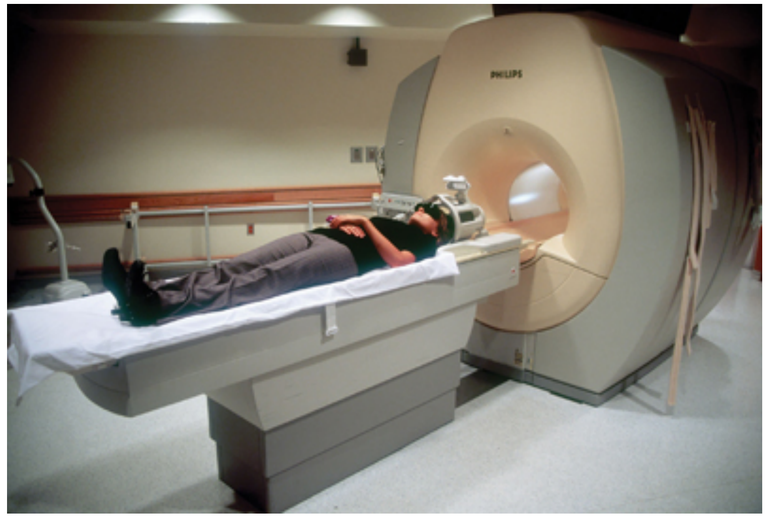
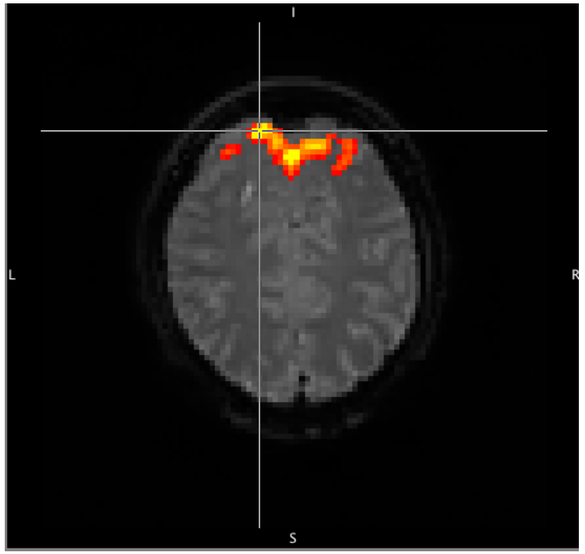
Patterns in time and space

Connectivity and Pattern analysis

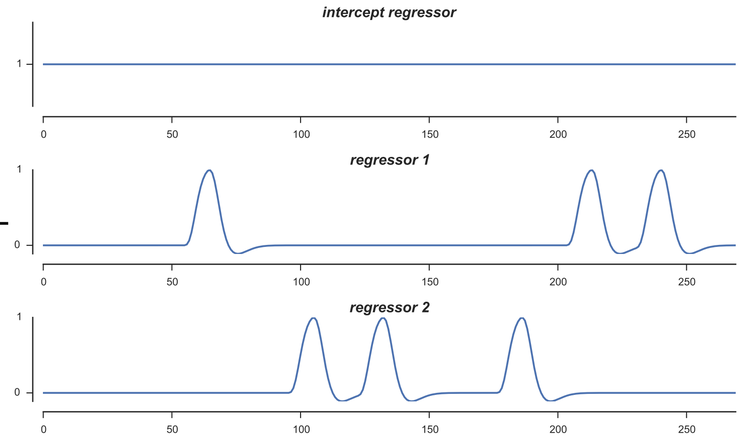
Tomas Knapen Brain Imaging VU 2021



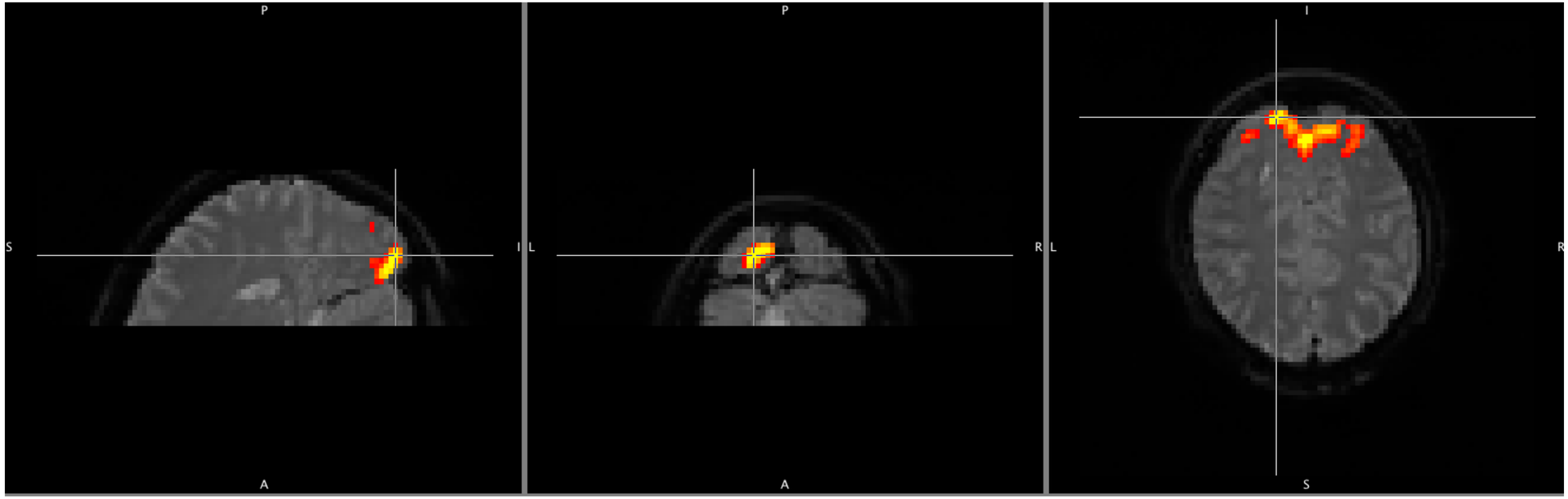
pre
processing



post-
processing

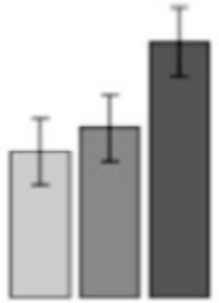


Univariate analysis a.k.a. ‘blobology’



Region
Of
Interest

avg
activity



1 2 3

condition

Thresholding problem

$t > 3$

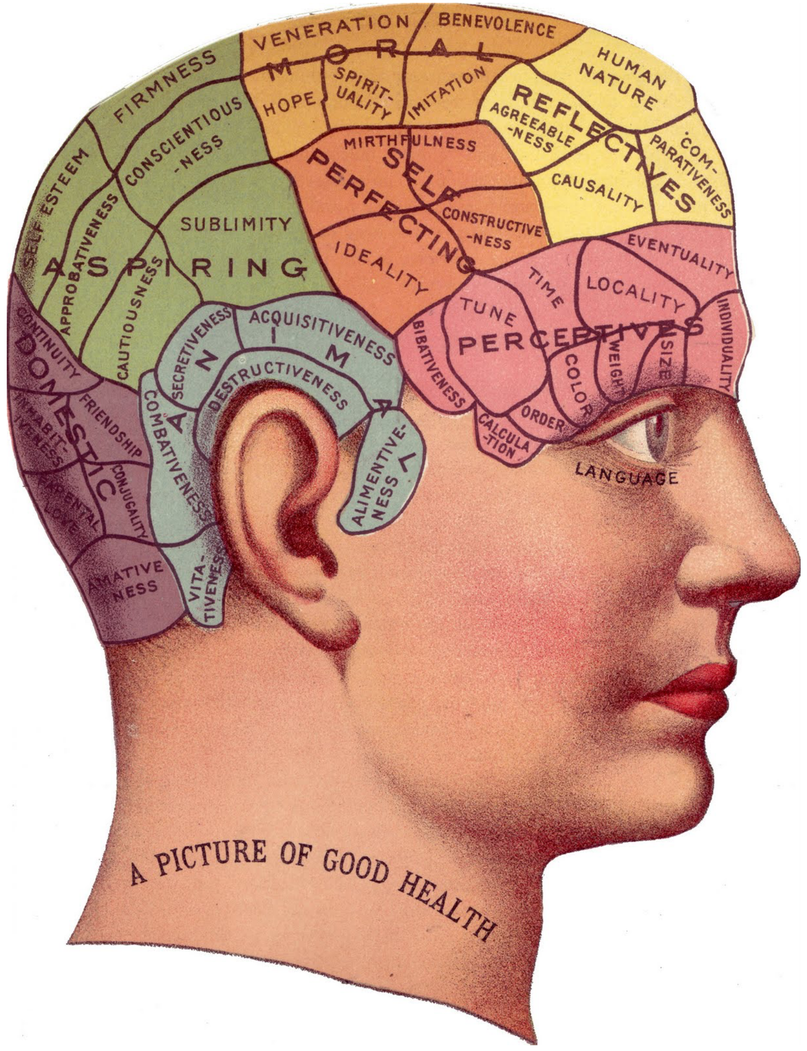
"Concept *X* is **locally** represented in the left dorsolateral prefrontal cortex"

$t > 2.3$

"Concept *X* is **globally** represented in a **network** of the dorsolateral PFC, precentral gyrus, TPJ, and ATL"

function processed locally,
or in a network?

