brain+cognitive sciences

CENTER FOR Brains Minds+ Machines

MIT

Tutorial

Psychophysics

Kohitij Kar
PostdoctoralAssociate
DiCarlo Lab

Just a reminder of how you might start thinking about systems neuroscience

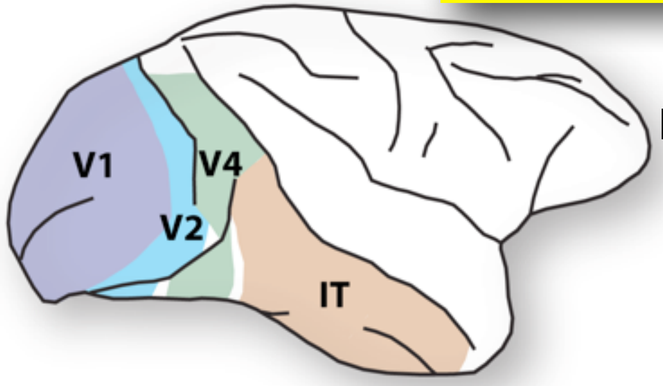
Psychophysics

Quantitative study of the relationship between physical stimuli and perception

Sensory Stimulus

(e.g. Image: glass of water)

Encoding models



Decoding models

Perception

Was there water in the glass?

Psychophysics

- **Three methods of measuring perception**
- **Two alternative forced choice experiments and Signal Detection Theory**
- **Brief intro to Amazon Mechanical Turk**

Psychophysics

- **Three methods of measuring perception**
- **Two alternative forced choice experiments and Signal Detection Theory**
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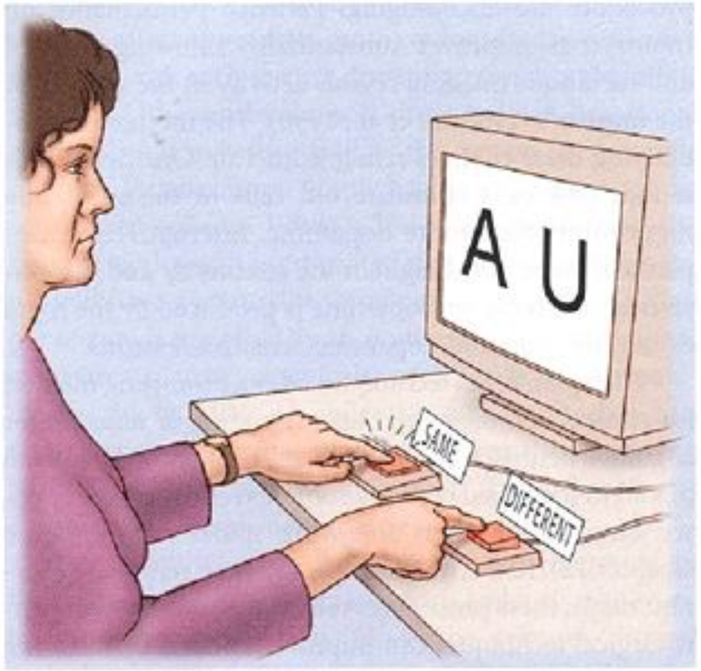
Psychophysics

Three methods for measuring perception

1. Magnitude estimation
2. Matching
3. Detection/discrimination

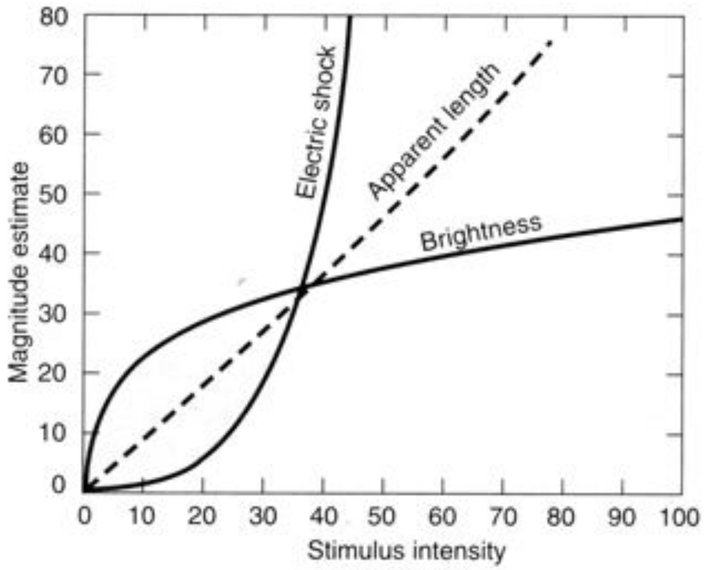


LiveSlide Site
https://isle.hanover.edu/Ch02Methods/Ch02MagnitudeEstimationLineLength_evt.html

LiveSlide Site
https://isle.hanover.edu/Ch02Methods/Ch02MagnitudeEstimation_evt.html

Magnitude estimation

Have subject rate (e.g., 1-10) some aspect of a stimulus (e.g., how bright it appears or how load it sounds)..



Steven's power law

Steven's power law

Stevens (1957, 1961) developed an equation to try to encapsulate this full range of possible data sets. It is called Stevens' Power Law

$$P = c * I^b$$

Relationship between intensity of stimulus and perception of magnitude follows the same general equation in all senses

Continuum	b	Stimulus condition
Angular acceleration	1.4	5 s rotation
Brightness	0.33	5° target in dark
Brightness	0.5	Point source
Brightness	0.5	Brief flash
Brightness	1	Point source briefly flashed
Cold	1	Metal contact on arm
Discomfort, cold	1.7	Whole-body irradiation
Discomfort, warm	0.7	Whole-body irradiation
Duration	1.1	White-noise stimuli
Electric shock	3.5	Current through fingers
Finger span	1.3	Thickness of blocks
Heaviness	1.45	Lifted weights
Lightness	1.2	Reflectance of gray papers
Loudness	0.67	Sound pressure of 3000 Hz tone
Muscle force	1.7	Static contractions
Pressure on palm	1.1	Static force on skin
Redness (saturation)	1.7	Red–gray mixture
Smell	0.6	Heptane
Tactual hardness	0.8	Squeezing rubber
Tactual roughness	1.5	Rubbing emery cloths
Taste	1.3	Sucrose
Taste	1.4	Salt
Taste	0.8	Saccharin
Thermal pain	1	Radiant heat on skin
Vibration	0.95	Amplitude of 60 Hz on finger
Vibration	0.6	Amplitude of 250 Hz on finger
Viscosity	0.42	Stirring silicone fluids
Visual area	0.7	Projected square
Visual length	1	Projected line
Vocal effort	1.1	Vocal sound pressure
Warmth	1.6	Metal contact on arm
Warmth	1.3	Irradiation of skin, small area
Warmth	0.7	Irradiation of skin, large area

