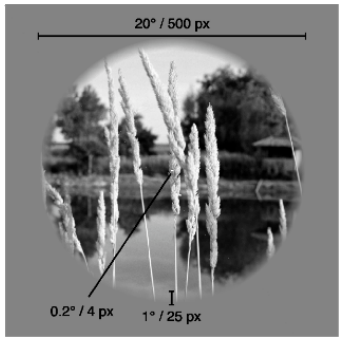
215A, Final Project

Yuval Benjamini (based on An Vu's talk)
Department of Statistics, UC Berkeley

Goals

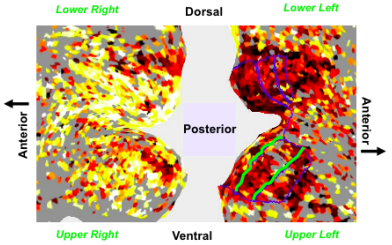
- Quantitative model - both stimulus and response high-dimensional



Natural Input
(Image or video)

Encoding

Decoding



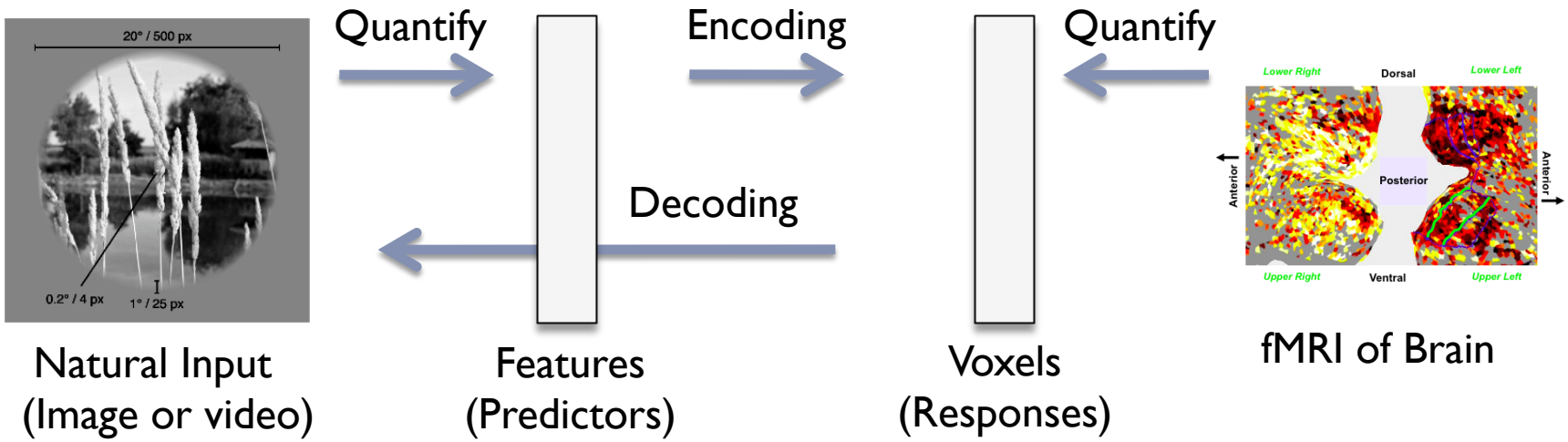
fMRI of Brain

Focus on Prediction

- Complementary tasks
  - Build predictive models of how brain reacts to images
    - 1. Check that models are valid
    - 2. Learn/ Interpret how brain works
  - Decoding makes sure encoding is rich in information

Analysis stages

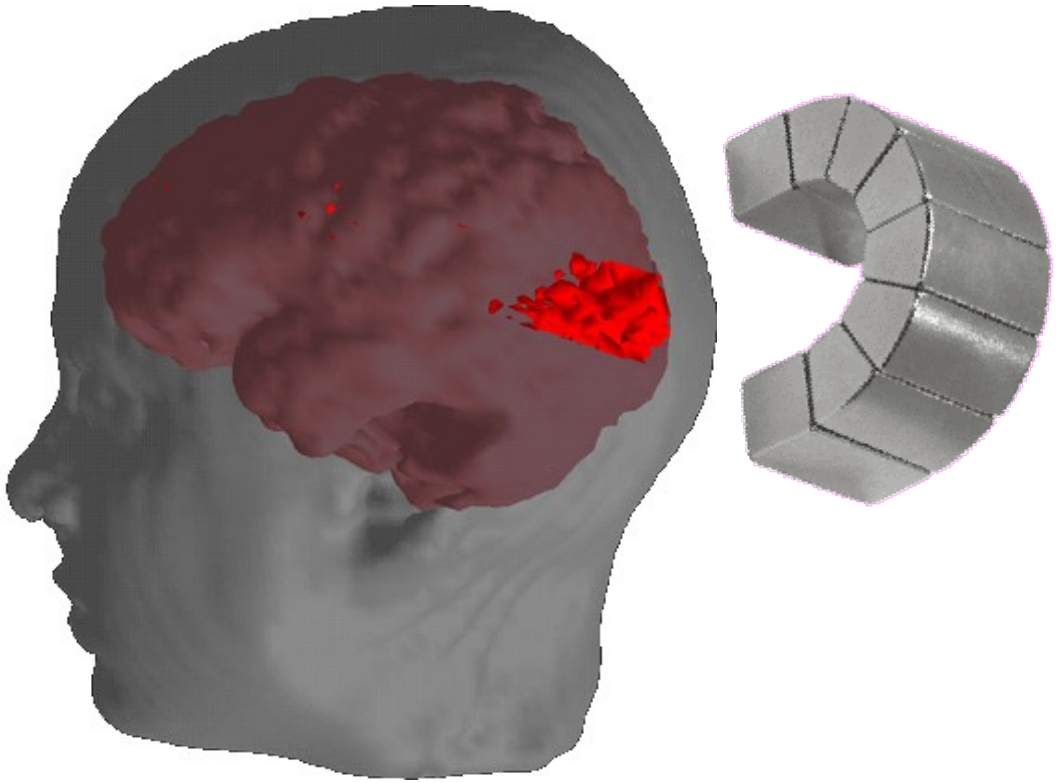
- Quantitative model - both stimulus and response high-dimensional



- Quantify images so encoding becomes linear!
- Hard Problem:
  - High dimensional stimuli
  - Limited observations
  - Both signals may be continuous (in case of video)

