COMP 546

Lecture 9

binocular disparity & disparity space defocus blur

Thurs. Feb. 9, 2019

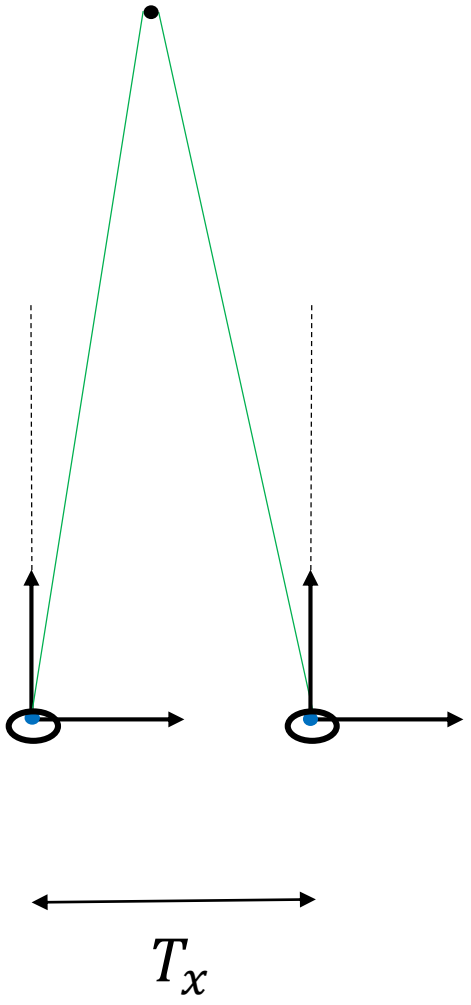
Recall: Binocular disparity and depth

Let x_l and x_r be visual direction to a 3D point.

(In lecture 1, we used the notation θ_l and θ_r for this.)

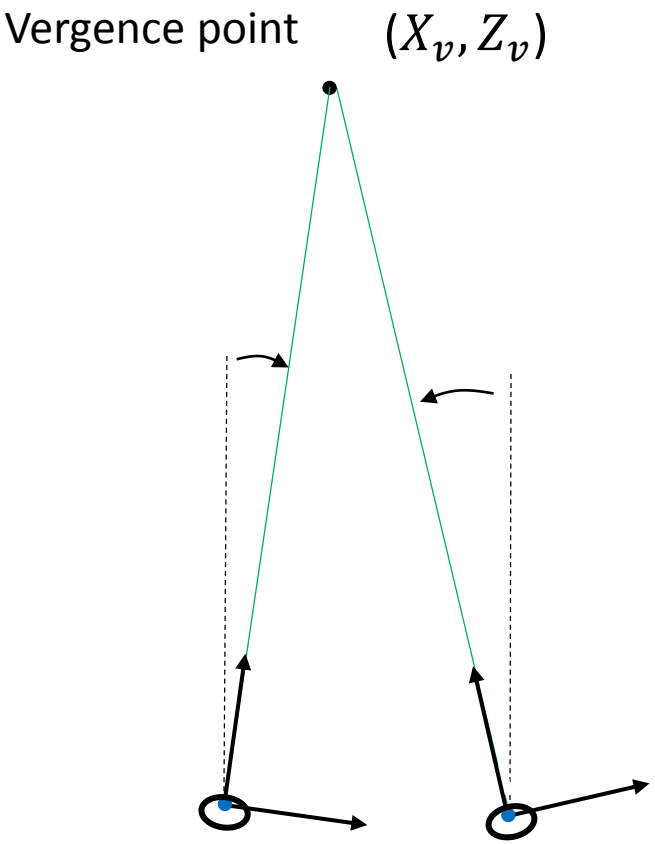
$$\text{disparity} \equiv x_l - x_r = \frac{T_x}{Z_0}$$

(Take $f = 1$ in lecture 1, if you are uncomfortable.)



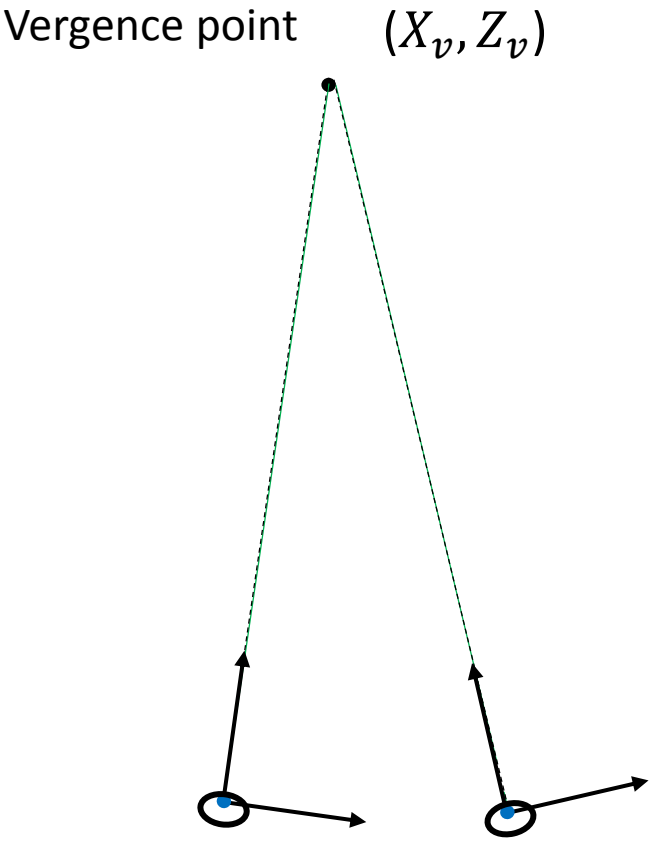
Recall: Binocular vergence

Suppose the eyes rotate to look at this 3D point.



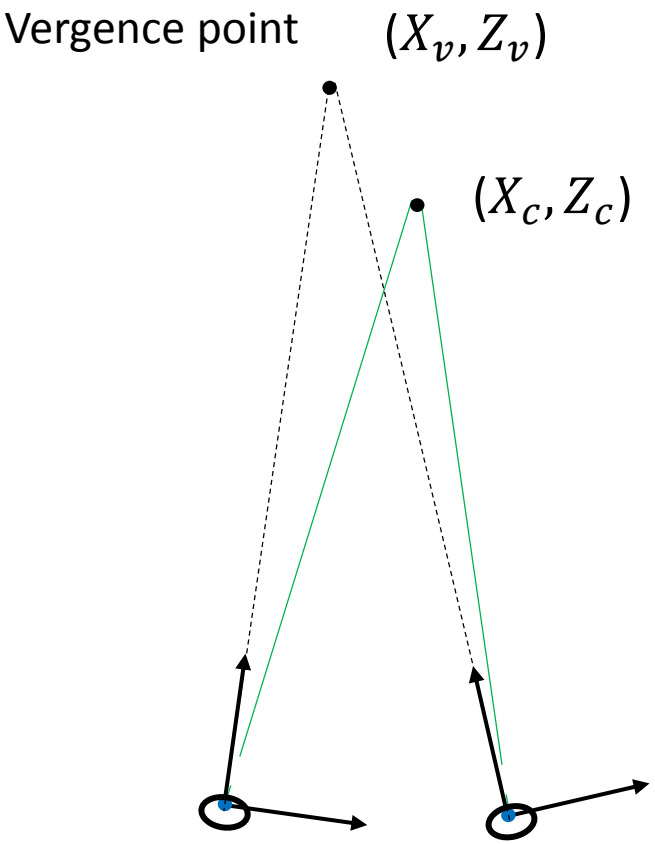
After the eyes rotate to look at this 3D point, then $x_l = 0$ and $x_r = 0$ for this point.

disparity $\equiv x_l - x_r = 0$



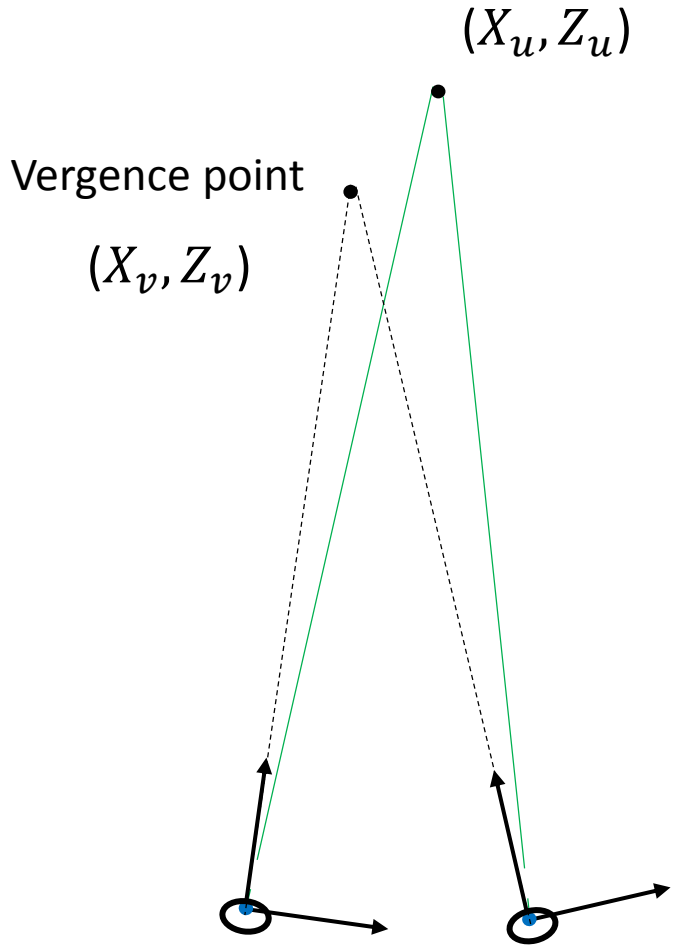
Crossed disparity

A 3D point that is closer than the vergence point is in direction x_l and x_r in the left and right eyes. We say it has crossed disparity.



disparity $\equiv x_l - x_r > 0$

Uncrossed disparity

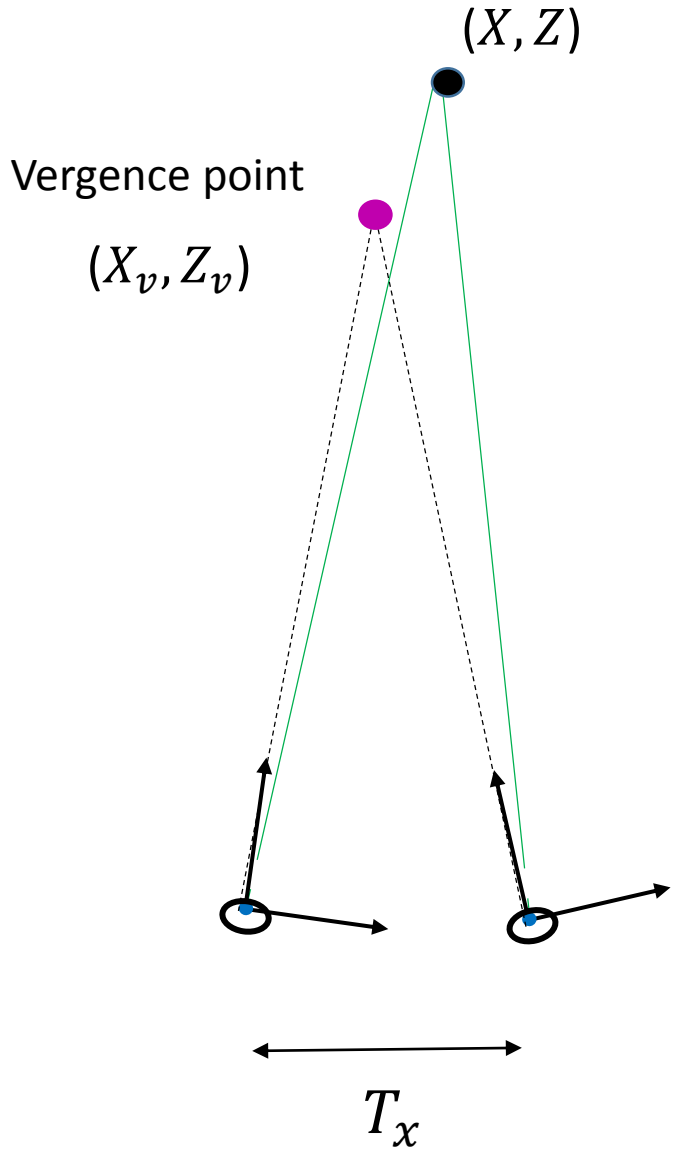


A 3D point that is farther than the vergence point is in direction x_l and x_r in the left and right eyes. We say it has uncrossed disparity.

