Advanced HCI
Lecture 3

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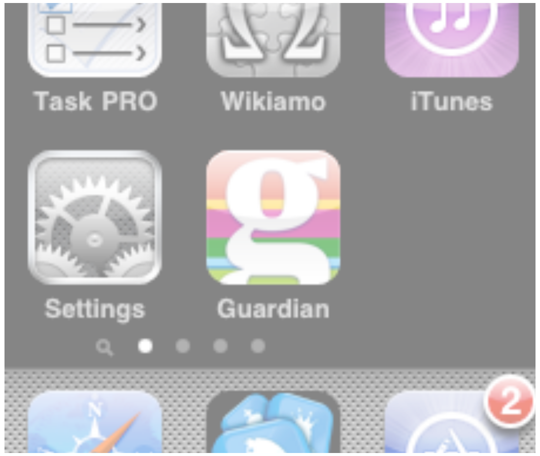
Adaptive Interaction

- **People choose what to do by finding strategies that exist within the space defined by three things:**
- **The environment**. Bounds imposed by the environment including computers, tablets, smartphones etc.
- **Bounds** imposed by human psychology, including memory, vision, and motor-systems.
- A **utility function**. People have goals, preferences, tasks. They must weight various trade-offs including, for example, speed and accuracy.

putting perception and motor control together



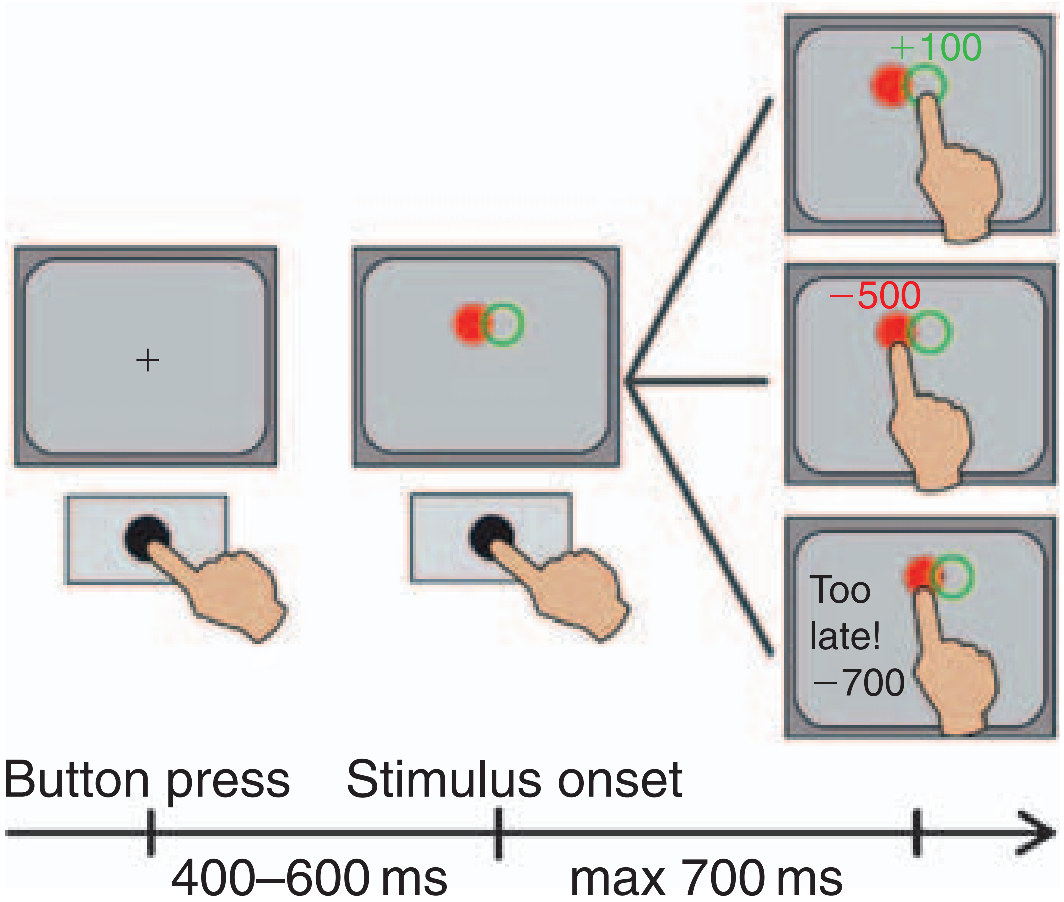
+

- Your task is to press the "Guardian" icon.
- Your eyes start focused on the crosshair.
- Make the required eye movements, pick your aim point, and press the button.
- Achieving this goal requires your brain to process the verbal instructions, choose an aim point, control muscles in your face and eyes, muscles in your hand, arm, and upper body. All of this activity needs to be coordinated so as to press a button.

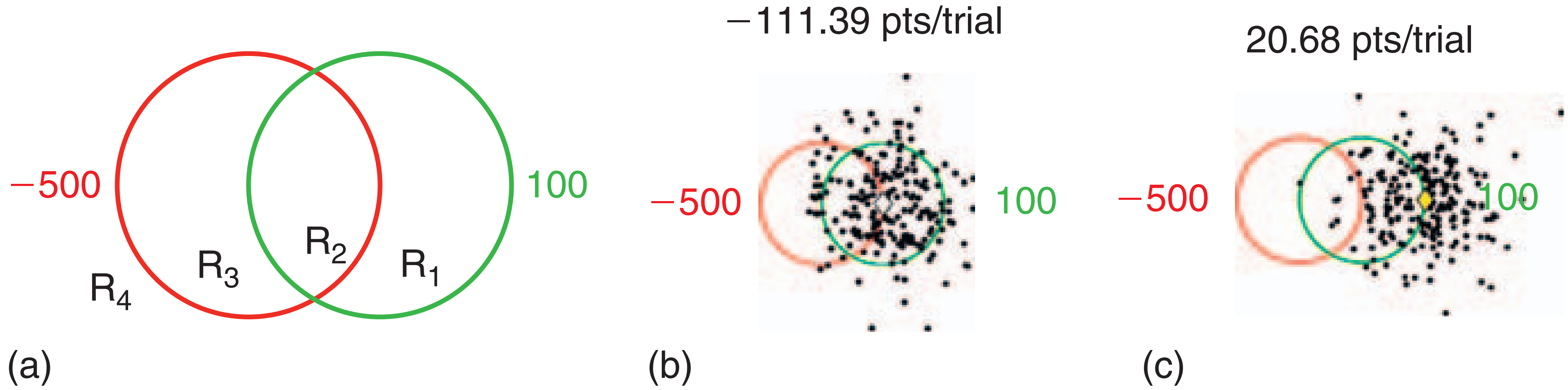
Modeling

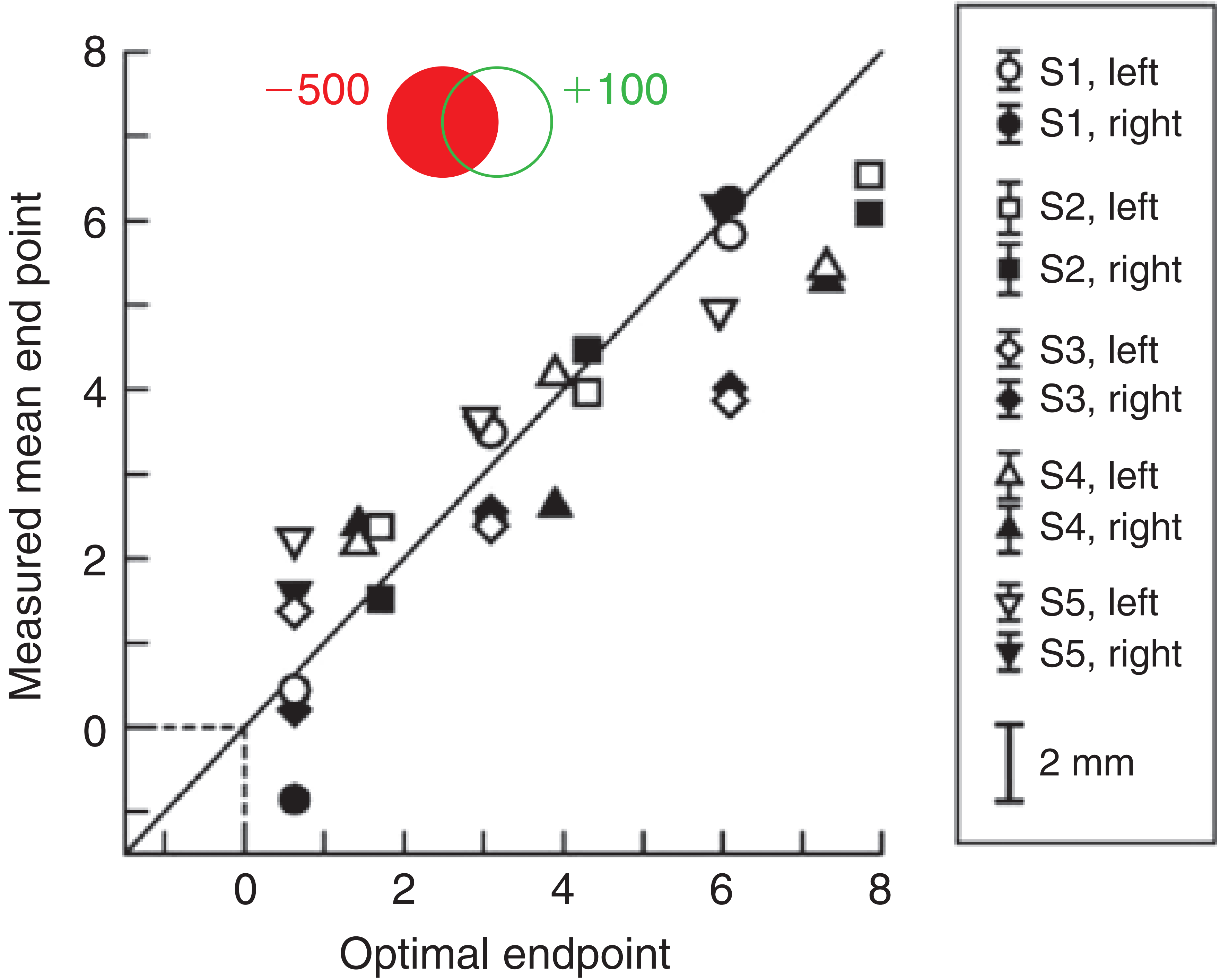
- We can use what we know about vision and motor control to predict and explain performance on this task.