Experimental design

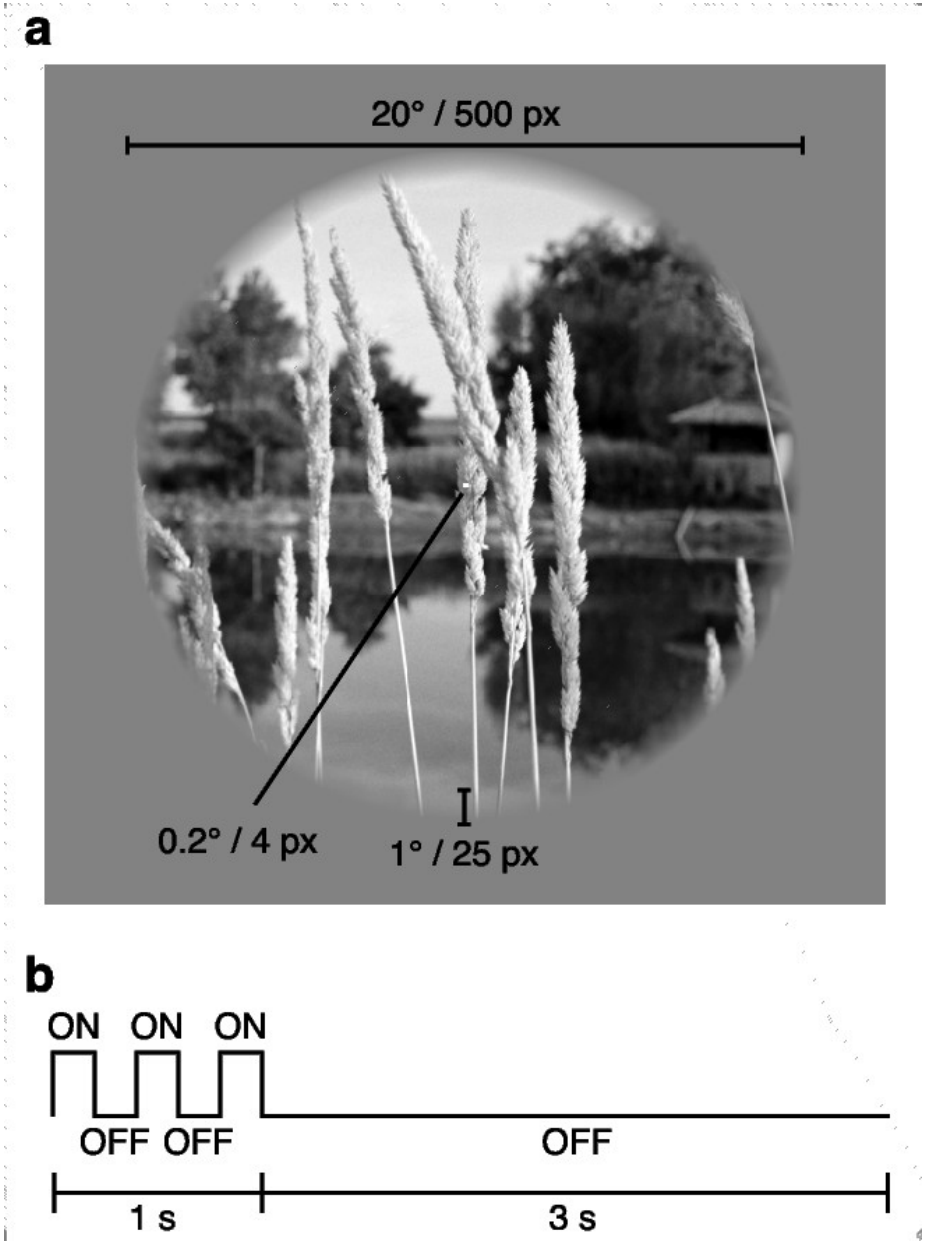
Stim = X, Response = Y



$$s_n(x,y) = X_n \longrightarrow r_n(x,y,z) = Y_n$$

$$n = \{1,2,3\ldots1750\}$$

Stimuli Details

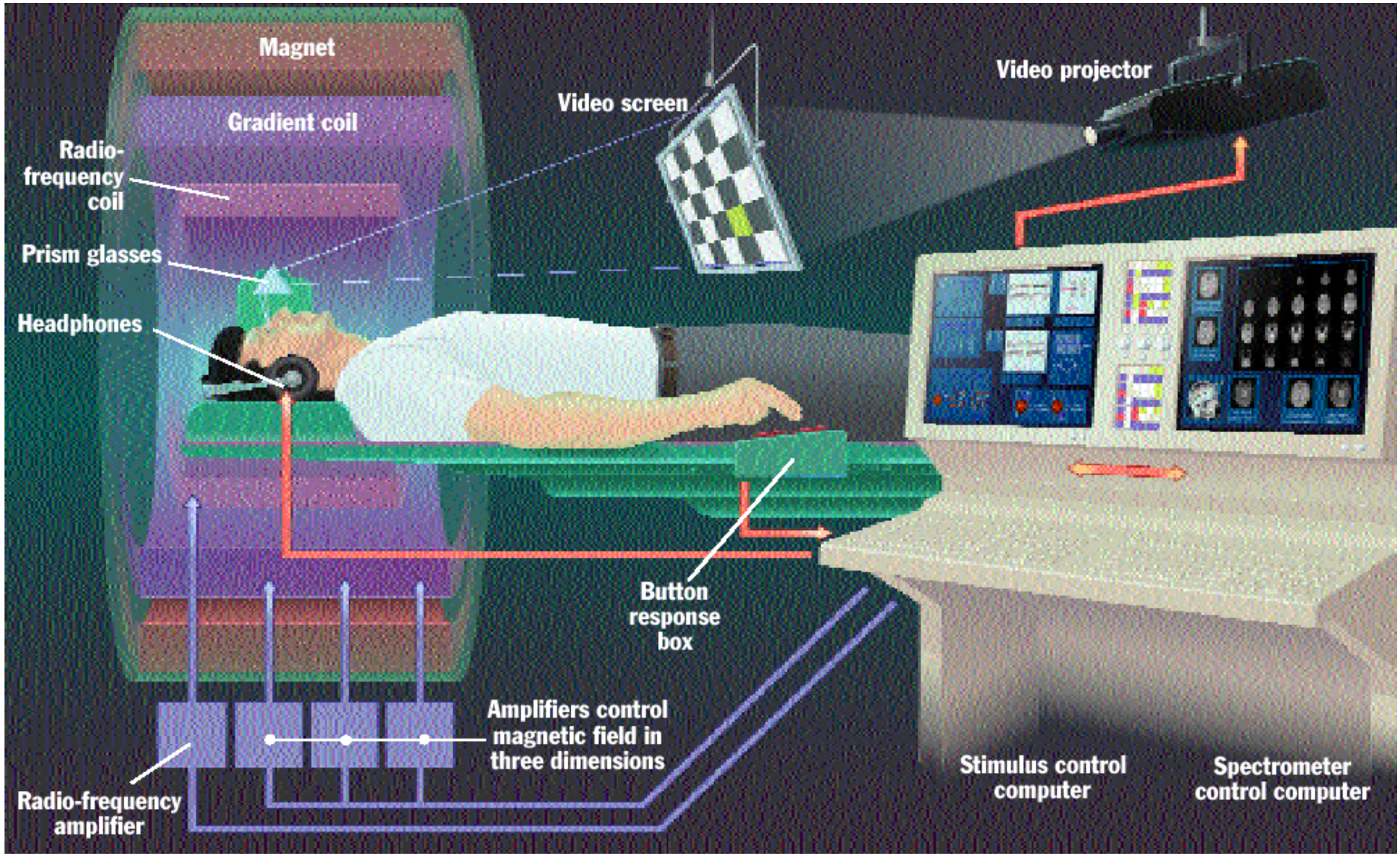


Experimental details

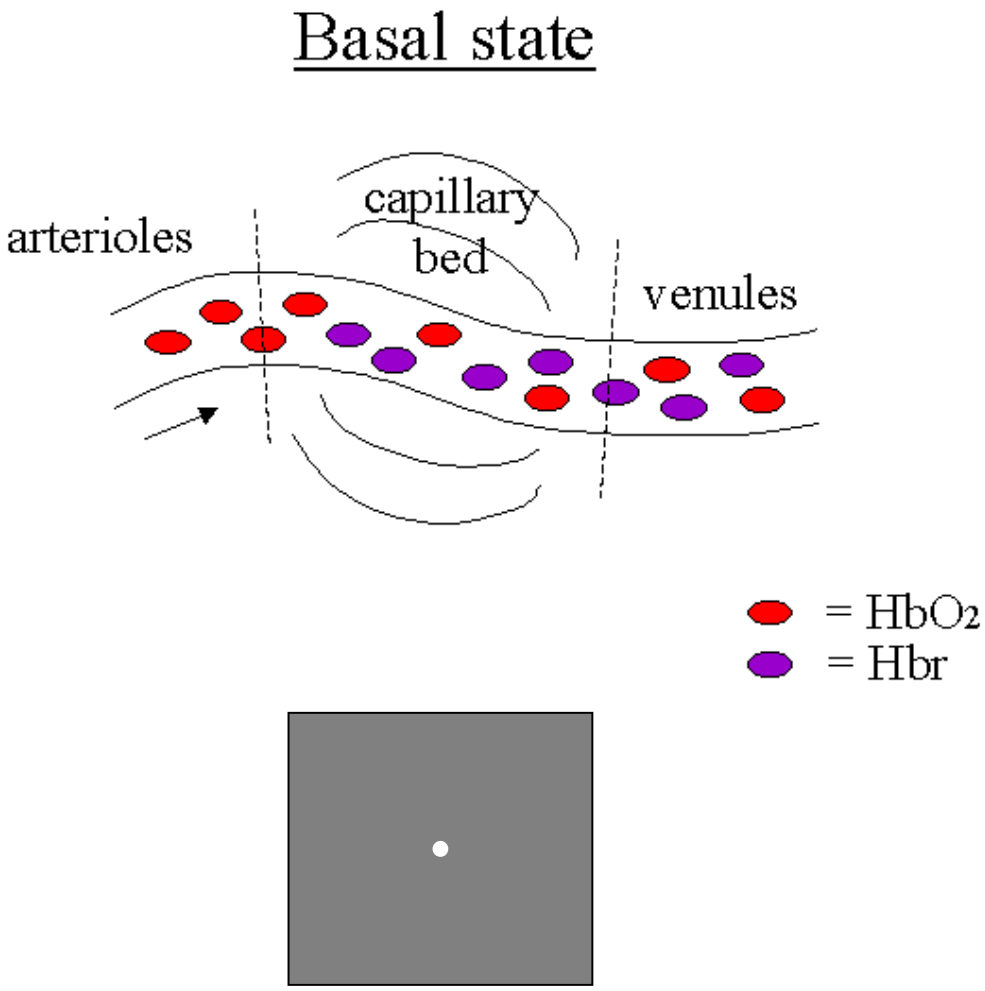
- Anatomicals
  - 1.5 T Brucker magnet at Martinez VA
- Stimuli
  - Grayscale photographs of natural scenes
  - 20x20 visual degrees
  - 1750 training photos (2 reps)
  - 120 validation photos (13 reps)
- fMRI Data Acquisition Parameters
  - 4T Varian magnet
  - (Details not relevant here)

