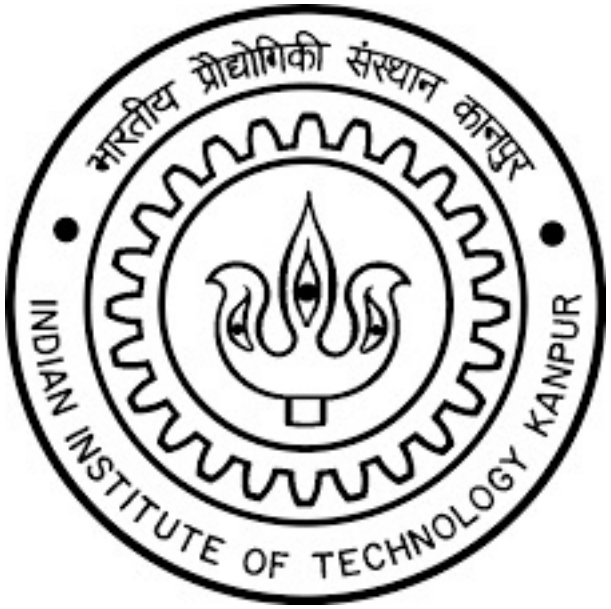

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Presents

Course Title:

Basic Cognitive Processes

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Lecture 15: Signal Detection Theory

