

Multi-voxel pattern analyses

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Univariate versus multivariate analyses

Traditional: univariate or 'uni-voxel' analyses

- **GLM is estimated for each voxel separately**
- **Nearby voxels are treated as being similar:**

Mostly in two ways:

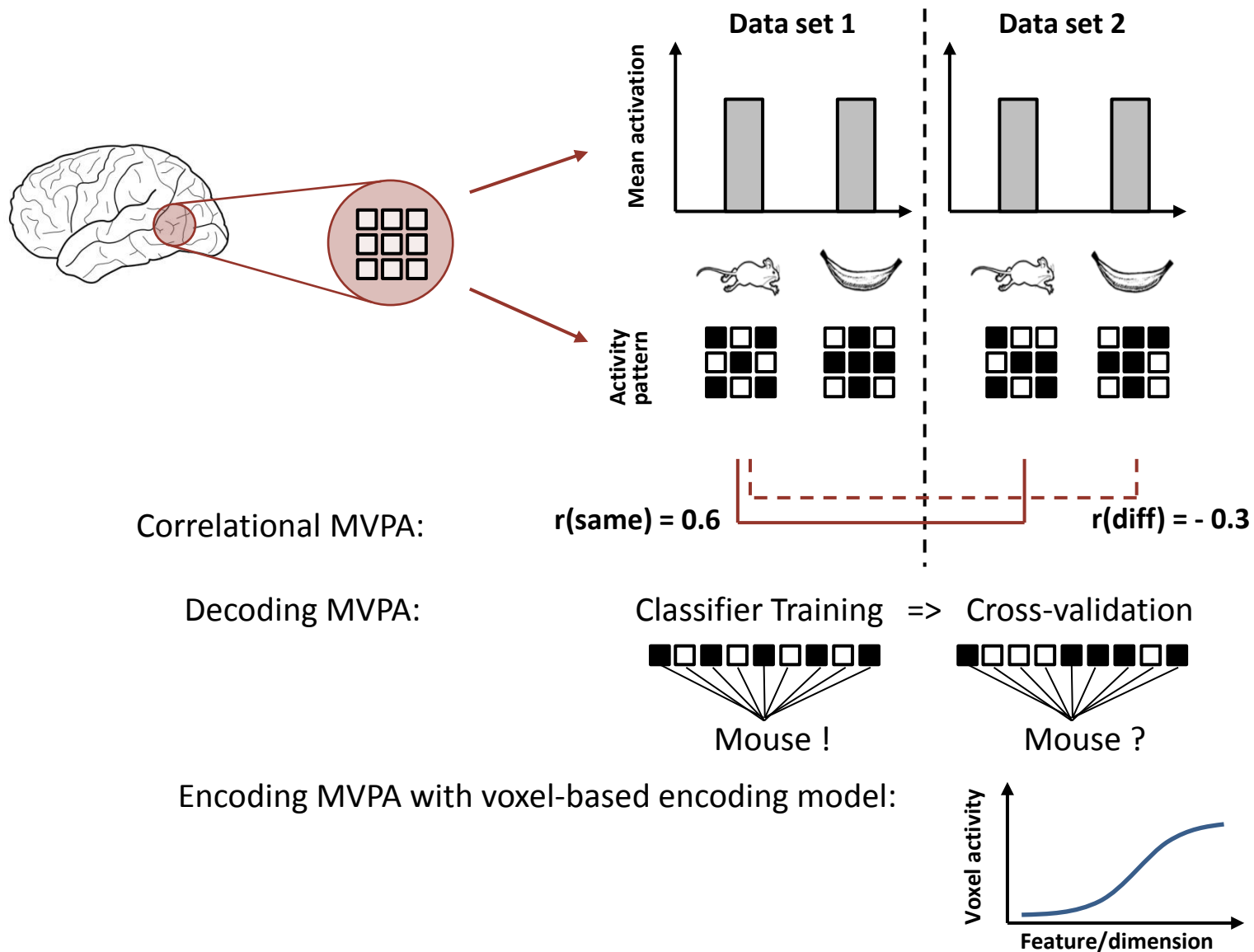
1) Gradual: Smoothing

2) All-or-none: average of ROI

Here: multivariate or multi-voxel analyses:

- **Search for differences between voxels**
- **What is the spatial pattern of the differences between voxels?**

MVPA comes in different flavors

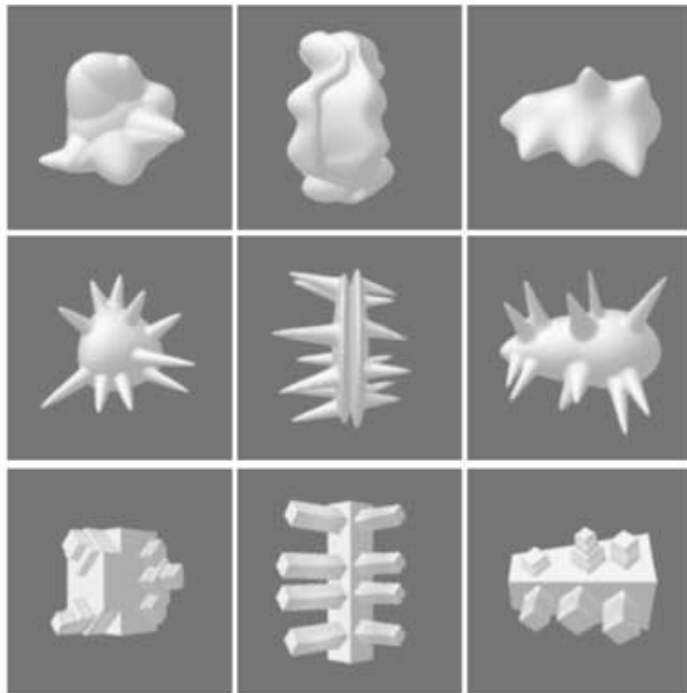


Overview of this lecture

- 1) Correlational MVPA**
- 2) Decoding MVPA
- 3) Encoding MVPA
- 4) Multiple scales: From ROIs to whole-brain
- 5) Interpretation of MVPA results

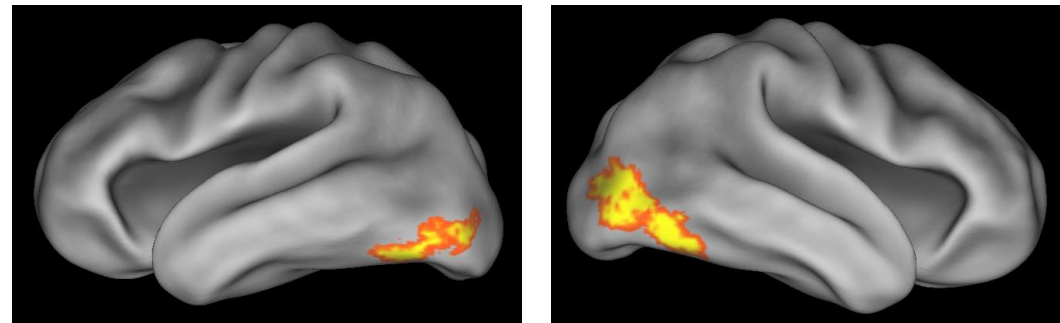
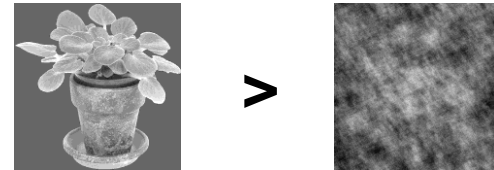
MVPA example: Object selectivity