Neo-phrenology



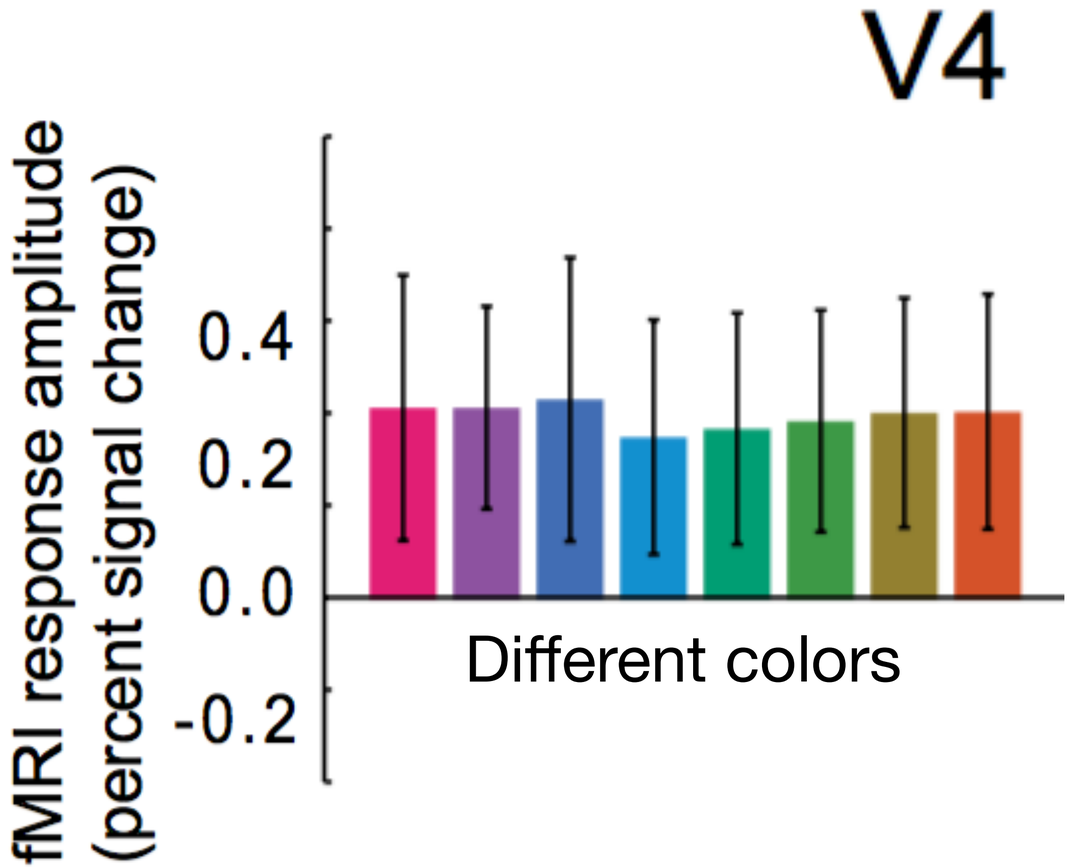
phrenology
localising functions
in the brain

phren = mind
logos = knowledge

big overlap in
functions especially
in higher-order cortex

Per-ROI amplitude averages

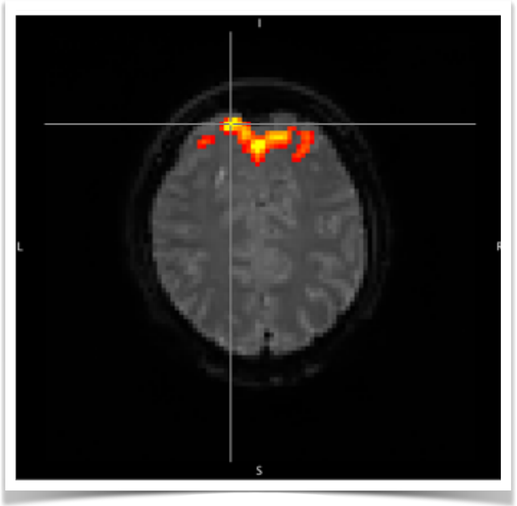
cannot distinguish between stimulus types within ROI



Reverse Inference Problem

- inverse inference problem

cause ← effect



"color stimulus"

more specific	more general
yellow stimulus	visual stimulus
yellow cabs	visual attention

what is it about your stimulus that drives the effect?

Limitations of Univariate Analyses

- cannot distinguish stimulus types within ROI

- reverse inference: what is it about your stimulus that drives activity?

This Lecture

Pattern Classification

Other Lectures on Receptive Field Models

Forward Models

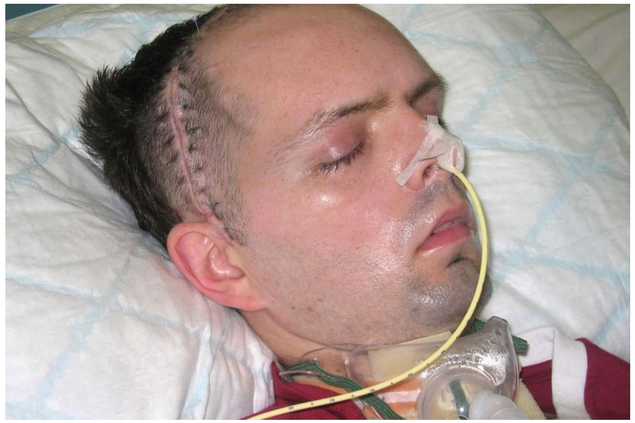
MVPA

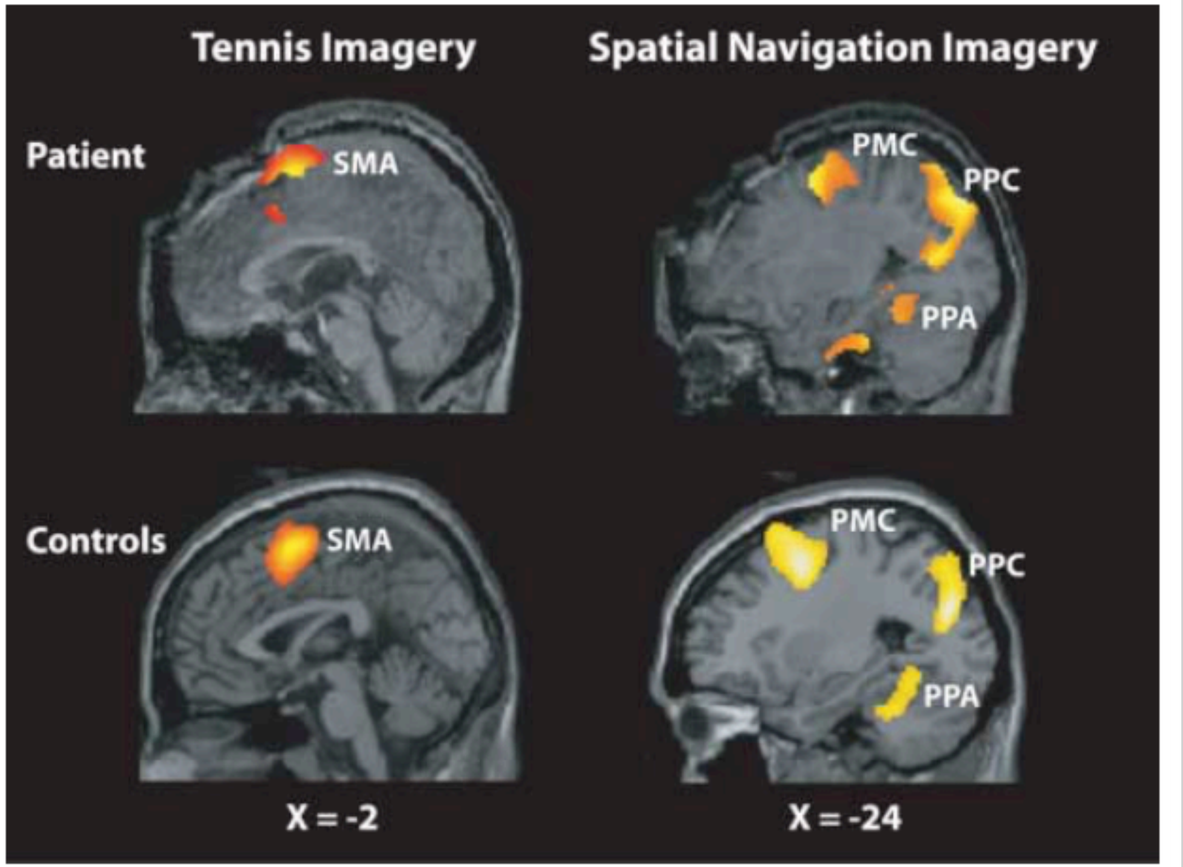
Multivariate pattern analysis

Going Multivariate

Detecting Awareness in the Vegetative State

Adrian M. Owen,[1*] Martin R. Coleman,[2] Melanie Boly,[3] Matthew H. Davis,[1]
Steven Laureys,[3] John D. Pickard[2]