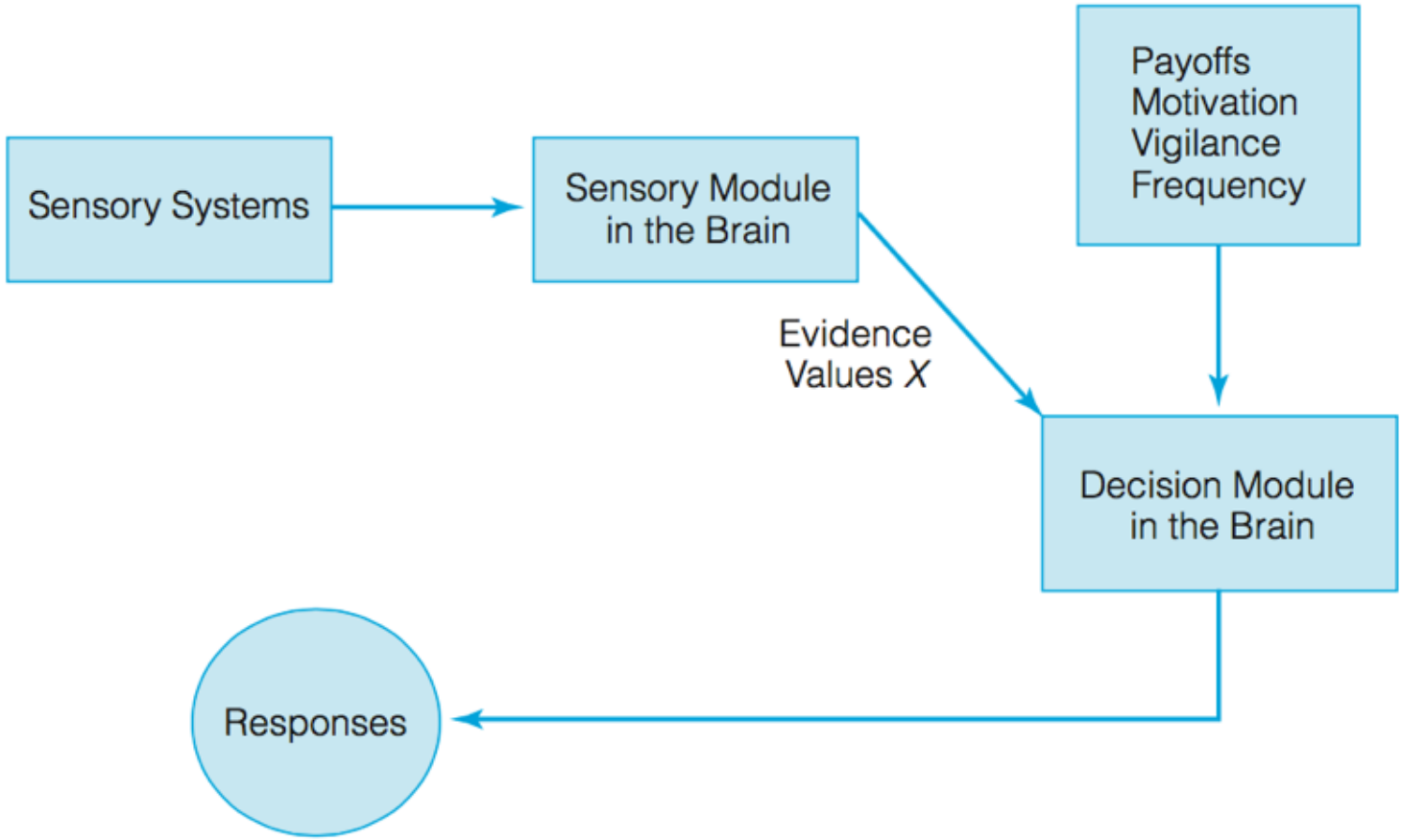
Signal Detection Theory

- What if we do not need to determine threshold?
  - according to the **theory of signal detection**, our perception in general is controlled by evidence & decision processes.

- a signal or stimulus creates (hypothetical) evidence that depends on the intensity of the signal and the acuity of the observer, which partly determines a “yes” response.

- there could also be other factors, that influence the willingness of an observer to say “yes”.

- these response - bias influences include the payoff for being accurate, the frequency of the signal & so on.



▼ FIGURE 6.3

A Theoretical Look at What Happens in Signal Detection. Sensory analysis sends evidence values (*X*) to the decision module. The values of *X* are a function of signal strength and the acuity of the observer. The payoffs, motivation, and attention processes send response bias information to the decision module. Together, the sensory and bias components determine the response of the observer. The *X* evidence values are on the abscissa of Figures 6.4 and 6.5. The payoffs and so on determine the position of the criterion.

- examples: imagine your friend has set up a blind date for you. The costs (a wasted evening) are probably less than the possible benefits (an exciting evening now & many in future).

- in such scenarios, where the (perceived) costs are less than the (perceived) benefits, a highly likely response is a "yes" response.

- the decision would be based on costs & benefits, since information about the stimulus is lacking.

- however, if the decision has high costs (accepting or offering a marriage proposal).

- people would be very careful/conservative.

- in terms of decision theory, most of us are conservative decision makers when costs are higher relative to benefits (costs of an unsatisfactory marriage vs. cost of a bad date).

- the sensory process transmits a value to the decision process.

- if the value is high, the decision process is more likely to yield a “yes” response, once costs & benefits are considered.

- if the value is low, the decision process is more likely to yield a “no” response, once again taking into account costs & benefits.

- What determines the quality of the signal?
  - signal detection theory assumes that **noise,** a disturbance that can be confused with signals, is always present when a human attempts to detect signals.
  - e.g. environmental changes, equipment changes, spontaneous neural activity, & direct experimental manipulations.

- An Experiment
  - Imagine sitting in a soundproof booth, wearing headphones.
  - On each of several hundreds of trials, you must decide whether you heard a faint tone combined with white noise or only white noise itself.

- a trial might begin by the presentation of a flashing light, to get you ready.
- then you hear a burst of white noise, which may or may not contain the faint tone signal.
- you say “yes” if you think a tone signal was present & “no” if you think it was not.

- Signal detection theory assumes that any stimulus, even noise, produces distribution of evidence.

- the evidence on each trial is only one point & the distributions are built up from many trials, each occurring at a different point in time.

