Multivariate Pattern Analysis of fMRI data

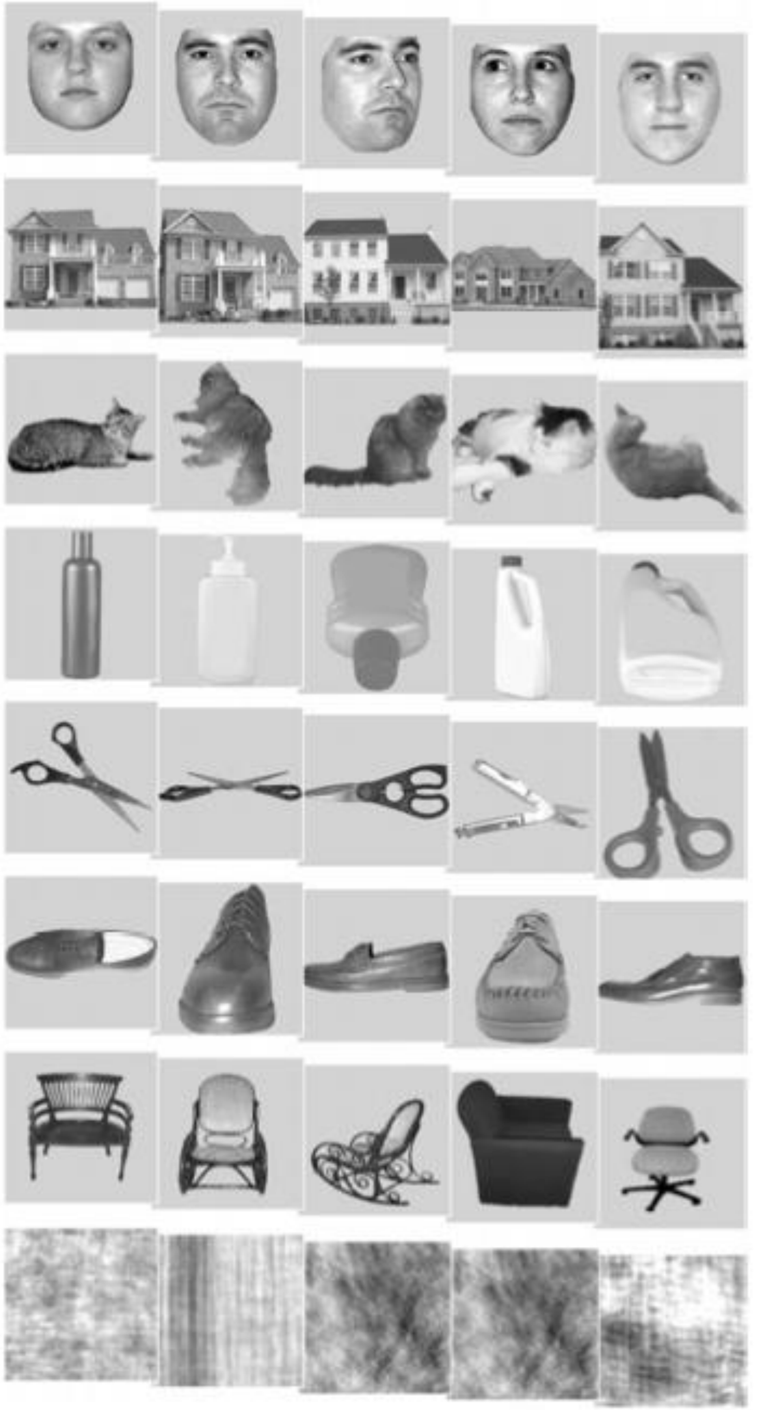
Goal of this lecture

- Introduction of basic concepts & a few commonly used approaches to multivariate pattern analysis
- Pros & cons, as well as limitations

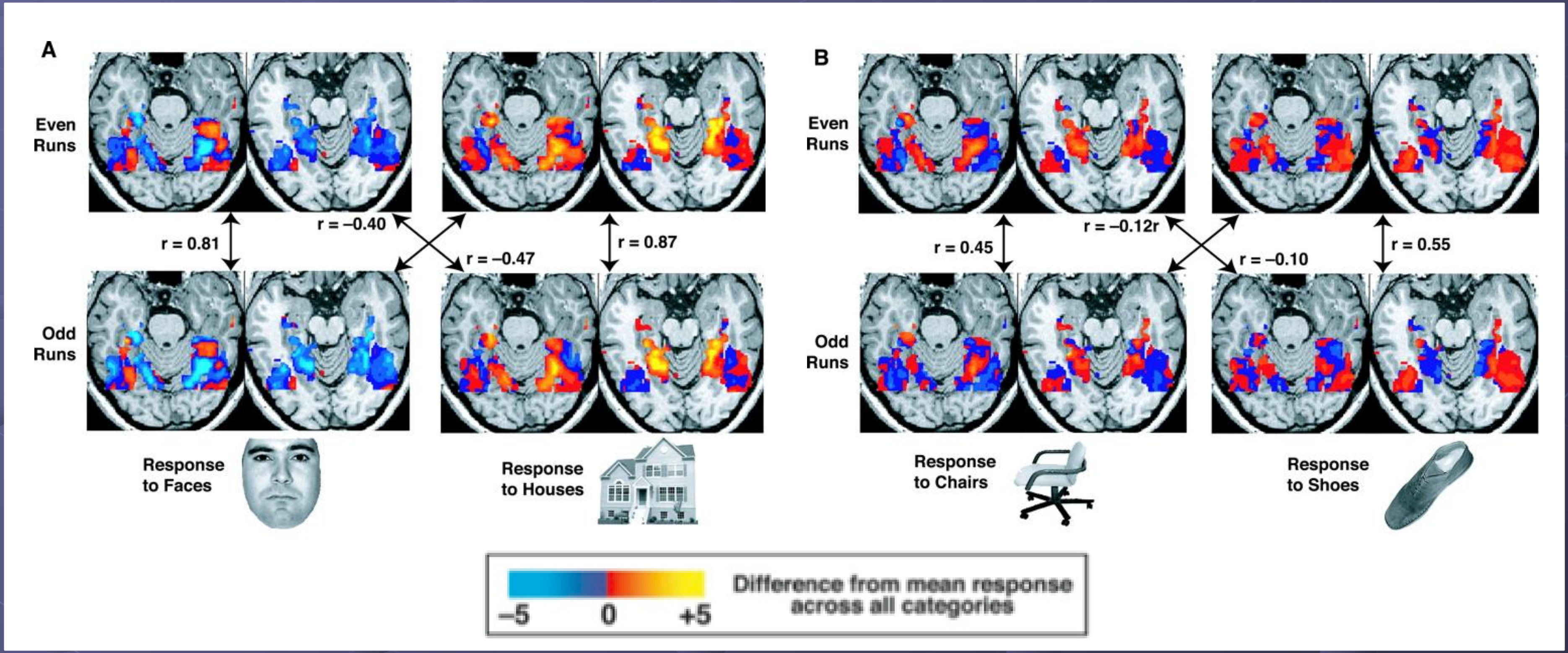
- Conventional univariate analysis of fMRI data is based on applying a general linear model to the average signal across a specific region-of-interest (ROI) or to the whole brain in a voxel-by-voxel manner

- Haxby et al. (2001) first demonstrated that patterns of neural activities contains information univariate analysis failed to reveal, which lay the ground for the whole multivariate regime

- They scanned people while viewing different object categories, which is known to activate the ventral temporal cortices
- It's been done hundreds, if not thousands, of times. So what's so special?



