COMP 546

Lecture 13

Psychophysics

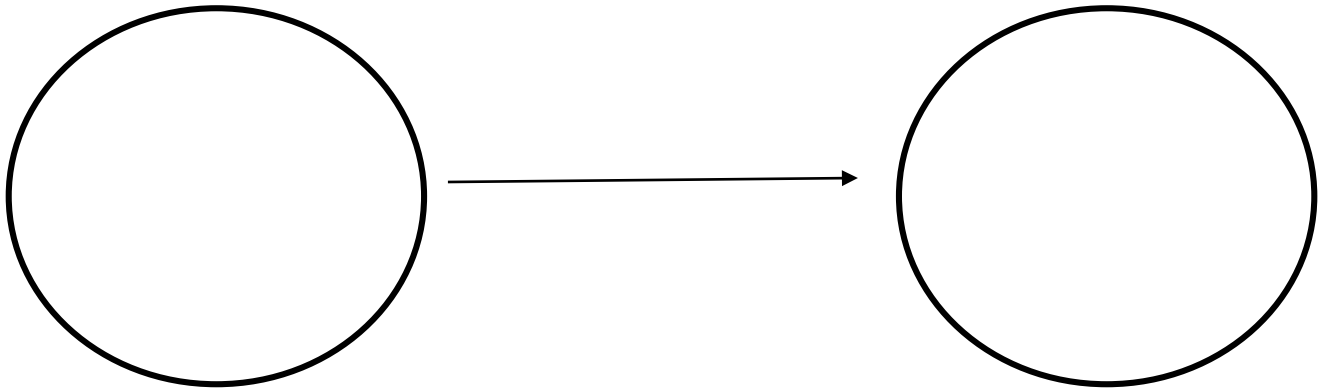
Thurs. Feb. 21, 2019

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

- color or luminance (intensity)
- orientation of lines
- depths from binocular disparity
- 3D surface shapes (slant, tilt, curvature, …)
- …..

"Psychophysics" : (loose definition)

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



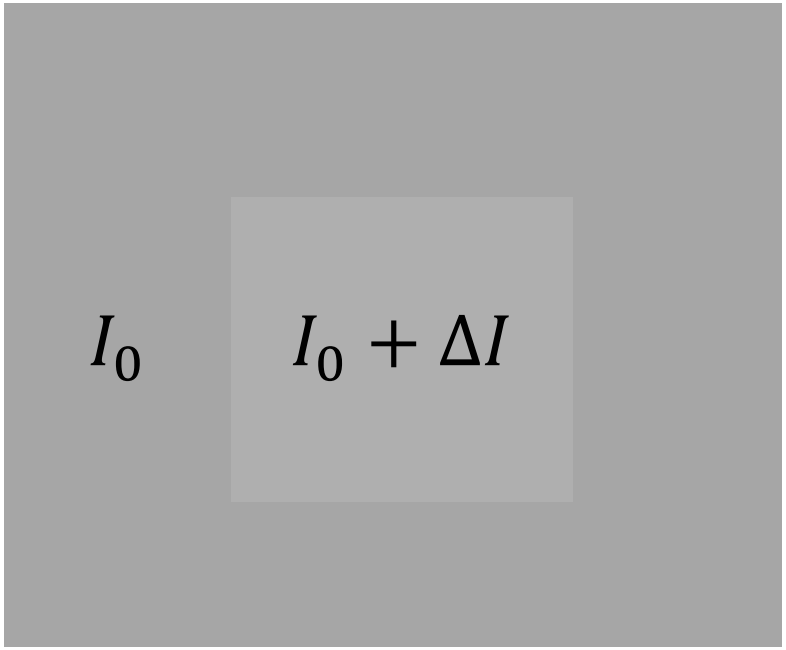
stimulus

(physical)

response

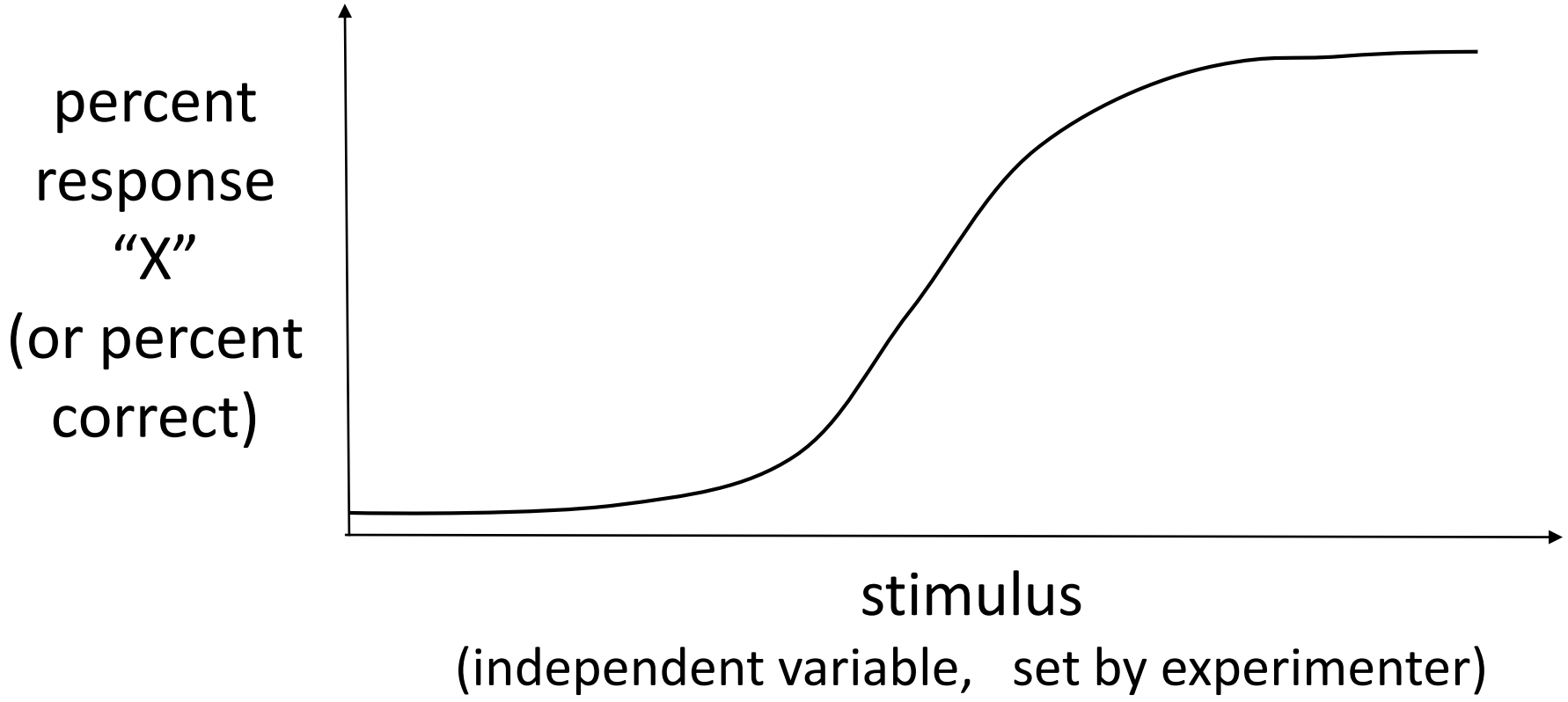
(perceptual -- measured by behavior)

Example 1a: intensity discrimination (or detection)

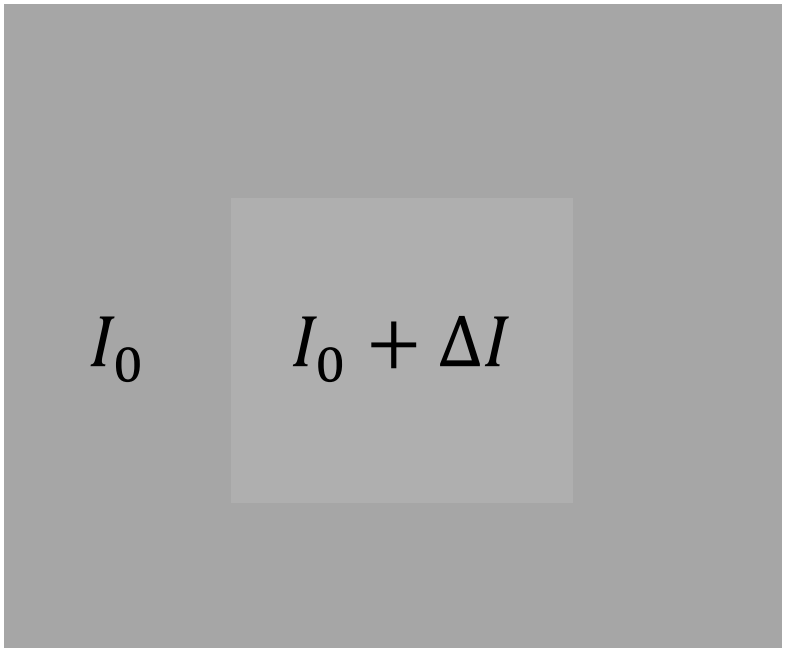


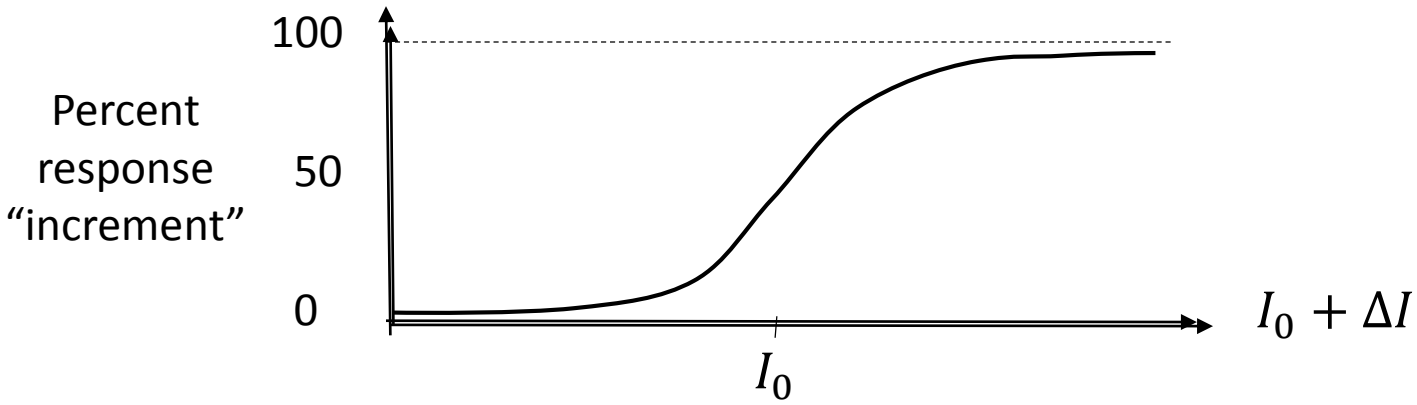
Is the central square brighter
or darker than the background?

