Network dynamics of the world and our brains

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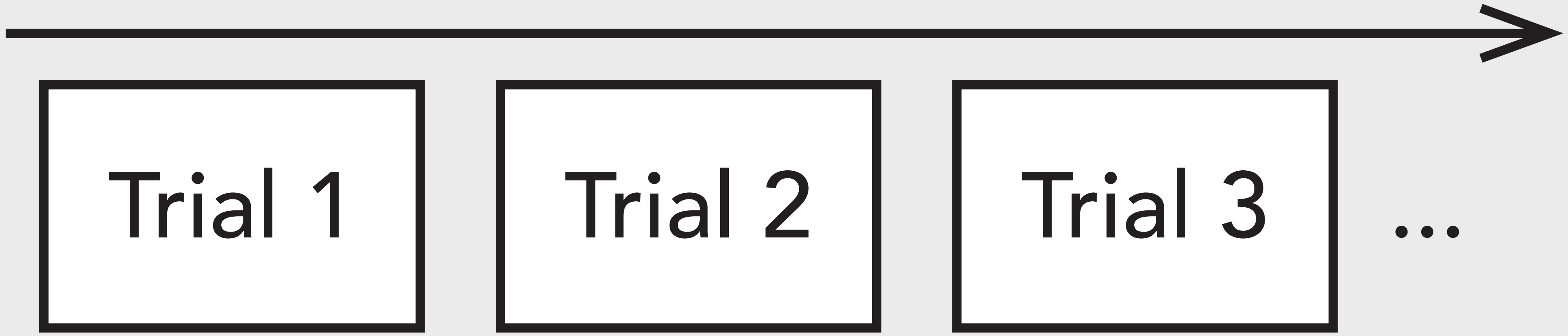
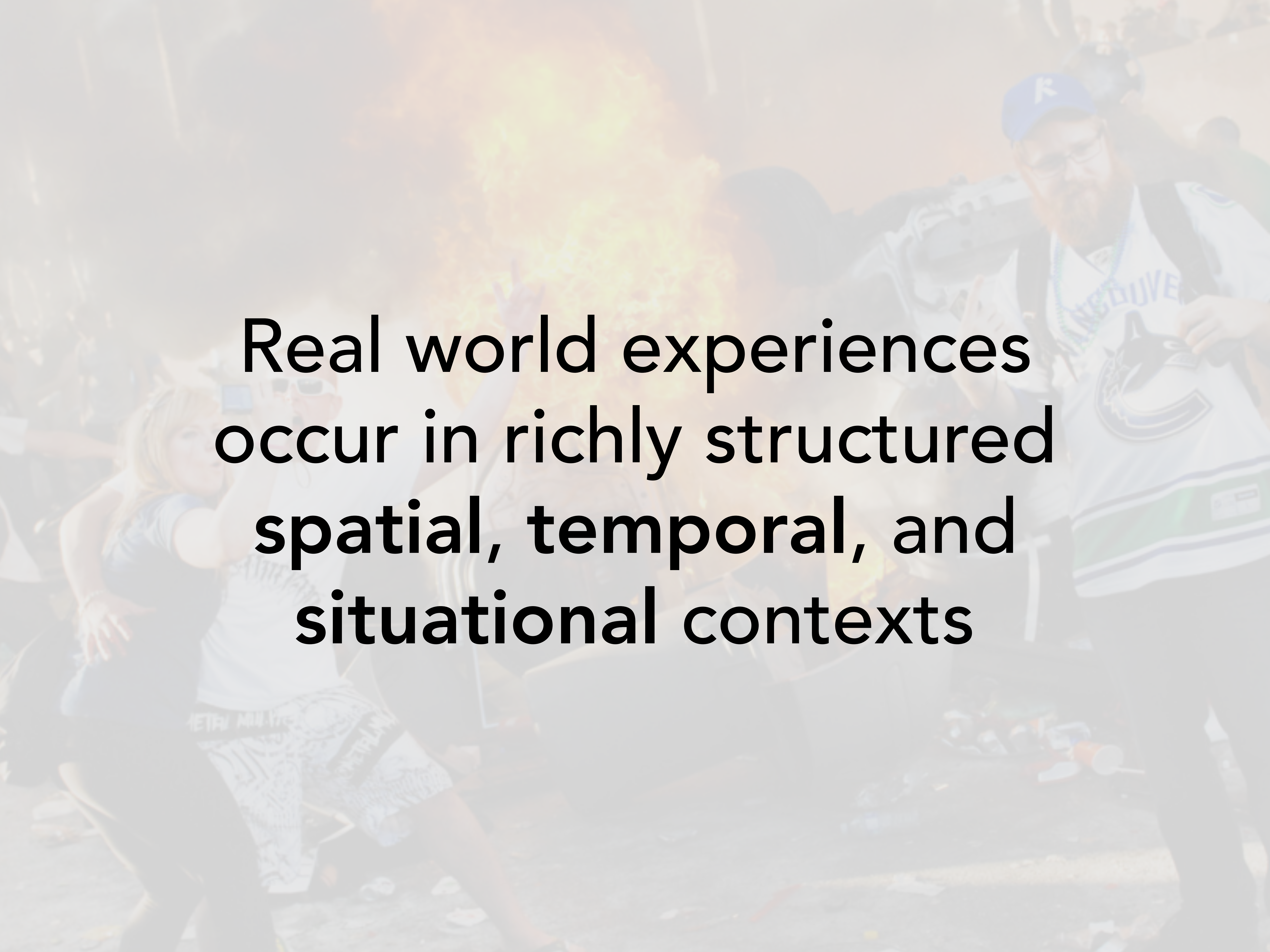
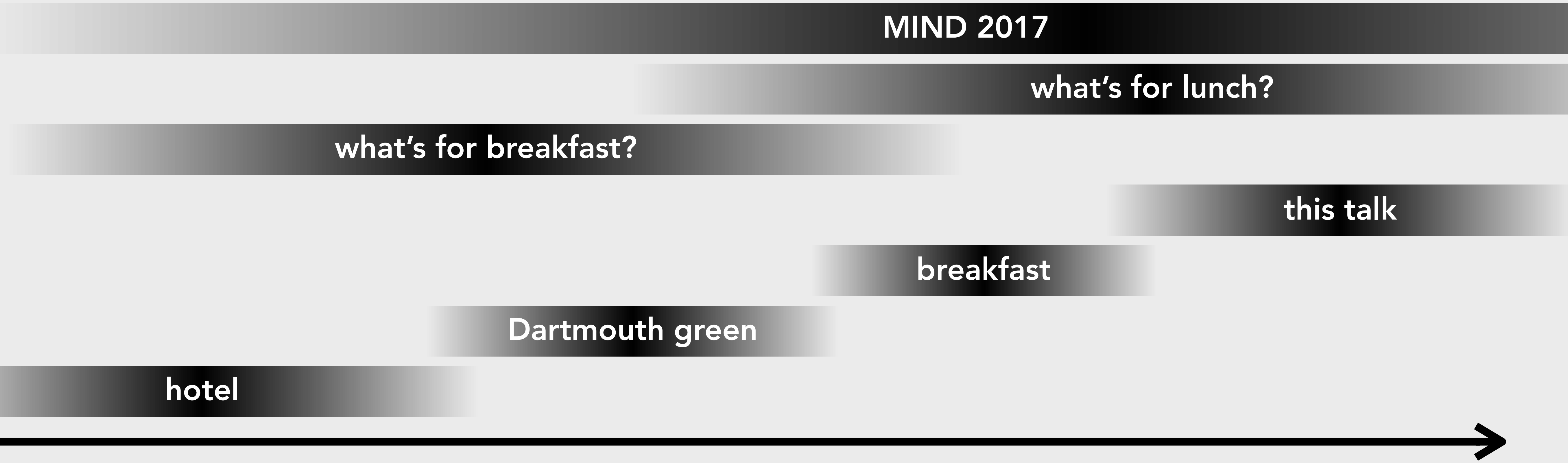
The (usual) way things are done