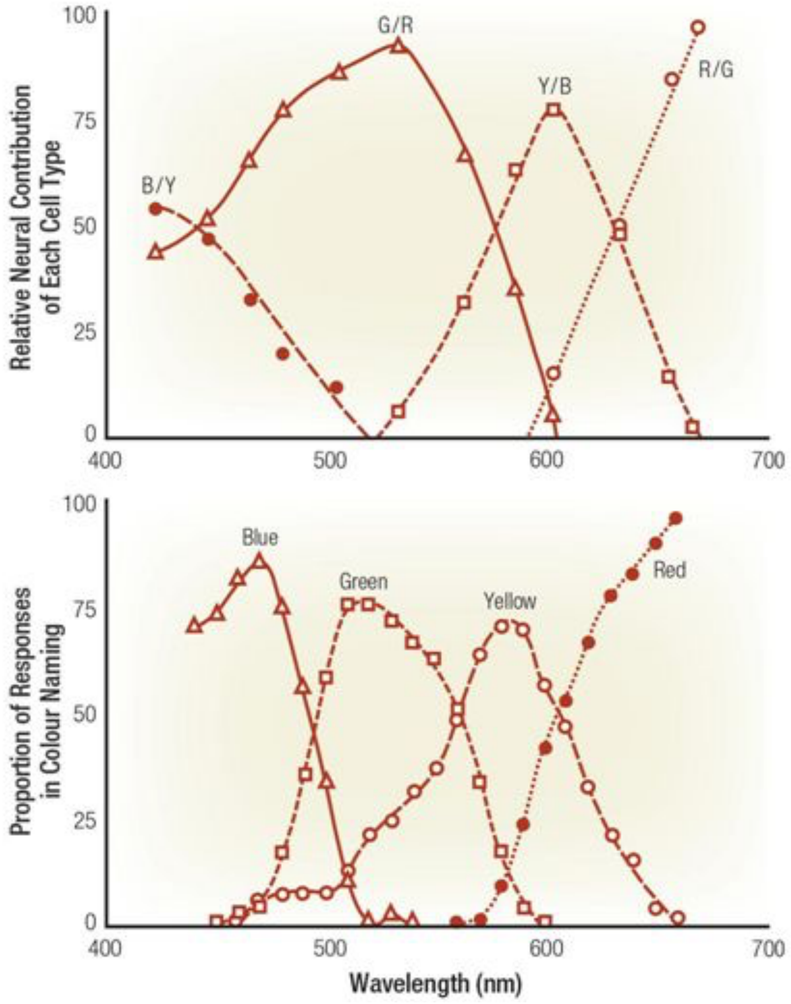
LiveSlide Site
https://isle.hanover.edu/Ch02Methods/Ch02PowerLaw_evt.html

Matching

In a matching experiment, the subject's task is to adjust one of two stimuli so that they look/sound the same in some respect.

LiveSlide Site
https://graphics.stanford.edu/courses/cs178/applets/colormatching.html

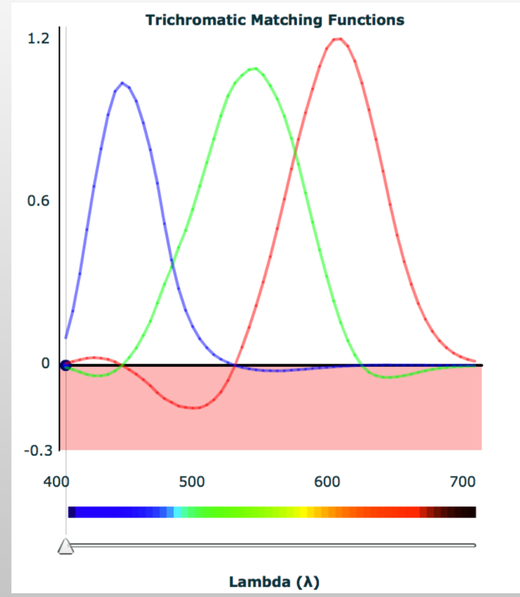
Psychophysical vs. Physiological Results



DeValois & DeValois (1975)
Monkey LGN data

Boynton & Gordon's (1965)
Color Naming Results

Present brief-flash of mono-chromatic light; Identify appearance using four color categories: RED, YELLOW, GREEN or BLUE



Detection / discrimination

In a detection experiment, the subject's task is to detect small differences in the stimuli.

Psychophysical procedures for detection experiments

- Method of adjustment.
- Yes-No/method of constant stimuli.
- Forced choice.

The method of adjustment

Ask observer to adjust the intensity of the light until they judge it to be just barely detectable

Example: you get fitted for a new eye glasses prescription. Typically the doctor drops in different lenses and asks you if this lens is better than that one.

LiveSlide Site
https://isle.hanover.edu/Ch02Methods/Ch02MethodOfAdjustment_evt.html

Terrible Method

The method of adjustment

Why?

Ask observer to adjust the intensity of the light until they judge it to be just barely detectable

Example: you get fitted for
prescription. Typically the
lenses and asks you if this
one.

- ☒ **introspectionist/subjective.**
- ☒ **subjects can be inexperienced**

Yes/no method of constant stimuli

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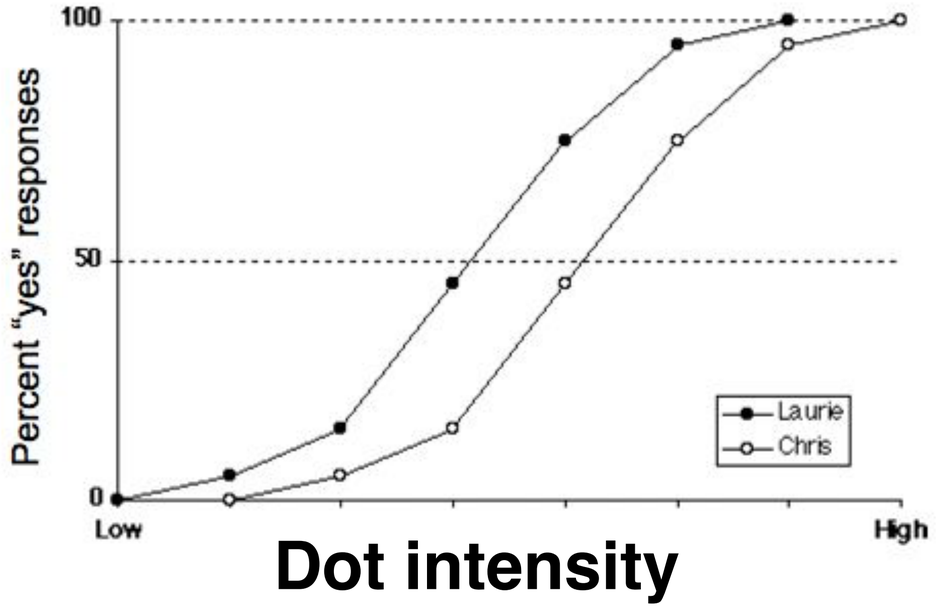
https://isle.hanover.edu/Ch02Methods/Ch02MethodOfConstantStimuli_evt.html

Yes/no method of constant stimuli



Do these data indicate that Laurie's threshold is lower than Chris's threshold?

Something is wrong!