Shape envelope



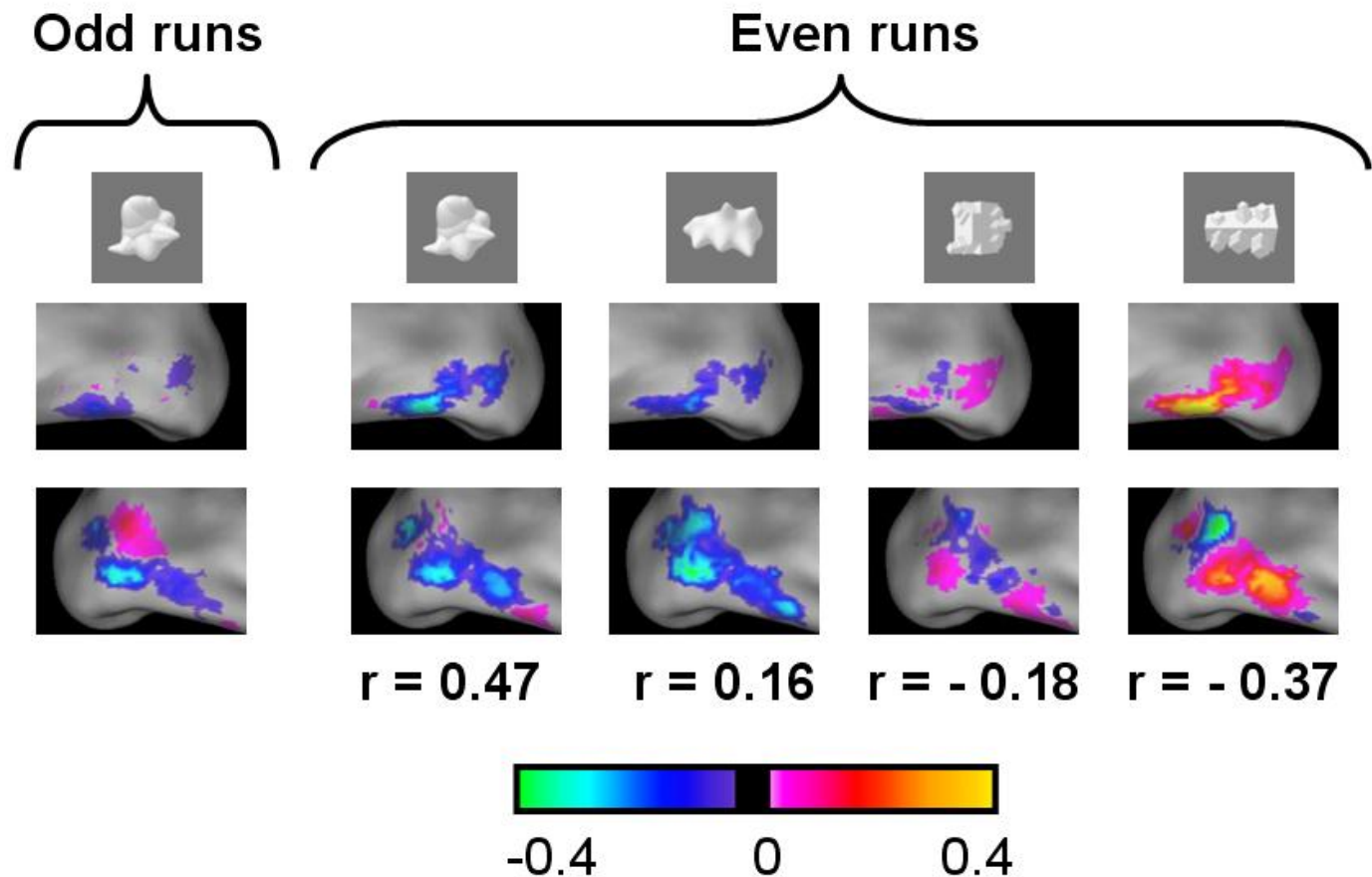
Activated region:

Lateral occipital complex



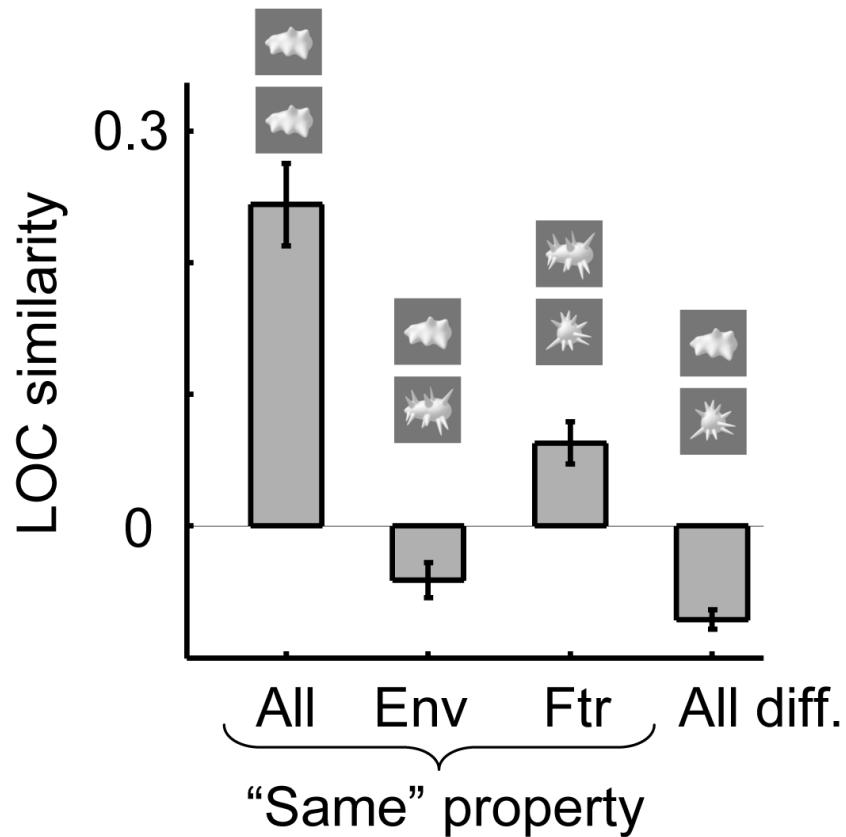
MVPA: From objects in general to specific types of objects

Selectivity patterns, without statistical thresholding:

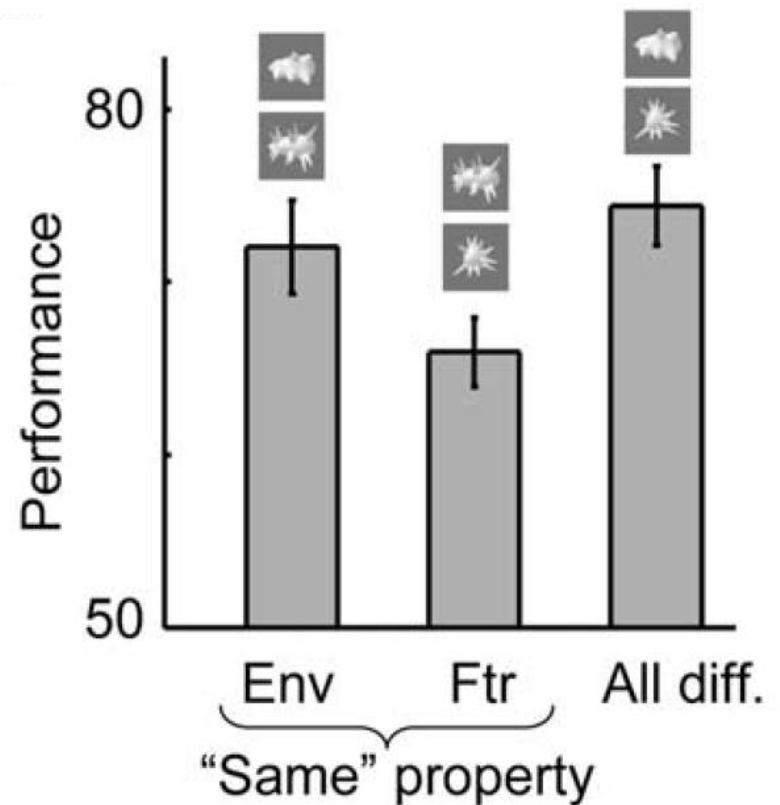


Correlational and decoding MVPA

Correlational MVPA:

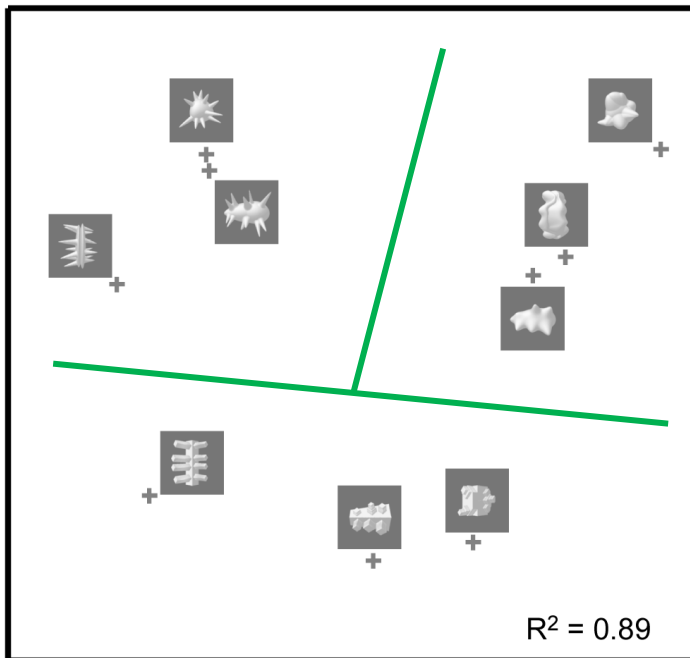


Decoding MVPA:

