Psychophysics

- Tries to quantify the relationship between a physical stimulus and the psychological perception of it, or how people or animals detect, discriminate, identify, categorize or describe defined stimuli
- purpose: investigating the processes underlying perception

- Usually the experimenter starts from:
  - a physical stimulus (*stimulus domain*)
  - response made by the subject to whom it is presented
- The stimulus is varied along different dimensions, for example:
  - light → wavelength/size/shape
  - sound → frequency/intensity/duration
- Response may be (*task domain*):
  - a verbal response, like “yes”/”no” “I see it”/”I did not see it”
  - a mechanical response, such as pressing two different buttons corresponding to yes/no, respectively

Thresholds

- Determine how well a subject can detect a stimulus, or the minimal quantity that can be detected (*threshold*)

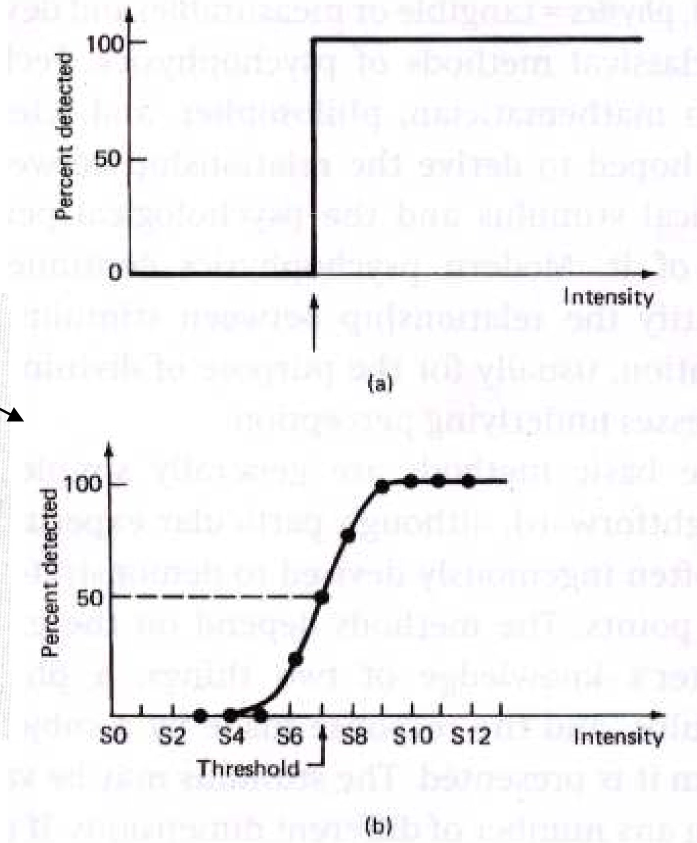
Methods of Limits/Adjustment

- *Method of limits*, start with an undetectable stimulus and increase its intensity until the subject detects it
- *Method of adjustment,* the subject adjusts a variable stimulus until it is detected

