Where are we?

- Estimate the neuron response, given a stimulus. The impulse response h(t).

- Case of discrete response: use STA, case of continuous response use Wiener kernel/linear approximation. If white noise stimulus, use STA.

- Example of V1 (Ringach & Shapley, 2004). h(x,y,t) by subspace reverse correlation. Gabor kernel. Use h(t) to study the orientation selectivity of V1 cells, and its time course.

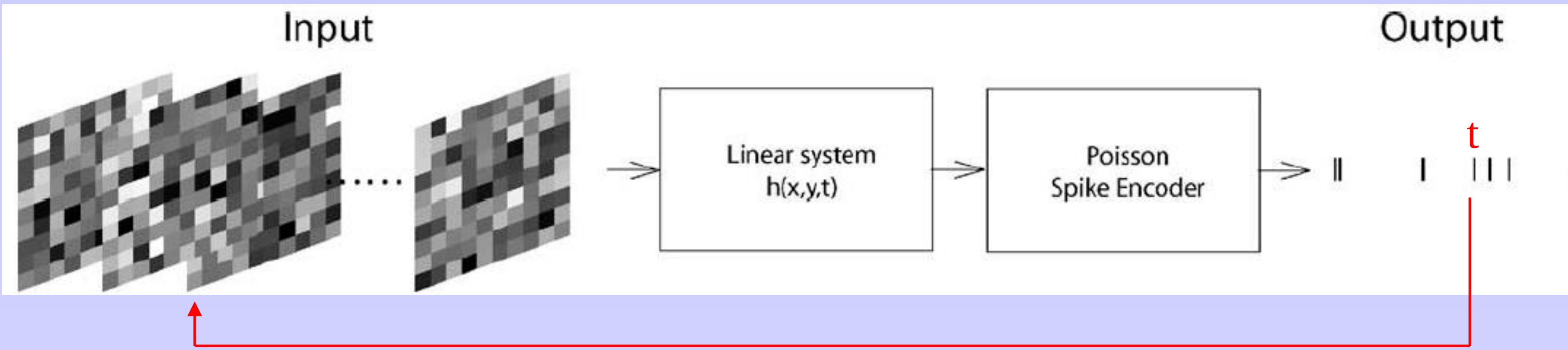
- Next: Example of V1 (Usrey, Sceniak and Chapman, 2003)

h(x,y,t) → $\langle h() \rangle_{x,y}$ Impulse response

h(x,y,t) → $\langle h() \rangle_{t}$ Receptive field

V1 - Spatial receptive field

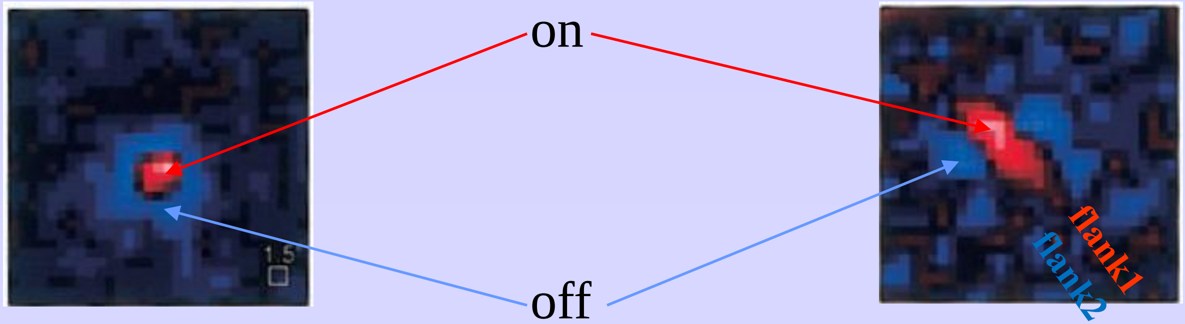
➔ Receptive field = Average spatial response. No temporal information.



Reverse correlation

Temporal average as a function of (x,y) – Ferret V1, Layer 4

There are center-surround V1 cells!

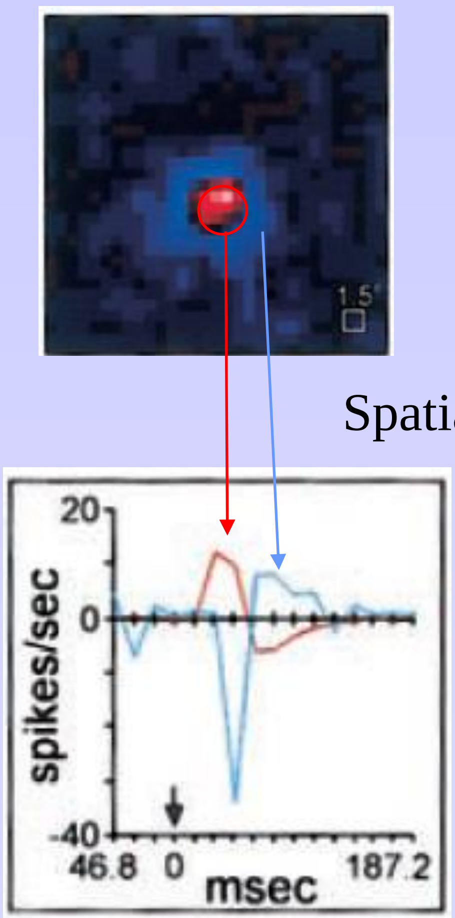


(Usrey et al, 2003)

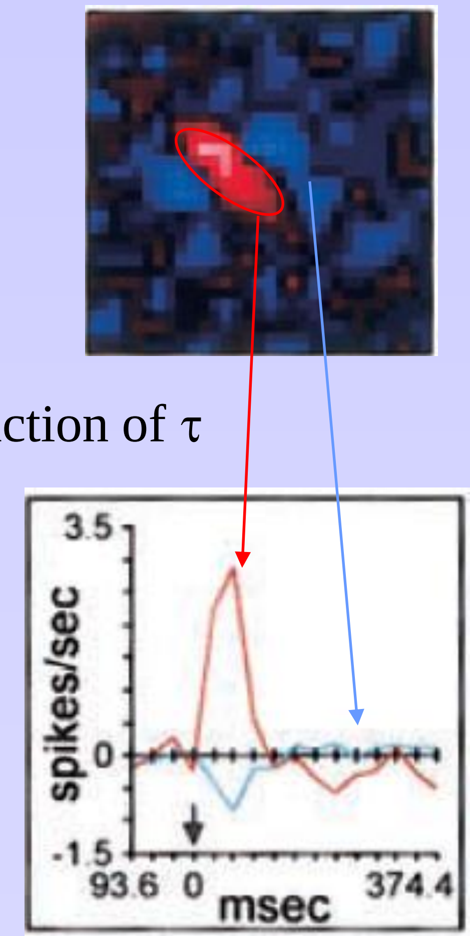
- Separating the excitatory and inhibitory spatial regions

V1 - Impulse function

- Impulse response calculated for each spatial subregions. Separating the ‘excitation’ and ‘inhibition’ time courses.



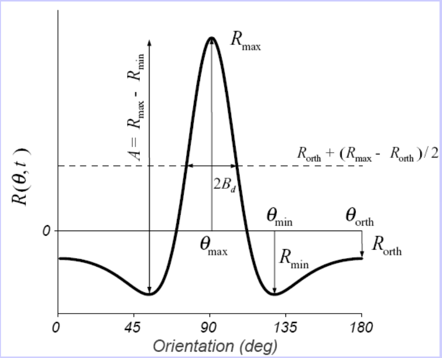
Spatial average as a function of τ



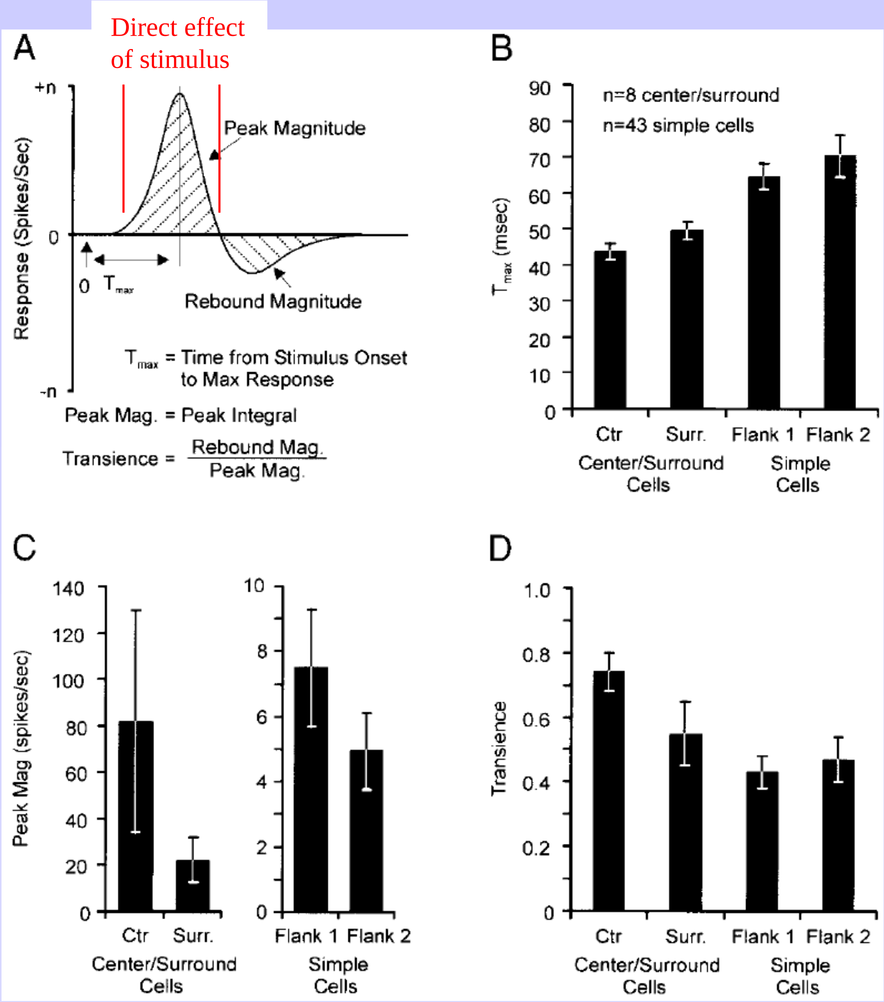
(Usrey et al, 2003)

Impulse function

- How does one quantify an impulse function?



(Ringach shapley)



(Usrey et al, 2003)

- B: Max response fastest for center/ surround cells.

- C: Magnitude of peak smallest for center/ surround cells.

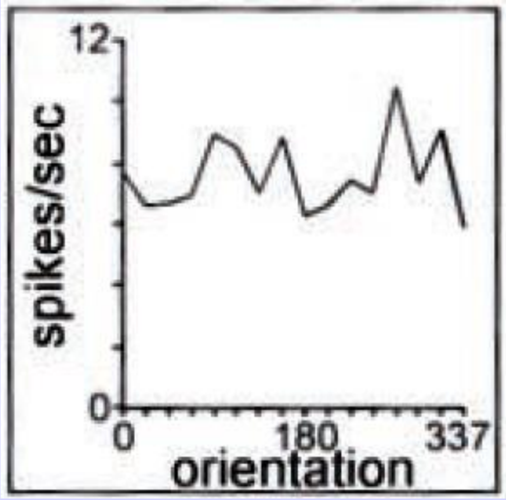
- D: ‘Transience’ largest for center/surround cells.

