

Representational similarity analysis

Dr Ian Charest,



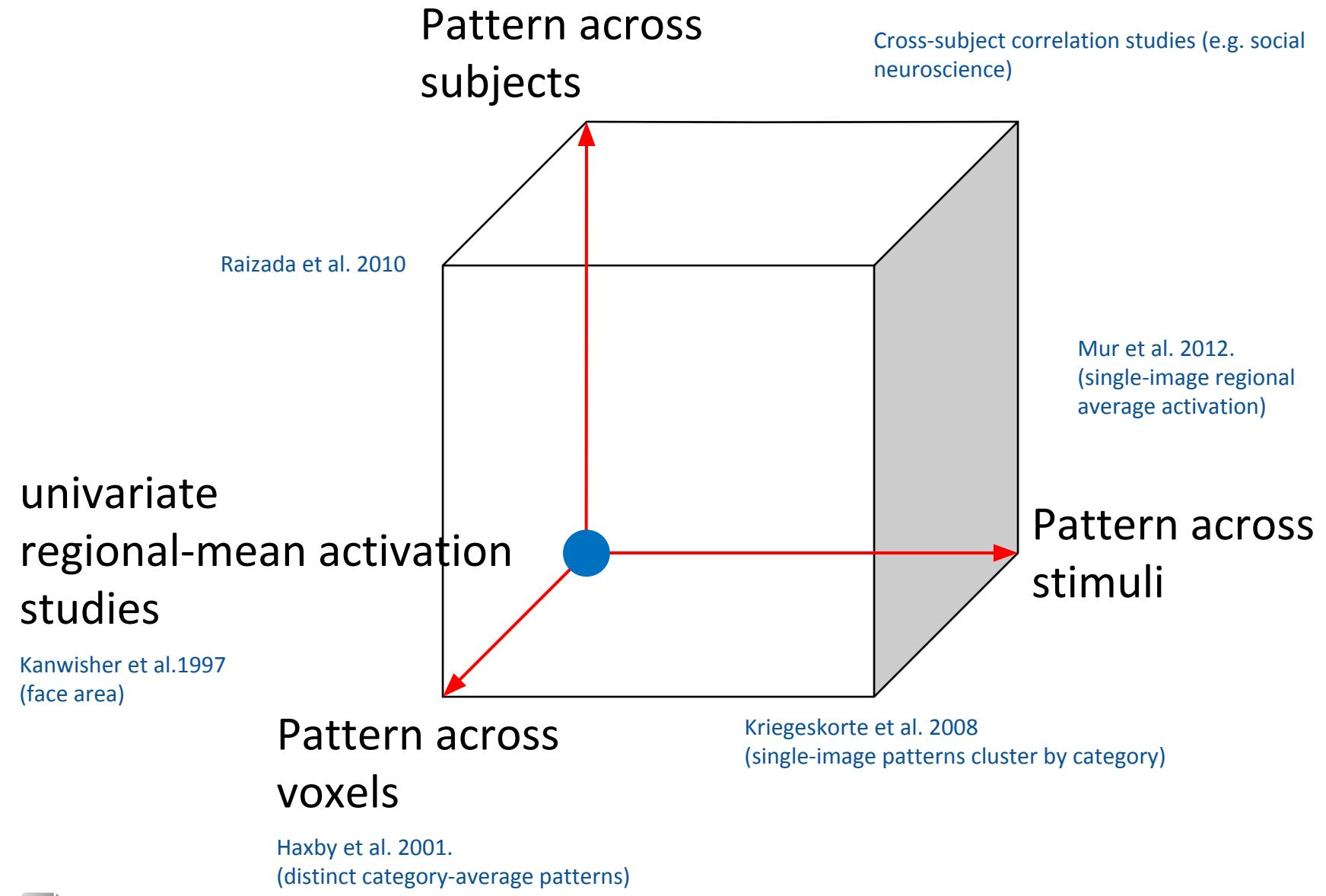
European Research Council

Established by the European Commission

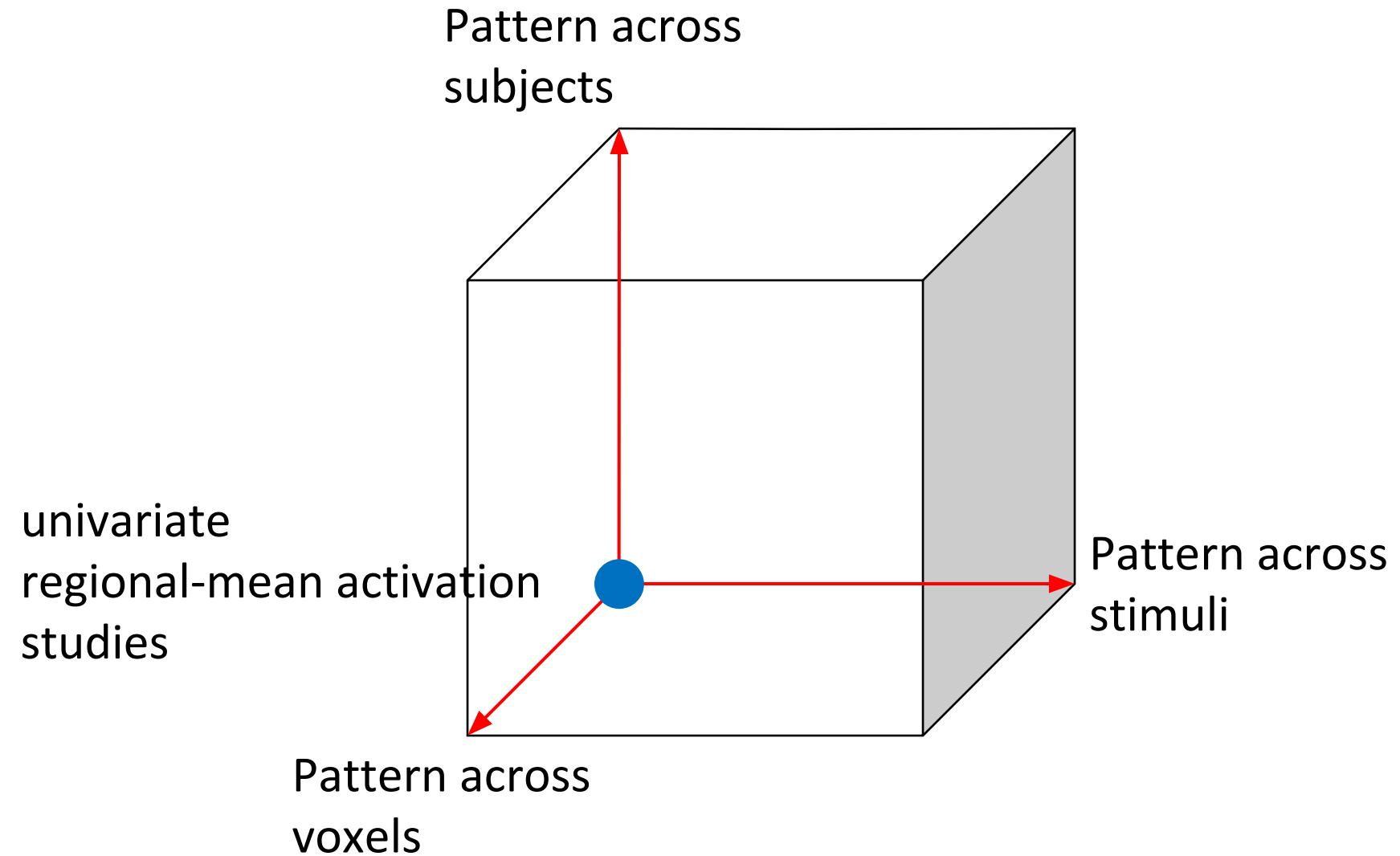
Edinburgh, April 2019



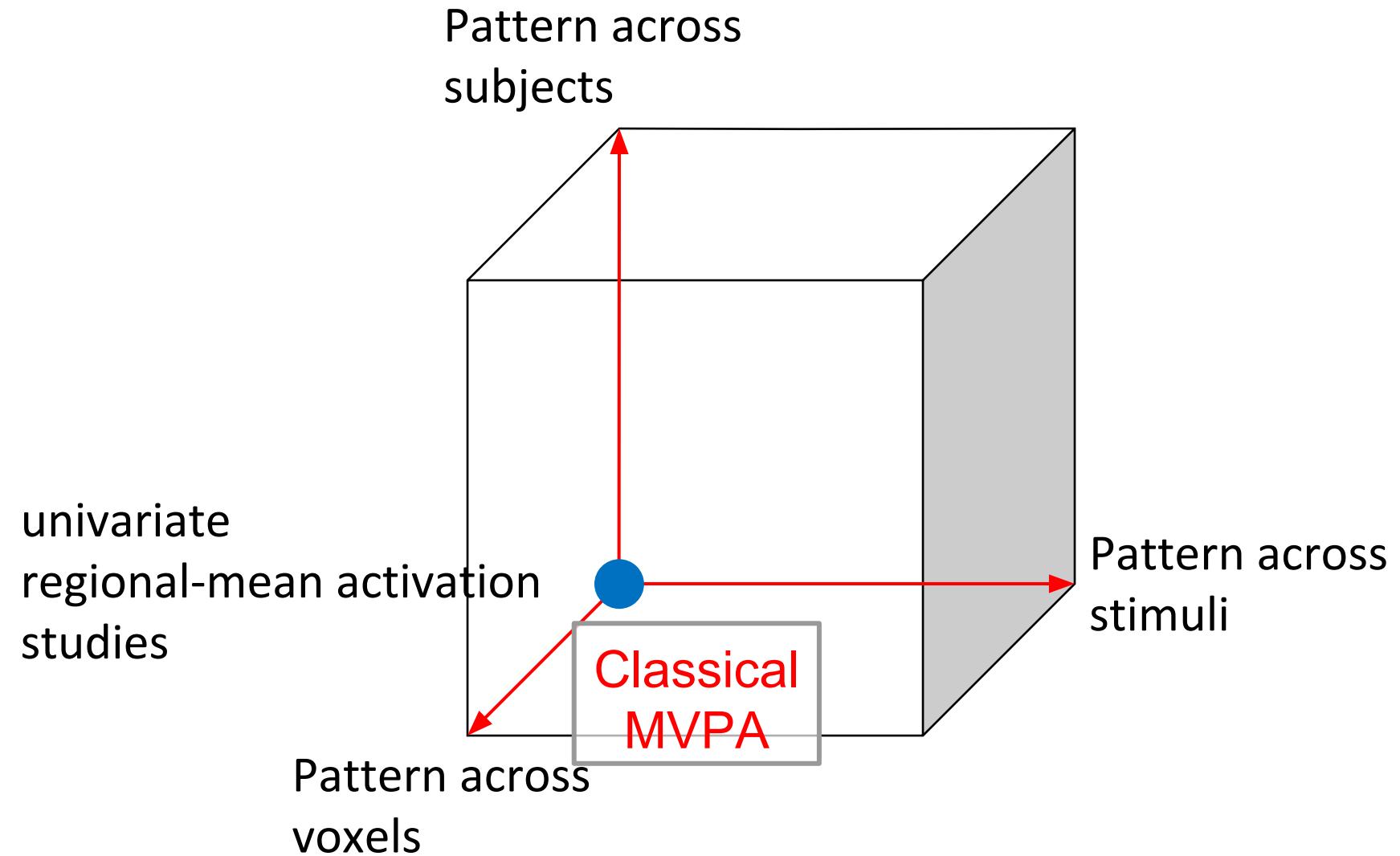
A space for neuroimaging studies



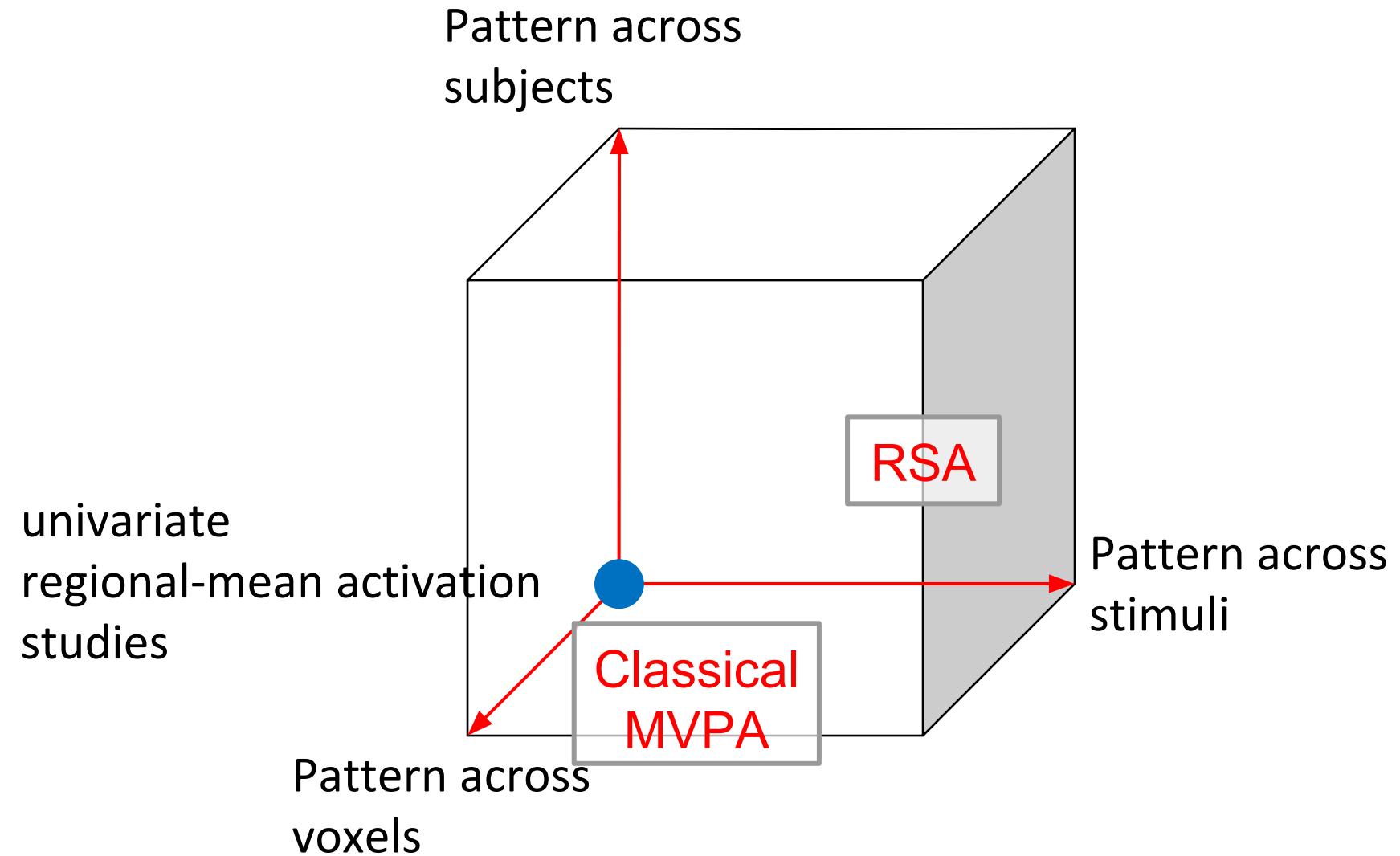
A space for neuroimaging studies



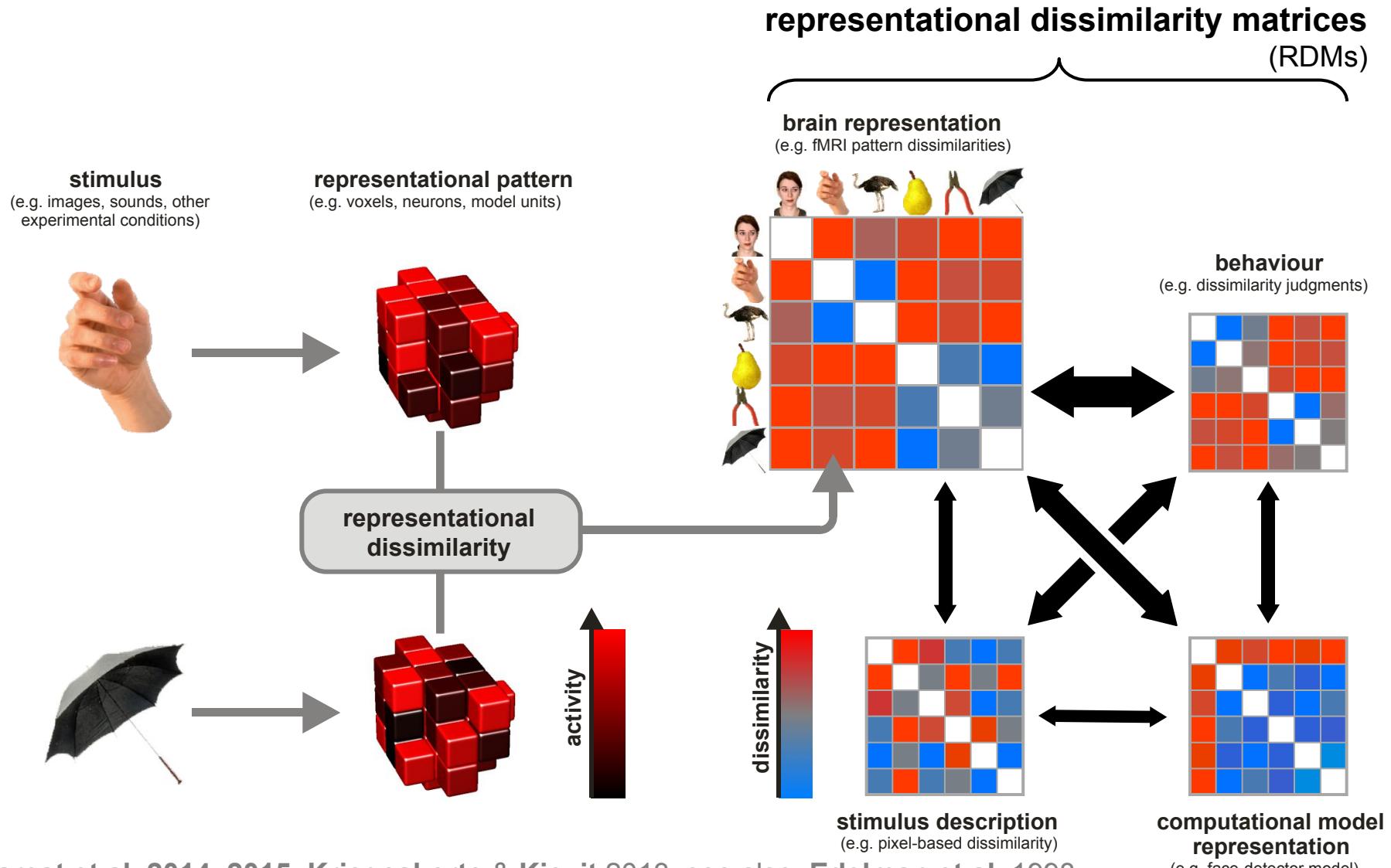
A space for neuroimaging studies



A space for neuroimaging studies

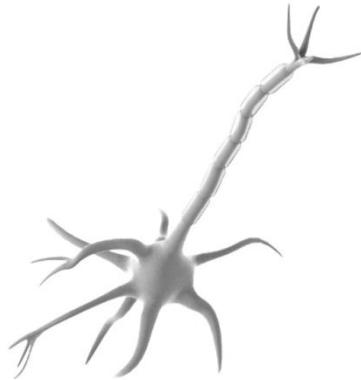


Representational similarity analysis

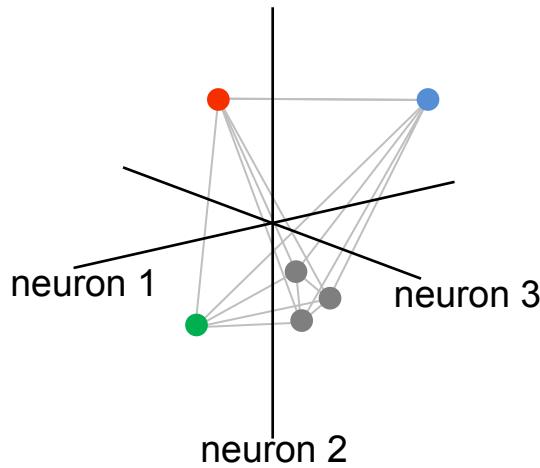


Charest et al. 2014, 2015, Kriegeskorte & Kievit 2013, see also: Edelman et al. 1998, Laakso & Cottrell 2000, Op de Beeck et al. 2001, Haxby et al. 2001, Aguirre 2007, Kriegeskorte et al. 2008

