Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Basic Cognitive Processes

Lecture-15
Signal Detection Theory
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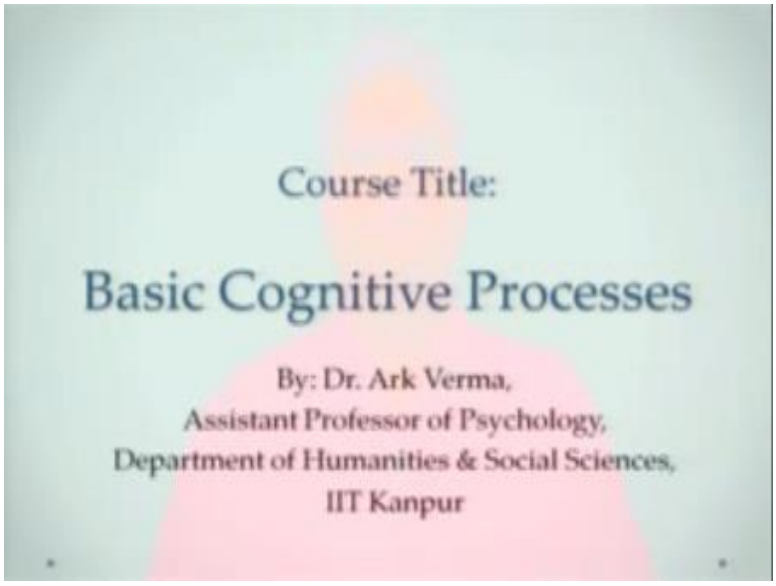

Hello everyone welcome to the lecture series on basic cognitive processes I am Dr. R karma from IIT Kanpur.

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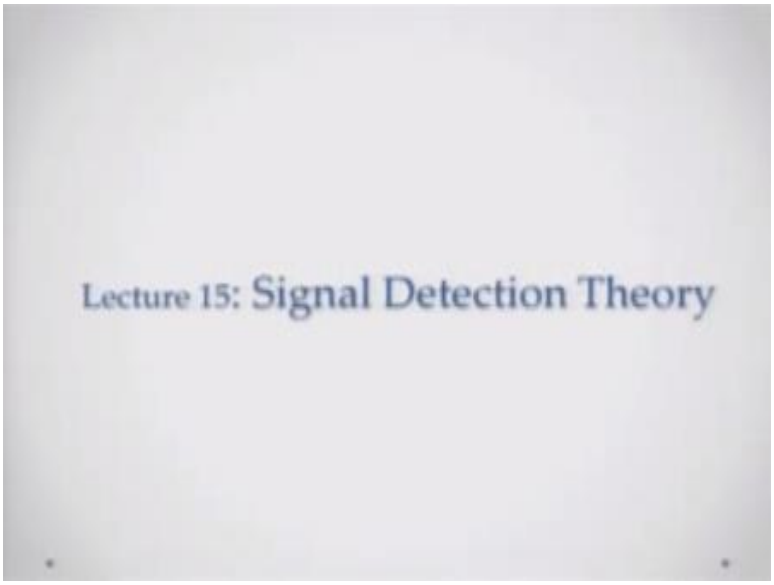

Today we are going to talk about signal detection theory as you know in the last lectures we have been talking about sensation and perception we have been talking about, how to measure sensation in one of the earlier lectures I have told you about classical psycho physics and how it has been used to measure elements of sensation we have talked about quite a few methods most of which come under classical psychophysical theory in order to determine concepts like absolute threshold different threshold etc.

We have seen that these processes basically help us identify when a person is feeling a particular sensation and how that sensation can be quantified using some of the methods like the method of adjustment or the method of constant stimuli etc. Today I will be talking to you about a particular theory which kind of diverges its approach towards measuring sensation this particular theory is called signal detection theory.

We will see some of the merits and maybe you know how this theory is slightly different from other class classical psychophysical methods, now we have been talking about the importance of thresholds is not it how did you know how would it be if say for example we do not need to determine threshold in the first place can we do with something else can we do with the you

know related concept which does not really merely you know depend on determining at what point somebody perceives a particular you know physical stimulus according to the theory of signal detection our perception in general Is controlled.

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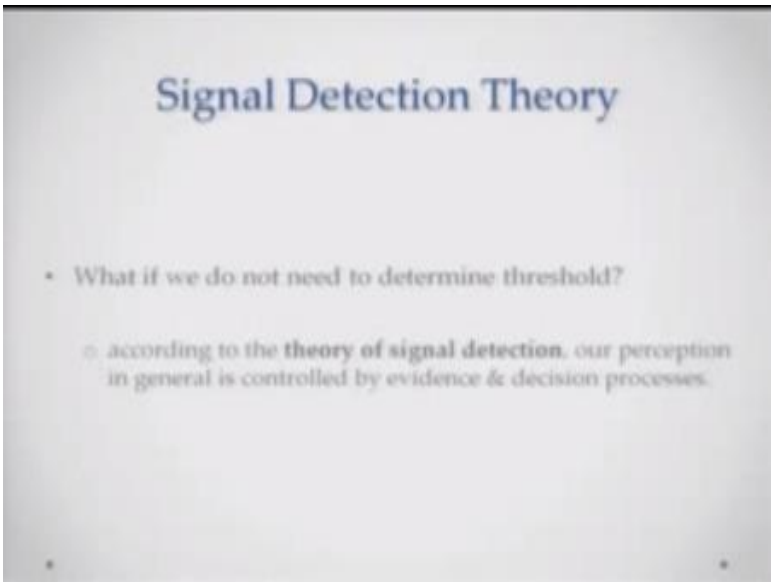

By evidence and decision processes so any air you know stimulus in the environment can be treated off as an evidence if for example a particular array of light falling on the retina is evidence of light you know that is therein the external environment and you have to take a decision whether the light is let us say bright either for not or whether the light whether there is any light at all in the first place, so signal detection here you basically you know assumes these processes as a sum of both evidence which is you know the property of the stimulus and decision processes that are the property of the perceiver a signal or a stimulus creates.

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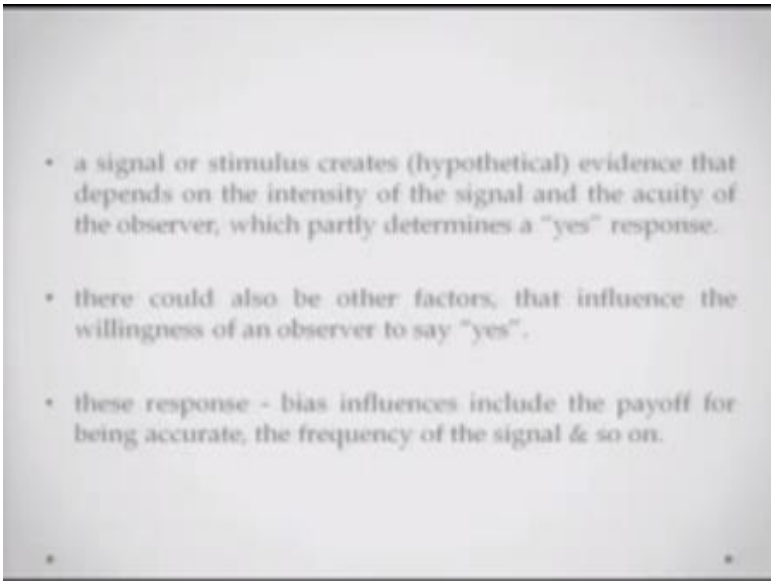

Evidence that depends on the intensity of the signal and also the equity of the observer say for example I asked you to distinguish between two shapes partly this depends upon, how different the two shapes are from each other if it is you know a small line and some very large lines next to it also it depends on your ability to see the difference between the two stimuli, so that is equity of you equity of the perceiver or the observer both of these factors interact to determine whether you will give a yes response to the question that things are different or whether you have detected something.

