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Visualization for Data Science
DS-4630 / CS-5630 / CS-6630

Introduction to Perception

data

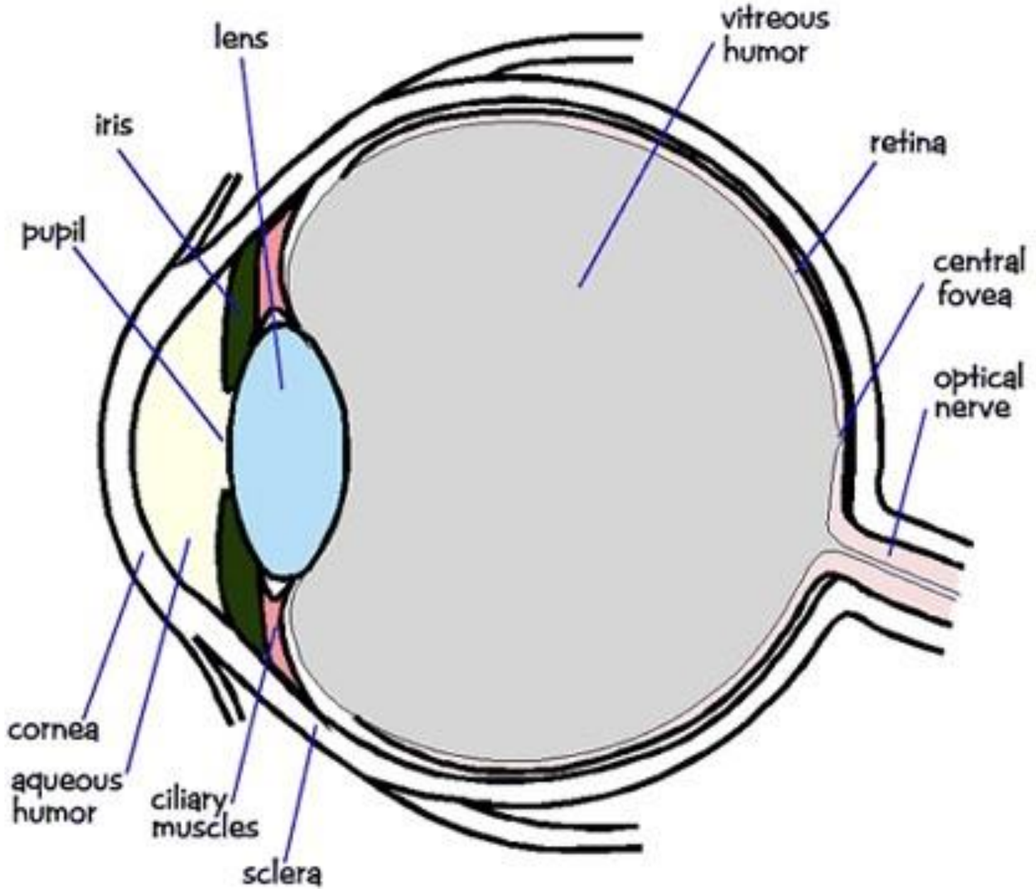
knowledge

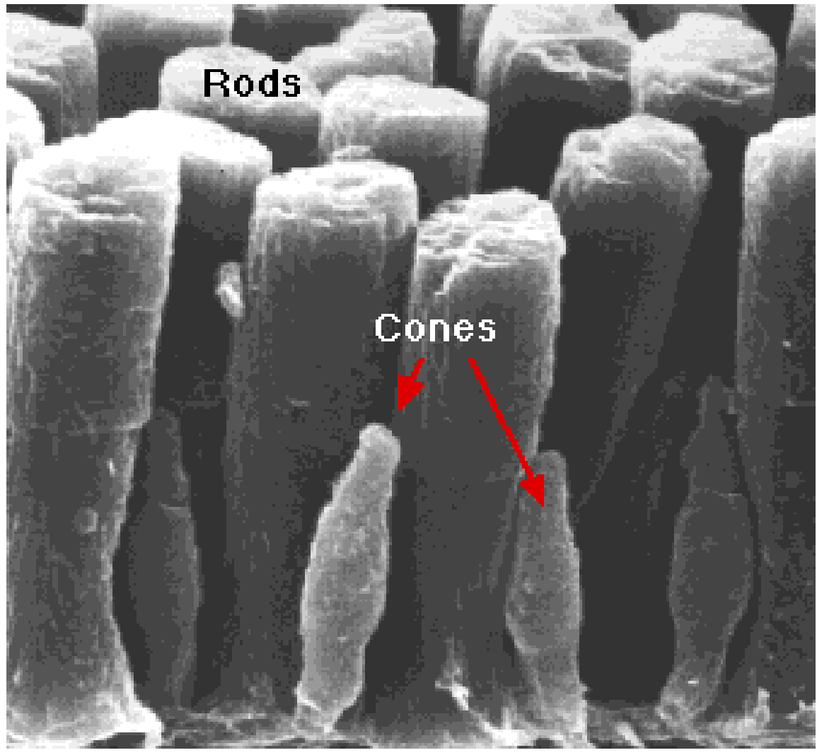
(analysis—stats, ML, etc.)

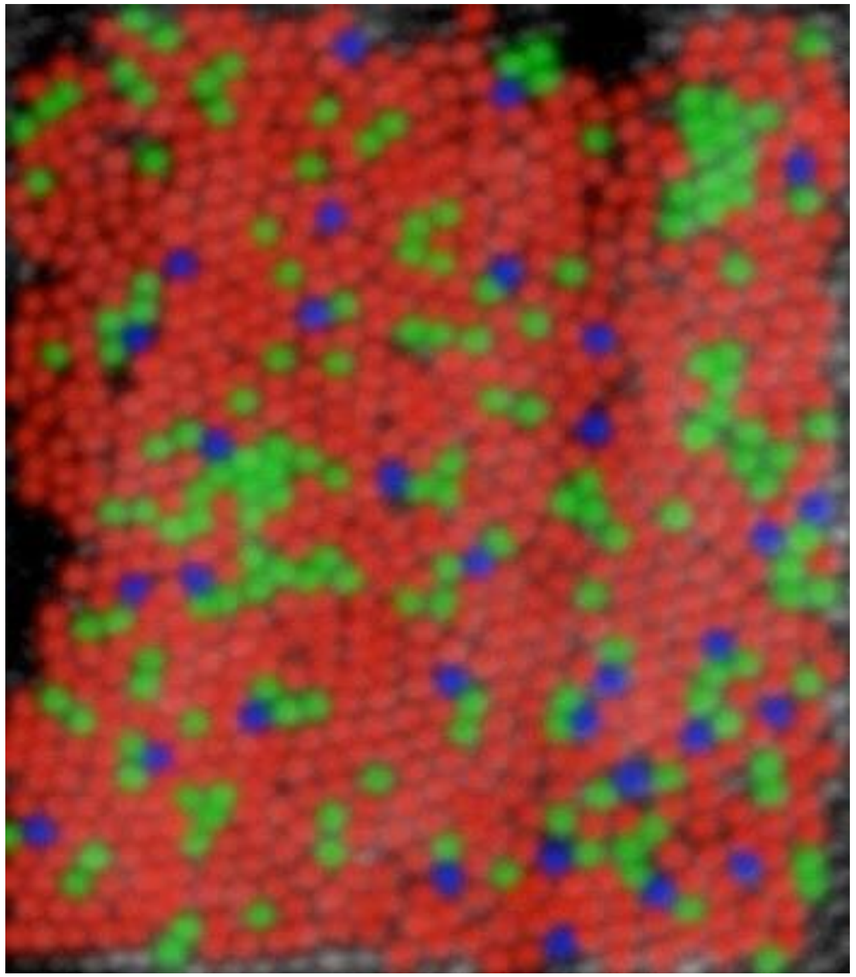
(visualization)

(perception)

(cognition)


lens
vitreous humor
iris
retina
pupil
central fovea
optical nerve
cornea
aqueous humor
ciliary muscles
sclera



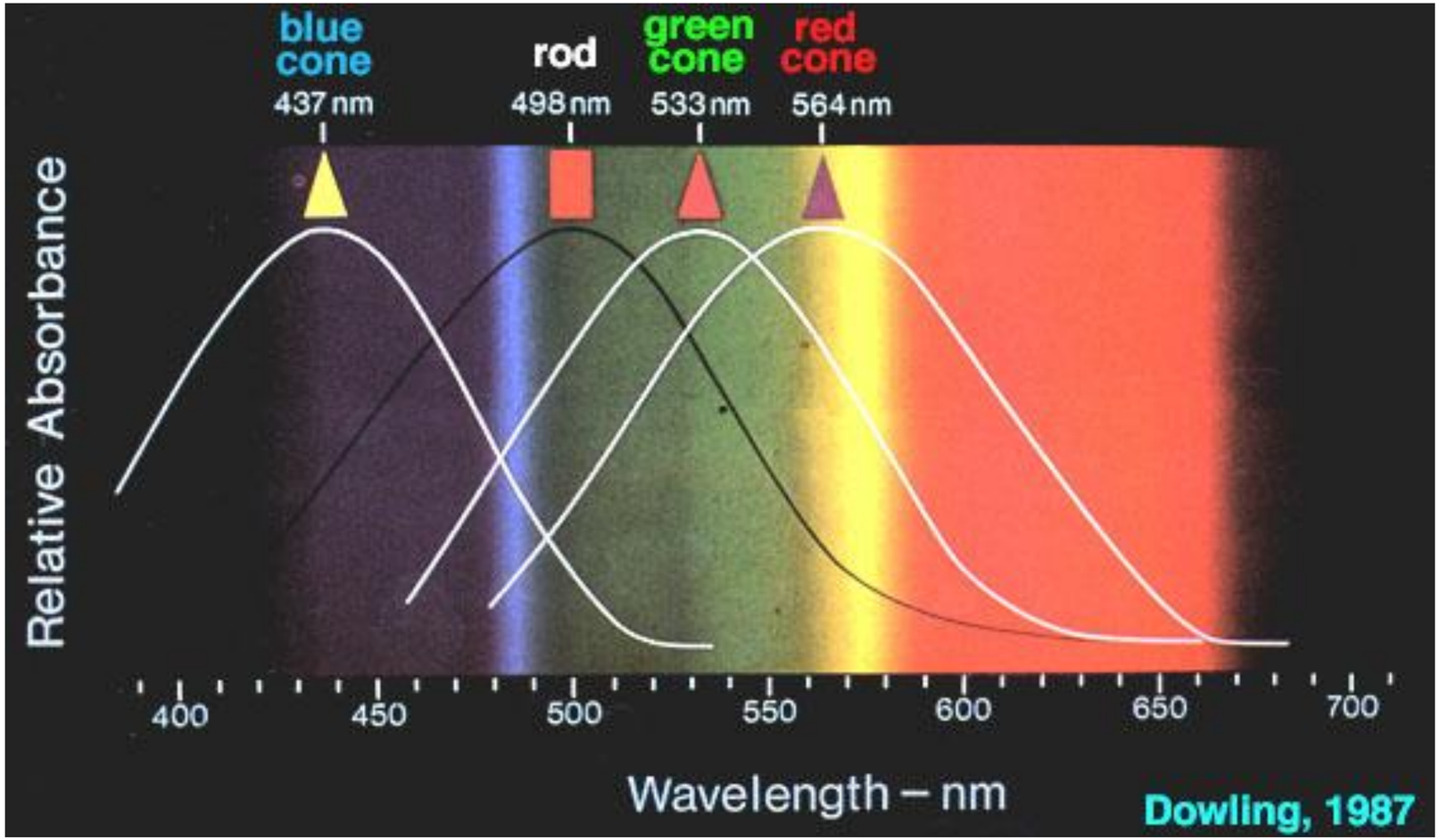


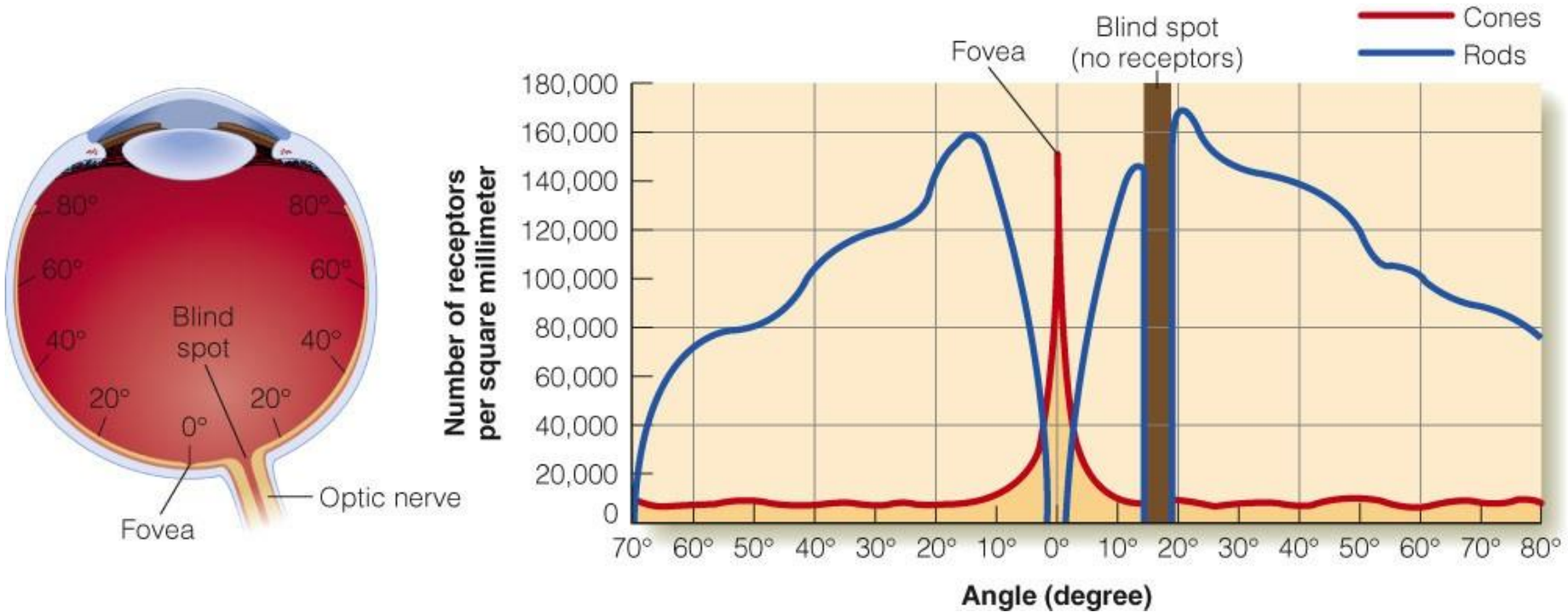
120 million rods

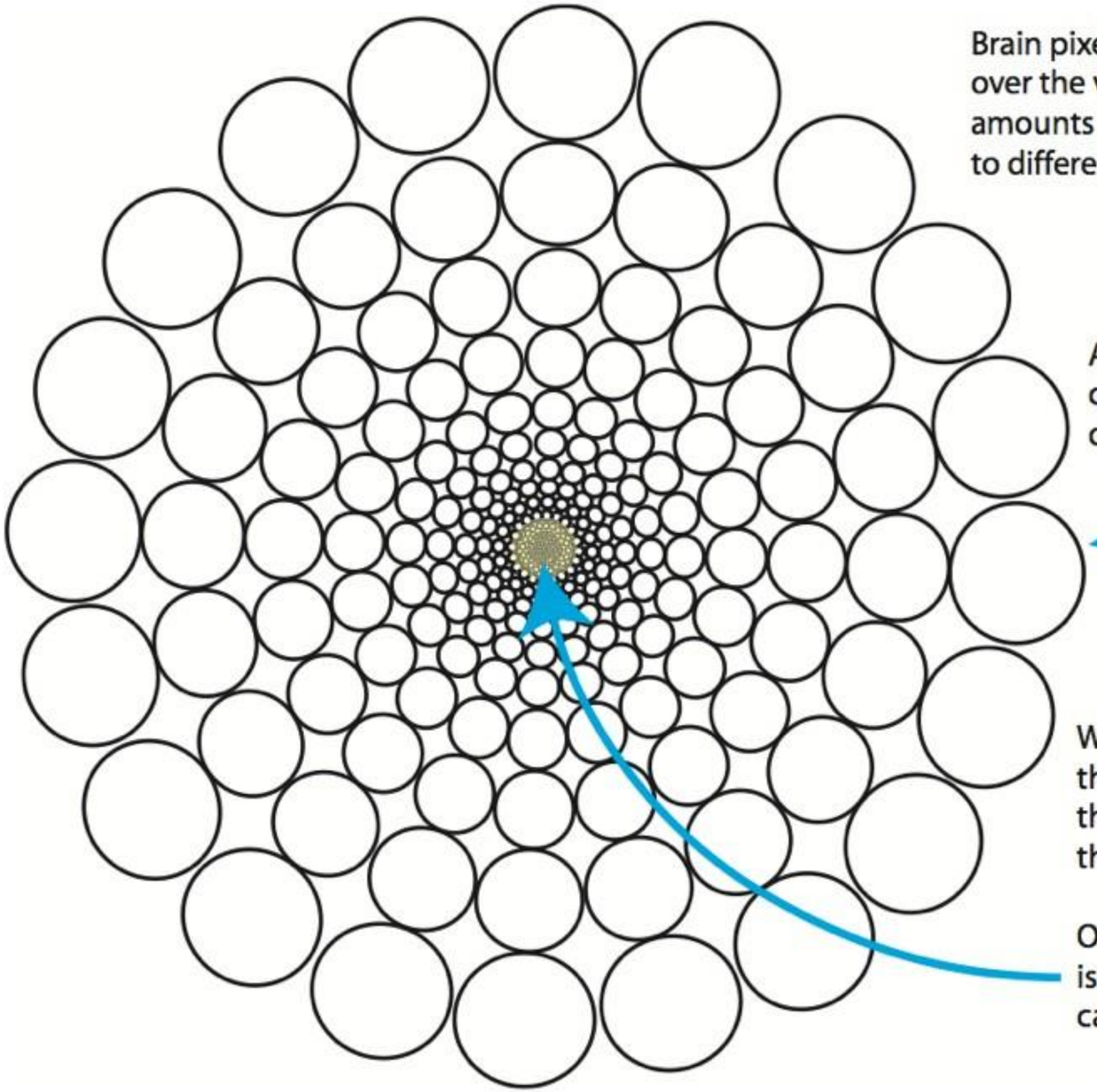
5-6 million cones

Wandell, "Foundations of Vision" (left) David R. Williams, Univ. of Rochester (right)