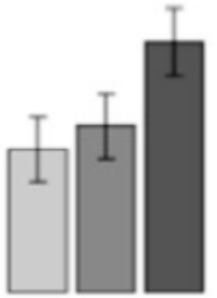


Distinguishing between stimulus types

Univariate

Region
Of
Interest

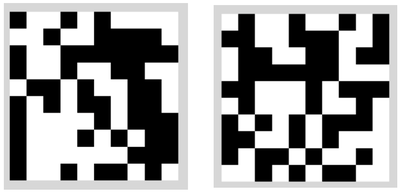
average
of activity



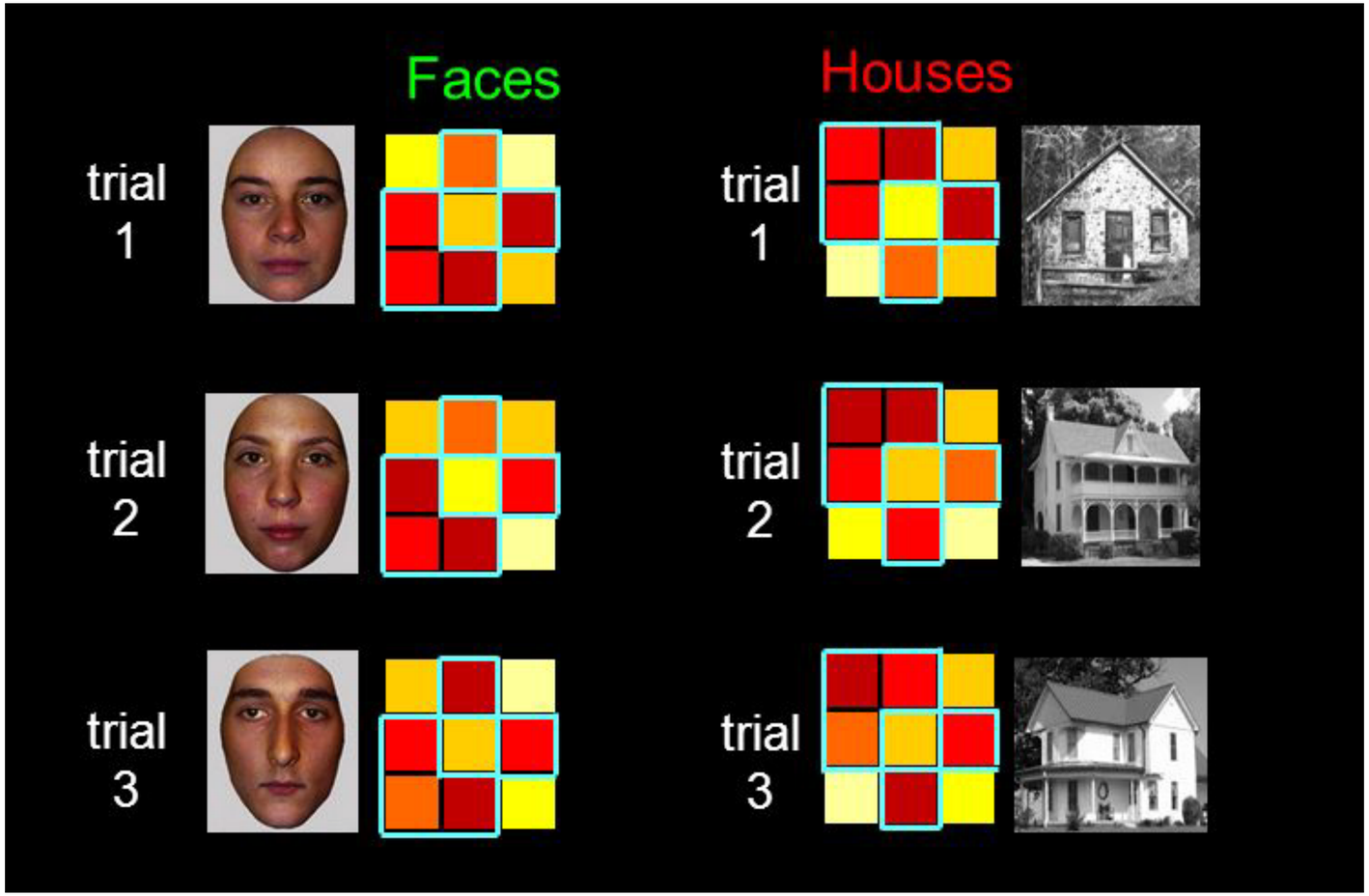
Multivariate (MVPA)

Region
Of
Interest

pattern
of activity
(βs)

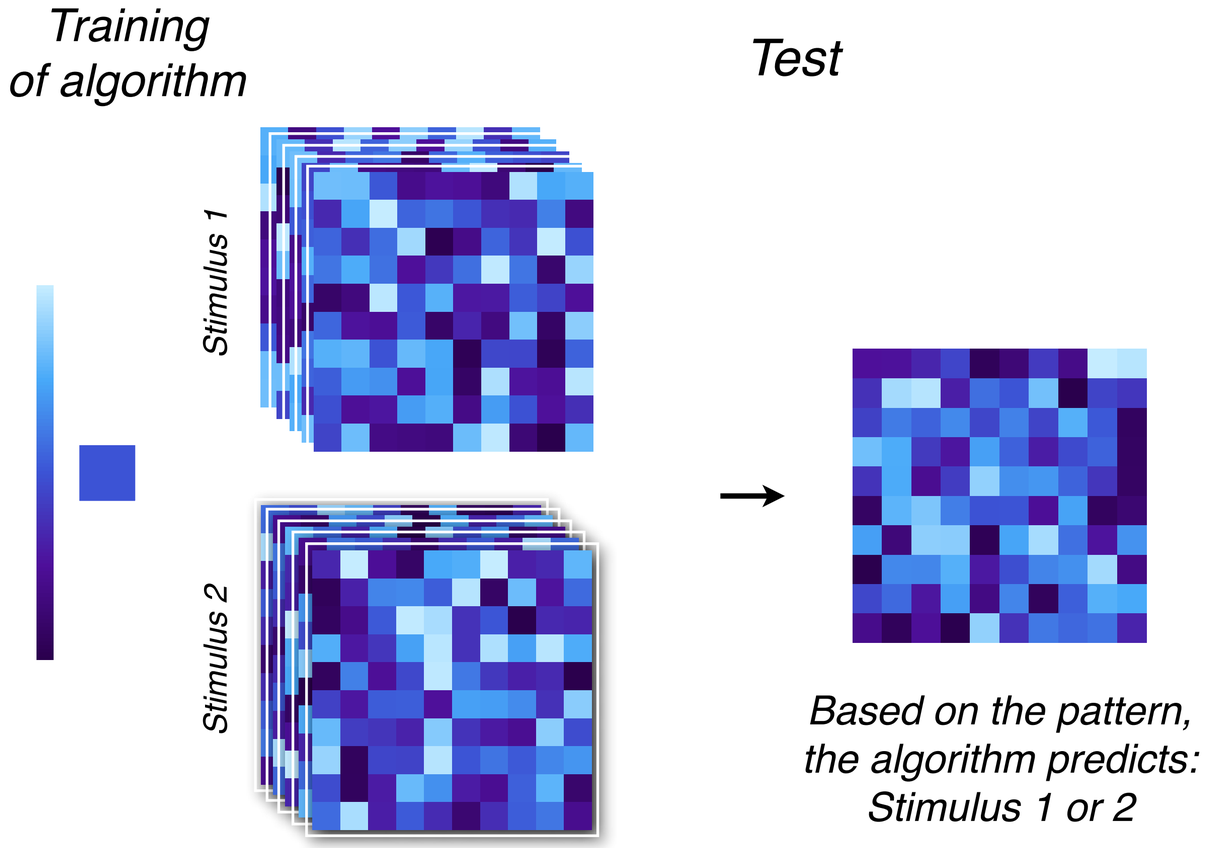


Can we distinguish between stimulus types within ROI



Pattern classification

*Not mean signal intensity, but within-area **pattern** of activity, is used to classify what the brain state is.*

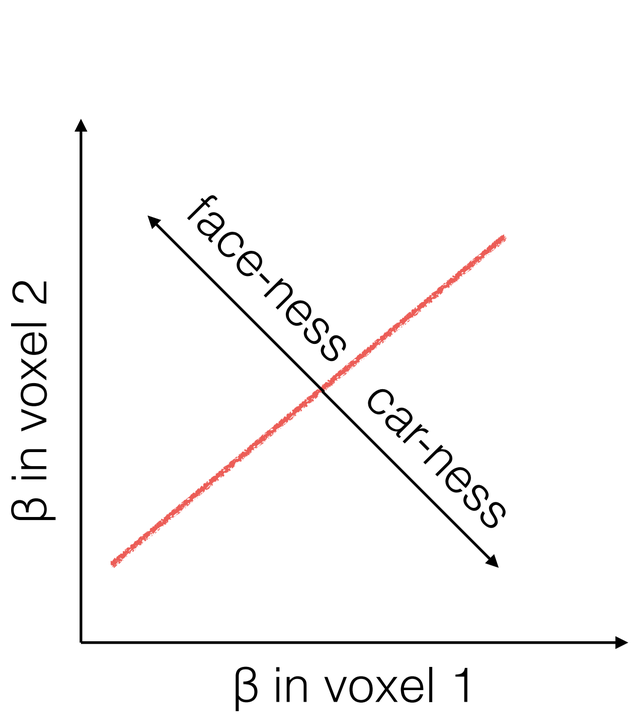


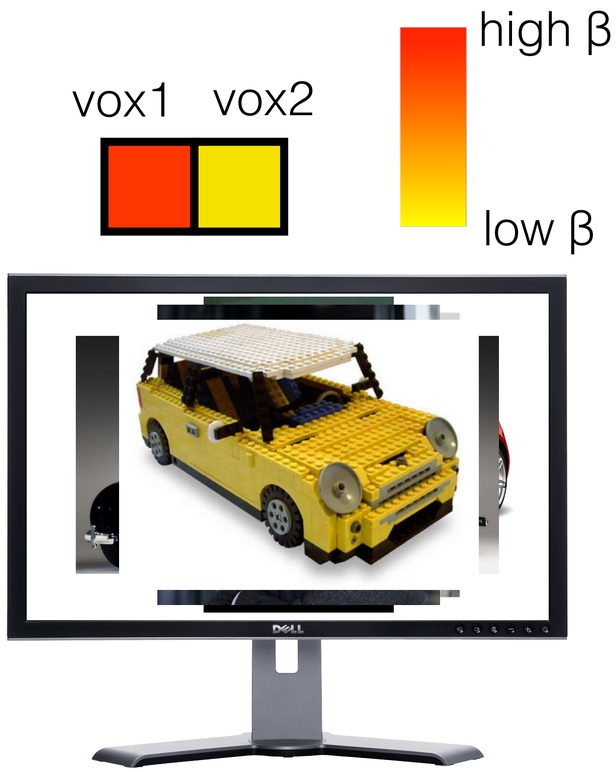
Performance of algorithm expressed as accuracy

-

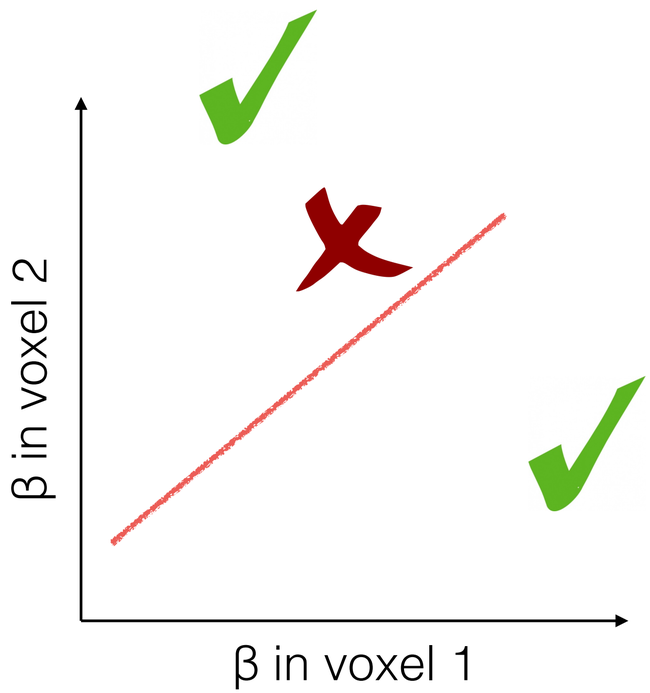
gauge on “information content” in a specific region of interest