fMRI basics

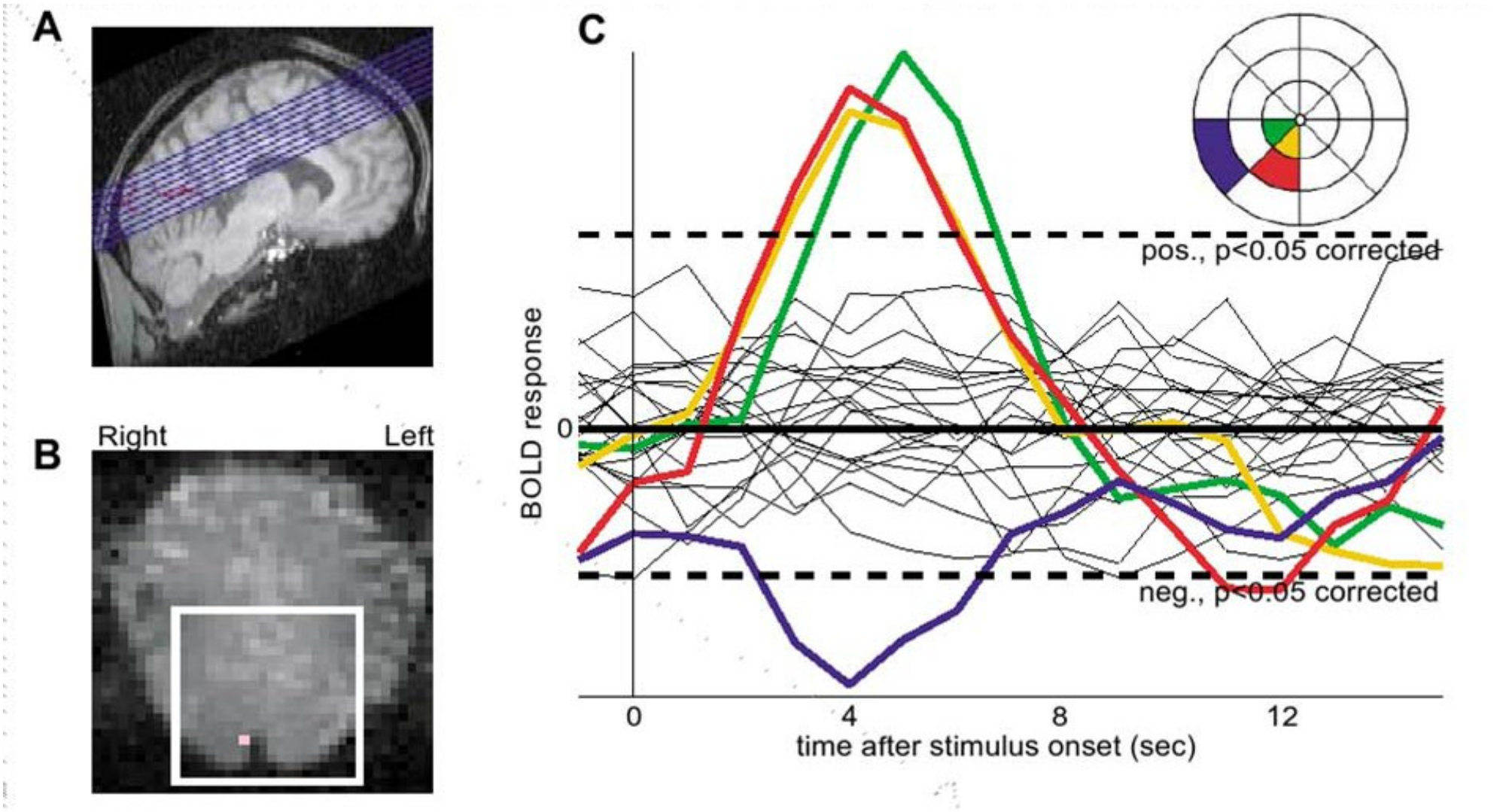
MRI machine


Magnet
Gradient coil
Radio-frequency coil
Prism glasses
Headphones
Video screen
Video projector
Button response box
Amplifiers control magnetic field in three dimensions
Radio-frequency amplifier
Stimulus control computer
Spectrometer control computer

What does fMRI measure?



Voxel Responses: Space & Time components



Hansen et al 2004

Outline

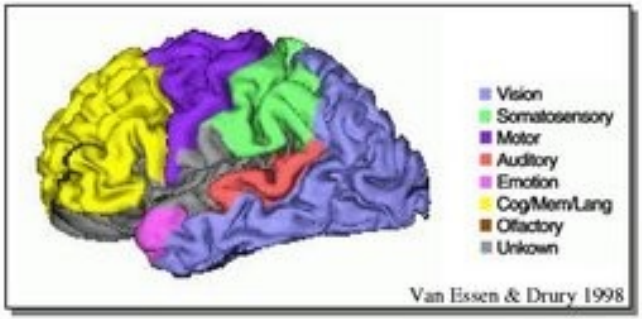
- Data Details
- Experimental Design
- Voxel selection prior
- fMRI Basics
- Human Visual System
- G – Gabor Wavelet Pyramid Basis Set
- A step beyond predictions

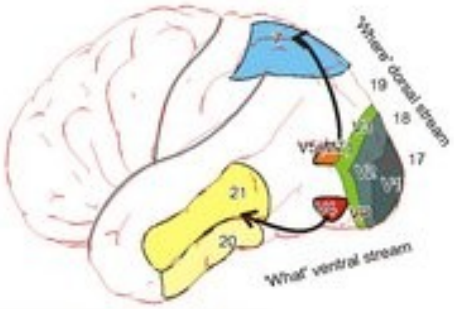
fMRI basics & the visual system

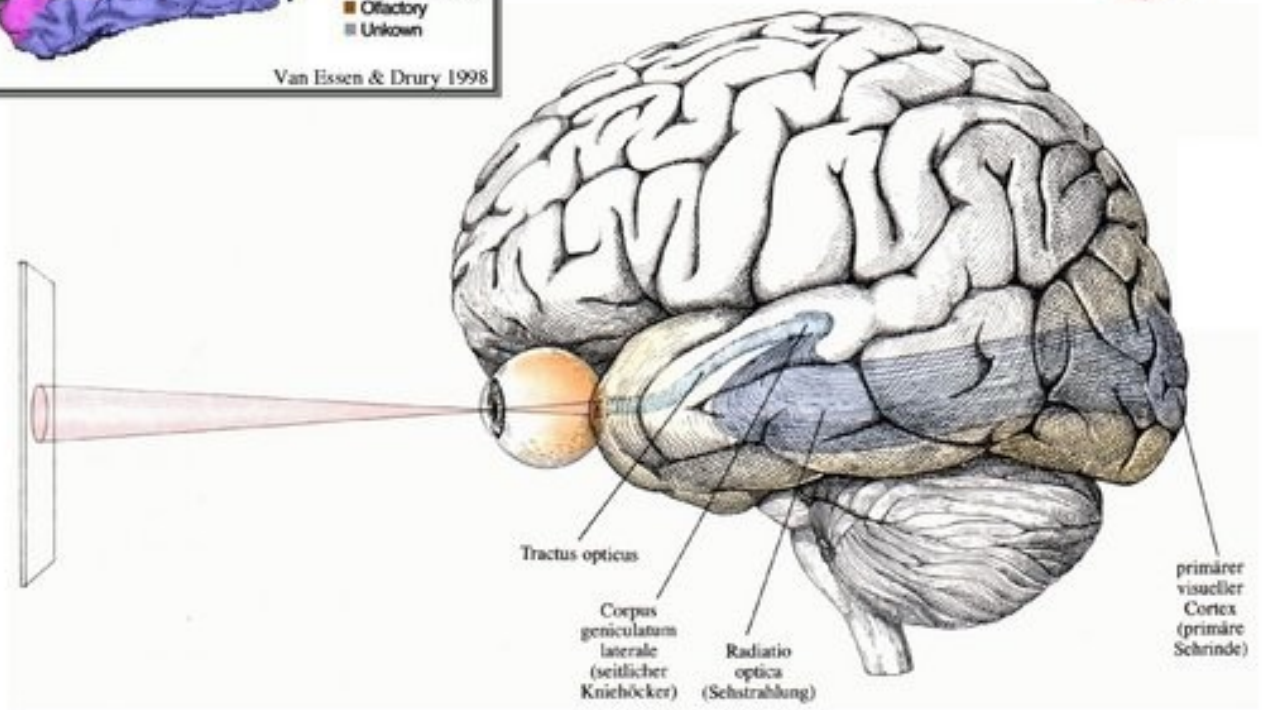
The visual system:
Voxels Map Topographically

HUGE PRIOR!!!

