Introduction to MVPA

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16/03/10

MVP...what?

- Multi-Voxel Pattern Analysis (MultiVariate Pattern Analysis)

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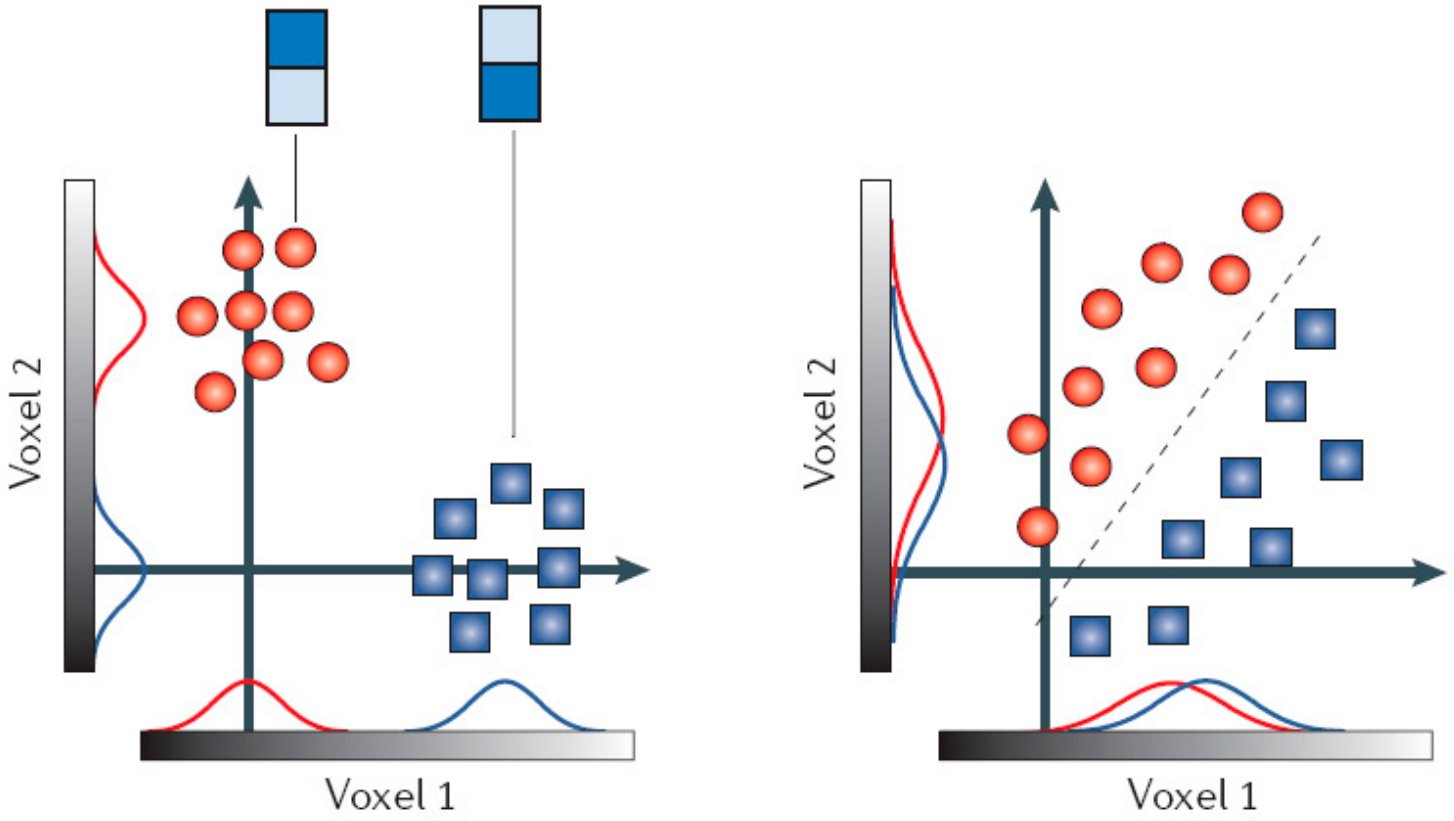
Overview

- Why bother?
- Different approaches
- Basics of designing experiments and analysis for MVPA

Why bother with MVPA?



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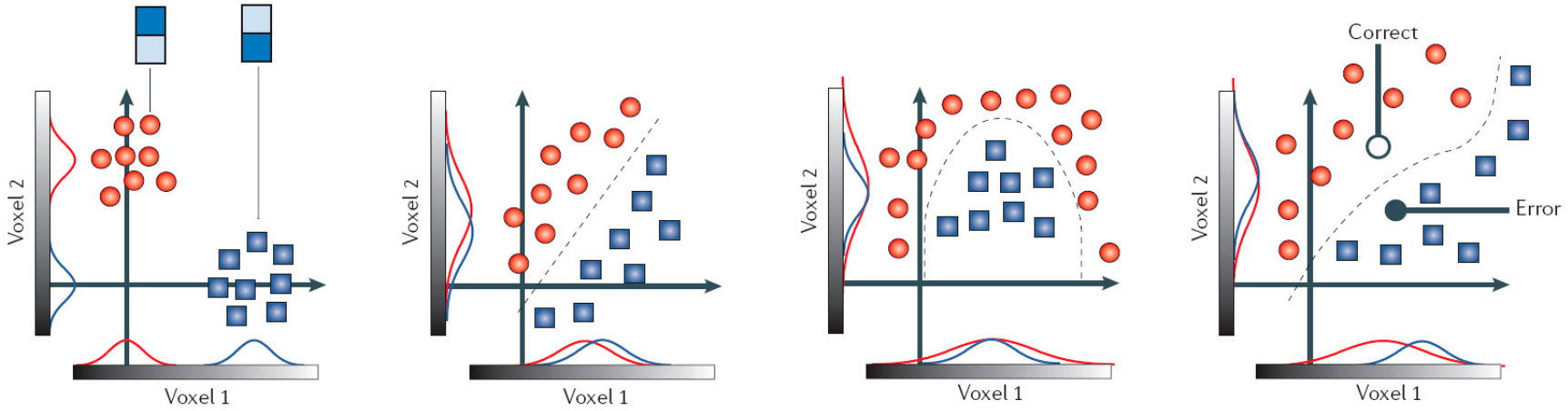

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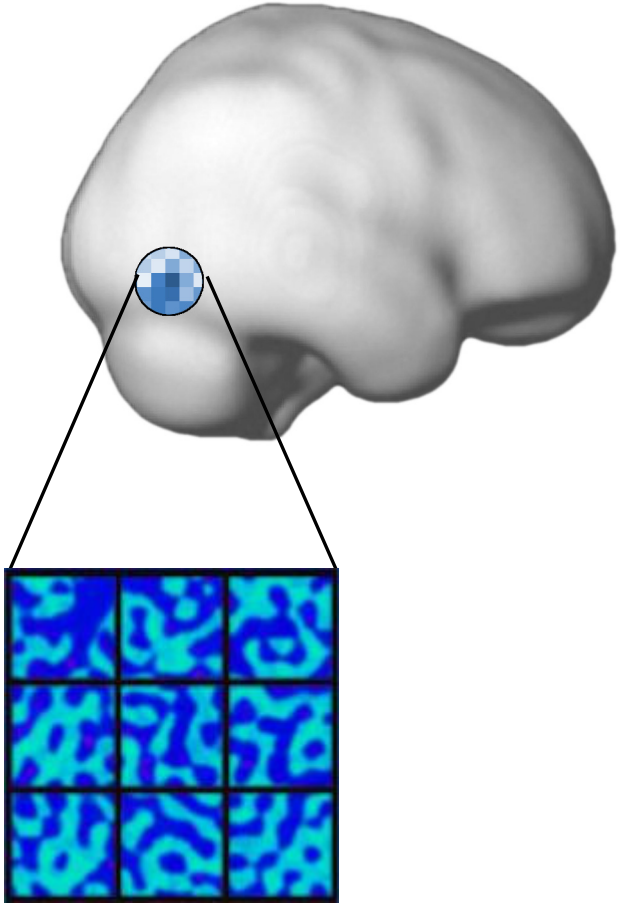