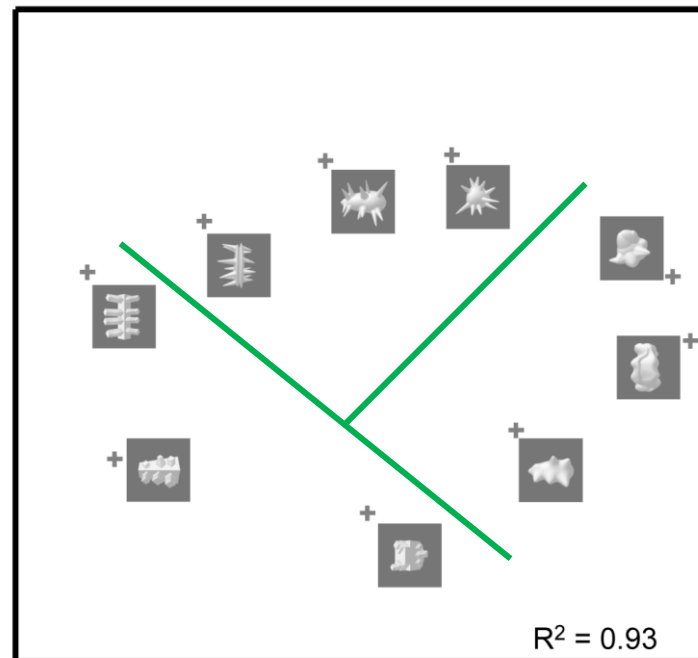


Potential of MVPA for testing psychological theories

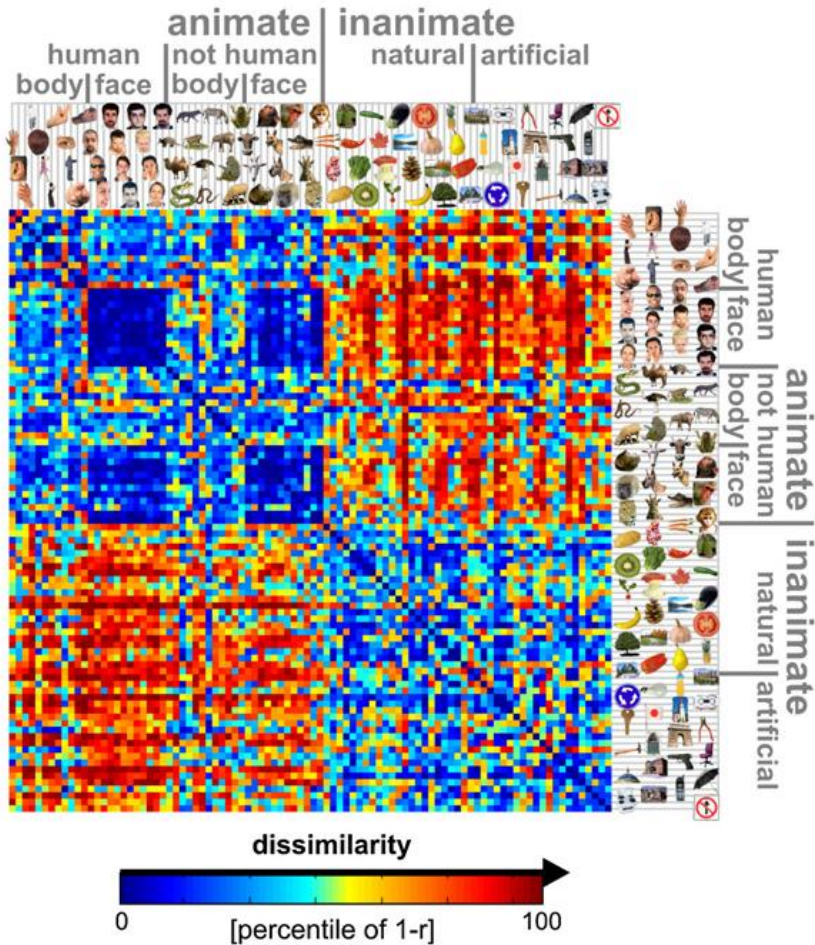
Perceptual space:



Neural/fMRI space:



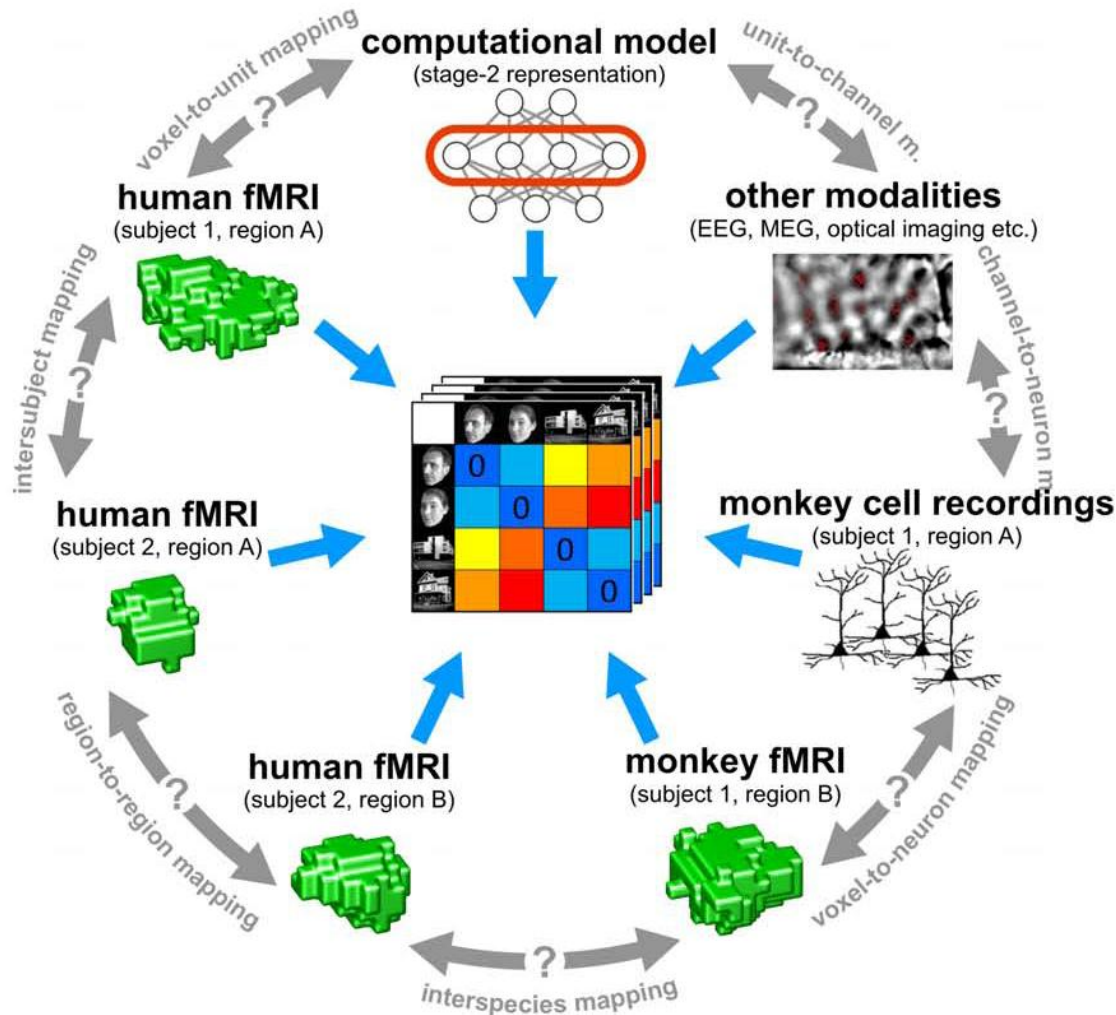
Multi-condition experiments



Kriegeskorte et al., 2008, Neuron

Note: Multi-conditions works by averaging across matrix cells!

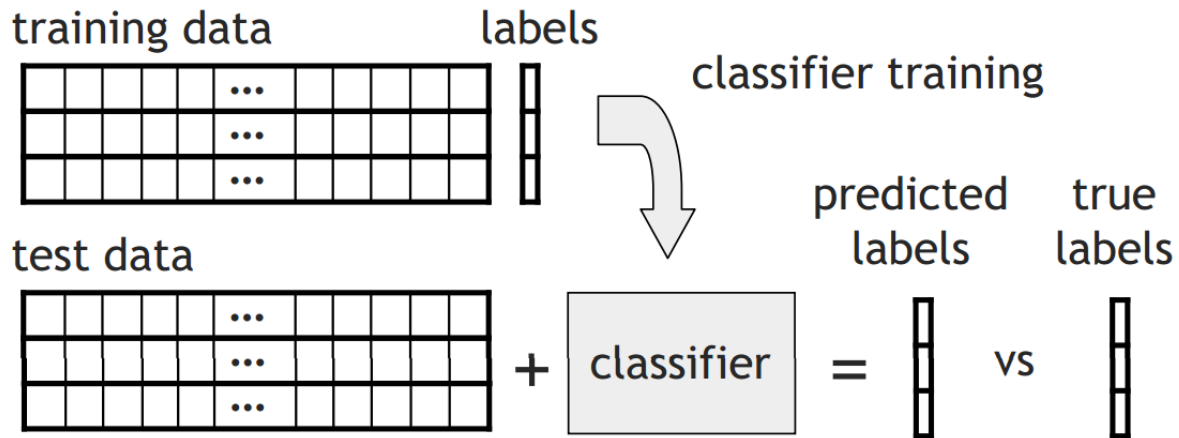
Representational dissimilarity analysis



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Decoding MVPA



What do you want?