The visual system

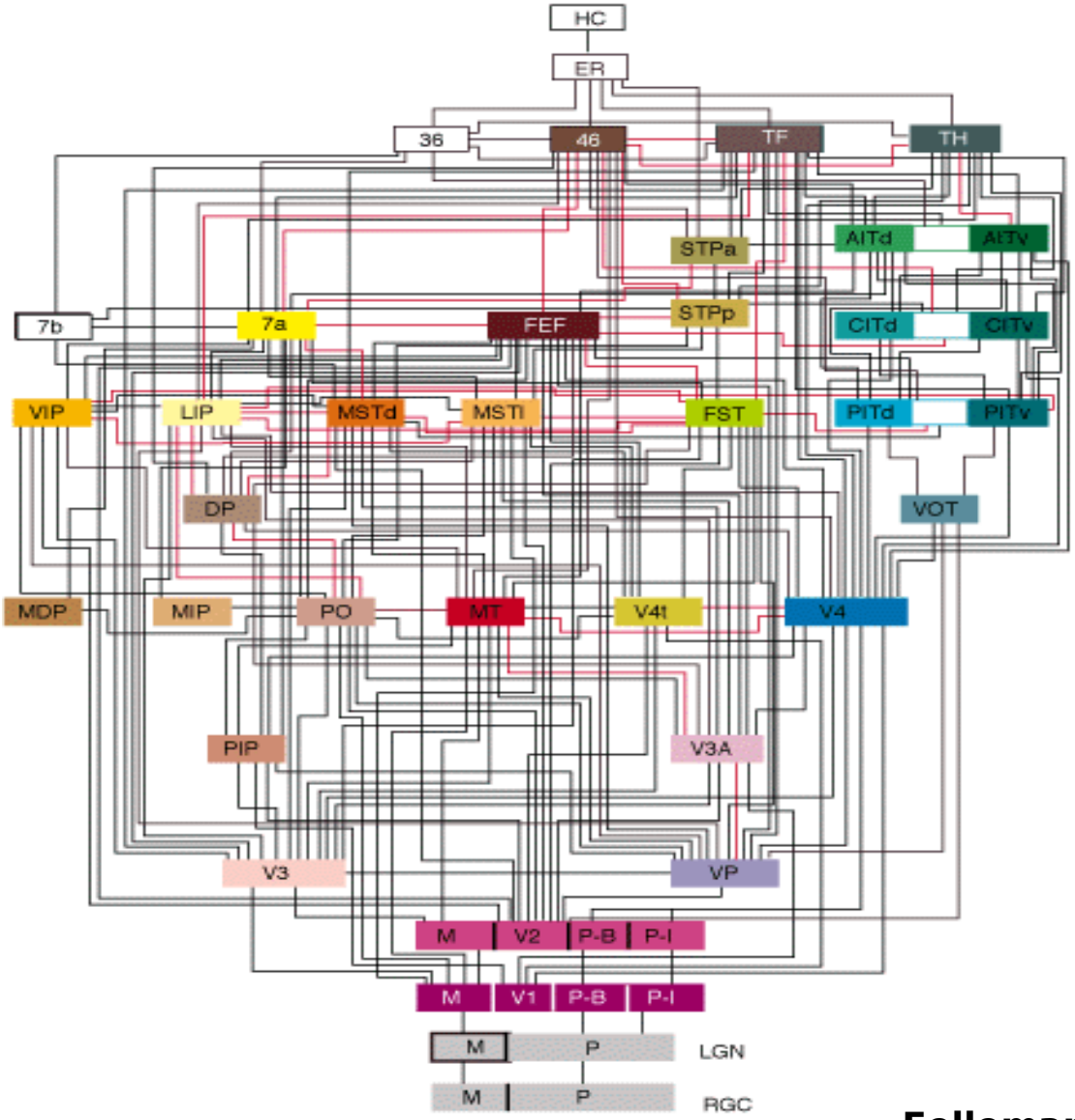






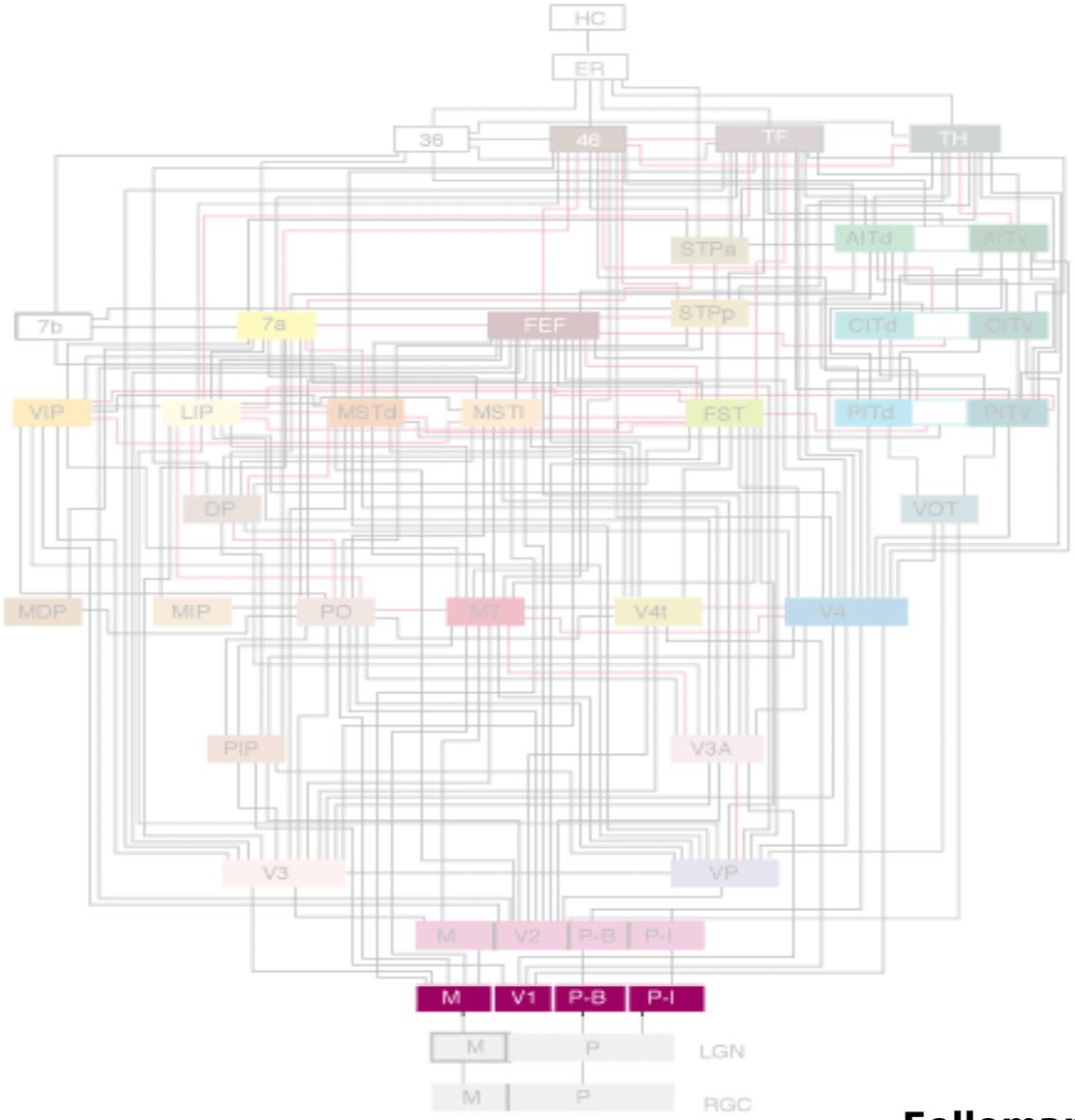
Hubel 1985

The visual hierarchy



Felleman & Van Essen 1991

The visual hierarchy

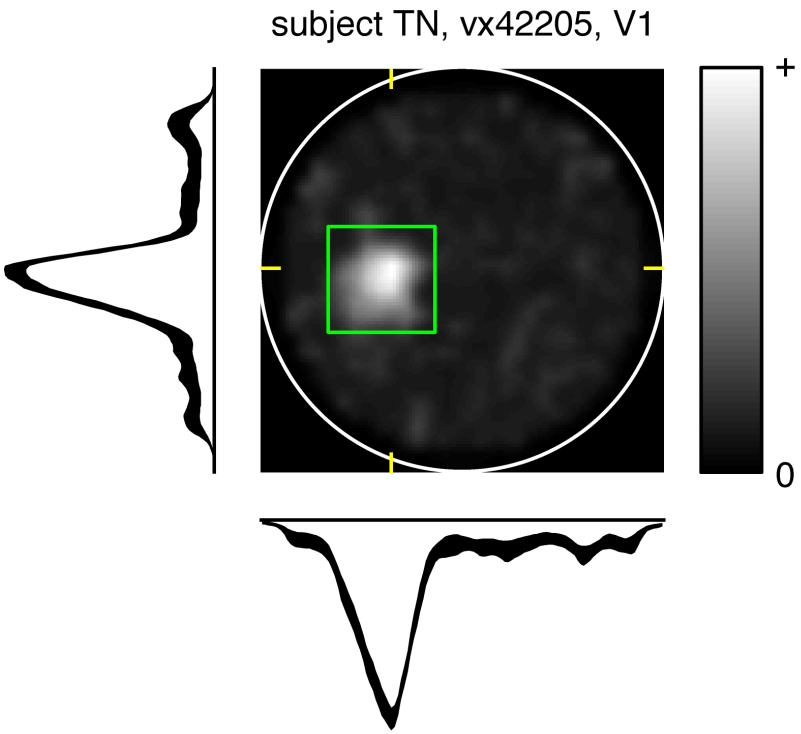


Felleman & Van Essen 1991

The visual system:
3 Voxel Properties

Voxel property #1: Spatial Selectivity

1) Spatial RF estimation

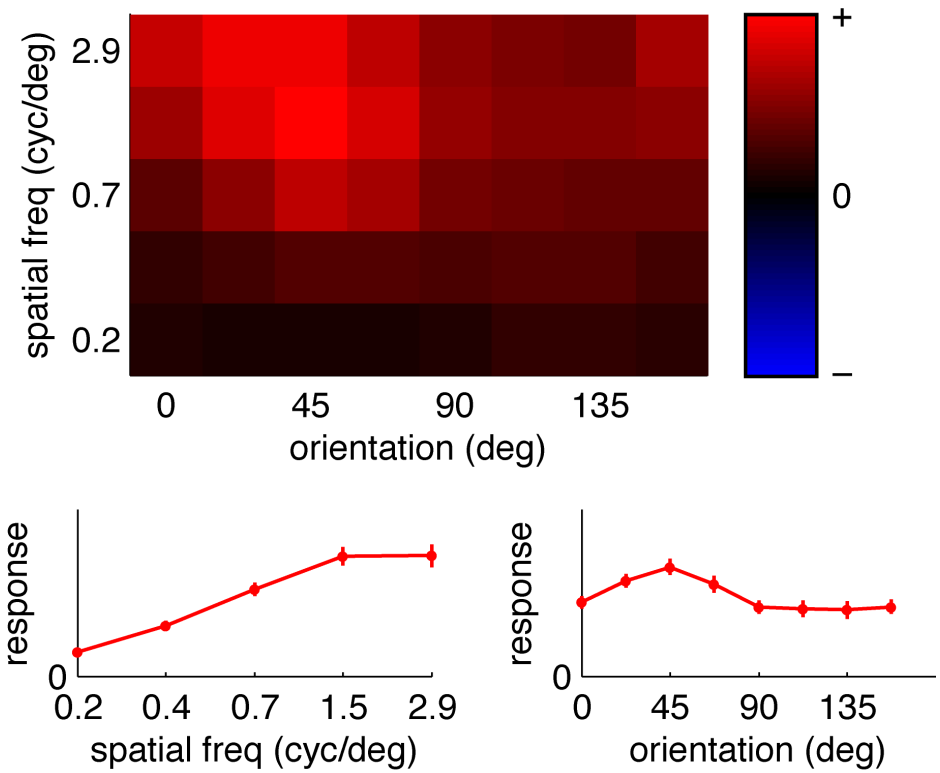