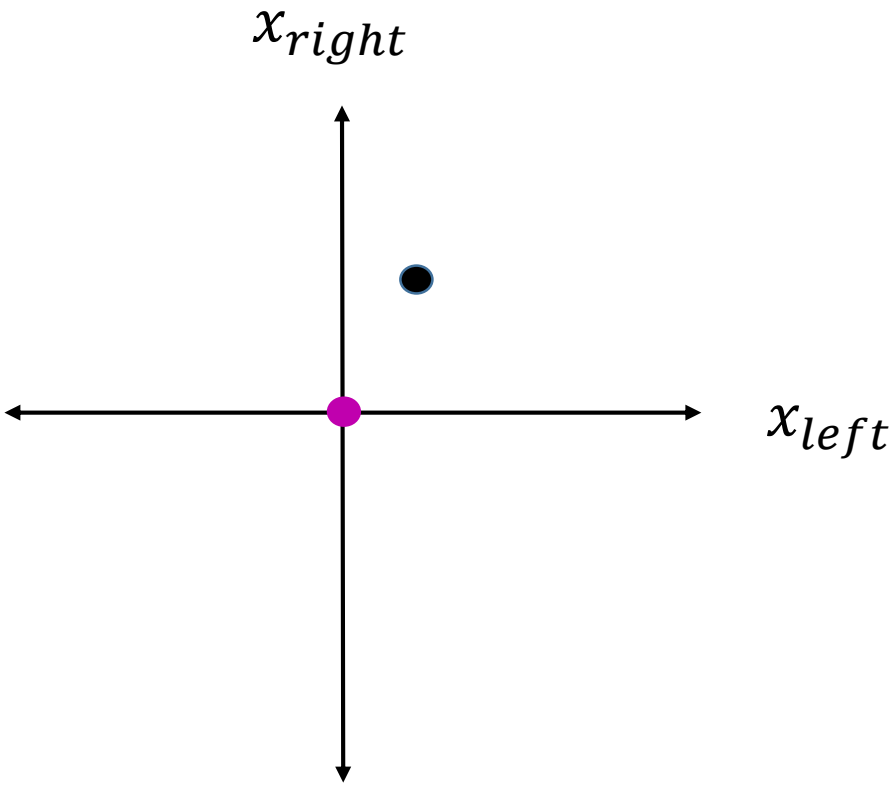
disparity $\equiv x_l - x_r < 0$

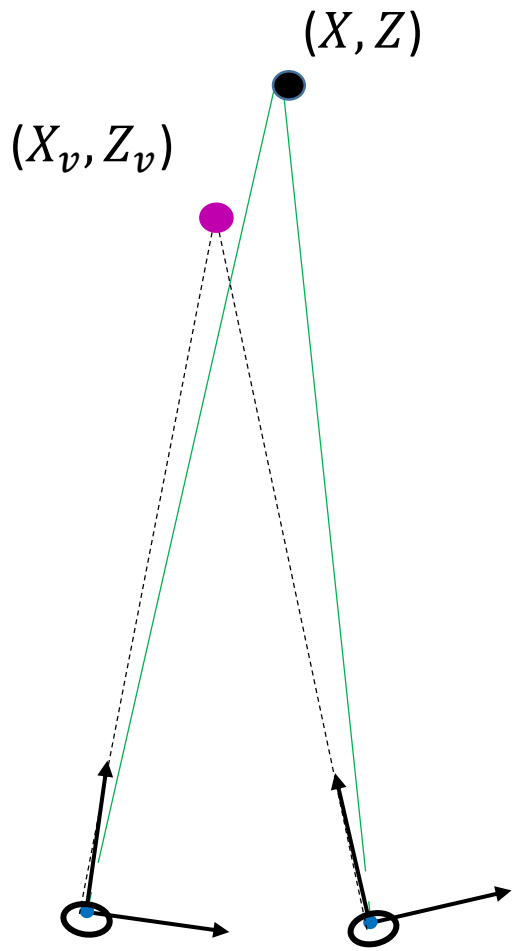
Recall disparity and depth

$$disparity = T_x \left| \frac{1}{Z} - \frac{1}{Z_v} \right|$$

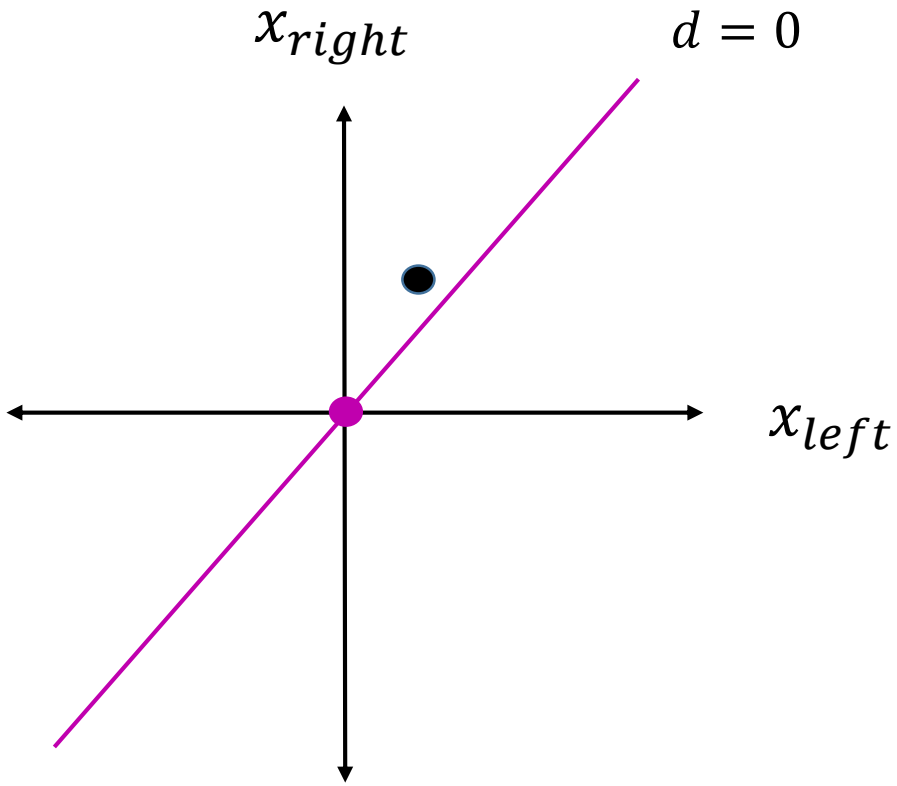


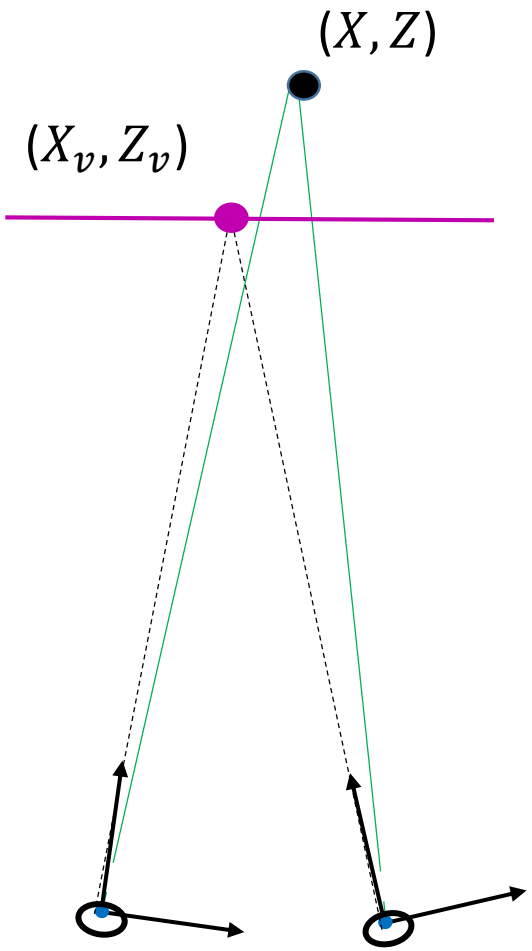
Disparity Space



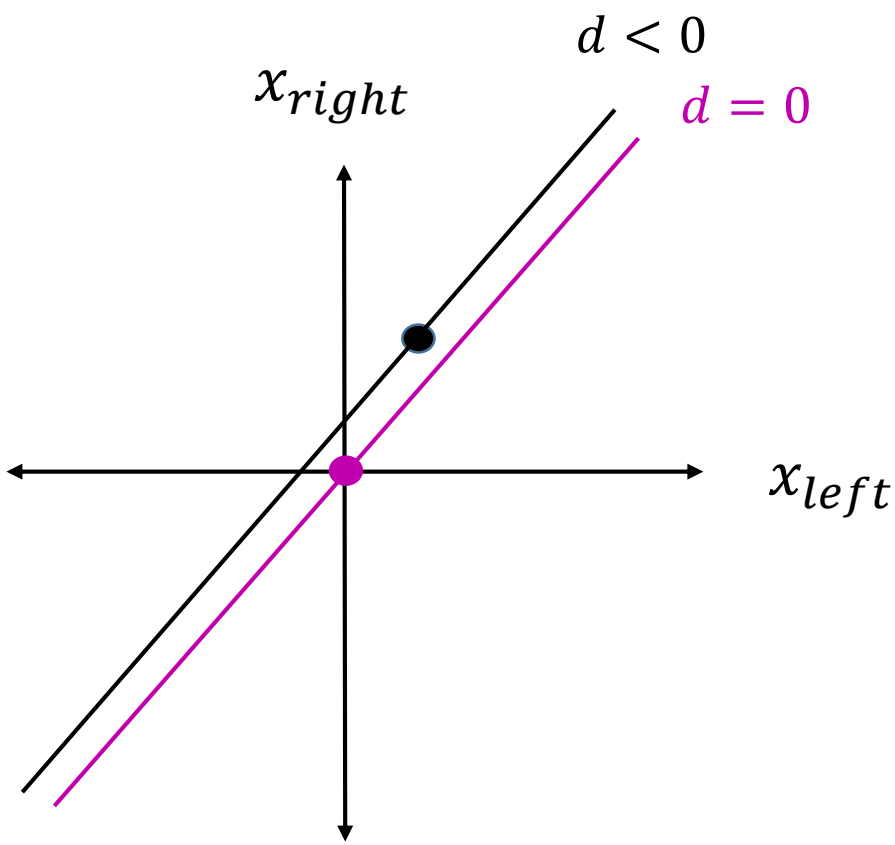


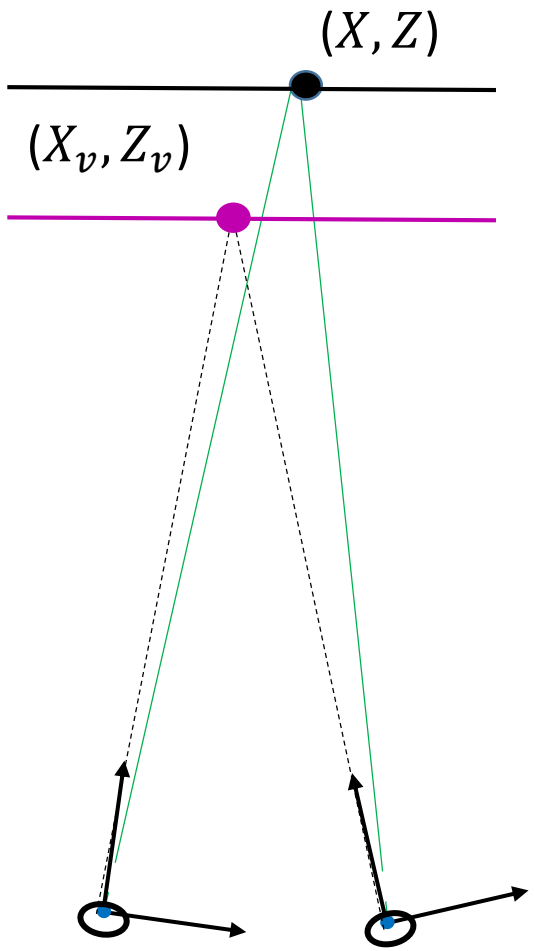
Disparity Space



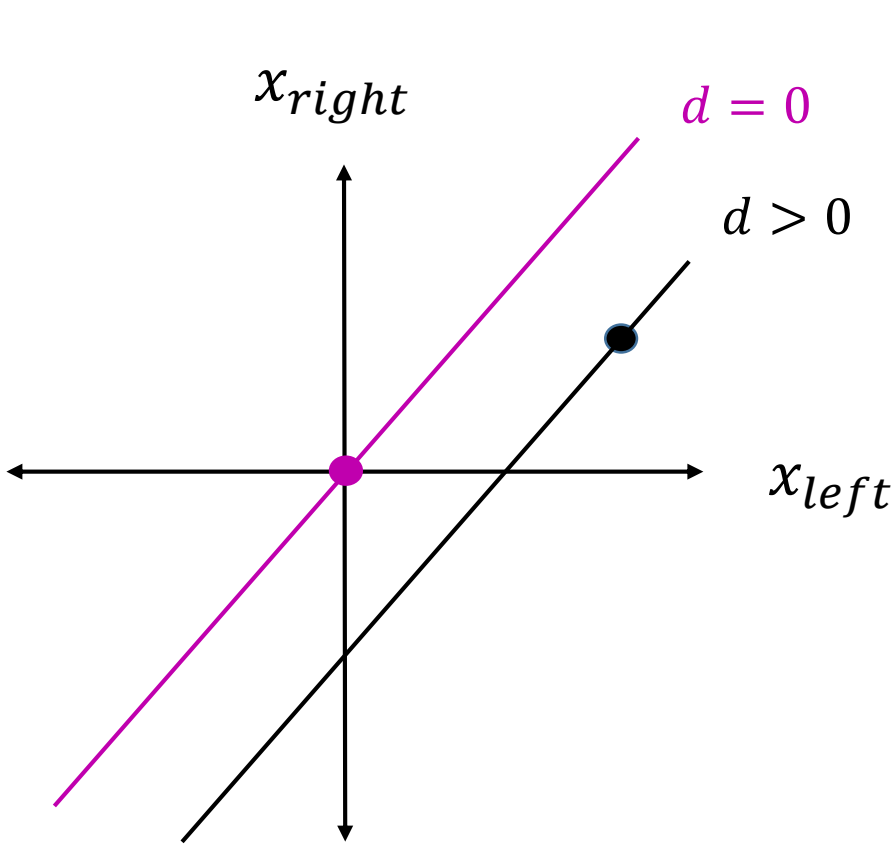


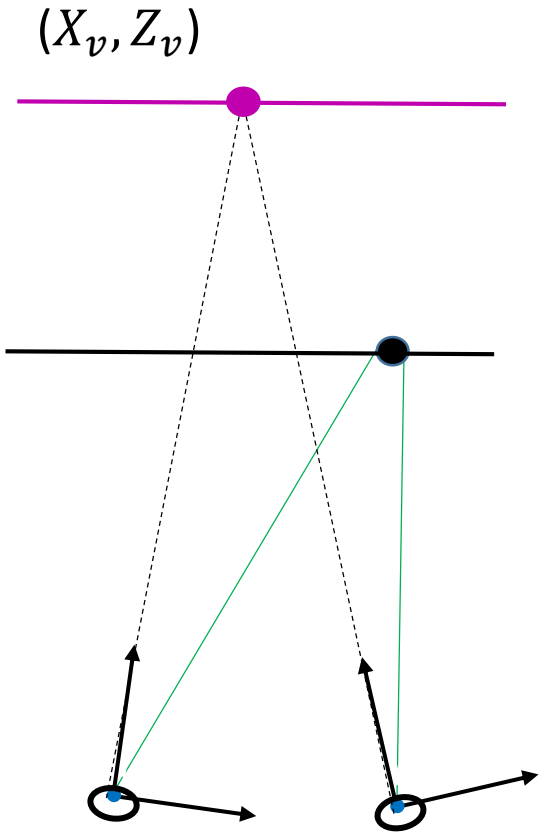
Disparity Space





Disparity Space





How to study binocular stereo vision ?