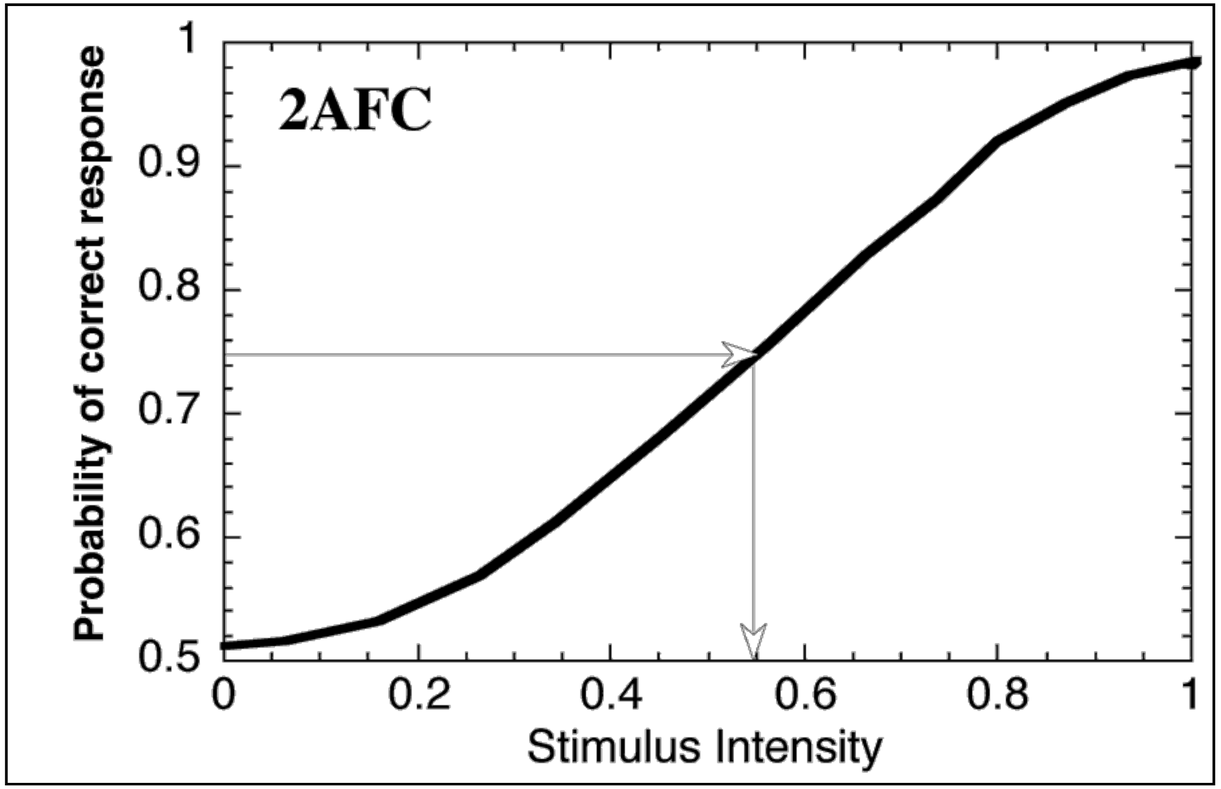
All of the trials are signal trials. There are no catch trials (blanks, noise-alone trials). We only get hits and misses. We can make no estimate of false alarms.

Forced Choice

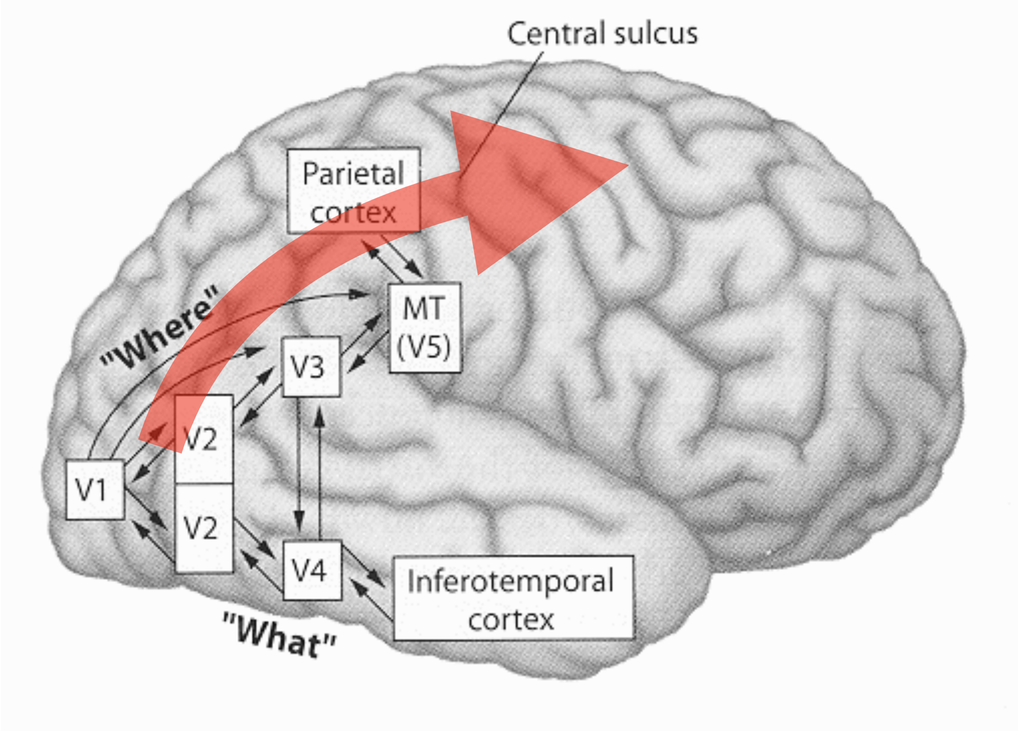
- Present signal on some trials, no signal on other trials (catch trials).
- Subject is forced to respond on every trial either ``Yes" the thing was presented'' or ``No it wasn't''. If they're not sure then they must guess.
- Advantage: With the forced choice method, we have both types of trials so we can count both the number of hits and the number of false alarms to get an estimate of discriminability independent on the criterion.

LiveSlide Site
https://isle.hanover.edu/Ch02Methods/Ch02Forced-Choice_evt.html

Two Alternative Forced Choice



The dorsal stream has been linked with motion perception



Visual Neuroscience (1996), **13**, 87–100. Printed in the USA.

A relationship between behavioral choice and the visual responses of neurons in macaque MT

K.H. BRITTEN,[1] W.T. NEWSOME,[1] M.N. SHADLEN,[1] S. CELEBRINI,[1] AND J.A. MOVSHON[2]

[1] Department of Neurobiology, Stanford University School of Medicine, Stanford
[2] Howard Hughes Medical Institute and Center for Neural Science, New York University, New York

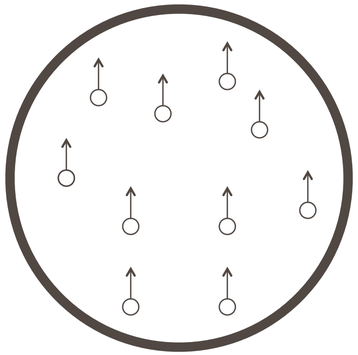
(RECEIVED February 24, 1995; ACCEPTED May 30, 1995)

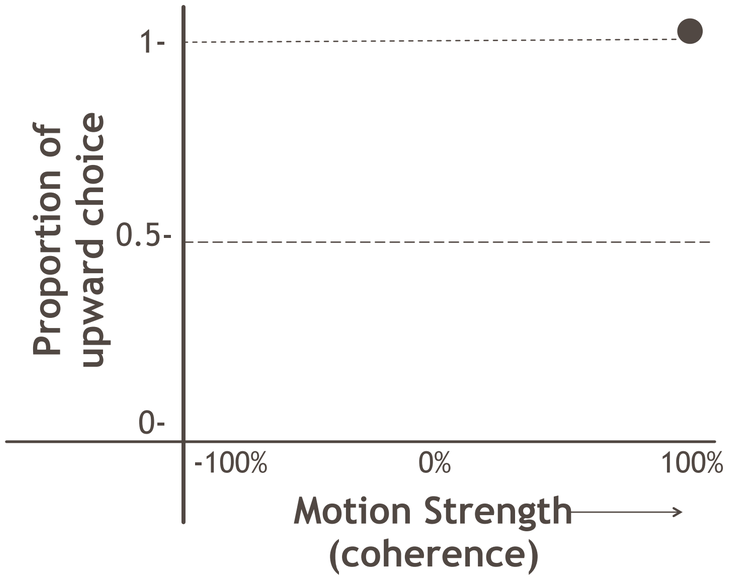
Two Alternative Forced Choice

Visual motion discrimination task

Test Stimulus

Random Dot Motion stimulus (coherence = 100 %)