Psychometric function

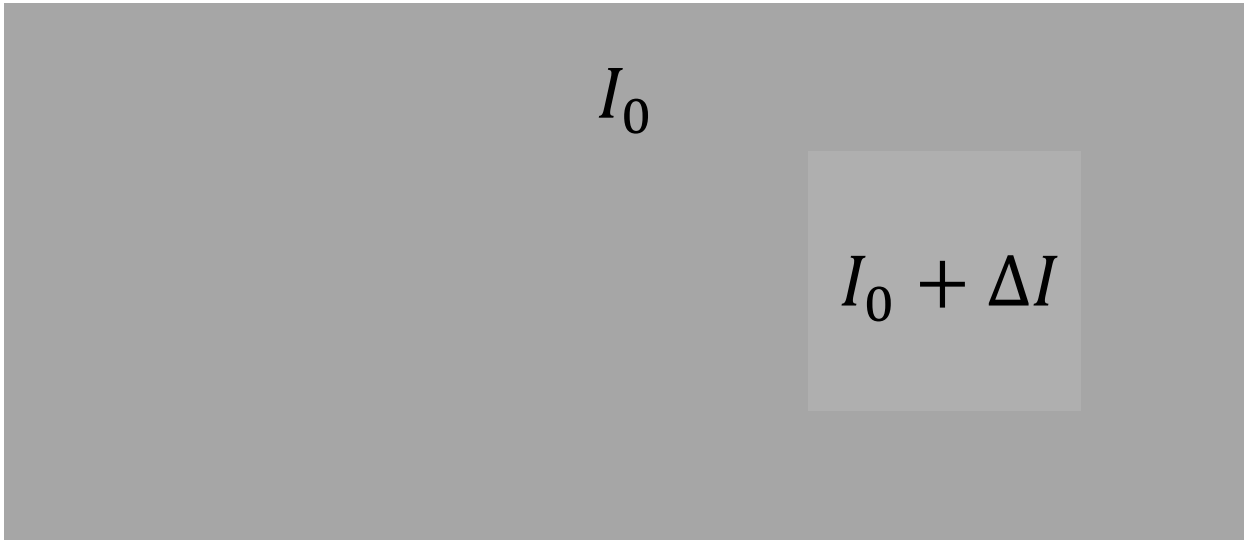


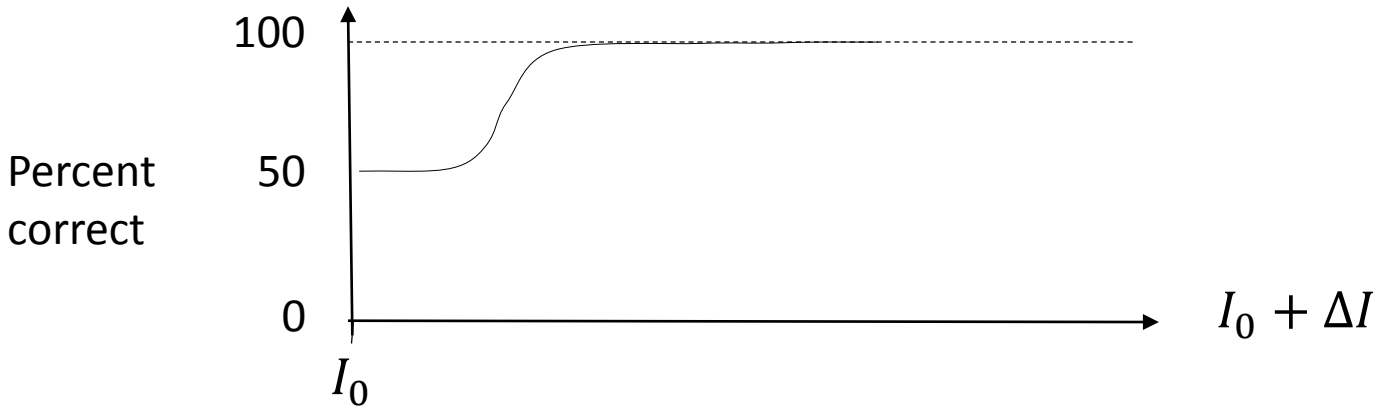
Example 1a: intensity discrimination (increment or decrement?)





Example 1b: intensity detection (left or right?)





Q: Why are psychometric curves not step functions ?

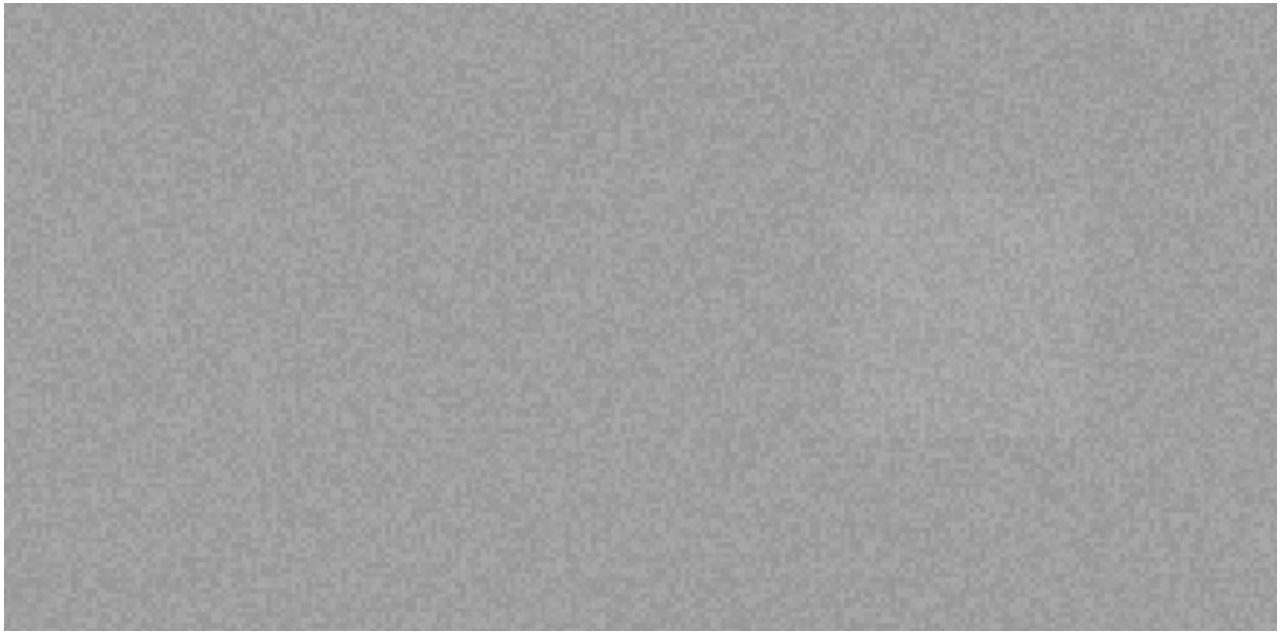
A:

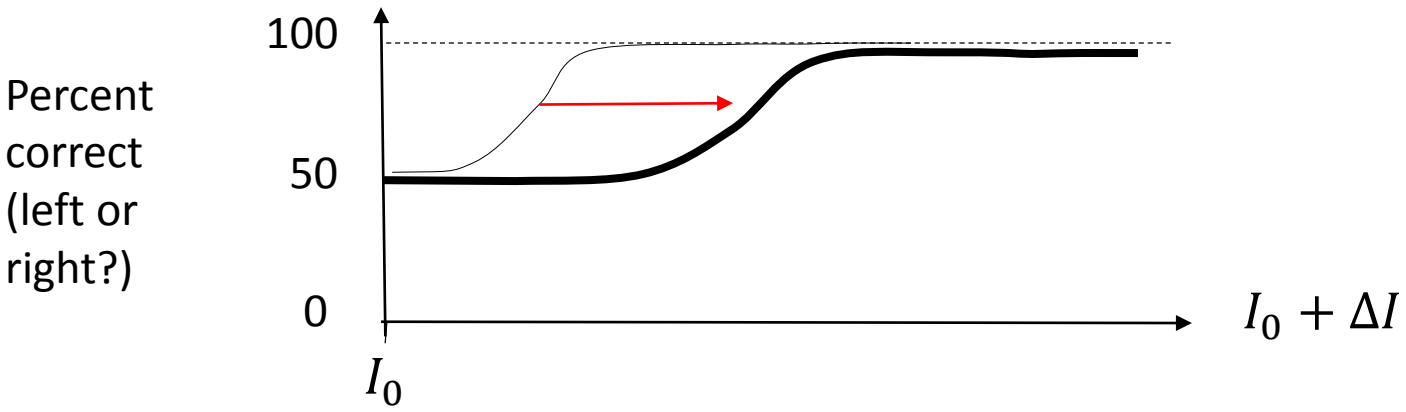
Q: Why are psychometric curves not step functions ?

A:

- noise in the display or stimulus
- noise in the sensors/brain
- limited resolution: finite samples
- subjects press the wrong button (stop paying attention)

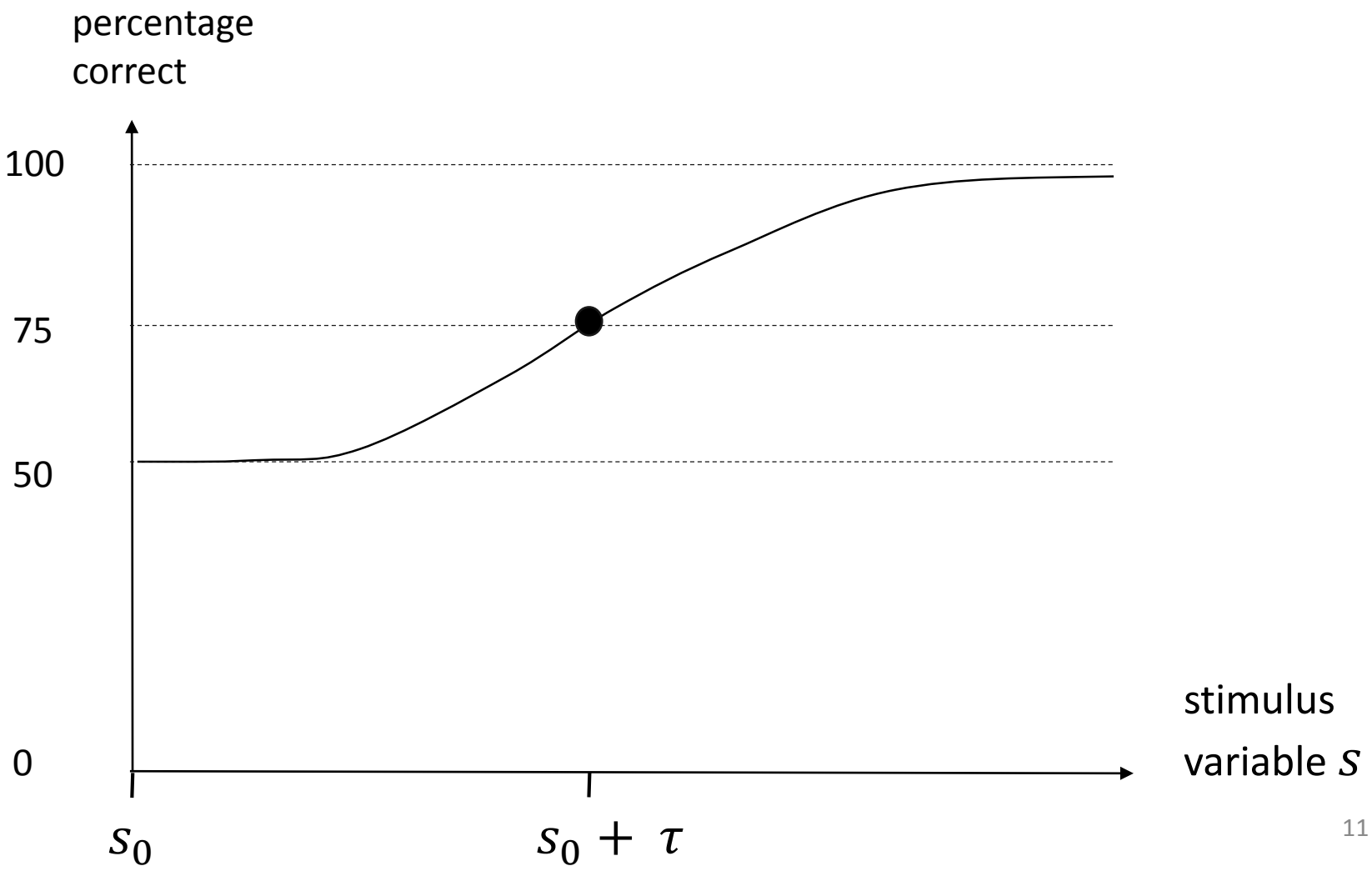
Example 1c: intensity increment (left or right? *with added noise*)