Cone Response




80°
80°
60°
60°
40°
40°
20°
20°
0°
Blind spot
Optic nerve
Fovea
Cones
Rods
Fovea
Blind spot
(no receptors)
Number of receptors per square millimeter
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70° 80°
Angle (degree)



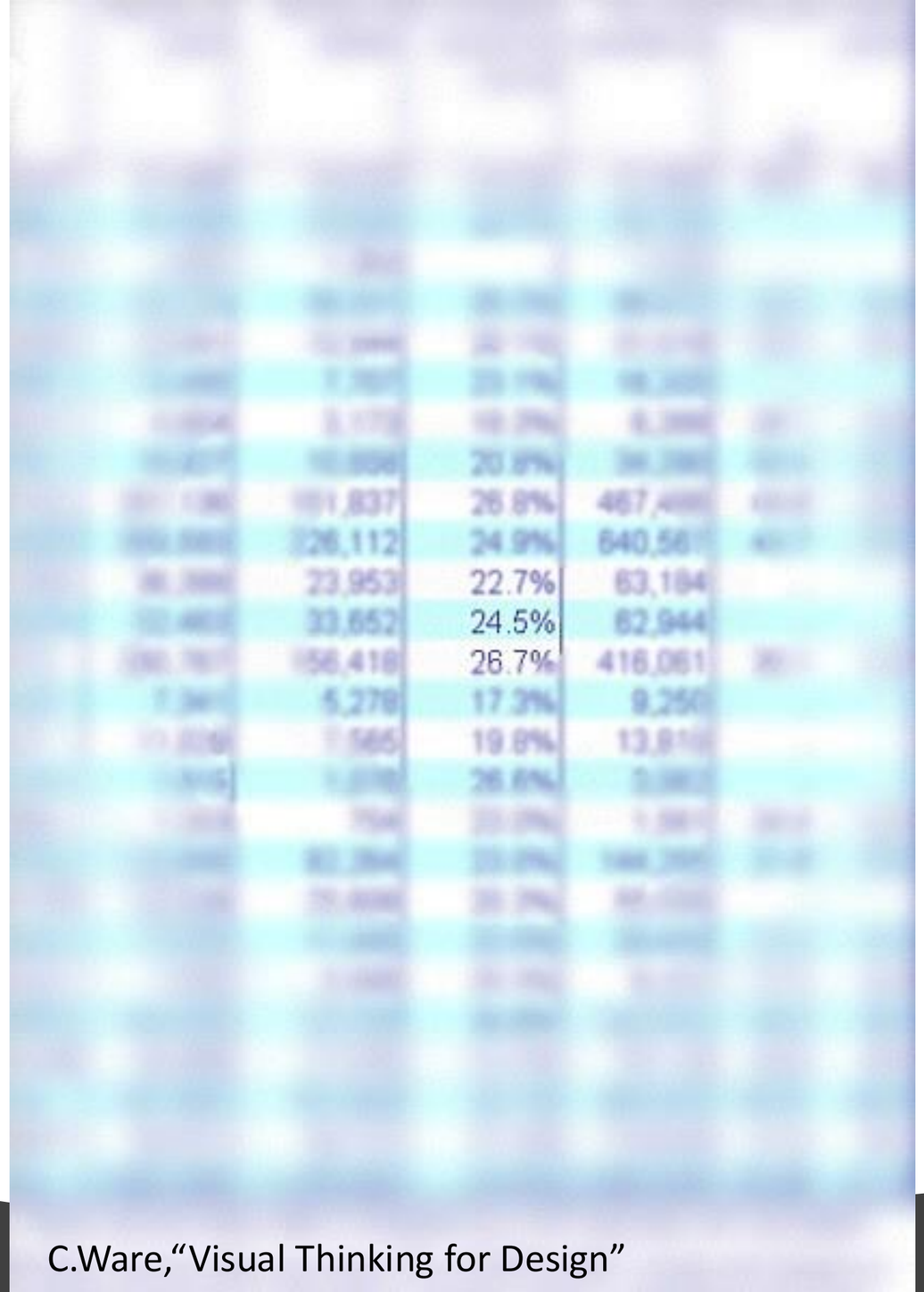
Brain pixels vary enormously in size over the visual field. This reflects differing amounts of neural processing power devoted to different regions of visual space.

At the edge of the visual field we can only barely see something the size of a fist at arm's length.

We can resolve about 100 points on the head of a pin held at arm's length in the very center of the visual field called the fovea.

Over half of our visual processing power is concentrated in a slightly larger area called the parafovea.

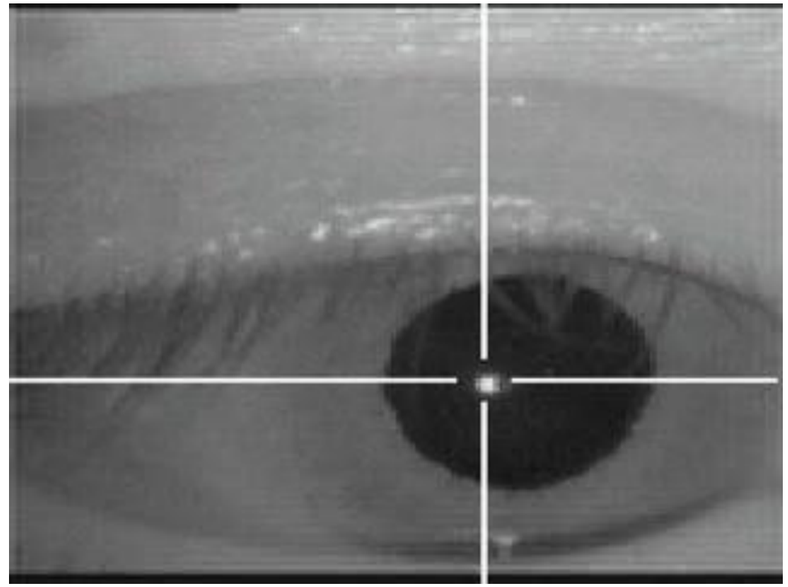
Foveation is relatively easy to see. The key to recognizing the phenomenon is to stair at a single **word** on the printed page. Then, without moving your gaze, note the blurriness of the surrounding text.



C.Ware,“Visual Thinking for Design”

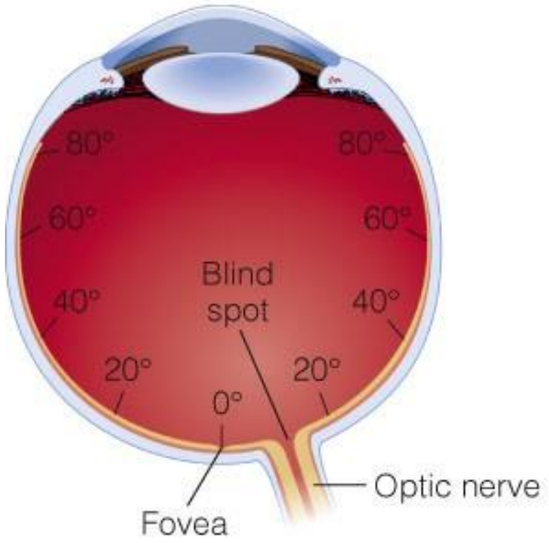
saccadic eye movements

- rapid involuntary eye movements
- moving: 20-100 ms
- fixations: 200-600 ms



http://vision.arc.nasa.gov/personnel/jbm/home/projects/osa98/osa98.html

Blind Spot



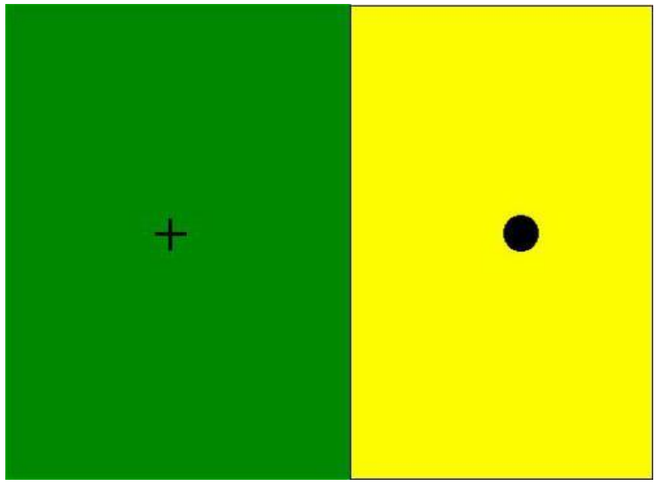
+ ●

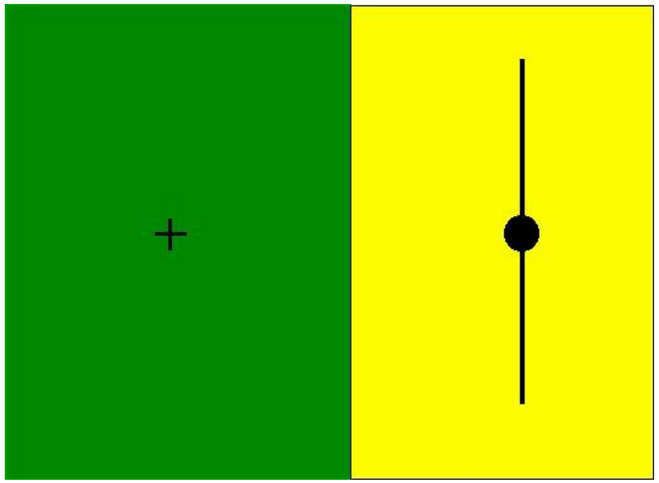
Close **left** eye

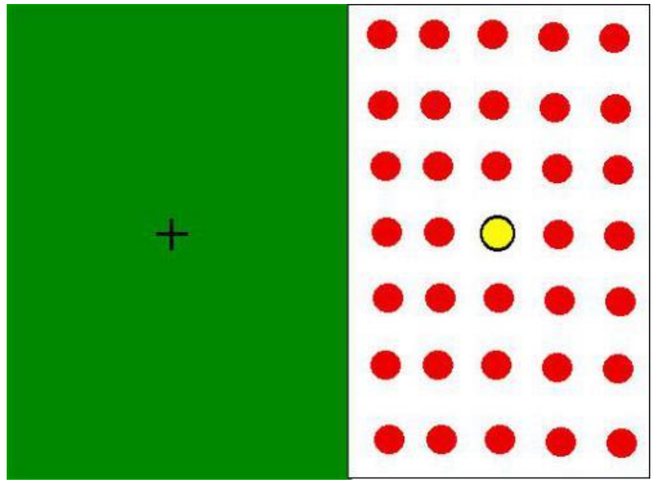
Stair at **+**

Move forward and backward until ● disappears

Blind Spot







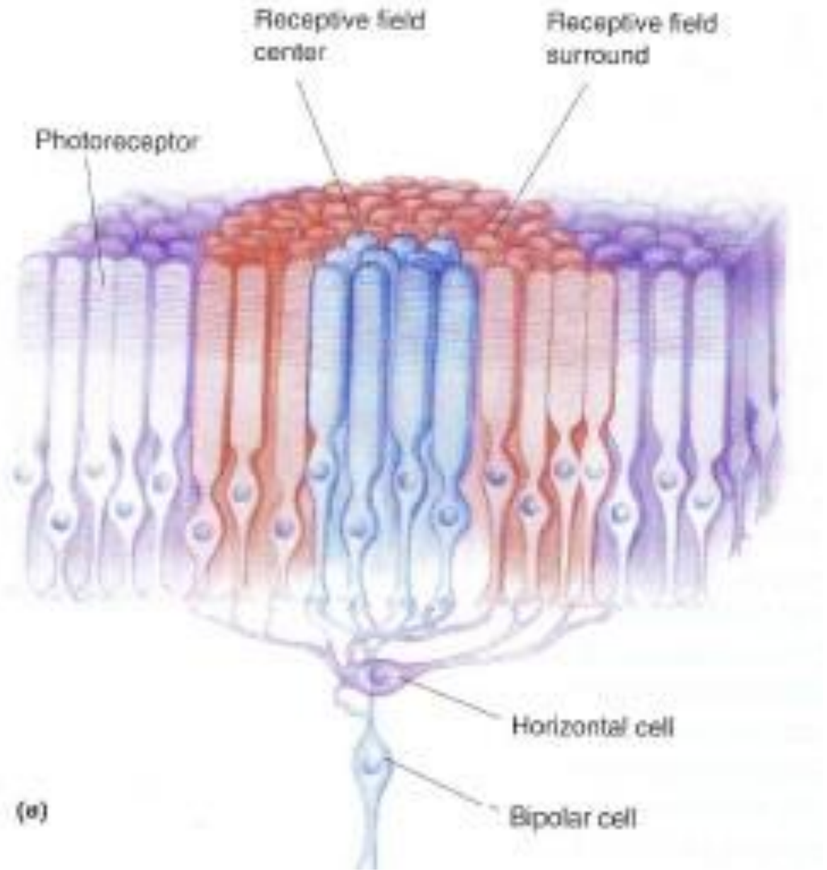
Takeaway

- Our vision at any given moment is relatively limited. Our brain “fills in the missing pieces” using a variety of evolved tools.

- **Be careful placing too much data on the screen. Crisp and clear visualizations will result in the best interpretation.**