Predicting stimulus type:
training a classifier



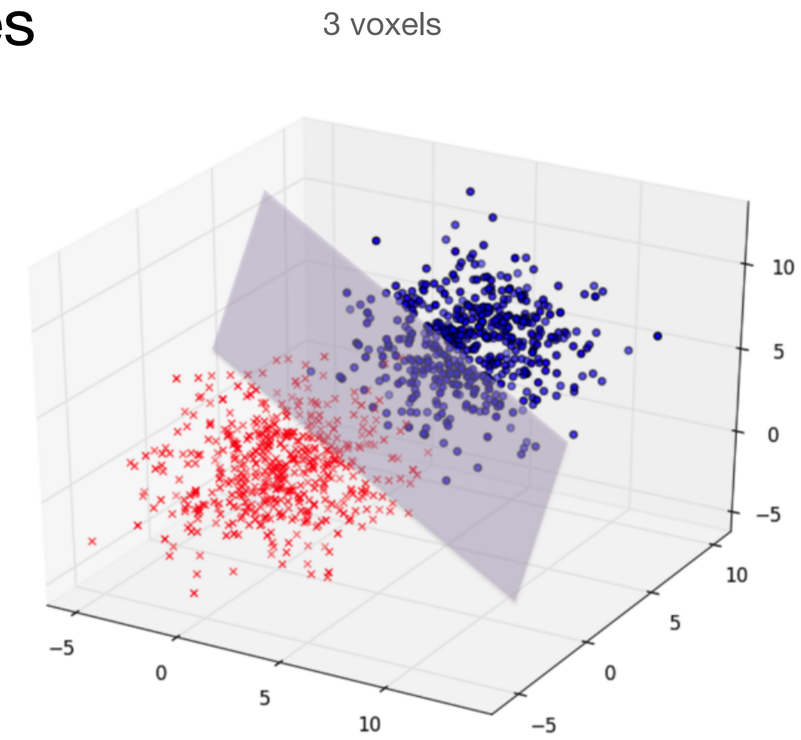


Predicting stimulus type:
testing the classifier



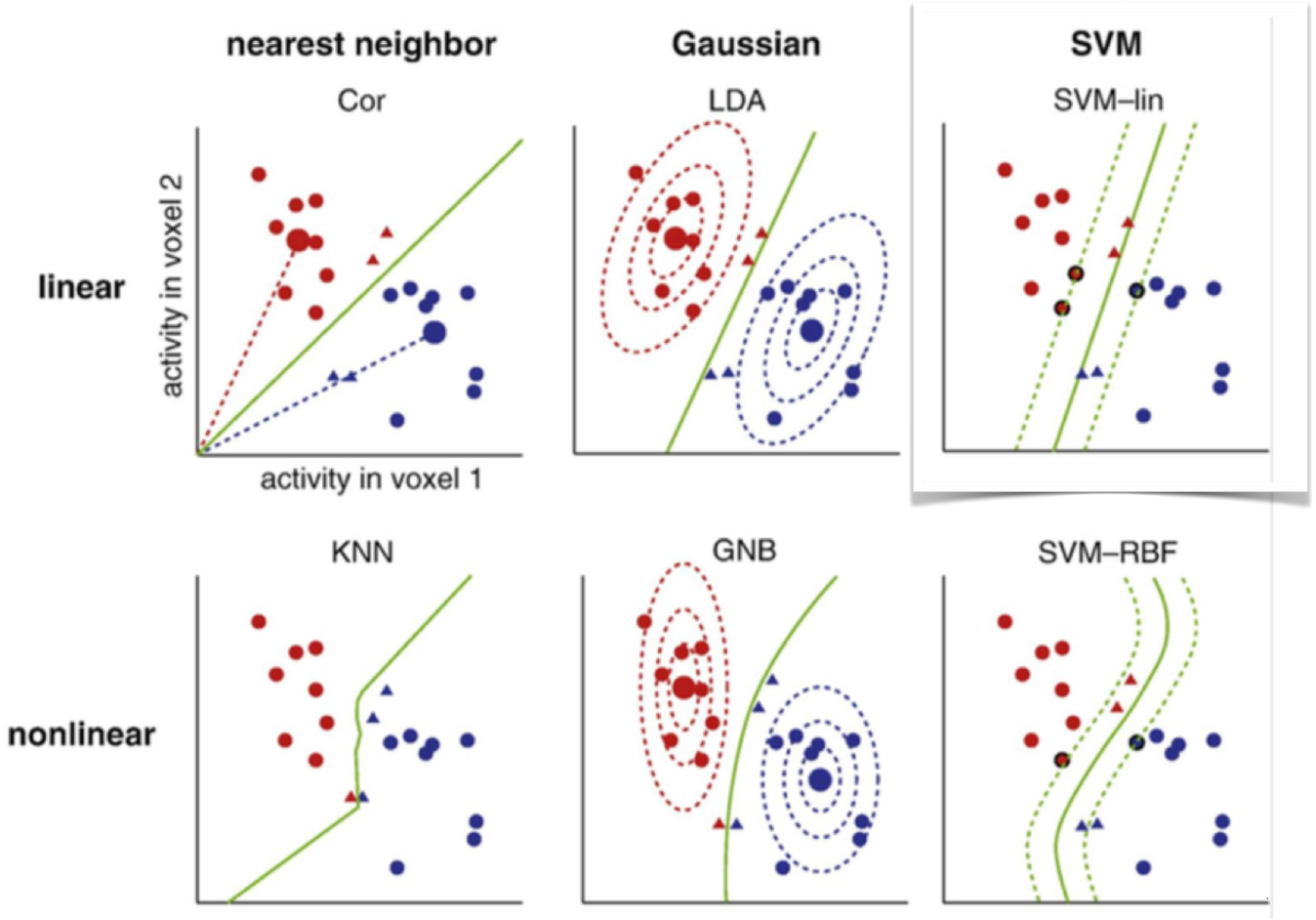
Extending to more voxels

- Finding the n-dimensional plane that separates patterns across n voxels



Machine Learning Algorithms:

how to draw the line/plane?



Hint: Stanford Machine Learning Course on Coursera

Why separate training and test data?

Training the algorithm finds predictive relations in the data.
Are these relations: 1. accurate, 2. sensitive, 3. consistent

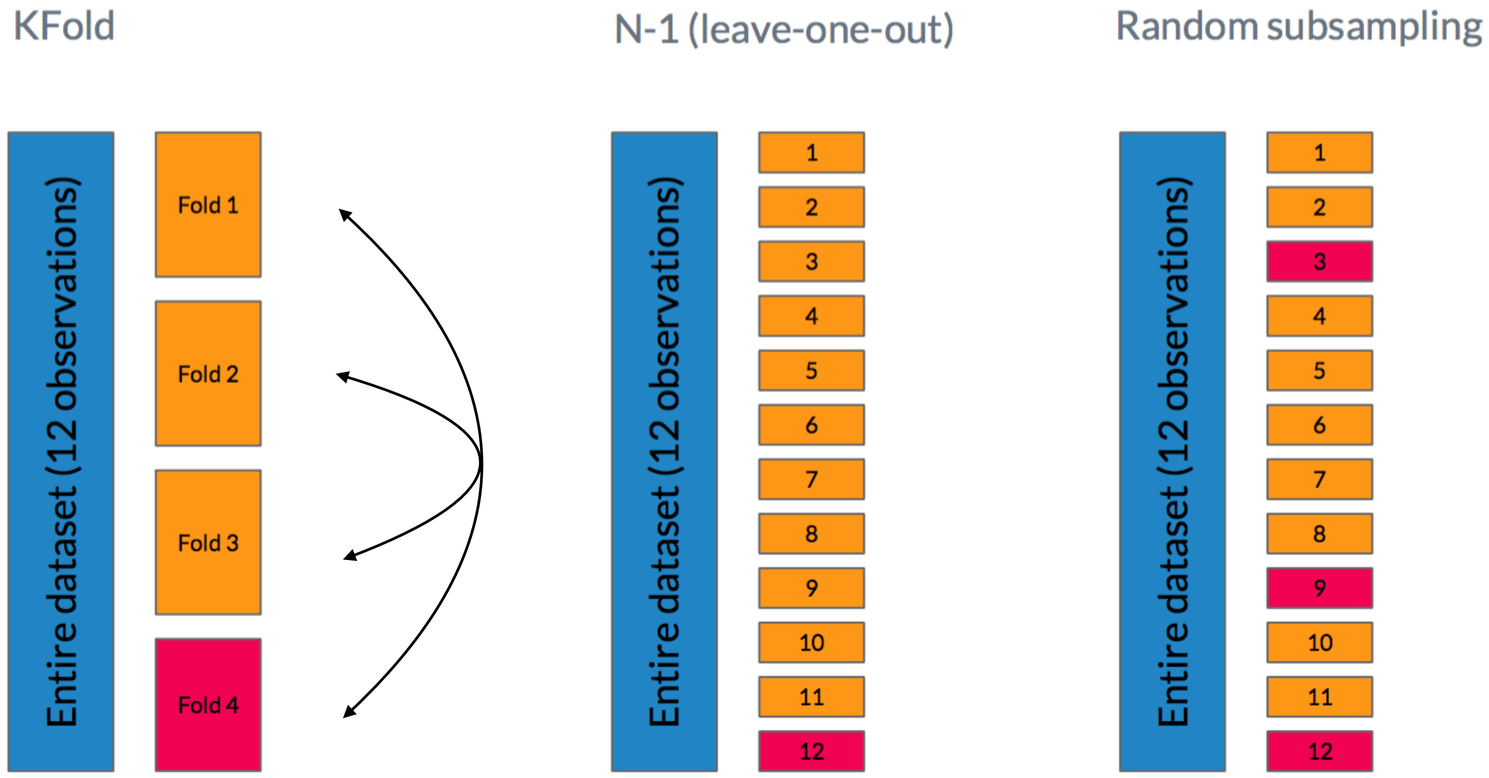
Test on a separate test dataset: does the algorithm perform well on data it hasn't seen before?

