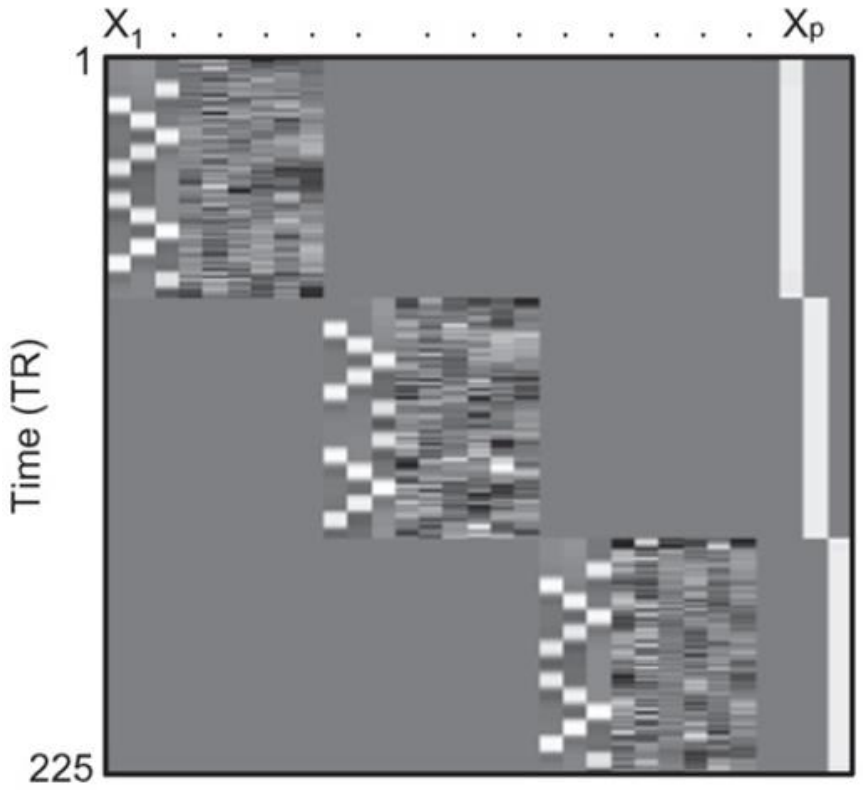
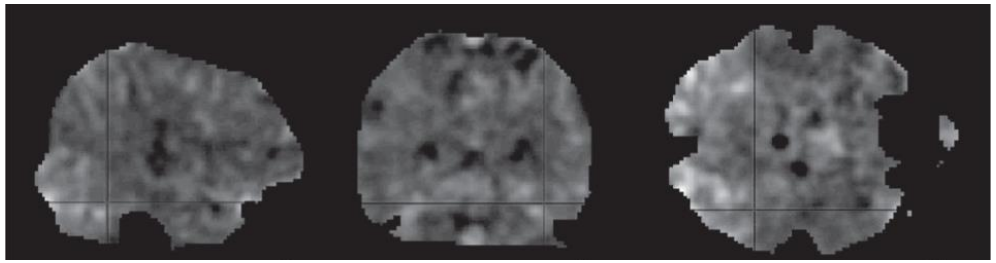
Multivariate analyses in fMRI

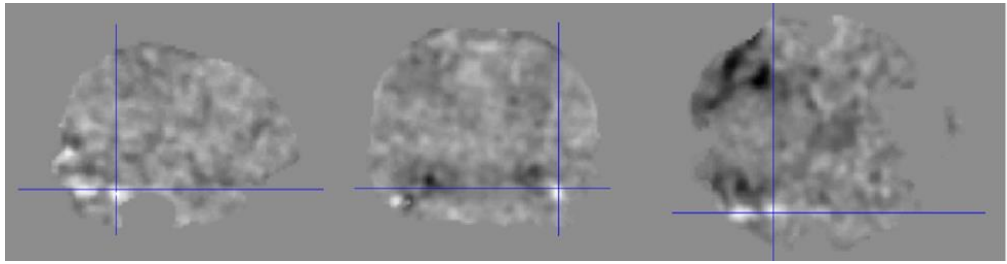
Univariate analyses



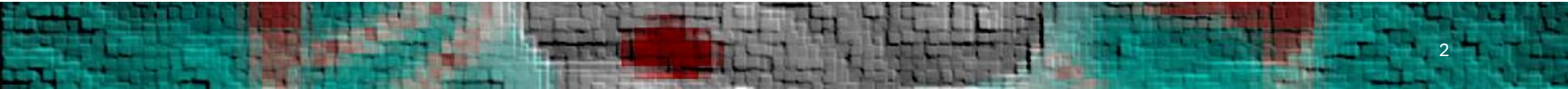
Map of beta values:



Map of contrast values:
(faces-objects)

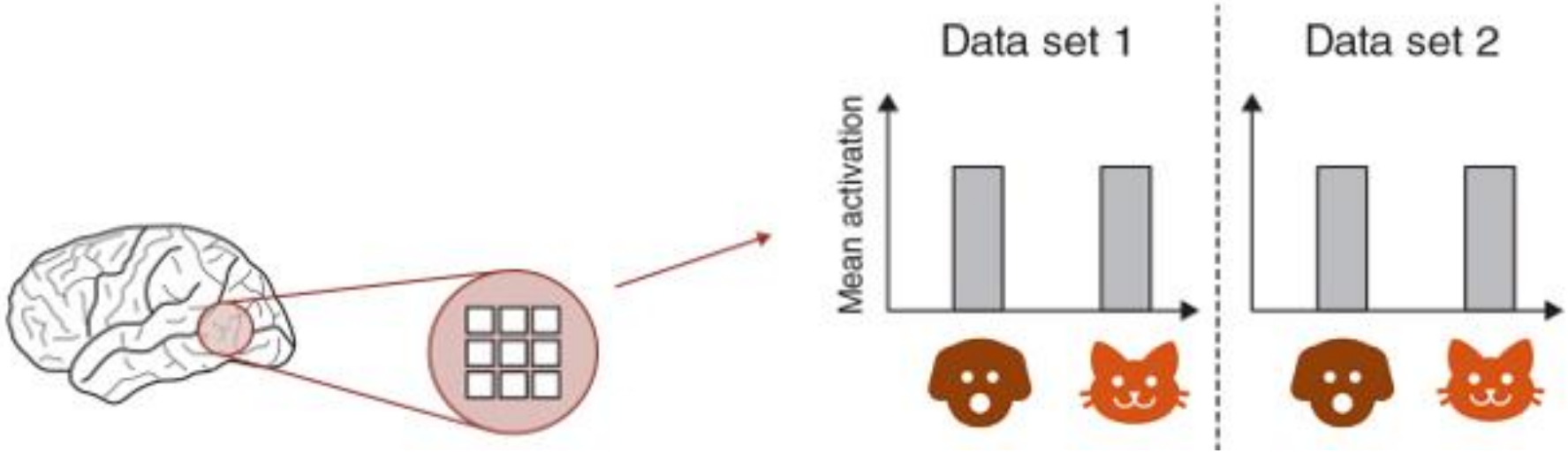


Thresholded contrast:
(on structural scan)