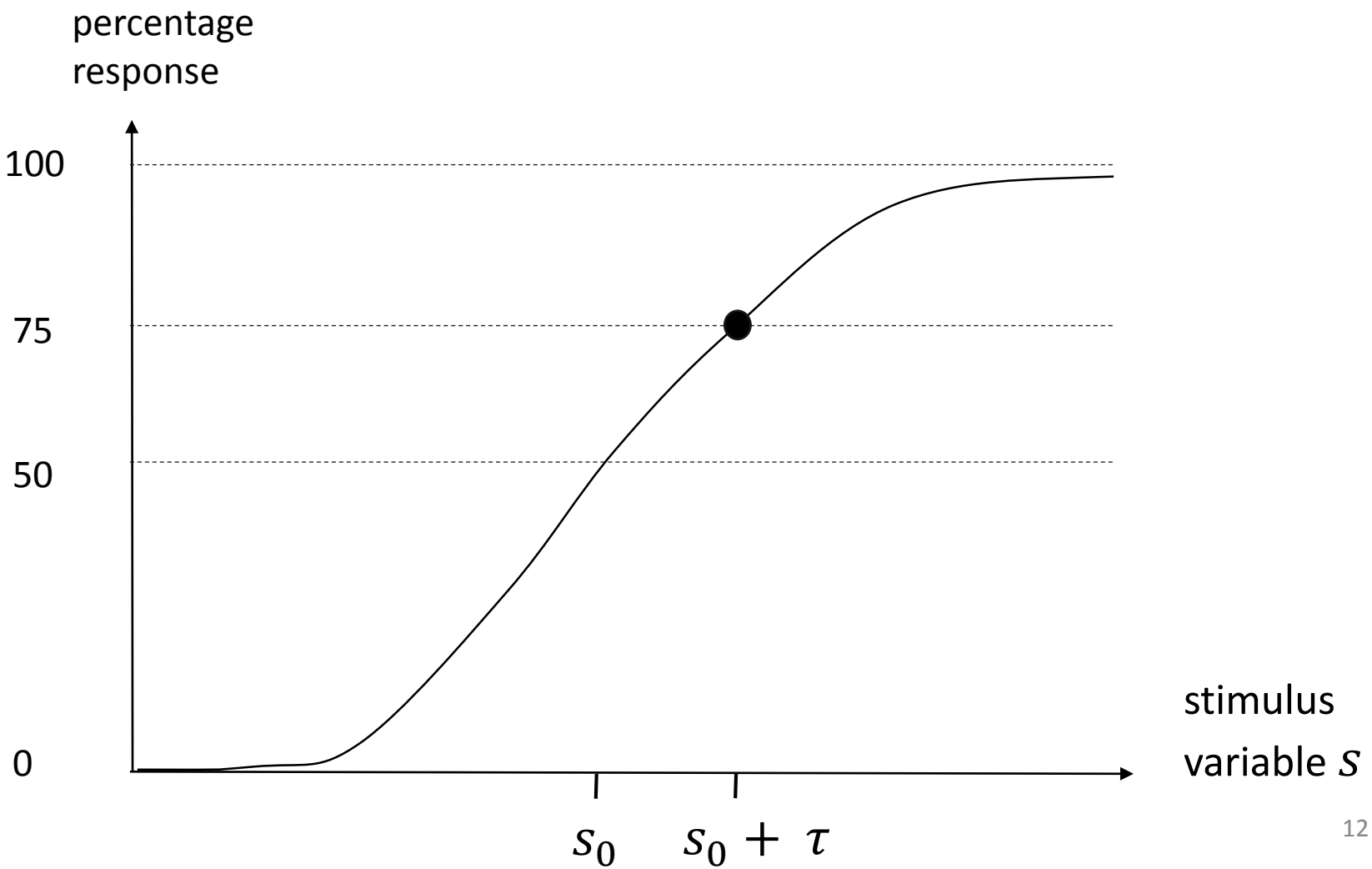
Psychophysical threshold τ

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

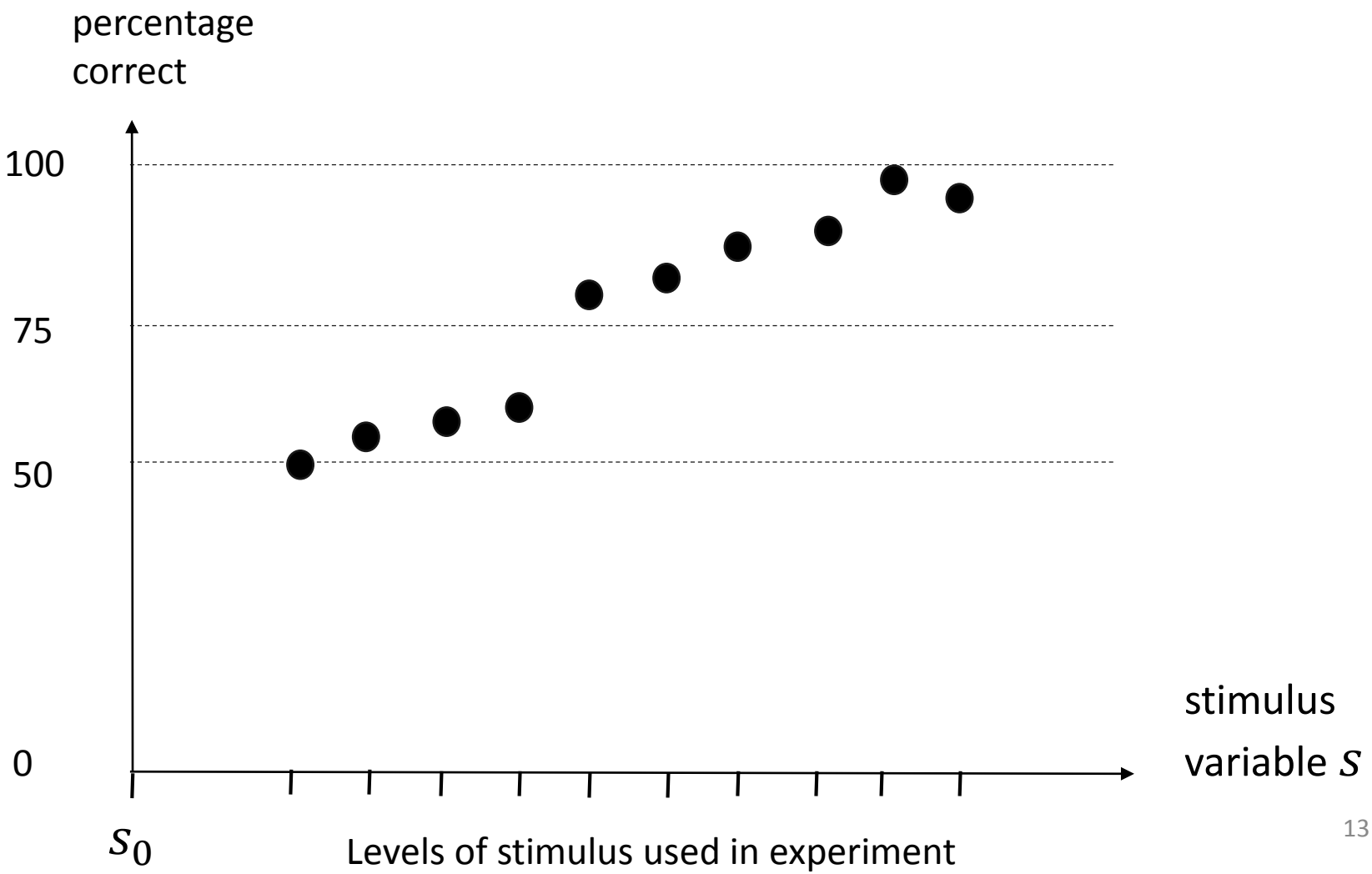


Psychophysical threshold τ

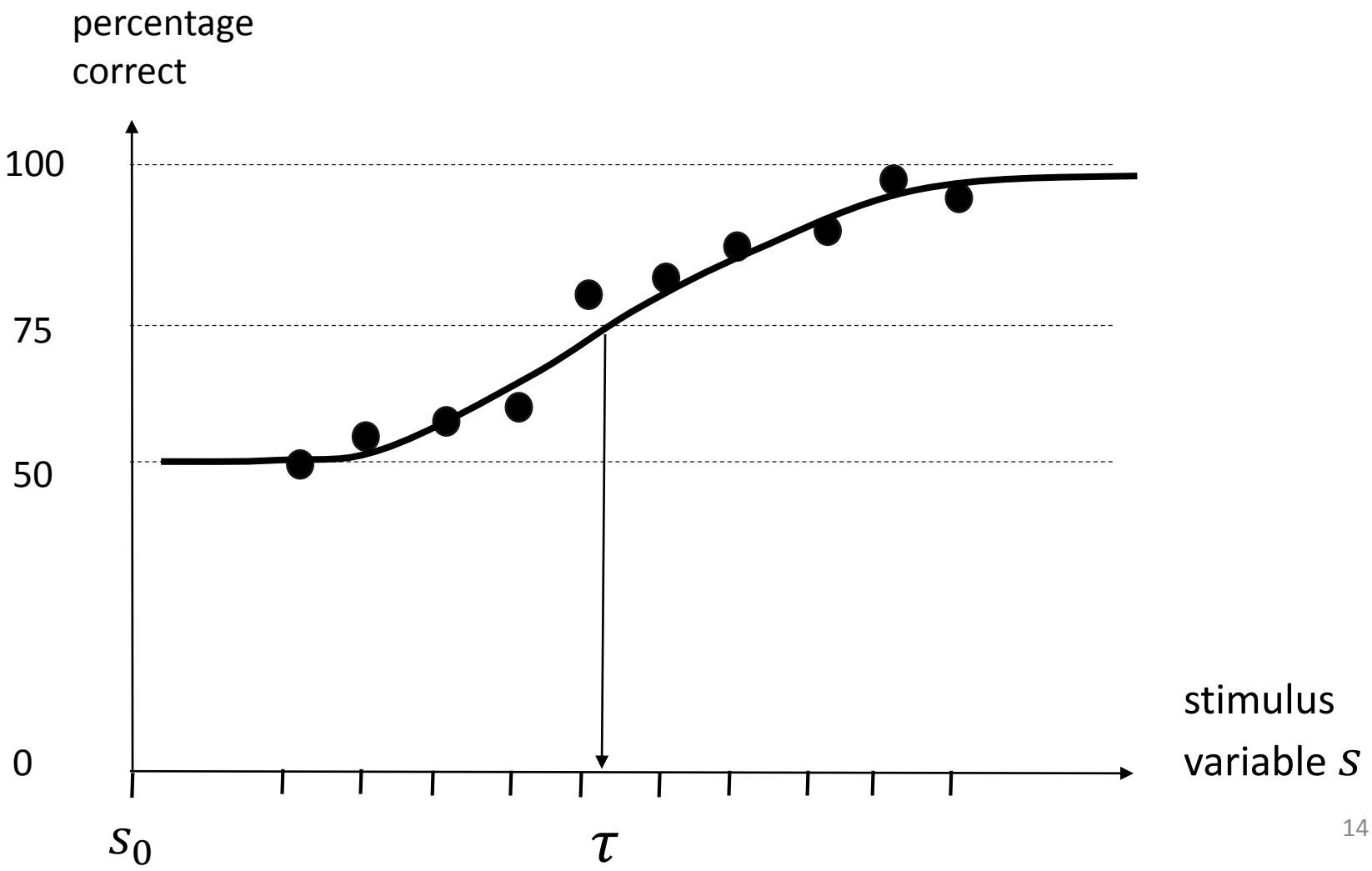
Defines the stimulus level that gives a particular performance level e.g. 75% correct.



How to estimate a threshold τ ?



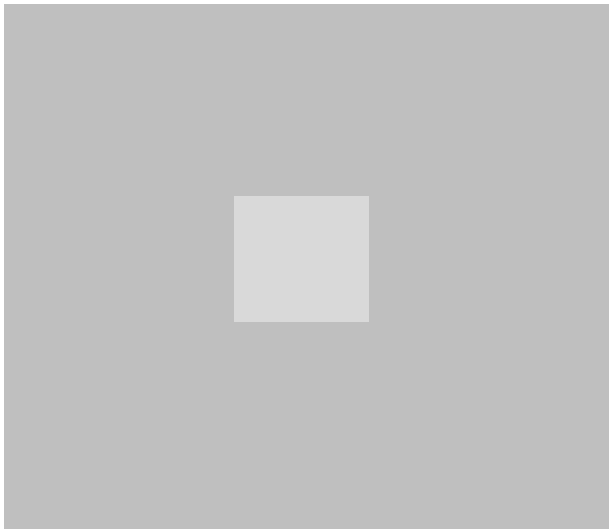
How to estimate a threshold τ ?
Fit a (sigmoid shaped) curve.



Overview

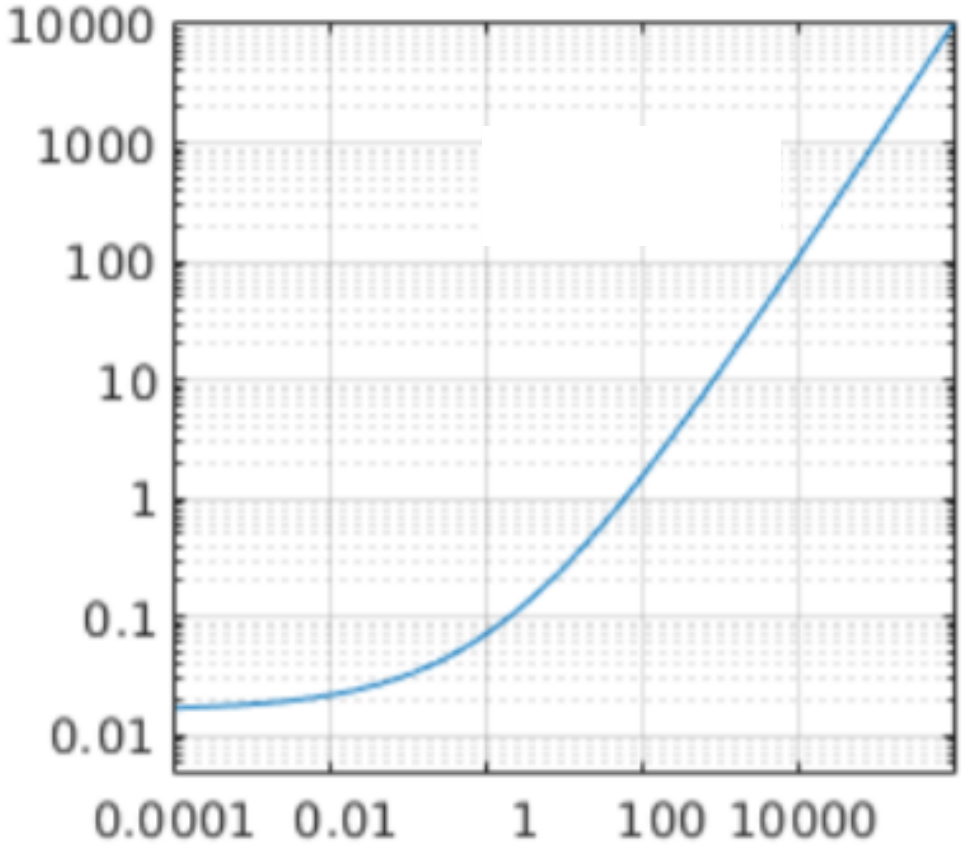
- Psychometric function
- Threshold
- Examples
  - Contrast Sensitivity
  - Depth discrimination (binocular disparity)
  - Slant from texture

