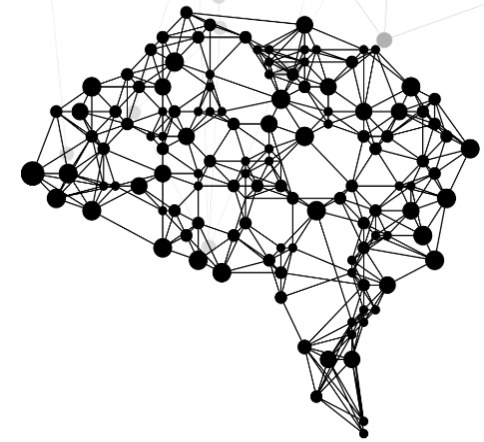
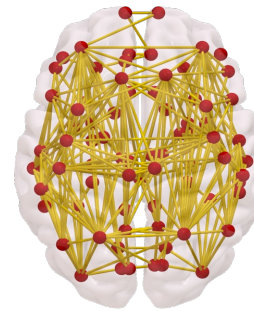
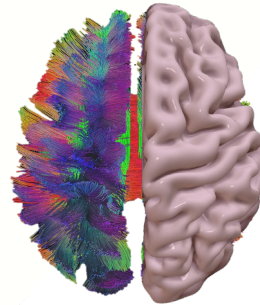


Competitive interactions shape brain dynamics and computation across species



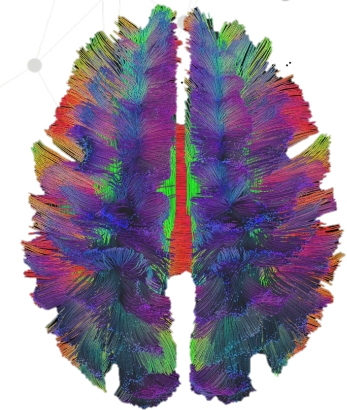
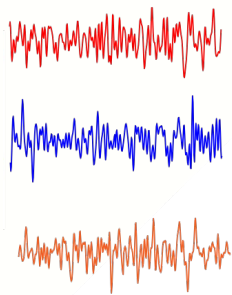
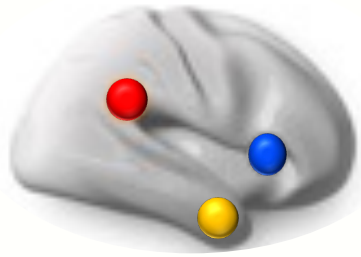
**Division F Conference
October 7th 2025**



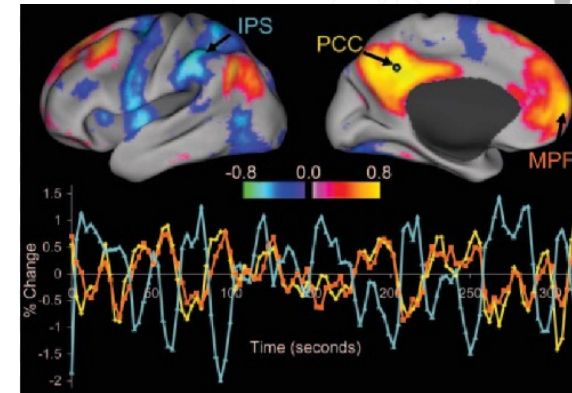
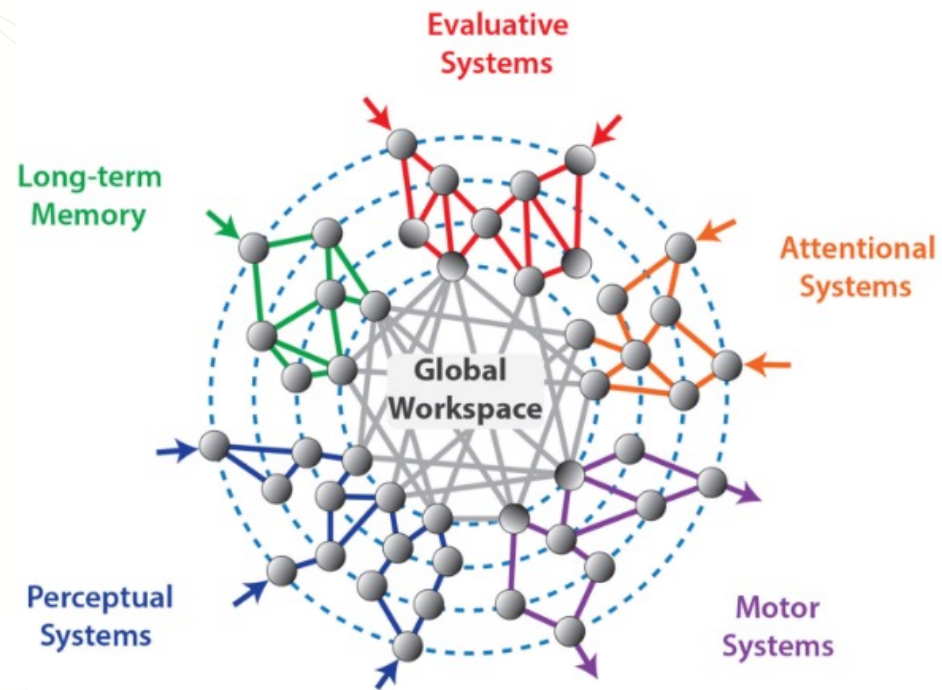
Dr Andrea Luppi
Research Fellow, St John's College Cambridge



Neural information-routing architecture

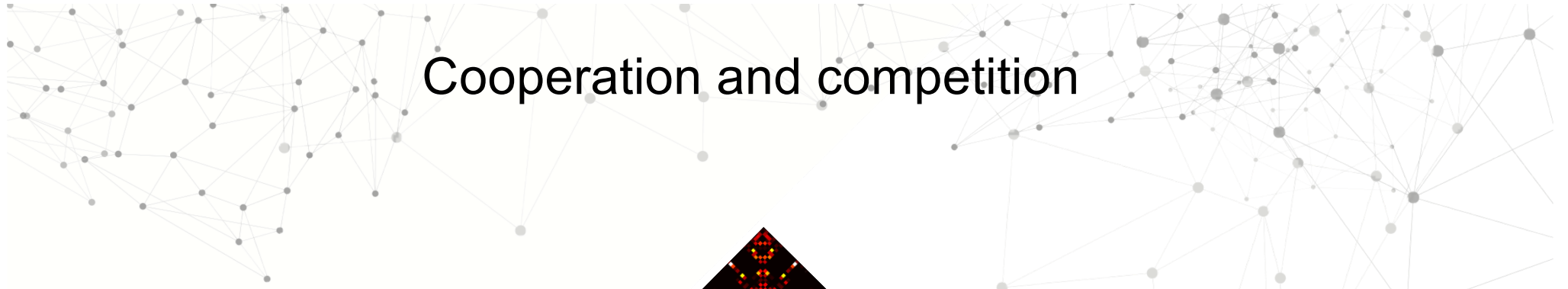


Cooperation and competition

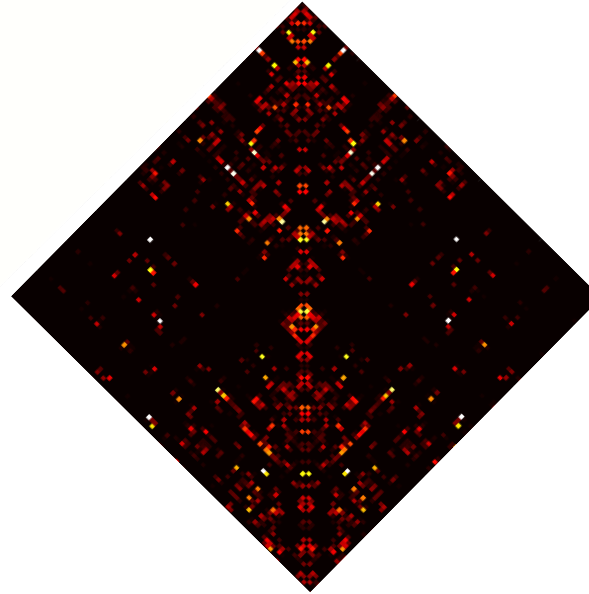


Mesulam 1998 *Brain*
Fox *et al.* 2005 *PNAS*
Dehaene and Changeaux 2011 *Neuron*
Cocchi *et al.* 2013 *TICS*

Cooperation and competition

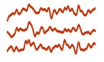


Does the brain's network architecture include competition?



How do competitive interactions shape brain dynamics?

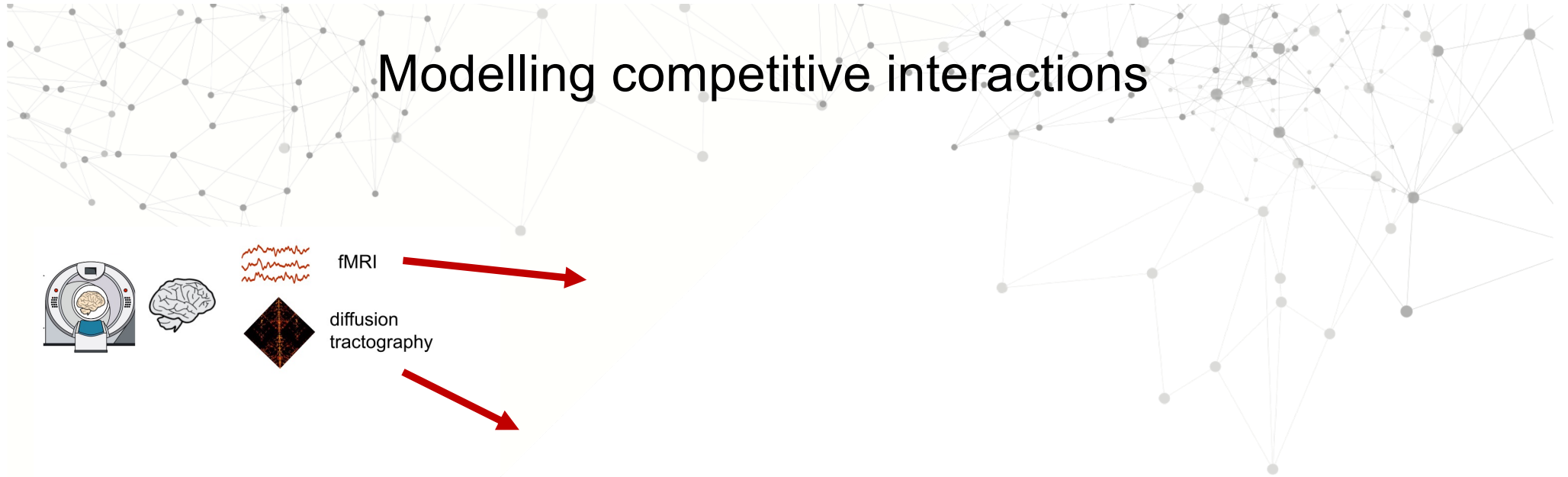
Modelling competitive interactions



fMRI



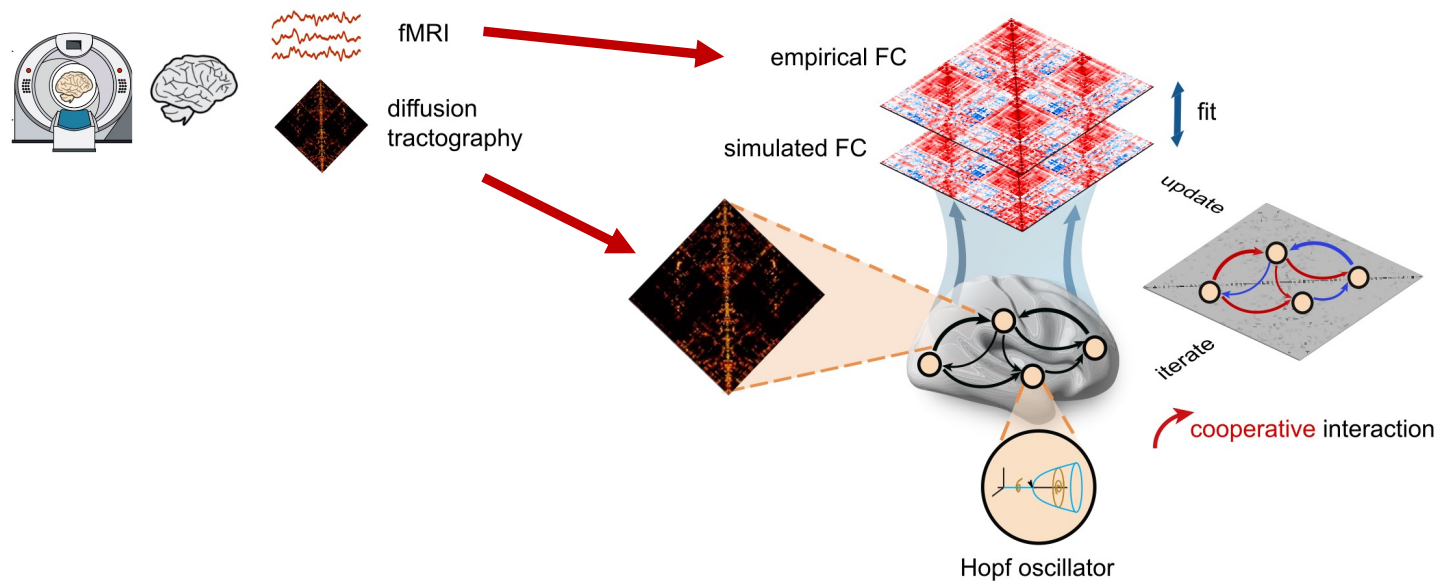
diffusion
tractography



Modelling competitive interactions

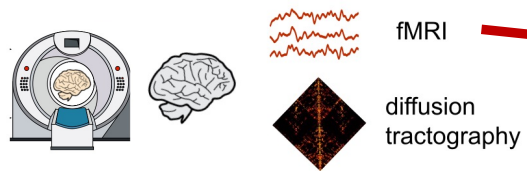
a | species-specific brain activity and connectivity