example: targeting



from Trommershauser, Maloney, Landy (2008)


−500
100
R4
R3
R2
R1
(a)
−111.39 pts/trial
−500
100
(b)
20.68 pts/trial
−500
100
(c)

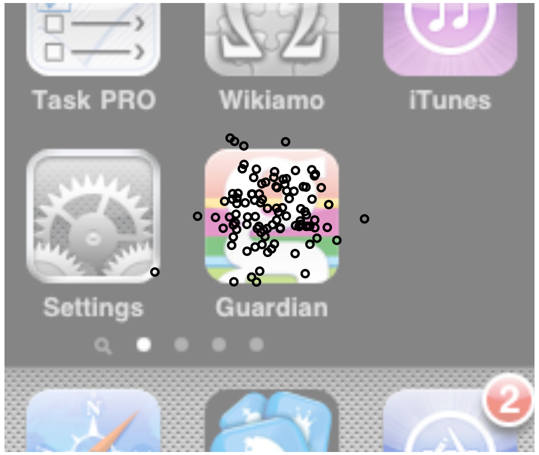


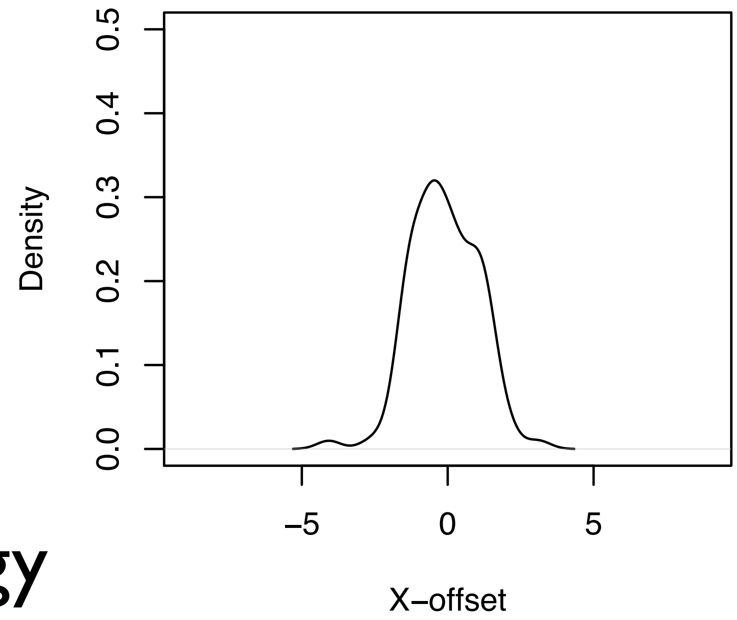
Measured mean end point
Optimal endpoint
−500
+100
S1, left
S1, right
S2, left
S2, right
S3, left
S3, right
S4, left
S4, right
S5, left
S5, right
2 mm

key features

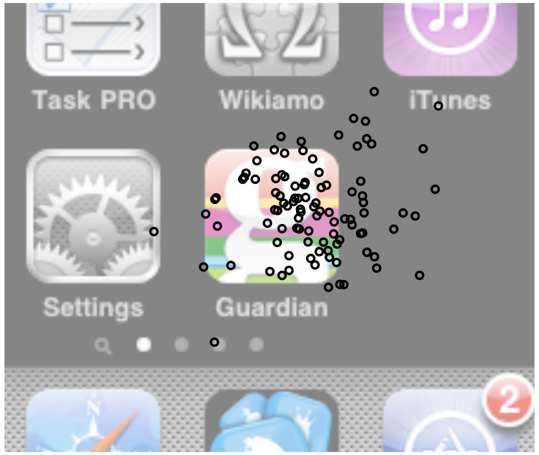
- **environment**: simple button arrangement, some with adjacent buttons some without.
- **bounds**: targeting variance; size and location of buttons; cut-off duration.
- **utility** = hits - penalties

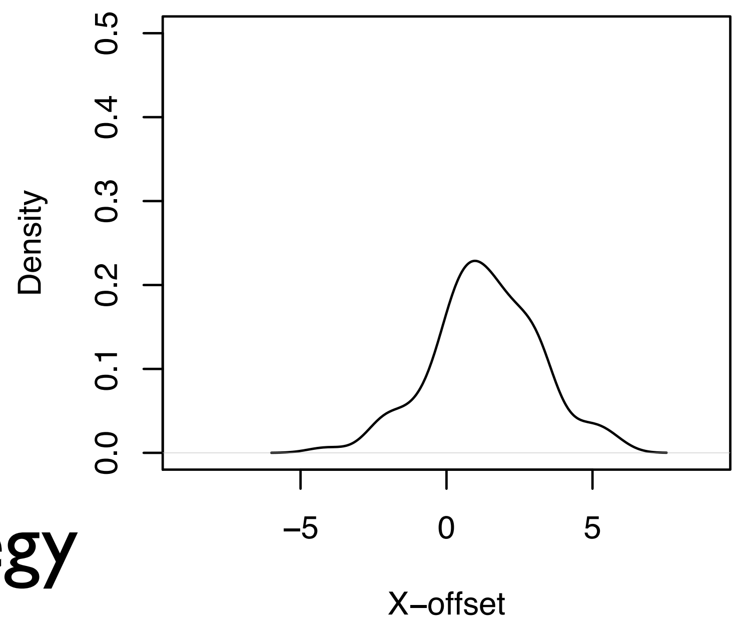
- These imply a set of **strategies**...





low variance strategy





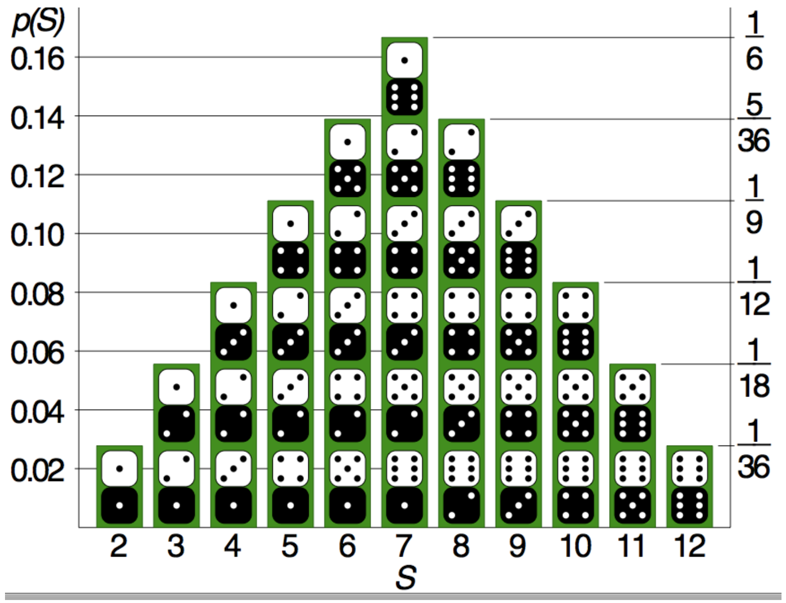
high variance strategy

strategy choice

- the strategy space is at least two dimensional
  - how fast to perform (implying a level of noise)
  - where to aim
- which strategy an individual chooses will depend on
  - utility (e.g. how much they value time),
  - bounds (their own motor noise), and
  - environment (the noise in the environment).

probability density functions (p.d.f.)

