

The topology of mental states.

Combining data science and graph theory to reveal neural networks for cognitive functions.

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COLUMBIA UNIVERSITY
THE ITALIAN ACADEMY
FOR ADVANCED STUDIES IN AMERICA



**Center for Theoretical
Neuroscience**

The problem

Characterization of brain networks underlying “mental” states using data science tools

The problem

Characterization of brain networks underlying “mental” states using data science tools

- mental

The problem

Characterization of brain networks underlying “mental” states using data science tools

- mental
- brain as a network

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Characterization of brain networks underlying “mental” states using data science tools

- mental
- brain as a network
- data science

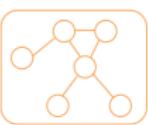
The problem

Example: brain network of Alzheimer disease.

The problem: example

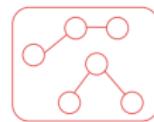
The problem: example

Non-pathological network



Subject 1

Alzheimer network



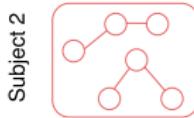
Subject 2

The problem: example

Non-pathological network



Alzheimer network

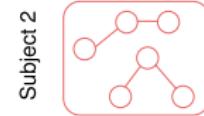


The problem: example

Non-pathological network

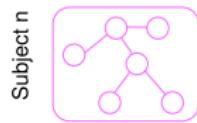


Alzheimer network

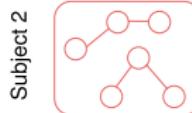


The problem: example

Non-pathological network



Alzheimer network



The problem: example

Non-pathological network

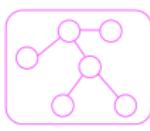
Subject 1



Subject 3

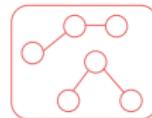


Subject n



Alzheimer network

Subject 2



Subject 4



Subject m



The problem: example

Non-pathological network

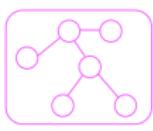
Subject 1



Subject 3

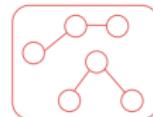


Subject n



Alzheimer network

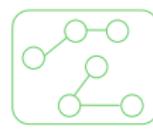
Subject 2



Subject 4

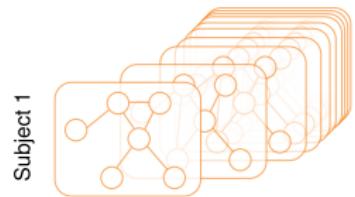


Subject m



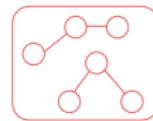
The problem: example

Non-pathological network



Subject 1

Alzheimer network



Subject 2



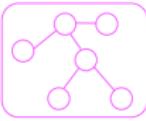
Subject 3



Subject 4

⋮

Subject n

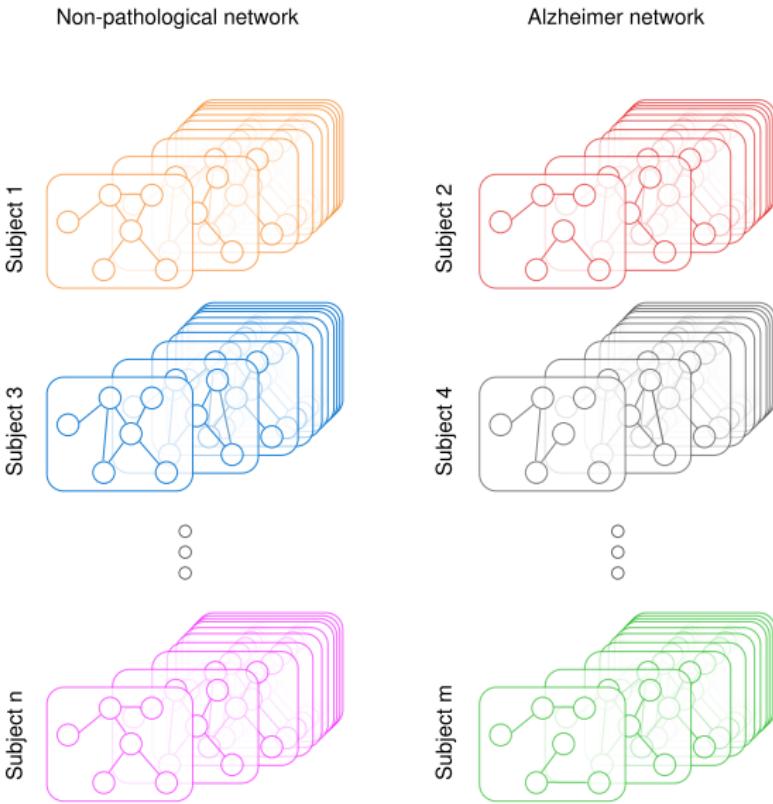


⋮

Subject m



The problem: example



The problem and subproblems

- Characterization of brain networks underlying “mental” states using data science tools

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- Separate different sources of variability/noise

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- Separate different sources of variability/noise
 - classify individuals