Univariate analyses

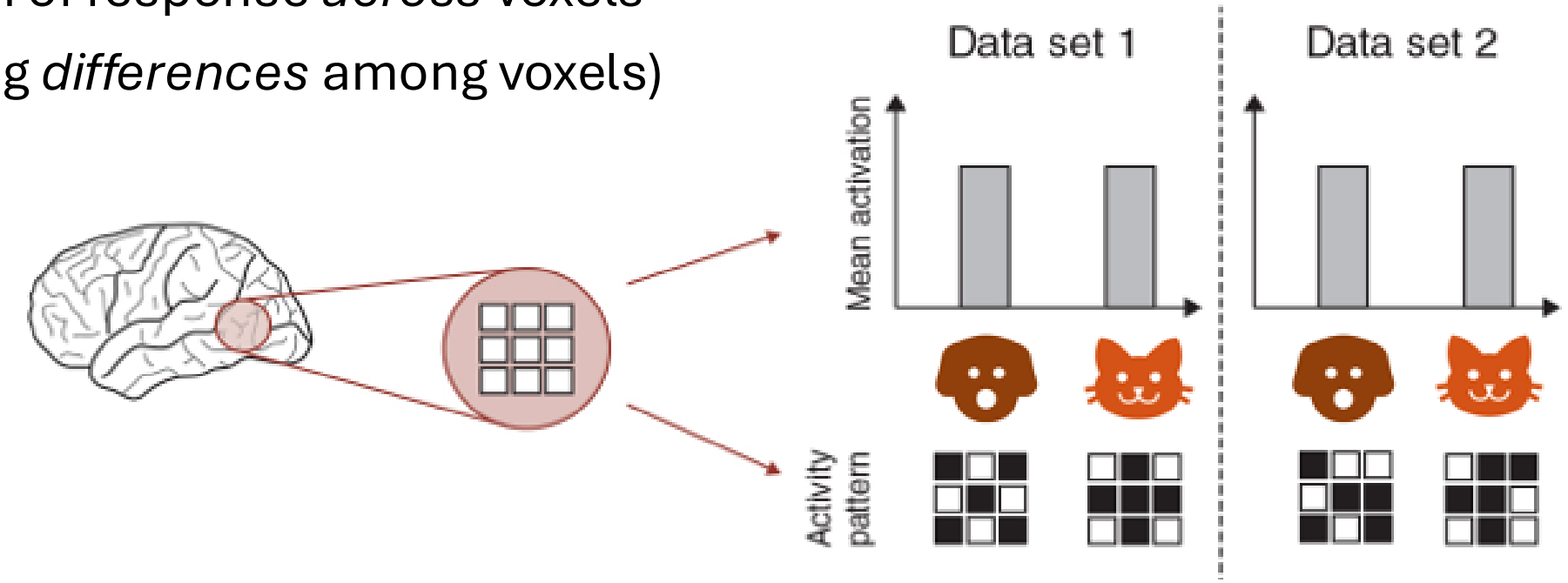
Region of interest: Average of beta values



Multivariate analyses

Pattern of response *across* voxels

(= using *differences* among voxels)



Variety of names:

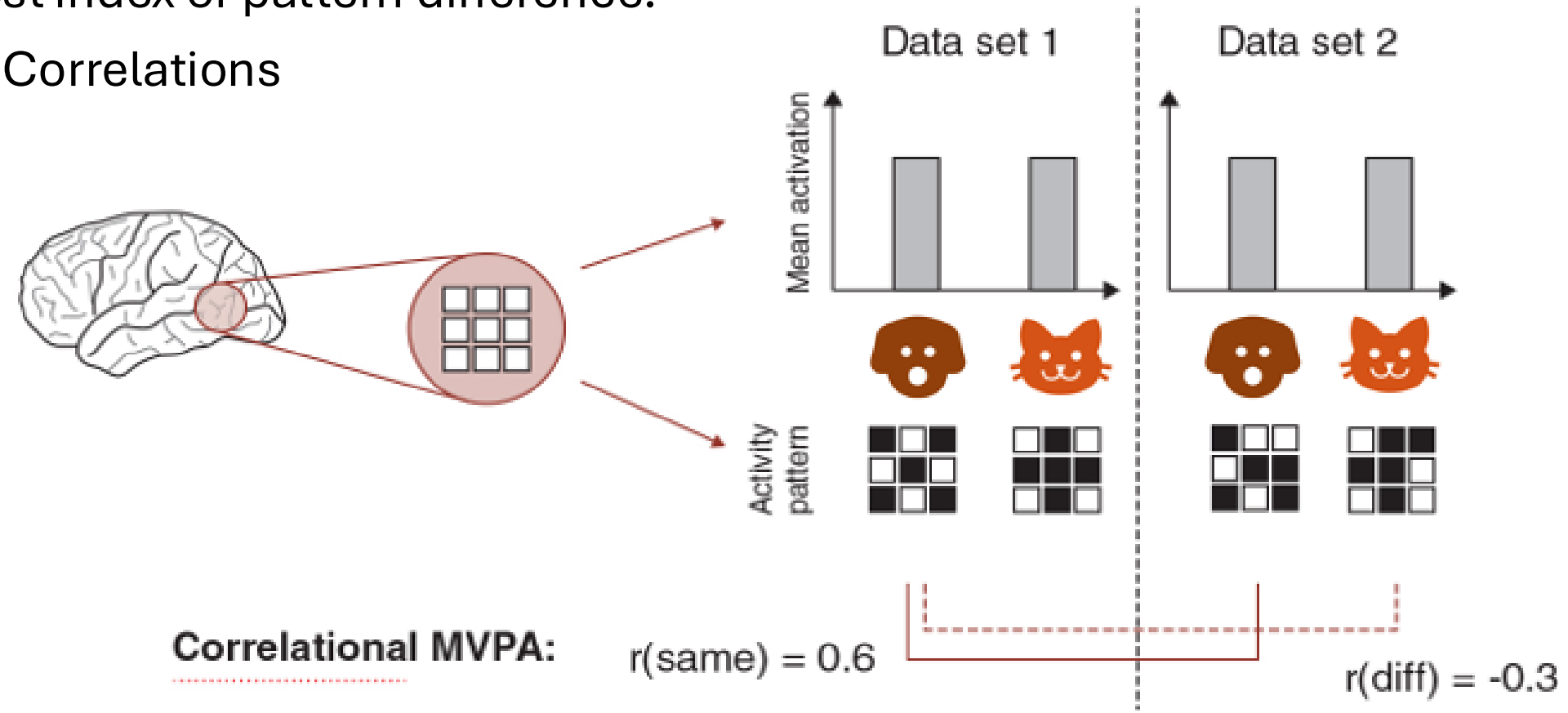
multivariate fMRI, multivoxel pattern analyses (**MVPA**),

brain decoding, brain reading, representational similarity analyses

Multivariate analyses

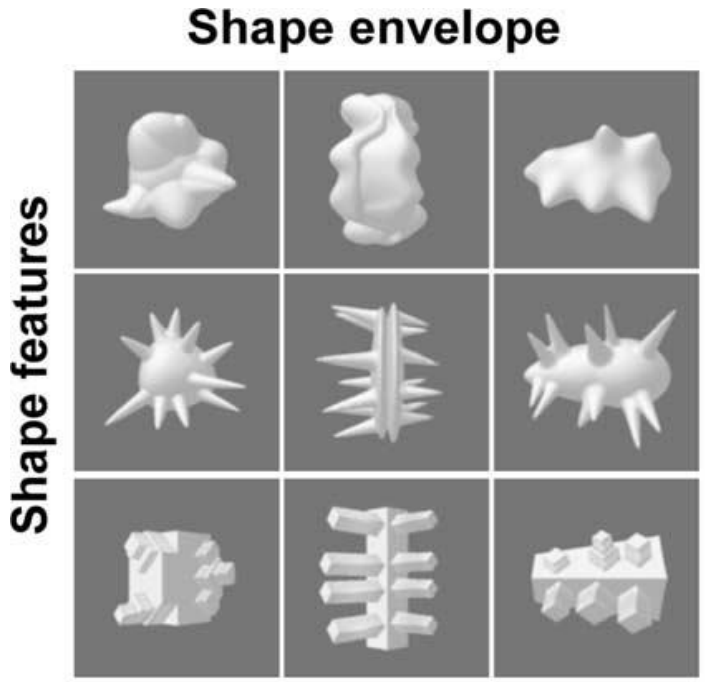
Simplest index of pattern difference:

Correlations

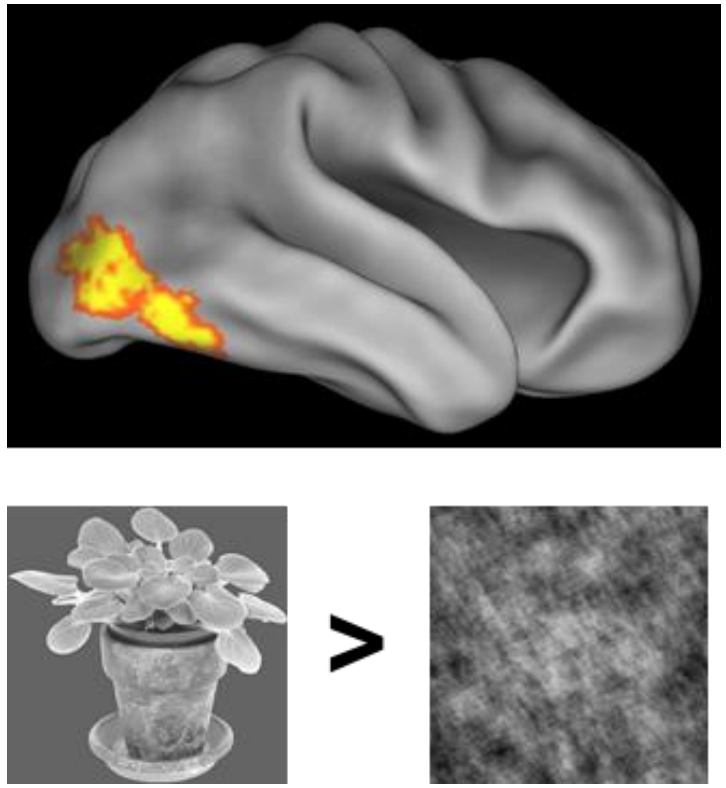


A simple example of MVPA

Shape representation in object-selective cortex



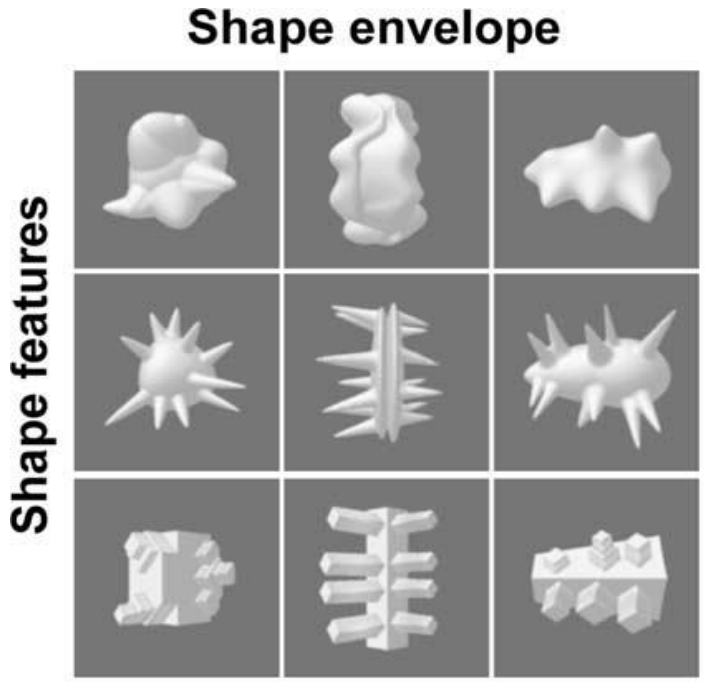
Why MVPA?