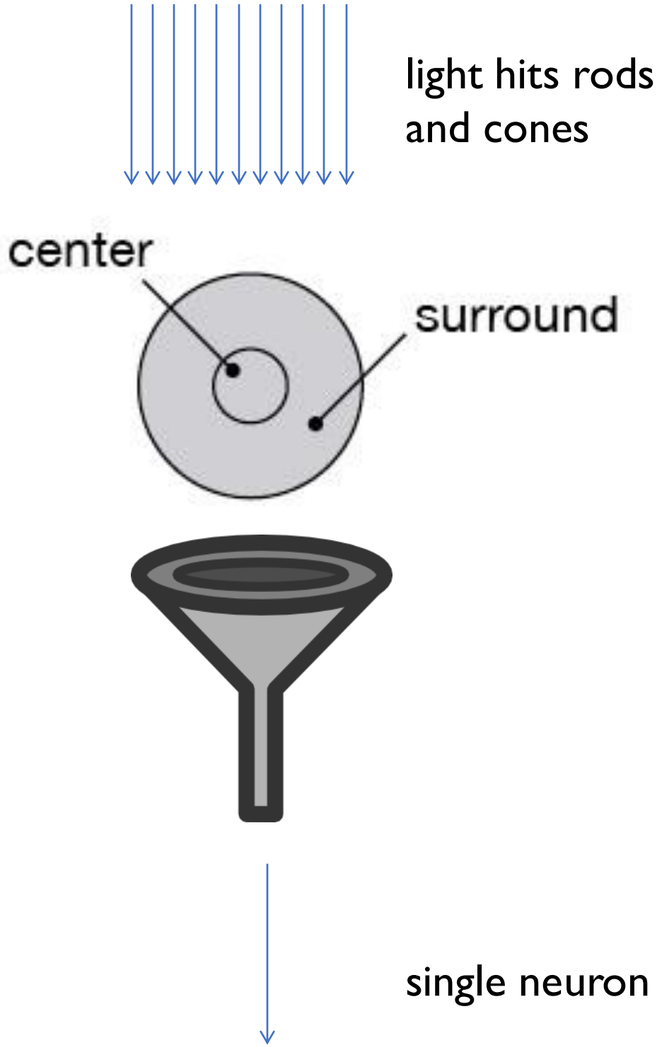
edge detection

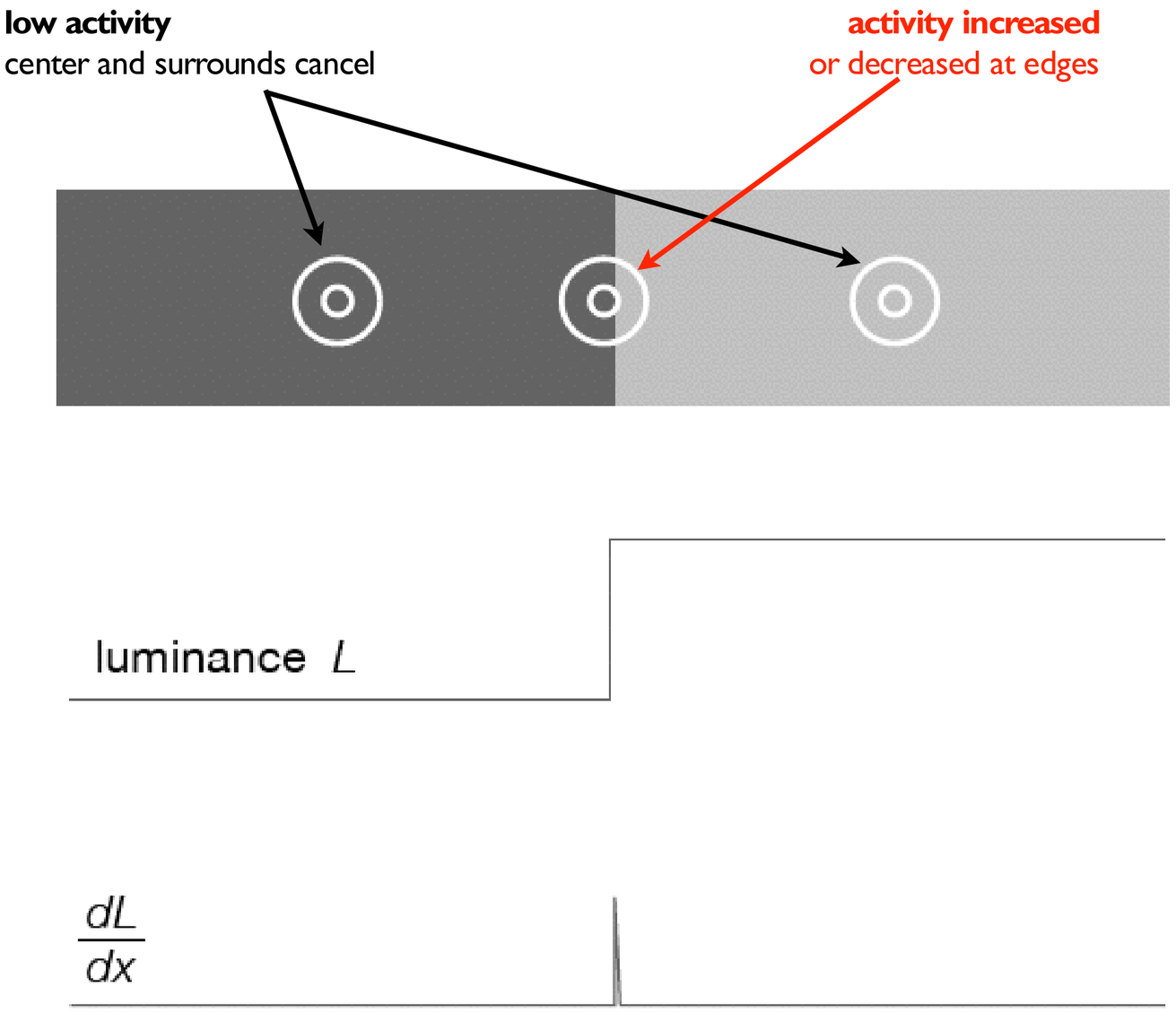
receptive field



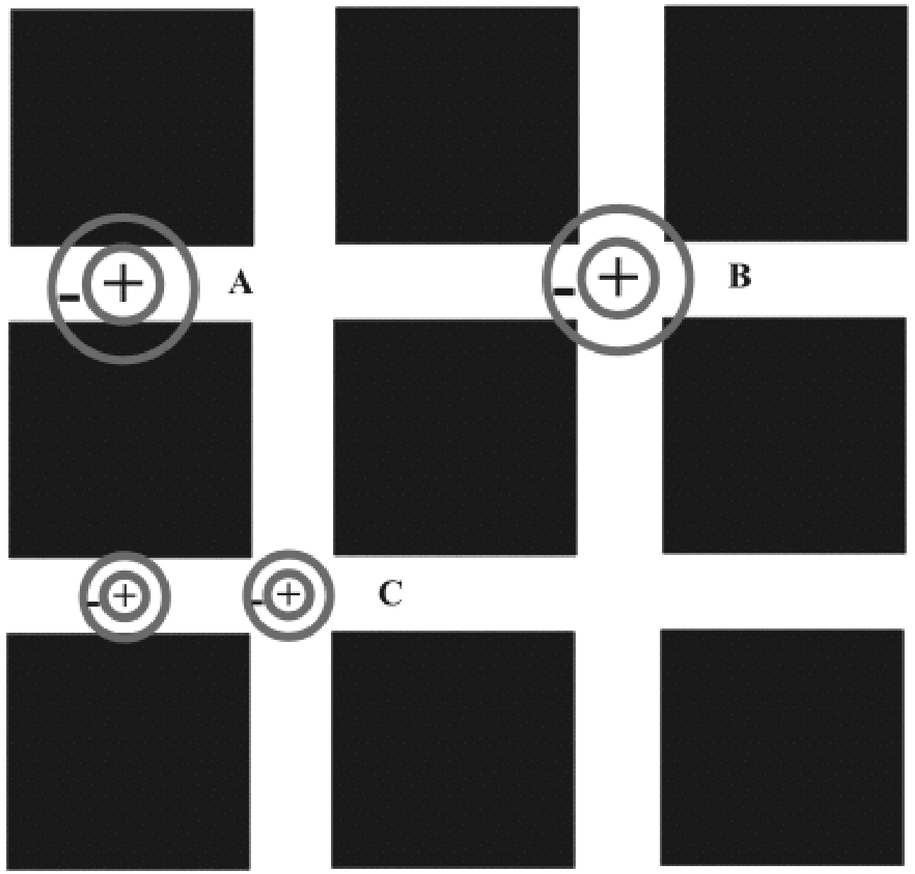
100M rods and cones

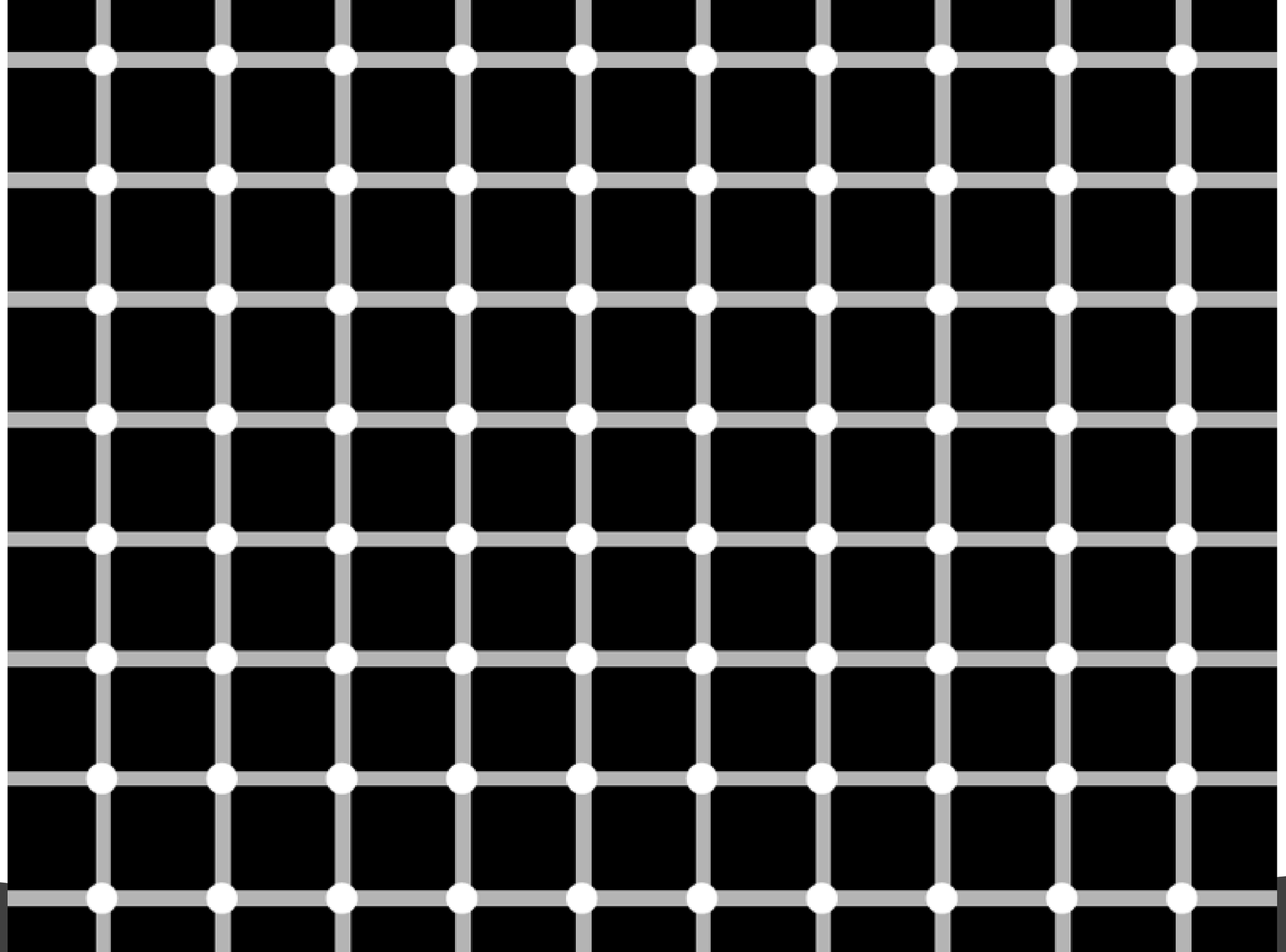
1M ganglion cells




low activity
center and surrounds cancel
activity increased
or decreased at edges
luminance L
dL
dx

