


Introduction to representational similarity analysis

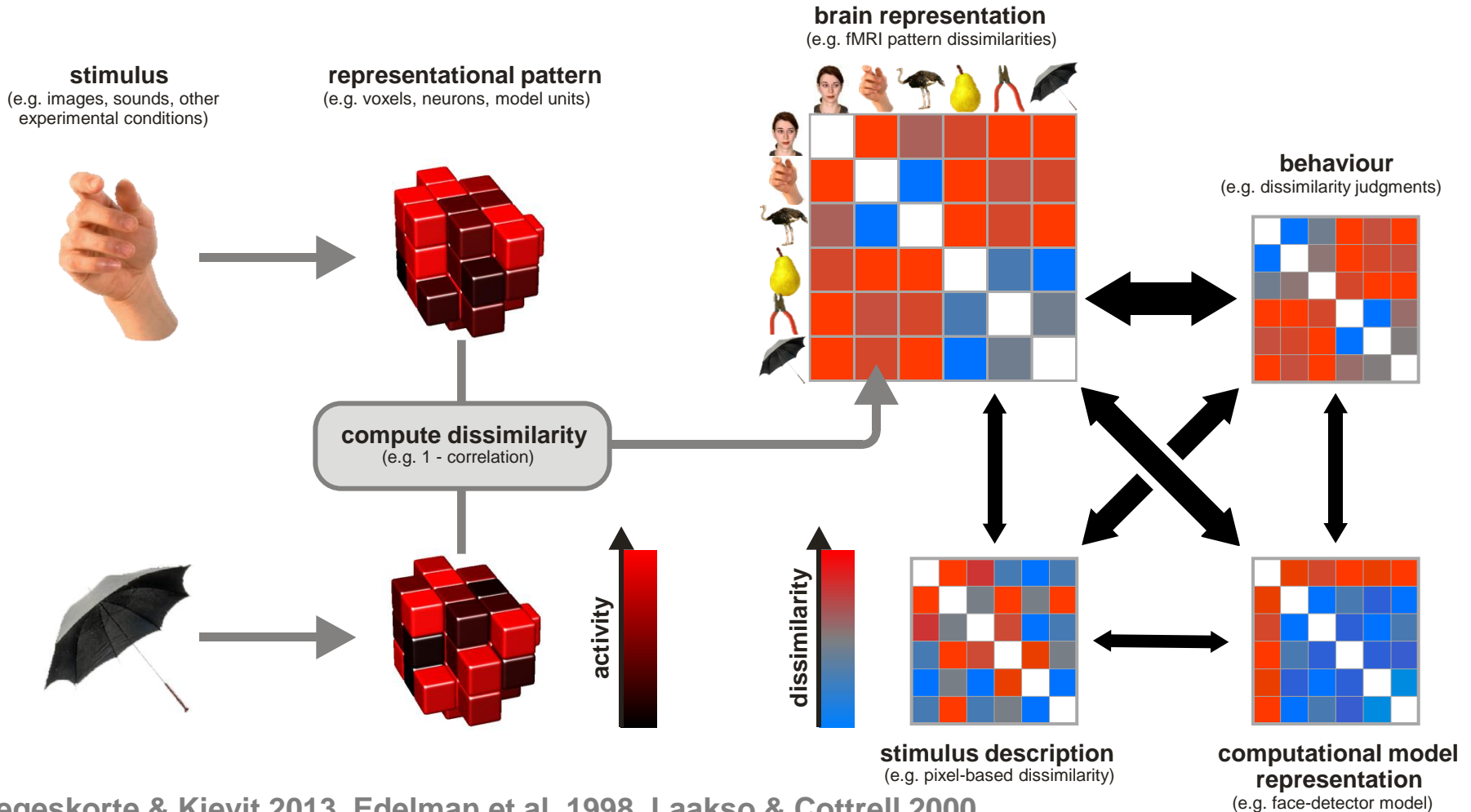
A large flock of sheep in a field, with several sheep in the foreground looking towards the camera. The sheep are of various breeds, including some with thick, curly wool and others that are more slender. The background is a soft-focus field of more sheep.

Nikolaus Kriegeskorte

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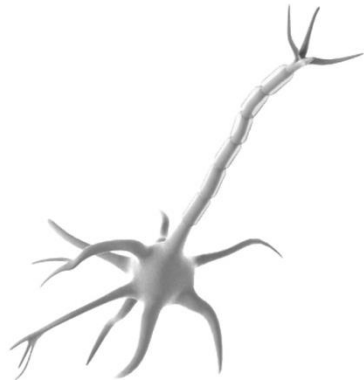
Cambridge RSA Workshop, 16-17 February 2015

Representational similarity analysis

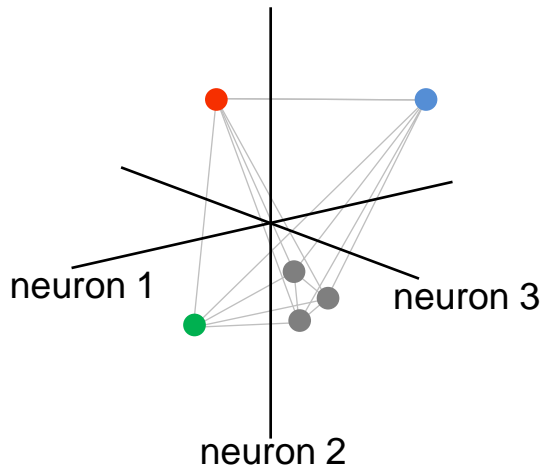
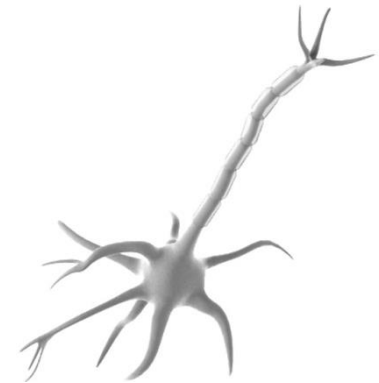


Kriegeskorte & Kievit 2013, Edelman et al. 1998, Laakso & Cottrell 2000, Op de Beeck et al. 2001, Haxby et al. 2001, Aguirre 2007, Kriegeskorte et al. 2008, Diedrichsen et al. 2011

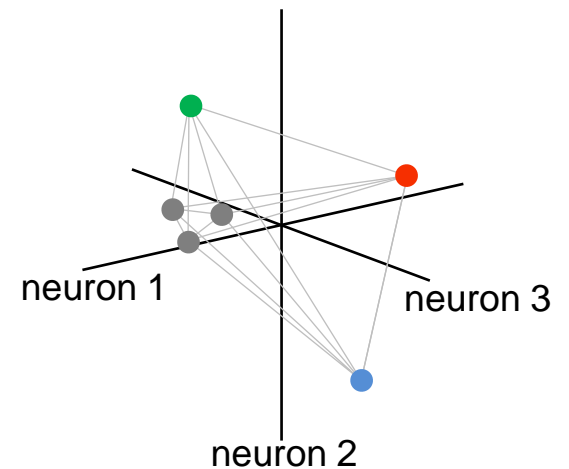
Why investigate representational geometries?