The problem and subproblems

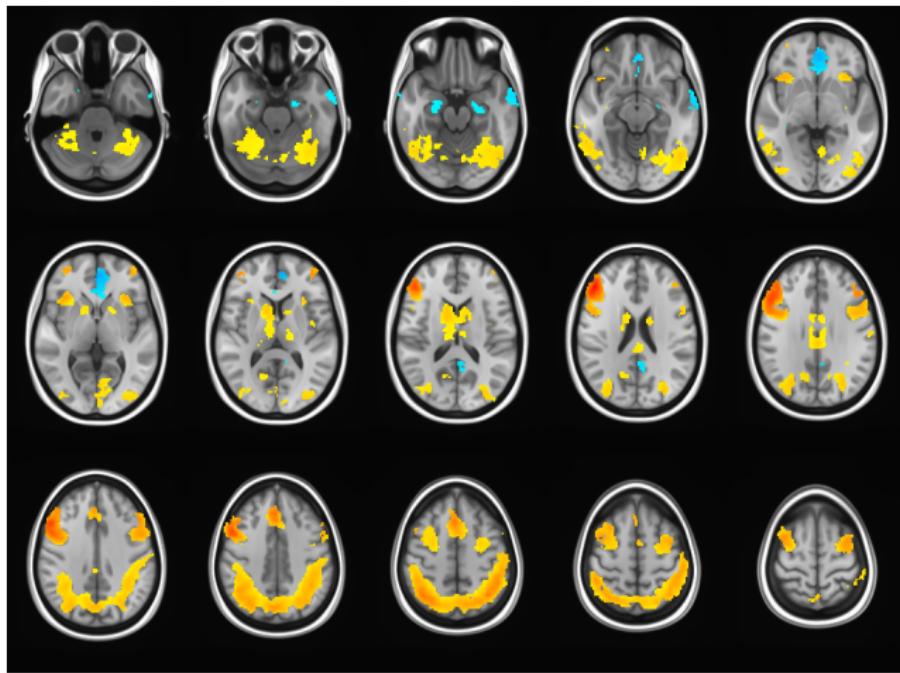
- Characterization of brain networks underlying “mental” states using data science tools
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The problem and subproblems

- Characterization of brain networks underlying “mental” states using data science tools
- Separate different sources of variability/noise
 - classify individuals
 - classify conditions
 - extract networks underlying each classification

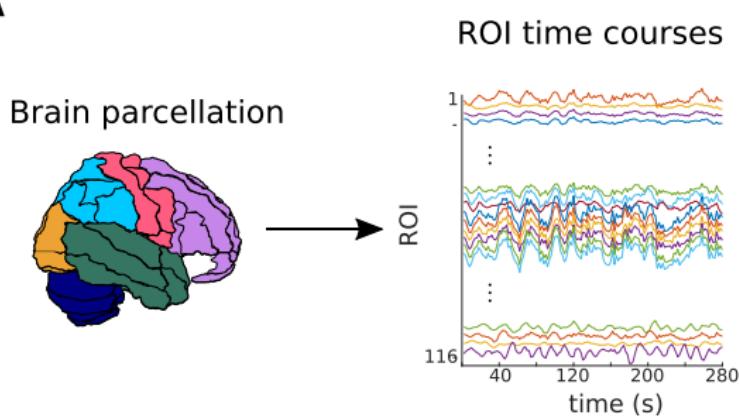
Data

- fMRI
- BOLD signal

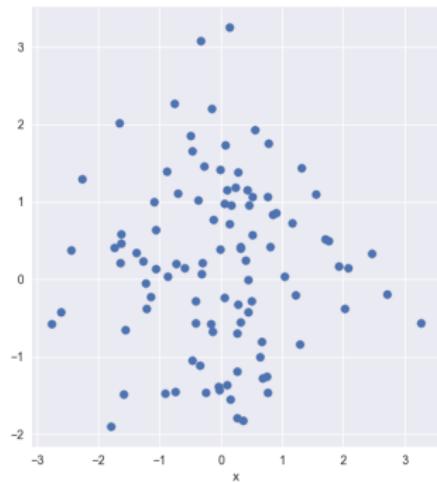
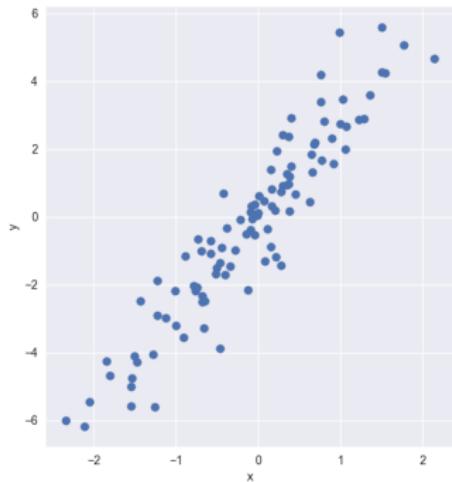