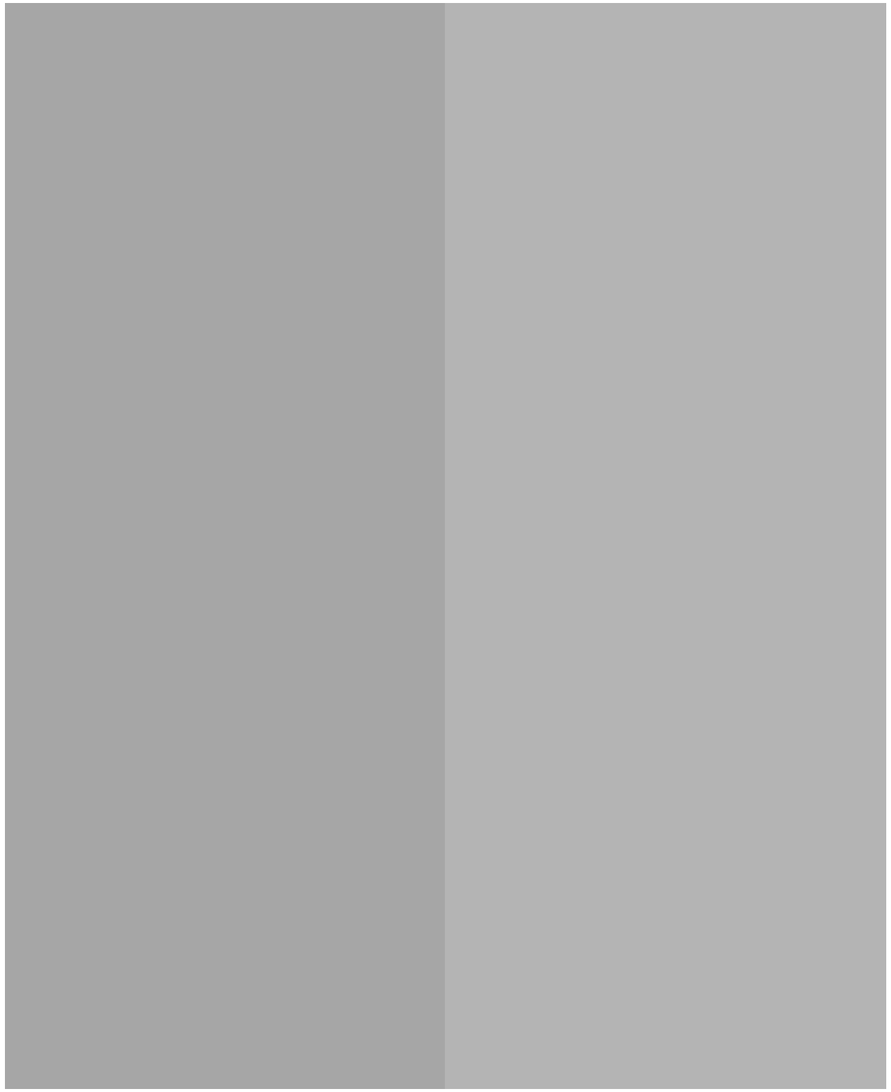
Hermann grid effect



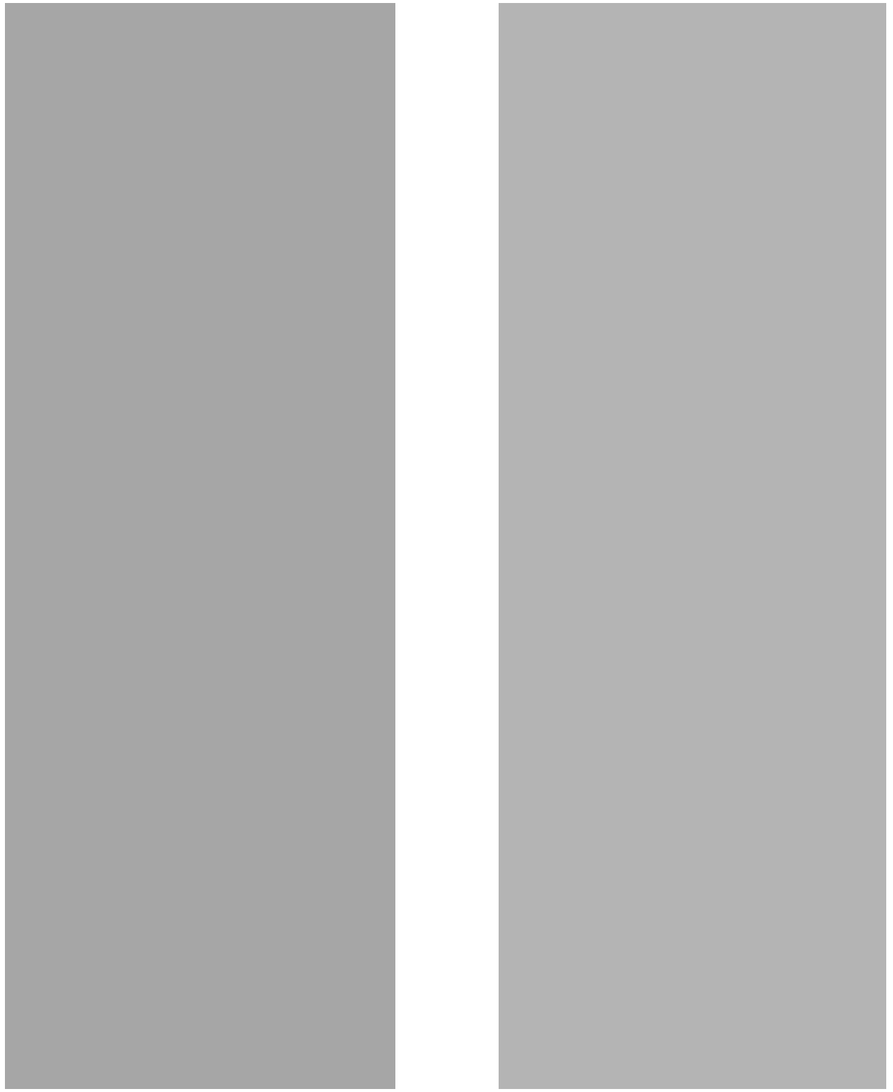


consequences of edge extraction

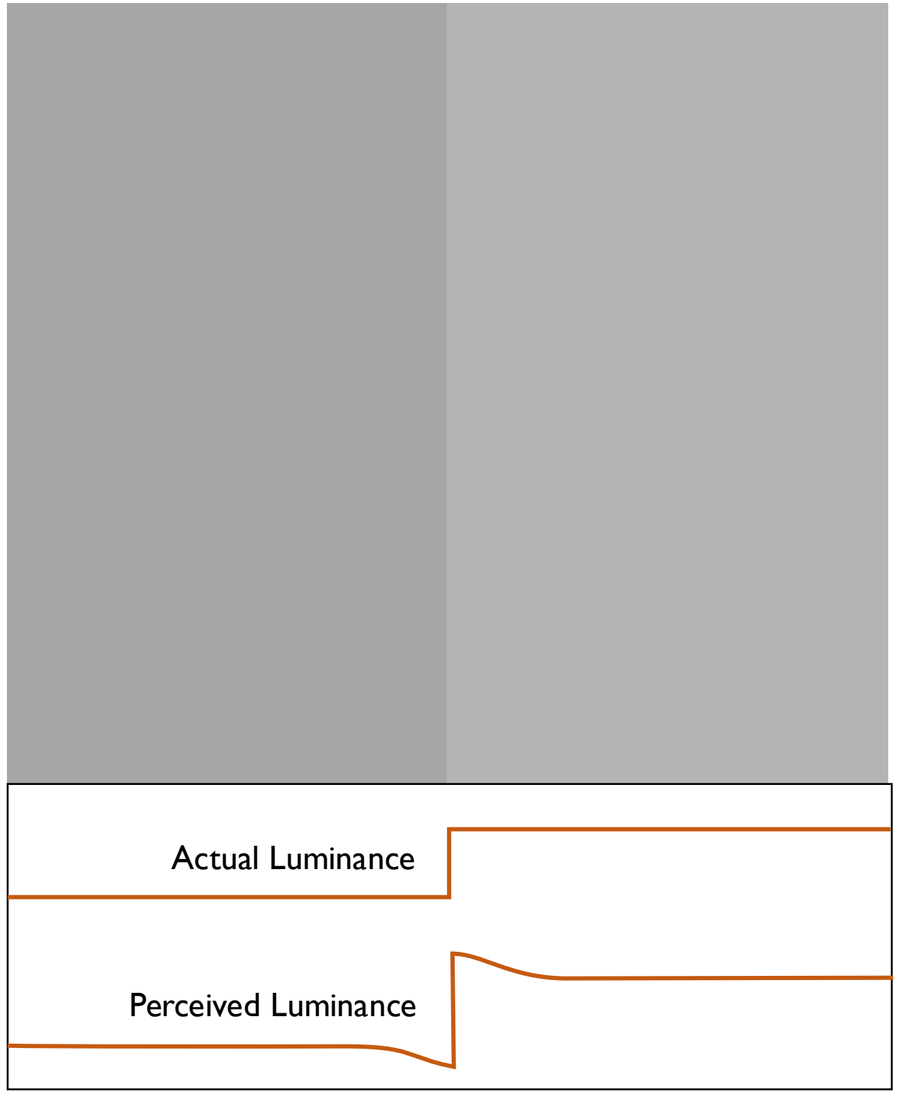
Cornsweet Illusion



Cornsweet Illusion

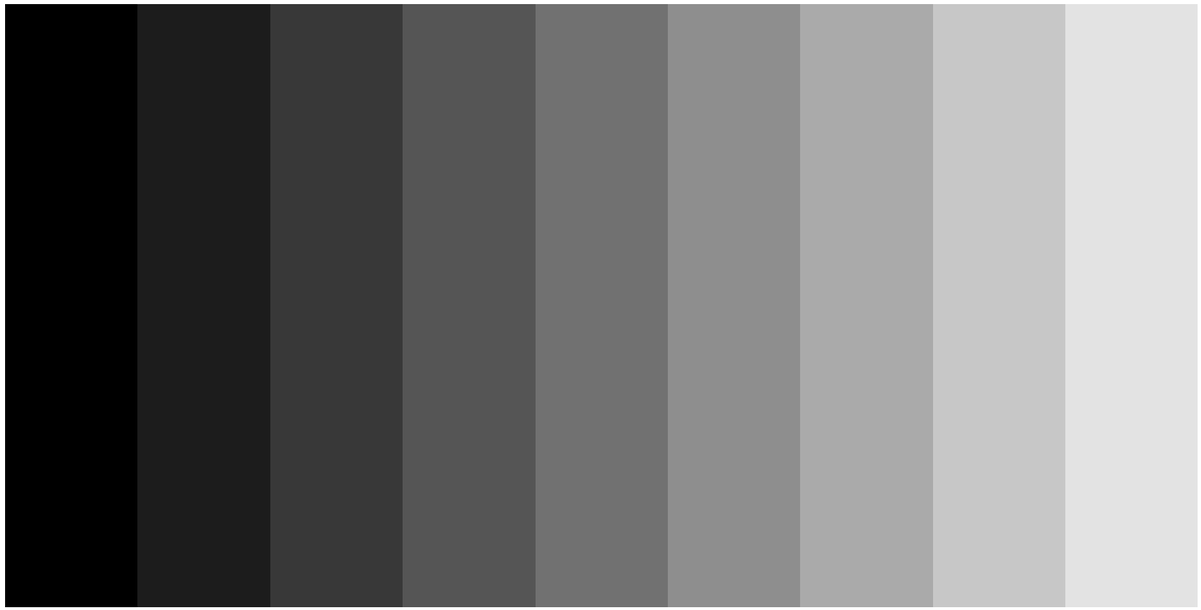


Cornsweet Illusion



Cornsweet Illusion

Mach Banding



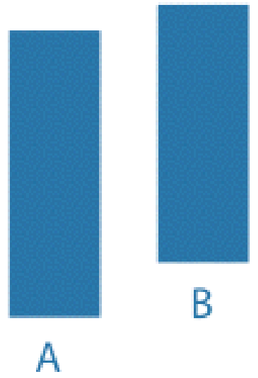
Takeaway

- Our visual system is attracted to edges and is sensitive to differences, not absolute values.

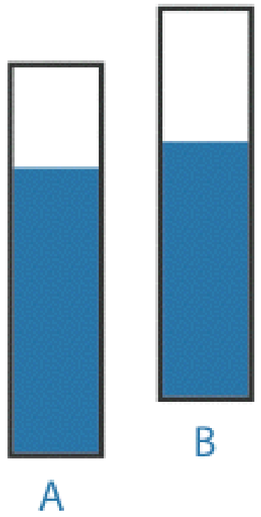
- **Maximize the contrast with the background if the outlines of shapes are important.**

WEBER'S LAW

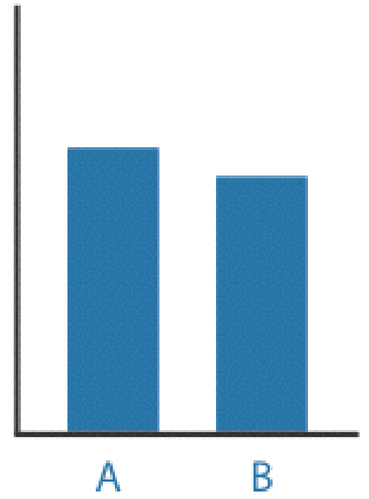
- we judge based on relative, not absolute, differences