- BW photos, 20x20 deg: 1750 training (2 reps), 120 validation (13 reps)
- 4T varian magnet, 2x2x2.5mm voxels
- BWT model fit by boosting, 1458 parameters (729 rectified)

Kay et al. 2008

Voxel property #2-3: f & θ

2) Frequency 3) Orientation tuning

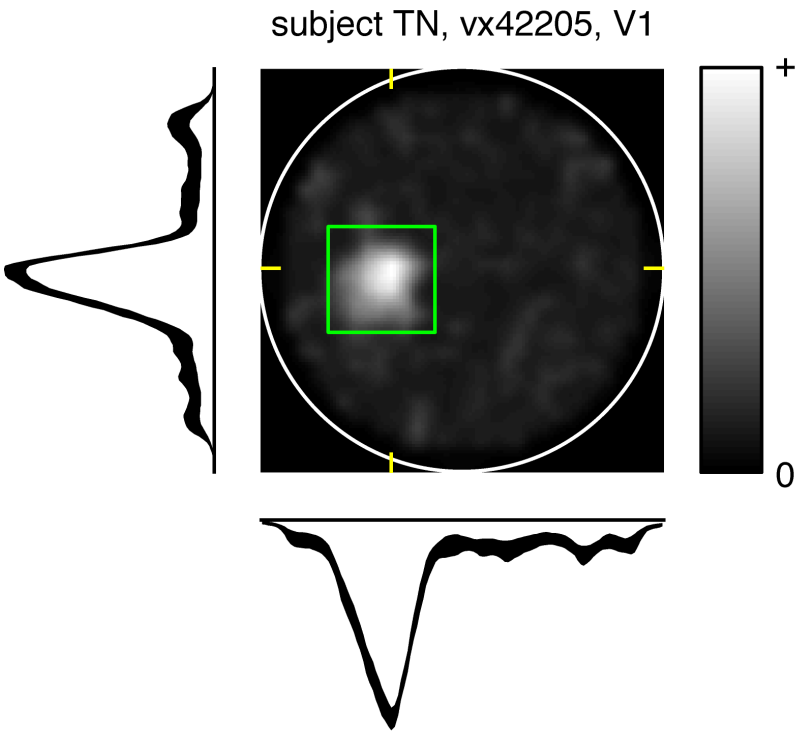


- BW photos, 20x20 deg: 1750 training (2 reps), 120 validation (13 reps)
- 4T varian magnet, 2x2x2.5mm voxels
- BWT model fit by boosting, 1458 parameters (729 rectified)