Orientation selectivity

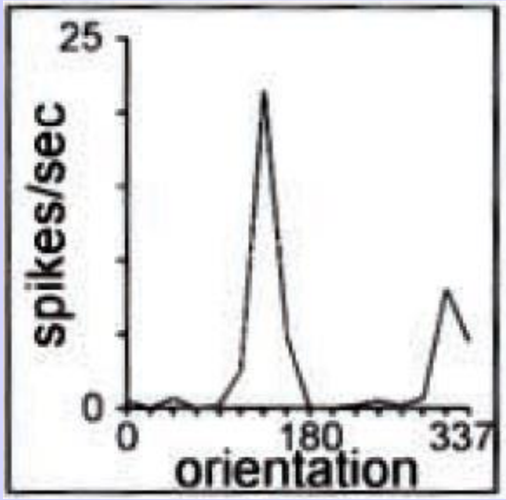
Stimuli:
Moving gratings

➔ Orientation tuning curve: Average response (firing rate) per orientation

Not selective



Selective

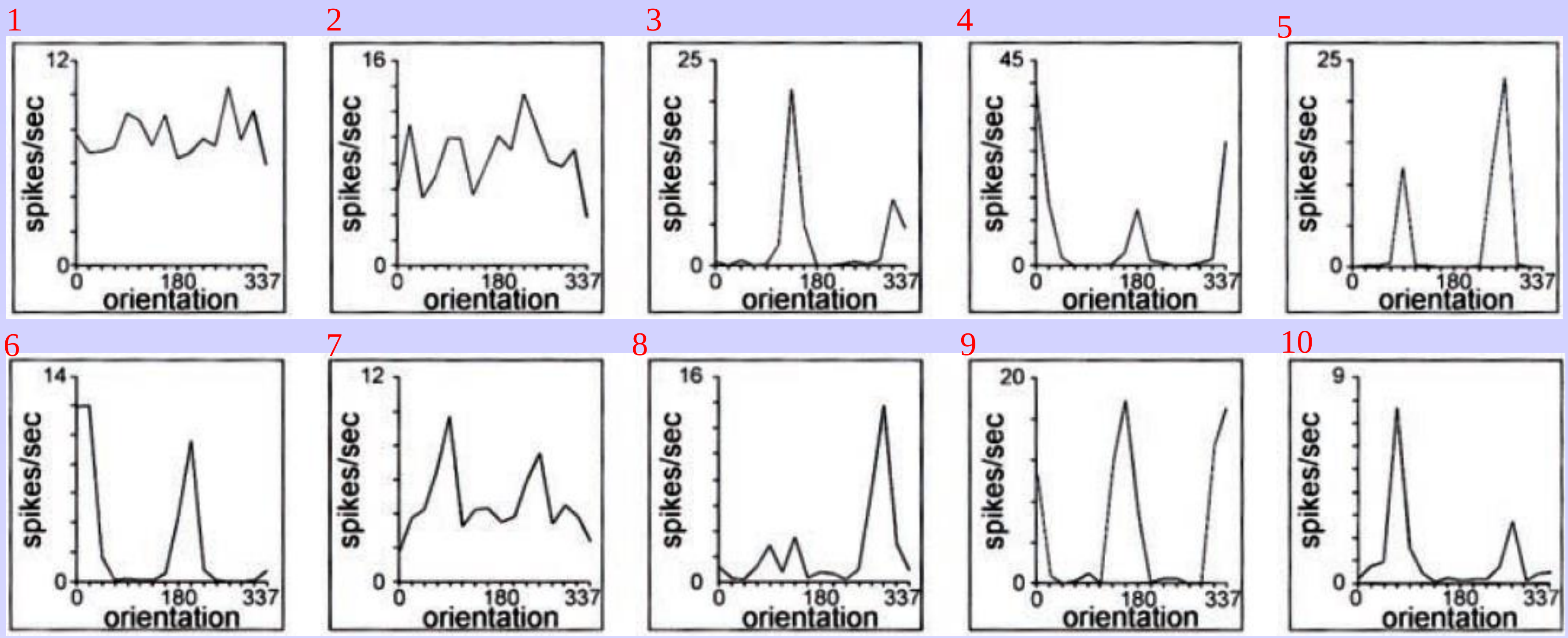


(Usrey et al, 2003)

→ Again….No temporal information…

Orientation selectivity plots

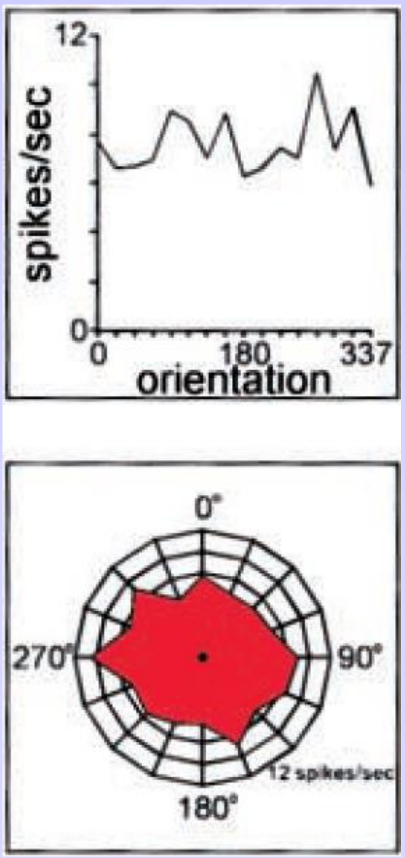
- Different types of selectivity: What do you see, qualitatively ?

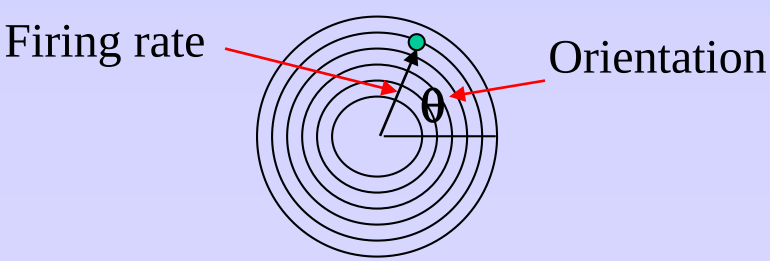


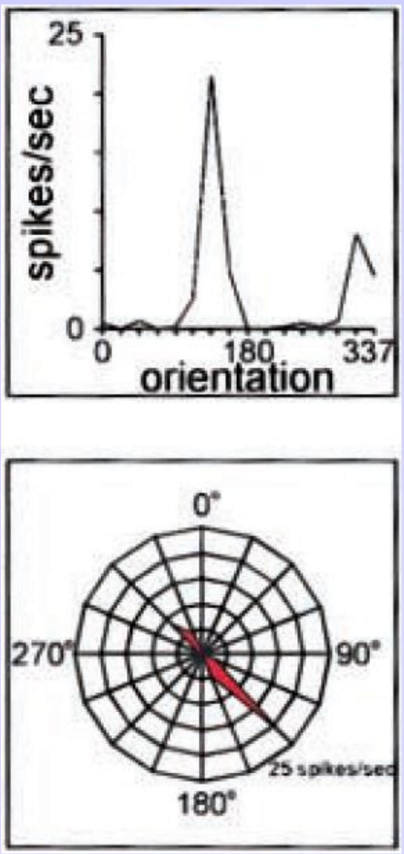
(Usrey et al, 2003)

Orientation selectivity plots

- Can we find *one graphic* per cell that characterizes its orientation selectivity?
- From Cartesian to Polar plots.
- Intuitive graphics… quick visualization … no loss of information



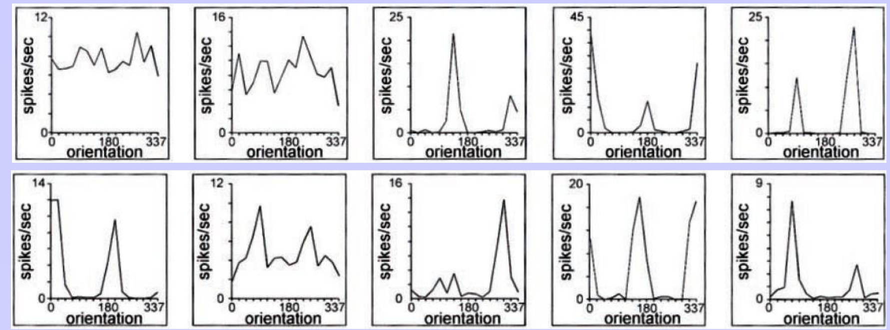


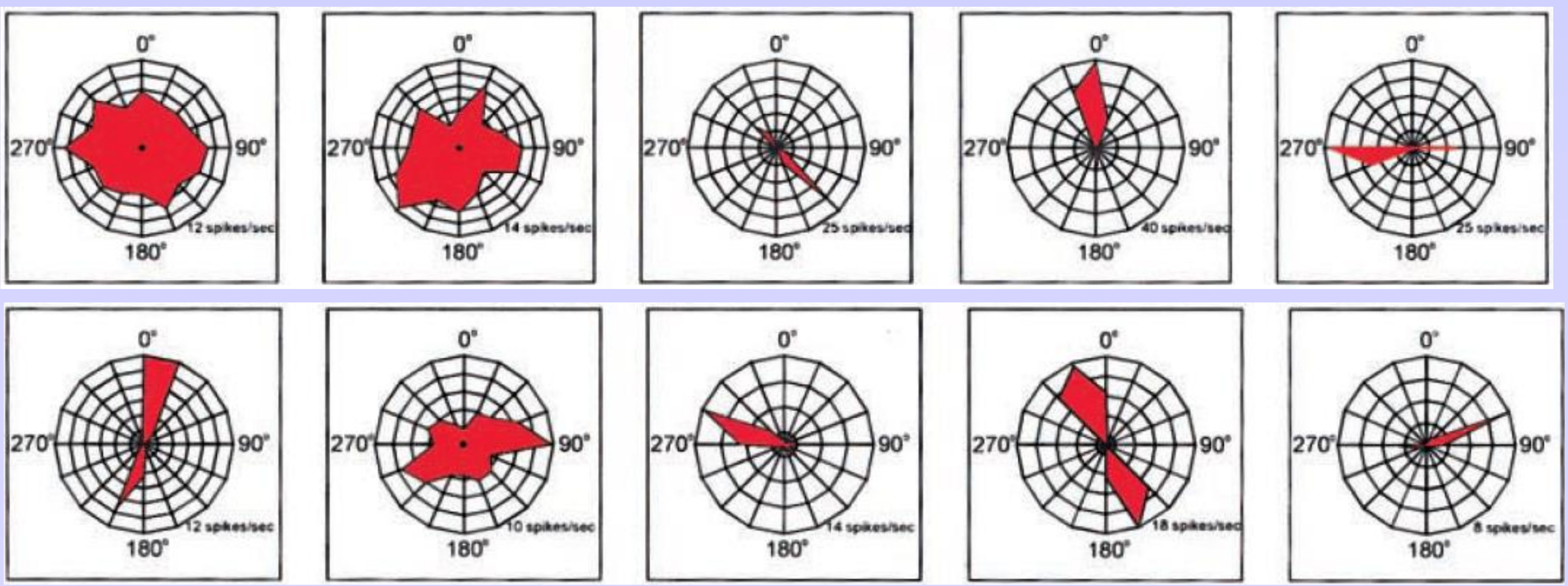


(Usrey et al, 2003)

Orientation selectivity plots

- Different types of selectivity: What do you see ?