Engineers:

The higher the decoding performance, the better.

Neuroscientists:

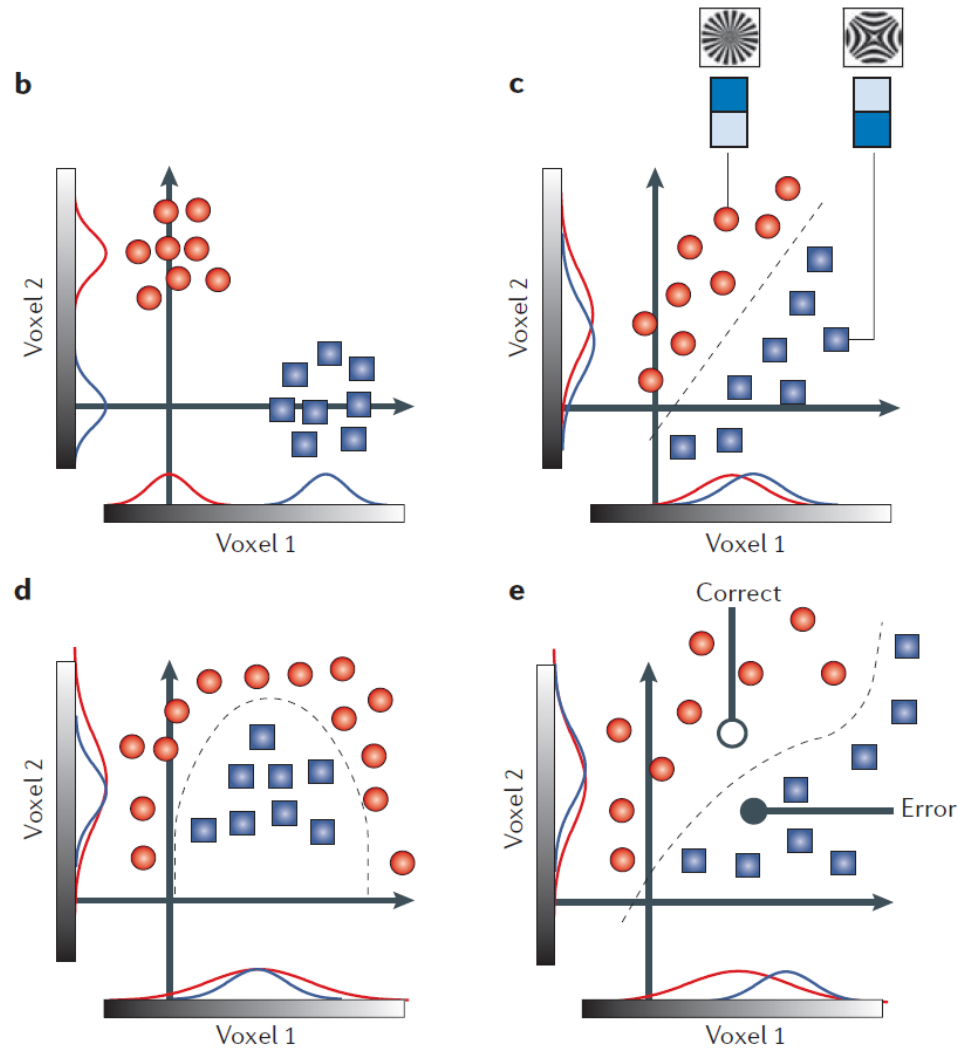
The easier the results can be interpreted, the better.

The two perspectives are not fully independent, but still different!

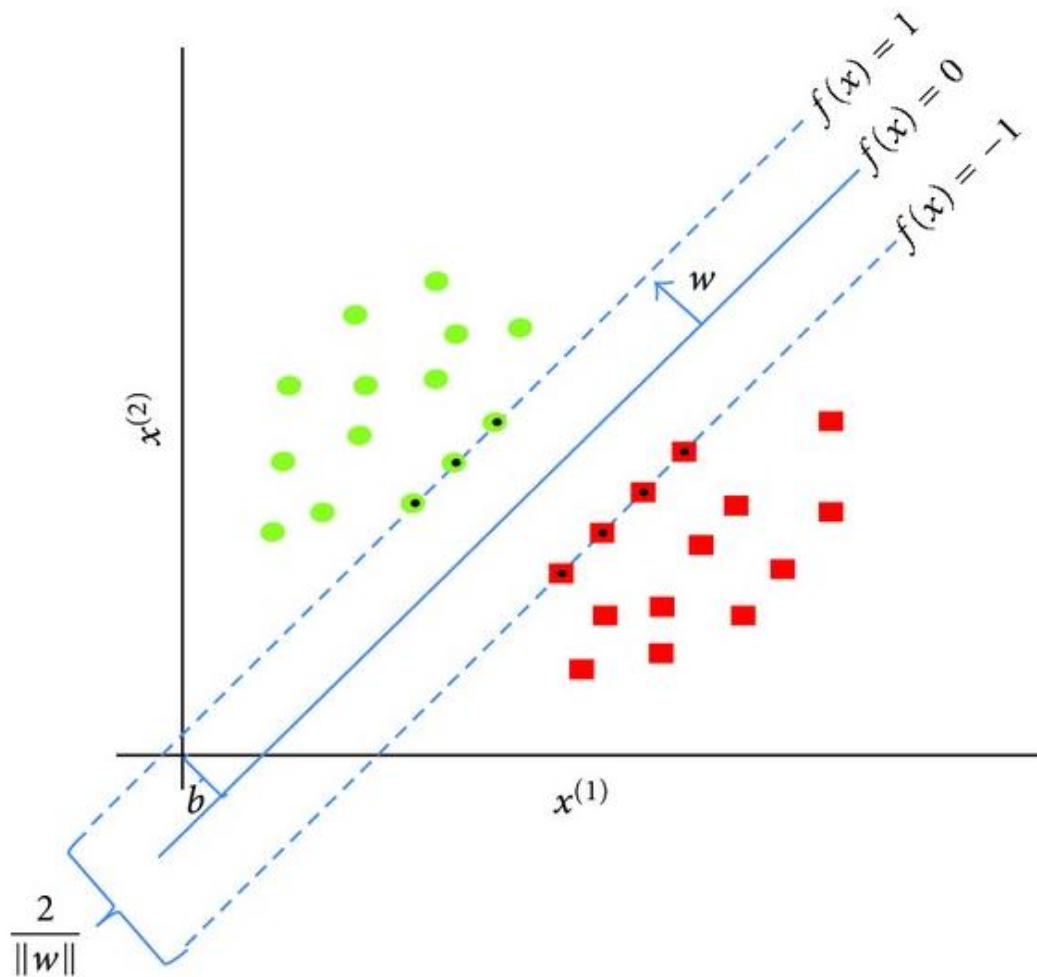
Considerations for decoding MVPA

- **Linear and nonlinear classifiers**
- **Different algorithms to model the decision boundary**
 - **Fisher linear discriminant**
 - **Support vector machines**
 - **Neural networks**
 - **...**
- **Regularization and overfitting**
- **Cross-validation (e.g., *nrRun* times leave-one-run-out)**
- **Feature extraction (GLM; ROI; training/test cycles)**
- **Optimization**
- **Statistical significance? (chance level; permutation tests)**

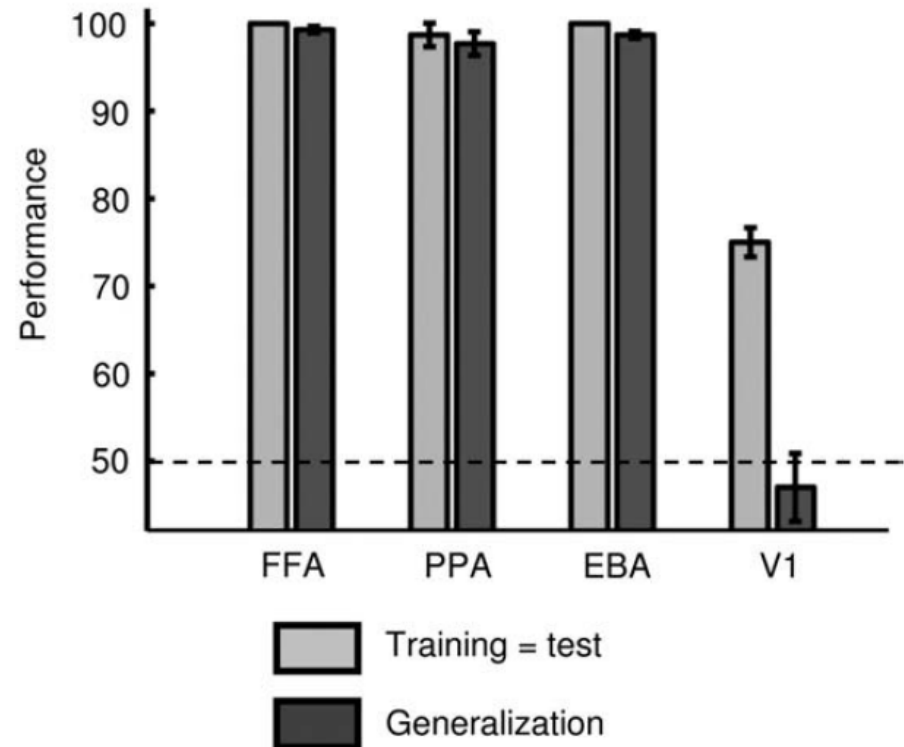
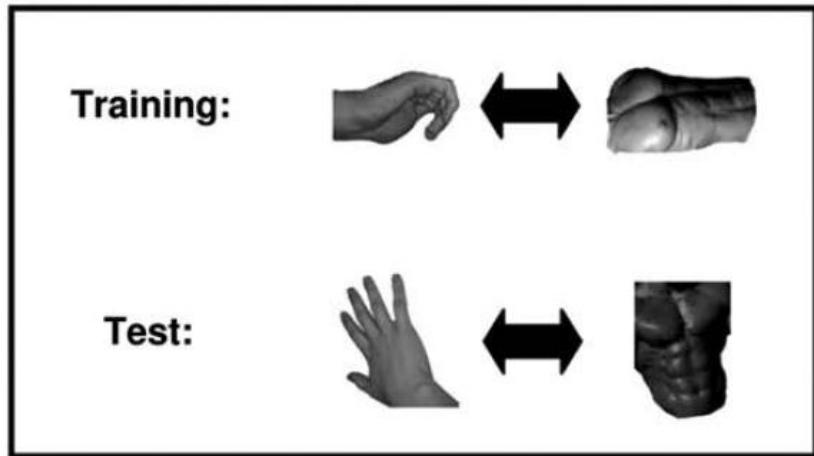
Which type of decision boundary?