Neuroscience

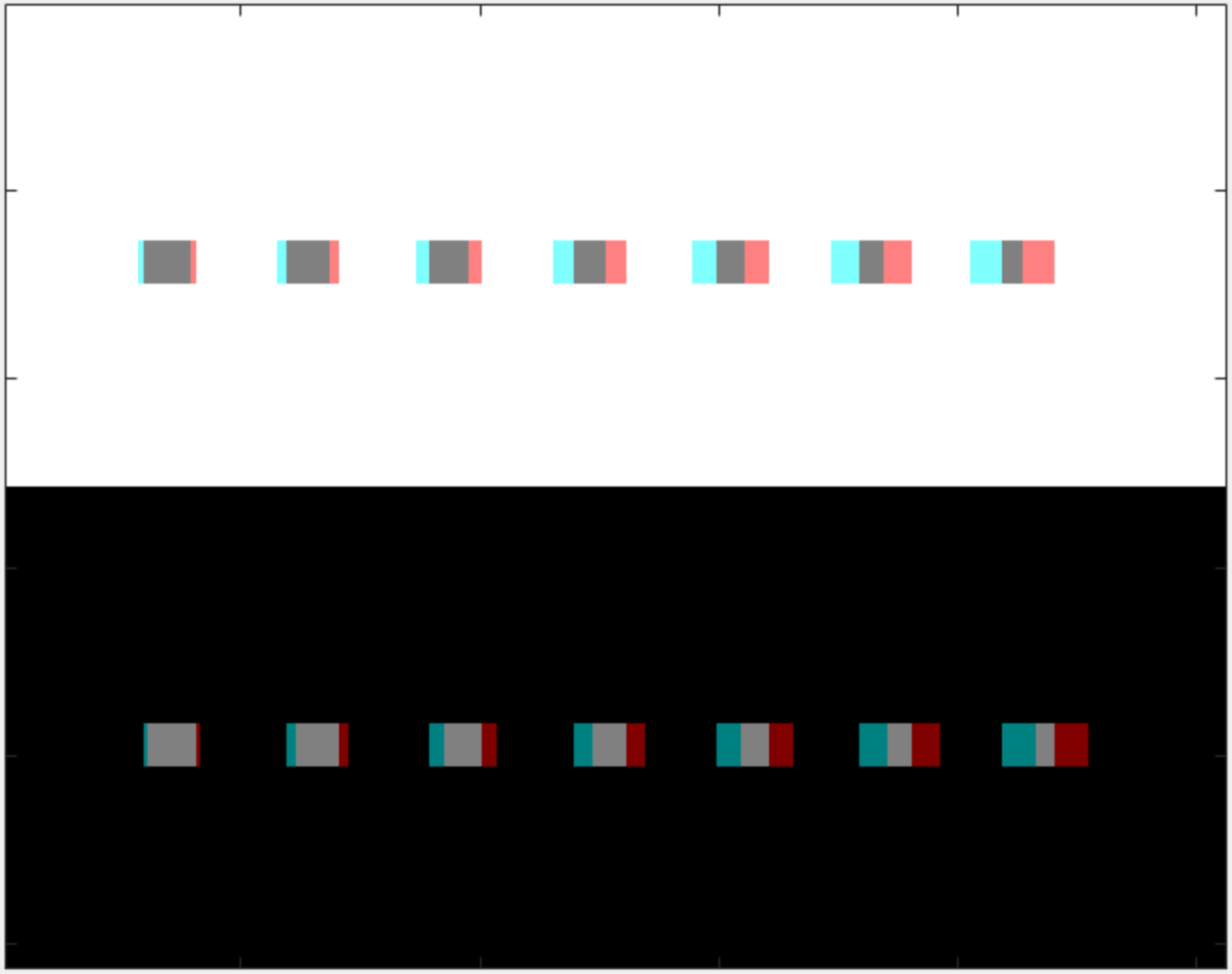
- Show animals (cats, monkeys) or people different images to the left and right eyes and measure brain activity.

Computer Vision

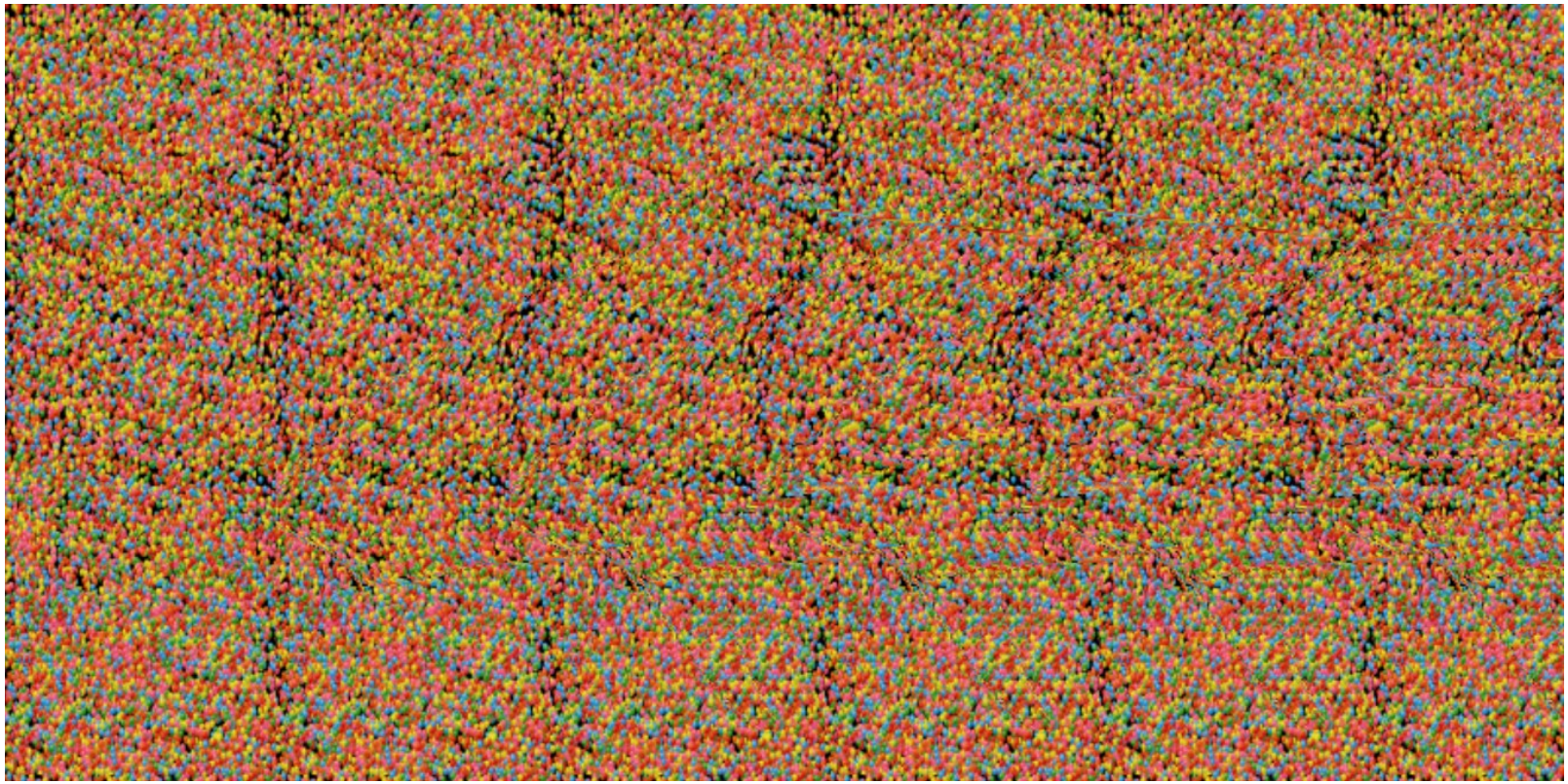
- Write a computer program that finds matching points in left and right images

Psychology

- Show people different images to the left and right eyes and measure how well they judge depth.



“Autostereogram”



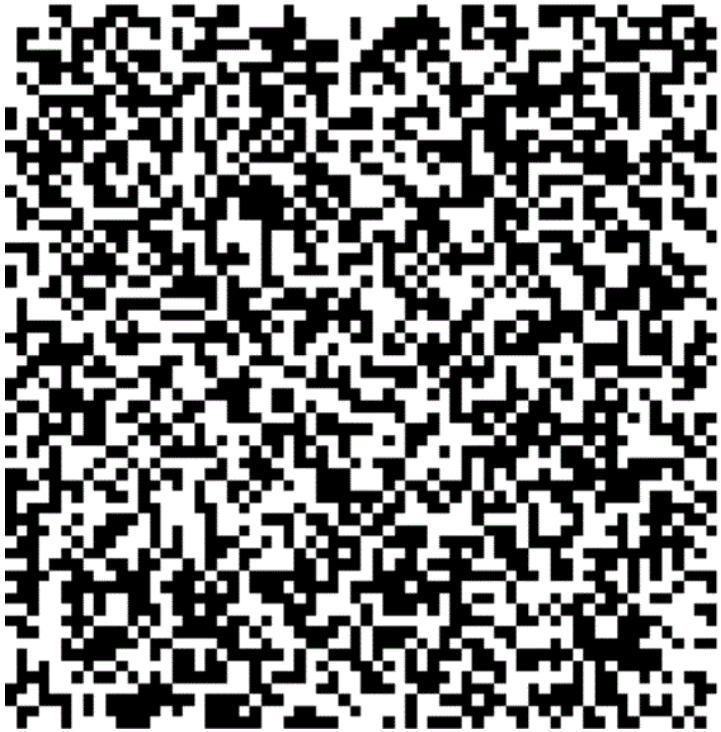
These are typically not used in vision science, as they are relatively complicated to construct and explain.