They could also be other factors which determine how you know you are going to respond to that question say for example the willingness of an observer to say yes maybe if you are not very sure may be if the decision is slightly you know valuable to make maybe you not say yes, okay maybe you will wait for completely more you know completely a convincing case and more evidence to say yes these kind of influences which determine whether you want to say yes or not or your willingness to say yes or not are called response biases these response bias influences.

You know also include the payoff for being accurate or the frequency of the signal and so many other factors we talked about them as we move ahead.

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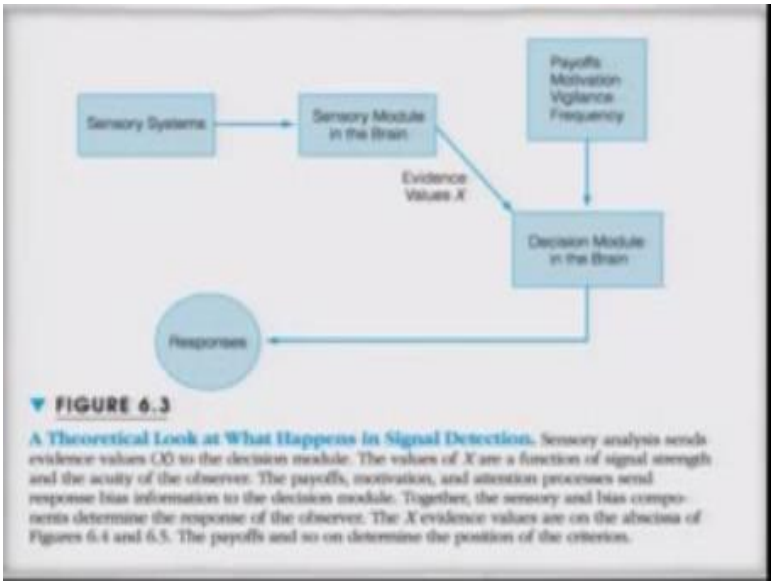

▼ FIGURE 6.3

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.

Look at this figure here you will see this is basically how you know a theoretical representation of what signal detection really means, you can see that there are sensory systems here there is a particular sensory module in the brain and essentially module in the brain kind of you know evaluates the evidence values which is basically the intense visual stimulus and those kind of things then you will see that these evidence values feed on to a particular box which is the decision model you know the brain has to decide.

Whether to say different or not different or whether to say detected or not detected and in there you see a modulating factor is the payoffs or the motivation or vigilance, how alert you were if you were you know is that when that signal was presented what is the frequency of that signal does it happen once in hundred times or does it happen let us say 60 times 100 times okay this decision-making module of the brain, actually you know leaves on to the kind of responses that you end up giving.

So this in nutshell is how signal detection theory is really a you know approaches this whole aspect of people detecting particular person particular sensations, let us take an example of the

fact you know of the willingness thing so for example imagine if your friend has setup a blind date for you okay.

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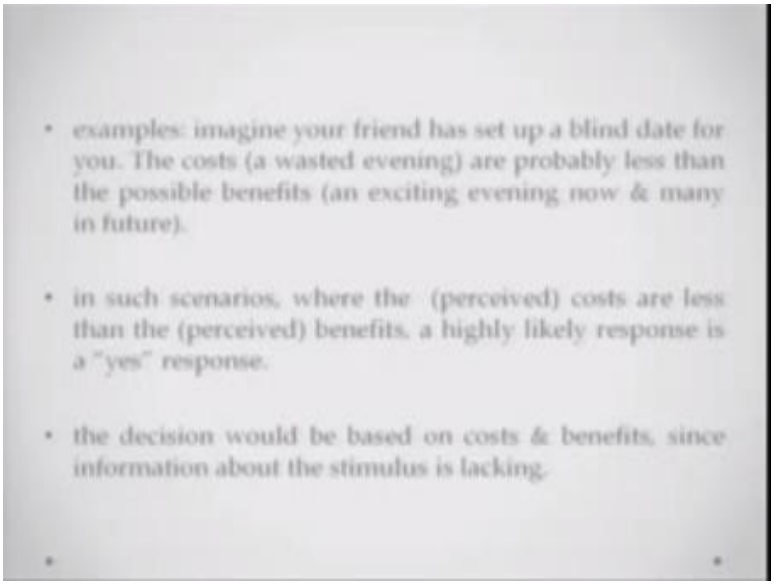

Now you have to really tell him by within one hour or so whether you are interested in going on that date or not, now you are thinking now what could be the cause of such a decision you know the maximum cost for you know saying no to a blind date or saying, yes to a blind date in that sense could be let us say you waste an evening you know you do not like the person you were set up with and you did not like their behavior and stuff, so maximum what will happen you based in evening maybe you will say for example.

Not even like the food these course a slightly lesser is not it and you know then the possible benefits could be much higher say for example if you like the person if the you know if the two of you strike a chord and you know an exciting evening happens, and many more happen in the future so this kind of is cost versus benefit analysis of this decision okay, in such scenarios when the costs are slightly lesser as compared to possible benefits people basically you know highly favored are yes strategy.

So what they will do is that they will kind of you know evaluate what are the cost what are the benefits if they find that the benefits are slightly more than the course they will actually go on with the yes response more often than not this decision basically, if you see now is based on the analysis of costs and benefits because you do not really have any information about the stimulus you do not know about the girl it is a blind date you do not know what else to take into account that is one of doing it.

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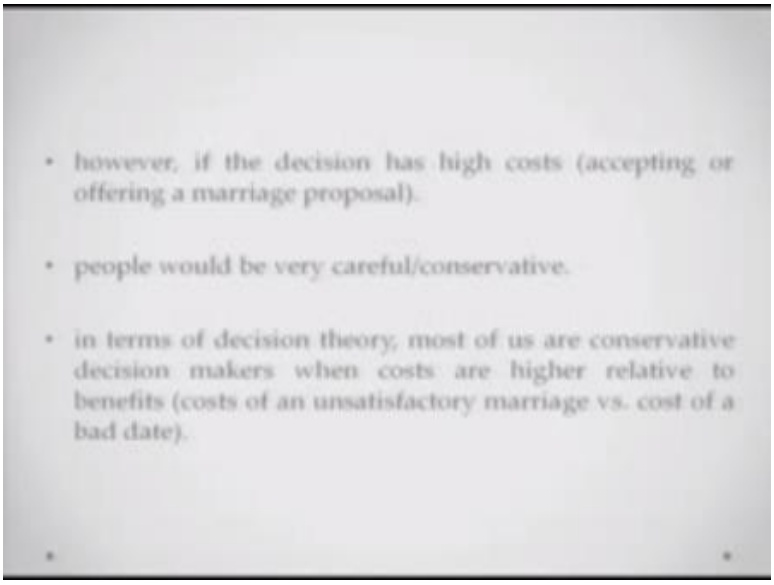

However if you have a high-cost decision to make say for example if you have to say yes or no to a marriage proposal that maybe one of your parents have brought to you, now you say if you do not know you know any information about the girl you do not know you know what is what does she look like what is the reduction other things that you are going to consider how do you do it then people have been found to be very careful and very conservative in scenarios where the possible benefits or you know where the in third costs are much more than the possible benefits interms of decision.