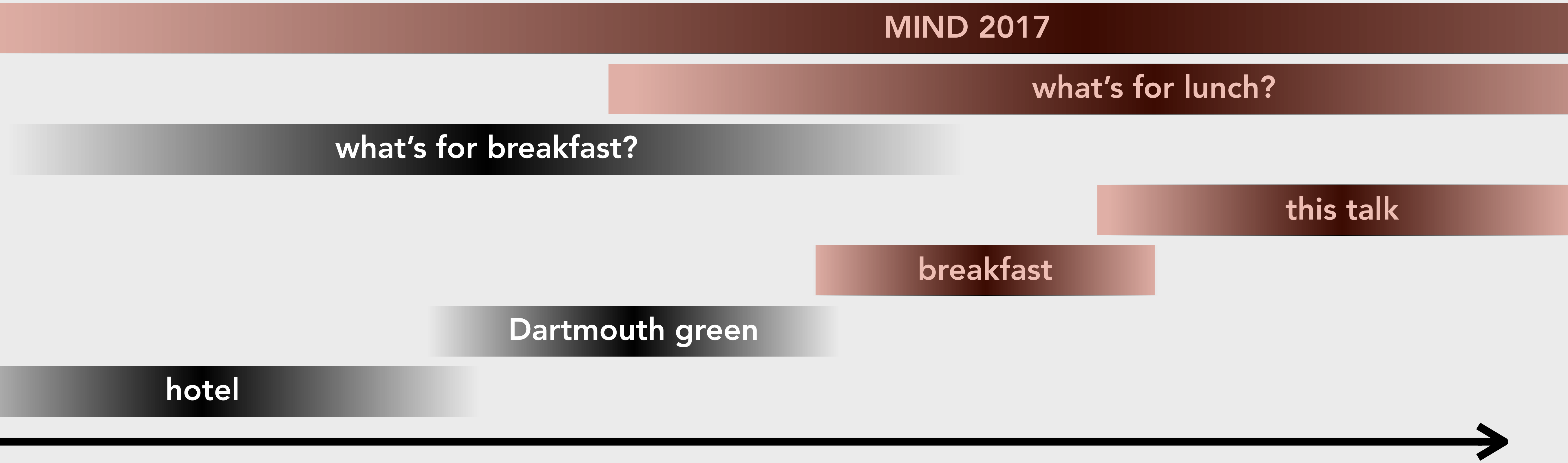
Real world experiences occur in richly structured **spatial**, **temporal**, and **situational** contexts

How did you get here?

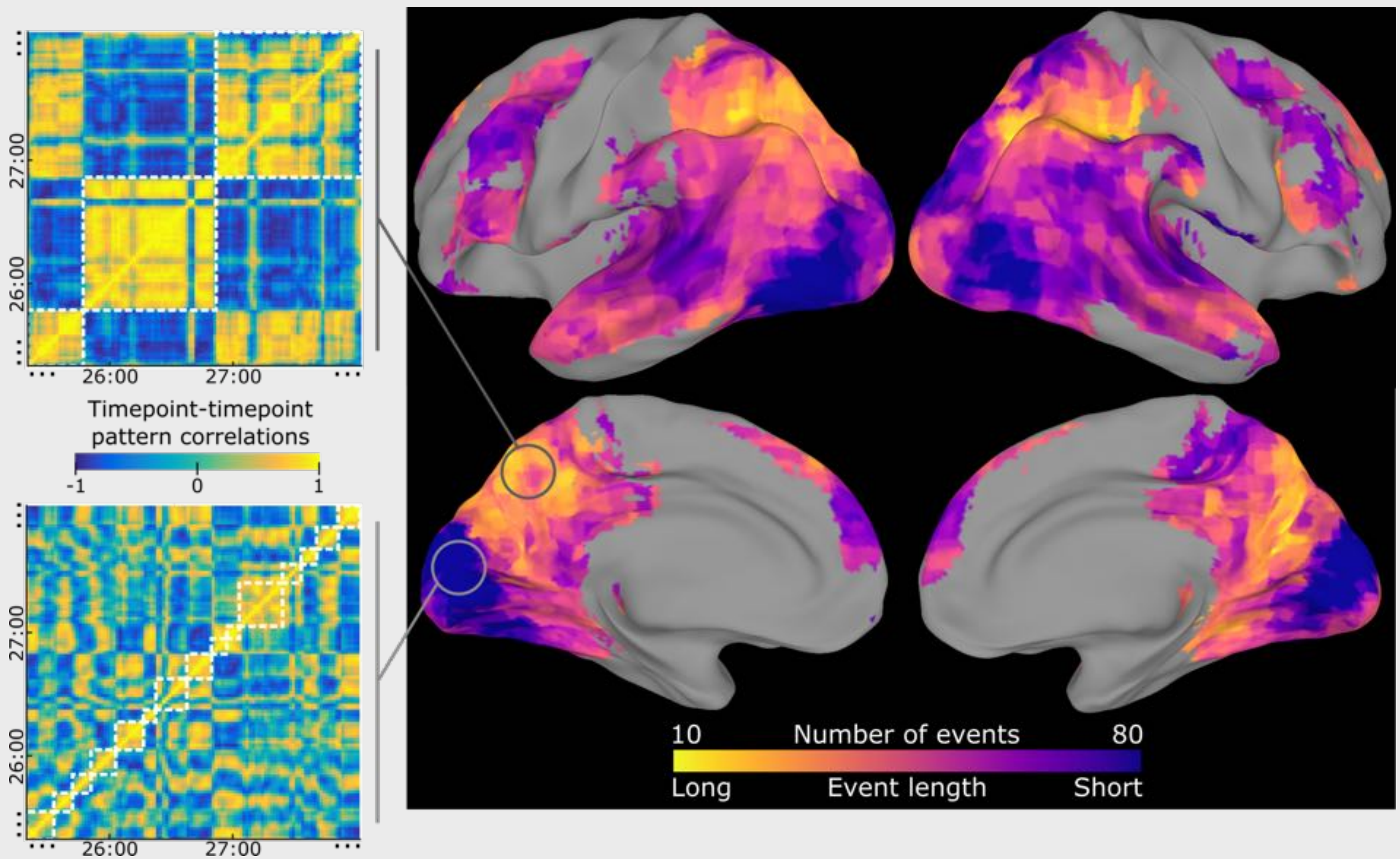




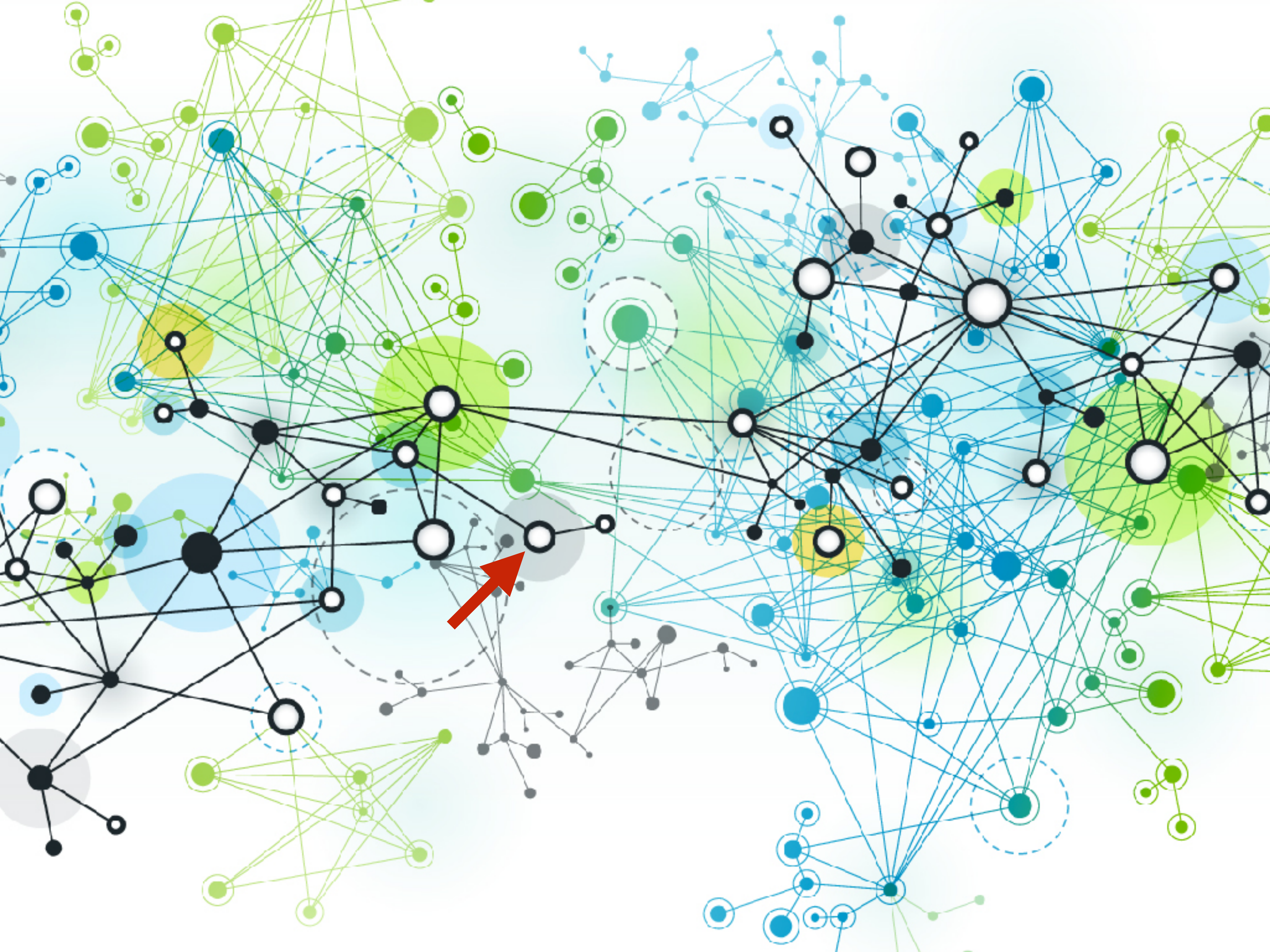

How did you get here?