Random Dot Stereogram

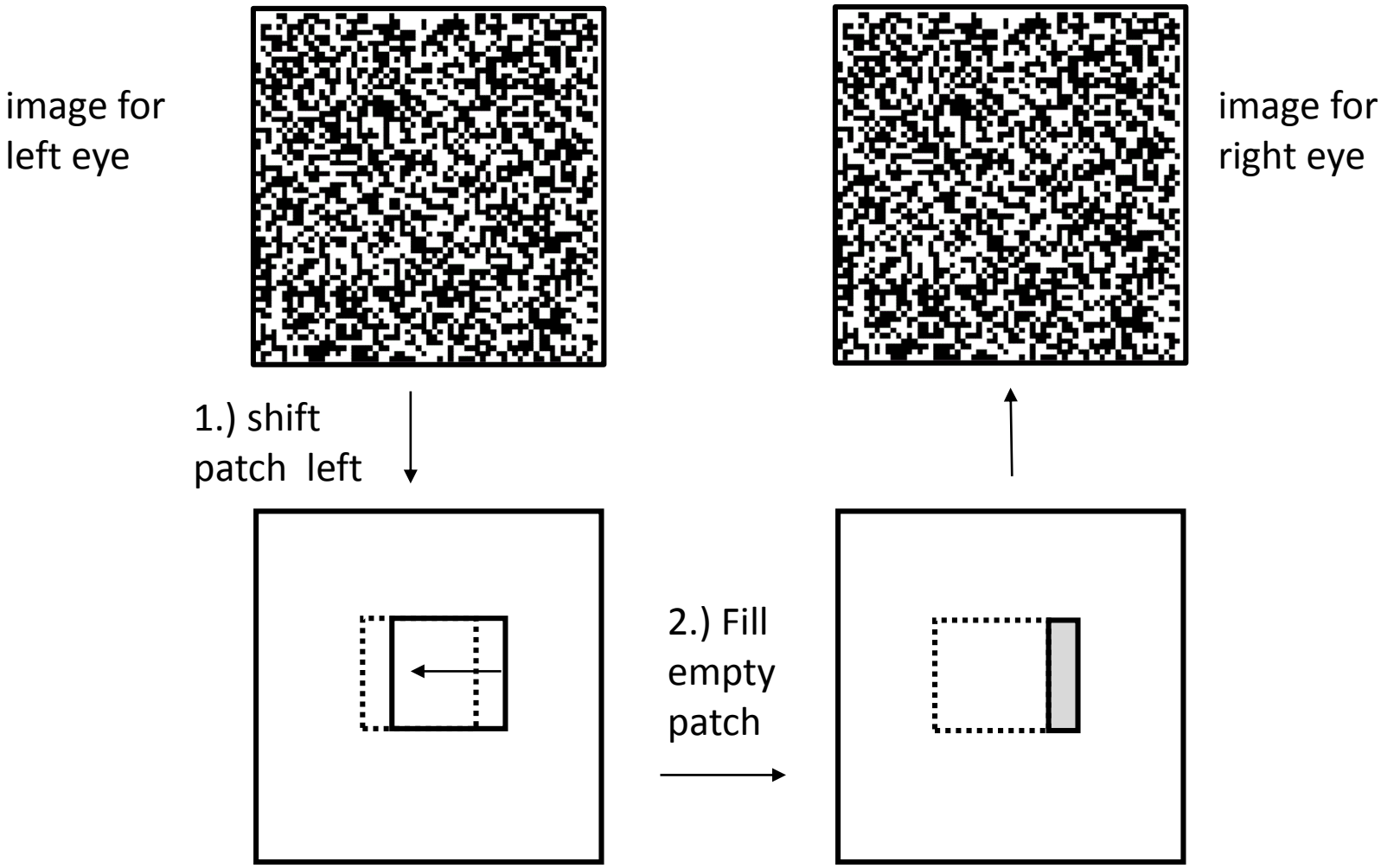
Bela Julesz, “Binocular depth perception *without familiarity cues*” *Science* 1964.

left eye image

right eye image



How to make a random dot stereogram?



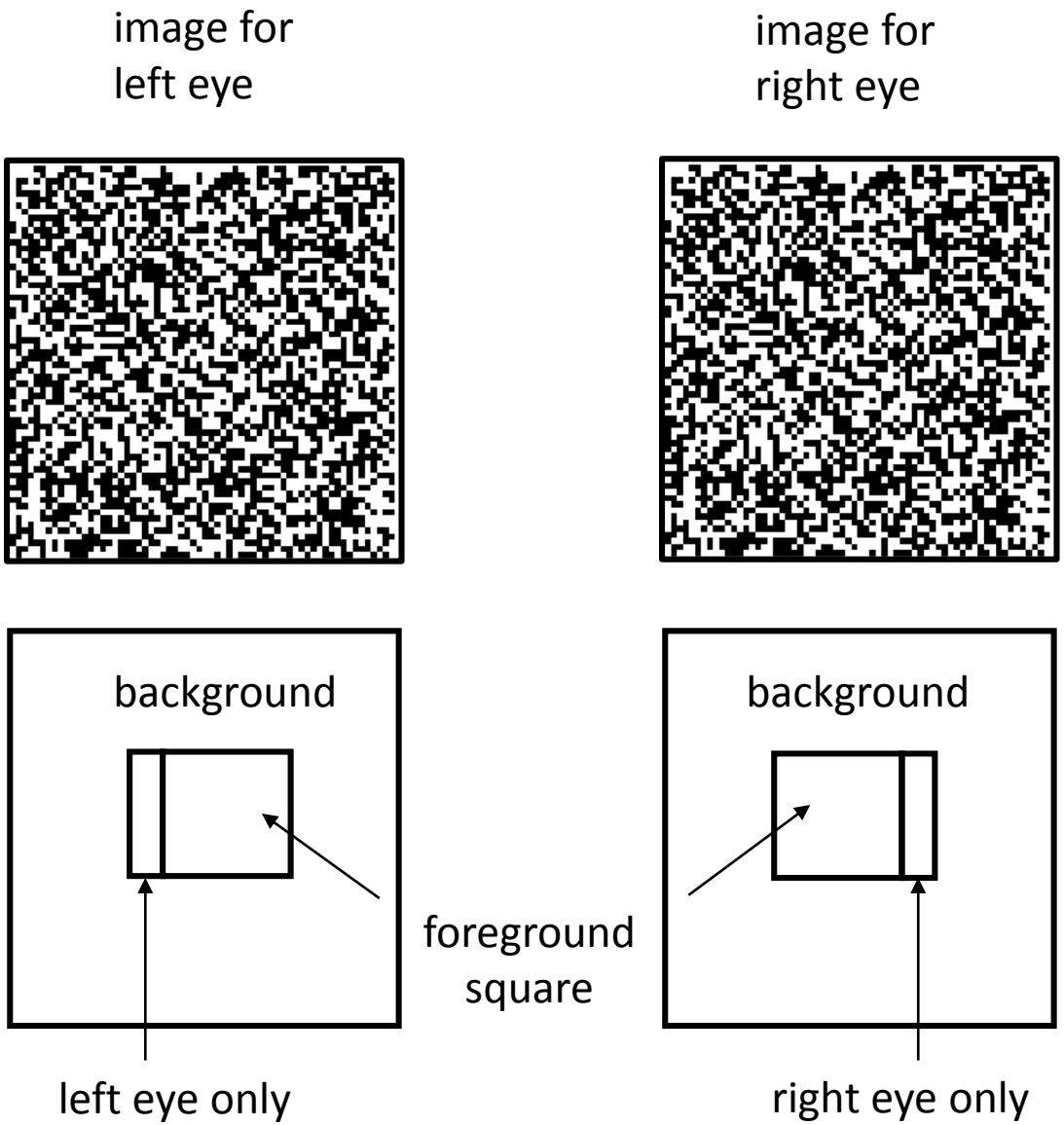
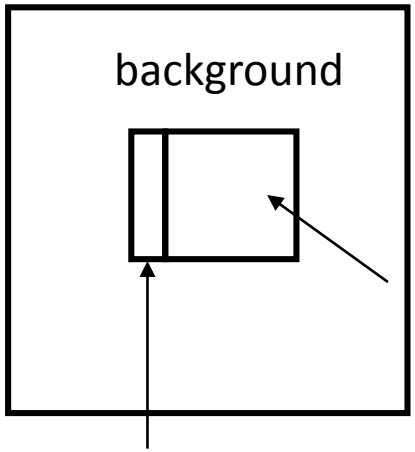


image for
left eye
image for
right eye
background
background
foreground
square
left eye only
right eye only