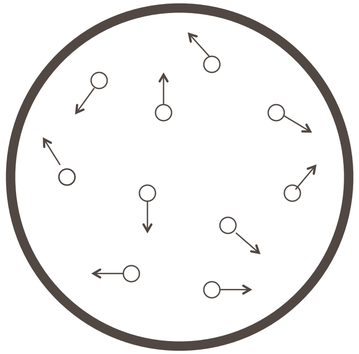


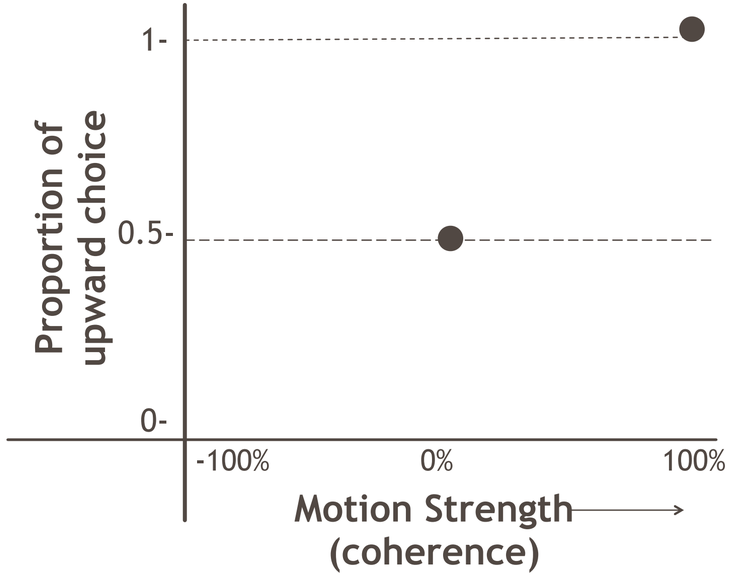
Test Stimulus

Visual motion discrimination task

Test Stimulus

Random Dot Motion stimulus (coherence = 0 %)



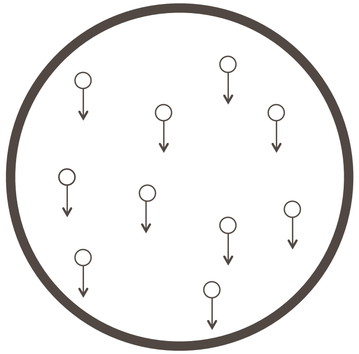


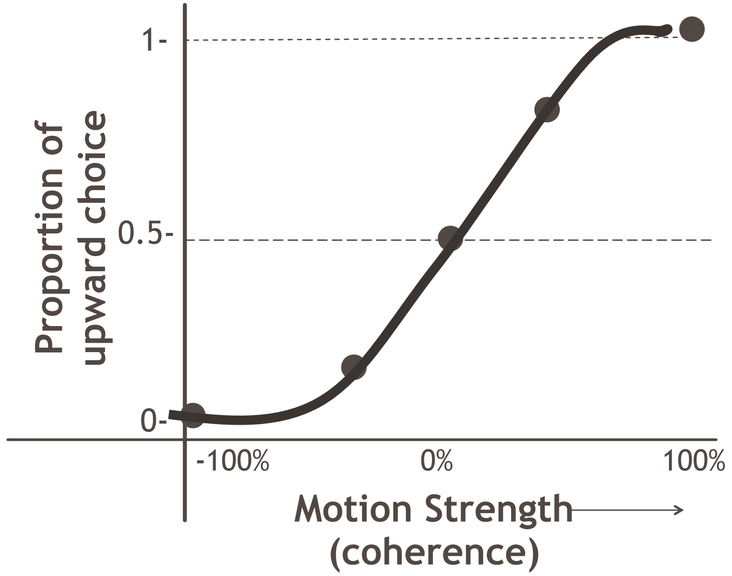
Test Stimulus

Visual motion discrimination task

Test Stimulus

Random Dot Motion stimulus (coherence = -100 %)

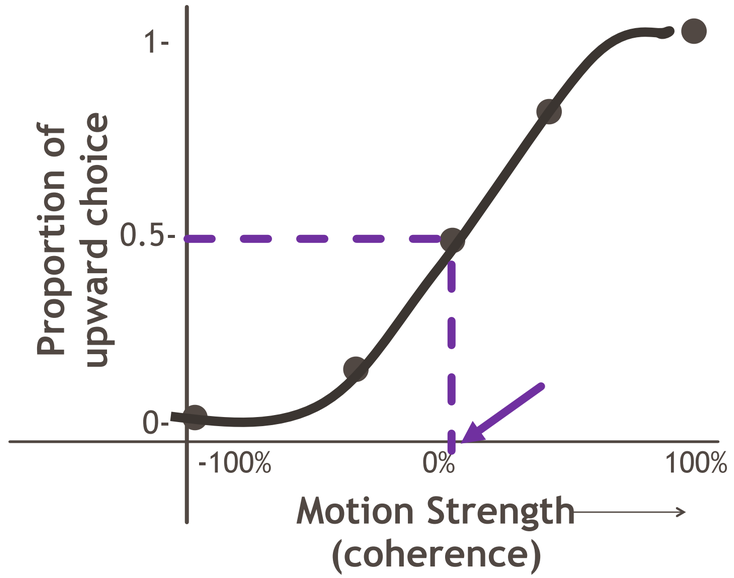




Test Stimulus

Characterizing a psychometric function

1. Point of Subjective Equality

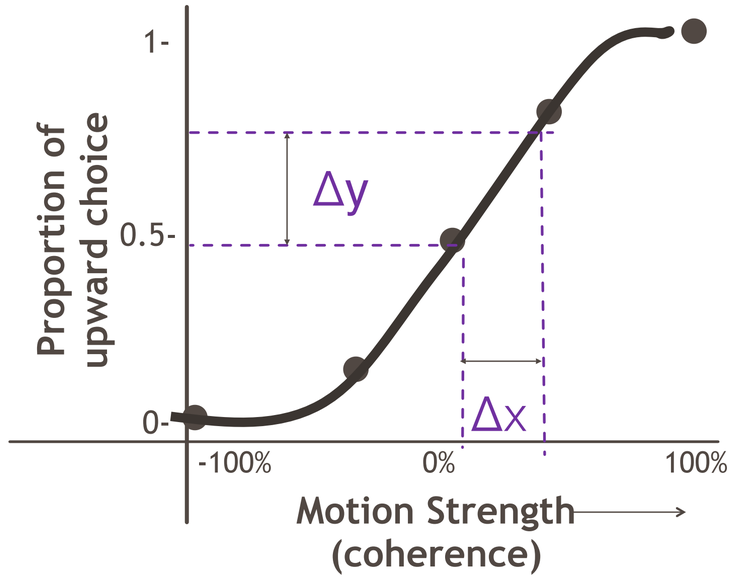


Characterizing a psychometric function

1. Point of Subjective Equality

2. Slope (Sensitivity)

$\Delta y / \Delta x$



Characterizing a psychometric function

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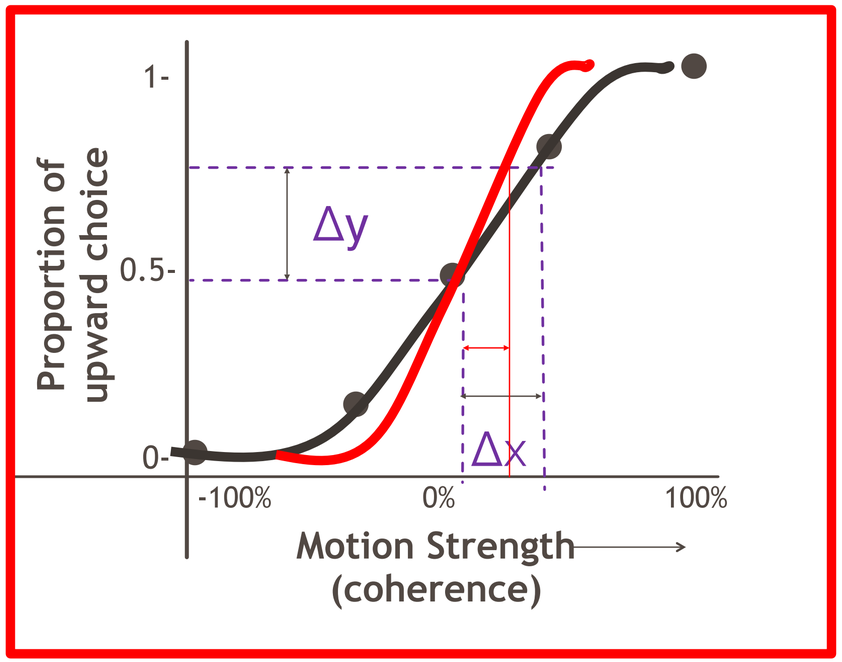
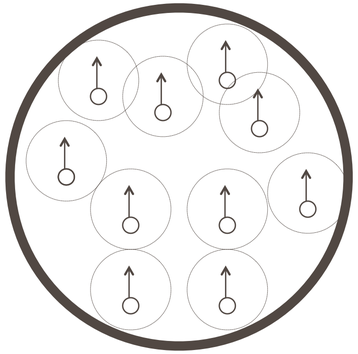