downstream neurons
can read out the same
information from these
codes

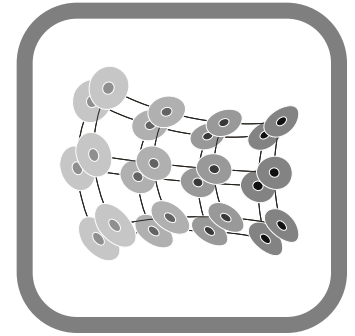
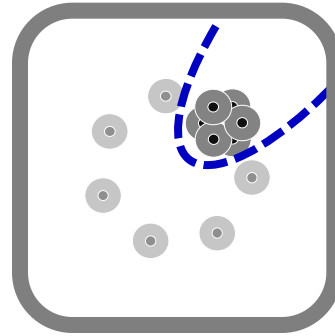
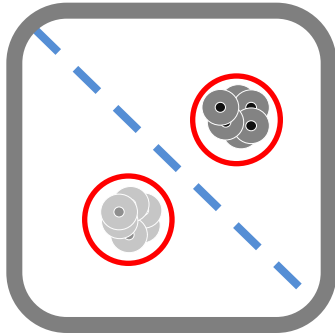
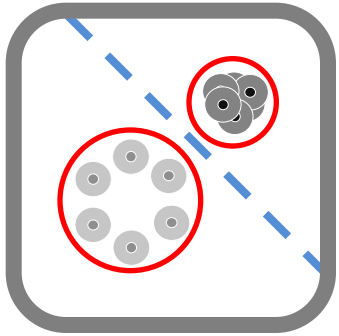
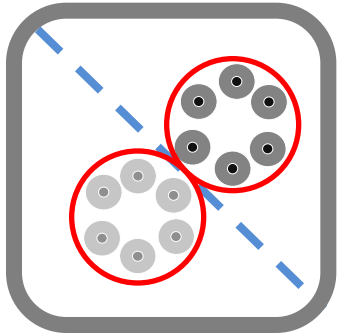
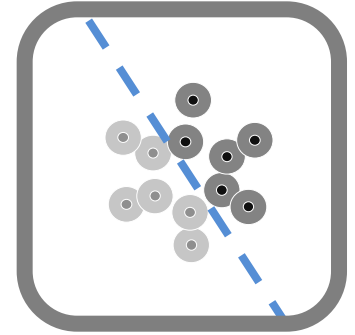
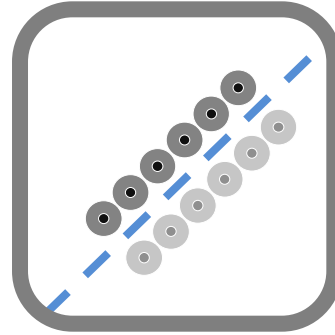
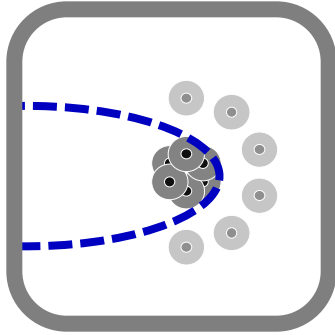
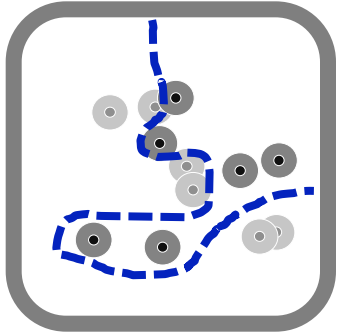


same geometry
→ same information
→ same format

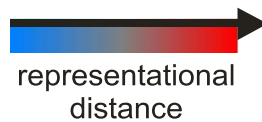
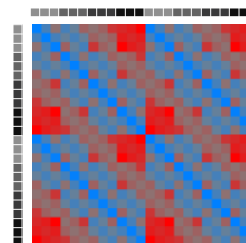
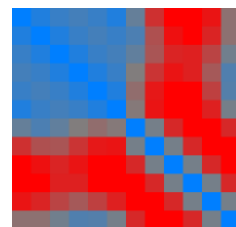
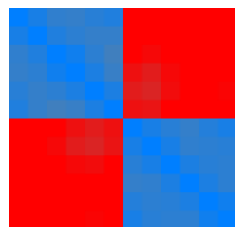
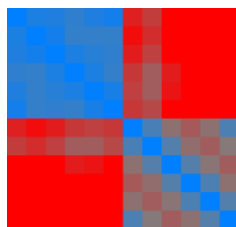
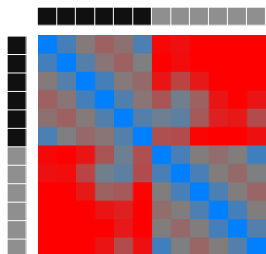
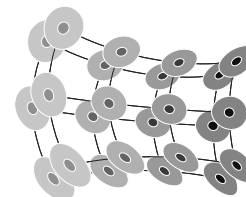
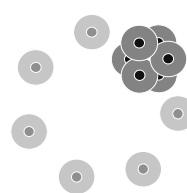
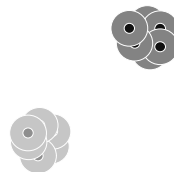
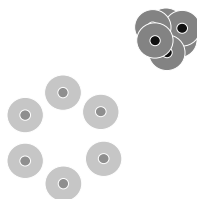
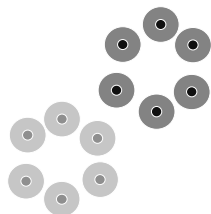
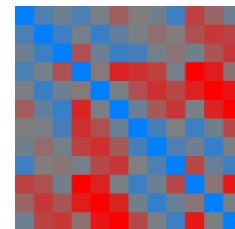
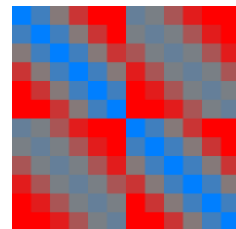
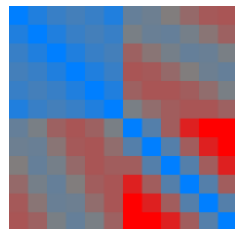
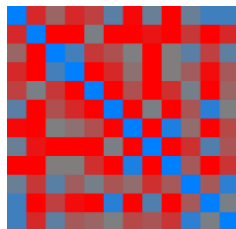
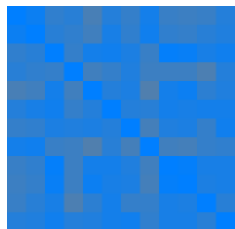
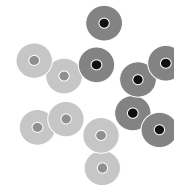
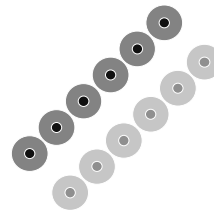
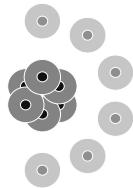
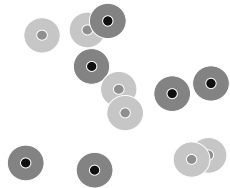


Representational geometry

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

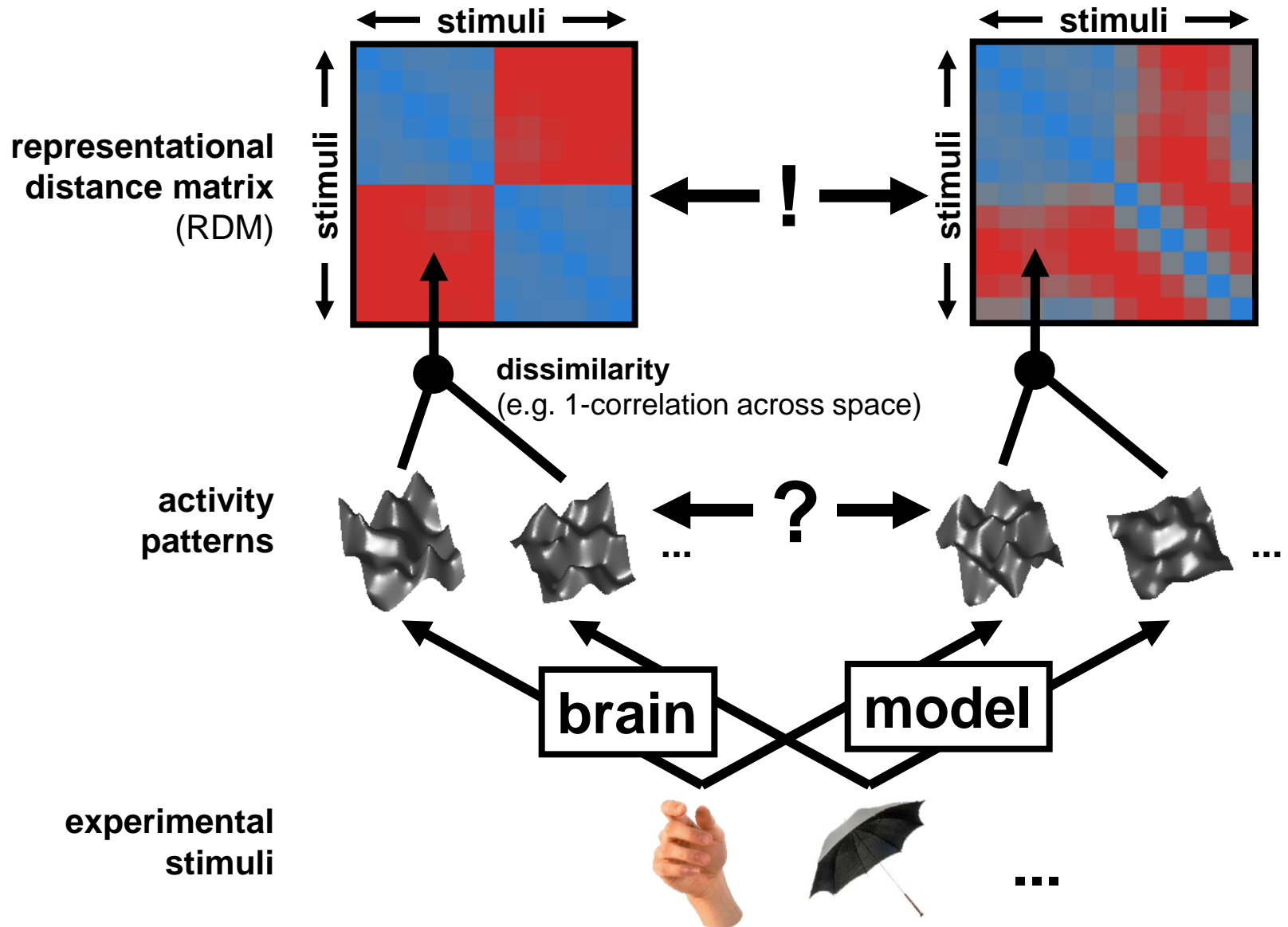


category information
...for linear readout
...for nonlinear readout
...inherently categorical

