COMP 546

Lecture 13

Psychophysics

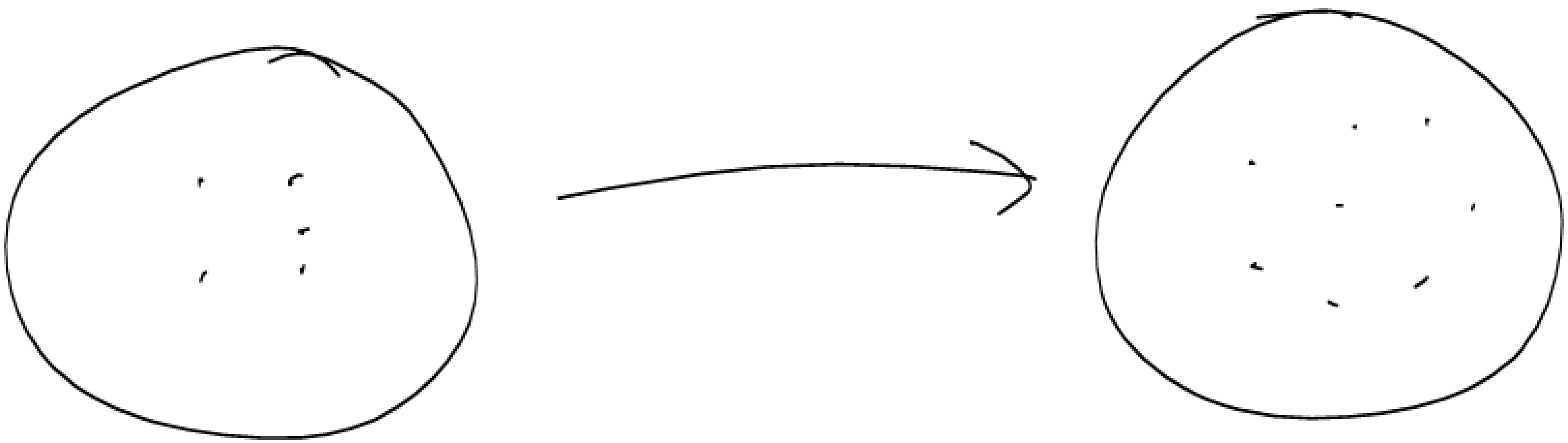
Thurs. Feb. 22, 2018

How do we measure how well someone can perform a vision task? E.g. How well can one *discriminate …*

- color or luminance (intensity)
- orientation
- depth from binocular disparity
- 2D velocity
- 3D surface shapes (slant, tilt, curvature, …)
- …..

"Psychophysics" :   (loose definition)

the study of mappings from physical variables to perceptual variables, *as measured by behavioral response*



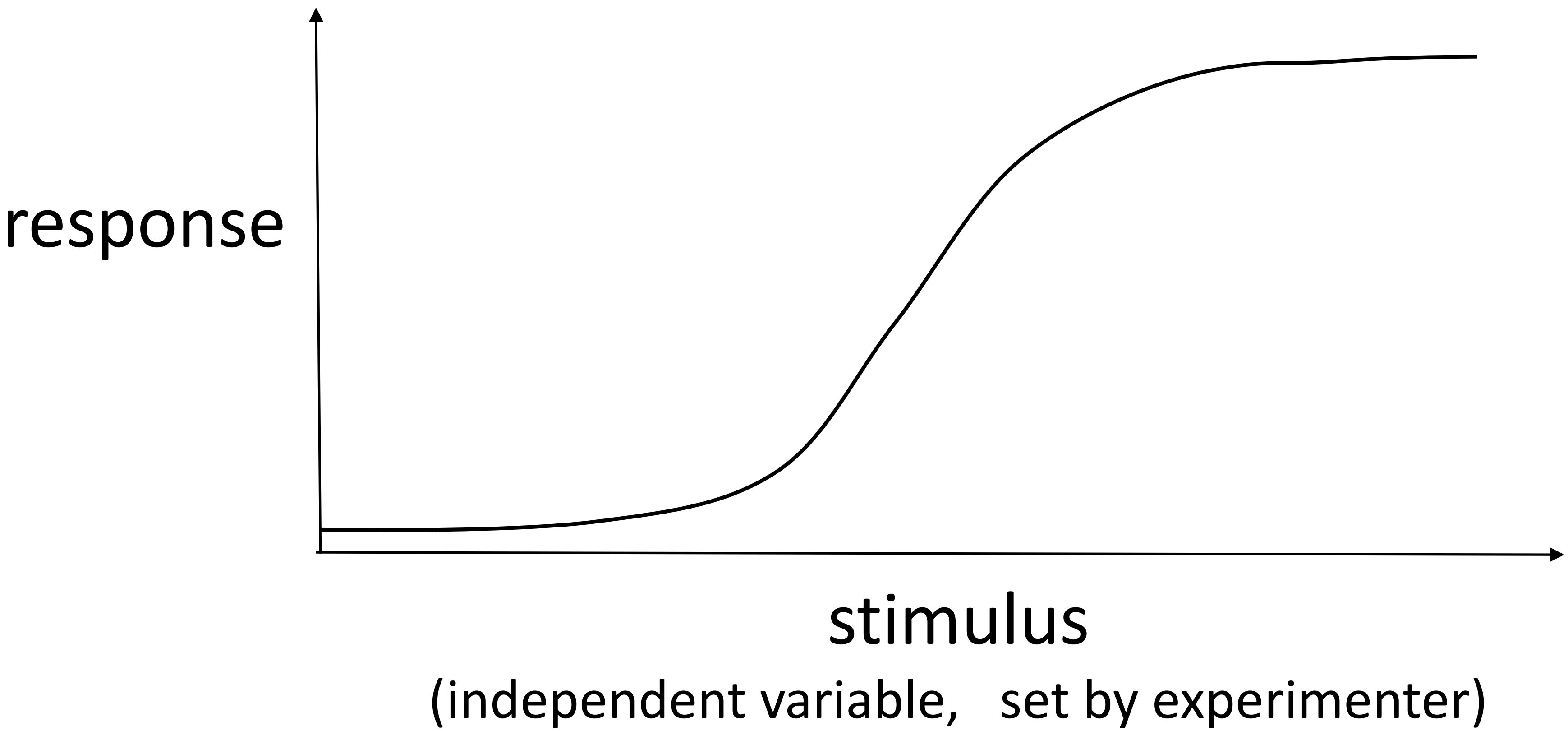
stimulus

(physical)

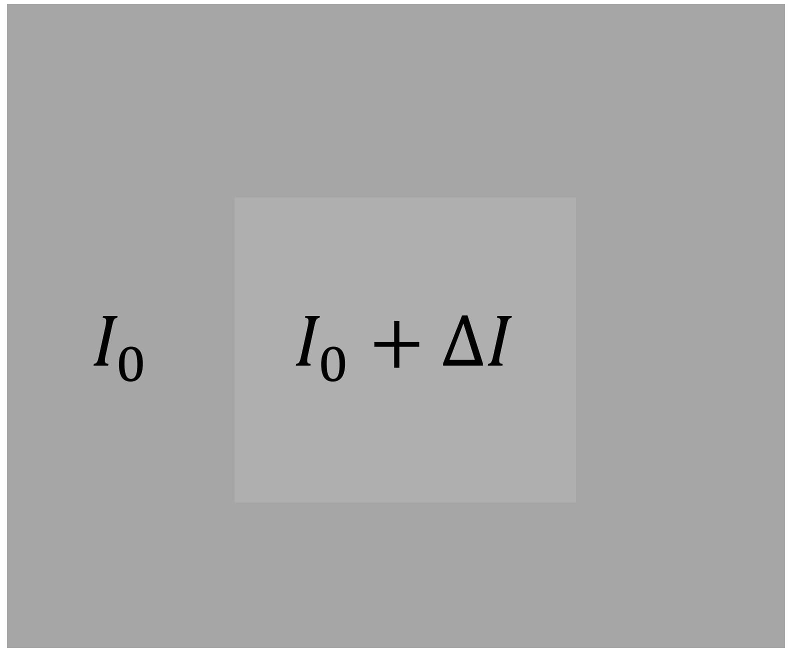
response

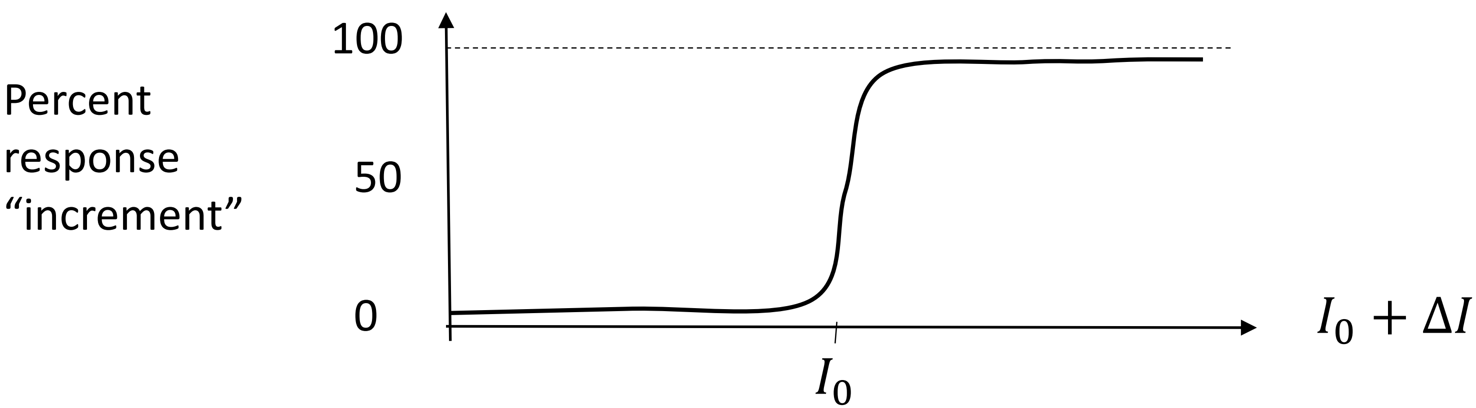
(perceptual --
measured by behavior)

Psychometric function

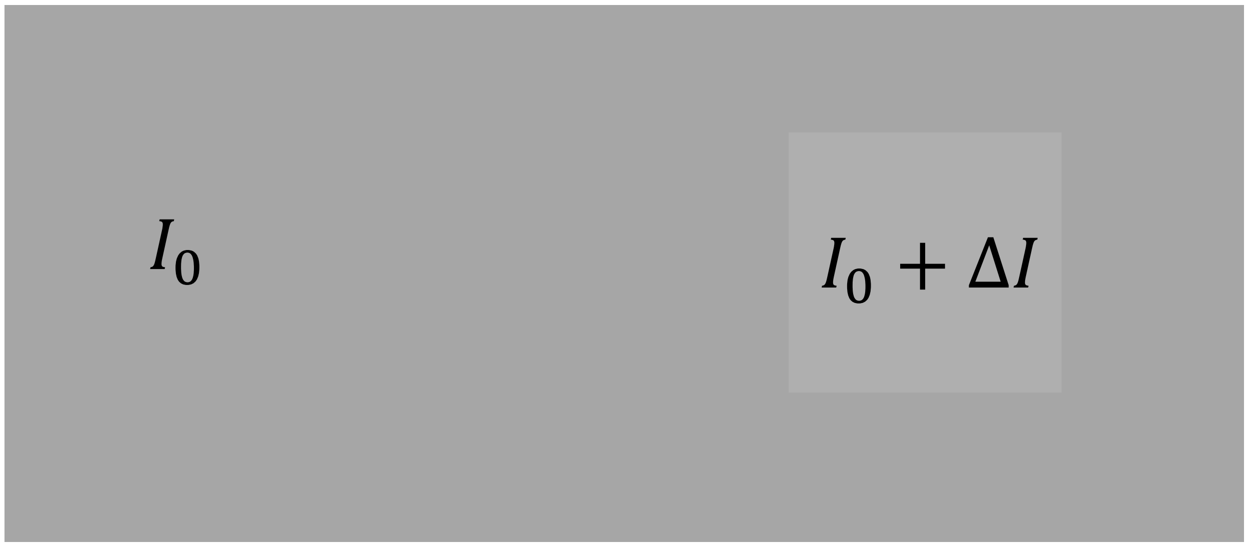


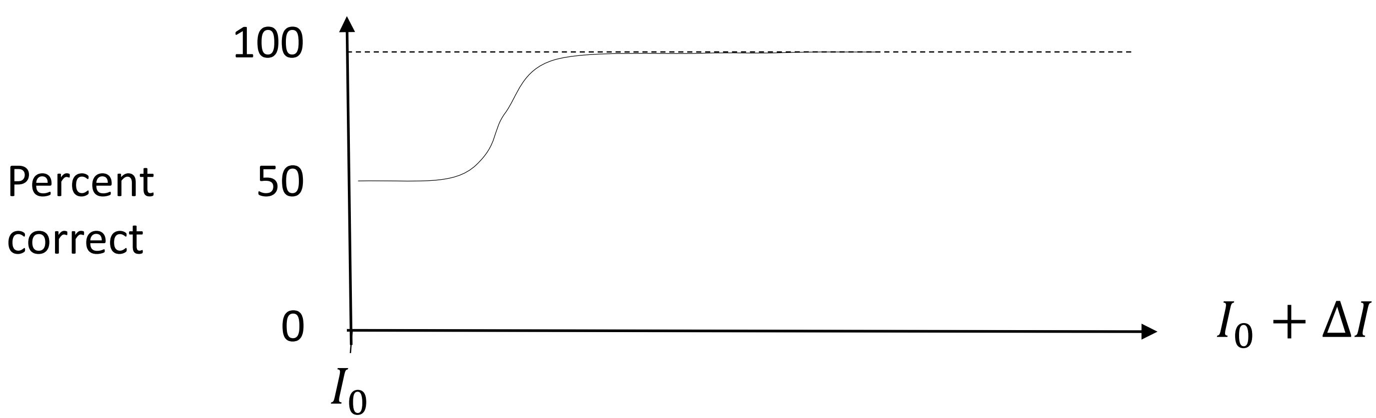
Example 1a: discriminate brightness (increment or decrement?)