Contrast (recall Assignment 1)



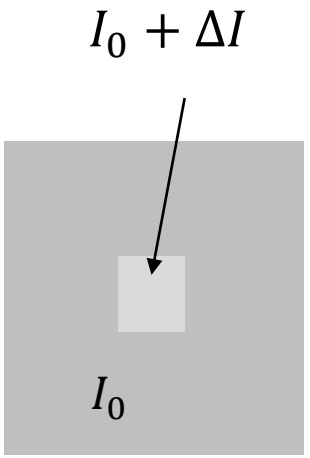
Weber Contrast $\equiv \dfrac{\Delta I}{I_0}$

Threshold versus Intensity (“tvi”)

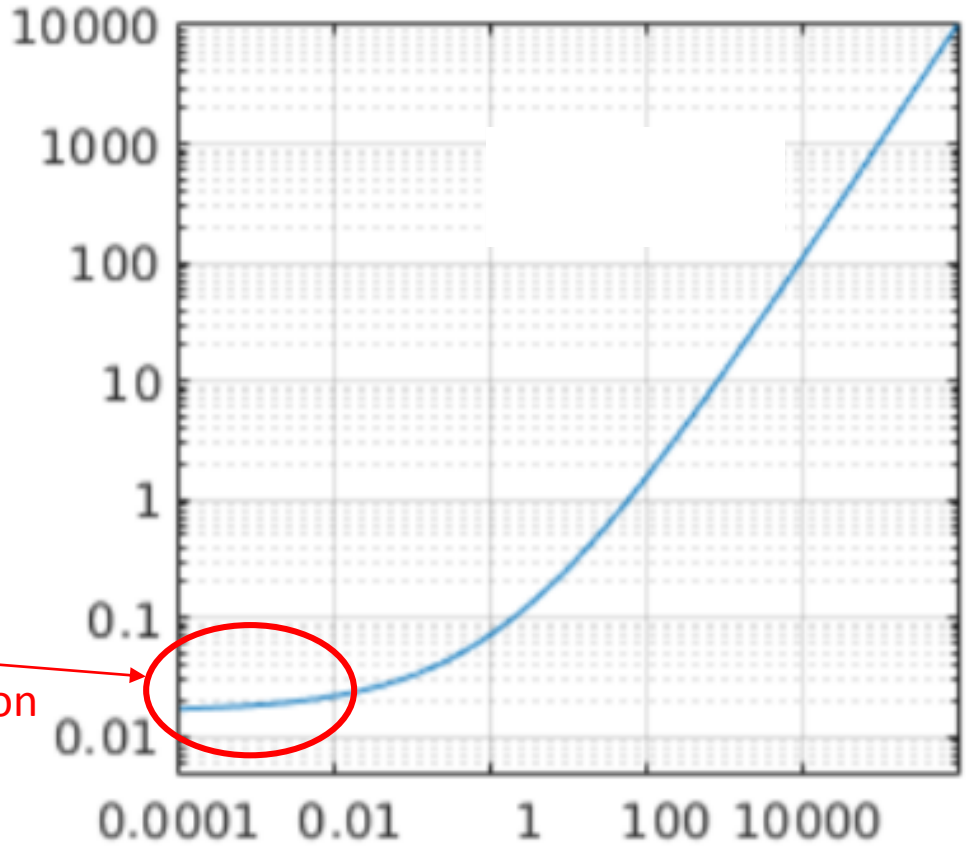


$\log_{10}(\Delta I)$

$\log_{10} I_0$



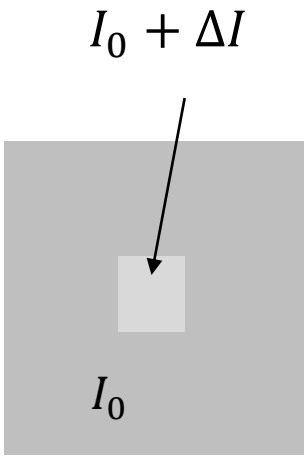
Threshold versus Intensity ("tvi")



$\log_{10}(\Delta I)$

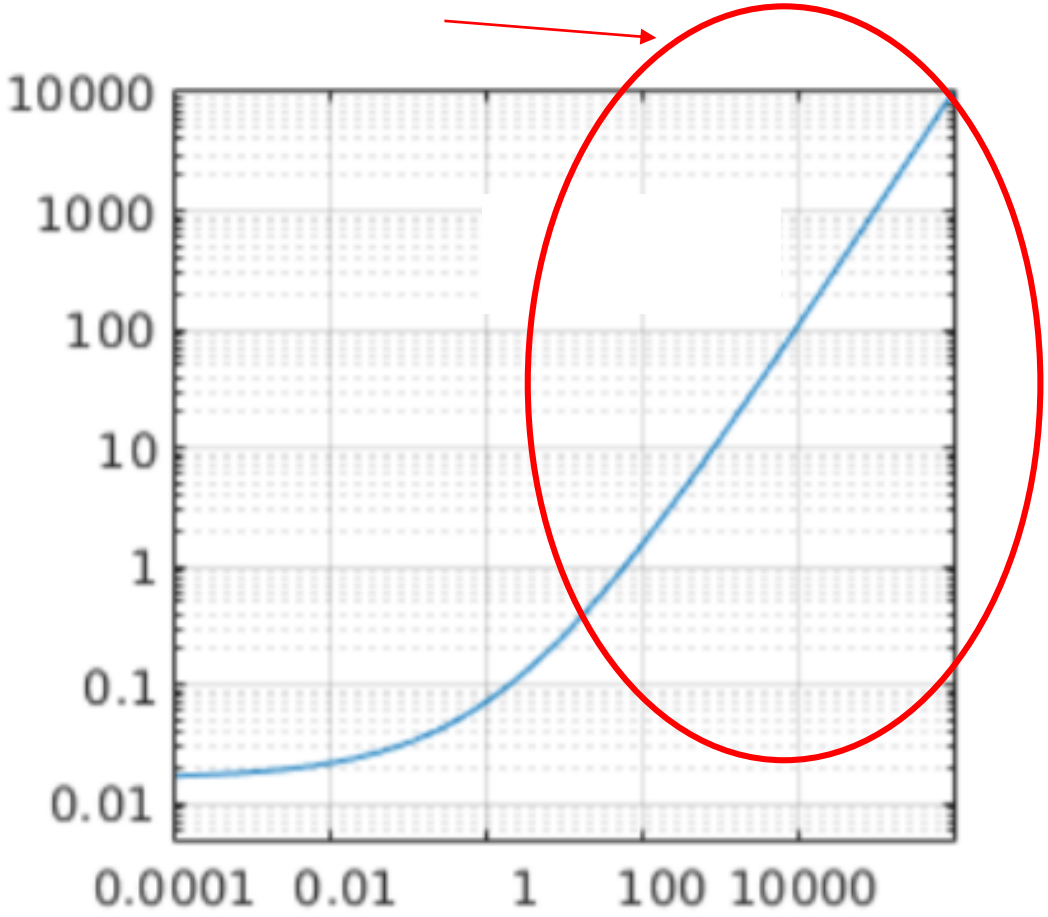
$\log_{10} I_0$

Absolute detection threshold (independent of background I_0)



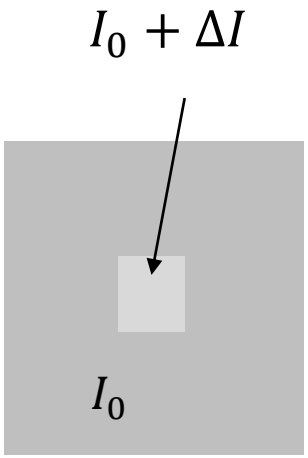
Threshold versus Intensity ("tvi")

ASIDE: Linear on a log-log plot means a power law.

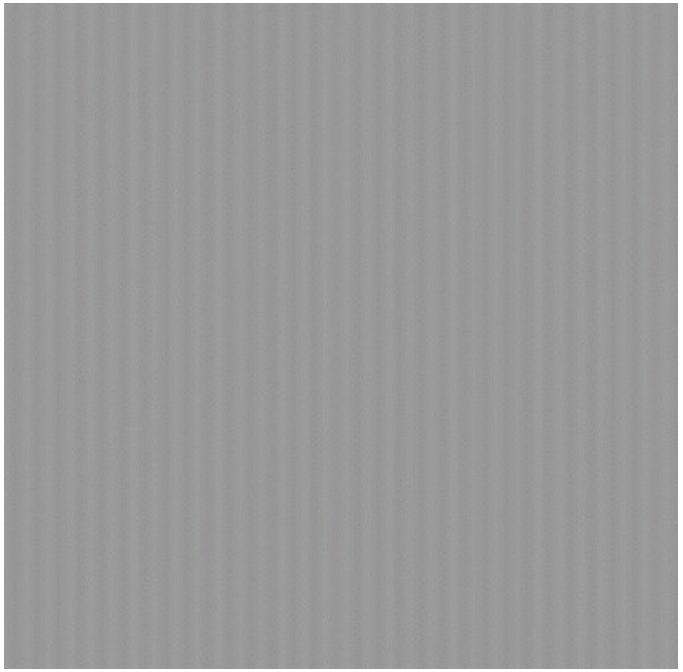


$\log_{10}(\Delta I)$

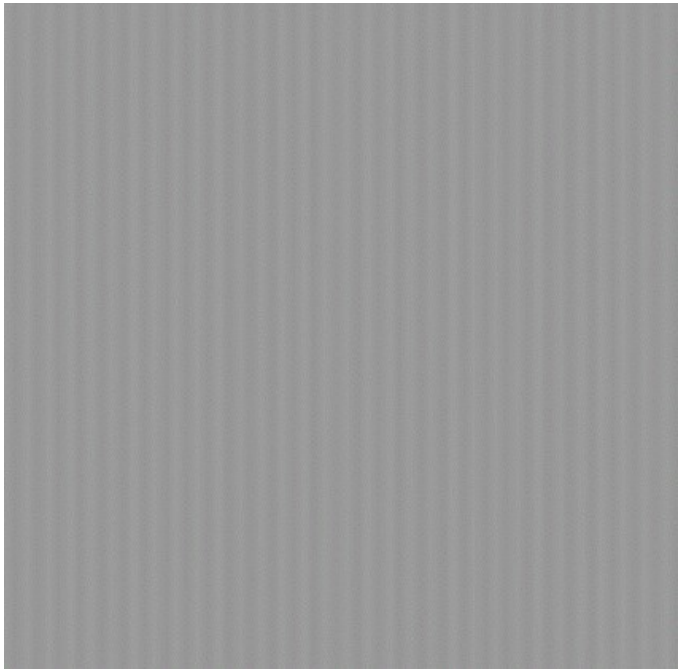
$\log_{10} I_0$



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

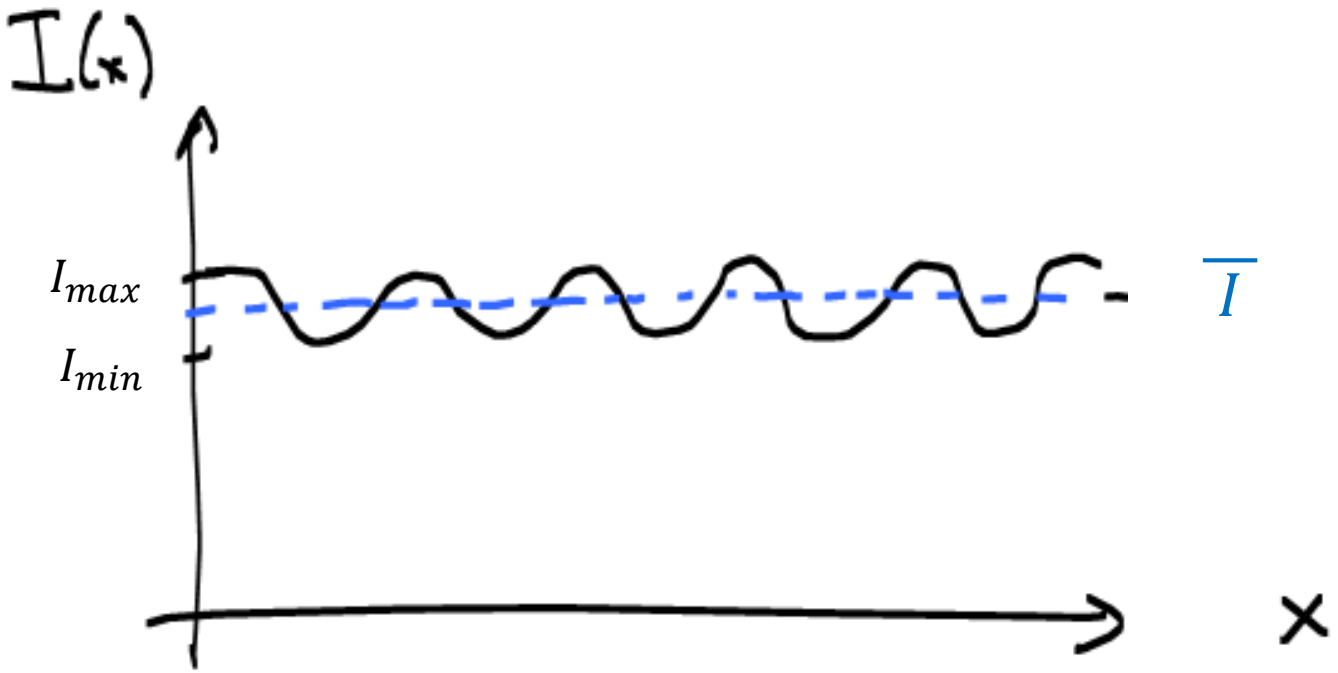


Example 2: Detecting a 2D sinusoid grating
(vertical or horizontal?)