b | generative effective connectivity from whole-brain modelling

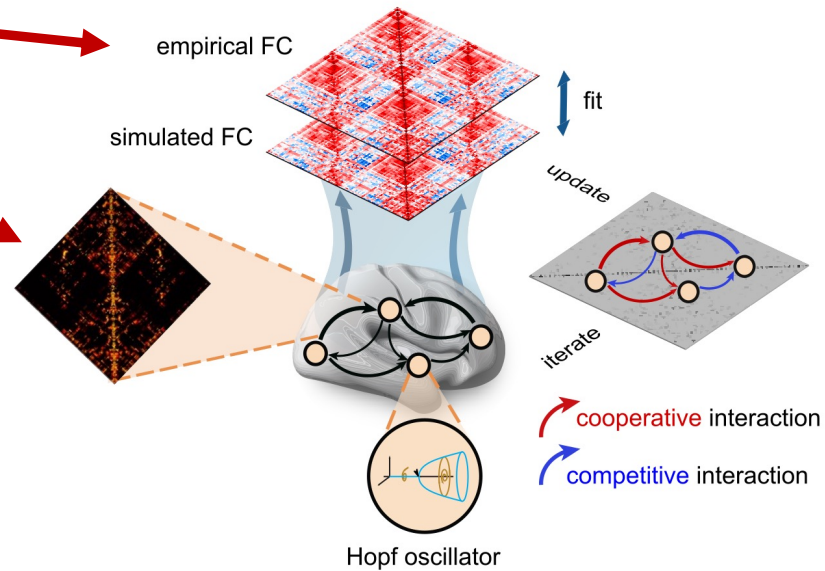


Modelling competitive interactions

a | species-specific brain activity and connectivity

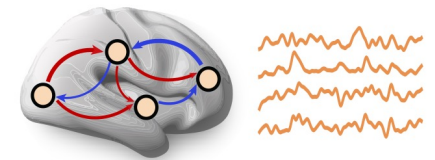


b | generative effective connectivity from whole-brain modelling



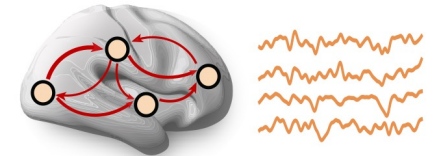
c | simulated dynamics

cooperative + competitive model



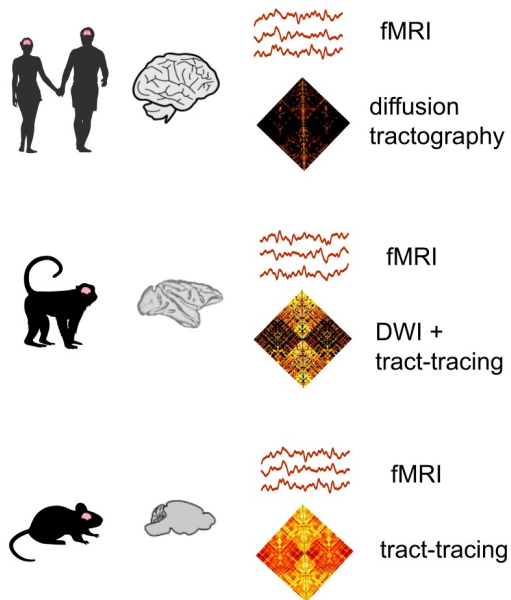
vs

cooperative-only model

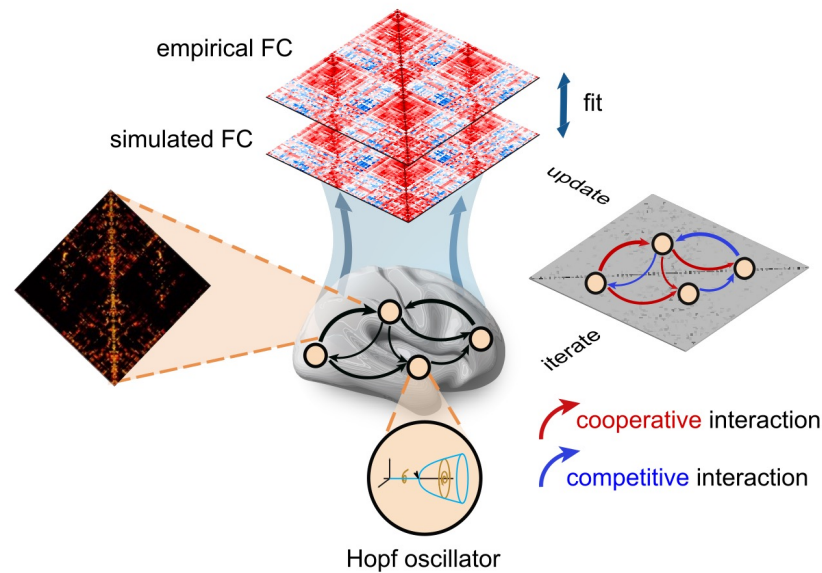


Modelling competitive interactions across species

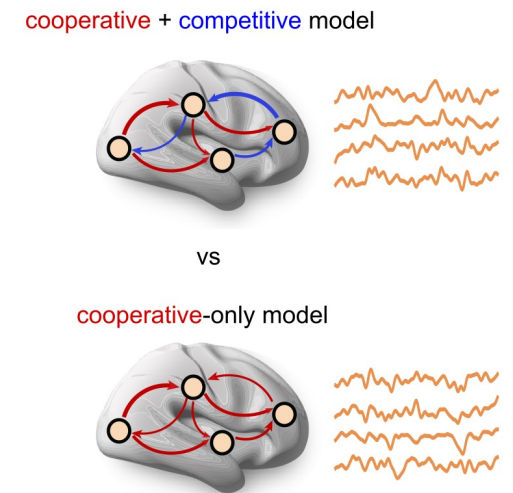
a | species-specific brain activity and connectivity



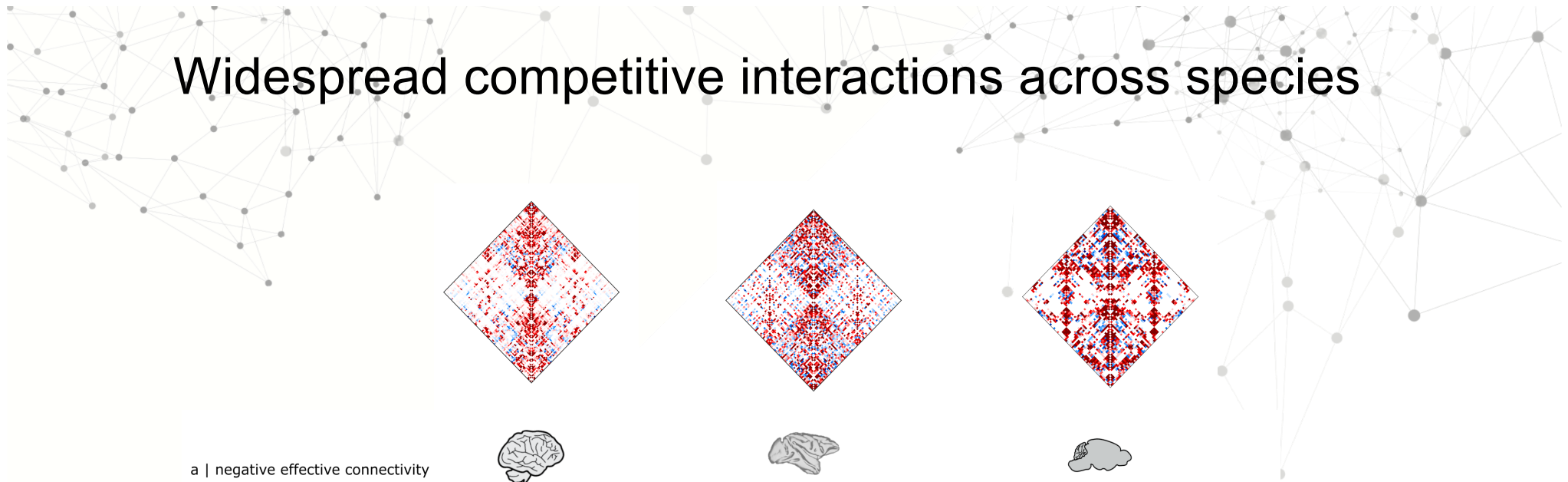
b | generative effective connectivity from whole-brain modelling



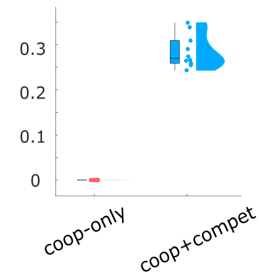
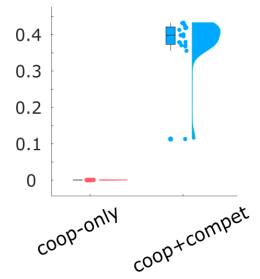
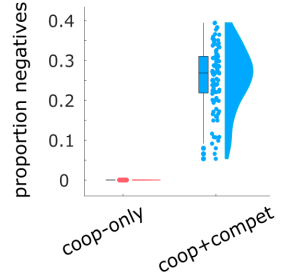
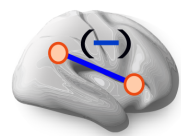
c | simulated dynamics



Widespread competitive interactions across species

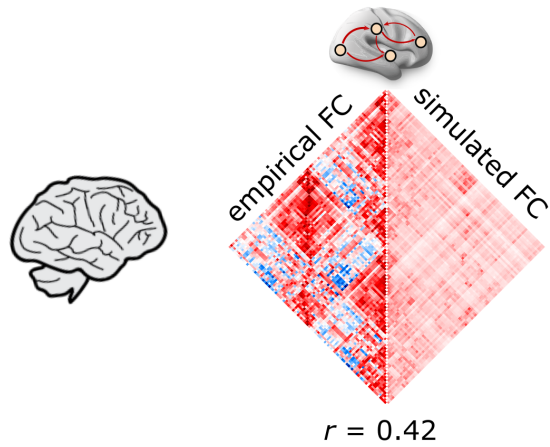


a | negative effective connectivity



Superior group-level fit to empirical FC

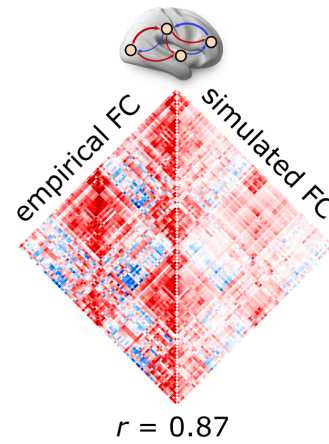
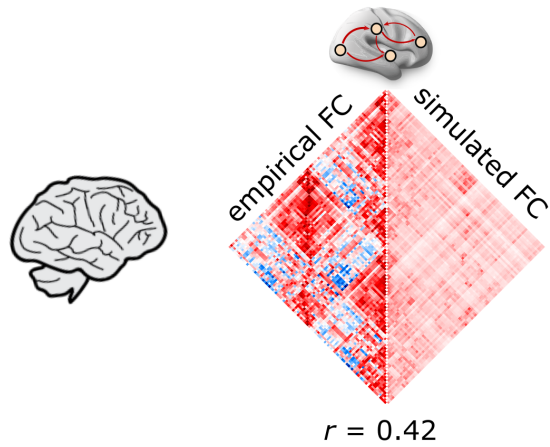
a | group FC fit cooperative-only