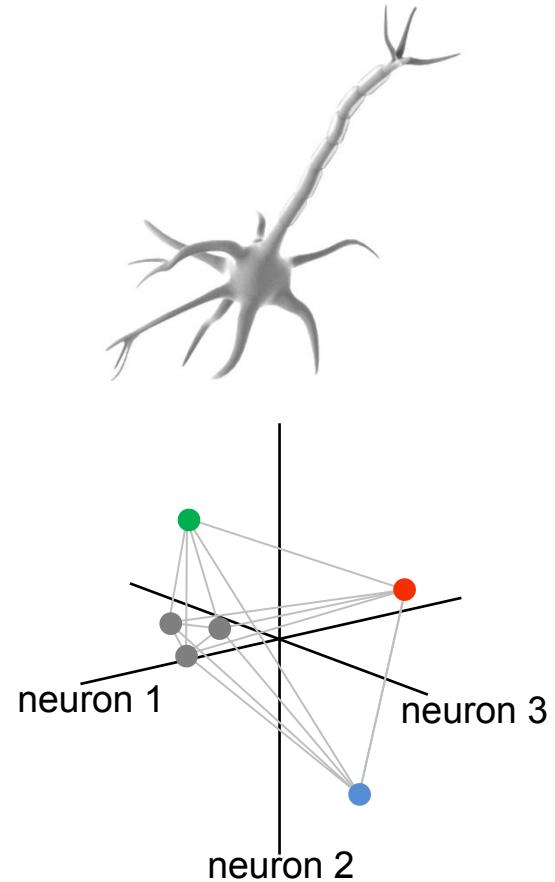
**Why investigate representational
geometries?**



downstream neurons
can read out the same
information from these
codes

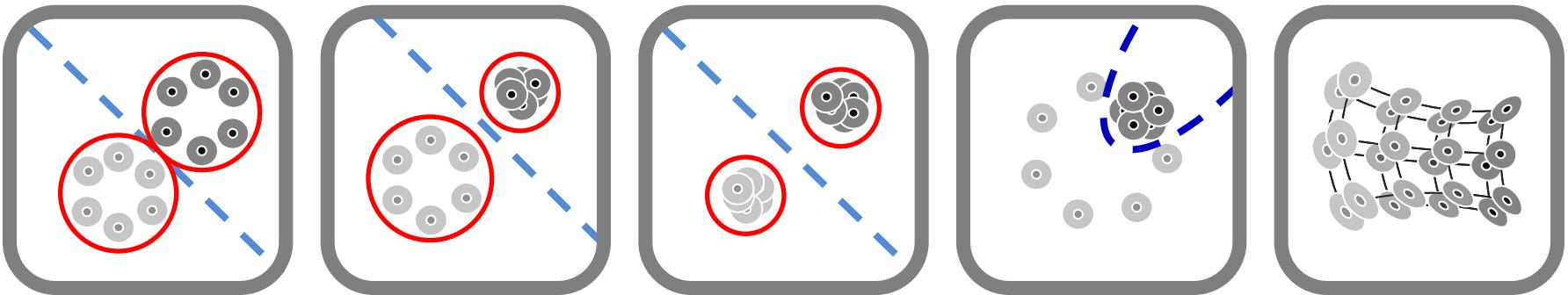
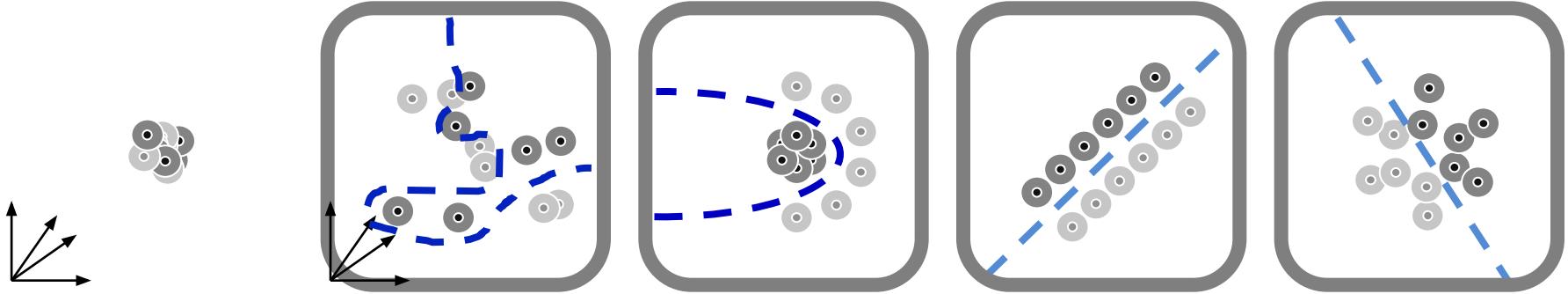


same geometry
→ same information
→ same format

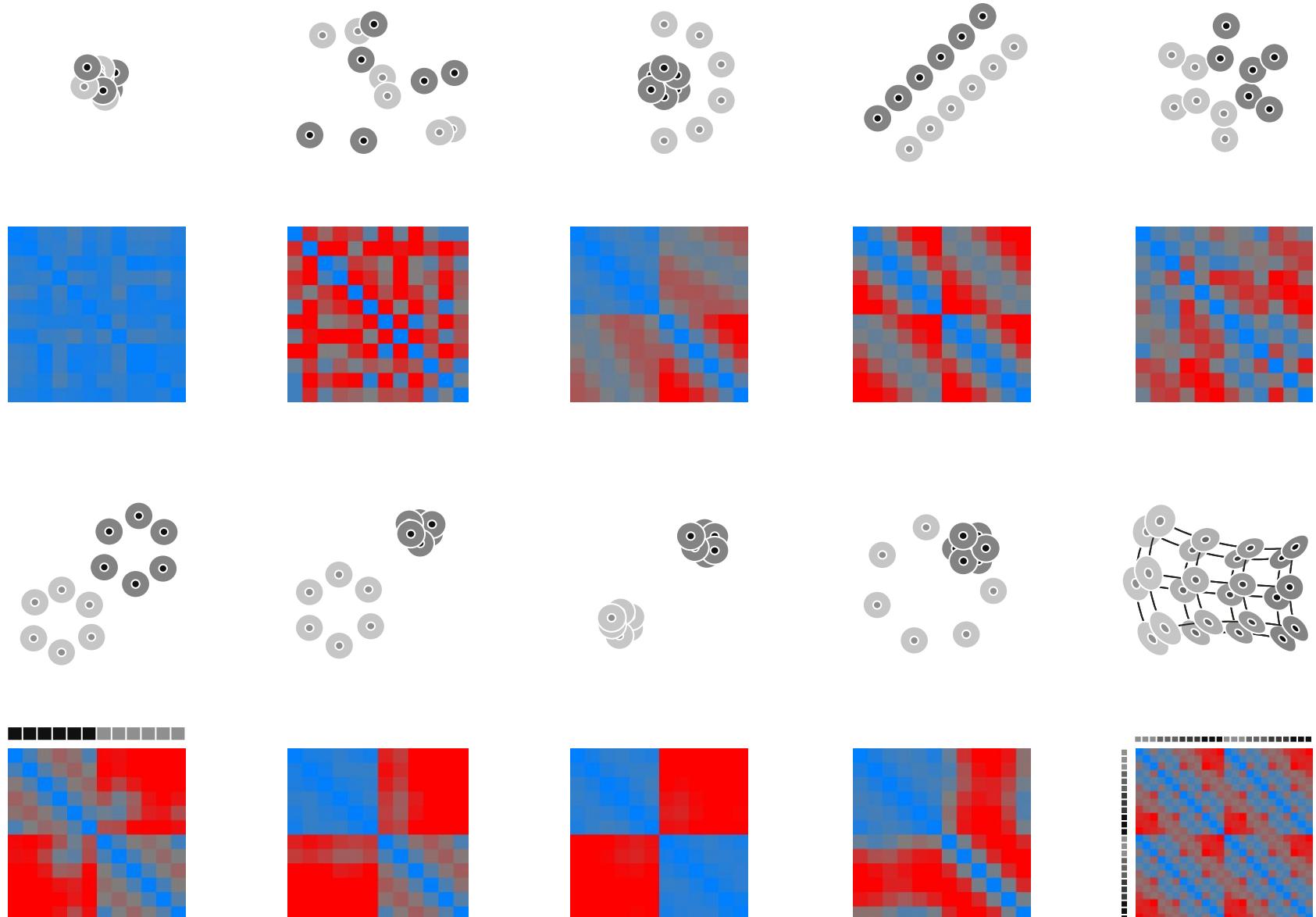


Representational geometry

The geometry of the points in a high-dimensional response pattern space, which are thought to represent particular stimuli.

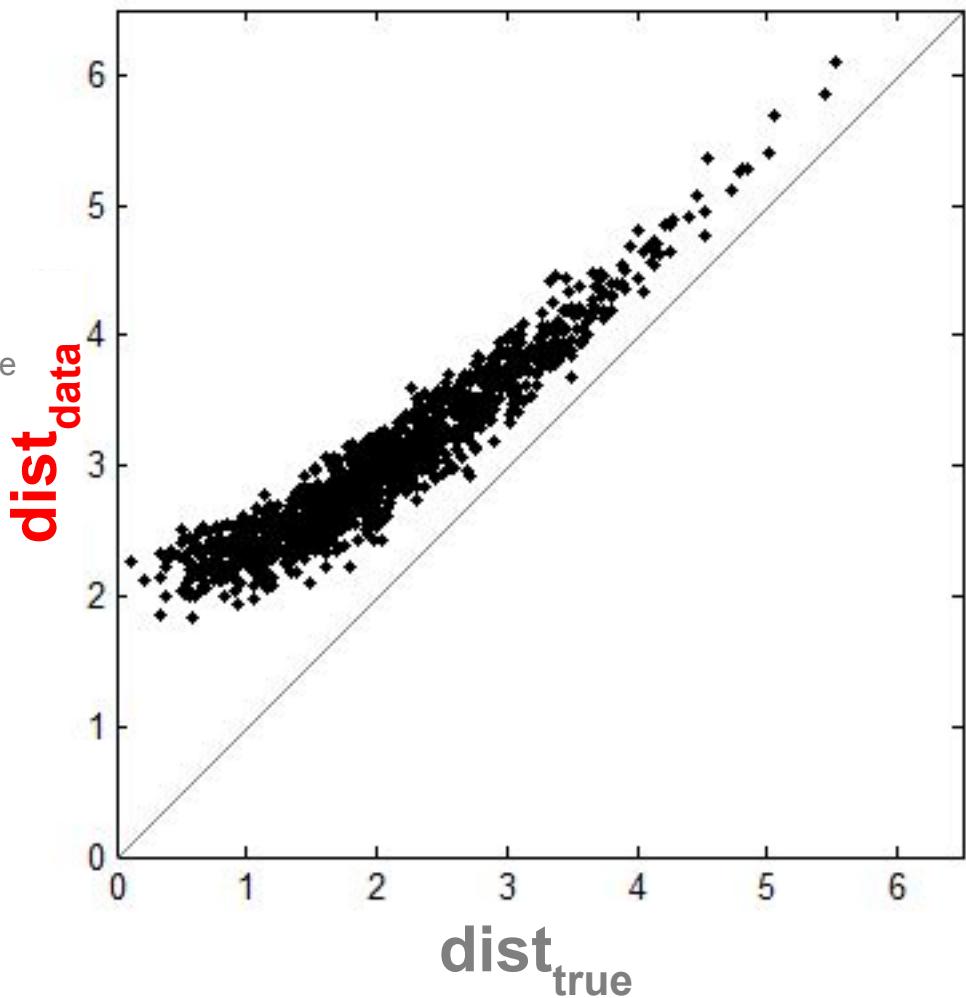
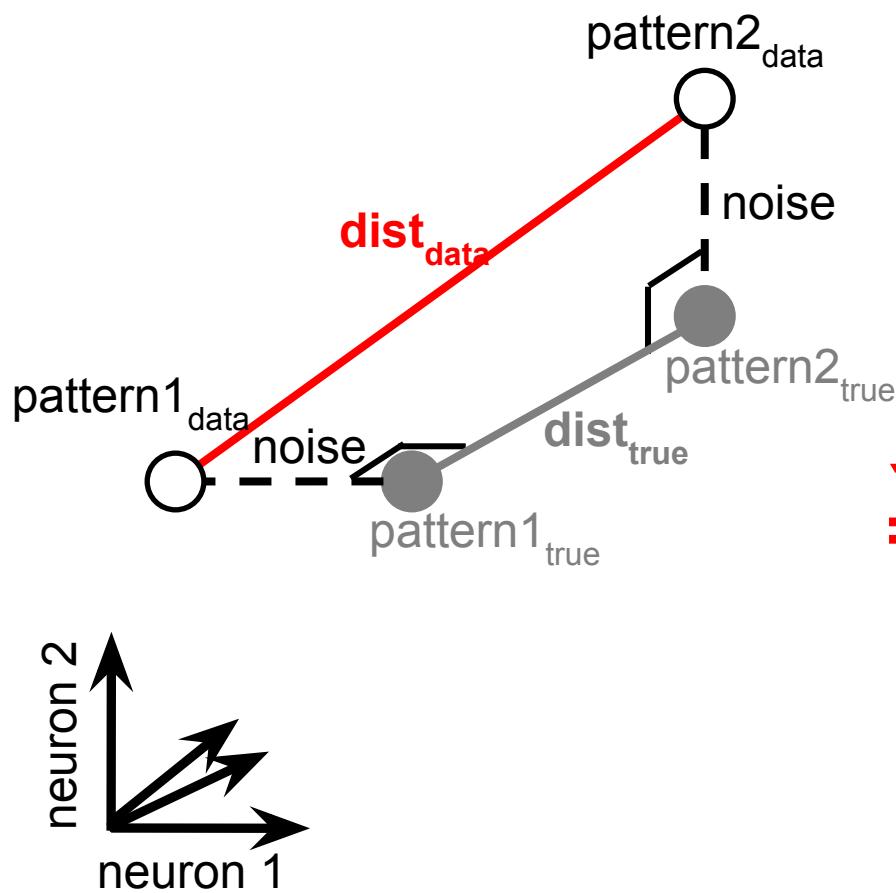


category information
...for linear readout
...for nonlinear readout
...inherently categorical



**How can we best measure
representational distances?**

Distance estimates are positively biased



**Distances are positively biased
– just like training-set decoding accuracies!**

Euclidean distance

Straight-line distance between two patterns in Euclidean space

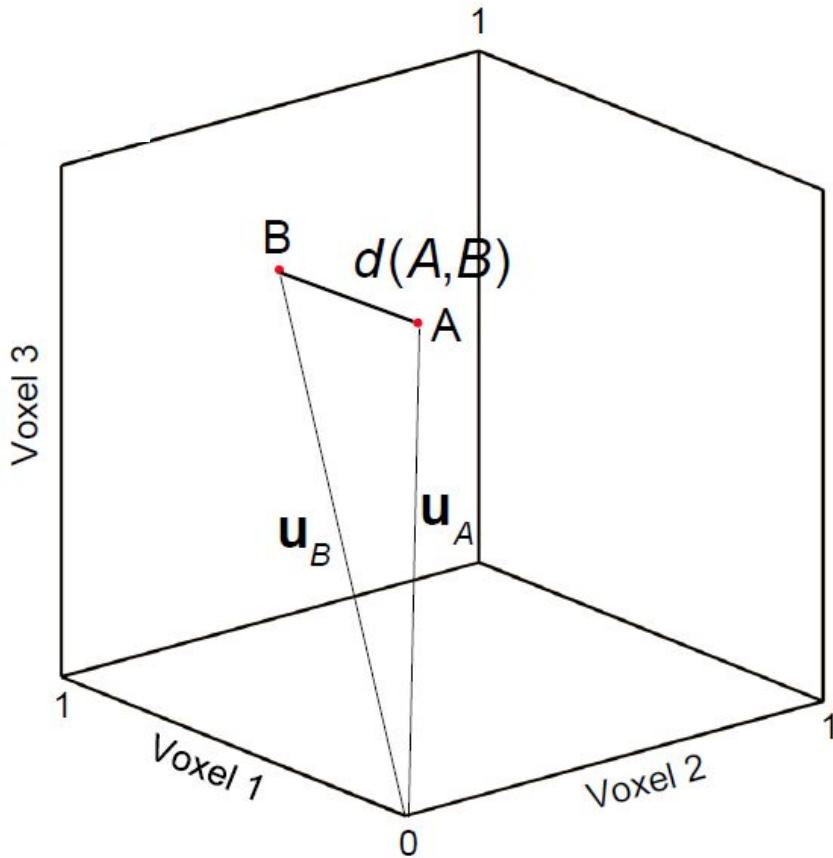


Image from Alex Walther
RSA workshop 2015

Correlation distance

1 – correlation

Correlation = cosine of the angle between normalised patterns

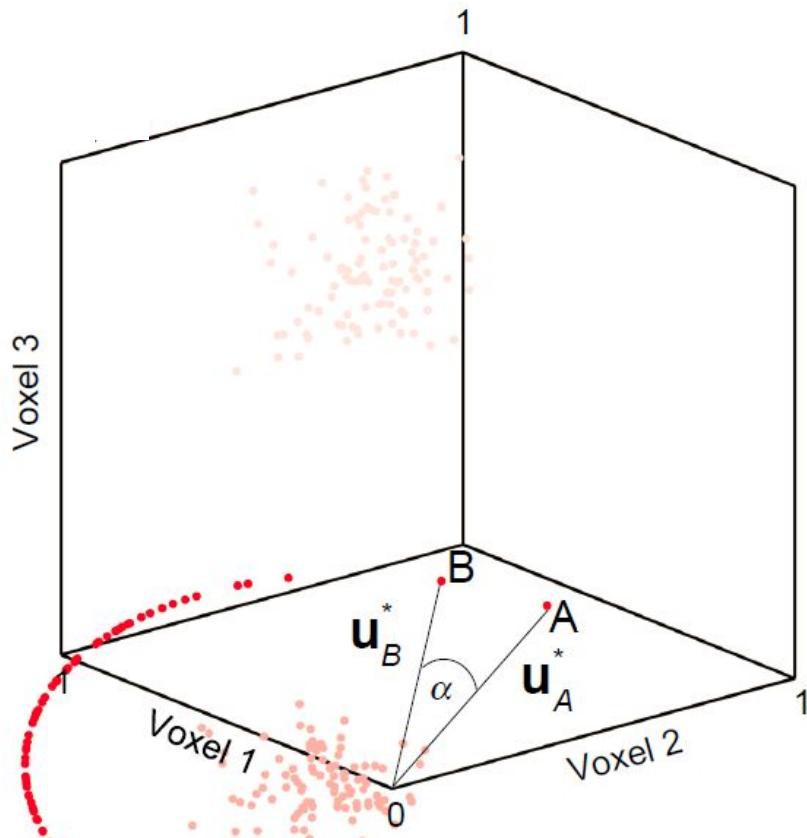


Image from Alex Walther
RSA workshop 2015

Linear discriminant contrast (LDc)

The default distance measure used in the RSA toolbox
(based on the Euclidean distance).

It has two desired properties:

1. Multivariately noise normalised
2. Cross-validated

Noise normalisation

Noise normalisation of the fMRI response patterns increases the reliability of the estimated pattern distances.