Theory most of us there in these kind of scenarios a very conservative decision makers when costs are higher relative to the benefits okay.

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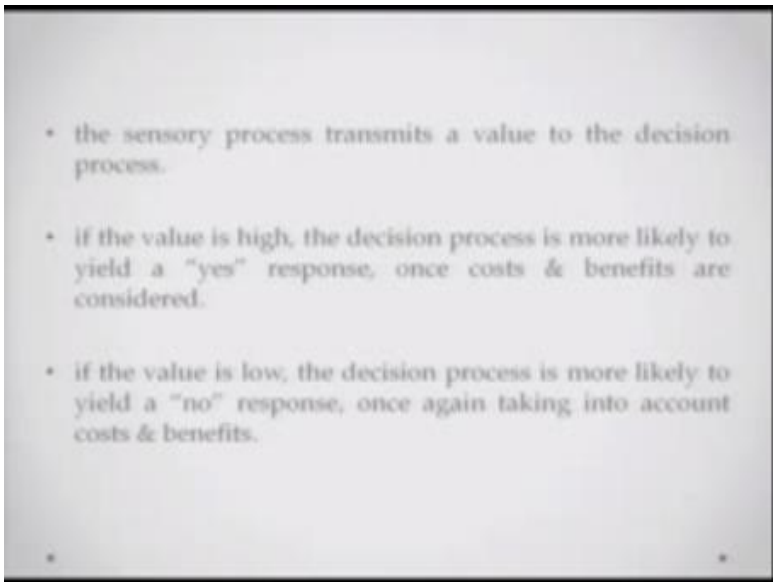

Now leaving aside this kind of a process let us talk about the sensory processes here so the sensory processes basically you know they transmit a particular, value to the decision making modules the decision processes if this value is considerably higher the decision is more likely to yield a yes response because you have enough evidence to say yes okay, about any decision about the fact that there is light in the room about the fact that there is a you know a particular kind of temperature and thereon those kind of things obviously.

You evaluate the costs and benefits if this value given by the sensory processes to the decision making process is low the evidence is less then basically what will happen is that you are more likely to eat a no response okay, once again take after taking into account the costs and the benefits.

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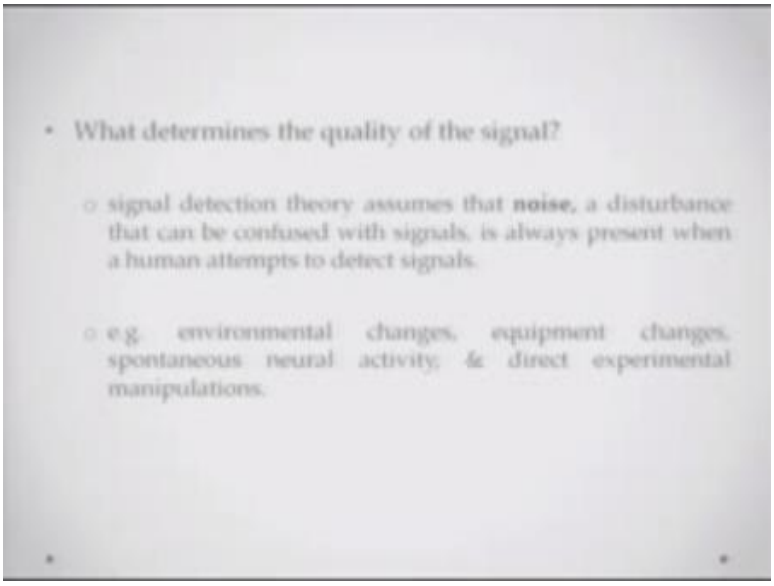

Now what determines the quality of this signal you know what determines what kind of signal that is coming in, signal detection theory has two assumptions first is that it has used that there is always noise present you know there is always a disturbance that can be confused with signals and is always present whenever a human being attempts to you know detect any kind of signal and this and this the source of this noise could be anything it could be environmental changes it could be equipment changes maybe you are measuring you know temperature.

For example you different kinds of thermometers there will be some degree of error you know this is concept of 0 error in the physical measurement instruments it could be spontaneous neural activity, because here the measurement is not actually an external device the measurement is you yourself maybe you are not attentive enough at that point in time maybe you are just slightly tired and so somebody is speaking and you cannot really attend to it very you know attentively say okay.

So in that sense it is very possible that somebody is telling you something and you kind of you just mind your mind wandered somewhere and you missed the details of what was said a lot of time that might happen, when somebody is giving out the shopping list you kind of you know

slightly not concentrating and some of the important ingredients are left out and you know athlete that might lead to problems there could be other sources of this kind of you know as noise as well say for example you know different kind of experimental manipulations can be done with a receiver let us look at one of this kind of experimental manipulation.

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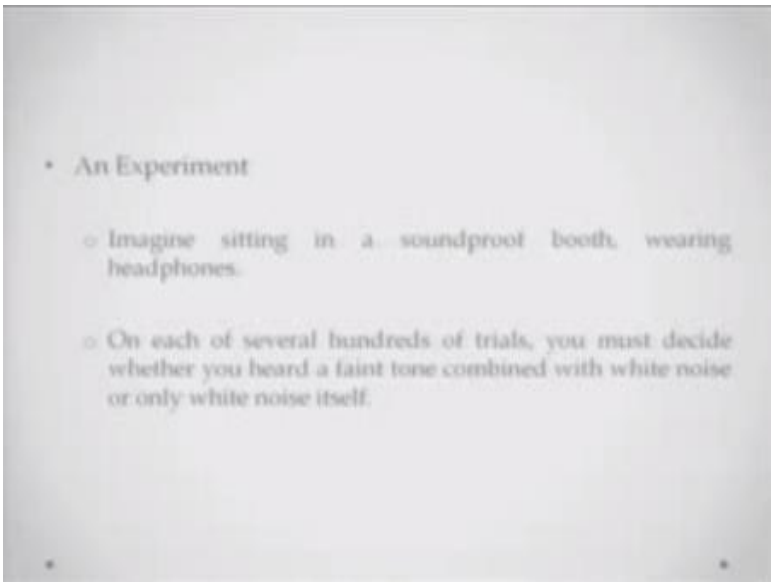

Imagine if you are sitting in a soundproof booth wearing headphones you know it is a soundproof booth you are just given headphones and you have been asked to decide whether you have heard a faint tone combined with white noise or you only heard white noise maybe it could be just a machine generated tone like something like that and it is you know mixed with white noise which is again system generated noise does not have a lot of meaning a trial might begin by presentation.