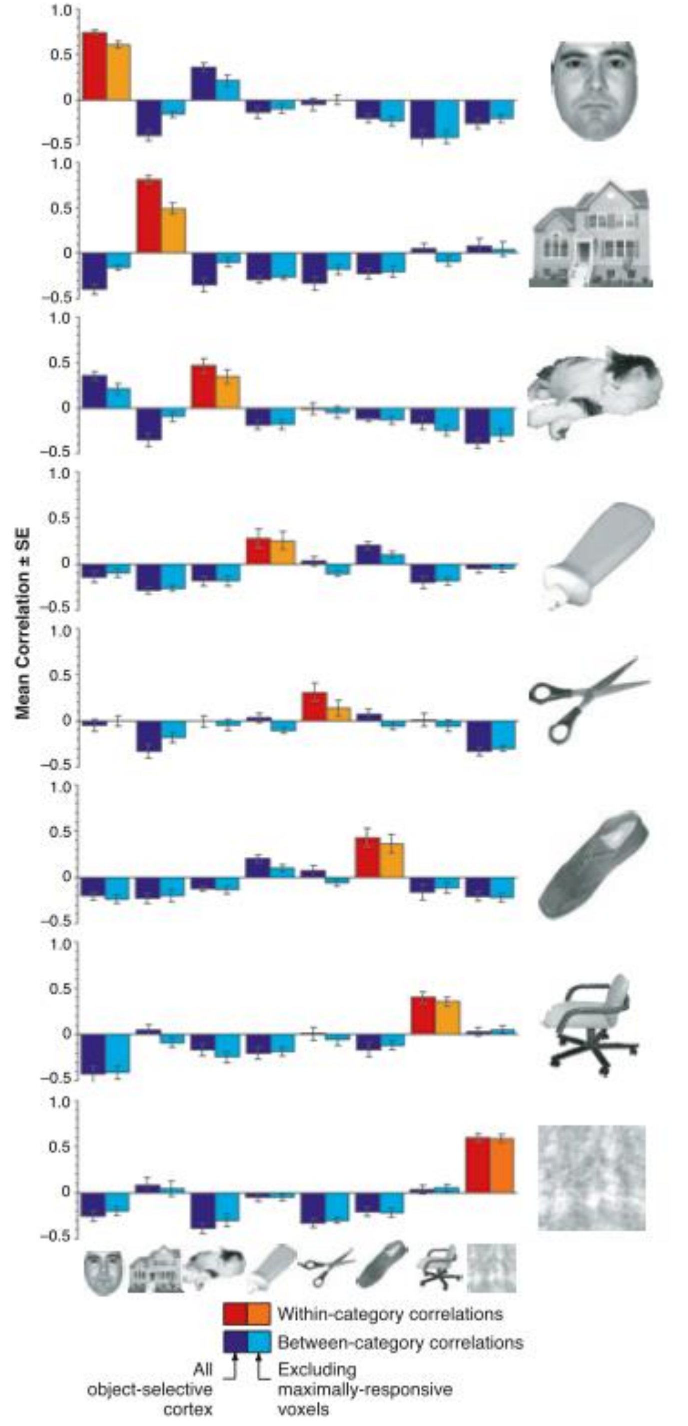
- When they examine the cross-correlation of the distributed brain activities between same & different object category during two independent sets of runs, interesting results emerged



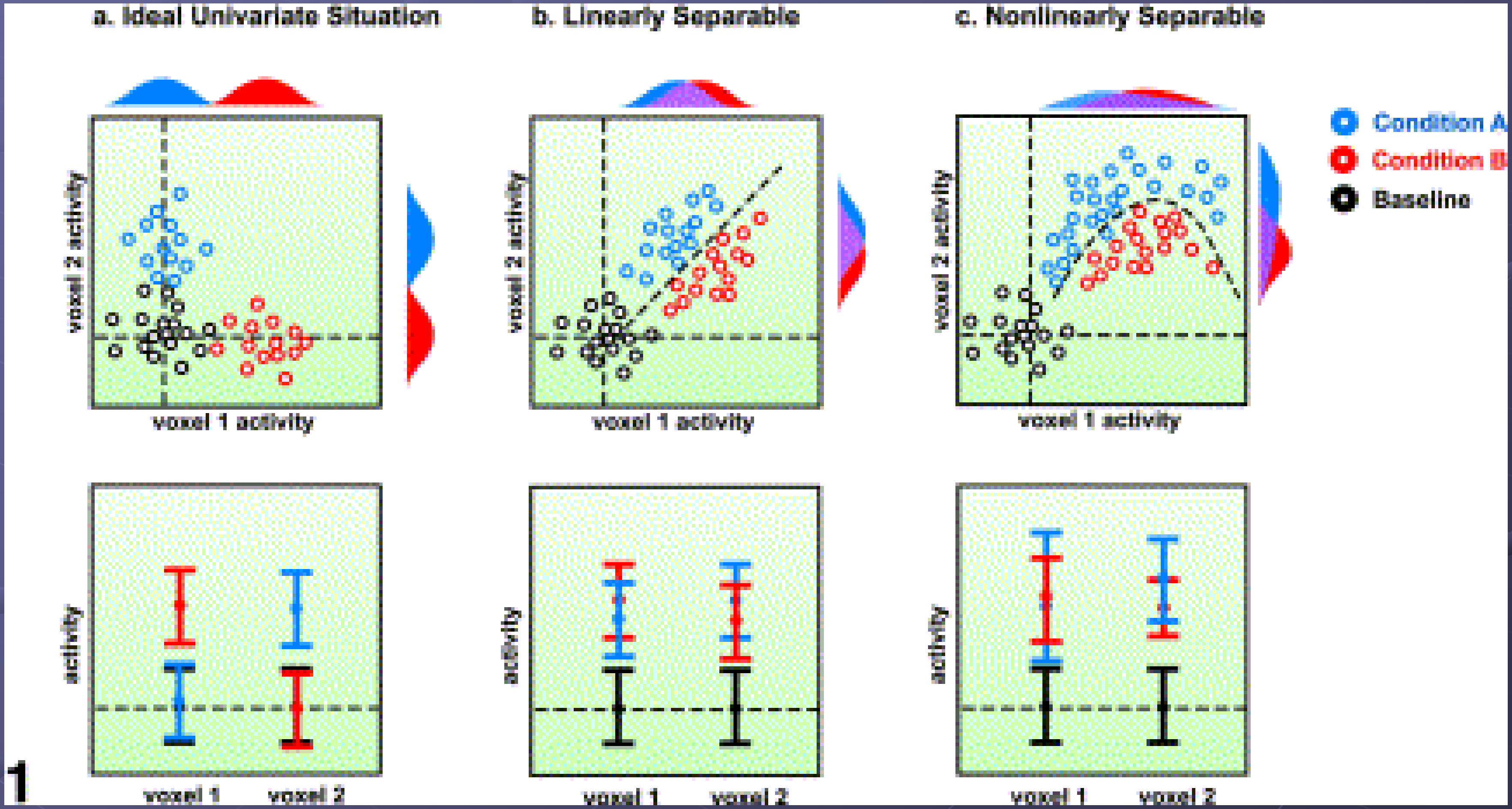
- The within-category correlations are consistently and significantly higher than the between-category correlations

- Conclusion: category-specific information is represented in the overall <u>*pattern*</u> of activations in ventral temporal cortices

- But how?



