Towards the use of spatial network metrics for characterizing brain mental states

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The use of network science for characterizing brain networks and discriminating different mental states, has become a powerful tool in the last decade. Large part of the methods have focused on extracting topological properties of the network, such as centrality, modularity and efficiency, thus neglecting its intrinsic spatial nature. However, the brain is a spatial network [1], where the three-dimensional position of the nodes correspond to precise locations of differently specialized areas.

To evaluate the potential of integrating spatial information in the discrimination between different brain states, we considered functional brain networks estimated from EEG signals (N=74 nodes) recorded in a healthy trained subject during resting states (75 repetitions) and simple hand-motor imagery tasks (75 repetitions) (Fig.1-A). We then approximated the spatial distance between the different nodes, corresponding to different brain sites, by computing the Euclidean distance d_{ij} between all node pairs. By performing a progressive thresholding and binarization of the original fully connected and weighted connectivity matrices, we finally reported the average spatial distance $\langle d \rangle$ between the connected nodes only (Fig.1-B). Results, showed a significant decrease of the average spatial distance for the motor condition for a broad ranges of threshold values (Wilcoxon test, $p<0.001$). Instead, we did not report any significant difference between the two brain states when using a well-known topological metric, such as the global-efficiency (Fig.1-C).

From a neurophysiological perspective, the significant decrement of $\langle d \rangle$ may reflect automatization processes consisting in recruiting more local resources after human motor learning [2]. Our work is a preliminary step towards a better comprehension of the fundamental and practical advantage of spatial network features to isolate organizational mechanisms of functional brain networks.

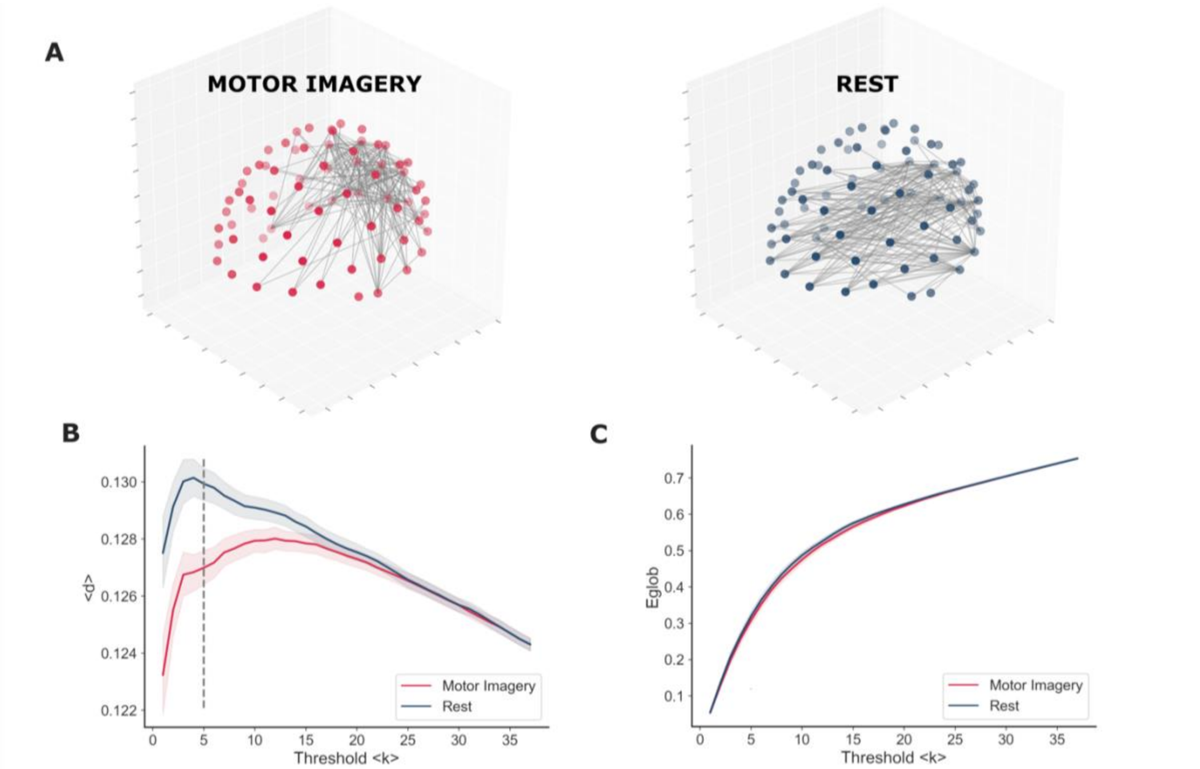

Fig. 1 - **A**) Brain networks. **B**) Average spatial distance across different threshold values. Solid lines show the mean across the 75 task repetitions for each condition (Motor imagery and Resting state). Threshold values correspond to average node degree k. Vertical dashed line spots out the most significant statistical difference between conditions (k=5). **C**) Same plot as before with global-efficiency values.

[1] Bassett D S and Stiso J 2018 Spatial brain networks *Comptes Rendus Physique* **19** 253–64

[2] Corsi M-C, Chavez M, Schwartz D, George N, Hugueville L, Kahn A E, Dupont S, Bassett D S and De Vico Fallani F 2020 Functional disconnection of associative cortical areas predicts performance during BCI training *NeuroImage* **209** 116500