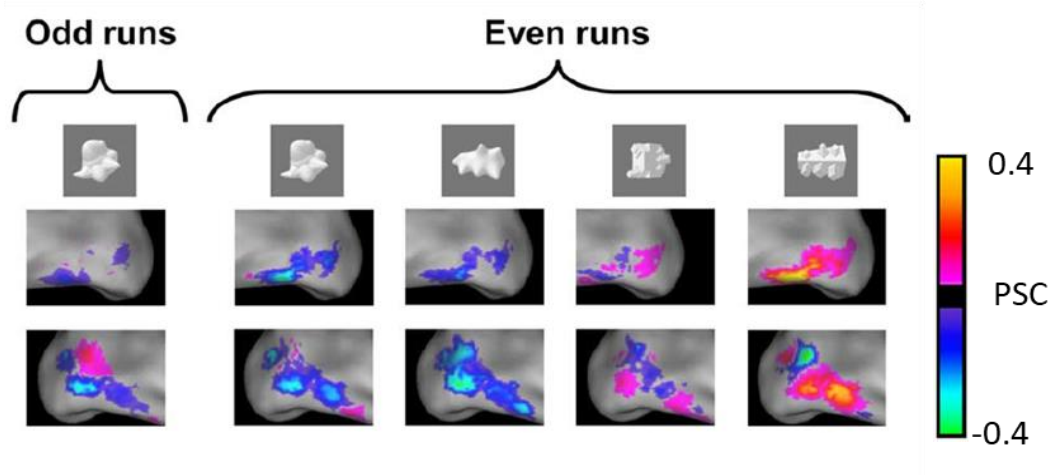


Op de Beeck et al., 2008

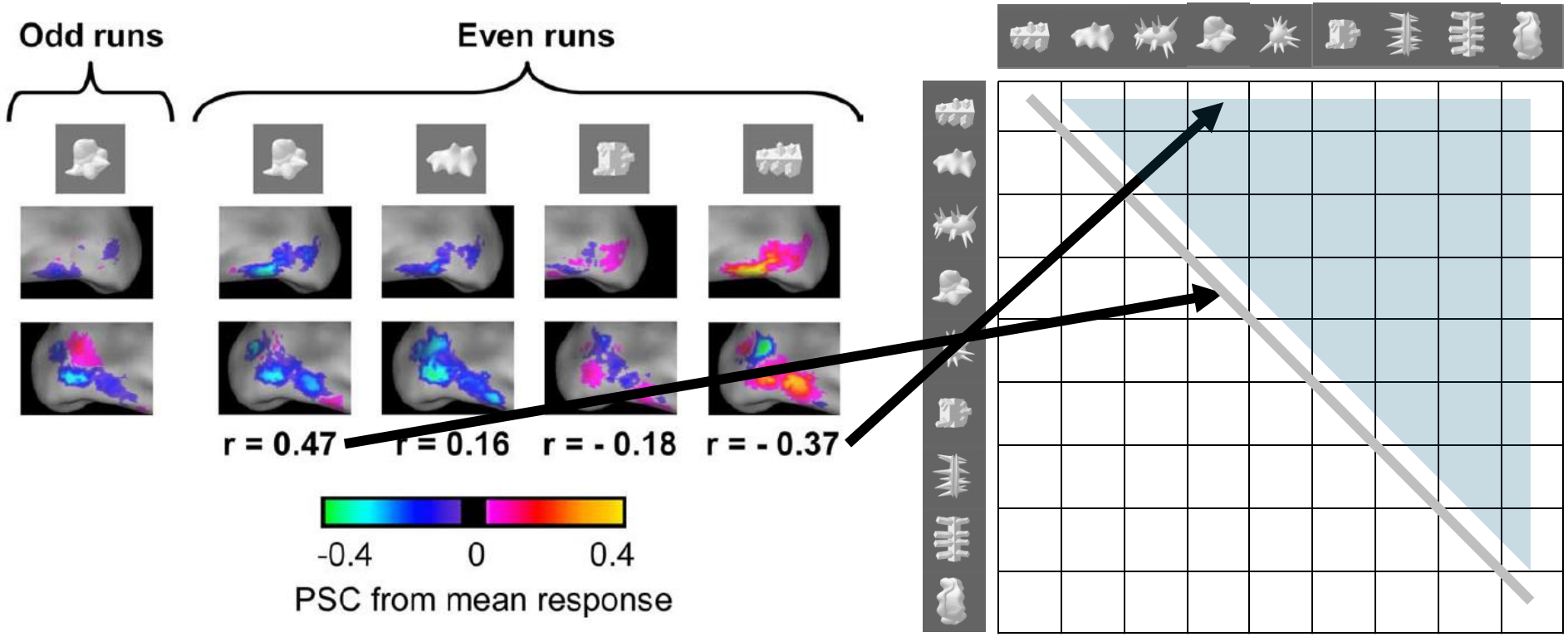
A simple example of MVPA

Shape representation in object-selective cortex





Correlation matrix

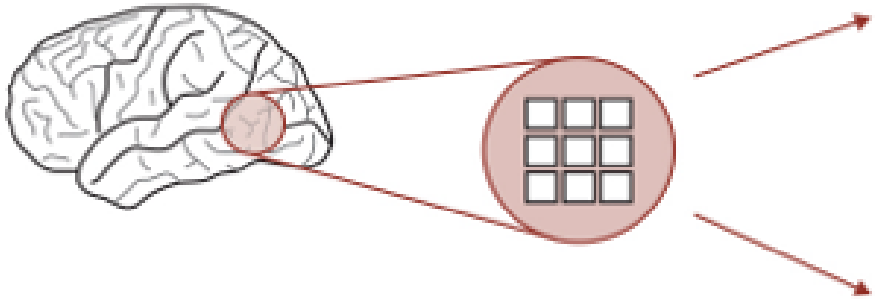


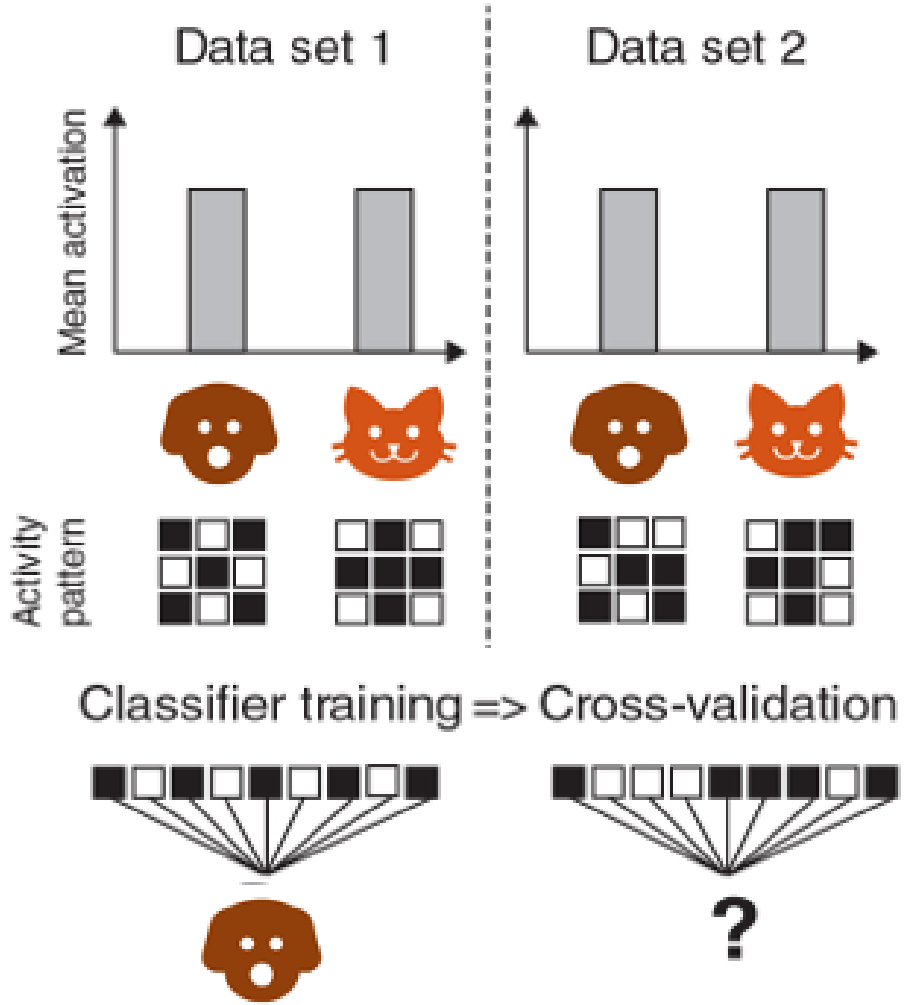
Common term: Representational (Dis)similarity Matrix (RDM/RSM)

Alternative metrics of (dis)similarity

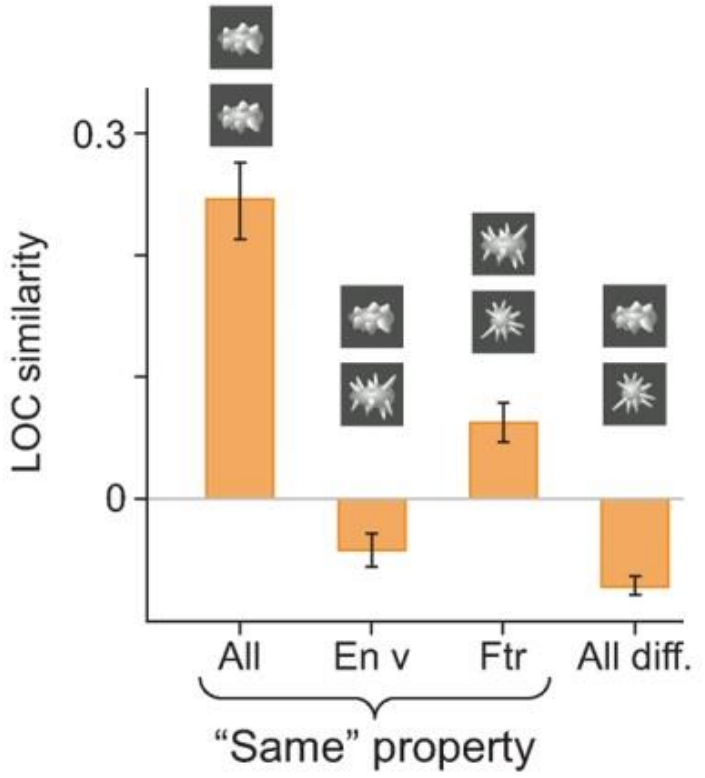
Brain decoding:

Classification performance





Consistency between metrics



Correlation
distance: 1 – corr

Classifier performance
(LDA; SVM; …)