40

Motion Aftereffect – a consequence of motion adaptation

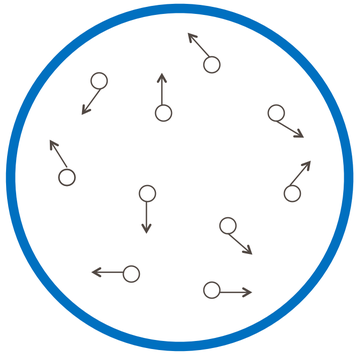
Adapter Stimulus

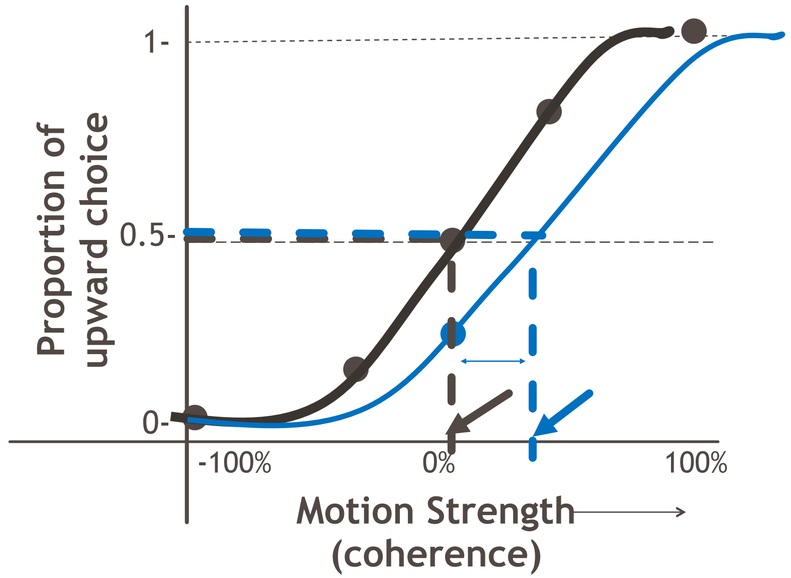
Random Dot Motion stimulus (coherence = 100 %)



Test Stimulus

Random Dot Motion stimulus (coherence = 0 %)





Test Stimulus

Psychophysics

- ✅ Three methods of measuring perception
- ⬜ **Two alternative forced choice experiments and Signal Detection Theory**
- ⬜ Brief intro to Amazon Mechanical Turk

Brief intro to signal detection theory:

Theory on how we detect signals from various sensory stimuli

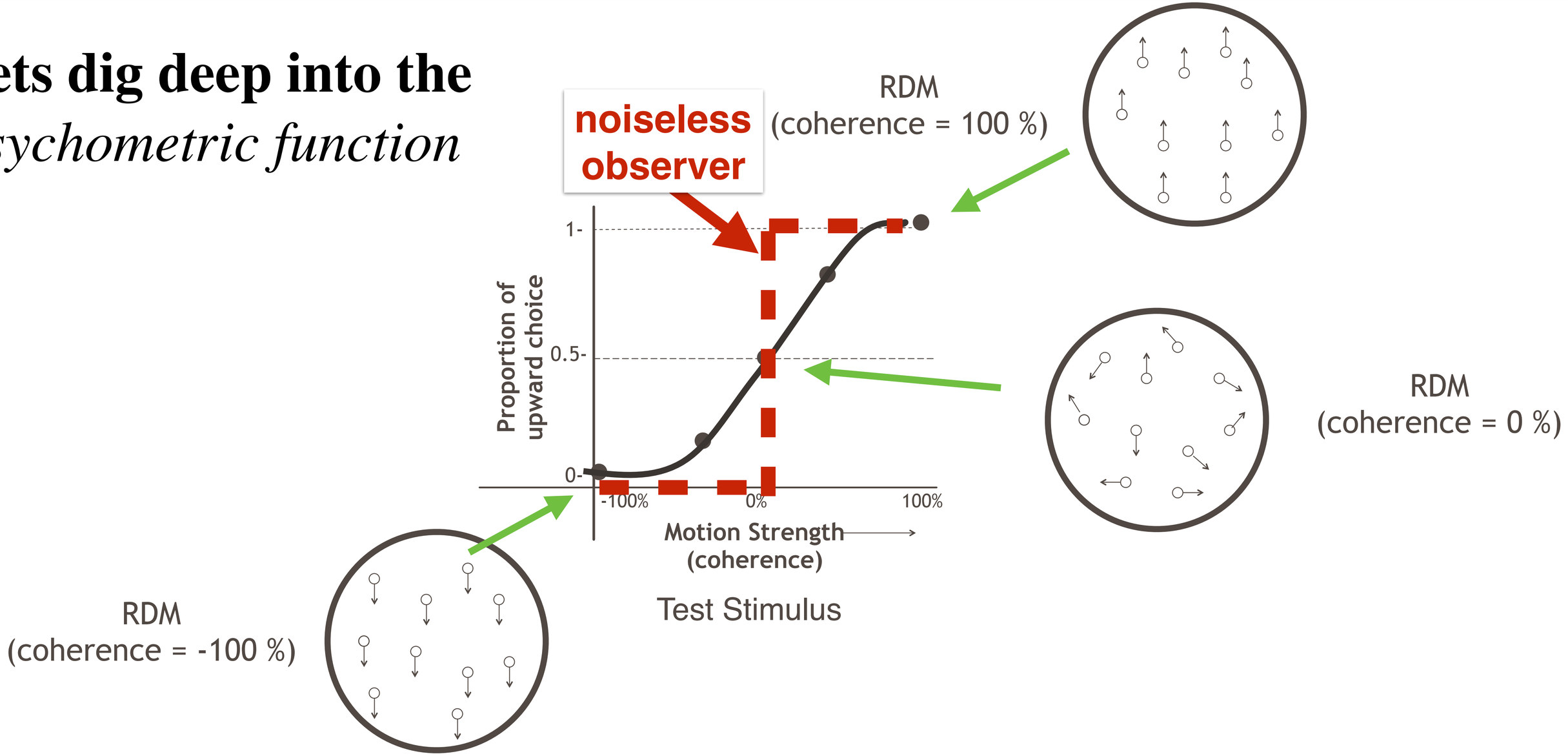
- Your ability to perform a detection/discrimination task is limited by internal noise.