ideal case, perfect threshold

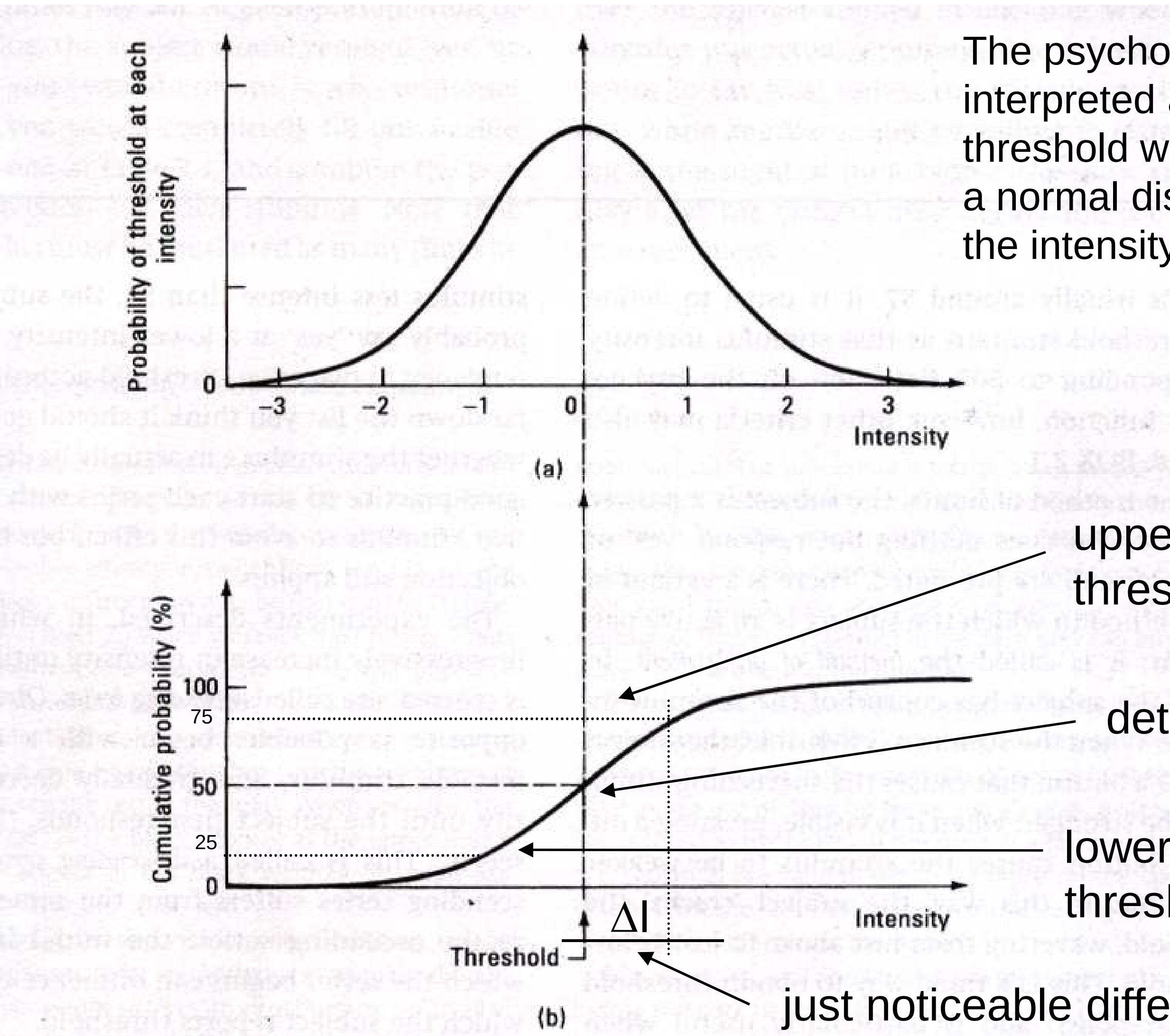
realistic case (due to noise), the response of the subject is not constant across trials

Stimulus	Trial 1	Trial 2	Trial 3	Trial 4	Pecentage Detection
S1	N	N	N	N	0
S2	N	N	N	N	0
S3	N	N	N	N	0
S4	N	N	N	N	0
S5	N	N	N	N	0
S6	Y	N	N	N	25
S7		N	Y	N	50
S8		N		Y	75
S9		Y			100
S10					100
S11					100
S12					100



Psychometric function

The psychometric function can be interpreted as if the value of the threshold was distributed according to a normal distribution, whose peak is at the intensity corresponding to 50%



- Errors can arise from anticipation and habituation if we start from the same stimulus, it is best to change the initial stimulus and average across different trials
- also: mix *ascending series* and *descending series*

Method of Constant Stimuli

- When the stimulus is transient, or we want to avoid anticipation by the subject
- The order of presentation of the stimuli is randomized, each stimulus presented many times
- Results are averaged across trials as seen before

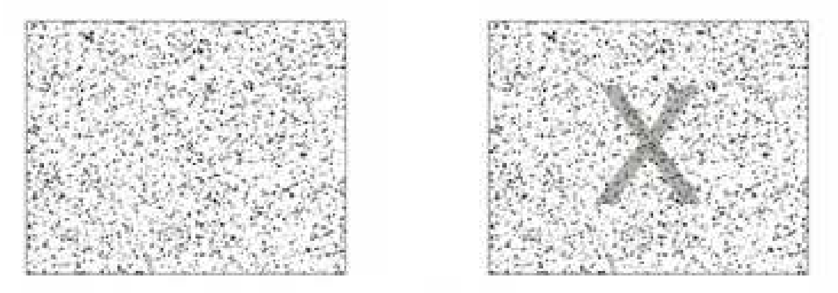
Still problems

- The experimenter has no control on the criterion applied by the subject

- Subjective: different subjects can have different criteria
- Variable behavior: the same subject can change the criteria during the experiment