Our brains are sensitive to this structure



Baldassano et al., 2017

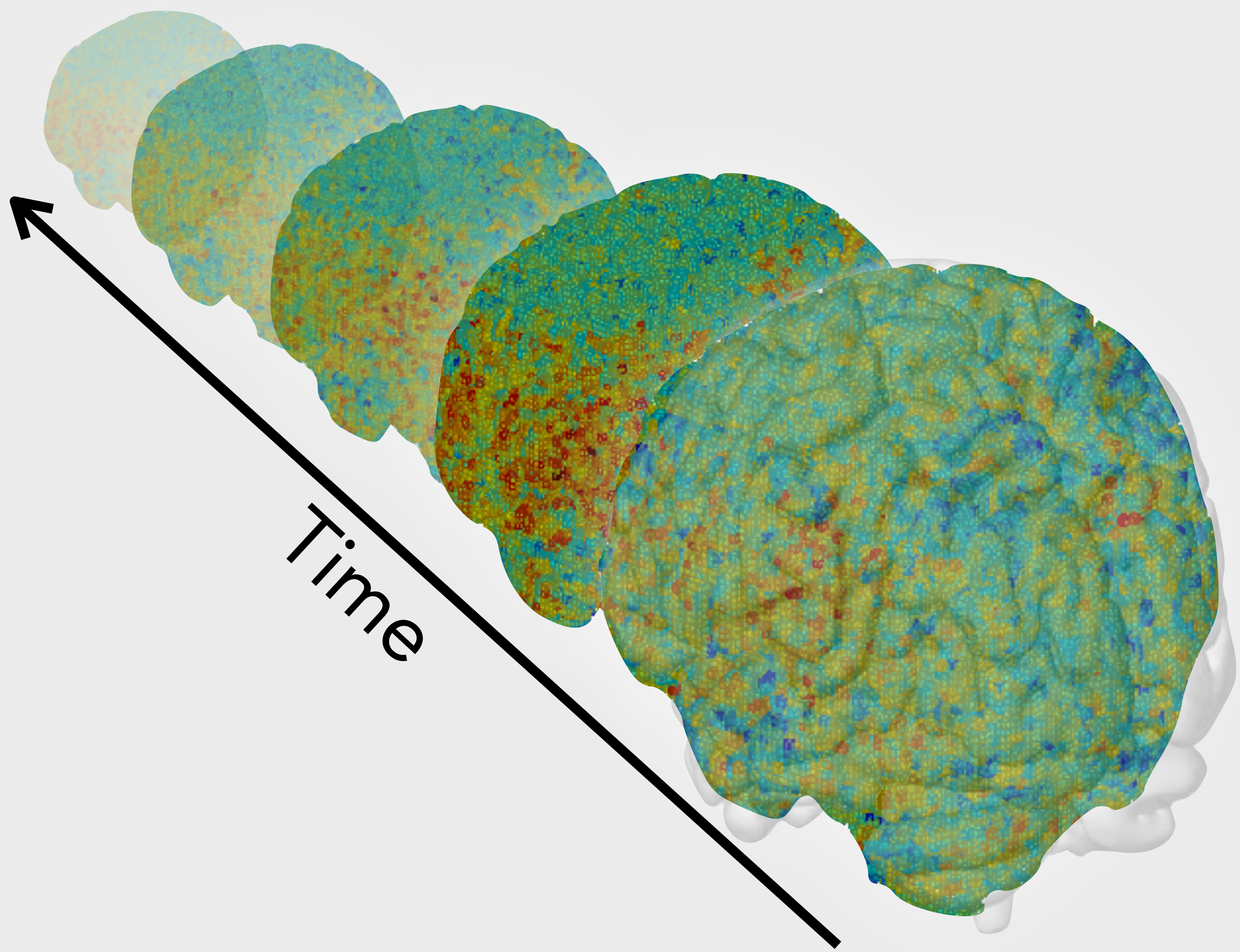


Claim: if we are interested in how our brains reflect the network dynamics of life, we should also look at network dynamics in brain data

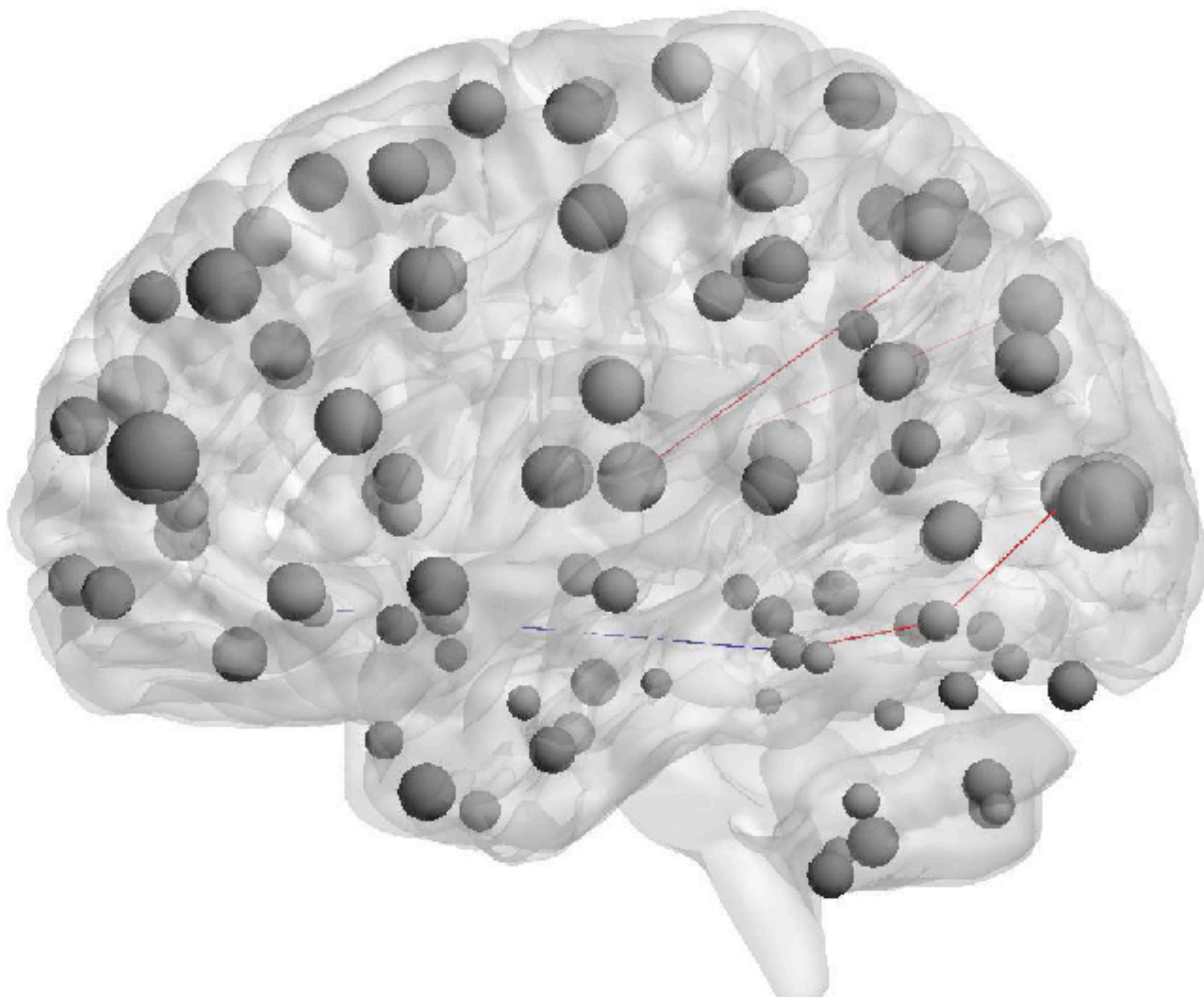
Brains as dynamic networks

- Brain structures operate within the context of a **broader network**
- Network properties change **dynamically** according to what our brains are doing