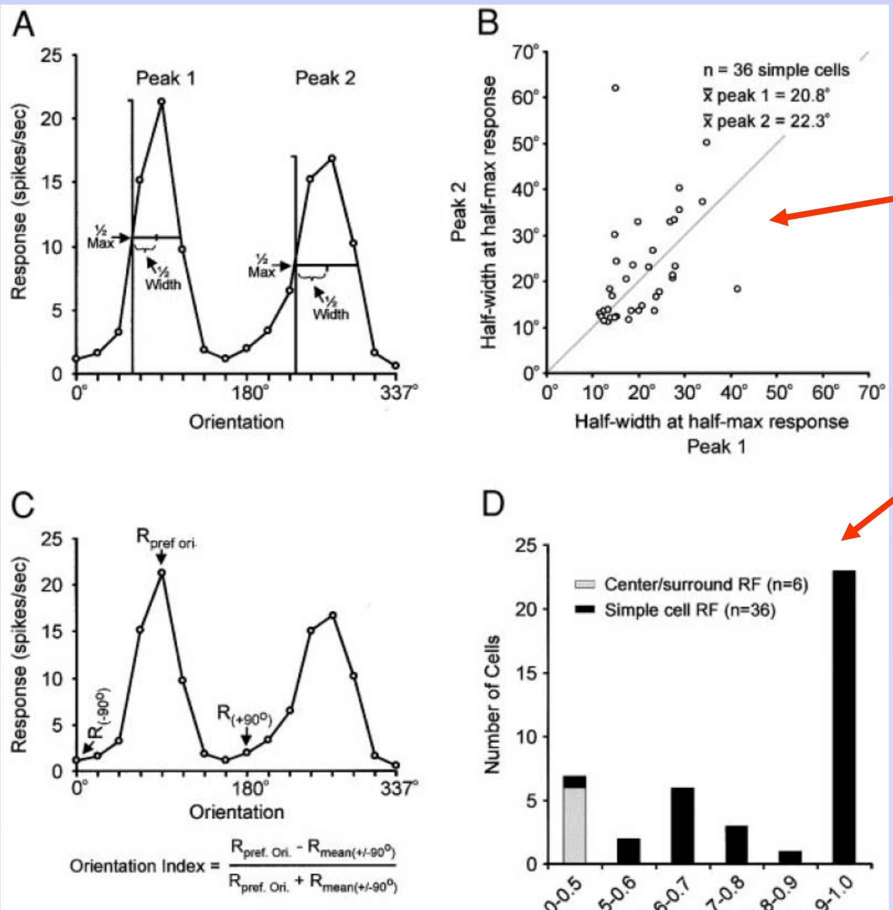




(Usrey et al, 2003)

Orientation selectivity: building an 'index'

- Can we find *one number* per cell that characterizes its orientation selectivity?
- From Qualitative to *Quantitative*: How does one quantify an orientation selectivity curve?



(Usrey et al, 2003)

-'tightness' or 'selectivity' of orientation.

- 'strength' of orientation selectivity (**orientation index**)

$$OI = \frac{R_{prefOrient} - R_{mean(\pm 90^o)}}{R_{prefOrient} + R_{mean(\pm 90^o)}}$$

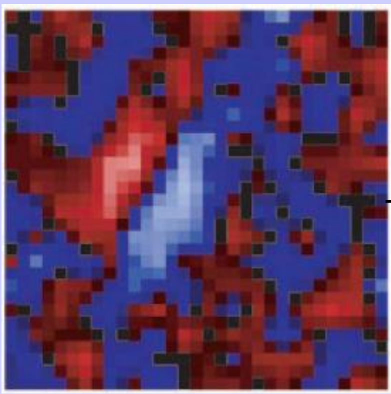
0 → ?

1 → ?

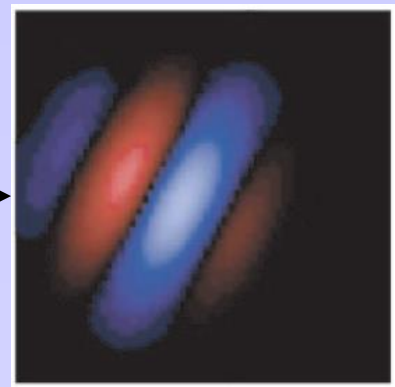
Orientation Selectivity: data-driven simulation

- Now that we have a number …

→ Can orientation selectivity be (linearly) predicted from the receptive field structure?

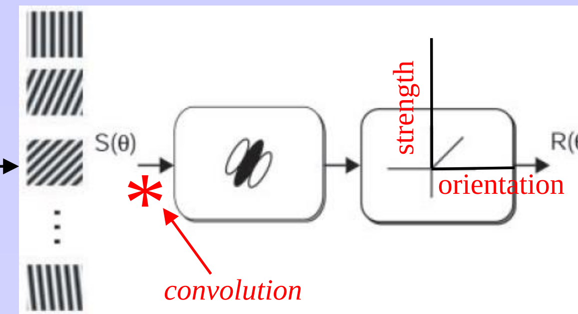


Fit (Gabor)

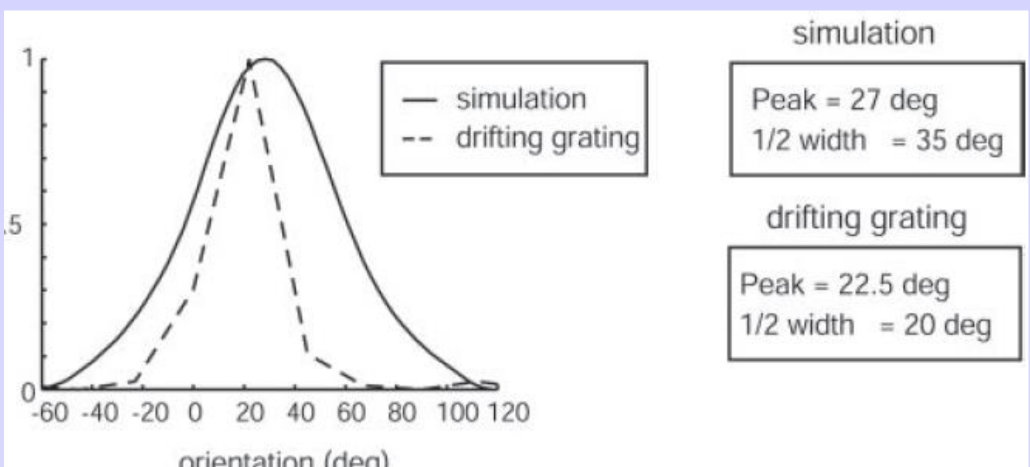


Predict

Data-driven simulation



Optimal spatial frequency, contrast, size… different orientations



(Usrey et al, 2003)

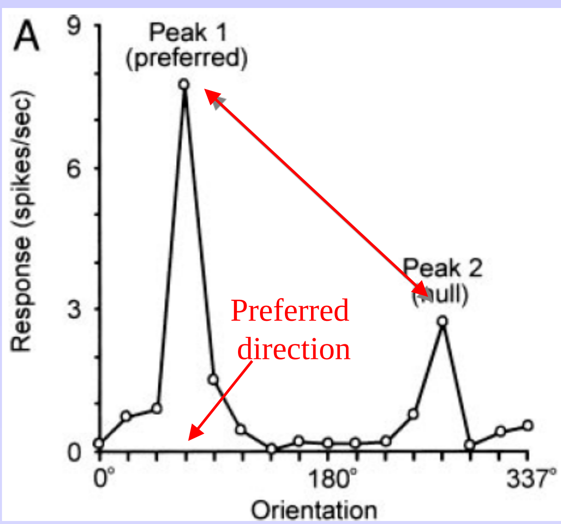
- Good for peaks
  i.e. orientation preference
- Bad for half-widths
  i.e. sharpness/selectivity

→ Selectivity = non linear consequence of receptive field?

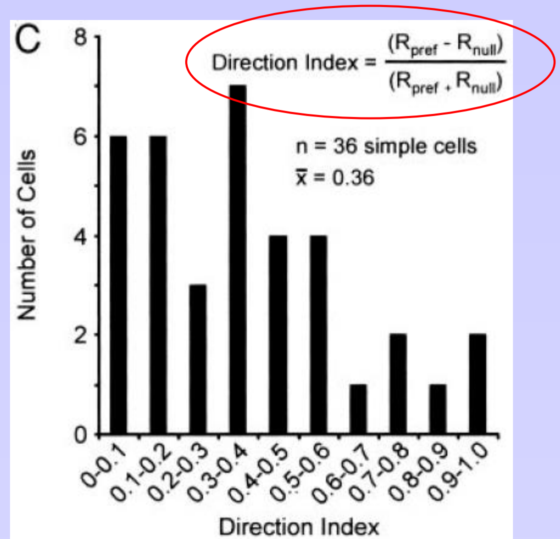
Direction selectivity

- Now that we have a number …

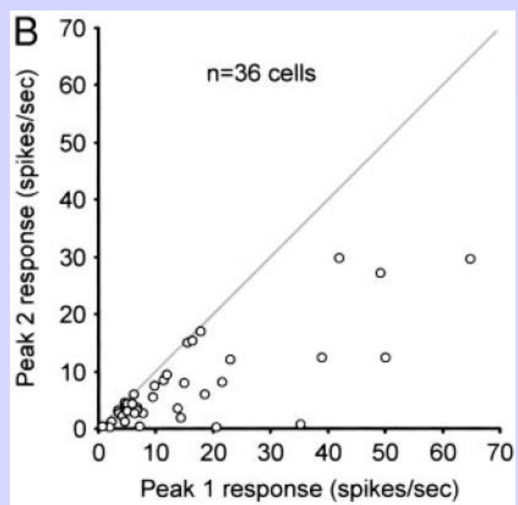
→ The same analyses can be done for other features/indexes. Example: direction selectivity



(Usrey et al, 2003)