Forced Choice

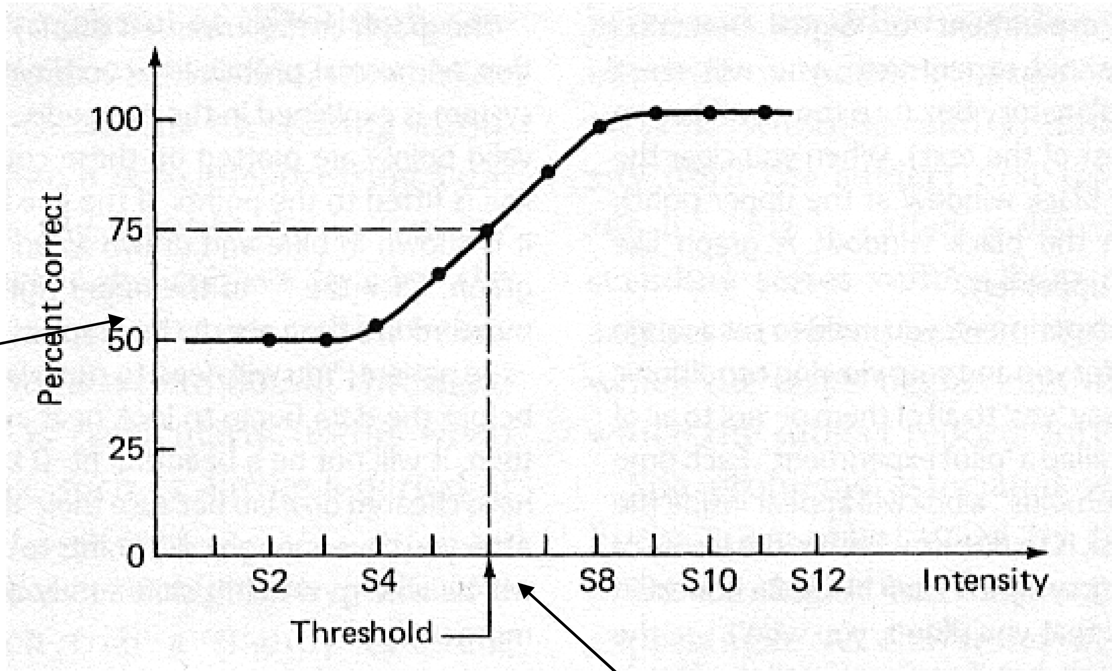
- The subject is presented two o more alternatives and must pick one (even if she thinks she did not see the stimulus)
- For example, the subject might appear in two windows, and the subject must decide where the stimulus is present
- If the subject does not see the stimulus is forced to guess



A B

Psychometric function for the Forced Choice method

More difficult to estimate the threshold, the minimum in this case is 50%, because the subject is forced to choose even when the stimulus is not detected (and roughly 50% of the times will be lucky)



usually gives lower threshold because the subject has to provide an answer (in the other methods the subject can say “no” if unsure)

- We reduce this value by increasing the number of choices so that it is more difficult for the subject to “guess” the correct answer
  - two alternative forced choices (2AFC) 50%
  - 3AFC → 33%
  - 4AFC → 25%
  - ...
- but the more alternatives, the higher the possibilities to confuse the subject (usually 4AFC is optimal)

Differential Sensitivity

- So far we asked if a subject could detect an *absolute* stimulus
- Another question is whether the subject can detect the *difference* between two stimuli (*differential threshold* or *just noticeable difference, jnd*)
- *jnd* is the minimum amount by which stimulus intensity must be changed in order to produce a noticeable variation in sensory experience:

$$I_0 \quad \text{standard stimulus}$$

$$I_c \quad \text{current stimulus}$$

$$jnd = \Delta I = I_c - I_0$$

- it can be determined by using any of the methods we described (replace ΔI for I)
- We get a different psychometric function for any given I_0