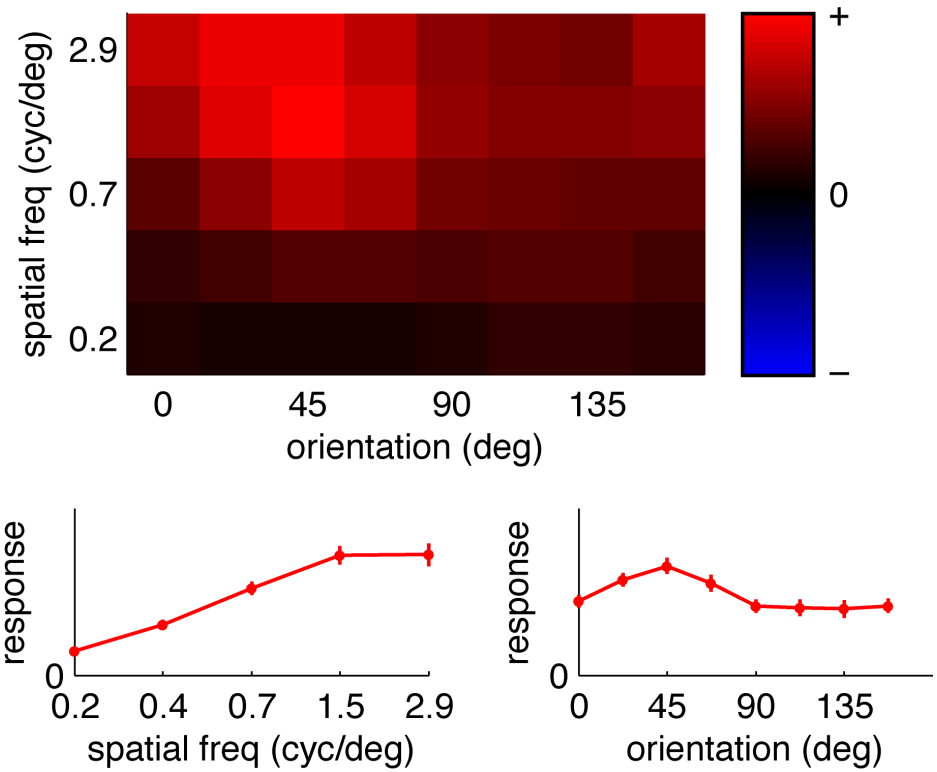
Kay et al. 2008

Voxel properties

1) Spatial RF estimation



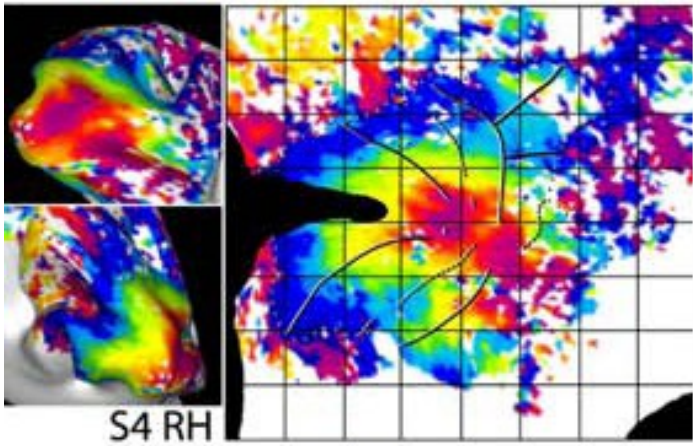
2) Frequency 3) Orientation tuning

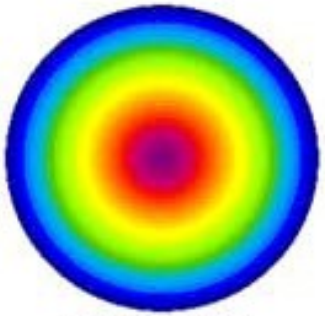


- BW photos, 20x20 deg: 1750 training (2 reps), 120 validation (13 reps)
- 4T varian magnet, 2x2x2.5mm voxels
- BWT model fit by boosting, 1458 parameters (729 rectified)

Kay et al. 2008

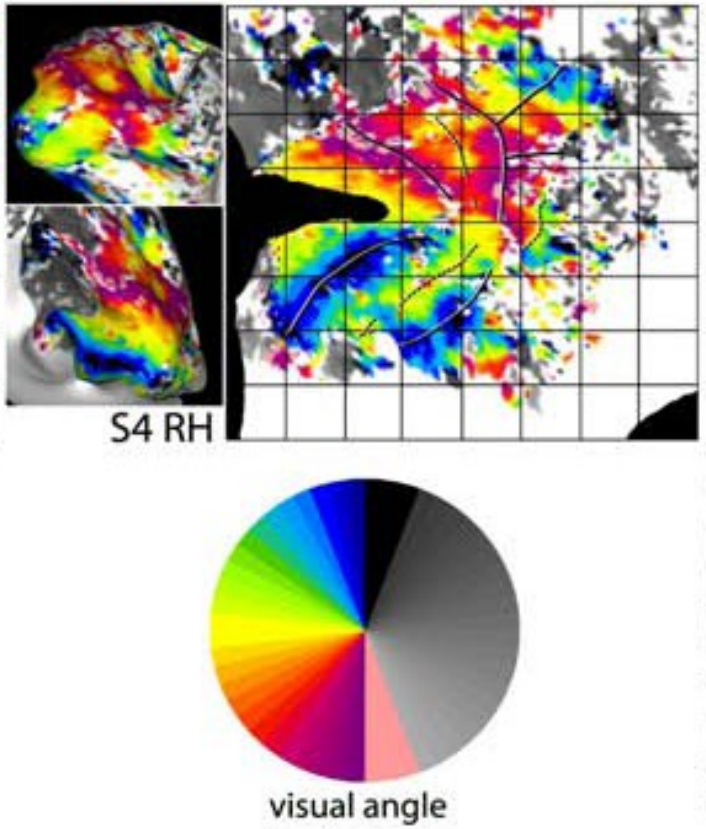
Human retinotopic eccentricity





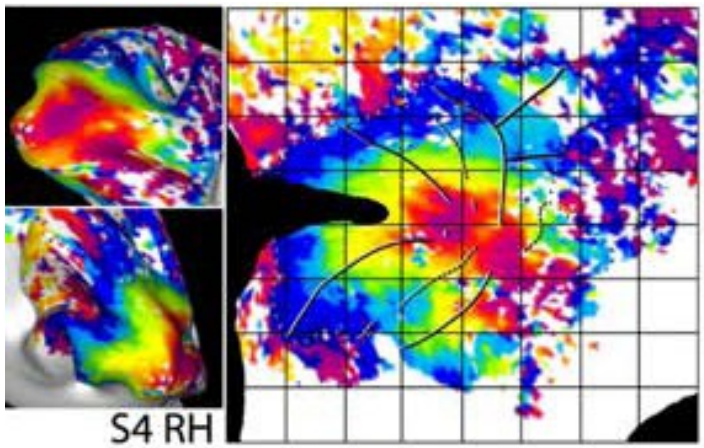
Hansen, Kay and Gallant 2007

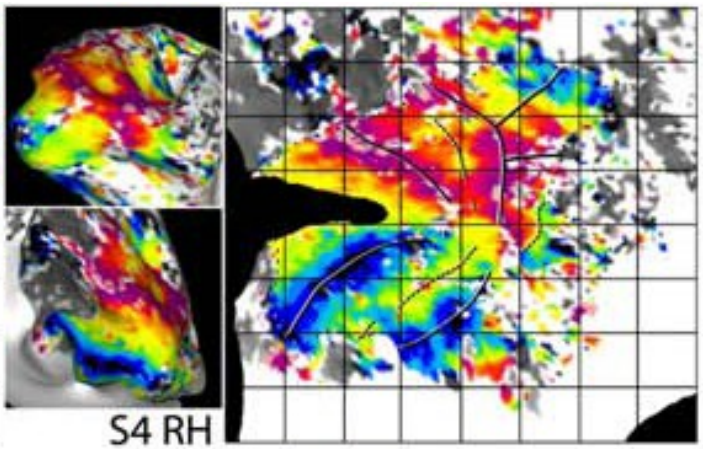
Human retinotopic angle

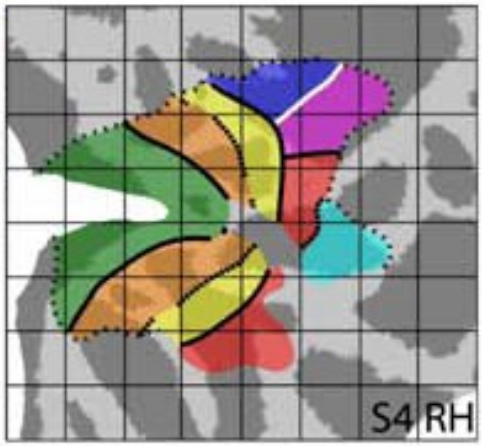


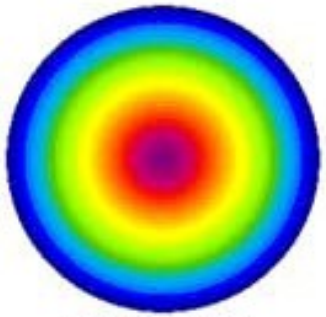
Hansen, Kay and Gallant 2007

Human retinotopic visual areas








eccentricity


visual angle

Central field portions of

V1 V3B V3A
V2 V4
V3 lat-occ

vertical meridian
horizontal meridian
V3A/B offset parafovea
peripheral limit of stimulated cortex