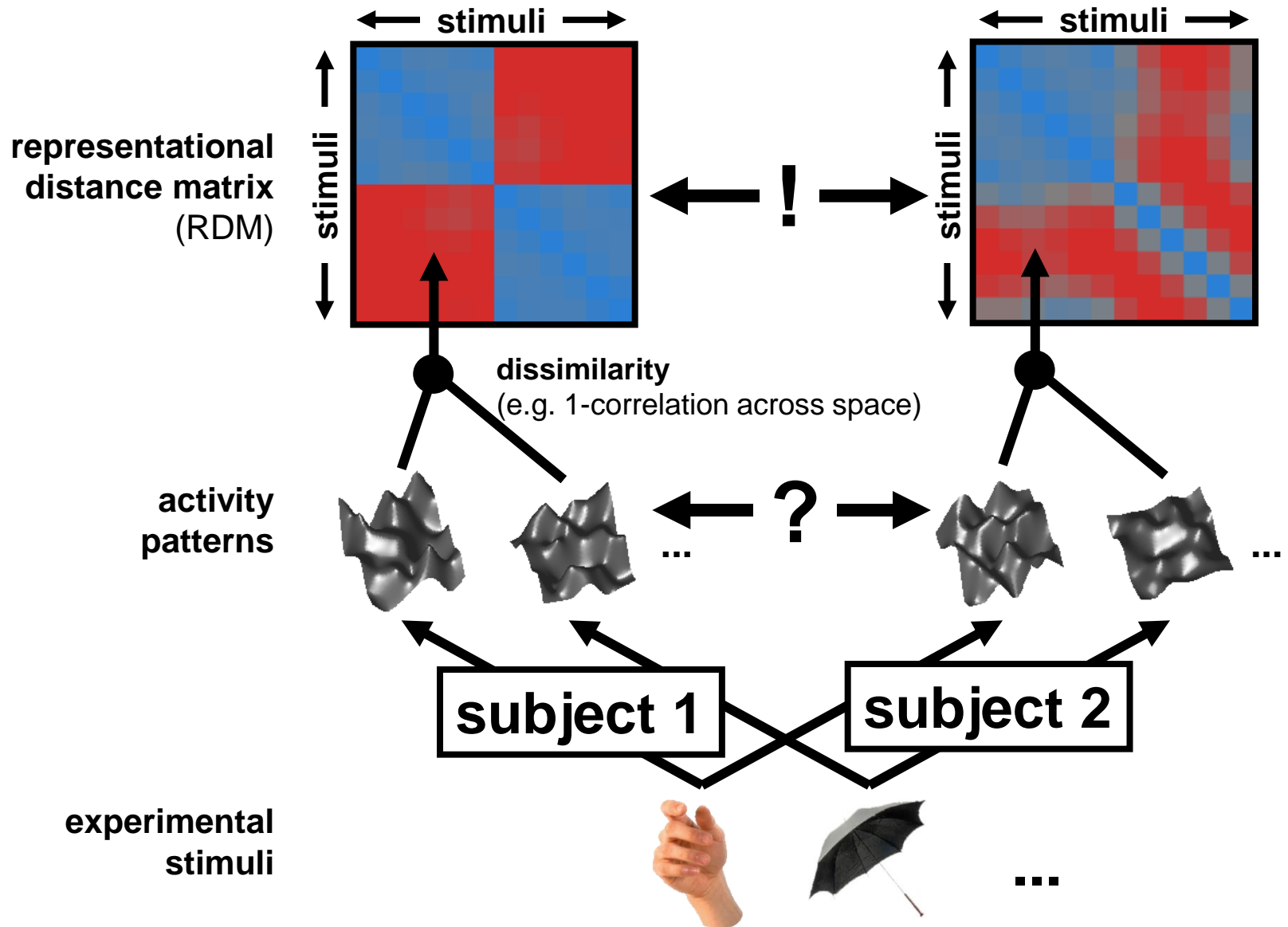


Kriegeskorte & Kievit 2013

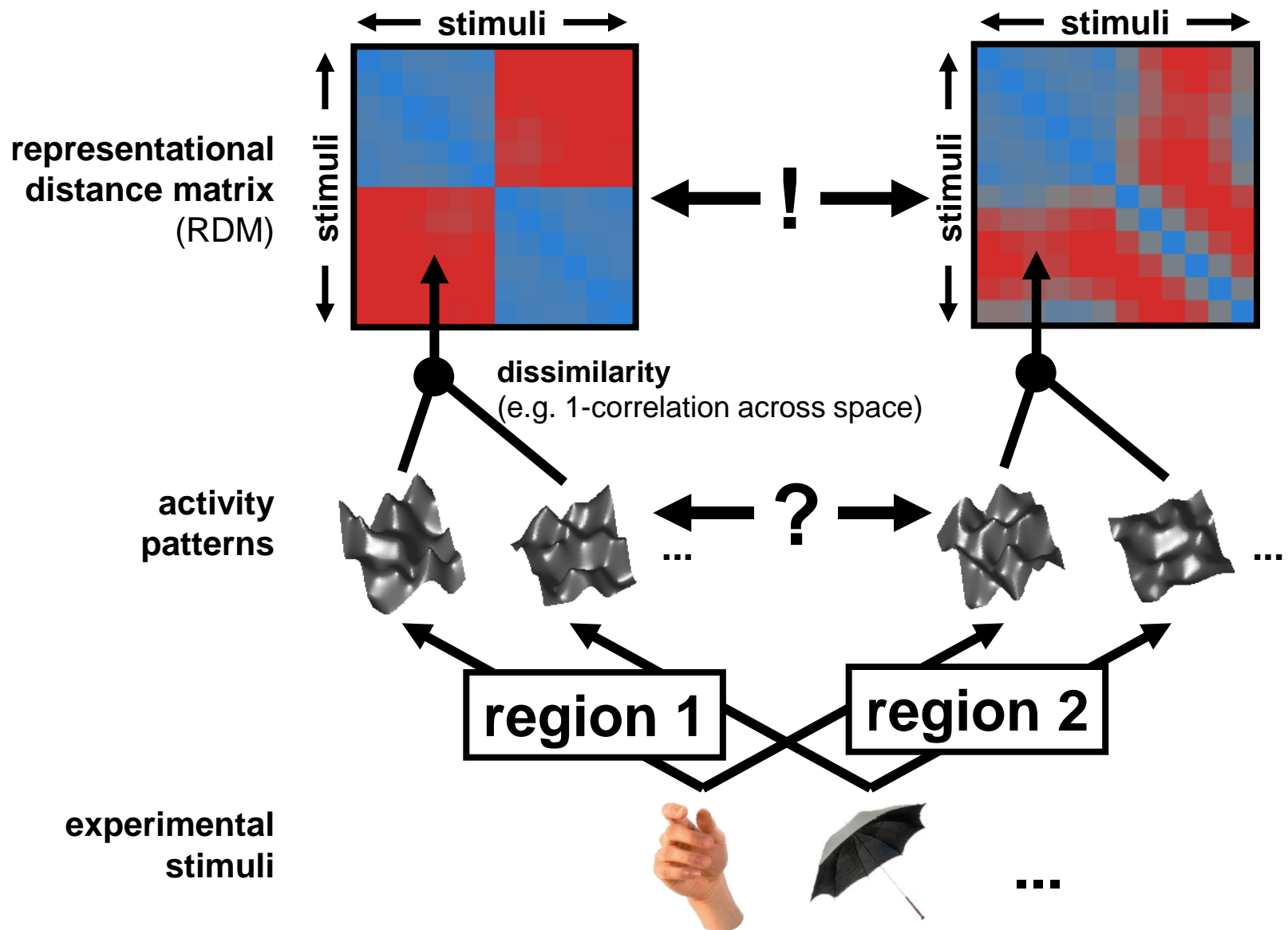
The representational similarity trick



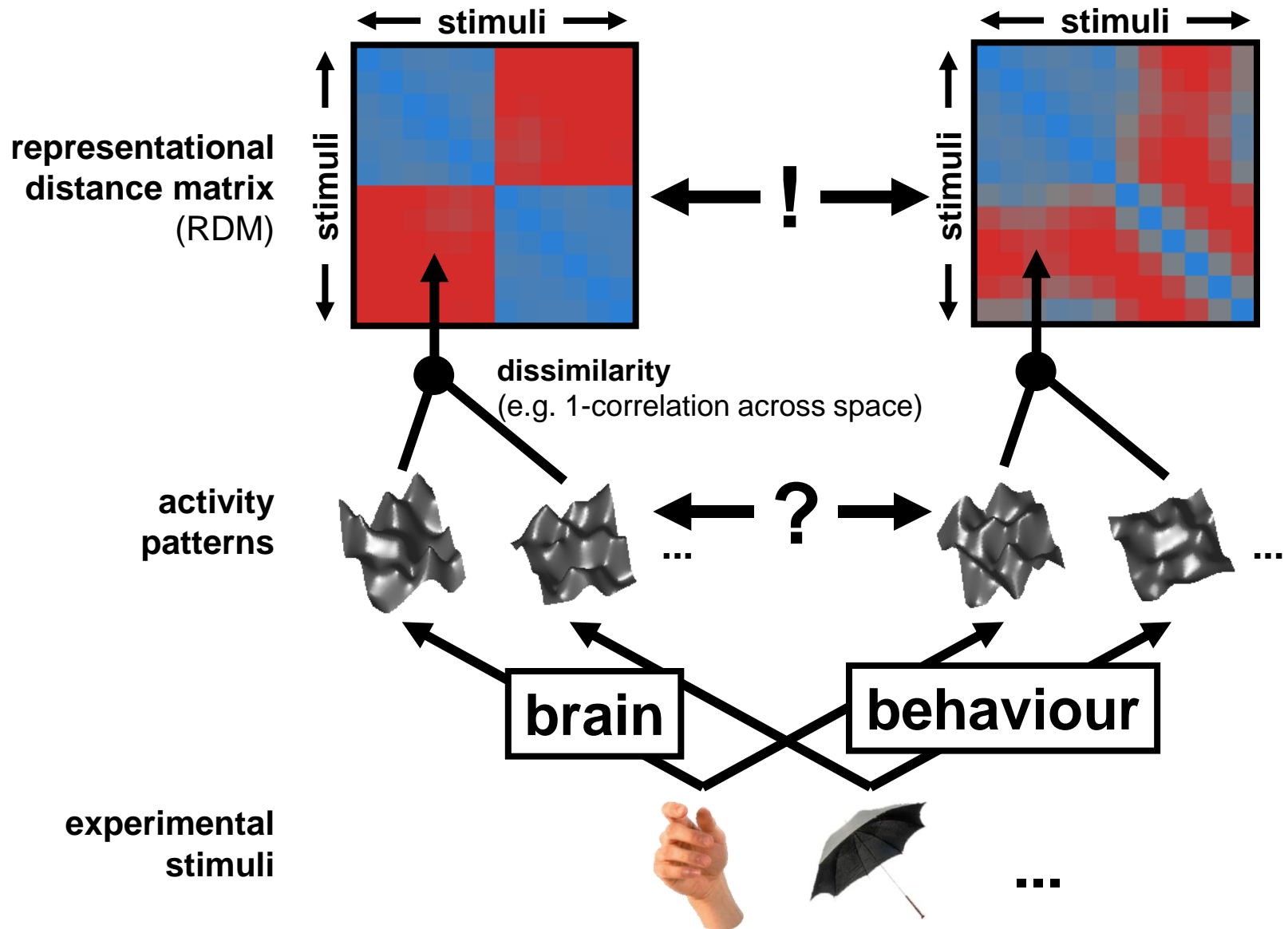
