McGill

Signal detection theory

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Yes/no or A/B task

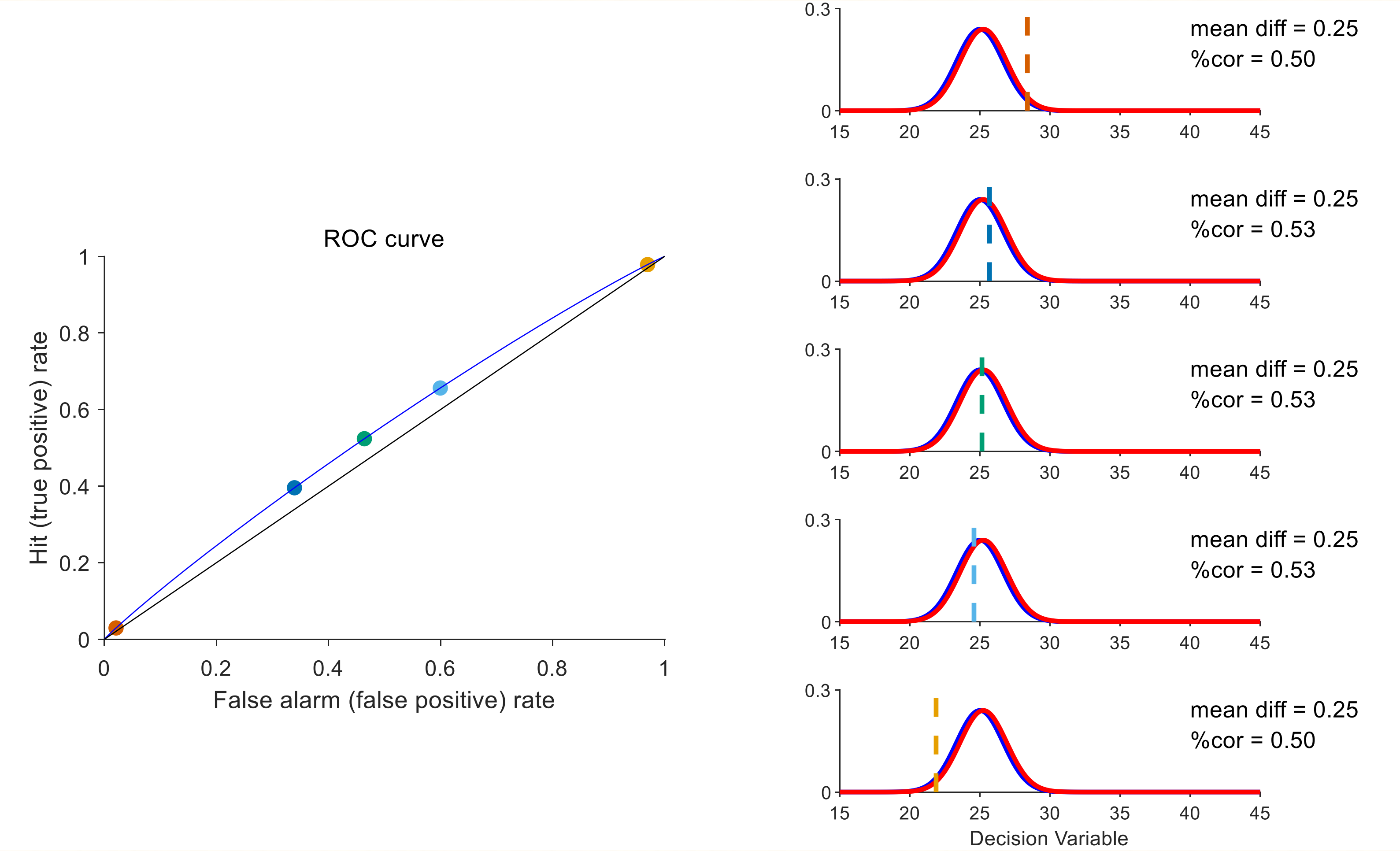
	Respond yes, Respond A, etc.	Respond no, Respond B, etc.
Stimulus present, Stimulus A etc.	Hit or Correct detection or Correct yes or Correct A	Miss or False rejection or or Wrong no or Wrong B
Stimulus absent, Stimulus B etc.	False alarm or False detection or False yes or Wrong A etc.	Correct rejection or True no or Correct B etc.

WRONG	CORRECT

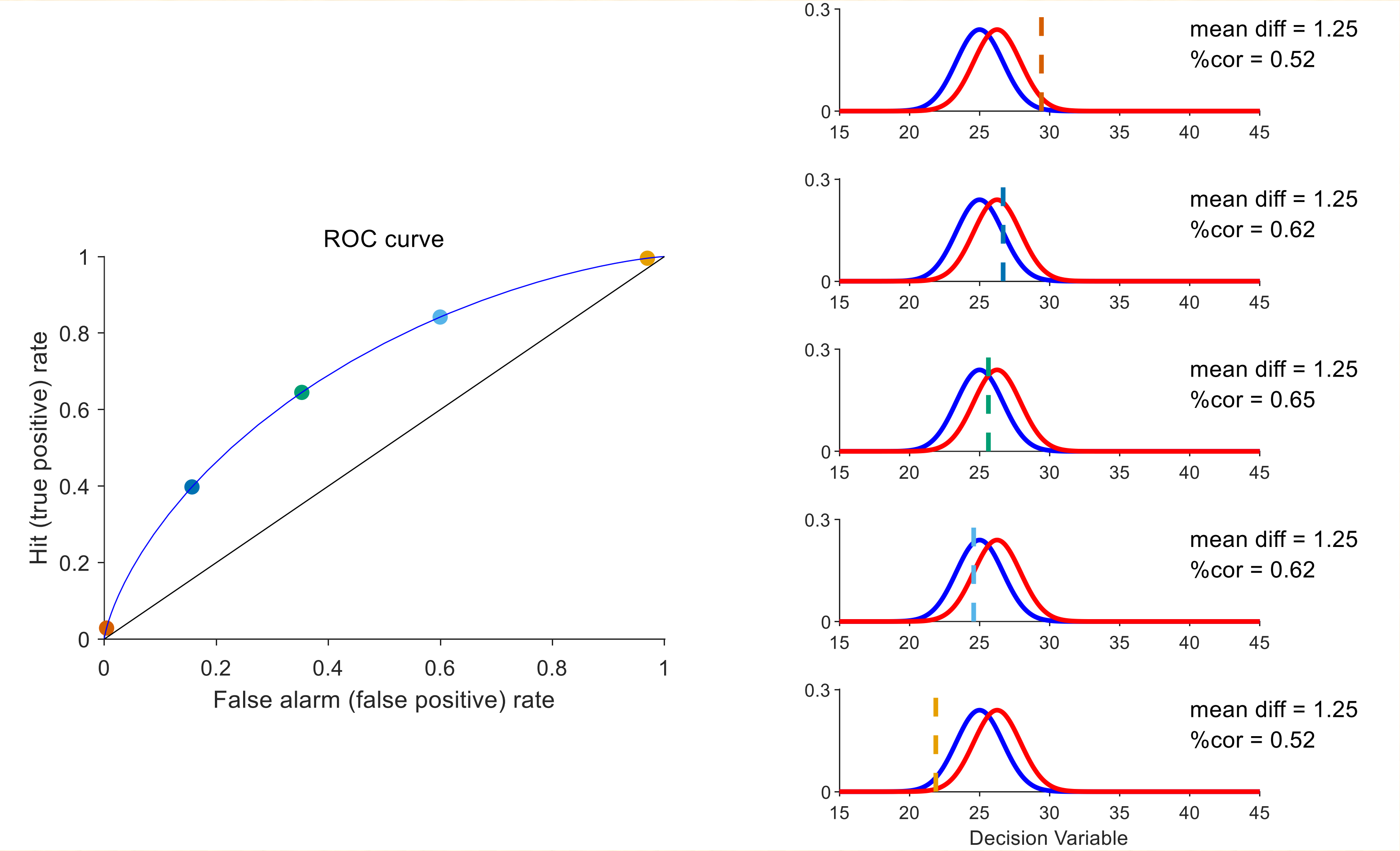
Criterion shift and ROC curve

The next 5 slides are meant to be scrolled through like frames in a movie. Use the arrow key.