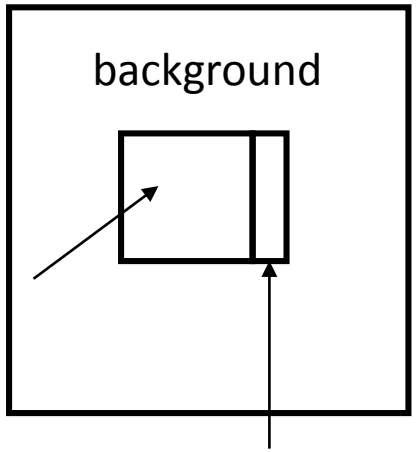
image for
left eye

image for
right eye

perceived depths

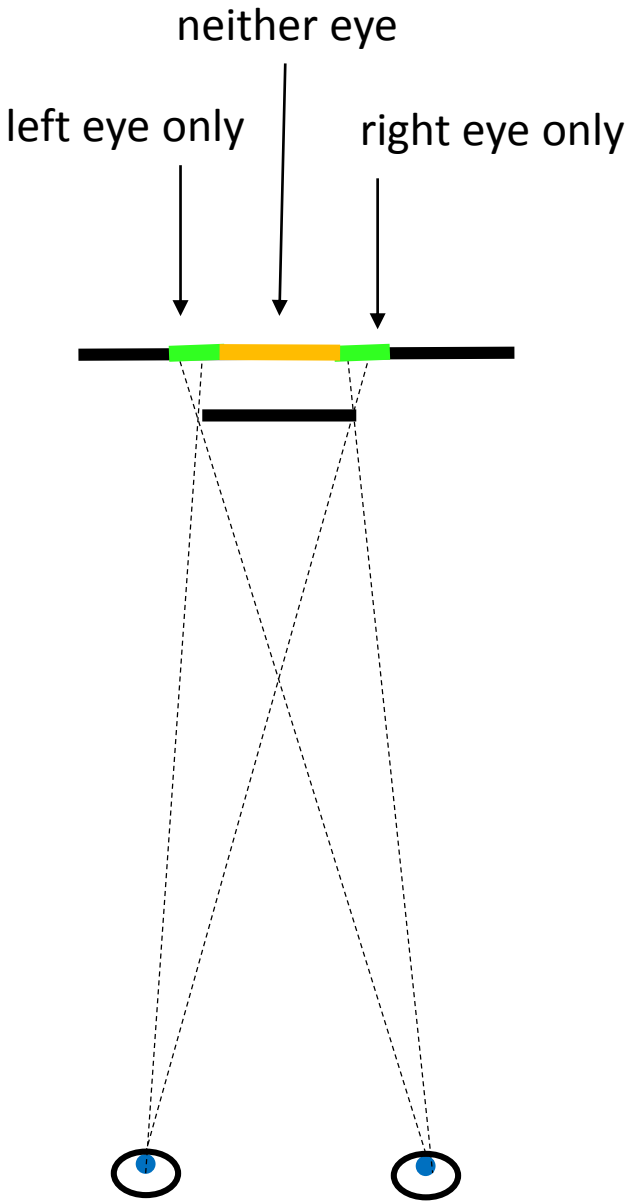


foreground
square

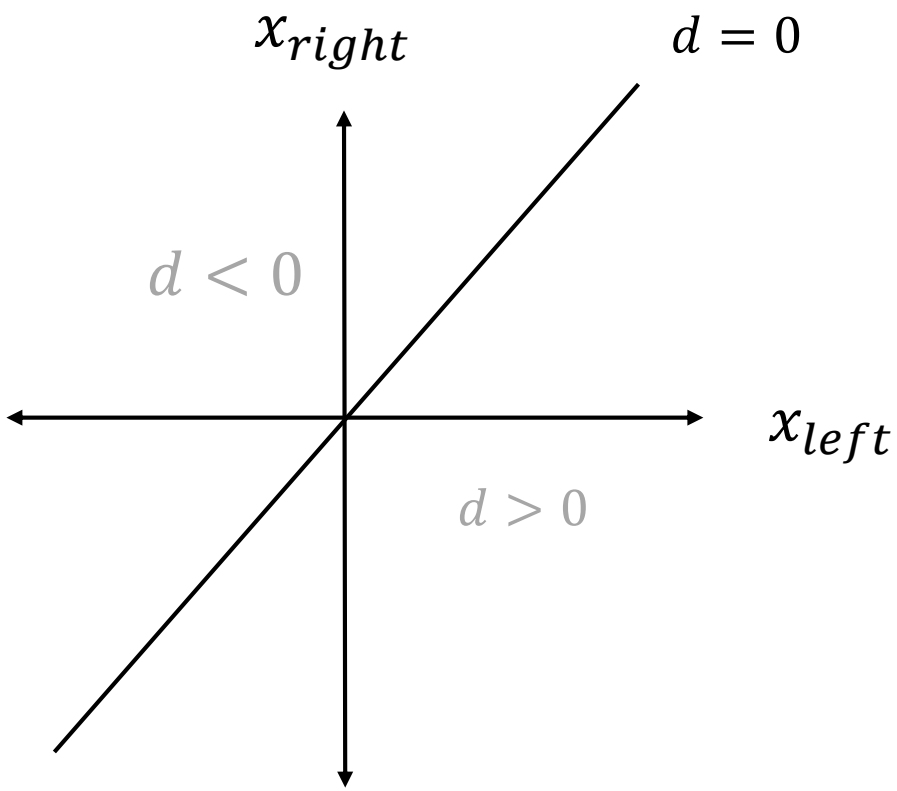


left eye only

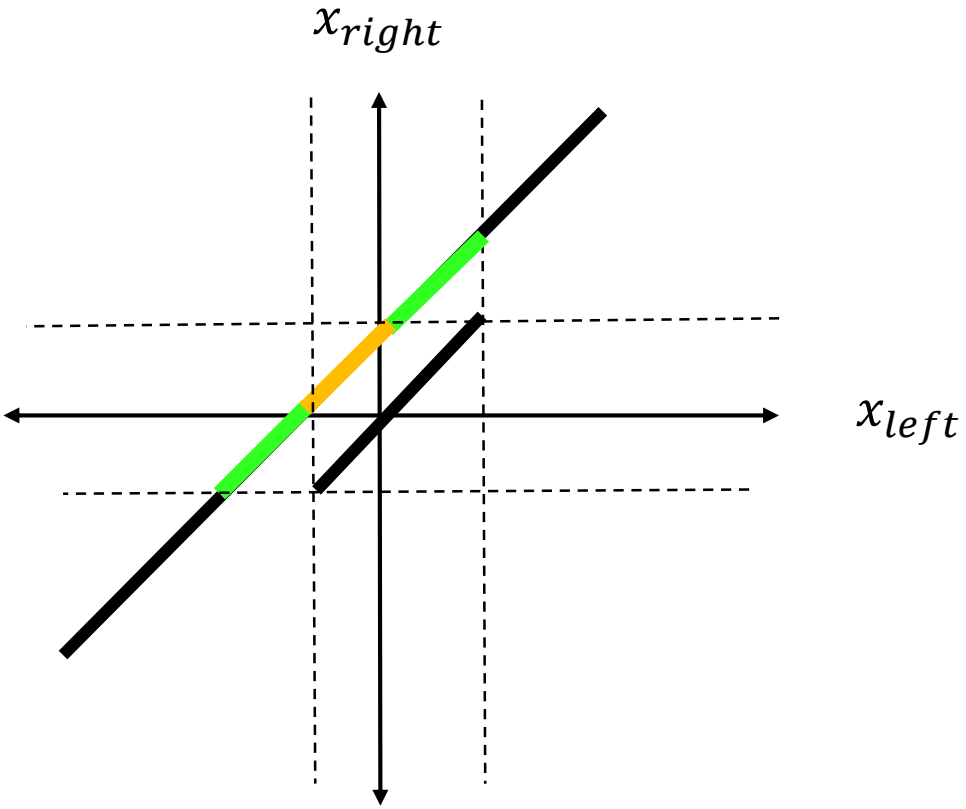
right eye only

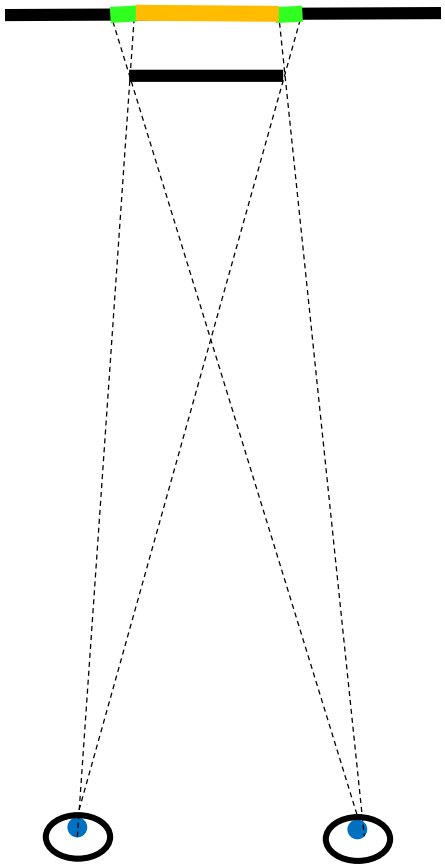

neither eye
left eye only
right eye only

Disparity Space



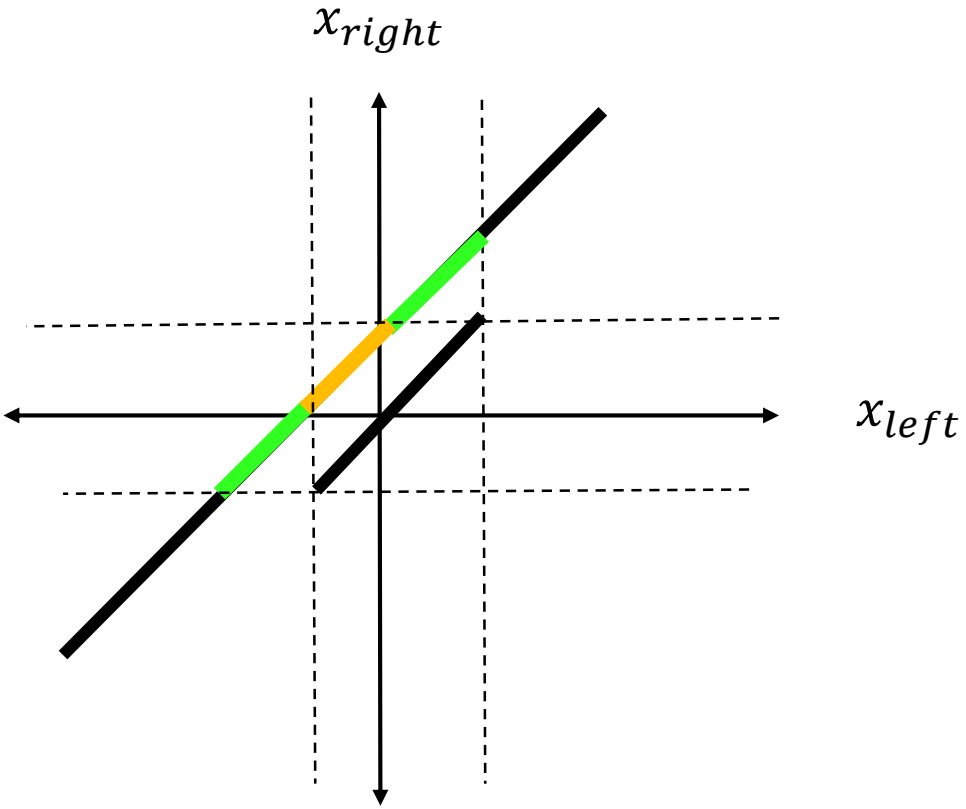
Disparity Space

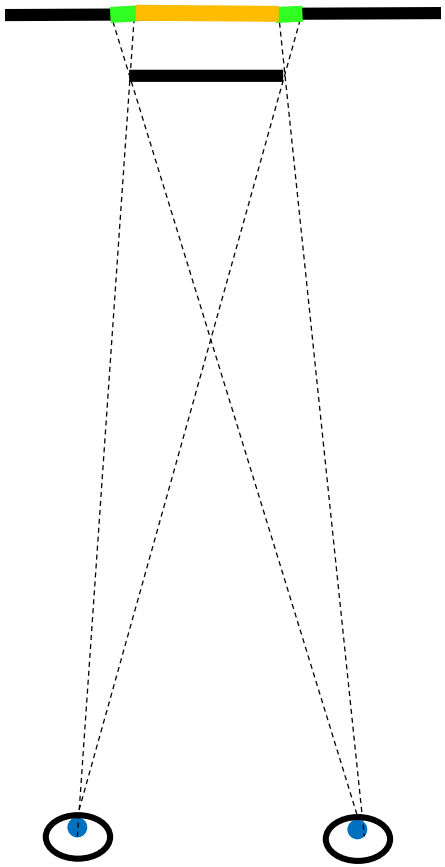




Q: where are the eyes verging?

Disparity Space





Q: where are the eyes verging?

A: at (0,0) in disparity space, by definition

How to study binocular stereo vision ?

Neuroscience

- Show animals (cats, monkeys) or people different images to the left and right eyes and measure brain activity.

Computer Vision

- Write a computer program that finds matching points in left and right images

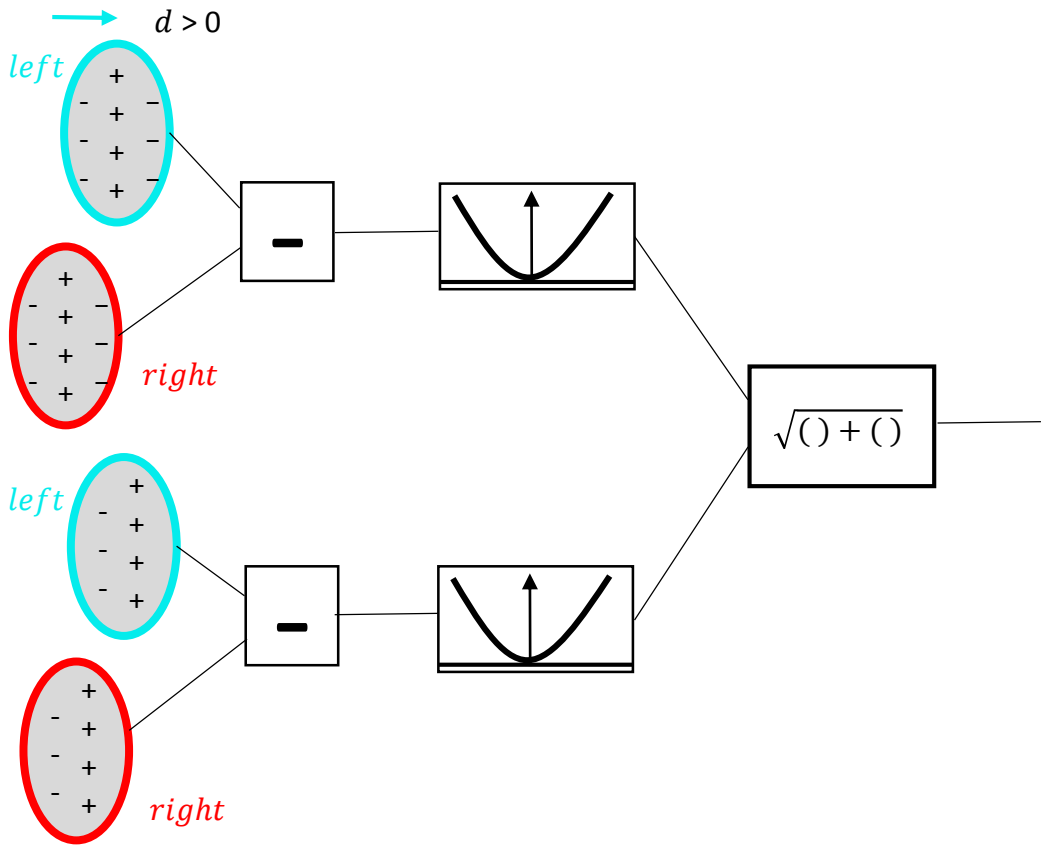
Psychology

- Show people different images to the left and right eyes and measure how well they judge depth.