Example 1b: detect a brightness increment (left or right?)





Q: Why are psychometric curves not step functions ?

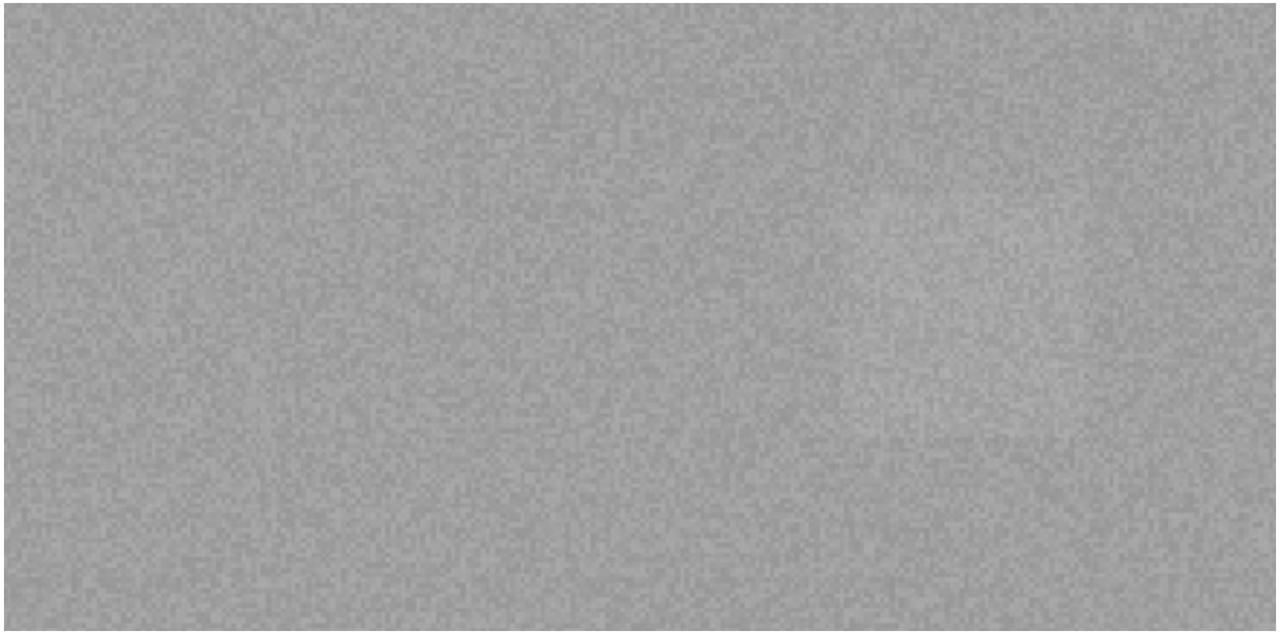
A:

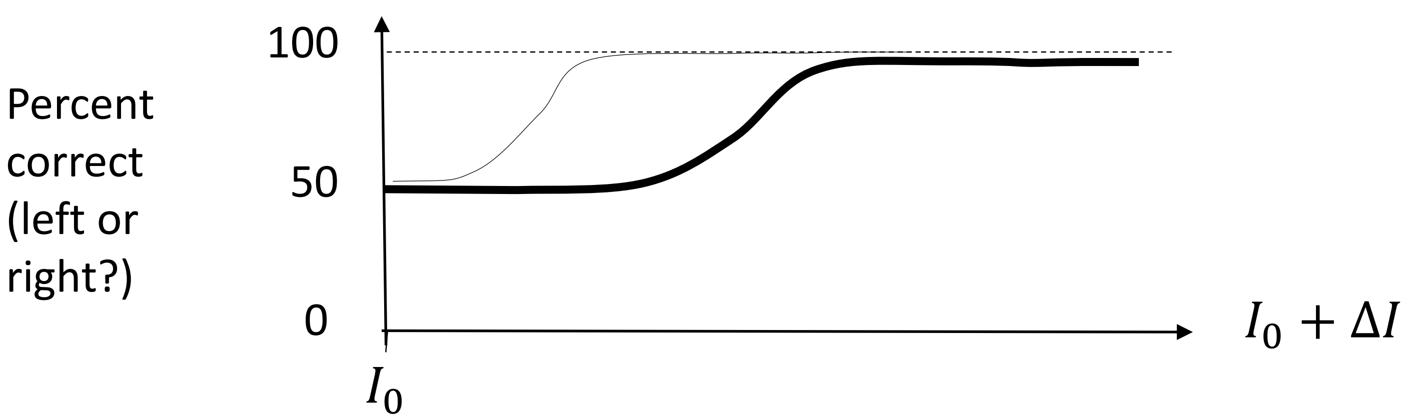
Q: Why are psychometric curves not step functions ?

A:

- Noise/randomness in the display or stimulus
- Noise/randomness in the sensors/brain
- Limited resolution: finite samples
- Subjects press the wrong button   (stop paying attention)

Example 1c: detect a brightness increment left or right? *(with added noise)*





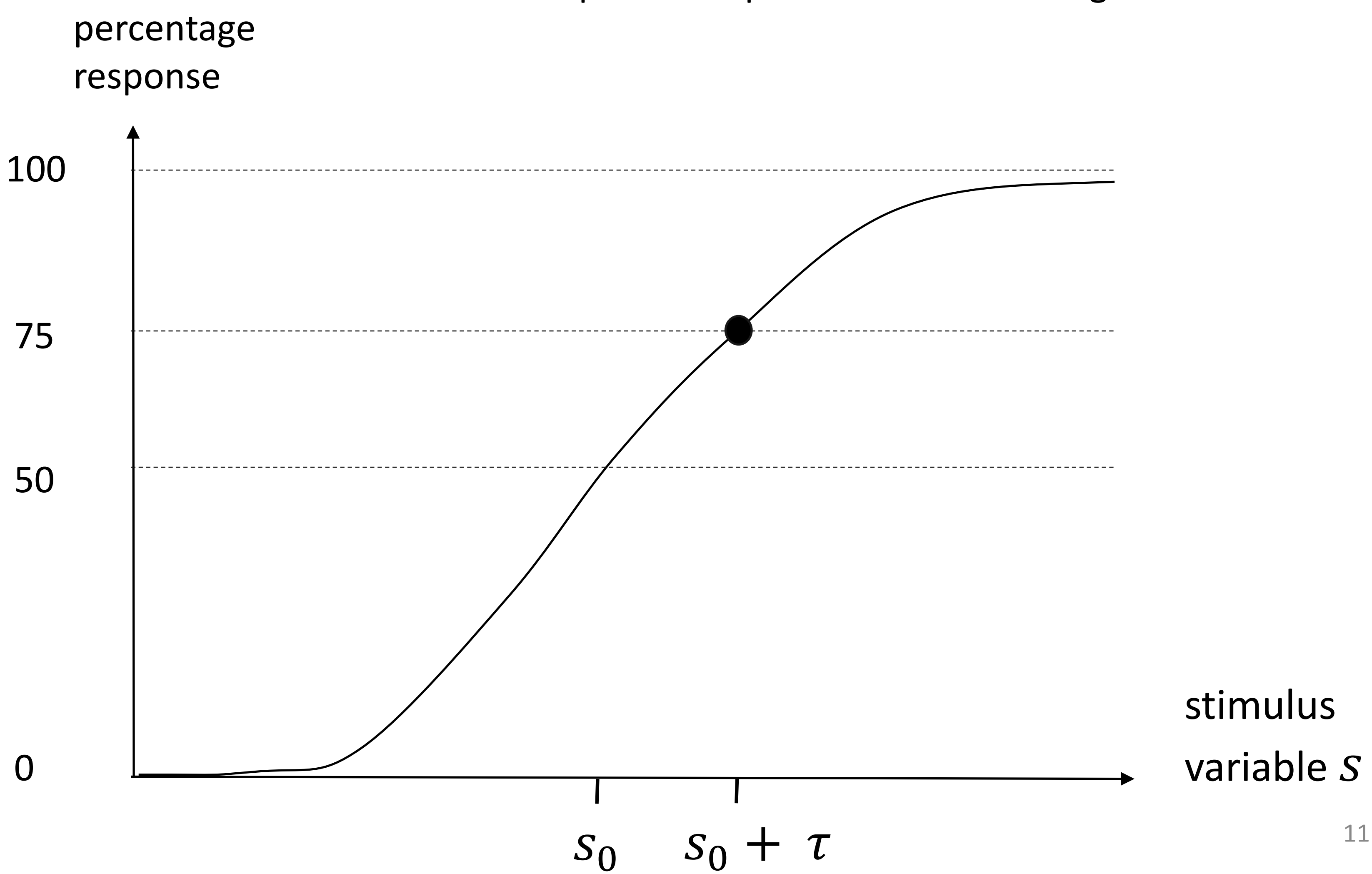
Ideal Observer

Even an “ideal observer” who knows the code used to generate the images would not get 100% correct, because code uses a random number generator.

One can compare human performance to that of an ideal observer.
(Technical details omitted.)

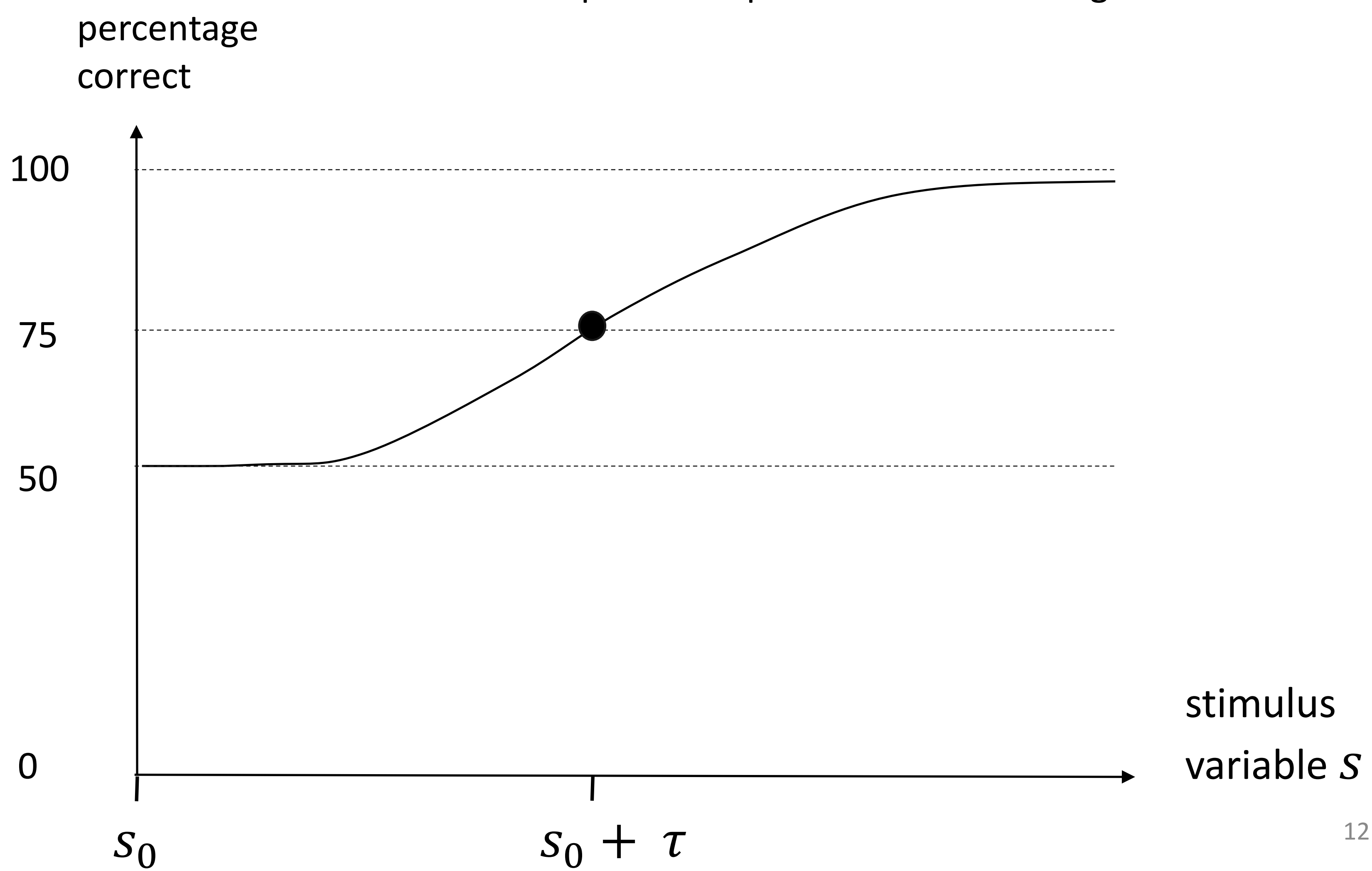
Psychophysical threshold τ

Defines the stimulus level that gives a particular performance level e.g. 75% correct.