Unframed
Unaligned



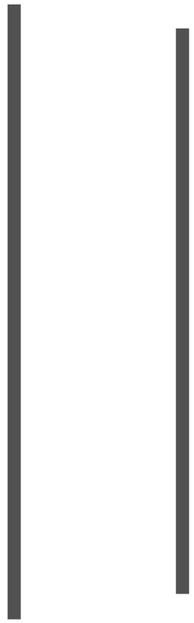
Framed
Unaligned



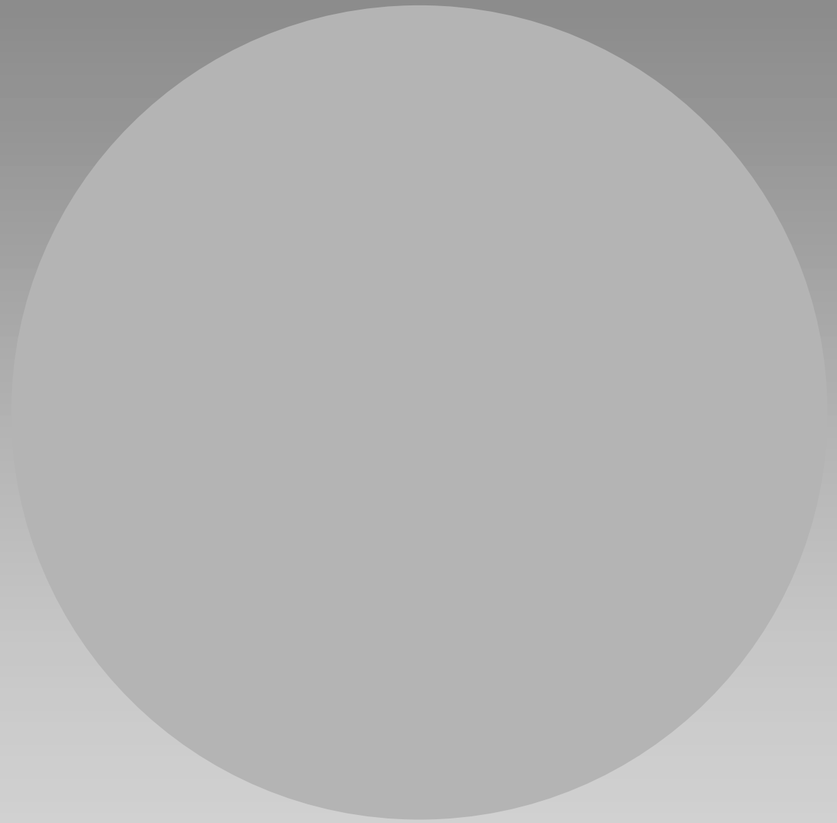
Unframed
Aligned

AXIS OF ALIGNMENT

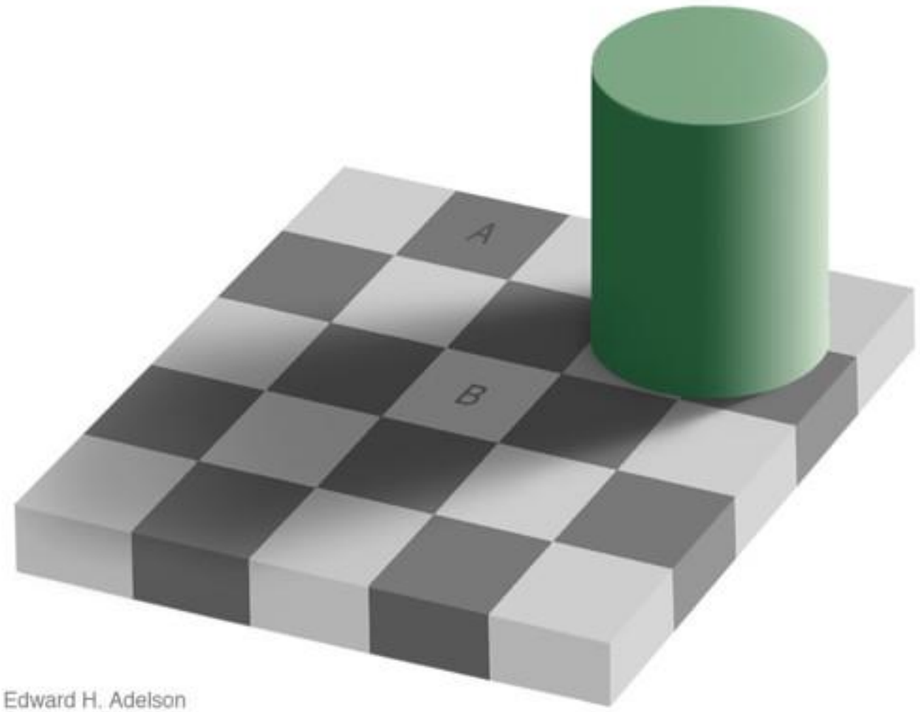
AXIS OF ALIGNMENT



simultaneous contrast



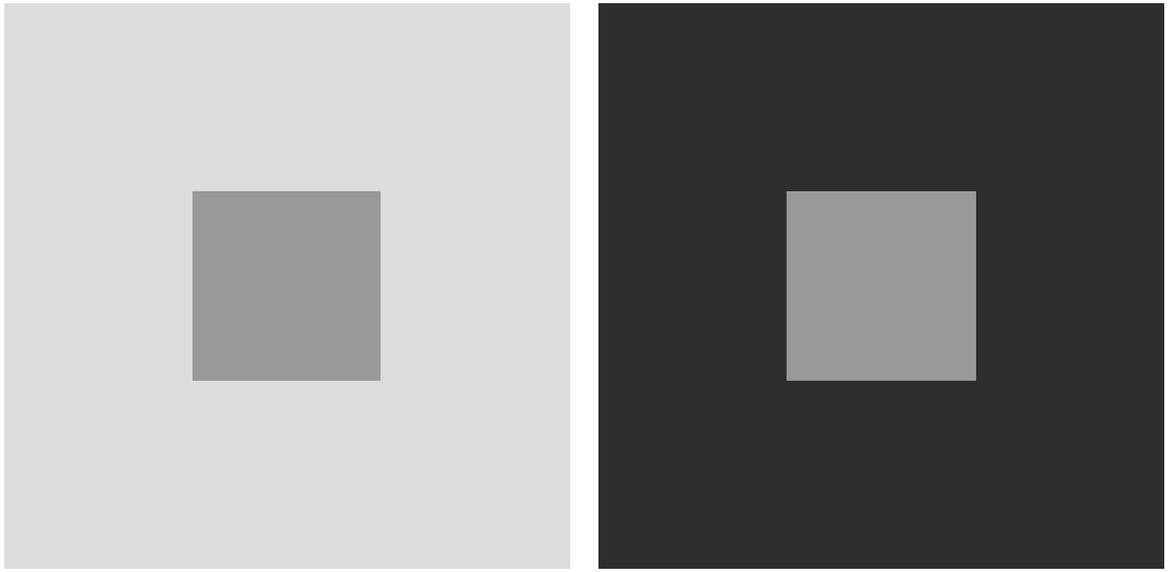
simultaneous contrast



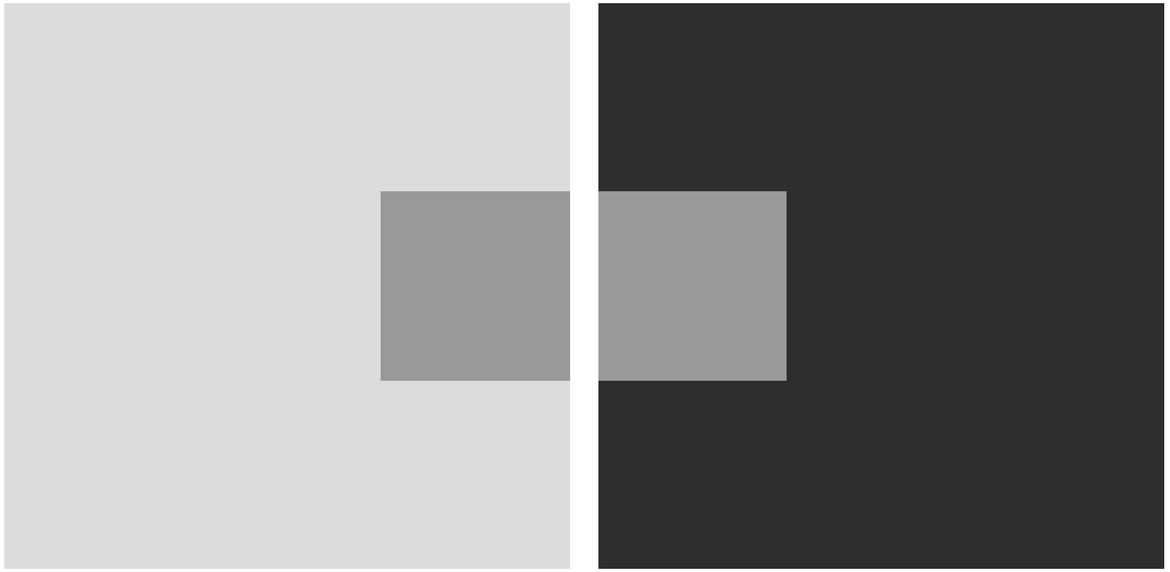
Edward H. Adelson

http://persci.mit.edu/_media/gallery/checkershadow_double_full.jpg

SIMULTANEOUS CONTRAST



SIMULTANEOUS CONTRAST



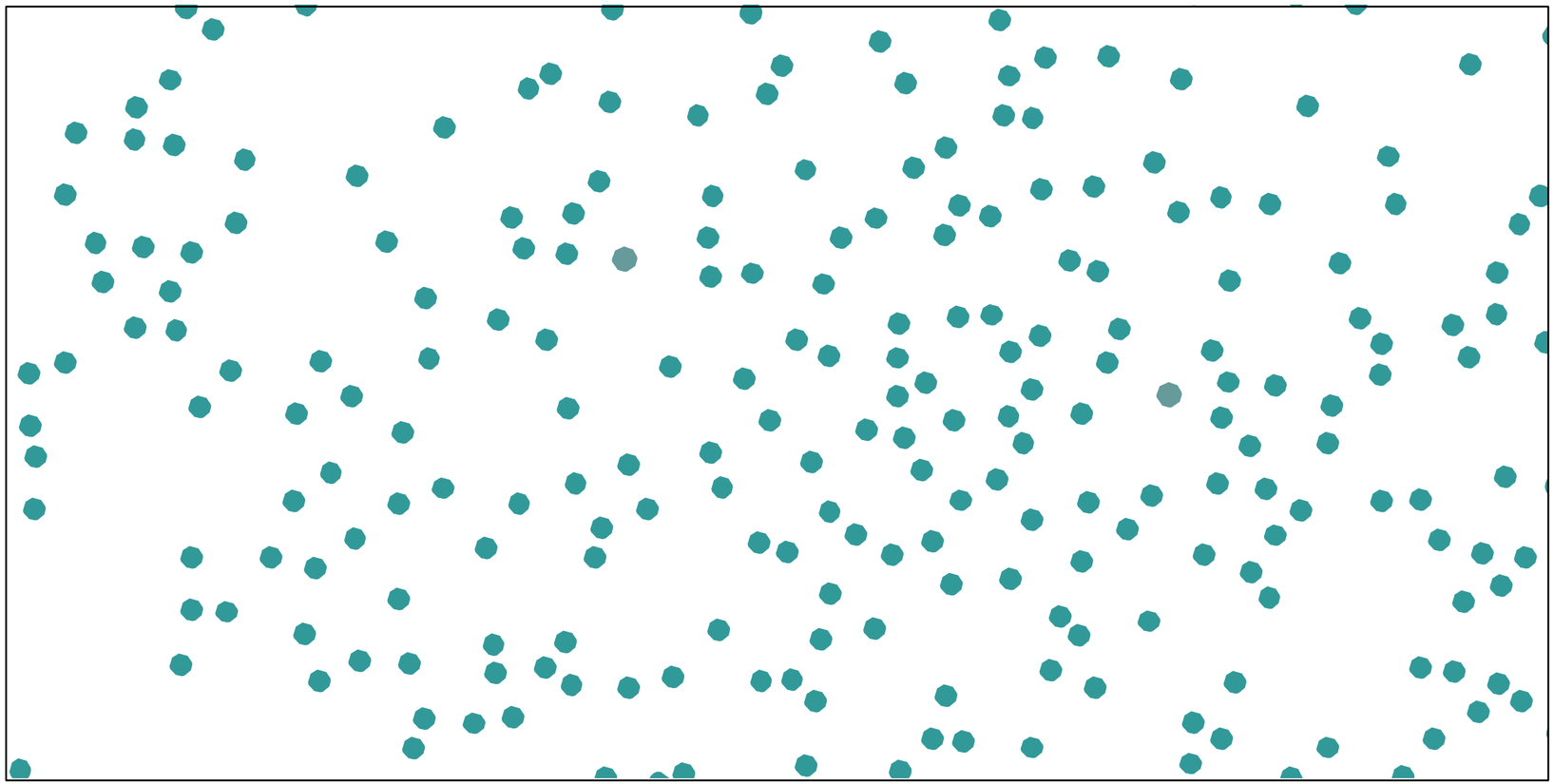
SIMULTANEOUS CONTRAST

Takeaway

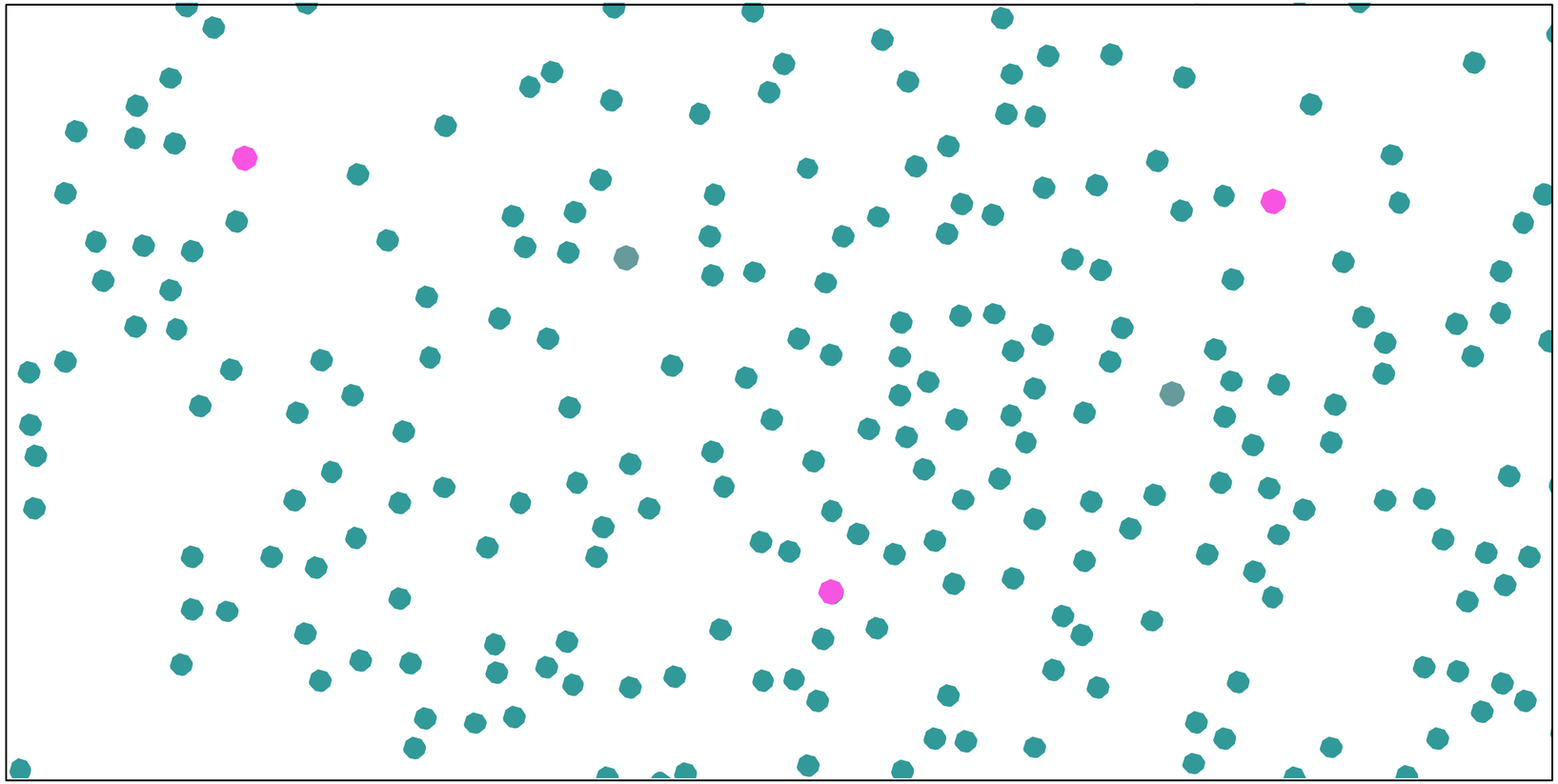
- We have a strong propensity to assume our judgments are absolute, when in fact they are generally relative to the local context.

- **Do your best to not place data in difficult contexts. Choose position and orientation of objects carefully.**

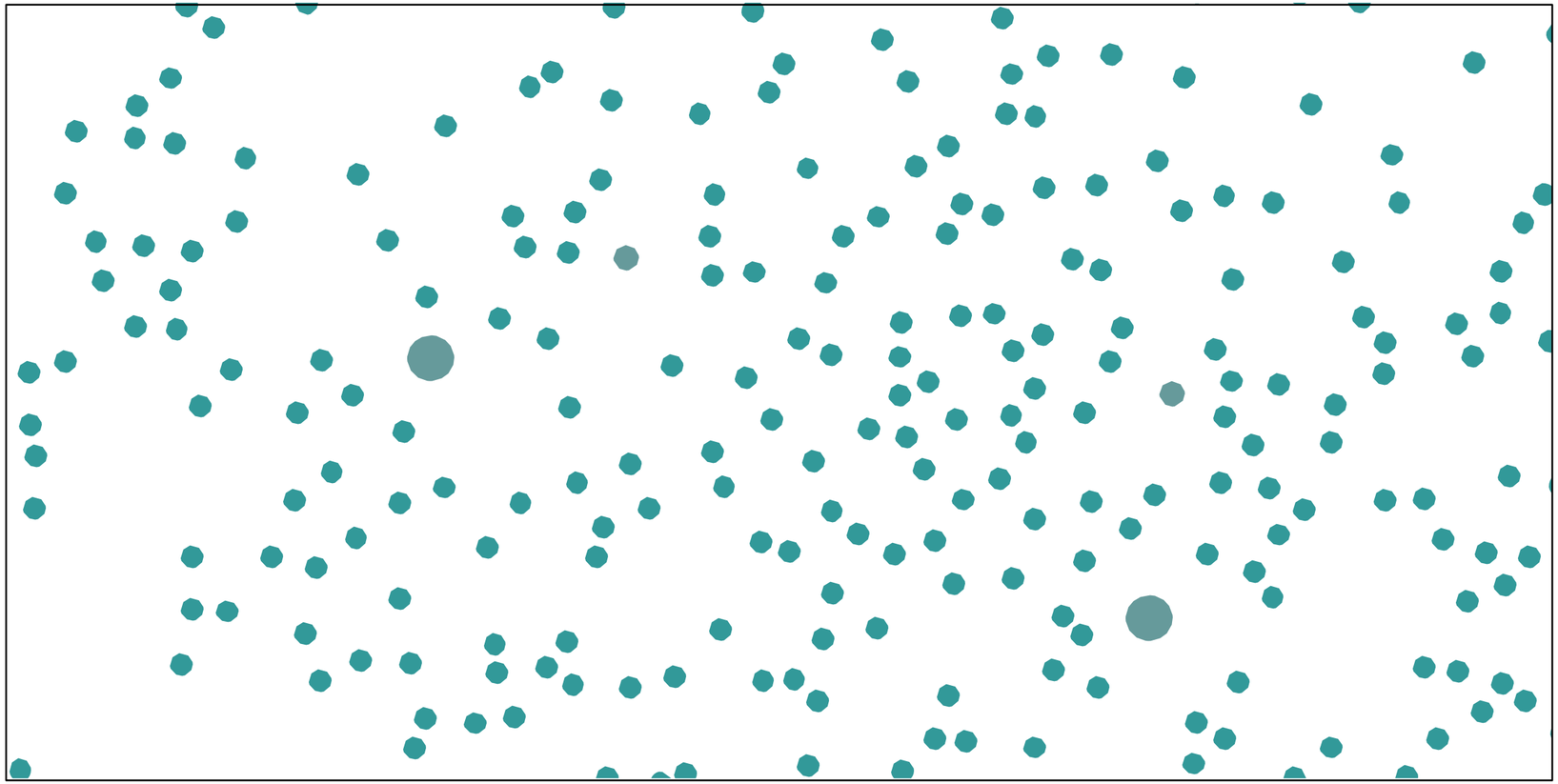
POPOUT



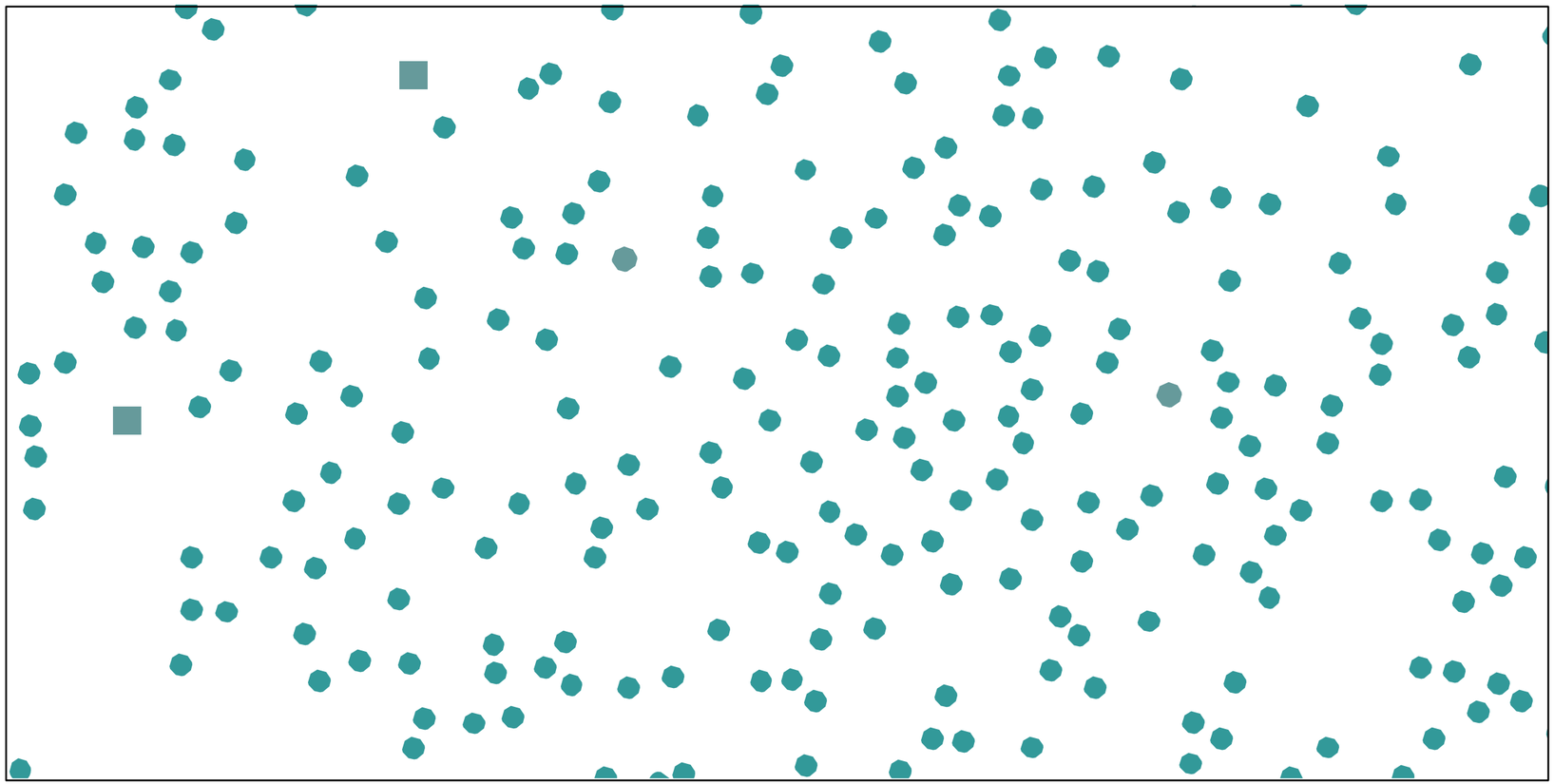
POPOUT



POPOUT



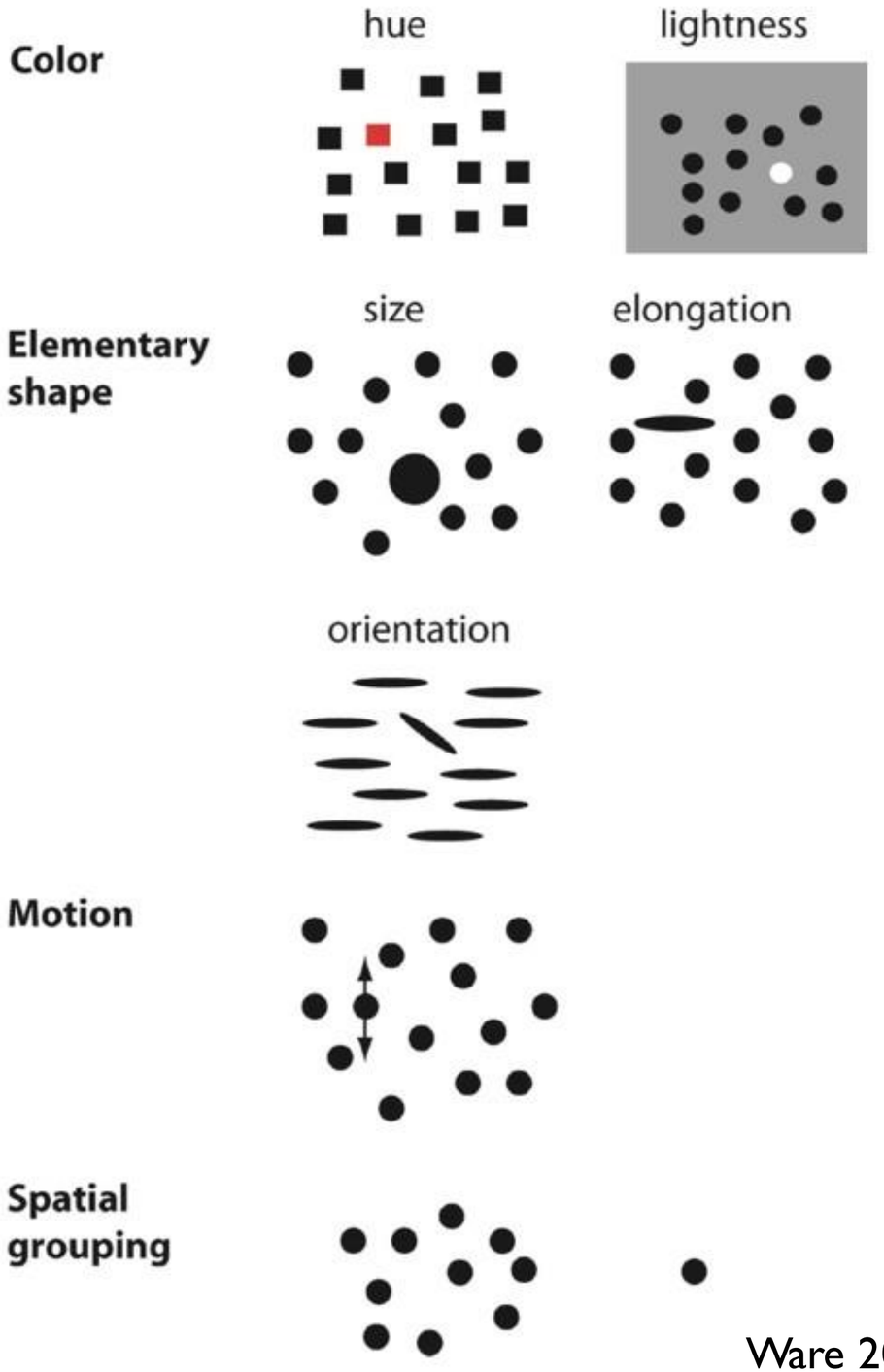
POPOUT



PRE-ATTENTIVE PROCESSING

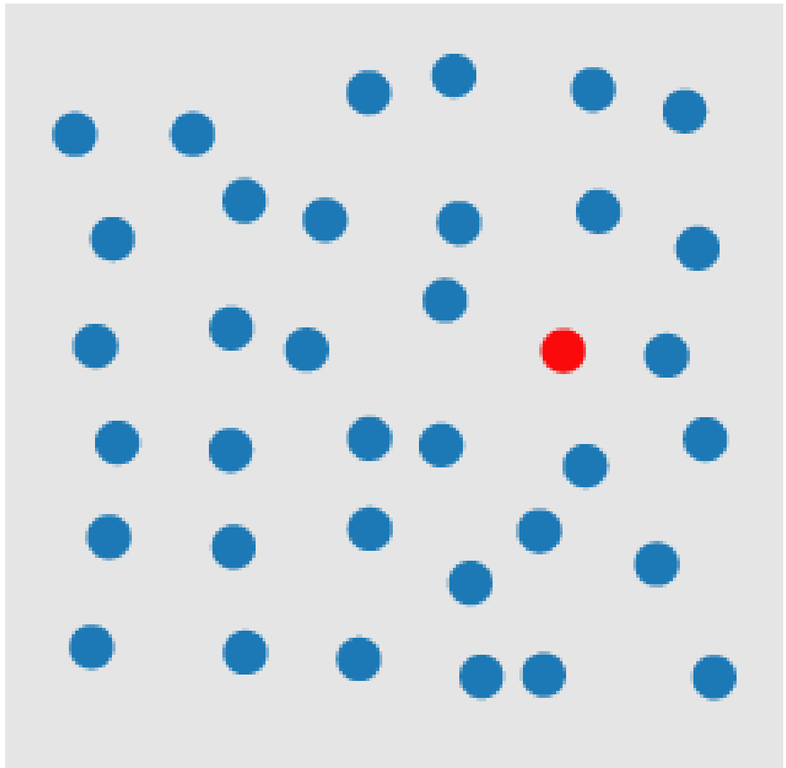
- requires attention, despite name
- very fast: <200 ms
- what matters most is contrast between features