Data

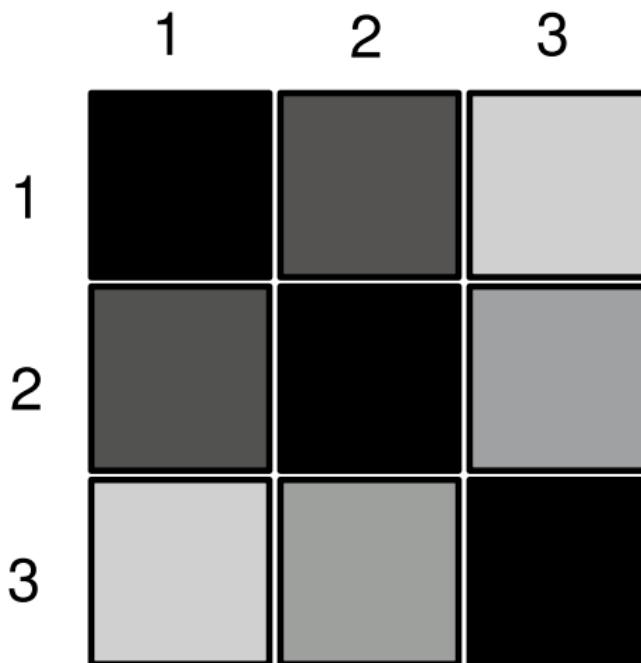
A



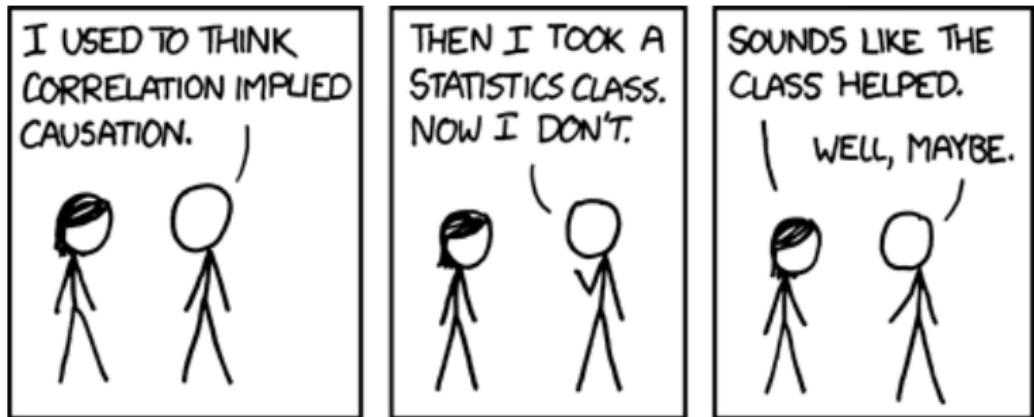
Statistical association: correlation

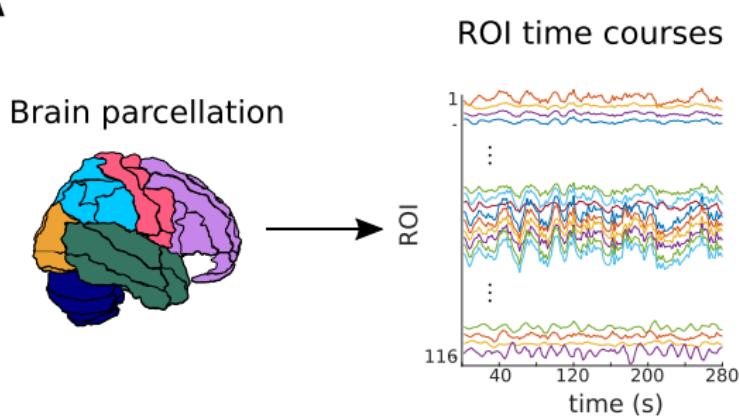


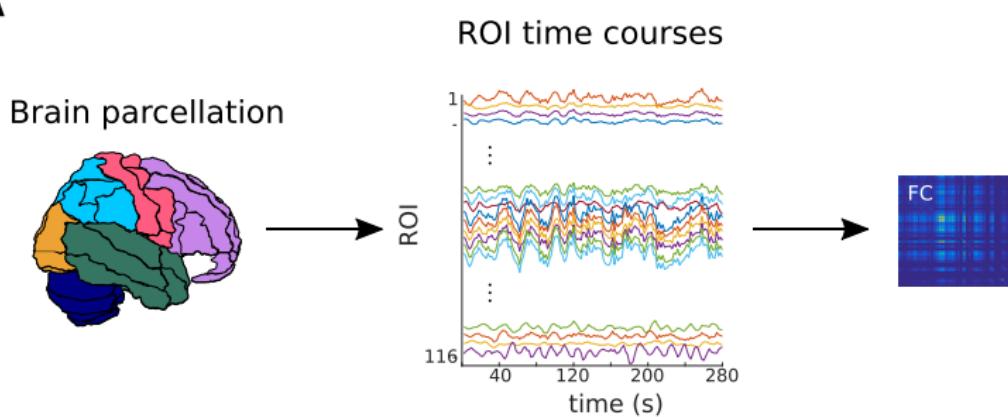
Statistical association: correlation

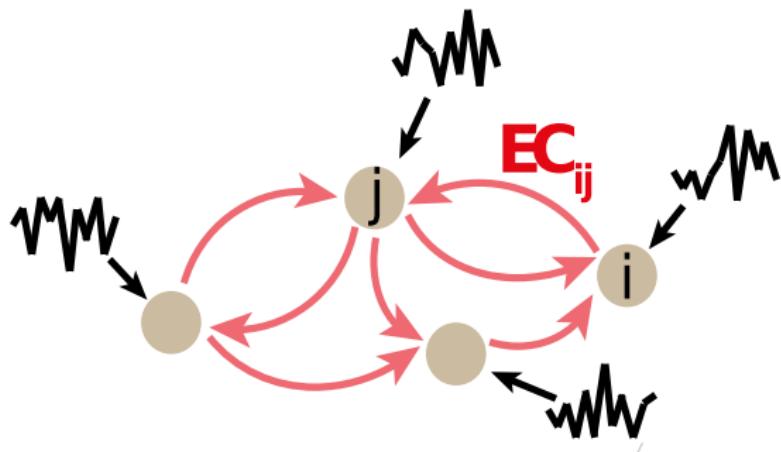


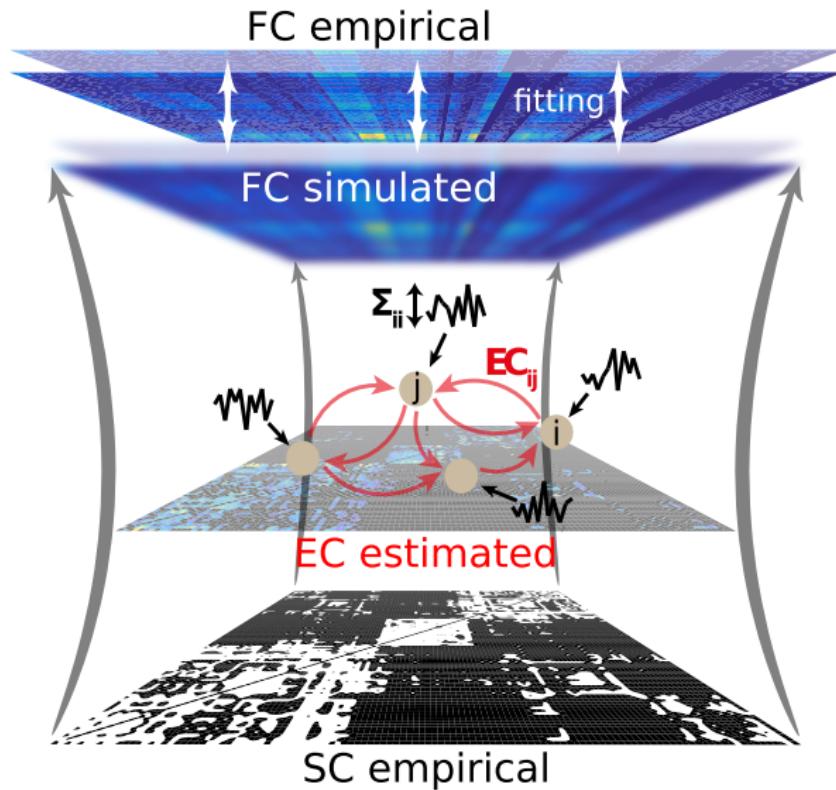
Statistical association: correlation



A

A

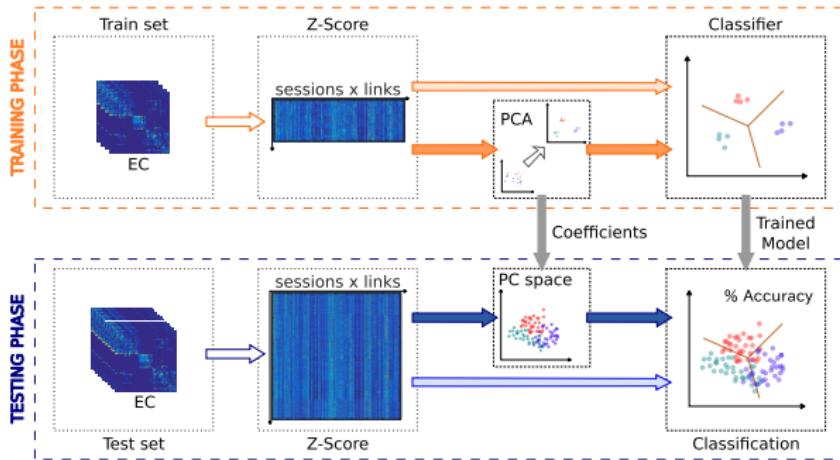