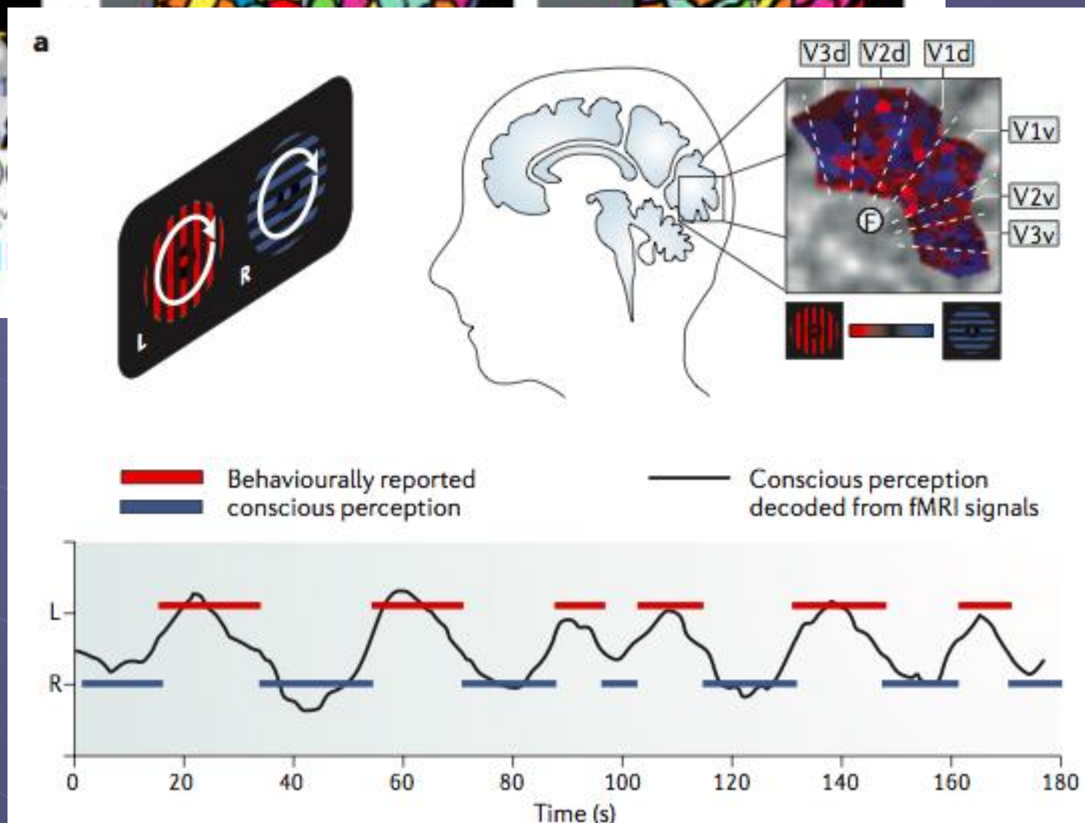
- Multivariate analysis is able to exploit the pattern of fMRI signals to extract fine-grained information and provide a more sensitive measure of presence of information in the brain



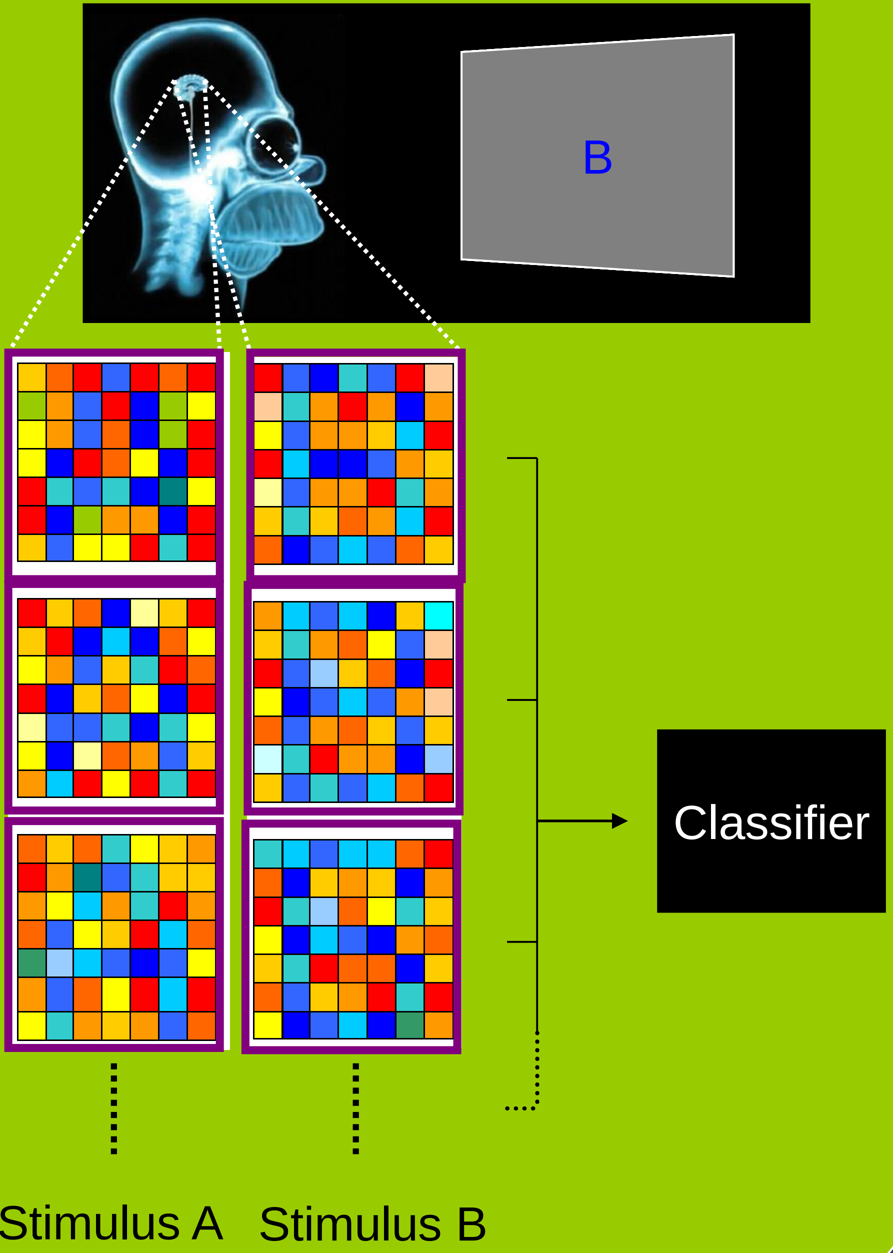
(Cox & Savoy, 2003)

(Kamitani & Tong, 2005)

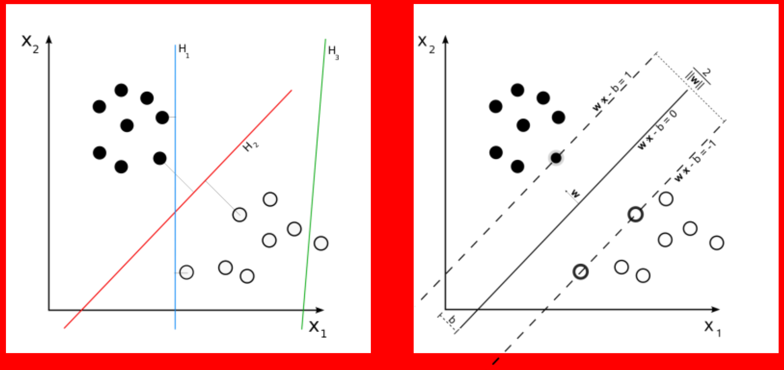
(Haynes & Rees, 2005)



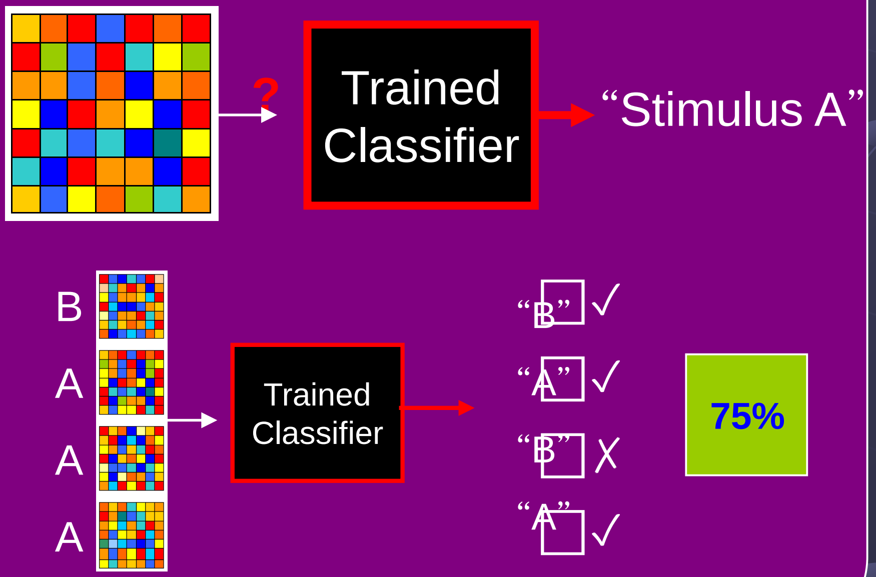
Training a Classifier



Classifier (e.g. Support Vector Machine)