Superior group-level fit to empirical FC

a | group FC fit cooperative-only

b | group FC fit with competition

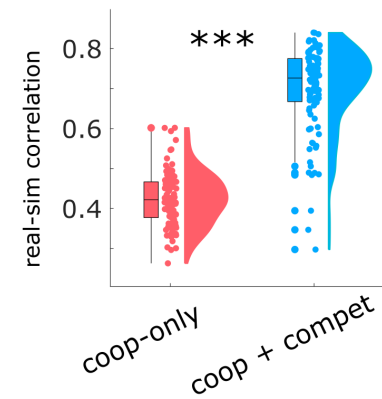
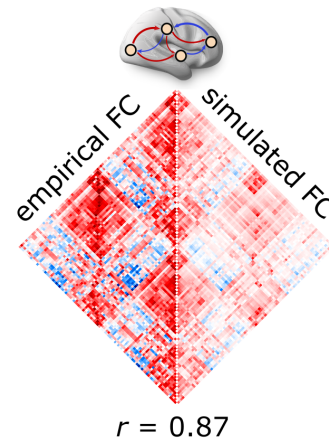
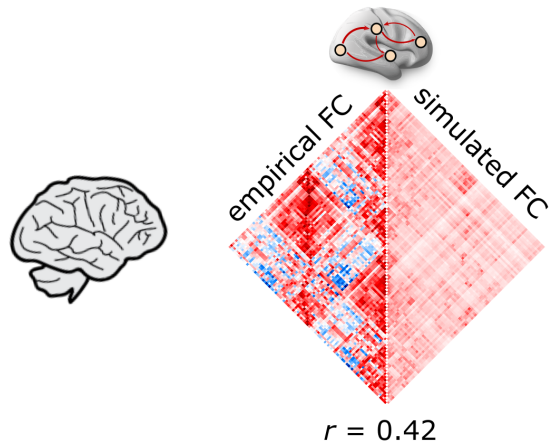


Superior subject-wise fit to empirical FC

a | group FC fit cooperative-only

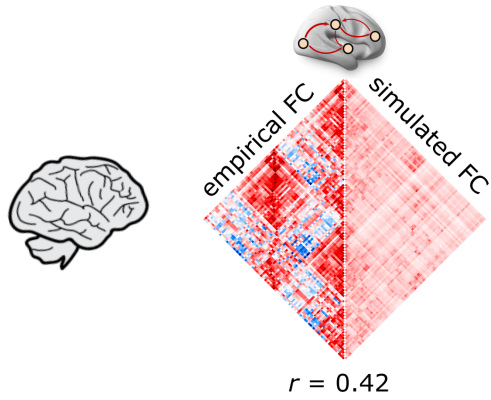
b | group FC fit with competition

c | subject-wise FC fit

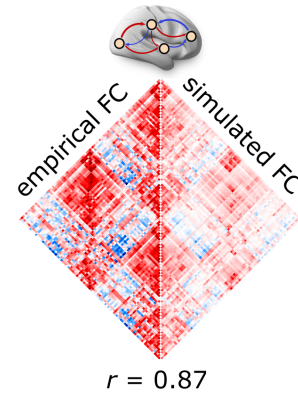


Superior FC fit across species

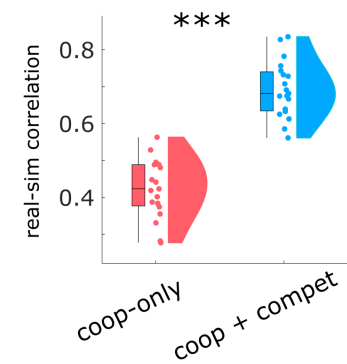
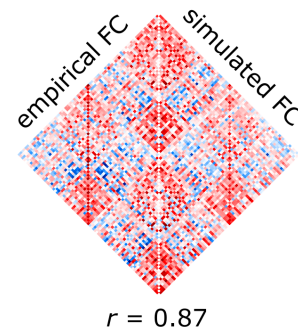
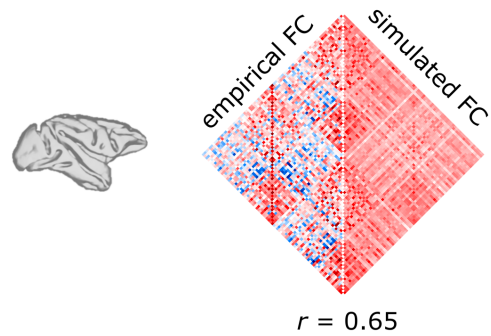
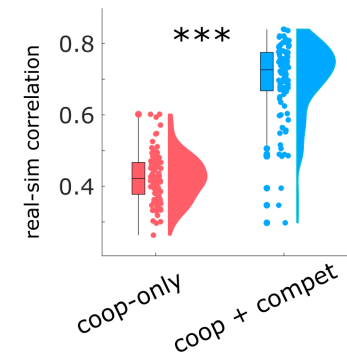
a | group FC fit cooperative-only



b | group FC fit with competition

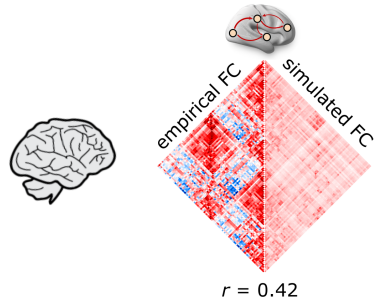


c | subject-wise FC fit

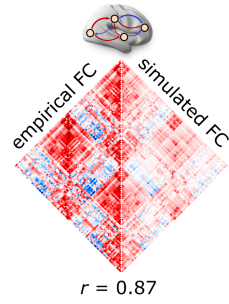


Superior FC fit across species

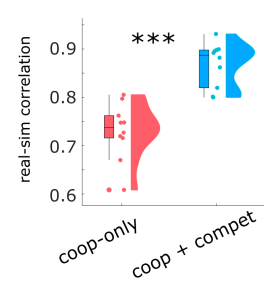
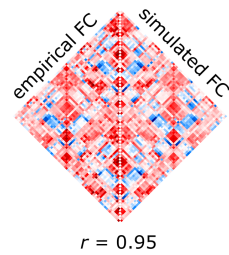
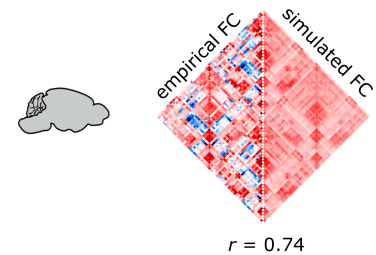
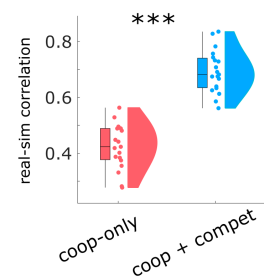
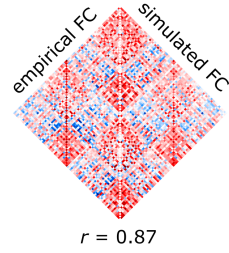
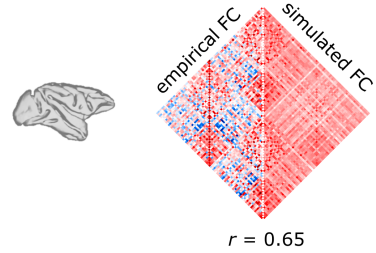
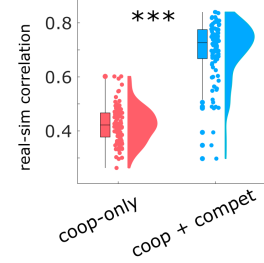
a | group FC fit cooperative-only



b | group FC fit with competition



c | subject-wise FC fit

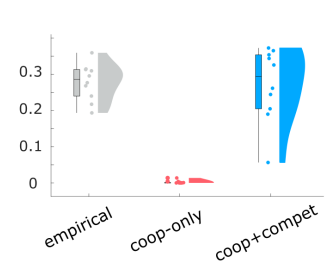
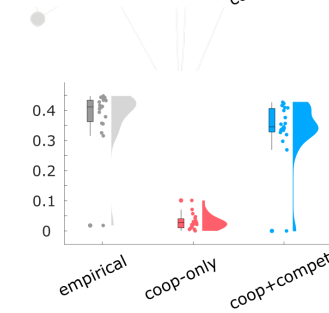
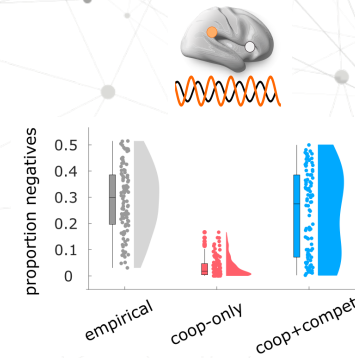
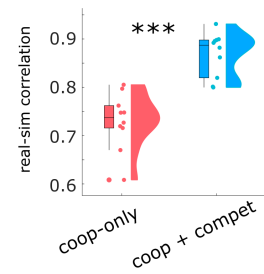
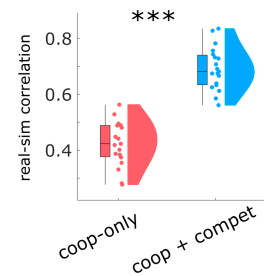
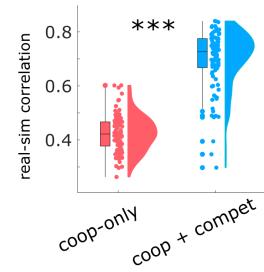
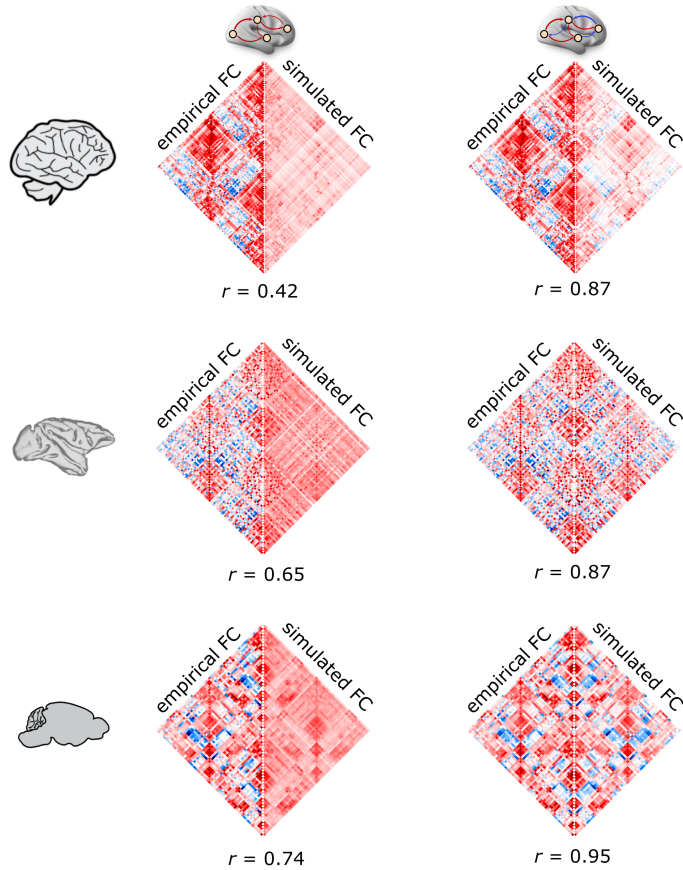