Subjects classification: EC as fingerprint



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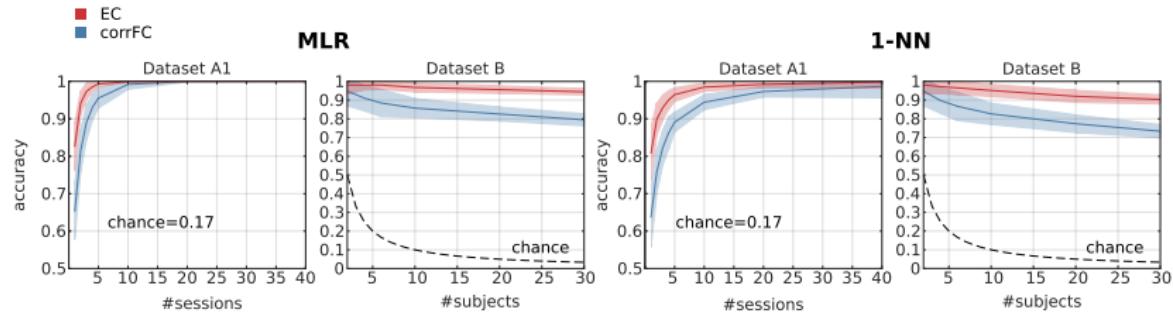
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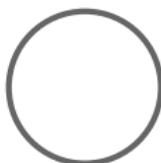
Subjects classification



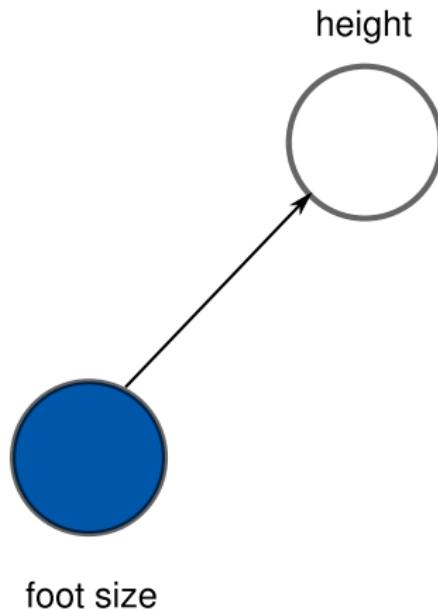
The classifier

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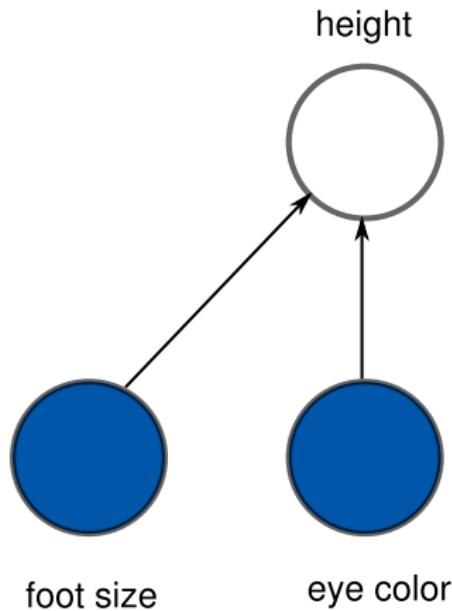
height