Univariate:

Divide each voxel's beta weight by its standard deviation
→ t value

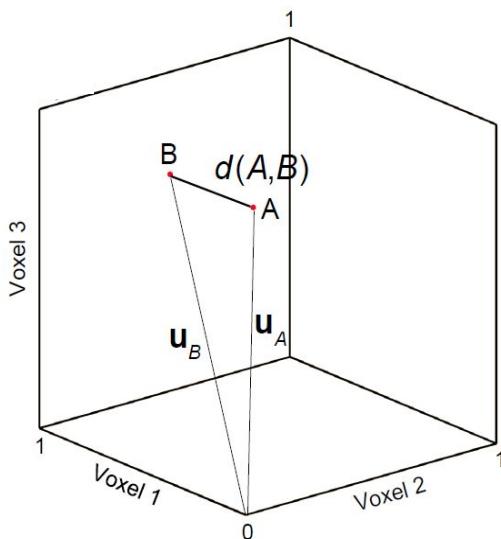
Multivariate:

Multiply each pattern with the inverse of the (square-rooted) covariance matrix → Mahalanobis distance

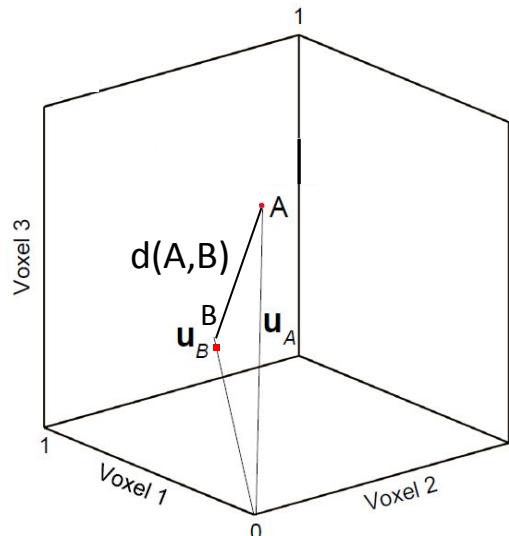
Cross-validated distance measures

Noise → distance measures are positively biased.

Cross-validated distance measures are unbiased and have an interpretable zero point.



data set 1



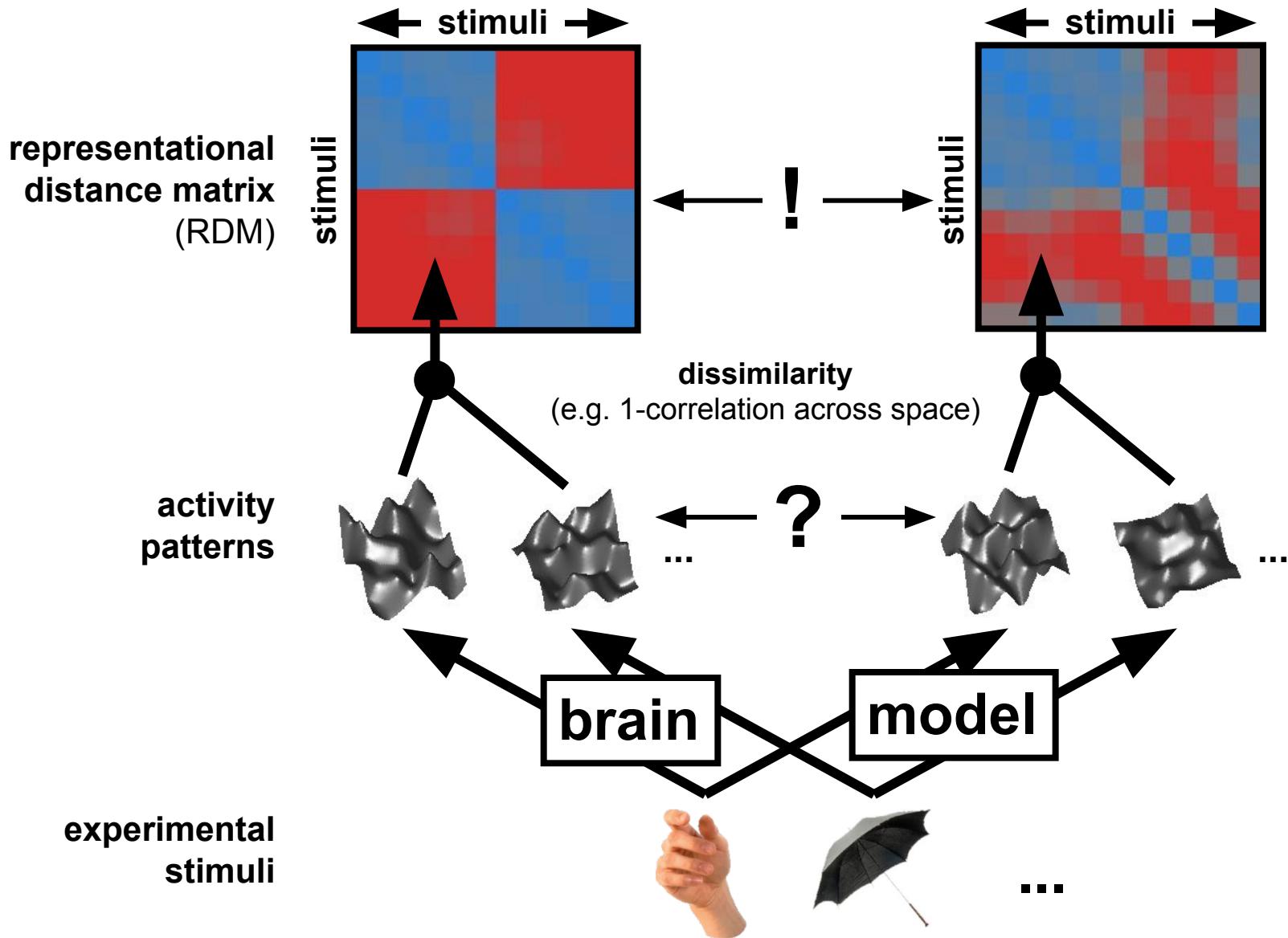
data set 2

LDc

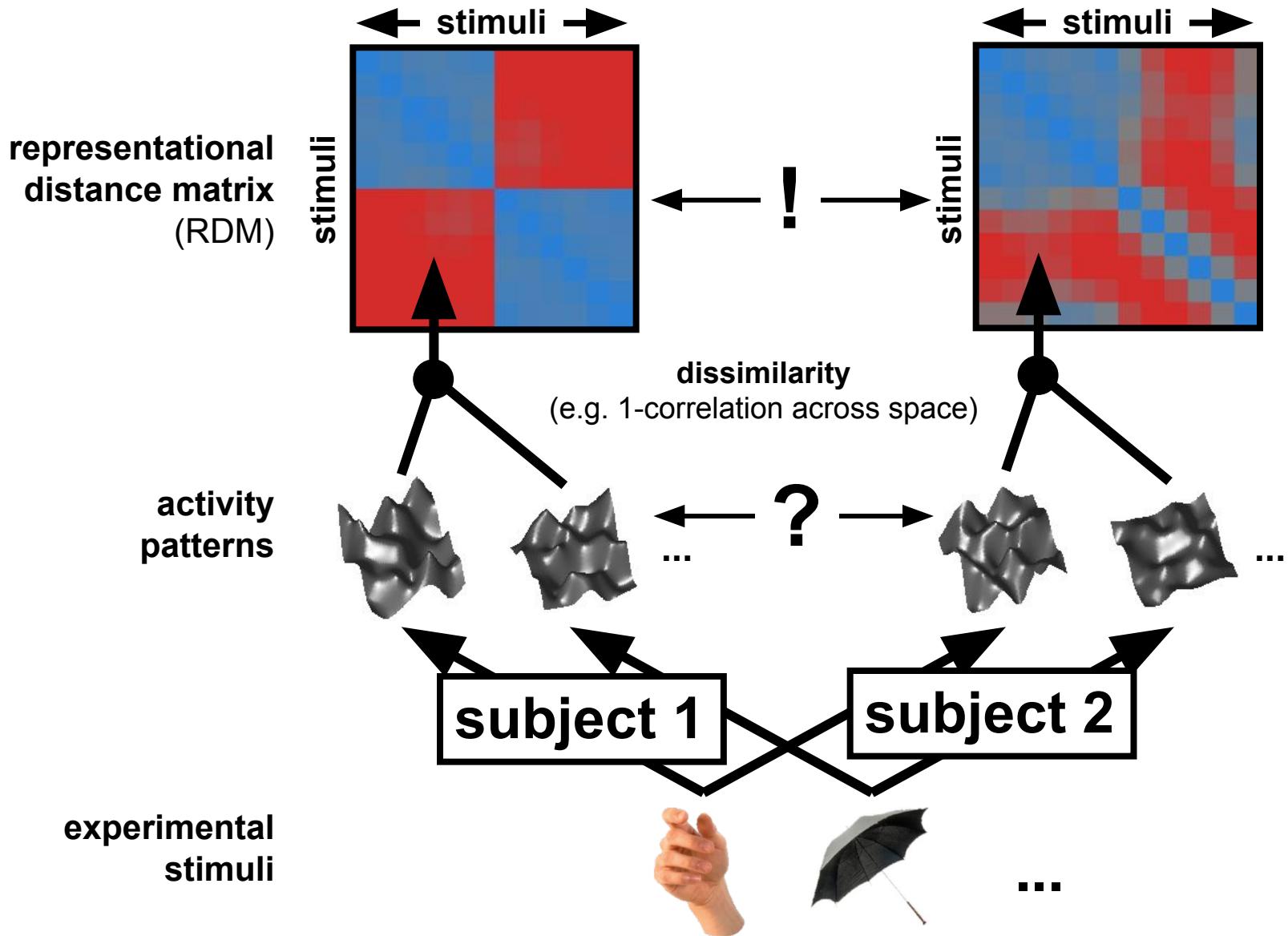
The cross-validated
Mahalanobis
distance