Matching anticorrelations

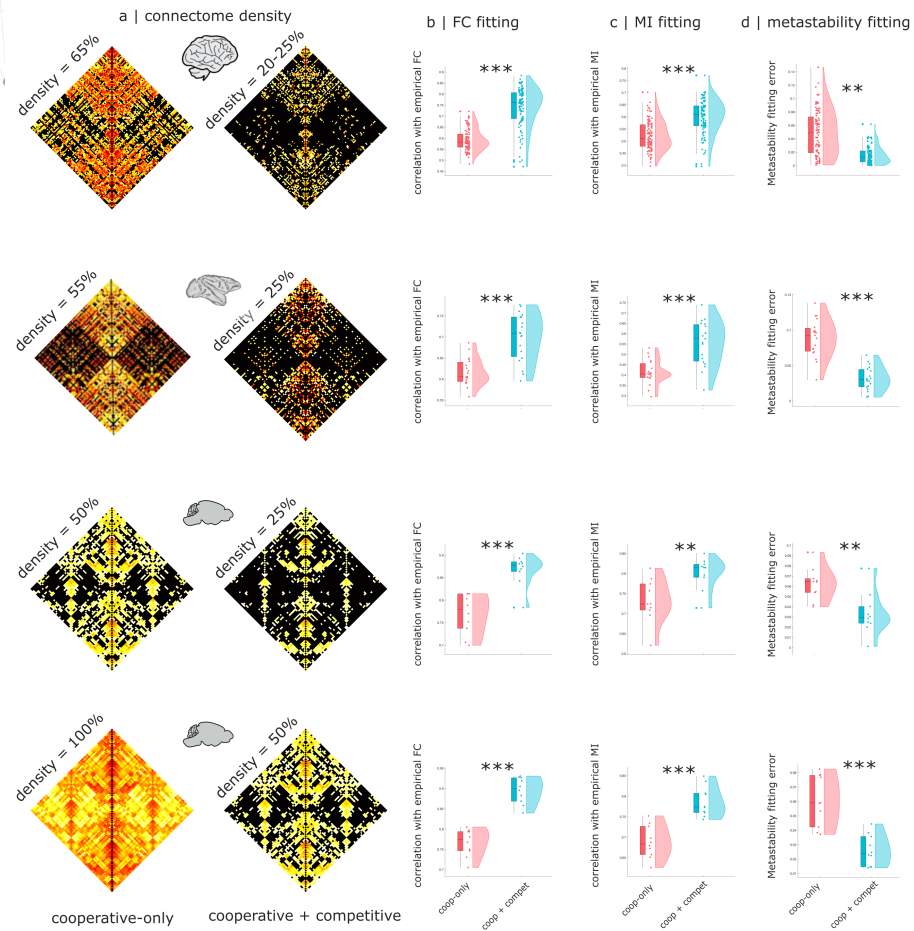
a | group FC fit cooperative-only

b | group FC fit with competition

c | subject-wise FC fit

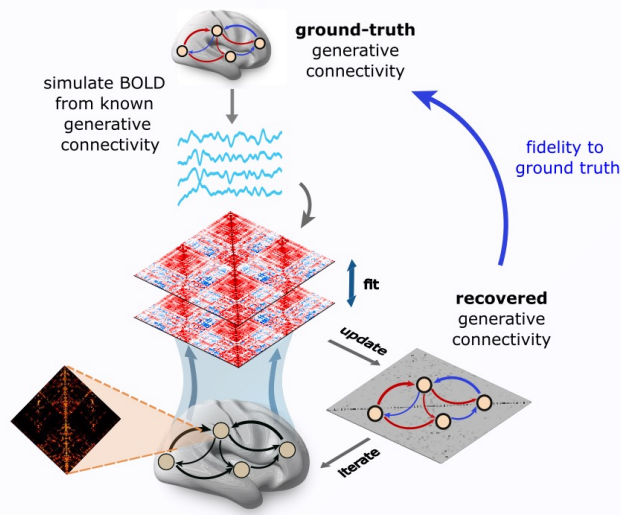


Competitive interactions: better than 2X parameters

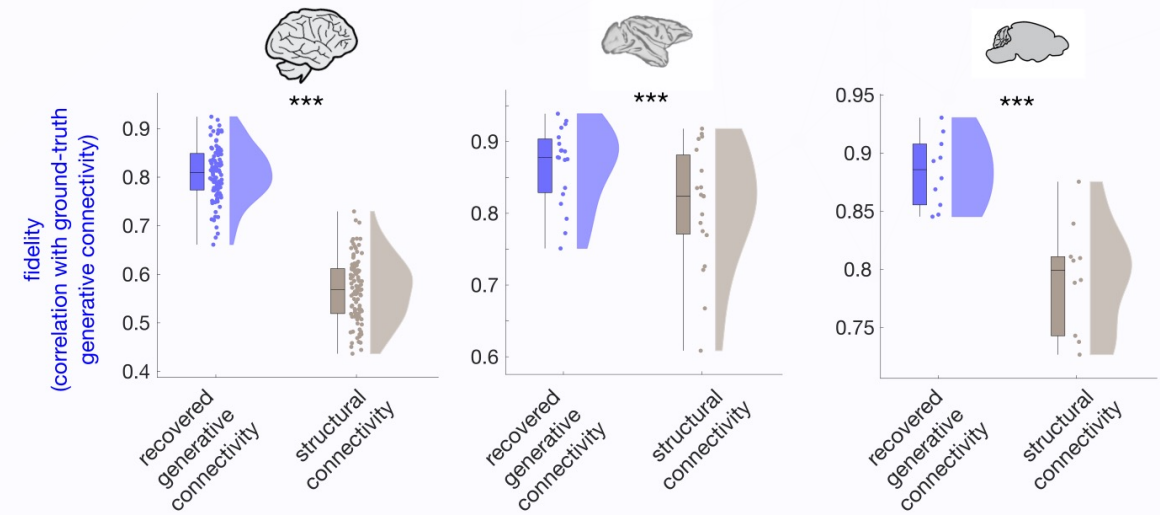


Recovering ground truth

a | using simulation to assess model fidelity to ground truth

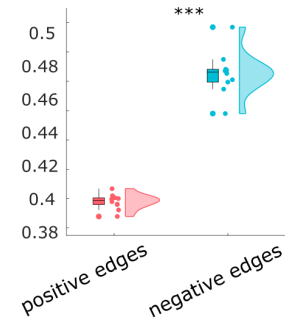
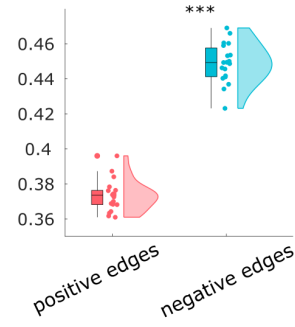
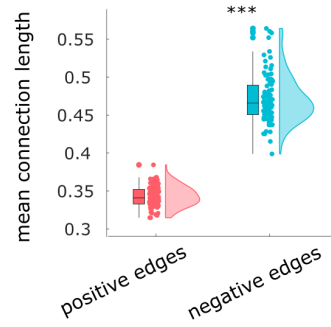
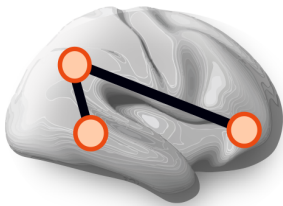


b | generative connectivity recovered by the model has high correspondence with underlying ground-truth connectivity



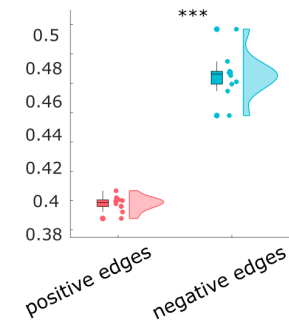
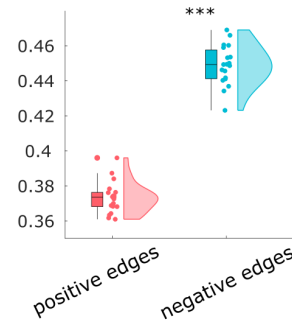
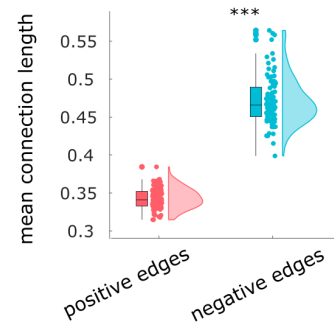
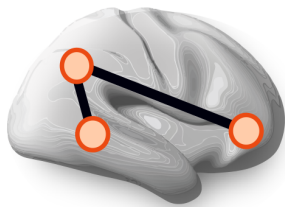
Systematic organisation of competitive connections

c | connection length

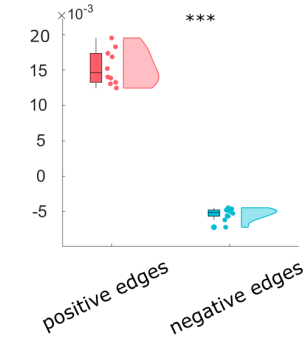
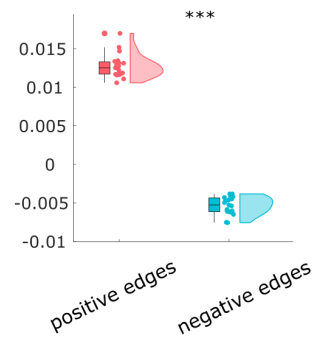
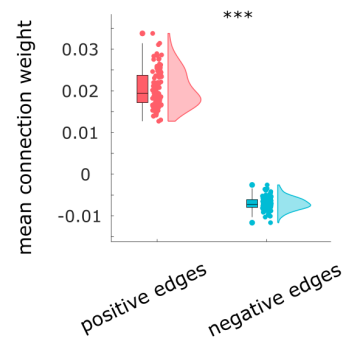
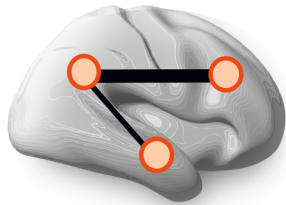


Systematic organisation of competitive connections

c | connection length

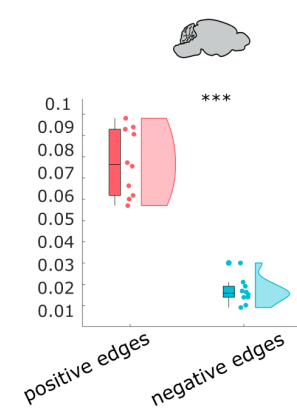
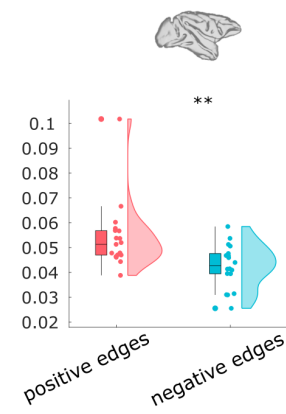
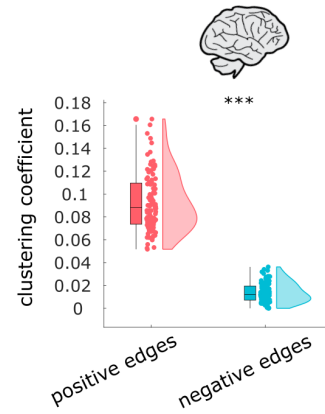
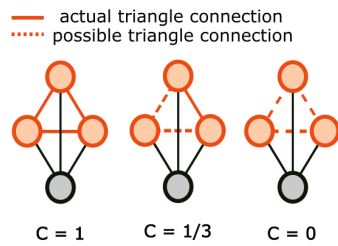


d | connection weight

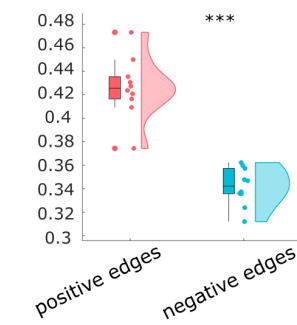
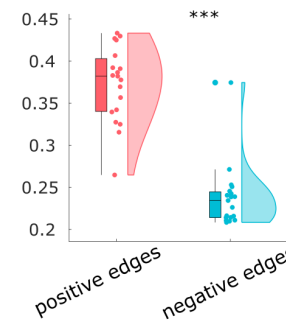
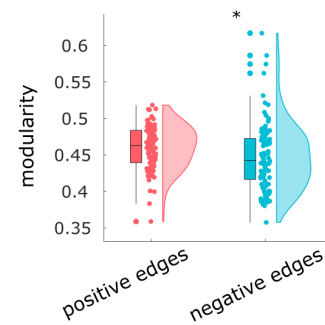
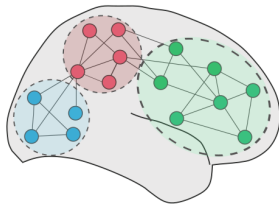