Linear support vector machines

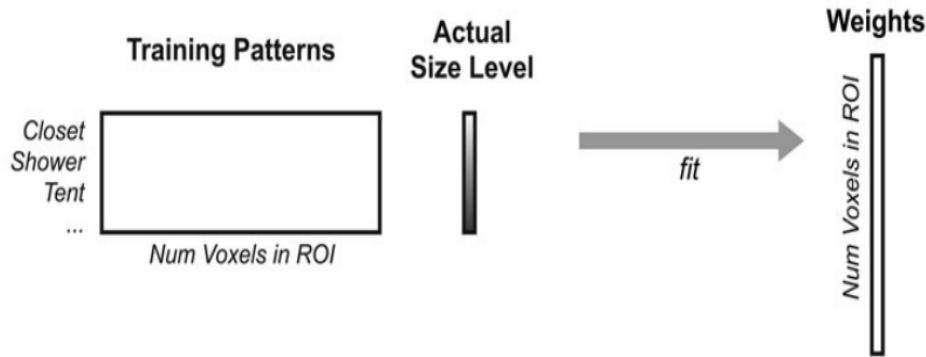


From classification to generalization

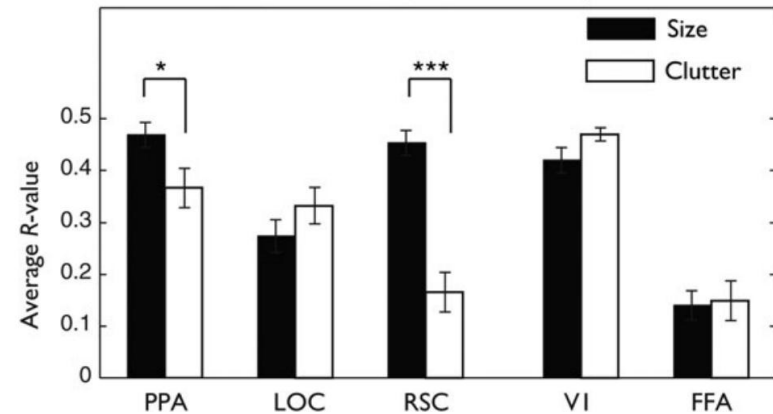
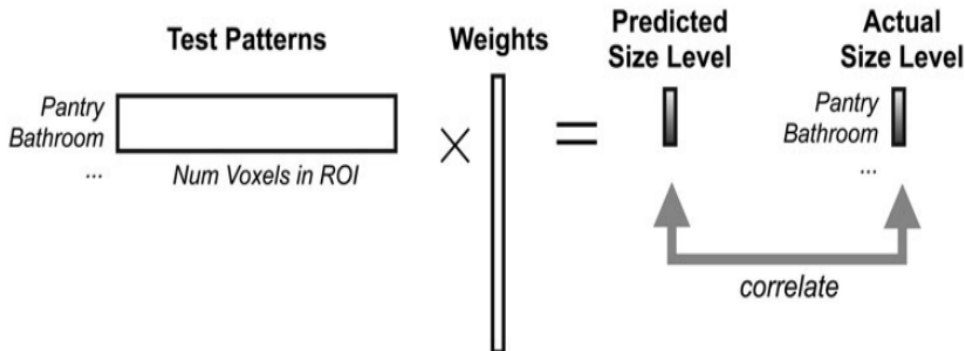


From classification to regression

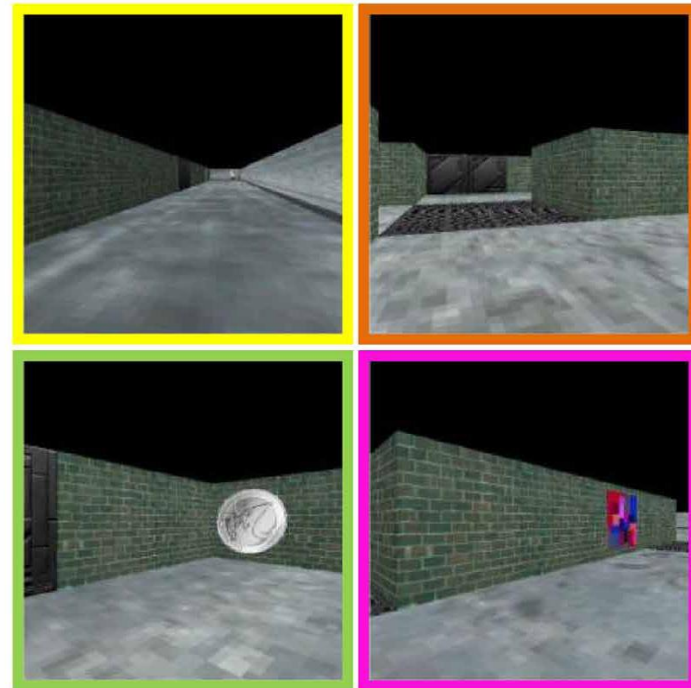
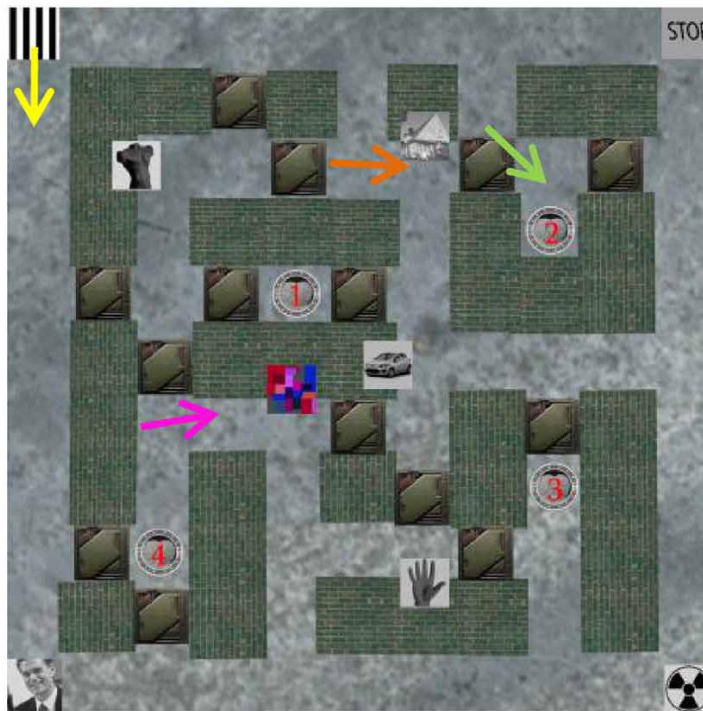
Train: Use the patterns from 30 scene categories (train data) and the actual size levels to fit model (weight vector)