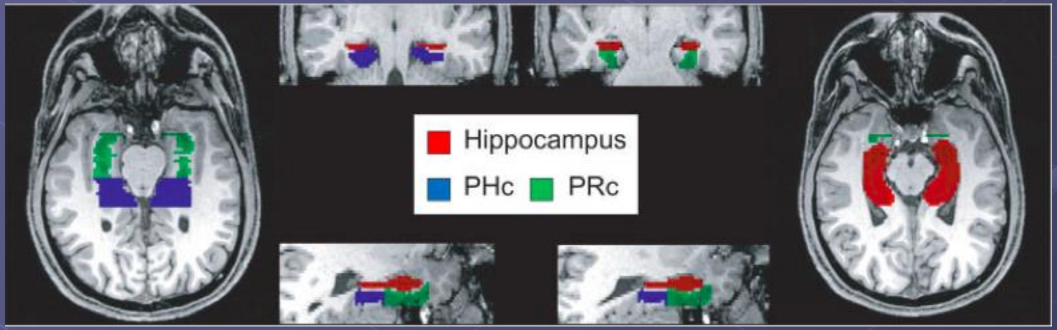


Prediction/Testing a Classifier

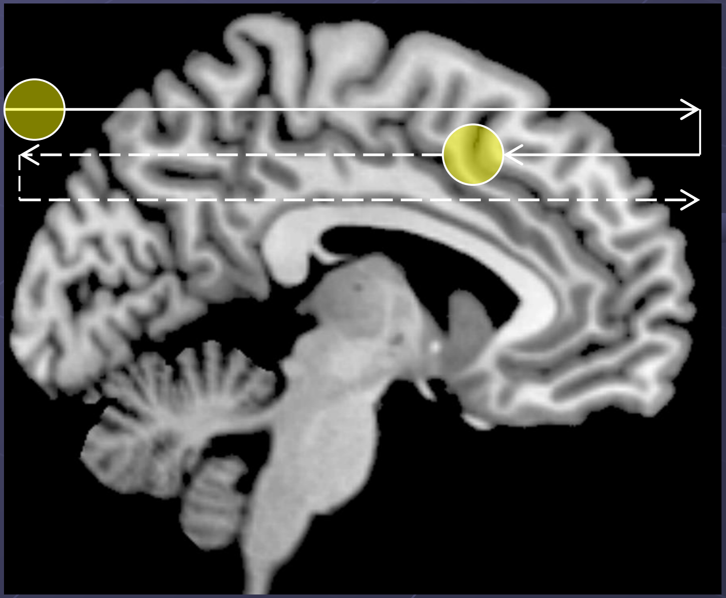


- It is important to note that the training & testing data set should be independent from each other – no double dipping!
  - Odd – even run splitting
  - Leave-n-out sampling

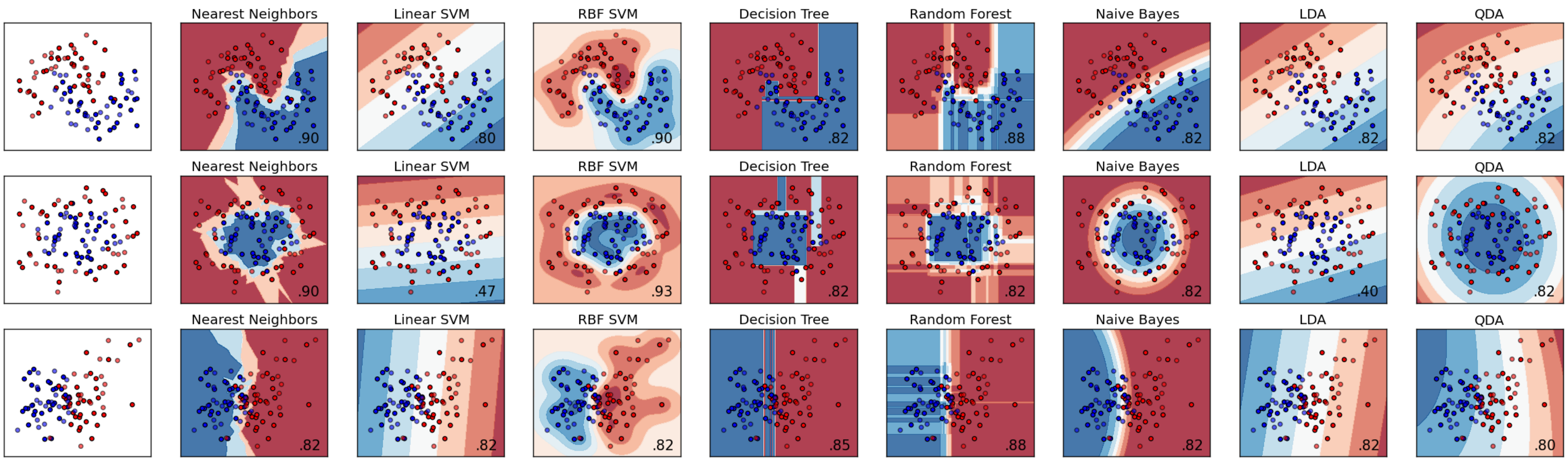
- Training & testing of classifier can be done with voxels in
  - Region-of-interests (functional or anatomical)
  - Whole-brain searchlight
  - Whole-brain recursive feature elimination (RFE)



(Diana et al, 2008)



- Different classifiers



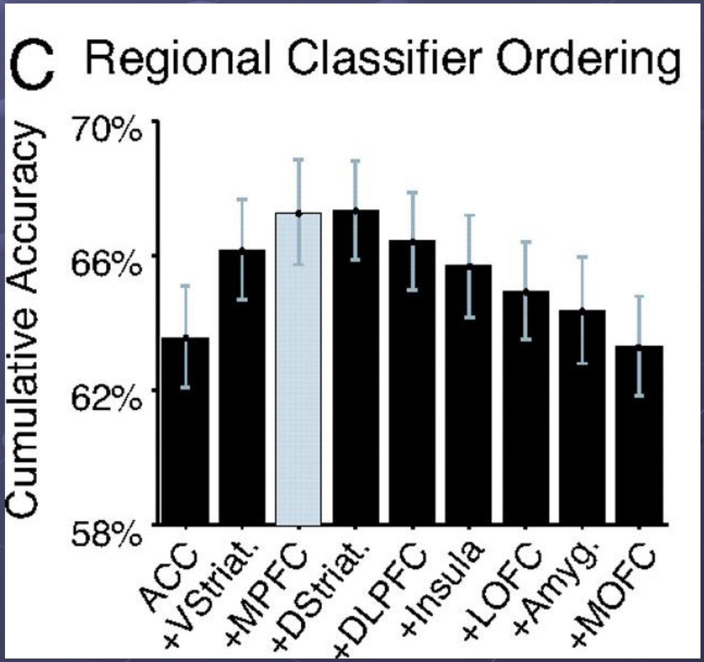
- Toolboxes for MVPA
  - Matlab-based: Princeton MVPA toolbox, Pronto, Searchmight
  - Python-based: PyMVPA, Scikit Learn

Applications

- Since the incorporation of this statistical technique on imaging studies, researchers had extend the application from visual perception to higher cognitive functioning, e.g. language, memory processes, decision-making

- MVPA applied to multiple brain regions can help us to test the respective role of components in a particular brain circuit

- One could test specific hypothesis on the components of cognitive processes by training a classifier with data from one task & cross-validate with data from another cognitive task