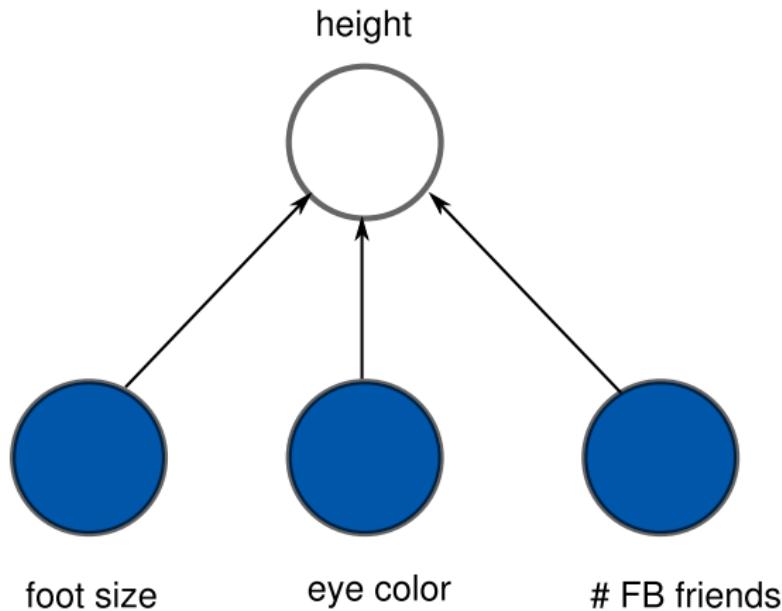
The classifier



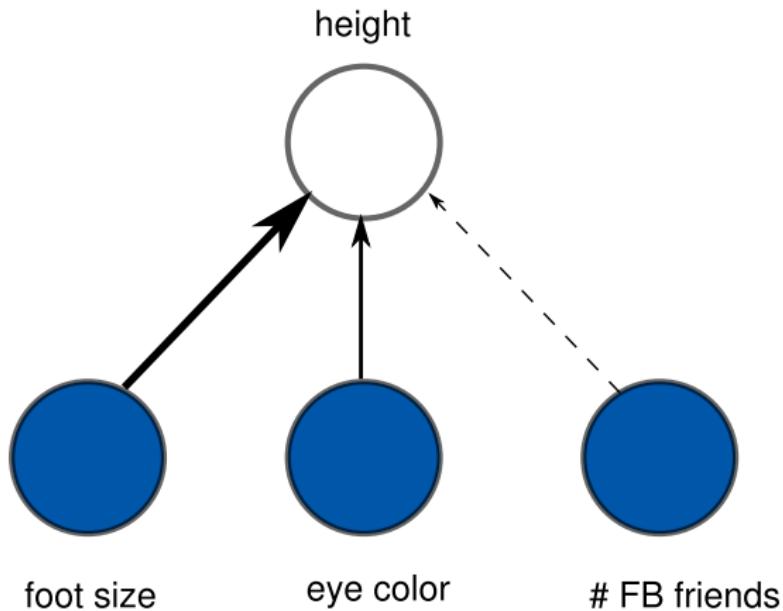
The classifier



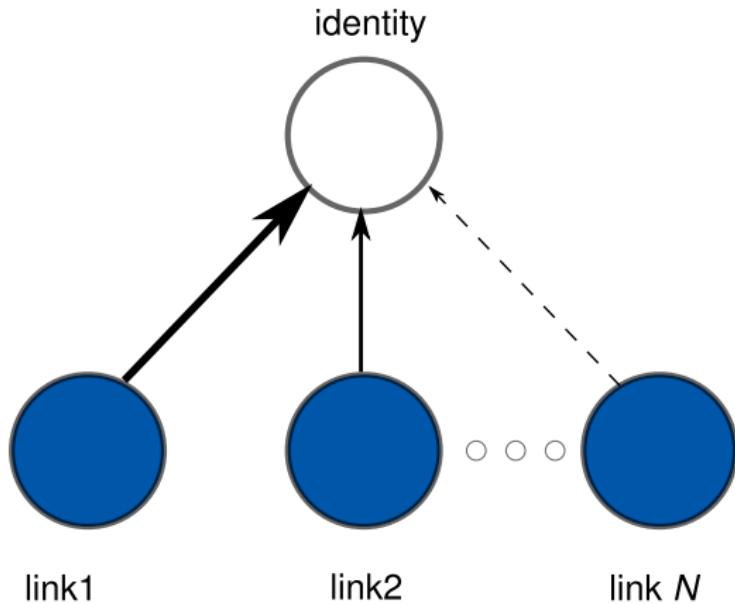
The classifier



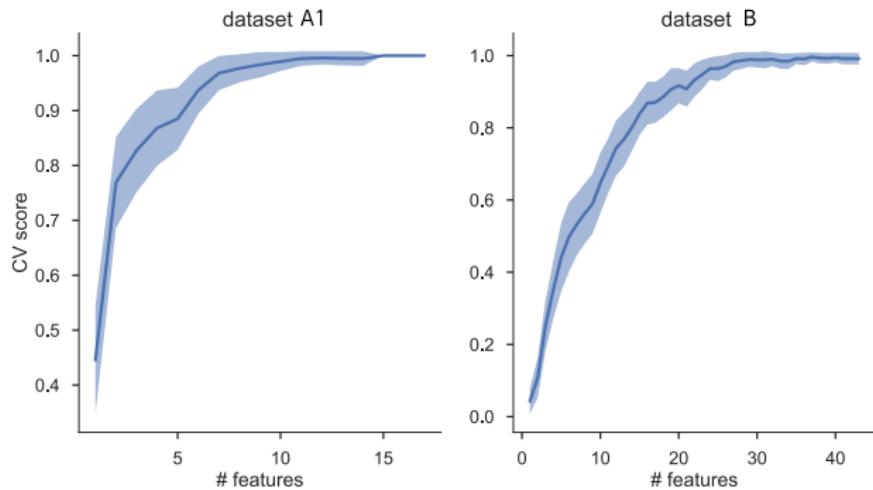
The classifier