Systematic organisation of competitive connections

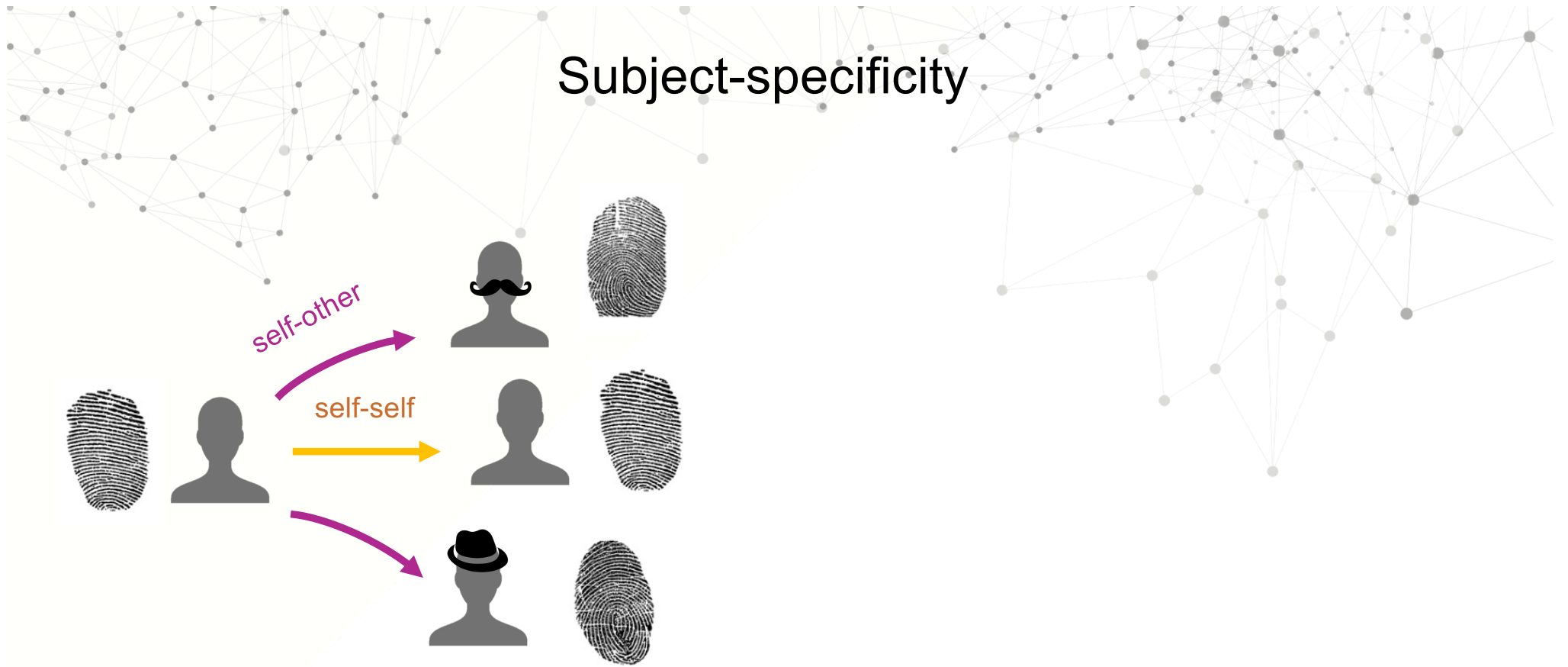
a | network clustering



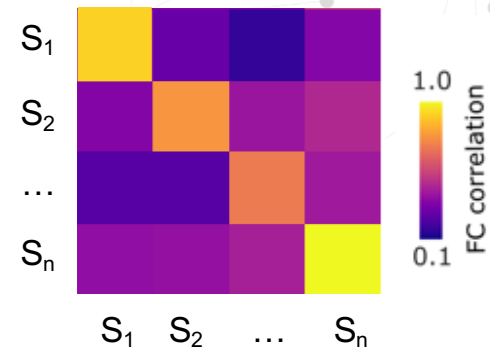
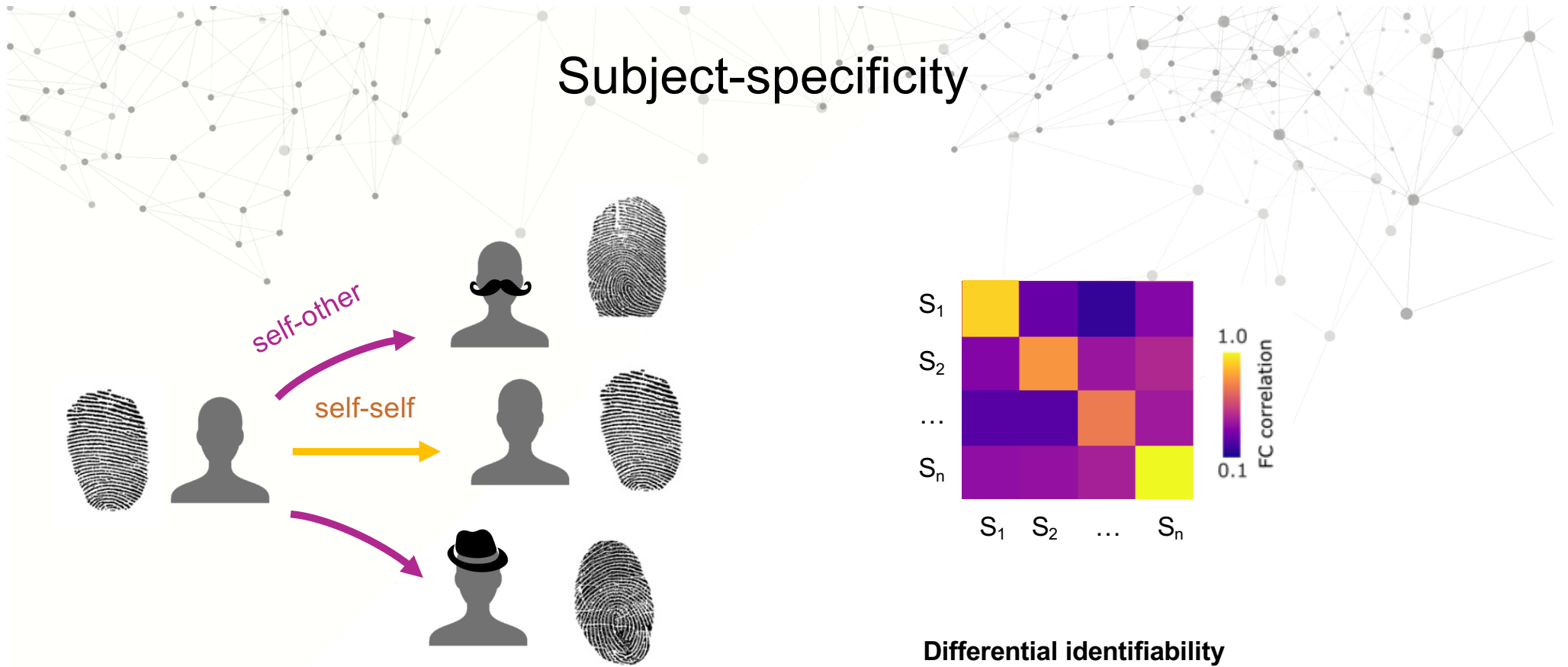
b | network modularity



Subject-specificity

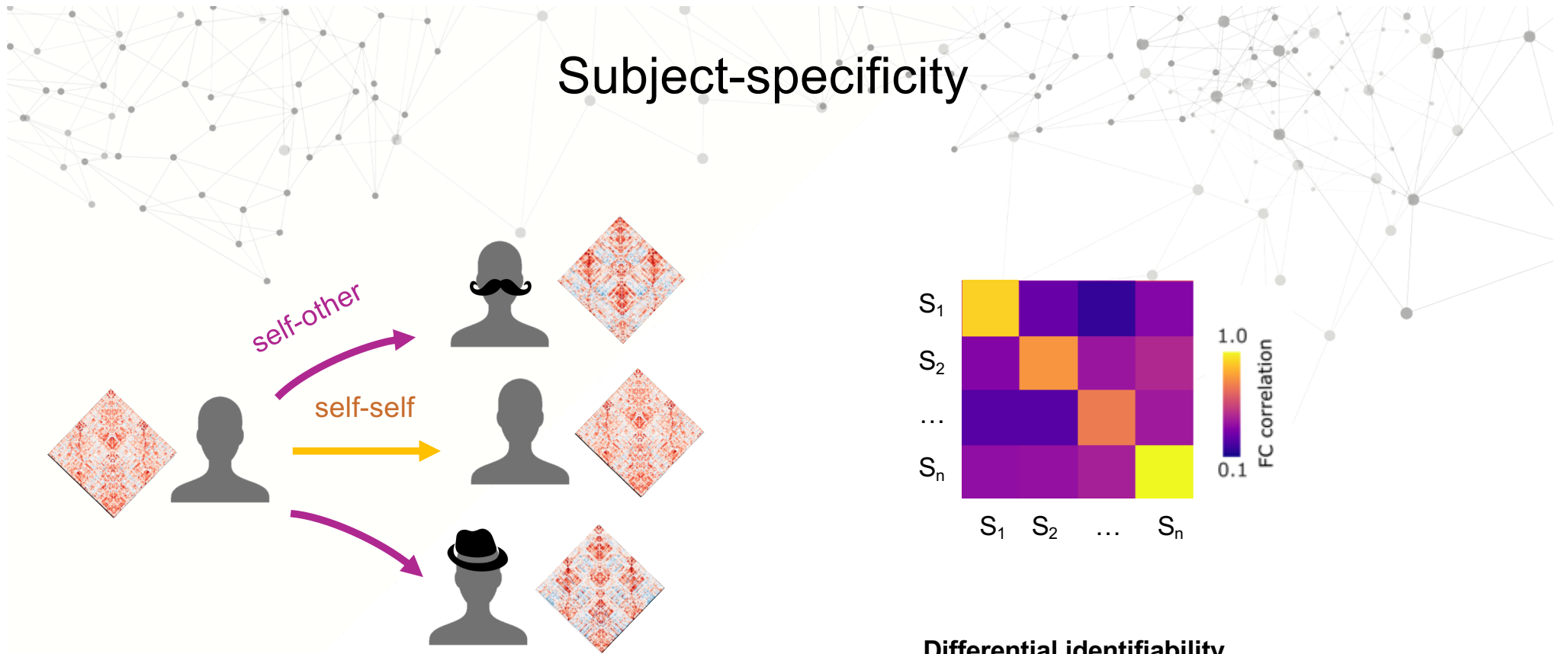


Subject-specificity



Differential identifiability
=
self-self (diagonal)
minus
self-other (off-diagonal)

Subject-specificity



Differential identifiability

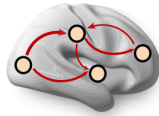
$$= \text{self-self (diagonal)} \\ \text{minus} \\ \text{self-other (off-diagonal)}$$

Enhanced subject-specificity

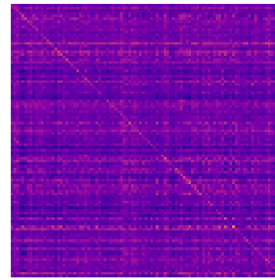
a | individual-specificity of model fit



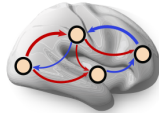
coop-only



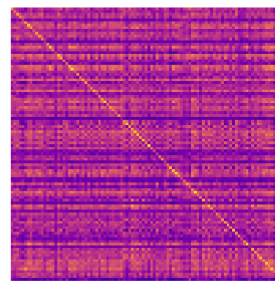
subjects (simulated)



coop + compet

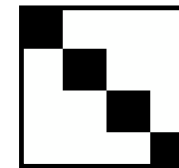


subjects (simulated)



subjects (empirical)