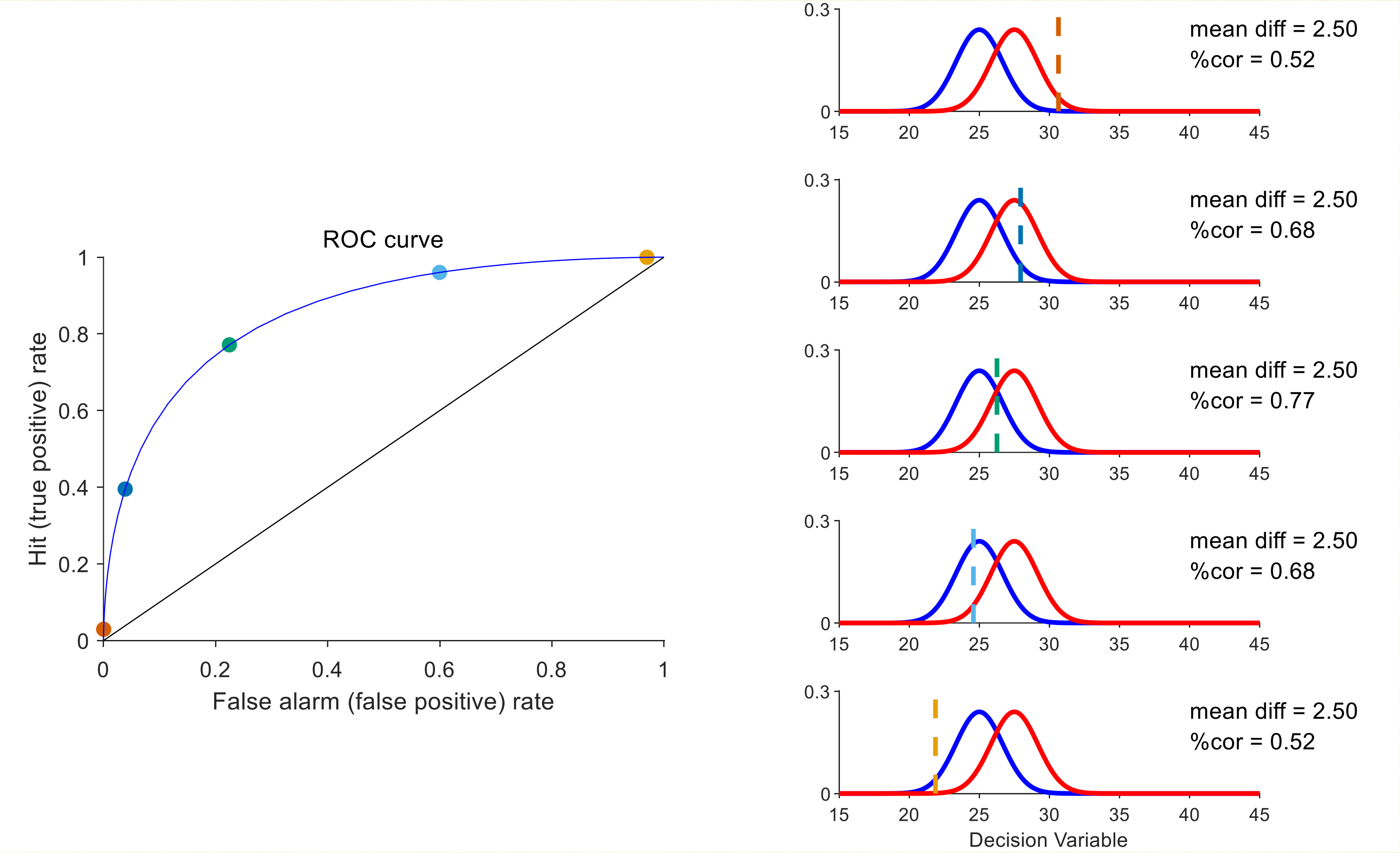
Criterion shift and ROC curve



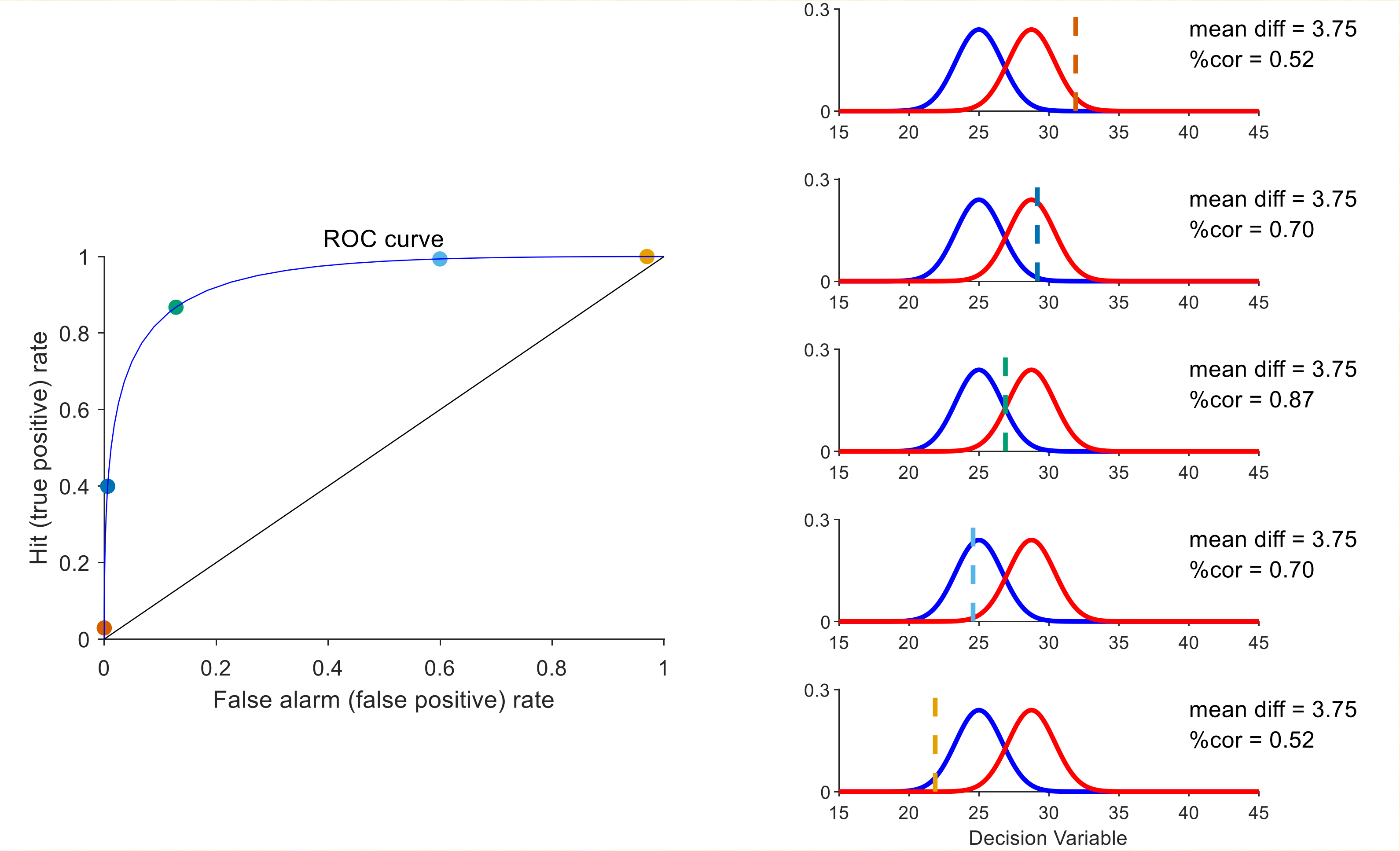
Criterion shift and ROC curve



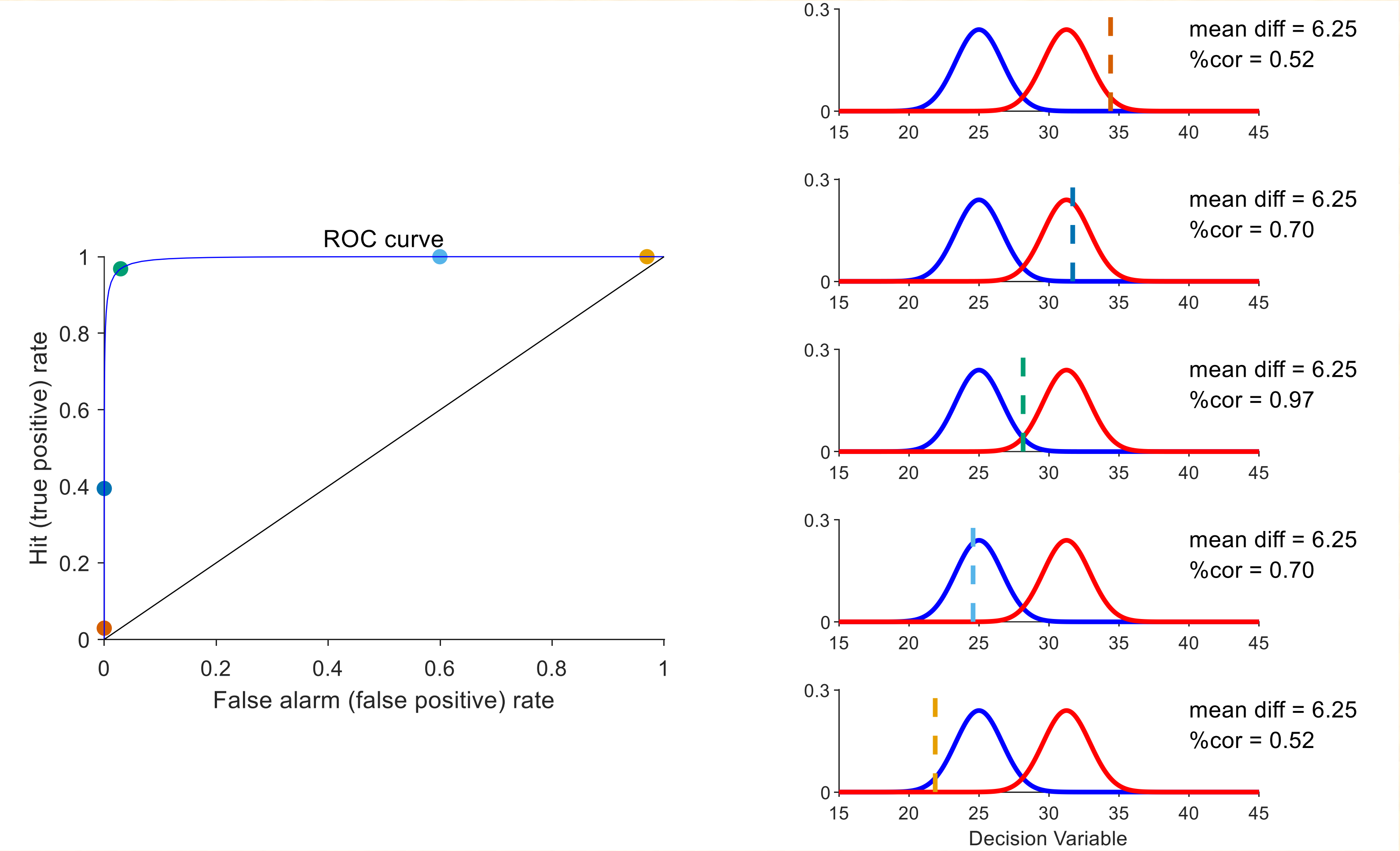
Criterion shift and ROC curve



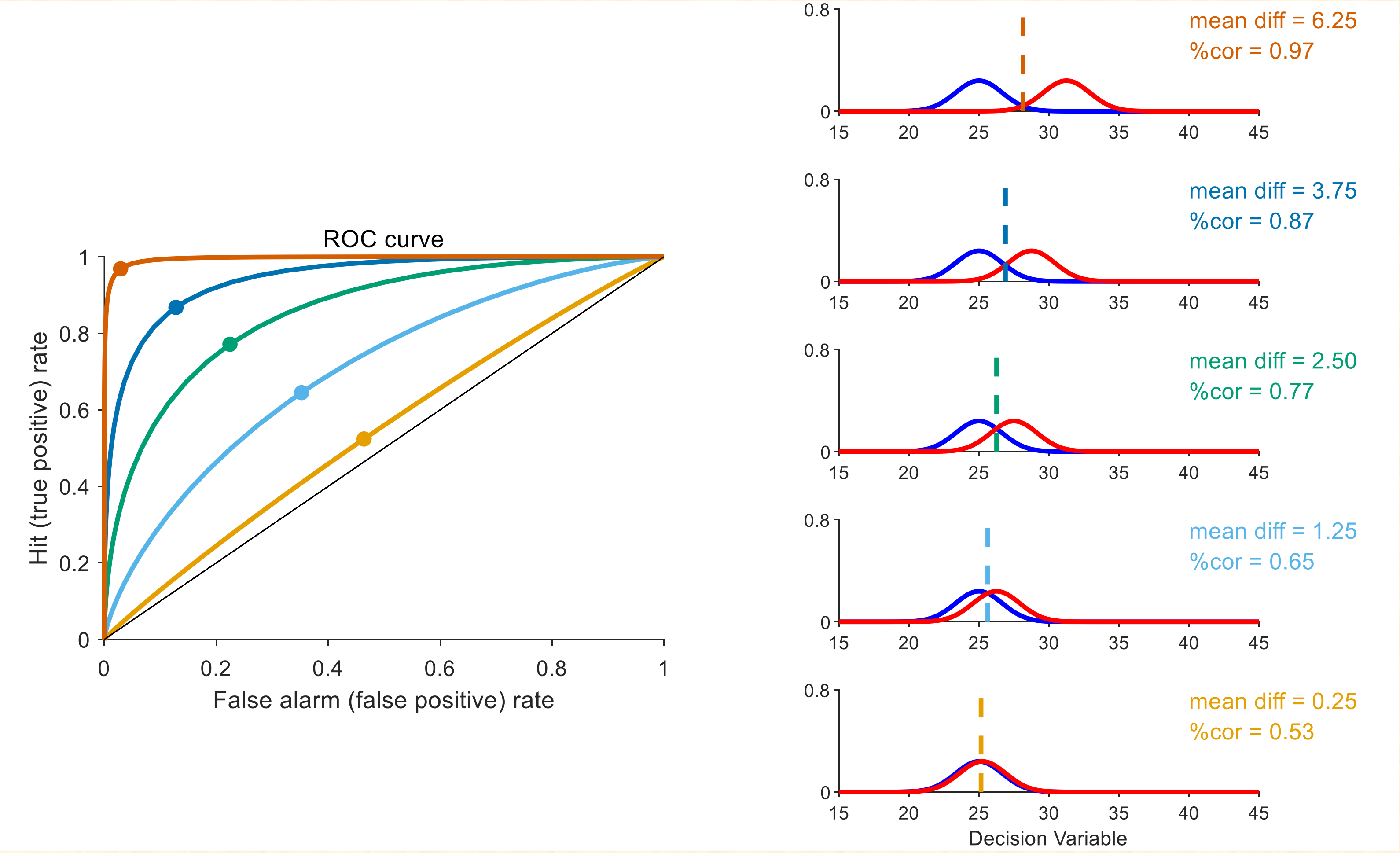
Criterion shift and ROC curve



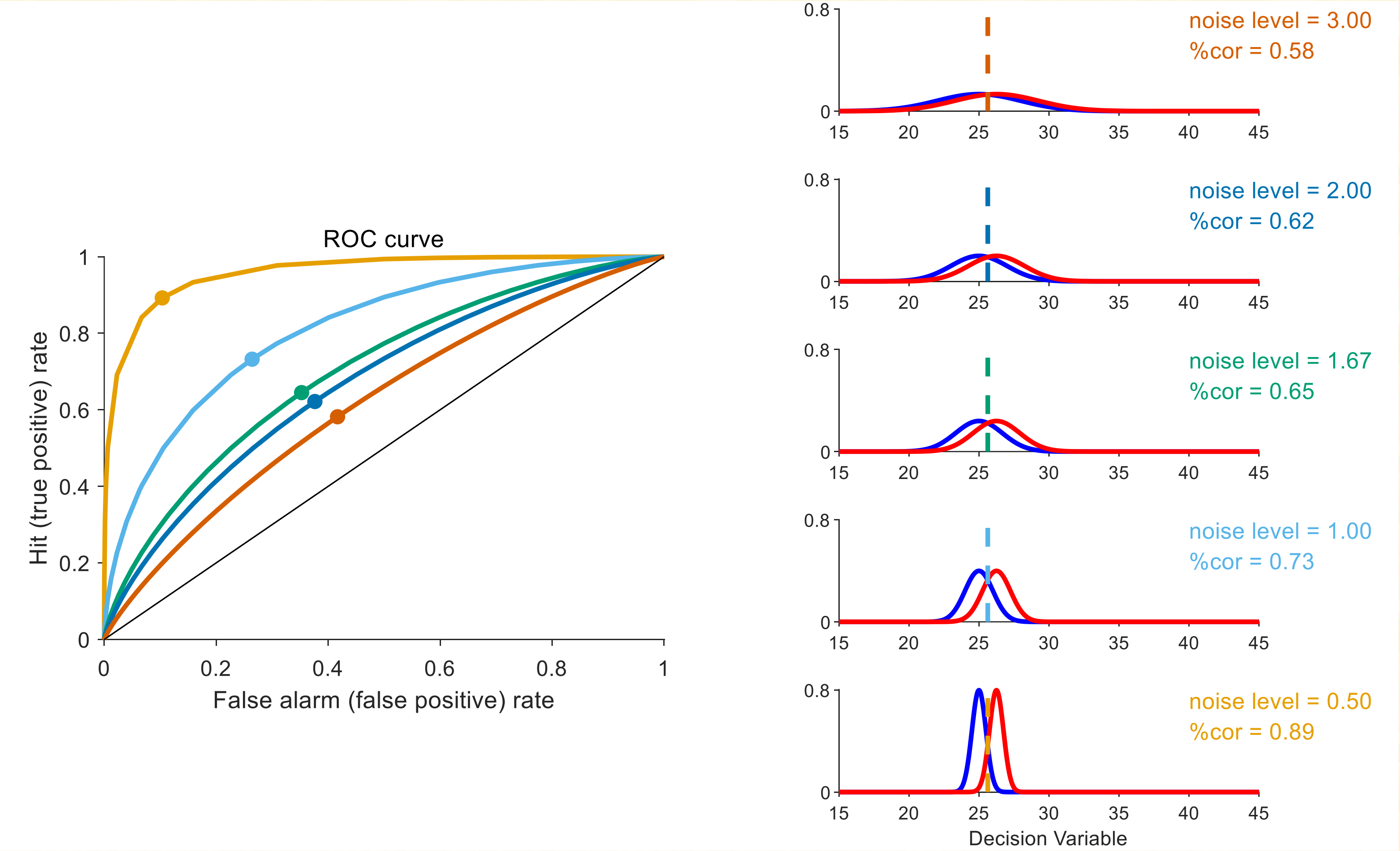