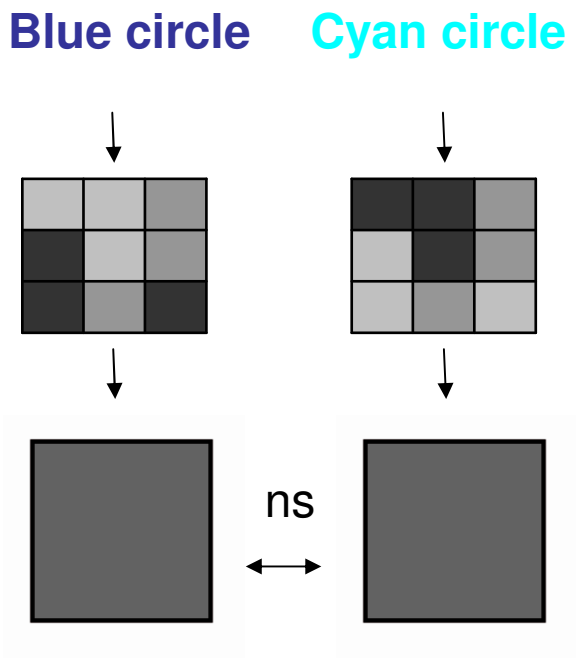

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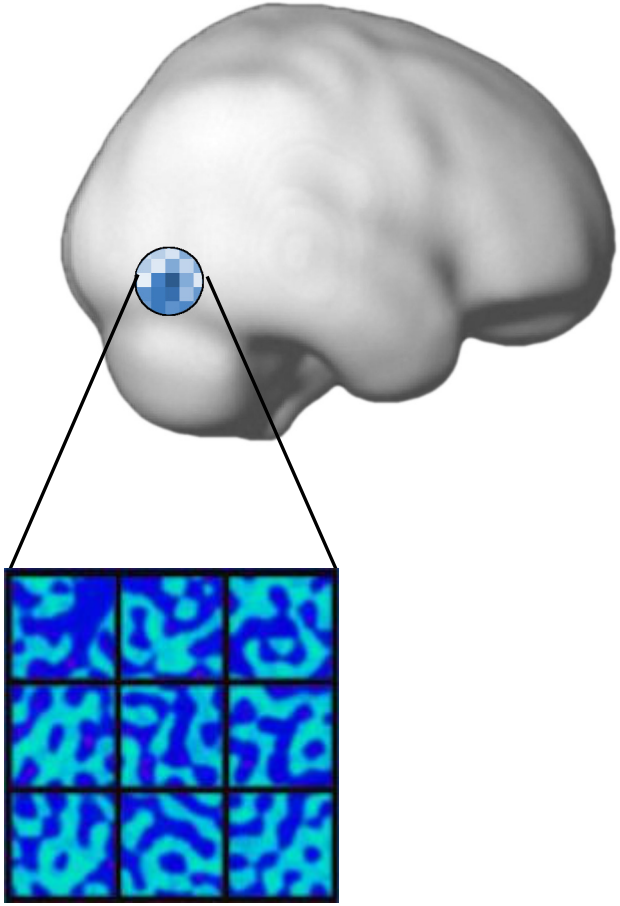

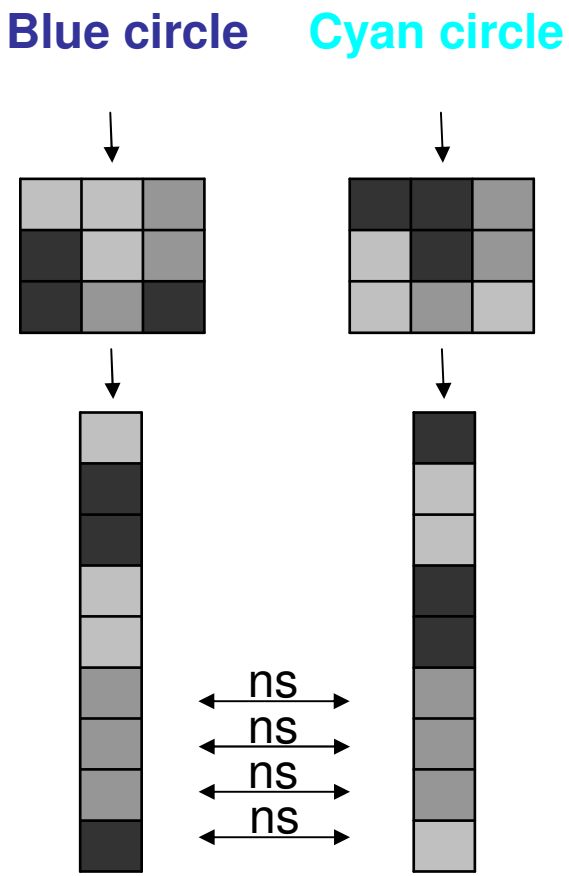

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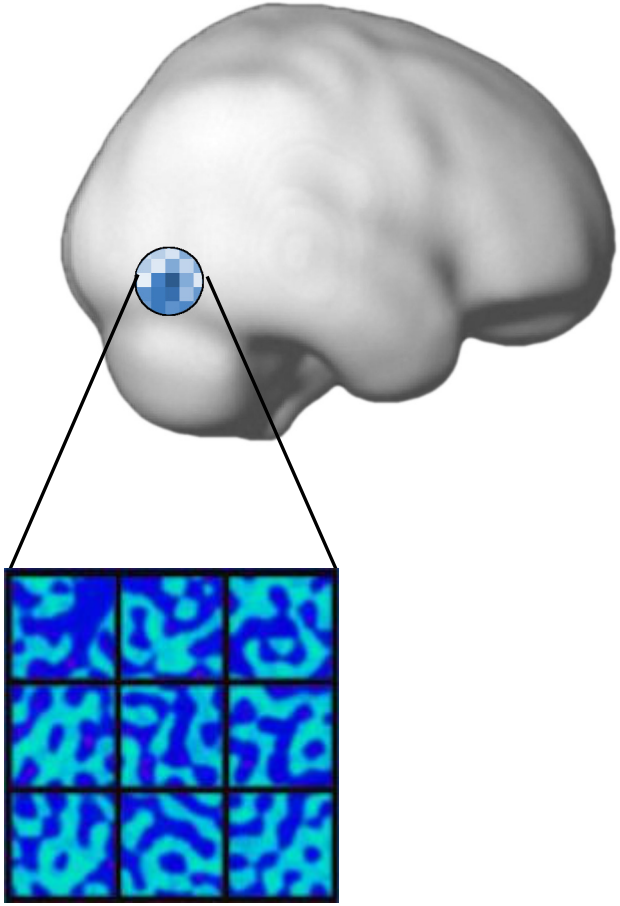
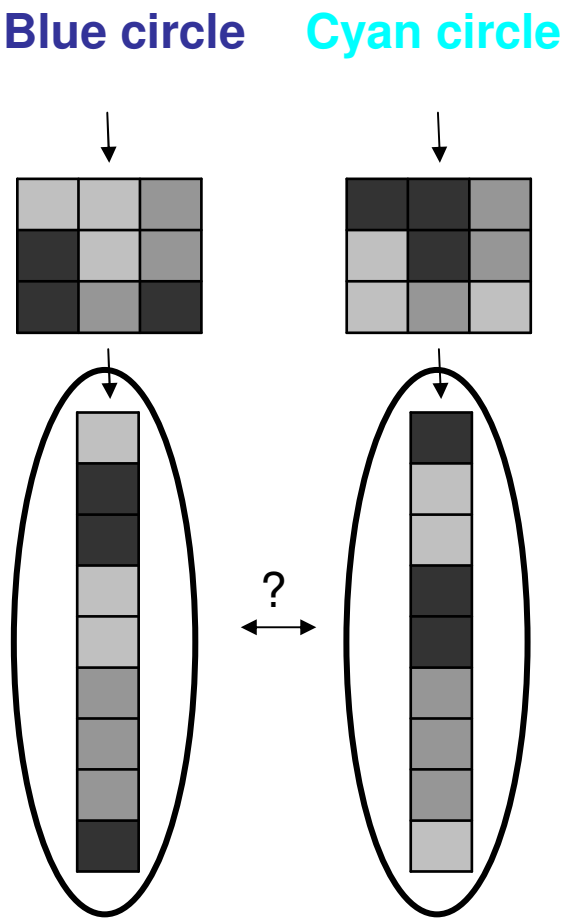
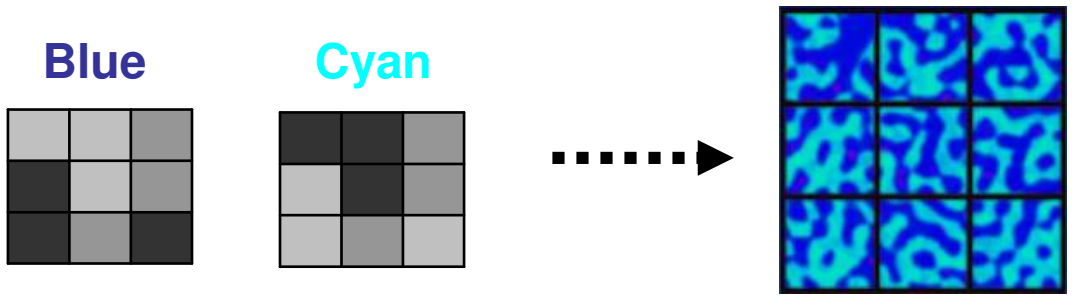




Why bother with MVPA?