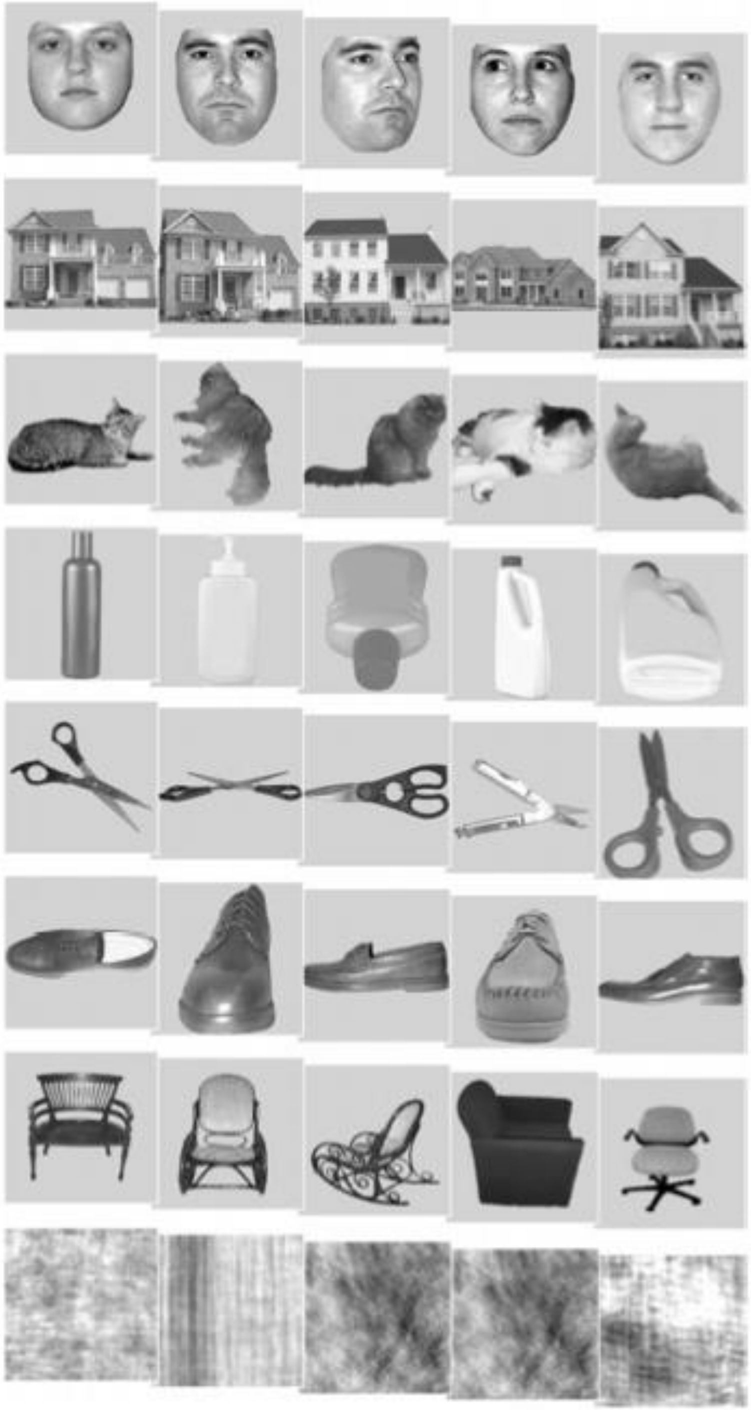


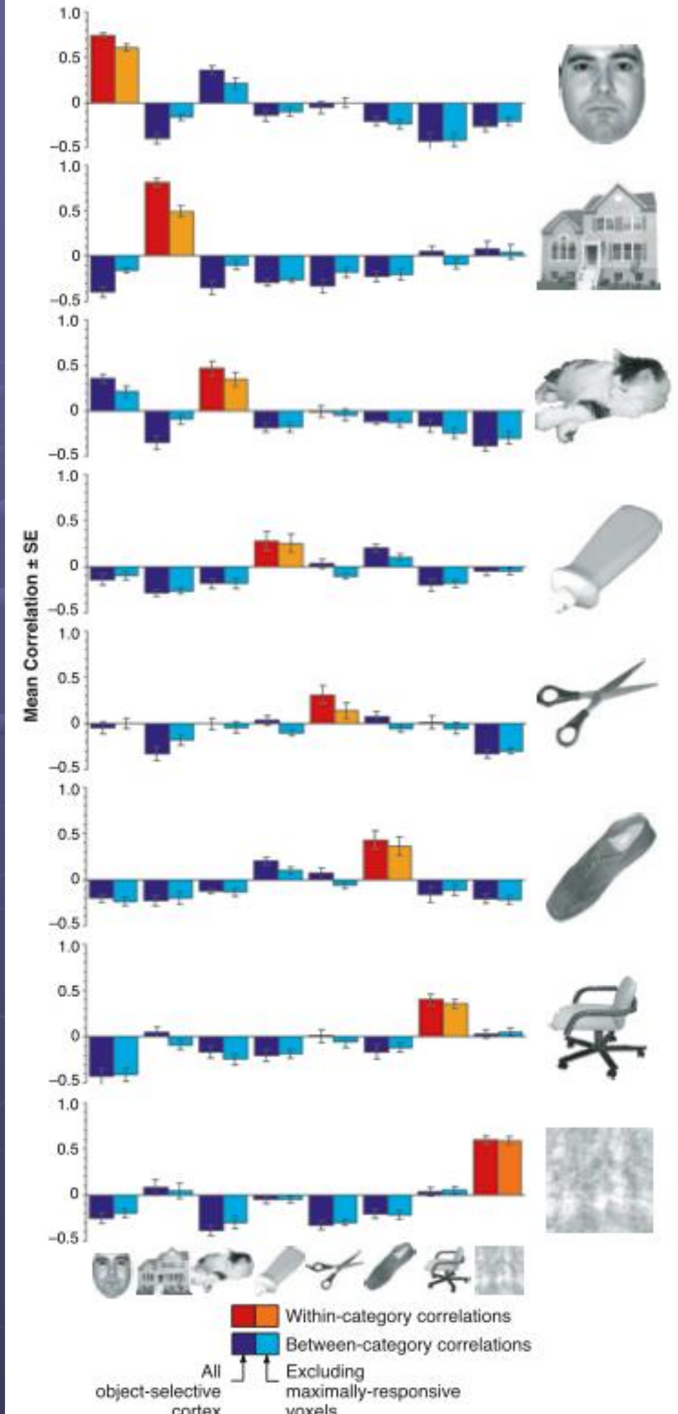
(Hampton & O’ Doherty, 2007)