Weber's law

- The relationship between ΔI and I_0 is not linear
- It was found that the increment in stimulation required for a *jnd* is proportional to the size of the standard stimulation, or:

$$\Delta I = k \cdot I_0, \qquad k < 1$$

Fechner's law

- Magnitude of Sensation, given a stimulus, how large does it "seem" to be?
- F's law: variation of sensation can be written as:

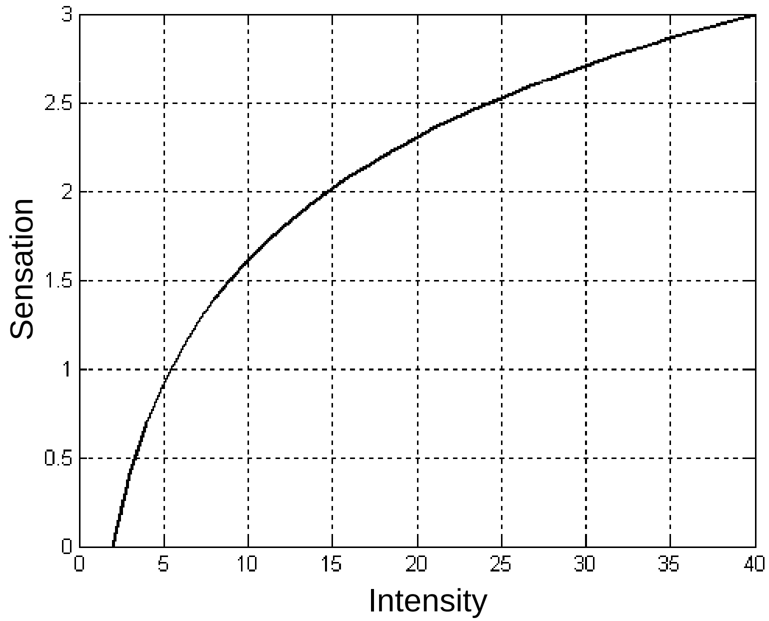
$$\Delta S = k \cdot \frac{\Delta I}{I}$$

$$S = \int k \frac{\Delta I}{I} = k \ln I + C$$

S=0 when $I=I_0$ (threshold stimulus)

$$C = -k \ln I_0$$

$$\Rightarrow S = k \ln \frac{I}{I_0}$$



Static Invariances

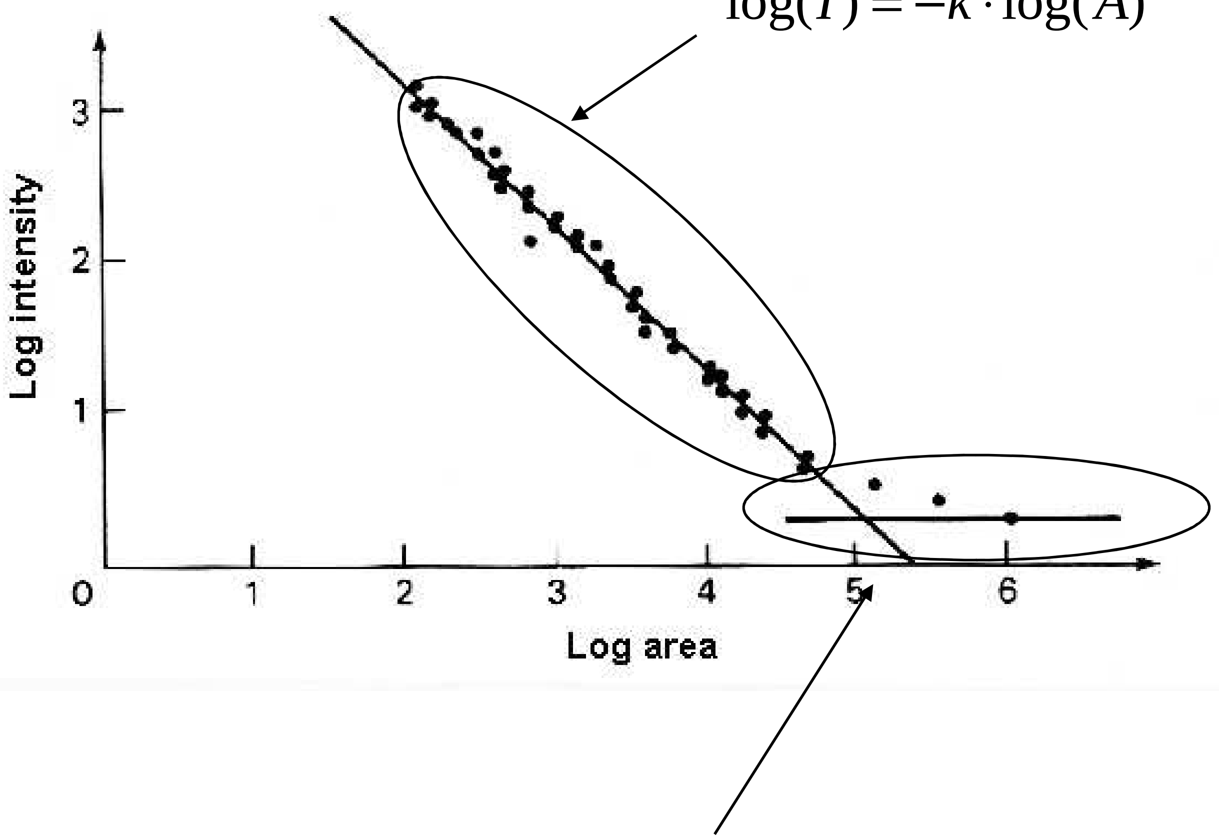
- How stimulus parameters can be changed so that two different stimuli can be judged the same
- Two classes:
  1. judgment of intensity
  2. quality