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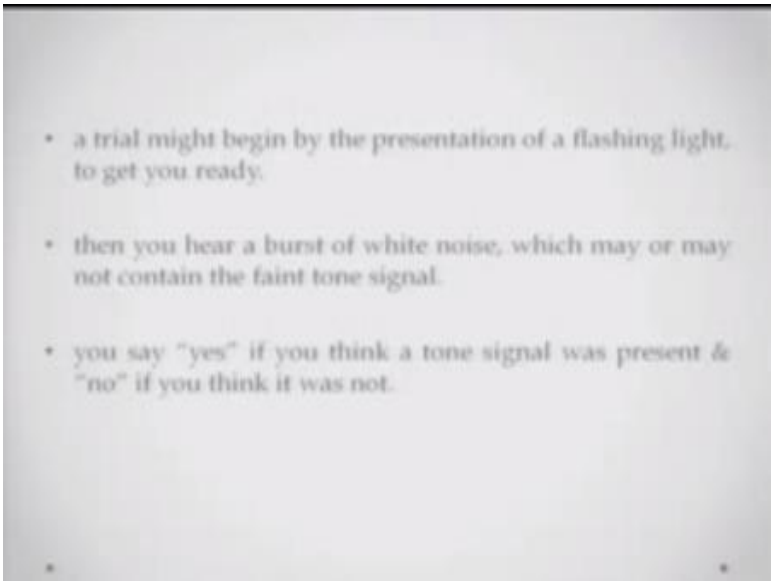

Of a flashlight that is to gain your attention to get you ready then what you hear is a burst of white noise which now may or may not contain the faint tone signal, now you have to decide whether this white noise contain that signal or not you would say yes, if you think a tone signal was present you would say no if you think it was not.

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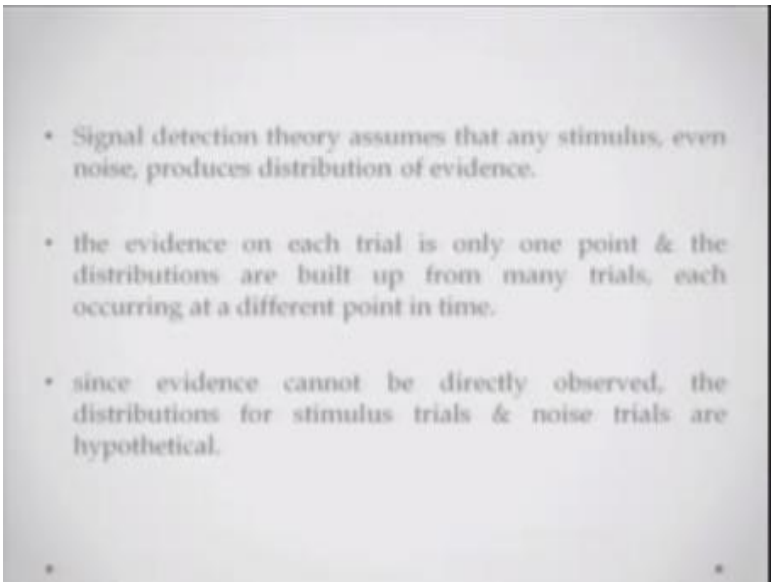

Now signal detection theory in these kind of scenarios assumes that any stimulus even noise produces what is called a distribution of evidence yeah there will be different points, so each the evidence on each trial will be just one point, but you actually go through many such trials so there will be a distribution of all of these you know points, so basically what will happen and say for example also since evidence will not be directly observed that solution for stimulus trials and noise trials a both will be hypothetical.

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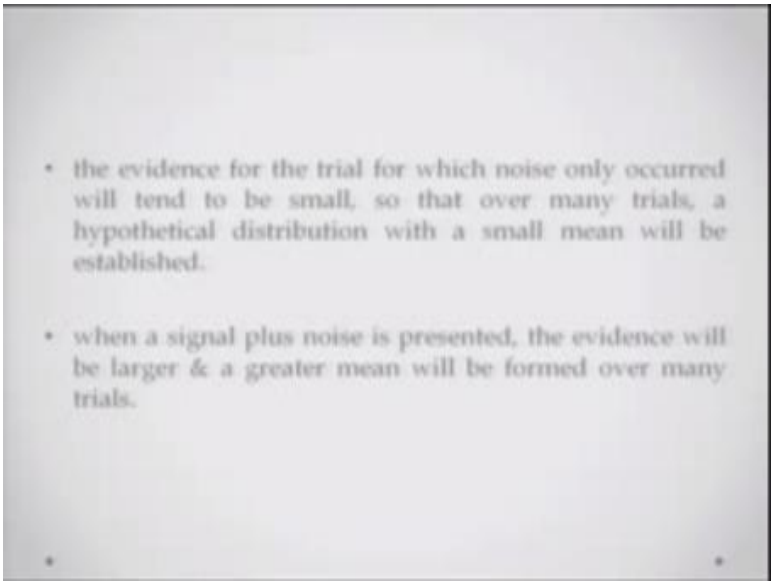

What you might have is that the evidence would try for which only noise occurred will tend to be small there will be less evidence there, so that over many trials a hypothetical distribution with a very small mean will use service if you are trying to just draw a distribution of the noise trials a very few trials had noise a very small mean and a very small distribution will be there if you think of trials where noise and signal that is the faint tone work both presented you will basically have a larger distribution with a greater mean again form the word many trials what you are still talking about that experiment now.

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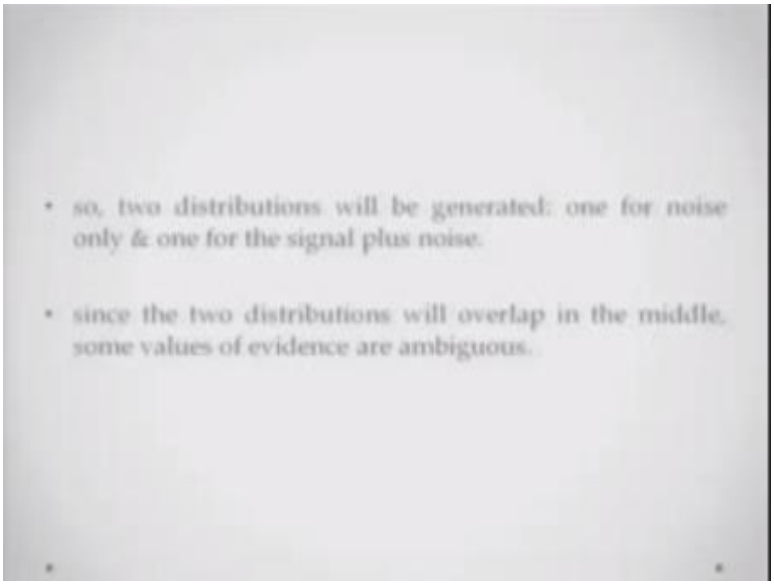

So you will have two distributions one will be the noise distribution then there will be the signal plus noise distribution since these two distributions way anyways overlap somewhere in the middle, some values of evidence will be slightly ambiguous you know those are values where you are not really sure about whether there was noise or whether there was only noise or whether it was signal in the noise as well here is what this distribution might look like.

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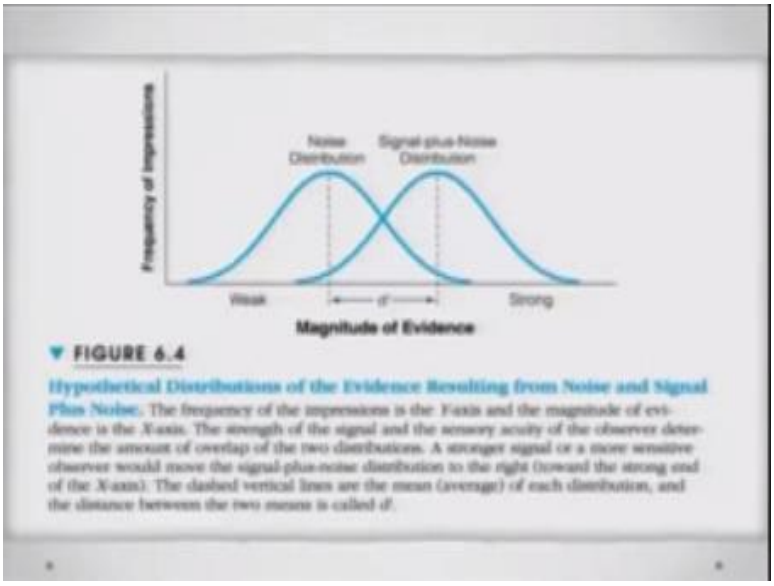

▼ FIGURE 6.4

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'*.