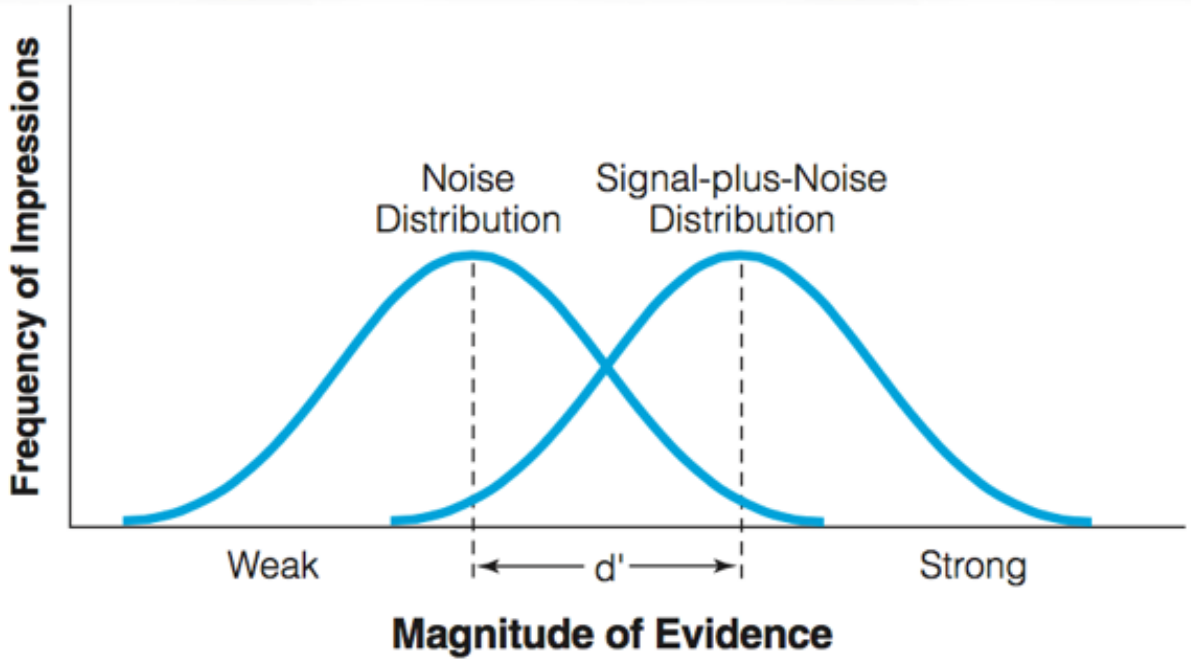
- since evidence cannot be directly observed, the distributions for stimulus trials & noise trials are hypothetical.

- the evidence for the trial for which noise only occurred will tend to be small, so that over many trials, a hypothetical distribution with a small mean will be established.

- when a signal plus noise is presented, the evidence will be larger & a greater mean will be formed over many trials.

- so, two distributions will be generated: one for noise only & one for the signal plus noise.

