Individualized parcellation enhances relationships between brain network and dual-task performance

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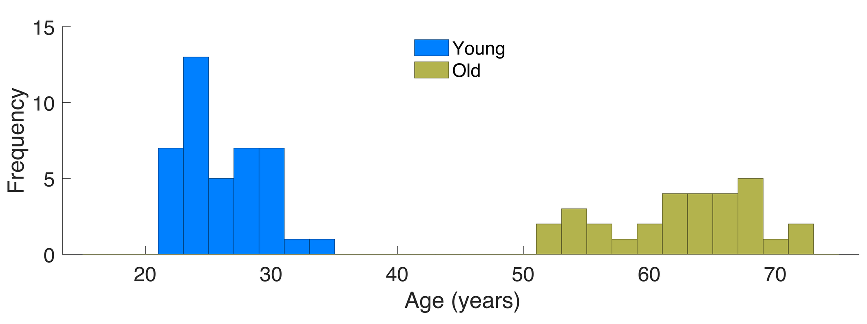
Introduction

- Brain parcellation is a fundamental step for defining brain regions and estimating structural and functional brain networks **[1]**. Conventional population atlases provide a common reference framework, but **applying the same atlas to every individual may obscure inter-individual variability** in cortical functional organization.
- **This limitation may reduce the sensitivity of detecting brain–behavior associations, particularly for complex cognitive functions. Dual-task performance provides a stringent behavioral test because it requires the coordination of multiple cognitive processes, such as different stimulus–response mappings and response–code conflict resolution.**
- Aging further challenges brain–behavior inference because older adults differ from younger adults in both dual-task performance and large-scale brain network organization **[2]**.
- **Aims:** We tested whether **individualized brain parcellation [3]** improves the characterization of multimodal **brain networks** and strengthens their **associations with dual-task performance across age groups.**

Methods

Multimodal MRI data

- T1-weighted, diffusion-weighted, resting-state and dual-task fMRI
- 41 young (21 females; 25.6 ± 3.4 years) and 30 older (12 females; 62.0 ± 5.8 years) adults