The representational similarity trick



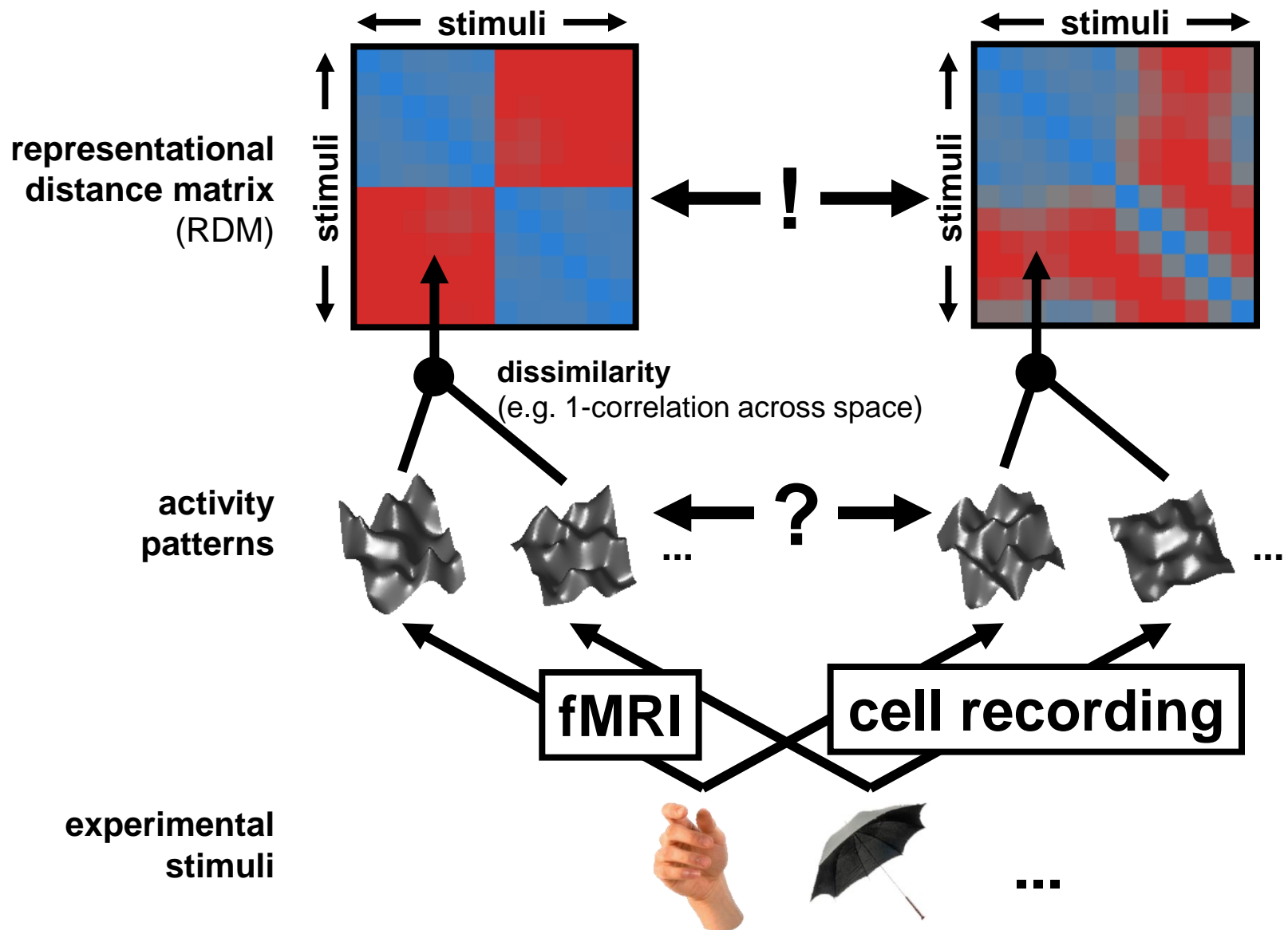
The representational similarity trick



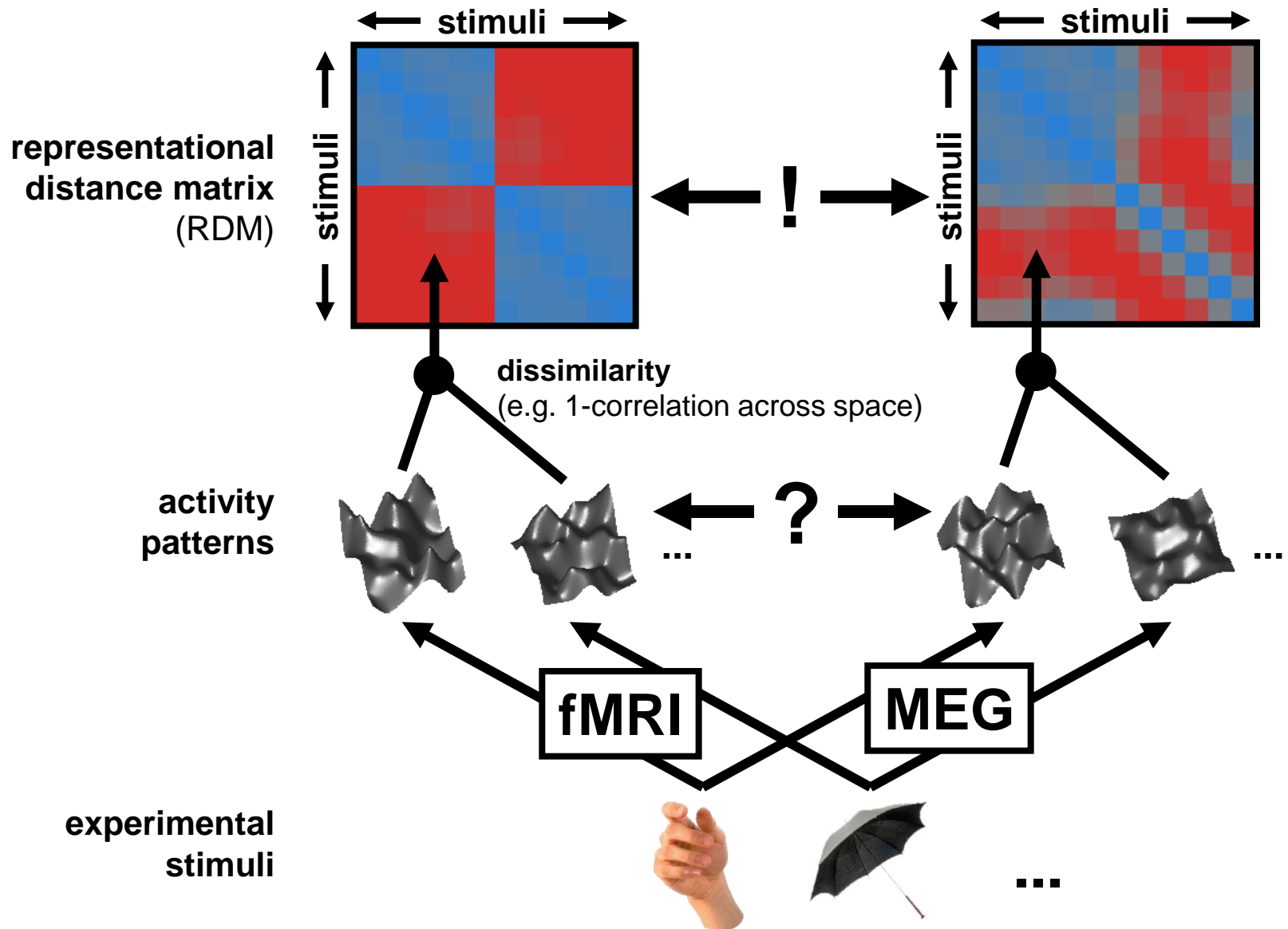