What we have



What we want

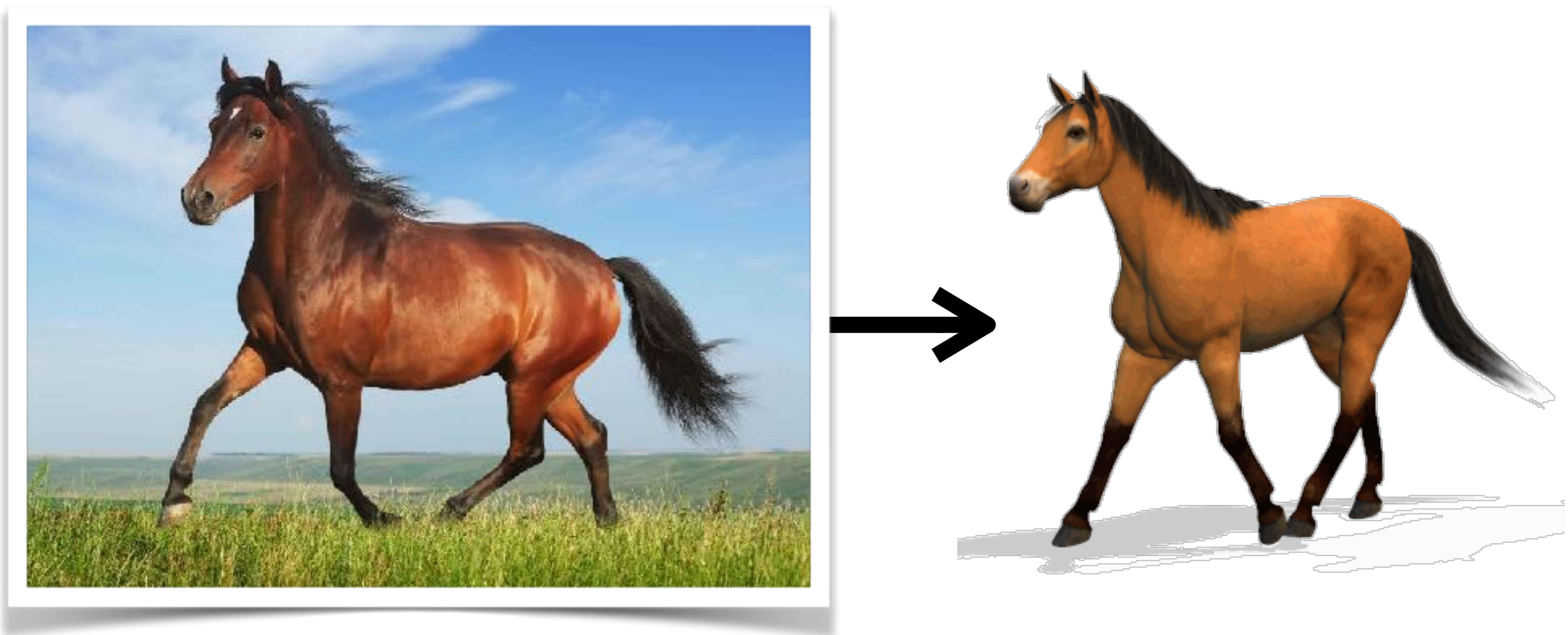


Challenges

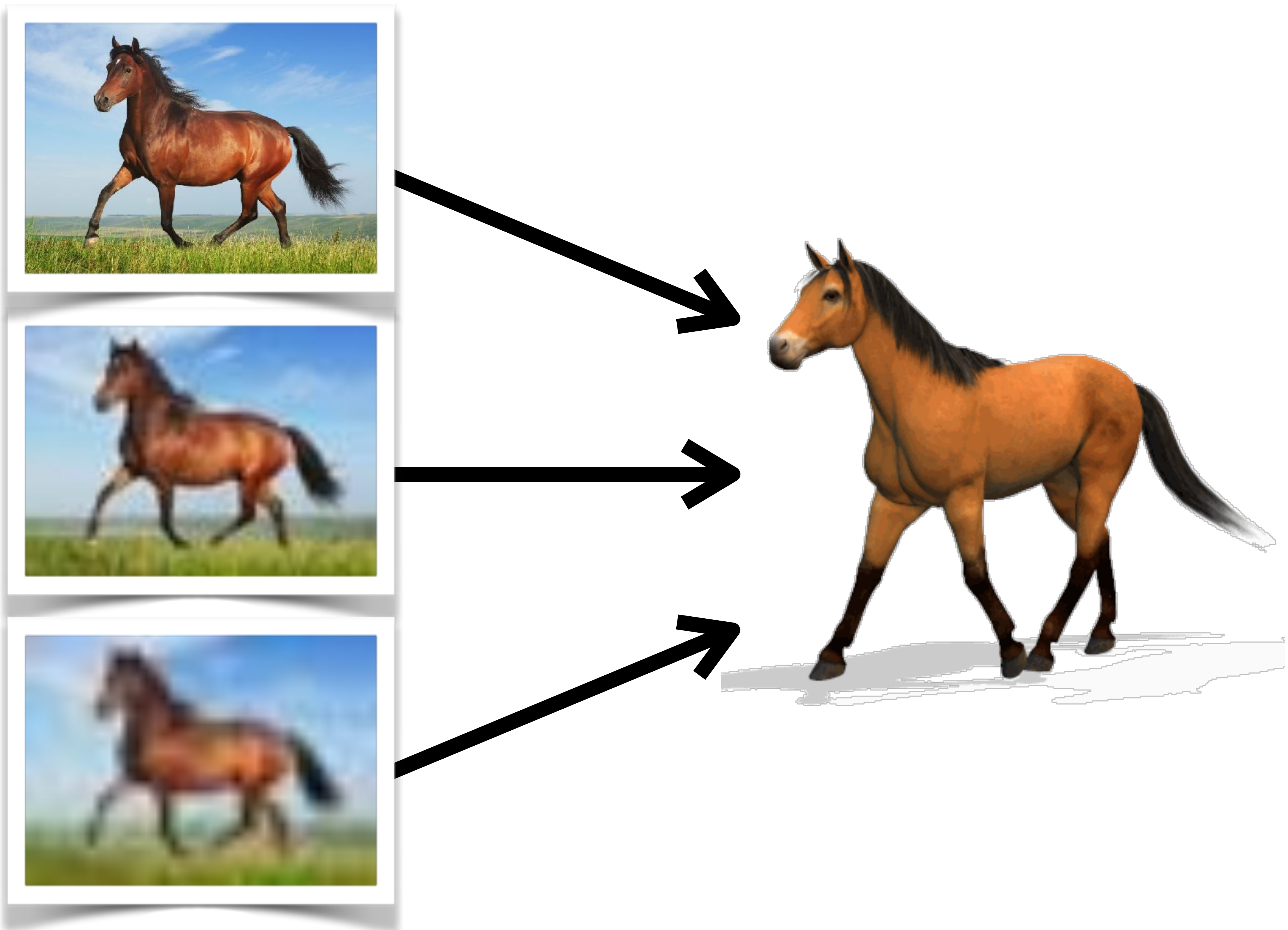
- We want to know about **dynamic network interactions**
- We can’t measure those network dynamics directly
- We need **models** to infer those dynamics