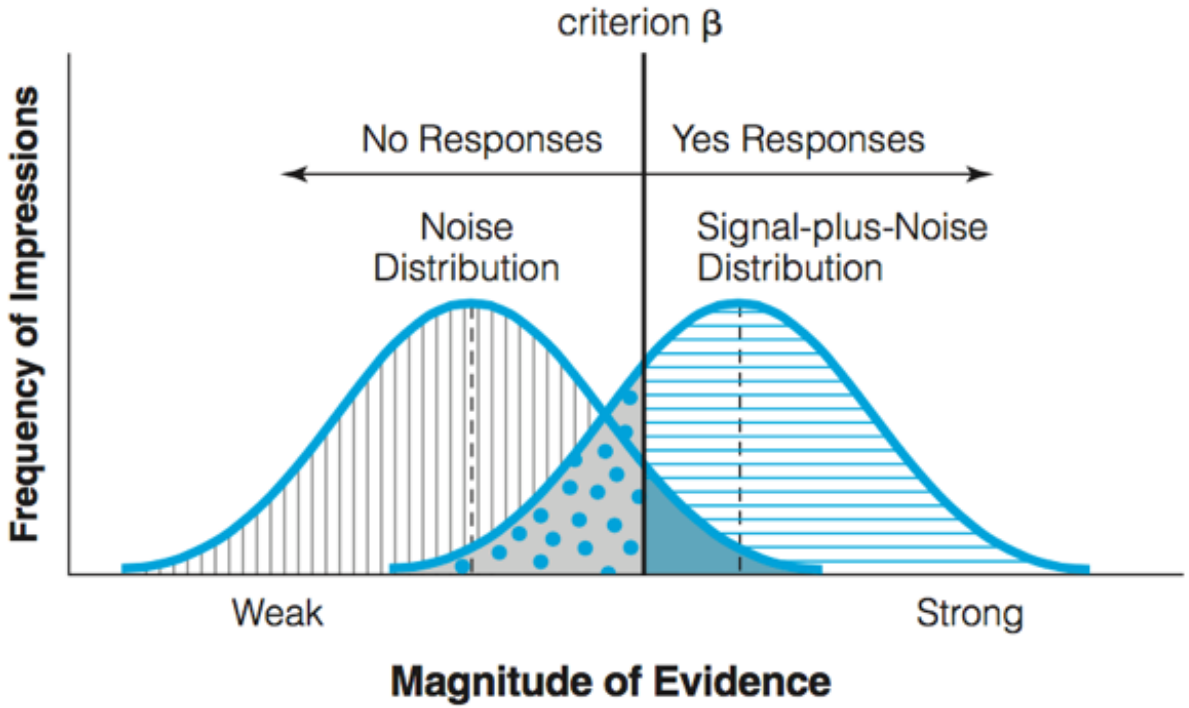
- since the two distributions will overlap in the middle, some values of evidence are ambiguous.



▼ FIGURE 6.4

Hypothetical Distributions of the Evidence Resulting from Noise and Signal Plus Noise. The frequency of the impressions is the *Y*-axis and the magnitude of evidence is the *X*-axis. The strength of the signal and the sensory acuity of the observer determine the amount of overlap of the two distributions. A stronger signal or a more sensitive observer would move the signal-plus-noise distribution to the right (toward the strong end of the *X*-axis). The dashed vertical lines are the mean (average) of each distribution, and the distance between the two means is called d'.

- a criterion therefore, must be set to determine whether a response will be “yes” or “no”.
- the position for this criterion is set by the decision process.
- if costs & benefits favor a liberal decision policy, the criterion will be set far to the left, so that most responses will be “yes”.
- if a conservative decision policy is used, the criterion moves to the right, so that most responses will be “no”.



▼ FIGURE 6.5

Hypothetical Distributions of "Yes" or "No" Responses as a Function of the Criterion and the Magnitude of the Evidence. The decision criterion (β) determines whether a "yes" or "no" response will be made. Strong evidence to the right of the criterion will lead to "yes" responses, and weak evidence to the left will lead to "no" responses. Correct detection of the signal ("yes" responses in the horizontally striped area) are called hits. Correct "no"responses when noise occurs (the vertically striped portion) are called correct rejections. Misses occur when a "no" response occurs to weak signals to the left of the criterion (the dotted portion of the signal-plus-noise distribution). False alarms are incorrect "yes" responses to noise that is to the right of the criterion (the black portion of the noise distribution).