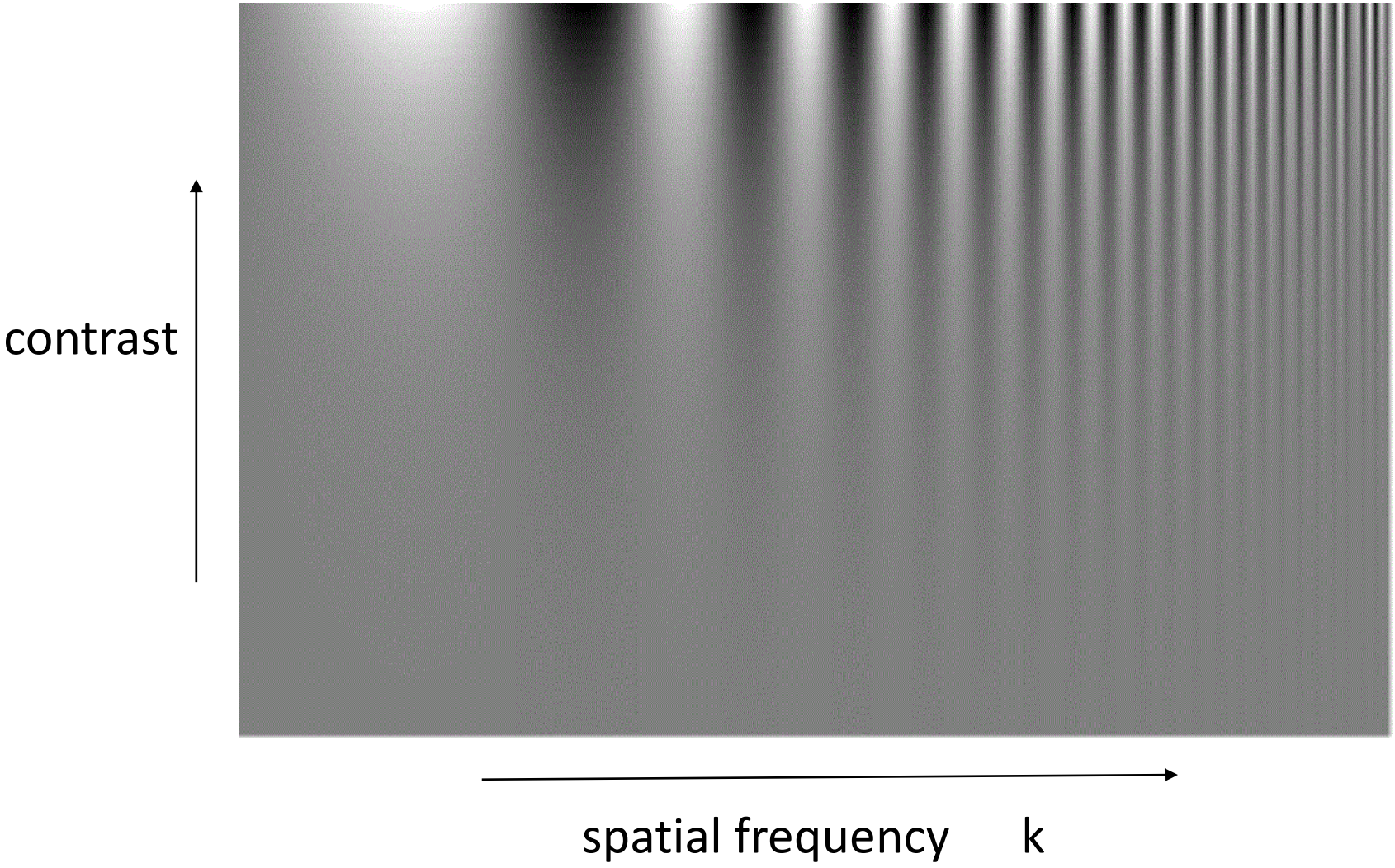
$$\text{Michelson Contrast} \equiv \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

It is always between 0 and 1.

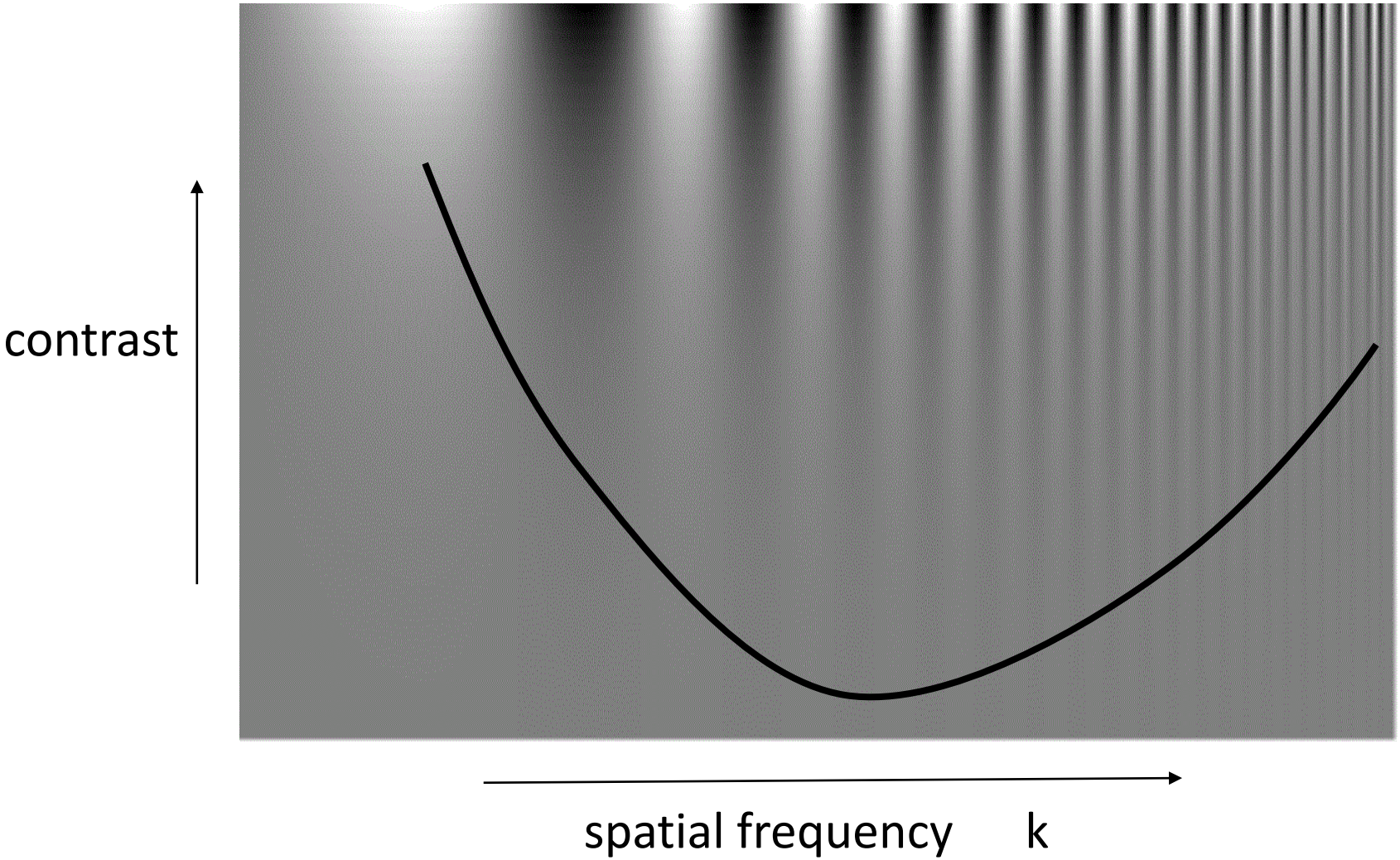


Michelson Contrast $$\frac{\Delta I}{\overline{I}} = \frac{(I_{max} - I_{min})/2}{(I_{max} + I_{min})/2}$$

Contrast thresholds depend on spatial frequency

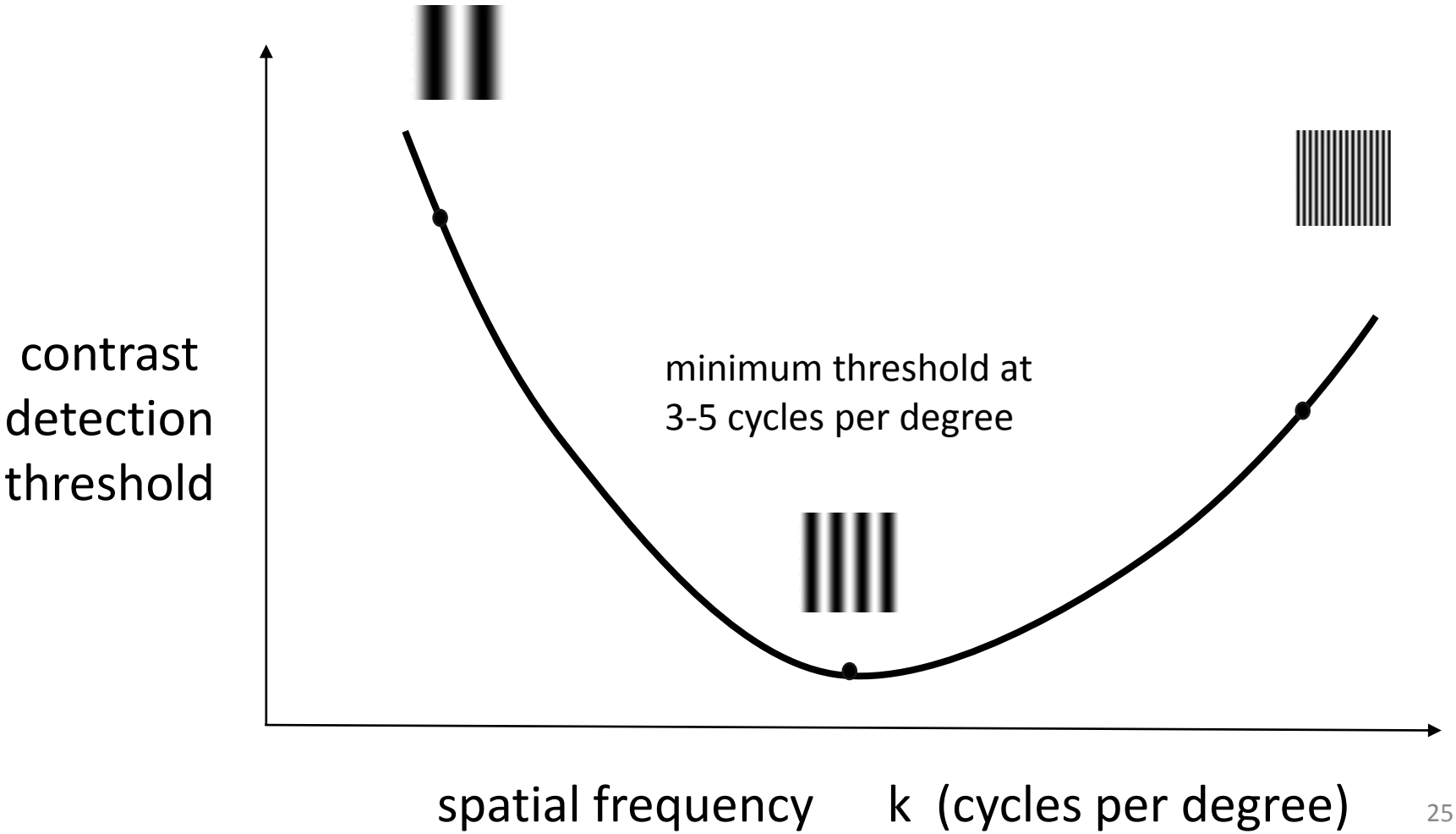


Contrast thresholds depend on spatial frequency

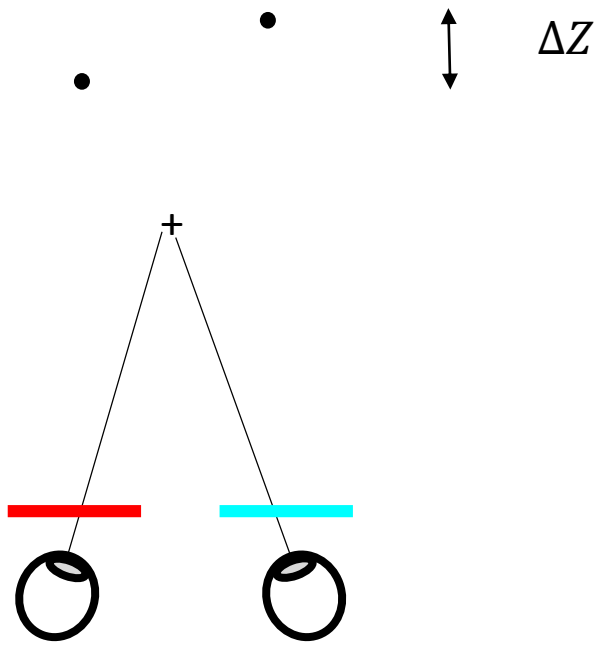


Measure detection threshold at each spatial frequency.