Euclidean distance

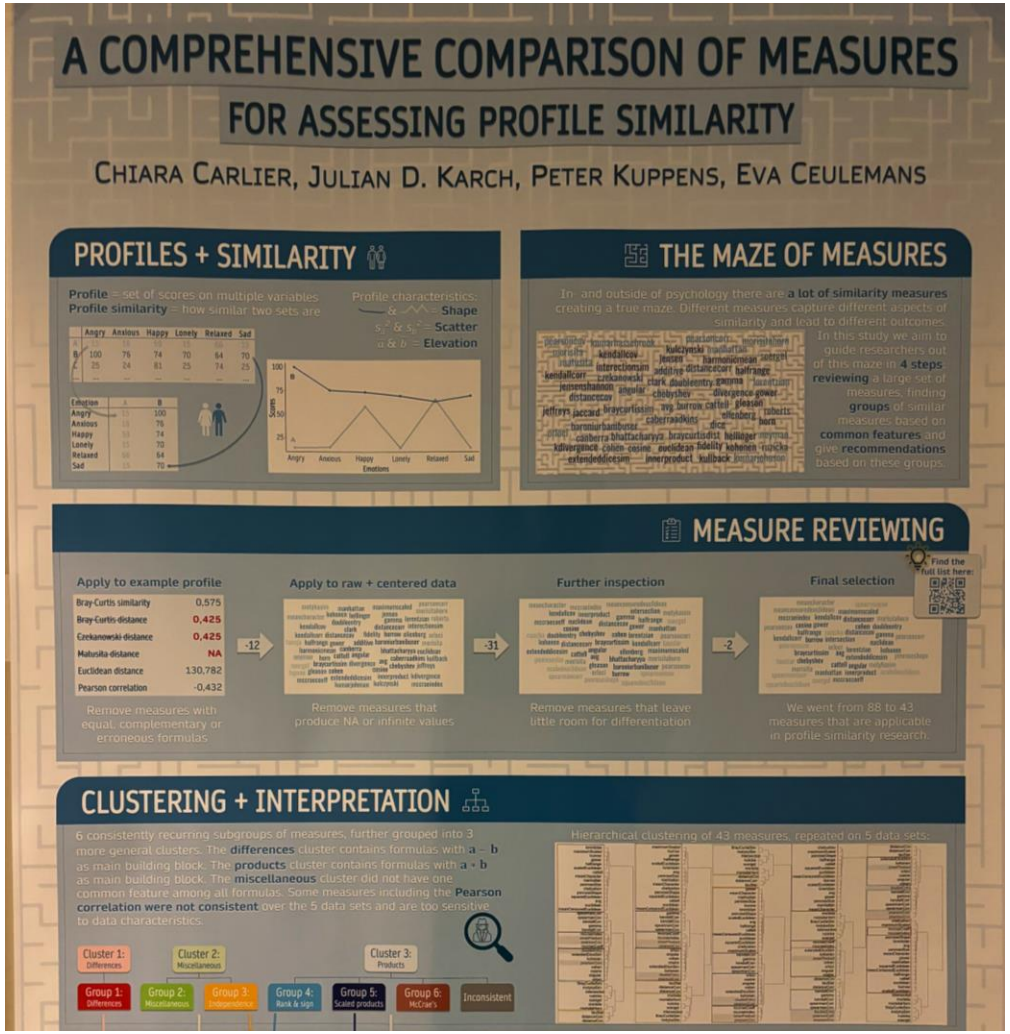
Mahalanobis distance

Cross-validated or not?

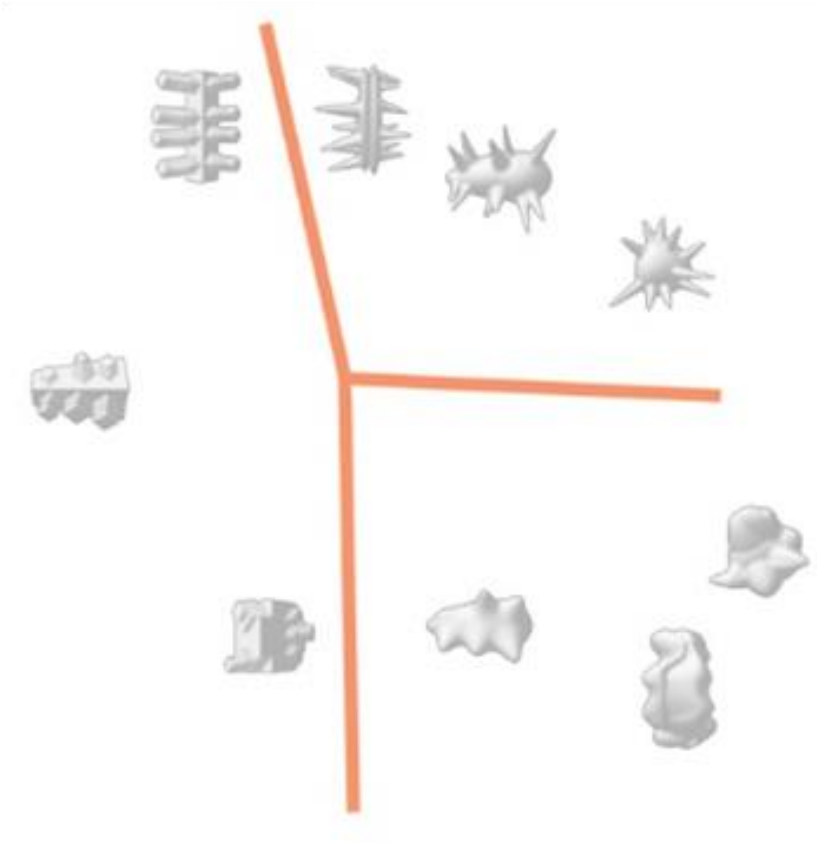
A lot of fuzz about metrics

Multiple sessions:

- “Battle of the metrics”
- “Quantifying Similarity between Neural Population Codes”



Analyzing a (dis)similarity matrix



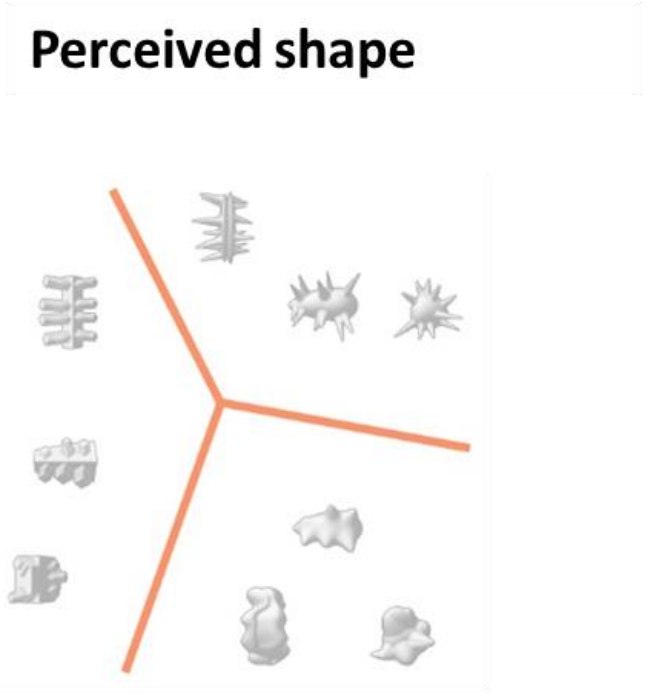
Multidimensional Scaling (MDS)

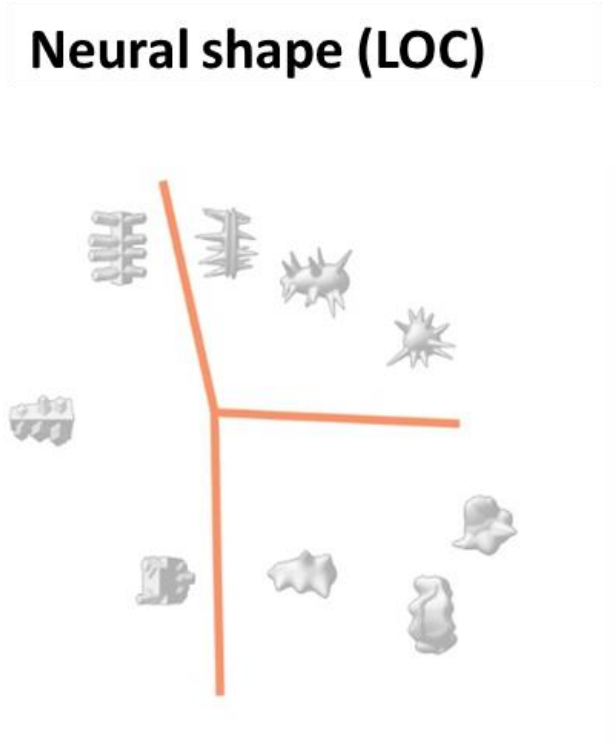
Principal Component Analysis (PCA)