- Overlapping representations
- New inferences:
  - Regularities in voxel-wise patterns suggest consistent underlying neural code
  - Beyond “what brain area active in task X?”
  - *What information* represented by patterns of activity in that area?

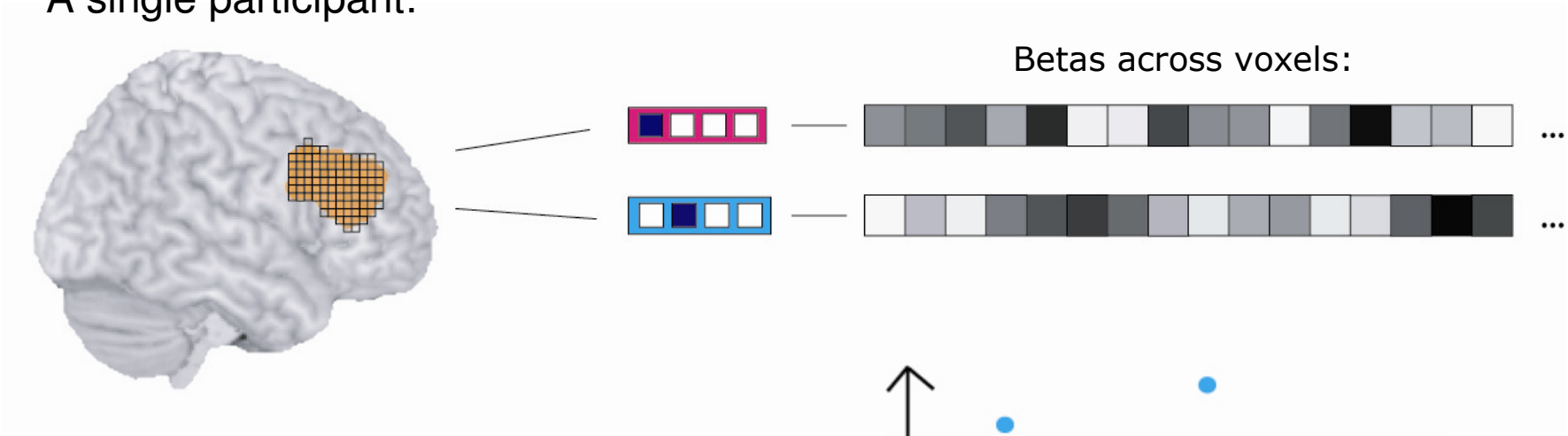


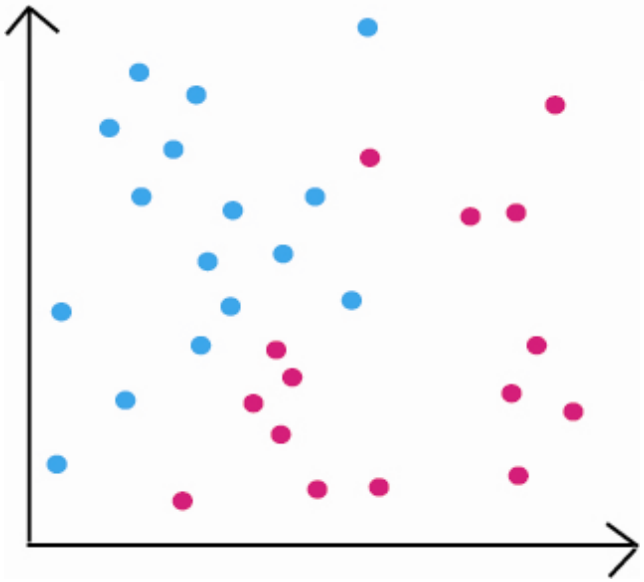
Approaches to MVPA

- Test / Train Classification
- Distance measures

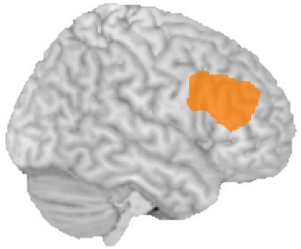
Test / Train Classification

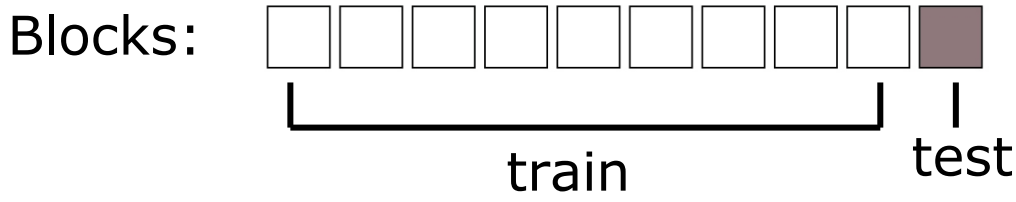
A single participant:

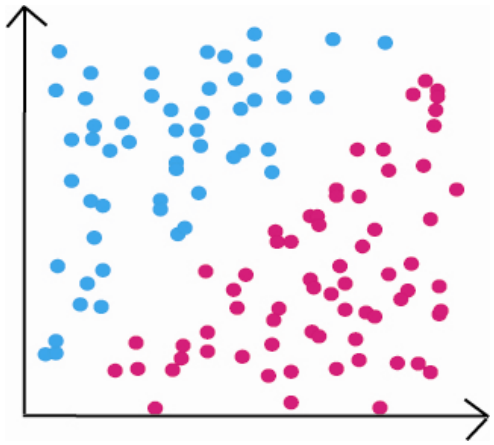




Test / Train Classification







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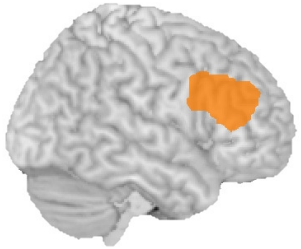

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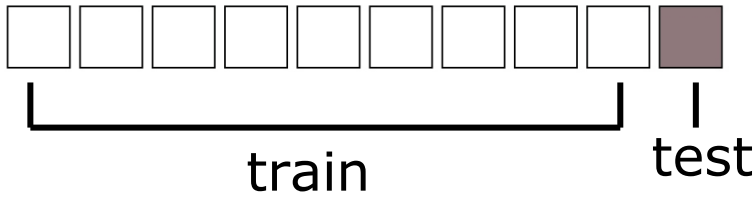
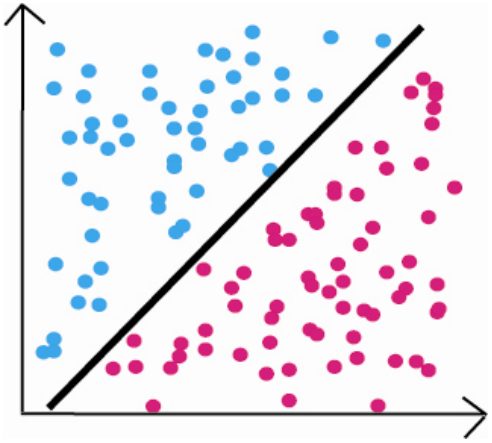


Pattern Classifier:



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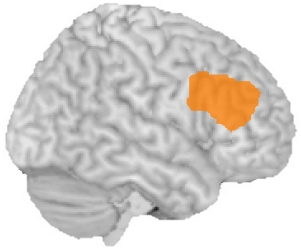

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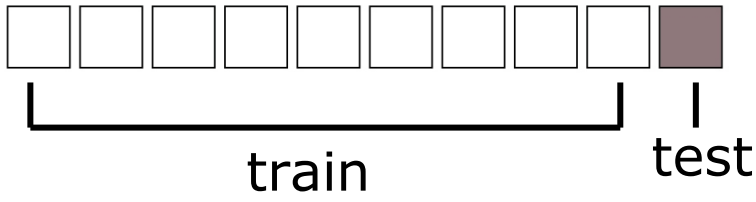

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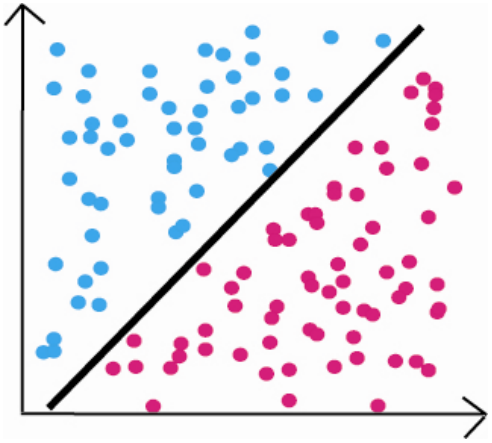