The representational similarity trick



The representational similarity trick

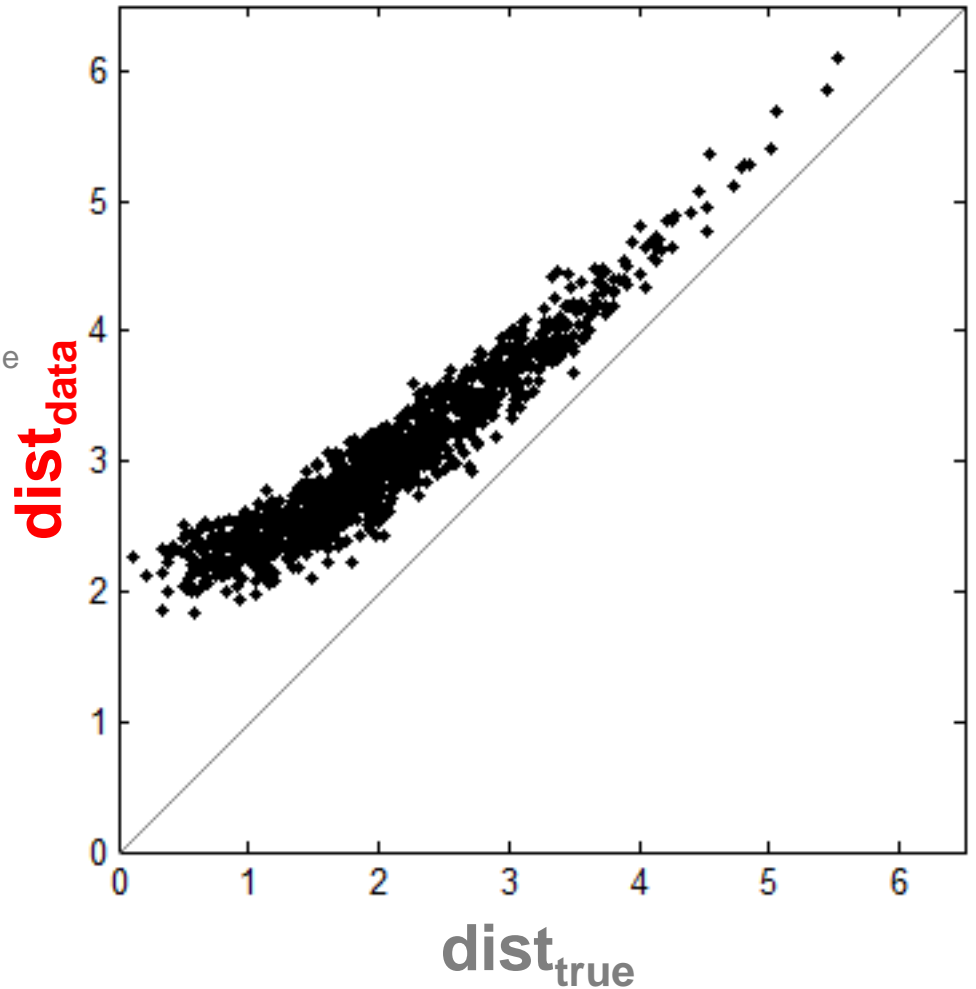
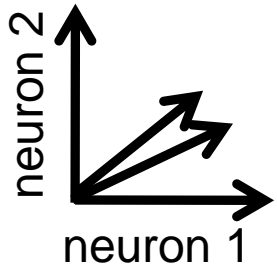
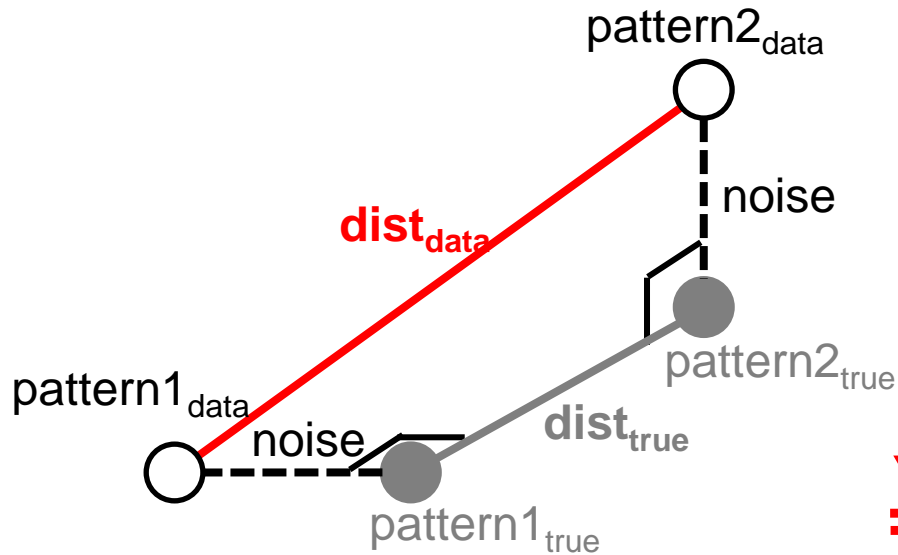