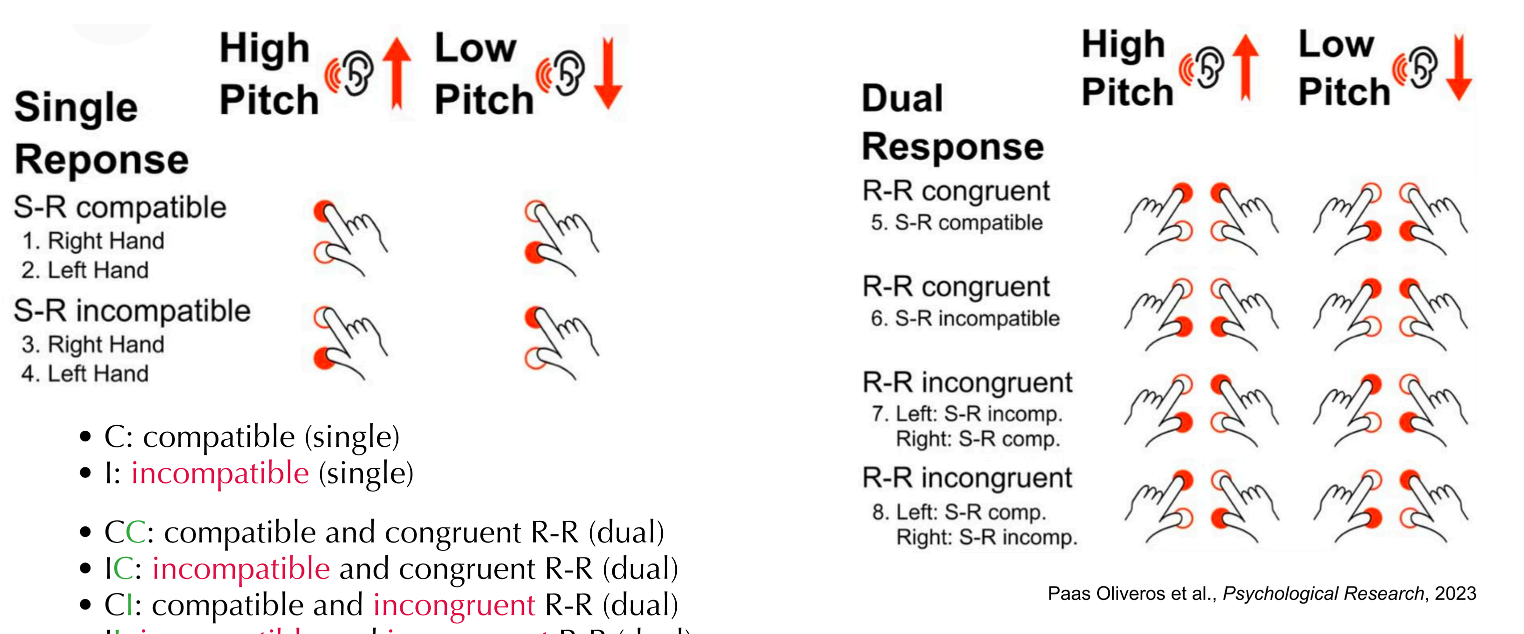
Day 1

- T1-weighted MRI
- Resting-state fMRI
- Task-related fMRI

Day 2

- Diffusion-weighted MRI
- **Reaction time:** Dual-task fMRI

Dual task: a single-stimulus dual-response task

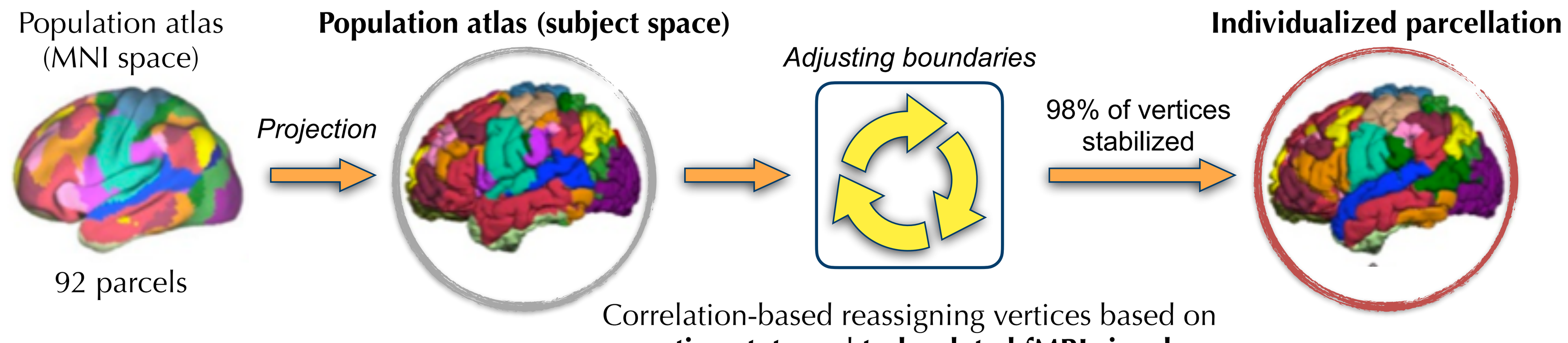


- C: compatible (single)
- I: incompatible (single)

- CC: compatible and congruent R-R (dual)
- IC: incompatible and congruent R-R (dual)
- CI: compatible and incongruent R-R (dual)
- II: incompatible and incongruent R-R (dual)

Paas Oliveros et al., *Psychological Research*, 2023

Population atlas and individualized parcellation [3]



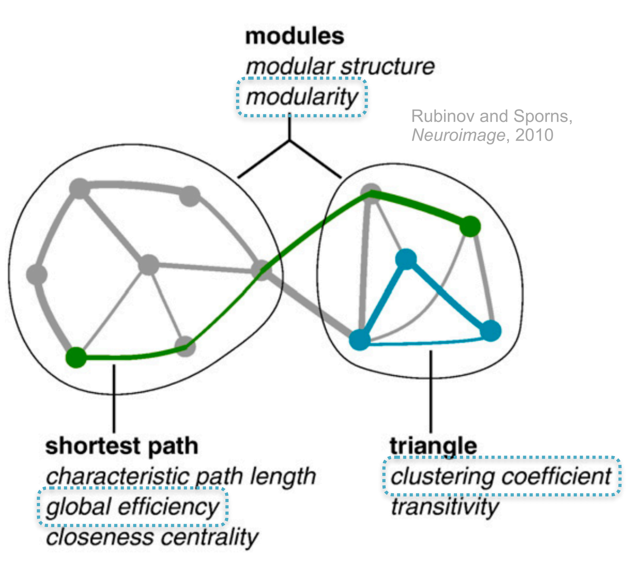
Correlation-based reassigning vertices based on **resting-state** and **task-related fMRI signals**