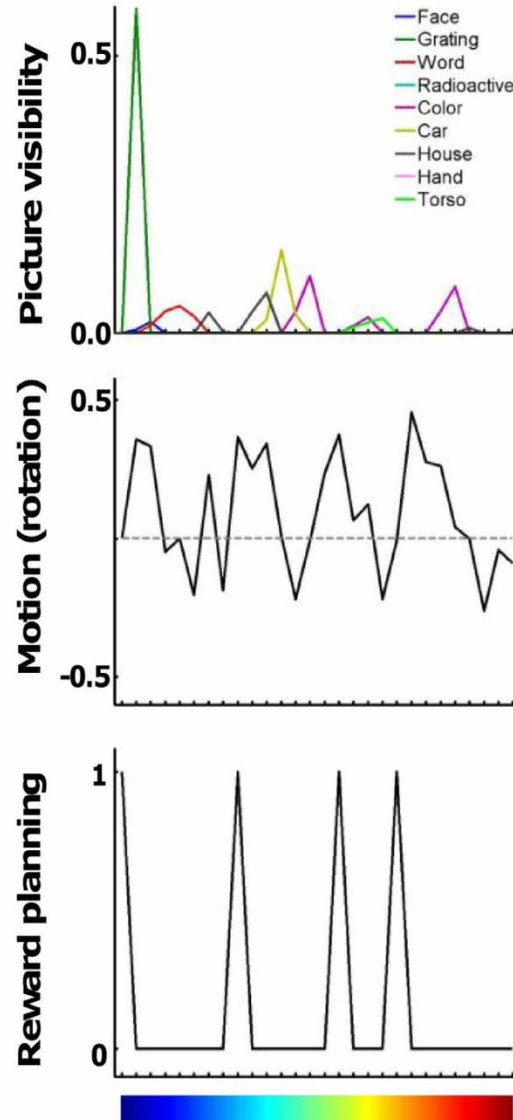
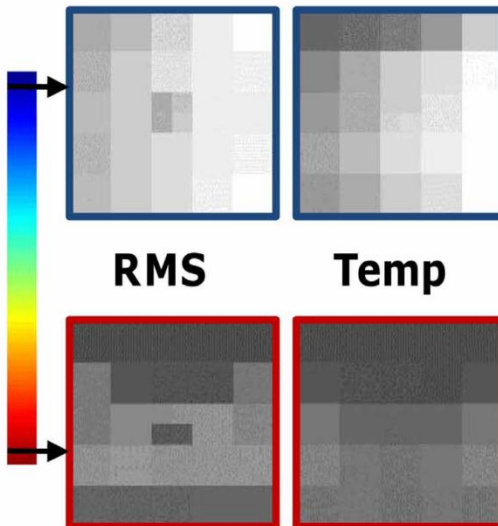
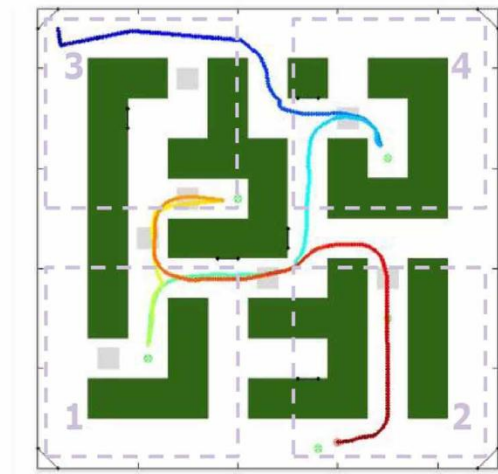
Test: Use model to predict the size levels of the 6 remaining scene categories (test data), and correlate with the actual size levels to assess model performance



Combinatorial brain decoding: Cutting a complex problem into pieces



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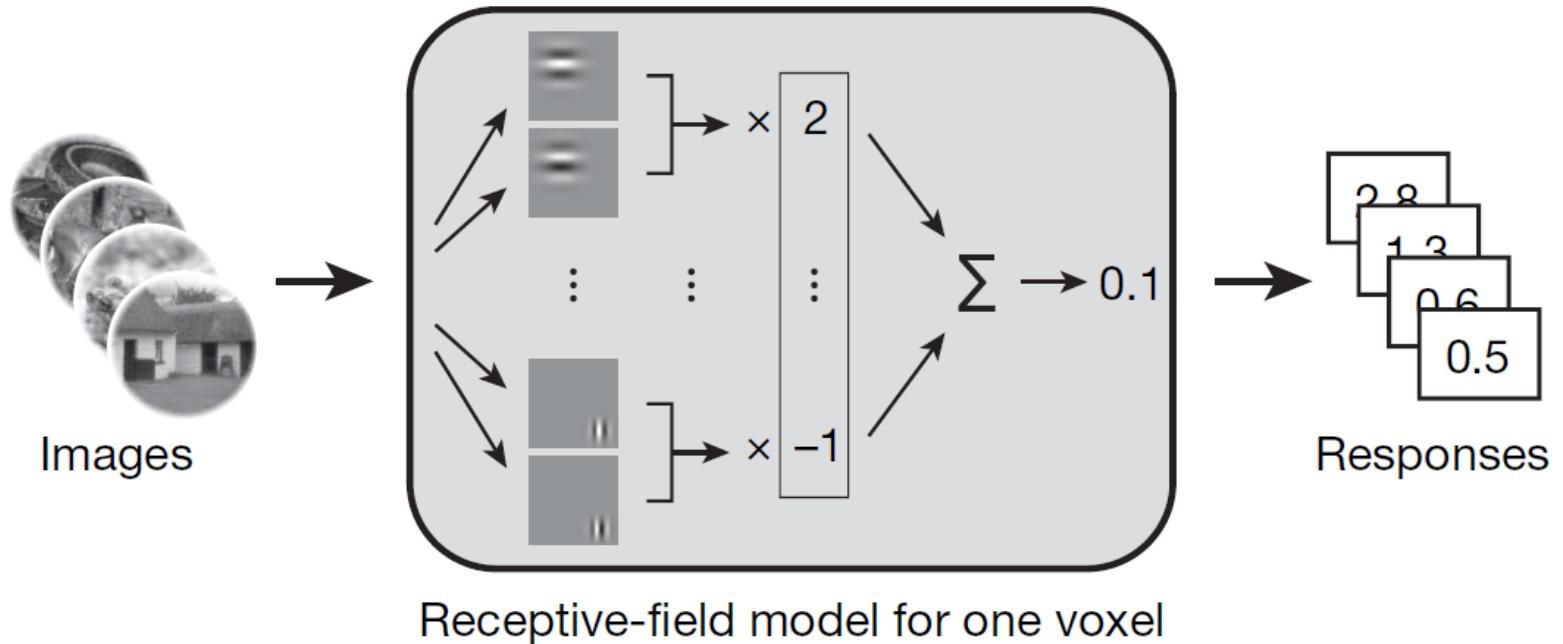
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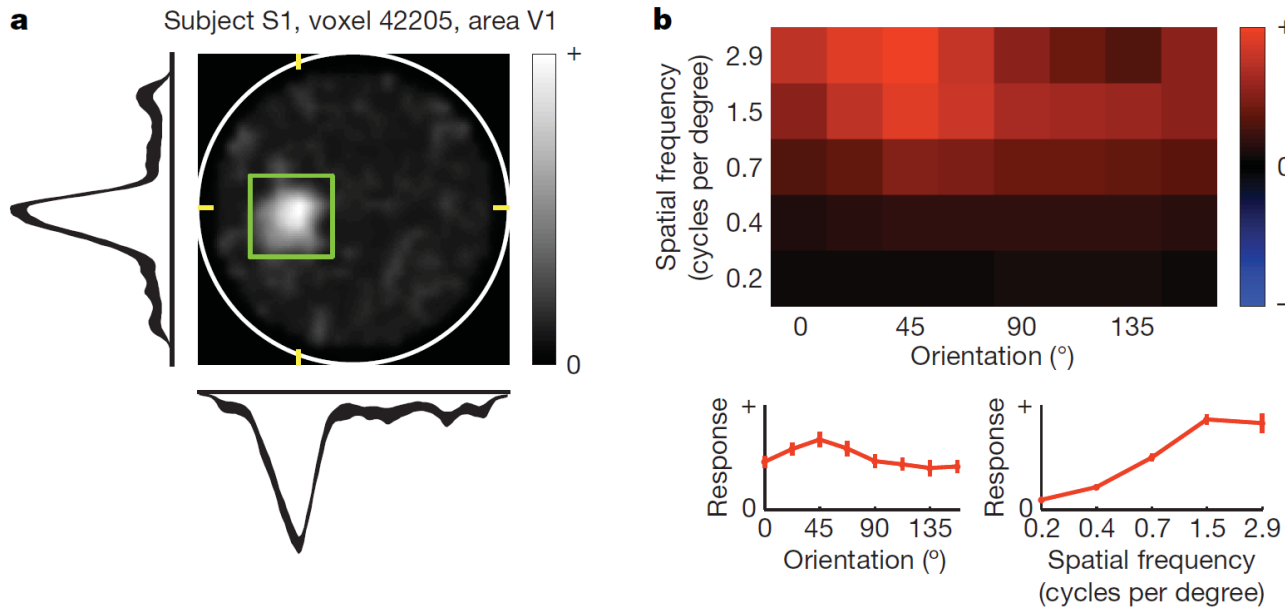
Example of encoding MVPA