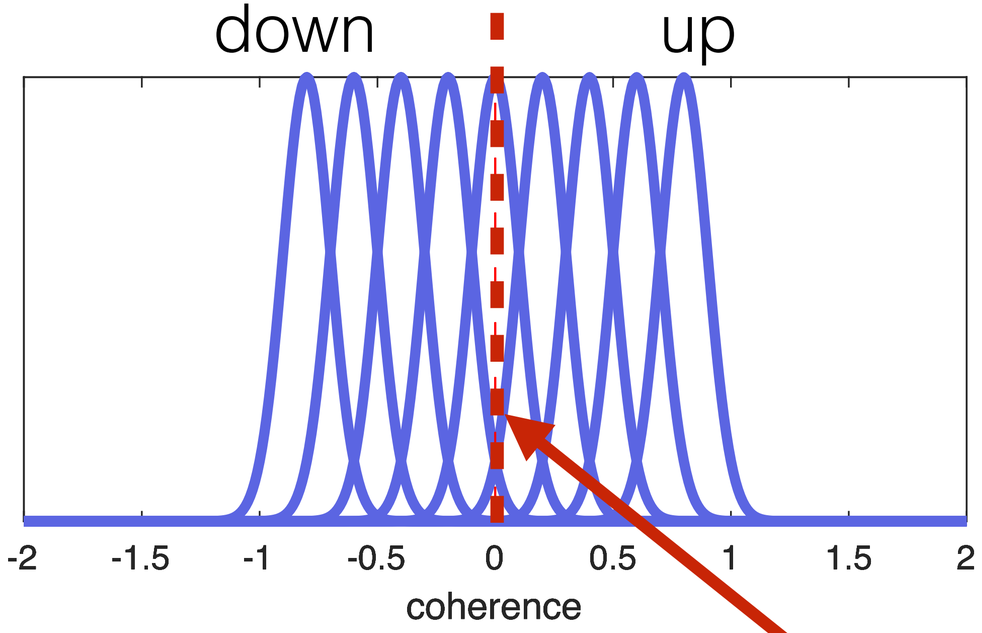
- Information (e.g., **signal strength**) and **criterion** are the 2 components that affect your decisions.
  They each have a different kind of effect on the decisions.

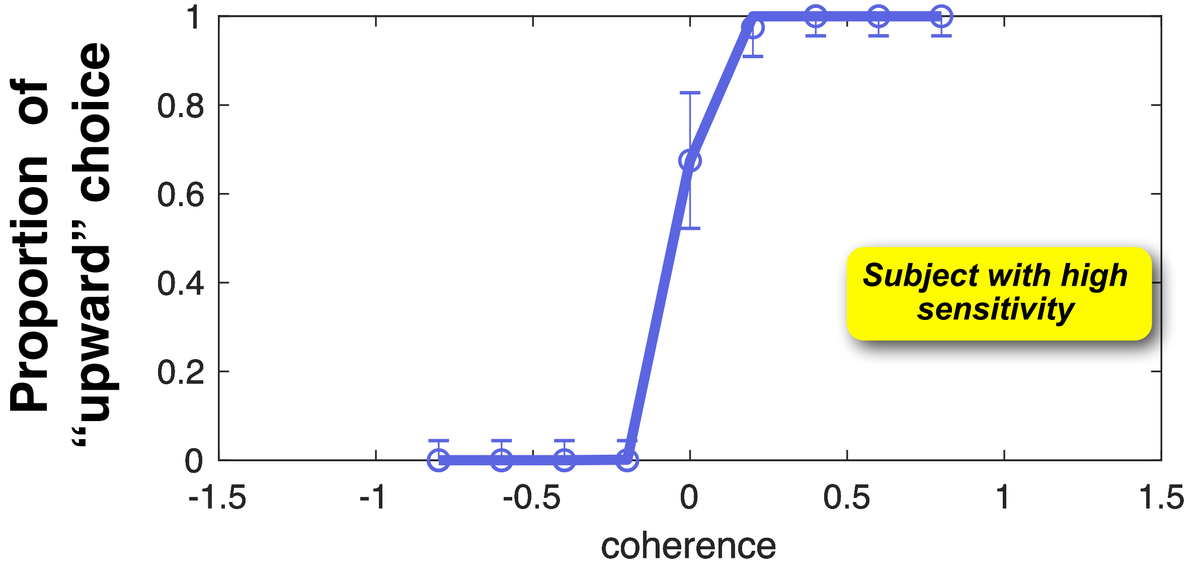
- By measuring both hits and false alarms, we can get an estimate of d' that is a measure of task difficulty and that is independent of the criterion.

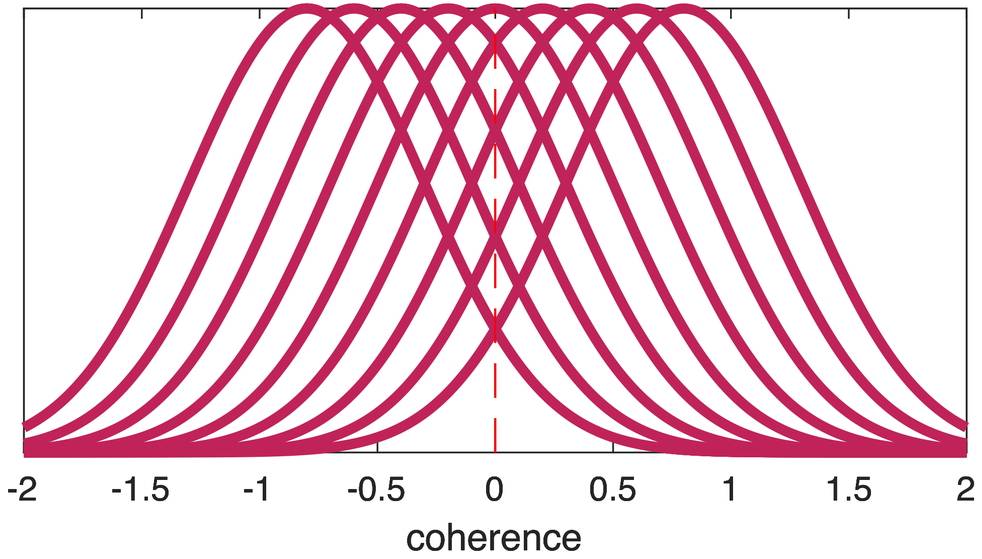
Lets revisit motion discrimination in the light of SDT

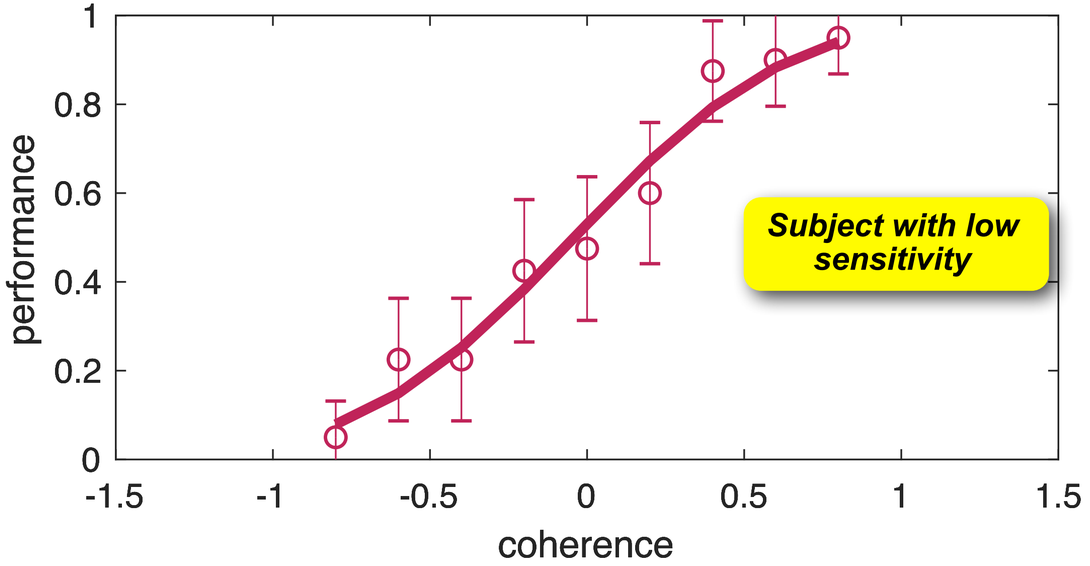
Lets dig deep into the *Psychometric function*




down
up
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
coherence
criterion