Criterion shift and ROC curve



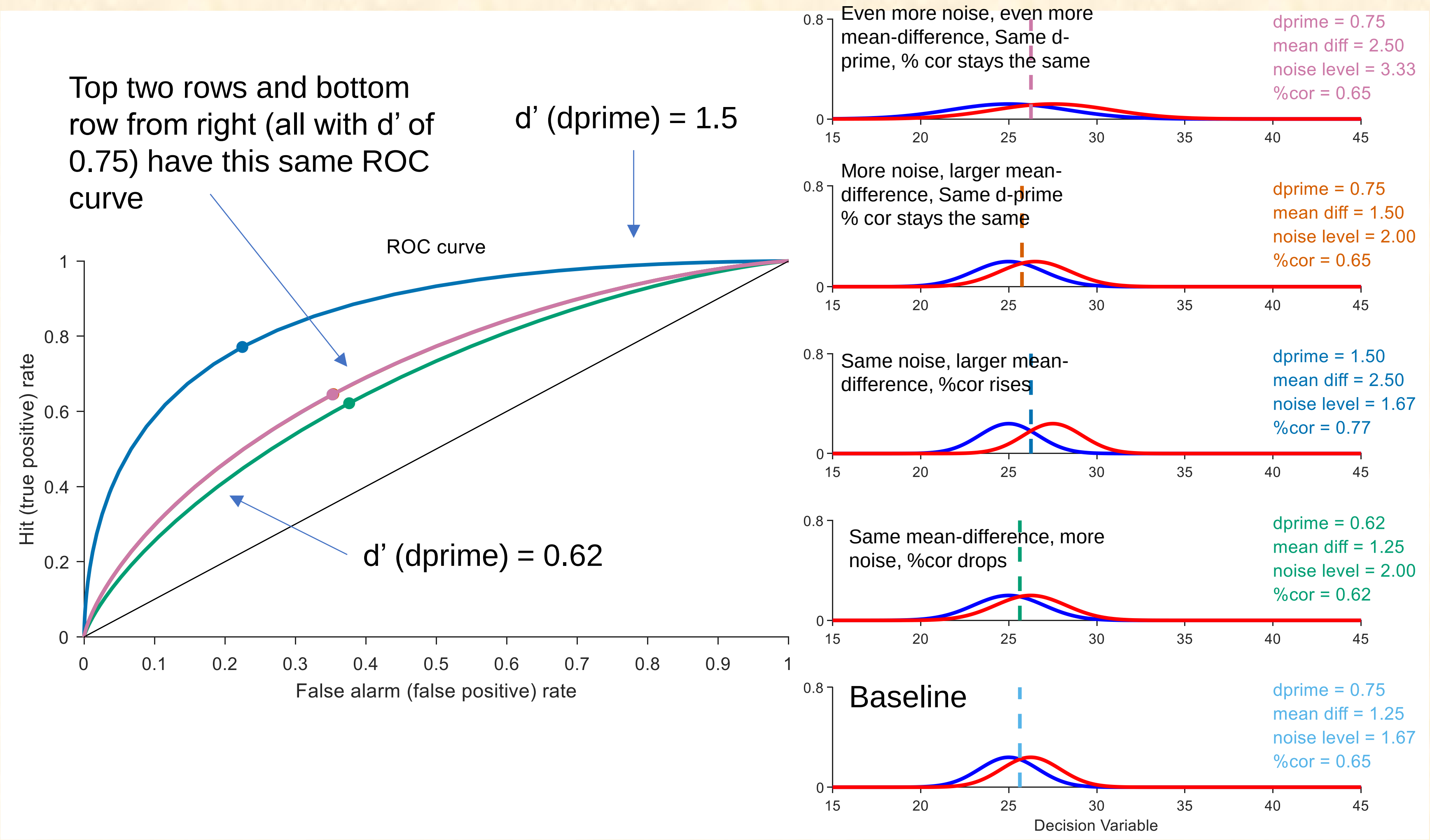
Greater mean difference=larger AUROC



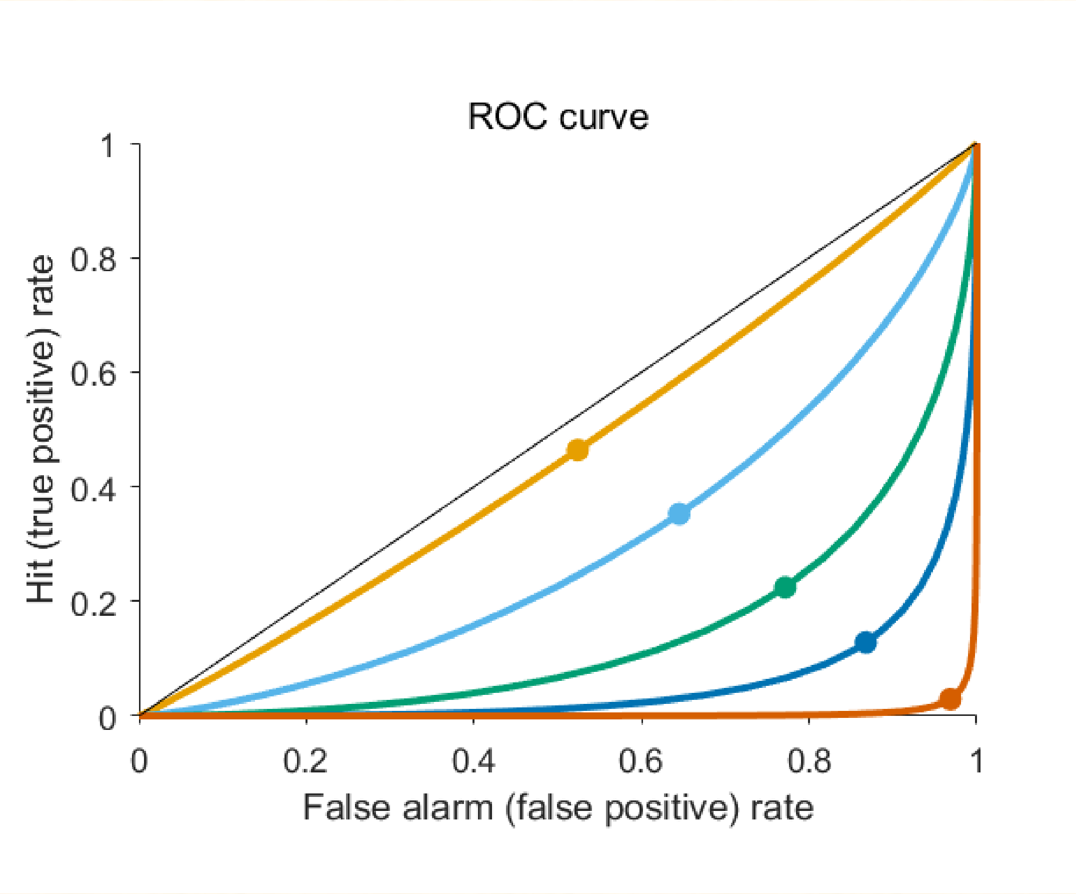
Lower variance (with same mean difference) = larger AUROC (better performance)



It is all about dprime = mean difference /stdev (just like z-score, and the related t-statistic)