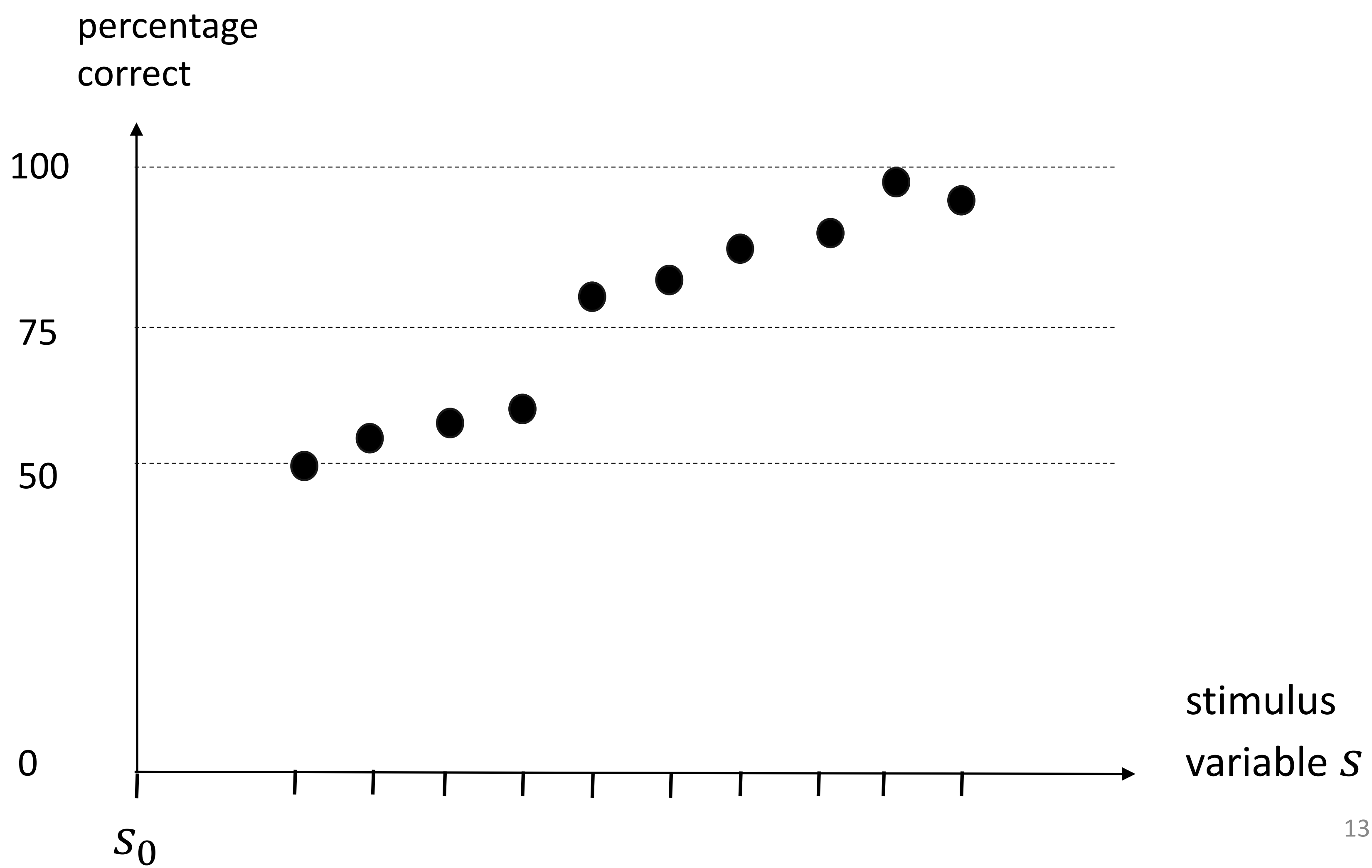


Psychophysical threshold τ

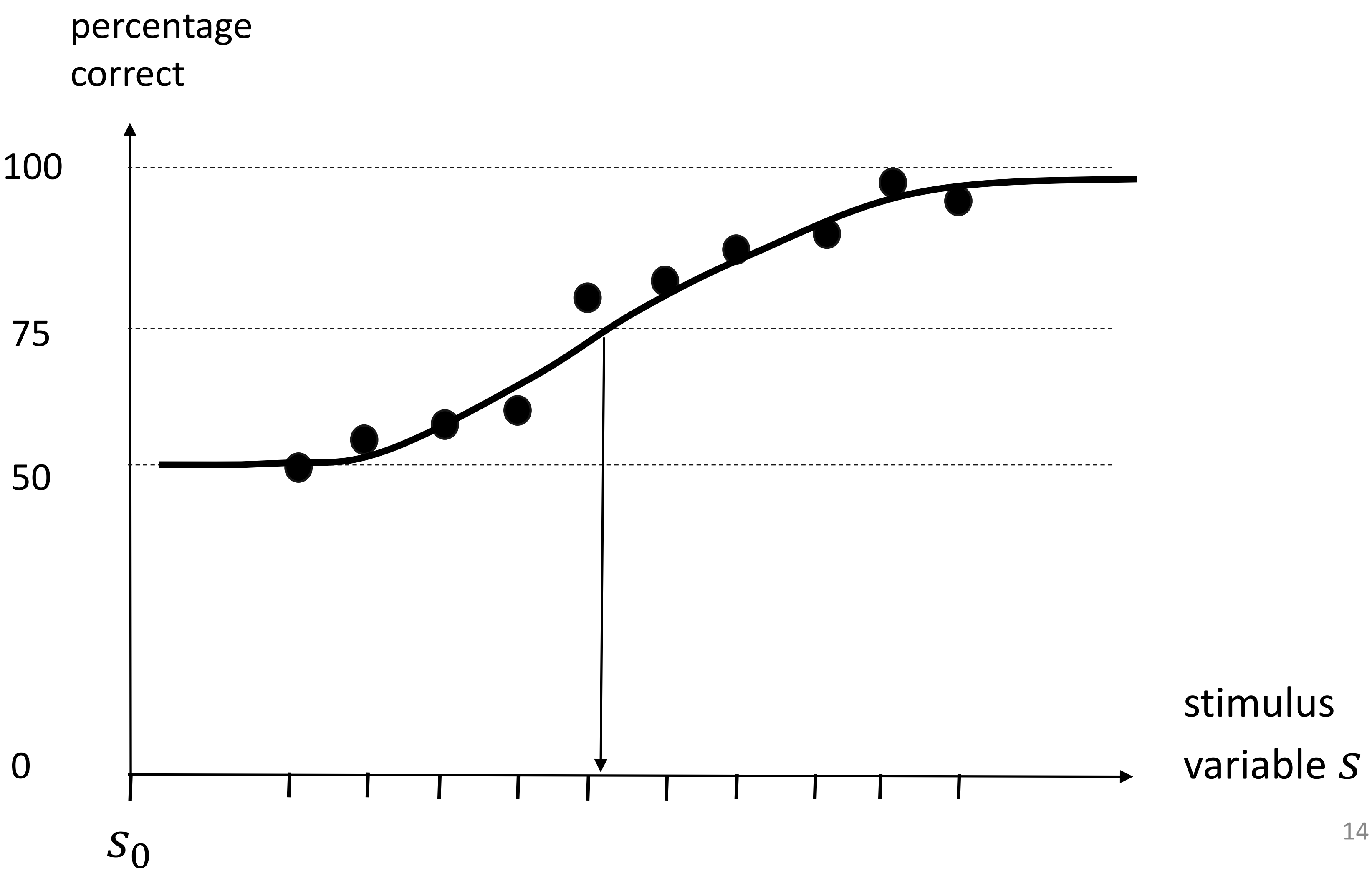
Defines the stimulus level that gives a particular performance level e.g. 75% correct.



How to estimate a threshold τ ?



How to estimate a threshold τ ?
Fit a (sigmoid shaped) curve.



Overview

- Psychometric function
- Threshold
- Examples
  - Contrast Sensitivity
  - Depth discrimination (binocular disparity)
  - 2D Motion
  - Slant from texture

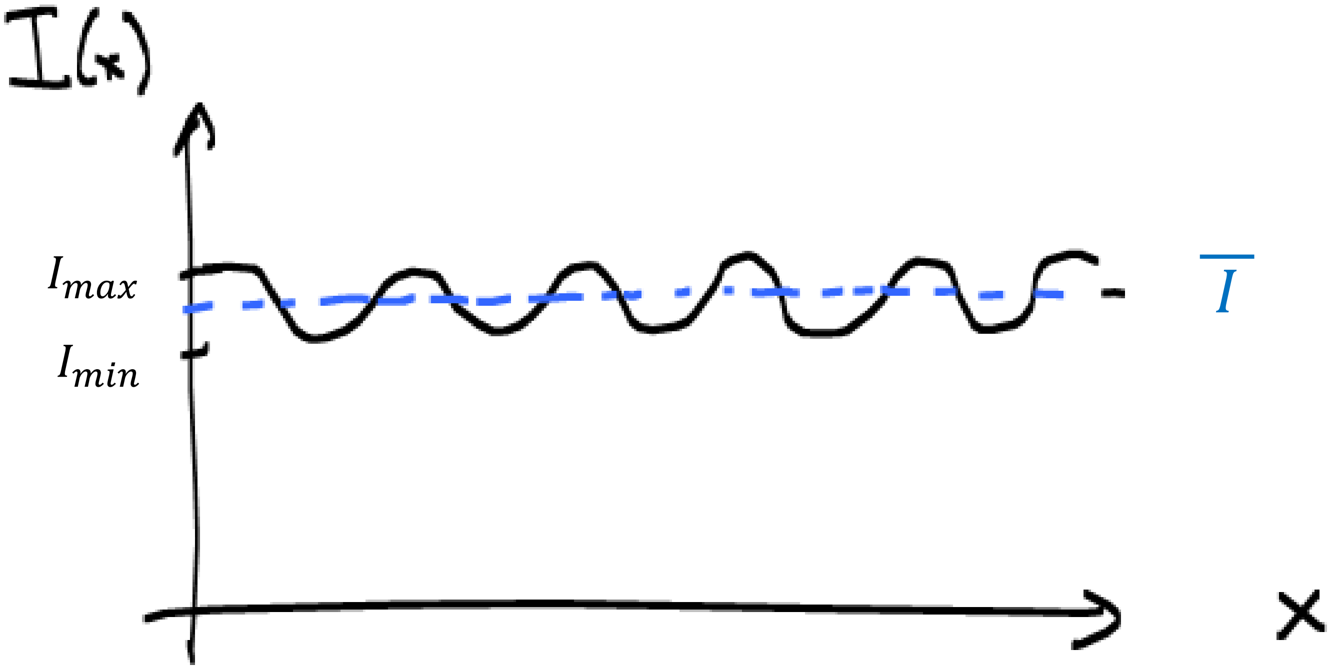
Luminance Contrast revisited (Assignment 1)

Michelson Contrast $\equiv \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$

It is always between 0 and 1.

