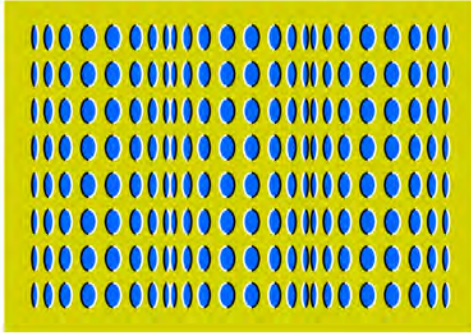


Announcements



1

Psychophysical methods OUTLINE

- Psychometric and psychophysical function
- Types of measurements
 - Absolute threshold
 - Difference threshold (JND) - (example)
 - Point of subjective equality (PSE)
 - Weber's law
- Methods for measuring thresholds and PSEs
 - Adjustment
 - Limits
 - Constant stimuli (example)
 - Staircase method (example)
- **Signal detection theory**

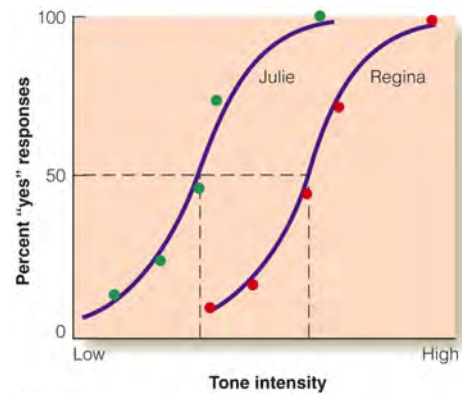
2

Signal Detection Theory

Baggage screening example



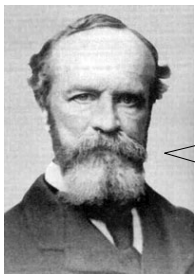
3



Julie's threshold is lower than Regina's, but is Julie **really more sensitive** to the tone than Regina?

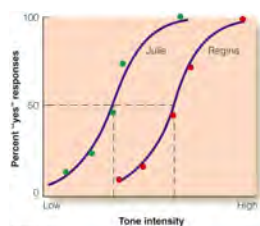
4

Problem of criterion



William James (1842 - 1910)

".. we must never take a person's testimony, however sincere, that he has felt nothing, as proof positive that no feeling has been there."



5

Problem of criterion

• perceptual decisions are influenced by many factors:

- Strength of signal relative to background level of noise
- **Person's sensitivity to the signal**
- Relative frequency of occurrence of the signal
- Person's level of motivation
- Costs associated with hits and false alarms
- Personal biases (individual differences)

SOLUTION:

Measure **sensitivity** independently of **crit**erion = Signal detection theory

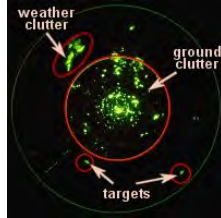
6

Signal Detection Theory (SDT)

SDT explains perceptual performance (& decision making) under conditions of uncertainty.
The goal of SDT is to distinguish performance changes/differences attributable to **sensitivity** to those attributable to **criterion**.

Originates from World War II: aircraft detection on radar signals.
Today, SDT is widely used in psychophysics, medicine, radiology, machine learning...

- detecting faint sounds (e.g., murmur heard through stethoscope)
- interpreting "blips" on a radar screen ("plane vs flock of birds")
- stock market transactions ("buy or sell?")
- jury decision ("innocent vs guilty")
- deciding whether or not two lines are identical in length
- diagnosing X-ray images (e.g., "is it a tumor?")
- detecting weapons in screened luggage

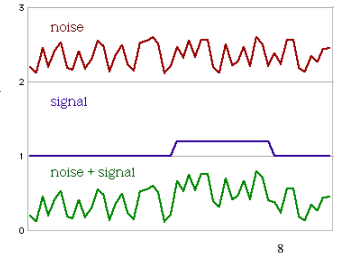


Signal Detection Theory (SDT)