- Are crucial to understanding human behavior.
- Consider the simple pdf for throwing two dice.
- We will see a lot more pdfs in the next two lectures.



human decision making

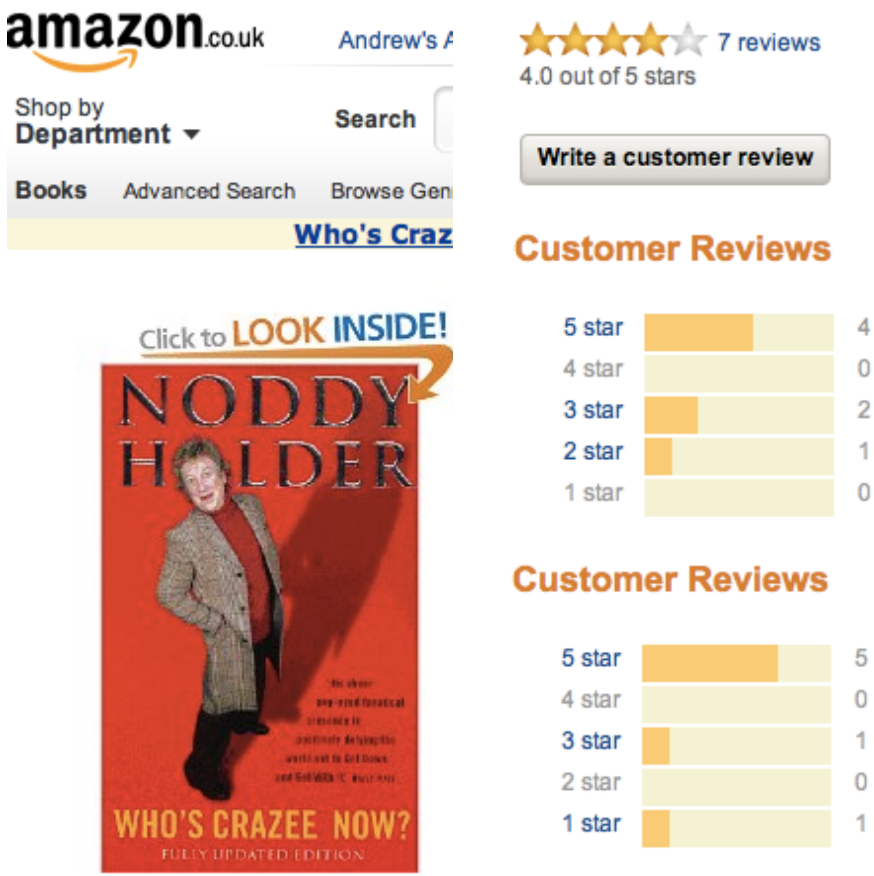
Signal Detection Theory

- Nearly all human capabilities, including vision, take place in the presence of some uncertainty.
- As we have seen uncertainty about vision increases with eccentricity, distance, from the fovea.
- Uncertainty about motor targeting increases with speed of action and has consequences for aiming strategies.
- Here are some other examples:

http://www.cns.nyu.edu/~david/handouts/sdt/sdt.html

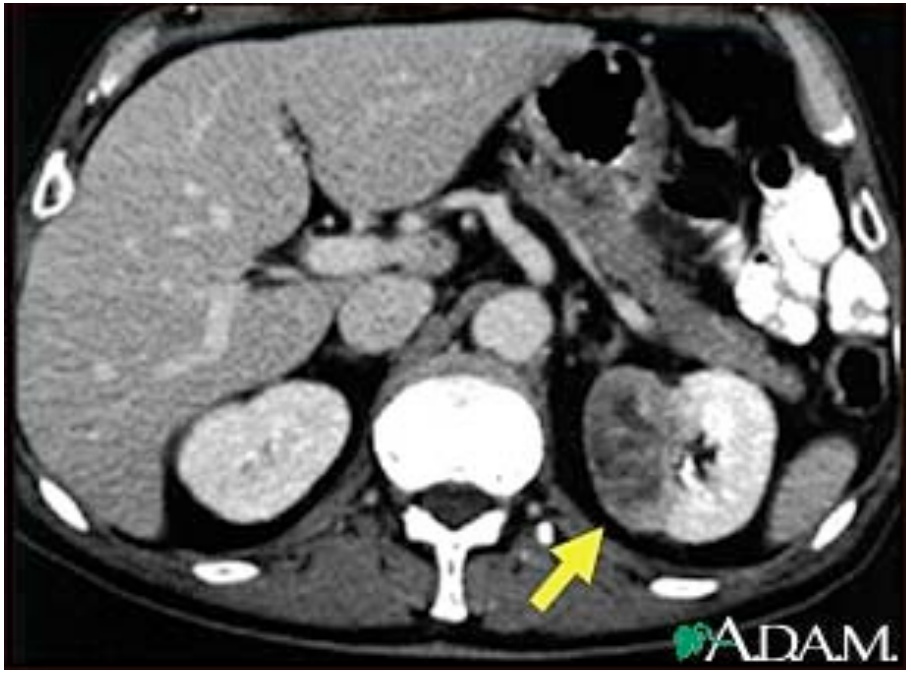
purchasing uncertainty

- You may be personally uncertain about the quality of a book.
- You might attempt to reduce your uncertainty by looking at the average customer rating.
- The average rating is itself a function of uncertainty.
- In this case the average is a function of a distribution of customer opinion.



Kidney tumor CT-scan

- CT-scan or "computed tomography" is a type of x-ray that produces images in slices.
- Imagine that we are trying to build a new app so that Doctors can view CT-scans on a tablet or a smartphone.
- On the right is a scan of a kidney tumor. This one is quite pronounced. cf the left kidney.
- But the smartphone provides a much smaller image of the scan than other types of display.
- How much harder is the tumor to detect?



monitor

phone tablet

- David C. Dugdale, III, MD, Professor of Medicine, Division of General Medicine, Department of Medicine, University of Washington School of Medicine; Read more: http://www.umm.edu/imagepages/1168.htm#ixzz27rhUeKUo

an empirical test

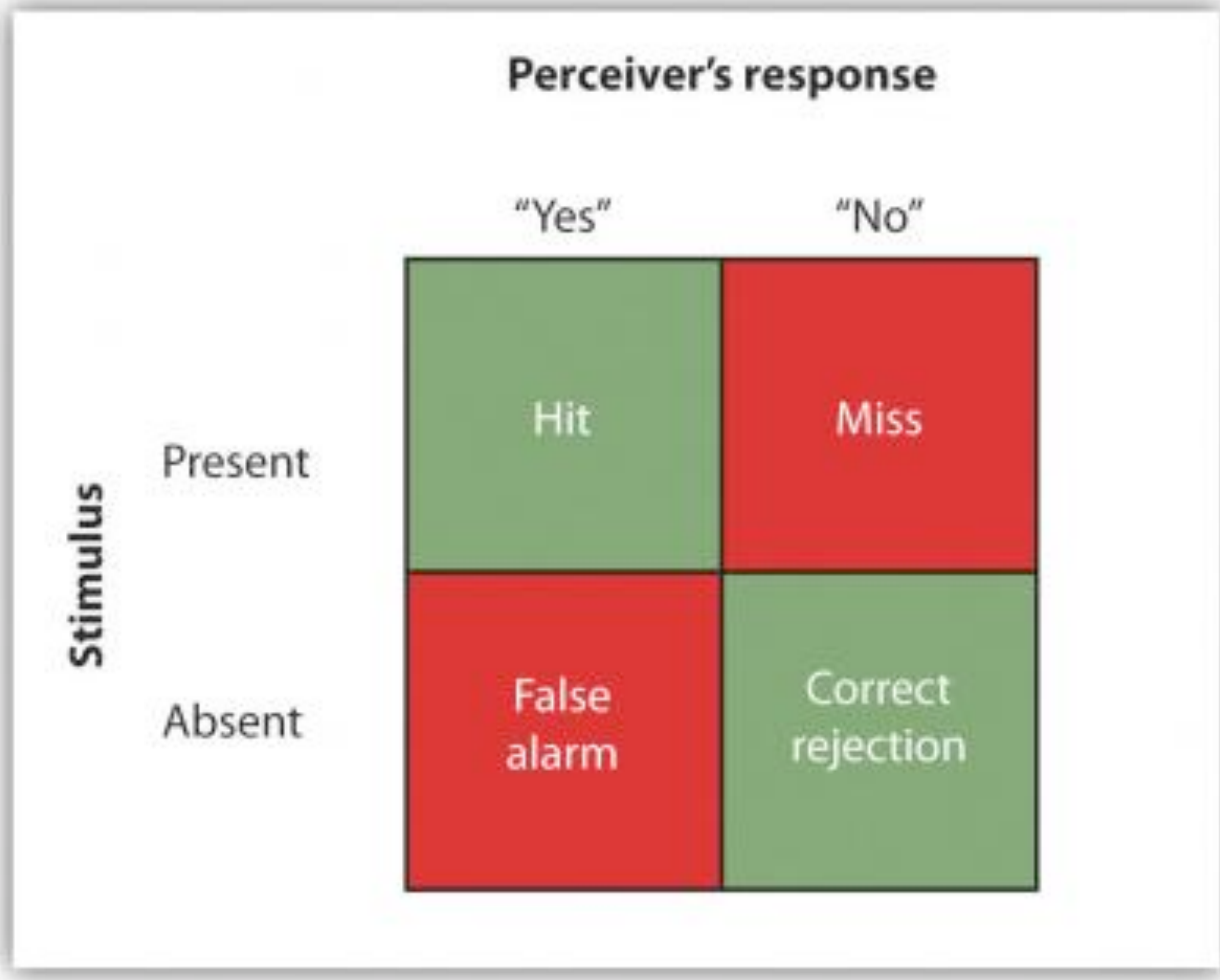
- we might get 100 CT-scans of kidneys with tumor and 100 without and see how well doctors did at discriminating them when displayed on each display type.