Stage 1: model estimation

Estimate a receptive-field model for each voxel



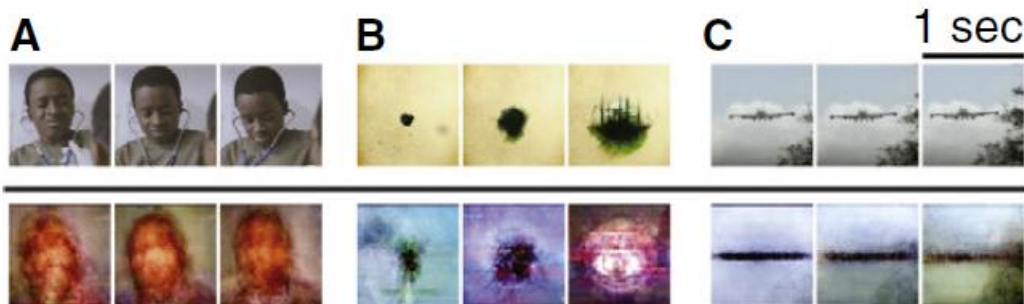
Examples of encoding MVPA



Kay et al., 2008

Presented movies

Reconstructed movies (AHP)

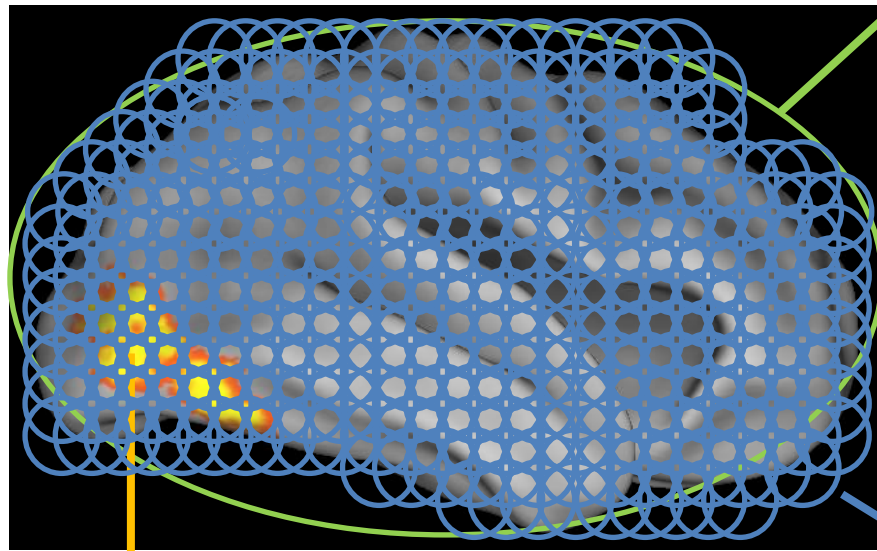


Nishimoto et al., 2011

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Multiple scales of MVPA



Whole-brain or very large ROI
- Feature selection?
- Functional contrast?
Search for distributed info

'Typical' ROI or area

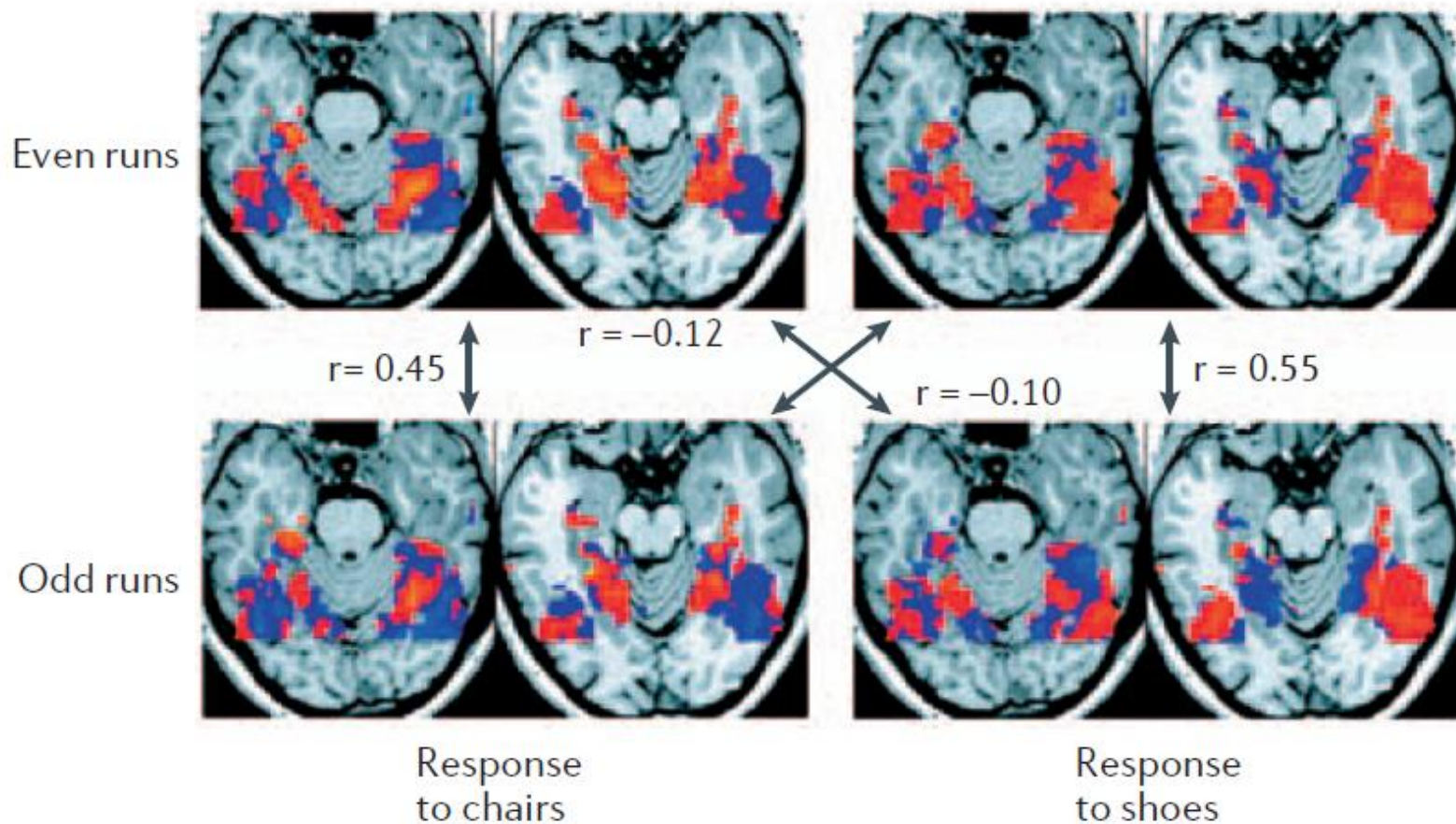
Searchlight analysis
- Whole-brain or large ROI
- Statistical threshold?
Search for very local info

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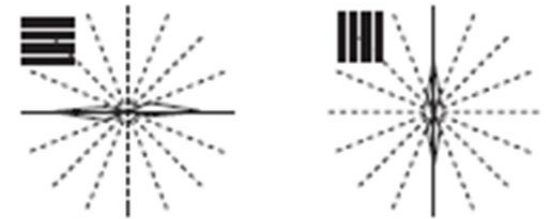
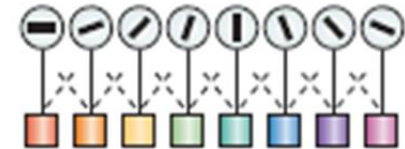
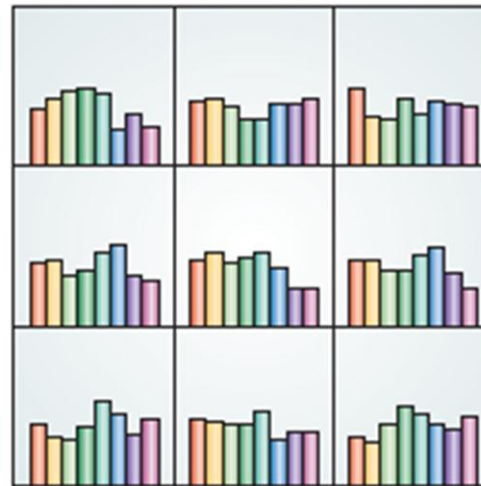
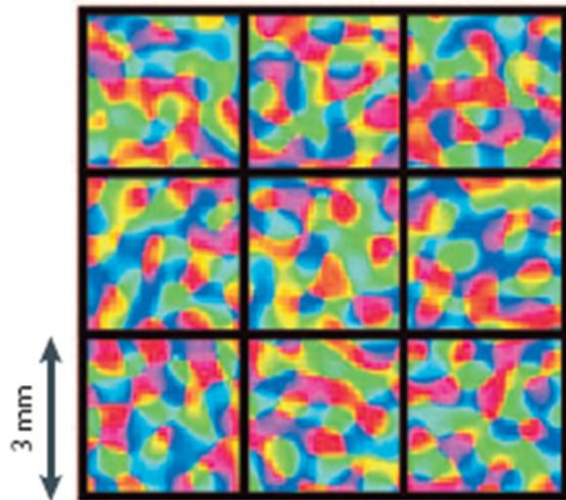
What do we measure with MVPA?

Large-scale, distributed maps:



What do we measure with MVPA?