Graph-theoretical network properties

Modularity
- Community structures
- Functional segregation

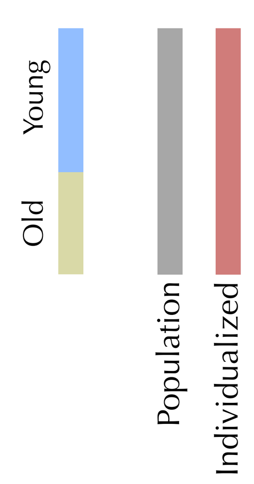
Global efficiency
- Shortest path lengths
- Functional integration

Clustering coefficient
- Fraction of triangles
- Regional segregation



Two-factor mixed ANOVA

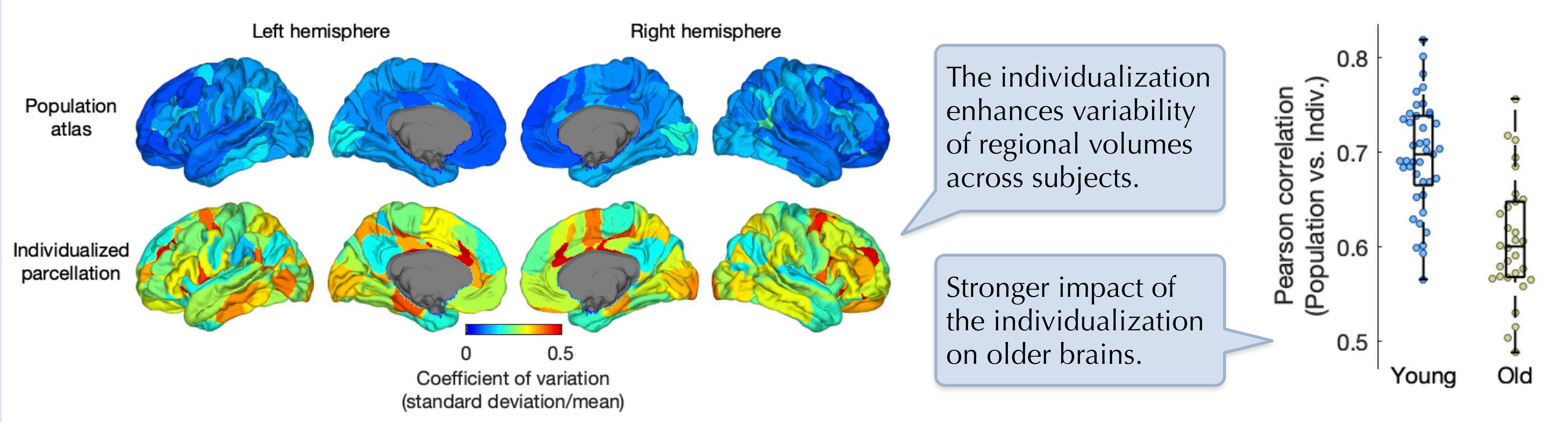
{age groups} x {parcellation conditions}