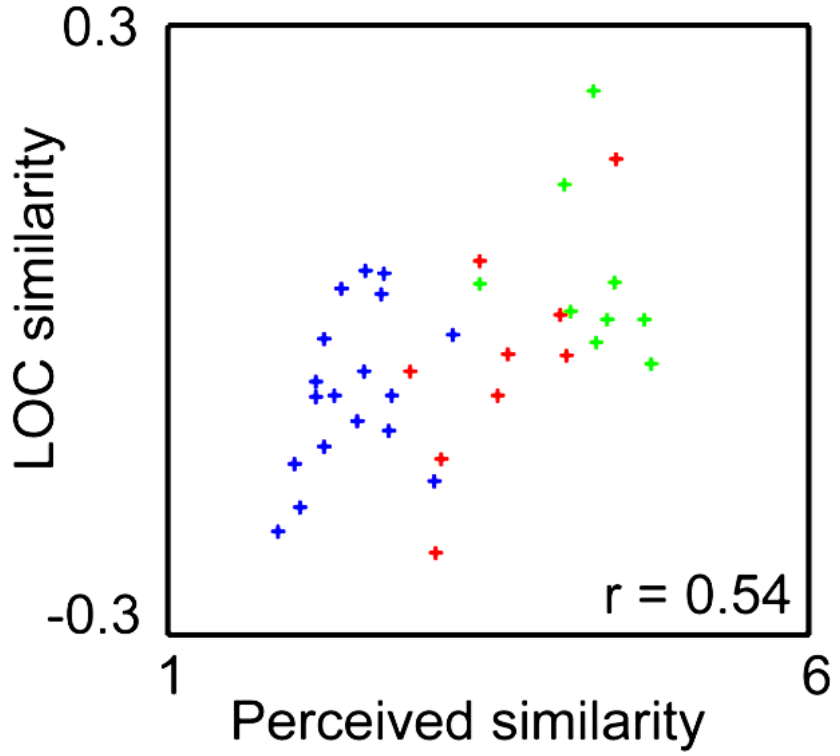
Hierarchical Cluster Analysis

Nonlinear Dimensionality Reduction (t-SNE)

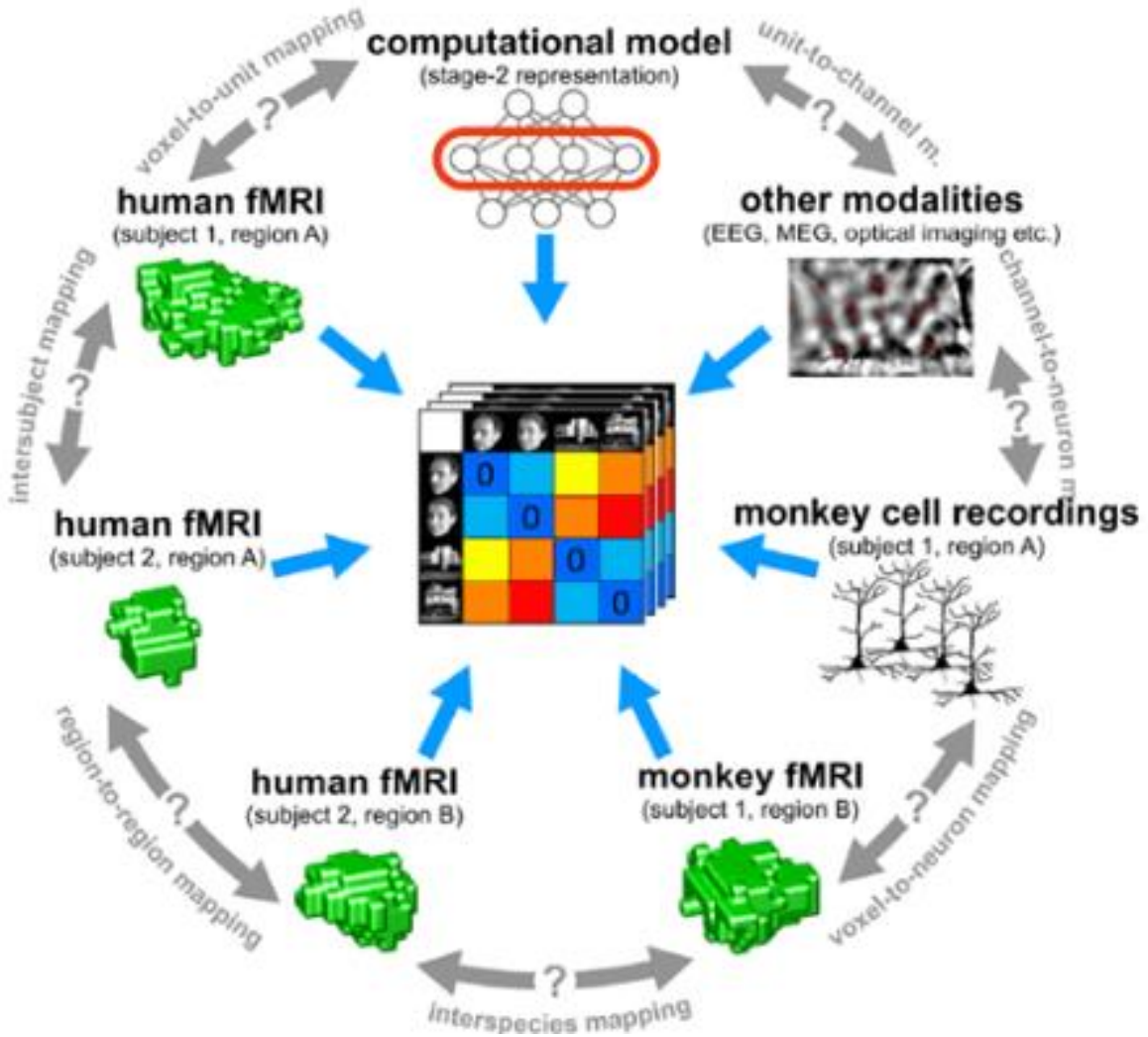
Comparing (dis)similarity matrices







Representational Similarity Analysis (RSA)



Similarity structure

Representational geometry

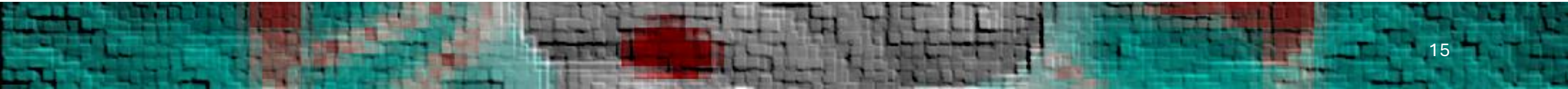
Which metric to use?

Kriegeskorte et al., 2008

How complex to make my analysis pipeline?

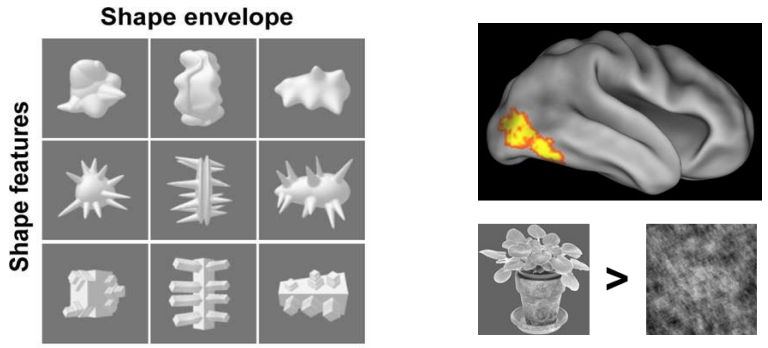
"Overall, we suggest being conservative before adding steps and complexities to the (pre)processing pipeline for RSA."