Each observation (e.g., bag screening) is either a case of "just noise" or a "signal plus noise"

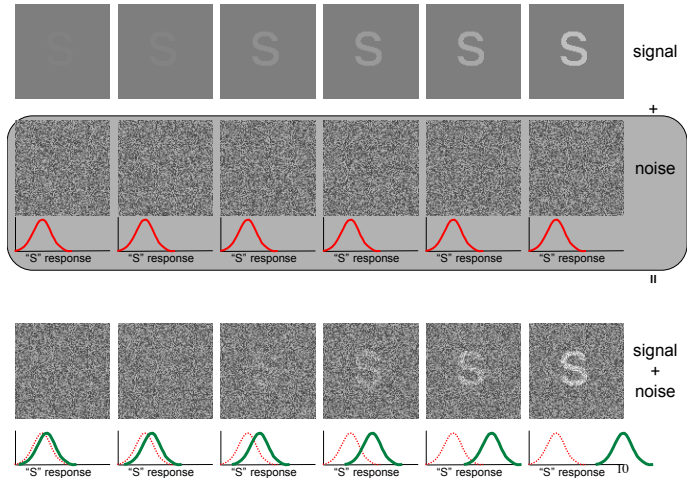
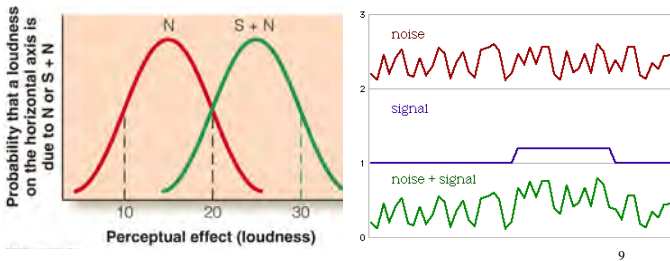
"noise" is anything that complicates detection of "signal" by introducing uncertainty about whether or not the signal is present

- misleading evidence in a legal trial
- flock of birds on a radar screen
- scar tissue on a mammogram
- background noise in a hearing task
- coins in your luggage



Signal Detection Theory (SDT)

Each observation (e.g., bag screening) is either a case of "just noise" or a "signal plus noise"



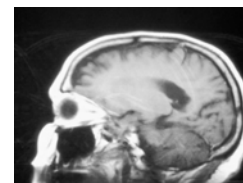
Signal Detection Theory (SDT)

Four possible outcomes:

- Signal was present and person says "yes" - **HIT**
- Signal was present and person says "no" - **MISS**
- Signal was not present and person says "no" - **CORRECT REJECTION**
- Signal was not present and person says "yes" - **FALSE ALARM**

Example application: medical diagnosis

- Hit – correct diagnosis of disease
- Miss – physician tells patient that no disease exists when one does
- False alarm – unnecessary operation or treatment
- Correct rejection – patient properly diagnosed with no disease



Patient's condition
no tumor tumor

Diagnosis	normal	correct	incorrect
	abnormal	incorrect	correct

Hit – correct diagnosis of disease
Miss – physician tells patient that no disease exists when one does
False alarm – unnecessary operation or treatment
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		Patient's condition	
		no tumor	tumor
Diagnosis	normal	correct	incorrect
	abnormal	incorrect	correct

13

		Patient's condition		Which error is more costly?
		no tumor	tumor	
Diagnosis	normal	Correct rejection	Miss	
	abnormal	False alarm	Hit	

14

Which error is more costly?