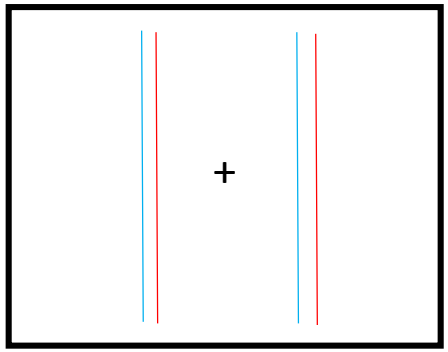
(For 2D sinusoid of size 20x20 degrees)



Example 2a: Depth discrimination from binocular disparity

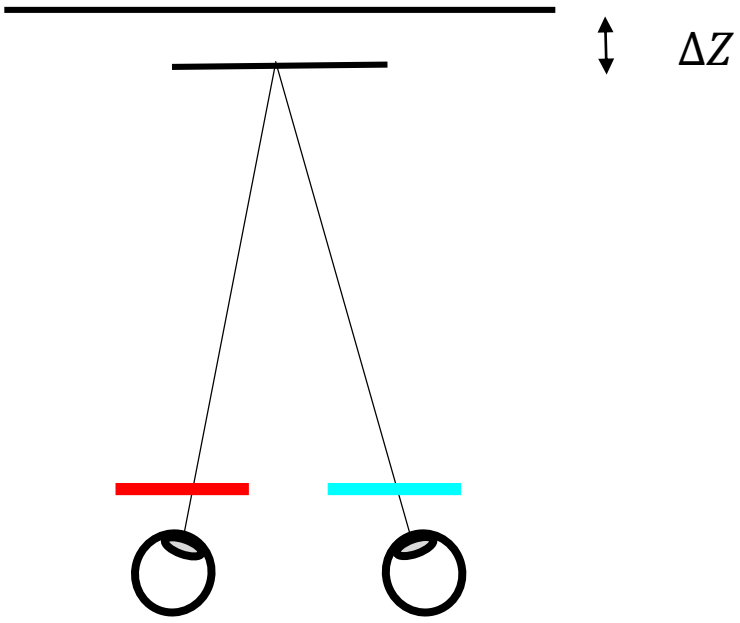


anaglyph image

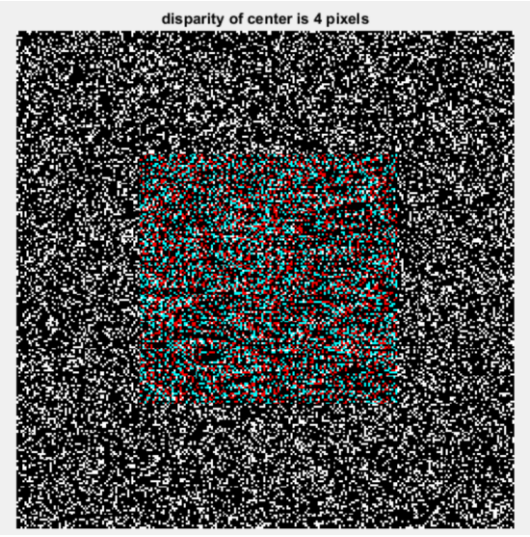


Which is closer to viewer? Left or right?

Example 2b: Depth discrimination from binocular disparity



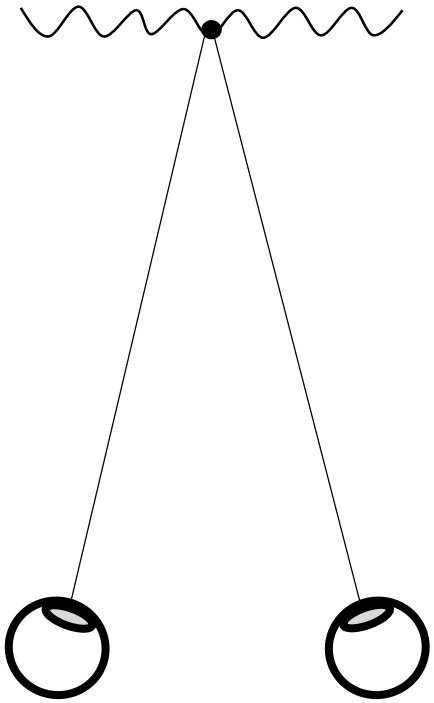
anaglyph

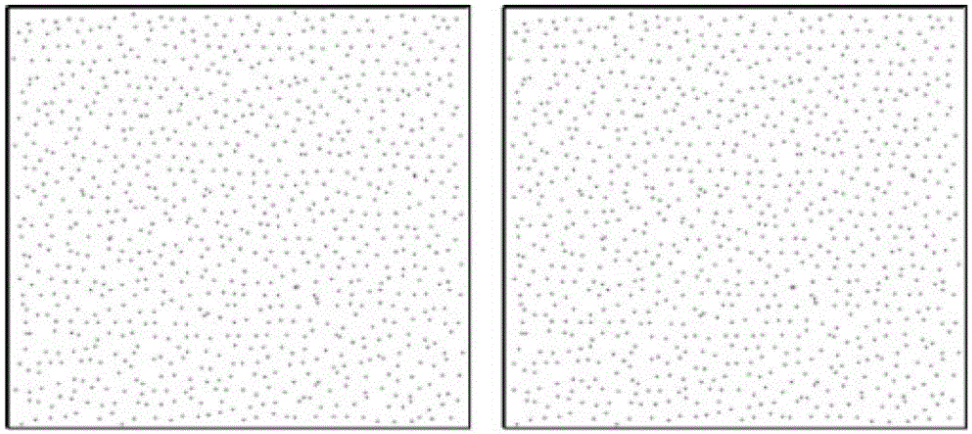


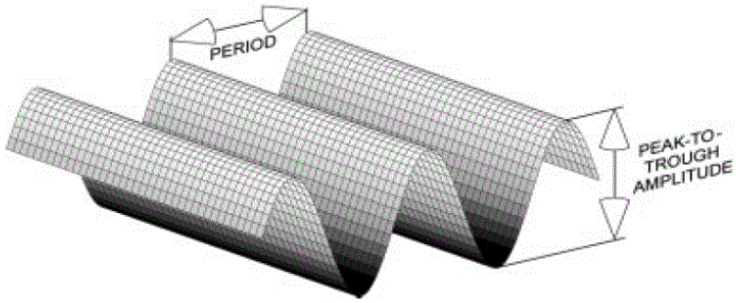
Is square closer or farther than background?

(measure Weber contrast)

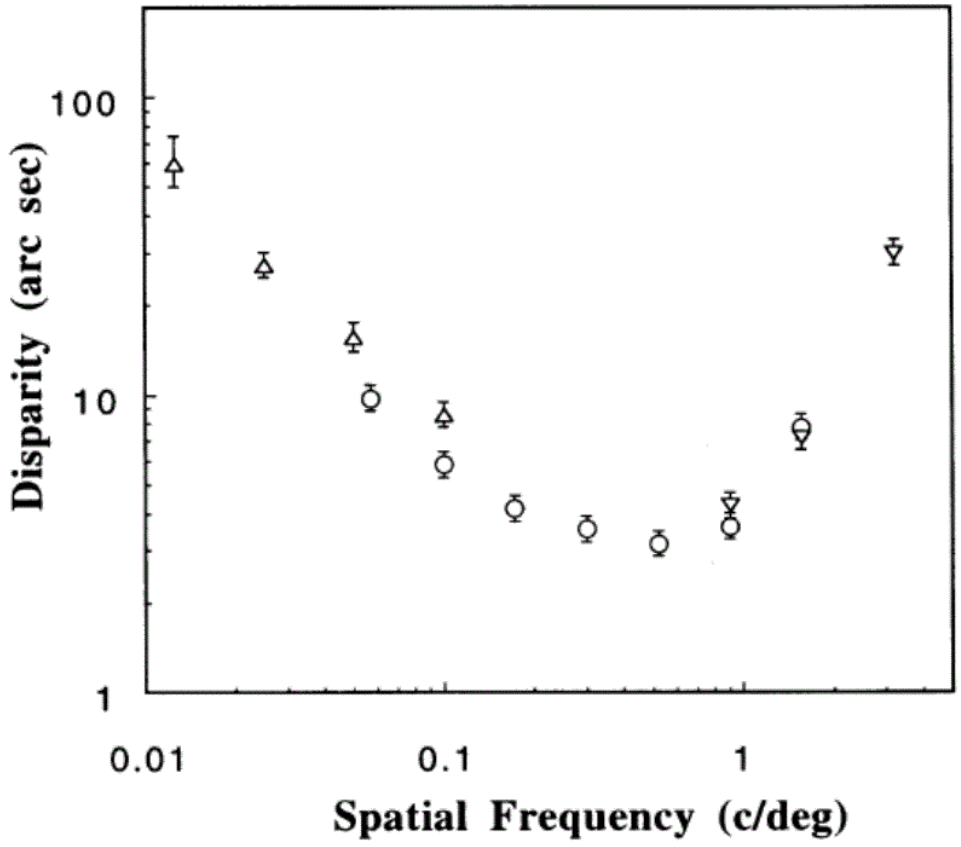
Example 2c: Depth discrimination for 2D sinusoidal binocular disparity





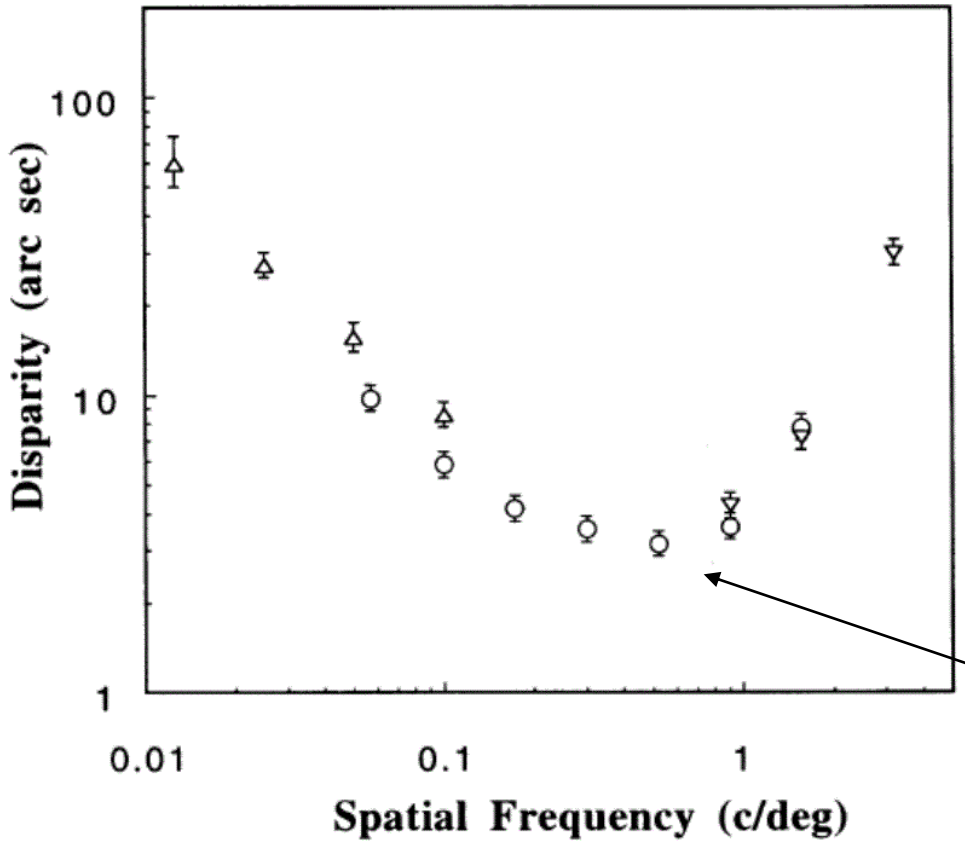


Example 2c: Depth discrimination for 2D sinusoidal binocular disparity



[Bradshaw and Rogers 1999]