The intuition

The intuition

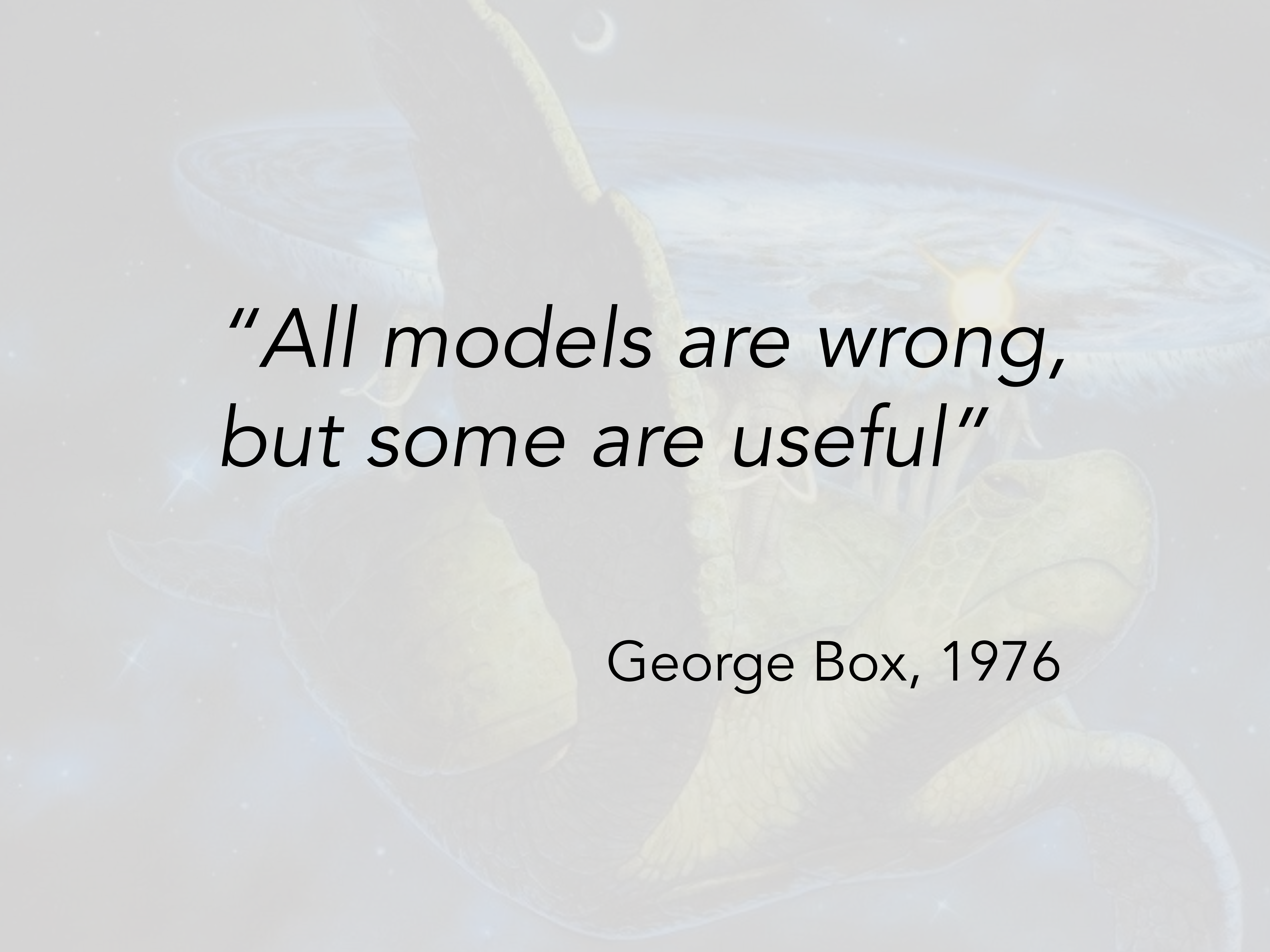


The intuition



(More) intuition

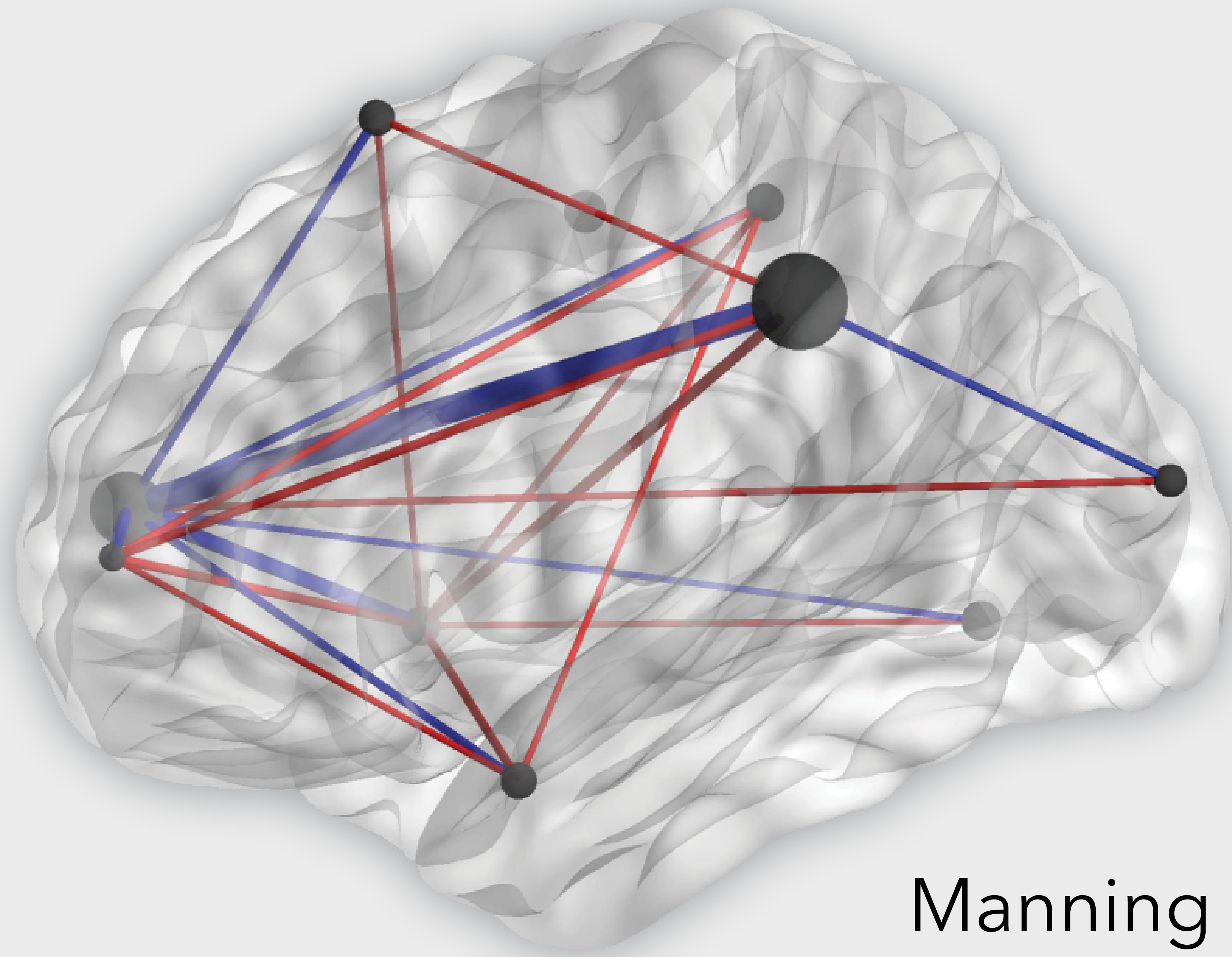
- Make a model of the **brain**
- Describe how states of the **brain** give rise to measurements
- Observe the measurements
- Compute the most likely state(s) of the **brain**, given the observed measurements



"All models are wrong, but some are useful"

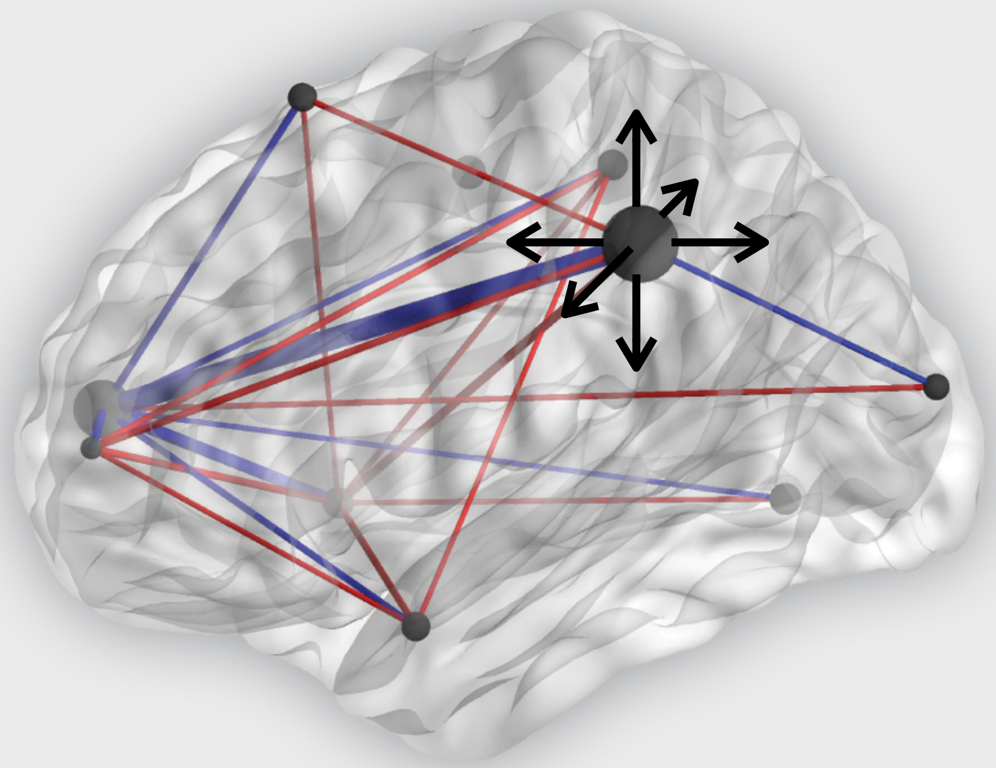
George Box, 1976

Topographic Factor Analysis



Manning et al. 2014
Manning et al. 2017

Topographic Factor Analysis



- Infer **number** of hubs, hub **locations**, and hub **widths**
- Then infer moment-by-moment hub **activations**
- Hubs are constrained to be in **similar locations across people**
- We can easily compare images of different **resolutions** and **modalities**