Interpreting scans is hard..

- Interpreting CT scans is hard. The task is so hard, there is always some uncertainty as to what is there and what is not there.
- Either there is a tumor (***signal present***) or there is not (***signal absent***).
- If the doctor thinks that they see a tumor (they respond "yes") or does not (they respond "no").
- These kinds of decisions can be understood with **Signal Detection Theory**.

Signal Detection Theory

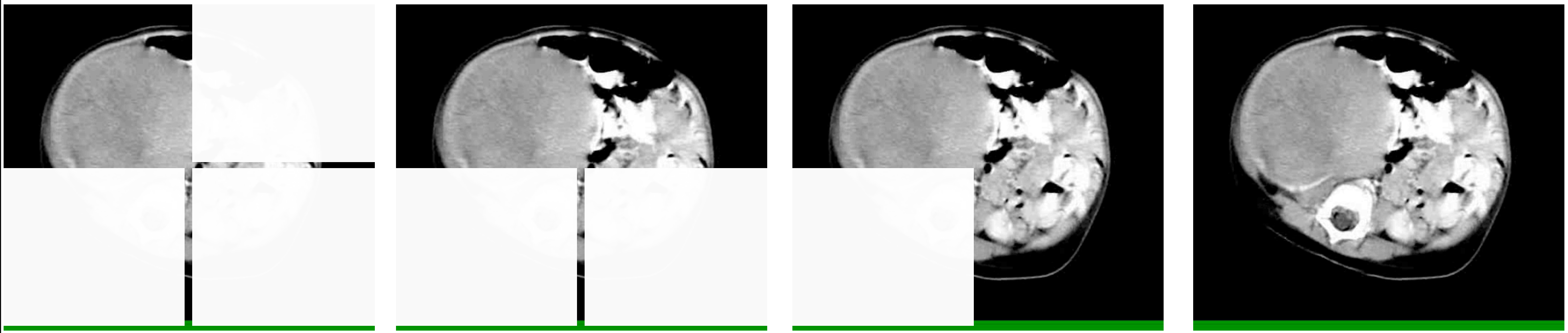
- ... is a means of deciding whether a signal, e.g. the tumor, is present or absent given noisy input.
- There are four possible outcomes:
  - hit (tumor present and doctor says “yes”)
  - miss (tumor present and doctor says “no”)
  - false alarm (tumor absent and doctor says “yes”)
  - correct rejection (tumor absent and doctor says “no”)
- Graphically...



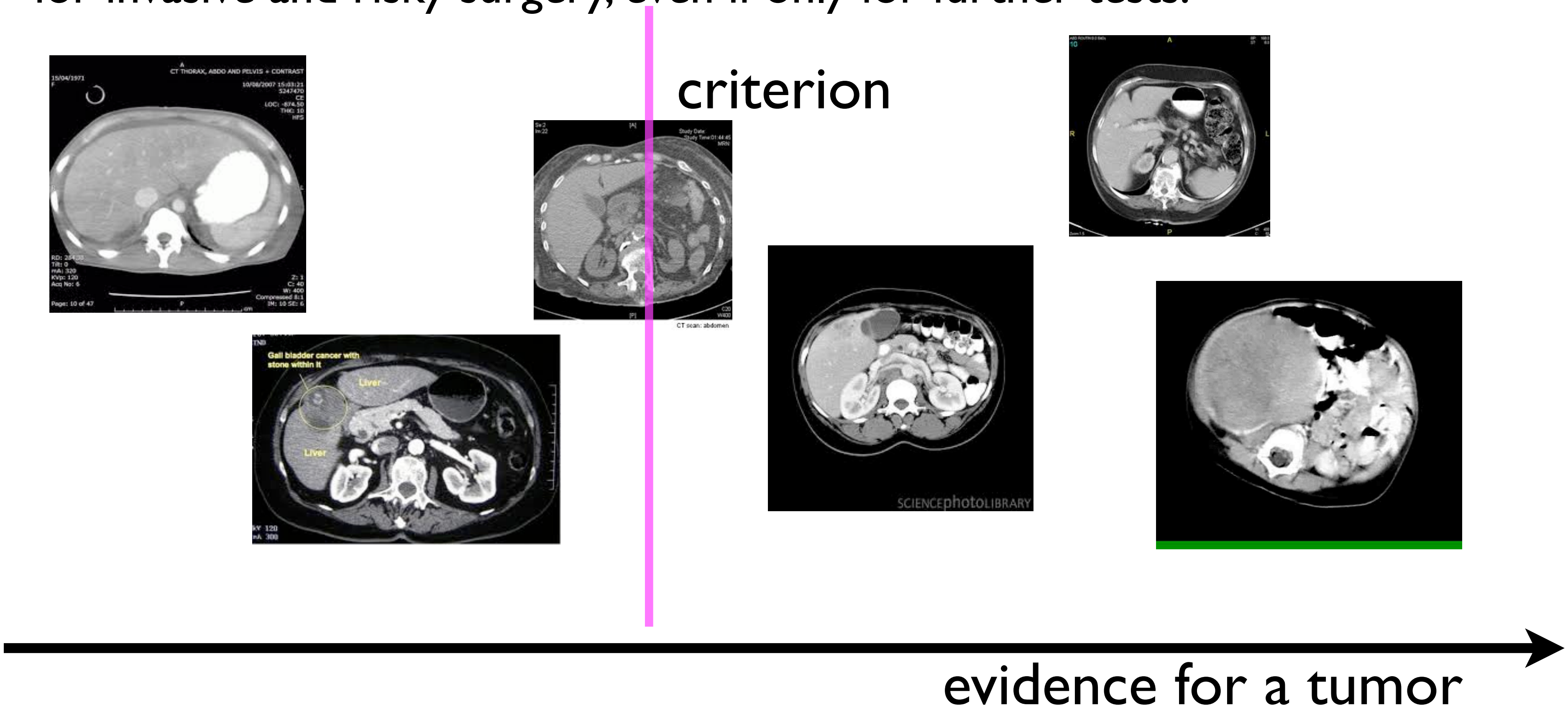
given the stimulus there are two components to generating the perceiver's response...

Information acquisition and criterion

- There are two components to the decision making process: information acquisition and criterion.
- **Information Acquisition**. There is about acquiring information in the scan. Healthy organs have a characteristic shape and shade. But even so some benign growths will look like tumors, some normal organs will look as though they may be cancerous and some cancers will look like healthy organs.



- **Criterion.** This is the clinicians strategy. A tumor looks darker but how dark does an area on the image have to be before it is inferred that a tumor may be present? If the criterion/threshold is "just a little bit dark" then perhaps lots of growths will be incorrectly diagnosed as cancers. If the criterion is "very dark" then perhaps lots of cancers will be missed.
- You might say be extra safe! And you'd be right but all medical decisions have costs as well as benefits. A "tumor" diagnosis might imply the need for invasive and risky surgery, even if only for further tests.

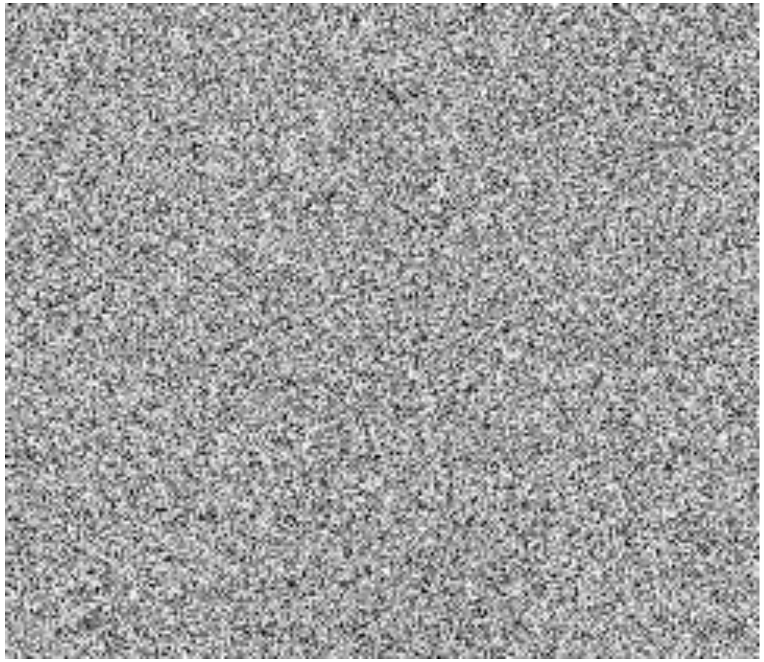


environment, bounds, and utility

- Two doctors with access to exactly the same information (**environment**) and knowledge (**bounds**) may make different decisions because they use different criterion levels (**utility**).
- The criterion is a strategy that implies the utility.