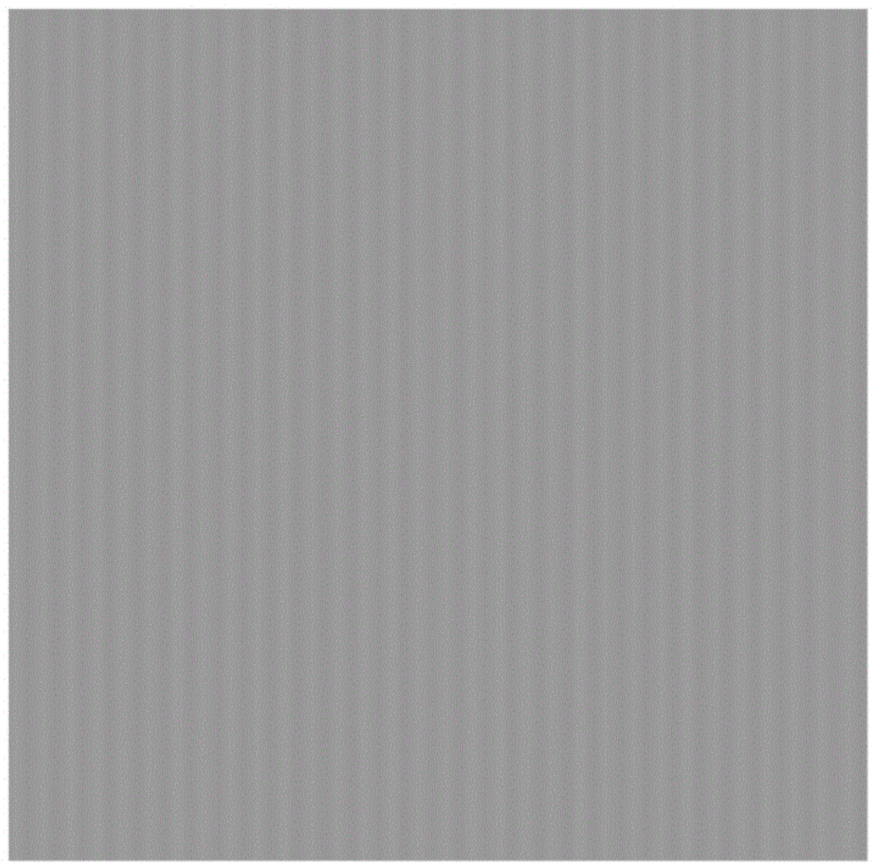
Michelson contrast is commonly used for sine functions.

$$\frac{\Delta I}{\overline{I}} = \frac{(I_{max} - I_{min})/2}{(I_{max} + I_{min})/2}$$



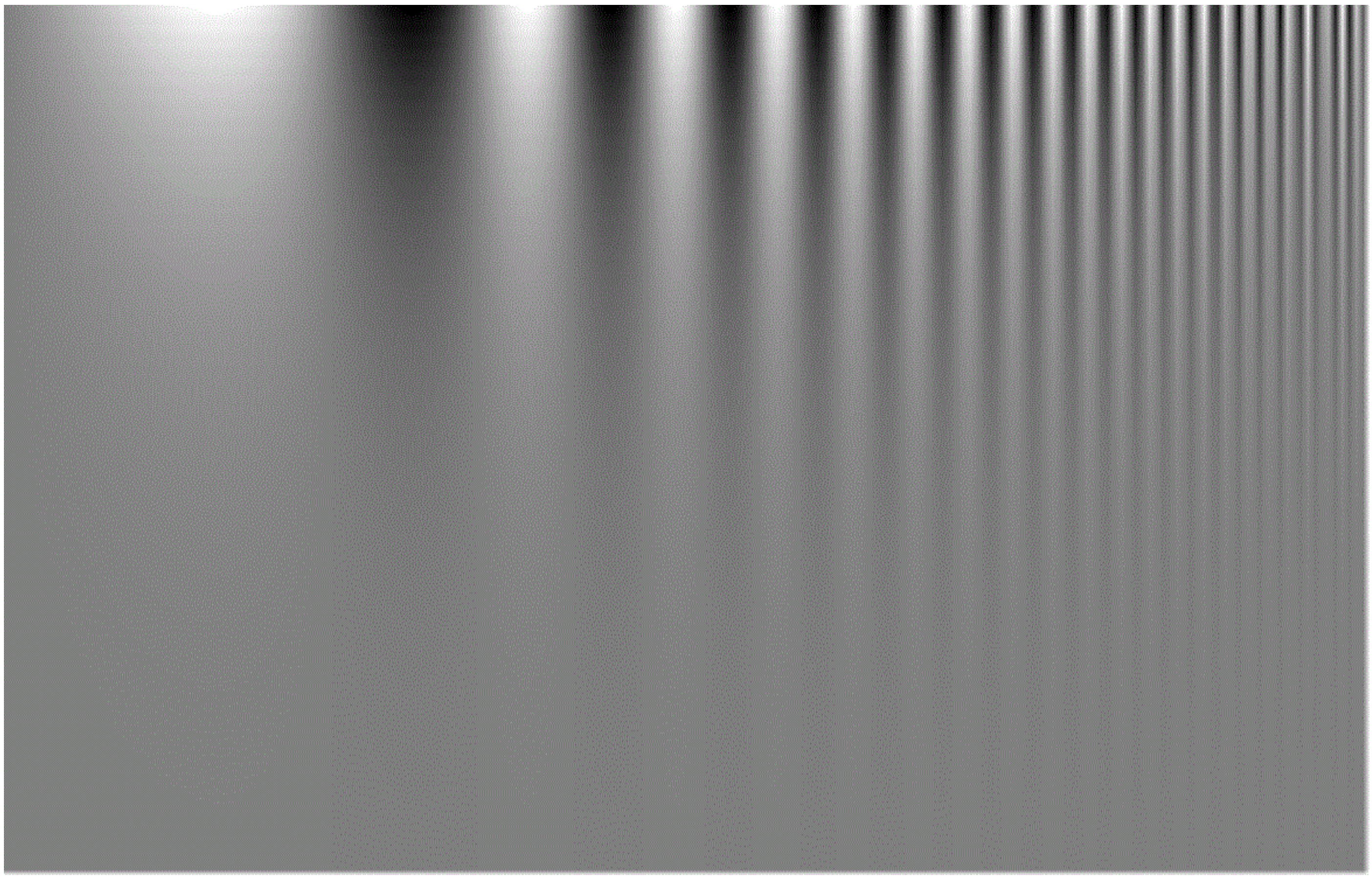
Example : Detecting a 2D sinusoid grating
(vertical or horizontal?)

Michelson contrast is 0.02



Luminance contrast thresholds depend on spatial frequency

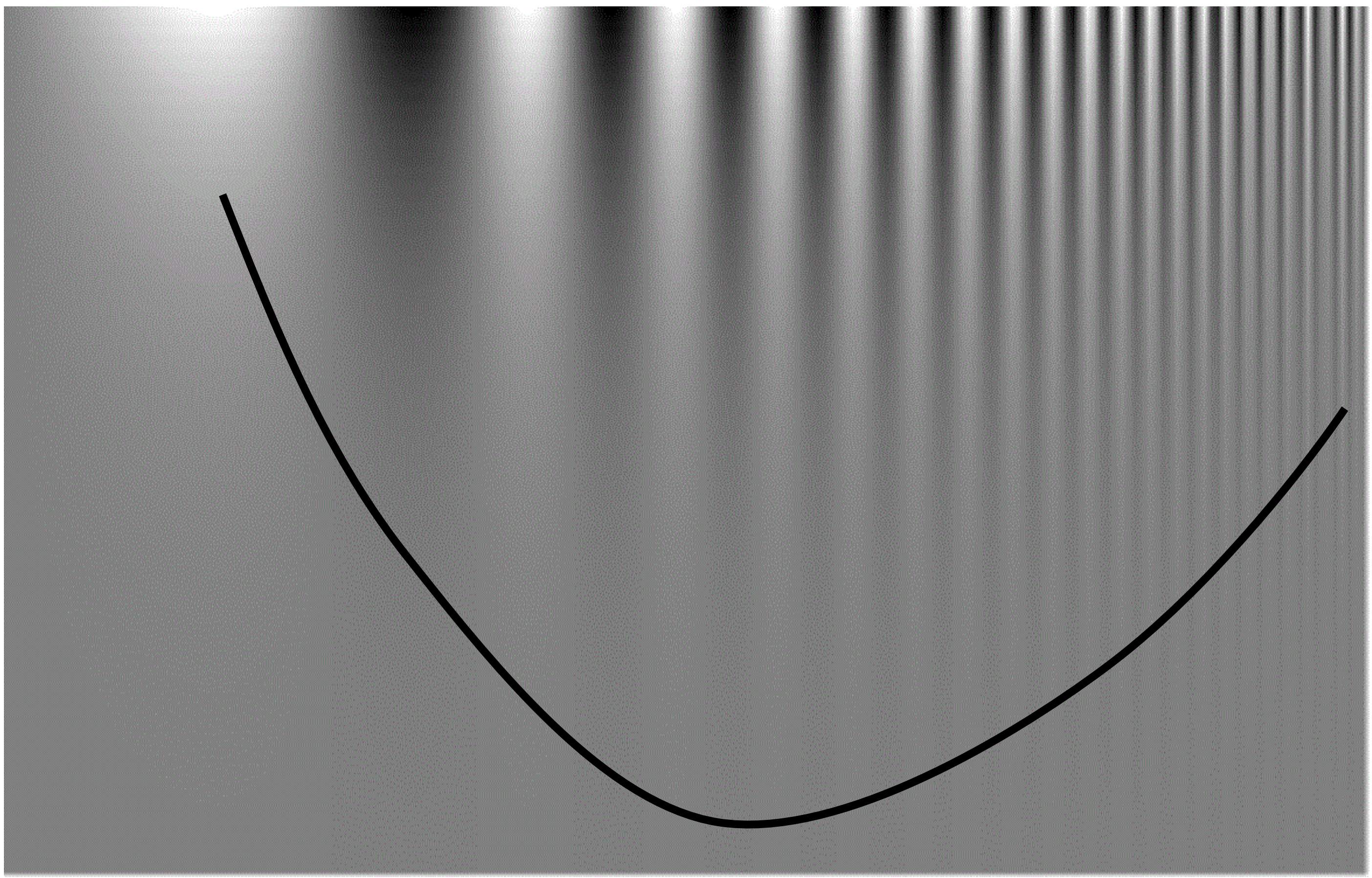
contrast



spatial frequency   k

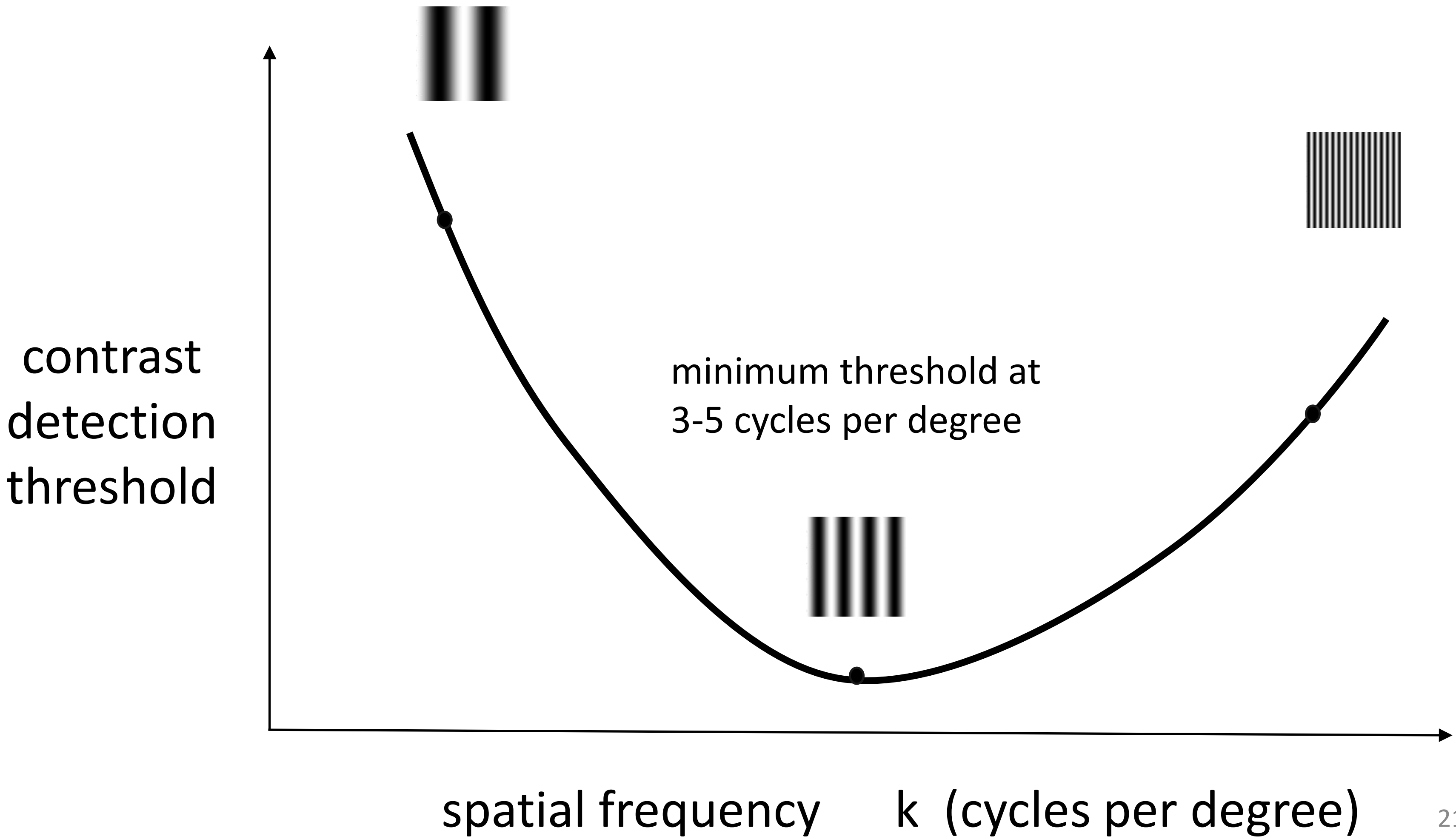
Luminance contrast thresholds depend on spatial frequency