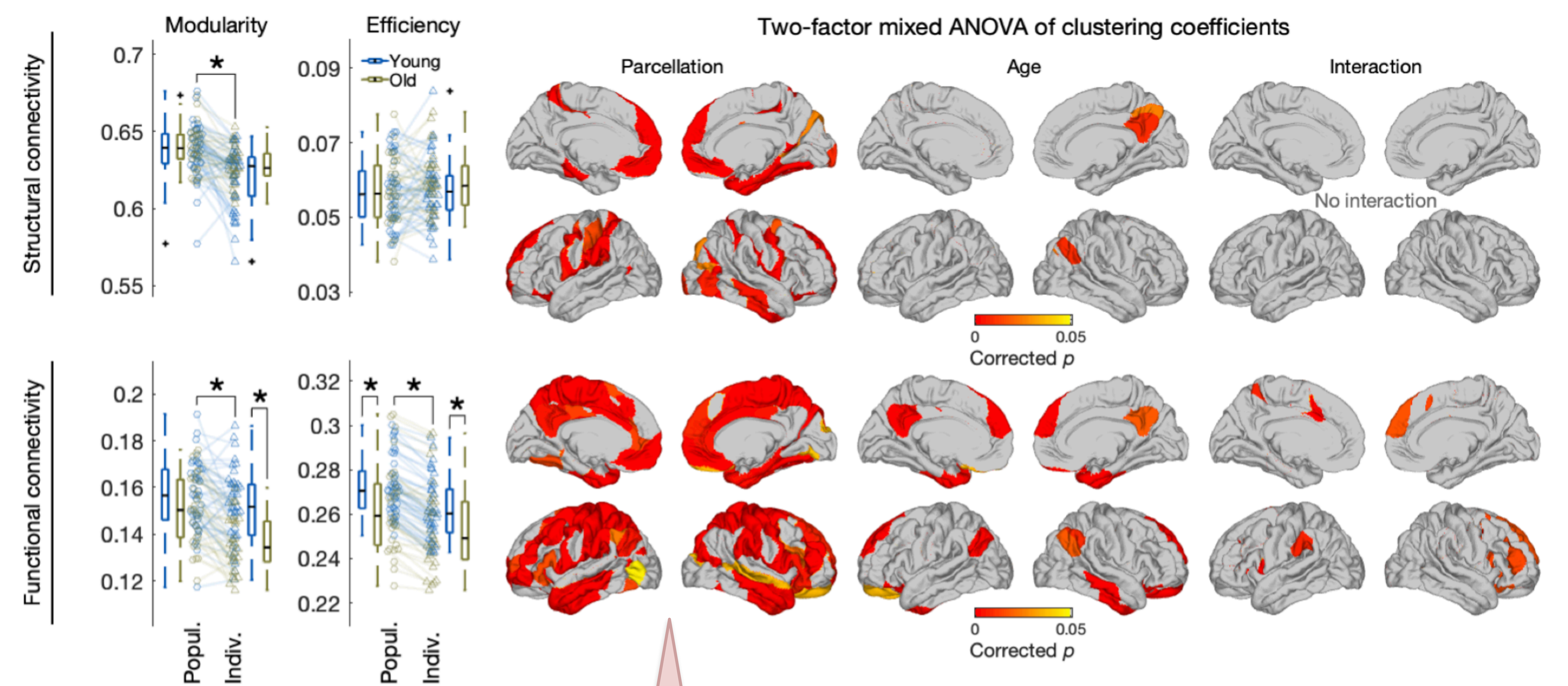
- Effect of parcellation
- Effect of age
- Interaction

Results

Altered regional volumes by individualizing brain parcellation



Impact on network properties



Clustering coefficients of functional connectivity are significantly changed in many brain regions.

Individualization and age strongly affect FC modularity and global efficiency. The impact of individualization on FC modularity was age-dependent, i.e., stronger reduction in old (vs. young) adults.

Modality	Network property	Parcellation	Age	Interaction
Structural connectivity	Modularity	**0.371****	0.029	0.023
	Efficiency	0.025	0.008	0.014
Functional connectivity	Modularity	**0.377****	**0.159***	**0.142***
	Efficiency	**0.821****	**0.067***	0.036