Thought exercise



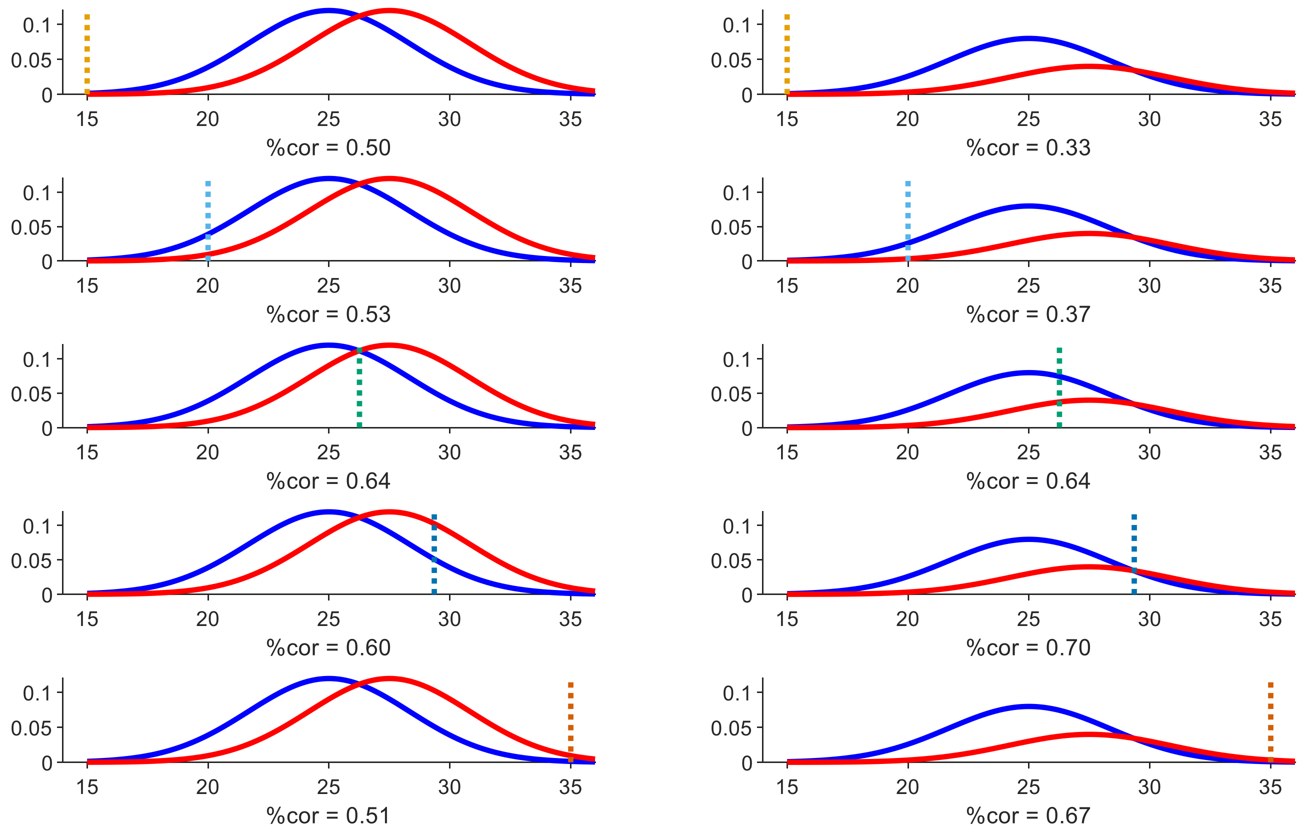
This is a modified version of the ROC curves from page 12 (lecture 3).

Remember that the diagonal line is the expected curve for a test at chance.

What is going on here ? Is the subject doing better or worse than chance ?

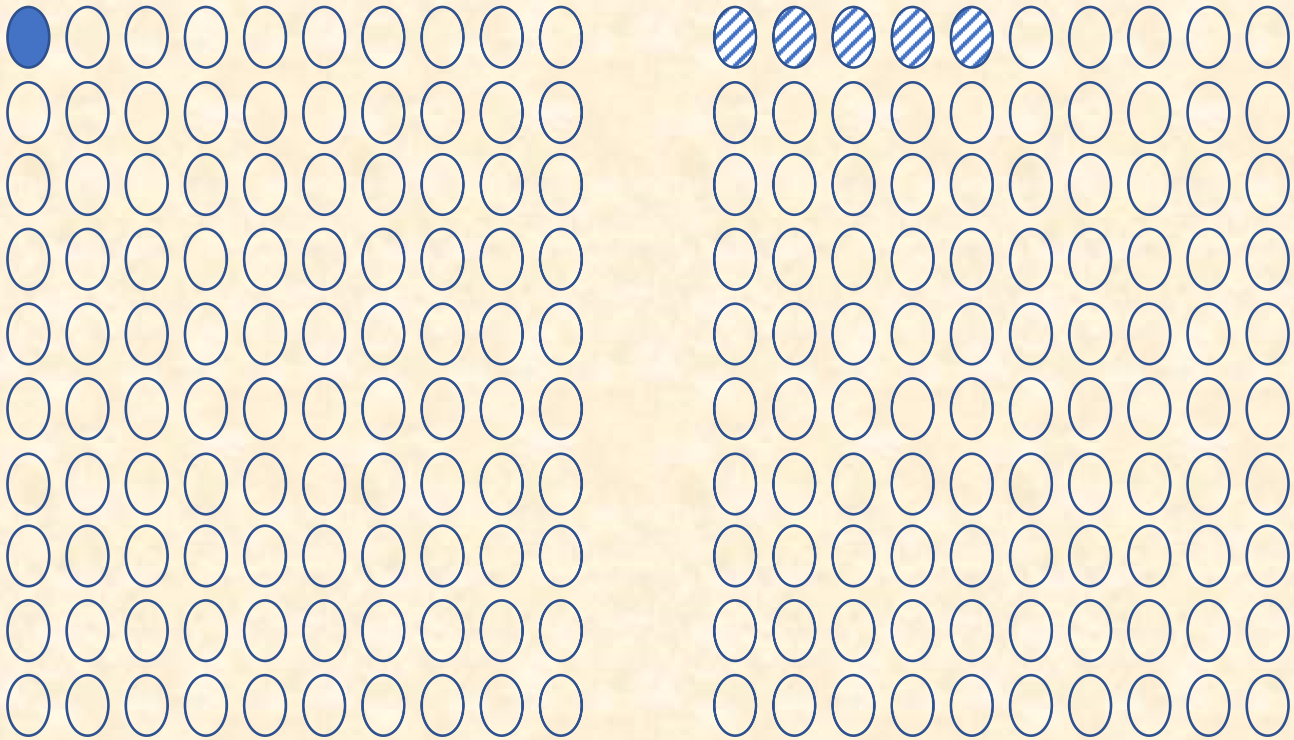
Worse than chance – because points below the line mean the subject is making more false-alarms than correct detects (hits). Can happen if labels are switched – or you press the wrong key – you detect the stimulus but press the did not detect button, and vice-versa.

If one stimulus is more likely/rewarded, ideal threshold shifts in the direction away from the mean of the more likely/rewarded stimulus



Optimal criterion still at point where likelihoods cross and red stimulus more likely to produce dv value than blue

Test interpretation



Sensitivity = True test-positives/(Total number of people with disease)

Specificity = True test-negatives/(Total number of healthy people)

PPV=Test-positives with disease/Total number of test positives

1 person in 100 has disease, 99 don't (this is the ground truth, that we might guess based on other populations, but we don't know for this set of 100).
Test is 100 percent sensitive, 95 % specific – so 1 true positive, 0.95*99 ~ 94 true negatives, 5 false positives.
Yet, positive predictive value (PPV) is only 1 in 6 = 16.7 percent

Characterizing behavior

- We have seen the large number of possibilities in choosing neural features.
- Now how about the mental side ? How do we characterize ongoing perception to correlate it with the neural responses ?
- Subset of consciously accessible, and behaviorally reportable/reported percepts.
- Today, mostly, we will talk about tasks with two alternatives: subject experiences a stimulus and responds with one of two choices – by a button press, for example.
- Could be yes/no, stimulus A/B, second stimulus was heavier/lighter than first, etc. The third one (2 interval-2 alternative forced choice) is conceptually different from the first two (yes-no), since there are two samples.
- Many subtleties depending on exact experiment being done.

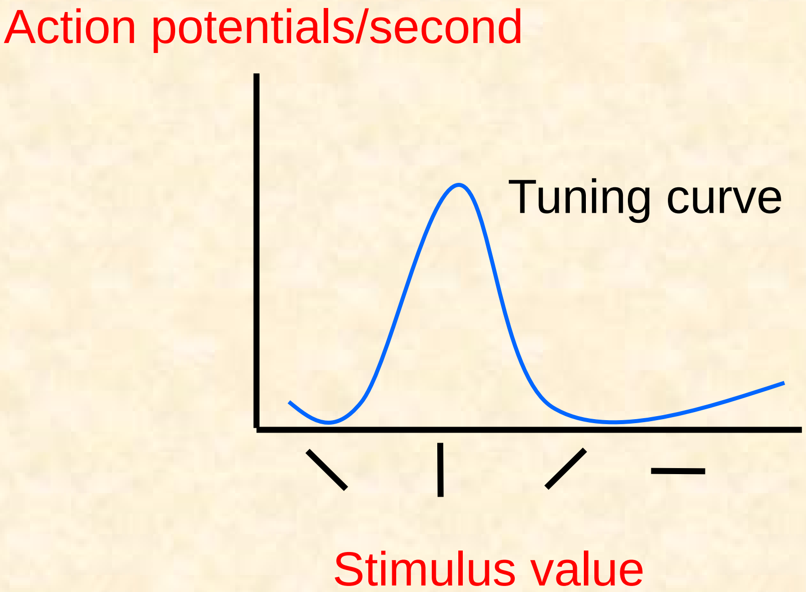
Neural codes

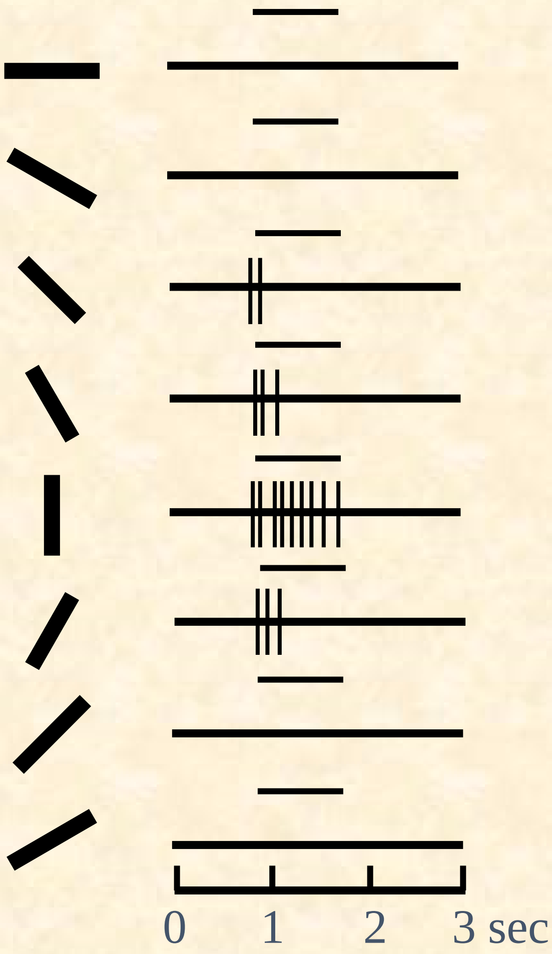
We try to link some feature(s) in this large amount of neural spiking information to ongoing perception, as reported by the subject. We are limited by what can be measured !

A. Spike-count in a small population of similar single-neurons from 1 area. Very common.
B. As in A, but contrasted with an anti-neuron population representing the opposite percept, or contrasted with a different neuron type.
C. Variation in spike-rate across time in this population: including strength of oscillatory activity, and fine-timing codes. Burstiness. Regularity.
D. Alignment of the spiking to the local field potential (LFP).
E. Synchrony of spikes across neurons: how closely do they fire in time ?
F. The patterns of spike-count across neurons: which neurons are firing more together or in opposition ? Correlation codes, *population codes*.
G. All of the above can also be done for 2 or more populations of neurons in different areas (e.g.: Oemish et al (PMID: 26400938), Totah et al (see below)
H. Variants of the above can also be calculated for LFPs, MEG/EEG/fMRI signals.