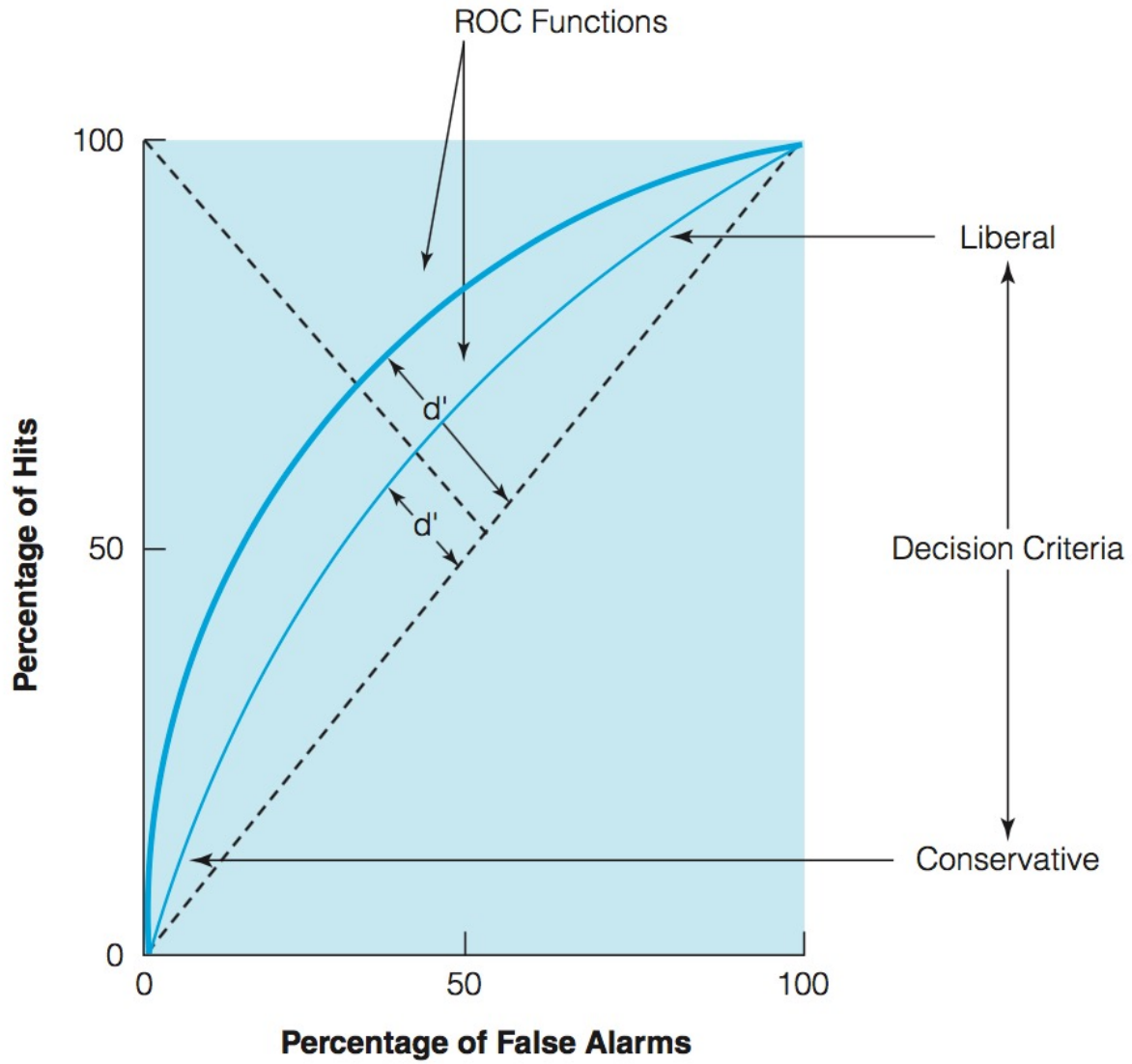
- either way, some errors of judgment are bound to happen.
- correctly detecting a signal when it is present is called a **hit**.
- incorrectly responding “yes”, when only noise is present is called a **false alarm.**
- With a liberal decision strategy there will be high number of hits & false alarms.
- With a conservative decision strategy there will be low number of hits & false alarms.