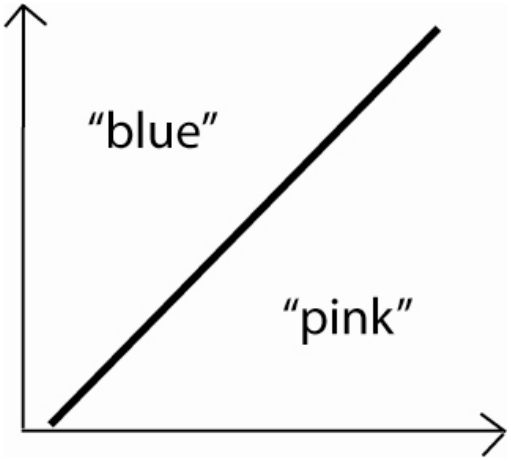

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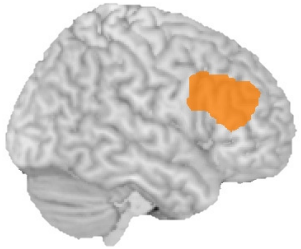

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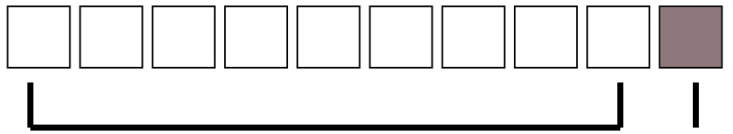
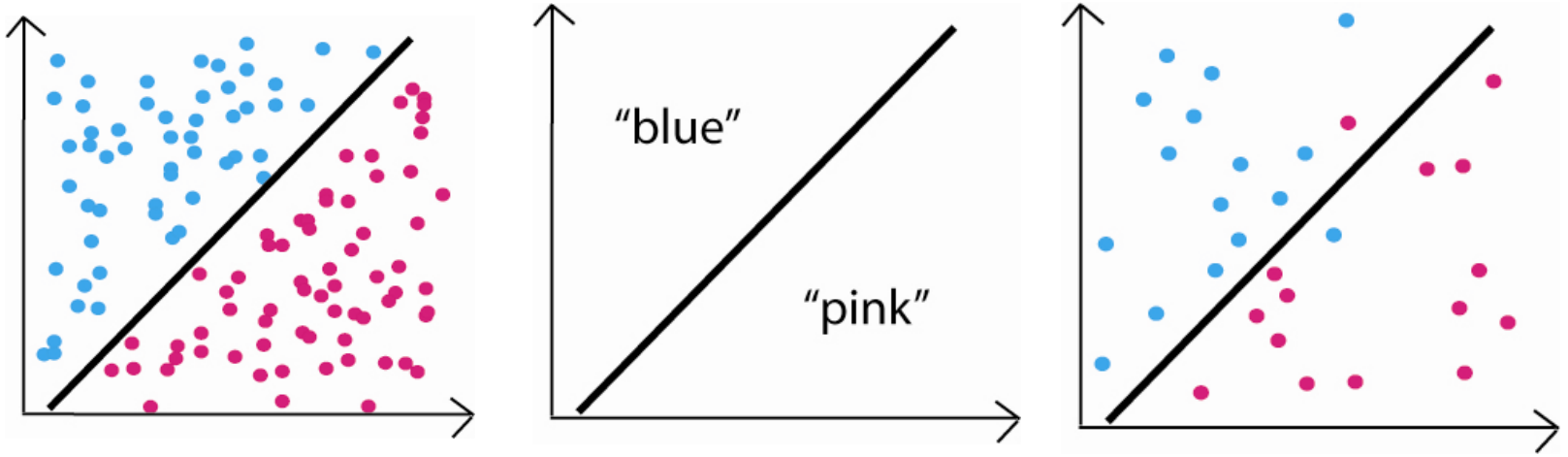


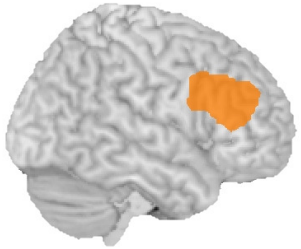
train

test

Pattern Classifier:



Test / Train Classification



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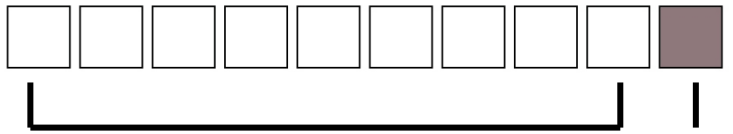

train

test

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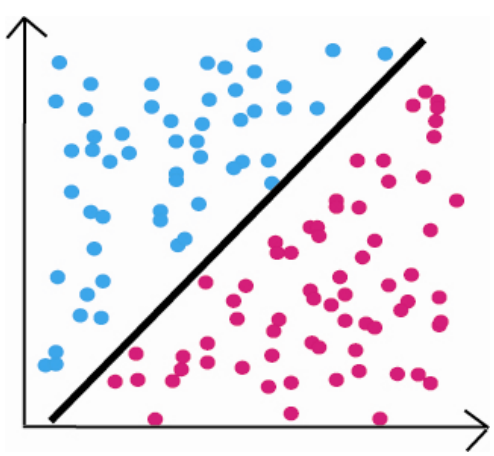

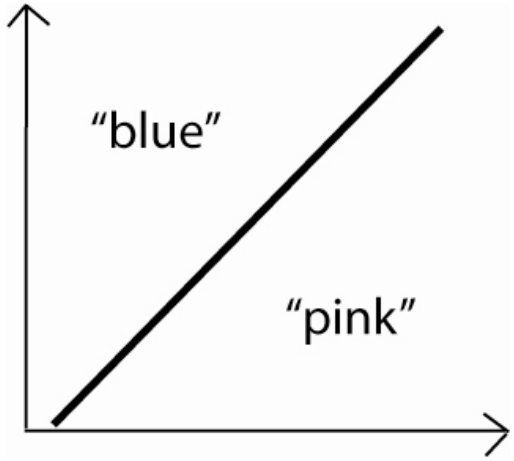

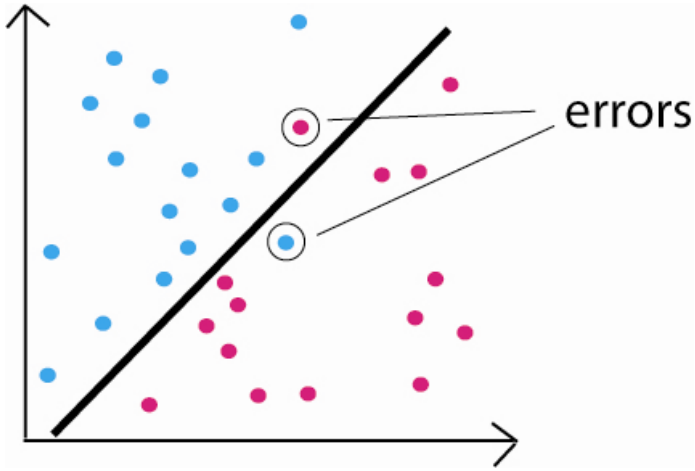

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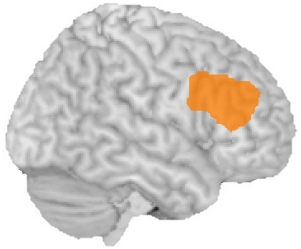
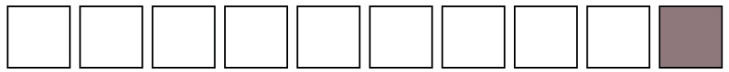
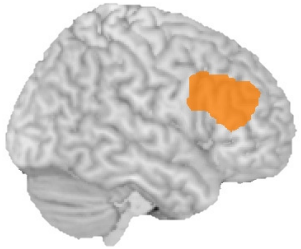


Blocks:  → error score

Test / Train Classification



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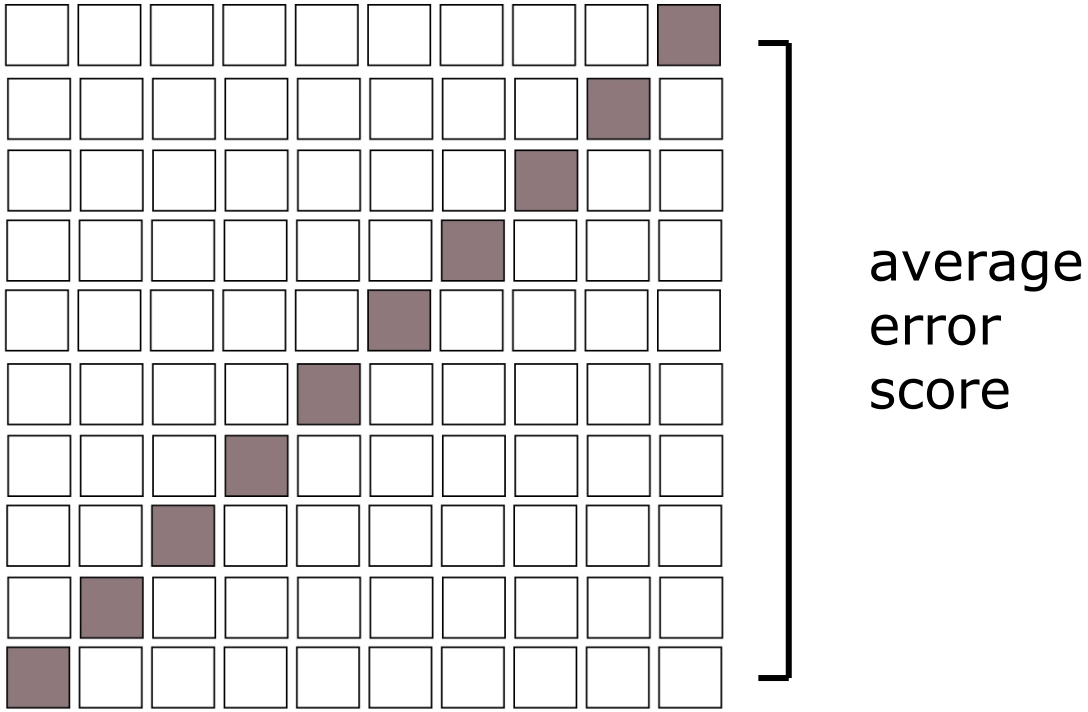