What happens when you test using data that the algorithm has been trained on?

Circularity!

Predicting stimulus type:
how to divide your data?

This is called ***cross-validation***



*Every '**Fold**' is the test set once*

*Every **run** is the test set once*

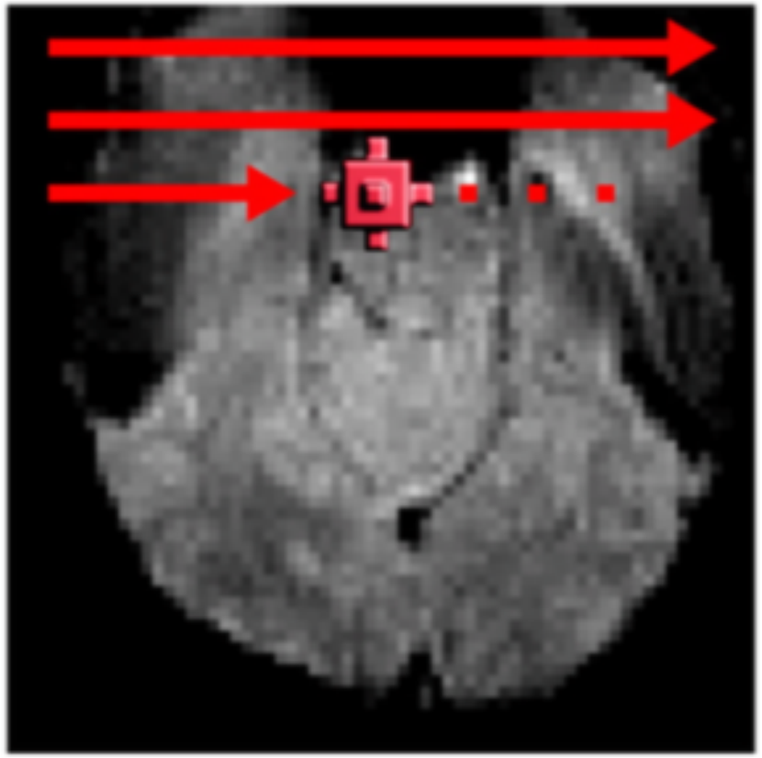
Many different test sets: as many as you like

Searchlight Analysis

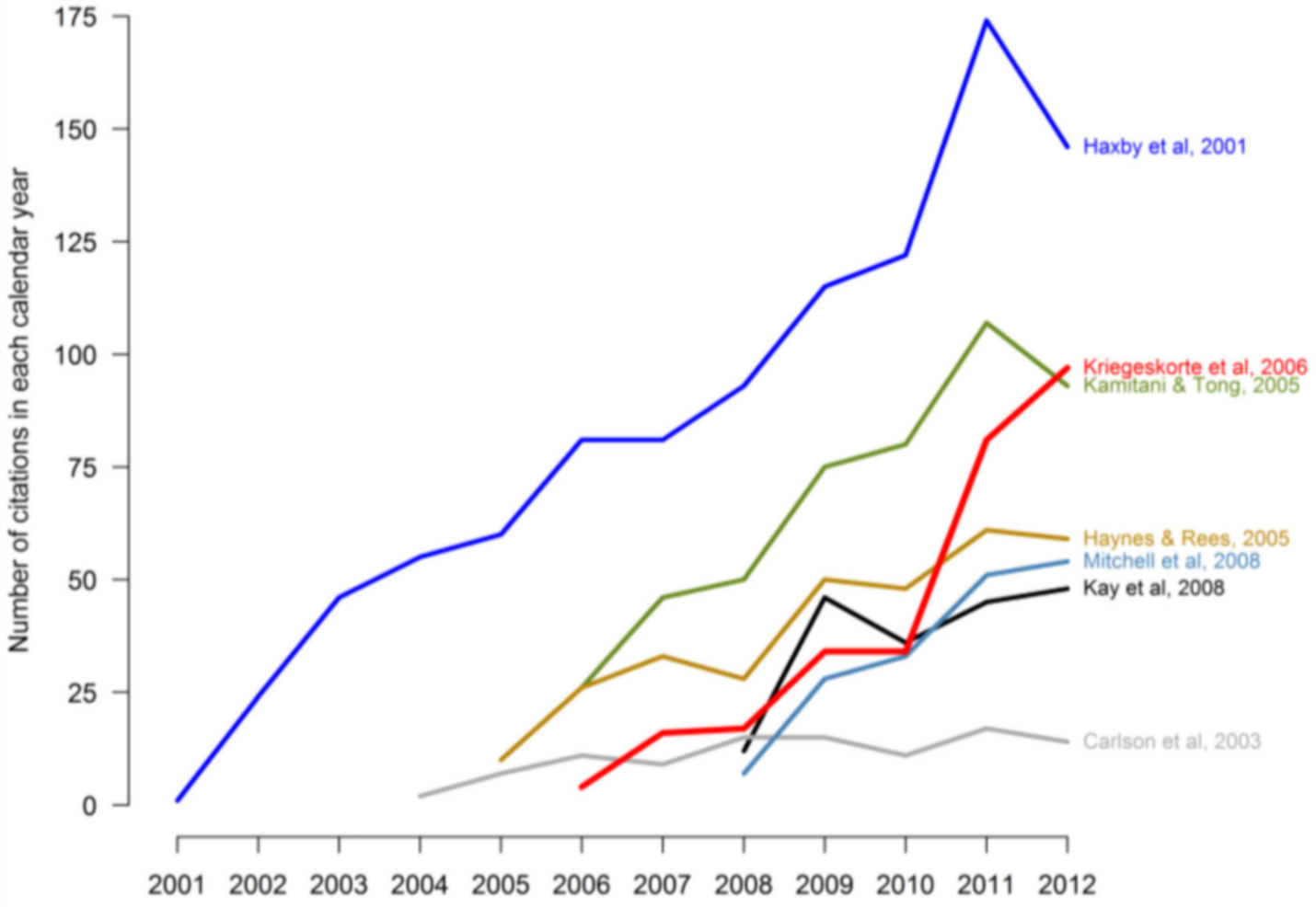
Flexible ROIs

Find ‘information’ not in a region of interest,
but throughout the brain

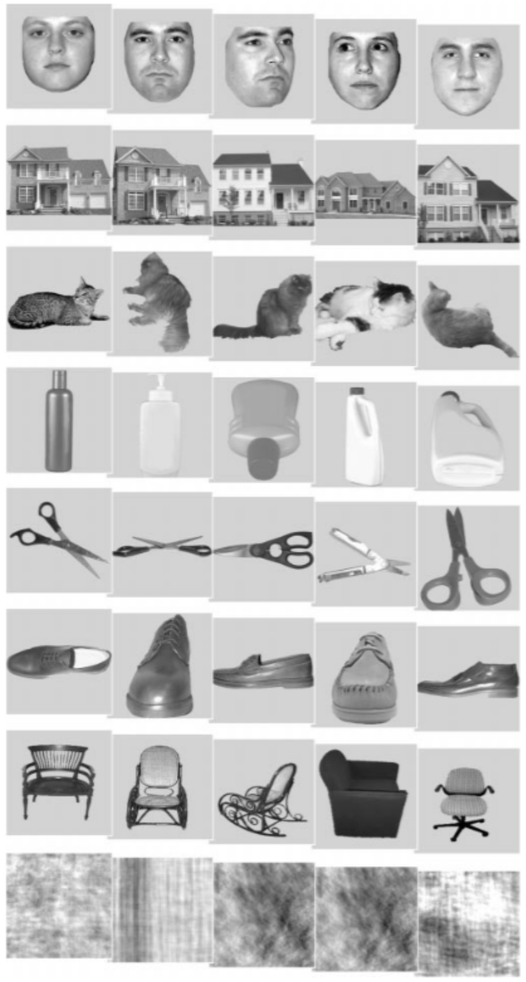
multivariate searchlight
(4-mm radius for 2-mm isotropic voxels)