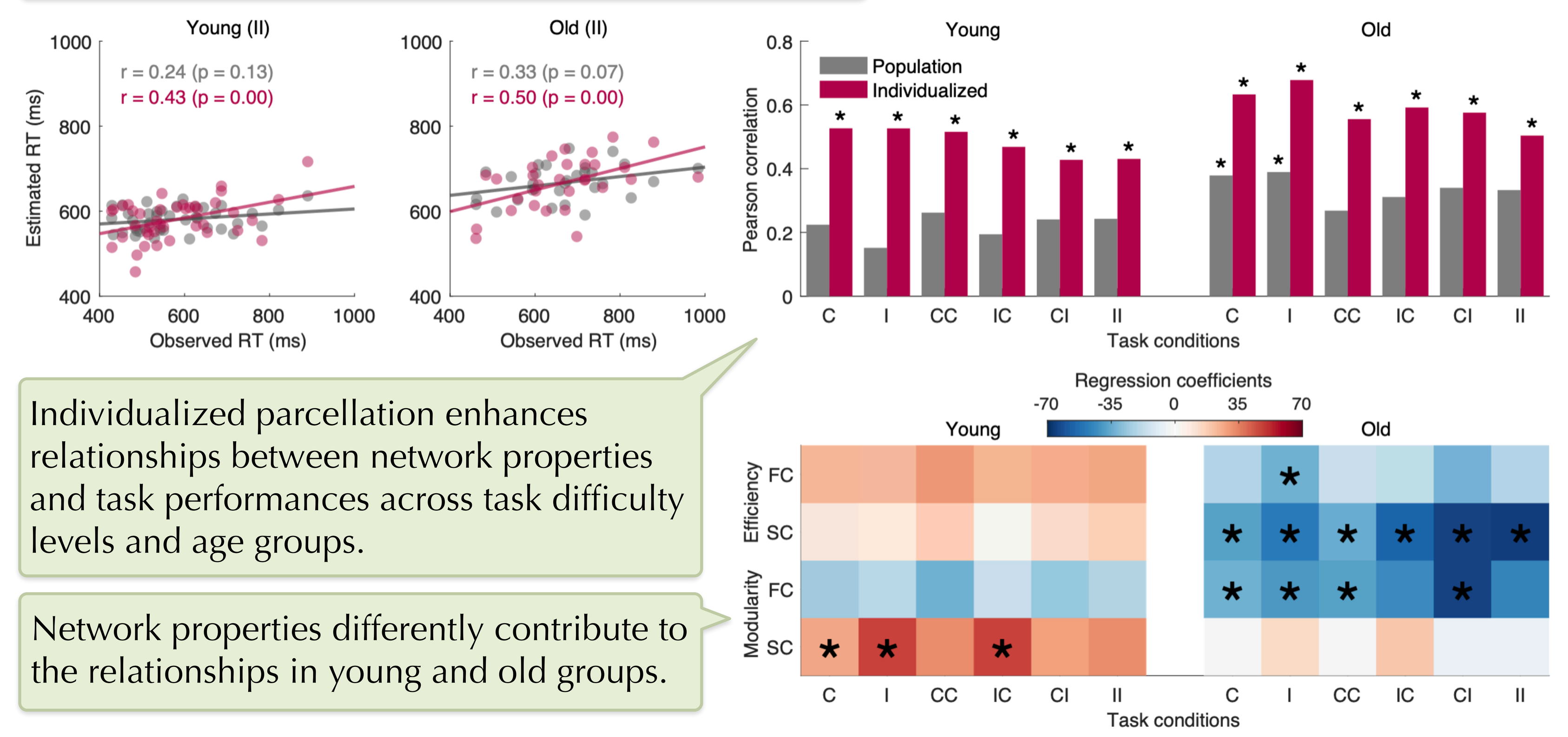
Significant effect sizes in **bold** as $p < 0.05$ with * and $p < 0.001$ with **

Relationships between network properties and dual-task performance

$$Y_{RT} = \beta_0 + \sum_{i=1}^{4} \beta_i X_i + \epsilon_{residual}$$

X_1 = Modularity of SC, X_2 = Efficiency of SC, X_3 = Modularity of FC, X_4 = Efficiency of FC

Multiple linear regression of network properties on dual-task performance



Individualized parcellation enhances relationships between network properties and task performances across task difficulty levels and age groups.

Network properties differently contribute to the relationships in young and old groups.

Conclusion

- Individualized parcellation substantially alters **regional volumes** and **brain network properties**, with stronger effects in **older adults**.
- Individualizing brain parcellation **strengthens brain-behavior relationships** across **task difficulty levels** and **age groups**.
- The findings suggest that population atlases may suppress individual differences by imposing atlas-related (group-level) attributes.
- **Individual variability** in network node anatomy is not merely noise; it affects network topology that may carry age-specific **behaviorally relevant information**.

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