The idea of hyperacuity: Investigation of fine-scale organization

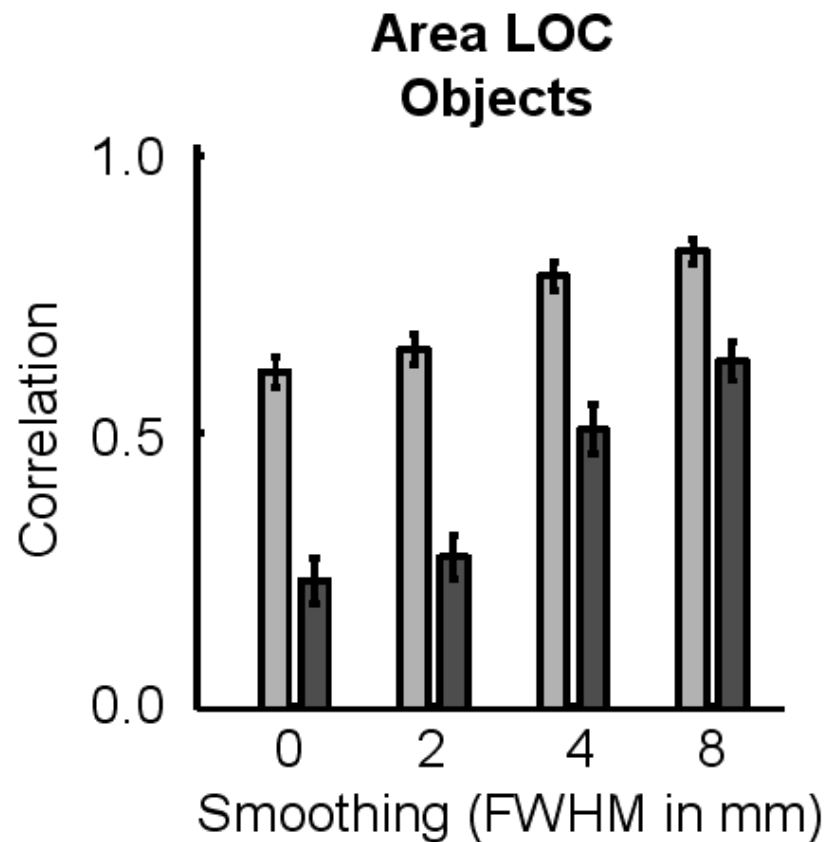
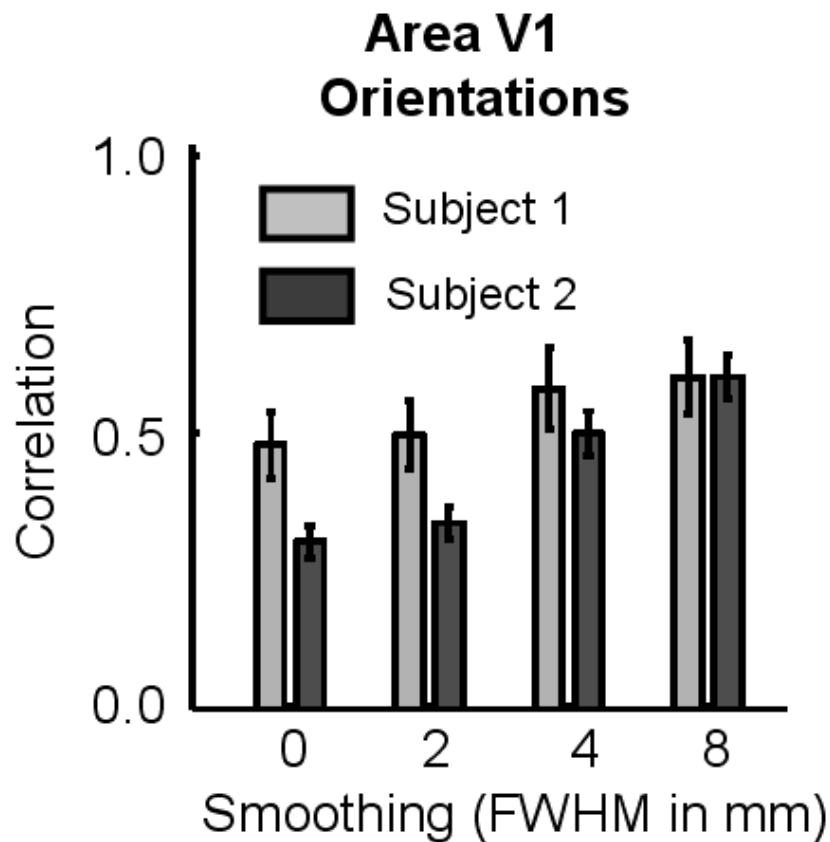


Haynes & Rees, 2006; Kamitani & Tong, 2005

Many researchers assume/hope that this is true.

Choice during analysis: no spatial smoothing.

Effects of spatial smoothing make us doubt to what extent hyperacuity underlies MVPA



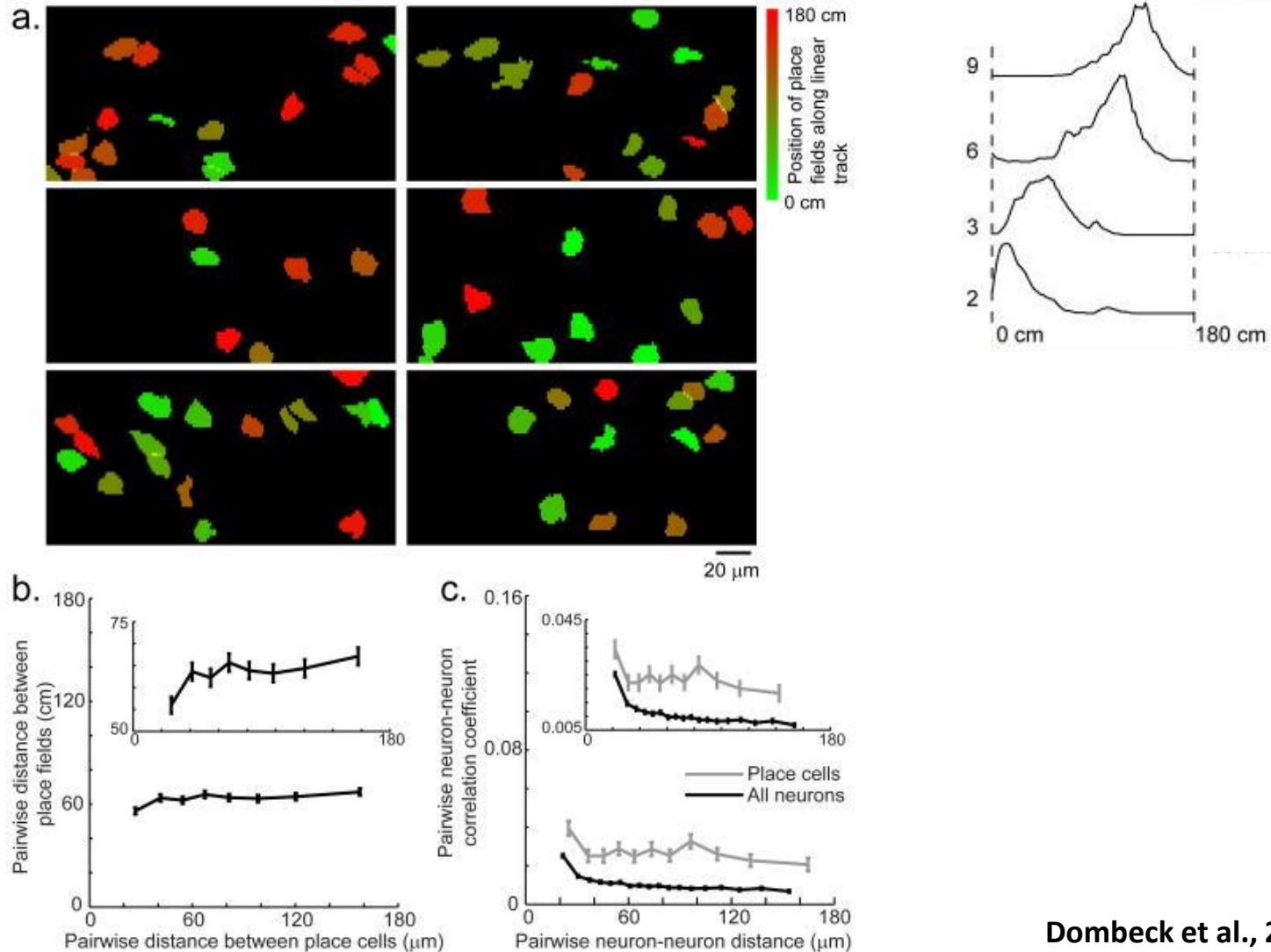
MVPA depends upon clustering

**MVPA is a good measure of selectivity at the level of single neurons
(neurally the most relevant scale!)**

IF AND ONLY IF

Clustering at the large scale is related to single-unit selectivity

Dissociations between selectivity and clustering: Example of hippocampus



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