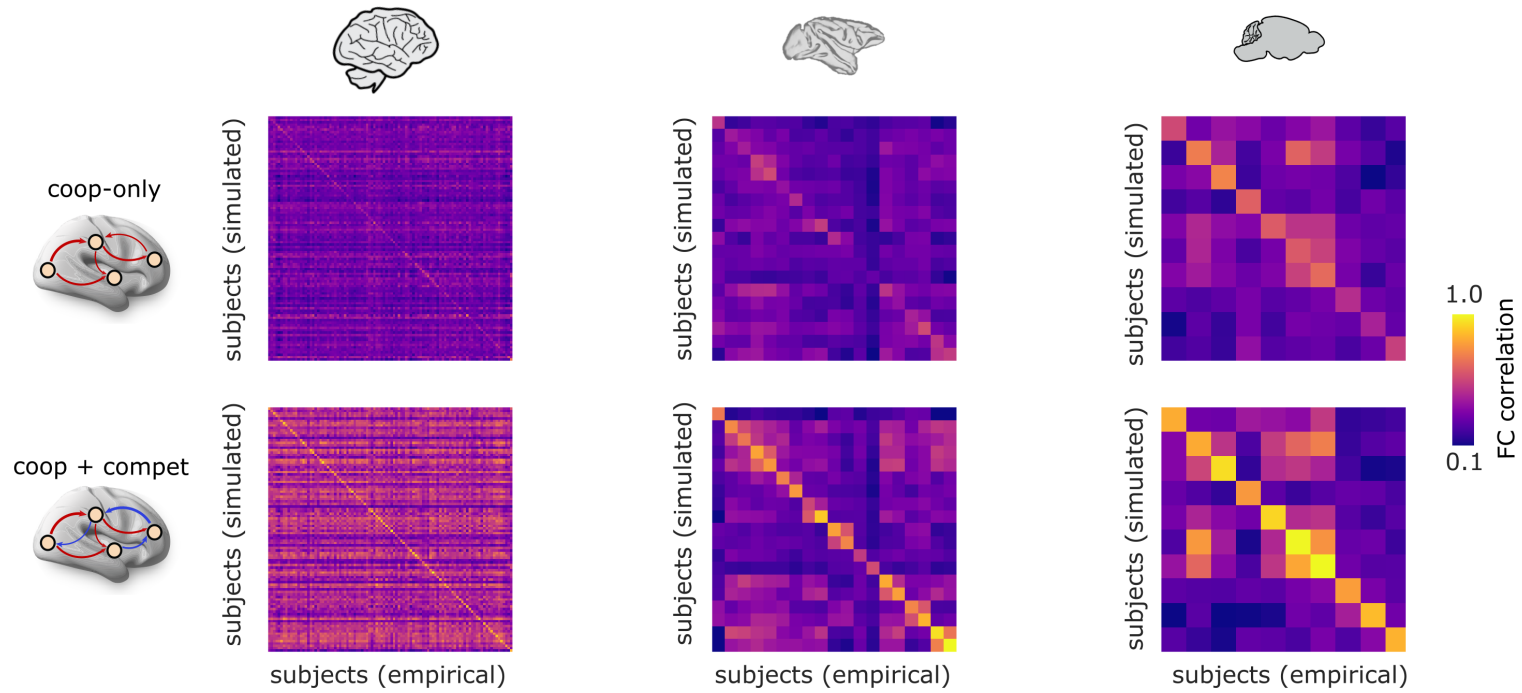
1.0
0.1
FC correlation



self-self similarity

Enhanced subject-specificity

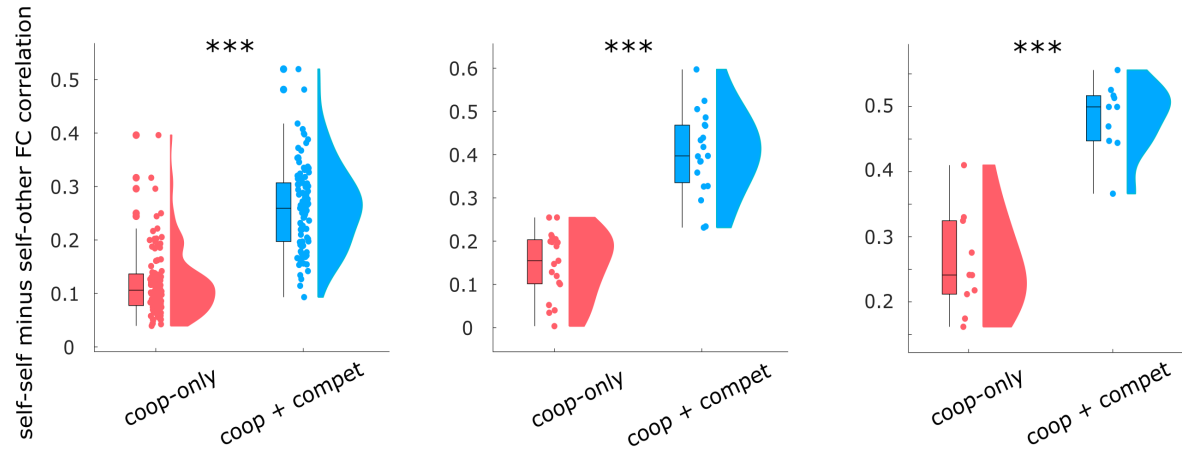
a | individual-specificity of model fit



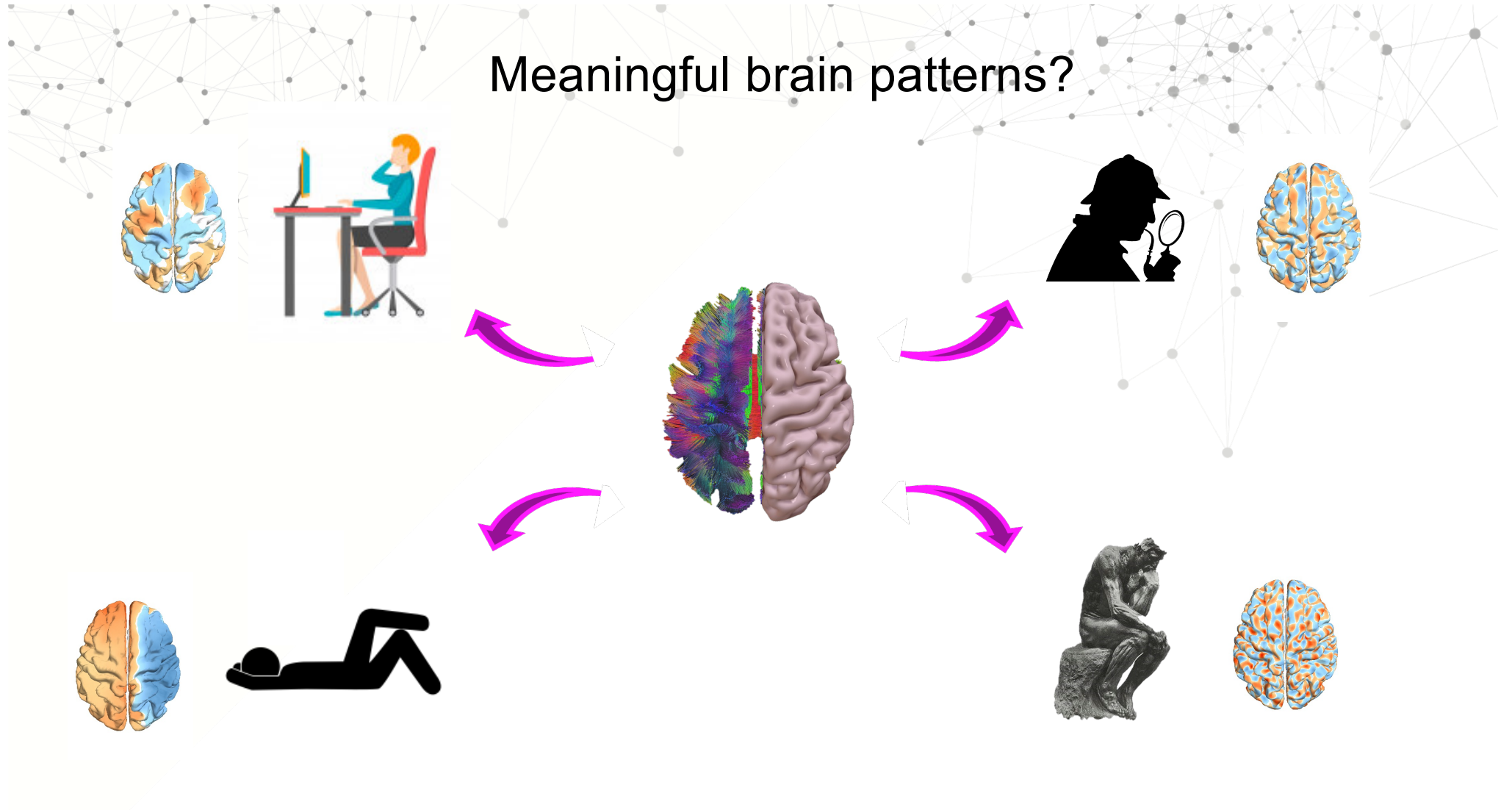
Enhanced subject-specificity



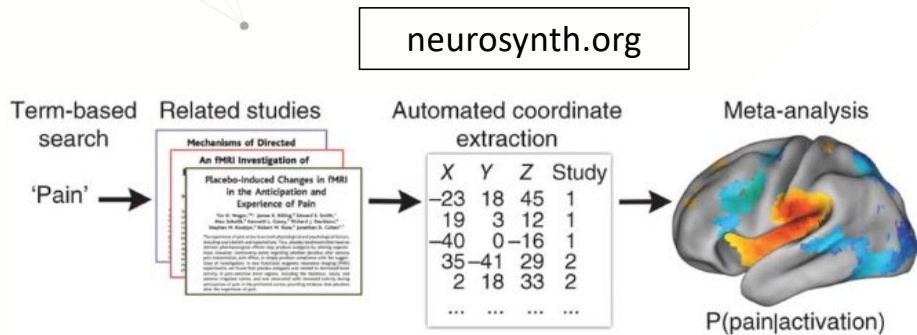
b | model with competitive interactions is more individual-specific



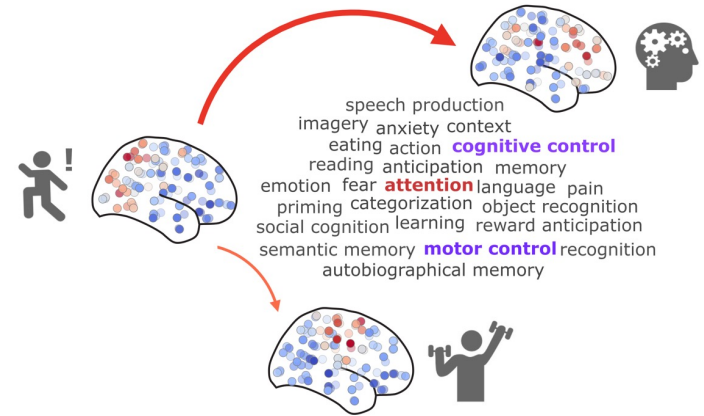
Meaningful brain patterns?