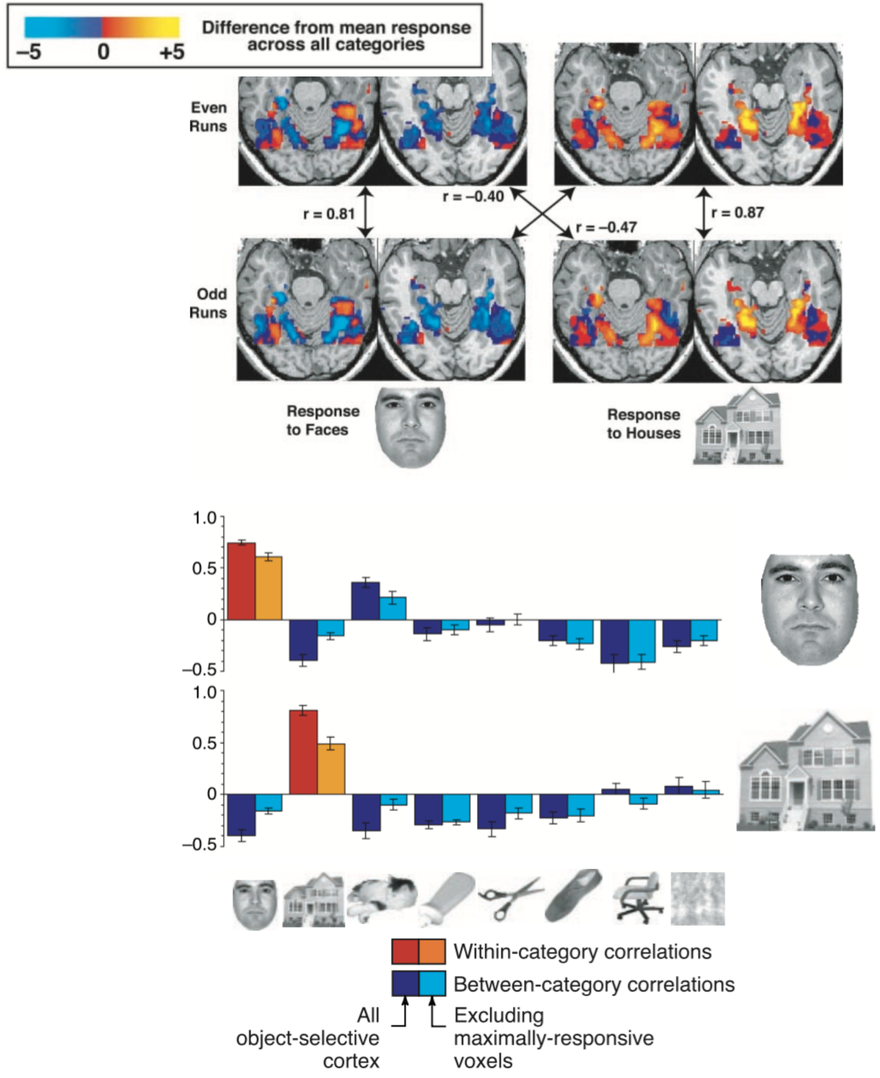
Applications of MVPA



Decoding stimulus category



Haxby et al. Science 2001

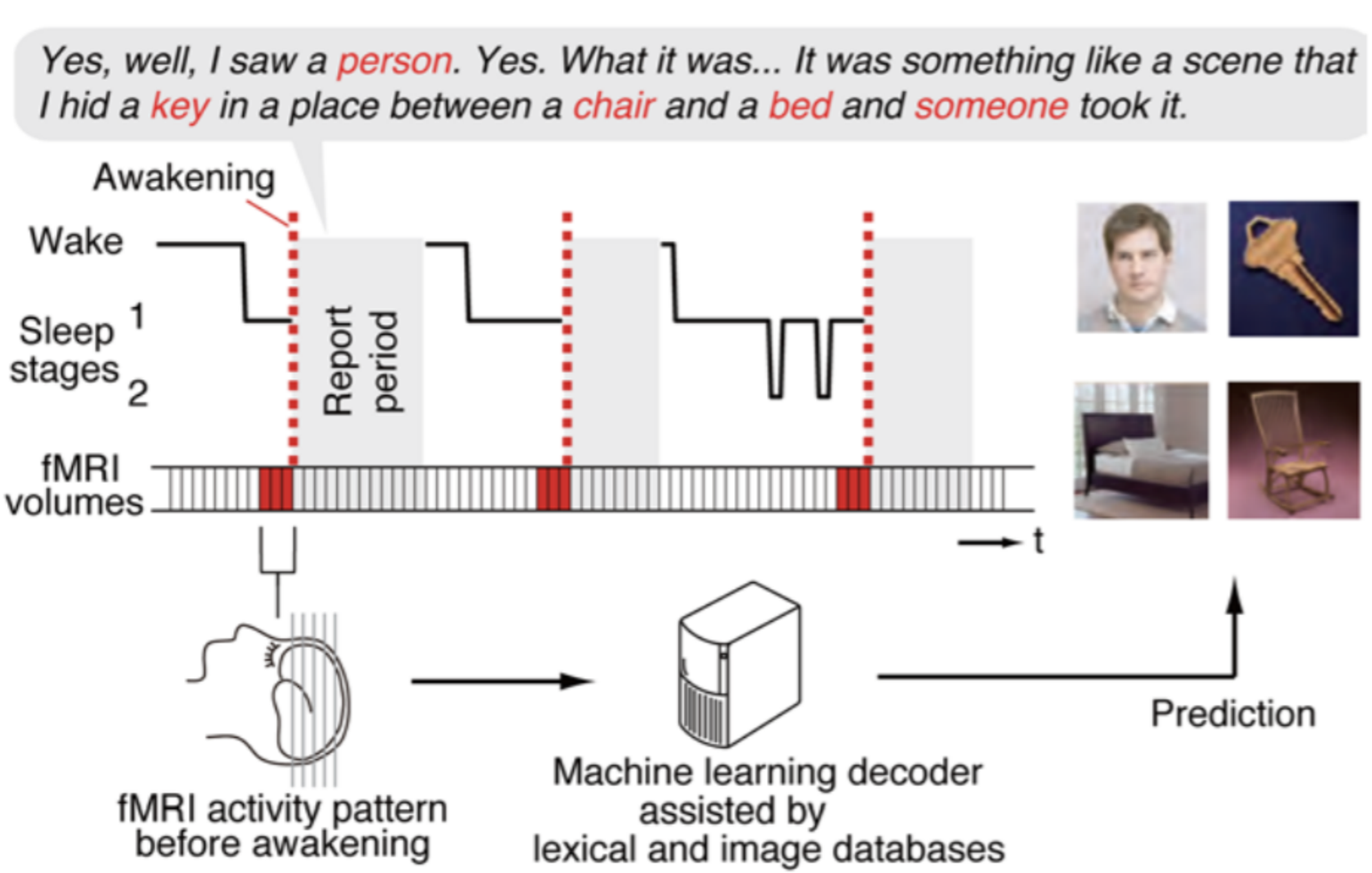


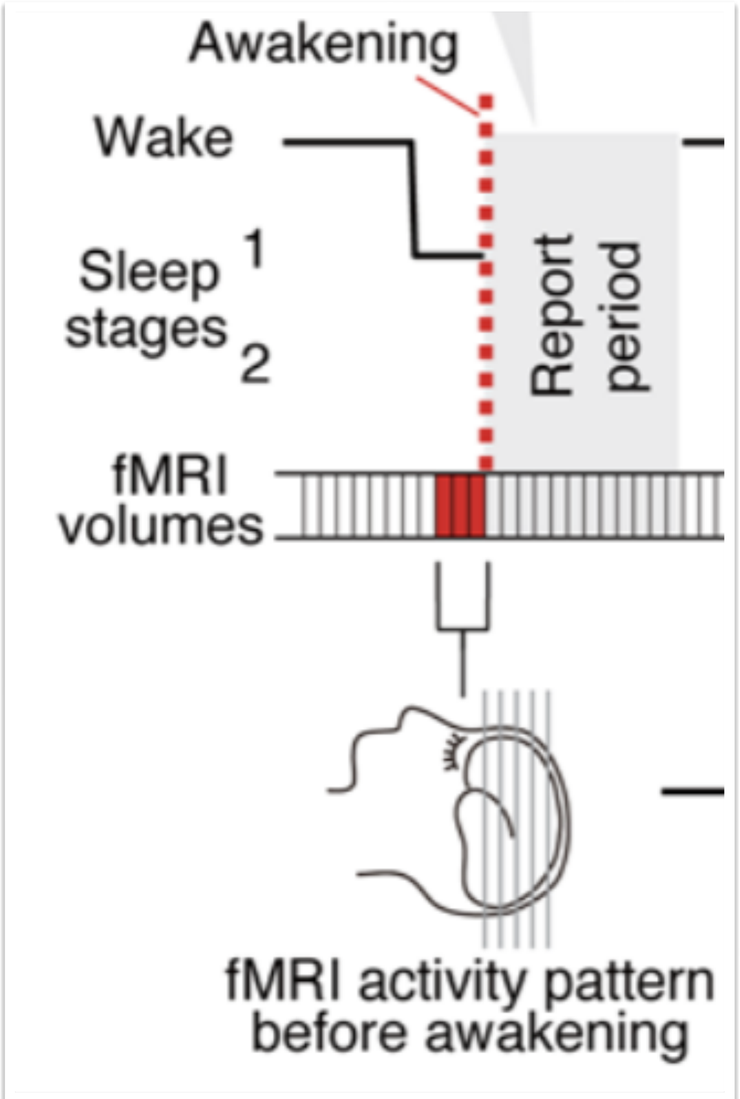
Decoding conscious perceptual state

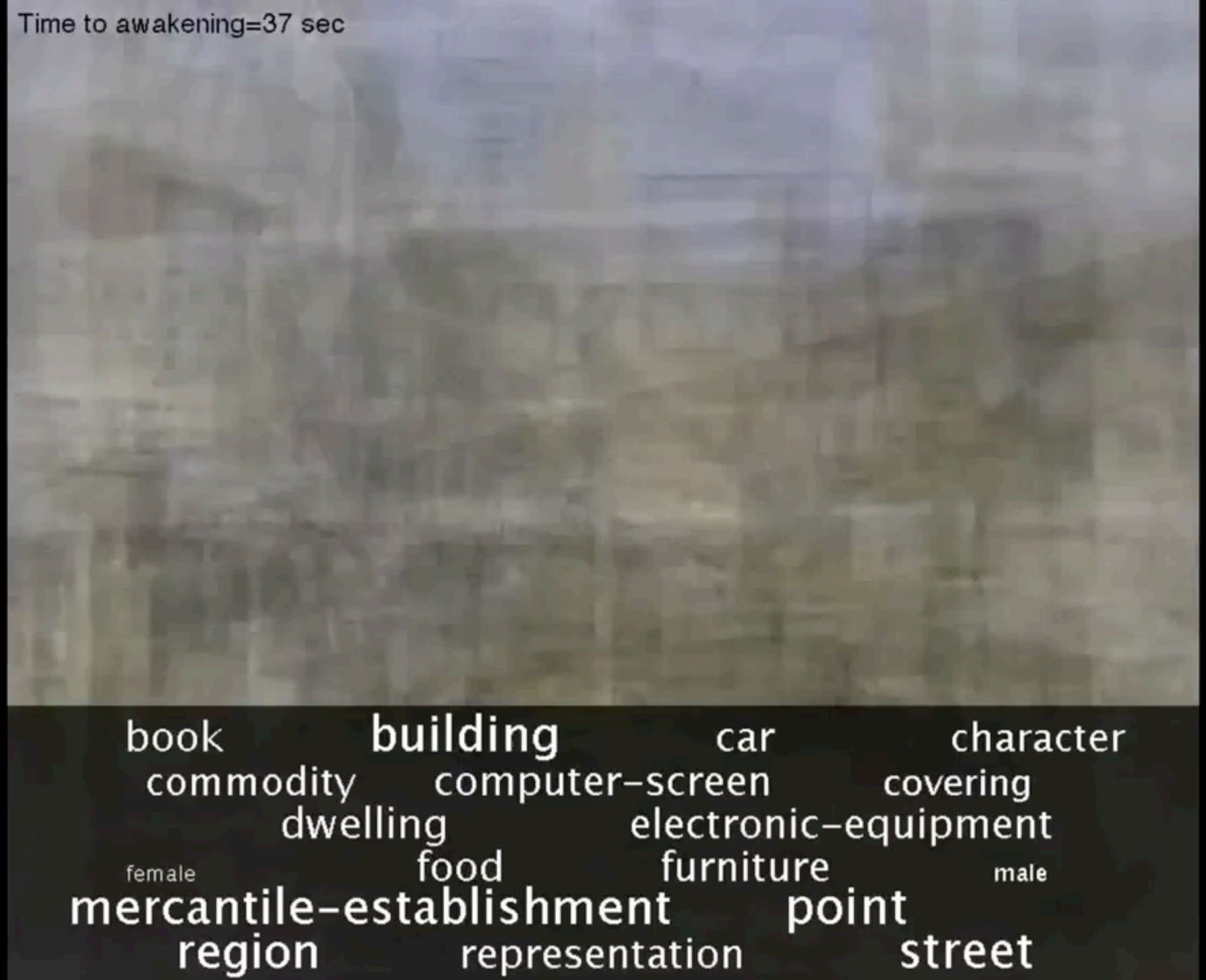
Haynes & Rees, 2005, Current Biology

Decoding unconscious perceptual state: Dreams