Example: Ricco's law

- Circular spot of light of a given wavelength
  total energy depends on:
  - intensity of the light (per unit area)
  - area of the stimulus
  - duration of the stimulus

Keep the duration constant. Energy depends on the product between intensity and area. Change area and ask the subject when the stimulus is perceived, we test in this case the threshold.

For small spots, the radiance required is inversely proportional to the area (*Ricco's law*), in other words if we double the area of the spot, the radiance required for the stimulus to be perceived is halved.



when the area becomes too large, additional area does not give additional advantage for detection (Ricco's area)

- Similar considerations apply if we vary the *duration* of the stimulus (Bloch’s law)

Signal Detection Theory

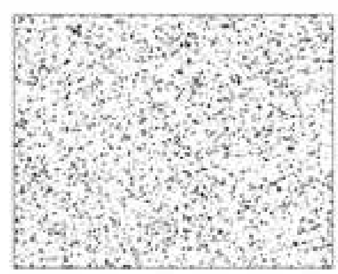
- How signals are detected within noise
- Method to measure detection performance

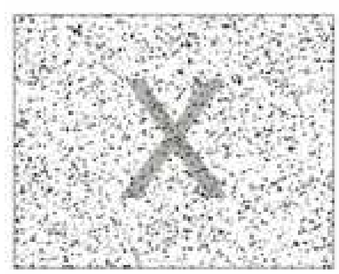
Applications:

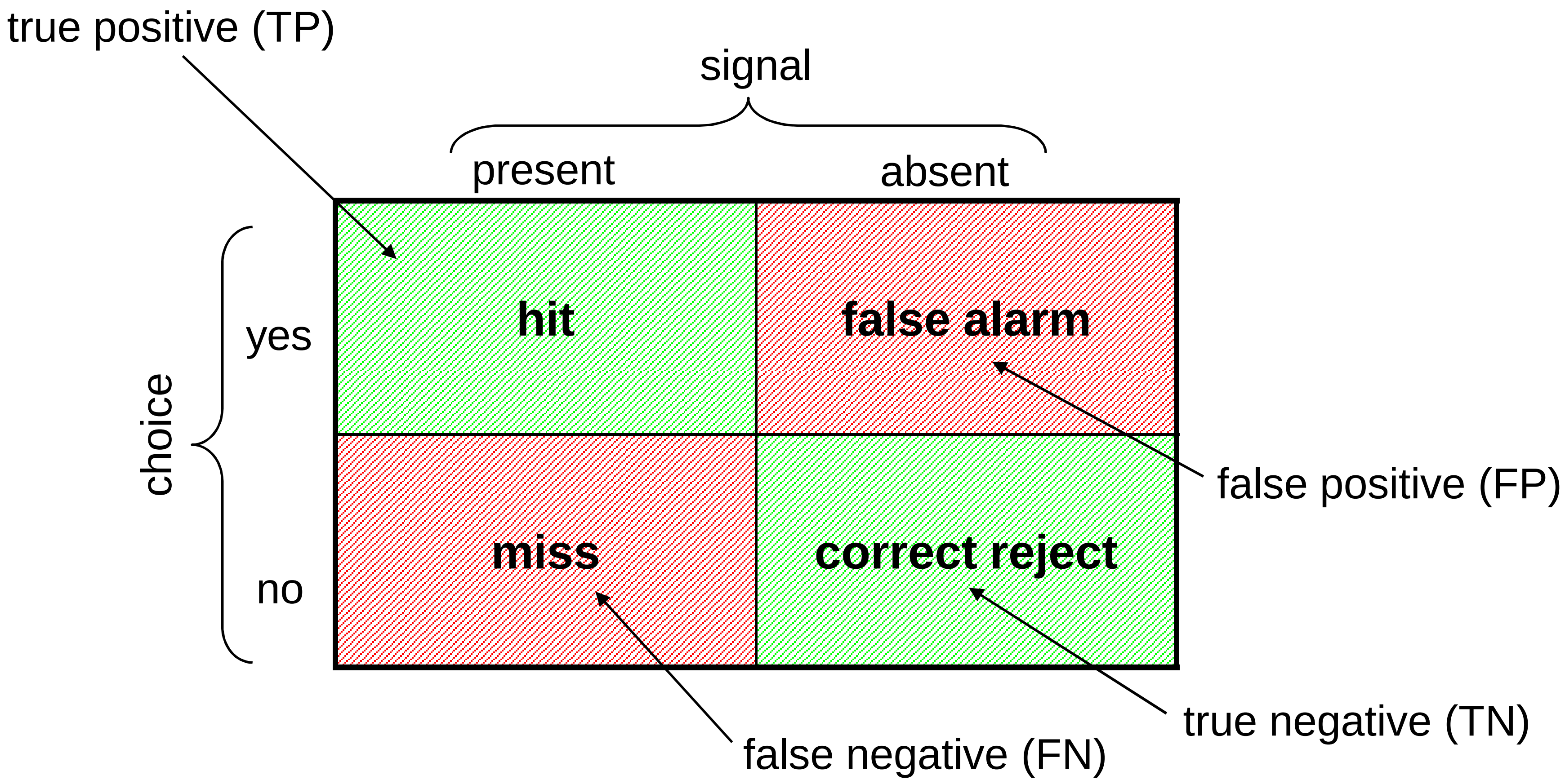
- Comparison of recognition algorithms in computer vision
- Detection and recognition experiments in psychophysics
- Detection systems (medical applications)

Examples

- Problem:
  Decisions depend on:
  - threshold
  - decision costs/benefits
  - prior probabilities