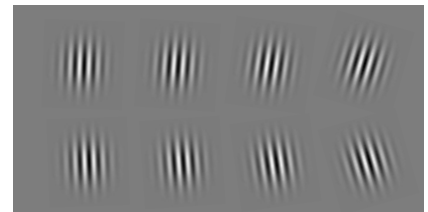


		Accused is	
		innocent	guilty
Jury decision	innocent	correct verdict	mistake
	guilty	mistake	correct verdict

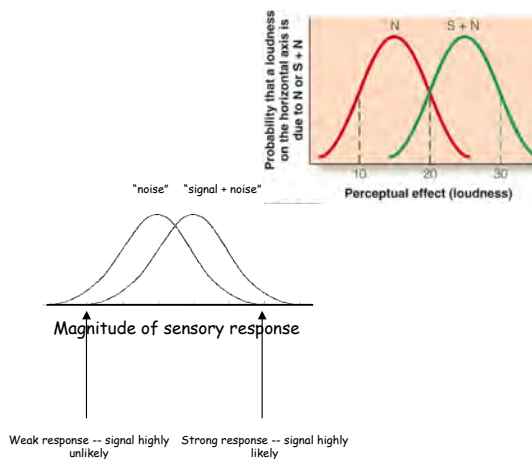
15

Signal detection demo

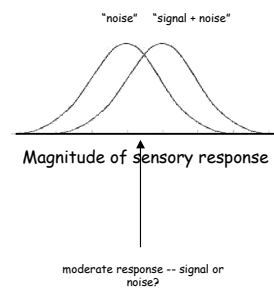
Orientation discrimination demo
YES - NO task
YES = presence of angular deviation
NO = absence of angular deviation



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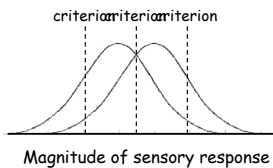


17



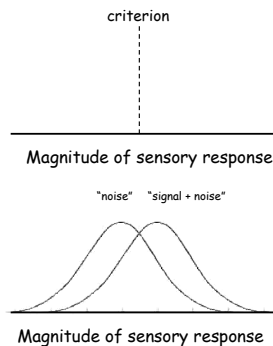
18

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



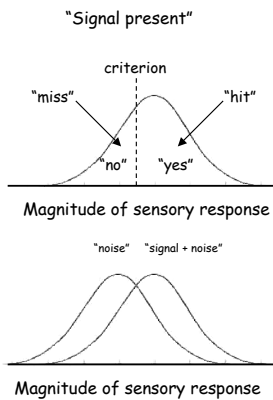
19

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



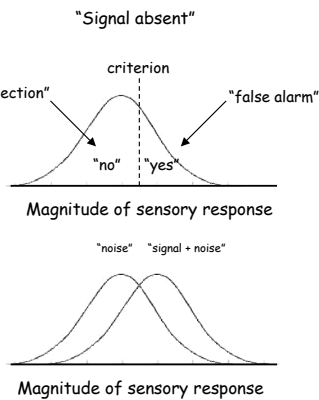
20

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



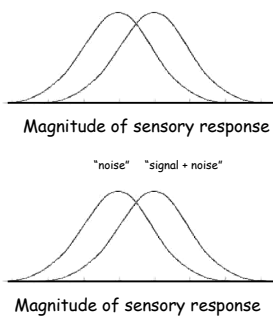
21

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



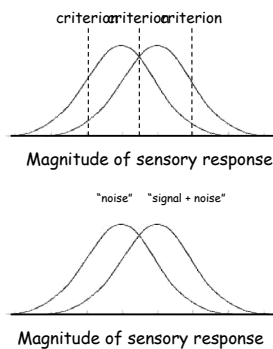
22

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



23

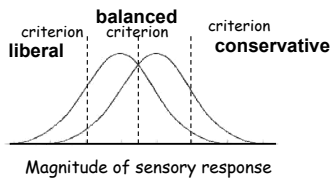
		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection



24

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection

Balanced: false alarm and miss rates are equal
Liberal: the observer says "yes" whenever there may be a signal
Conservative: decision is yes only when it is almost certain that there is a signal

