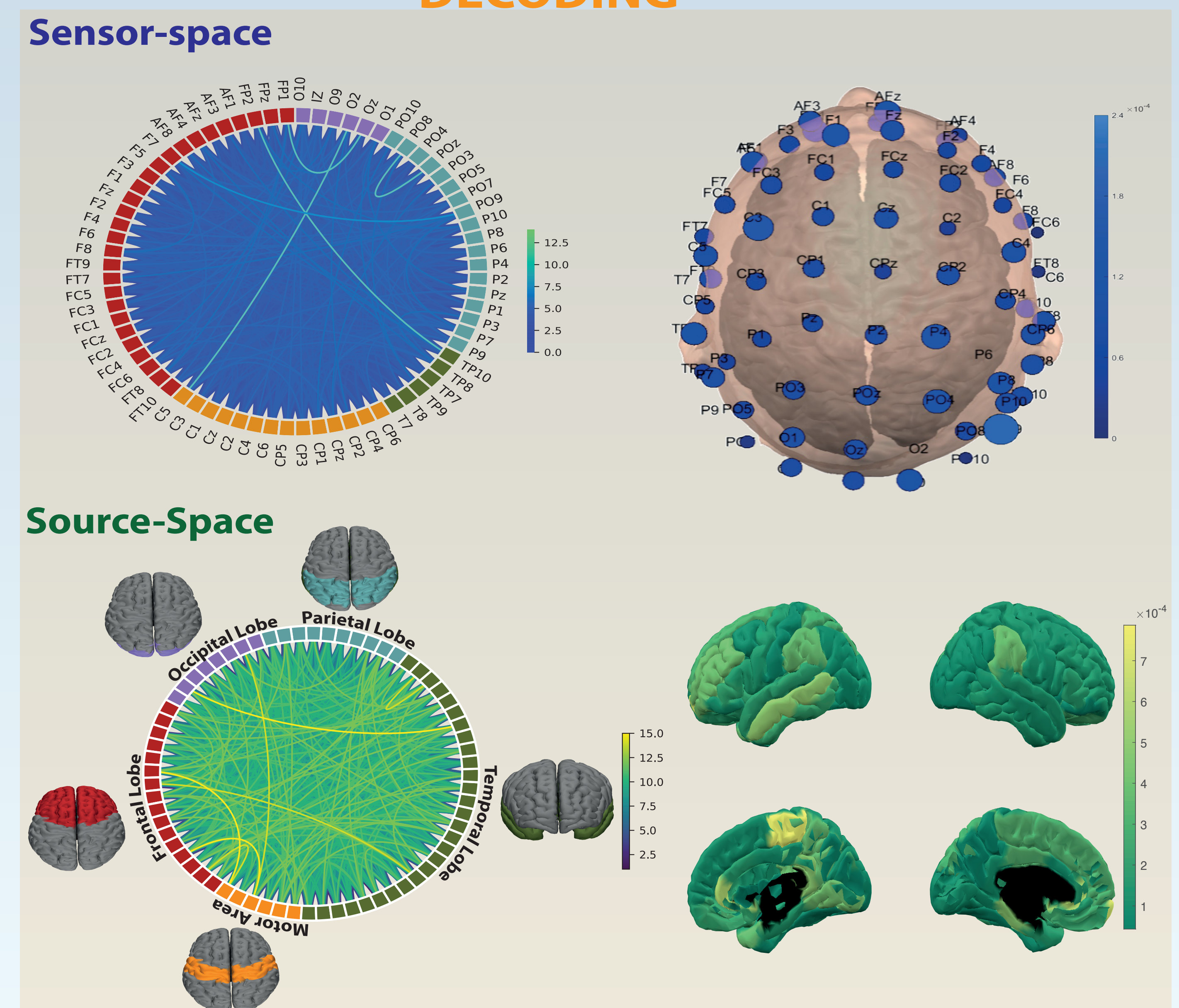
FOCUS ON ATM PIPELINE

Features selected in classification algorithm

ENCODING



DECODING



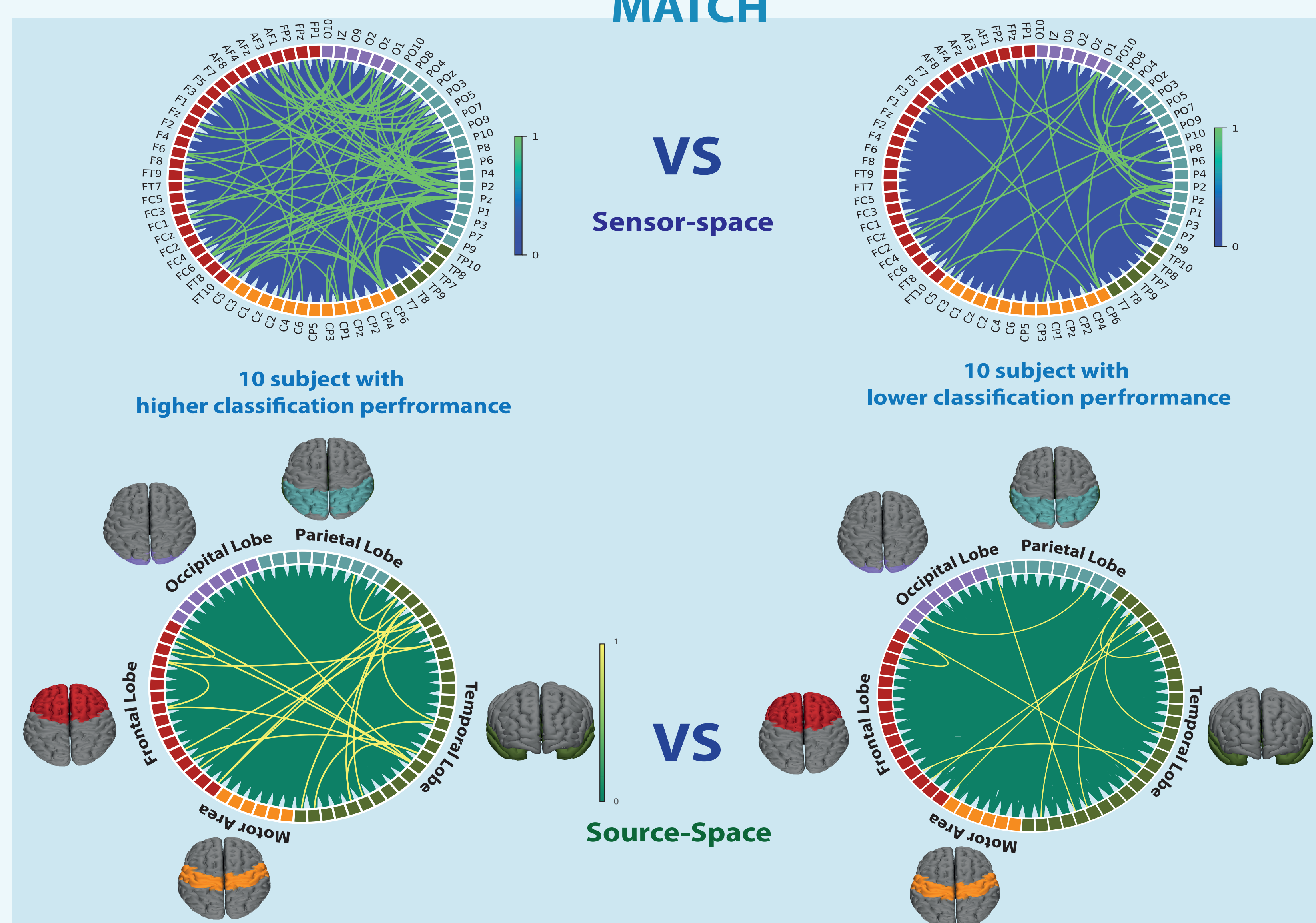
Reliably edges identified in encoding framework & selected by classification algorithm

MATCH

Comparison Sensorspace & Sourcespace

The most frequently selected features involved **central electrodes (C-CP)** at sensor-space, as the **paracentral area** in the source-reconstructed data implying **left motor-area**.

Our observations, obtained applying the ATM method, suggest that working in the **sensor space could provide enough spatial resolution** to perform the classification and to identify the reliably functional connections with a simpler framework than in the source space. Nevertheless, for deeper analysis investigating the **involvement of precise regions of interest**, work in the **source space would be advisable**.



Comparison Encoding vs Decoding

Comparison between the reliability edges and features selected with hugest weight. denoted a **higher level of match score with the ten subjects with a highest classification performance** as compared to the ten subjects with the lowest classification performance.