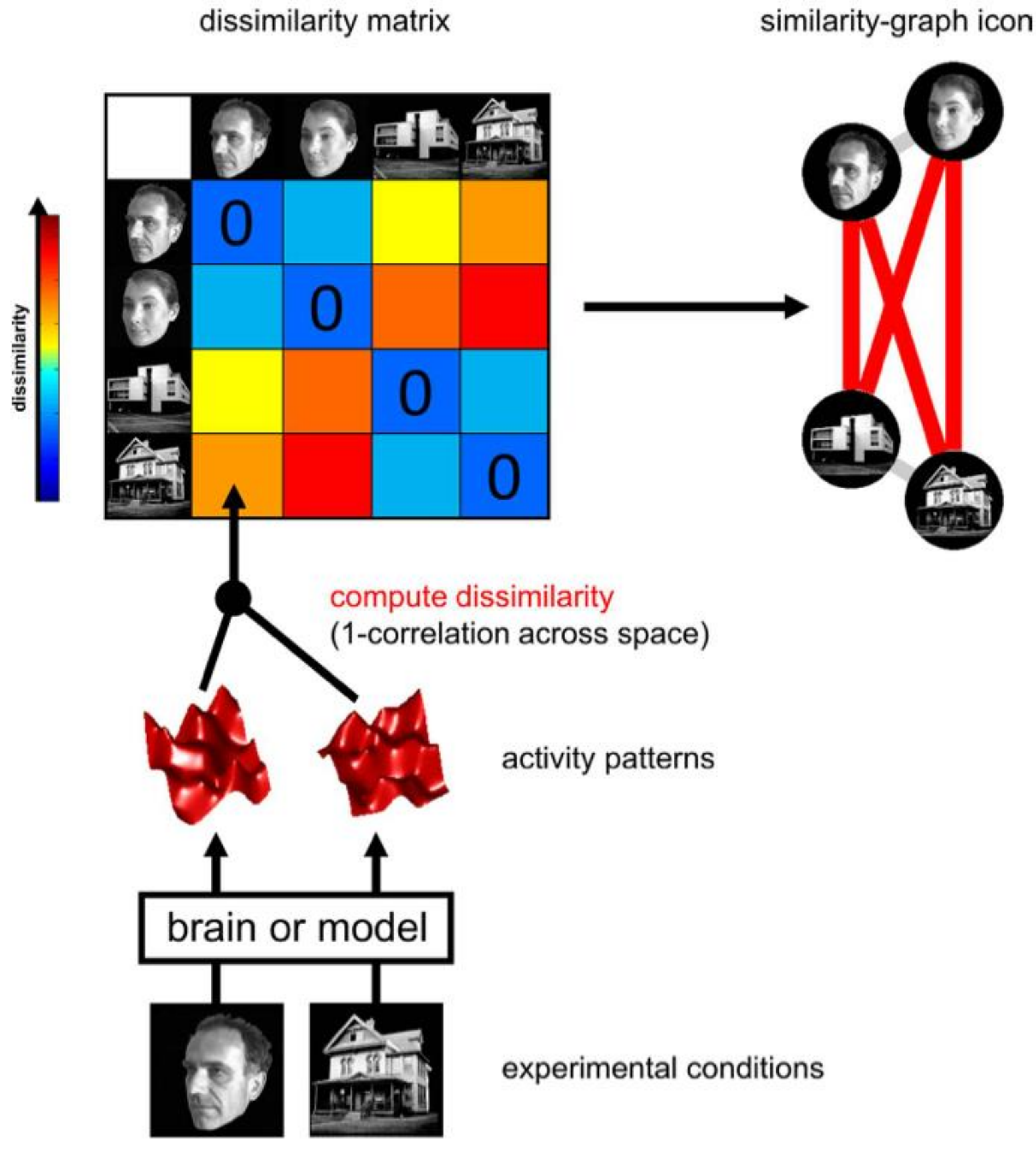
- Information mapping by training & testing a classifier is not the only way to harness the fine-grained information in brain activation patterns

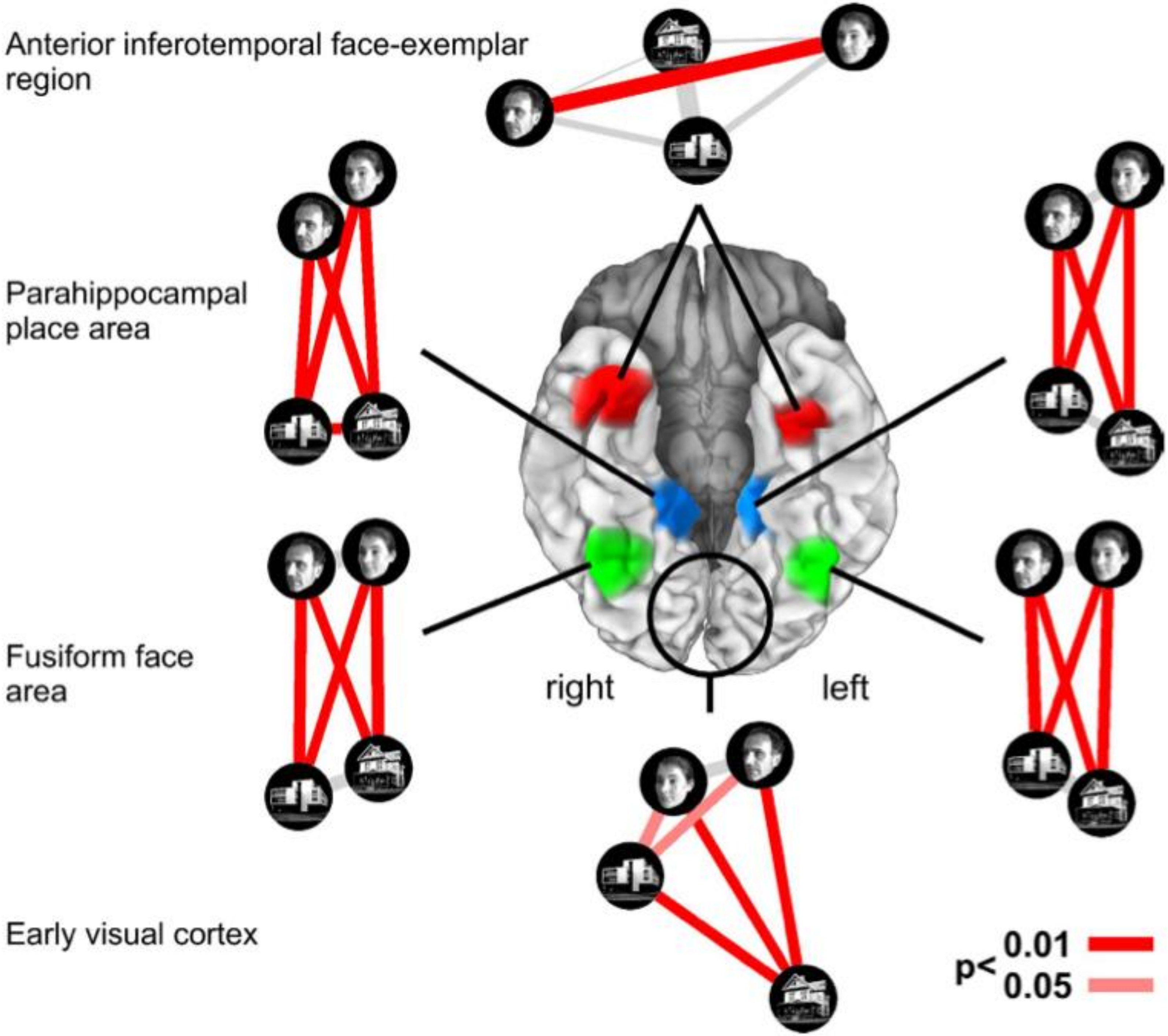
- Representational dissimilarity analysis (Kriegeskorte, 2008)