Images (adopted) from Alex Walther
RSA workshop 2015

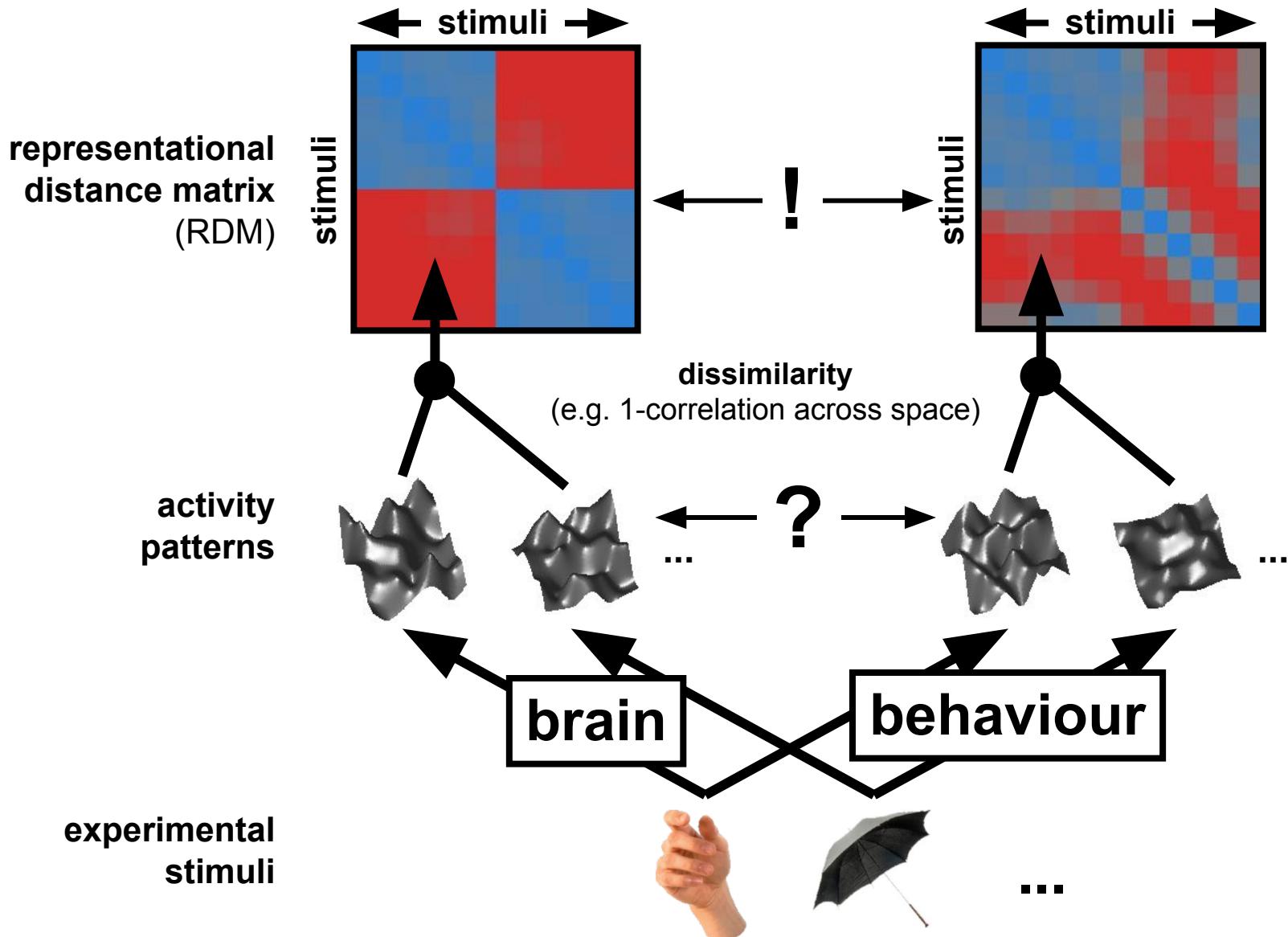
The representational similarity trick



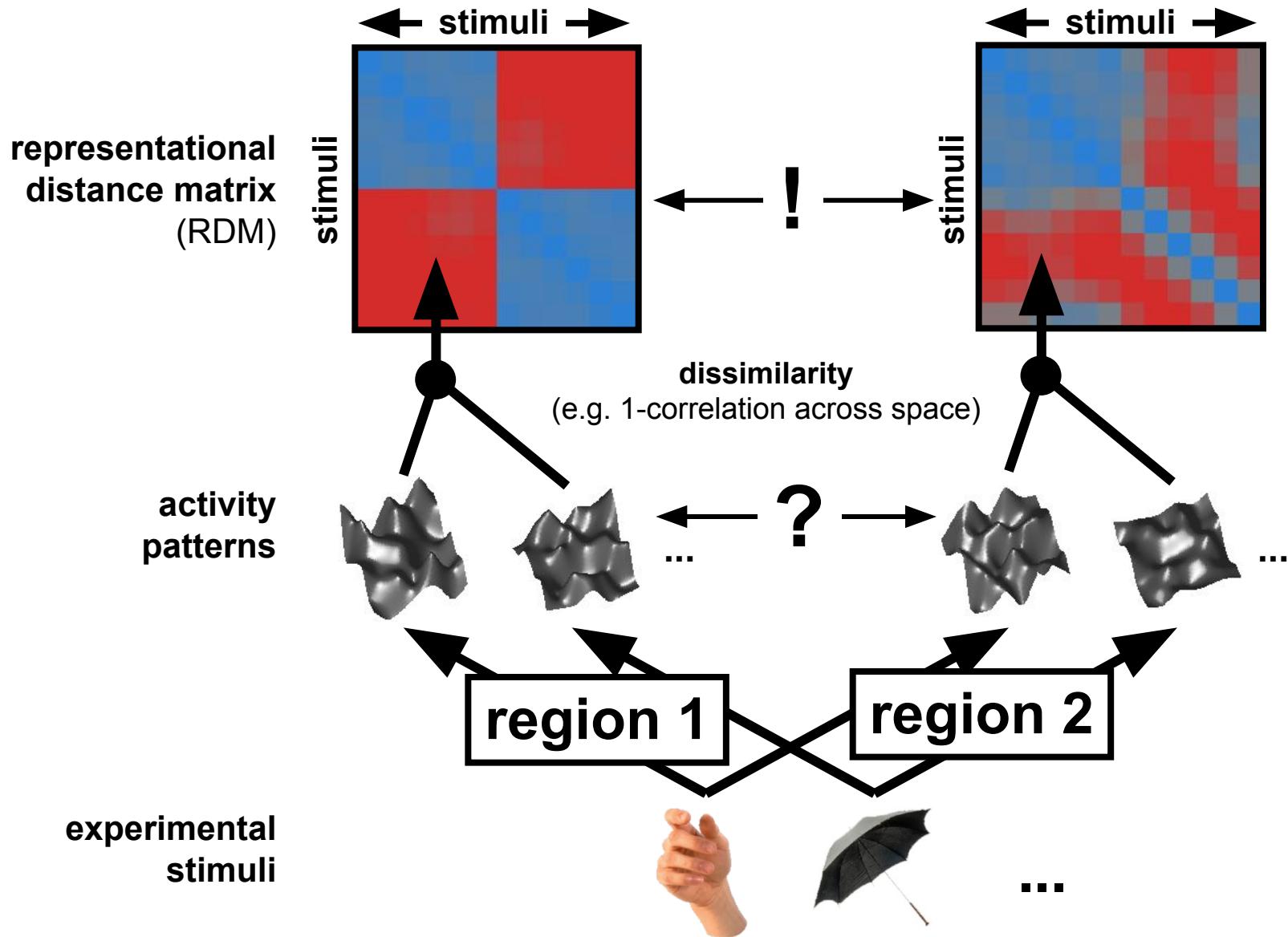
The representational similarity trick



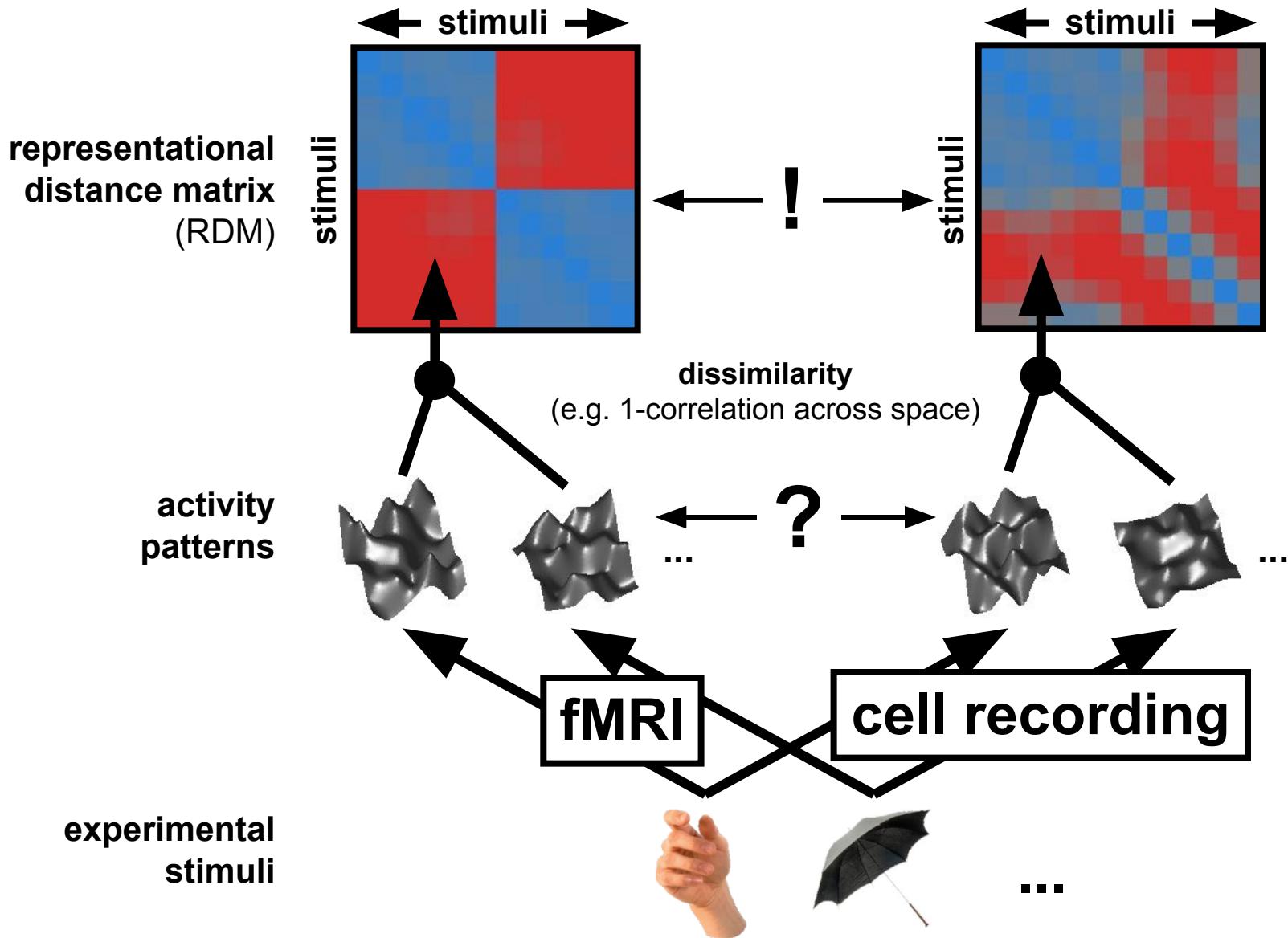
The representational similarity trick



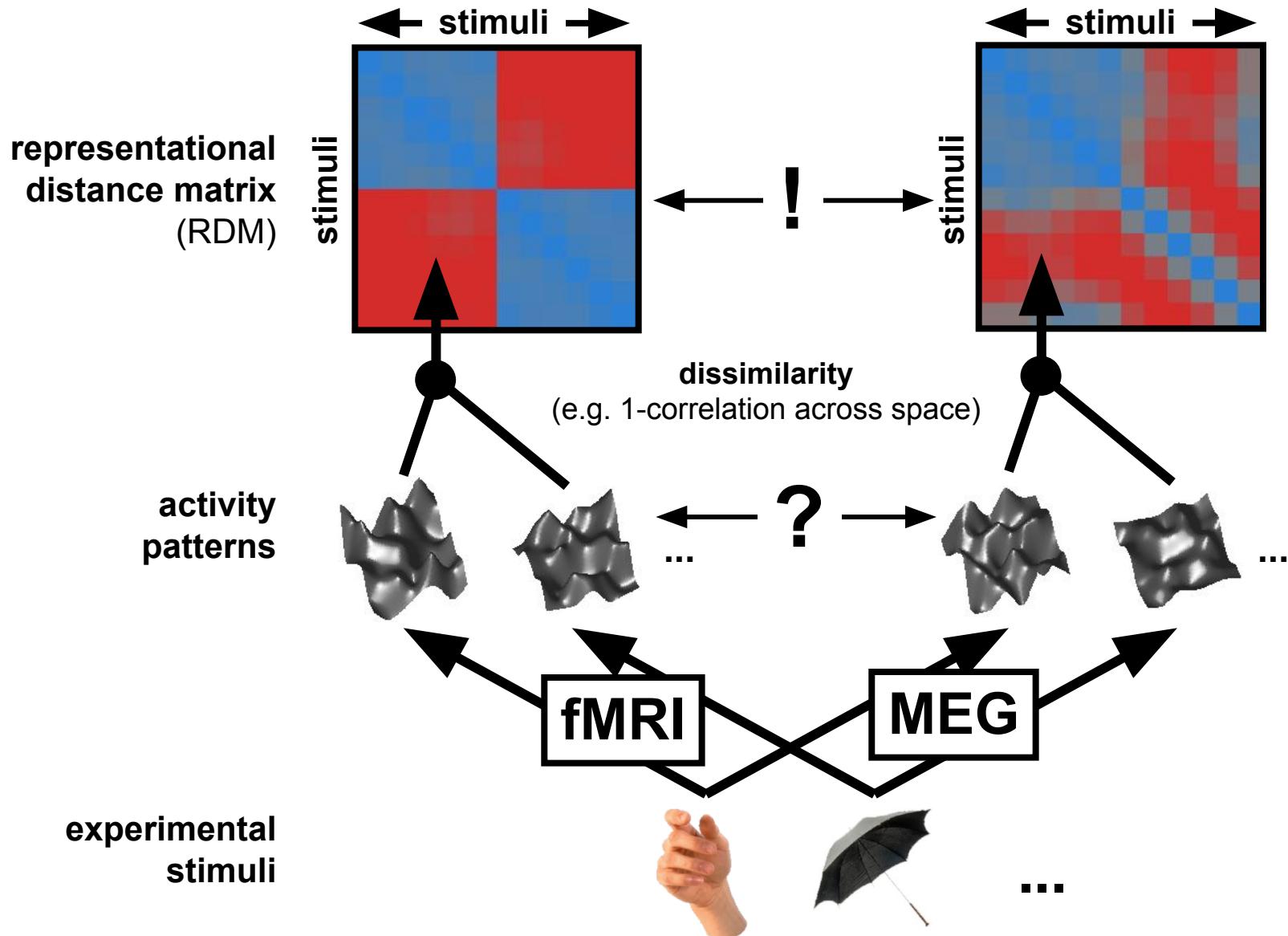
The representational similarity trick



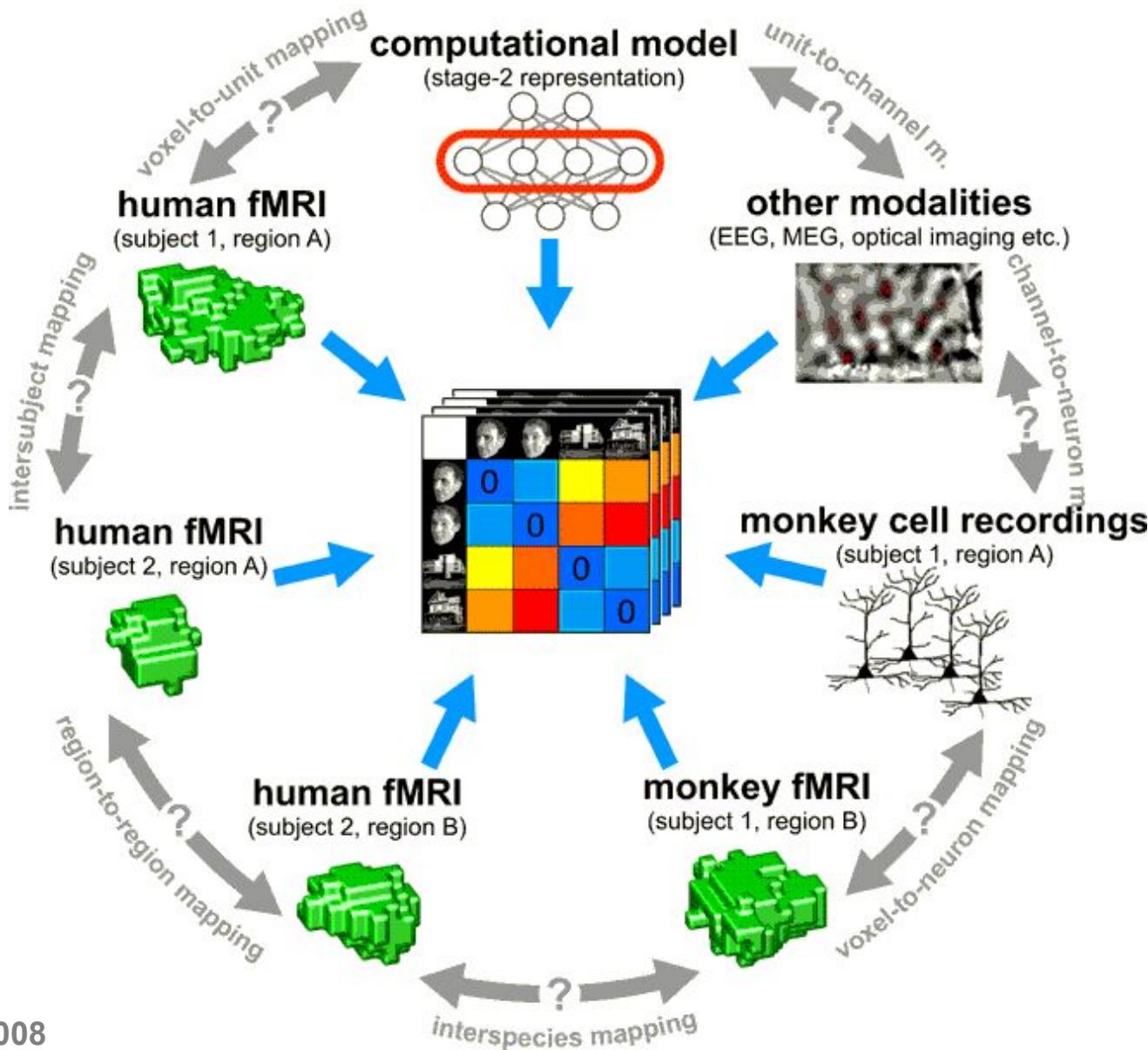
The representational similarity trick



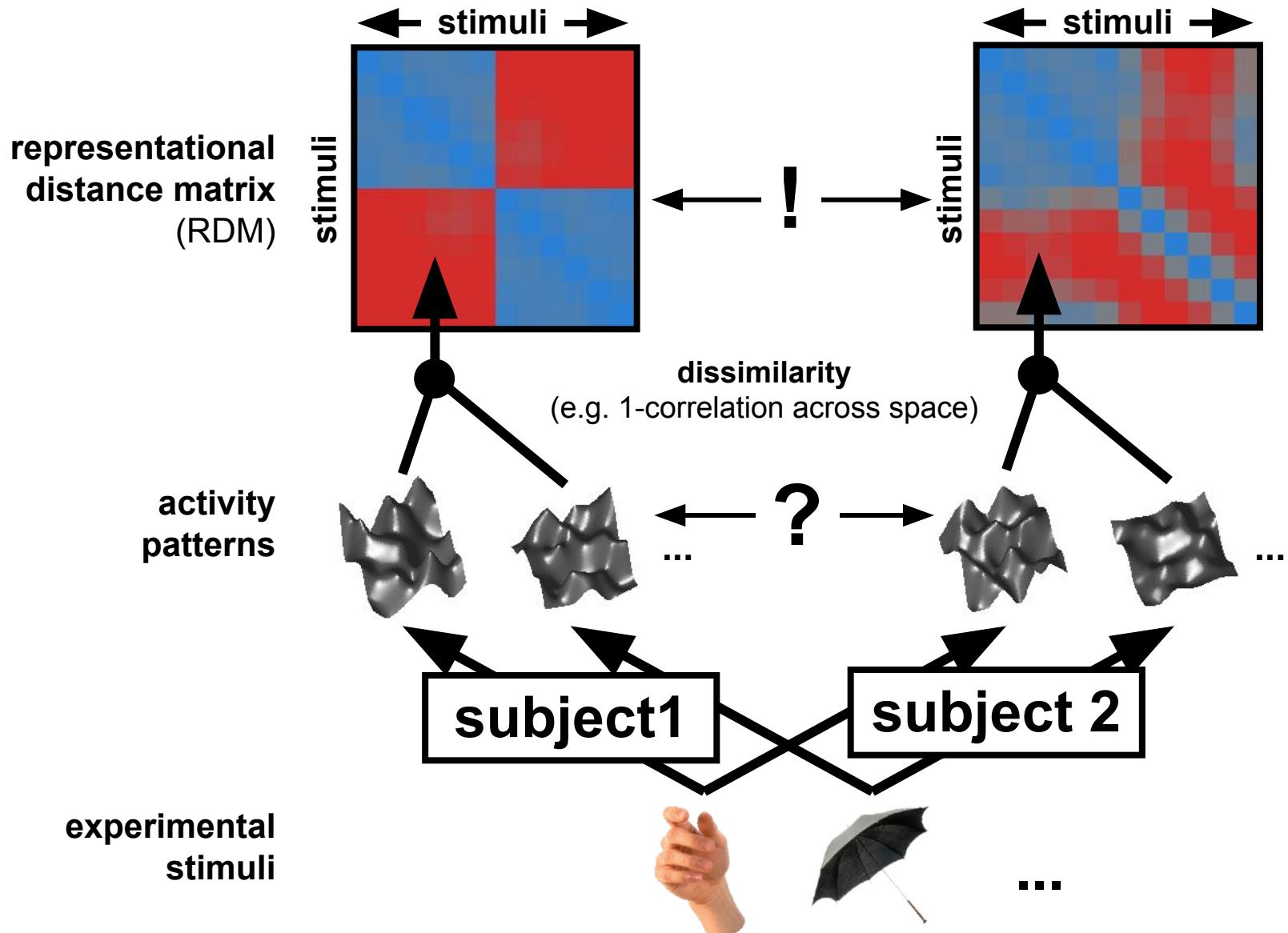
The representational similarity trick



The RSA trick



Comparing brain RDMs between people



Stimuli

animate

bodies



...

inanimate

faces



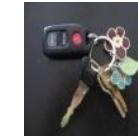
...

places



...

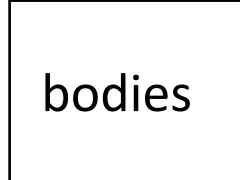
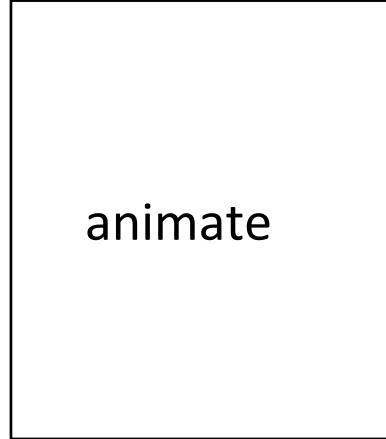
objects



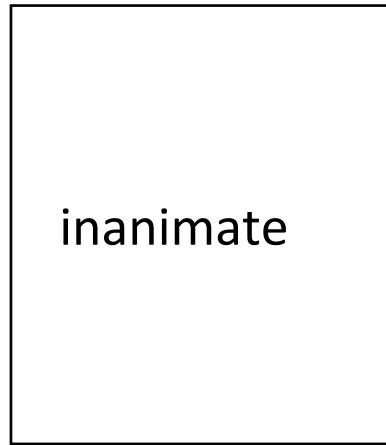
...

Stimuli

Objects from the subject's own photo-album



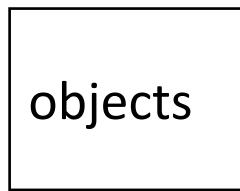
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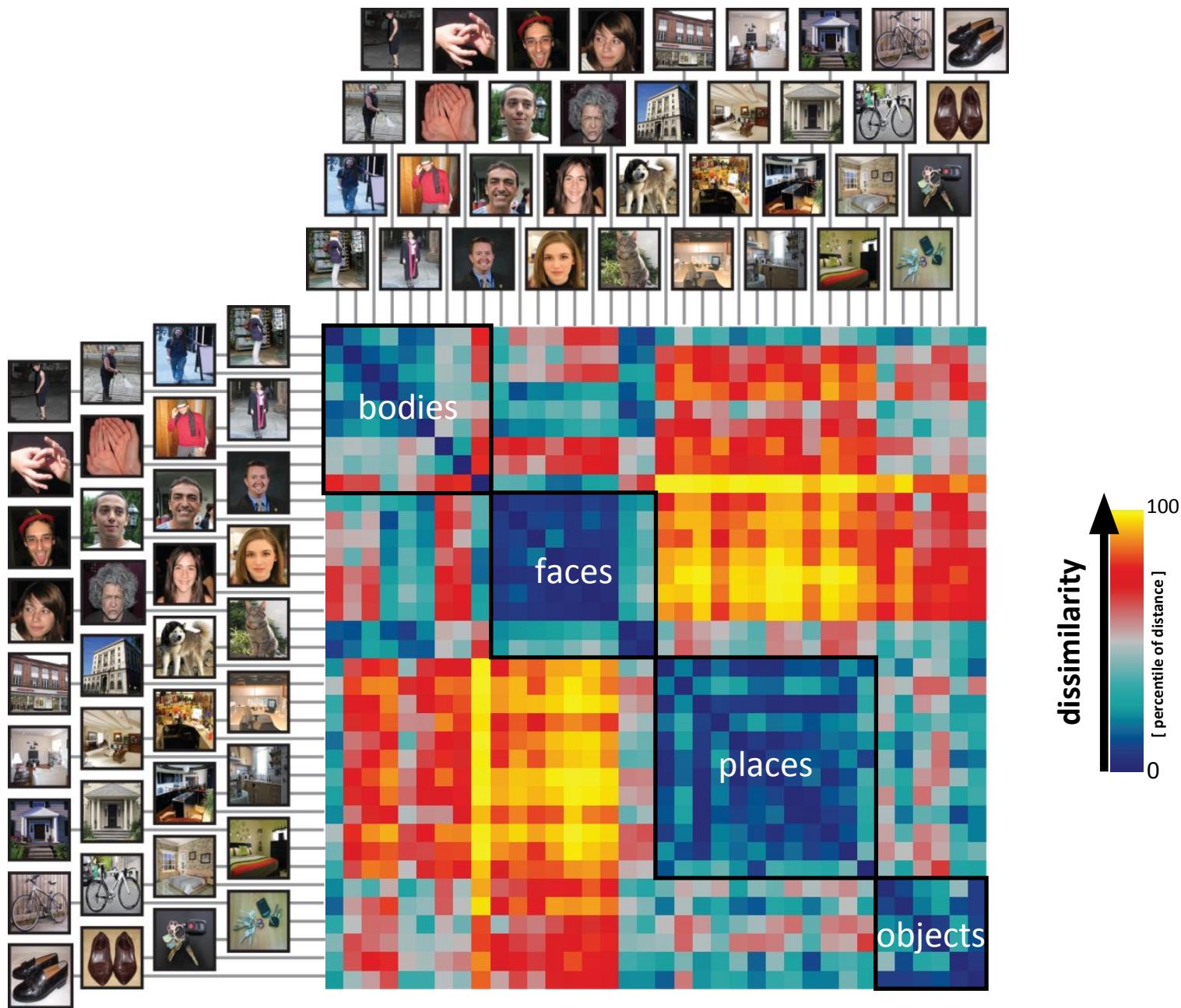
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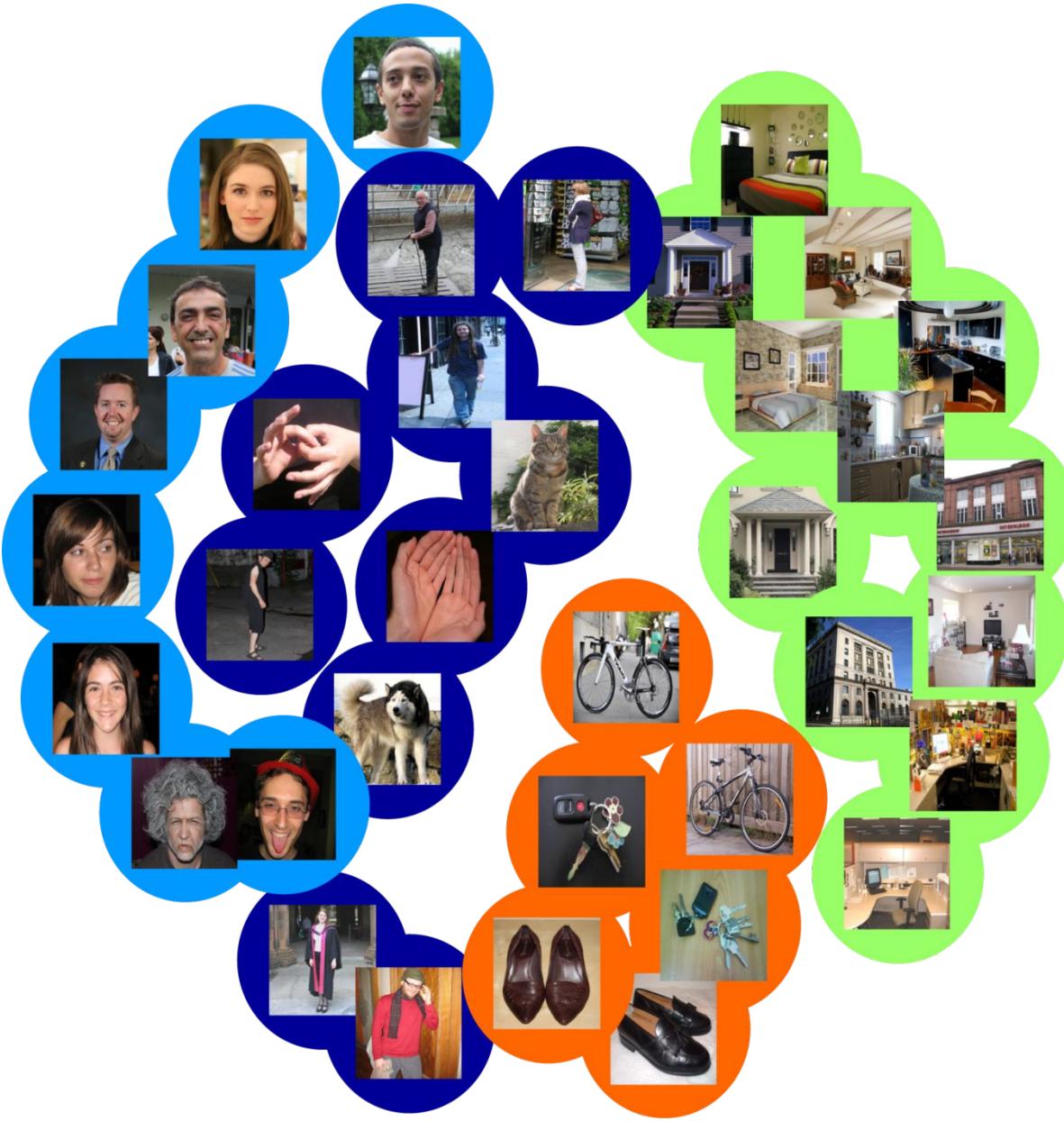
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Representational Dissimilarity Matrix (RDM)

subject 1
(hIT)

