Basics of Signal Detection Theory

SDT predicts potential outcomes on a detection and discrimination task.
Participants must decide whether a given stimulus was present using a yes/no response.
There are four possible outcomes:

- HIT (signal is present, participant says "yes")
- MISS (signal is present, participant says "no")
- CORRECT REJECTION (signal is absent, participant says "no")
- FALSE ALARM (signal is absent, participant says "yes")

The ability to correctly hit or reject the signal depends on a few factors - the strength of the signal, the noise present, and the participant's criterion are the ones we will focus most on for this lesson.

The classic example of SDT is a dim flash of light in the darkness. The flash serves as the signal, and external and internal "noise" accompanies it.

- Externally, the intensity of the light flash will vary.
- Internally, the neural response to the light flash will vary (photons scattered by the lens, for example).

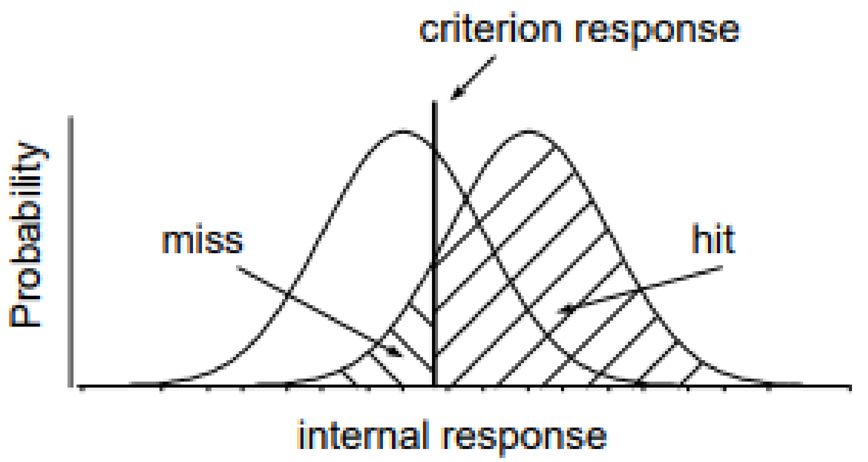
Noise is present even when the signal isn't, so we refer to the two potentials as "Noise" or "Signal + Noise", rather than "signal" or "no signal."

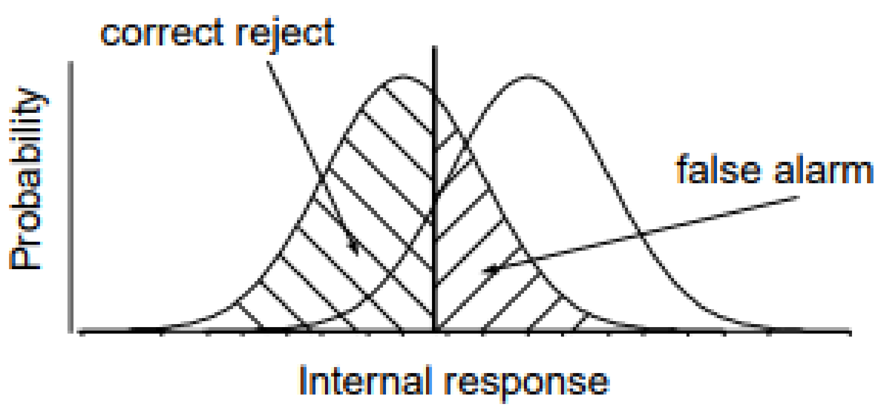
Two main components that influence the decision the participant makes:

- Stimulus strength (how bright the flash is, for example)
- Criterion (a decision making "threshold"). The criterion is determined by several things, like the stakes of a correct or incorrect decision.

When the internal response to the stimulus is greater than this threshold, the participant will respond with a "yes."
The participant makes a HIT in signal + noise trials where the internal response was greater than the criterion, and makes a FALSE ALARM in noise trials where the internal response was greater than the criterion.

A low criterion is more liberal and will result in a higher hit rate, but saying yes to almost everything also means there will be a high rate of false alarms.
Inversely, a high criterion is more conservative, so there will be fewer hits but fewer false alarms as well. The selection of criterion, again, will depend on the participant's perceived value of hits or false alarms.