- To start with, let’s recall Haxby’s seminal paper once again



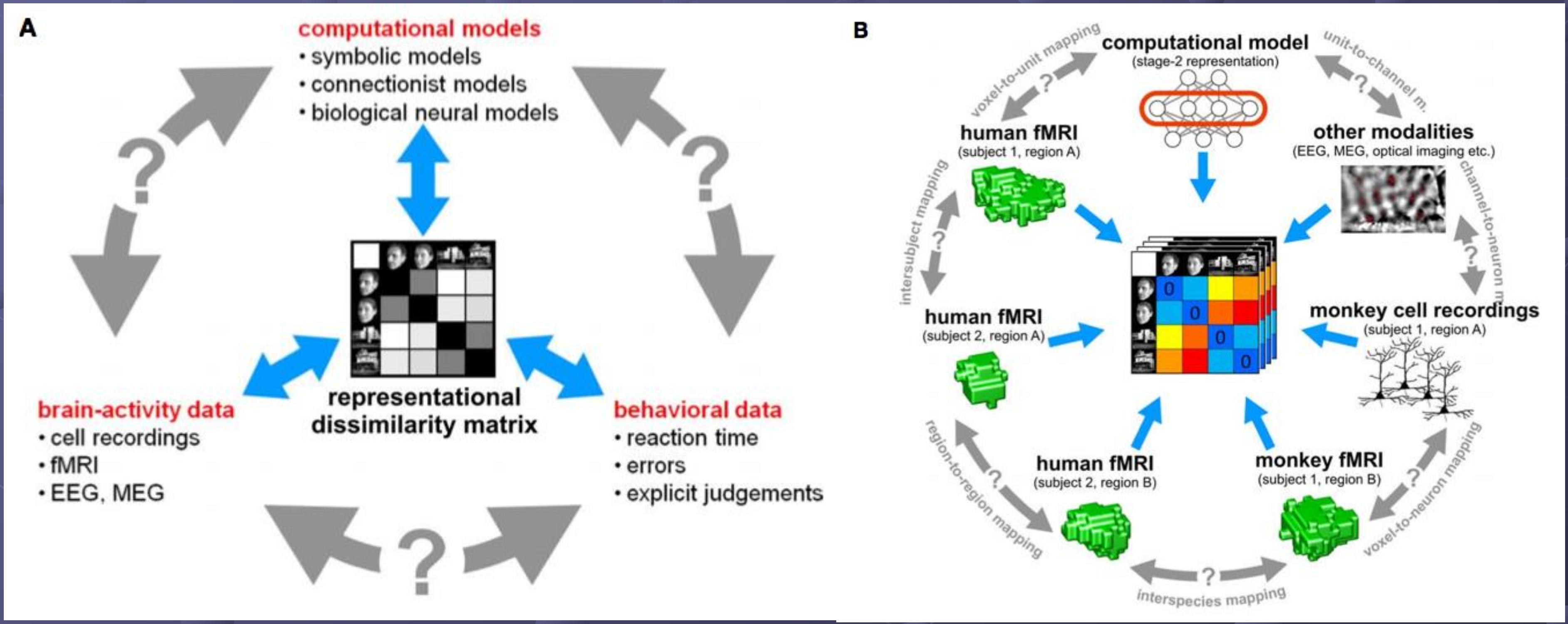

Mean Correlation ± SE
1.0
0.5
0
−0.5
Within-category correlations
Between-category correlations
All object-selective cortex
Excluding maximally-responsive voxels


dissimilarity matrix
similarity-graph icon
dissimilarity
0
0
0
0
compute dissimilarity
(1-correlation across space)
activity patterns
brain or model
experimental conditions

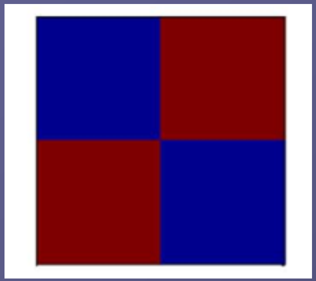


Anterior inferotemporal face-exemplar region
Parahippocampal place area
Fusiform face area
Early visual cortex
right
left
p< 0.01
0.05

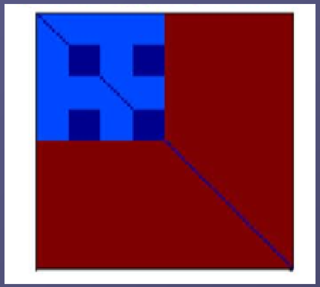
- Examine neural representations by dissimilarity matrix
- A RDM is an abstraction of response tuning in a brain region/neuronal assembly
- By comparing different RDMs, we could uncover the information content in a brain region