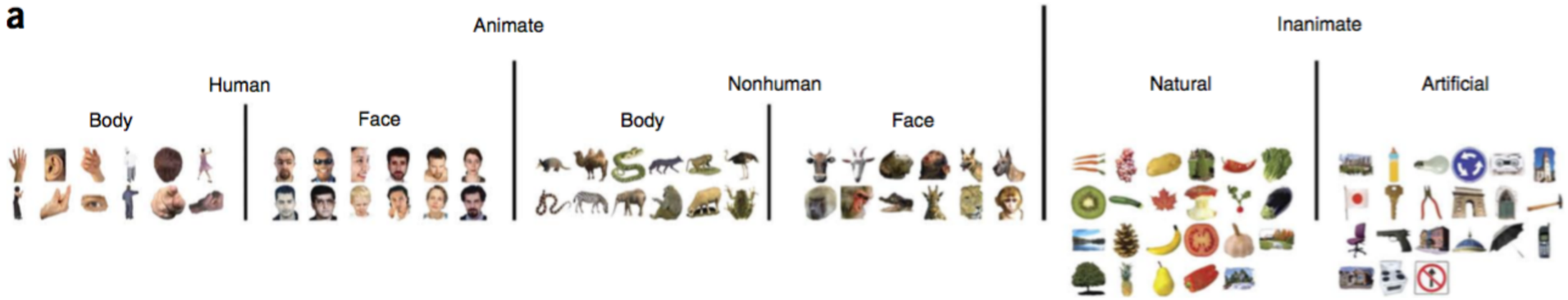
We can decode the content of people's dreams from their brains

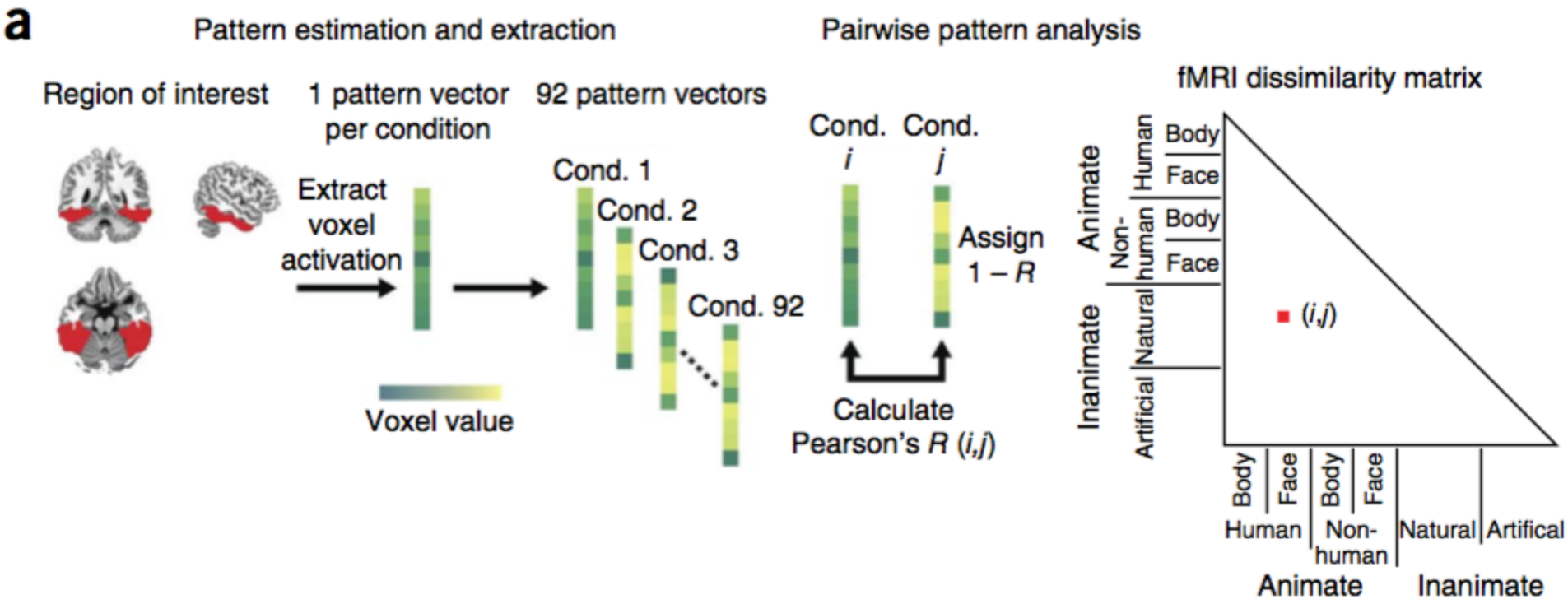





Time to awakening=37 sec
book
building
car
character
commodity
computer-screen
covering
dwelling
electronic-equipment
female
food
furniture
male
mercantile-establishment
point
region
representation
street