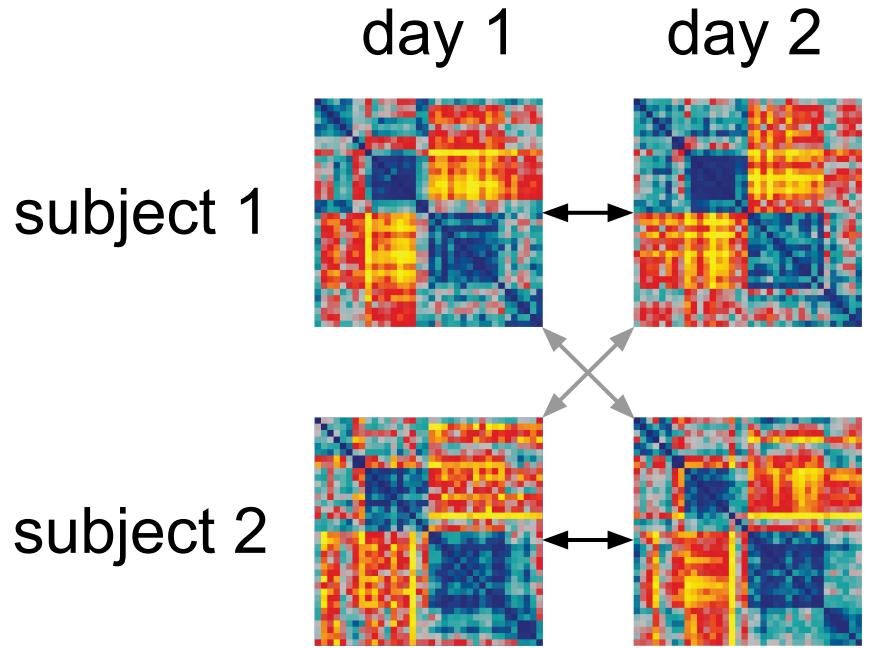


Multi-dimensional scaling



- bodies
- faces
- places
- objects

Comparing brain RDMs between people



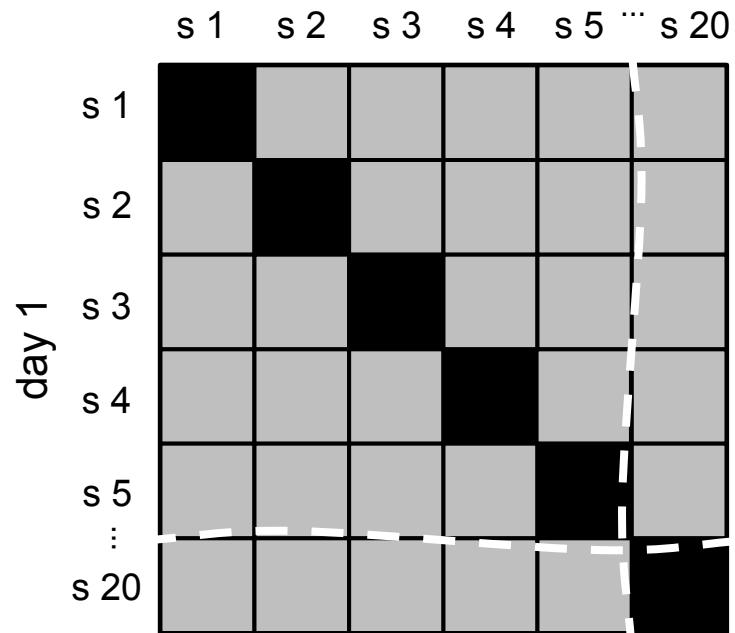
correlation

↔ within-subject (ws) ✓

↔ between-subject (bs) ✓

○ individuation index (ws - bs) ?

subject similarity matrix
day 2



Brain representations unique?