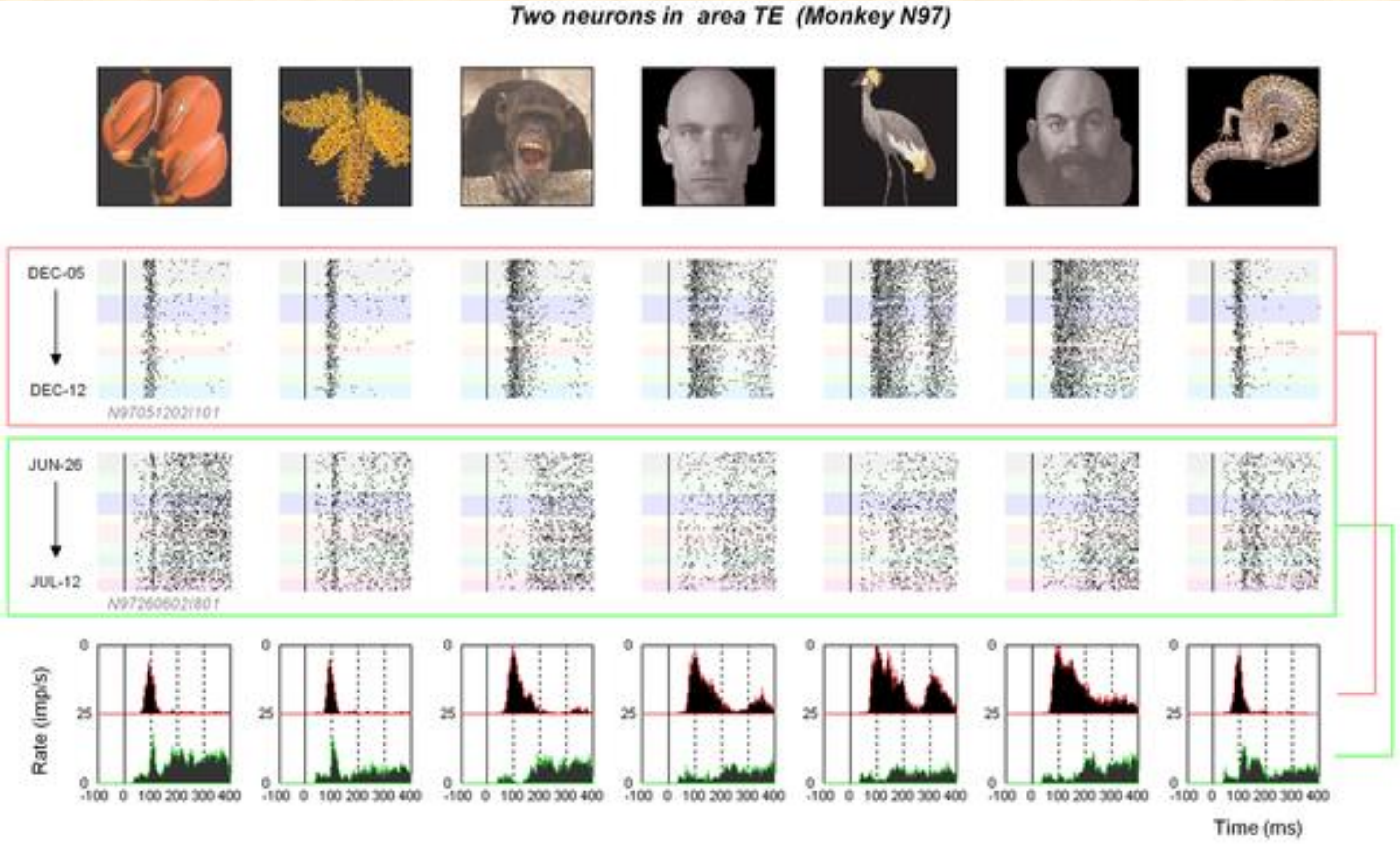
A. Spike-count carries information about stimulus identity (and location, etc).

Orientation
Motion direction
3D depth (binocular disparity)
Stimulus length
etc.



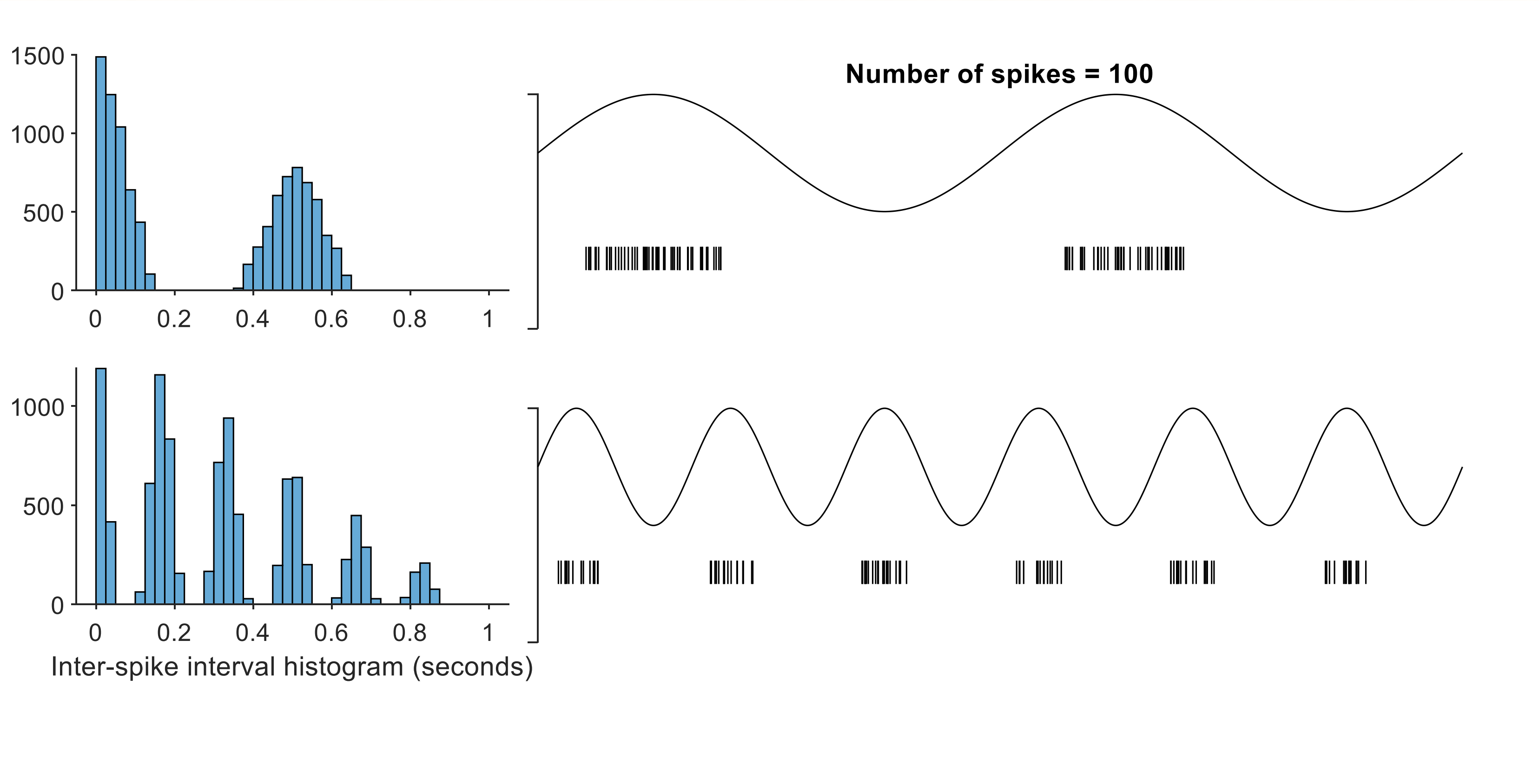


C1. Spike-rate variation with time carries information about stimulus identity



Bondar IV, Leopold DA, Richmond BJ, Victor JD, Logothetis NK (2009) Long-Term Stability of Visual Pattern Selective Responses of Monkey Temporal Lobe Neurons. PLOS ONE 4(12): e8222. https://doi.org/10.1371/journal.pone.0008222
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0008222

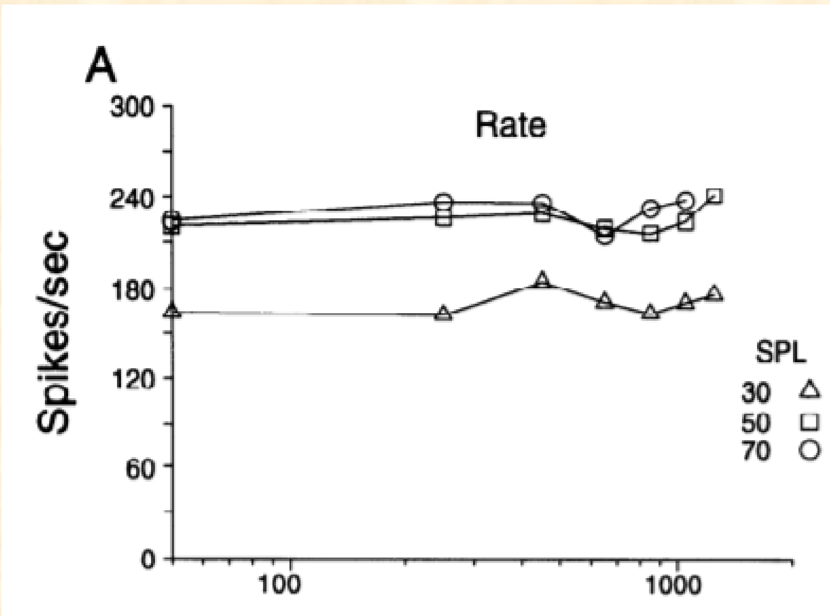
C2. Spike timing carries information about stimulus frequency – decreasing isih is confusing



Responses to amplitude-modulation in the cat

- auditory-nerve (Joris and Yin 1992, PMID – 1737873)
- most neuron-types in the cochlear nucleus (Rhode and Greenberg 1994, PMID – 8064349).

Code transformations



Auditory nerve (Rhode and Greenberg 1994)

1804 G. LANGNER AND C. E. SCHREINER

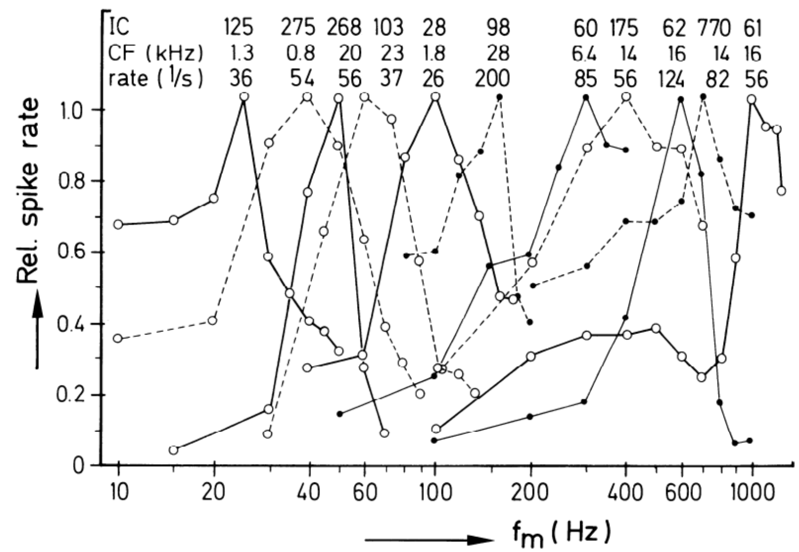


FIG. 3. Normalized modulation transfer functions (MTFs) for the firing rate of typical bandpass units of the ICC. Numbers above the MTFs indicate the unit number; the CF of the unit that also serves as carrier frequency of the AM stimuli; and the maximal firing rate corresponding to the tip of the MTF. Single units are indicated by *open circles*, multiple units by *closed circles*.