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

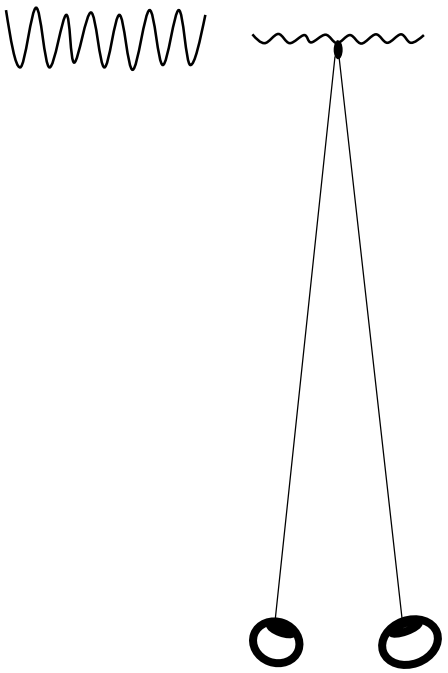


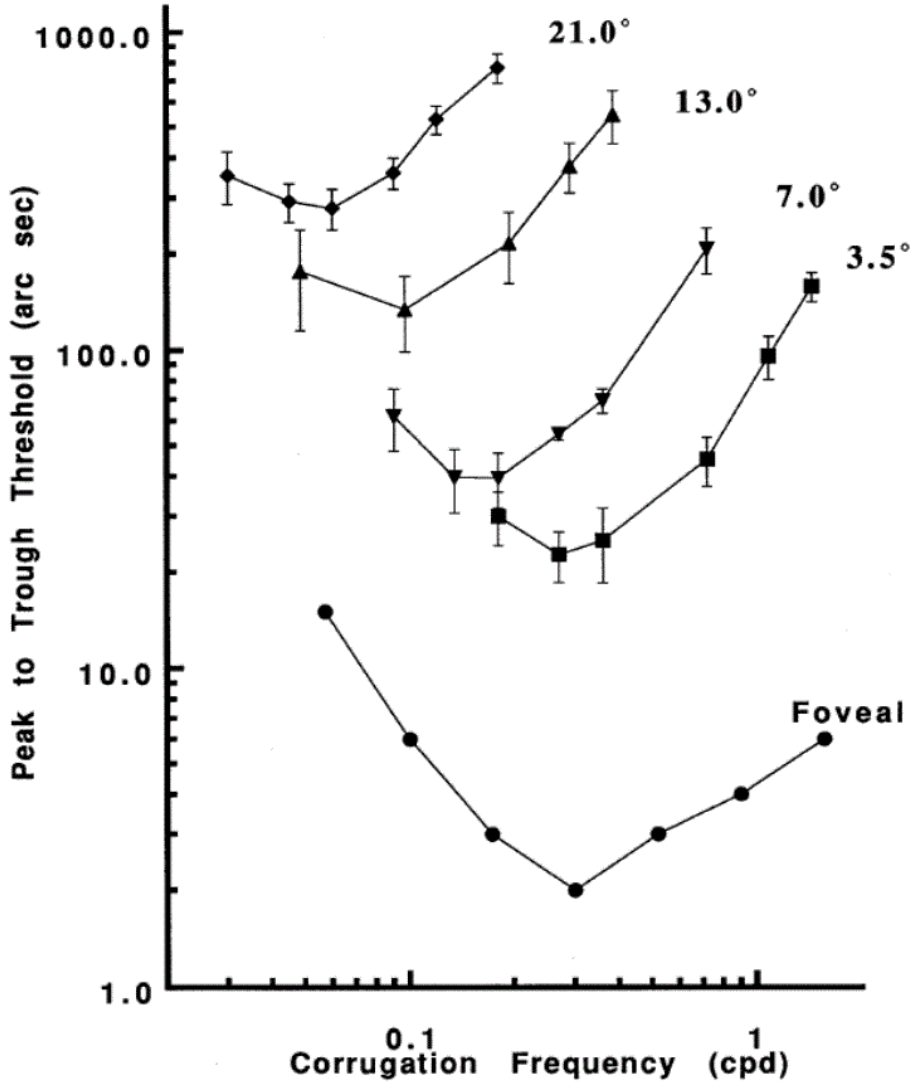
Minimum threshold occurs at much lower ($\frac{1}{10}$) spatial frequency than that of luminance contrast.

Why ?

[Bradshaw and Rogers 1999]

Disparity thresholds increase (worse performance) at larger eccentricity.





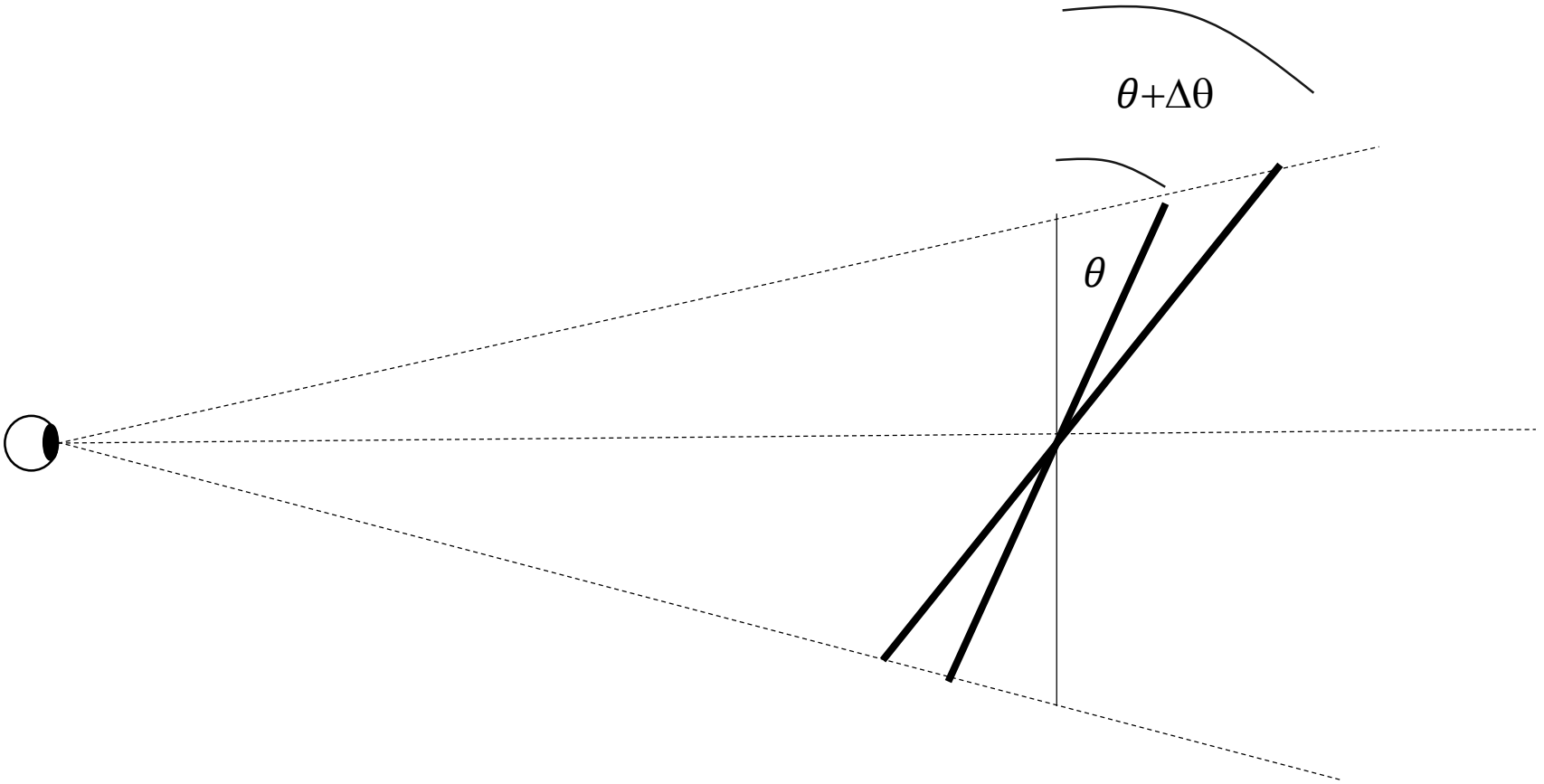
Example 3: Slant from texture

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

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

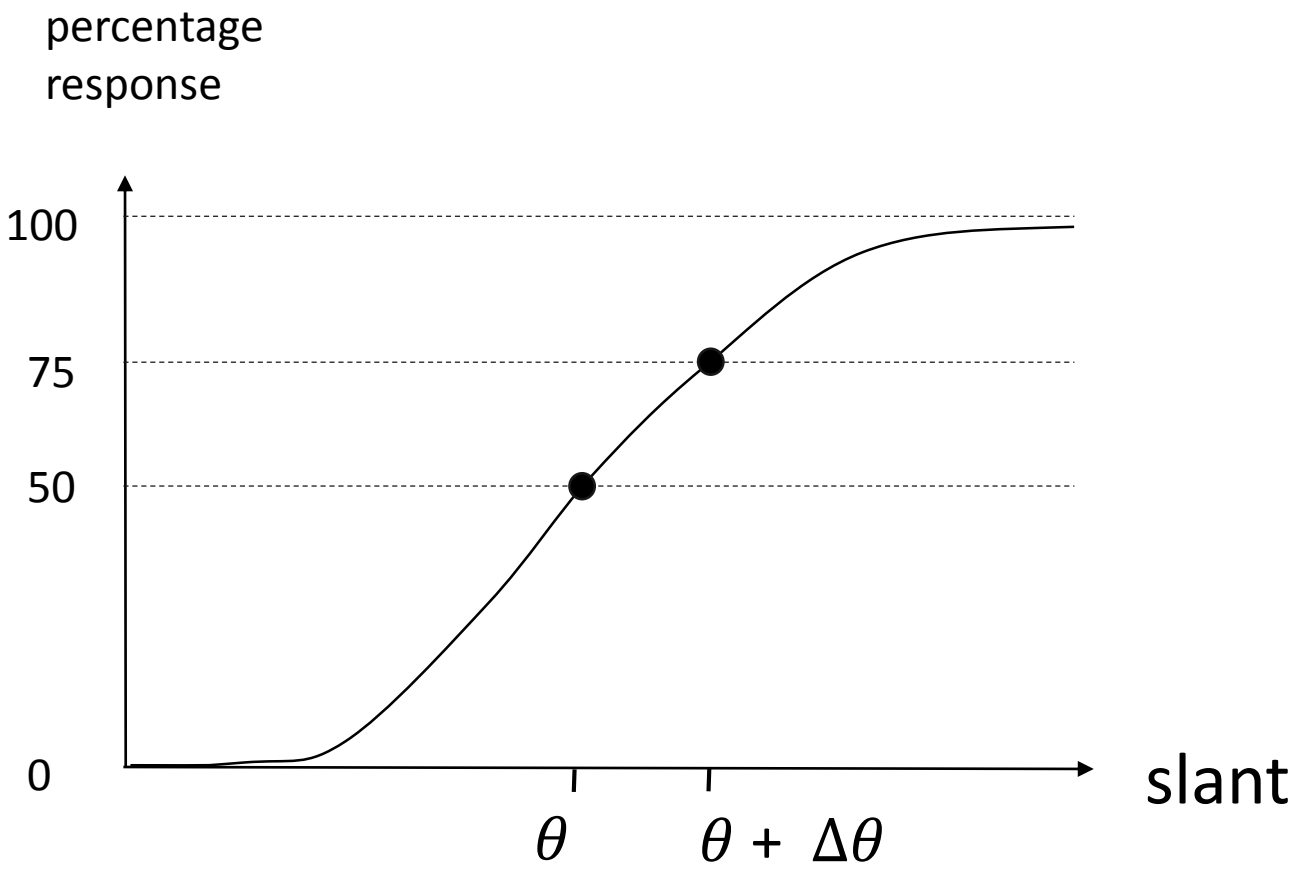
Given two images of slanted surfaces, which surface has greater slant ?