contrast

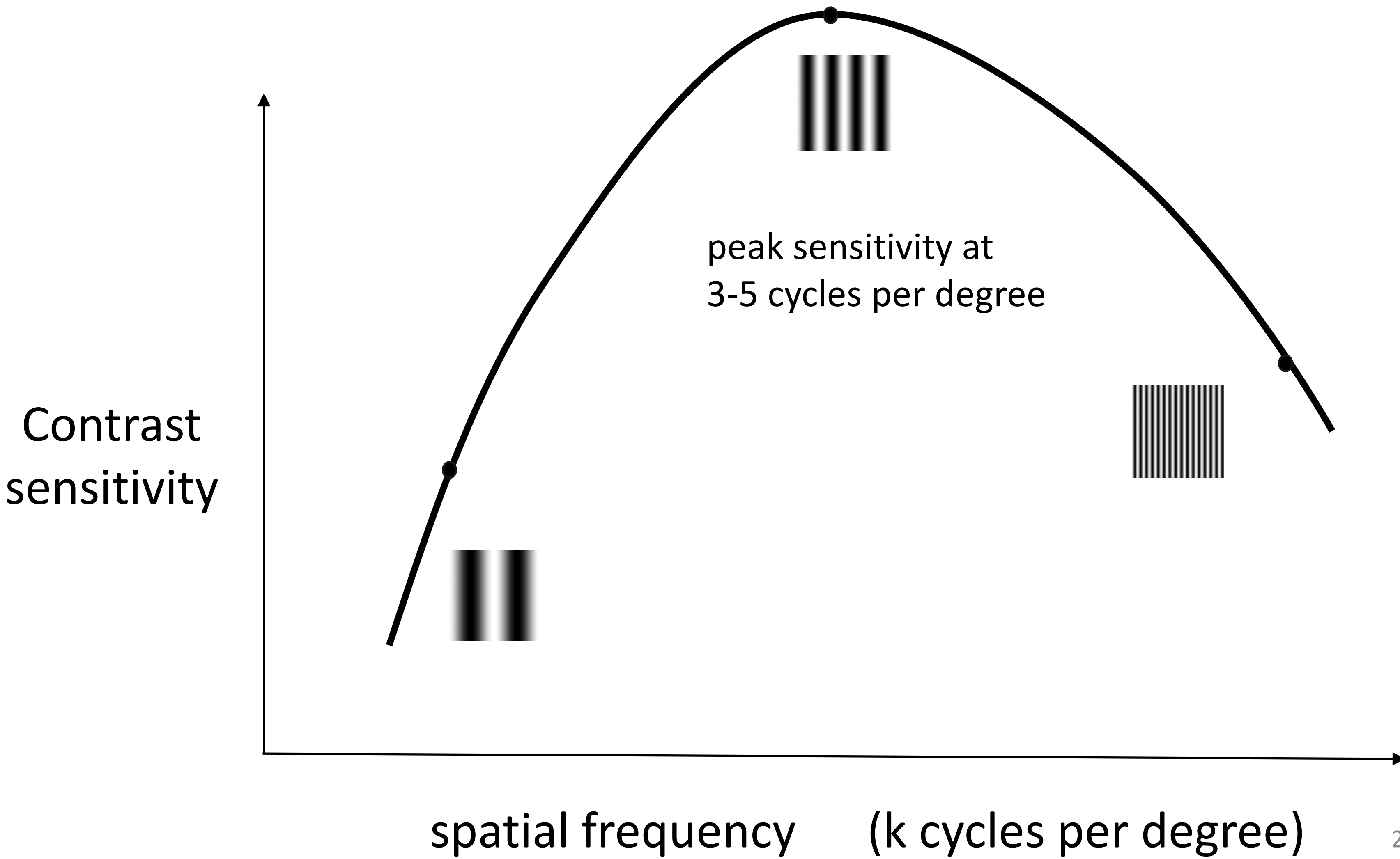


spatial frequency k

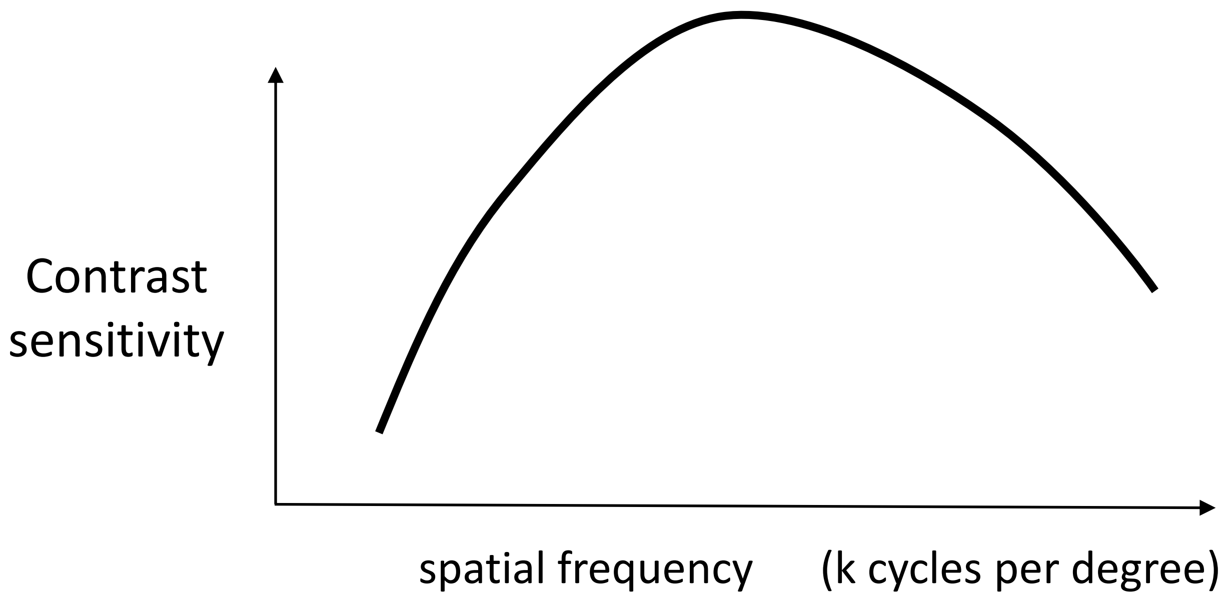
Measure threshold at each spatial frequency.
(For 2D sinusoid e.g. 20x20 degrees)



$$\text{Contrast sensitivity} \equiv \frac{1}{\text{contrast detection threshold}}$$



Why?

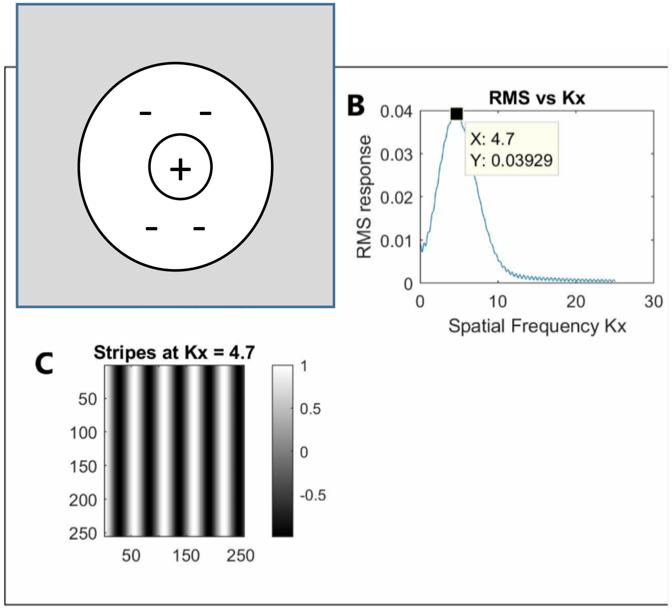


Contrast
sensitivity
spatial frequency
(k cycles per degree)

Assignment 1 Q2a

Question 2a (20 pts)

Intuitively, you should get the greatest response from convolving your DOG with your image of stripes when the width of the stripes matches the width of the DOG. This is what we observe. For example, here I have an on-center off-surround DOG made using $\sigma_1 = 12$ and $\sigma_2 = 13$. The on region of this DOG is about 27 pixels (Figure 1A). Convolving this with different k_x values and plotting the RMS for these convolutions gives a curve with a peak at roughly $k_x = 4.7$ (Figure 1B). My image is 256 pixels across, so this k_x corresponds to stripes of width 27 pixels (Figure 1C).

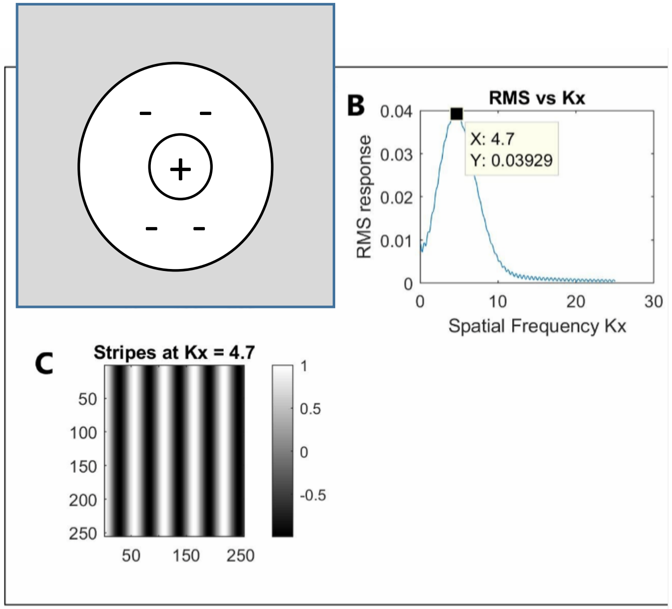


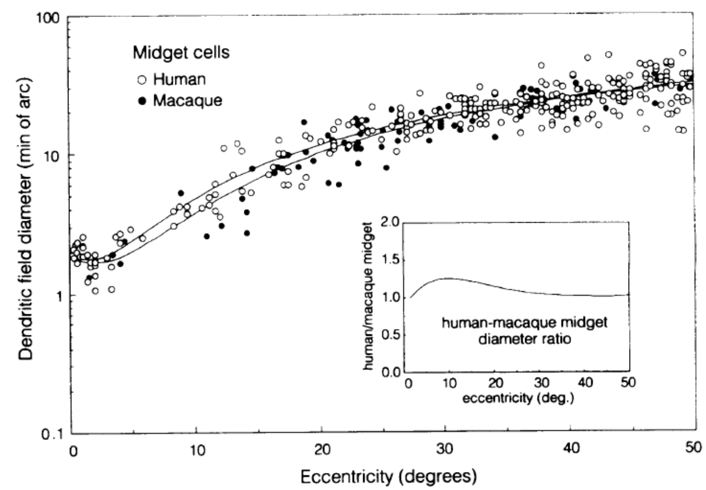
Assignment 1 Q2a

lecture 4

Question 2a (20 pts)

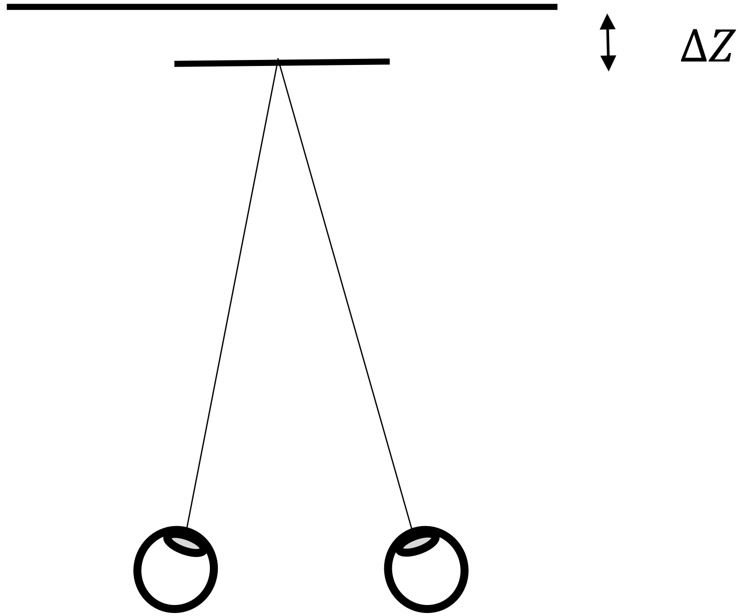
Intuitively, you should get the greatest response from convolving your DOG with your image of stripes when the width of the stripes matches the width of the DOG. This is what we observe. For example, here I have an on-center off-surround DOG made using $\sigma_1 = 12$ and $\sigma_2 = 13$. The on region of this DOG is about 27 pixels (Figure 1A). Convolving this with different k_x values and plotting the RMS for these convolutions gives a curve with a peak at roughly k_x = 4.7 (Figure 1B). My image is 256 pixels across, so this k_x corresponds to stripes of width 27 pixels (Figure 1C).