Representational geometries in human inferior temporal cortex

Neurotypicals

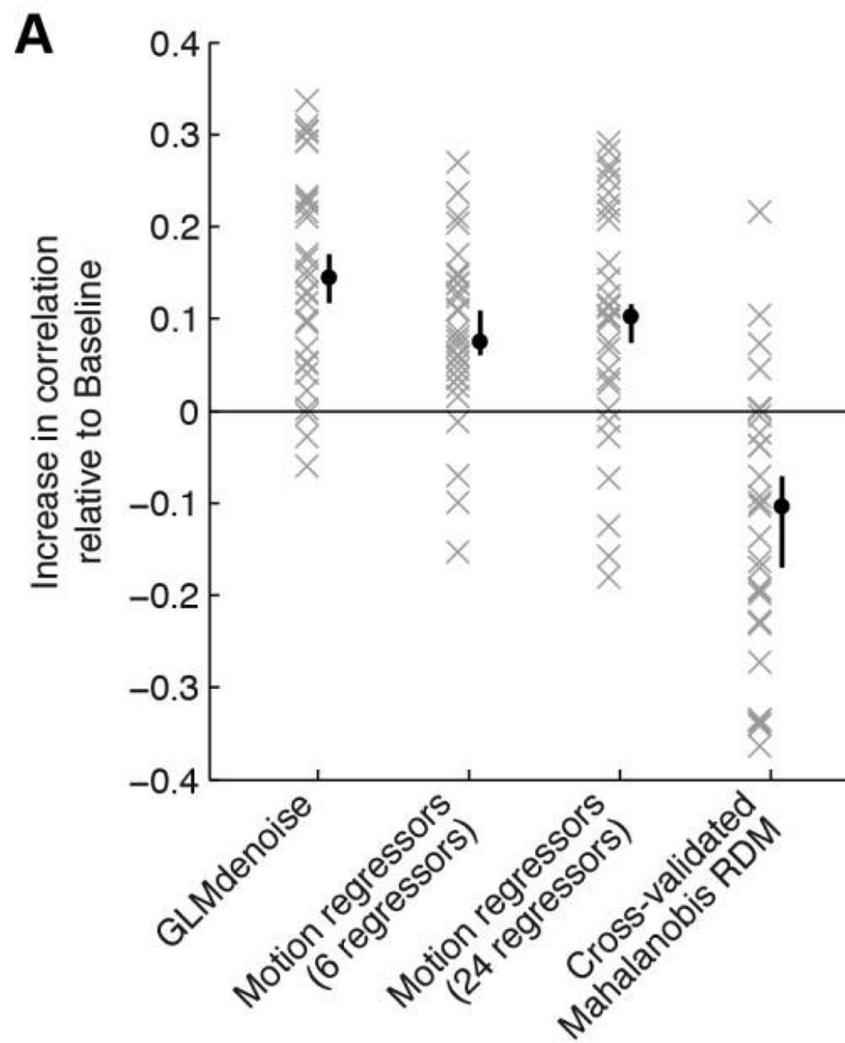
ASC

GLMdenoise improves MVPA analyses



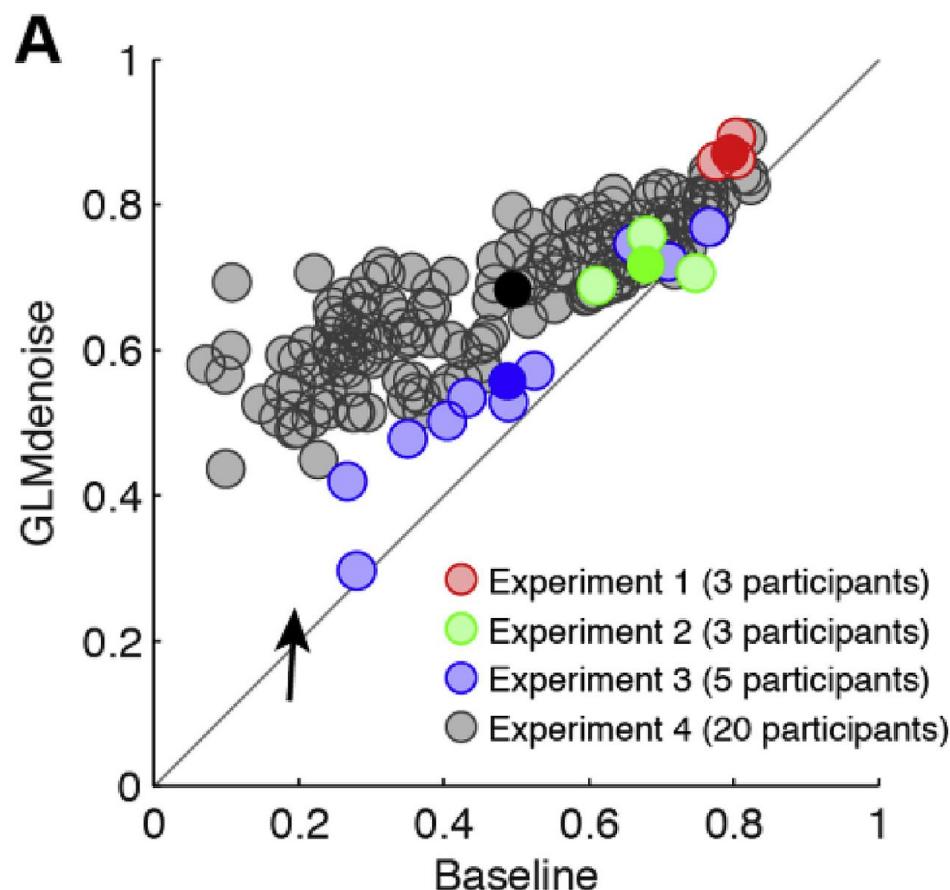
GLMdenoise improves MVPA analyses

Within-participant consistency is improved when using GLMdenoise

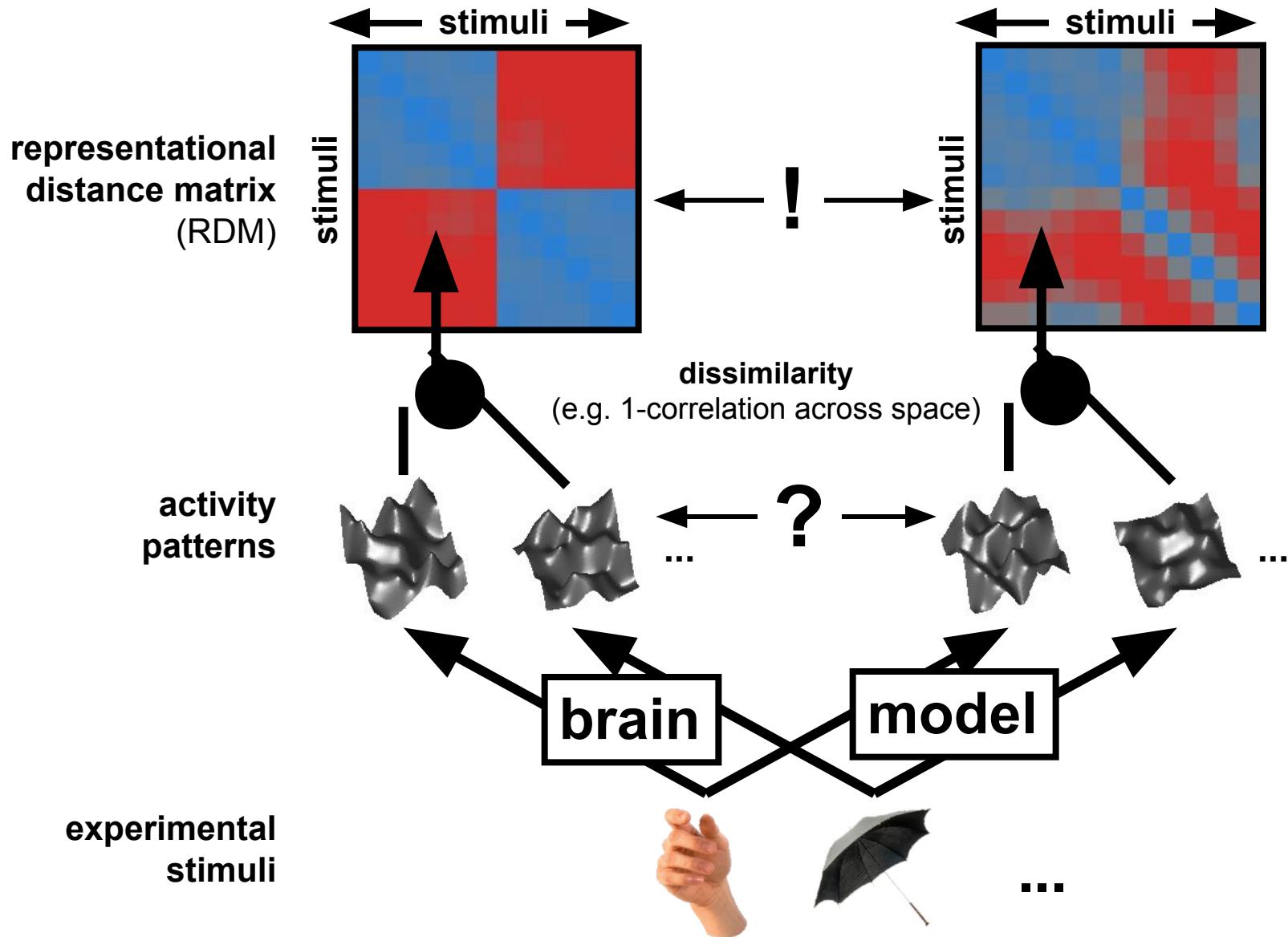


GLMdenoise improves MVPA analyses

Between-participants consistency is improved when using GLMdenoise



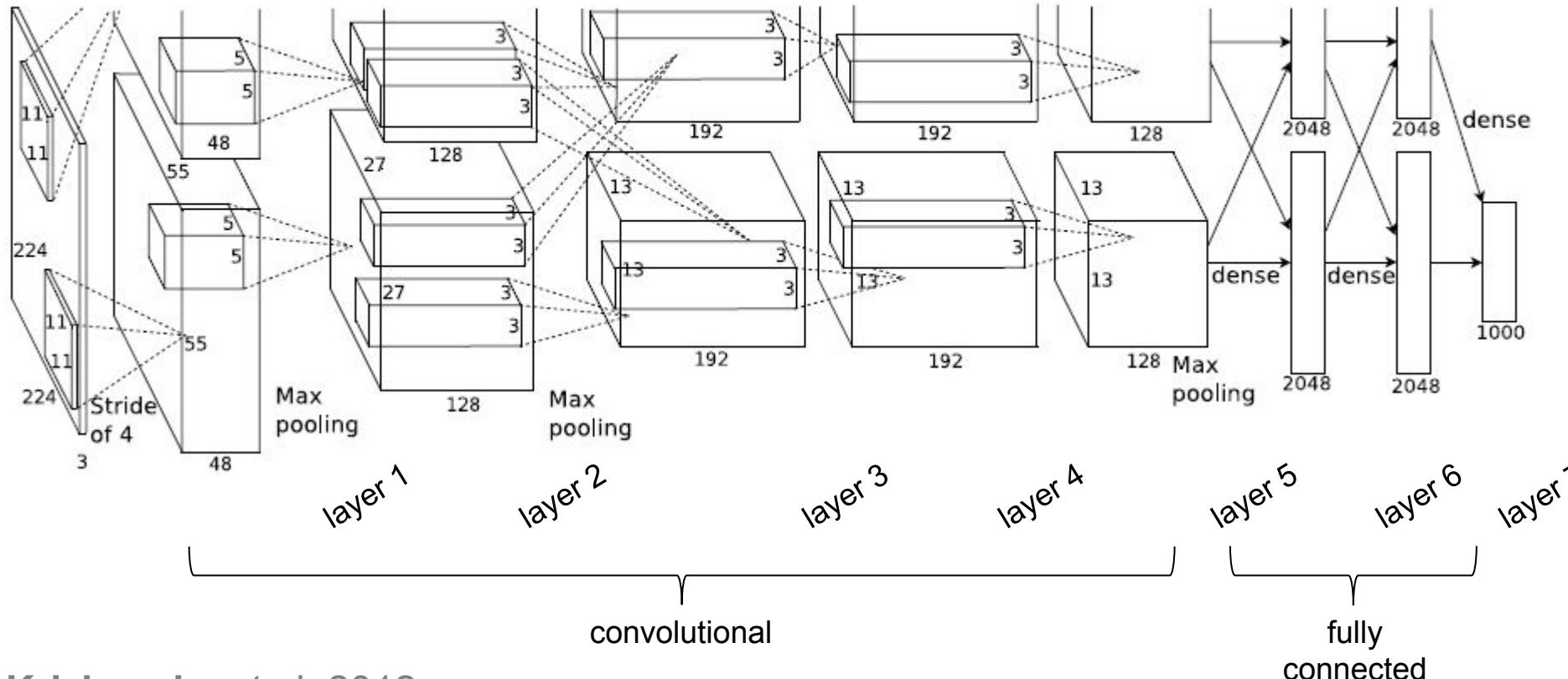
Relating brain and model RDMs

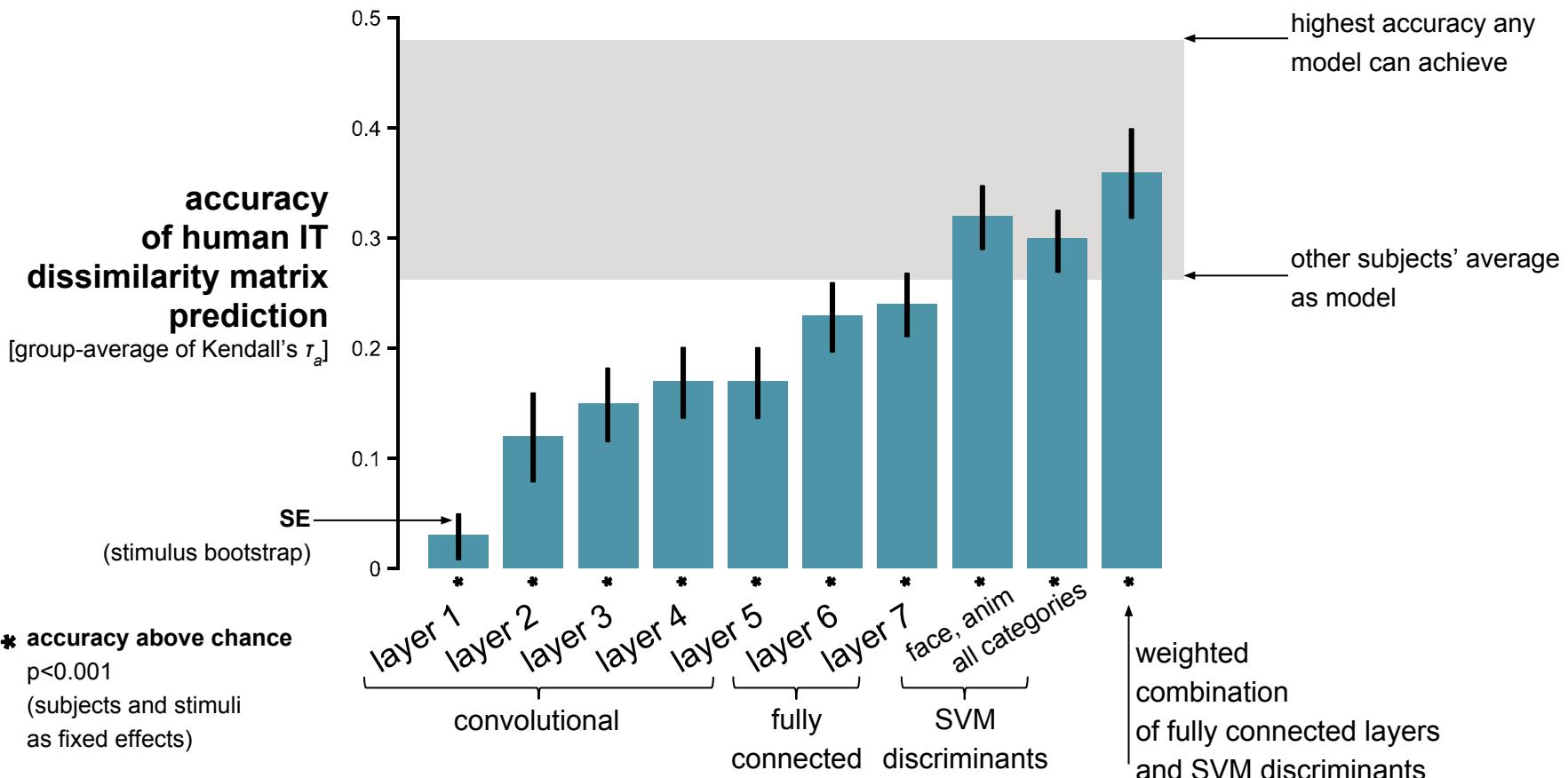


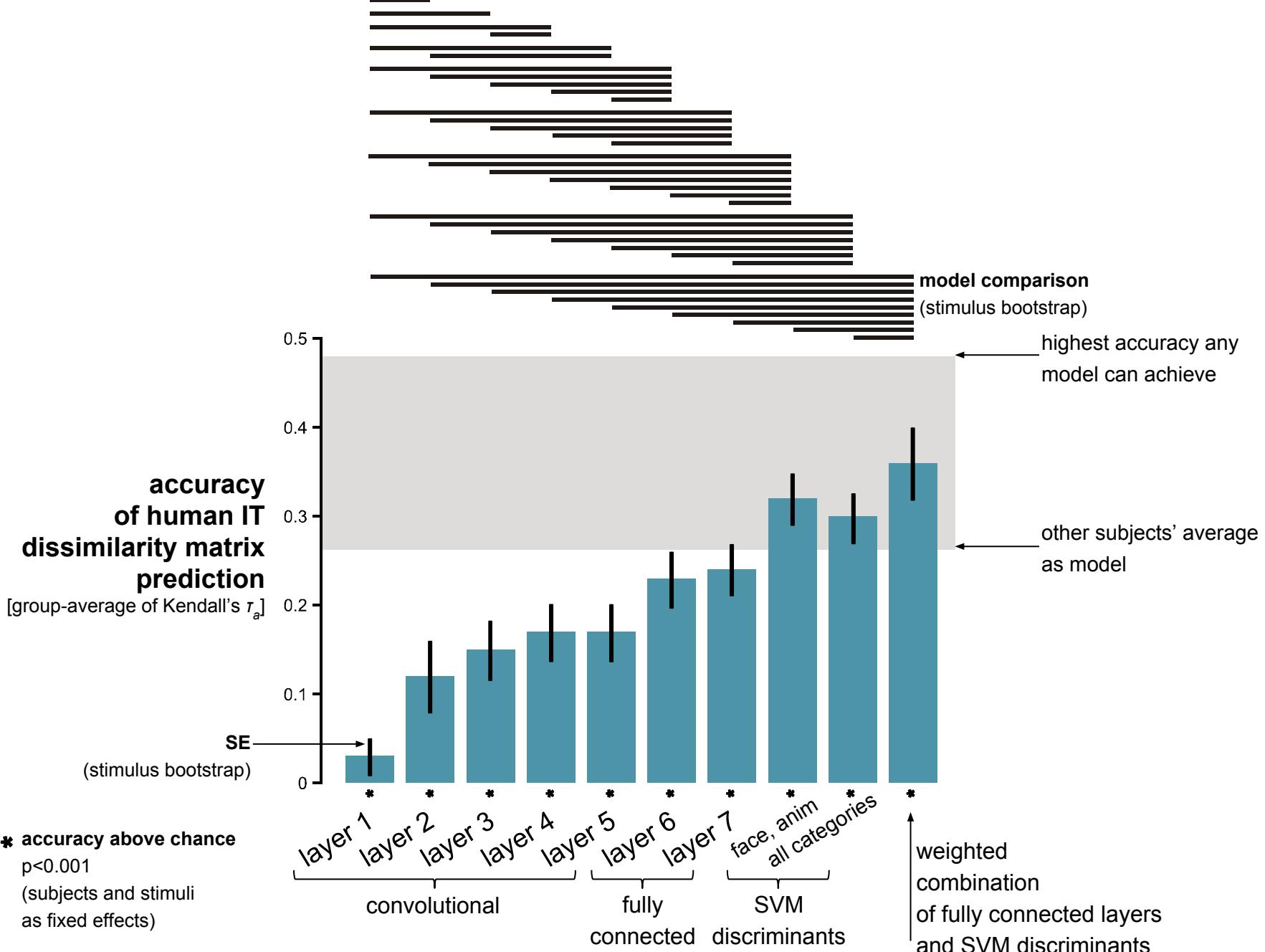
Deep convolutional neural network

- state of the art in computer vision
- trained with stochastic gradient descent
- supervised with 1.2 million category-labeled images
- 60 million parameters and 650,000 neurons

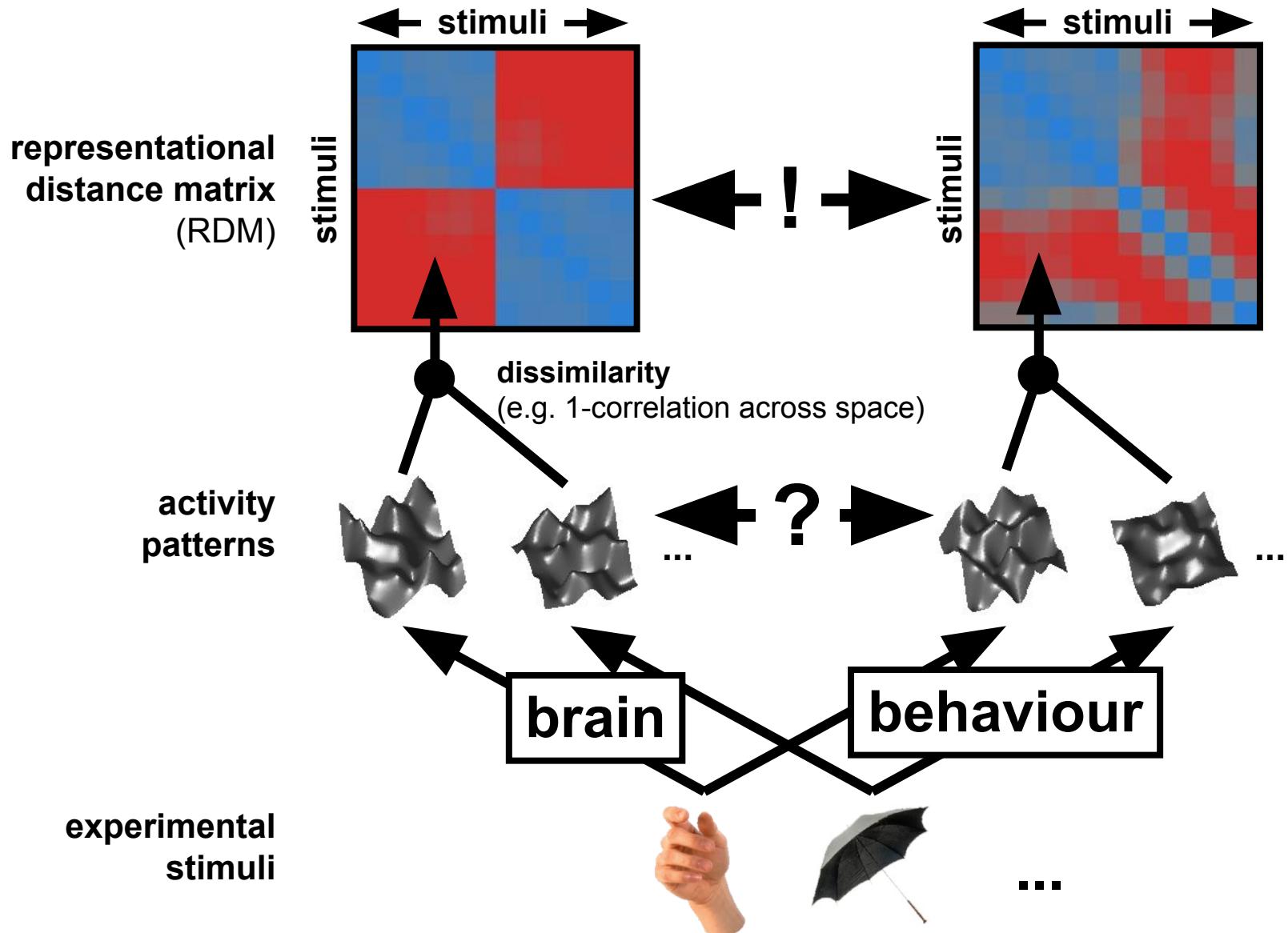
Is this network
functionally similar
to the brain?







Comparing brain RDMs and behavioural RDMs





MEADOWS

<http://meadows-research.com>



@meadowsresearch

Please arrange objects according to their similarity

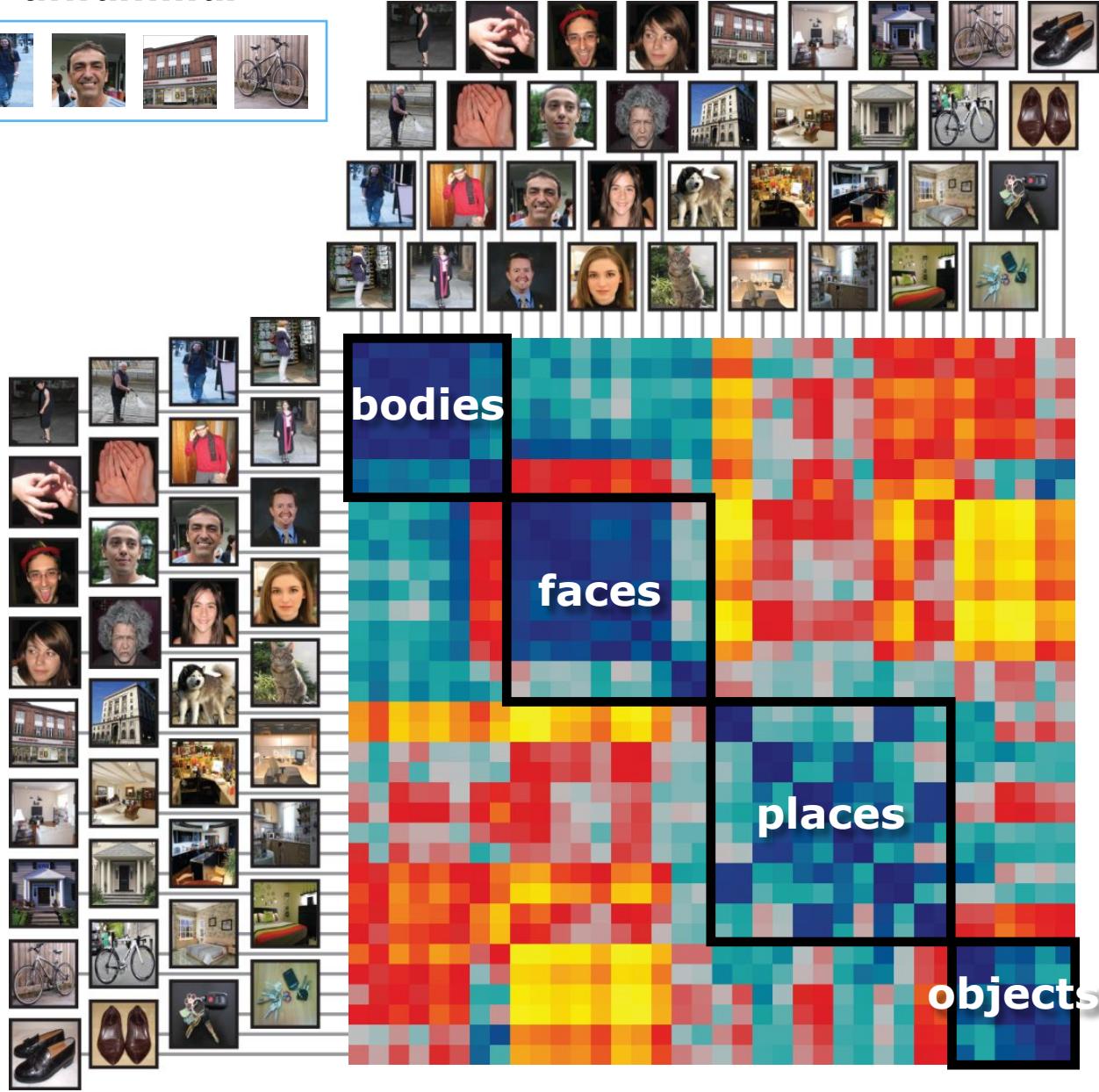


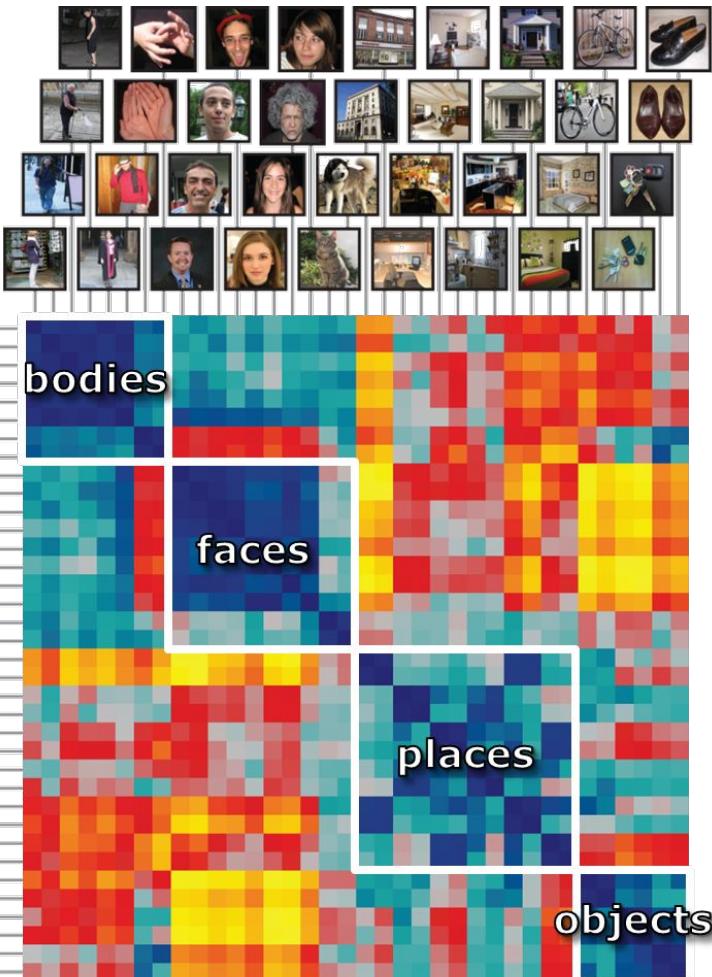
Judgment RDM

unfamiliar

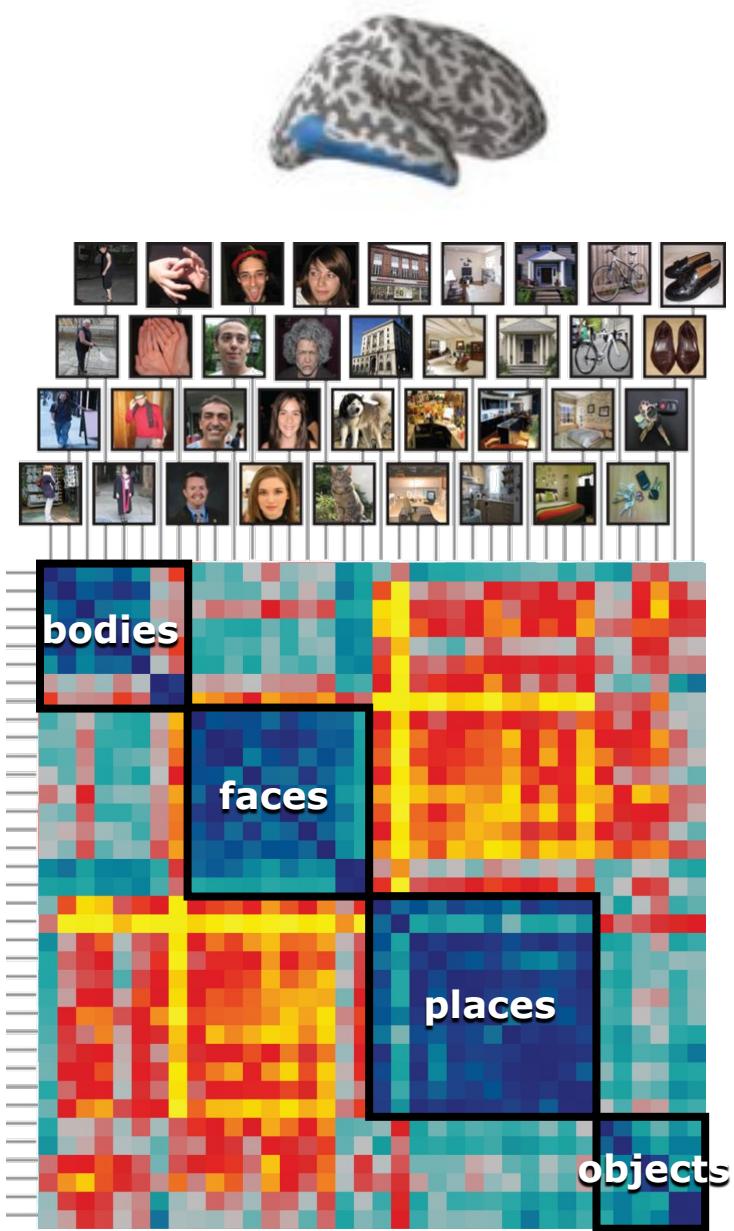


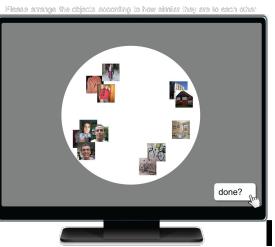
dissimilarity
[percentile of Euclidean distance]





Similarity Judgements





bodies



faces



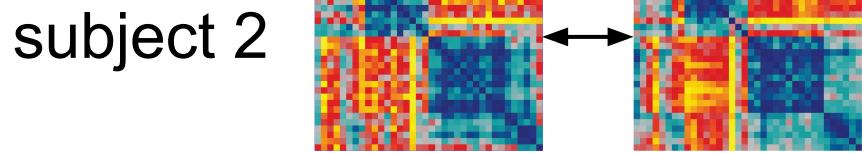
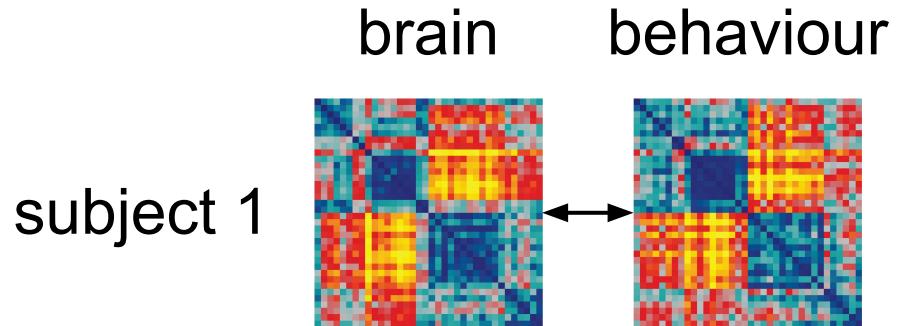
places



objects



Comparing brain RDMs and behavioural RDMs



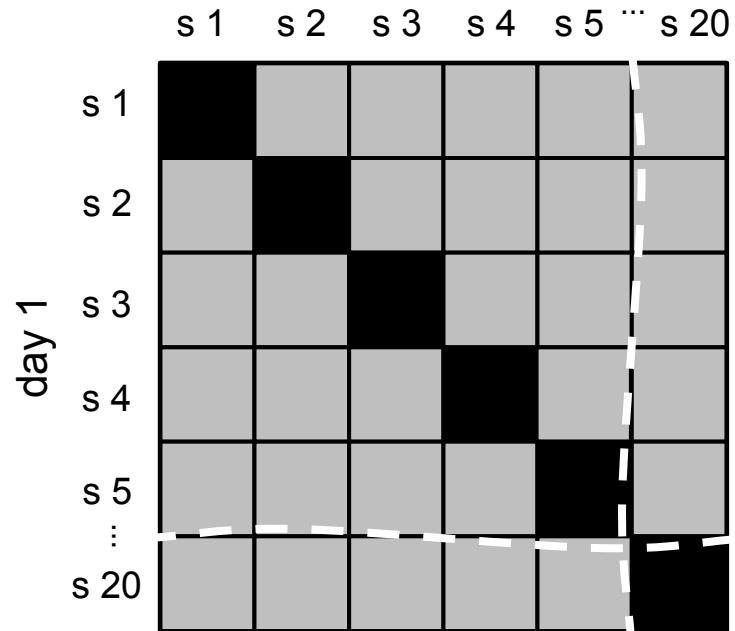
correlation

↔ within-subject (ws) ✓

↔ between-subject (bs) ✓

● individuation index (ws - bs) ?

subject similarity matrix
day 2



Brain-behavior relationship unique?