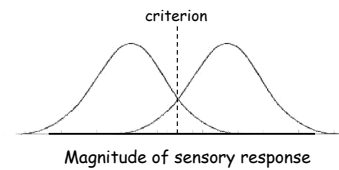


25

		stimulus event	
		present	absent
person's response	"yes"	hit	false alarm
	"no"	miss	correct rejection

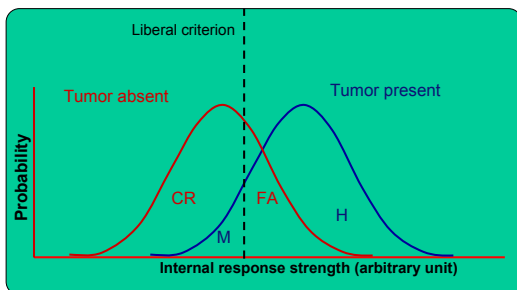
Discriminability:
 how well the observer can separate the presence of signal from its absence
 ~ overlap between the two distributions

Measured by d' (discriminability index, also called sensitivity)



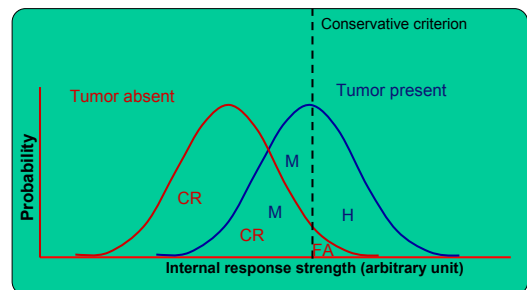
26

Practical example: medical diagnosis



27

Practical example: medical diagnosis



28

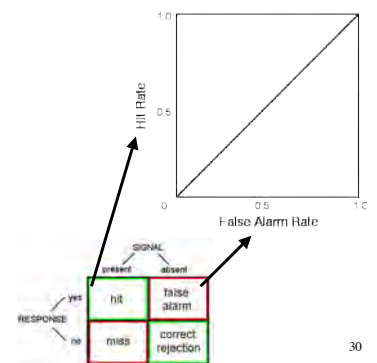
The ROC curve

Receiver Operating Characteristic: ROC

29

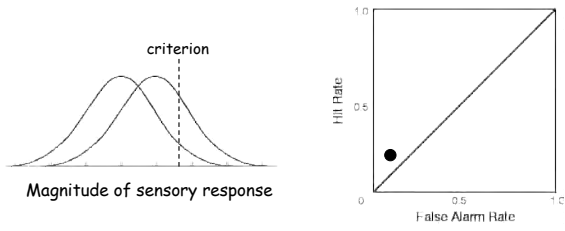
The ROC curve is traced out by plotting Hits against False Alarms as the criterion moves.