So you have a noise distribution you have signal plus noise distribution and you have a distance between the means of these two distributions this distance basically is called D ' which is basically your sensitivity okay we talked about this very shortly.

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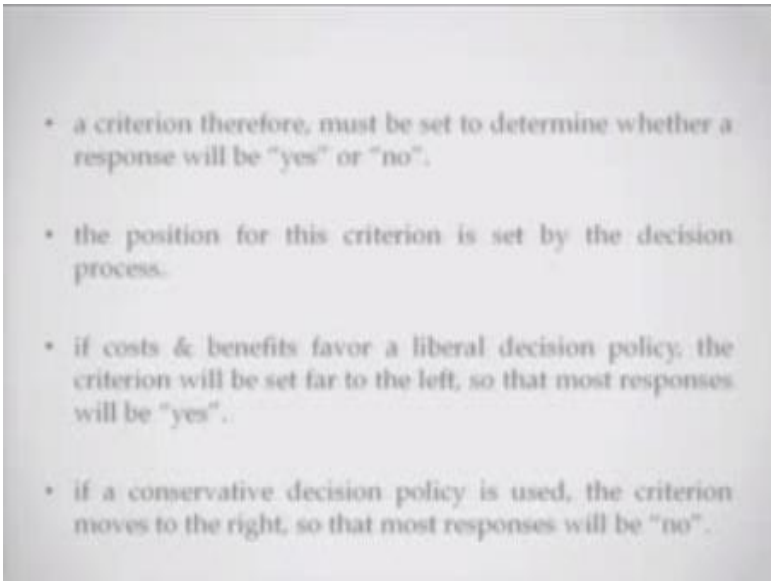

So how do you decide you know whether there was noise present or not you need to set some criterion that beyond this point I will say that yes the signal was present where before this point as I say no the signal is not present, so a criterion was therefore we set to determine whether you will give ayes response or a no response the position for this criterion is basically set up by what is called the decision process if the constant benefits analysis kind of you know says favors a liberal decision policy you know things like going on.

A blind date with somebody the criterion will be set slightly further to the left and so that most of the responses will use in yes response most of the trials will lead in a yes response if it is a conservative decision for here, something very important the criterion will move slightly towards the right and what you will do is you will say move no responses okay it basically depends on the value of the decision.

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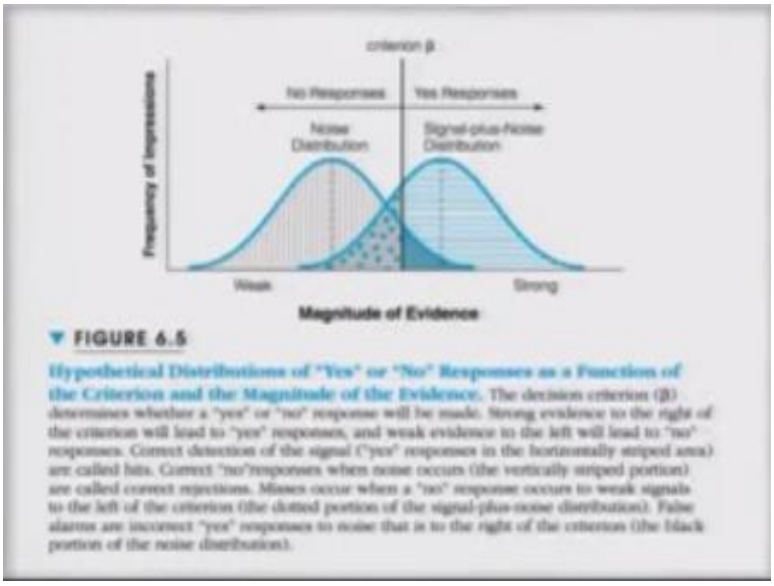

▼ FIGURE 6.5

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).

So here is how you make an or really plot the criterion you can move the criterion slightly to the right to use more no responses like you to the left to more yes responses, okay this is this decision criteria is called ß okay so it determines basically whether you will make a yes response and we will make a no response so if that is clear we can slightly move further we can understand that you know anyways any how this distribution turns up there will be some errors of judgment you know there will be some values where you not really be clear if you detected the correct signal for example this will be called a hit if say for example if incorrectly.

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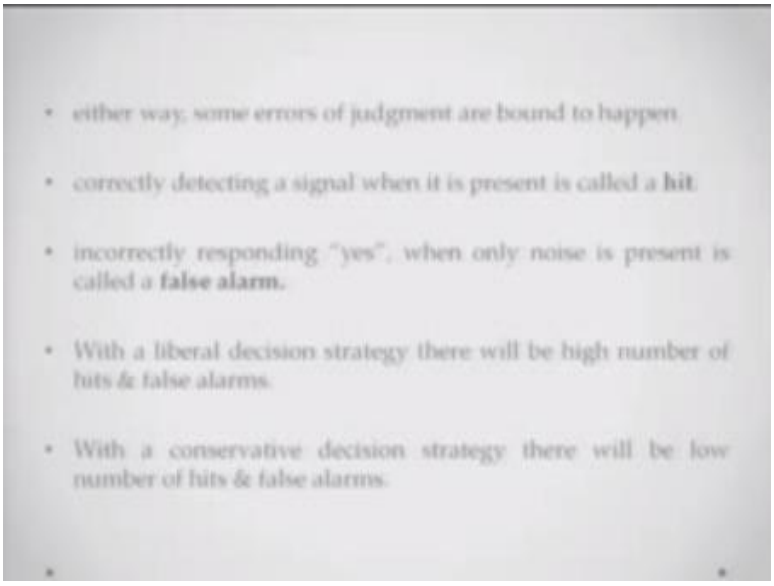

Responded yes where there was no signal then that scenario will be called a scenario of false alarm, so if you are following a very liberal decision-making side you are saying yes to everything then what you what will happen is you will have a lot of hits yes, but you will have a lot of false alarms is it because your tendency is to say yes to most responses on the other hand if you follow a conservative decision strategy will there will be low number of fits and it will also be low number of false alarms.

So you will probably have very few false alarms but you will have a lot of misses as well because you do not say yes when the signal was there because you following you want to be very really very sure of the presence of the signal, now if you plot this you know if you plot a function of hits as a function.

