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Brain Hierarchical Atlas: Multi-Scale versus Optimal Strategies in the Pathological Brain

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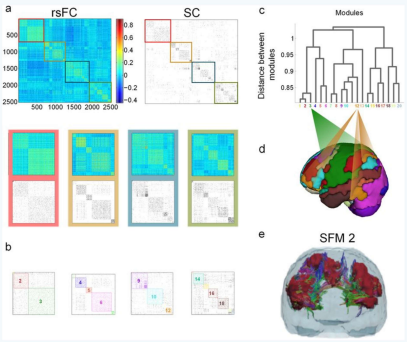
Motivation

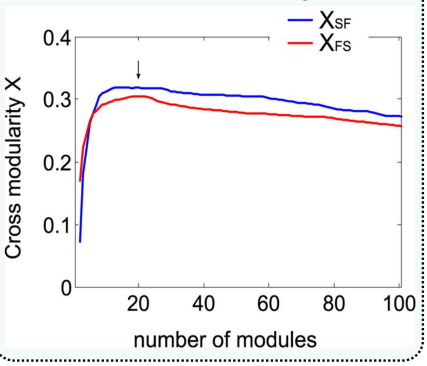
1. Elucidating the intricate relationship between brain structural (SC) and functional (FC) networks is a key challenge for modern neuroscience.
2. We adopt a systems approach that uses modular hierarchical clustering to combine SC and FC datasets into a common atlas that we name the brain hierachical atlas (BHA) [1].
3. Two strategies can be applied when using BHA: a multiscale approach vs an optimal brain partition.
4. For the multiscale approach we show first how brain networks reorganize after traumatic brain injury in a pediatric population [2]. Second, how structure-function brain networks can accurately predict brain aging [3]. Third, how structure-function connectomics reveals aberrant developmental trajectories[4] and the metastable dynamics in the restint state brain [5].
5. From the strategy of the optimal partition, we show first a complete characterization of the progressive alterations in SC patterns across severity stages in Alzheimer's disease [6], the redundant role of the DMN along lifespan [7], the variations in dynamic functional connectivity [8] and the high-order interdependencies in the aging brain[9].

Methods

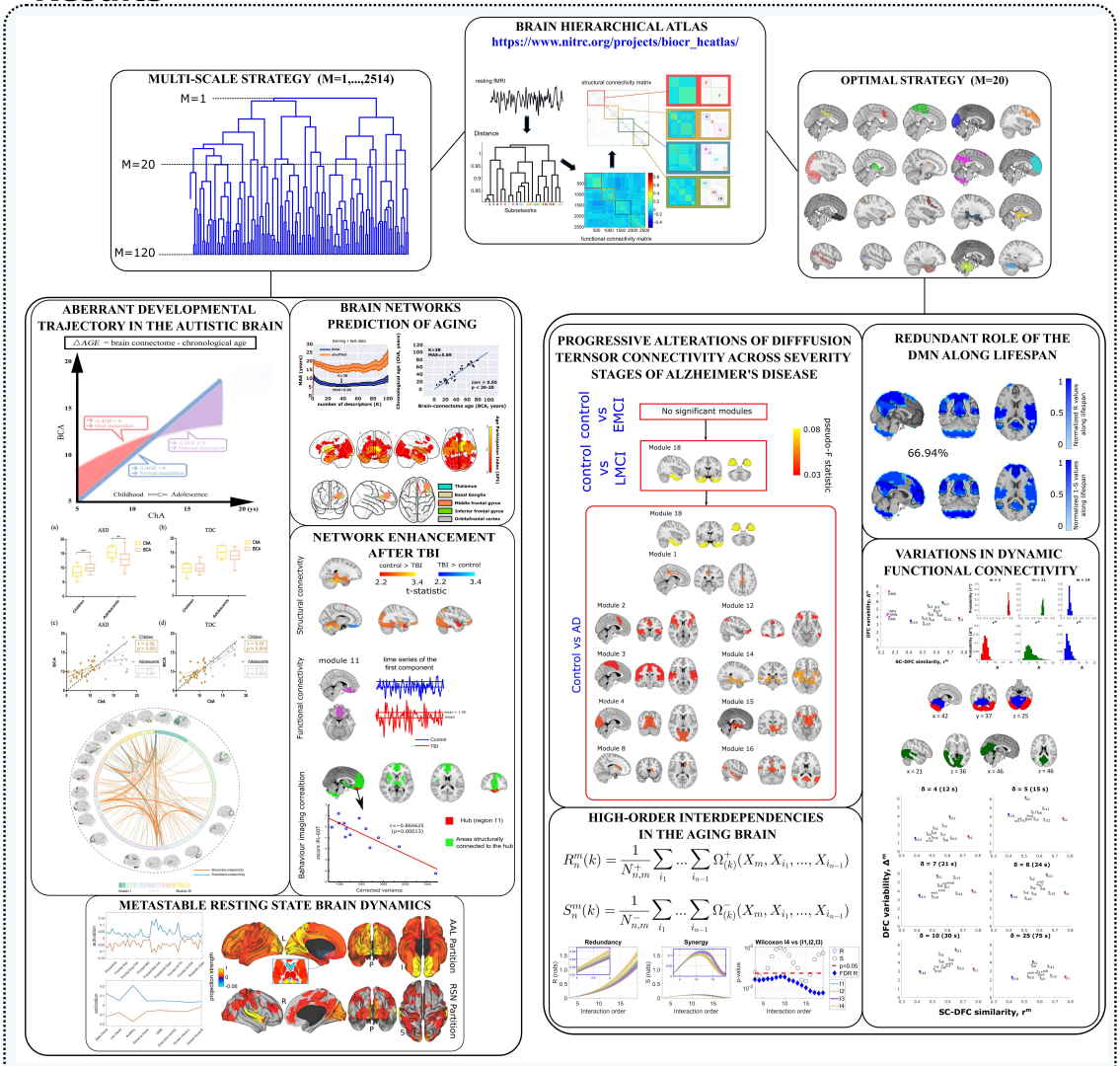
First, structural connectivity (SC) (fiber number) and functional connectivity (FC) matrices (pairwise correlation) were obtained.
Next, hierachical agglomerative clustering (HAC) was applied to extract brain modules on different scales.



Finally, the optimal brain partition was obtained basesd on the cross-modularity (X) between SC and FC, defined as the geometric mean between modularity of SC, modularity of FC and the mean Sorensen similarity between structural and functional modules. The value of M=20 was the one maximizing X.



Results



Conclusions

The use of the BHA guarantees four conditions simultaneously:
1. That the dynamics of voxels belonging to the same module is very similar.
2. that those voxels belonging to the same module are structurally wired.
3. When varying the level of the hierarchichal tree, it provides a multi-scale brain partition, where the highest dendogram level occurs for M=1 (coincident with the entire brain), whereas the lowest level M=2514 corresponds as many modules as ROIs.
4. The atlas with M=20 modules is optimal based on crossmodularity.
Since we published the atlas in 2015, in our group we have shown multiple applications of it in healthy and pathological conditions. At this time, different works are being done on the same atlas, so please, stay tuned!

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