Meaningful brain patterns from NeuroSynth

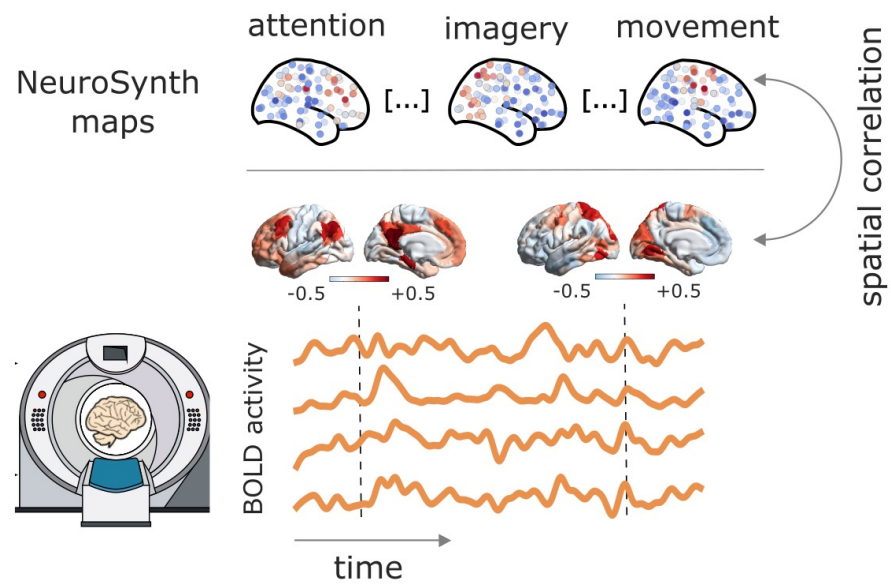


summary of
>14,000
neuroimaging
experiments



Matching cognitive brain patterns

a | cognitive matching

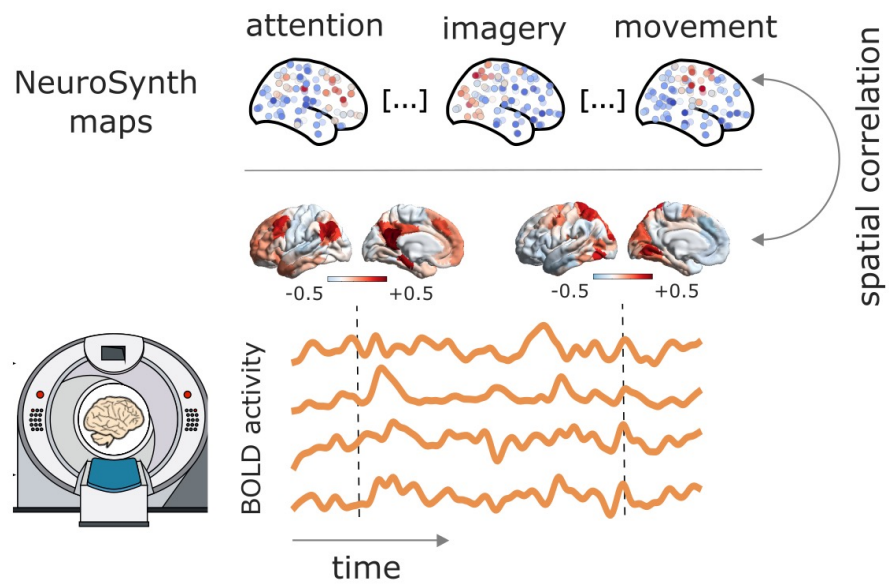


spatial correlation

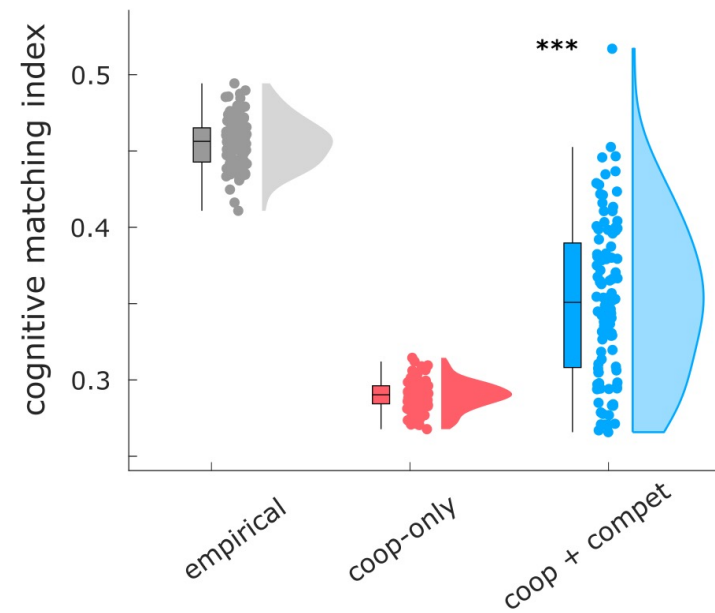
time

Matching cognitive brain patterns

a | cognitive matching



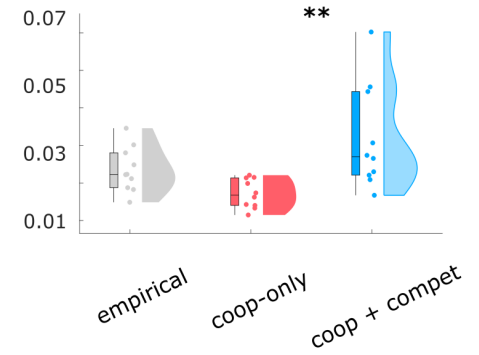
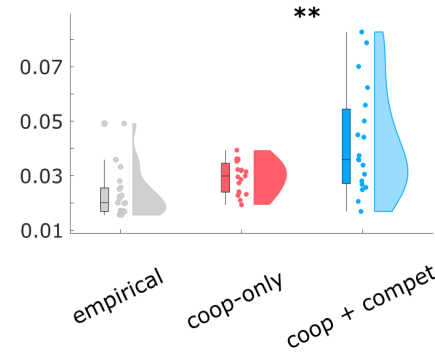
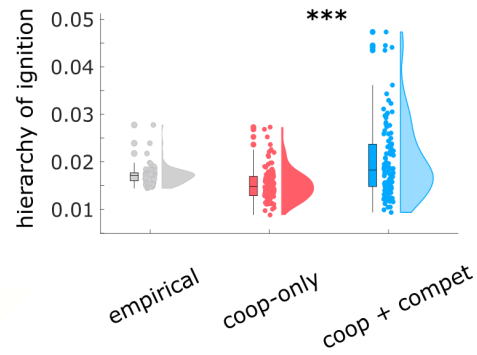
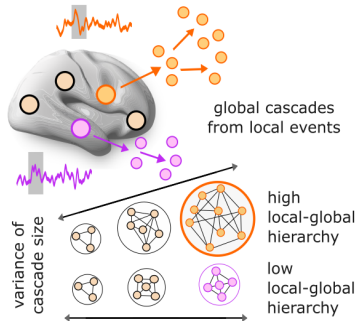
b | cognitive matching for model evaluation



Luppi et al. *Nature Human Behaviour* (2025)

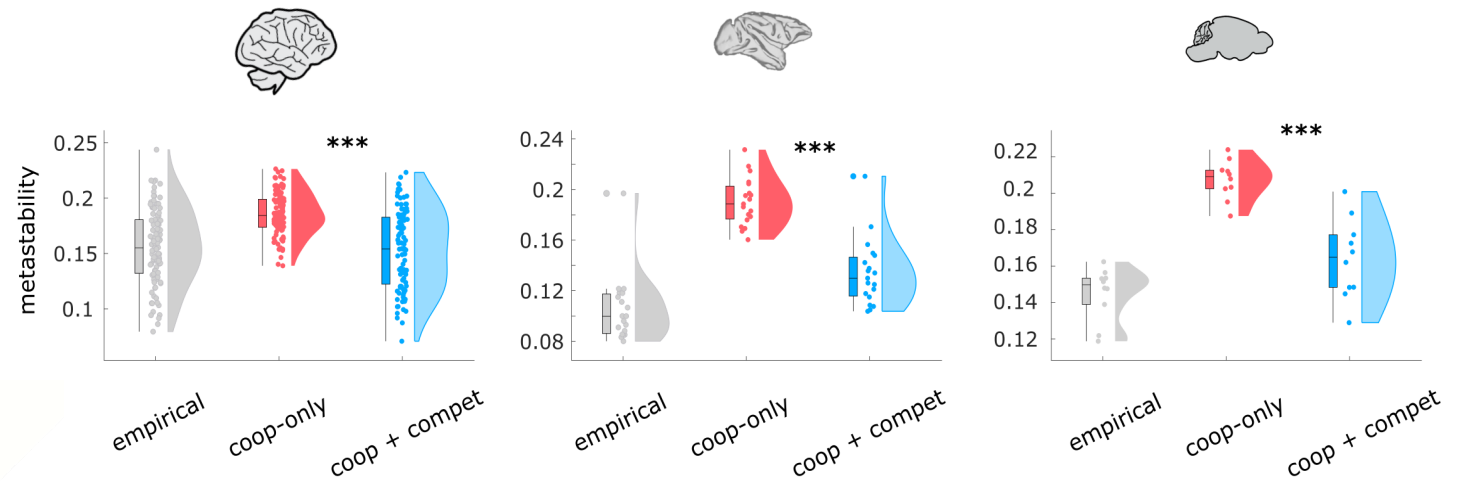
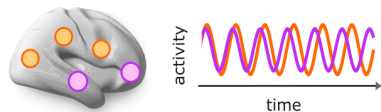
More hierarchical character

b | local-global hierarchy



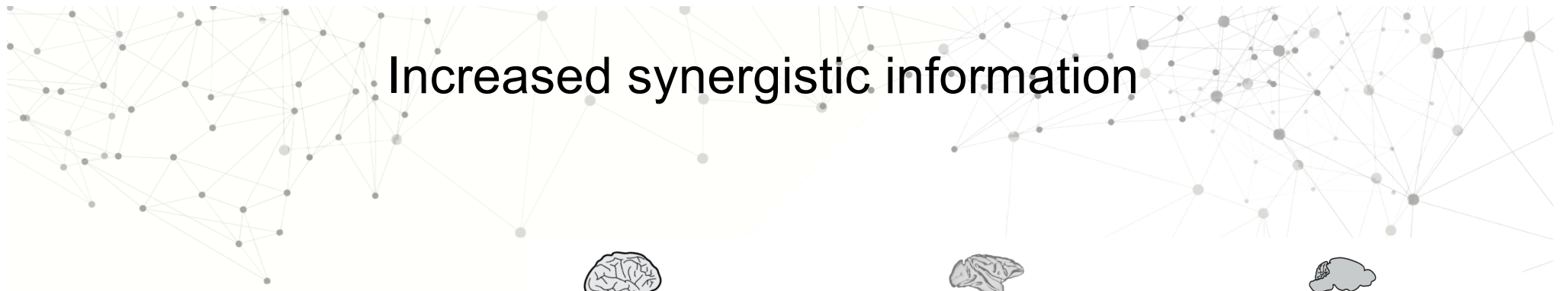
Competitive interactions stabilise metastability*

a | metastability

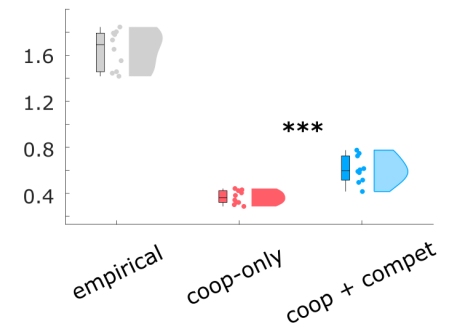
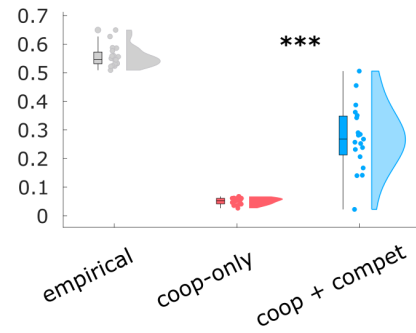
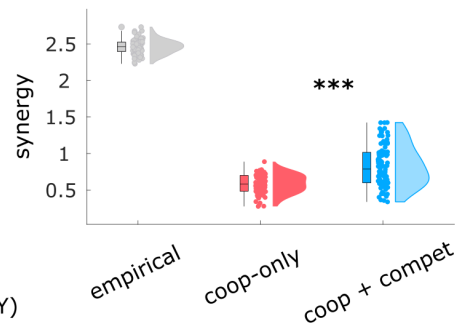
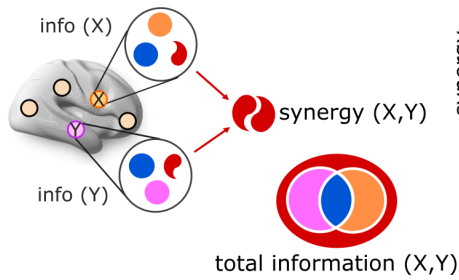


*see Hancock, Rosas *et (many) al.*
Nature Reviews Neuroscience (in press)

Increased synergistic information

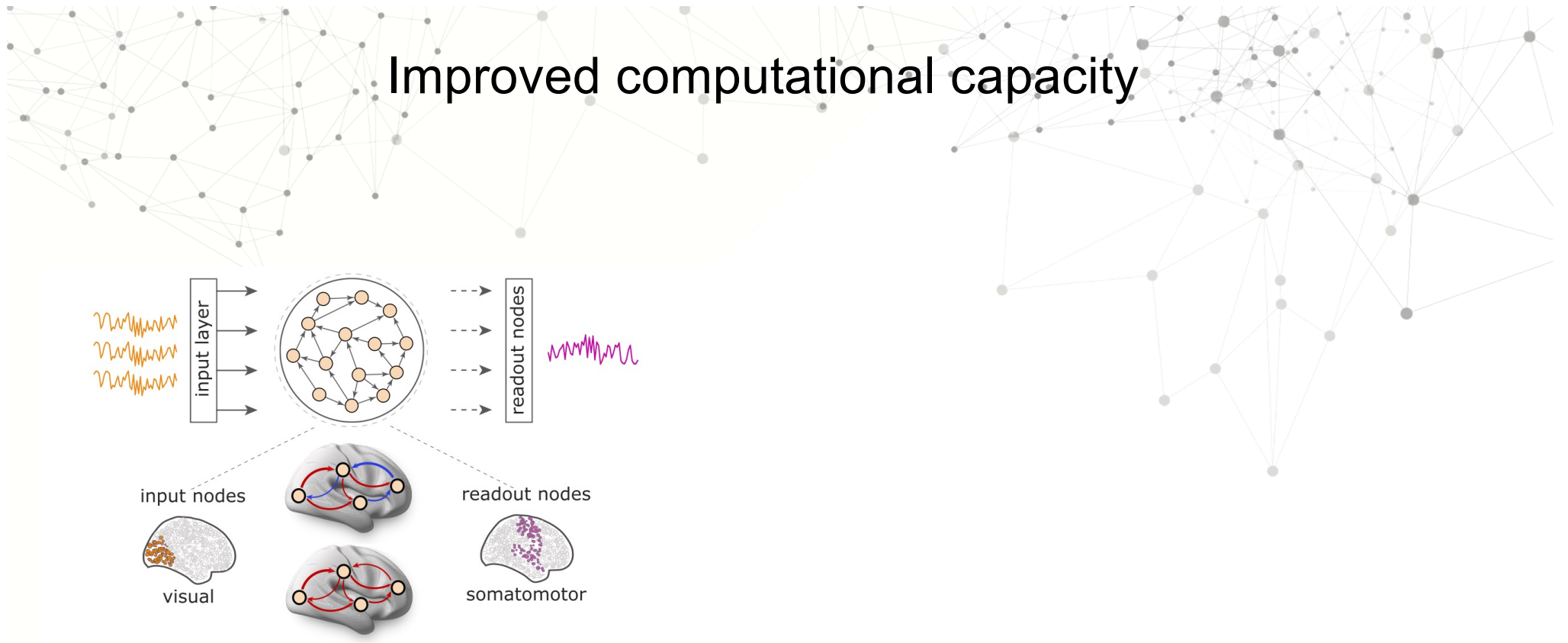


d | synergistic information

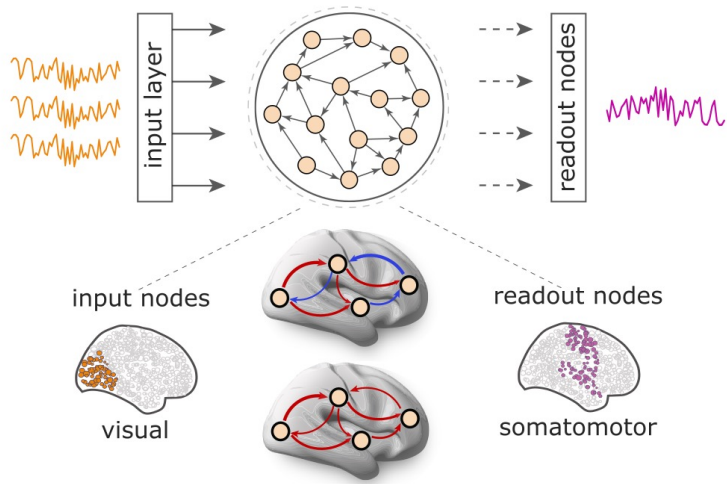


Luppi et al. Nature Neuroscience (2022)