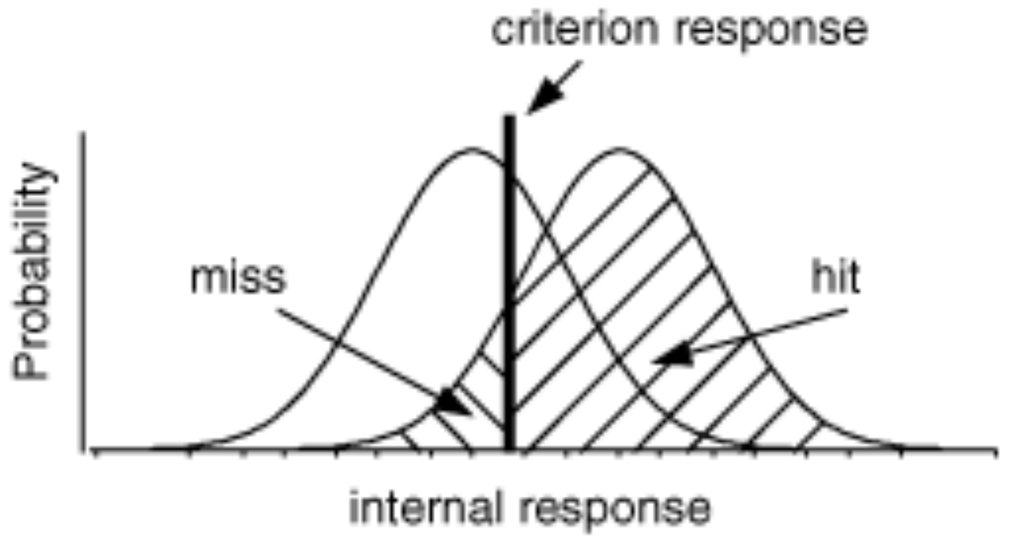

Proportion of "upward" choice
1
0.8
0.6
0.4
0.2
0
-1.5
-1
-0.5
0
0.5
1
1.5
coherence
Subject with high sensitivity

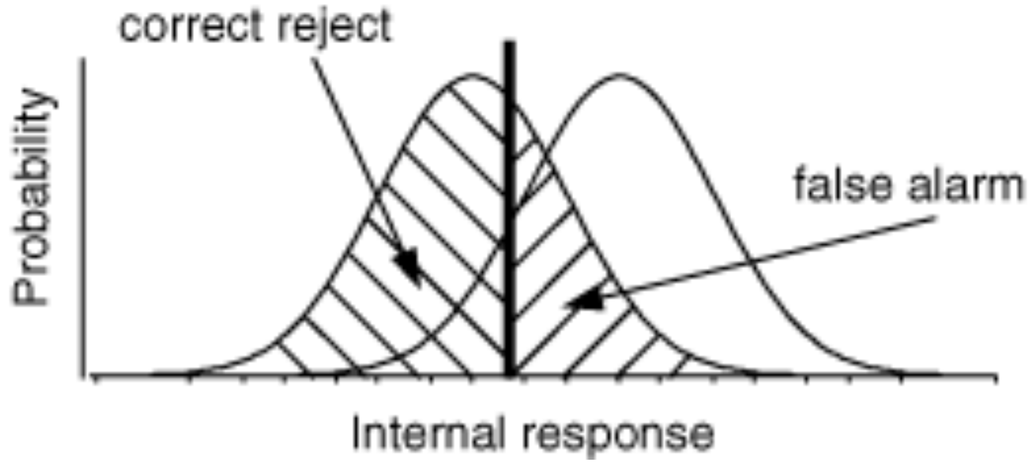

-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
coherence


performance
1
0.8
0.6
0.4
0.2
0
-1.5
-1
-0.5
0
0.5
1
1.5
coherence
Subject with low sensitivity

Signal Detection Theory

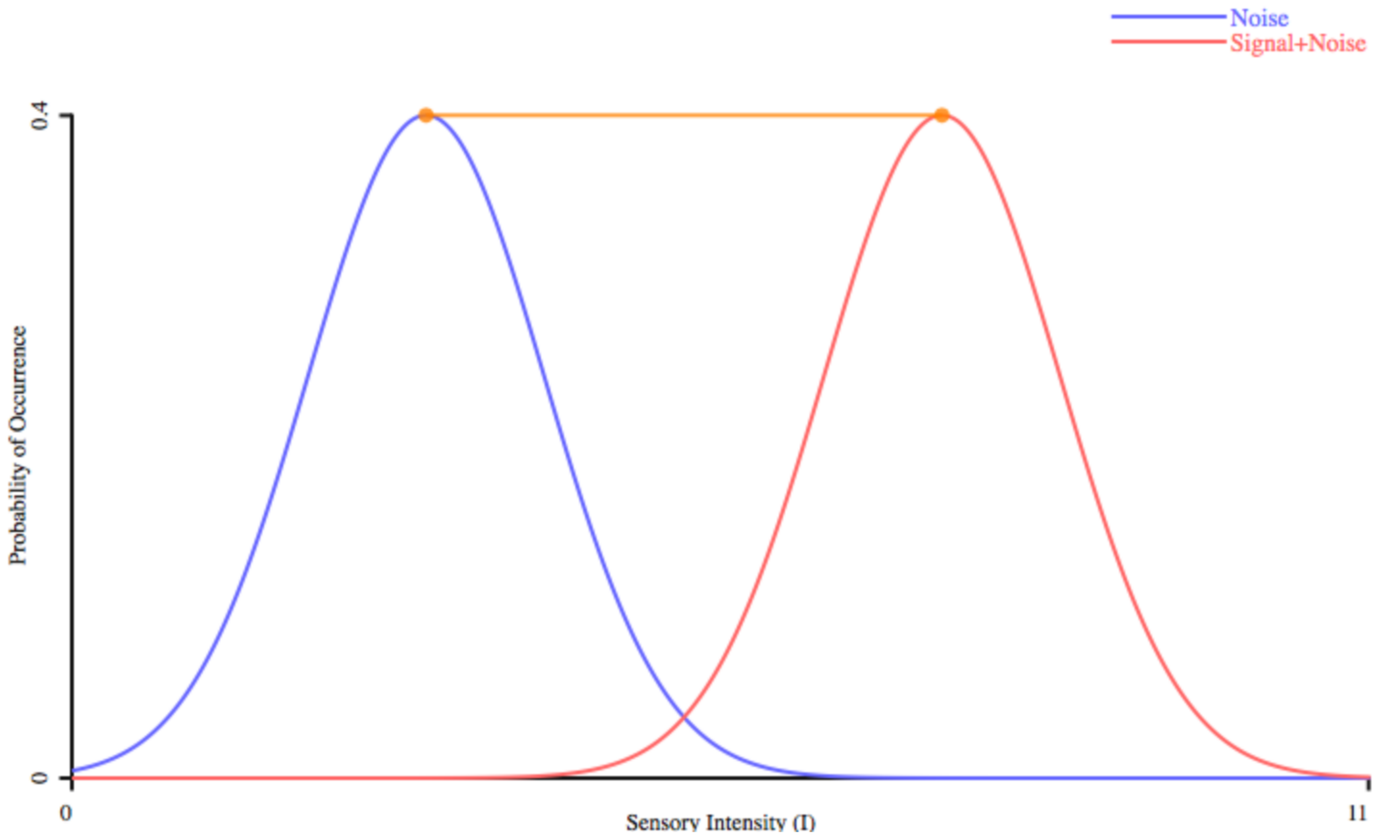
Dot Present	Subject says: Yes	Subject says: No
Yes	Hit	Miss
No	False alarm	Correct reject