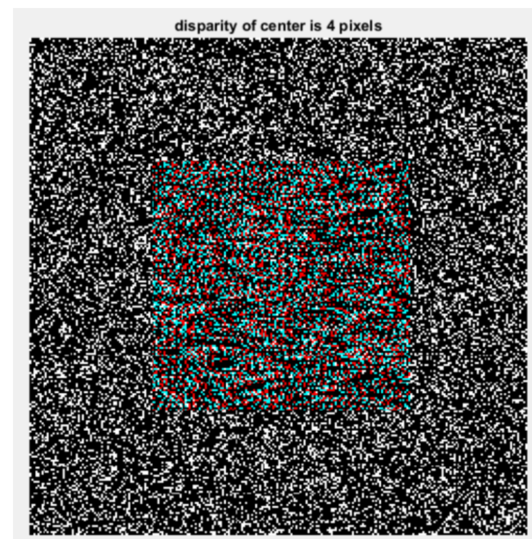


The shape of the contrast sensitivity function is believed to be a result of the range of DOG receptive fields (starting at the retina).

Example 2a: Depth discrimination from binocular disparity



anaglyph



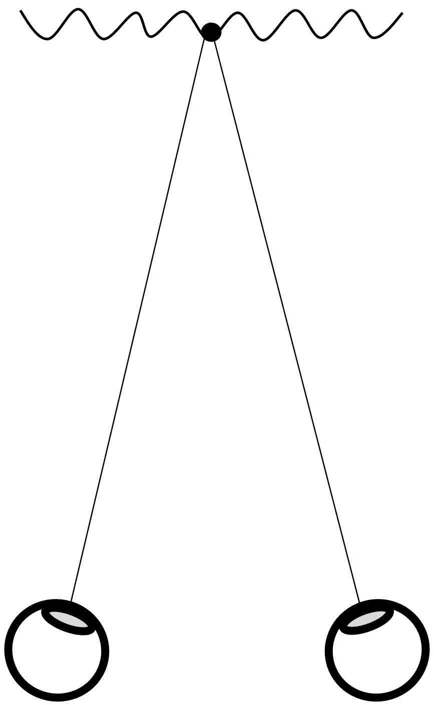
Is square closer or farther than background?

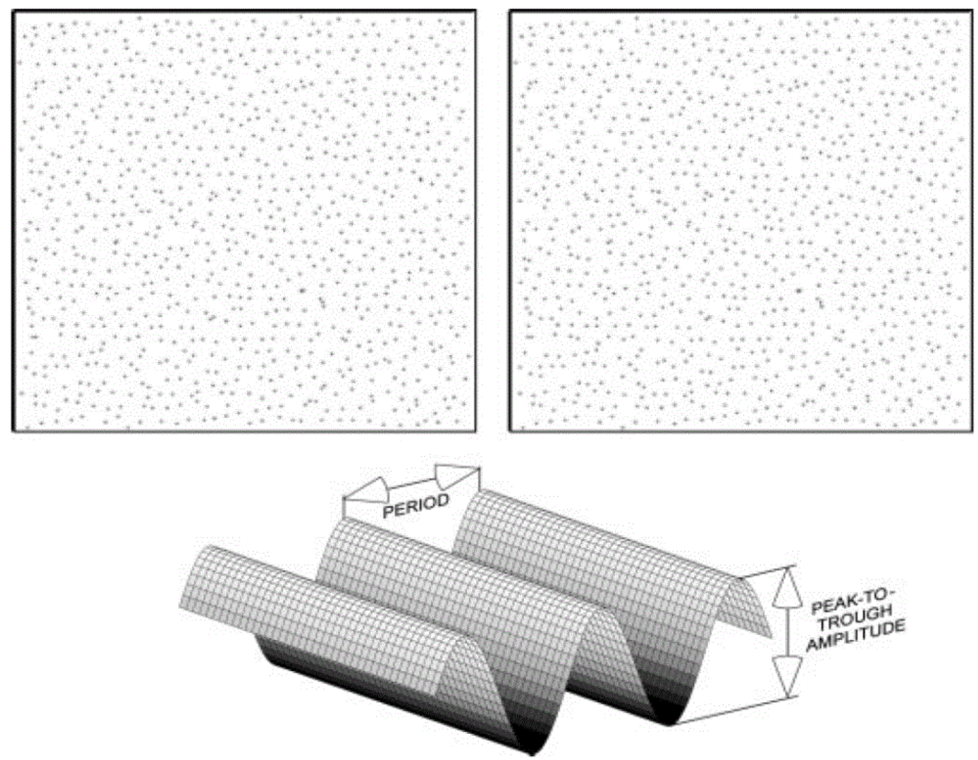
Assignment 2

Q1 (binocular disparity)

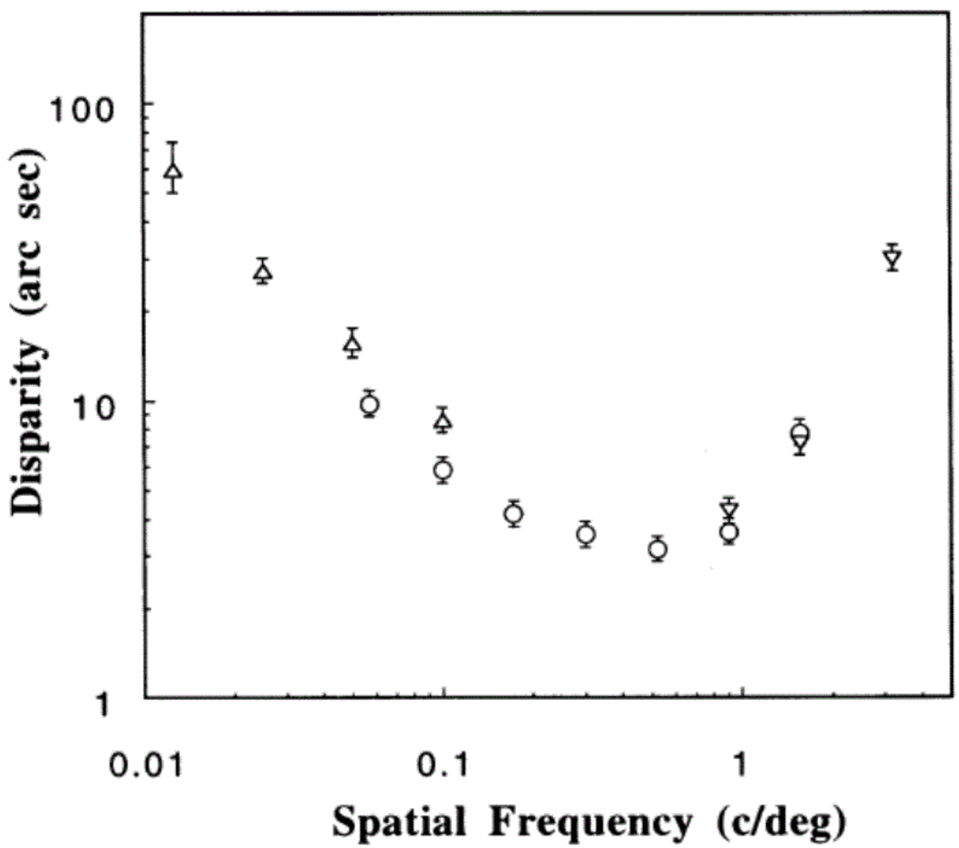
Even if there is no noise added, there is uncertainty in the disparity.

Example 2b: Depth discrimination for 2D sinusoidal binocular disparity





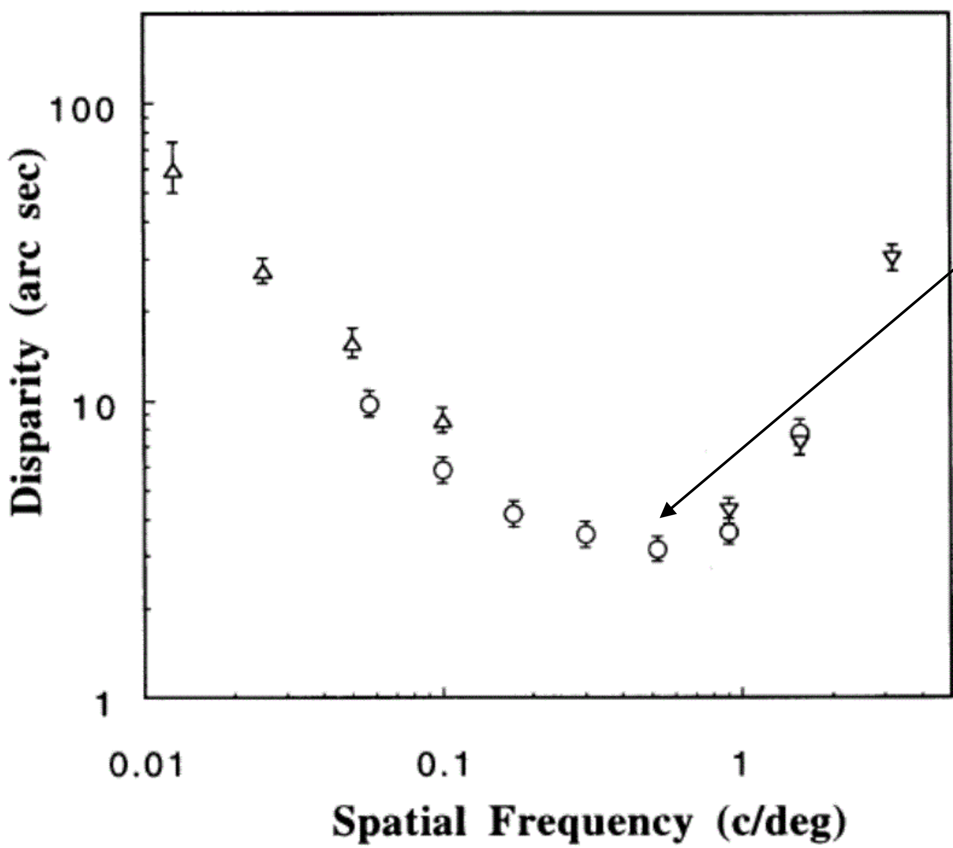
Example 2b: Depth discrimination for 2D sinusoidal binocular disparity



Why this dependence ?

[Bradshaw and Rogers 1999]

Example 2b: Depth discrimination for 2D sinusoidal binocular disparity



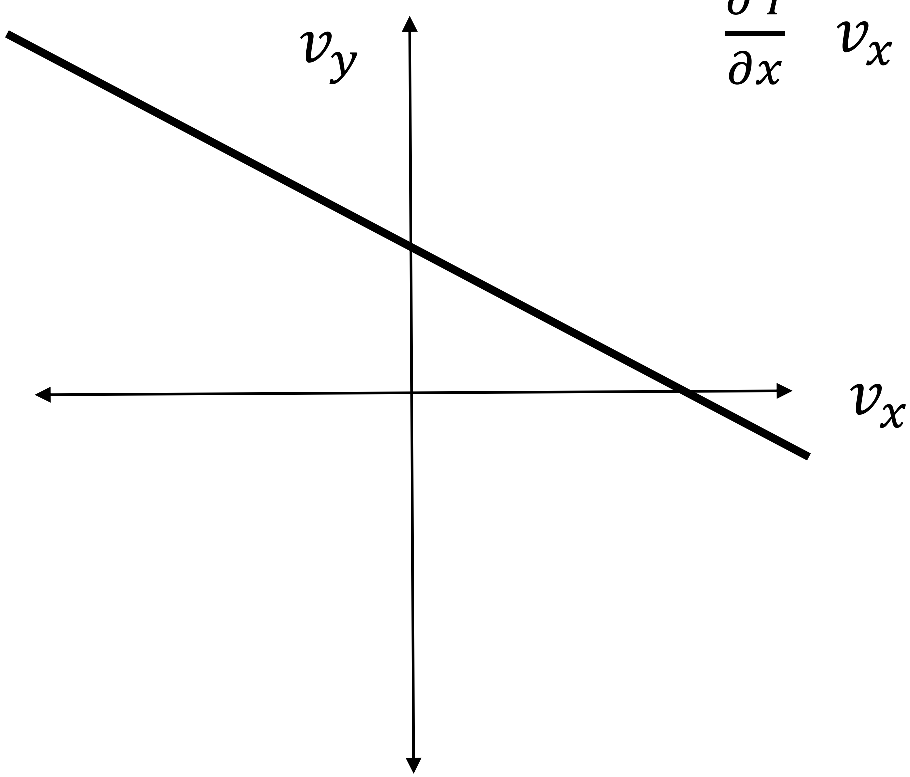
Lowest threshold occurs at much lower (about $\frac{1}{10}$) spatial frequency than for luminance contrast.

Why ?