Receiver Operating Characteristic: ROC



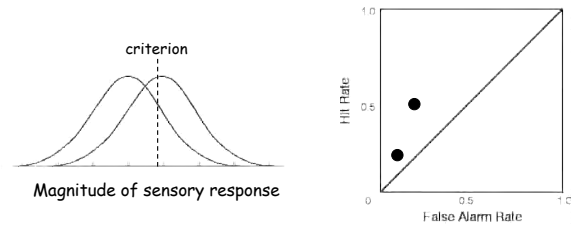
30

Receiver Operating Characteristic: ROC



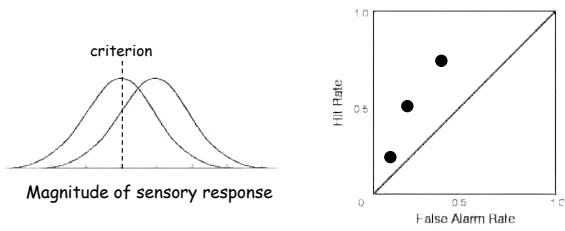
31

Receiver Operating Characteristic: ROC



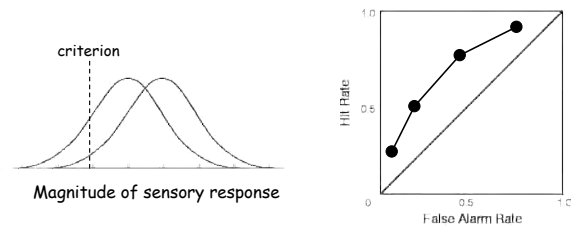
32

Receiver Operating Characteristic: ROC



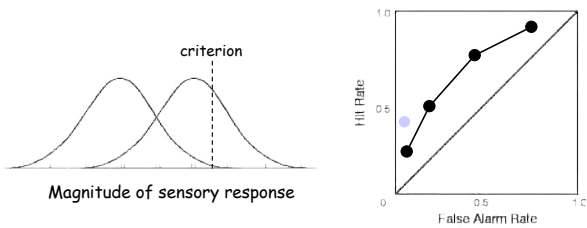
33

Receiver Operating Characteristic: ROC



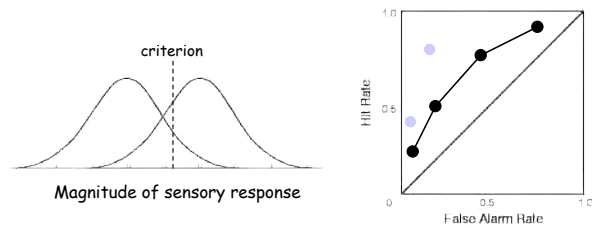
34

Receiver Operating Characteristic: ROC



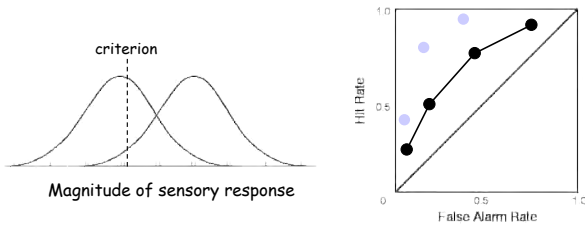
35

Receiver Operating Characteristic: ROC

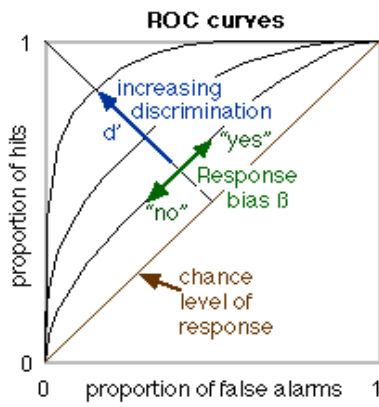
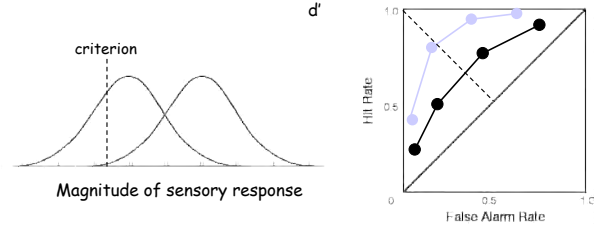


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Receiver Operating Characteristic: ROC