Computational models of perception (biological vision)

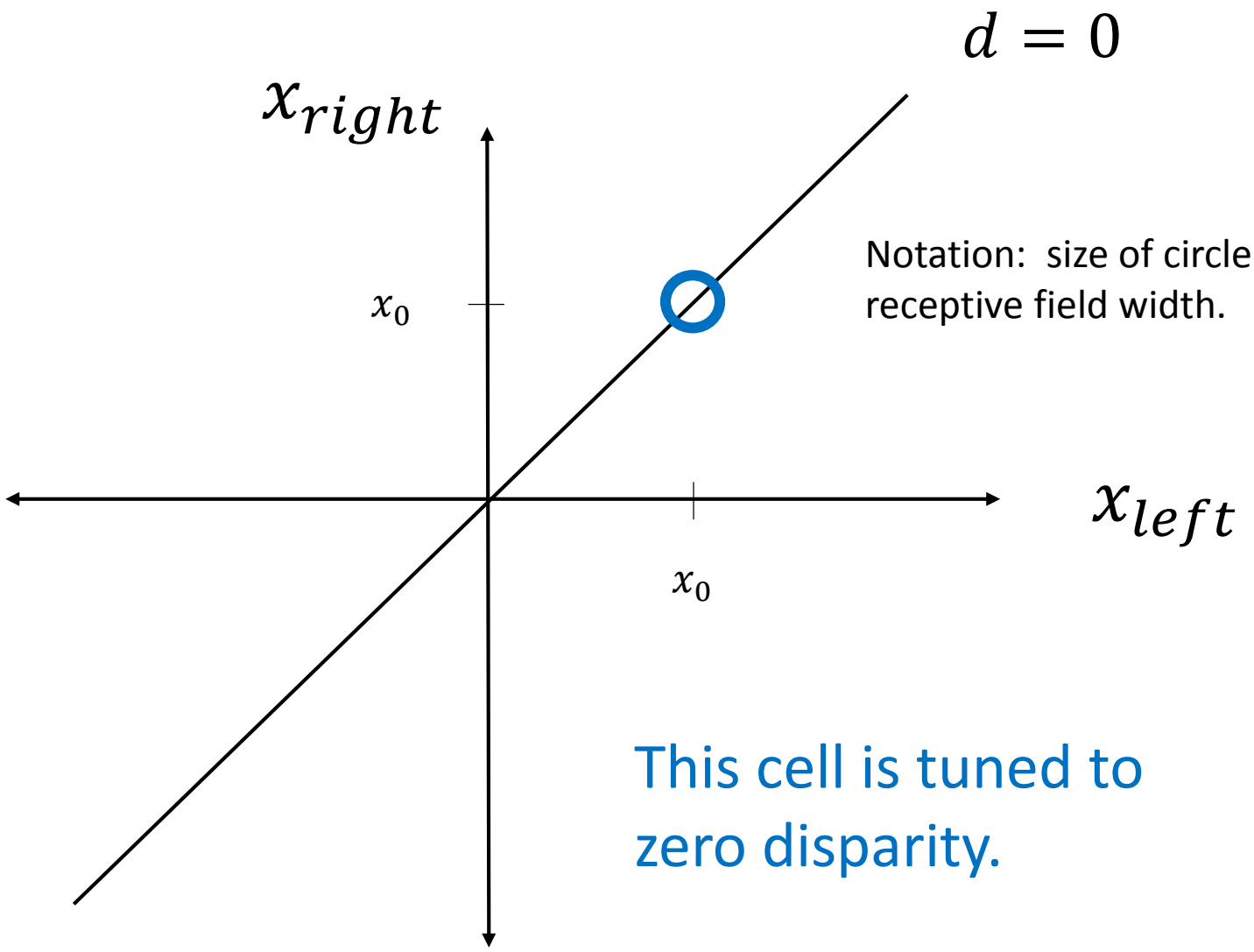
- Write a computer program that finds matching points in left and right images which is based on the operations performed in the brain.

Each binocular cell has receptive field location centered at (x_l, y_l) and (x_r, y_r) in the two eyes.



Q: How to visualize a "population" of such disparity tuned cells ?

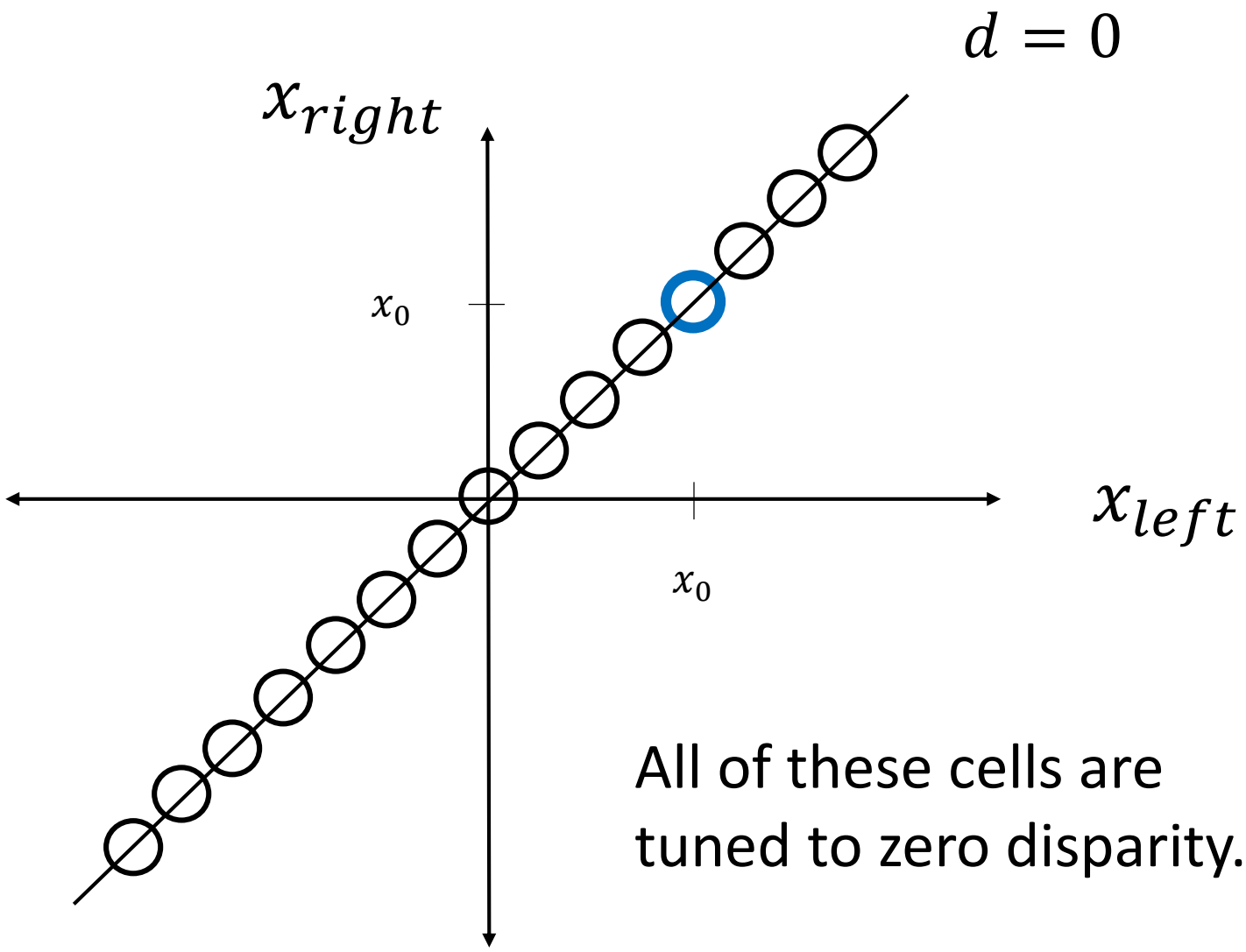
Disparity Space



Notation: size of circle indicates receptive field width.

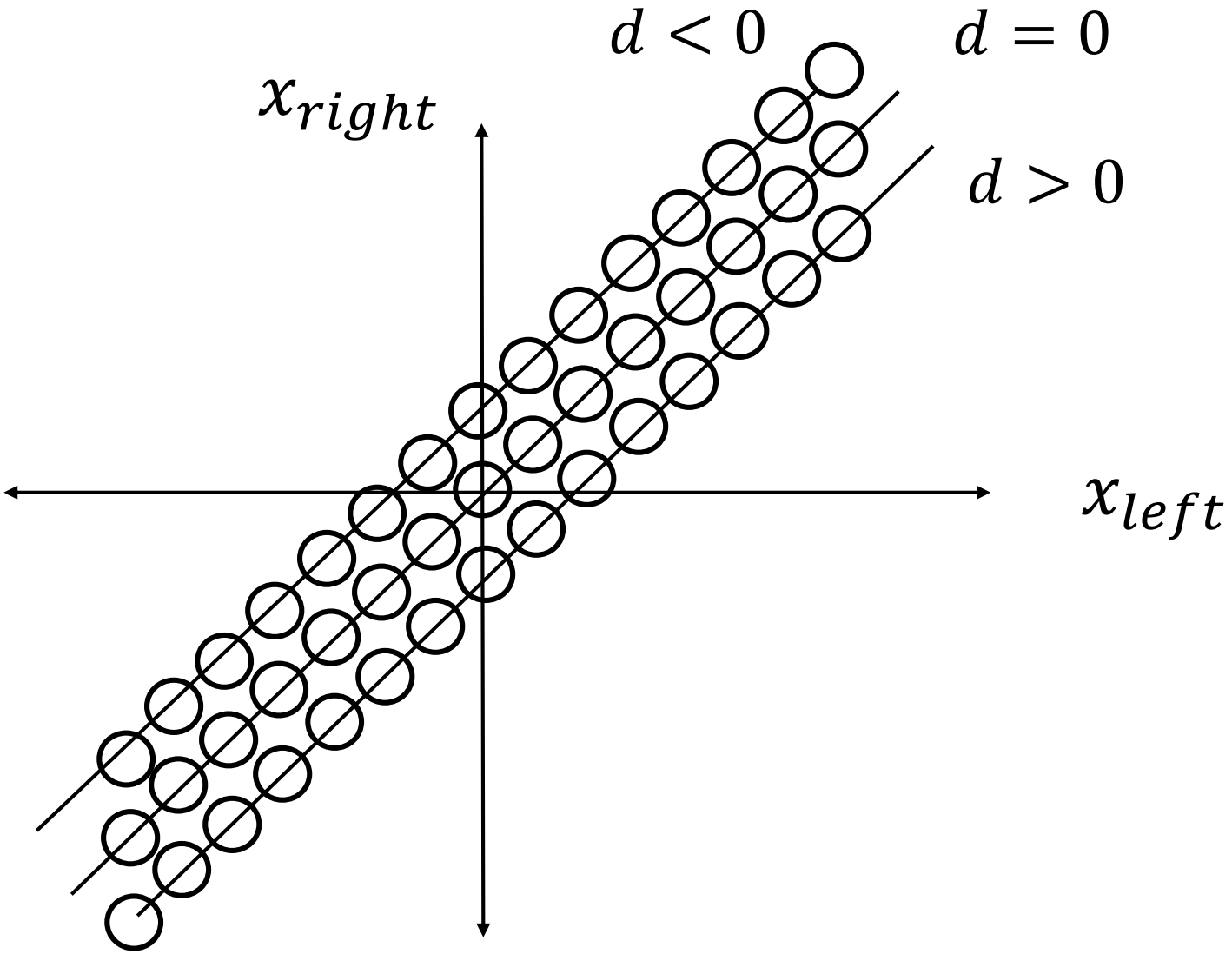
This cell is tuned to zero disparity.