Hansen, Kay and Gallant 2007

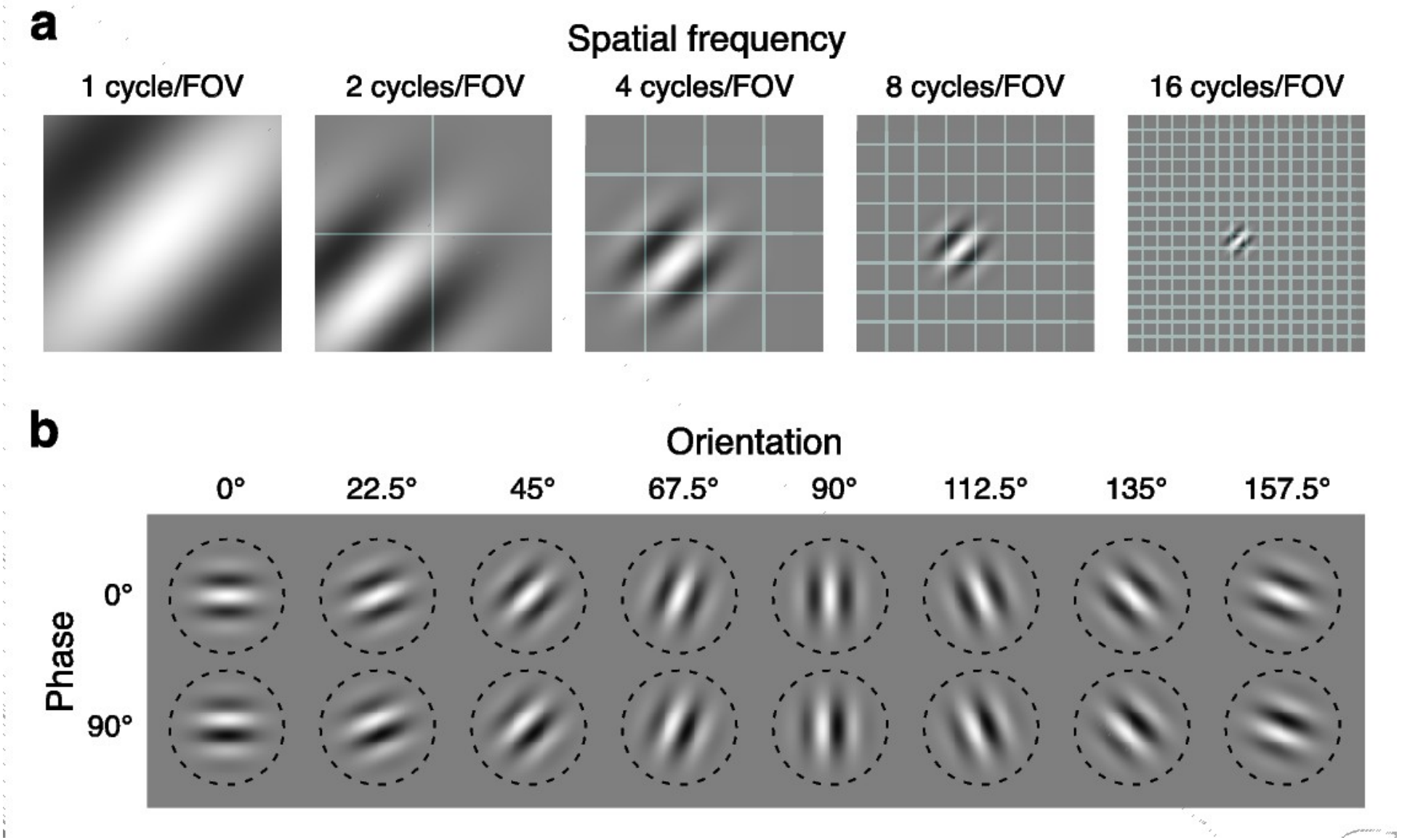
Outline

- Data Details
- Experimental Design
- Voxel selection prior
- fMRI Basics
- Human Visual System
- G – Gabor Wavelet Pyramid Basis Set
- A step beyond predictions