The representational similarity trick



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

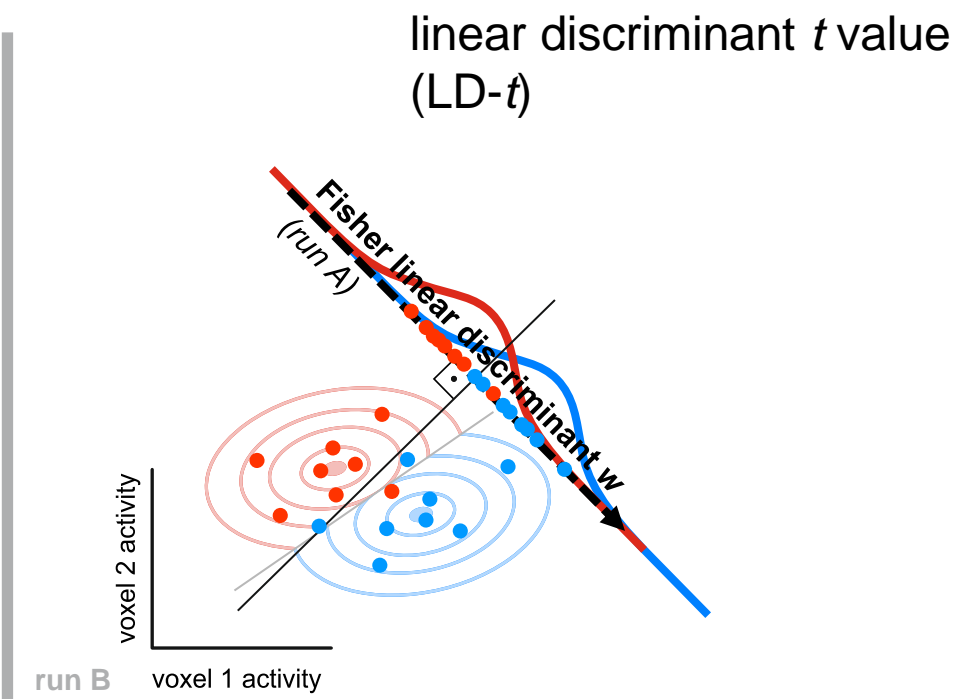
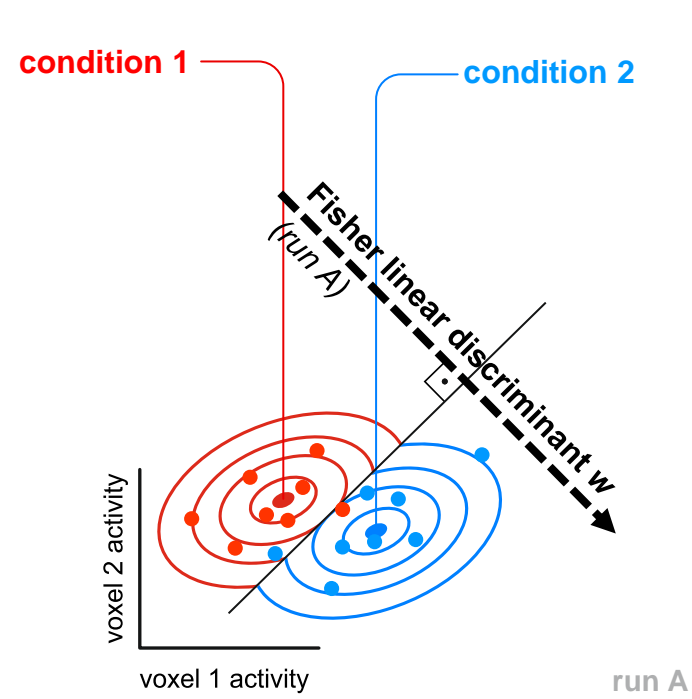
Distance estimates are positively biased



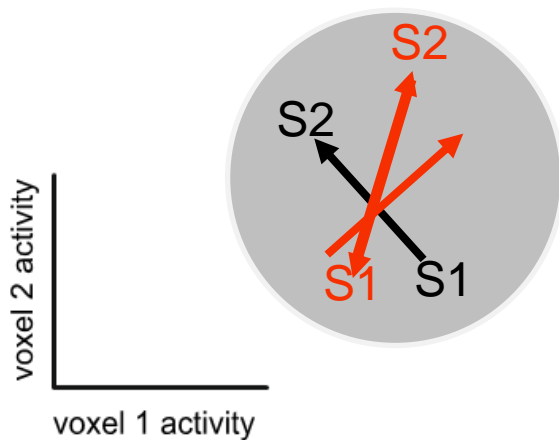
How are representational distances related to decoding accuracies?



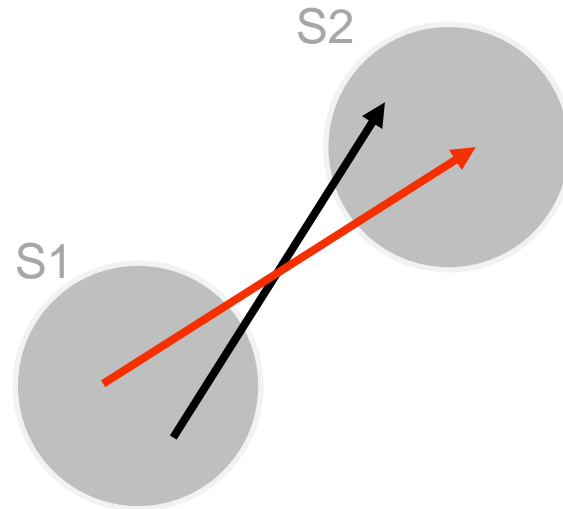
compute **decoding accuracy**?
or just do a *t* test?



Unbiased distance estimates through crossvalidation



true distance = 0
average angle = 90°
 $E(\text{inner product}) = 0$



true distance = 1
average angle $< 90^\circ$
 $E(\text{inner product}) > 0$

data set A
data set B

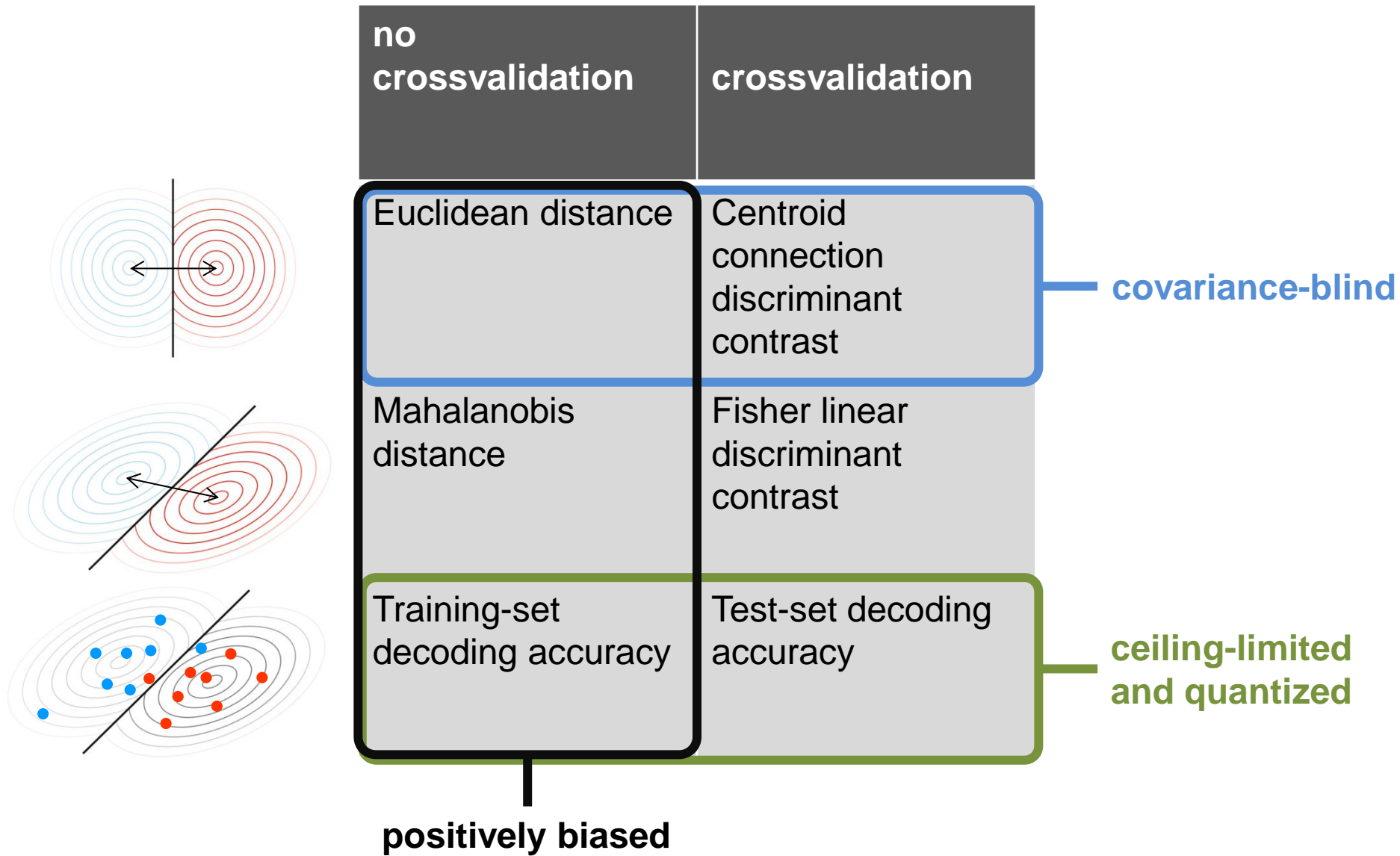
The linear discriminant contrast (LDC) is a crossvalidated variant of the Mahalanobis distance