- If we plot hits as a function of false alarms, as the criterion moves from conservative to liberal, we get the following figure.

- This is the ***receiver – operating characteristic (ROC)*** function.

  - Both hits & false alarms are infrequent (conservative criterion) at the lower left of the curve.

  - As the criterion gets more liberal, both hits & false alarms get more frequent & the ROC curve moves upward to the right.



▼ **FIGURE 6.6**

ROC Functions. The distance from the diagonal to the center of the curve is proportional to d'. The diagonal represents chance performance, with the observer guessing about the presence or absence of a signal. Thus, the percentage of hits equals the percentage of false alarms along this "guessing" diagonal. The heavy ROC function is farther away from the diagonal than is the lighter ROC function, which means that d' is greater for the heavy curve than for the light one. A larger d' can result from a stronger signal or a more acute observer.

- The slope of the ROC function tells us the crietrion.:
  - The flat slopes reveal a liberal decision criterion (generally, the upper right curve) &
  - The steep slopes reveal a conservative criterion (usually, the lower left of the curve).
- The slope of curves such as the ROC function is determined by the slope of a line that is drawn tangent to a particular point on the function and intersects one of the axes of the graph.

- The distance from the diagnoal to the ROC curve tells us how far apart the noise & signal – plus – noise distributions of Fig 6.4 lie.
    - When two distributions are far apart, indicating either a more discernible signal or a more acute observer, the ROC curve moves upward to the left, away from the diagonal, as shown by the heavy ROC function.
    - When the signal is less detectable or when the observer is less acute and the two distributions are close together, the ROC curve moves closer to the diagonal.
- Thus, the ROC function tells us about both the sensory processes (d', i.e. distance between signal plus noise & noise only distributions) and the decision process (β, the slope).

- ***Advantage of Signal Detection Methods***

  - a major advantage of signal – detection methods over a classical psychophysical procedure, such as the method of limits, is the ability to measure both sensitivity and response bias.

    - In many areas of applied psychology, the ability to distinguish between these two processes is very important.

  - Let us take an example: To determine how analgesics work, Clark and colleagues (Clark, 1969; Clark & Yang, 1974) conducted a number of experiments on pain analgesia.

- They decided to use a signal – detection procedure instead of a classical psychophysics one; so that both changes in sensitivity & decision processes could be assessed.

- In these experiments a dolorimeter was used to evoke pain by means of thermal stimulation.

- Initially, Clark found that analgesics such as aspirin reduced d', which means that the drug lowered the acuity of the sensory system with the outcome being that the aspirin reduced the ability of the people to distinguish between painful & non – painful stimuli.

- He, then went onto investigate whether placebos & accupuncture altered d' or whether placebos and accupuncture changed the willingness of the subjects to report pain.

- In both experiments, Clark found that placebos & accupuncture & placebos elevated the subject's decision crietrion, so that stronger stimuli than before were required to elicit a detection response.

  - This does not mean that placebos & accupuncture do not work, rather they change the decision threshold for reporting the pain that has been experienced.

- Drawing from the work done earlier by Hardy & colleagues (1952); it was found using method of limits that suggestion altered absolute threshold.

- Given, the signal – detection results found by Clark, it is reasonable to suppose that suggestion changed the absolute threshold by altering the decision criterion of subjects.

- The same could be true for few other occurrences like, "Why do naive observers have a lower pain threshold?".

- We could not have determined the cause of the same without using a signal – detection analysis/procedure.

To Sum Up

- Signal detection measures are a departure from the classical psychophysical methods as they take into account both the sensitivity of the observer, the evidence provided by the stimulus & the decision processes.

- They have an advantage over the classical methods because they help us understand the decision process of experiencing & reporting sensations.

References

- Kantowitz, B. H., Roediger, H. L., & Elmes, D. G. (2008) Experimental Psychology. 9th Ed. *Wadsworth Cengage Learning*.