The vertical line in these graphs represents the criterion. In locations where the signal + noise trial is beyond the criterion threshold, the participant will correctly say "yes" to the signal being present, resulting in a hit (Images CO Heeger, 1997).

d' is the strength of the signal in comparison to the noise, and is represented by the space between noise and noise + signal density curves (the distance between peaks). The skinnier the density curves are, the less "spread" the noise has, and the less the two curves will overlap. This means the signal is more easily detected.

The ROC Curve

ROC (or Receiver Operating Characteristic) curves give us the ability to demonstrate all the potential outcomes for a trial in a single curve. The curve shifts as a participant lowers or raises their criterion. ROC curves are plotted with the false alarm rate on the horizontal axis and the hit rate on the vertical axis.

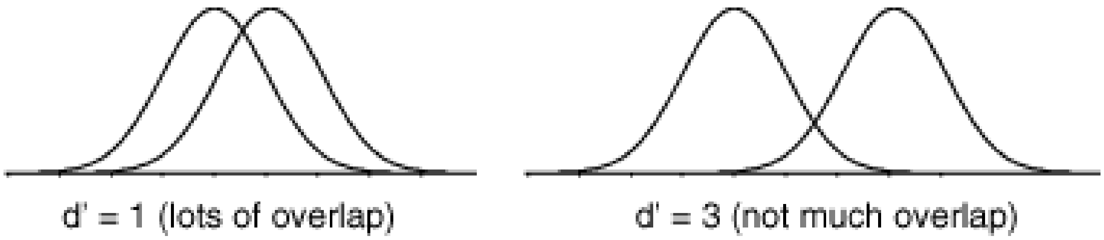
A higher criterion means both the false alarm rate and the hit rate will be low.

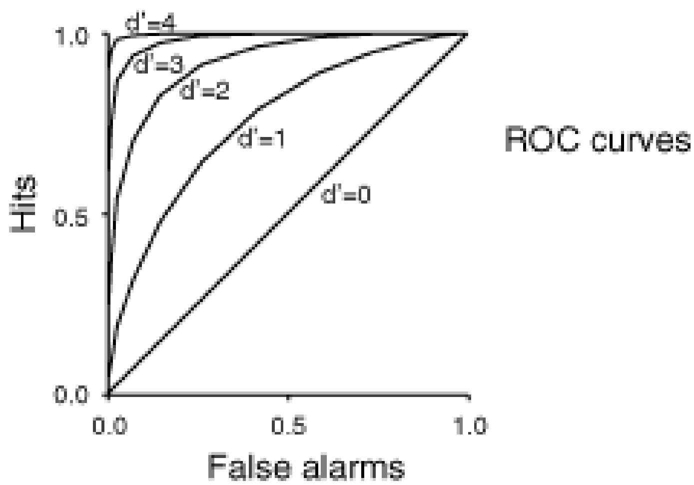
A lower criterions means the hit rate and the false alarm rate both increase.

There is no way to set a criterion that completely eliminates false alarms.

Highly arched ROC curves indicate a strong signal, and flatter curves reflect weaker signal strength. A straight-line, diagonal ROC (from the origin to the northeast) signifies the absence of a signal.

ROC curve tool: http://isle.hanover.edu/Ch02Methods/Ch02SDT_ROC.html





Here (Heeger, 1997) we can see that as d' increases or decreases, the curve bows closer or farther away from the flat diagonal "guessing" line (this means that d' = 0, and there is no discernable difference between noise and signal + noise trials, so the participant has no choice but to guess randomly at a response. This is called a random model).

The criterion set by the participant will fall somewhere on this curve, and that will help us predict the hit rate and false alarm rates! An ideal ROC curve rises toward the upper-left corner of the plot, indicating the participant will normally have a high rate of hits and a low rate of false alarms.

Great handout to reference for an overview of ROC curves and SDT:
Heeger, D. (1997). Signal detection theory. http://www.cns.nyu.edu/~david/handouts/sdt-advanced.pdf