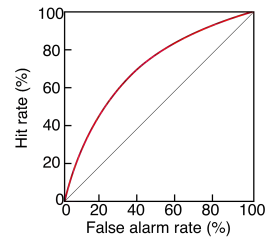


Receiver Operating Characteristic: ROC

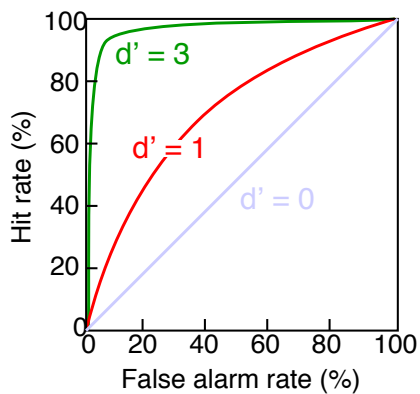


ROC Curve Questions

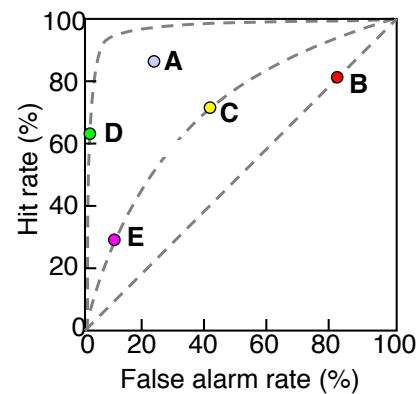
- Why do ROC curves start at (0,0)? Why do they go to (100,100)?
- If d-prime is zero, what is the shape of the ROC curve?
- If d-prime is large (e.g. 4 or larger) what is the shape of the ROC curve?



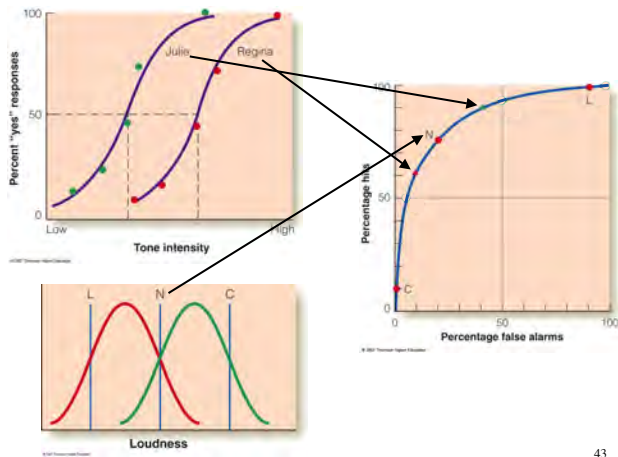
ROC Curve



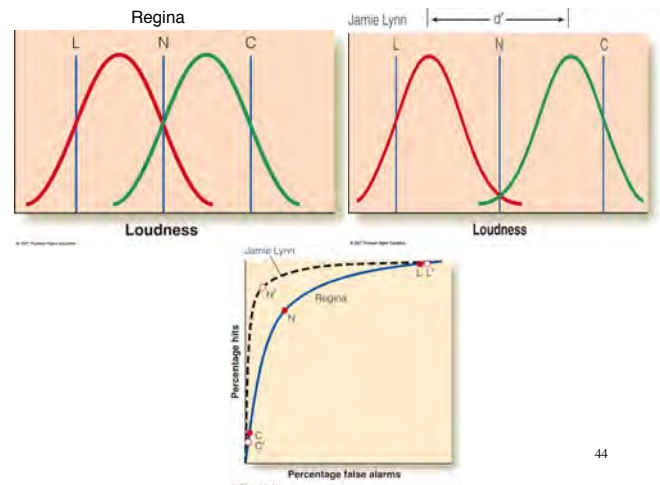
ROC Curve



- Which observer did best?
- Who was just there completing the subject pool requirement?



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Signal Detection Theory (SDT)- Online demos

<http://www-psych.stanford.edu/~lera/psych115s/notes/signal/>

<http://psych.hanover.edu/JavaTest/Media/Chapter02.html>
 Interactive Model 2.x: Signal Detection Theory
 Interactive Model 2.x: Signal Detection Illustration
 Interactive Model 2.x: Decisions In SDT
 Interactive Model 2.x: Receiver Operating Characteristic

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Signal Detection Theory (SDT)

- Explains yes-no decisions
- Detecting signal in noise (S + N)
 - Noise (N) is what makes detection hard (internal + external noise)
- **Sensitivity (discriminability) vs. criterion (bias)**
- Sensitivity (d') depends on
 - signal strength
 - noise strength
 - observer sensitivity
- Criterion depends on
 - Personal bias
 - Cost/benefit factors (risk factors)
 - Signal frequency
- ROC curve
 - used to visualize SDT concepts & results

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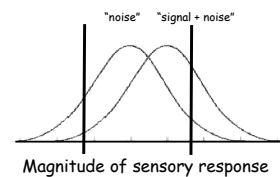
Signal detection theory = Measure **sensitivity** independent of **criterion**

Signal detection theory = Measure **sensitivity** independent of **criterion**

Let's do a quick review!