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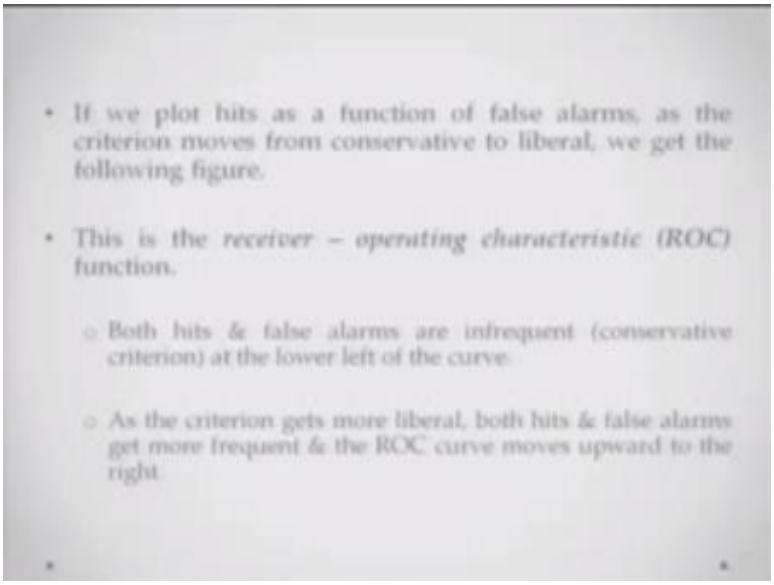

Of false alarms and as the criteria moves from conservative to liberal we get a particular figure this figure is basically known as the receiver operating characteristic or the ROC curve in this figure you can see and I will just show you in a moment that both hits and false alarms are in frequent are actually infrequent.

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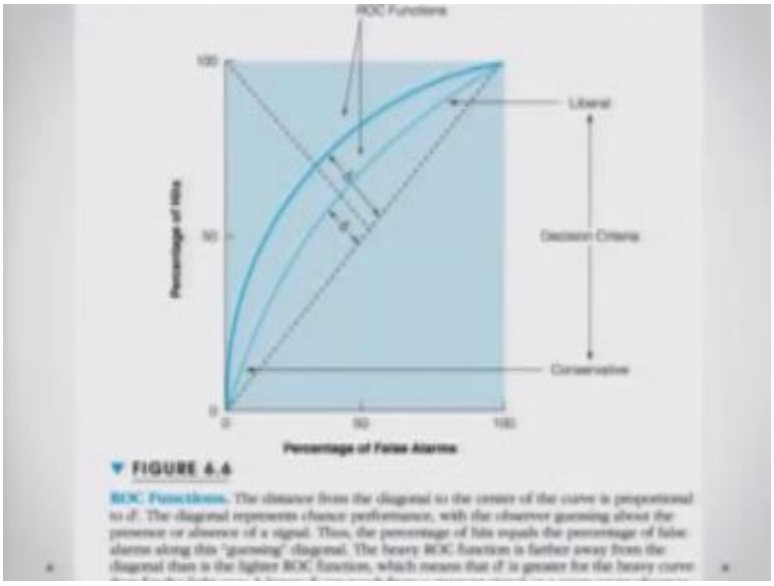

▼ FIGURE 4.4

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

At the lower left of the curve you can see the figure here at the lower left side of the curve but both hits and false alarms become more and more frequent , if you move towards the upper right side of this particular curve okay so this is basically something which tells you about the decision-making process as well that whether you are following a conservative process or a liberal process the slope of this particular function will tell you two things if there is a flat slope it will tell you that.

You have been following a liberal decision-making criterion if the slope is slightly steeper usually it when you feel a conservative criterion, that you have been you know having very few hits but very few false alarms as well the slope of this curve basically here such as the ROC function is determined by a slope of the line that is drawn as a tangent to this curve and you can connect either of the axis.

It might interact the x axis or the y axis if it is the curve is too steep in probably you know intersect with the y axis with the x axis, if it is slightly flatter it kind of you know intersect the y axis now the distance, if you see this figure again.

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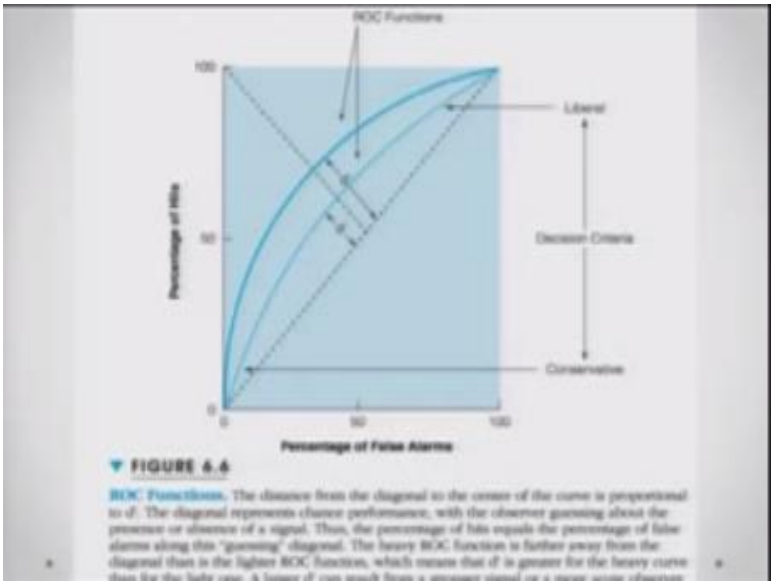

FIGURE 6.6

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

The distance from the diagonal to this curve.

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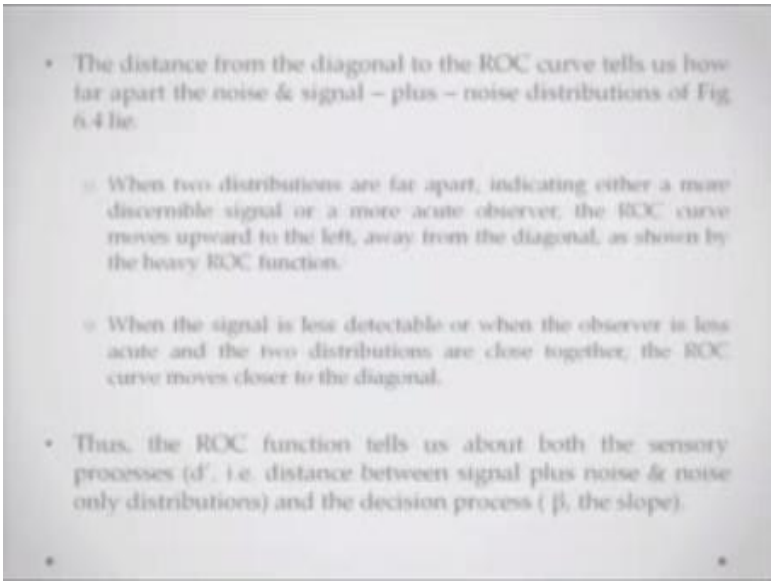

Tells us how far apart the noise and the signal plus noise distributions are when these two distributions are far apart they indicate and indicating either more discerning will signal or a more acute observer, so there could be two things is not it either the signal is very clear so that you can detect it all the time either you very good at detecting that signal, so whether it you know indicates a very desirable signal or whether it indicates a very acute observer the ROC curve moves upward to the left.

Okay and away from the diagonal as shown by the heavy ROC function you can see this one here you can see one of these figures is slightly higher dotted it's a slightly heavier line the one at the top okay, when the signal is less detectable or say for example the observer is not very good at detecting that and the distribution the distributions will be slightly closer together so the ROC curve will move slightly closer to the diagonals you can see here.