noise

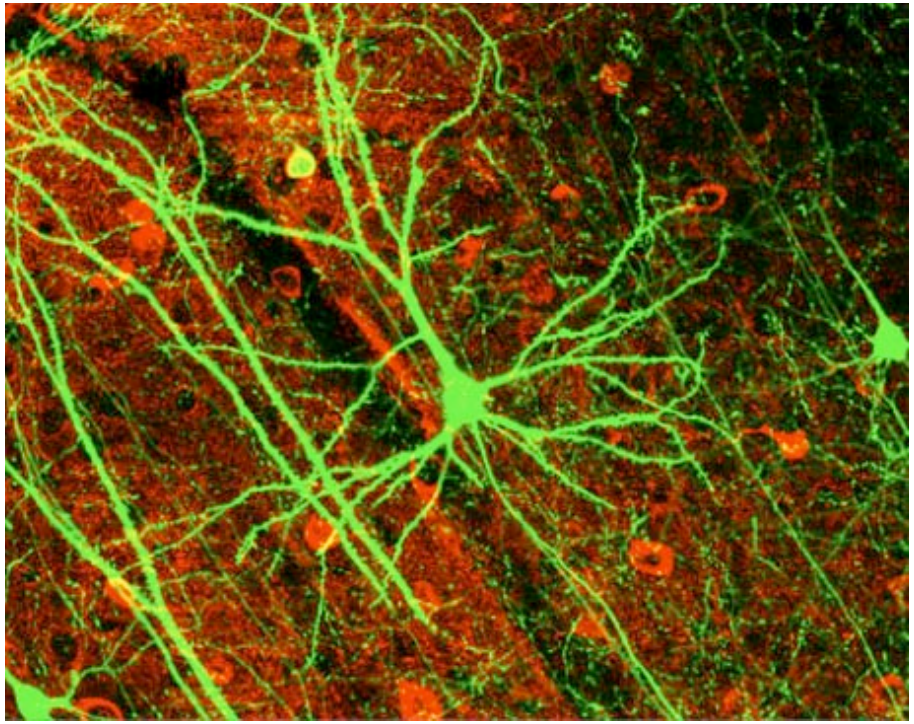
- There are two kinds of uncertainty both due to noise:
- **External noise**: e.g. part of the photographic process. A CT-scan produces an image with a certain resolution. FMRi scans have much lower resolution. We can design technologies that reduce external noise but some noise is inevitable.



http://physicsworld.com/cws/article/news/2010/mar/05/superconductors-could-simulate-the-brain

internal noise

- **Internal noise**: Neural responses are noisy. Imagine that we could stick an electrode into your brain and monitor the electrical signal generated by a particular CT-scan image.
- You might get a reading of 20 spikes per second. Later, you might get the same clinician to look at the same scan again and measure the same neuron. This time measure a firing rate of 40 spikes per second.



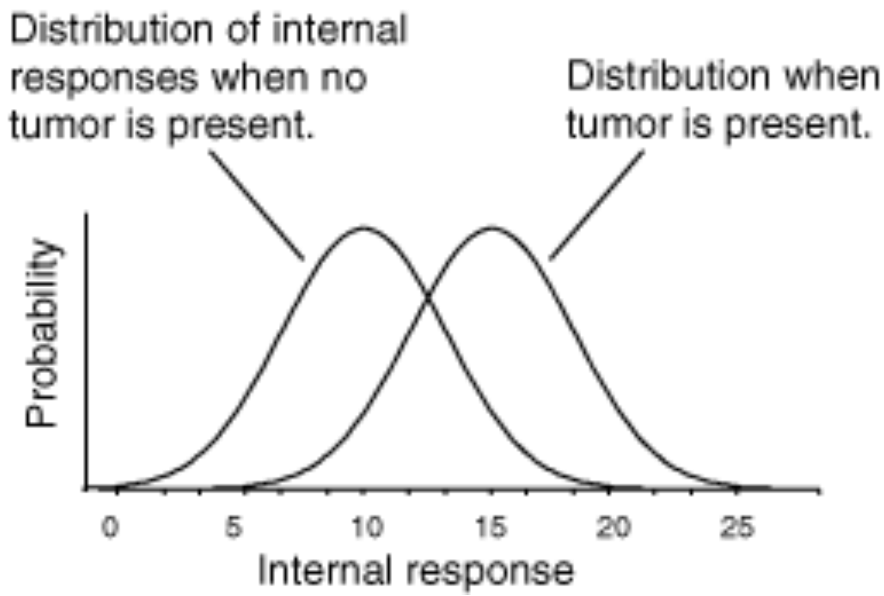
neuron in a mouse brain

internal response

- This firing rate, actually the firing rate over a cluster of neurons, is the **internal response** to the image.
- We are interested in the level of internal response that is required for the clinician to decide that there is a tumor present.
- We can model this with probability density functions.

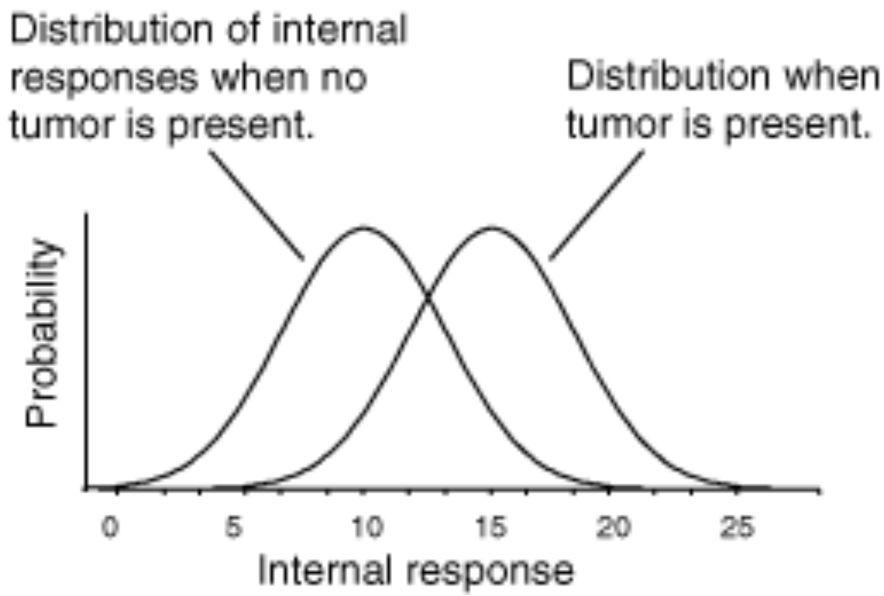
probability density function

- The horizontal axis is a measure of the internal response (e.g. neural firing rate).
- The vertical axis represents the probability of that firing rate for tumor absent and tumor present CT-scans.