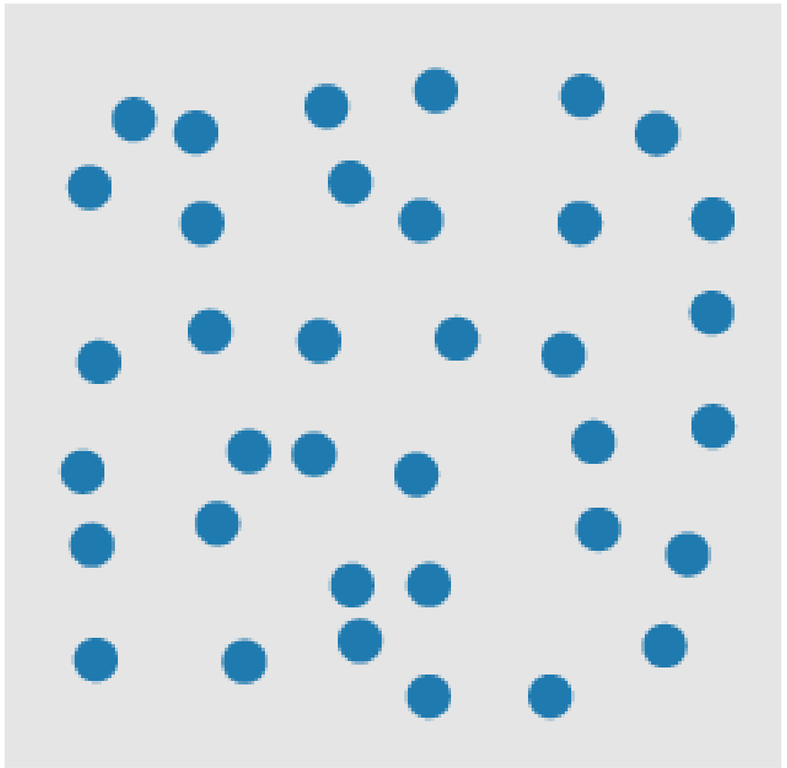
BASIC POPOUT CHANNELS



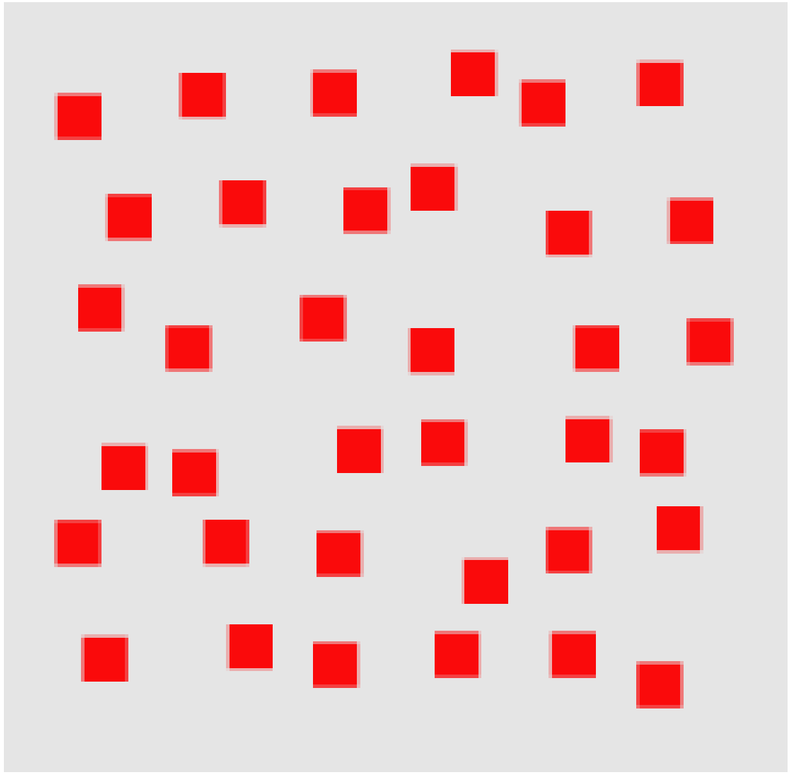
Ware 2008

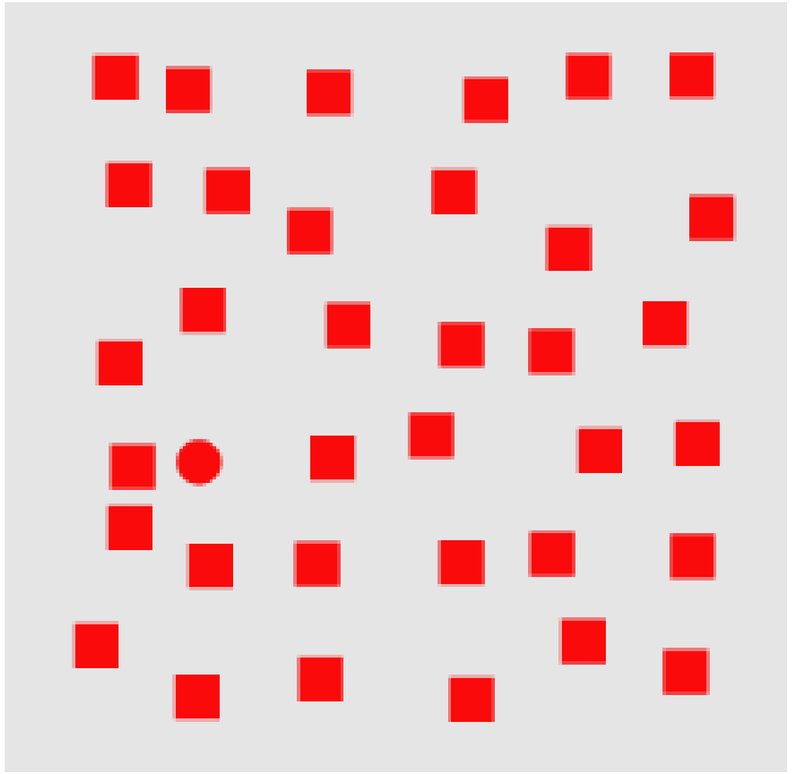
Pick the outlier



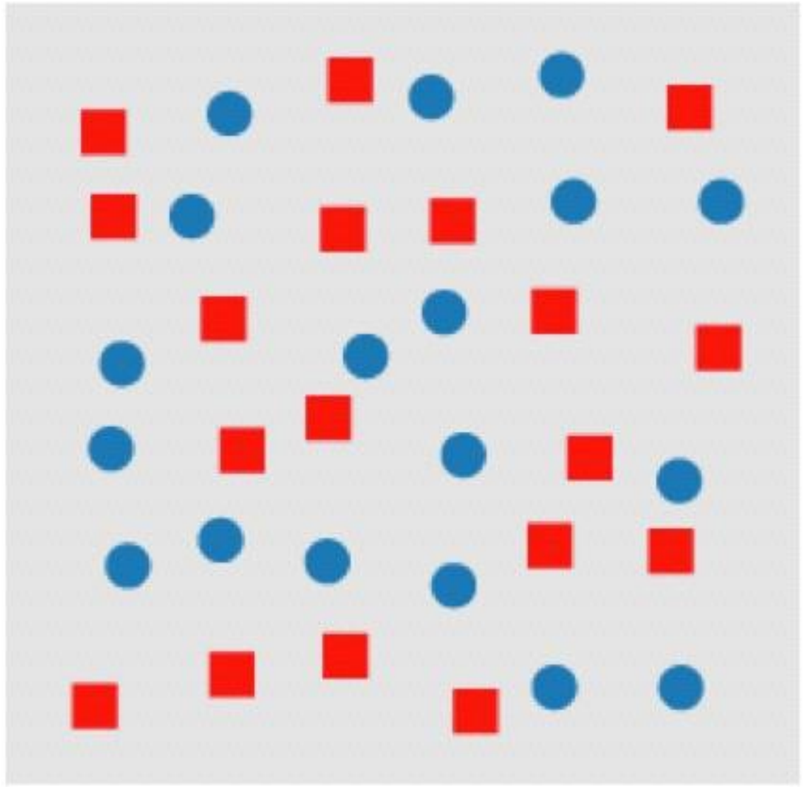


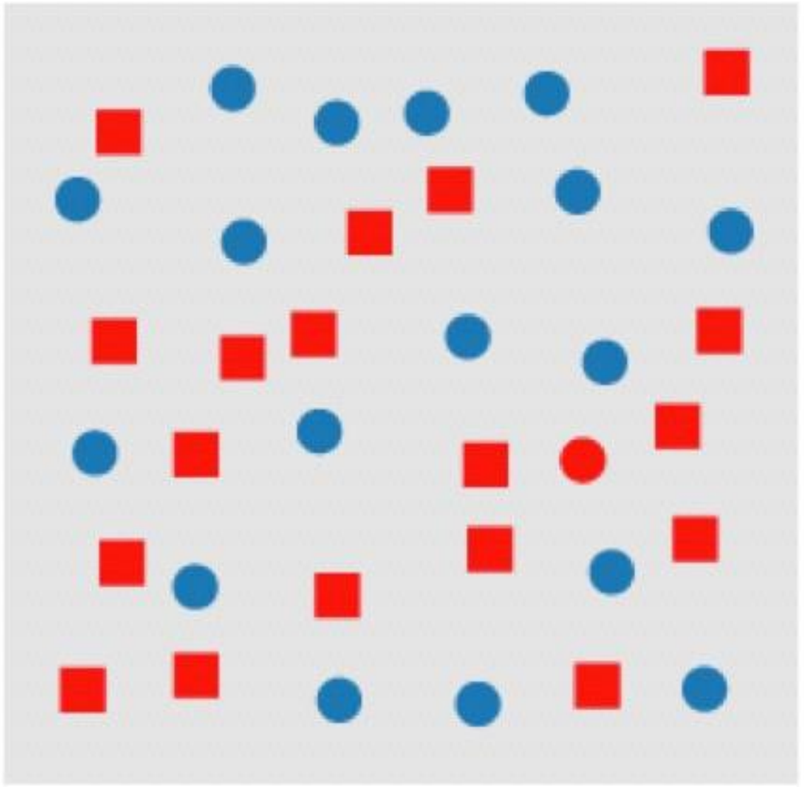
Pick the outlier



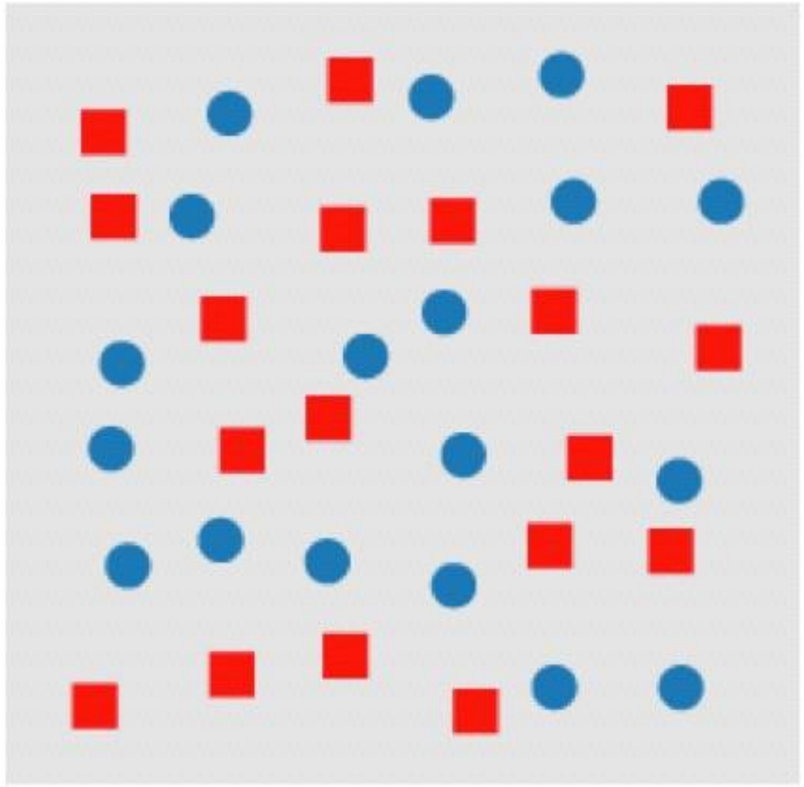


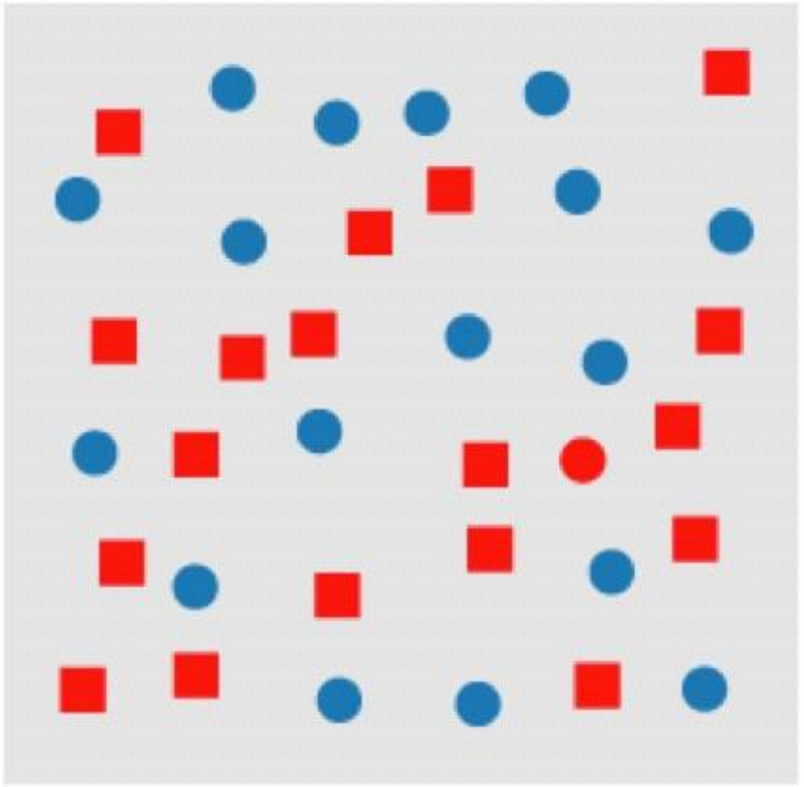
Pick the outlier



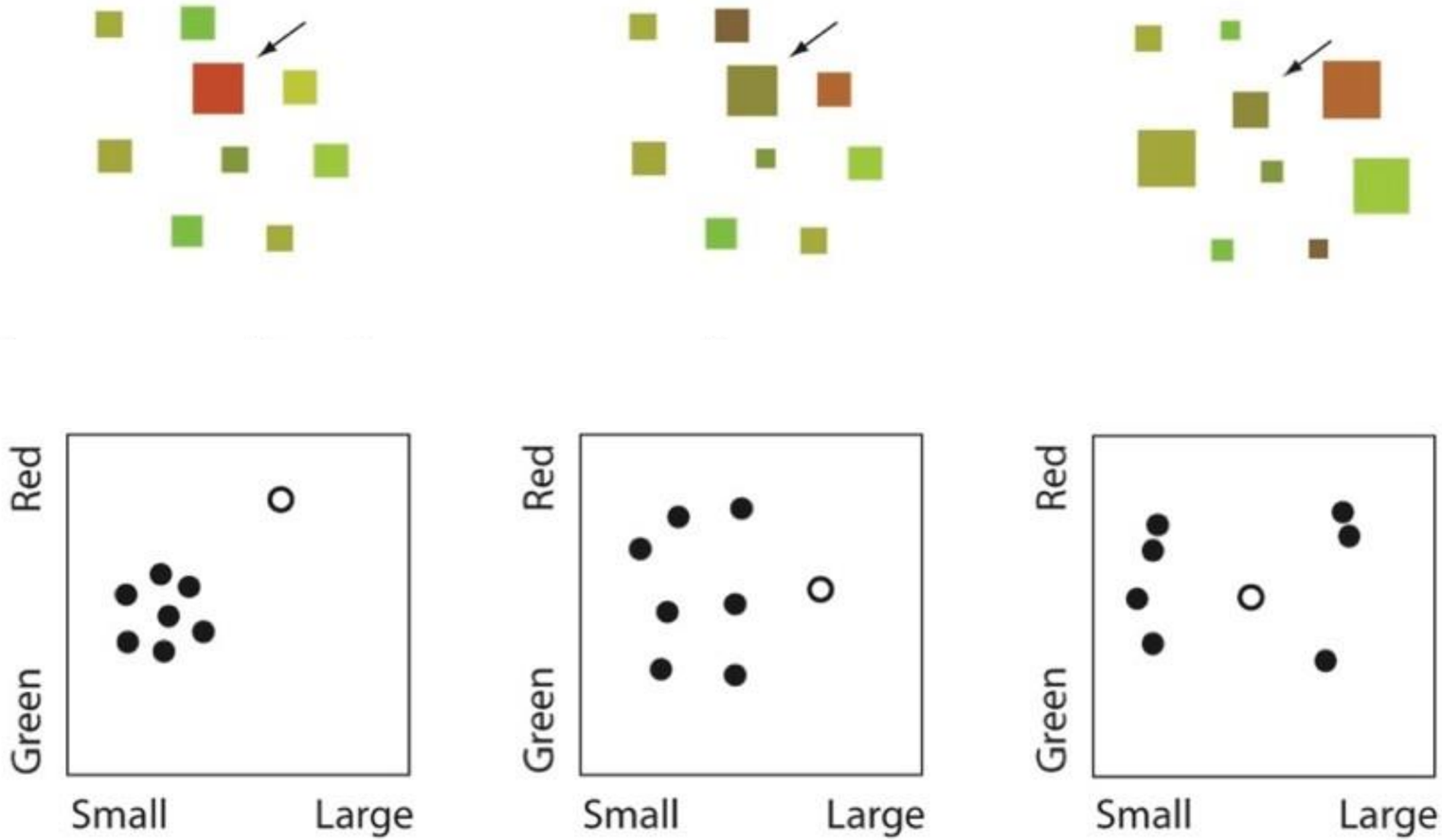


CONJUNCTION (or, why to use a single channel at a time)