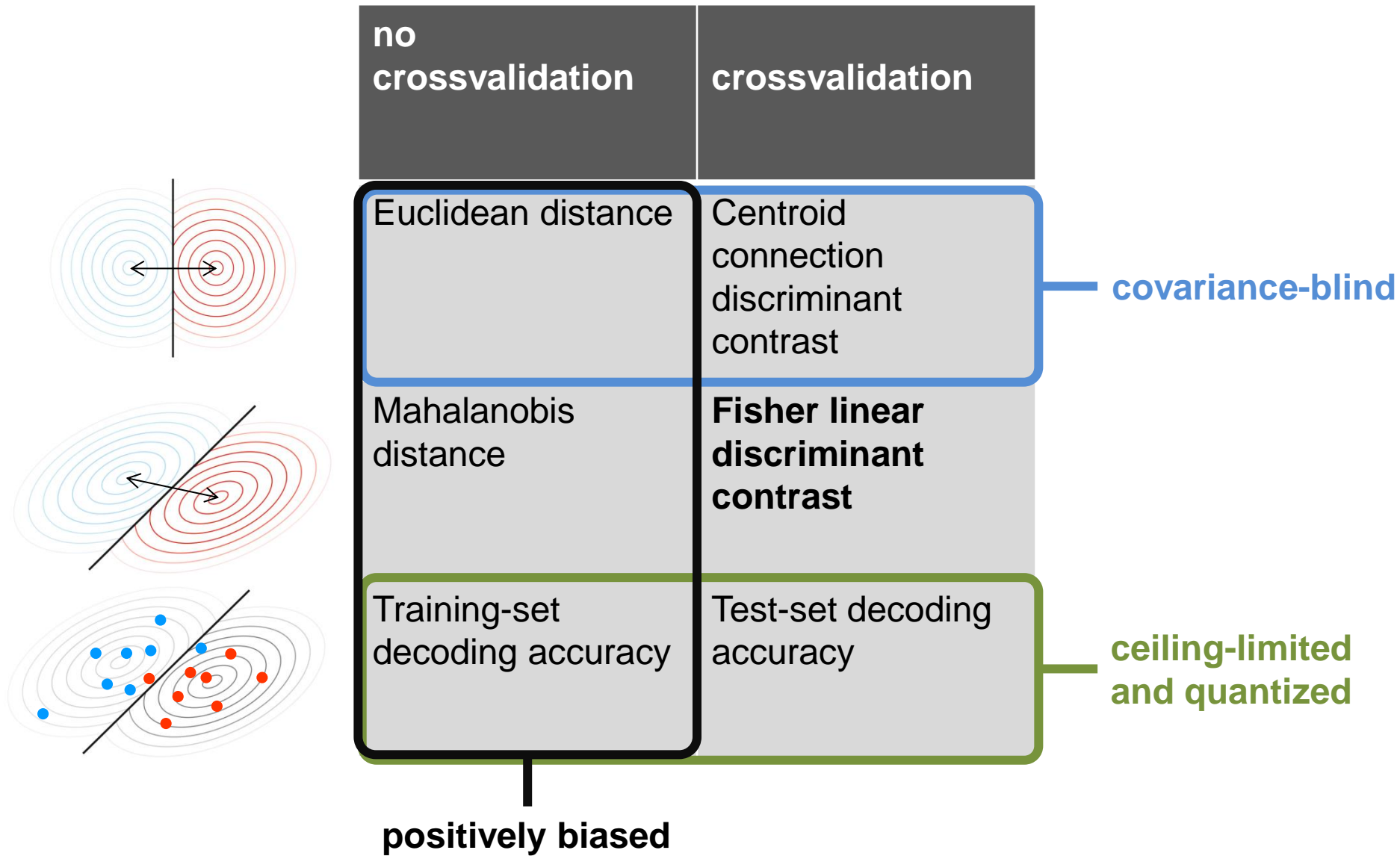
Mahalanobis distance (single data set)

$$\text{training set } (\mathbf{p2} - \mathbf{p1})^T \Sigma^{-1} (\mathbf{p2} - \mathbf{p1})$$

Fisher linear discriminant contrast (crossvalidated)

$$\text{training set } (\mathbf{p2} - \mathbf{p1})^T \Sigma^{-1} (\mathbf{p2}' - \mathbf{p1}') \text{ test set}$$





The best of both worlds...