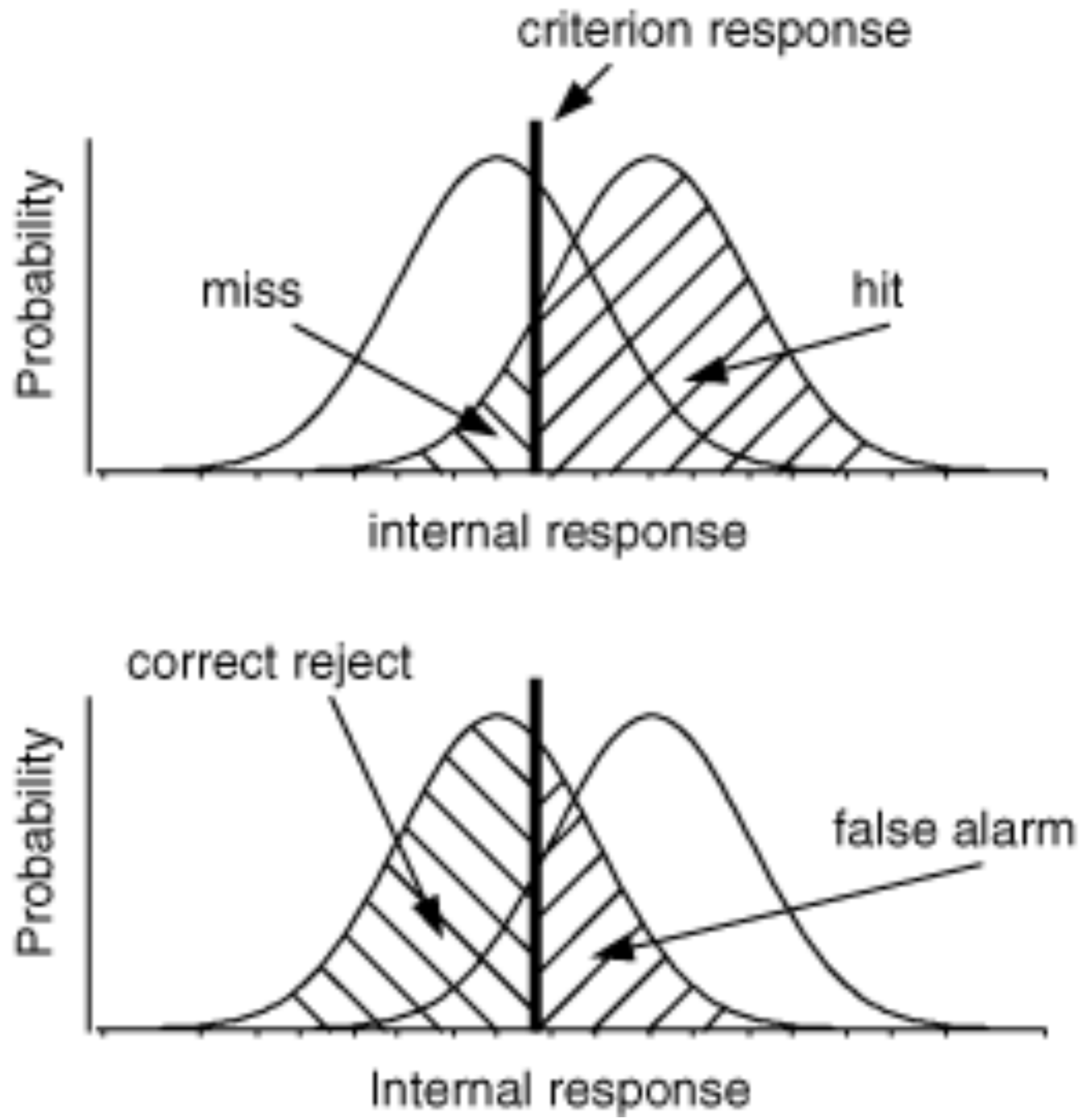
probability density function

- It is very likely that the internal response when the tumor is present will be 15 units.
- It is highly unlikely that the internal response will ever be 26 units and it is almost never 0.
- A response of 12.5 units is equally likely to be from either distribution.



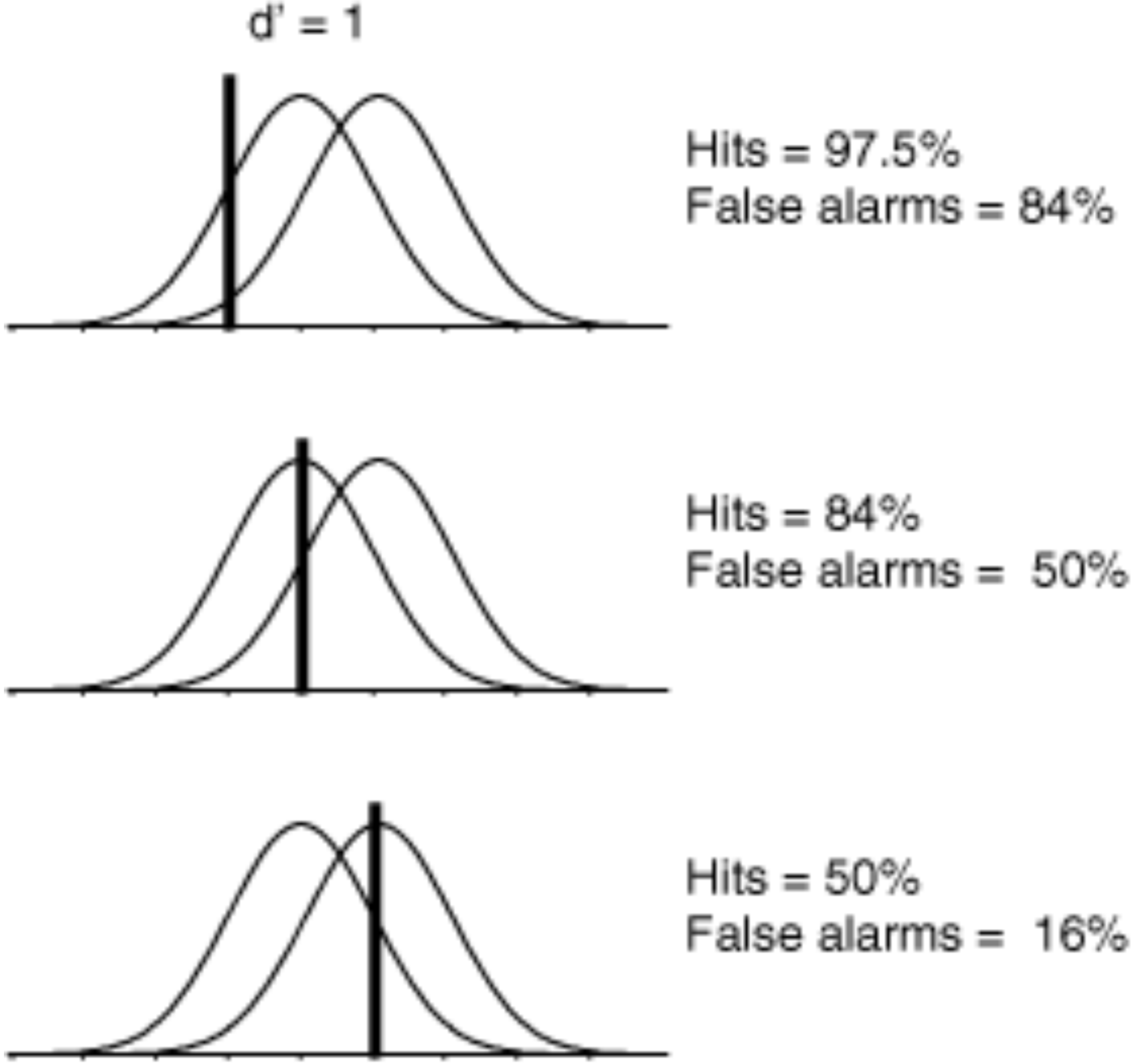
the role of the criterion

- The internal response and its pdf are determined by internal and external noise.
- Signal Detection Theory models the clinician's strategy as a criterion.
- Whenever the internal response is higher than the criterion then the clinician says "tumor present" and whenever the response is below the criterion then the clinician says "tumor absent".



criterion response
Probability
miss
hit
internal response
correct reject
Probability
false alarm
Internal response

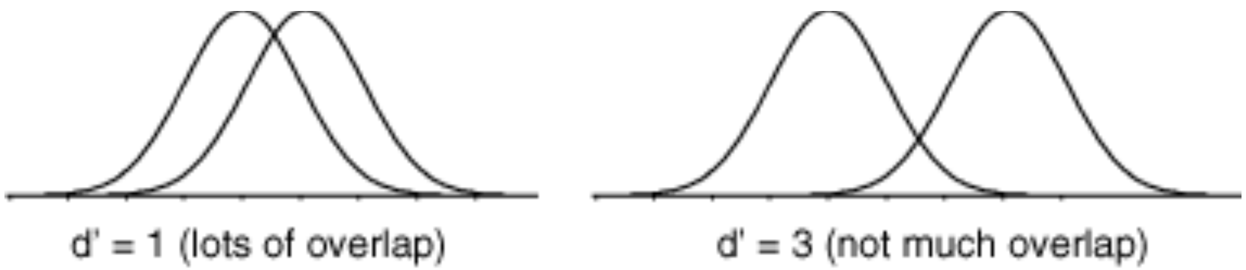
the effect of shifting the criterion



- There is a clear cost to increasing the number of hits. More false alarms might mean more unnecessary stress and unnecessary surgery.
- On the other hand, reducing false alarms, also reduces the number of hits.
- It is impossible for the doctor to set a criterion that achieves only hits. In other words, it is inevitable that some mistakes will be made. Diagnosis errors cannot be avoided.
- However, errors are systematic and, with signal detection theory can be understood and their rate predicted.
- Also, their costs can be minimized if training and experience is used to set an optimal criterion.
- And, design of technology can decrease external noise, and increase discriminability, giving higher hit rates for any given level of false alarm.

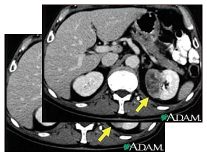
discrimination d’

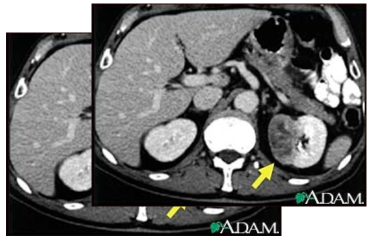
- one way to think of discrimination is as a measure of how easily hits and false alarms can be separated.
- d’ = separation / spread



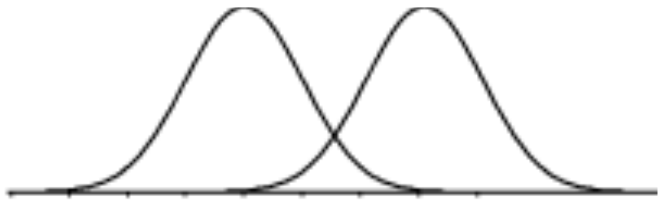
the effect of good design

- the effect of good design is to increase discrimination.
- bad design reduces discrimination.