RSA

Representational Dissimilarity Matrix (RDM)



human inferior temporal
(hIT)



voxels



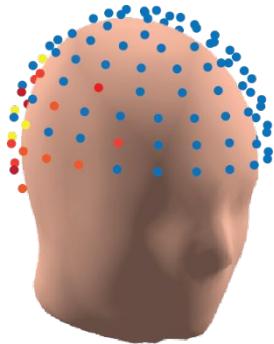
compute the dissimilarity
(e.g. $1 - \text{correlation}$)

representational pattern
(population code
representation)

... experimental stimuli

RSA

Representational Dissimilarity Matrix (RDM)

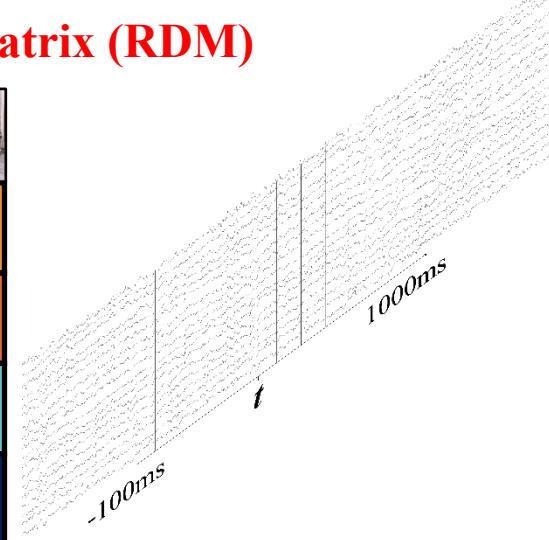


EEG activity-pattern
at time t



EEG Channel

amplitudes



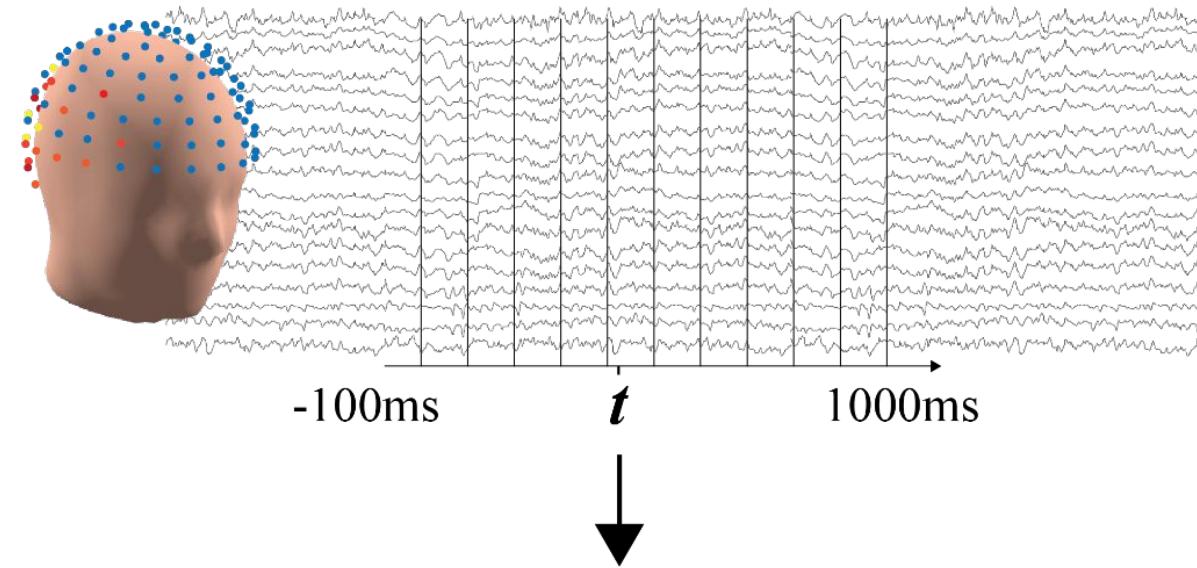
compute the dissimilarity
(e.g. $1 - \text{correlation}$)
linear discriminant analysis

representational pattern
(population code representation)

... experimental stimuli

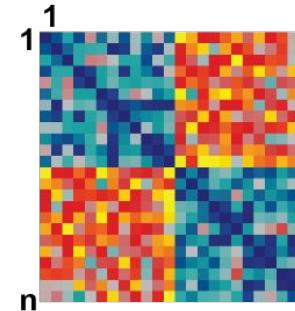
RSA

EEG Sensor
Activation
Patterns

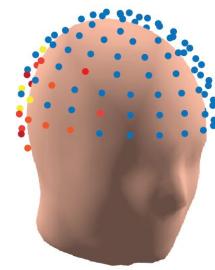
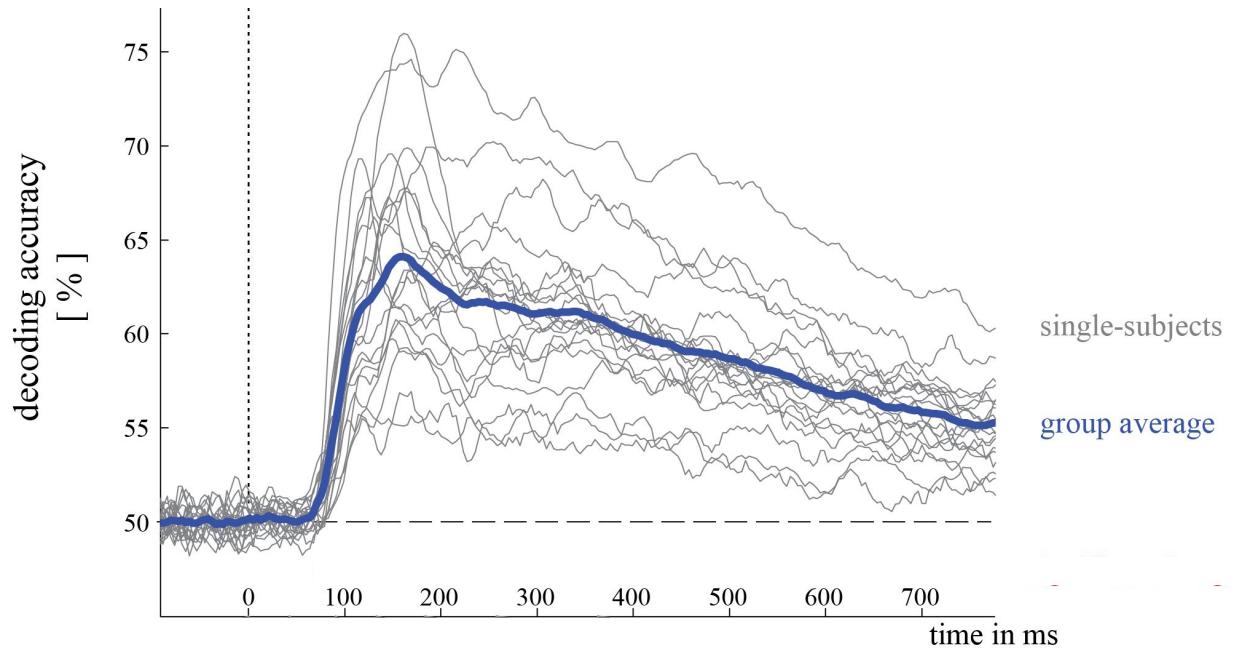


*decode pair-wise activation
patterns for objects 1:n*

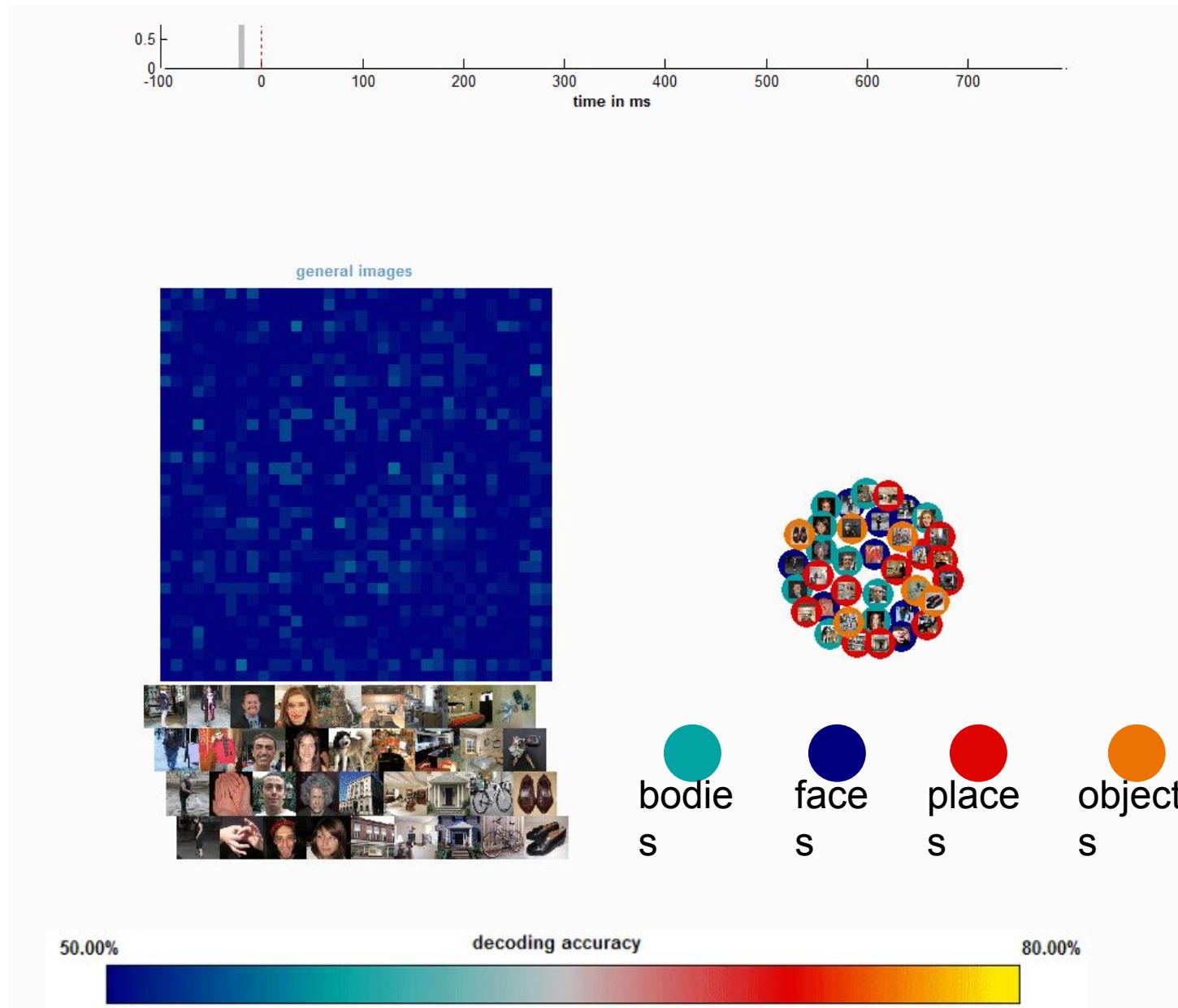
representational
dissimilarity matrix
at time t

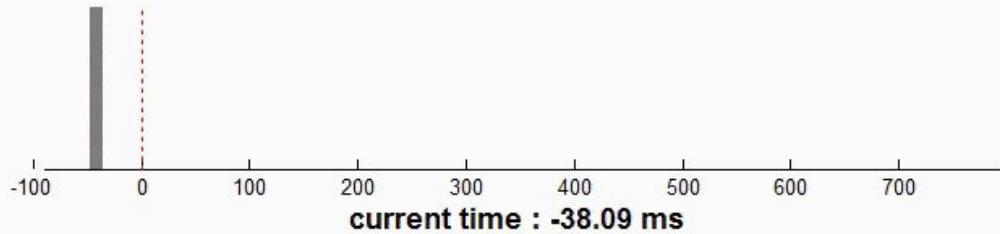


EEG contains rich topographic information from which you can distinguish mental states



EEG contains rich topographic information from which you can distinguish mental states





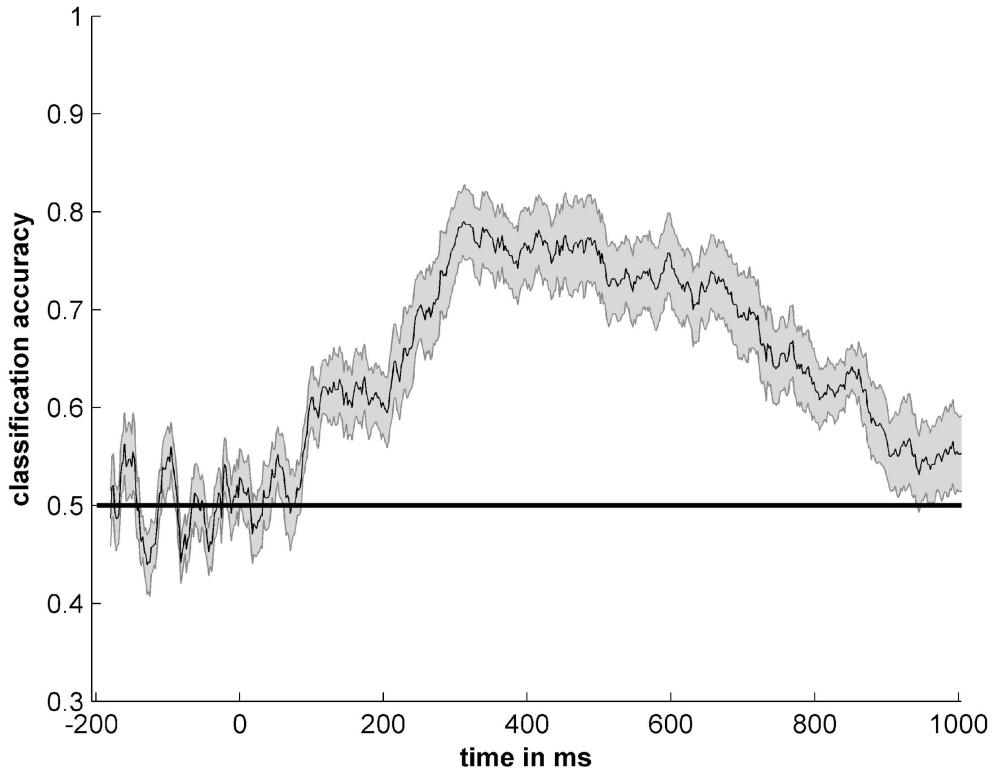
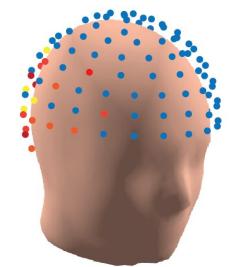
bodie
s

face
s

place
s

object
s

Object familiarity decoding from EEG activity patterns



unfamiliar

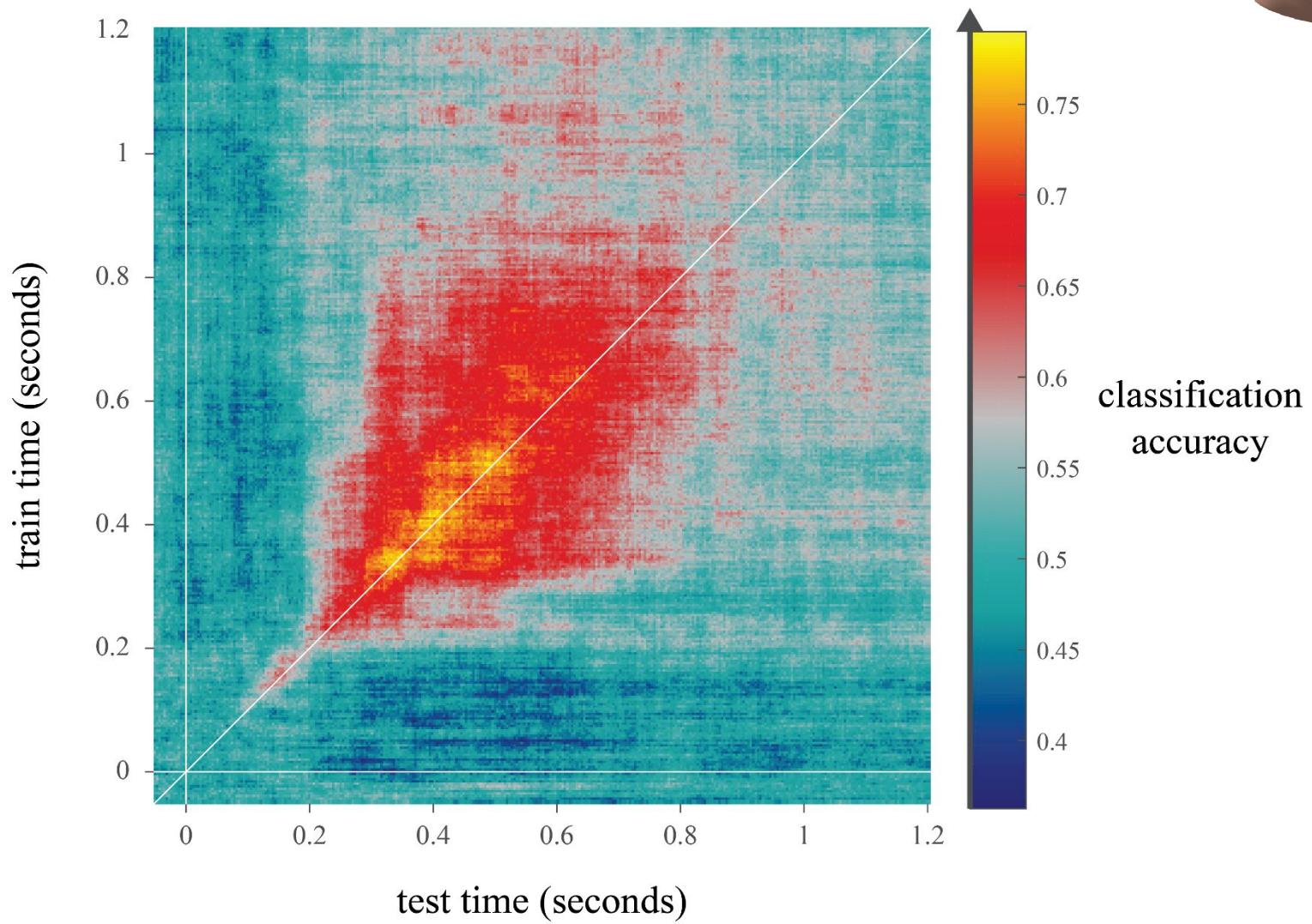
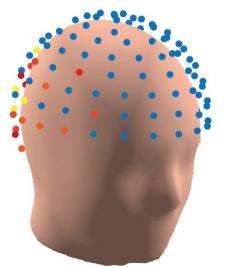