Inferior colliculus (Langner and Schreiner 1988)

Analogy: Total amount of money versus notes in which currency received

D. Spike-locking to LFP

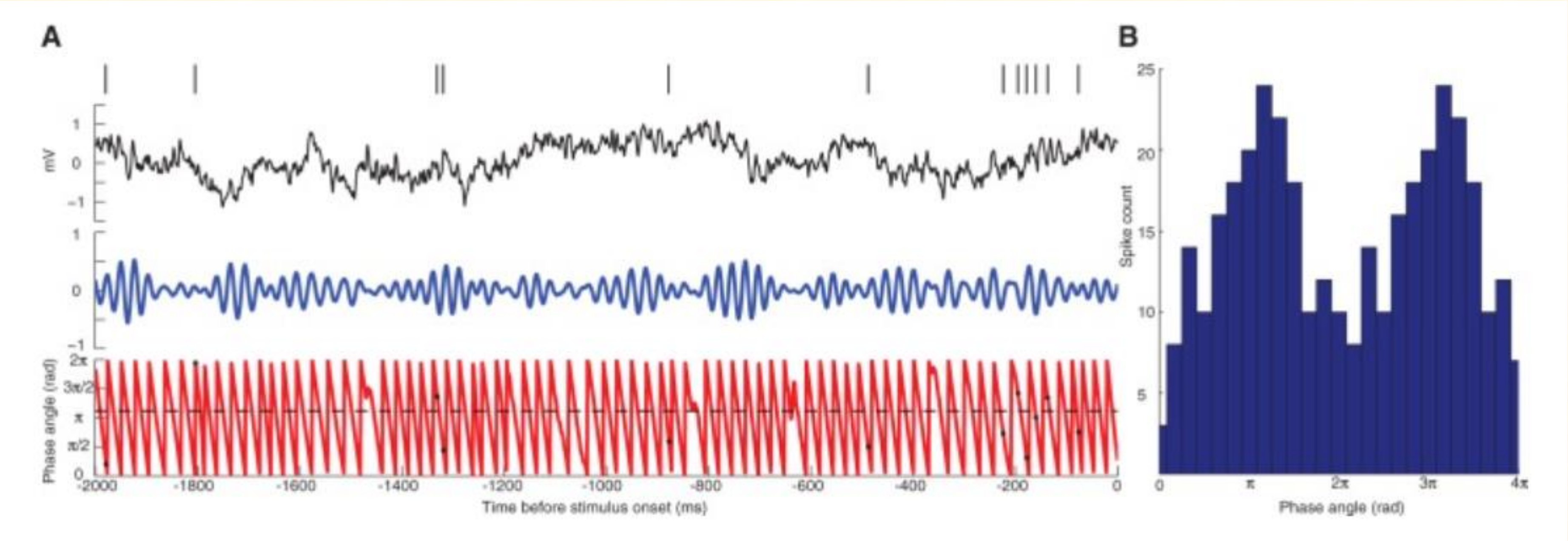
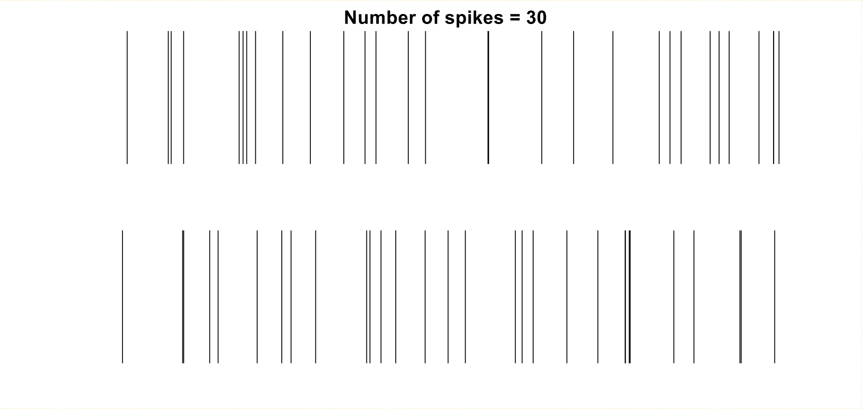
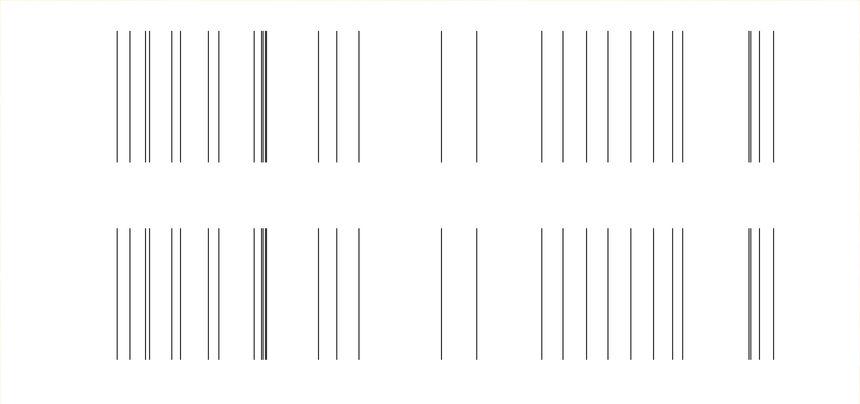


Figure 1, Totah et al., [Cereb Cortex.]() 2013 Mar; 23(3): 729–738. However, in this paper, spike-locking to LFP was correlated with performance, not identity.

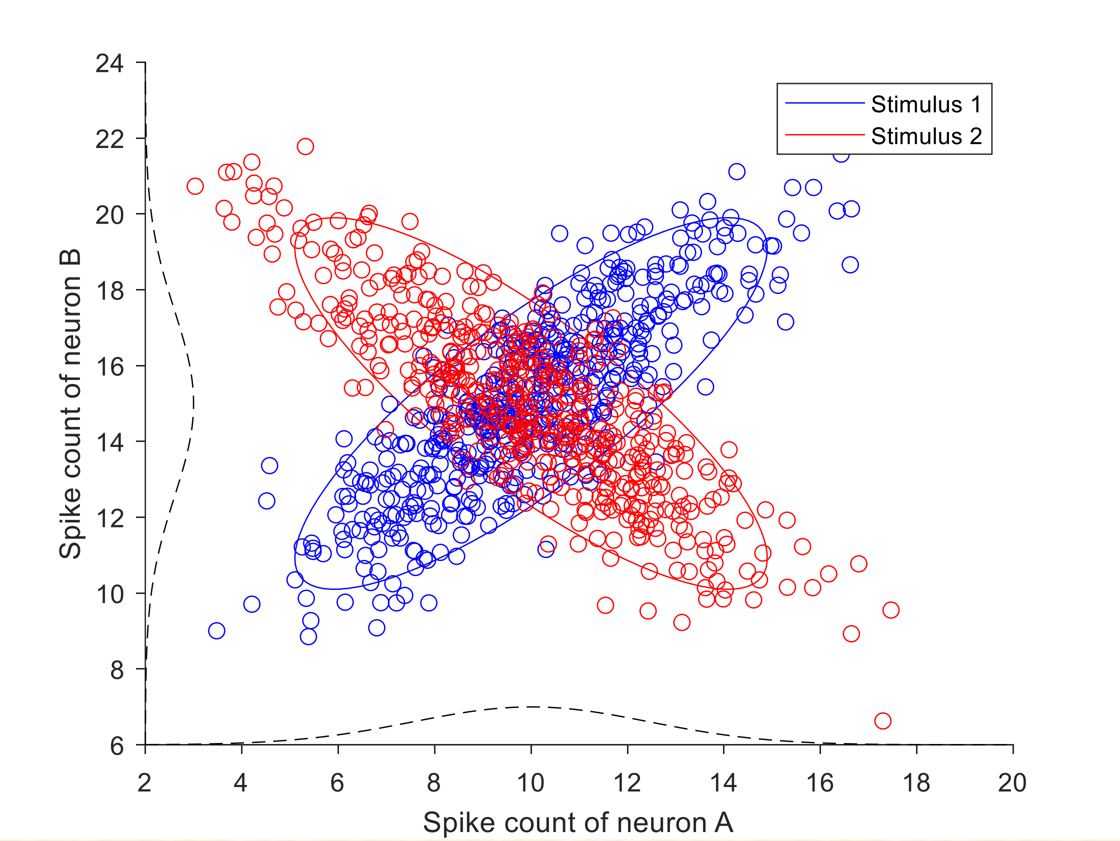
E. Synchrony





In this ***toy example***, the mint odor below leads these two neurons to synchronize perfectly, compared to the lemony odor above. All spike trains have 30 spikes. Real synchrony is less perfect.
Assemblies of synchronous firing in the olfactory system (e.g. Laurent and Davidowitz, 1994, PMID – 17797226)

F. Correlations



This is hypothetical, I think. I am still looking for an example where this has been shown.

See http://gentnerlab.ucsd.edu/publications/neuron.pdf for an interesting discussion

F. Example of “population code”: color

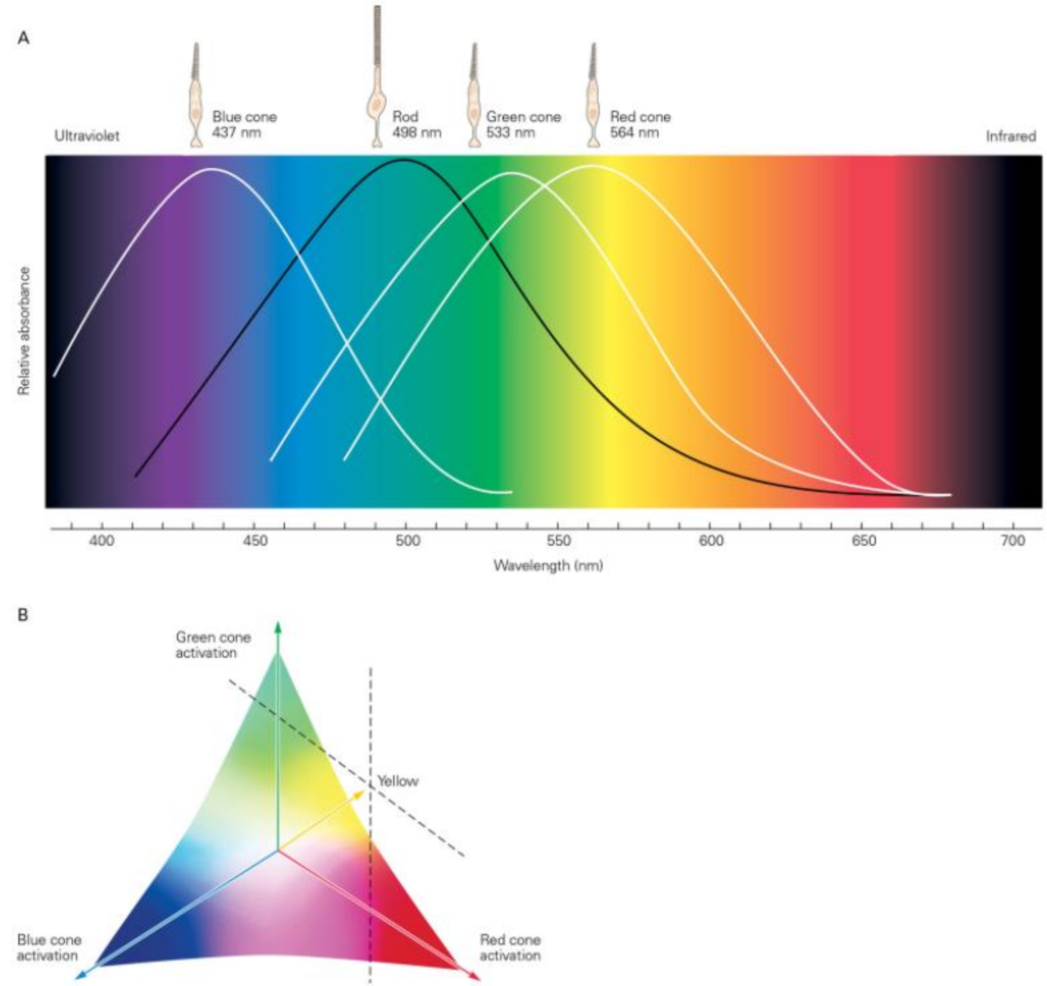


Figure 17–5 Human perception of colors results from the simultaneous activation of three different classes of photoreceptors in the retina.

See Kandel and Schwartz for details

Neural codes: notes

- Recording and analysis limitations; causal vs. correlational.