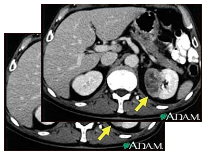
d' = 1 (lots of overlap)

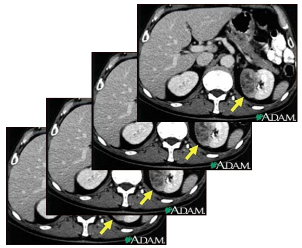


d' = 3 (not much overlap)

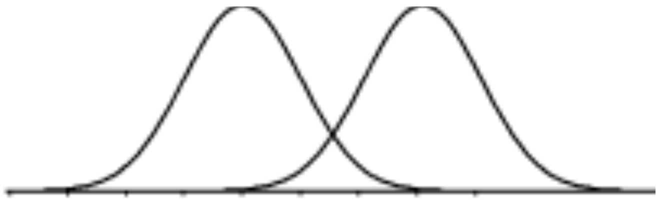
the effect of more information

- the effect of more information can also be to increase discrimination.
- though there are limits.

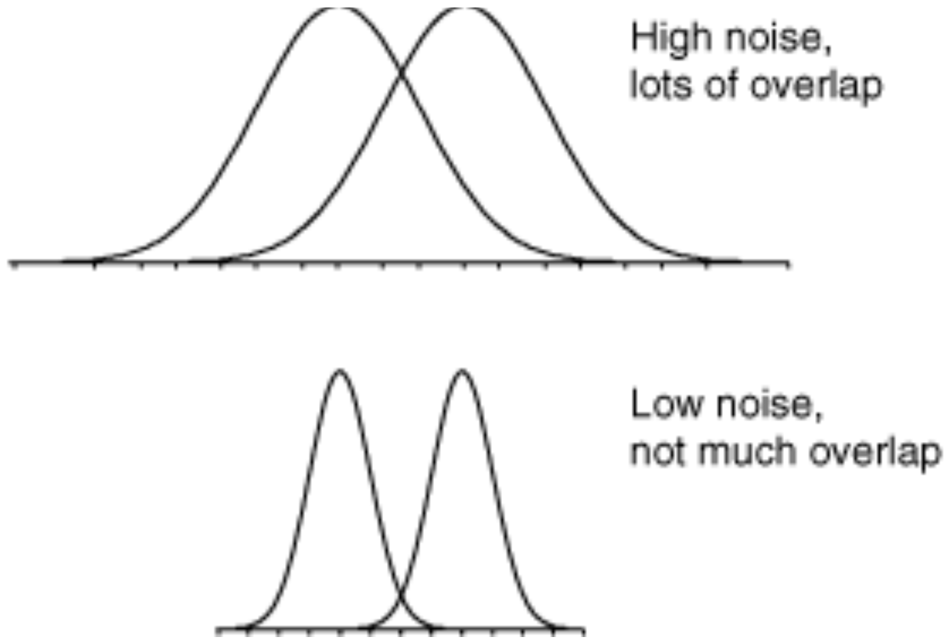


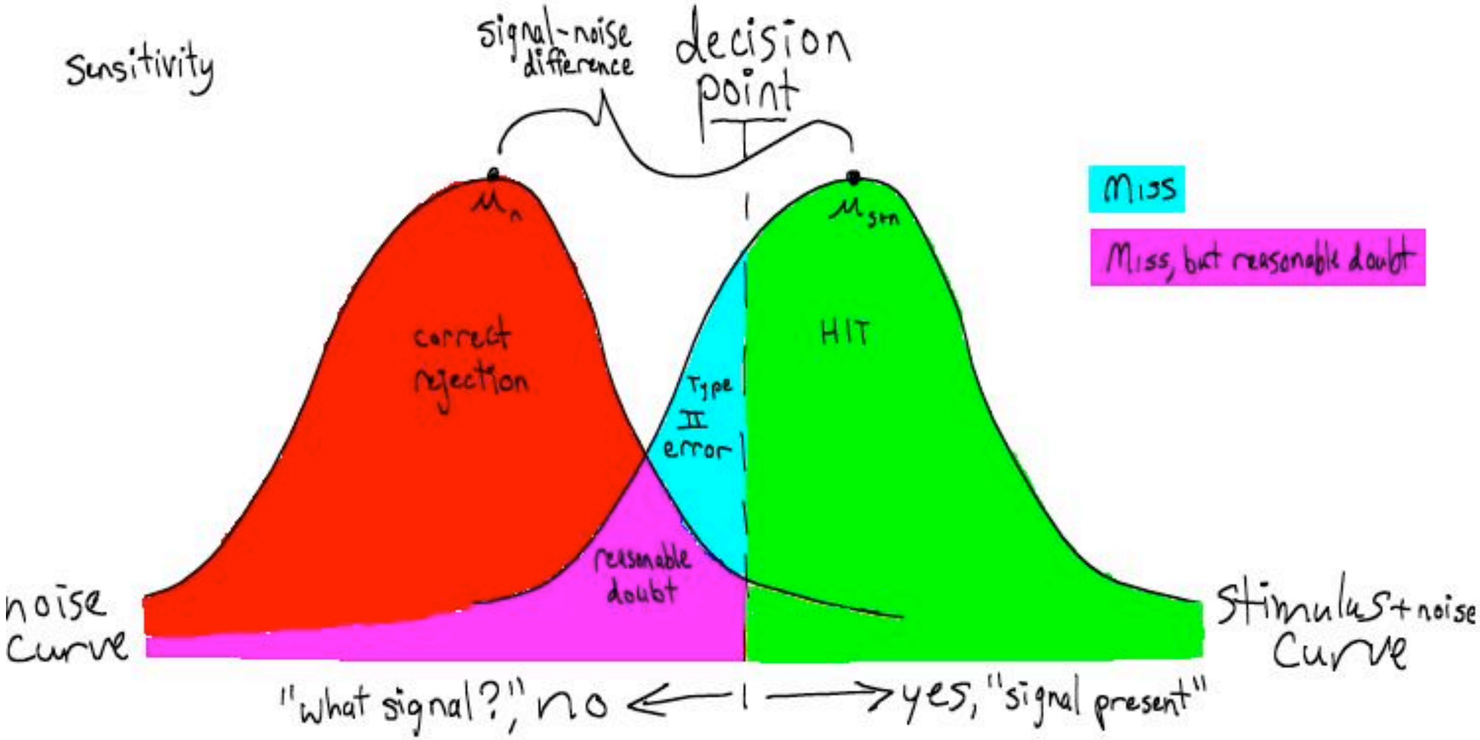


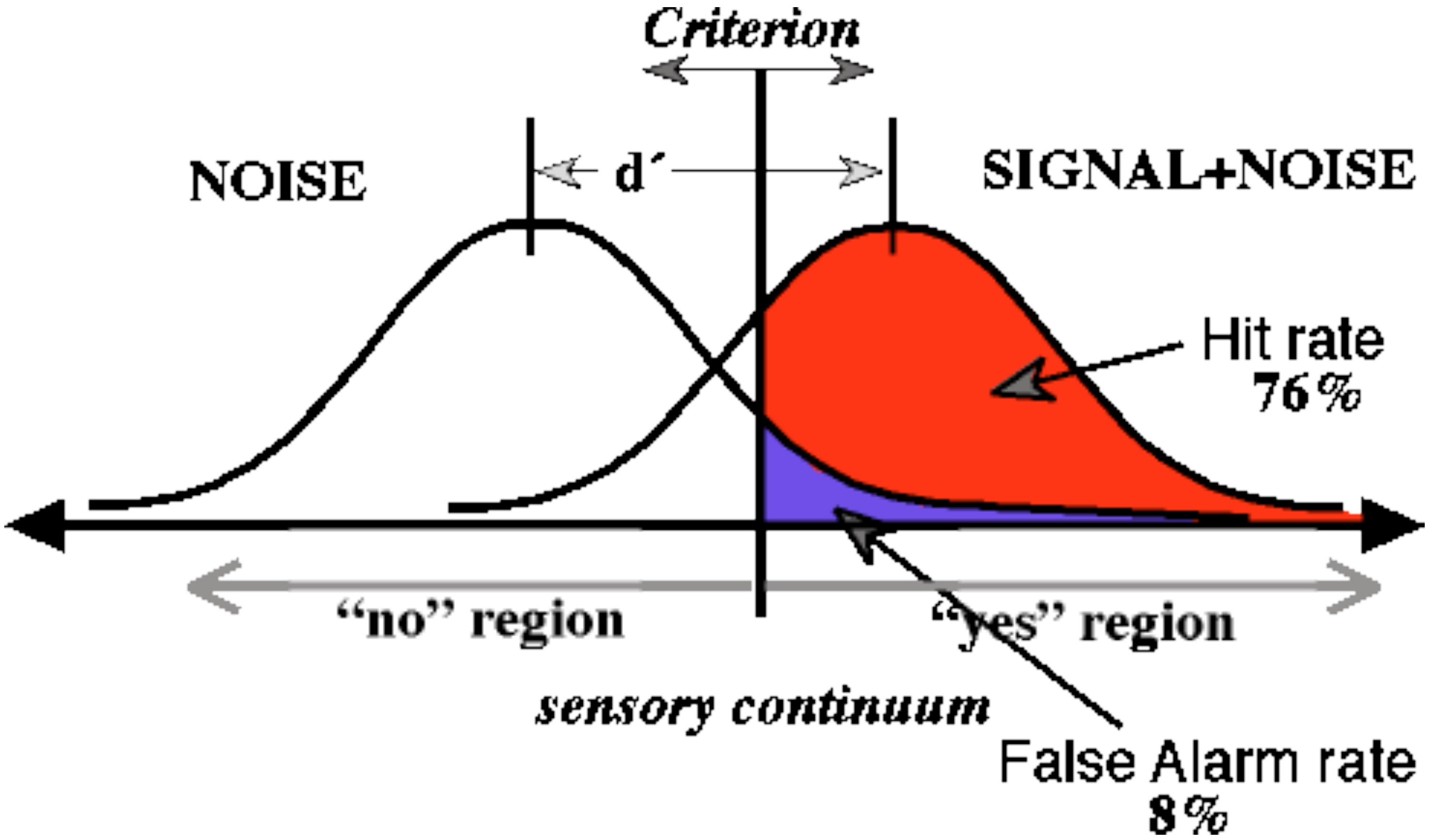
d' = 1 (lots of overlap)