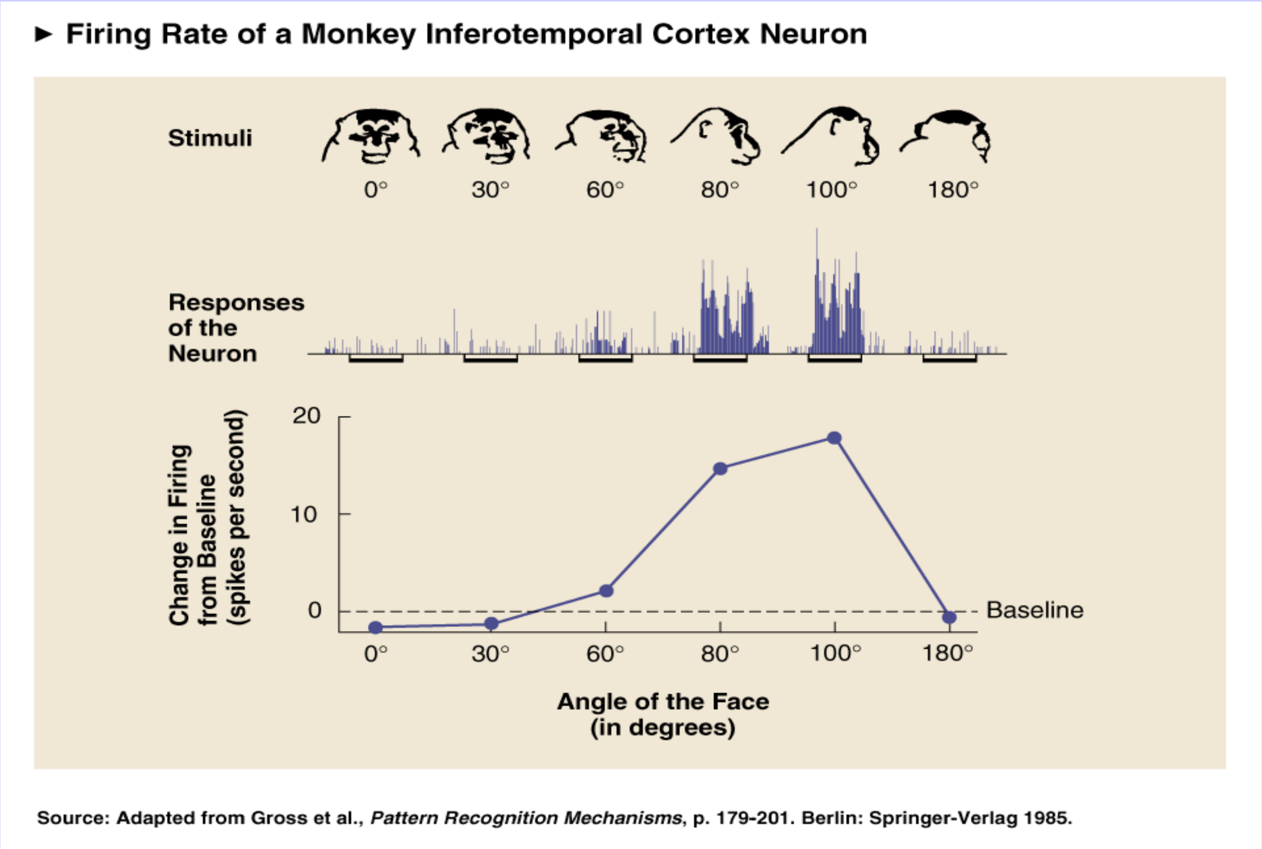


1→ strong direction preference



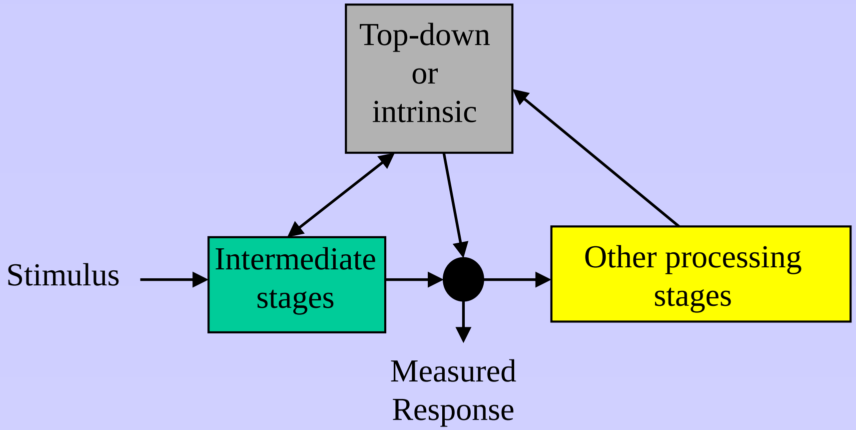
Tuning curves

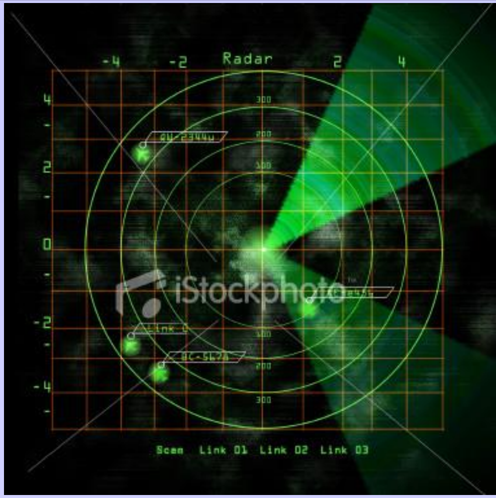
- Relationship: response ←→ stimulus is not necessarily linear
- Tuning curves: Firing rate Vs. stimulus feature



- Other tuning curves: Odors? Sounds?.... ⟶ Need ‘metric’

Signal Detection Theory





Measured response = Spike train = ‘Signal(s)’ + noise

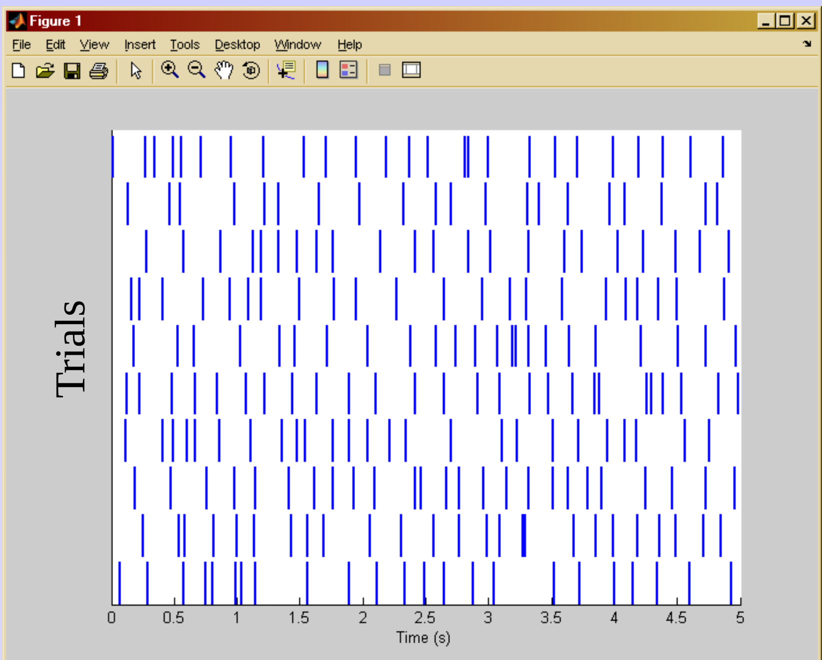
- **Detection** of a signal: signal? or Noise?
  > Is the neuron responding at all? (PSTH…)
- **Discrimination** between 2 responses: same signals? different signals?
  > Are two responses of the same cell ‘equal’? (tuning curves…)
- **Classification**: How many signals? Does the response contain one of several signals?
  > Are there different ways to respond to the same stimulus? (Information theory)

Discriminability

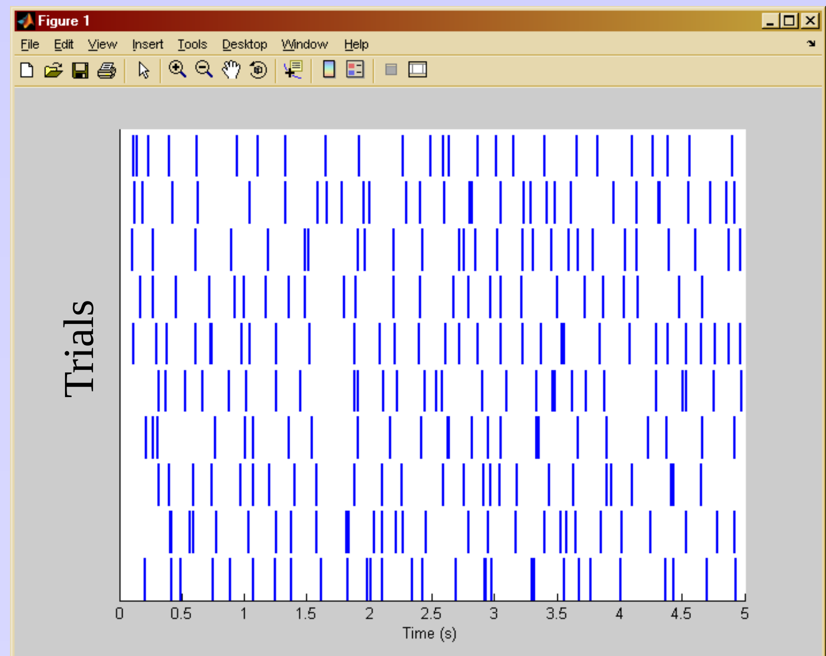
- Noise = spontaneous activity = ‘background signal’

General problem: Detection Vs. Discrimination

- Are these two experimental conditions different?