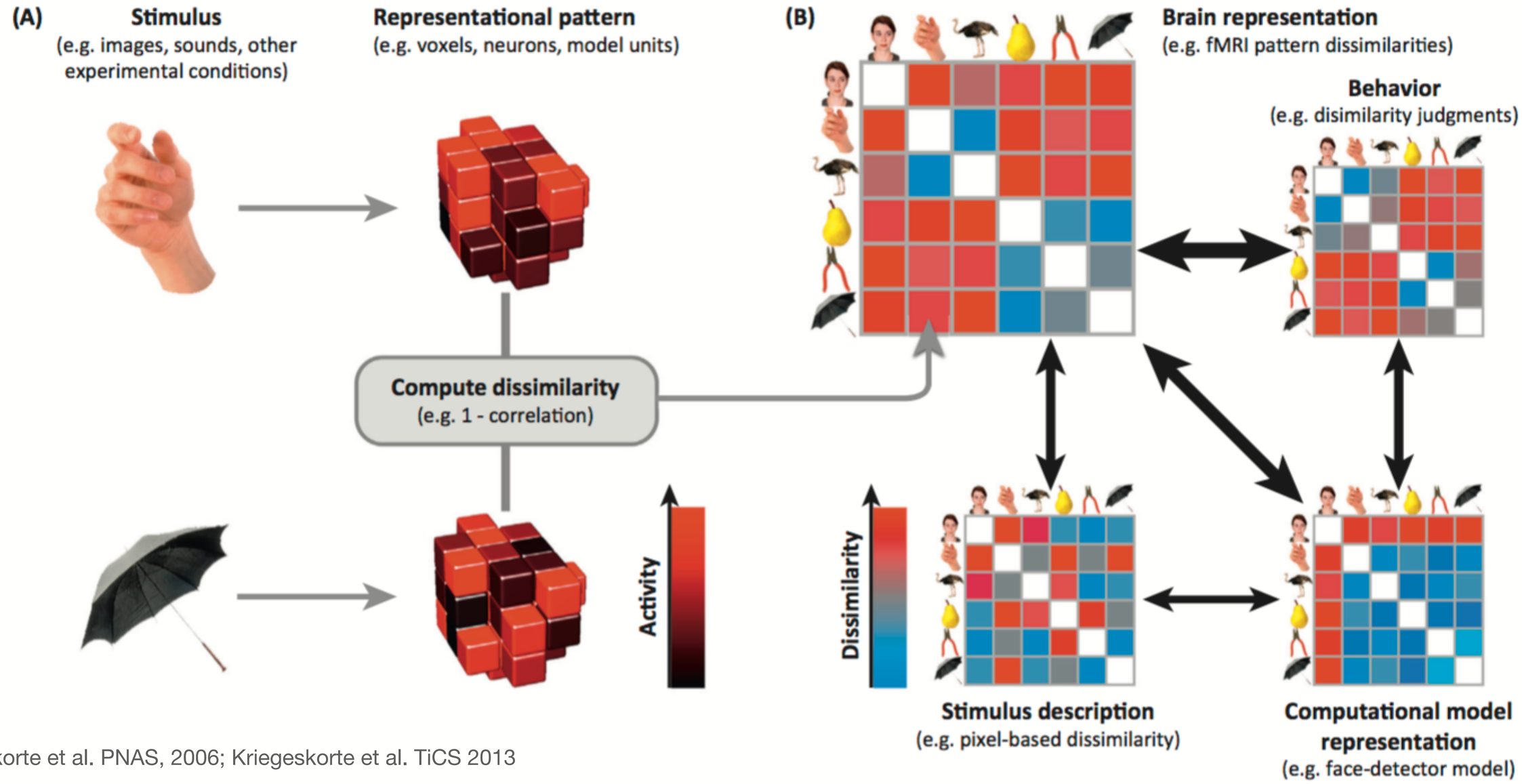
Representational Similarity Analysis





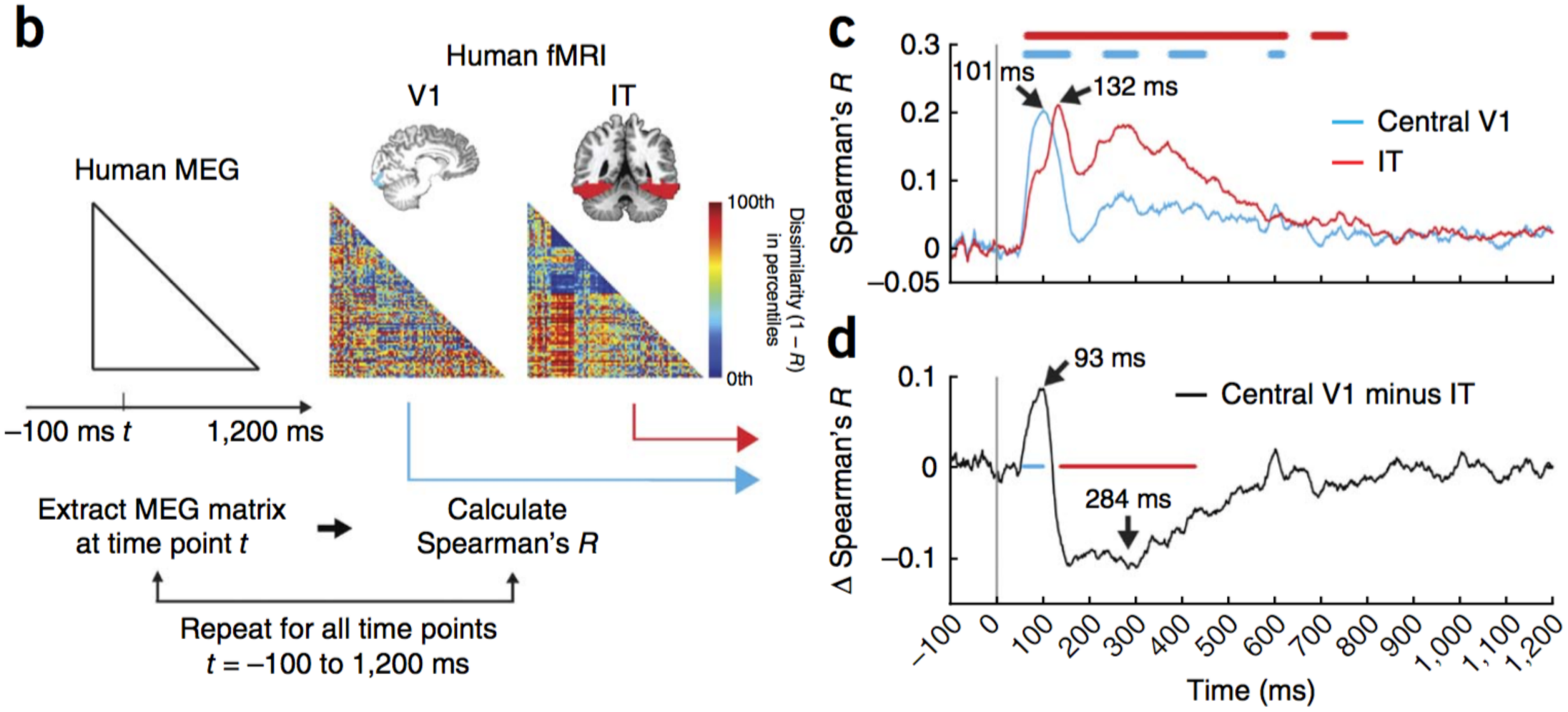
Kriegeskorte et al. PNAS, 2006; Kriegeskorte et al. TiCS 2013

Representational Similarity Analysis



Kriegeskorte et al. PNAS, 2006; Kriegeskorte et al. TiCS 2013

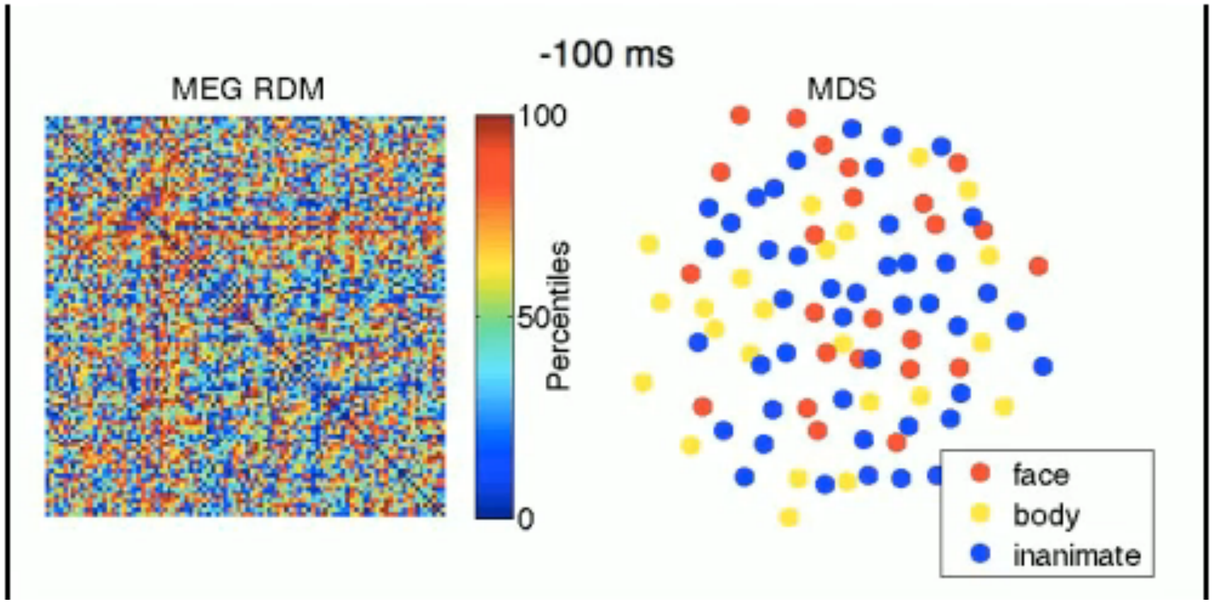
Representational Dissimilarity Analysis

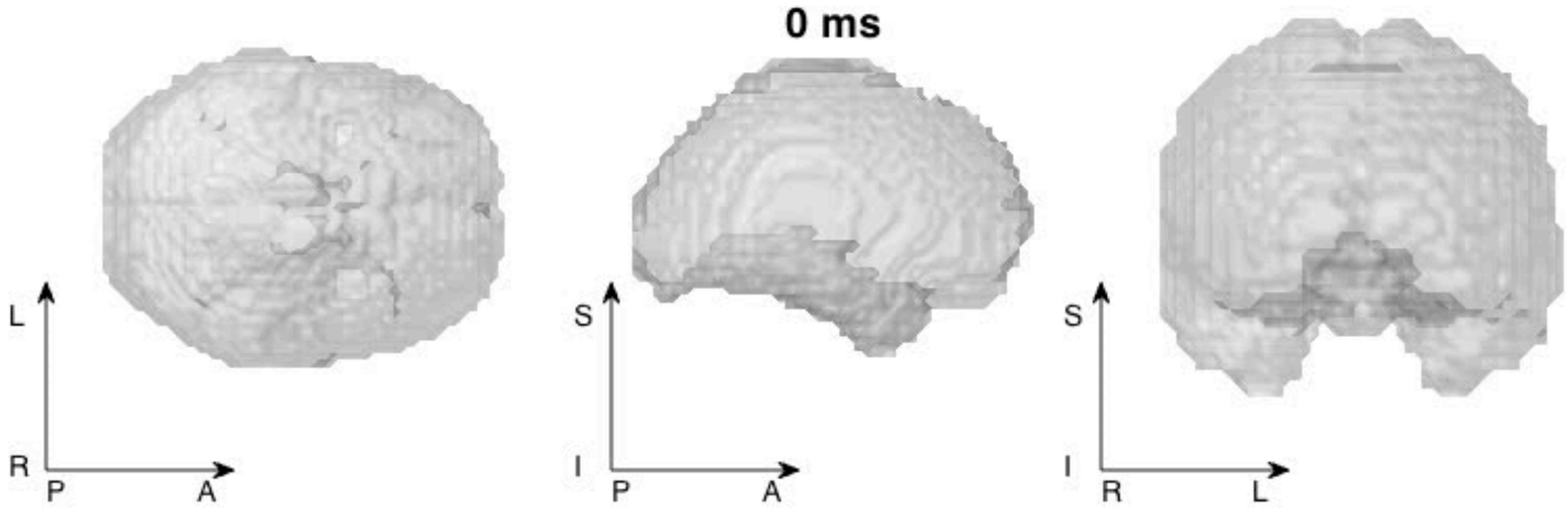


Chichy, 2014 Nature Neuroscience

Combining MEG & fMRI

Over time





Cichy et al. Nature Neuroscience, 2014; Cichy et al. BioRxv, 2016

how did MVPA help?

- Focus moved away from activation towards information

where in the brain can we find information about X?

how similar are stimulus X and Y?

- now able to tease apart stimuli that activate the same brain region equally strongly (on average)
- allowed comparison between modalities
(MEG - fMRI - behaviour - animal physiology)

How did MVPA not help?

- Thresholding problem remains (searchlight), but less prominently:
  the classification algorithm creates an elaborate (pattern-based) new ROI, for which some comparison is significant
- ***Important:*** The reverse inference problem remains: what is it really about the stimulus that causes an activation pattern.
  - Leaving the hard work to an algorithm makes the researcher blind
  - We still have no explicit model of computation and representation:
    Need forward model for that!
- *Perusall - Kay & Naselaris paper*