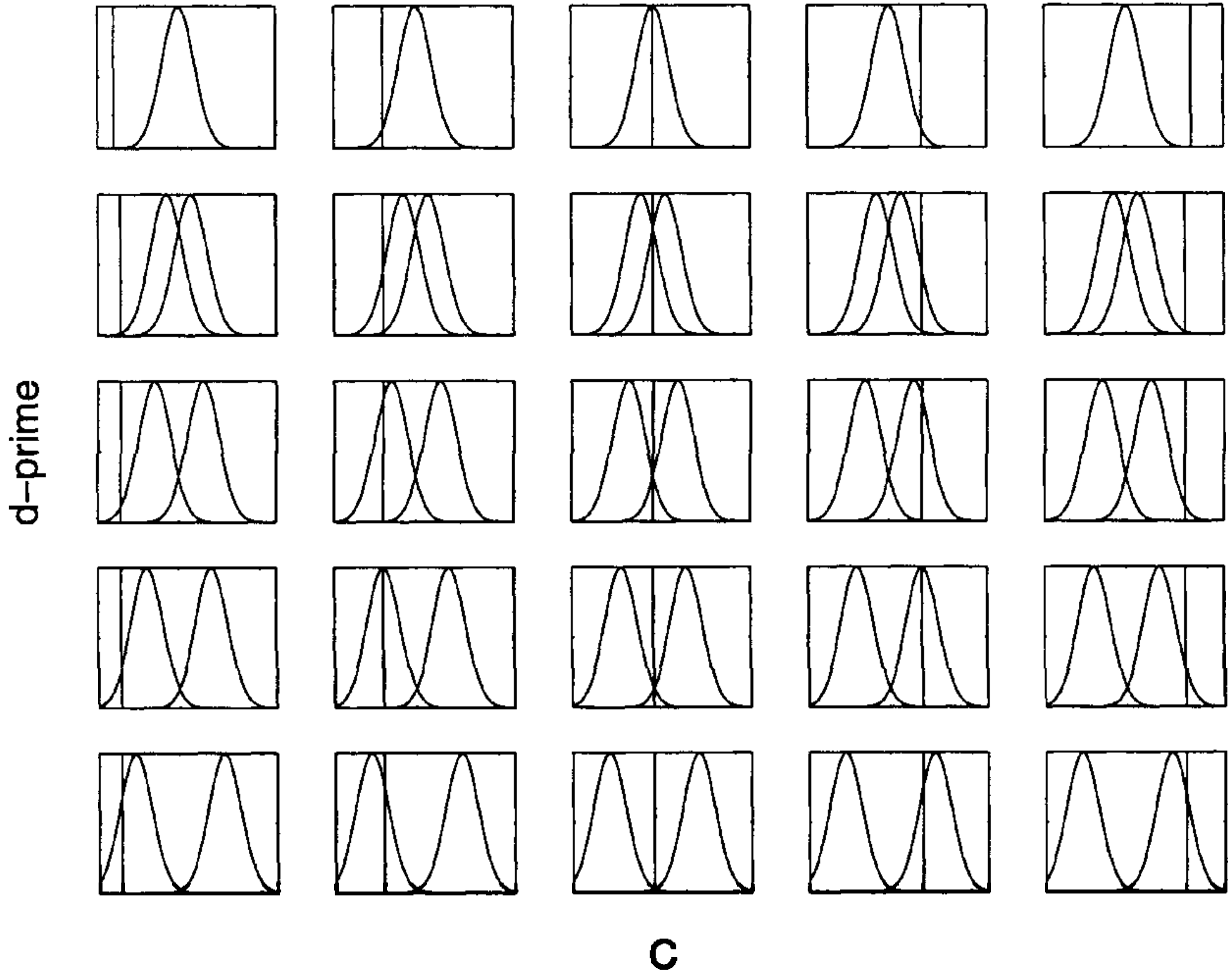
d' = 3 (not much overlap)


High noise,
lots of overlap
Low noise,
not much overlap


Sensitivity
signal-noise difference
decision point
μ_n
μ_{s+n}
Miss
Miss, but reasonable doubt
correct rejection
HIT
Type II error
reasonable doubt
noise curve
Stimulus + noise Curve
"what signal?", no
yes, "signal present"



Criterion
NOISE
d′
SIGNAL+NOISE
Hit rate
76%
"no" region
"yes" region
sensory continuum
False Alarm rate
8%



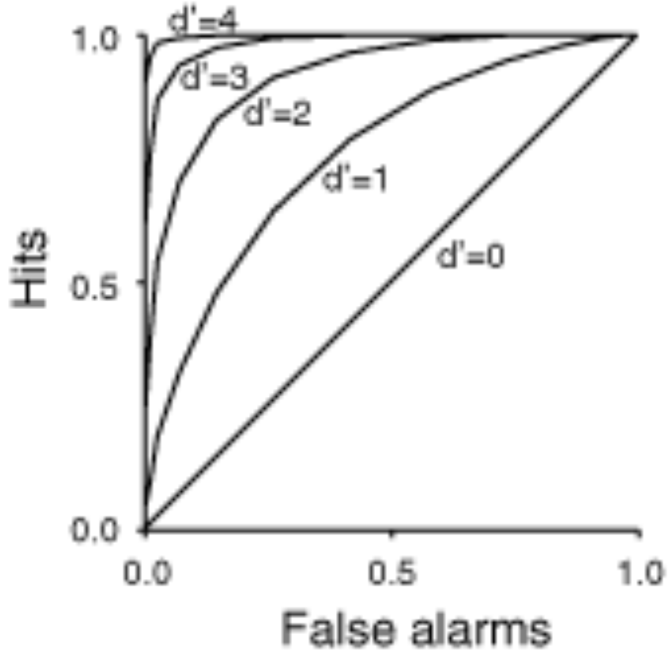
As Criterion increases there are fewer false alarms and fewer hits. As d-prime increases more hits can be achieved with fewer false alarms.
From O'Toole, Bartlett, Abdi, 2000

the normal distribution

- these probability density functions have a typical shape: They are normal or Gaussian.

the receiver operating characteristic

- the ROC graph is a plot with the false alarm rate on the horizontal axis and the hit rate of on the vertical axis.
- Each line plotted on the ROC curve is for a different d'.
- Given a d'=1, say, the clinician can pick a criterion anywhere along the plotted curve.
- Good design increases the value of d' until with d'=4, iit is possible to find a criterion (strategy) with the highest hit rate and lowest false alarm rate.



ROC curves

practical exercise

- Download the following paper and use it, and other papers, to help answer the following questions. Blog your answers and comment on the answers provided by others.
  - Sorkin, R.D. & Woods, D.D. (1985). Systems with human monitors: a signal detection analysis. Human-Computer Interaction, 1, 49-75.
- How can Signal Detection Theory help interface designers of systems that aim to automate some aspect of human decision making?
  - What is signal detection theory?
  - What is automation?
  - What does automation do to the human task?
  - How should a pilot set their criterion for responding to a stall warning system? How should the stall warning system's criterion be set?
  - What strategies are available to a decision maker using Signal Detection Theory?
  - What bounds are imposed by neural information system?
  - What form might a utility function take for using Signal Detection Theory?

references

- http://www.cns.nyu.edu/~david/handouts/sdt/sdt.html
- http://www.cs.bham.ac.uk/~howesa/Advanced-HCI-overheads3.key.pdf