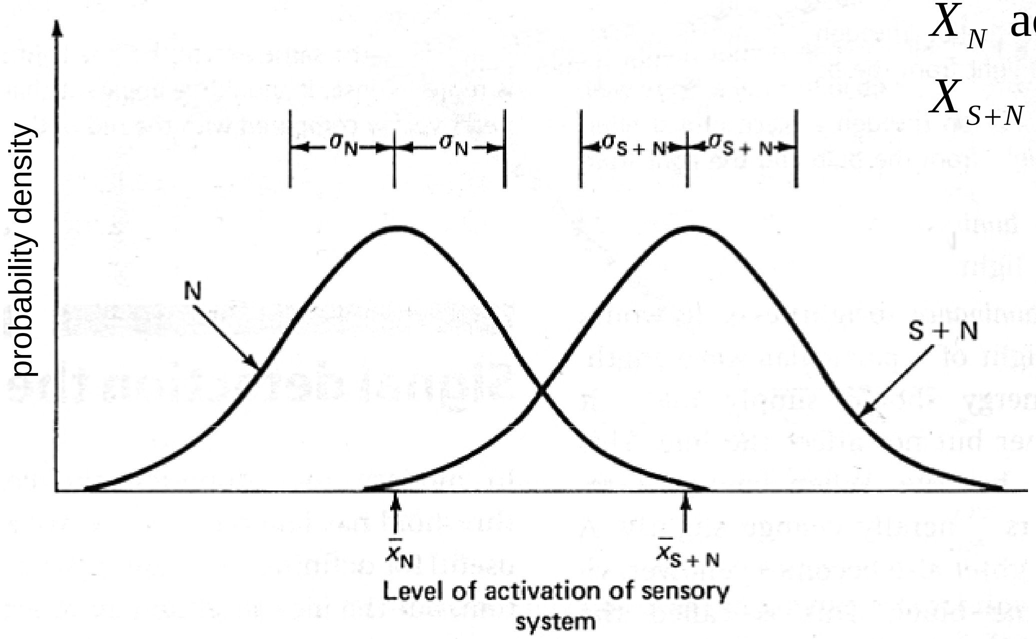


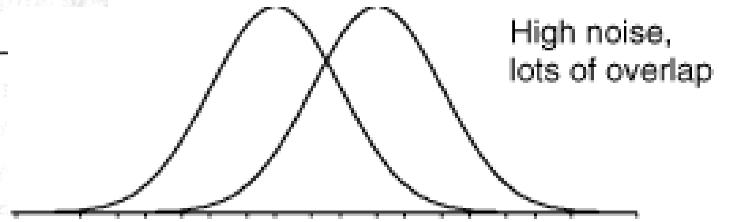

true positive (TP)
signal
present
absent
choice
yes
no
hit
false alarm
miss
correct reject
false positive (FP)
true negative (TN)
false negative (FN)

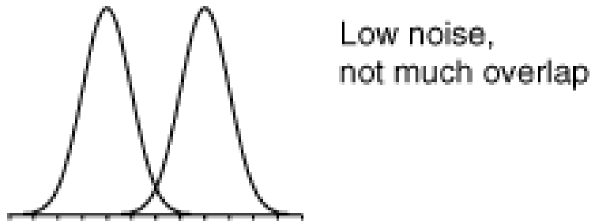
Model

X_N activation without signal (just noise)

X_{S+N} activation with signal (and noise)





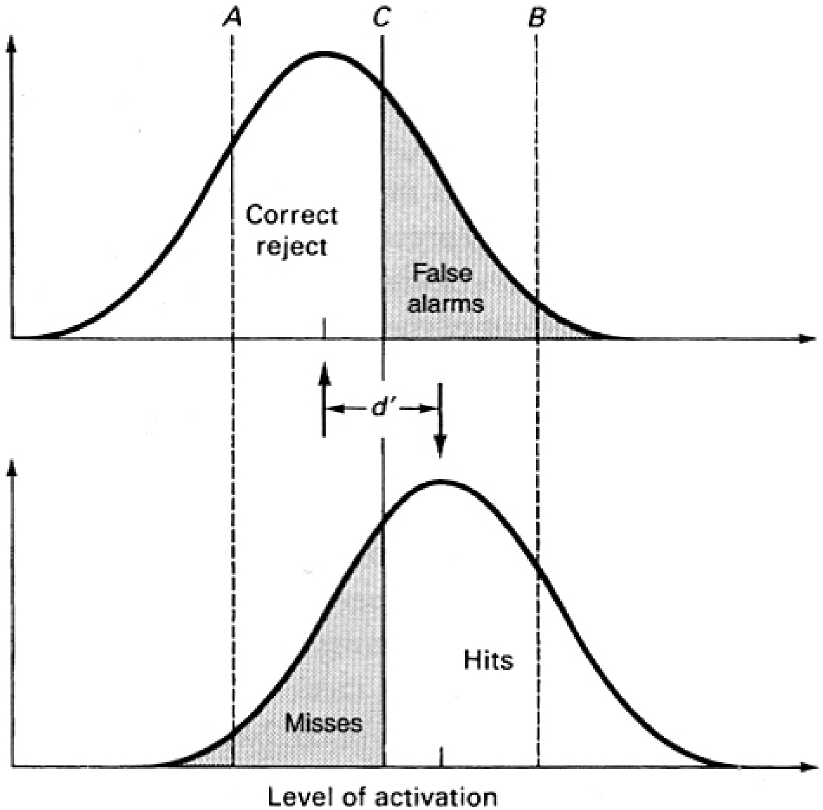


Discriminability index:

d' = distance/std

depends on the strength of the simulus and the level of the noise

Decision criteria



Threshold A:

- -large p(hits)
- -small p(misses)

but

- -small p(correct reject)
- -large p(false alarms)

Threshold B:

- -small p(false alarms)
- -large p(correct reject)

but

- -small p(hits)
- -large p(misses)

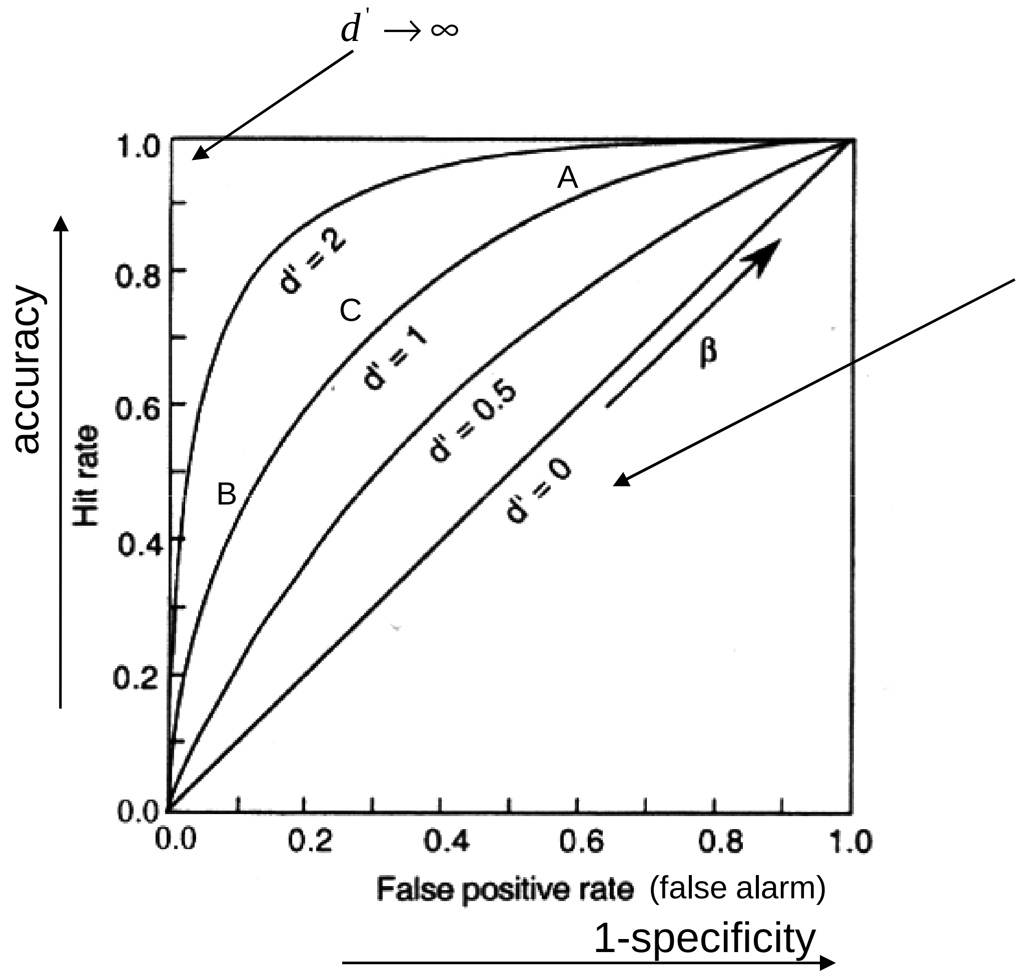
$$\text{hit rate} = \frac{\#\text{hits}}{\#\text{positives}}$$

number of times the signal was present

$$\text{false alarm rate} = \frac{\#\text{false alarms}}{\#\text{negatives}}$$

number of times the signal was absent

Receiver Operator Curve (ROC)



the area under the roc measure the detection performance, or the ability to classify correctly the stimulus:

>0.8 = good
0.6-0.8 = fair
<0.6 = fail

we can change the subject criterion by assigning penalties to false alarms and/or rewards to correct hits

How to compute d'

d' = distance/std
if std=1, *d'*=distance

1-p(FA) → Zn=2.05
1-p(HIT) → Zsn=0.39
d'=Zn-Zsn=1.66