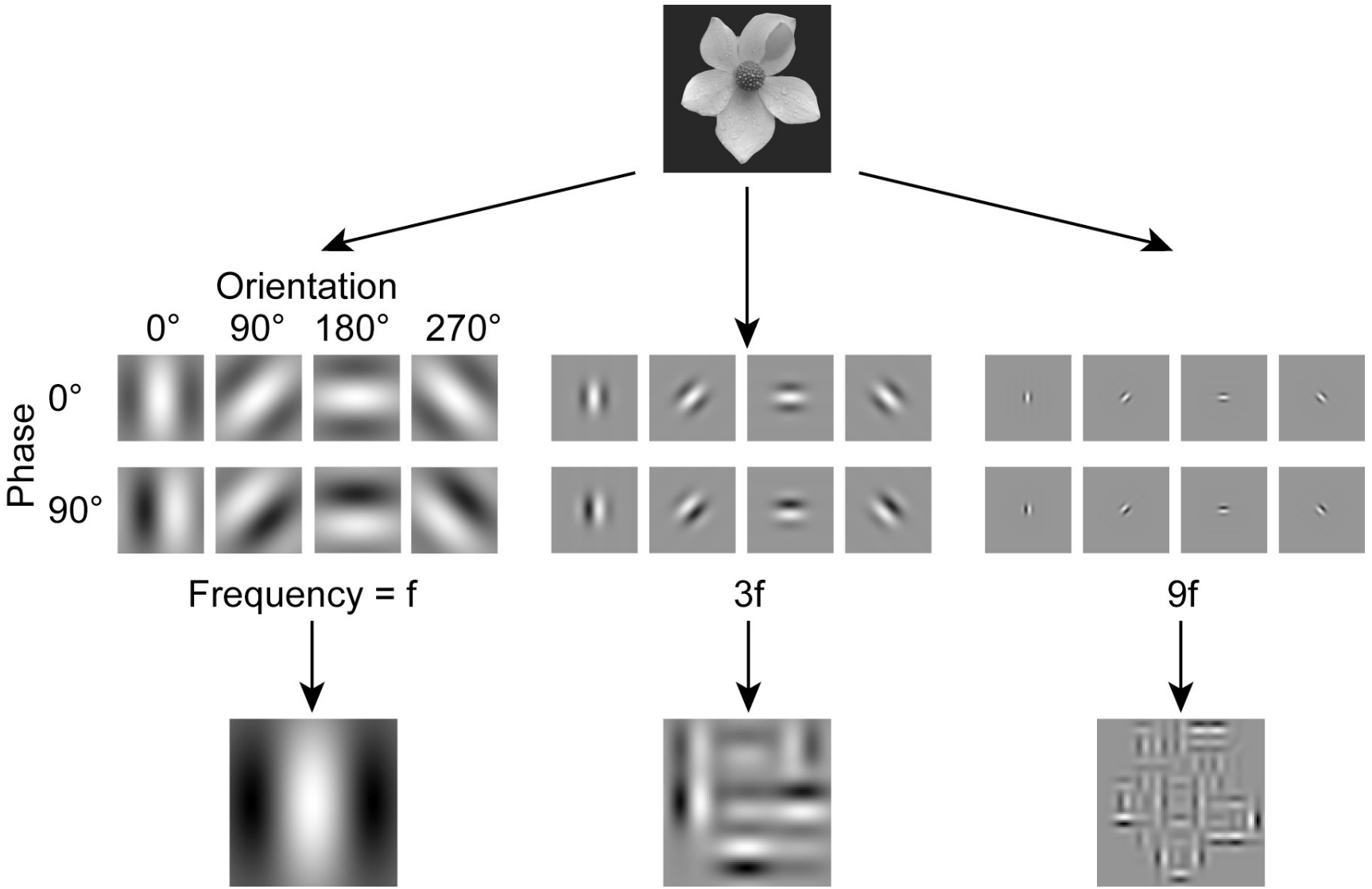
Non-linear transformation of Stim

=> Helps Responses become linear

The Gabor wavelet pyramid

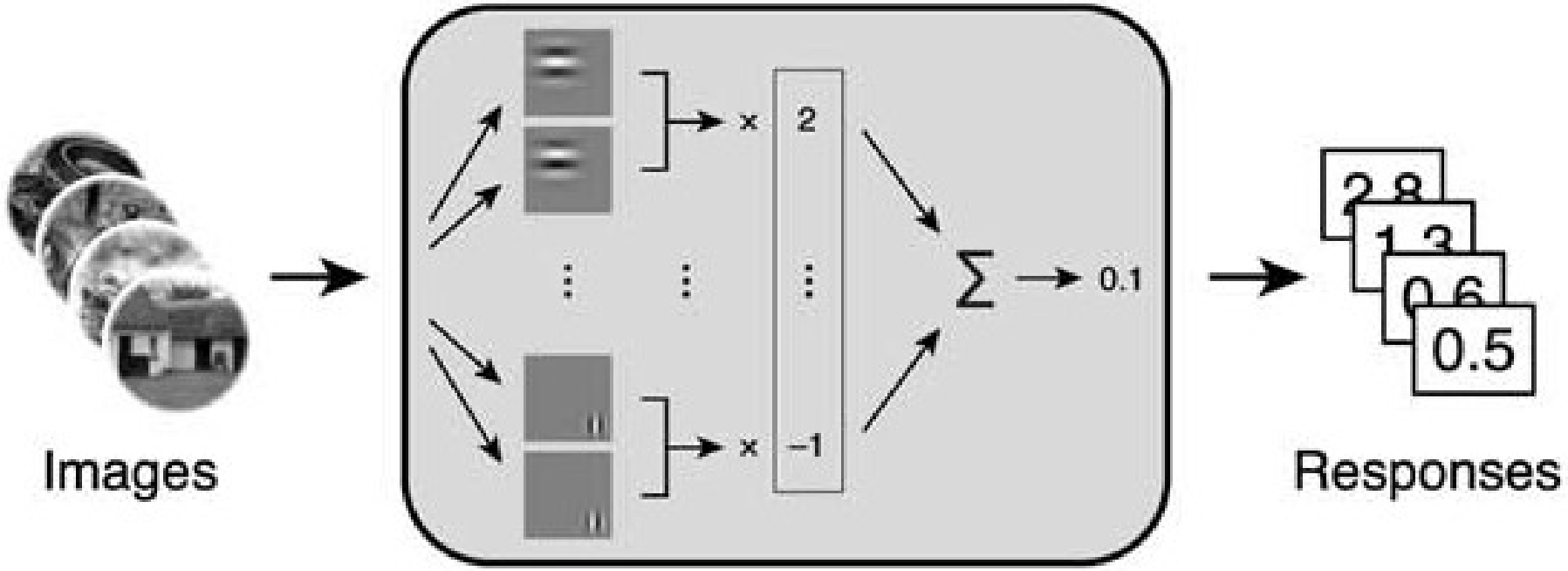


The Gabor wavelet pyramid



Process for fitting data

Estimate a receptive field model for each voxel



Receptive field model for one voxel

Kay et al 2008

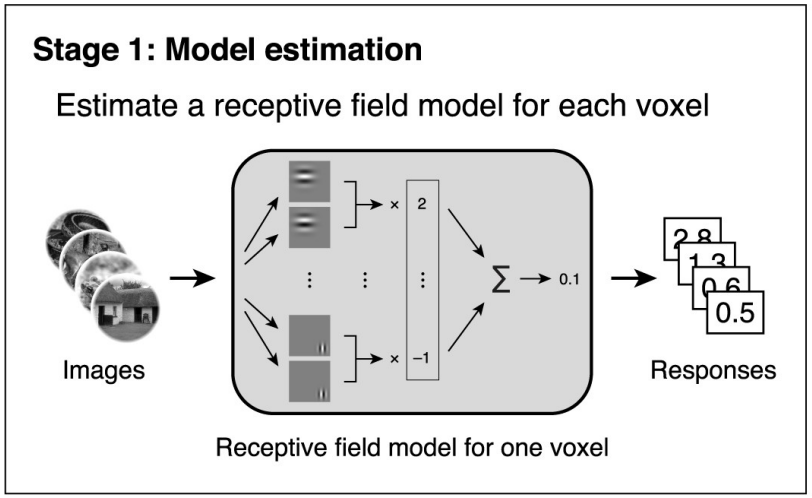
Outline

- Data Details
- Experimental Design
- Voxel selection prior
- fMRI Basics
- Human Visual System
- G – Gabor Wavelet Pyramid Basis Set
- A step beyond predictions - mind reading?

“Pick an image, any image”

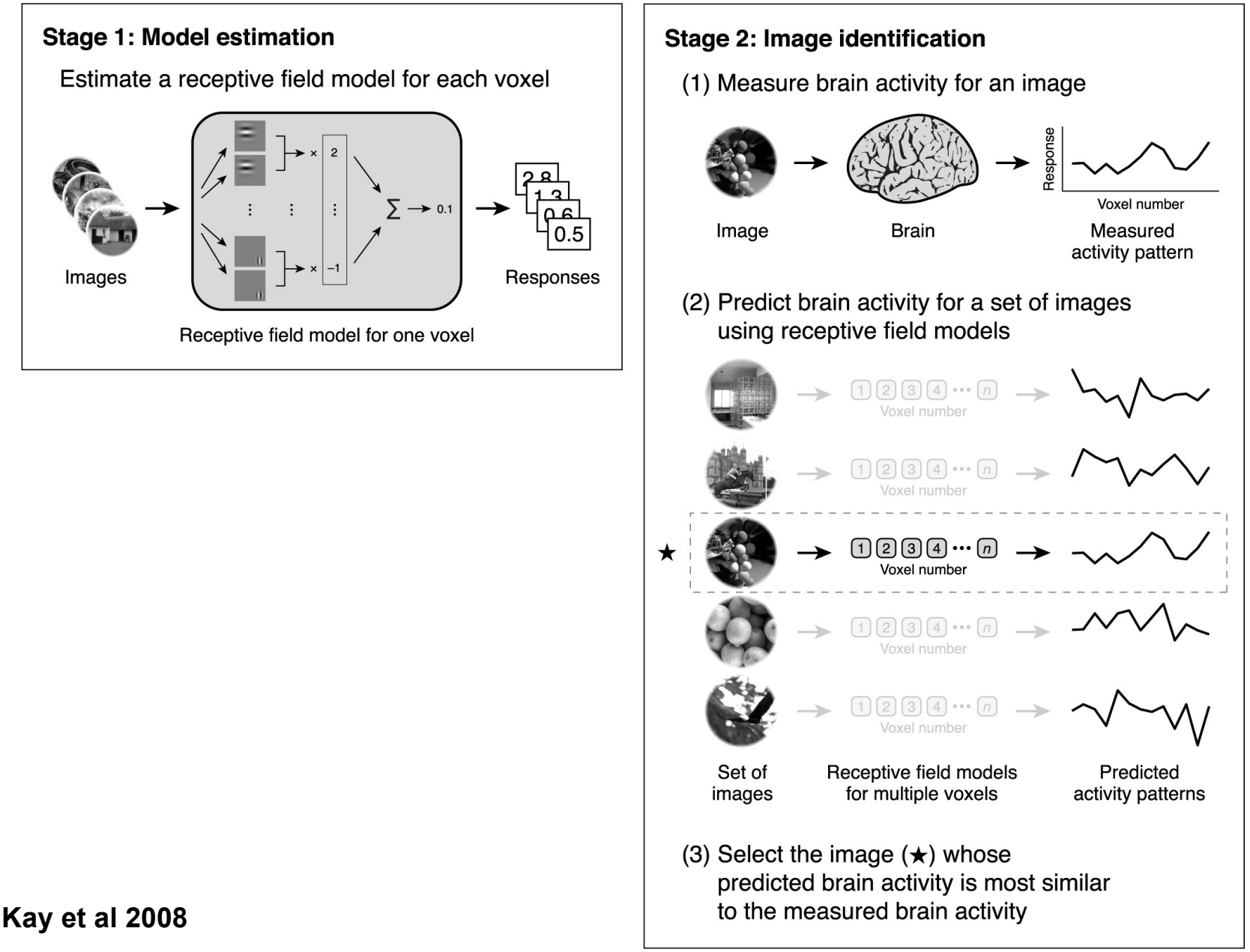
a type of magician mind reading?

a type of magician mind reading?



Kay et al 2008

a type of magician mind reading?



Kay et al 2008

The end

Acknowledgements

Gallant Lab

Kendrick Kay
Thomas Naselaris
Ryan Prenger
Jack Gallant

Yu Lab

Vince Vu
Pradeep Ravikumar
Guillherme Rocha
Bin Yu

Special Thanks

Charlotte Wickham
Kyle Jia