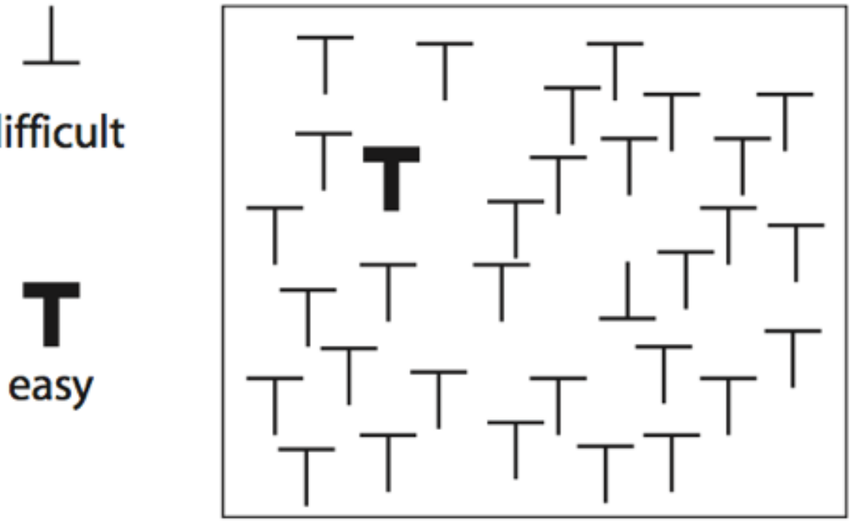




CONJUNCTION (or, why to use a single channel at a time)

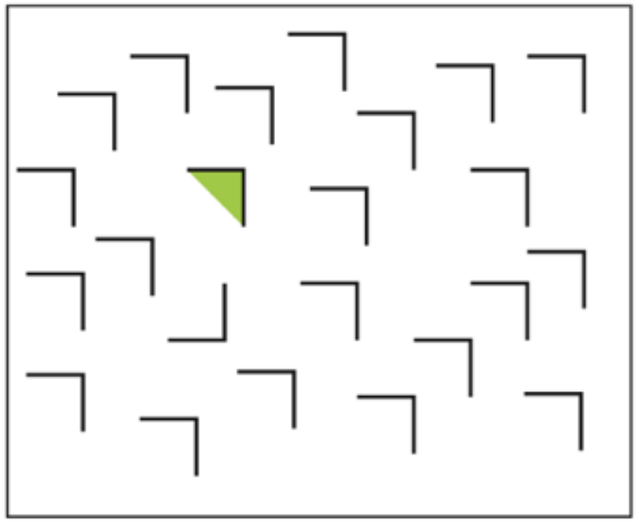


difficult



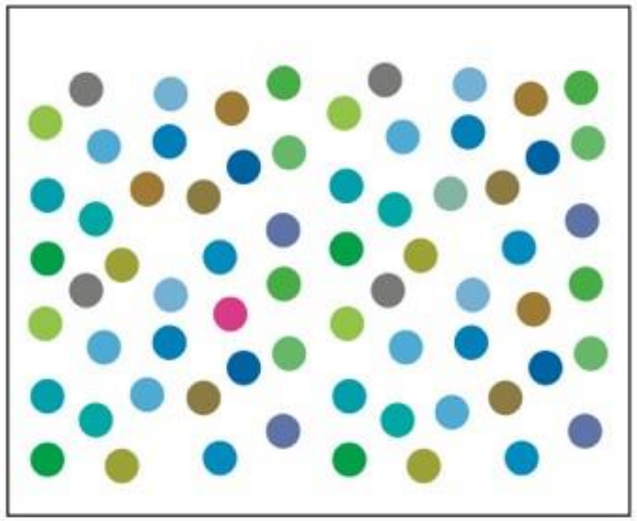
easy

difficult



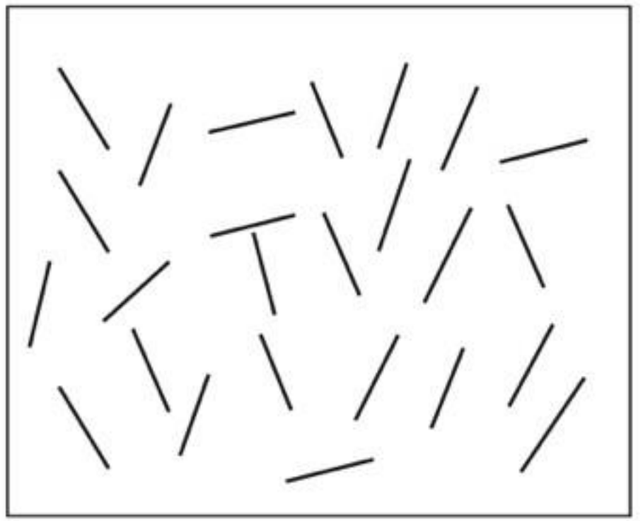
easy

difficult



easy

difficult



easy

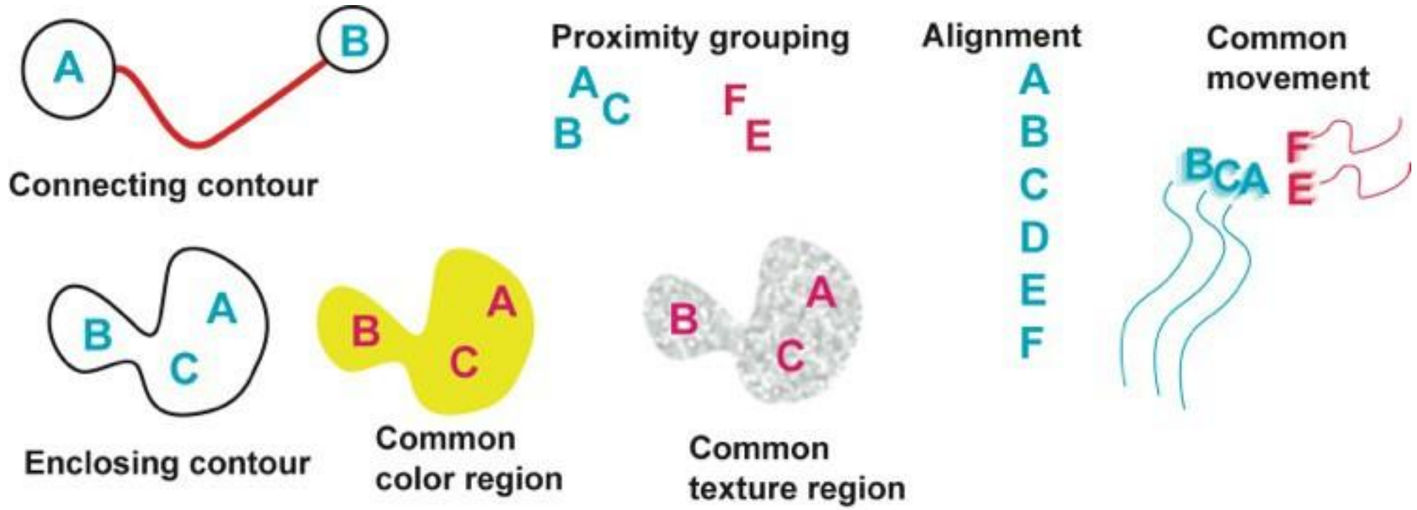
Takeaway

- We can easily see objects that are different in color and shape, or that are in motion.

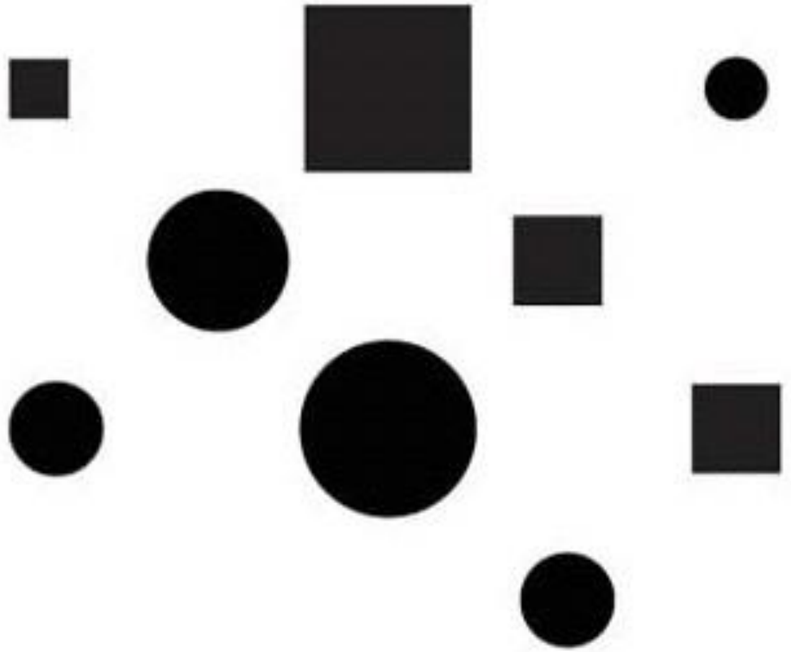
- **Use color and shape sparingly to make the important information pop out.**

Gestalt principles

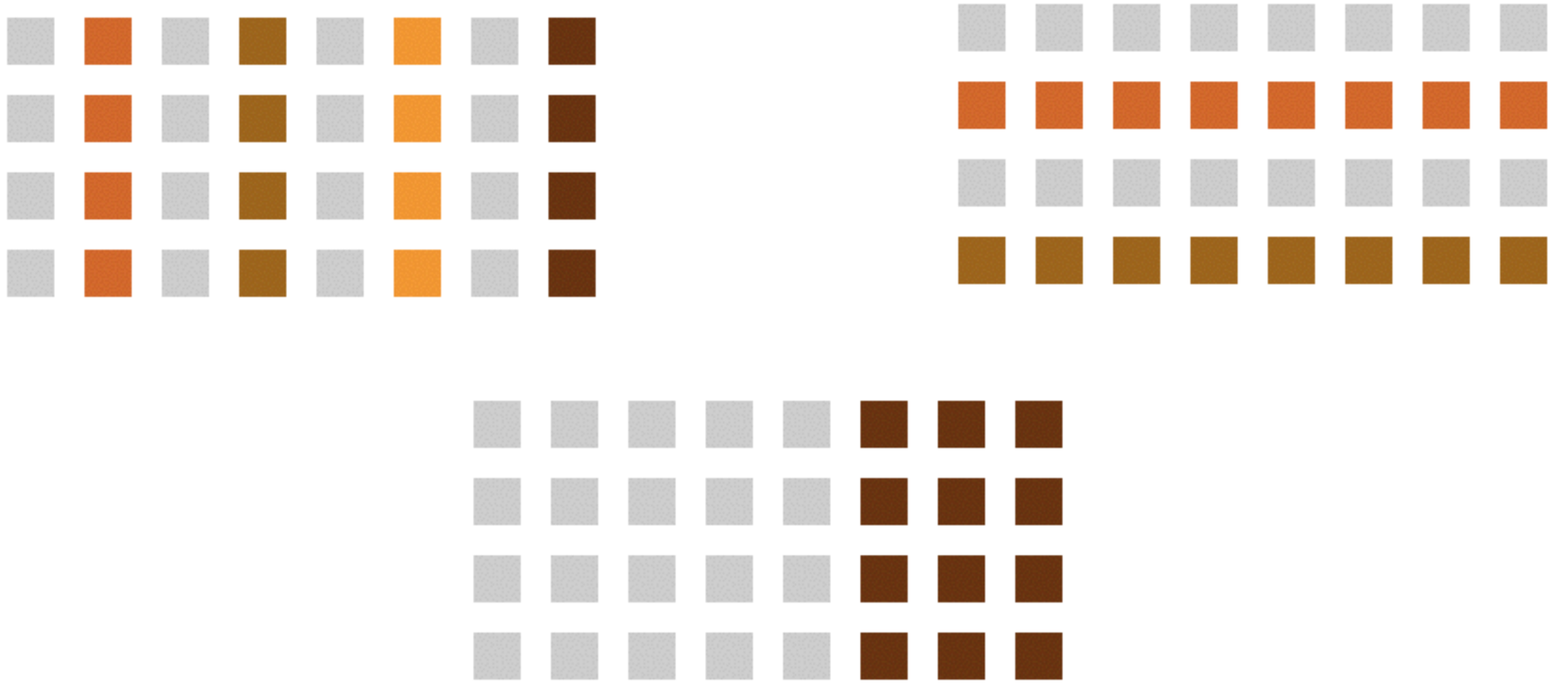
- German: “Gestalt” = form
- patterns transcend the visual stimuli that produced them