Stimulus

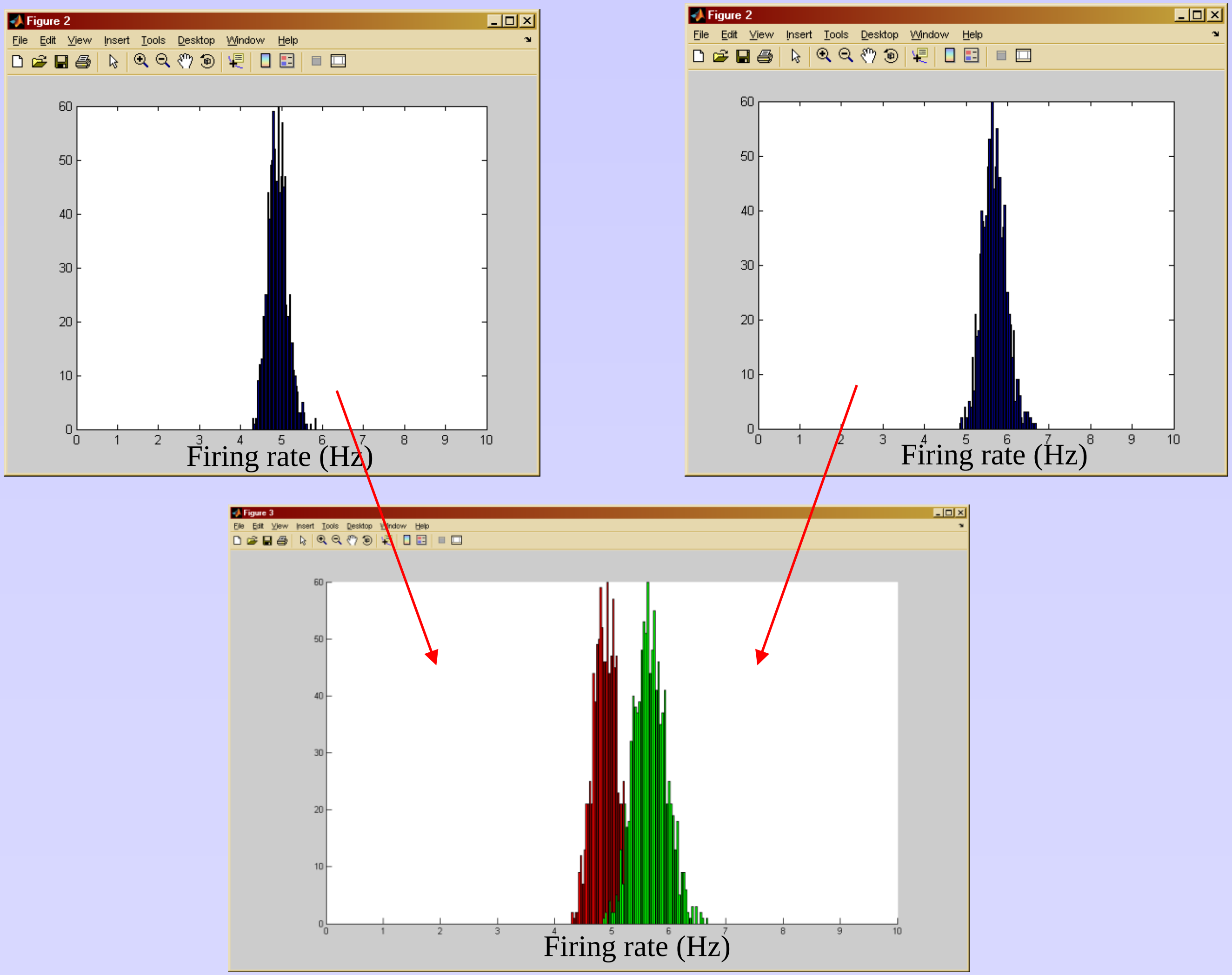


Stimulus

Discrminability

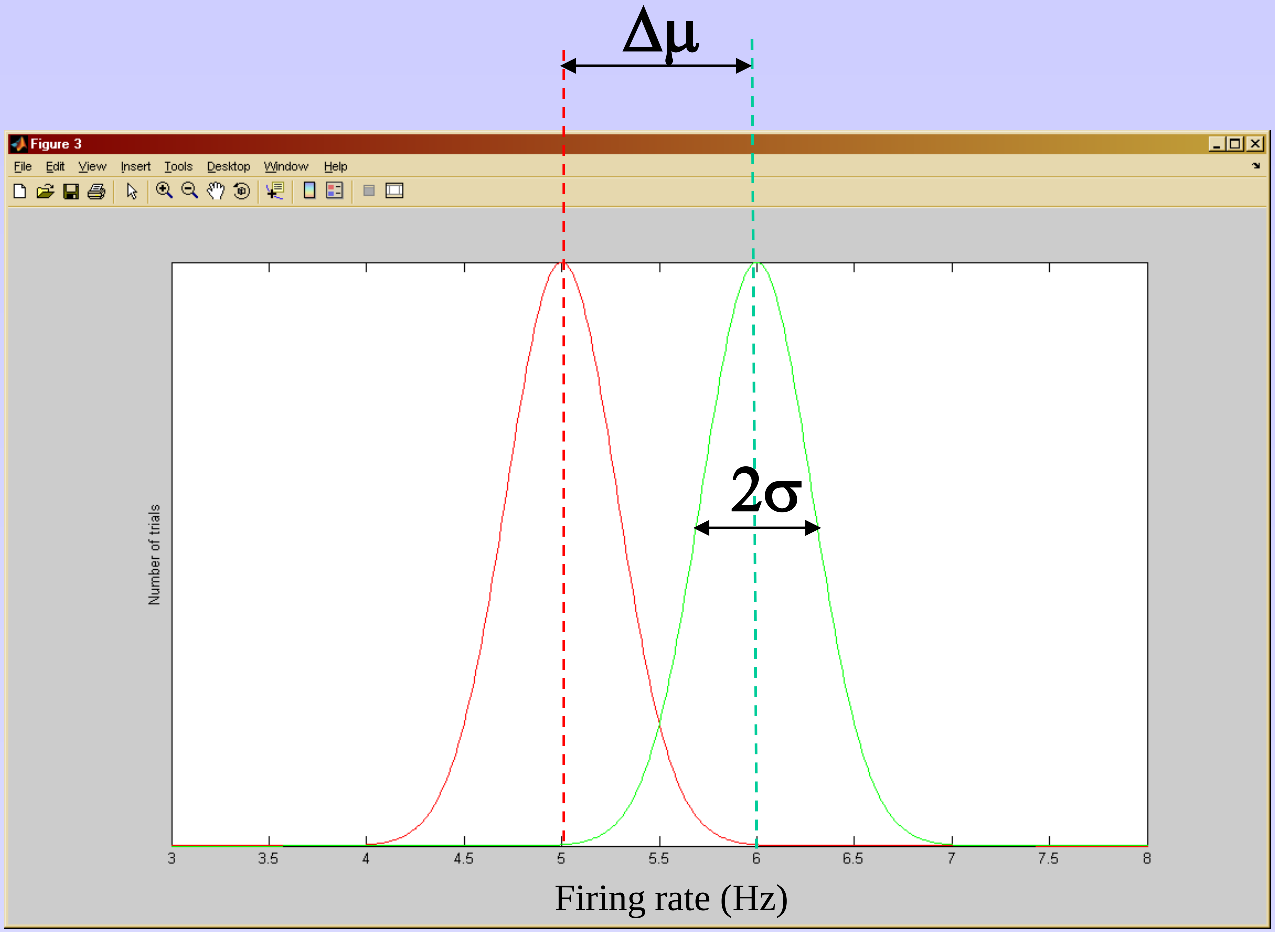
- Are the two experimental conditions different?

  → Are the firing rate histograms different?



Discriminability: d'

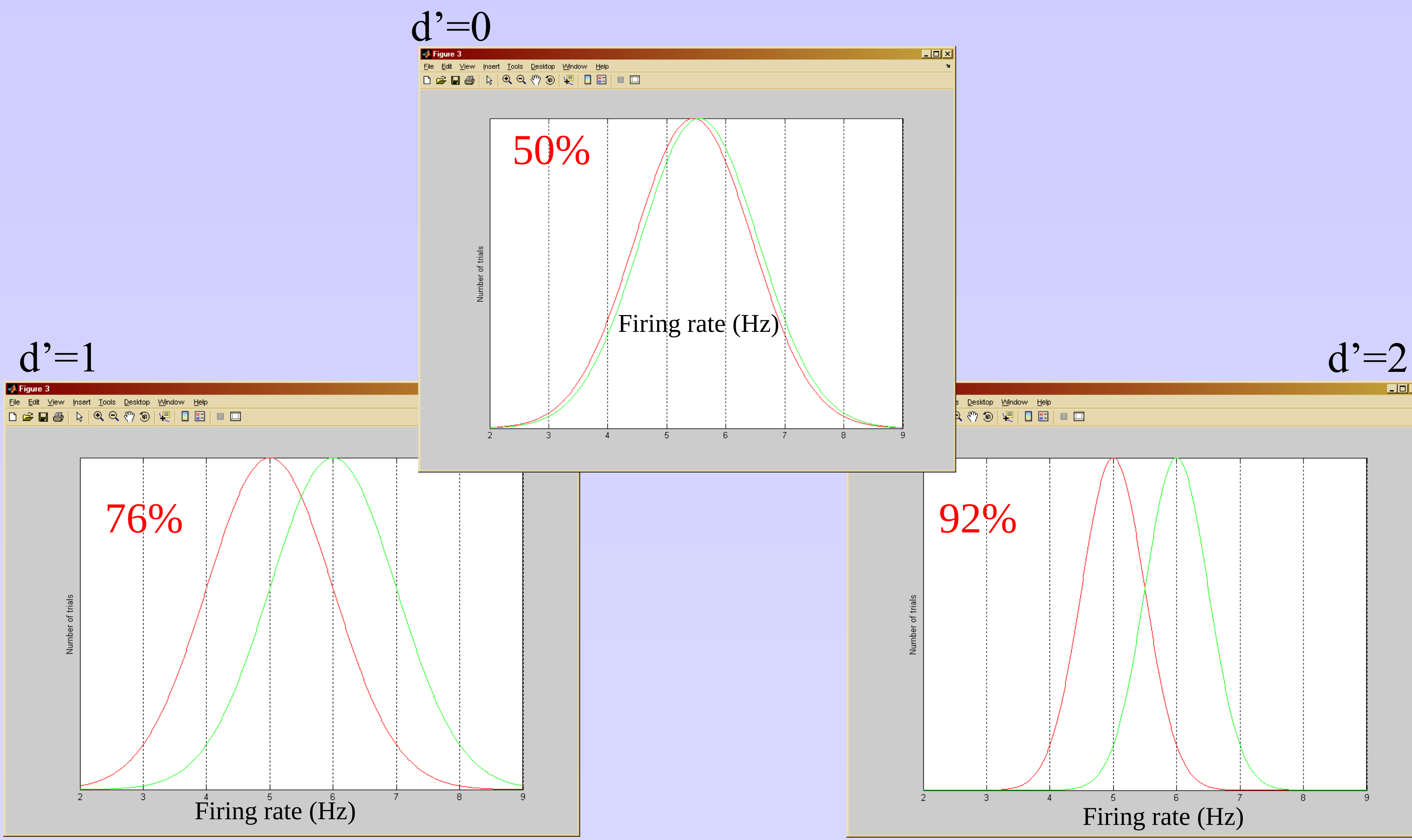
- Assuming the firing rate distributions are *displaced* Gaussian:



$$d' = \frac{\Delta\mu}{\sigma}$$

Discriminability: d’

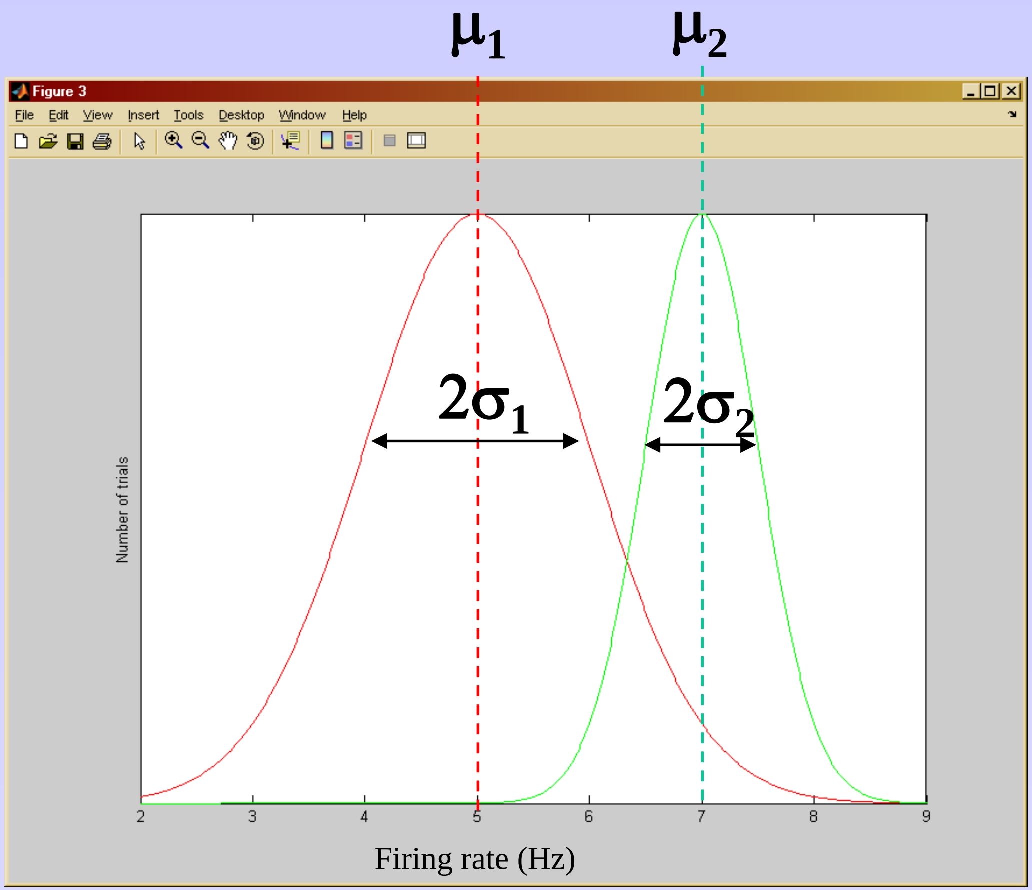
- Interpreting **d’**: If you were given a number within the red distribution… how likely are you of being right calling it ‘red’ ?