Average error score for this ROI, for this subject, for this contrast (blue vs pink)

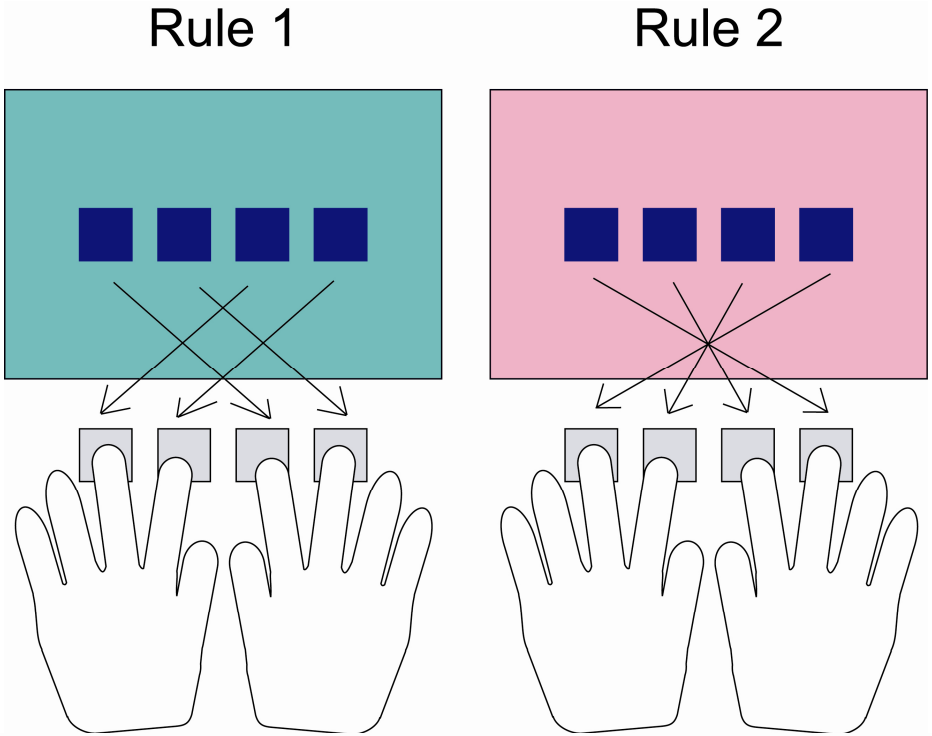
Test / Train Classification

- Significance testing:
  - Average score for each contrast for each subject for each ROI
  - Are the patterns reliable?
    - Is the average classification score greater than I would expect by chance?
    - One-sample t-test across subjects, against 50 %, within each ROI for each effect of interest separately
  - Differences between conditions
    - Paired t-tests, ANOVA etc etc

Test / Train Classification

- Pros:
  - (Fairly) easily interpretable
  - Well established
- Cons:
  - Basically limited to two way discriminations
  - Uses only part of your data at any one time

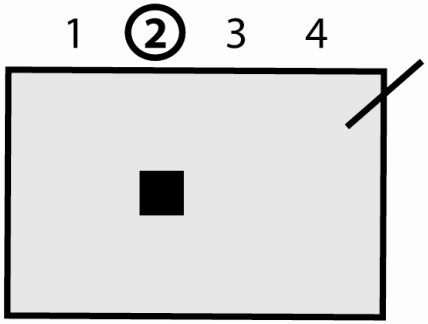
An example…



Rule
Position
Response

* Condition (hard and easy perceptual difficulty)

Stimulus Position:

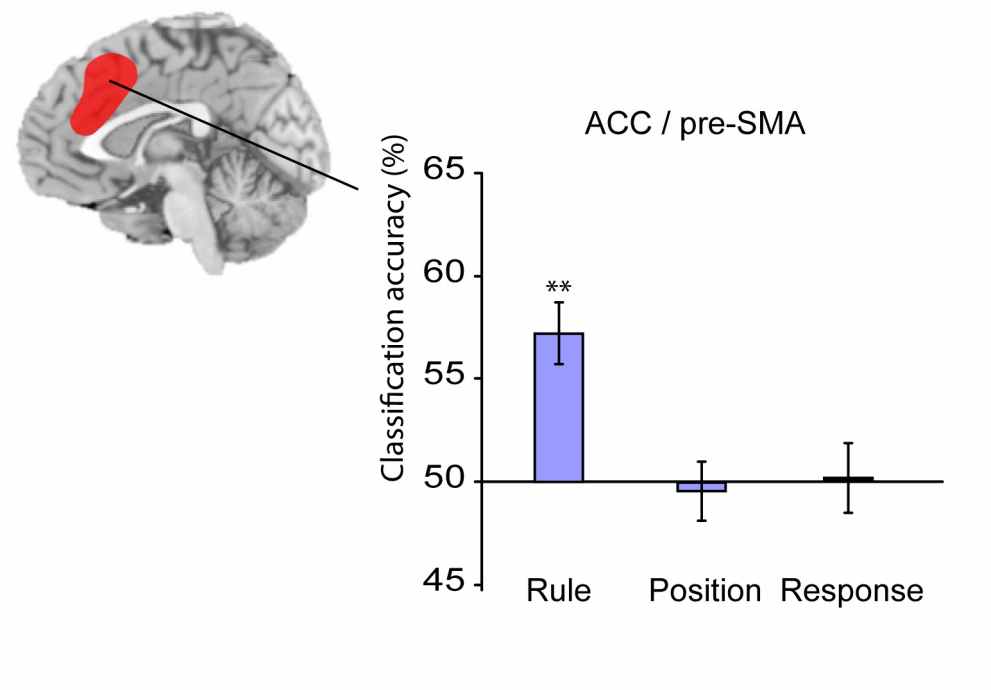


Background colour:

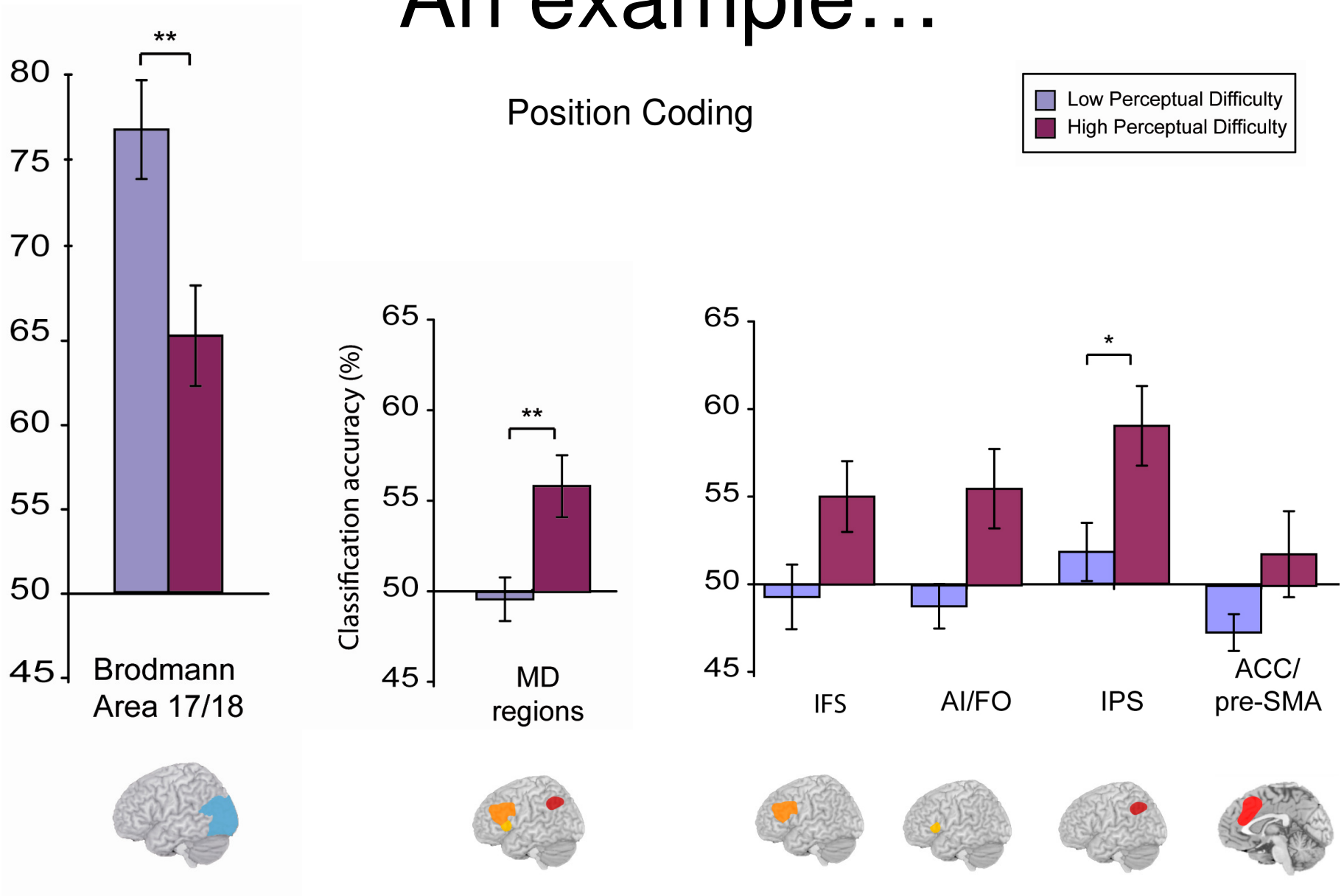
Blue or Yellow → Rule 1 → Response button 4 (right ring finger)

Pink or Green → Rule 2 → Response button 3 (right index finger)

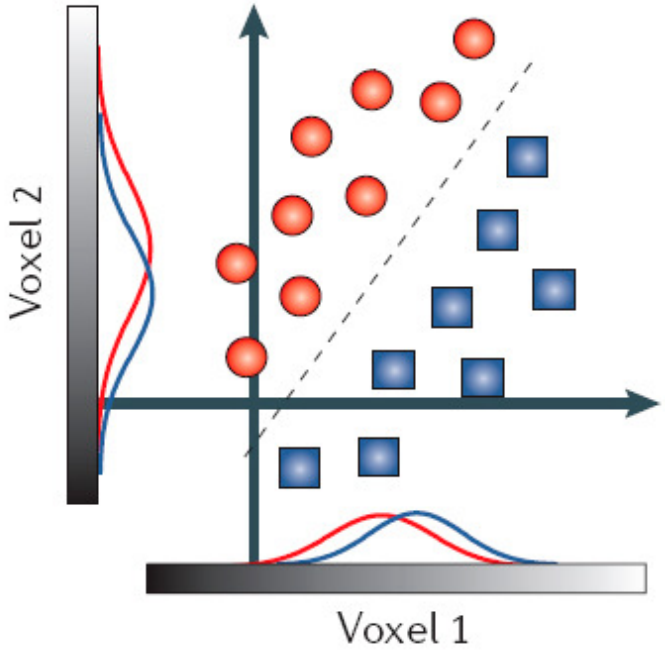
An example…


ACC / pre-SMA
Classification accuracy (%)
65
60
55
50
45
**
Rule
Position
Response

An example…


Position Coding
Low Perceptual Difficulty
High Perceptual Difficulty
Classification accuracy (%)
80
75
70
65
60
55
50
45
**
Brodmann Area 17/18
MD regions
IFS
AI/FO
IPS
ACC/ pre-SMA
*

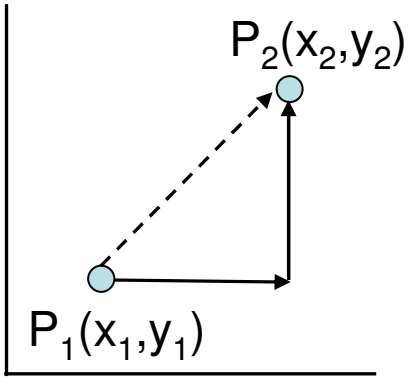
Distances



- Are within condition distances smaller than between distances?

Distances

Euclidean Distance (Pythagorus)



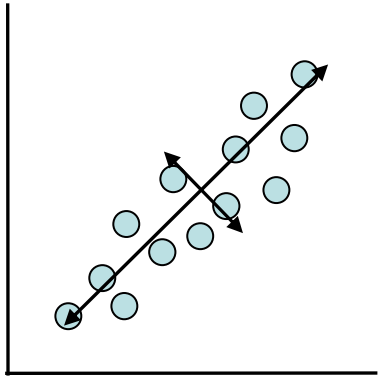
$$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

N dimensions:

$$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 \ldots + (n_1 - n_2)^2}$$

$$= \sqrt{\Sigma(x_i - x_j)^2}$$

Mahalanobis Distance



$$\sqrt{\Sigma\ (X_i - X_j)^2 / \sigma}$$

(where σ is the covariance matrix of errors for the n dimensions)

Correlation

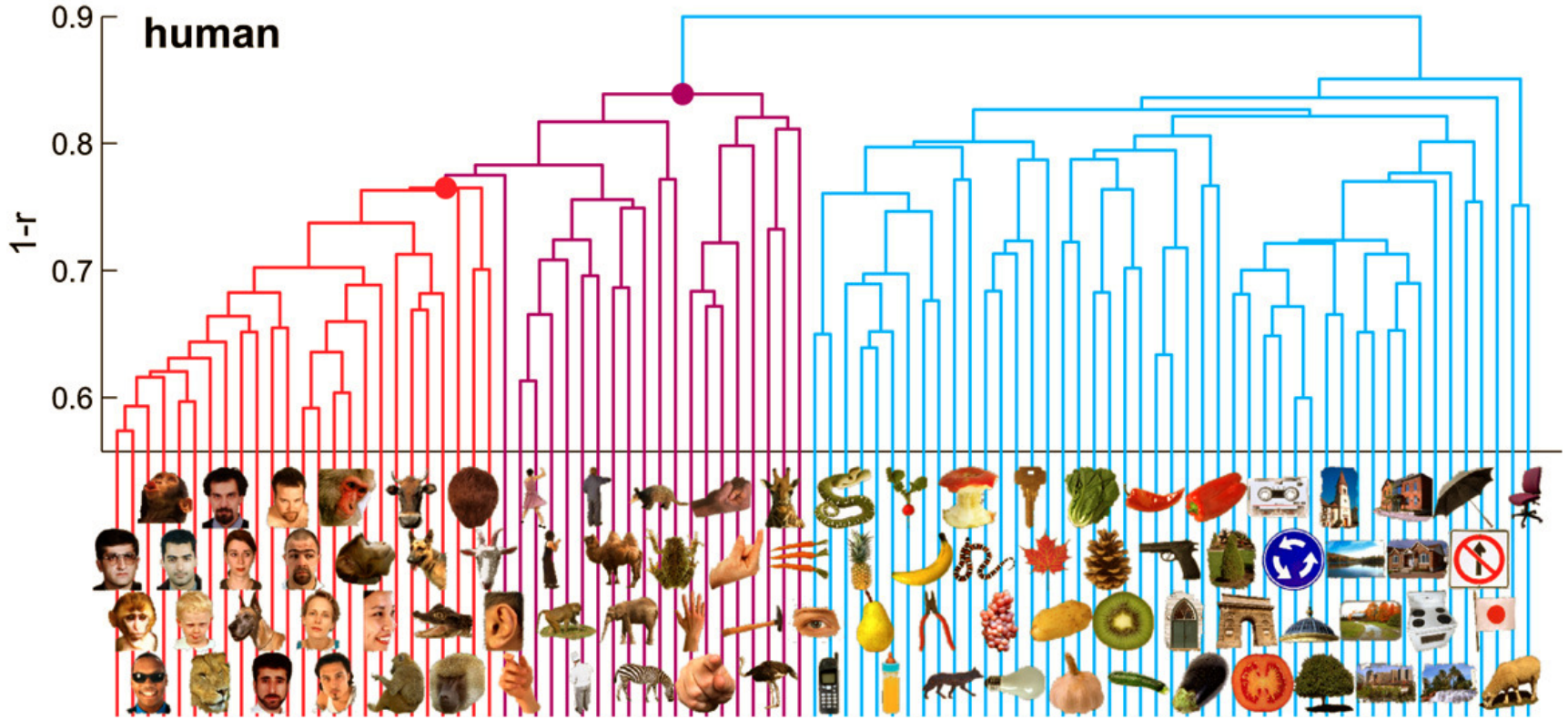
Distances

- Two conditions:
  - Are patterns of activation pertaining to the same event more similar than patterns pertaining to different events?
- More exploratory:
  - Multi-dimensional scaling (visualisation)
  - Cluster analysis
  - Representational similarity analysis (RSA)