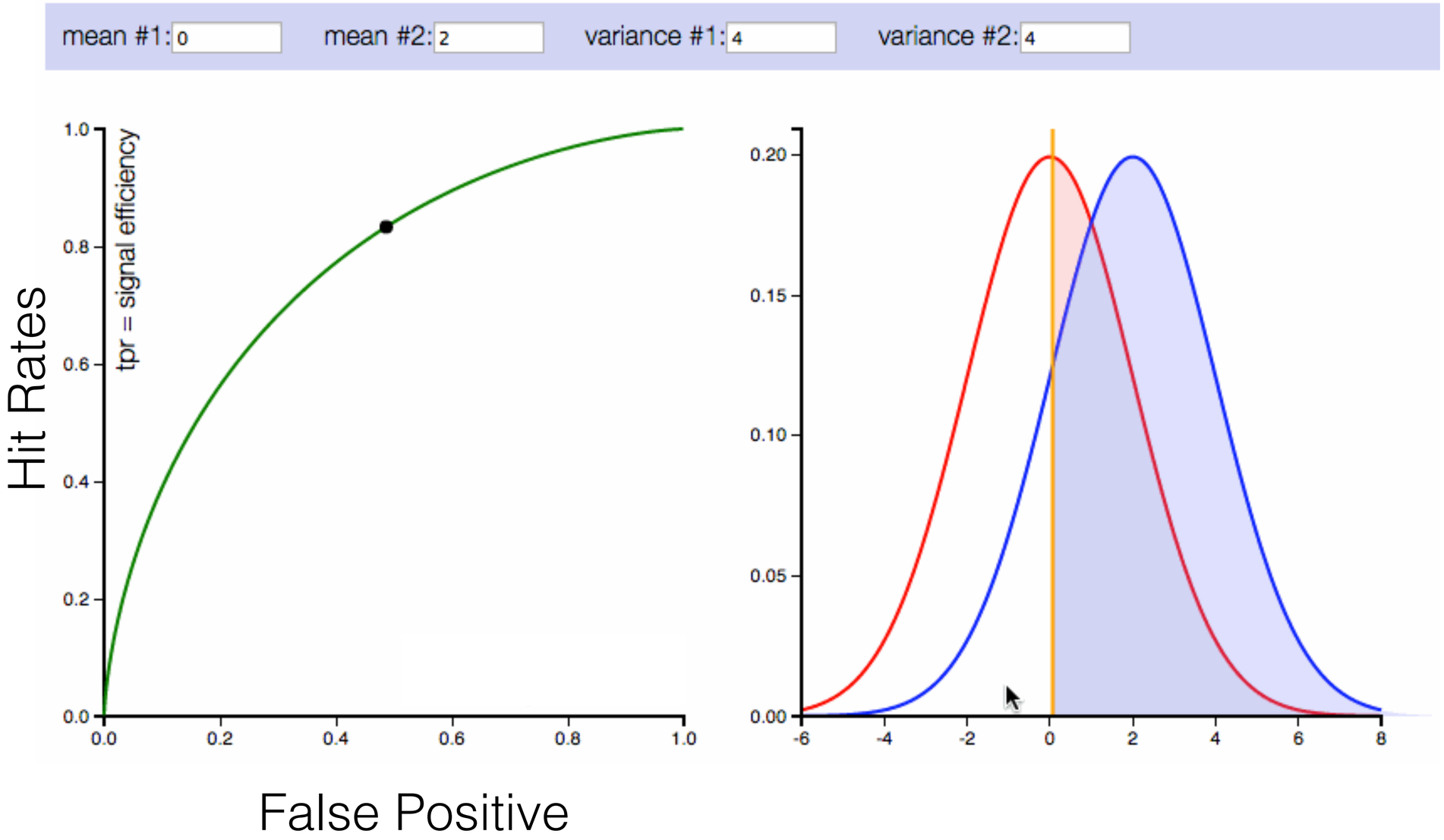


Signal Detection Theory

d' = separation / spread



Receiver Operating Characteristic (ROC) curve



Psychophysics

✅ Three methods of measuring perception

✅ Two alternative forced choice experiments and Signal Detection Theory

⬜ **Brief intro to Amazon Mechanical Turk**

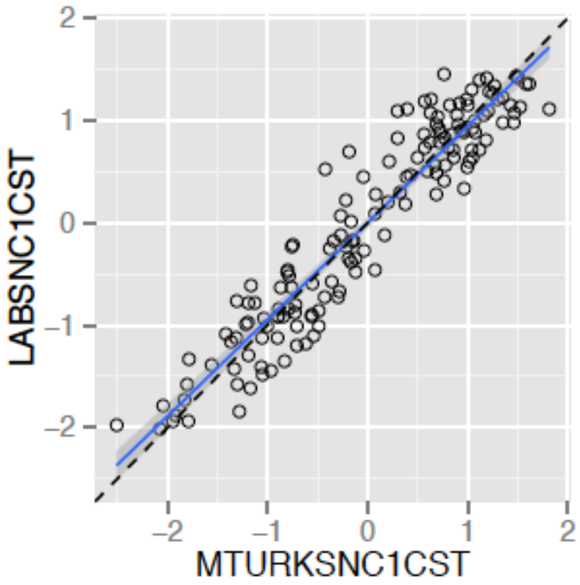
The original Turk

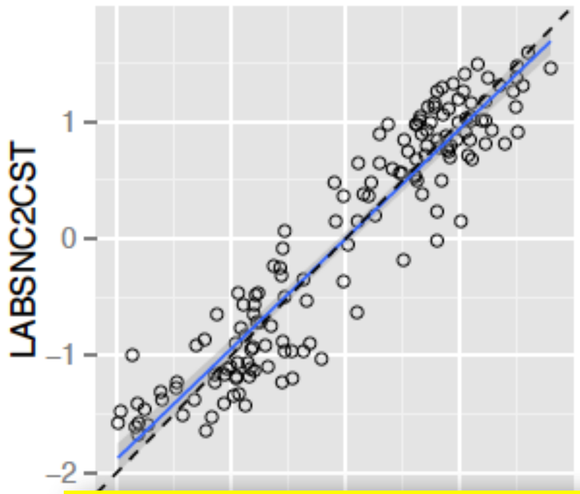
The Turk, also known as the **Mechanical Turk** was constructed and unveiled in 1770 by Wolfgang von Kempelen (Hungarian: Kempelen Farkas; 1734–1804) to impress the Empress Maria Theresa of Austria.

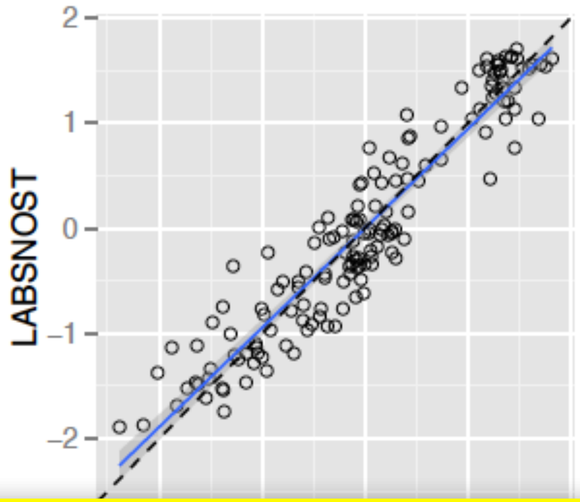
It was a fake chess-playing machine constructed in the late 18th century. From 1770 until its destruction by fire in 1854 it was exhibited by various owners as an automaton. The Turk was in fact a mechanical illusion that allowed a human chess master hiding inside to operate the machine.

LiveSlide Site
https://requester.mturk.com/

Quality of amazon mechanical turk data







At high levels of repetitions, mturk data is consistent with in-lab data

THANKS …