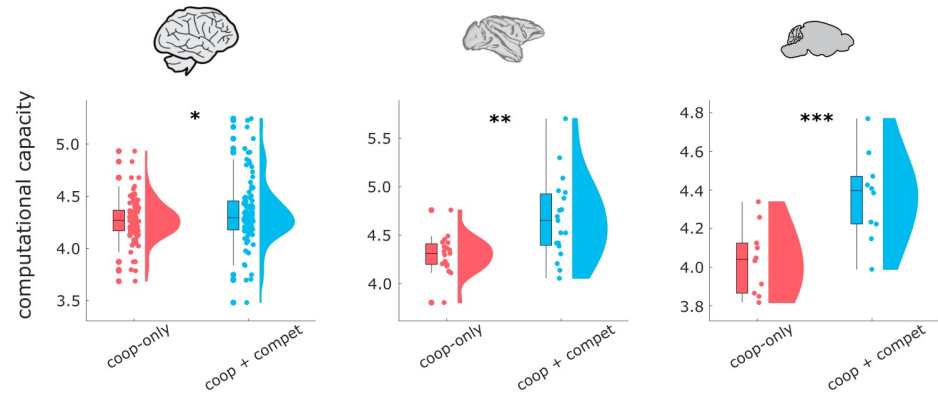
Improved computational capacity



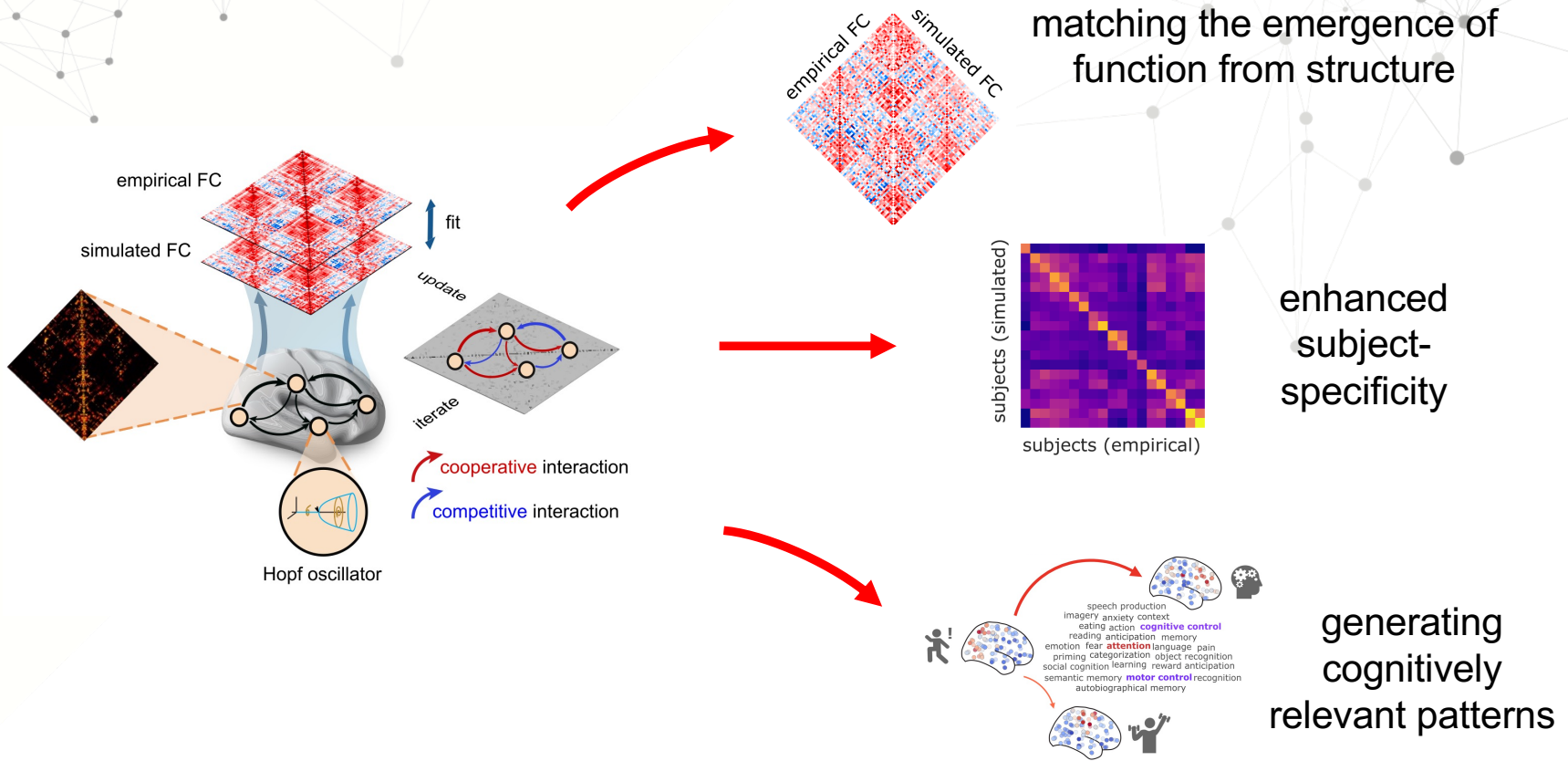
Improved computational capacity



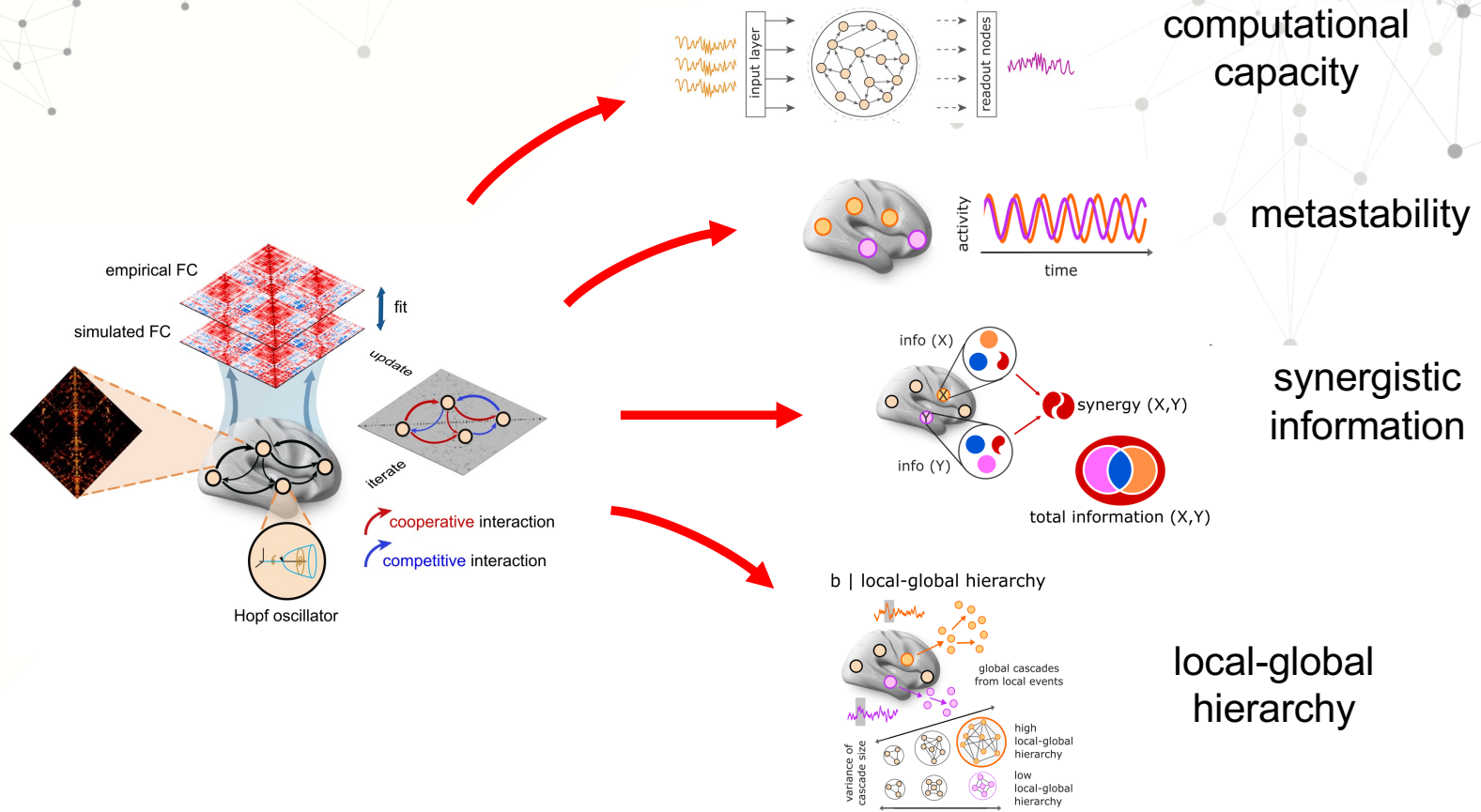
b | improved computational performance with competitive interactions



Improving models along multiple dimensions



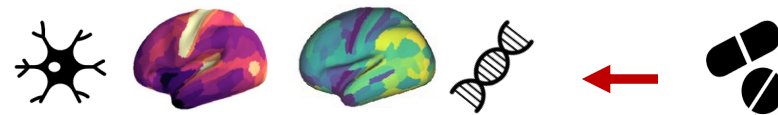
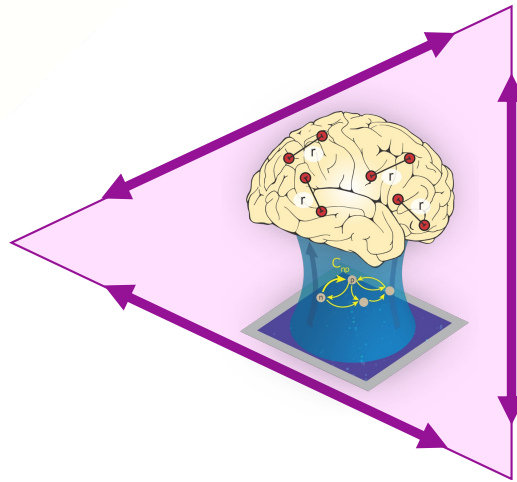
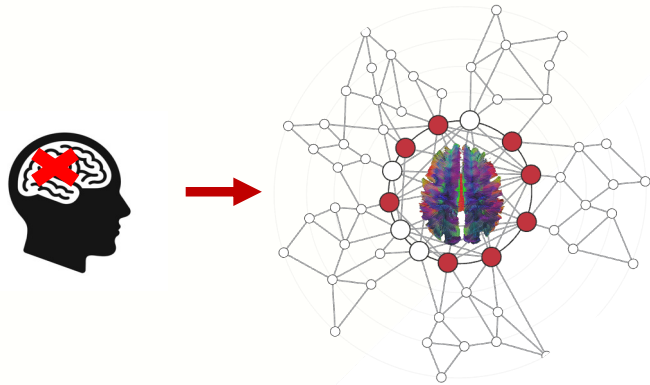
Dynamical consequences of competitive interactions



Long-term goal: Modelling as Rosetta Stone

Behaviour/Cognition/Symptoms

Network organisation















Micro- and Chemo-architecture

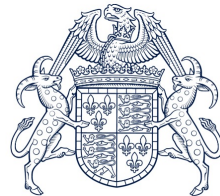
A Synergistic Effort



Competitive interactions shape brain dynamics and computation across species

 Andrea I. Luppi,  Yonatan Sanz Perl,  Jakub Vohryzek,  Pedro A. M. Mediano,  Fernando E. Rosas,
 Filip Milisav,  Laura E. Suarez,  Silvia Gini, Daniel Gutierrez-Barragan,  Alessandro Gozzi,
 Bratislav Mistic,  Gustavo Deco,  Morten L. Kringelbach

doi: <https://doi.org/10.1101/2024.10.19.619194>



The background features a photograph of a large, historic university building with a prominent Gothic-style tower, likely King's College Chapel at the University of Cambridge. The scene is captured at sunset, with a warm orange and pink sky. A white network overlay of interconnected nodes and lines is superimposed on the image. In the foreground, a body of water reflects the building and the sky.

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Any questions?

The background features a photograph of a large, historic university building with a prominent Gothic-style tower, likely King's College Chapel at Cambridge, during a sunset. The sky is a mix of orange, pink, and purple. A white network of lines and dots is overlaid on the image, connecting various points across the scene. In the foreground, a body of water reflects the building and the sky.

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~~Any questions?~~
answers??