Multi-dimensional scaling

Kriegeskorte 2008

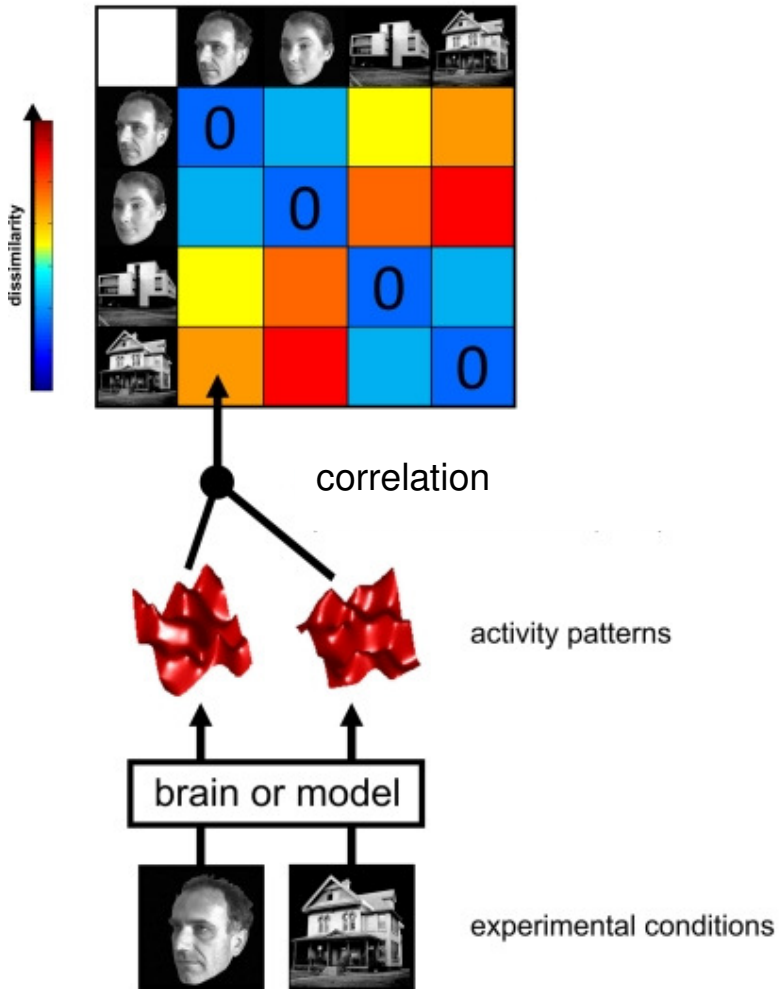
Cluster analysis



Kriegeskorte 2008

Representational Similarity Analysis

Blue = similar
Red = dissimilar



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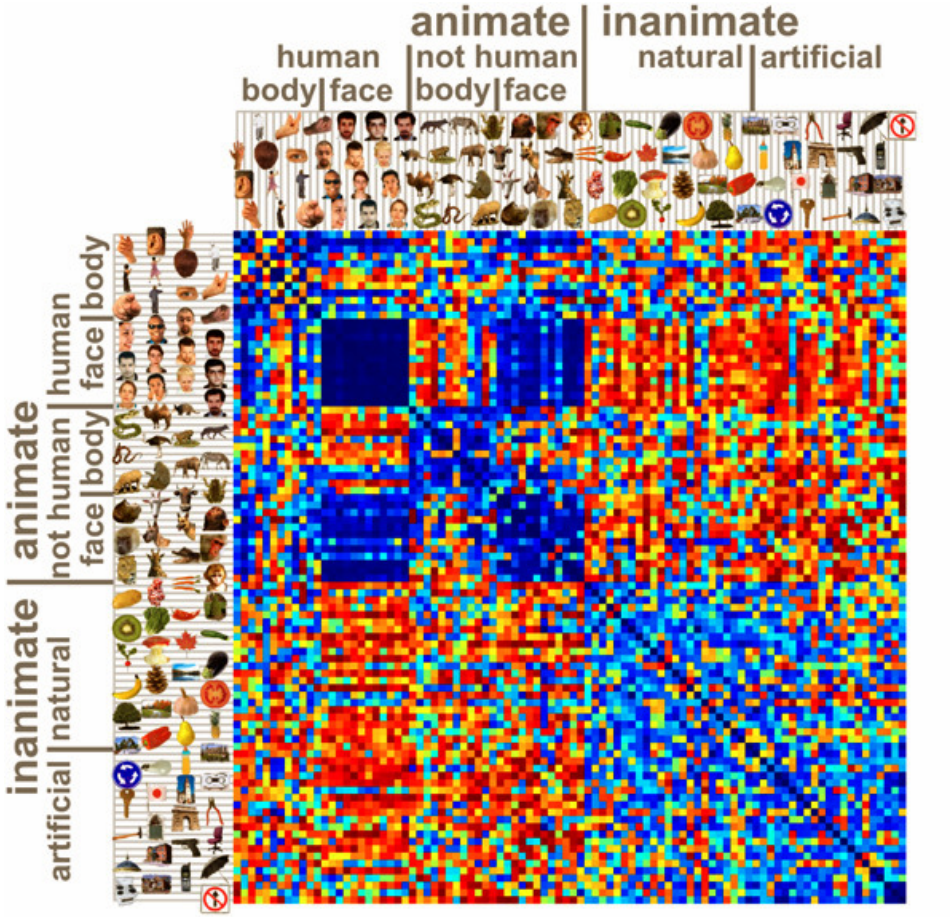
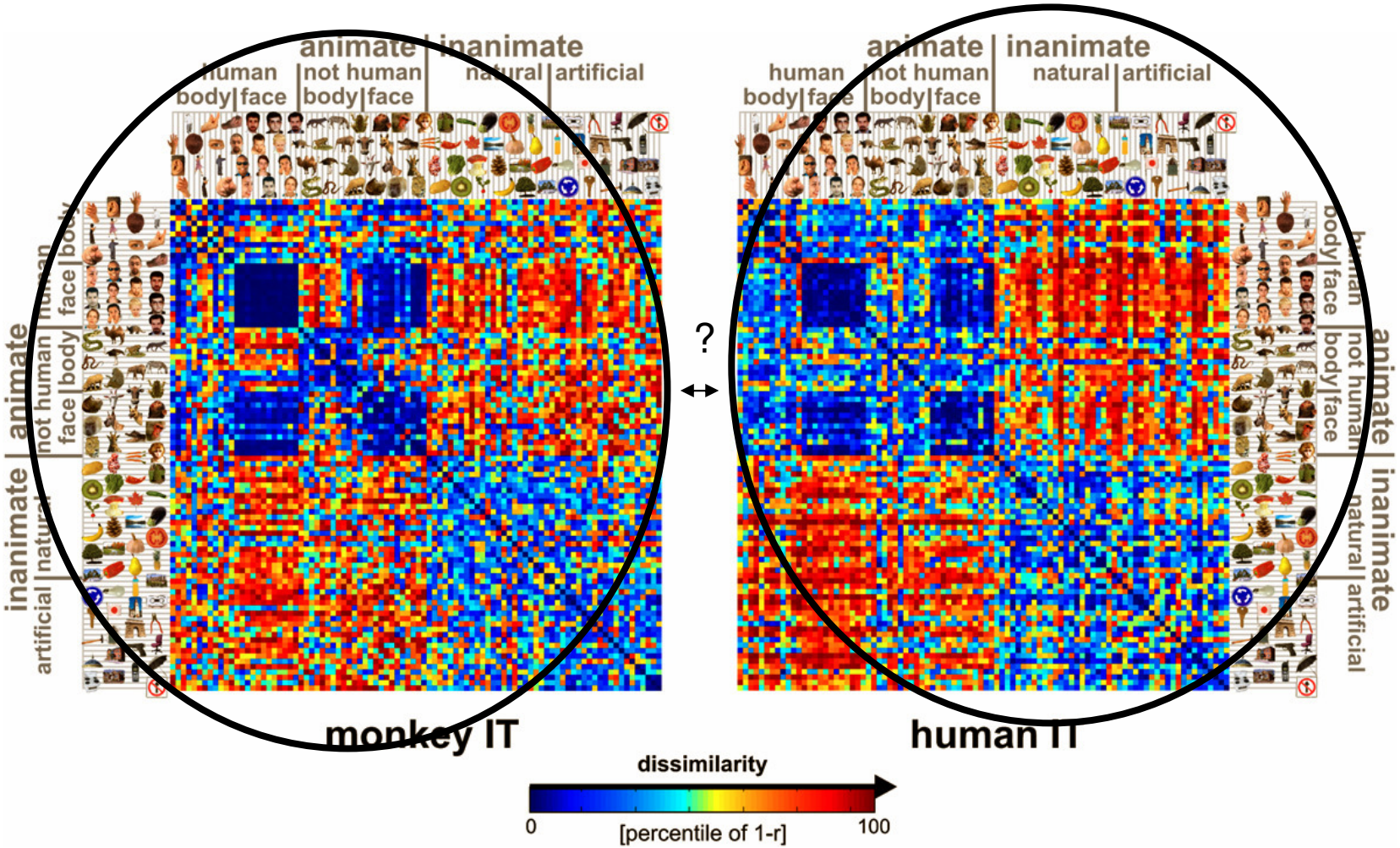
Representational Similarity Analysis



Representational Similarity Analysis



Distance measures

- More exploratory
- More flexible (possibility to test a range of models)
- Inference (e.g. test specific computational model)

Which shall I use?