Frank, an UR radiologist, was serving on a jury. After listening to the evidence, he had to make a YES-NO decision: whether the accused was guilty. **The evidence was mostly in support of a YES decision, but far from being conclusive.** Frank's decision was NO.

Later that day, Frank was reading a mammogram. Again, Frank had to make a YES-NO decision: whether to request a biopsy. **The evidence was mostly in support of a YES decision, but far from being conclusive.** This time, Frank's decision was YES.



47

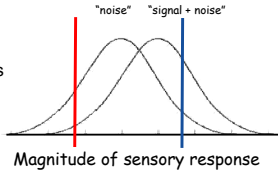
48

Signal detection theory = Measure sensitivity independent of criterion

Frank, an UR radiologist, was serving on a jury. After listening to the evidence, he had to make a YES-NO decision: whether the accused was guilty. **The evidence was mostly in support of a YES decision, but far from being conclusive.** Frank's decision was NO.

Later that day, Frank was reading a mammogram. Again, Frank had to make a YES-NO decision: whether to request a biopsy. **The evidence was mostly in support of a YES decision, but far from being conclusive.** This time, Frank's decision was YES.

- Criterion depends on
 - Personal bias
 - Cost/benefit factors
 - Signal frequency

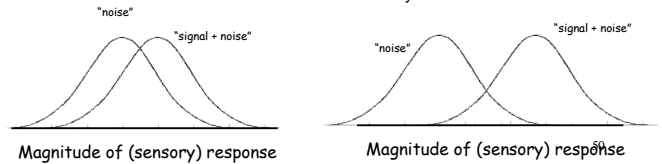


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Signal detection theory = Measure sensitivity independent of criterion

Frank was examining an MRI scan of an older patient. He had a large, easily identified, tumor in his right hemisphere, and a small, hard to see, tumor in his left hemisphere.

- Sensitivity (d') depends on
 - signal strength
 - noise strength
 - observer sensitivity

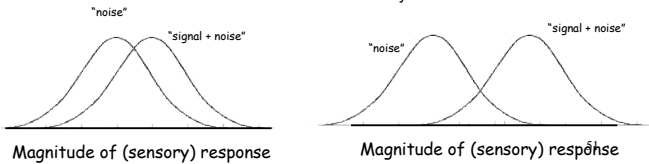


Signal detection theory = Measure sensitivity independent of criterion

Frank was examining an MRI scan of an older patient. He had a large, easily identified, tumor in his right hemisphere, and a small, hard to see, tumor in his left hemisphere.

Frank then showed the scans to a young resident. She was able to identify the large tumor, but did not notice the smaller one.

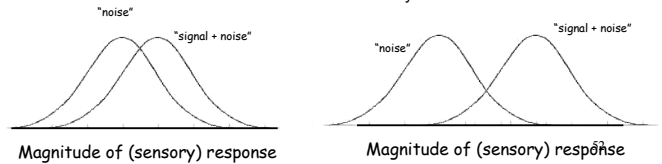
- Sensitivity (d') depends on
 - signal strength
 - noise strength
 - observer sensitivity



Signal detection theory = Measure sensitivity independent of criterion

Frank was unhappy with the X-ray machine at his new job as it was yielding X-ray images covered with many small gray dots. This made reading X-rays rather difficult. Fortunately, the department had enough funds to purchase a new X-ray machine that did not have this problem.