- Interventional methods like optogenetics might help but network problems

- Population drift of neural codes: https://www.theatlantic.com/science/archive/2021/06/the-brain-isnt-supposed-to-change-this-much/619145/

- Adaptation is another example of coding shifts / context-dependent code meaning; similarly age-related head-size changes

Detection

- Let us try to create a well-controlled task of the yes-no / A or B kind.
- A blunt stylus is used to gently press on your skin. The pressure is either P1 or P2 – with P1 being lighter than P2. After each touch, you have to report if it was the lighter stimulus or the more intense stimulus.
- Imagine you have access to responses from a touch fiber roughly like this:

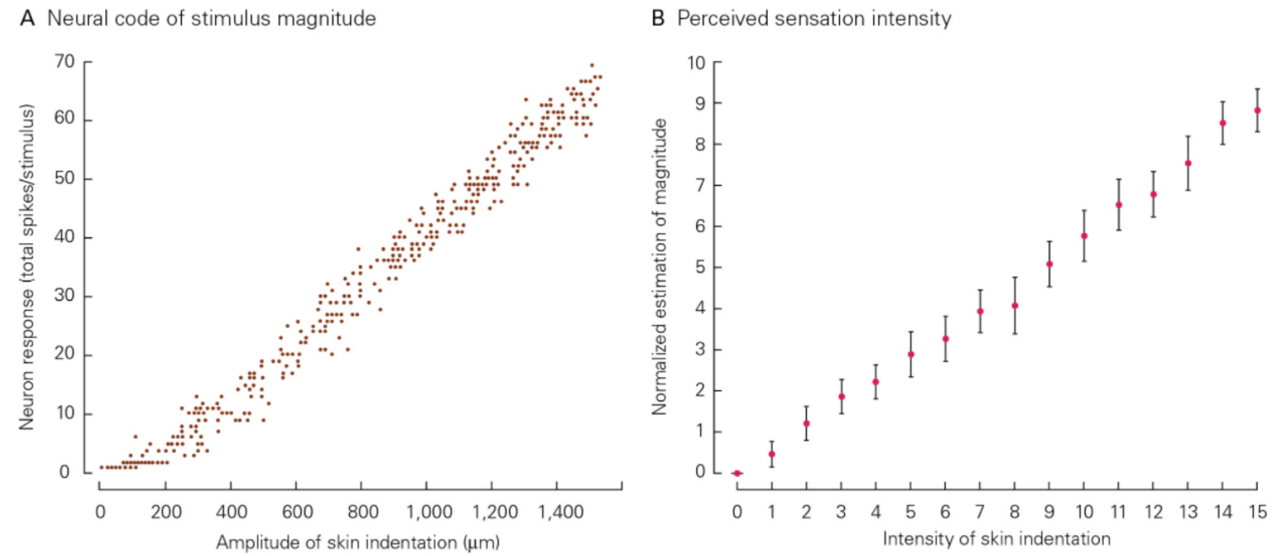
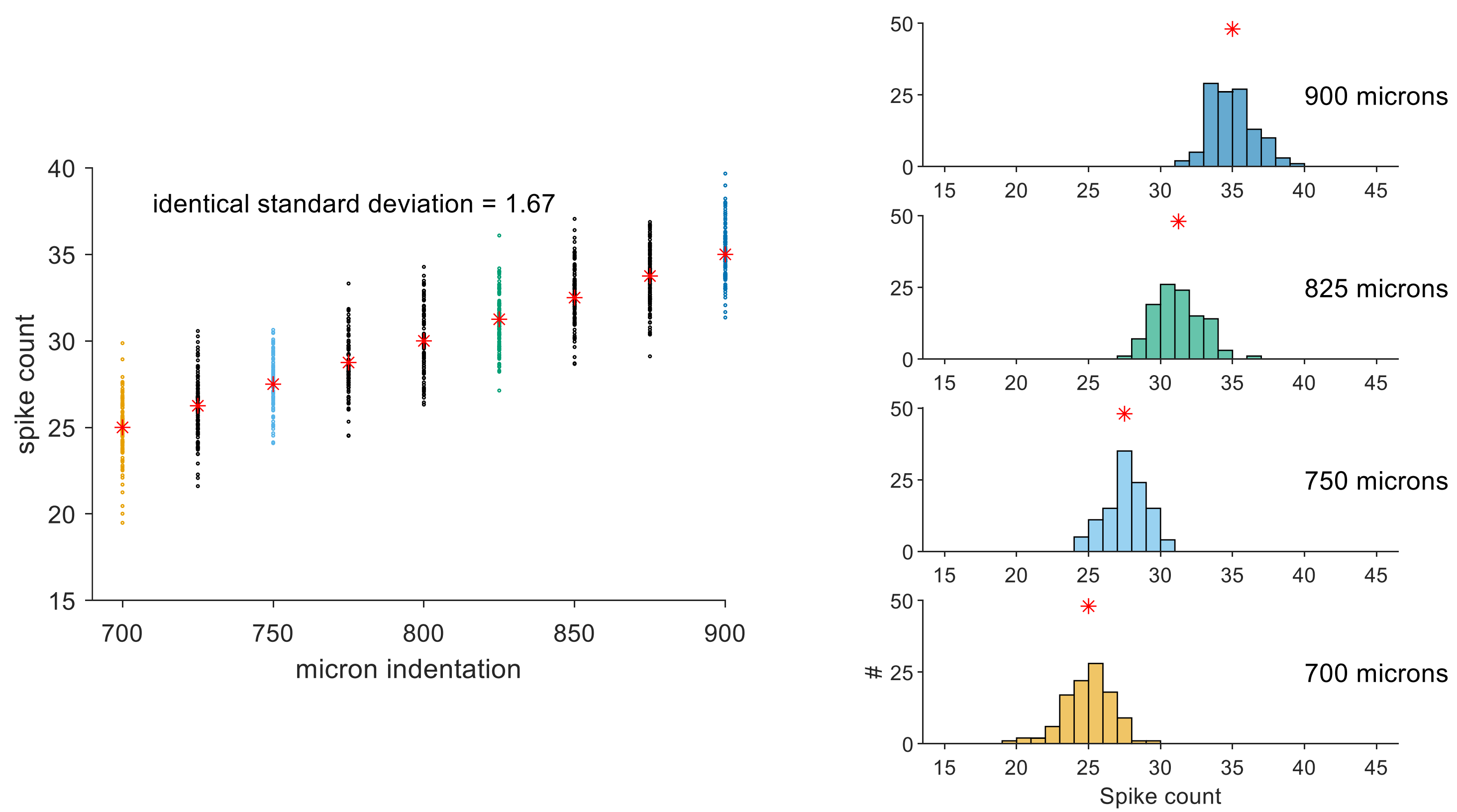
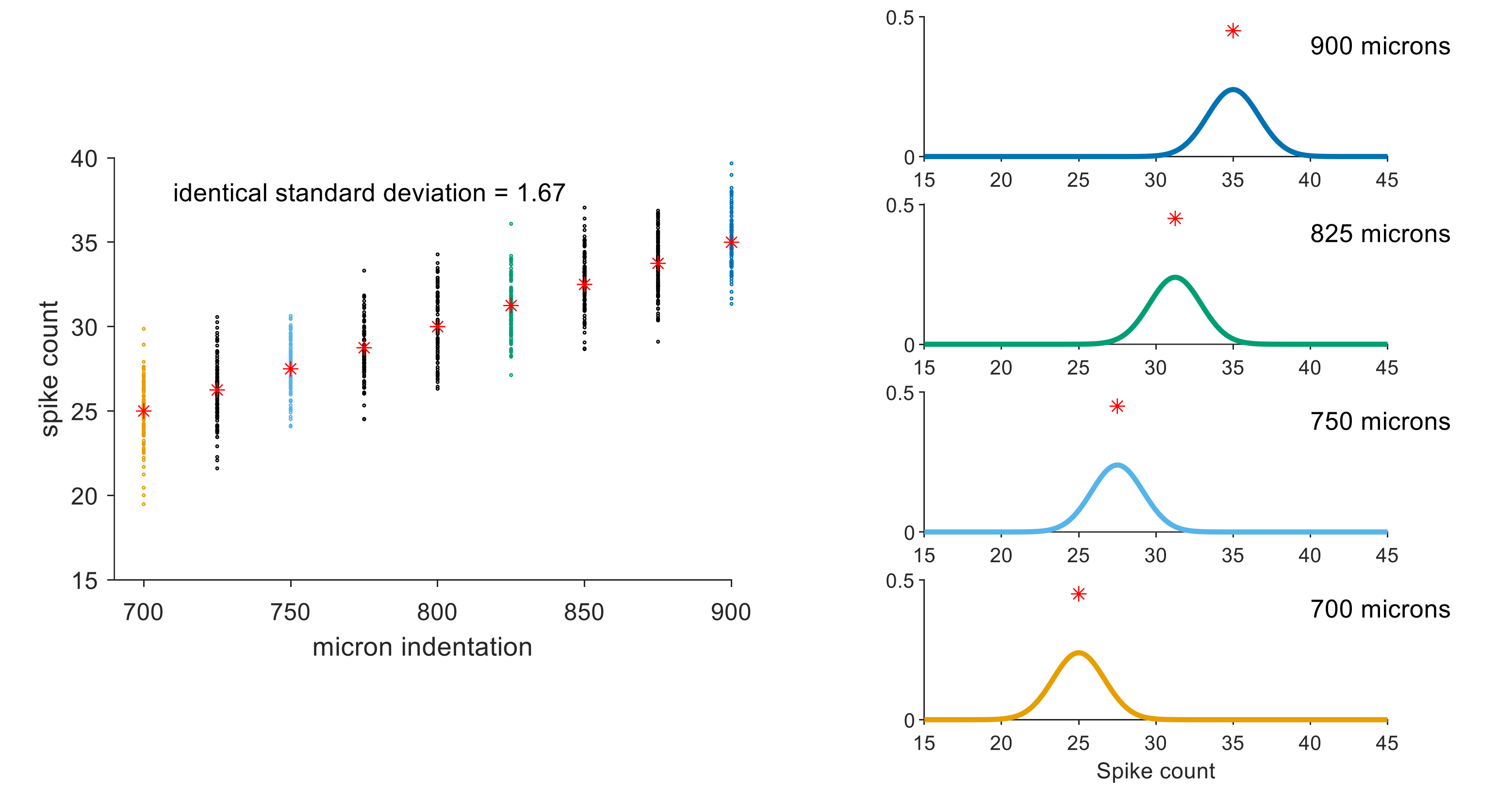


Figure 17–6 The firing rates of sensory neurons encode the stimulus magnitude. The two plots indicate that the neural coding of stimulus intensity is faithfully transmitted from peripheral receptors to cortical centers that mediate conscious sensation. (Adapted, with permission, from Mountcastle, Talbot, and Kornhuber 1966.)