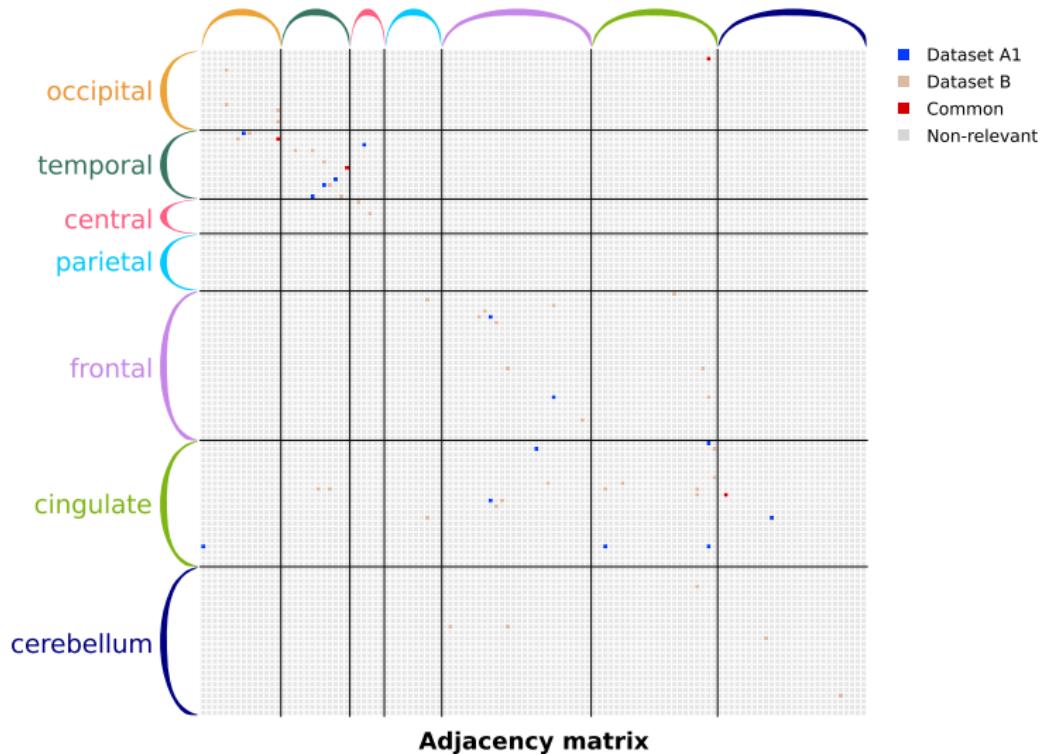
The classifier



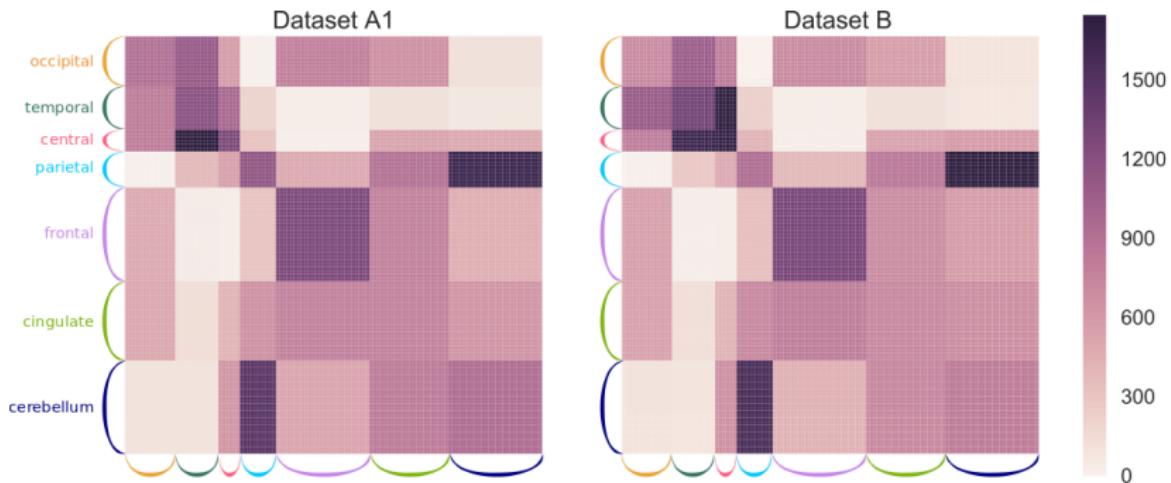
Subjects network



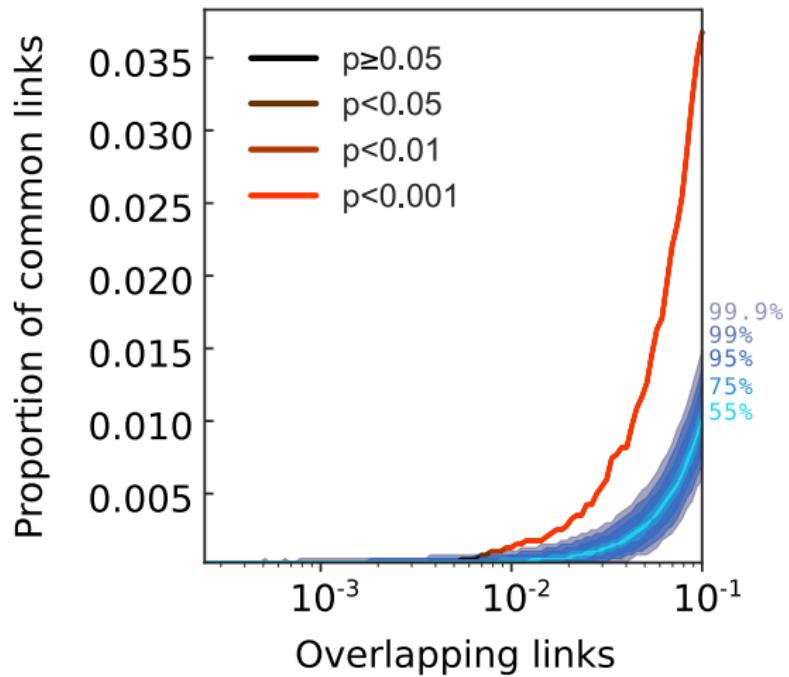
Subjects network



Agreement between datasets



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