(They might be displayed one after the other, in random order)

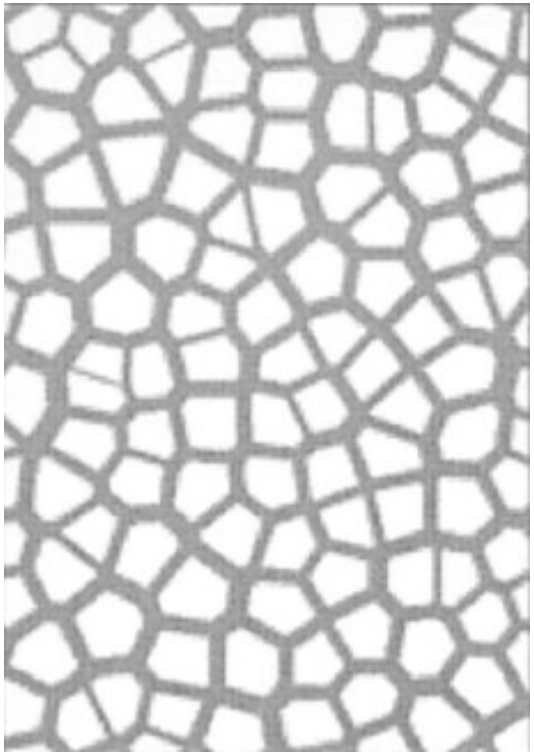


Slant discrimination threshold $\Delta\theta$

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



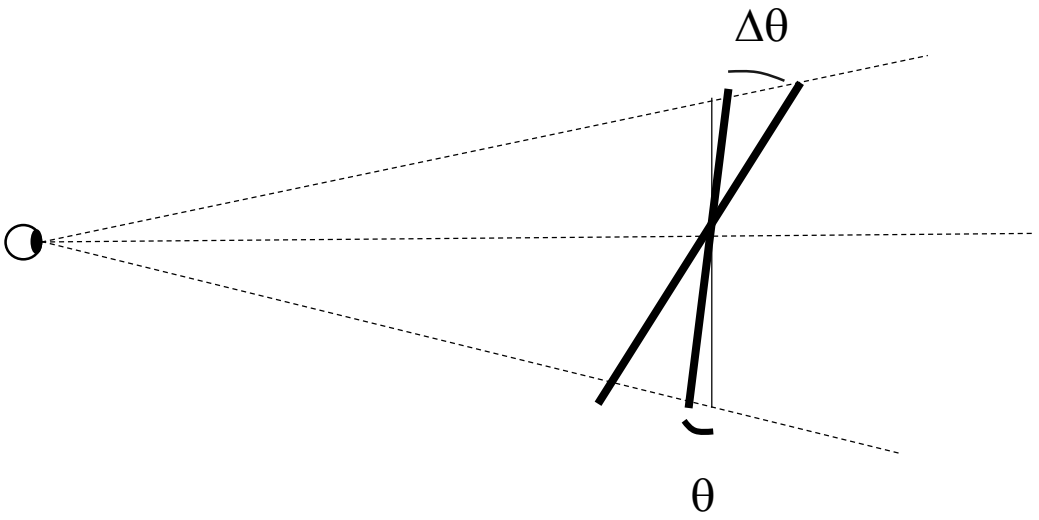
Thresholds $\Delta\theta$ depend on slant θ. How and why?

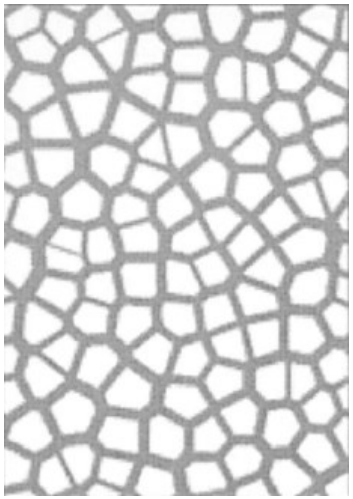


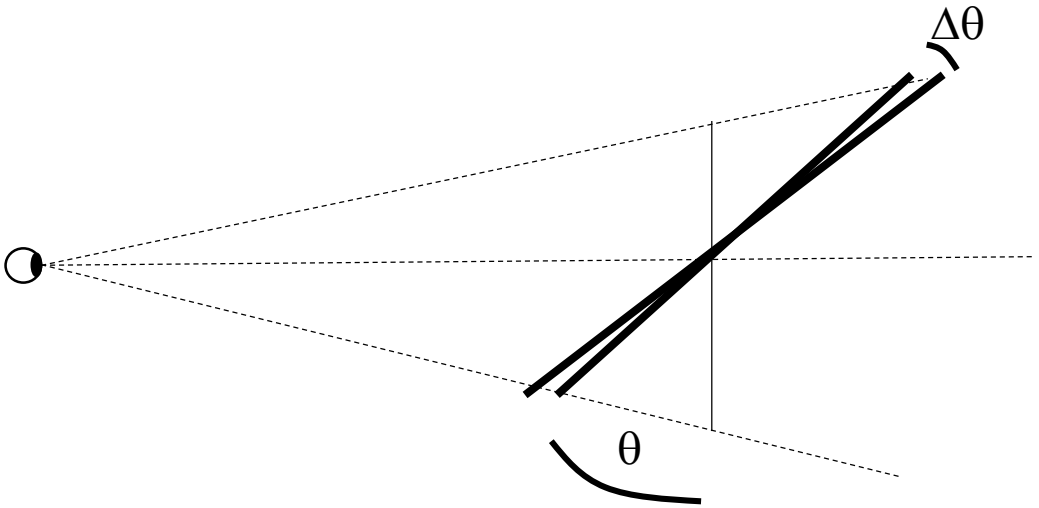
0 deg

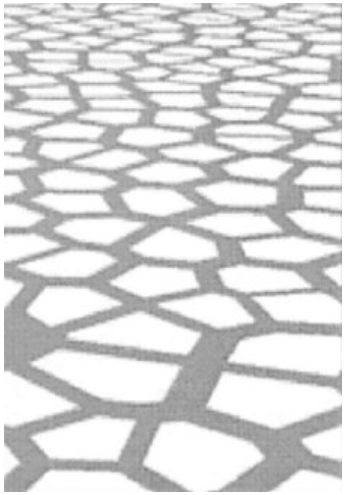
65 deg

$\Delta\theta$ threshold decreases as θ increases.

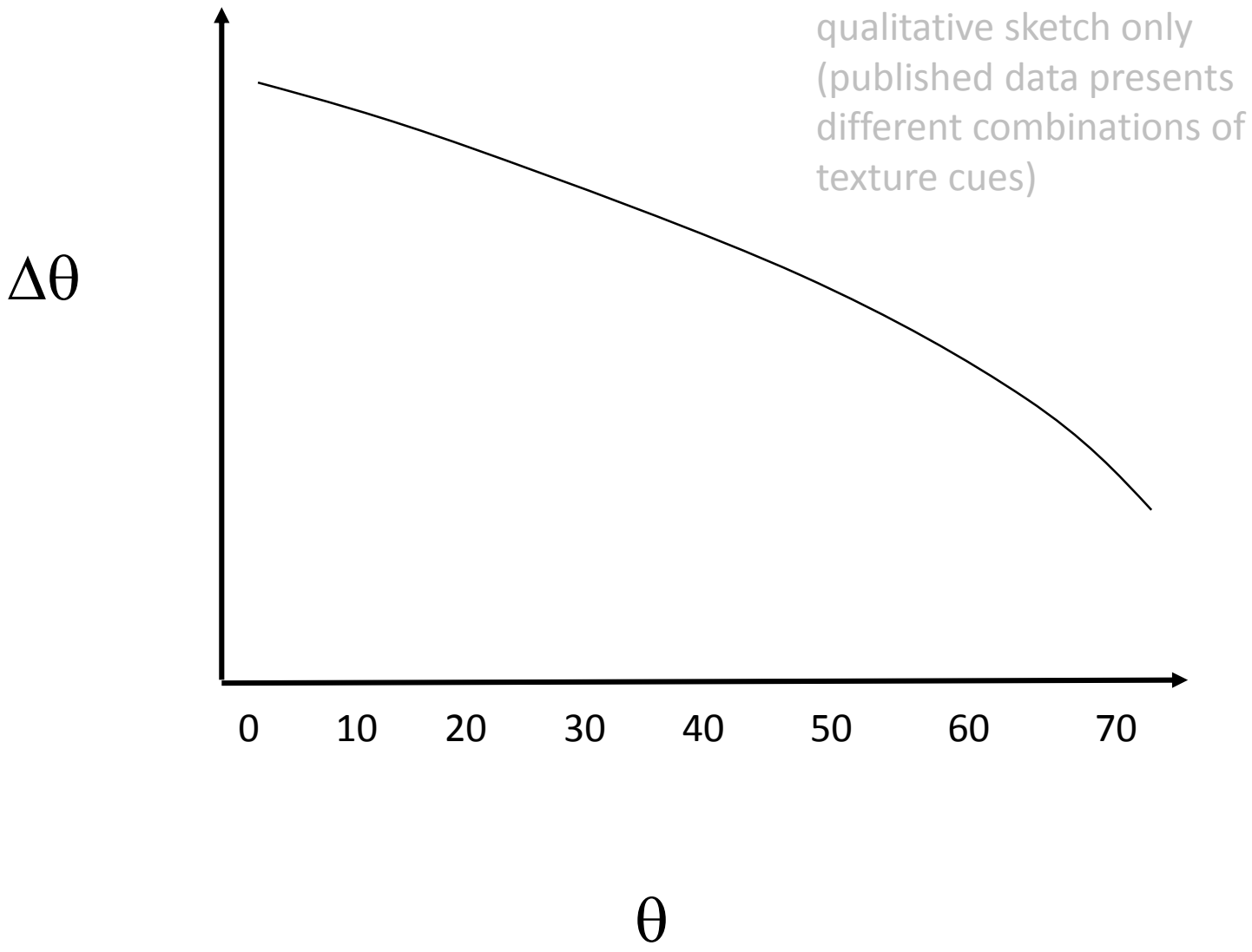








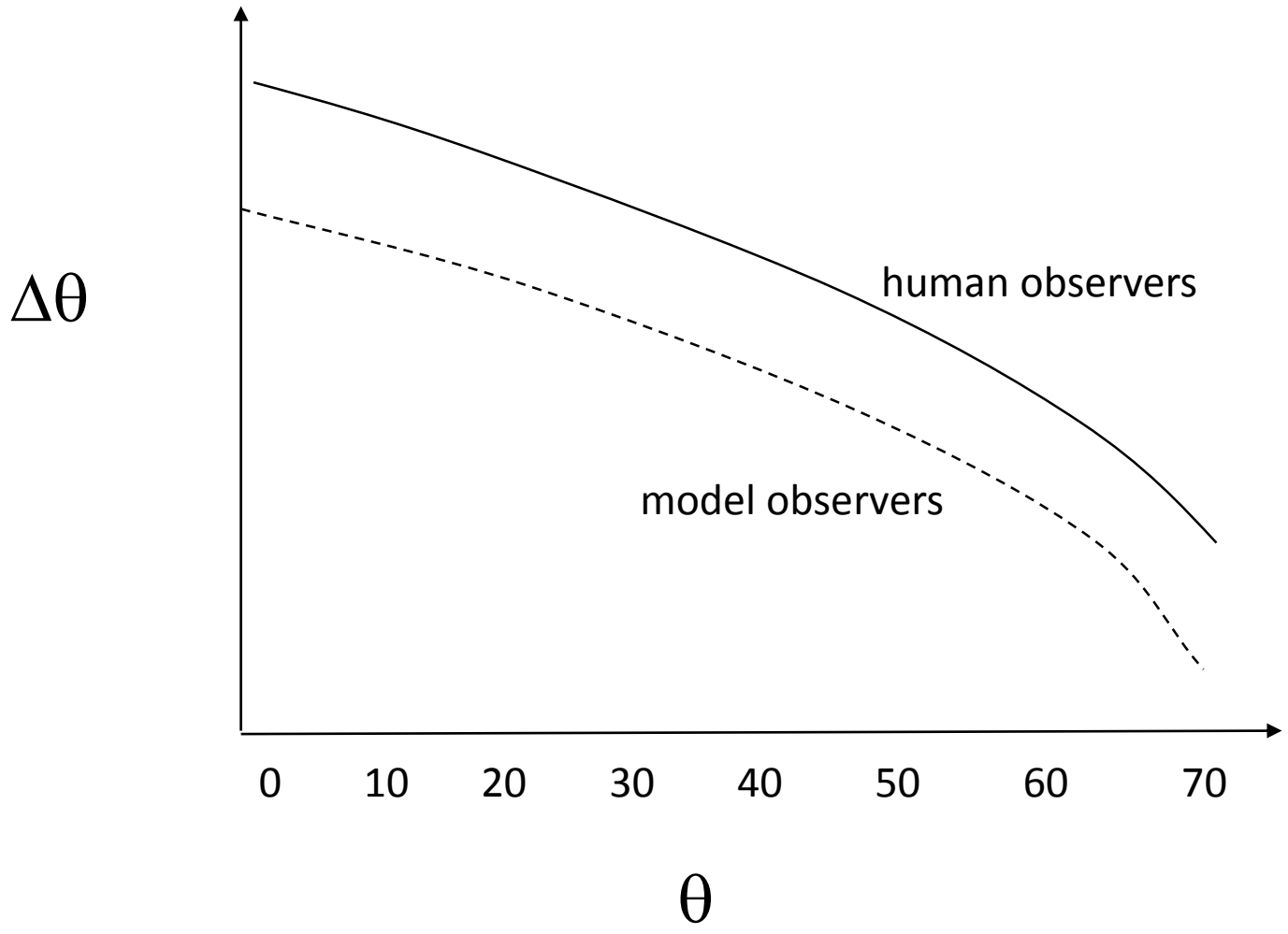
$\Delta\theta$ threshold decreases as θ increases.



Shape from texture: computational model

You can make a model that *knows* the laws of perspective: how do size, density, foreshortening vary in the image of a slanted surface ?

How do these models perform (on *random* texture) ?



[Knill 1998] and several others

Summary

Discrimination thresholds can tell us about:

- underlying mechanisms and models
  (how the brain codes of luminance, 2D orientation, disparity, surface slant …)

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