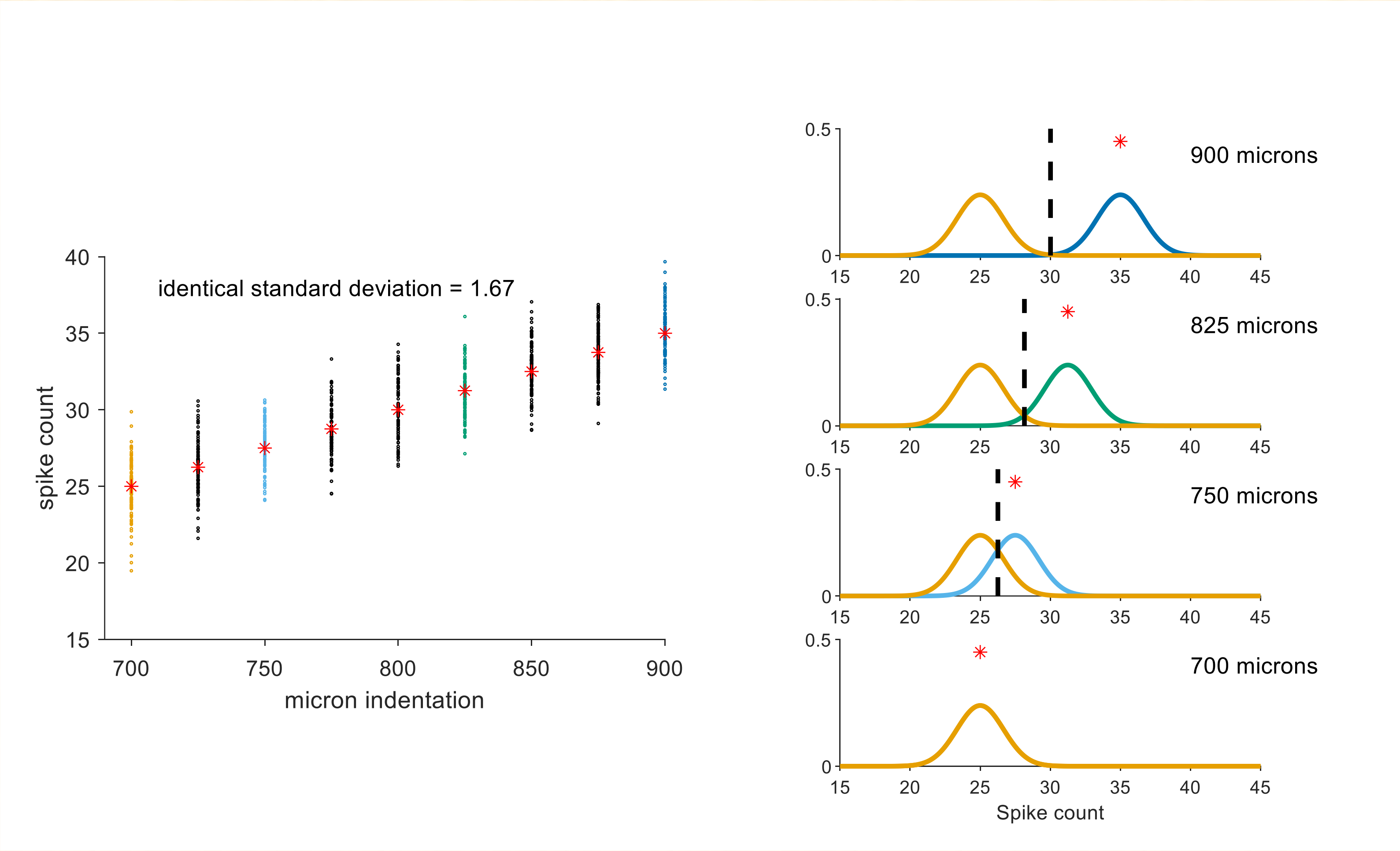
Yes/no signal detection



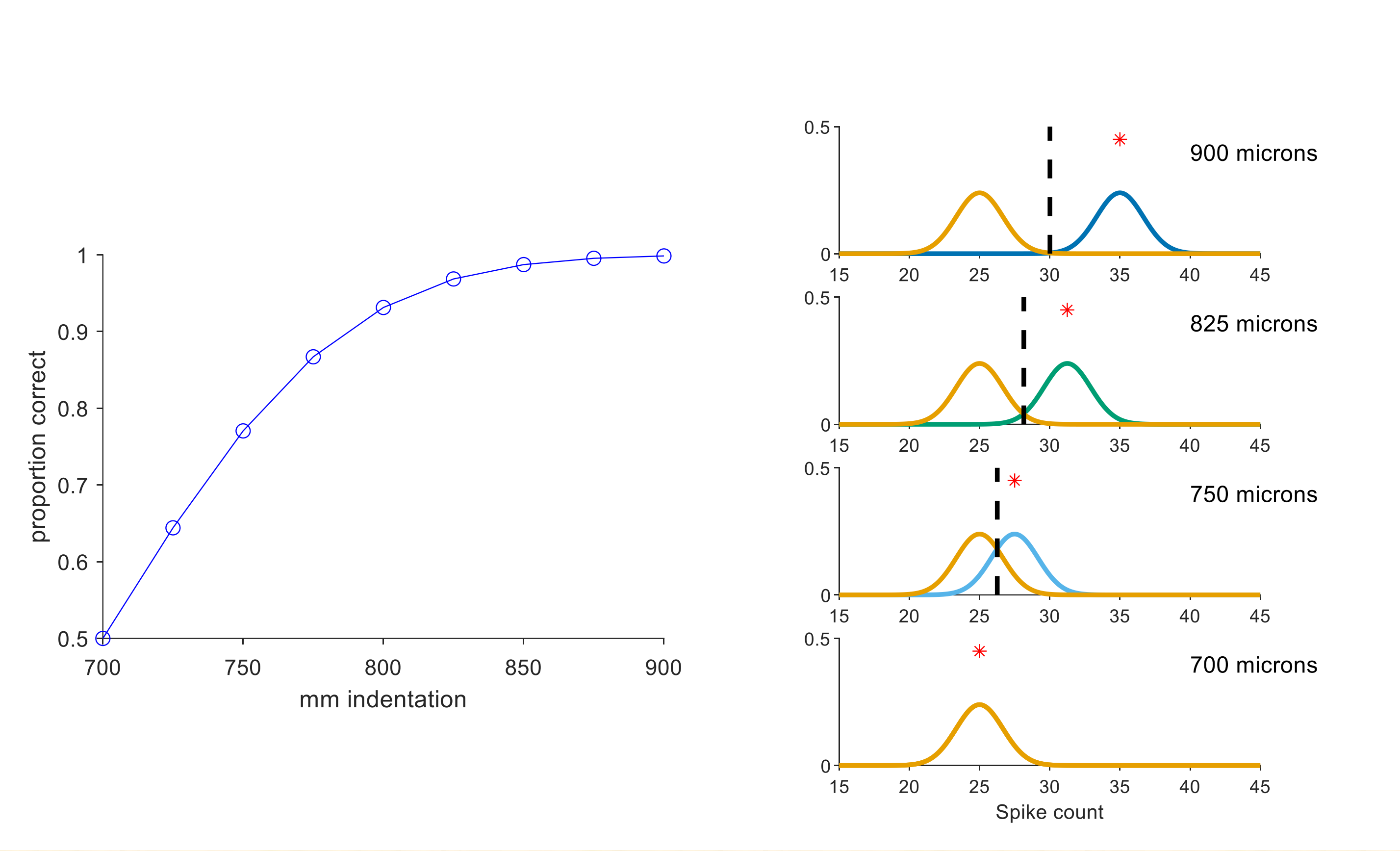
700 vs. each of rest signal detection



700 vs 750 (825,900)

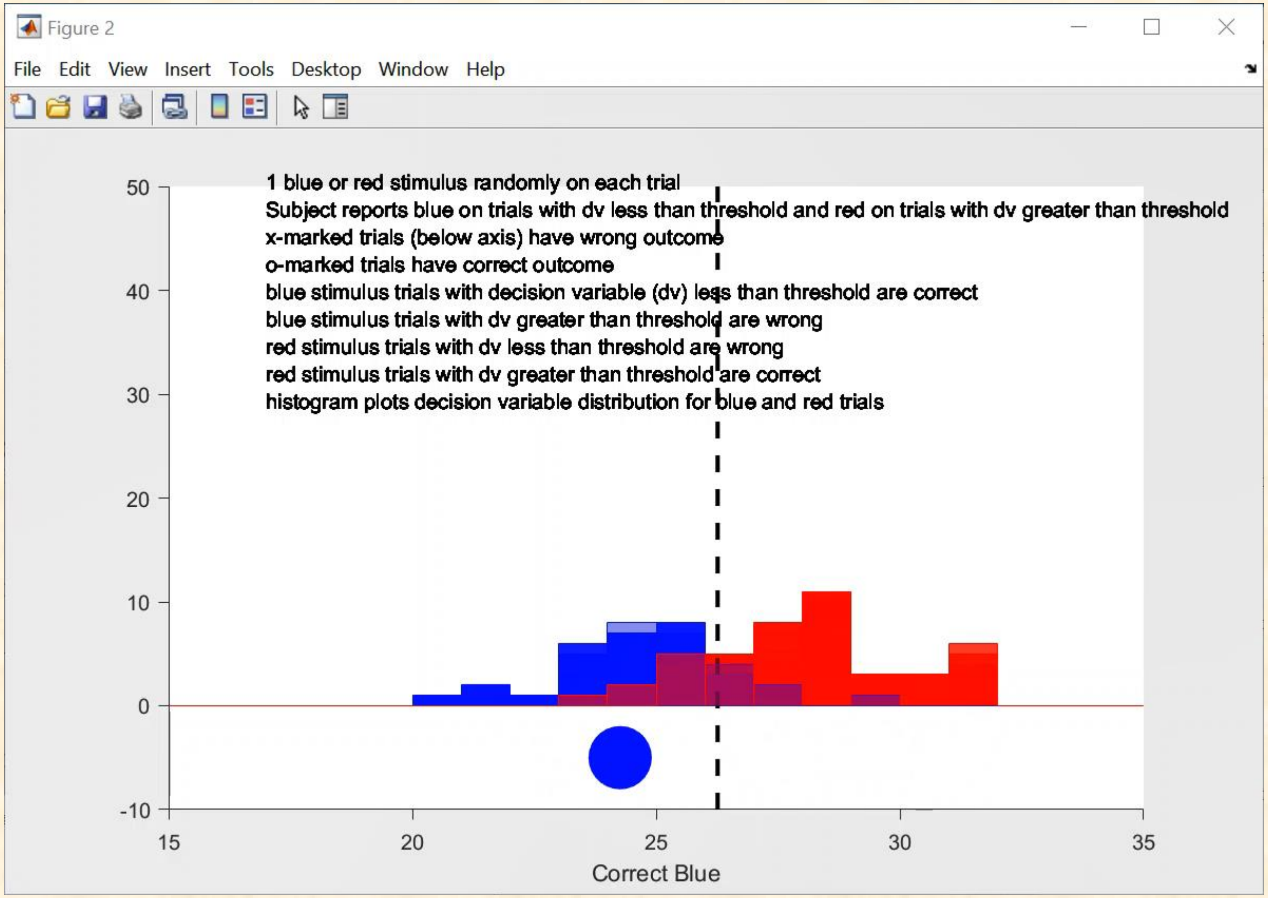


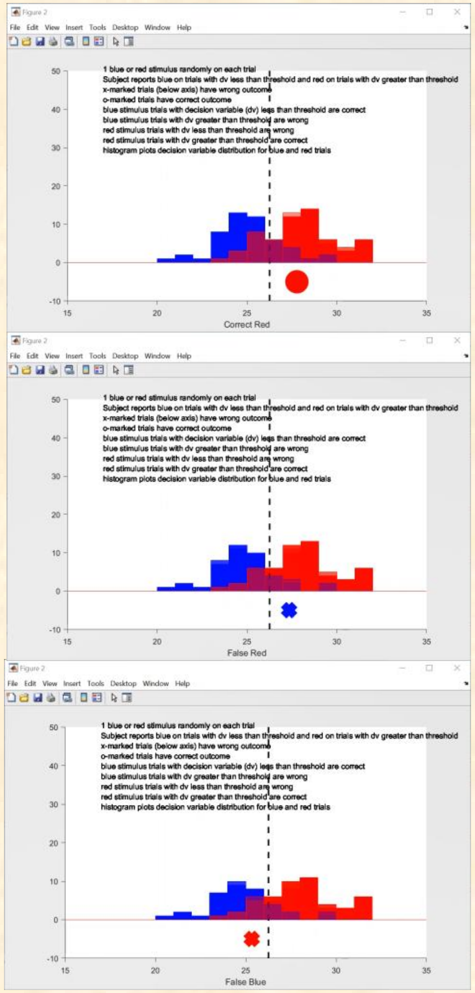
700 vs each of rest



Psychometric function based on spike-count distributions

Blue/red signal detection





Blue/red signal detection