- Sensitivity (d') depends on
 - signal strength
 - noise strength
 - observer sensitivity



Creative applications of Psychophysics

Creative applications of Psychophysics

How can we make visible, "invisible"

		Stimulus	
		present	absent
Perceiver awareness	conscious		(*)
	unconscious	*	

How can we make visible, “invisible”

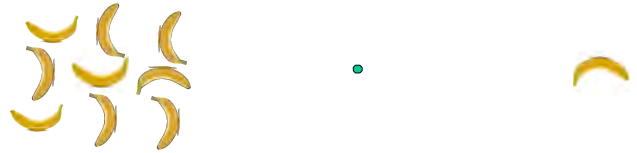
Degrading visual stimulation....



55

How can we make visible, “invisible”

Crowding....



56

How can we make visible, “invisible”

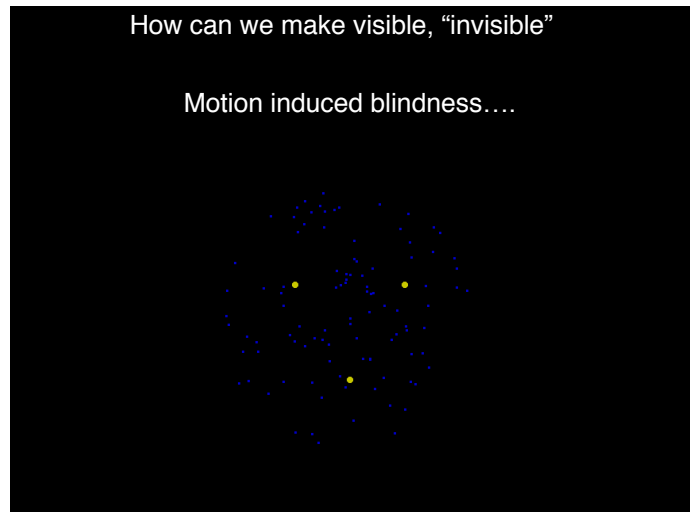
Masking....



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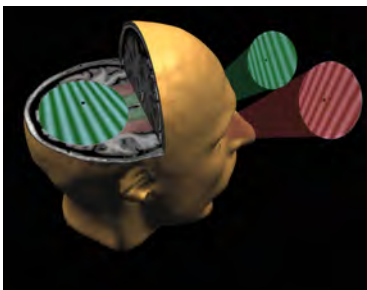
How can we make visible, “invisible”

Motion induced blindness....



How can we make visible, “invisible”

Binocular rivalry....



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How can we make visible, “invisible”

Bistable figures....



60

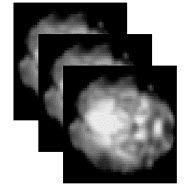
Strategies for Studying Perception

- What do things look like? (**phenomenology**)
- What are the limits of perception? (**Psychophysics**: thresholds, JND, PSEs)
- When does perception produce mistakes (study of illusions)
- Where in the brain does perception occur? (**fMRI**, EEG, TMS)
- When does perception fail? (clinical neurology)
- How does perception vary among individuals and among species?

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MRI images
brain structure



fMRI images
brain function
(BOLD signal)

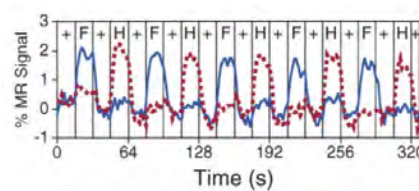
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Blood Oxygenated Level Dependent (BOLD) signal

1. Increased neural activity
2. Increased metabolic demand
3. Increased blood oxygenation
4. Higher concentration of oxy-hemoglobin level in blood, changes the magnetic susceptibility of hemoglobin.
5. Increased BOLD signal

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Study example: identifying face & house areas



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fMRI is not a magic wand

1. It measures blood flow, and not neural activity
2. BOLD signal is sluggish - peaks 5s after neural activity
3. Blind to neural changes that do not alter local metabolic demand
4. fMRI is a correlational method
 - e.g., fMRI study of difficult math problems

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