Topographic Factor Analysis: Generative process

1. Pick K (number of hubs)

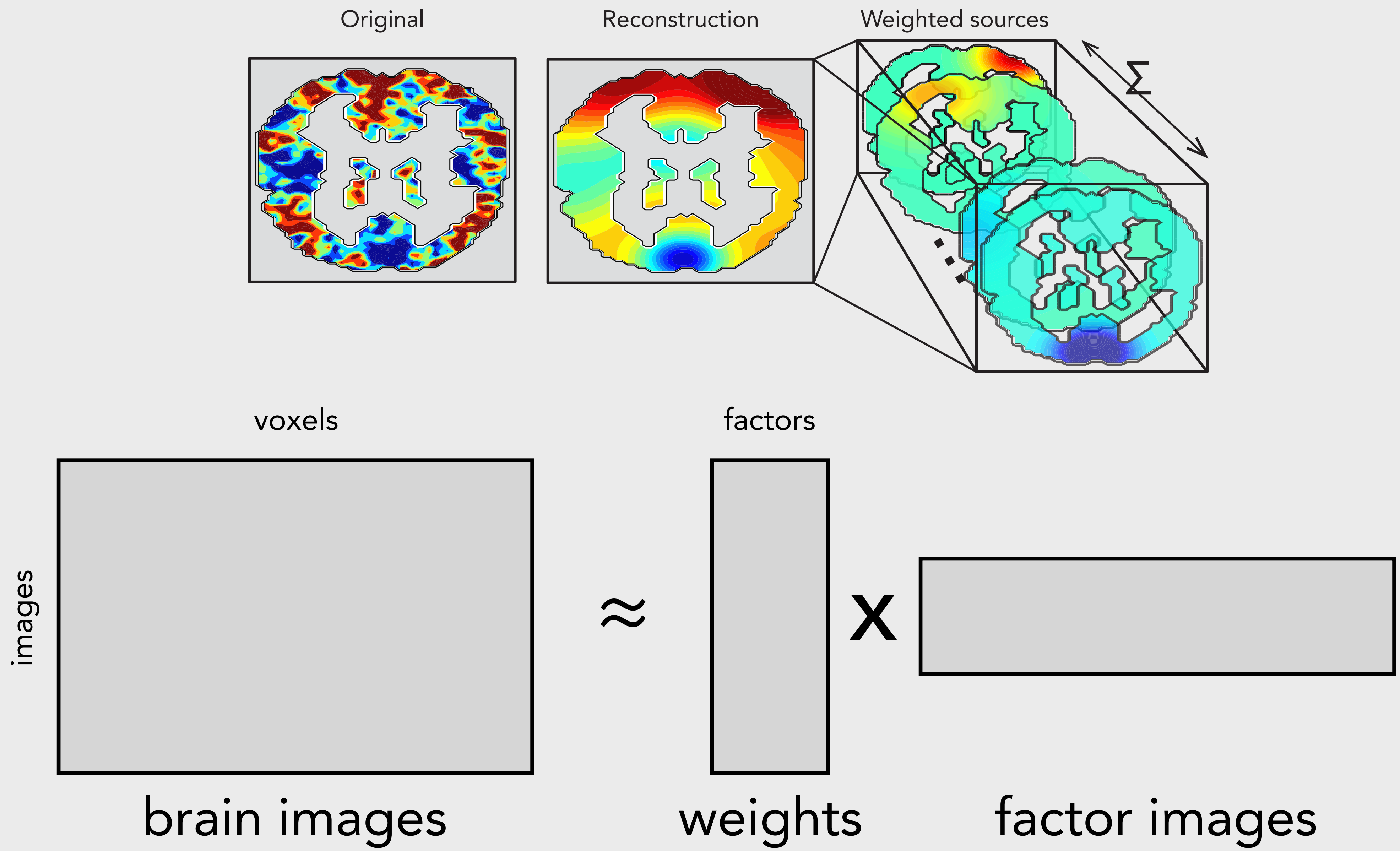
2. Draw K **hub centers** from around the brain

3. Draw K **hub widths** (positive, bias towards being small)

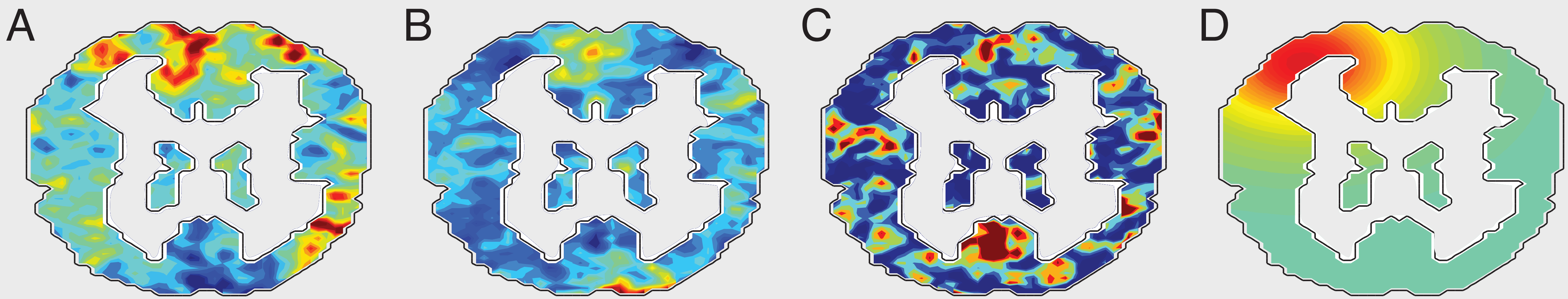
4. For each of T timepoints, draw K **weights**