- From Ritchie et al., 2021, NeuroImage

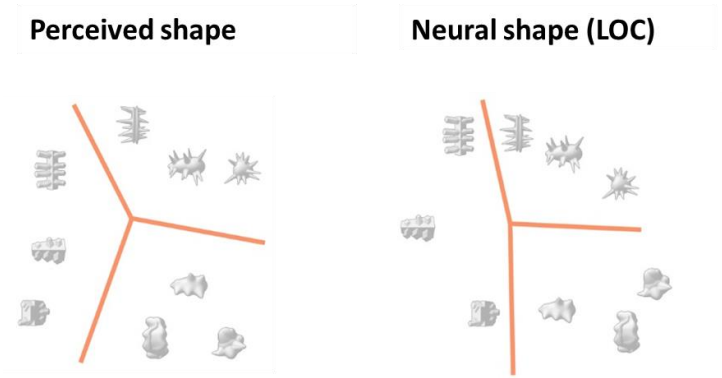


Main reasons to move to multivariate analyses

1) You are looking for a signal that is too weak or fine-scale to pick up with univariate analyses



2) Interest in similarity structure



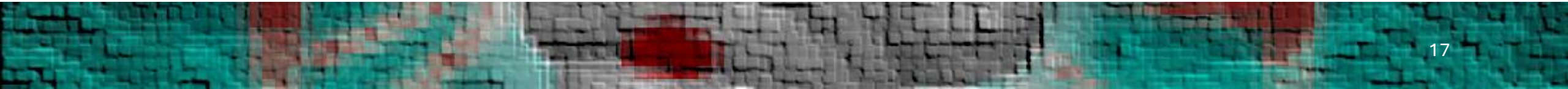
Design considerations for MVPA

1) You can have more conditions than in a traditional experiment

   Helps to introduce interesting similarity structure

2) Still, the more data per condition, the better

3) Try to go for shorter runs to get more runs (min. 4-6 for decoding)

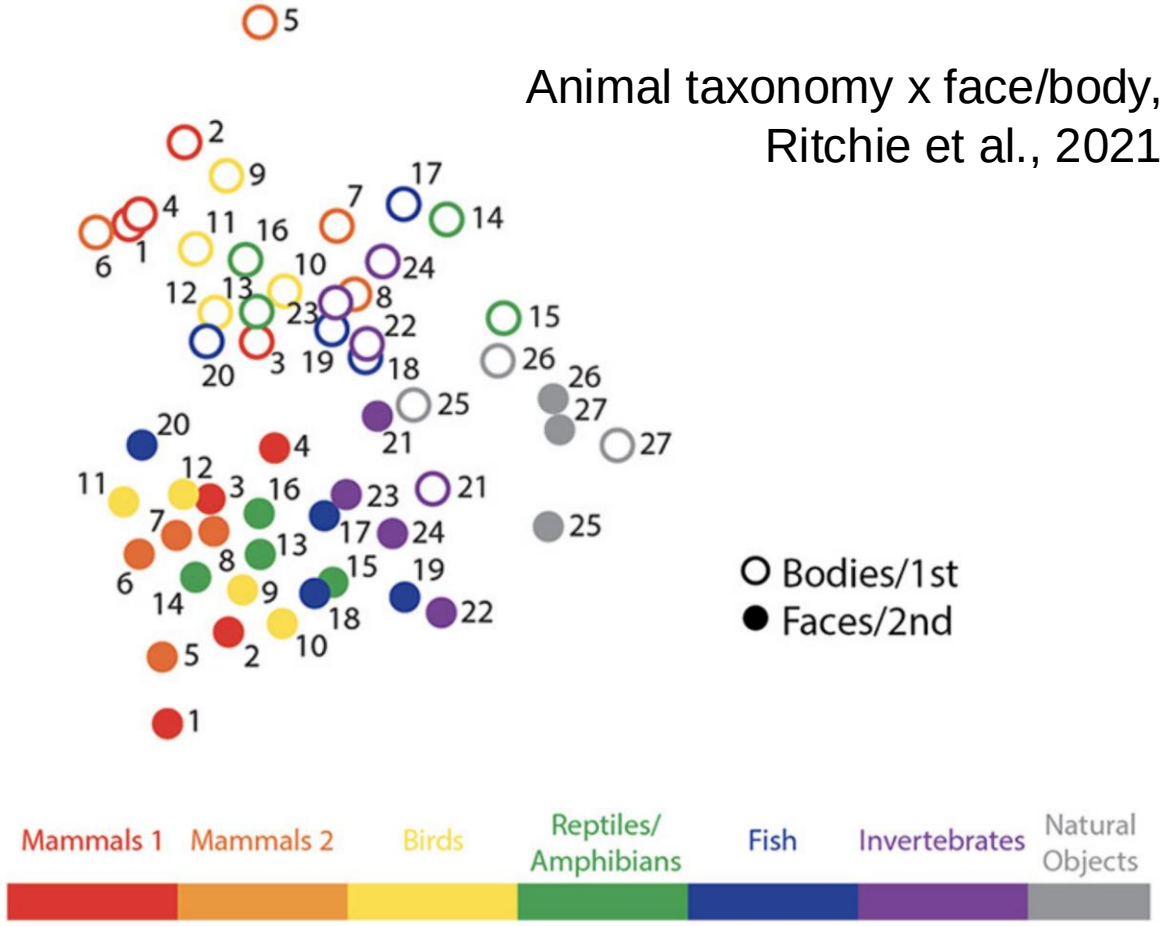


What works well, and what is borderline?

Large-scale similarity structures

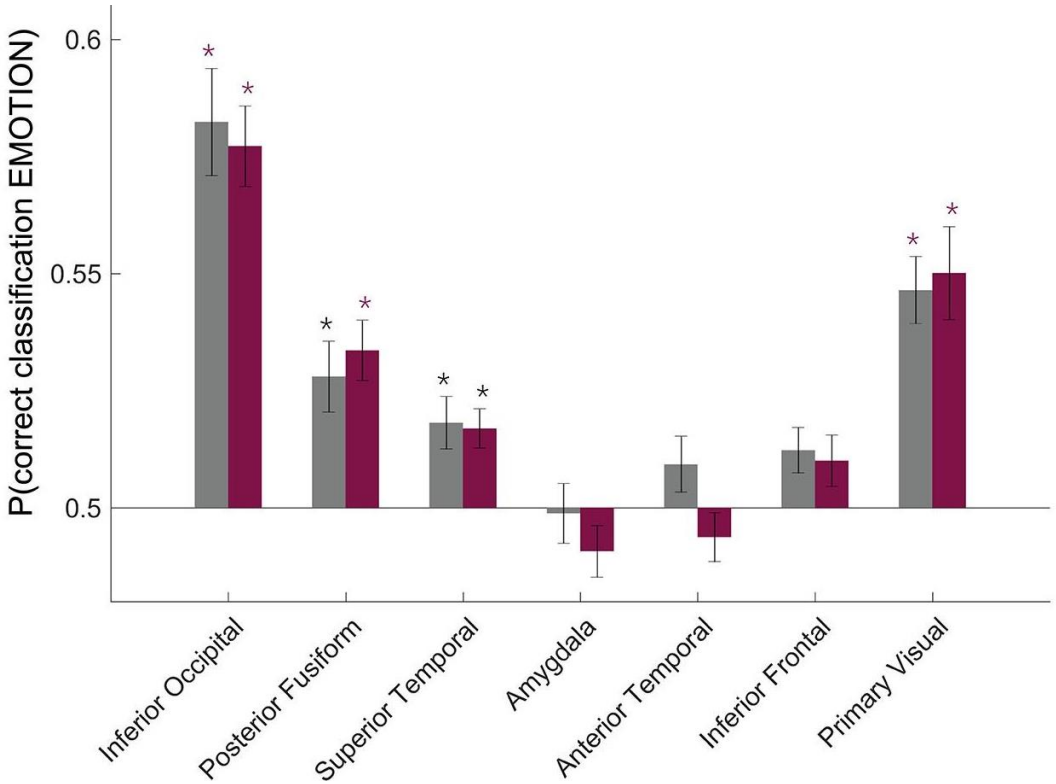
Shape x category space, Bracci et al., 2016