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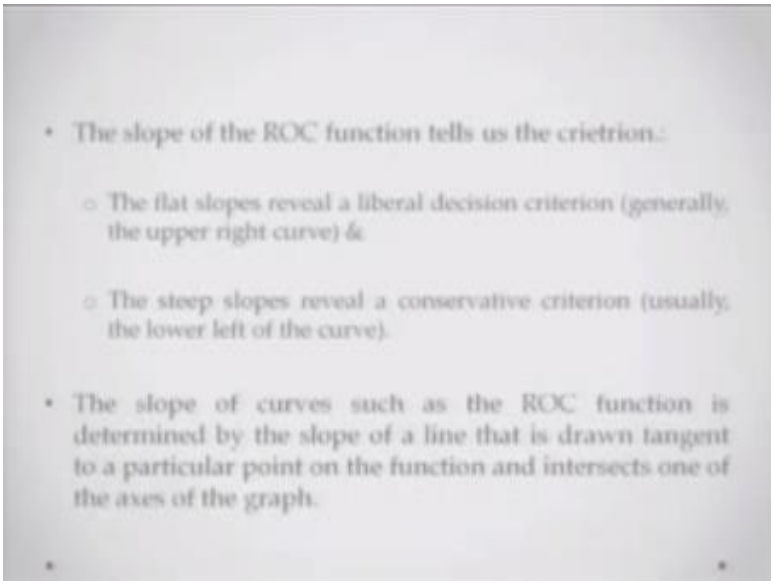

That this will be slightly you know closer to the diagonals which is the lighter ROC function between C here so the D prime basically is much smaller than the D prime in the earlier part okay, so the Roc function basically tells us about both it tells us about the sensory processes you know that is the distance between the signal plus noise and the noise and basically are the noisy solutions it also tells us the criteria which you have been following it also tells us about the decision making us which is ß.

Okay now what does this you know a signal detection method or what does this theory really have in for us okay one of the major advantage of the signal detection methods over a classical psychophysics psychophysical procedures like we had in the last lecture.

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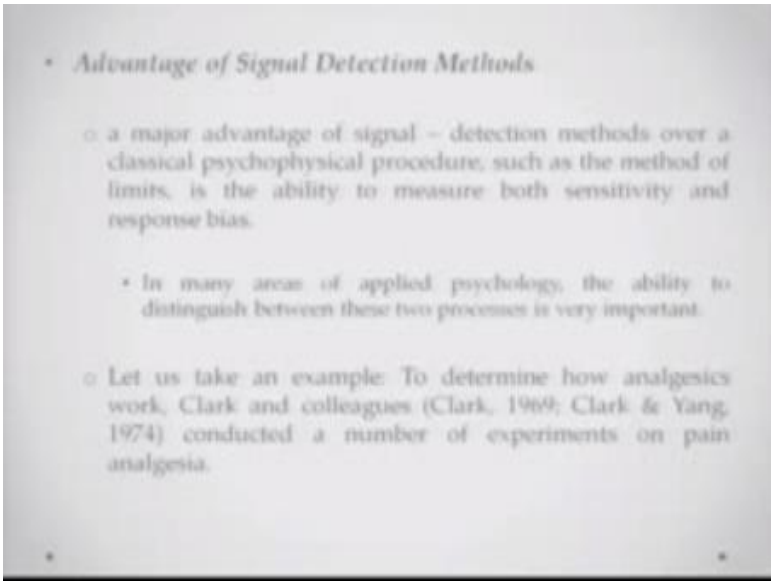

Such as for example the method of limits is that this ability to measure and quantify both the sensitivity of the observer and the responses, both can really be you know plotted and figured out here I have not gone into great detail about those calculations because again you are just you know doing this an introductory level you are not really going into much more detail but those of you interested that I can actually look into them and maybe ask questions but this ability of really talking about and quantifying.

Both sensitivity and response bias is really important in many areas of Applied Psychology say for example you know this ability to distinguish between these two processes very important I can take an example of say for example you know if there is a you know if there is a soldier at the border you know and it is basically reading taking readings from that at all you know whether a particular enemy is approaching or whether enemy is not approaching basically is a costly decision.

If the enemy is approaching and you miss it you are kind of you know outputting everybody else in danger if it is not the enemy and you know shoot down somebody by mistake you are still committing a grave crime so that's kind of decision slightly expensive to make so say for

example if you are a doctor and somebody comes and shows you there you know x-ray report and you have to detect whether there is a cancerous tumor present or not it can again be very costly decision.

If you go by a very conservative study and say yes there is tumor and you know there is a poor patient who is come you are showing him to you know a particular sort of buying very expensive medicines etc. Which will not need it in the first place or if you actually follow a very conservative stratagem you see no there is no tumor you are fine and the person kind of and that ends up if you are not dying because the tumor was not diagnosed in time then also you are committing a very grave mistake.

So in those kind of decisions you know in those kind of scenarios signal detection kind of methods are really very important and there have they have been extensively used as well I will take in example to a laboratory here, say for example to determine how n lg6 work clock in colleagues they conducted a number of experiments on pain analgesia they wanted to test whether how basically these analytics like aspirin etc work.

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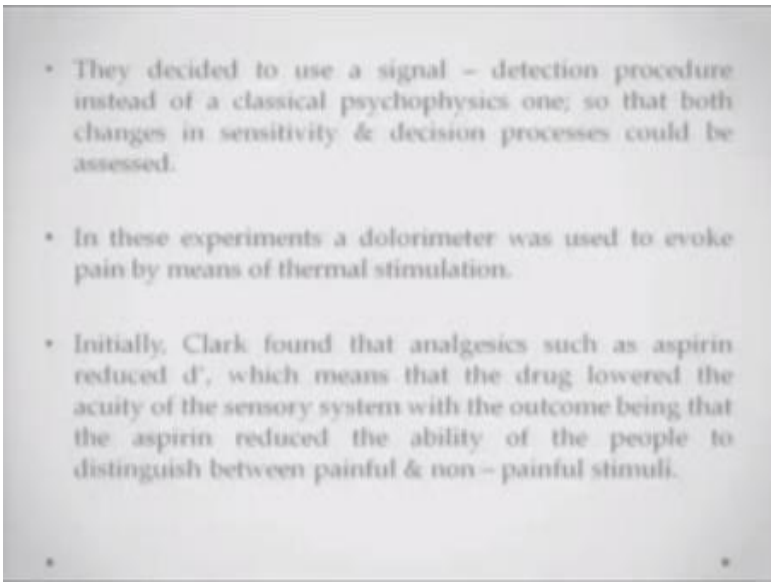

So they basically decided to use signal detection procedure instead of the classical psychophysics methods and what they do was you know they are basically in these experiments they use something called a delimiter to evoke pain by means of thermal stimulation, so it was a instrument that was applied on the skin a kind of you know delivered heat in some sense and that could you know either lead to pain or you know less pain or more pain something like that initially Clark found that analgesics such as aspirin reduced the d-prime they reduce the.

Sensitivity of the observer which means the drug basically you know is really reducing or lowering down the equity of the sensory system with the outcome being that you know as the ability of the observer to distinguish between painful and, non painful stimulus is lowered down it might this kind of thing might have its own benefits but then they went on to investigate method play see booths or acupuncture etc.