2-alternative-forced-choice

Discriminability: d'

- What if the two distributions have different standard deviations?

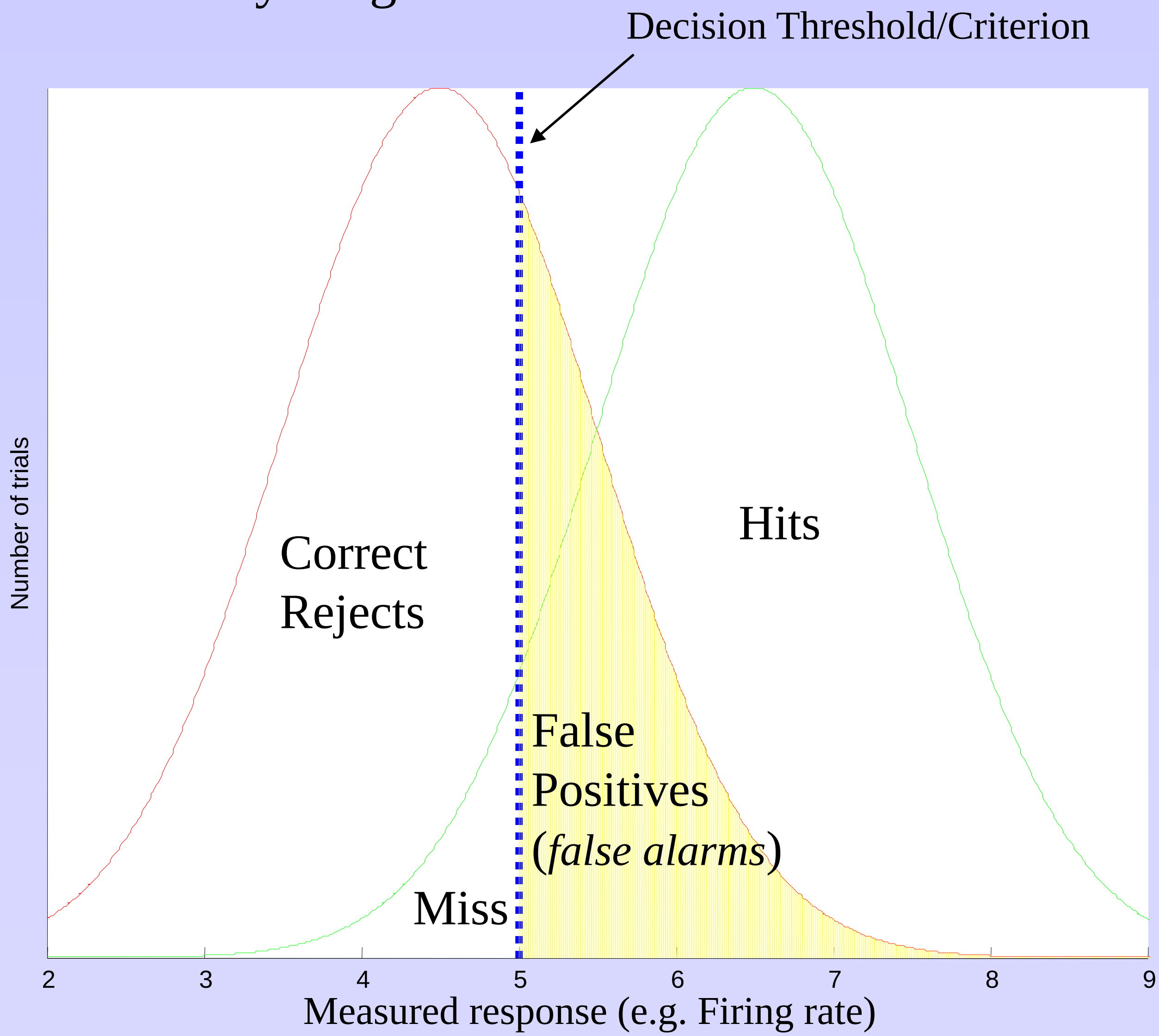


$$d' = \sqrt{2}\,\frac{|\mu_2 - \mu_1|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

- Other issues: different amplitudes, bimodal, non Gaussian….

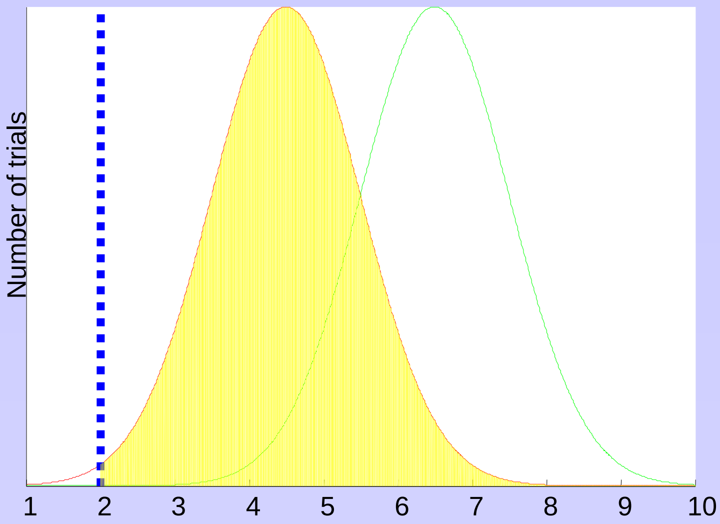
Signal Detection: ROC curves

- More general approach…
- Which spike trains carry a signal?