5. Given the hub centers and widths, and the weights for timepoint t, compute the **voxel activations** at timepoint t

Factorizing the brain

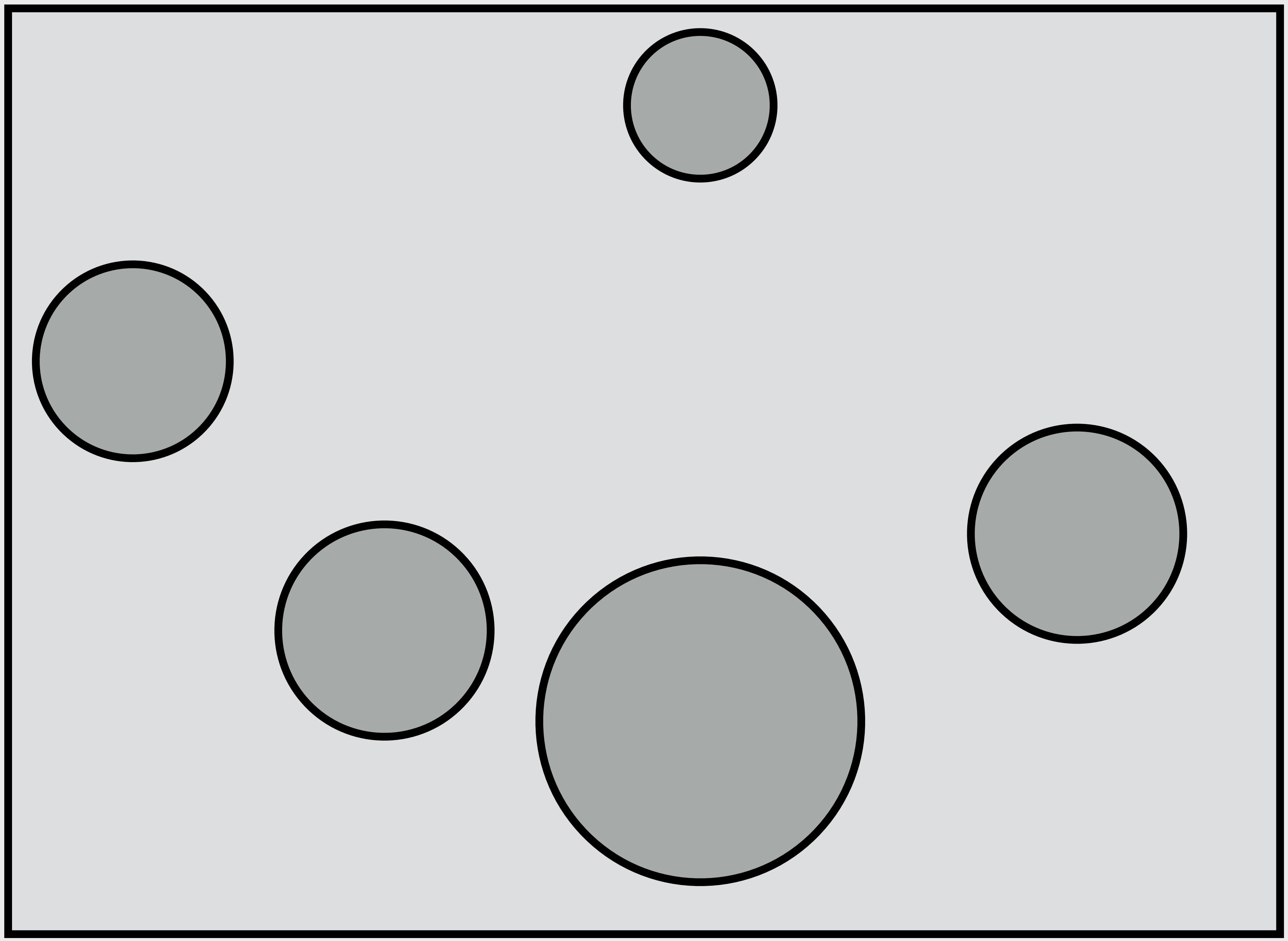


Comparing TFA to related techniques



Brain image PCA ICA TFA

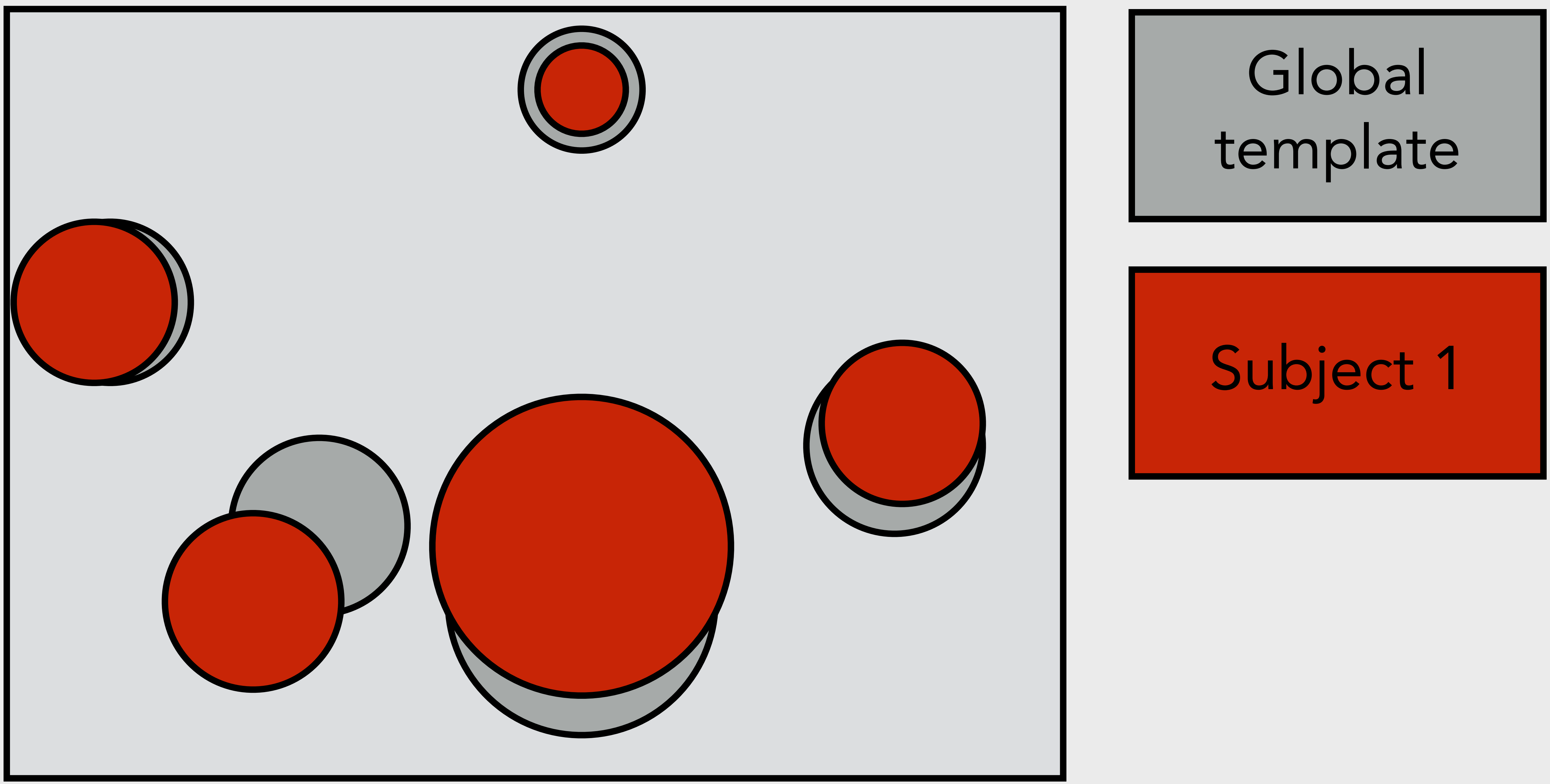
Multi-subject datasets



Global template

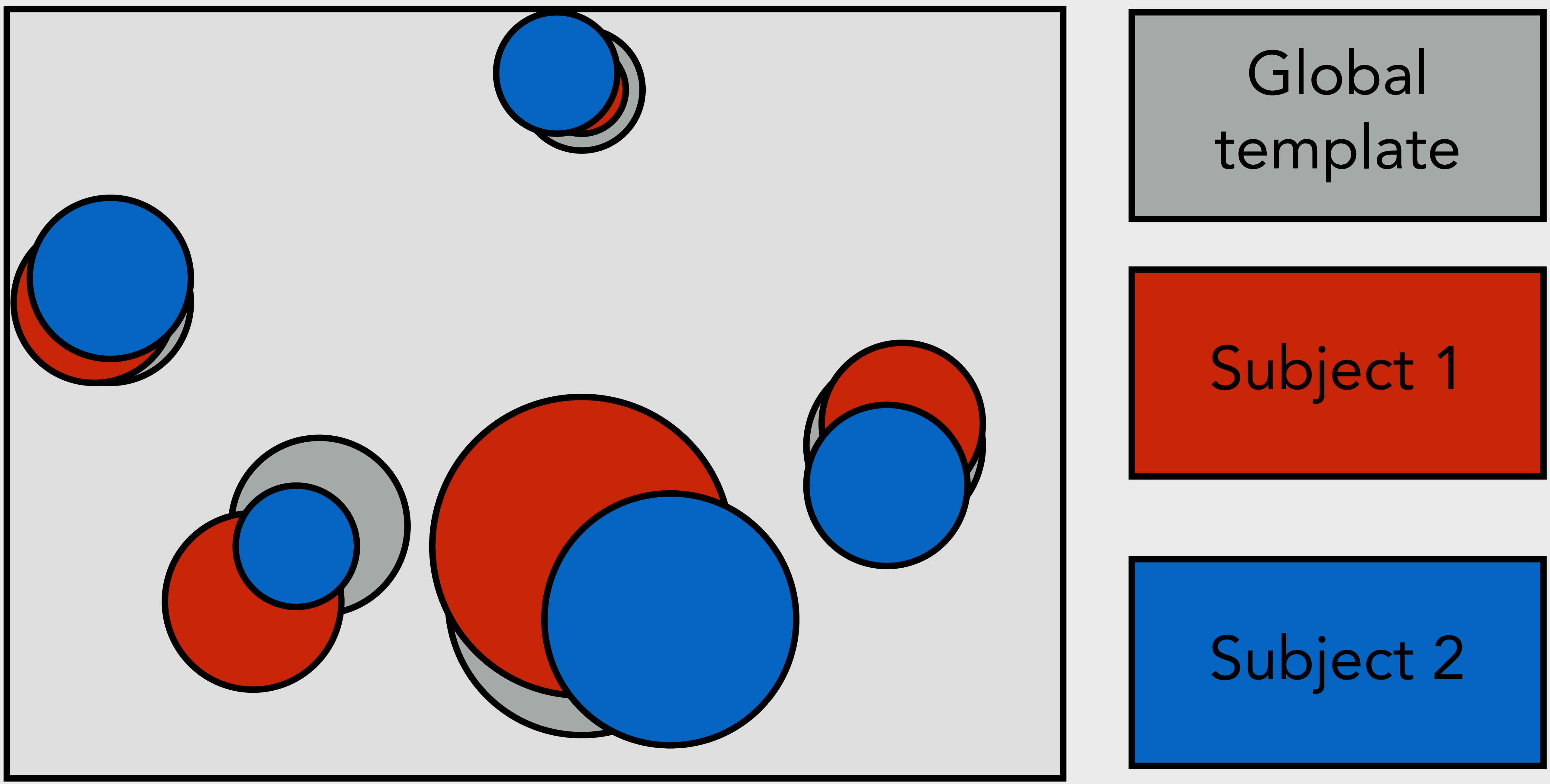
Manning et al., 2017

Multi-subject datasets



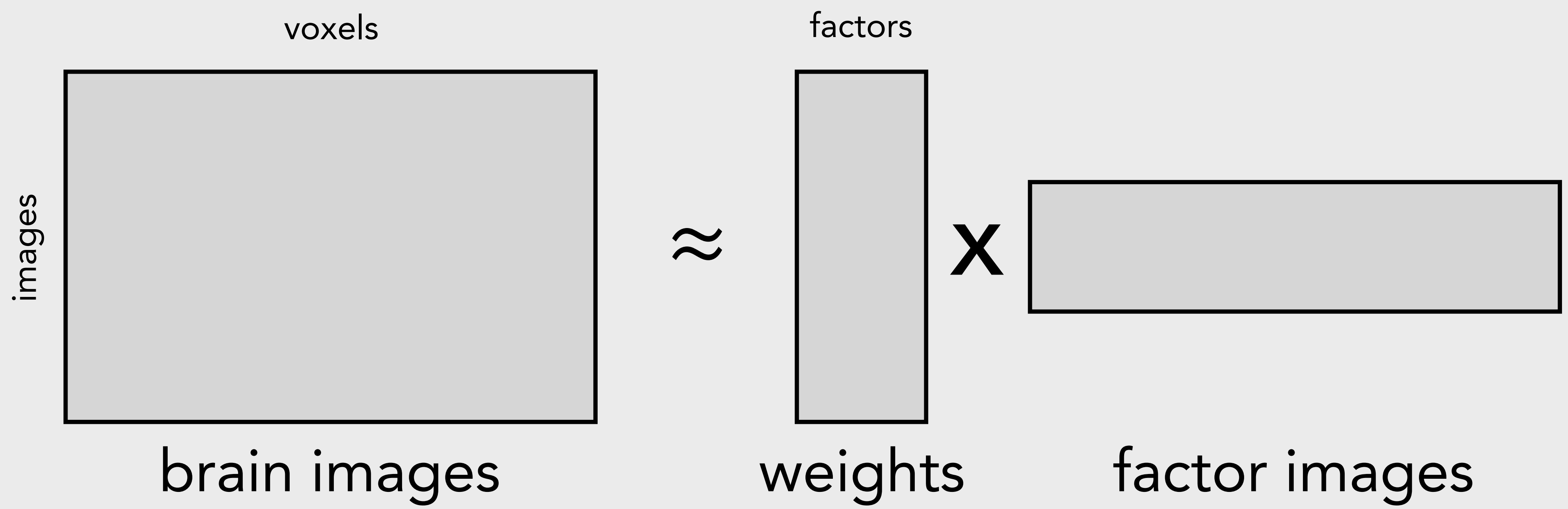
Manning et al., 2017

Multi-subject datasets



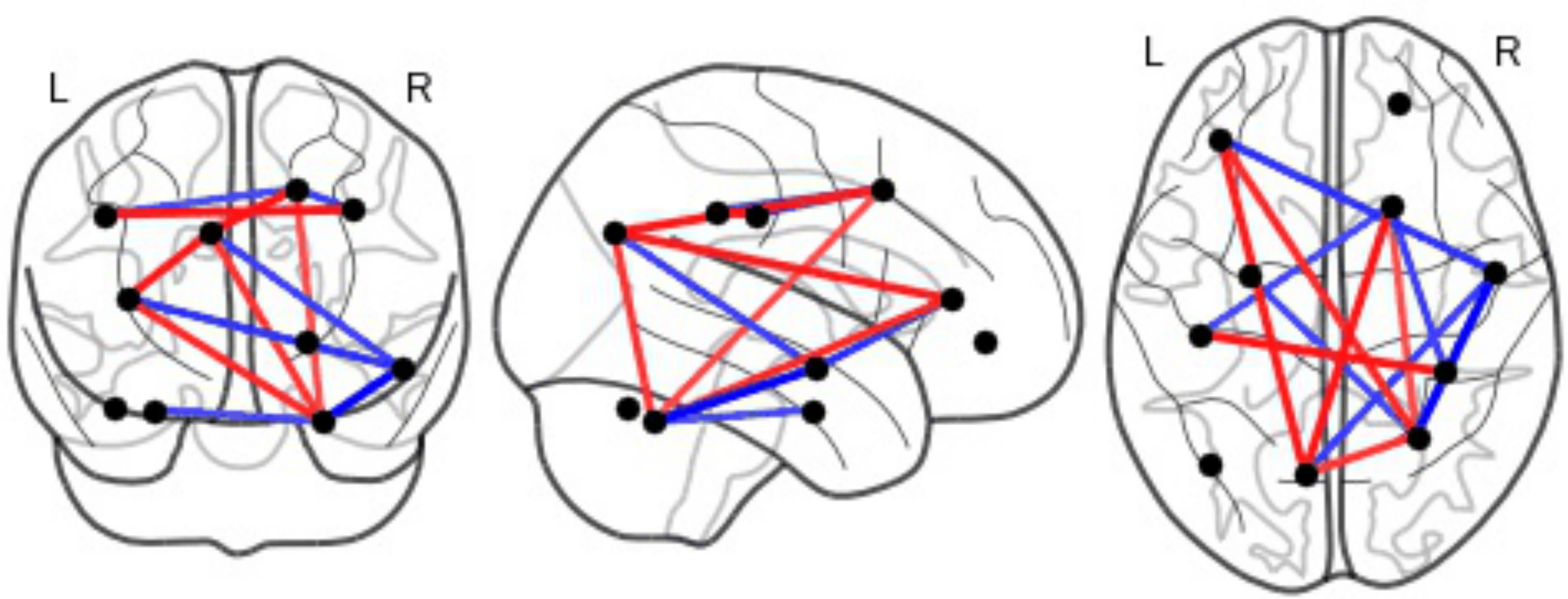
Manning et al., 2017

Network dynamics with TFA



- We can apply **connectivity metrics** to the factor weights (e.g. FC, ISFC, etc.)
- Use **sliding windows** to get dynamics

Network dynamics with TFA

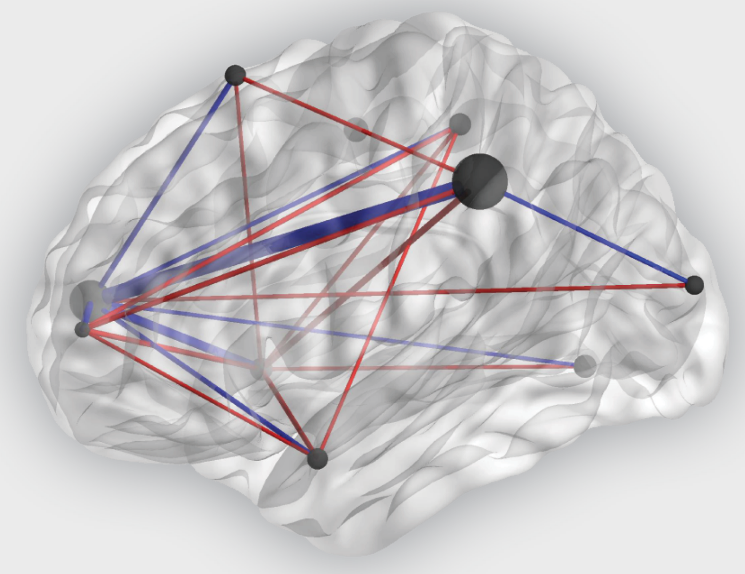


Why?

- Brain activity is reflected in voxel activity…
- …but **brains exist in real space, not voxel space** (Sam Gershman’s talk!)
- Different people could have brain regions that behave similarly, but that are in **slightly different locations** (Jim Haxby’s talk!)
- The structure we care about is often **spatially smooth** (Janice Chen's talk!)

TFA captures these intuitions within a common framework

- Finds network hubs in “real space”
- Hubs can move (a bit) across people
- Hubs smooth brain images



Other advantages of TFA (over voxel-based methods)

- **Highly compact** representation of brain patterns
- Each voxel can tell us about multiple hubs (**mixed membership**)
- Convenient way of examining **dynamic network patterns**

Team TFA

- **Xia "Ivy" Zhu** (Intel Labs)
- Ted Willke (Intel Labs)
- Rajesh Ranganath (Princeton)
- Kim Stachenfeld (Google DeepMind)
- Uri Hasson (Princeton)
- **David Blei** (Columbia)
- **Ken Norman** (Princeton)