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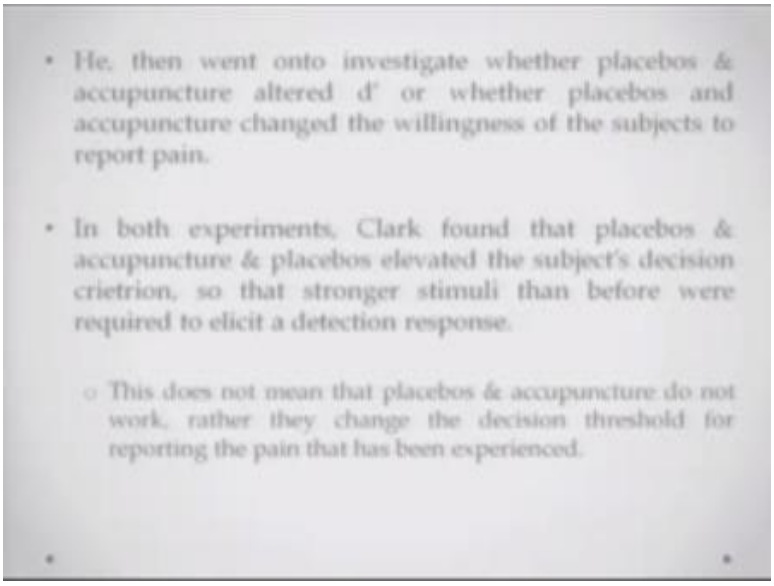

Altered d-prime or whether placebos or acupuncture change the willingness of the participant to report pain, in both these experiments Clark found that Laci was an acupuncture basically elevated the subjects of decision criterion, so a stronger stimulation was needed for the subject to say yes or for the subject to report pain detection response now this actually does not mean that

Macy was an acupuncturist cetera will not work but what they are doing is they are working with a slightly different method okay we are basically changing the decision threshold okay they are not changing the sensitivity of the observer the sensitivity is still there but the decision threshold is actually changed also drawing from earlier work then by hardly increase 1952.

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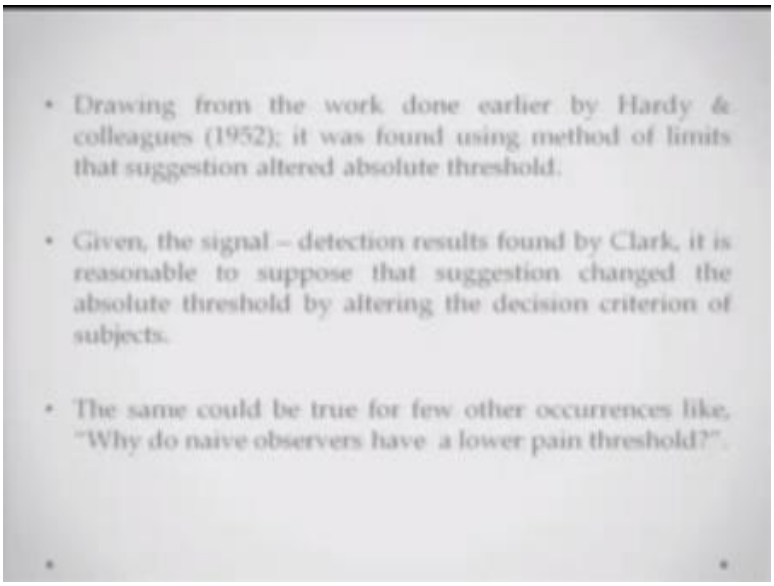

It was found that using methods was found using methods of limits that suggestions if you tell somebody the general you are not feeling being a stuff like that also alters absolute threshold, so given the kind of work we saw just now a signal detection the method used by Clark until if it is reasonable to suppose that suggestion basically what it did was it changed the absolute threshold by altering the decision criterion of subject so you are basically selecting to the person that know you not be feeling pain know you are not feeling.

Clean until the pain becomes unbearable for the participant to actually report pain okay so the same could be true for other kinds of occurrences as well say, for example if you have a knife observer somebody is not being part of the experiment and you kind of you know start this experiment with this kind of participant you see that the naive observers will have a very lower

threshold immediately say yes I felt faint I felt pain something like that now this basically these kind of things could not have been determined using classical psychophysical methods.

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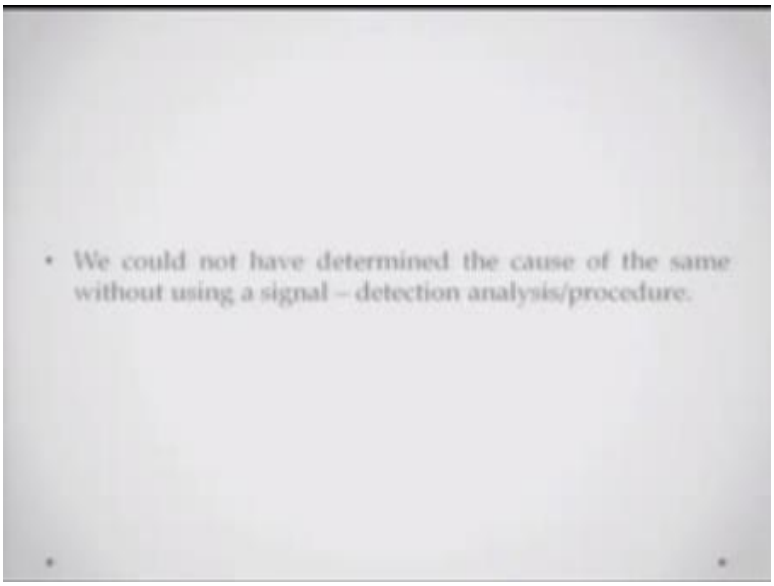

You know you cannot know about decision criterion etc. Using classical psychophysical methods and this in itself is a major advantage imagination advantage of signal detection practice methods, so coming to the close trying to sum up we found out that signal detection.

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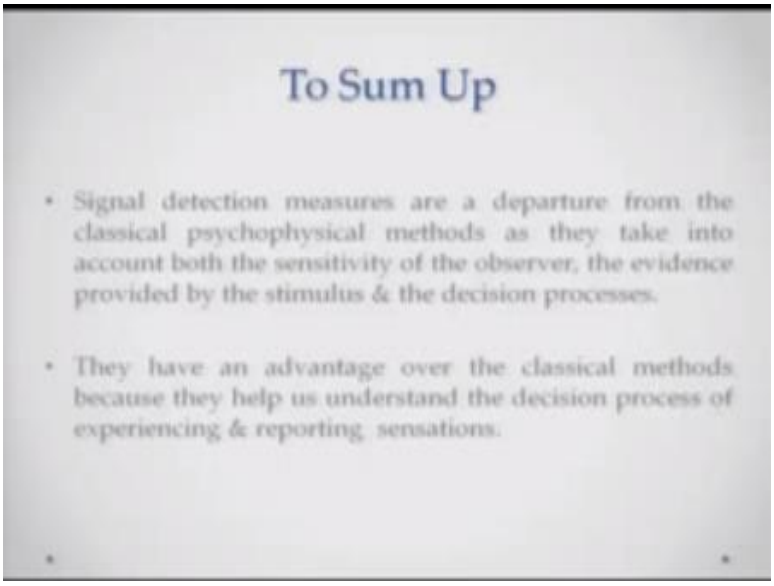

The measures are a departure from the classical psychophysical methods as they take into account both the sensitivity of the observer and the evidence provided by the stimulus and also the decision-making processes, so it kind of takes care of all of these three things and they are better because they help us understand the decision-making process of the participant experiencing and reporting these sensations, so this is basically you know the end of the series about psychophysics in the next owner to start talking about issues related to perception thank.

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