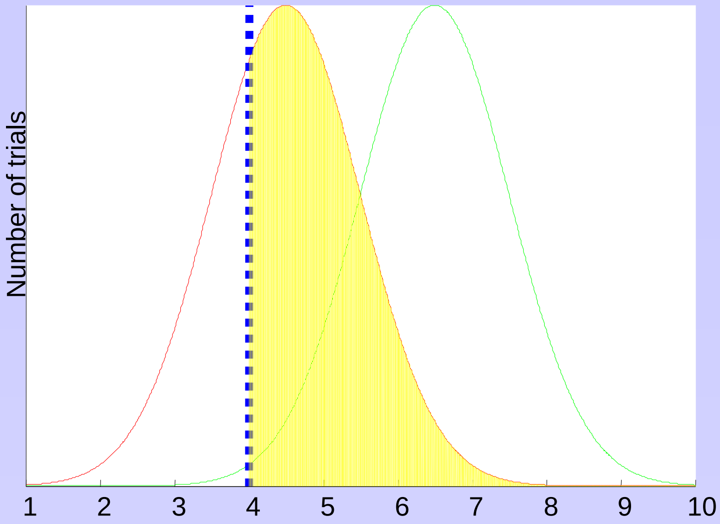


ROC curves: Changing the detection threshold

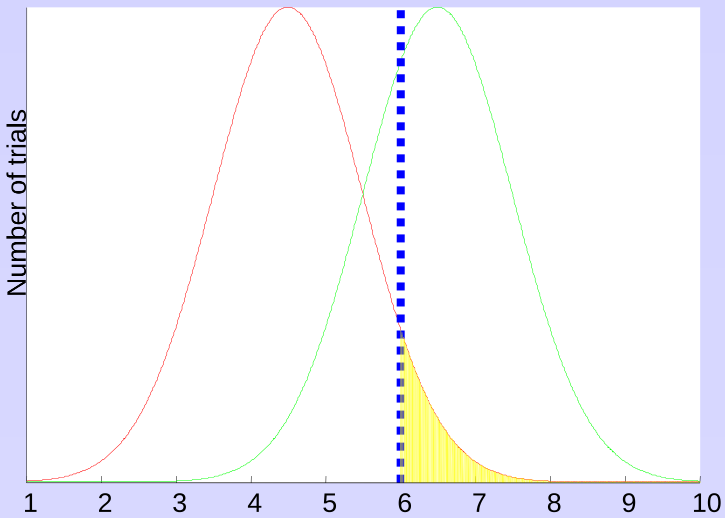
Hits=100%, False Alarms=99%



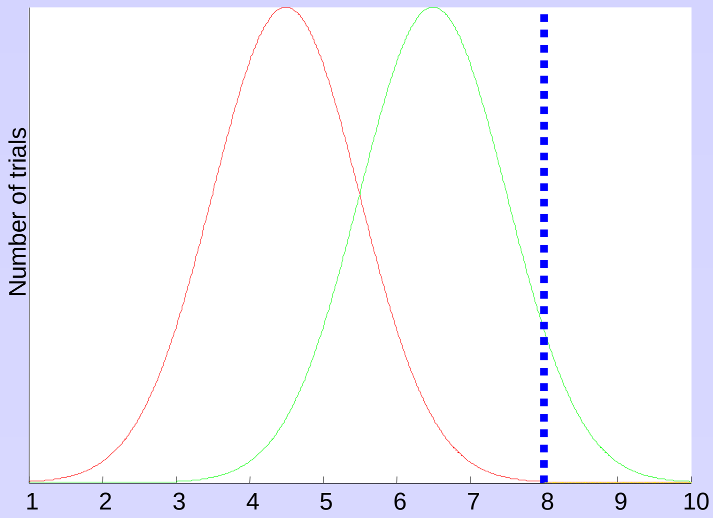
Hits=99%, False Alarms=69%



Hits=69%, False Alarms=6.6%

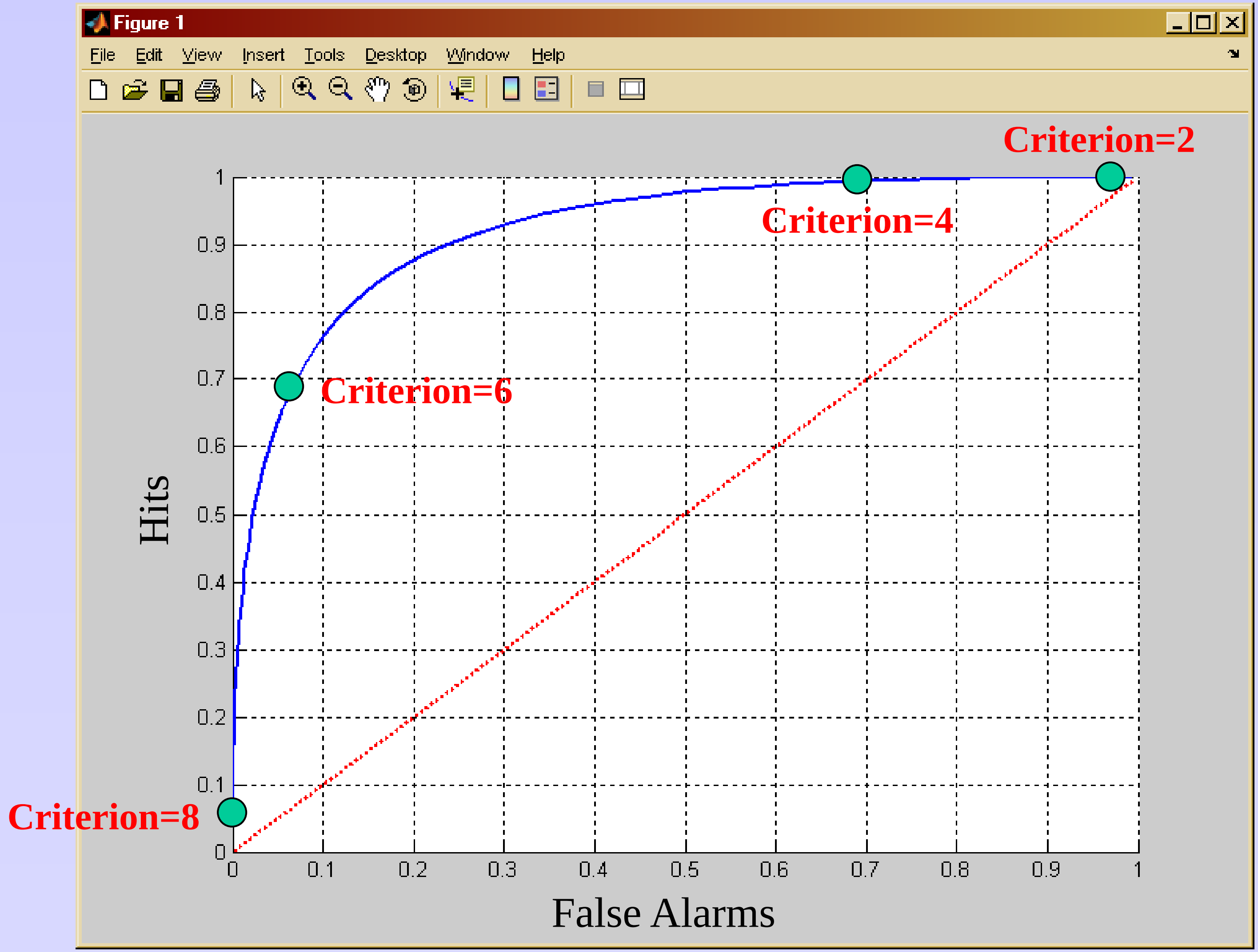


Hits=6.6%, False Alarms=0%



ROC curves

- The **R**eceiver **O**perating **C**haracteristic curve
- In general, can be built empirically (no need to know the distributions)



ROC curves: Fun facts…

- Tradeoff between Hits and False alarms ⇔ Tradeoff between Misses and Correct Rejects.

- The closer the curve follows the left-hand border and then the top border of the ROC space, the more accurate the 'test'.

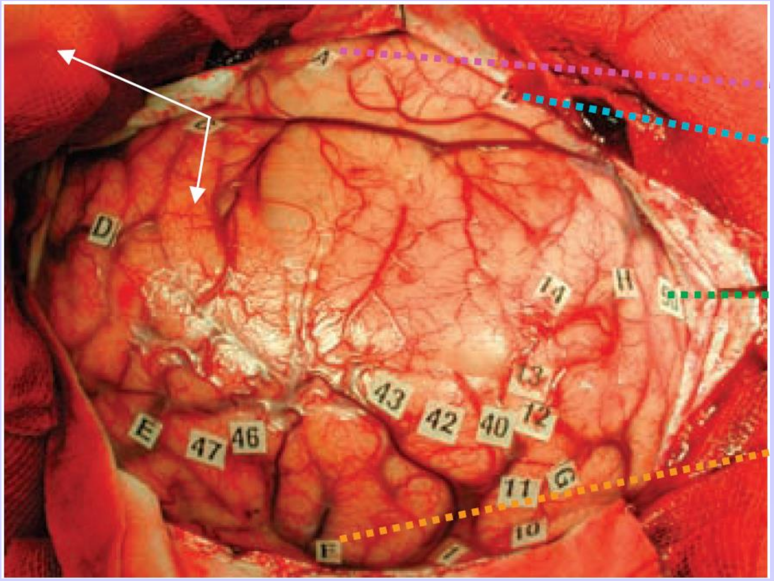
- The closer the curve comes to the 45-degree diagonal of the ROC space, the less accurate the 'test'. Diagonal=chance.

- The slope of the tangent line at any point gives the *likelihood ratio* (LR) for that value of the test.

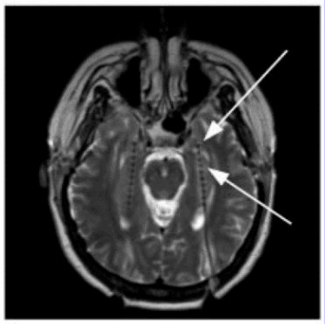
'*how much better will my hit rate be, if I tolerate a few more false positive*'

- The area under the curve is a distribution-free measure of performance.

Face and object cells in humans



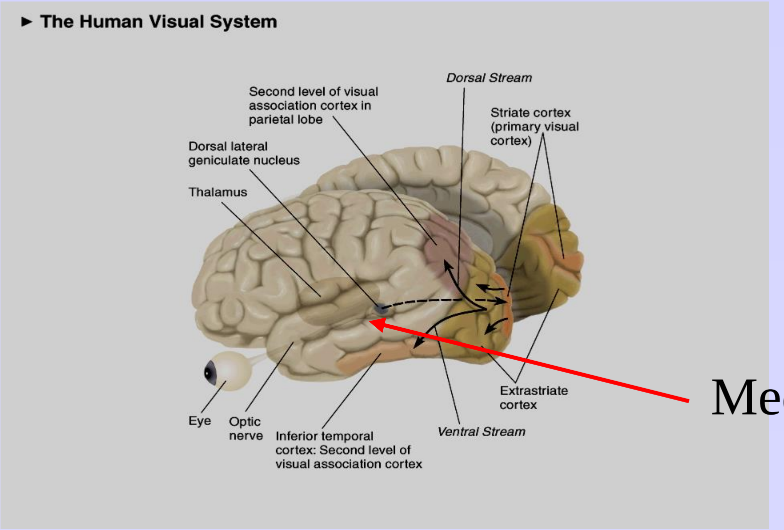
(Thiebaut de Schotten et al 2005)



(Trautner et al, 2004)

Chronic implants

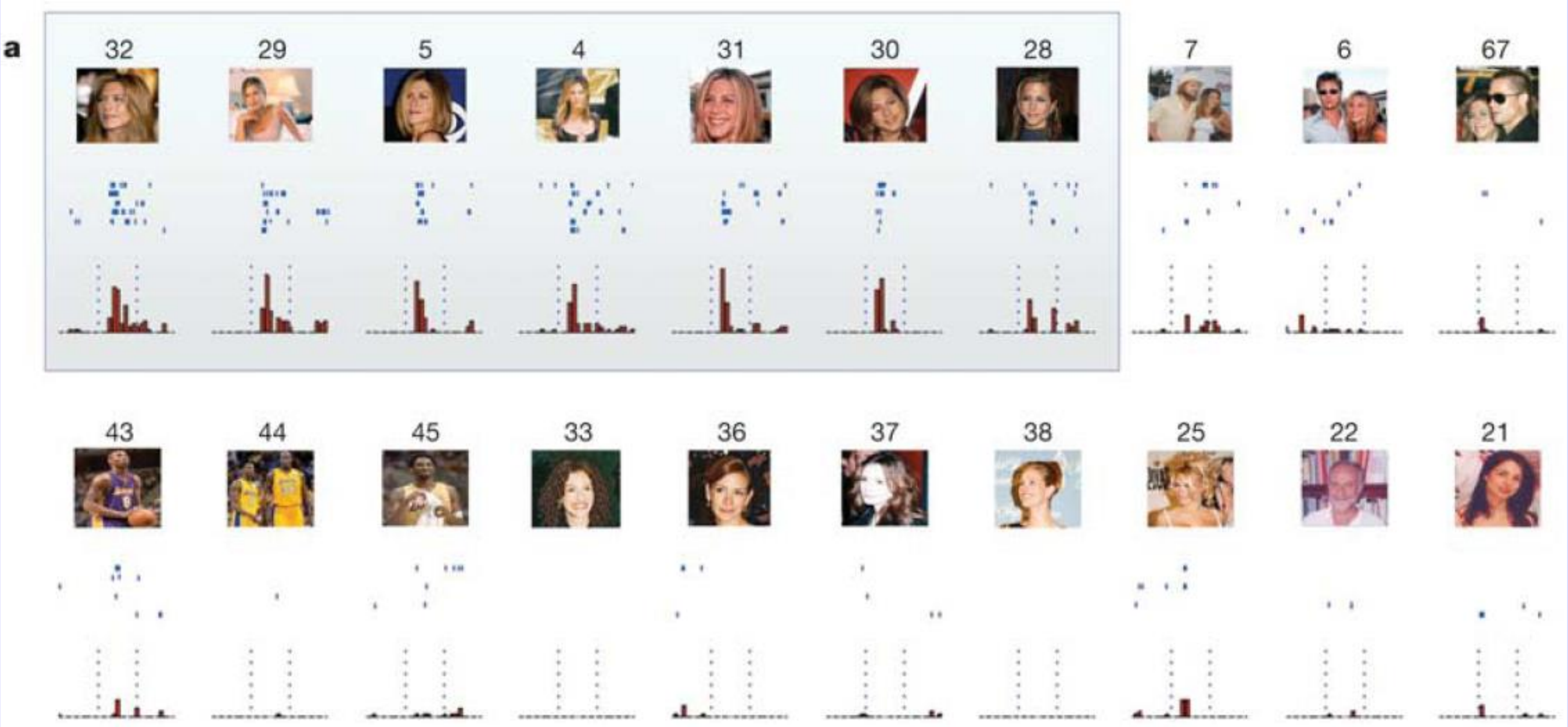
Psychophysical testing
Faces, landmarks, animals, objects