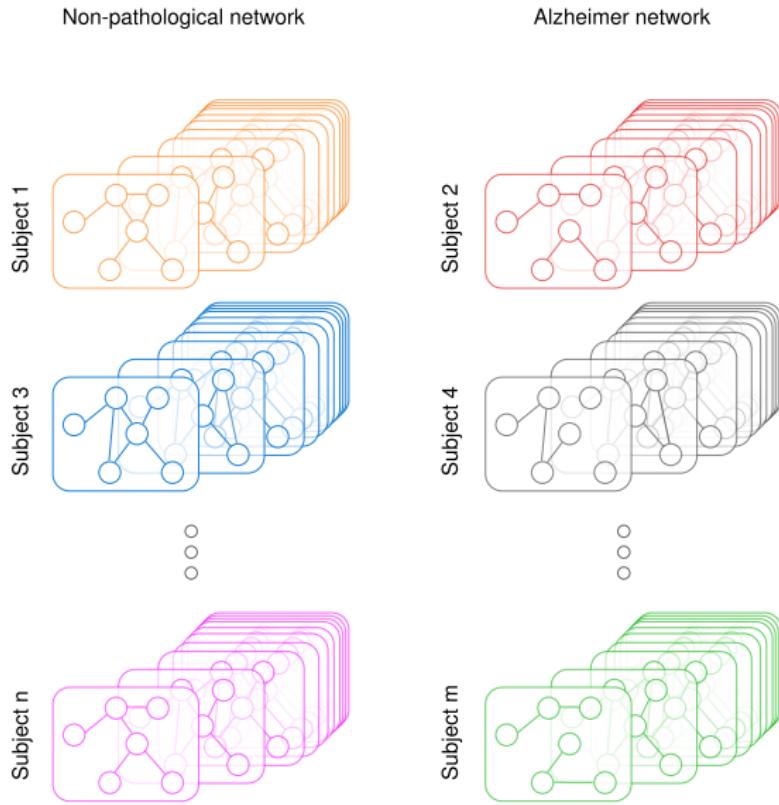
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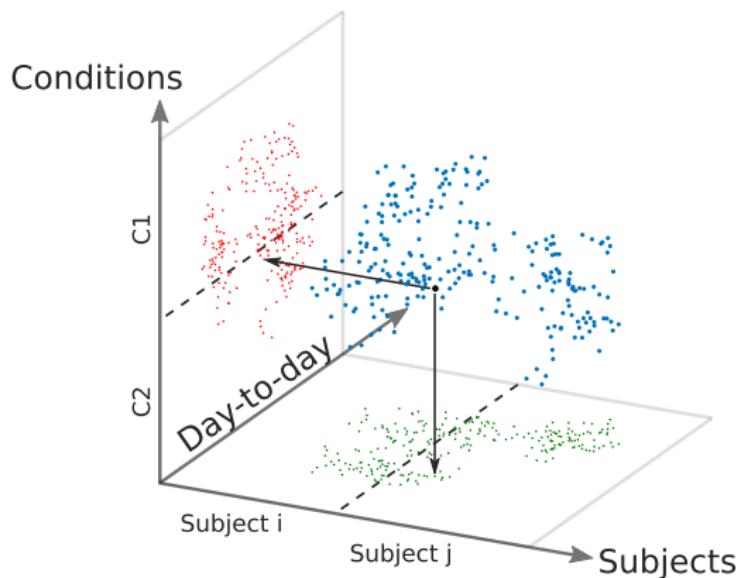
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Simultaneous classification: subjects and conditions