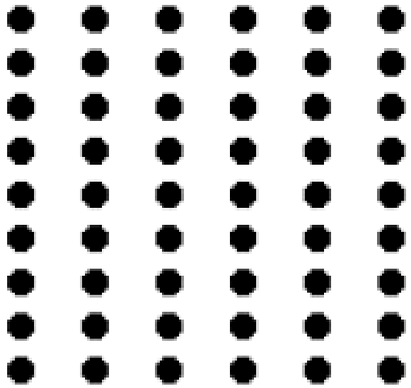
similarity

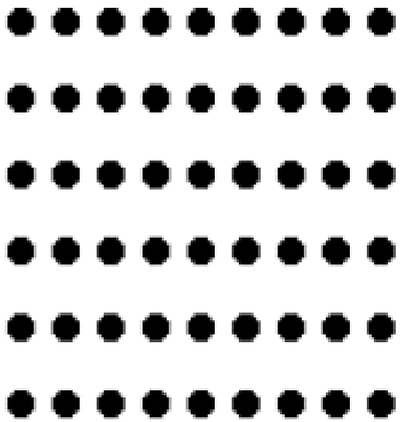


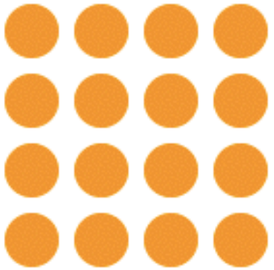
similarity

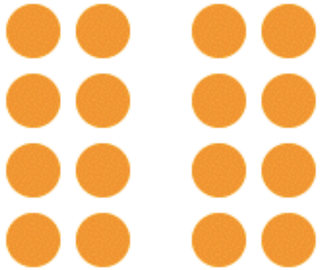


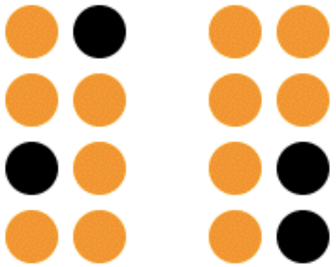
proximity



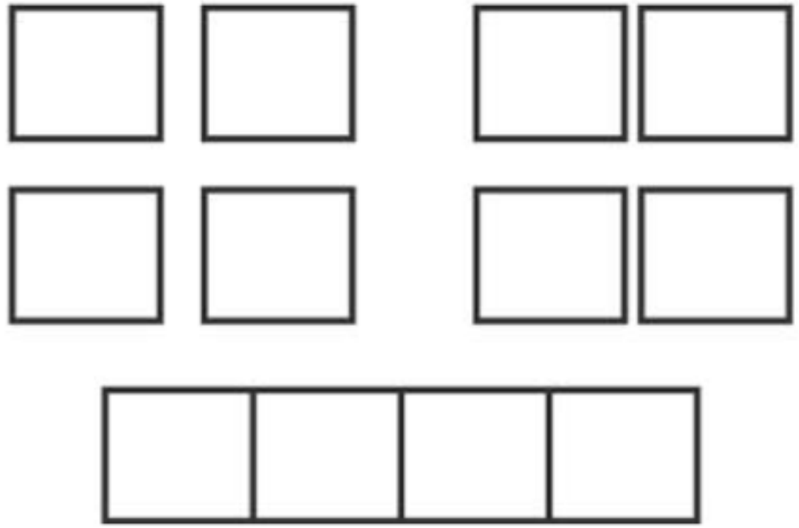




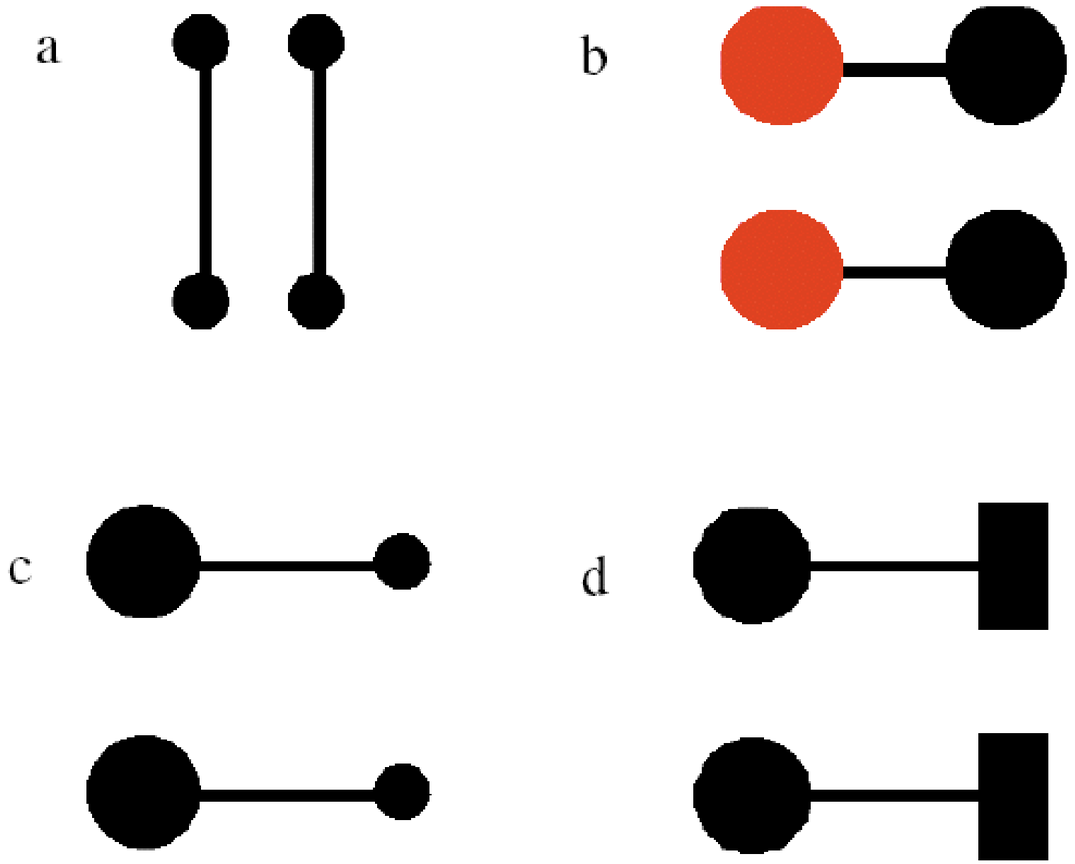




proximity

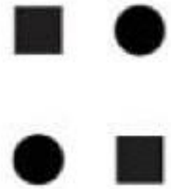


connectedness

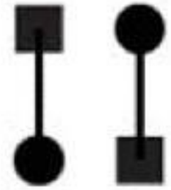


grouping

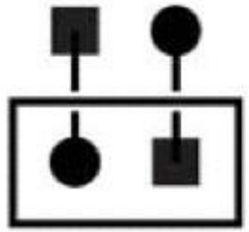
Similarity



Connection

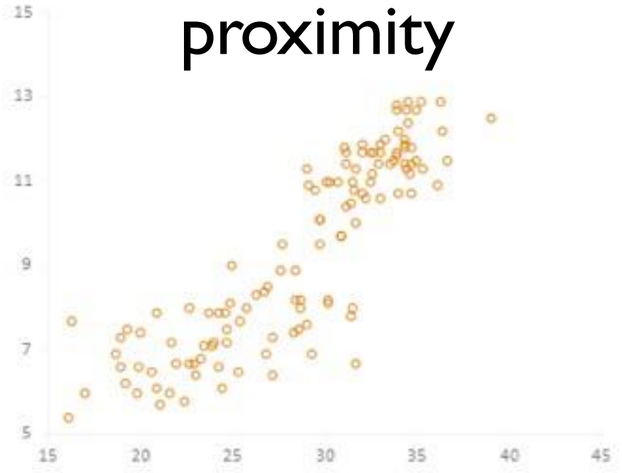


Enclosure

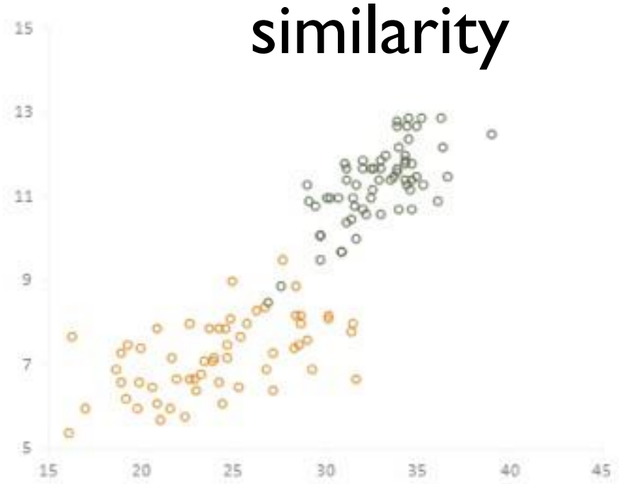


grouping

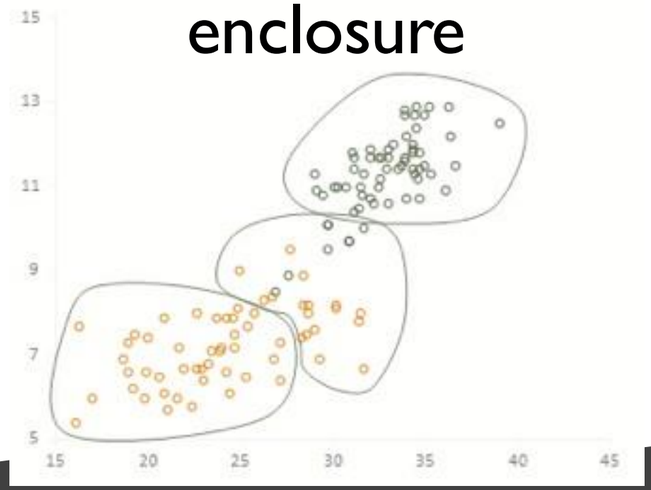
proximity



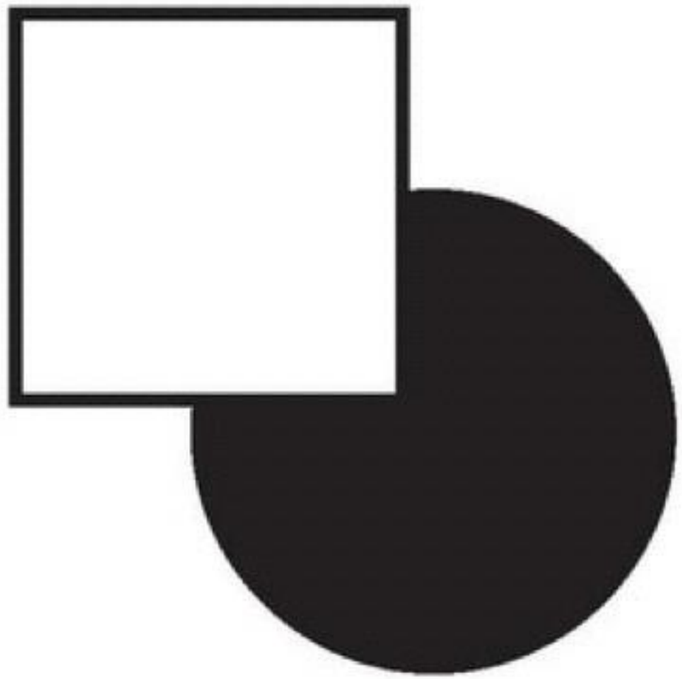
similarity



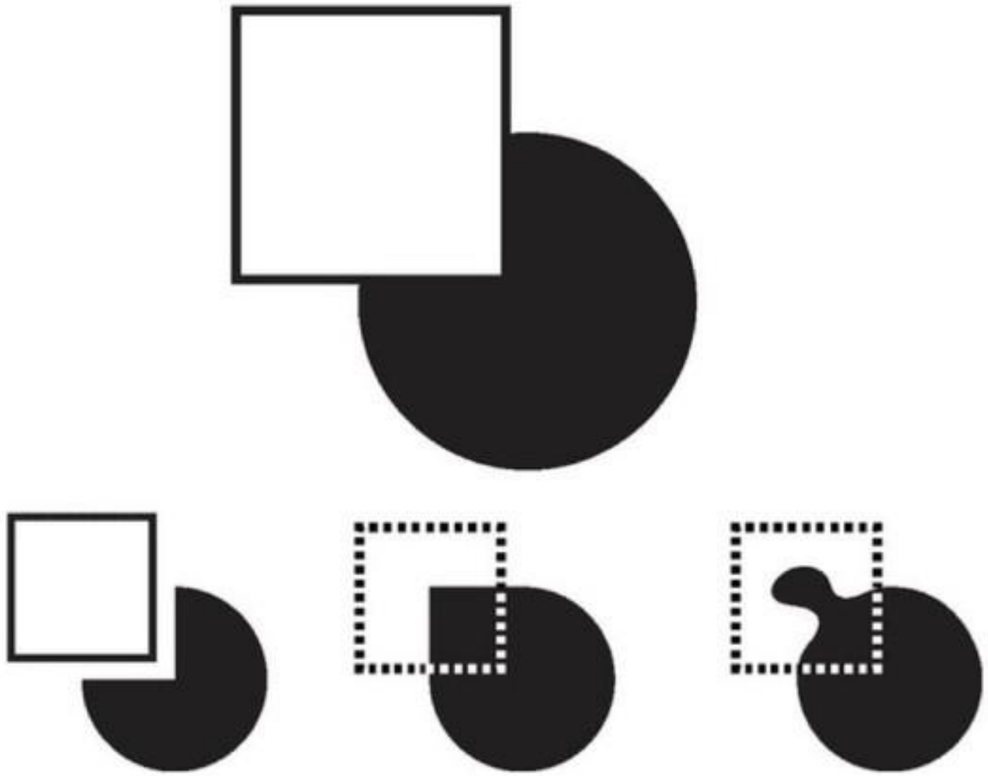
enclosure



continuity



continuity



closure

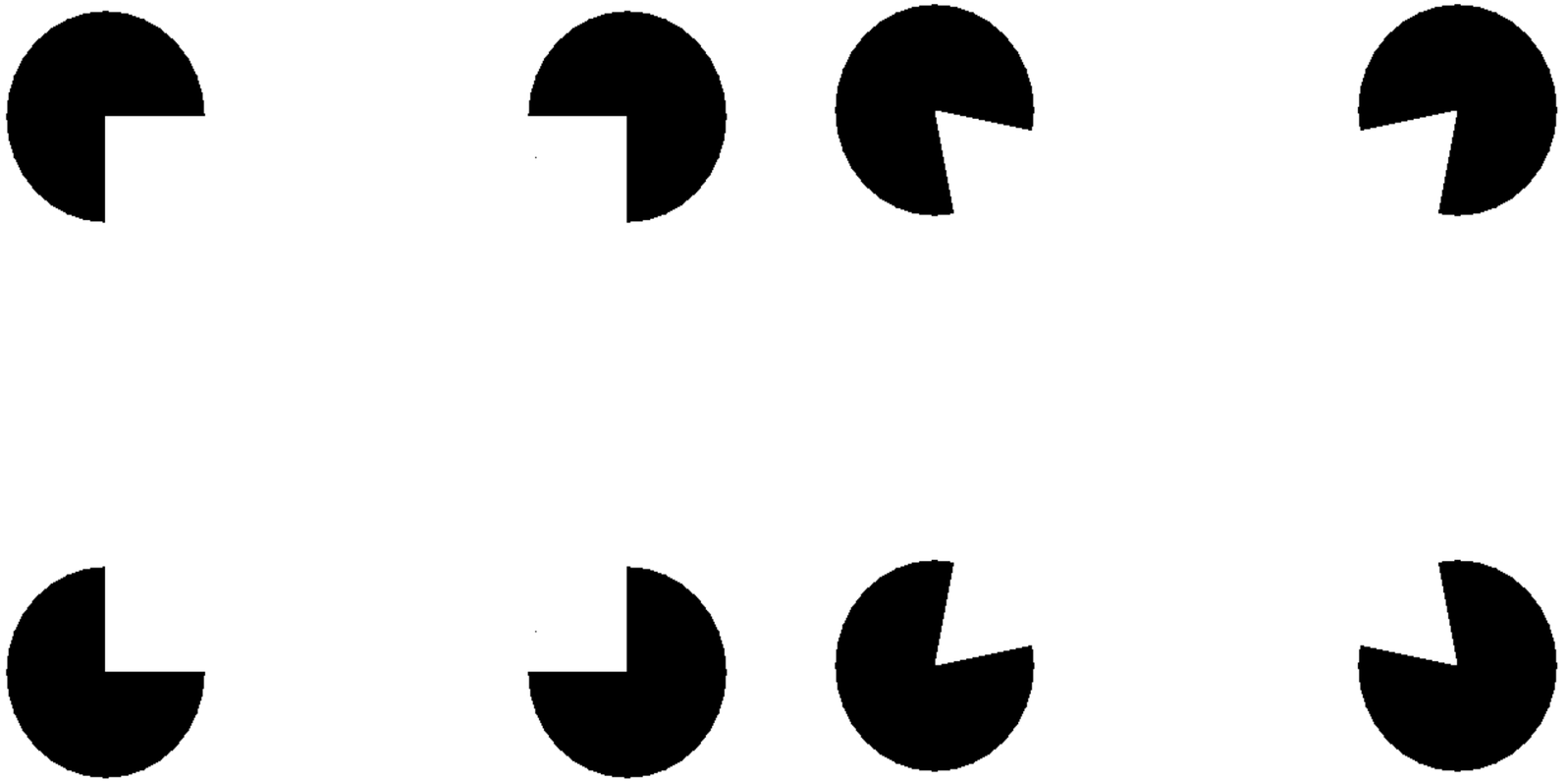
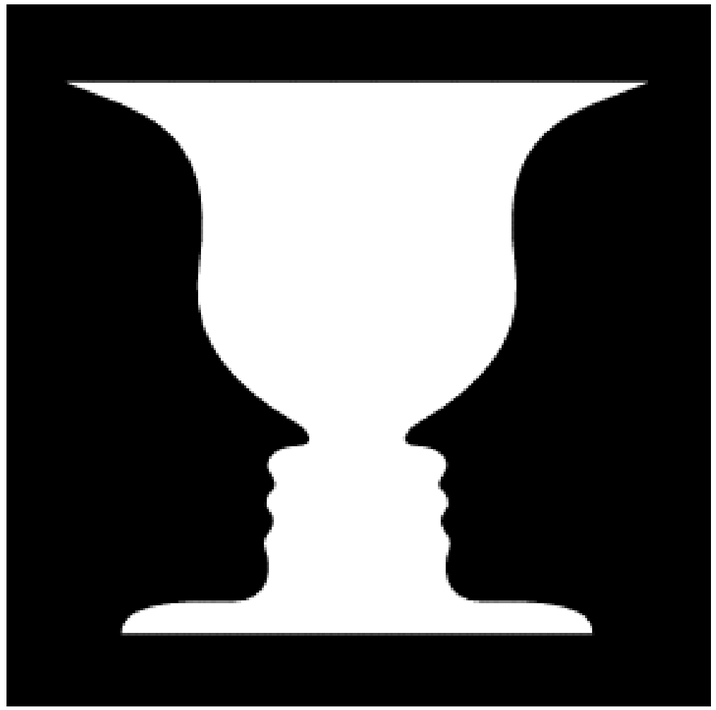
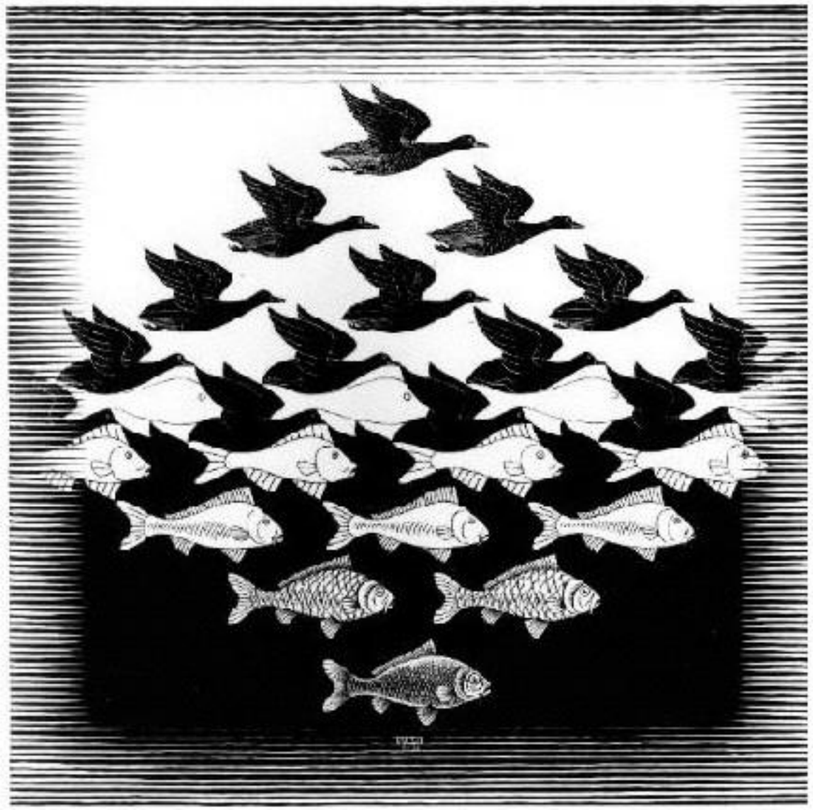


figure / ground





M.C. Escher: *Sky and Water I* 1938 woodcut

common fate

Gestalt principles

- **similarity**: things that look like each other (size, color, shape) are related
- **proximity**: things that are visually close to each other are related
- **connection**: things that are visually connected are related
- **continuity**: we complete hidden objects into simple, familiar shapes
- **closure**: we see incomplete shapes as complete
- **figure / ground**: elements are perceived as either figures or background
- **common fate**: elements with the same moving direction are perceived as a unit

Takeaways

- Gestalt principles give us a conceptual understanding of the way our mind converts shapes into structured thought.

- **Using the Gestalt principles wisely will lead improve performance in interpretation of visualizations. Poor use may cause users to see things that aren’t there…**