Cells tuned to zero disparity

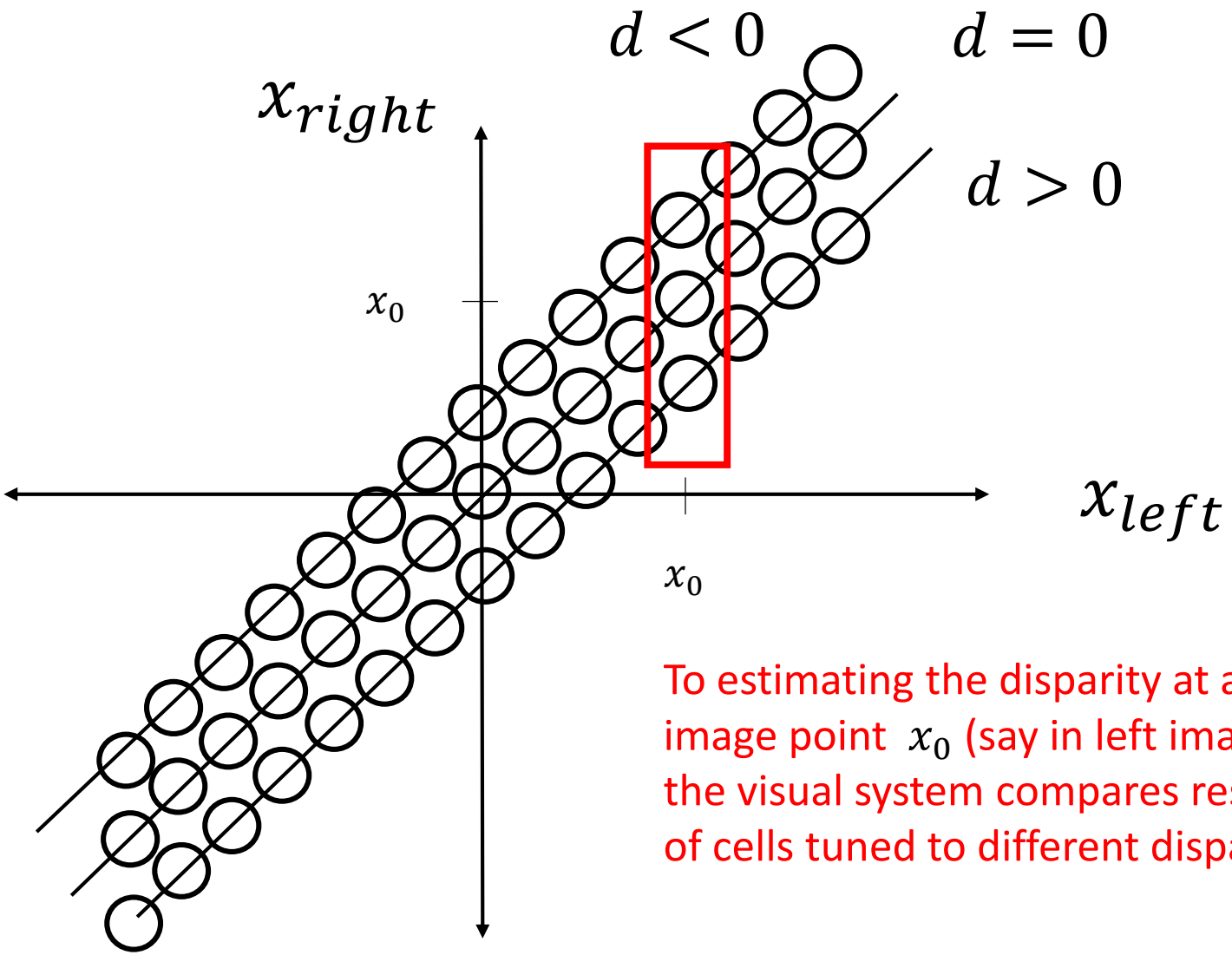


All of these cells are tuned to zero disparity.

Cells tuned to different disparities



Disparity Tuned Cells



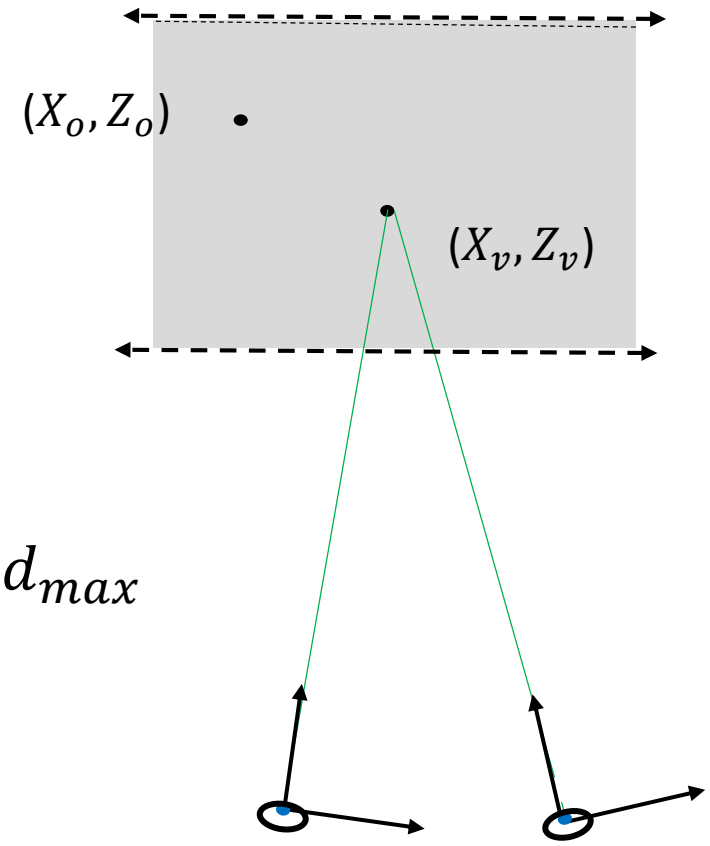
To estimating the disparity at an image point x_0 (say in left image), the visual system compares responses of cells tuned to different disparities.

Binocular Fusion (“Cyclopean Vision”)

If disparity is *sufficiently* small, then we fuse the left and right eye images.

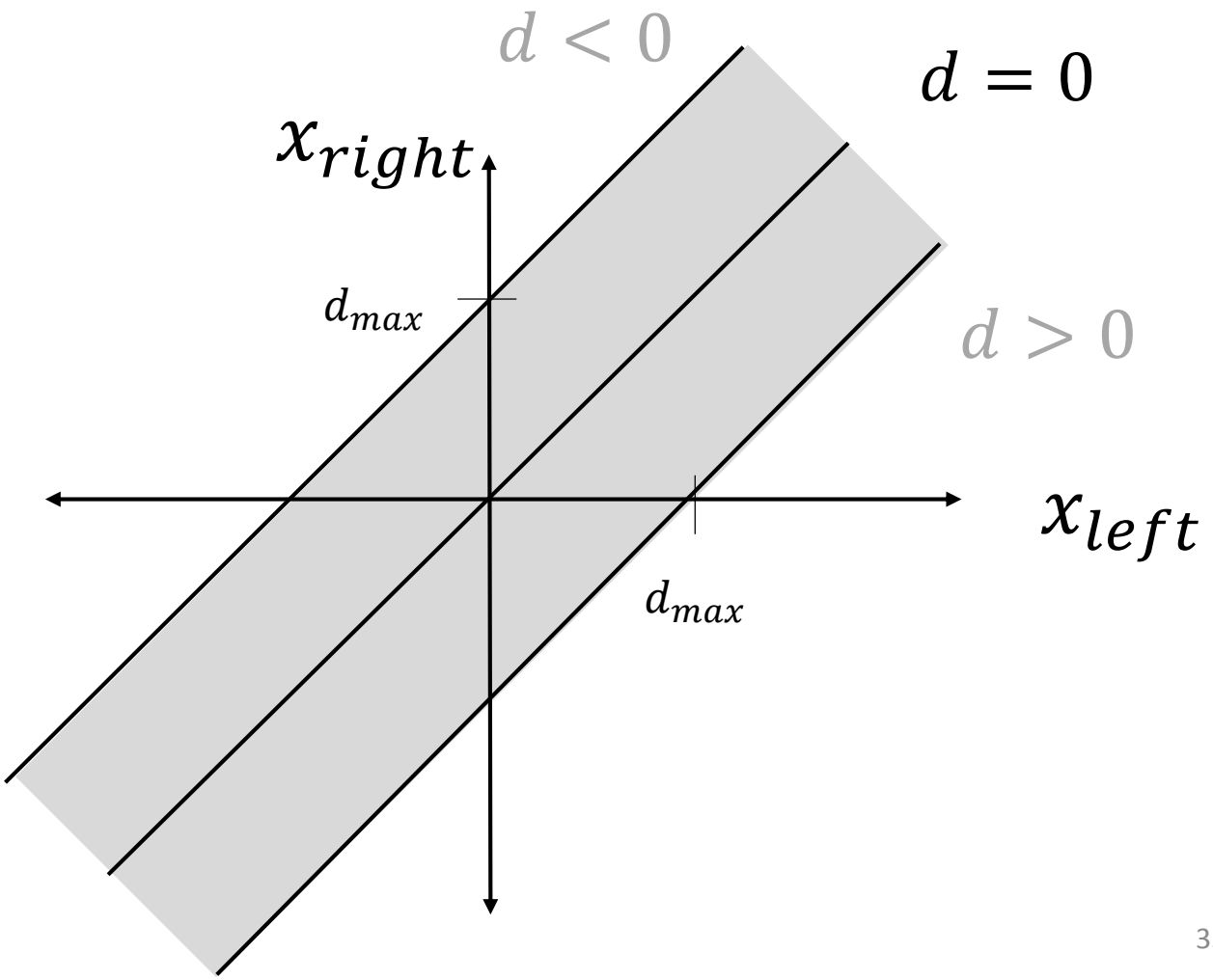
Otherwise, we perceive two images (“diplopia”).

Panum's fusional area and d_{max}

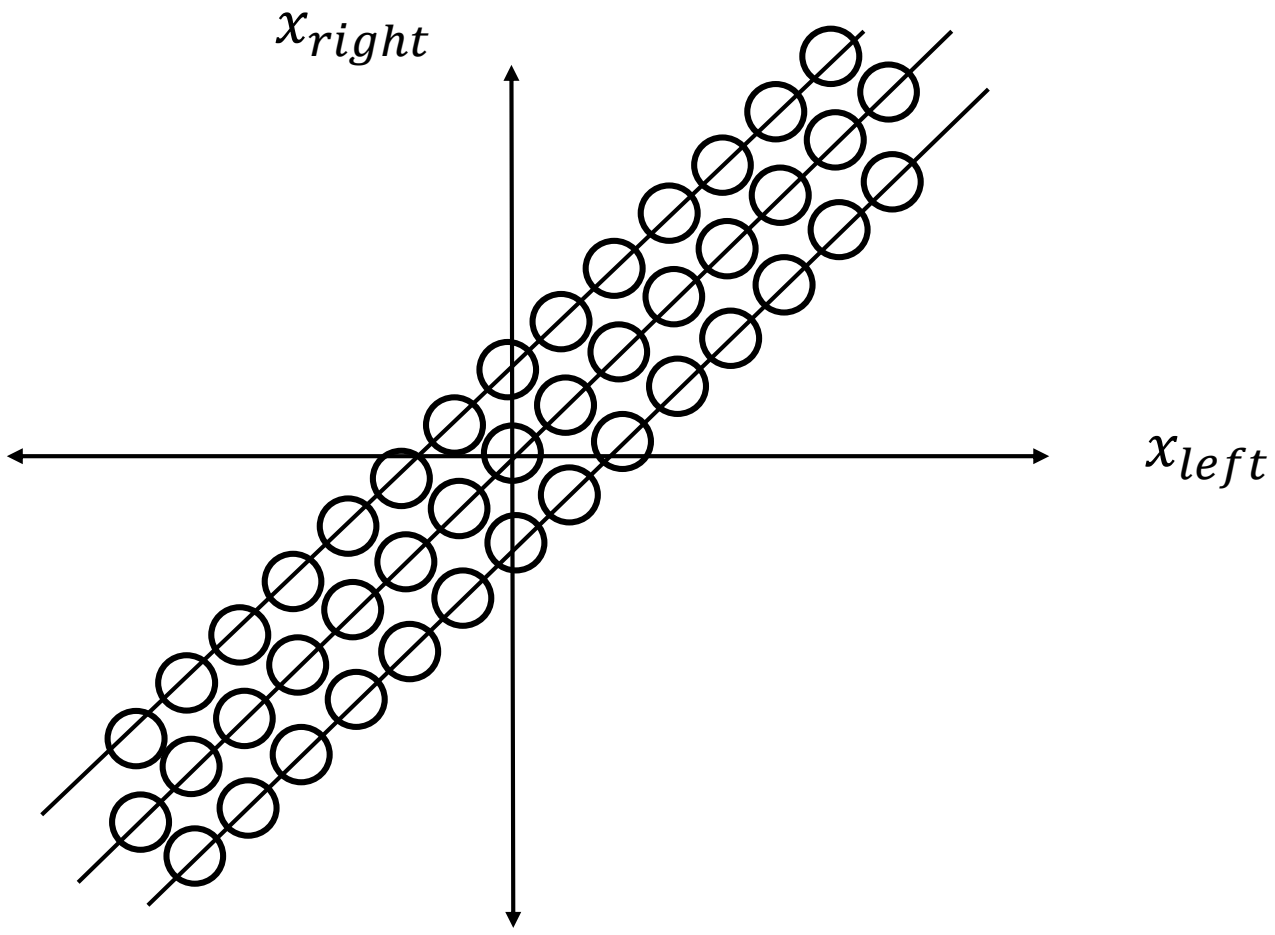


$$\text{disparity} \approx T_x \left| \frac{1}{Z_o} - \frac{1}{Z_v} \right| < d_{max}$$