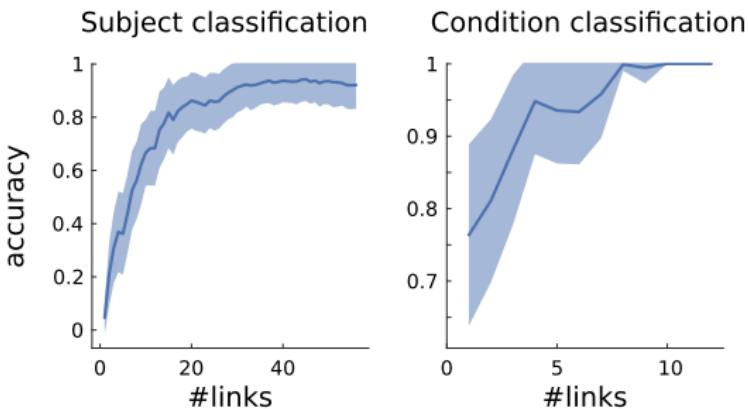


Simultaneous classification: subjects and conditions

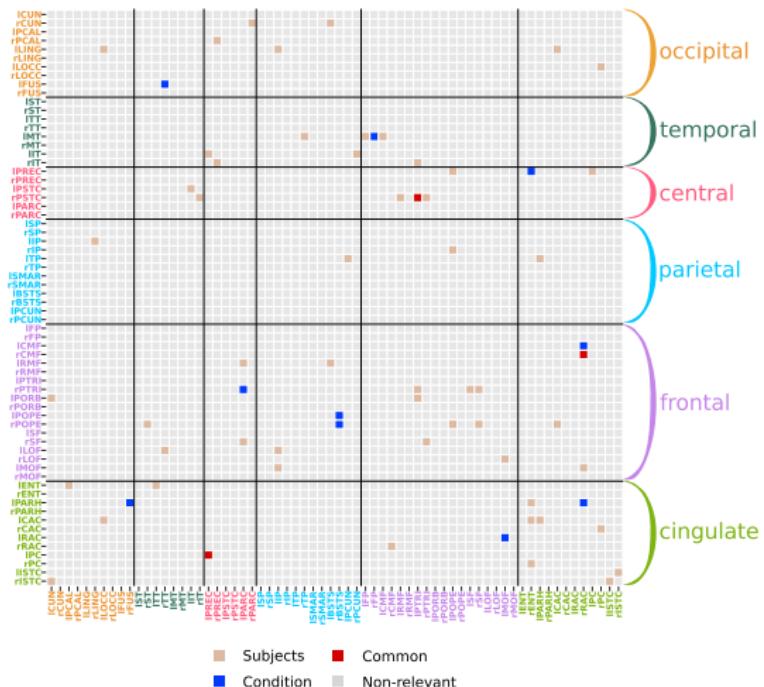


Simultaneous classification: subjects and conditions

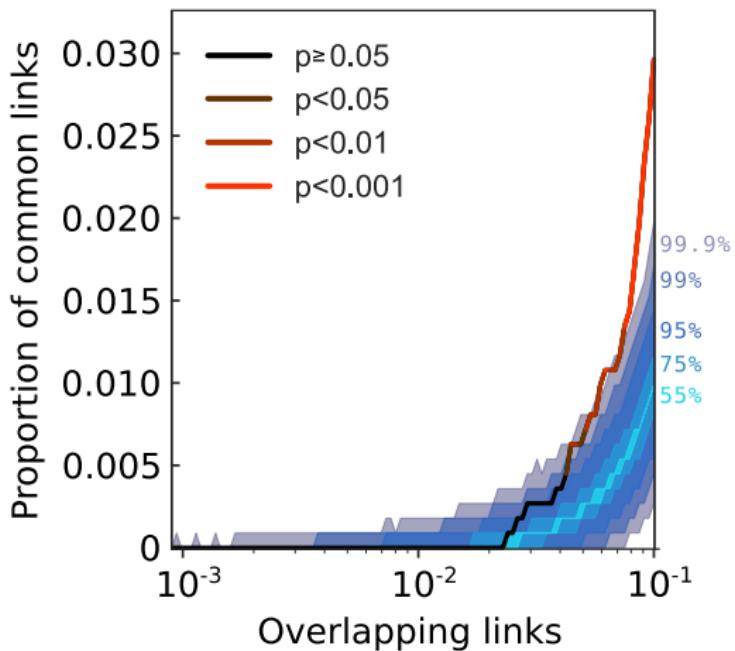
B



Simultaneous classification: subjects and conditions



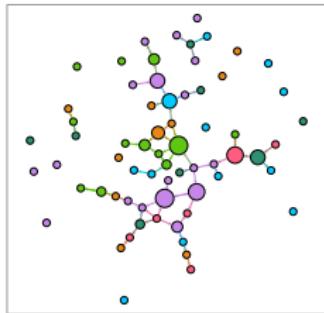
Simultaneous classification: subjects and conditions



Simultaneous classification: subjects and conditions

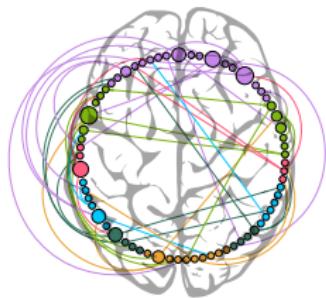
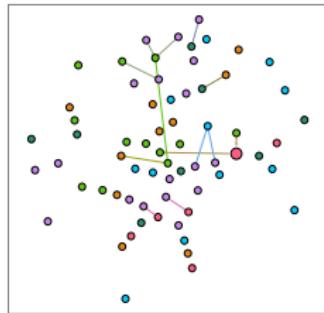
A

Support network of **subject** classification

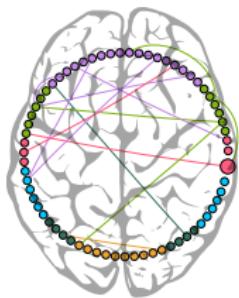


B

Support network of **condition** classification



- frontal
- cingulate
- central
- parietal
- temporal
- occipital



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Acknowledgments

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Matthieu Gilson

Ana Sanjuan

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Dante Mantini

Gustavo Deco



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Gustavo Deco



**THANK YOU FOR YOUR
ATTENTION**



ANY QUESTIONS?

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