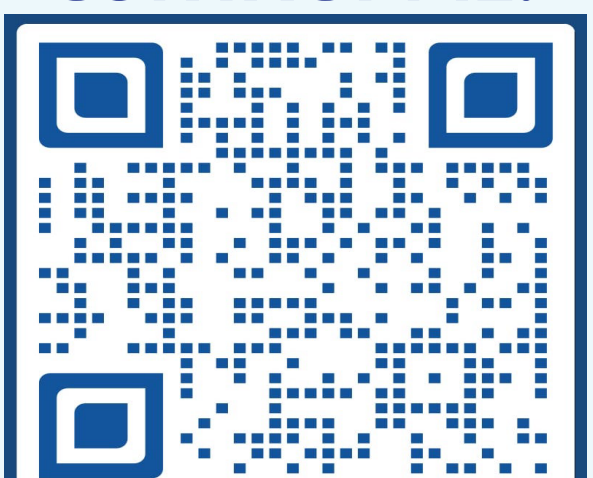
37% (Highest) vs 6% (Lowest) in Sensor-Space
48% (Highest) vs 24% (Lowest) in Source-Space

This finding suggests a possible way to apply a **dimensionality reduction in the features used in the decoding step**, to improve classification performance and to reduce the computational time as well.

CONCLUSION

Our observations suggest that the **integration of periodic and aperiodic features** would be a straightforward way to capture functionally relevant processes. Hence, **neural avalanches** could be applied to the **design of BCIs** and to **improve task classification**. The good performance of the ATMs on the EEG data is relevant to **translate our methodology to real-world scenarios**. So far, we tested this innovative marker only during a hand motor imagery BCI task; further work will consist in considering a **wider range of BCI paradigms for movements recovery applications**, as well as for **interfacing with various modalities such as iEEG, ECoG & N1 implant**.

CONTACT ME!



camilla.mannino@icm-institute.org