[Bradshaw and Rogers 1999]

Example 3: 2D velocity estimation

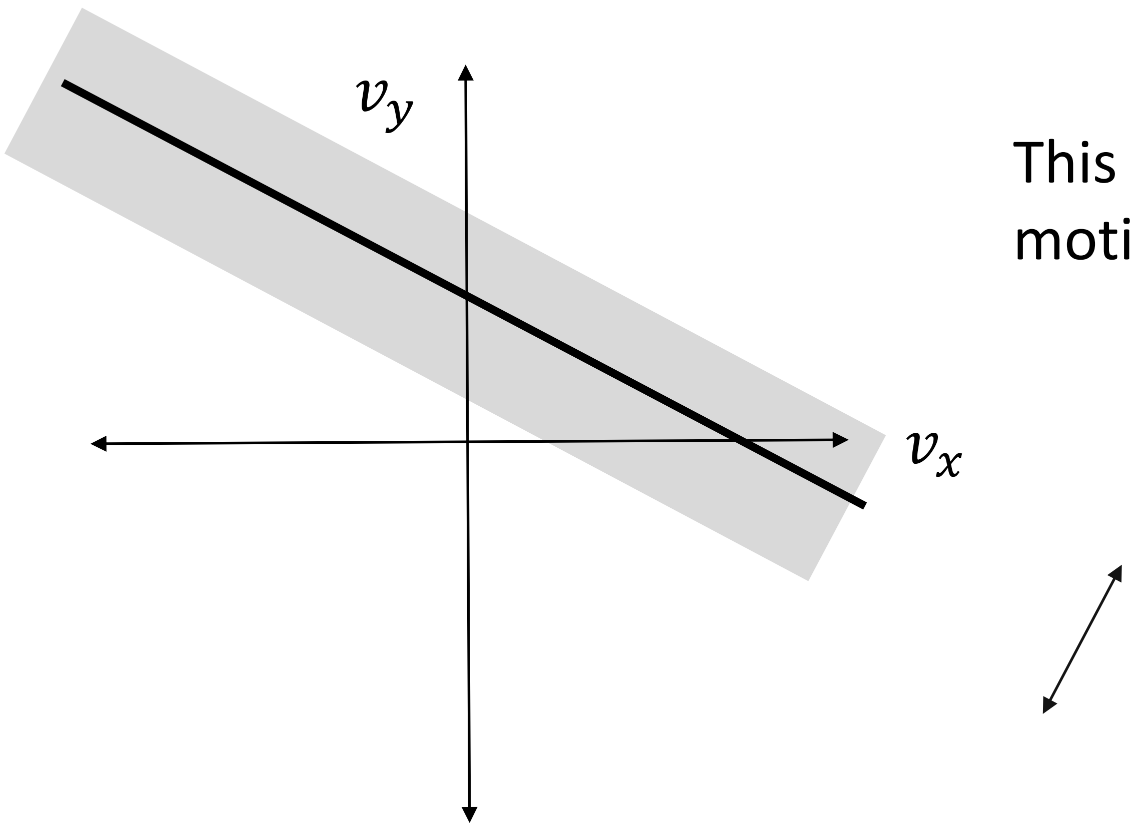
(How to think about image noise in this task?)



$$\frac{\partial I}{\partial x} v_x + \frac{\partial I}{\partial y} v_y + \frac{\partial I}{\partial t} = 0$$

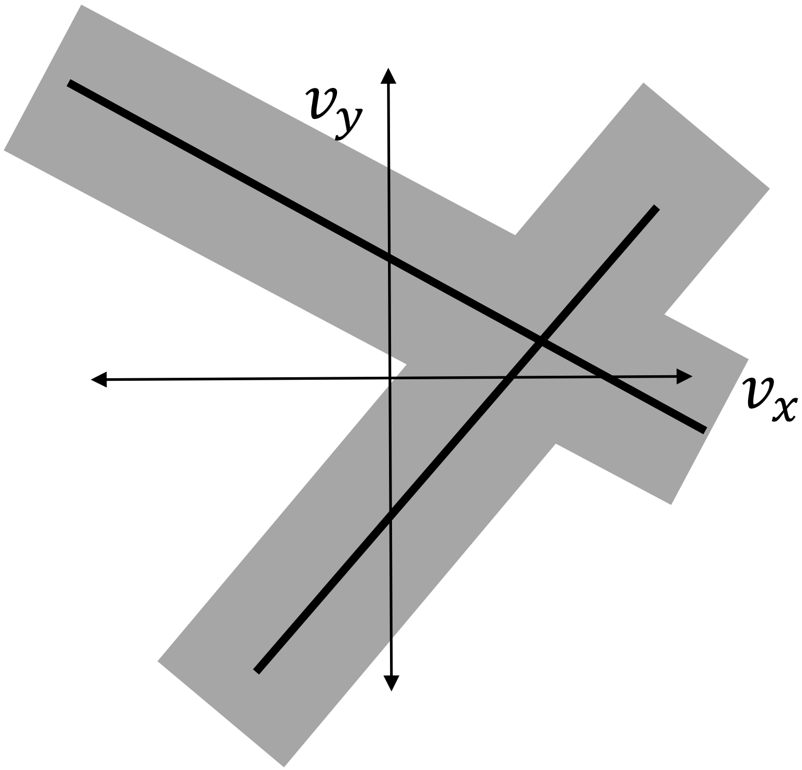
One must estimate image derivatives (subject to “noise”)

$$\frac{\partial I}{\partial x} v_x + \frac{\partial I}{\partial y} v_y + \frac{\partial I}{\partial t} = 0$$



This creates uncertainty in motion constraint line.

Recall: Intersection of Constraints (IOC)



Uncertainty in the motion constraint lines leads to uncertain in the 2D velocity estimates.

Assignment 2

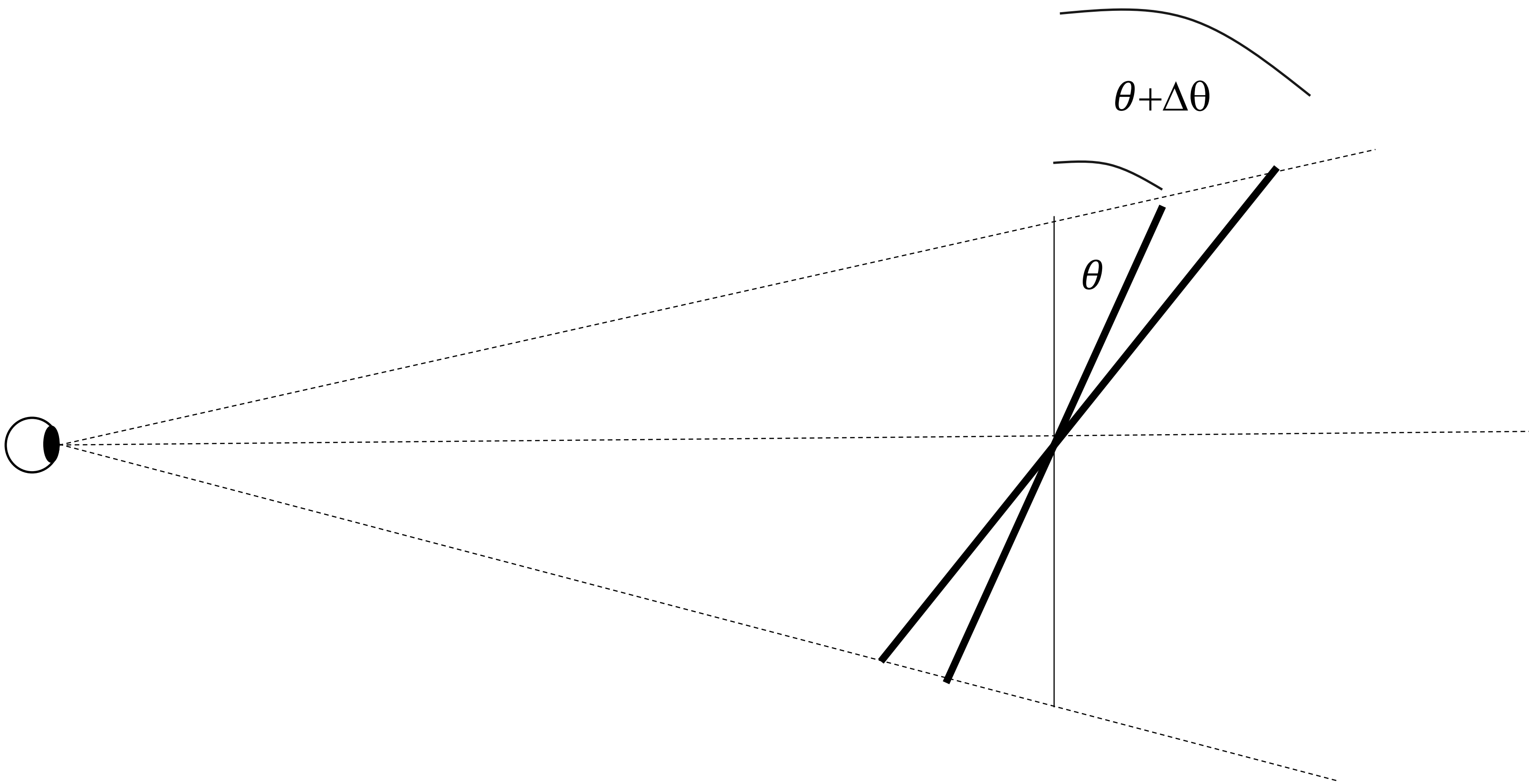
Q5, Q6 (motion):

Images are filtered with “shift detector” cells.

Even if there is no noise added, there is uncertainty in the 2D velocity estimate.

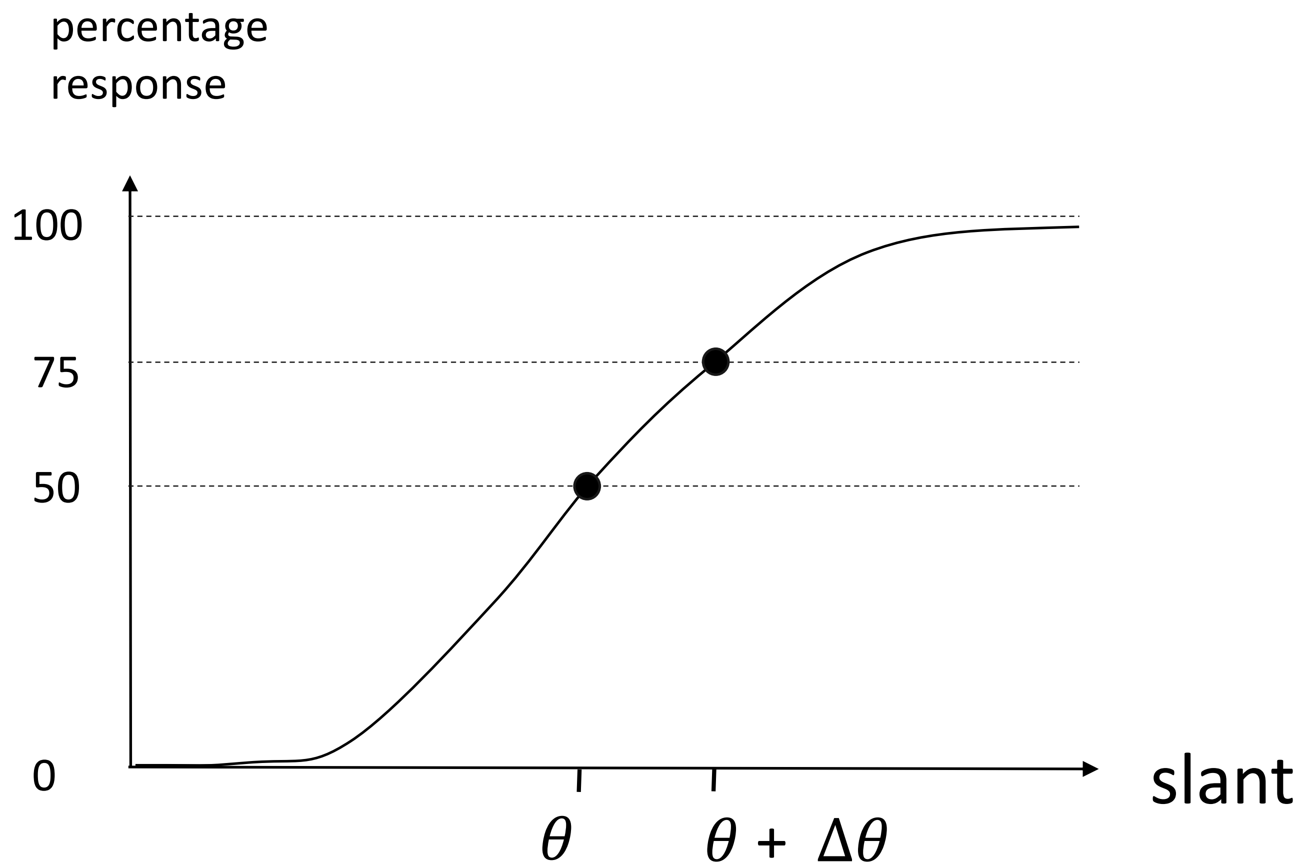
Example 4: Slant from texture

Given two images of slanted surfaces, which surface has greater slant ?



