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Identifying latent brain networks geometry markers: clinical applications in disorders of consciousness

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The complexity of the human connectome arises from several, integrated and segregated distributed networks around critical and participating cortical epicenters embedded in their physical space. The network topology is often intricately related to the physical distances between the nodes of the network: brain regions that are spatially close have a relatively high probability of being interconnected, while longer white matter projections are more expensive in terms of their material and energy costs. The observed topological properties arise from a hidden geometric space, where the nodes represent points and the closer they are the higher the likelihood to be connected. In recent years it has been demonstrated that the hyperbolic space might be a good geometric space of representation for complex networks, despite mapping a given network in the hyperbolic space remained a challenging issue. More recently, coalescent embedding, a class of topological-based unsupervised nonlinear dimension reduction machine learning has been developed in order to perform efficient mapping of complex networks in the 2D and 3D hyperbolic space, and potentially also in higher-dimensions [1]. Applying this new class of algorithms, we previously unsupervisedly discloses the hidden geometry of structural brain networks, demonstrating that it strongly relates to the known neuroanatomy [2]. Herein, we explore a more complex topic such as the human consciousness and its related disorders (DOC). We will demonstrate how simple geometric measures allow to identify latent network geometry changes and to distinguish between patients in minimally conscious state (MCS) and unresponsive wakefulness syndrome (UWS), starting from the mere functional connectivity estimated by resting state EEG recording. By contrast, the original distribution of the connectome weights cannot uncover significant differences between the functional connectomes of UWS and MCS patients ($p>0.05$). Therefore, coalescent embedding in the hyperbolic space enhanced our understanding of the whole-brain network geometry changes of brain connectomes, pioneering the new framework of network latent geometry markers characterization of brain diseases with application in DOC.We hope that this scenario has the potential to improve diagnosis, prognosis and therapeutic treatment evaluation of DOC patients.

References

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Key words

Connectome, consciousness, hyperbolic space, markers, network geometry, machine learning.