Panum's fusional area in disparity space



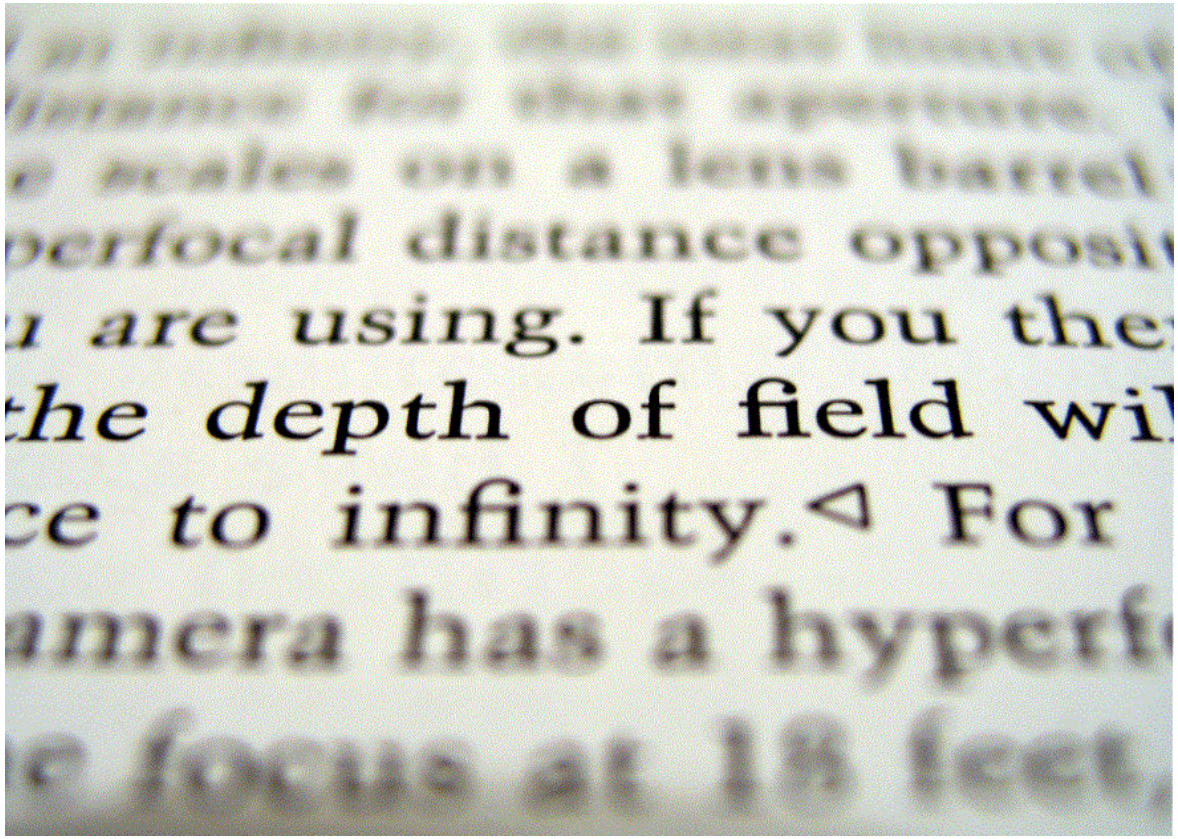
Panum's fusional area is believed to be due to the limited range of disparities of disparity tuned cells.



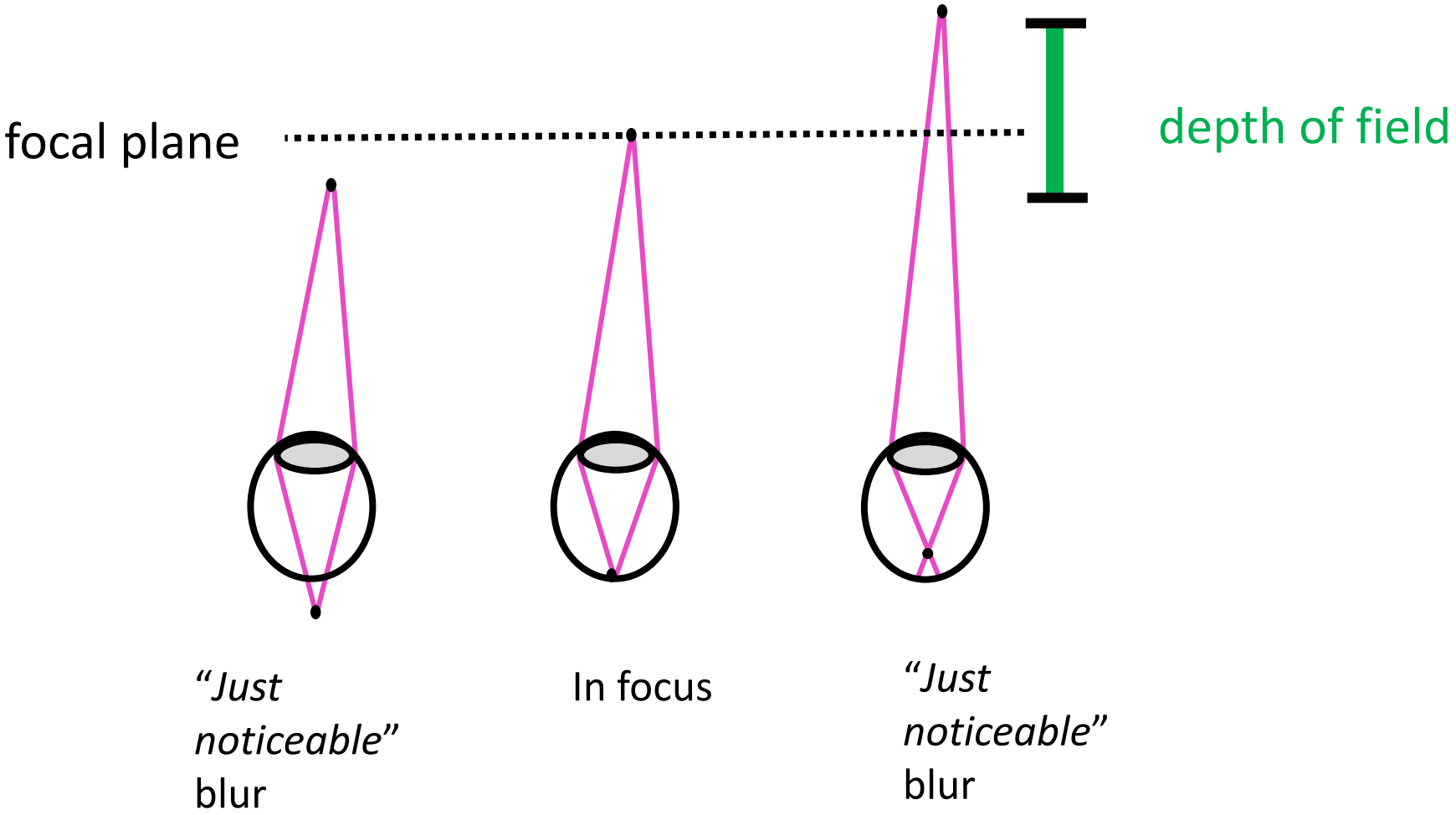
Recall defocus blur and depth

Depth of Field

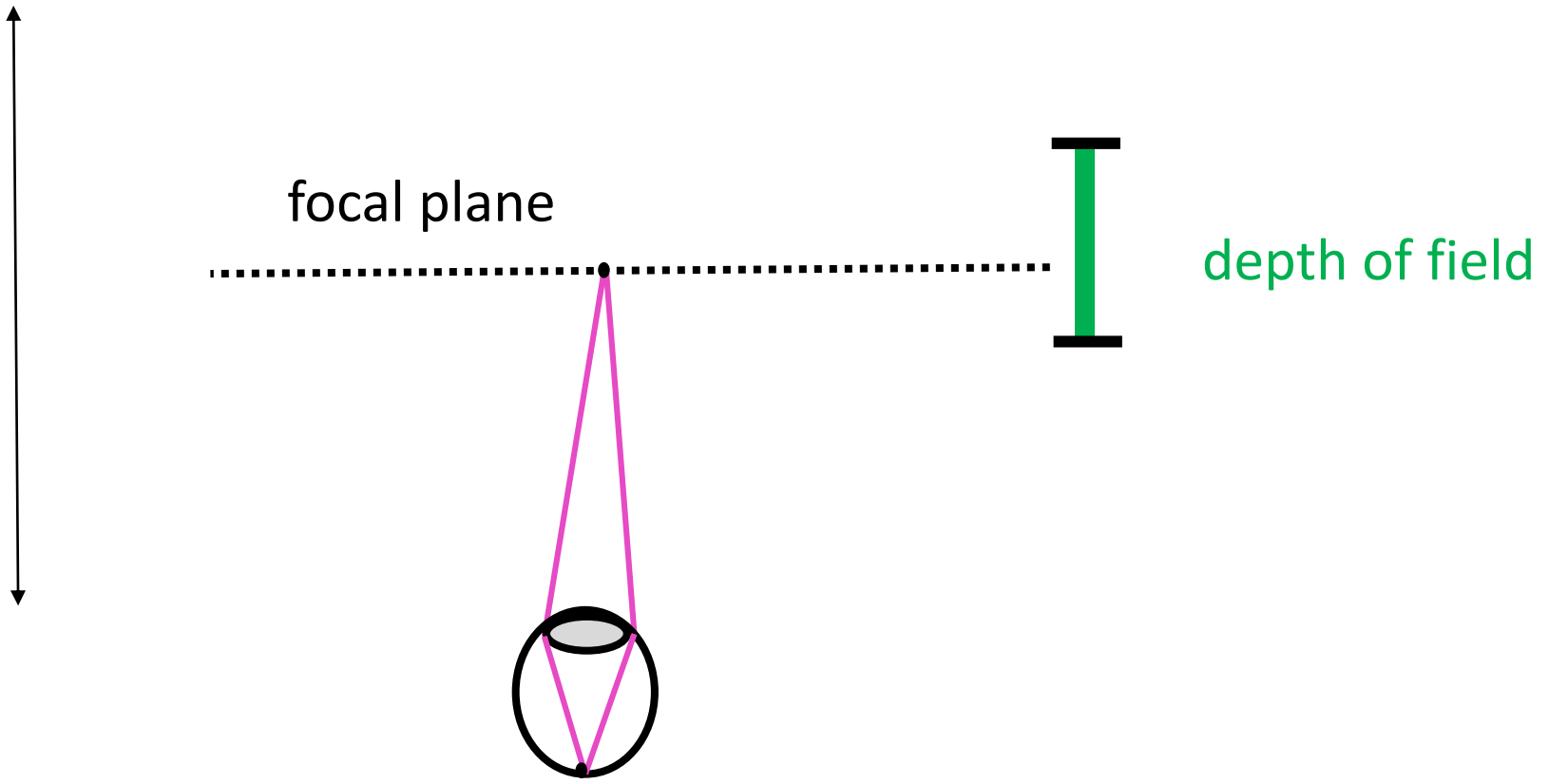
Depth of field is the range of depths that are *perceived* to be in focus. (In fact, only one depth is in perfect focus.)



$$\text{blur width} = \text{aperture} \left| \frac{1}{Z_{focalplane}} - \frac{1}{Z_0} \right|$$



accommodation



In focus

Accommodation and vergence systems are coupled.

(We tend to verge at the same depth as we focus even if one eye is closed.)

Monocular

Binocular

Accommodation-vergence conflict for 3D displays