- Depends on your question!
  - Few conditions incorporating binary distinctions -> classification
    - E.g. rule 1 vs rule 2, head turn left vs. right
  - Huge stimulus set varying along many dimensions -> RSA or similar
    - E.g. objects, semantics etc

Designing experiments

- What's your question?
  - Best suited to univariate or multivariate analysis?

Faces & Houses…

- A region that simply *responds more* to faces than houses, might be said to do face processing
    - Univariate question: where in the brain is there more activity for faces than for houses?
- But a region that was specialised for processing faces, might also *discriminate between* faces.
  – Not good enough to have a region doing "face detection" – that says "yes, it's a face" every time we see a person: we'd be hopeless at face recognition!
  – Need a region that discriminates BETWEEN faces
    - Multivariate question: are patterns of activity evoked by *different faces* discriminable?

      (don't really need houses at all, no specific prediction there)

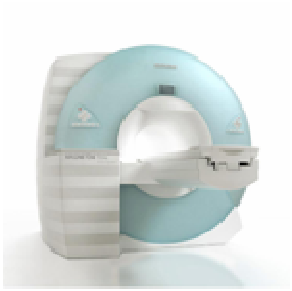
Designing experiments

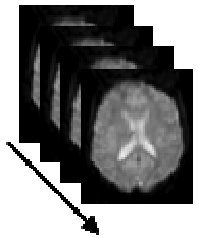
- What's your question?
  - Best suited to univariate or multivariate analysis?
- How many repetitions?
  - What analysis are you planning?
    - Classification – need lots of repetitions of each condition in blocks of time. Mine ~12 repetitions per condition per block, 10 blocks.
    - RSA – need repetitions of each ITEM for matrix. Don't need data in blocks. Niko: 12 repetitions of each item across the whole experiment. Need at least 8 items in your matrix to make the statistics work.
  - Talk to people (Johan, Russell, Alex)

Basics of analysis

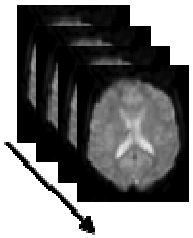
- Use unsmoothed native space images
  - Fine-grained patterns (lost in smoothing)
  - Pattern analysis at level of individual brain (no assumptions about correspondence of particular voxels between brains)

Overview of analysis

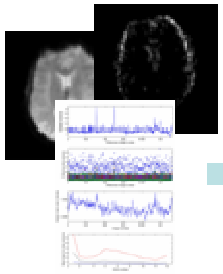




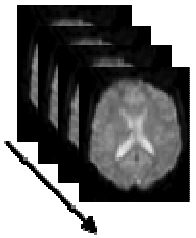
Images in dicom format



Convert to format used by SPM (nifti)

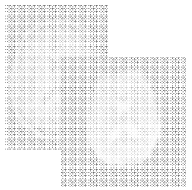


Initial image diagnostics (tsdiffana)

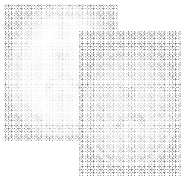


Within series processing:

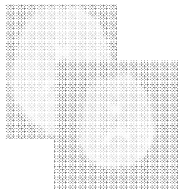
- Realignment
- Slice time correction
- Undistortion



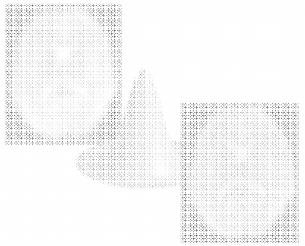
Coregister EPI data to structural image



Normalise structural



Normalise EPI images



Smooth EPI images

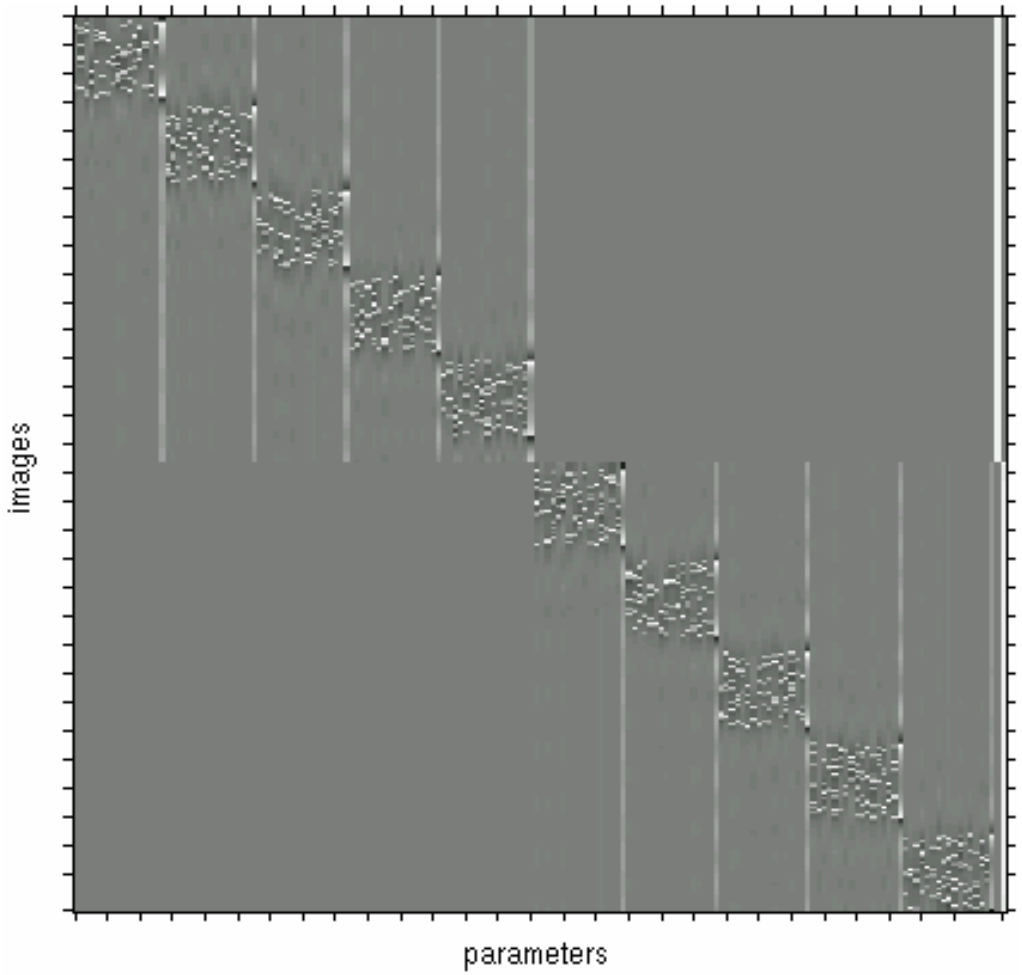
(MVPA analysis)

Publish…

Group stats

MVPA magic

First level…



-> betas for each item
or experimental condition

-> do MVPA on these

Resources for MVPA

- PyMVPA toolbox – for classification
  - http://www.pymvpa.org/
  - /imaging/aw02/examples/

- RSA toolbox under development by Cai Wingfield, Su Li and Hamed Nili

Useful papers

- Pereira et al 2009 “Machine learning classifiers and fMRI: a tutorial overview”, NeuroImage 45
- Mark Stokes’ Thesis (chapter on methods for MVPA)
- Kreigeskorte Respresentational Similarity paper, Frontiers in Systems Neuroscience 2008: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2605405
- Haynes & Rees 2006 Review “Decoding mental states from brain activity in humans”, Nature Reviews Neuroscience 7

Summary

- New inferences available from examining “fine-grained” patterns of fMRI activation
- Variety of techniques available depending on your question
- Design your experiment with your question in mind, different techniques for different types of questions