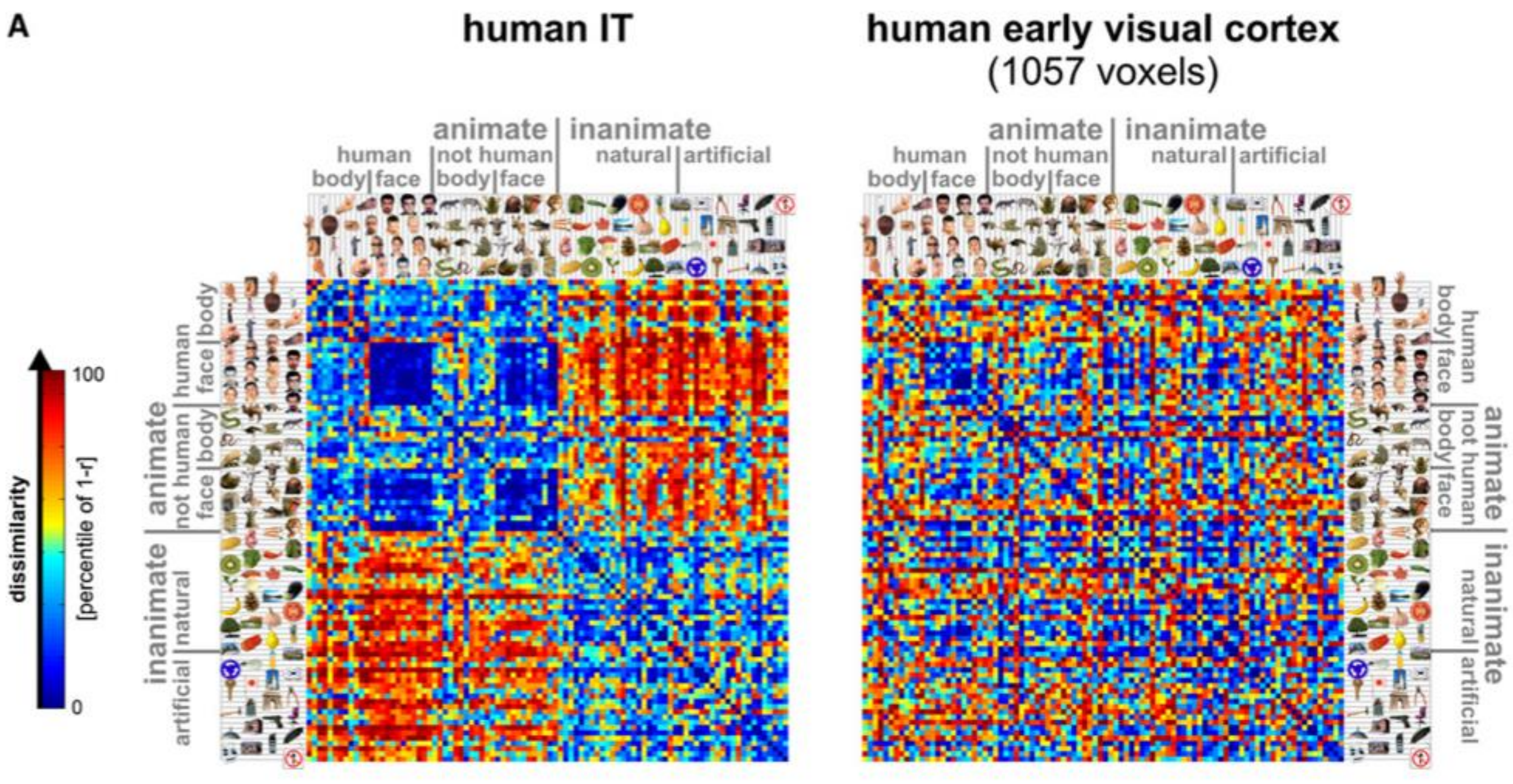


- e.g. Animate vs Inanimate

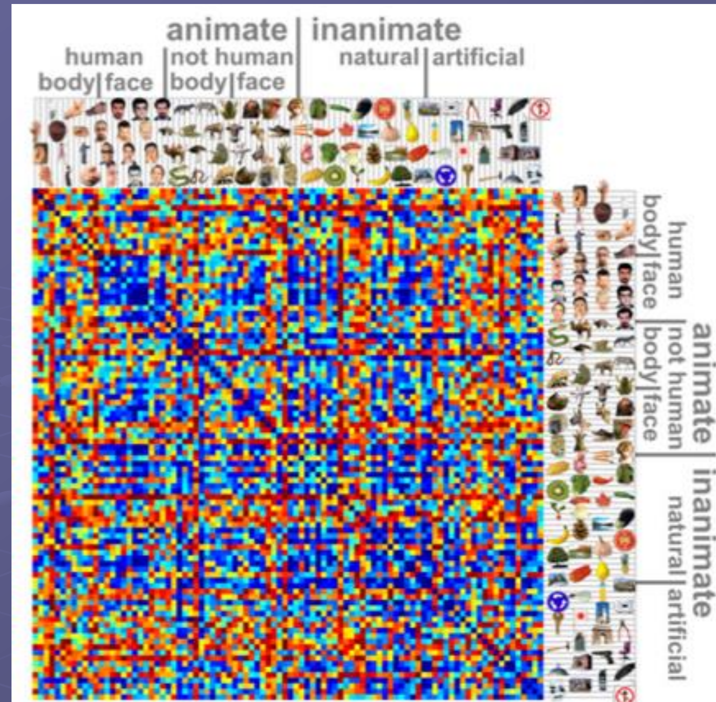


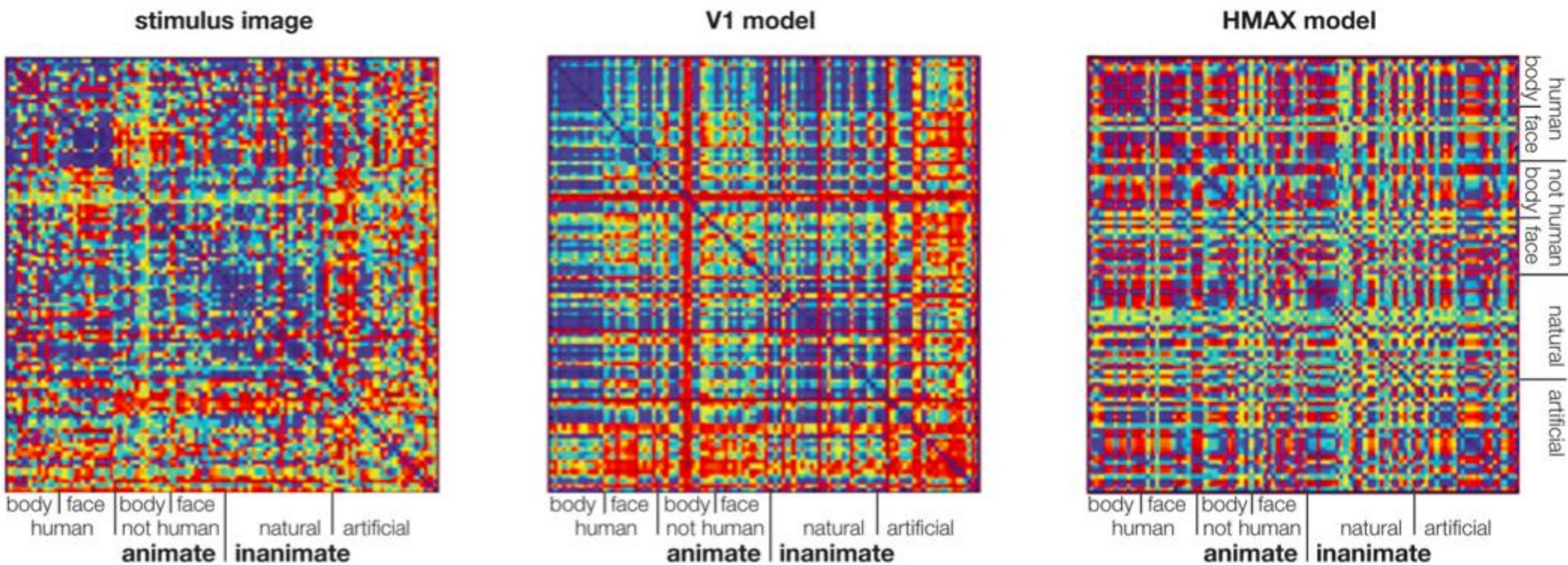
or



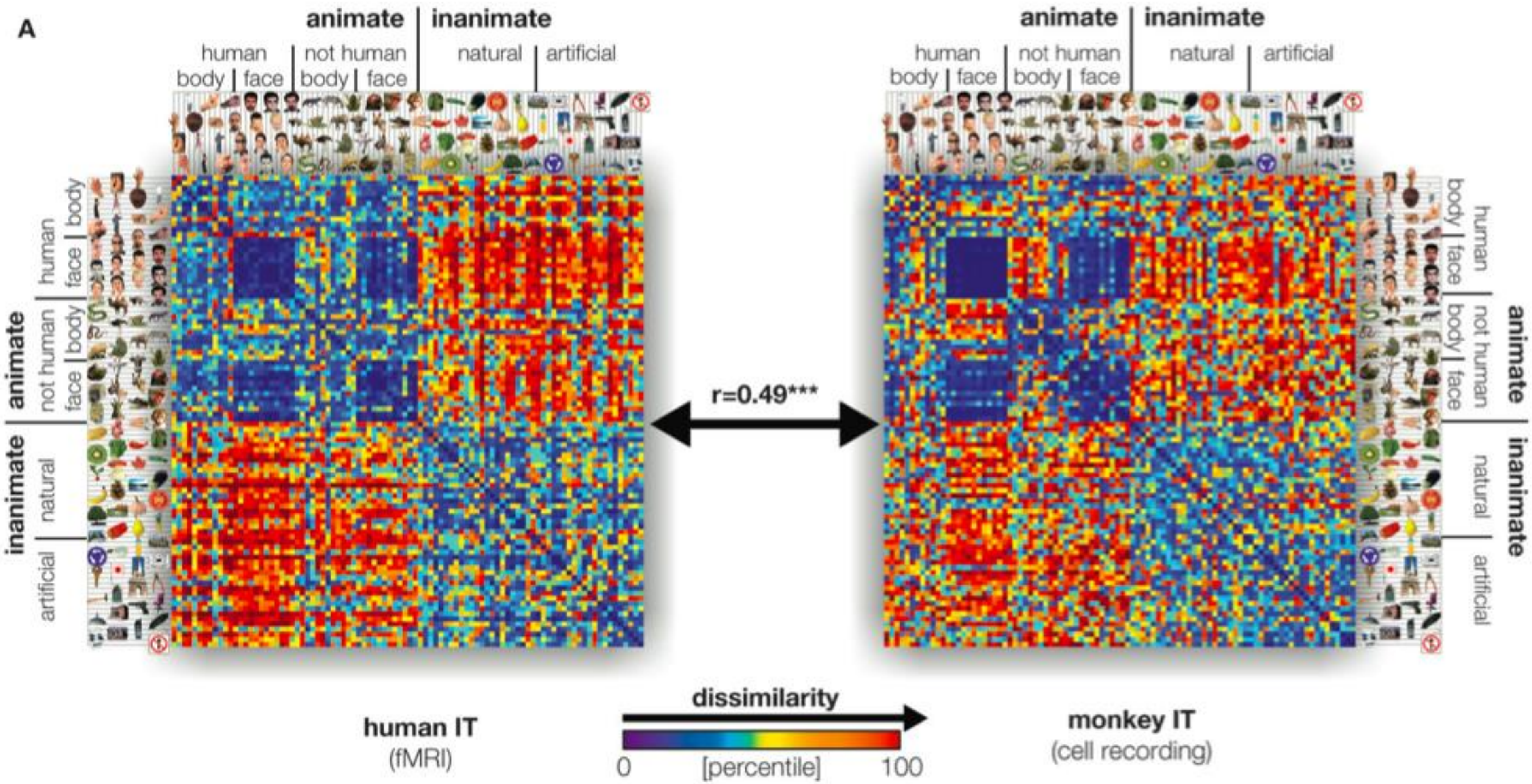


- vs Computation model





- Inter-species/subject comparison



Discussion

- Multivariate pattern analysis can give us a better sensitivity compared to conventional massive univariate analysis

- It is possible to harness very fine-grained information from the patterns of brain activities (recall orientation column), across different brain regions or different cognitive processes

- However, it's sexy & trendy but not always necessary
  - Computationally expensive, & proper design is needed
  - A classifier is a "black box"
  - Why go for all the troubles when univariate analysis had already shown robust results?

Questions & Comments