familiar

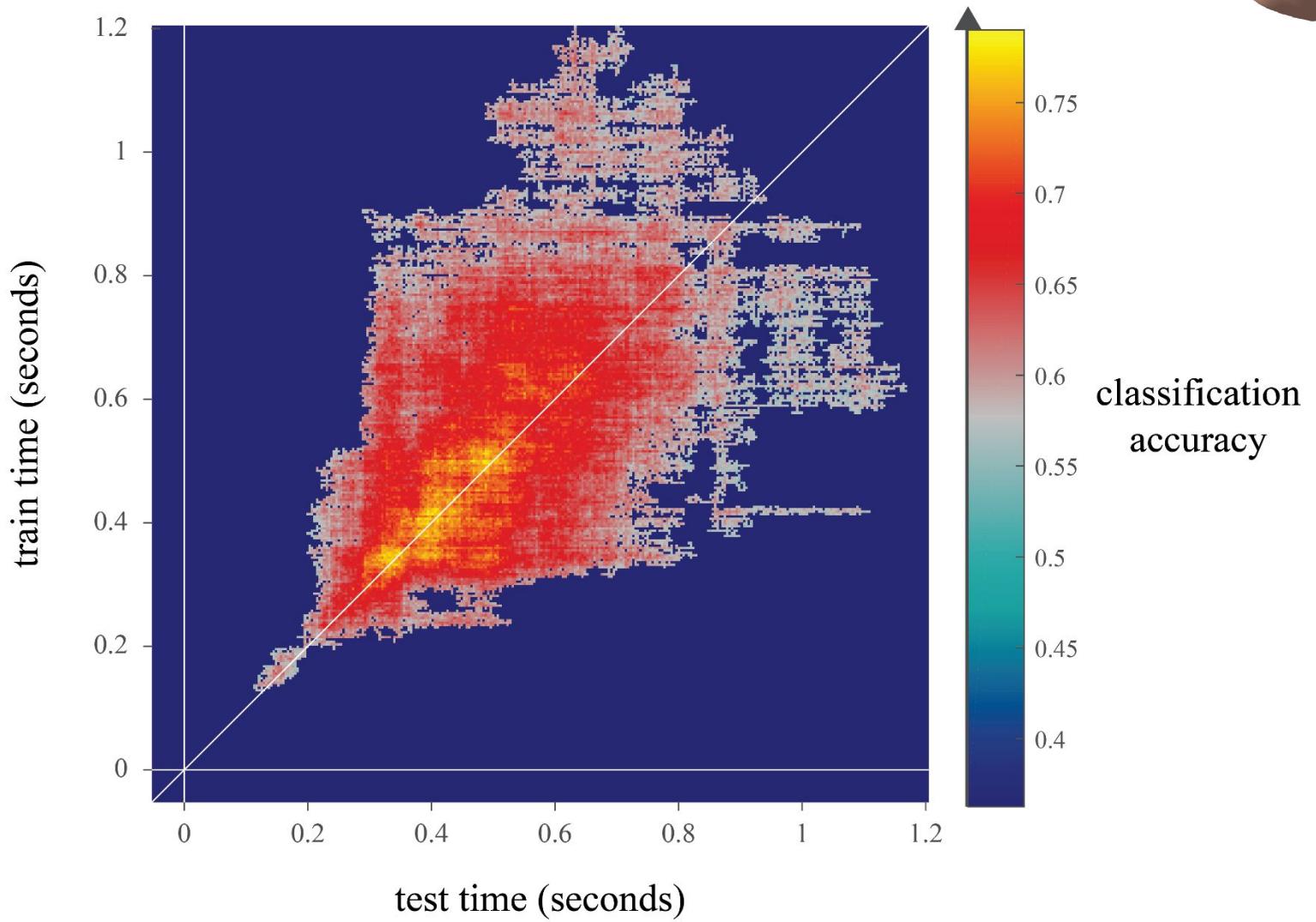
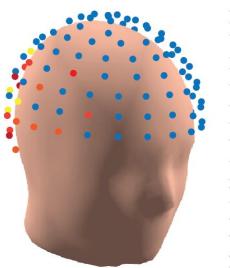


significant
above-chance
decoding

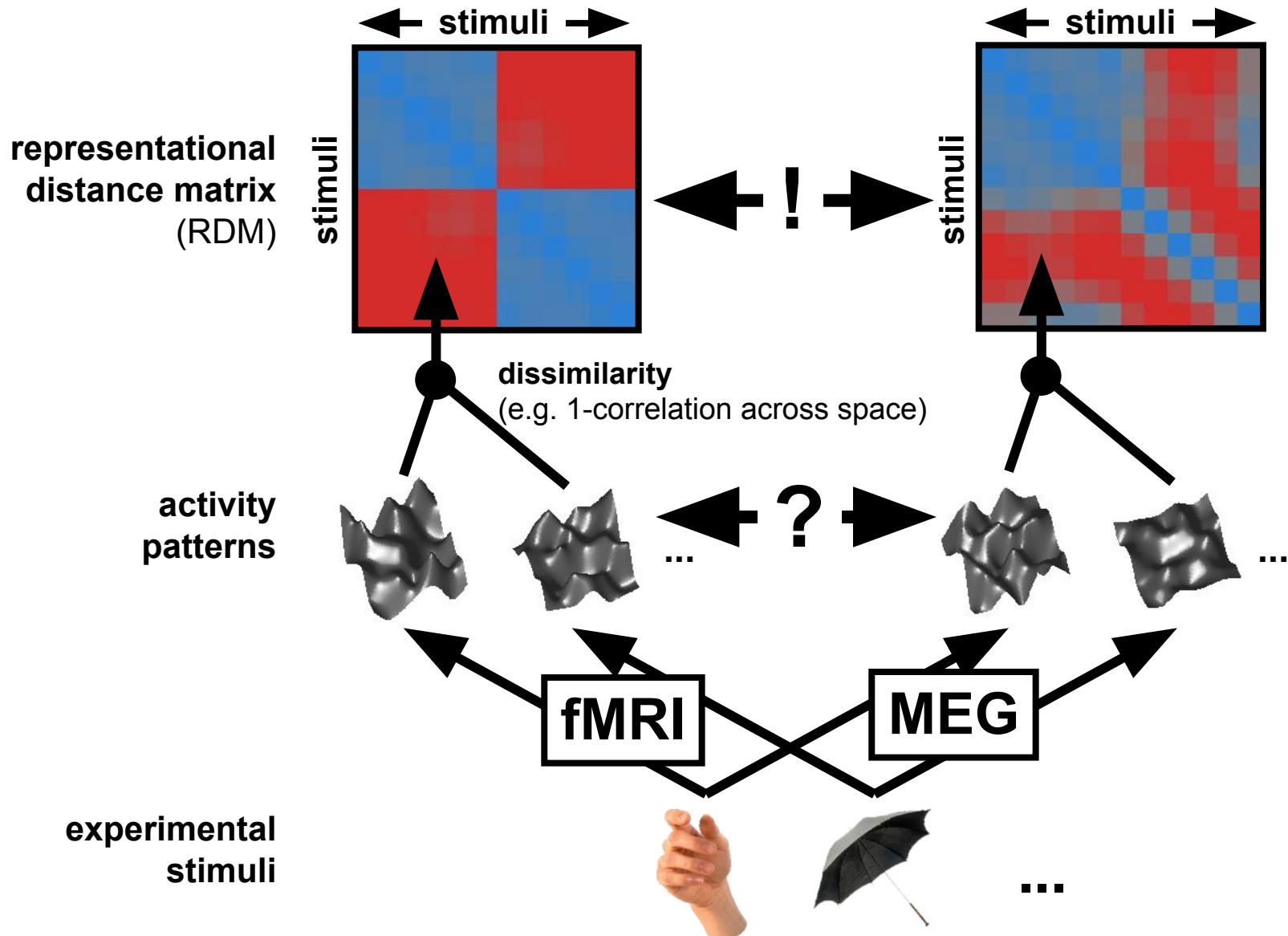
Object familiarity decoding from EEG activity patterns



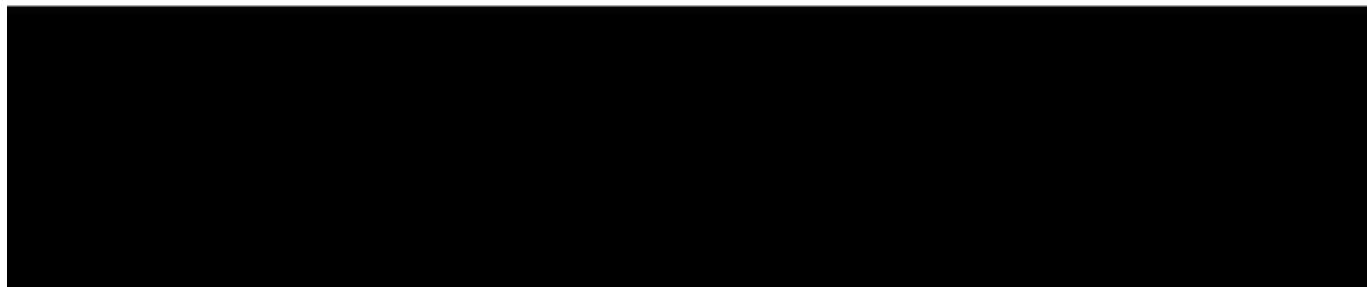
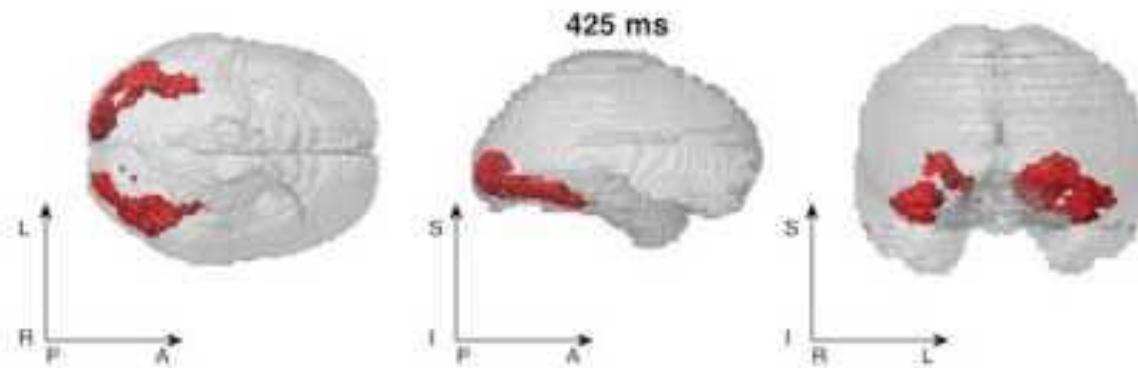
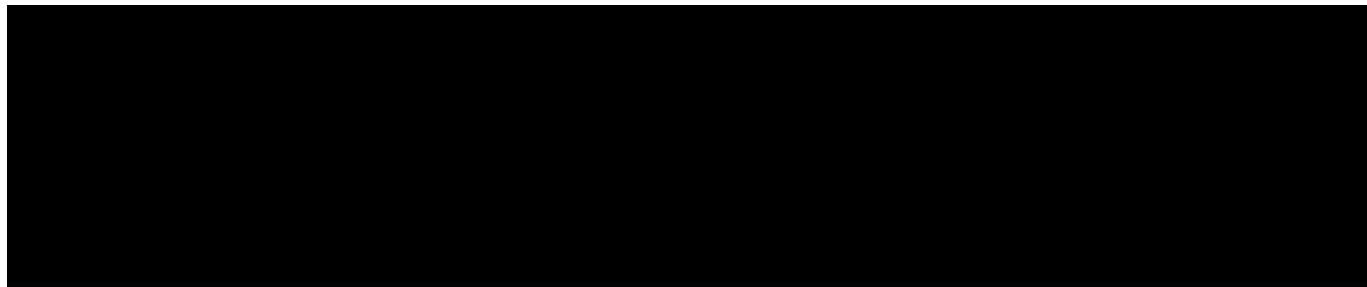
Object familiarity decoding from EEG activity patterns



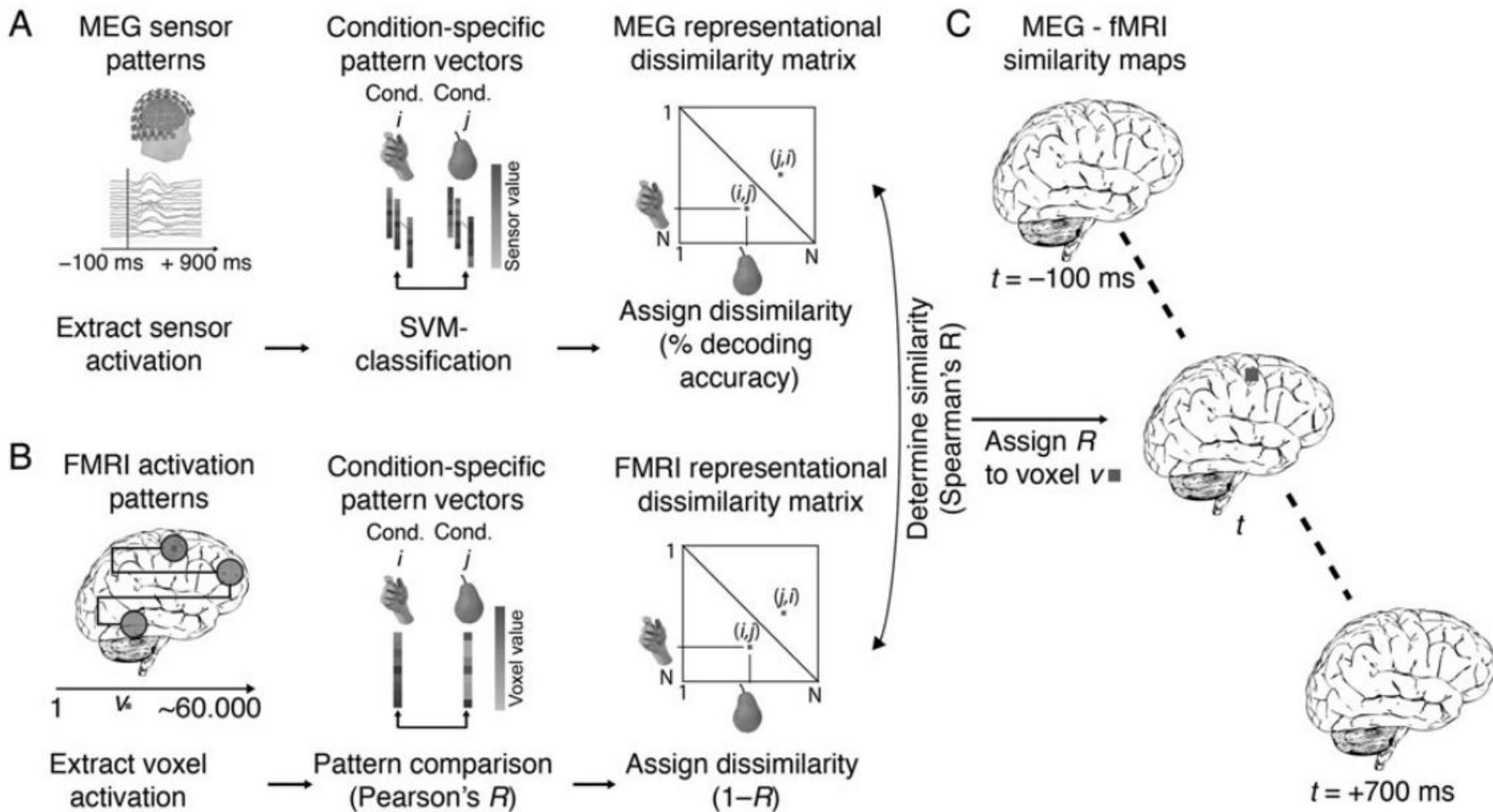
Comparing RDMs between measurement modalities



Similarity based fusion of M/EEG and fMRI



Similarity based fusion of M/EEG and fMRI



The spatio-temporal dynamics of personally meaningful objects



fusion for time-point: 417.97
[$p < 0.050$, corr. (TFCE)]

personally meaningful



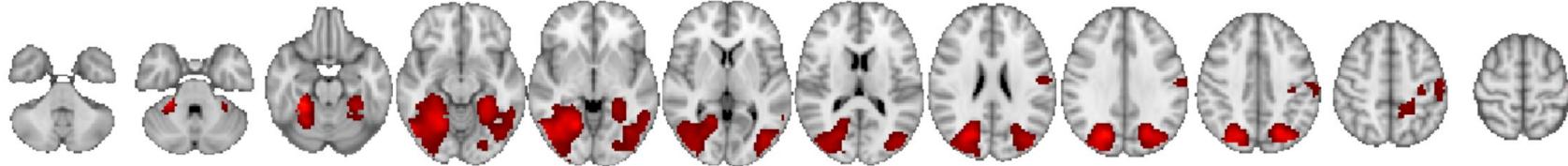
unfamiliar



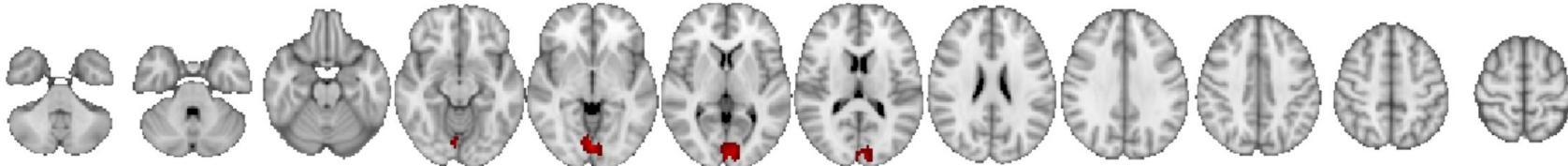
The spatio-temporal dynamics of personally meaningful objects

Spatio-temporal fusion (117ms)

  personally meaningful



  unfamiliar



Key insights

Representational geometries encapsulate the *content* and *format* of brain representations.

Representational geometries can be characterised by representational dissimilarity matrices (RDMs).

RDMs can easily be compared between brains and models, individuals and species, different brain regions, different measurement modalities, and brain and behaviour.

We can statistically compare multiple computational/theoretical models and assess whether they fully explain the measured brain response patterns.

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A Matlab toolbox for representational similarity analysis Edit

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iancharest committed on GitHub Merge pull request #8 from rsagroup/issue7-comparison-bar-bug ... Latest commit 445e8c6 on Mar 14

+rsa	Merge pull request #8 from rsagroup/issue7-comparison-bar-bug	a month ago
Demos	pure date change on files	10 months ago
Documentation	pure date change on files	10 months ago
Recipes	pure date change on files	10 months ago
.gitignore	Small changes to fitting OLS	2 years ago
README.md	Initial commit	2 years ago

README.md

rsatoolbox

A Matlab toolbox for representational similarity analysis