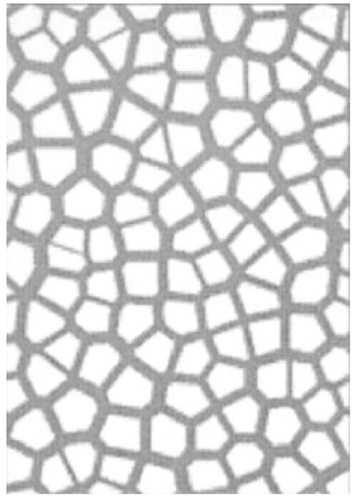
Slant discrimination threshold $\Delta\theta$

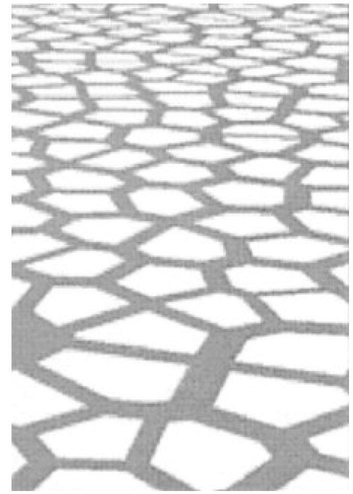
Which is more slanted? θ versus $\theta + \Delta\theta$?



Thresholds $\Delta\theta$ depend on slant θ. How and why?

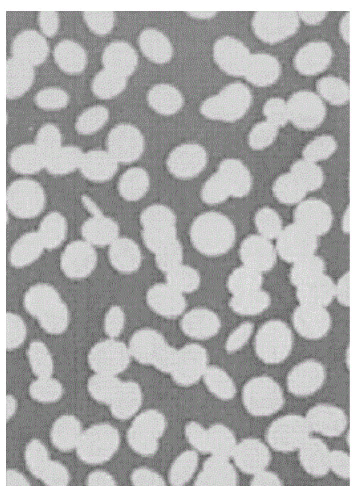
0 deg

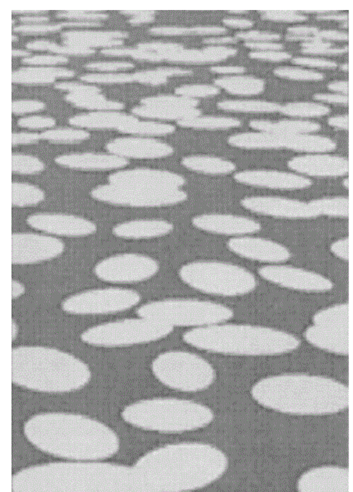




65 deg

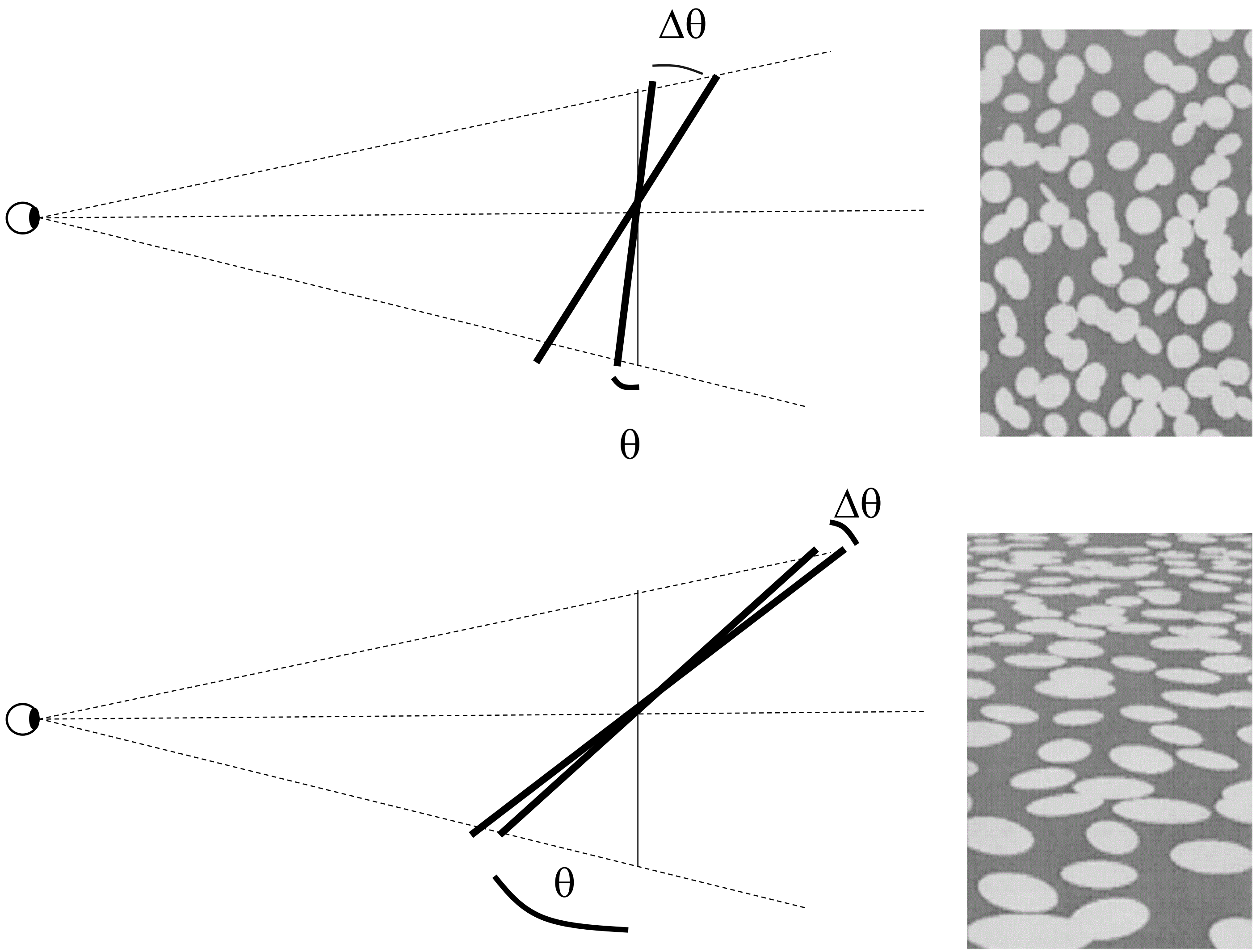
0 deg





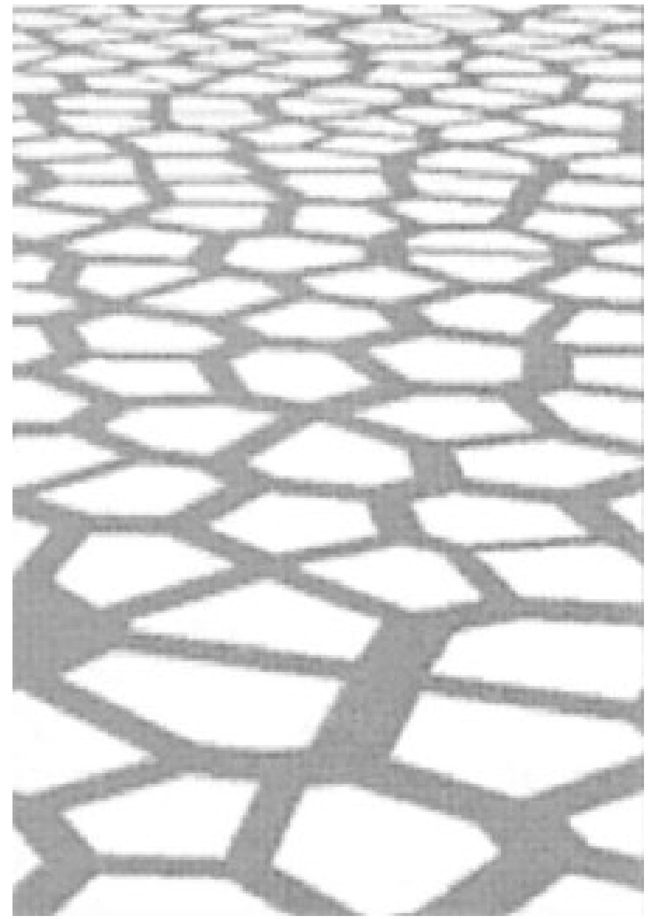
65 deg

Results: $\Delta\theta$ threshold is larger when θ is smaller.



Recall: Texture cues for slant & tilt
(lecture 11)

- size gradient (scale)
- density gradient (position)
- foreshortening gradient

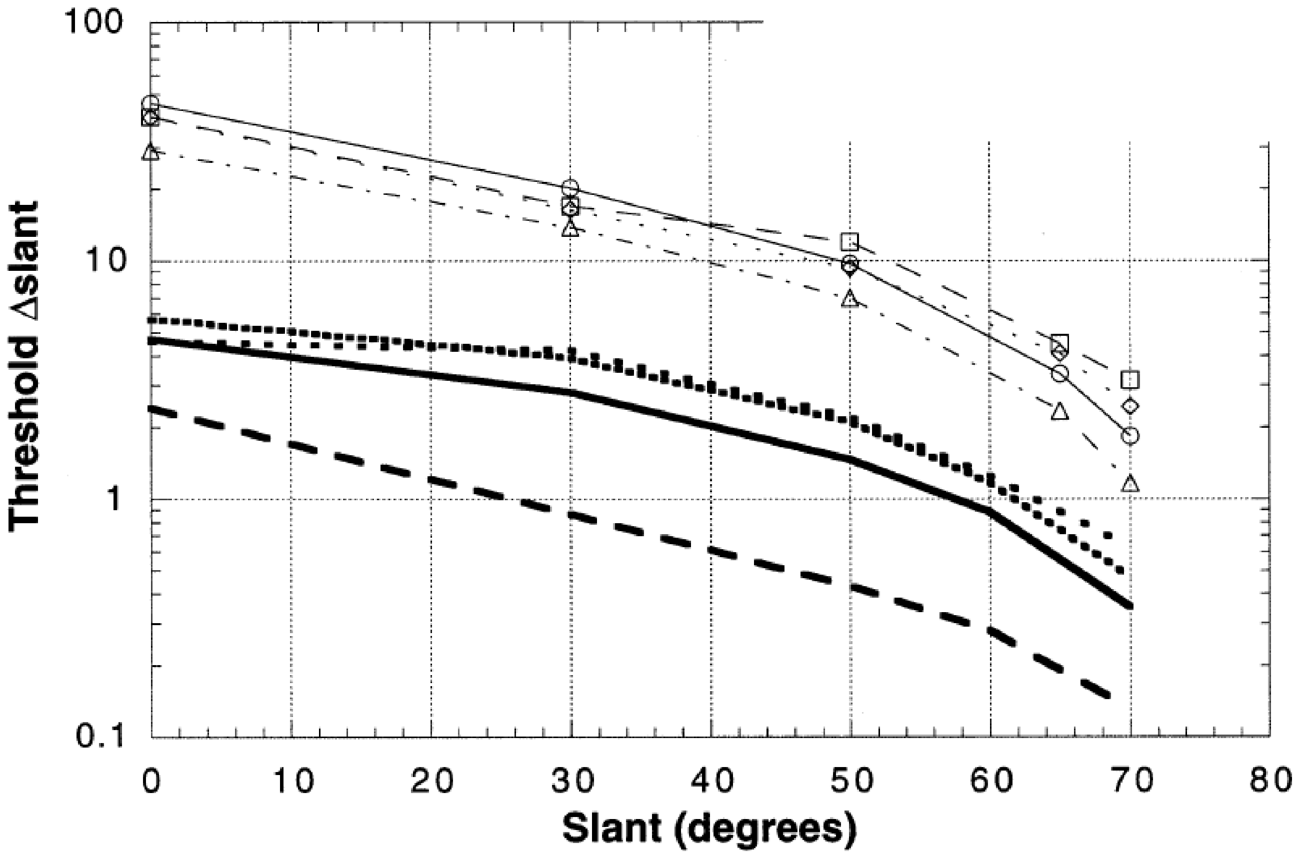


- How reliable are the size, density, foreshortening cues *for an ideal observer* ?

(What assumptions need to hold to make to estimate slant from these cues?)

- Do human observers have similar pattern of responses as ideal observers?

$\Delta\theta$ threshold is large when θ is small *for both human and ideal observers*.



human observers

“ideal” observers who know the probability model used to generate texture and who use various combinations of cues: size, density, foreshortening

[Knill, 1998]

Overview

- Psychometric function
- Threshold
- Examples
  - Contrast Sensitivity
  - Depth discrimination (binocular disparity)
  - 2D Motion
  - Slant from texture

Summary

Discrimination thresholds can tell us about:

- underlying mechanisms
  (how the brain codes of luminance, color, 2D orientation, disparity, 2D velocity, slant & tilt…)

- inherent difficulty of the computational problem
  that is due to randomness ("noise")