Medial Temporal
Lobe

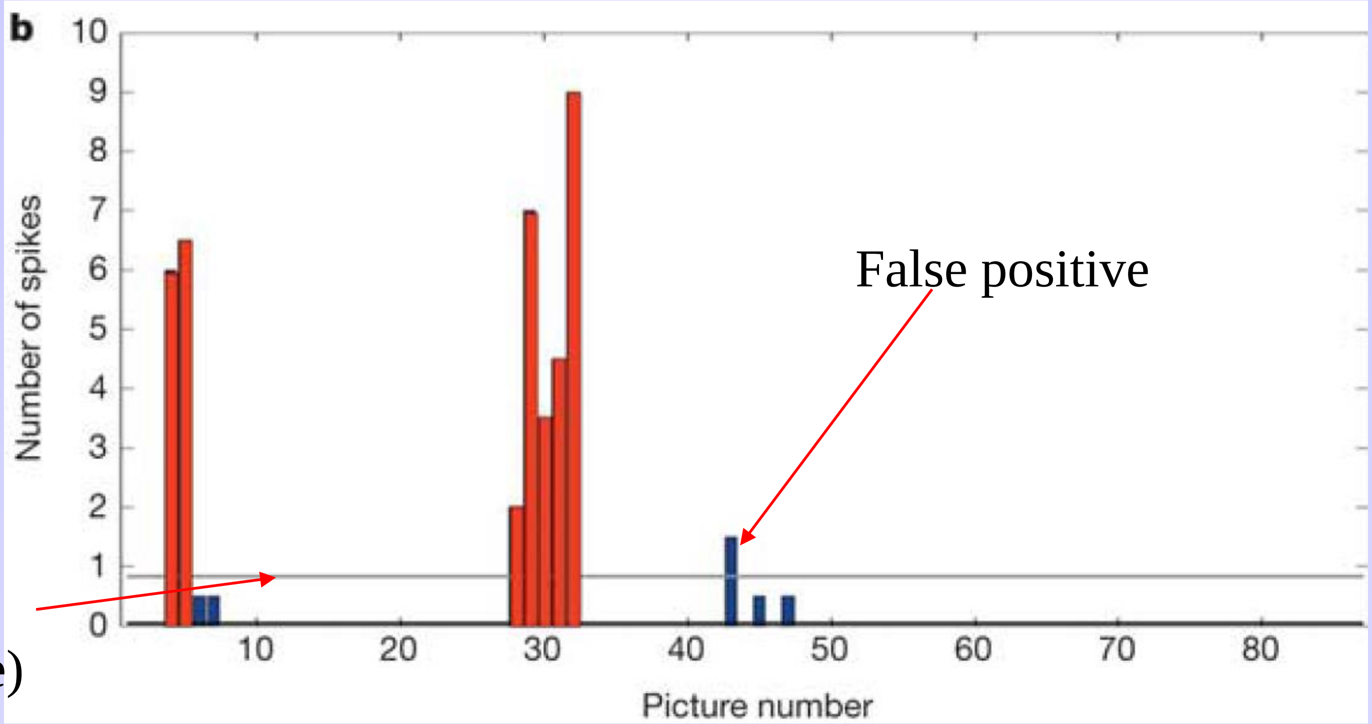
‘person’ selective cell

Left posterior hippocampus. 30/87 images



(Quiroga et al, 2005)

‘person’ selective cell



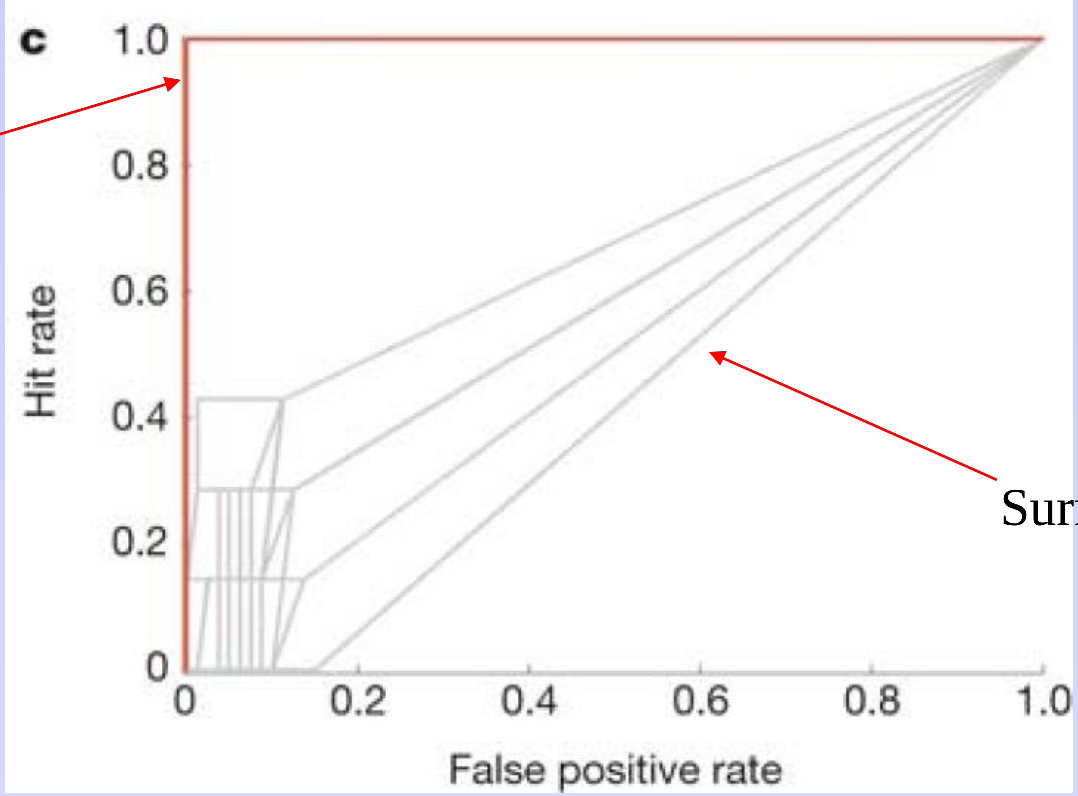
Detection **c**riterion:
Noise=baseline

Dc=Noise+5.std(noise)

(Quiroga et al, 2005)

‘person’ selective cell

J. Aniston alone

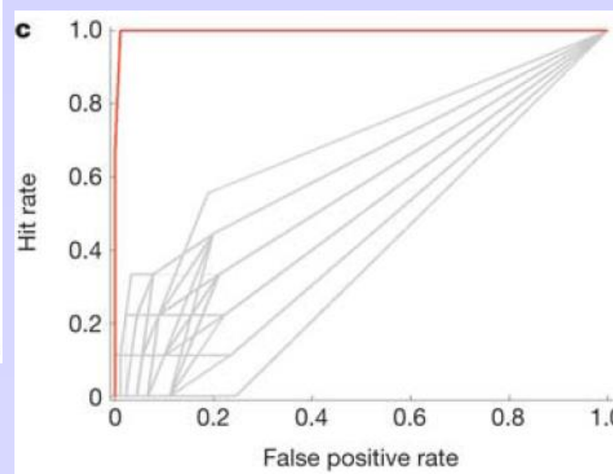


Surrogate sets

(Quiroga et al, 2005)

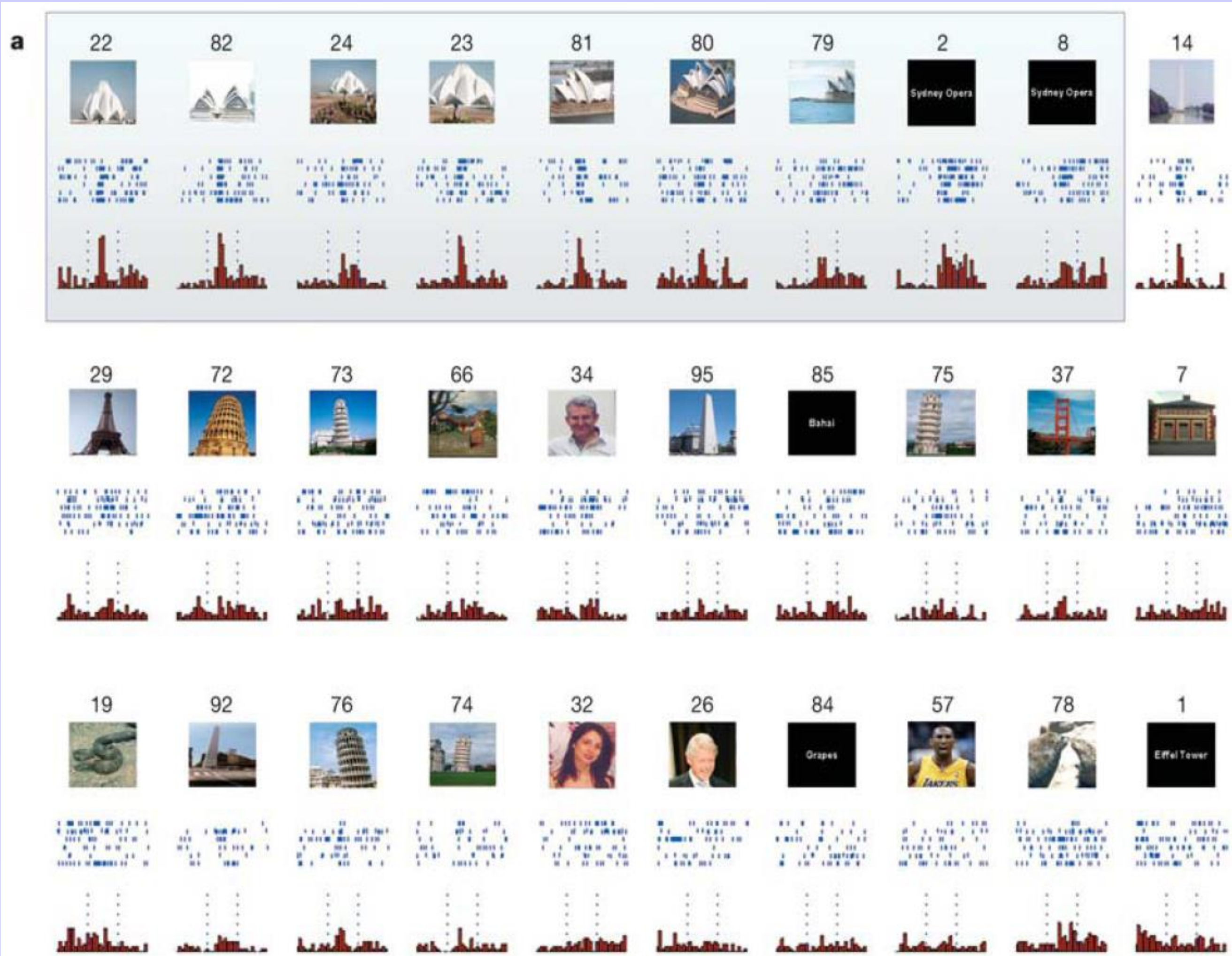
‘person’ selective cell

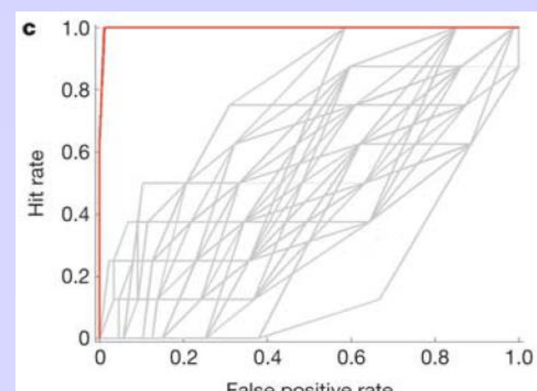
Drawing Disguised Letter string



(Quiroga et al, 2005)

‘Landmark’ selective cell





(Quiroga et al, 2005)

Note: task = ‘face?’ or ‘no face?’

Homework 4: ROC

- Create a function that generate a Gaussian distribution of 1000 random values between 1 and 10, and a STD less than 4. Plot two such distributions with about 30% overlap. Give the value of d'.
- Write a function that takes a decision threshold (between 0 and 10) and computes the fraction of false alarms and hits.
- Plot the ROC curve, and quantify its departure from the diagonal.