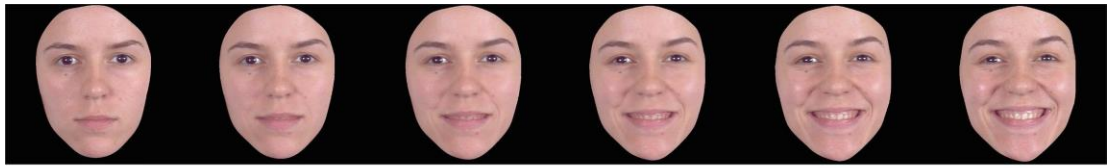
Animal taxonomy x face/body, Ritchie et al., 2021

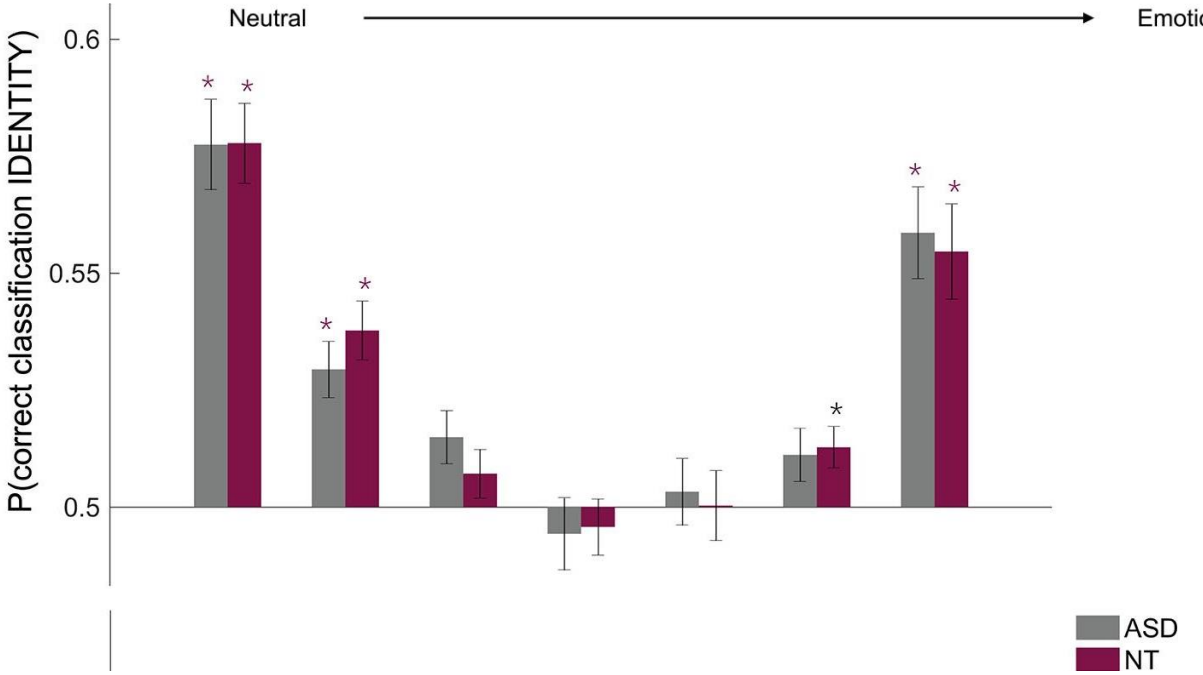


What works well, and what is borderline?

Subordinate differences can be ok-ish, but be careful



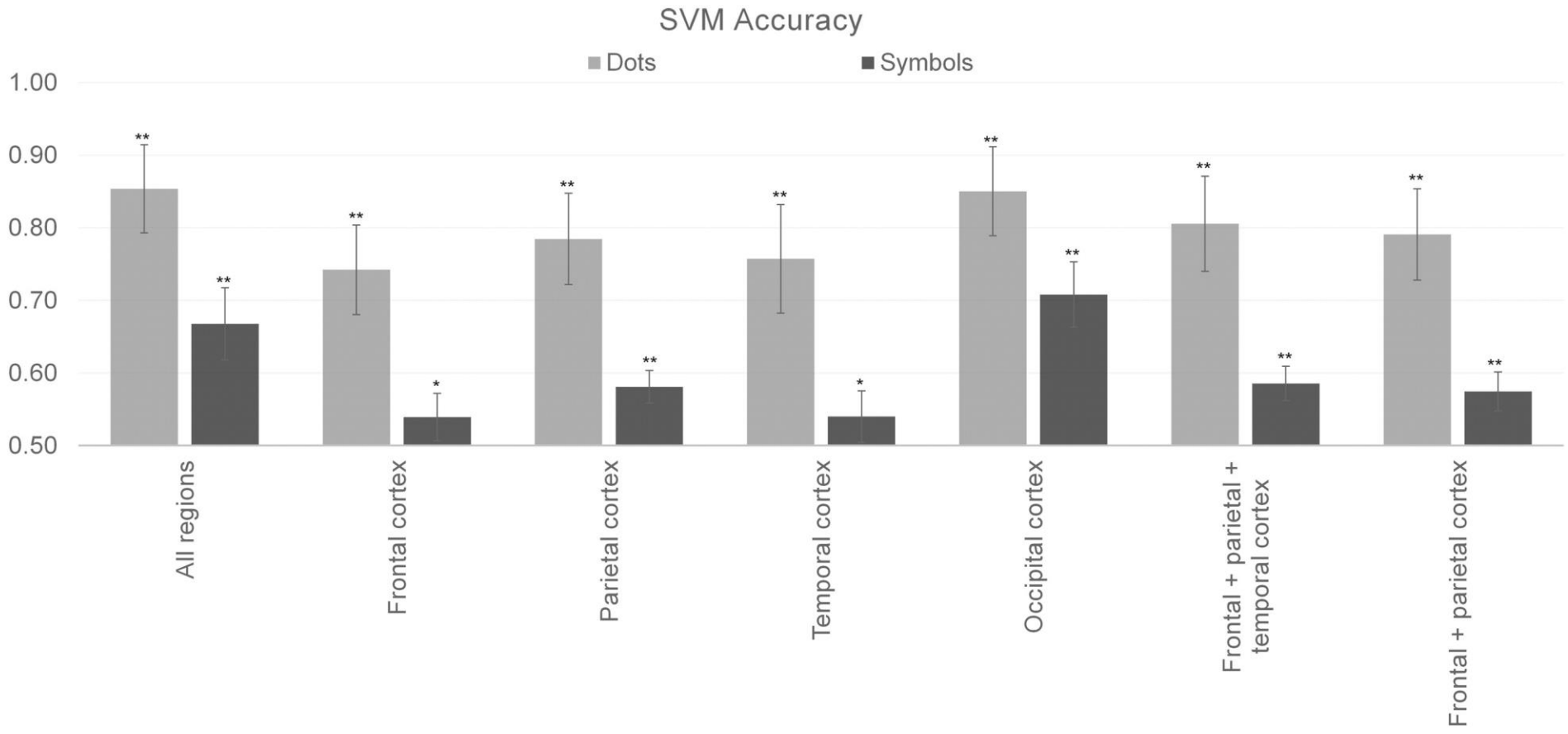




Hendriks et al., 2021; Also see Goesaert et al., 2013

What works well, and what is borderline?

Example from numerical cognition



Bulthé et al., 2014

Towards a hands-on example

Our current approach & alternatives:

- Preprocessing: fMRIPrep (or SPM)
- GLM model estimation in SPM12
- Input to the MVPA: beta maps from GLM
- MVPA: CoSMoMVPA (Matlab)

  Benefit: comprehensive & flexible
- Alternatives for CosMo:
  - PyMVPA (Python toolbox on which CoSMo was based)
  - Decoding Toolbox (official SPM toolbox, originally only decoding but now more comprehensive)
  - Rsatoolbox (Python; Kriegeskorte etc.)