Multivariate statistics

multinormal distribution

continuous measures of
multivariate separation

inference relying on
multinormality

Machine learning

pattern classifiers

crossvalidation

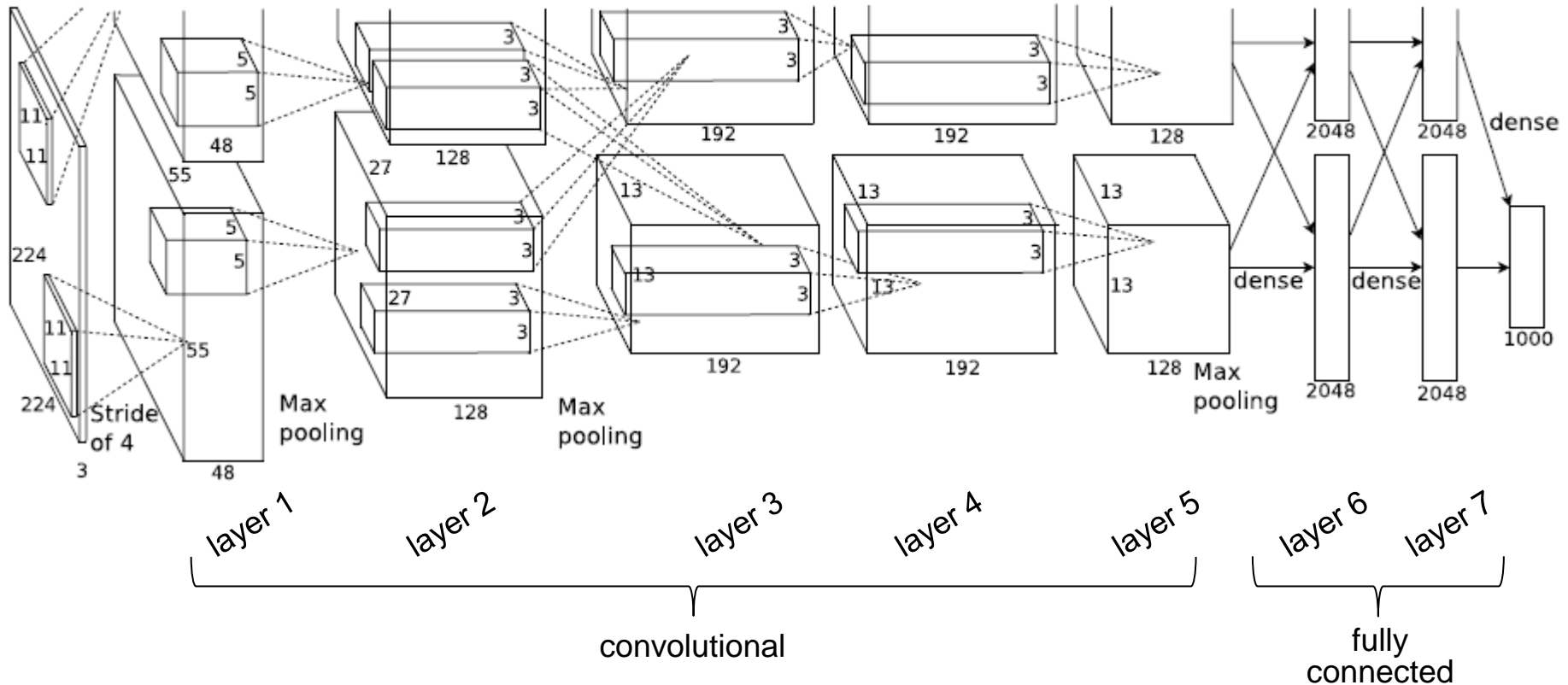
nonparametric inference
procedures

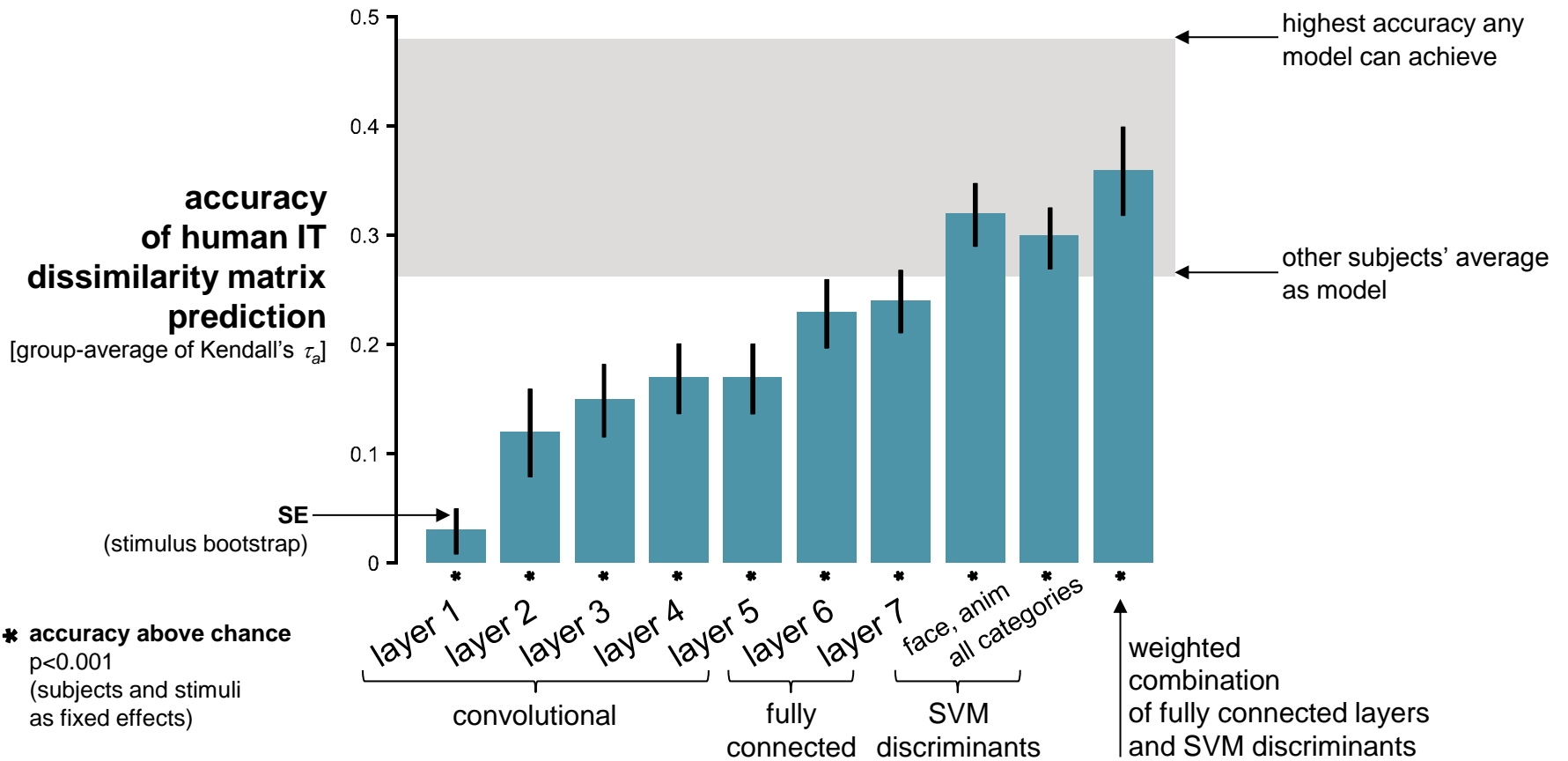
How can we test computational models?

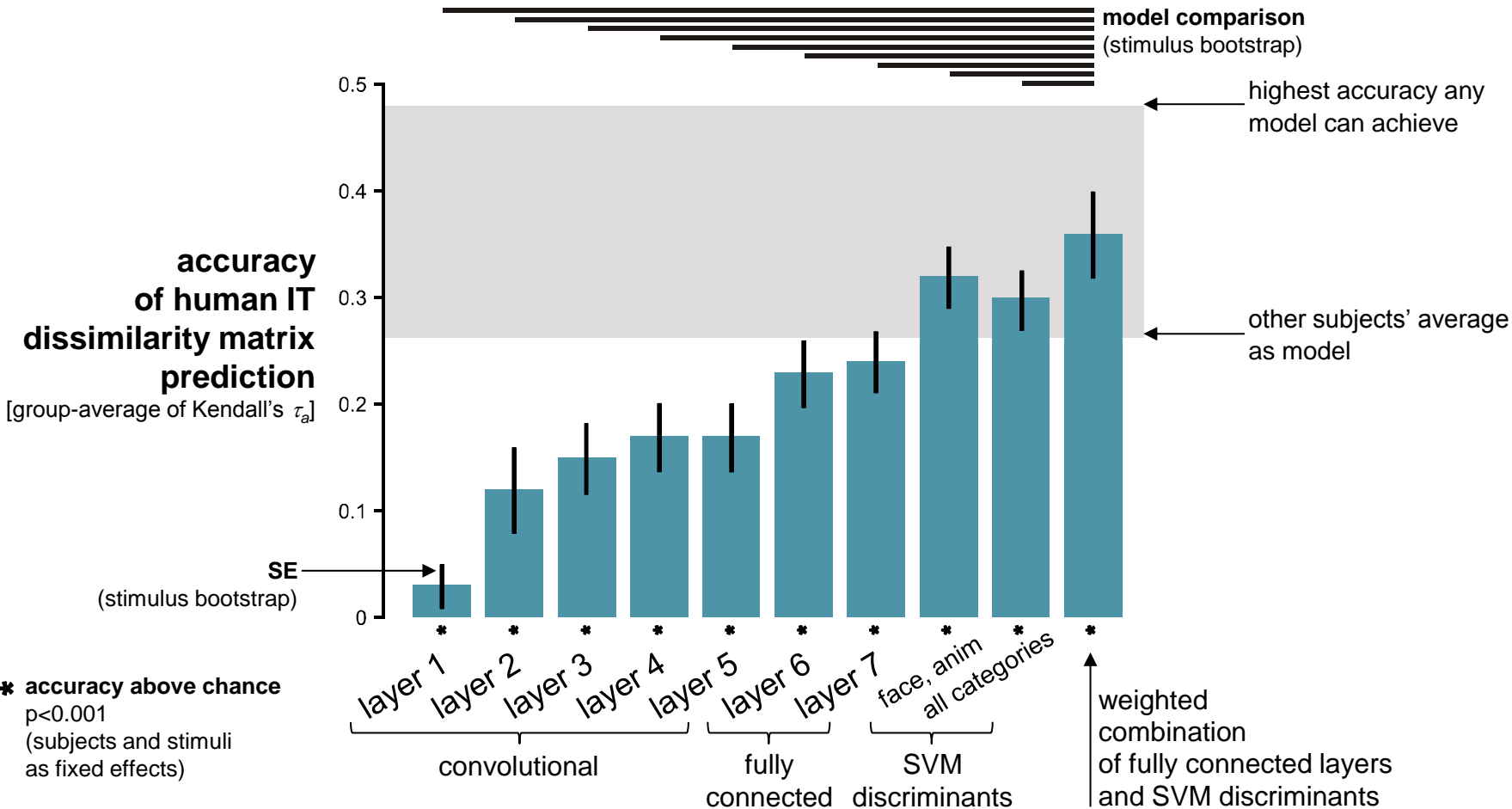
Deep convolutional neural network

- 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?







Key insights

- A1 Representational geometries encapsulate the *content* and *format* of brain representations.
- A2 Representational geometries can be characterised by representational dissimilarity matrices (RDMs).
- A3 RDMs can easily be compared between brains and models, individuals and species, different brain regions, and brain and behaviour.
- A4 We can statistically compare multiple computational models and assess whether they fully explain the measured brain response patterns.