SWINBURNE UNIVERSITY OF TECHNOLOGY

COS30045

DATA VISUALISATION

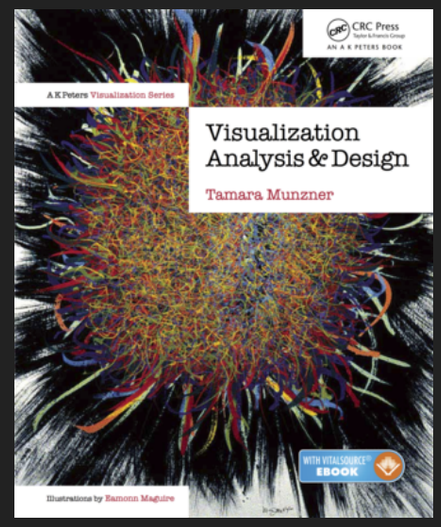
TOPIC 05: PSYCHOLOGICAL PRINCIPLES

Karola von Baggo

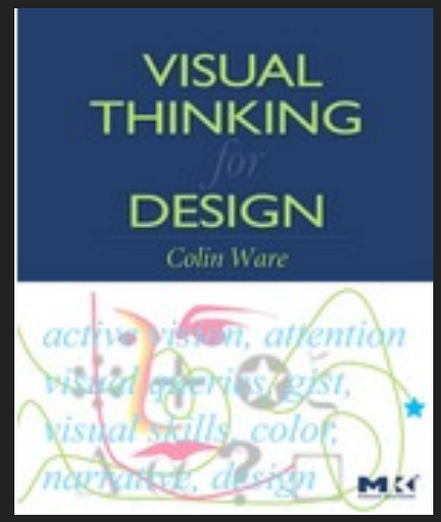
PERCEPTION, COLOUR AND ATTENTION

Lecture Readings

- VAD 10.2



- VTD Ch 1, 2 and 4



PERCEPTION AND ATTENTION

What:

- models of visual perception and attention

Why:

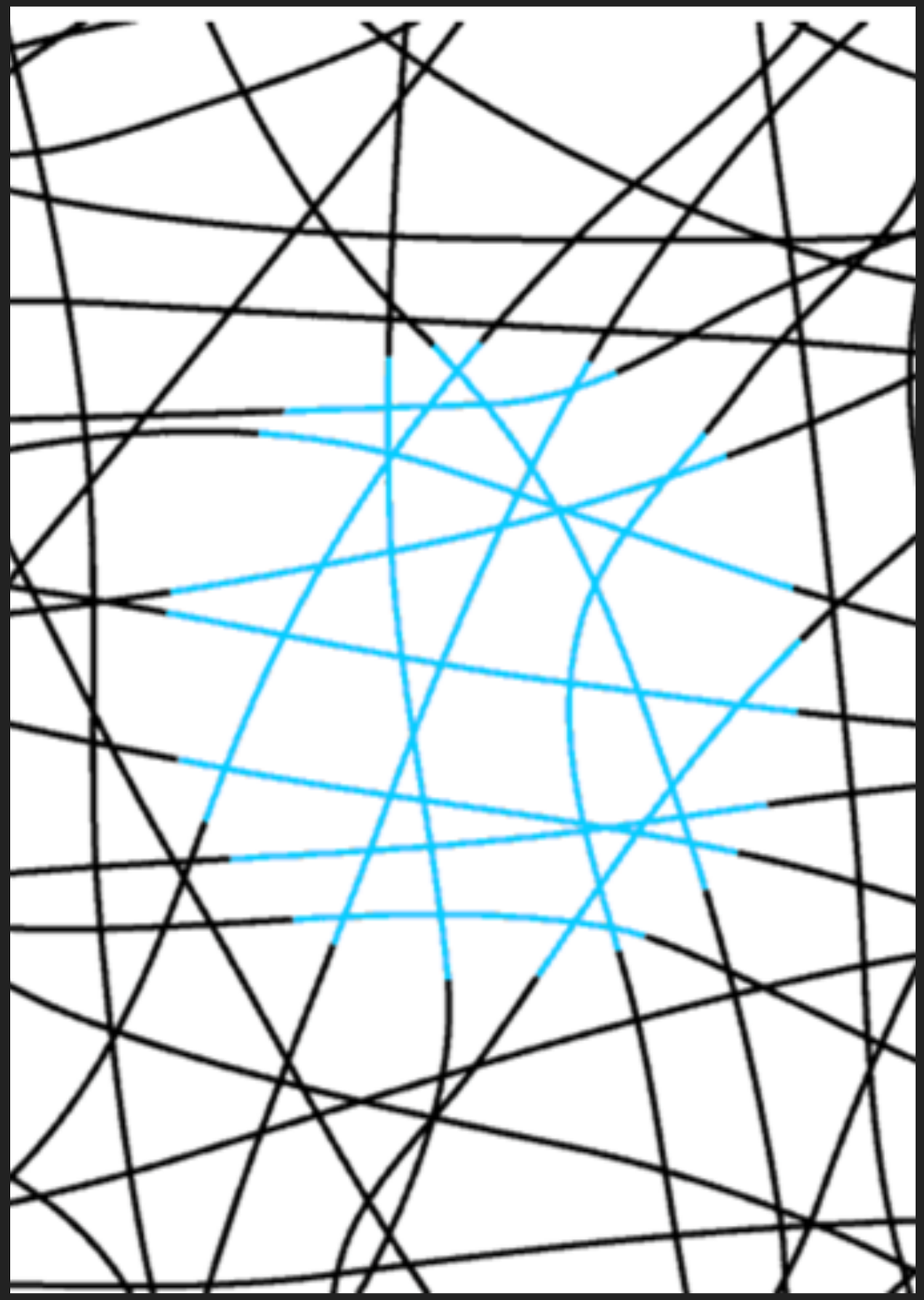
- design visualisations that exploit human perceptual and attentional strengths

How:

- understand the capabilities and limitations of human perception and attention

OVERVIEW

- 5.1 Sensation and Perception
- 5.2 Attention
- 5.3 Colour
- 5.4 Gestalt



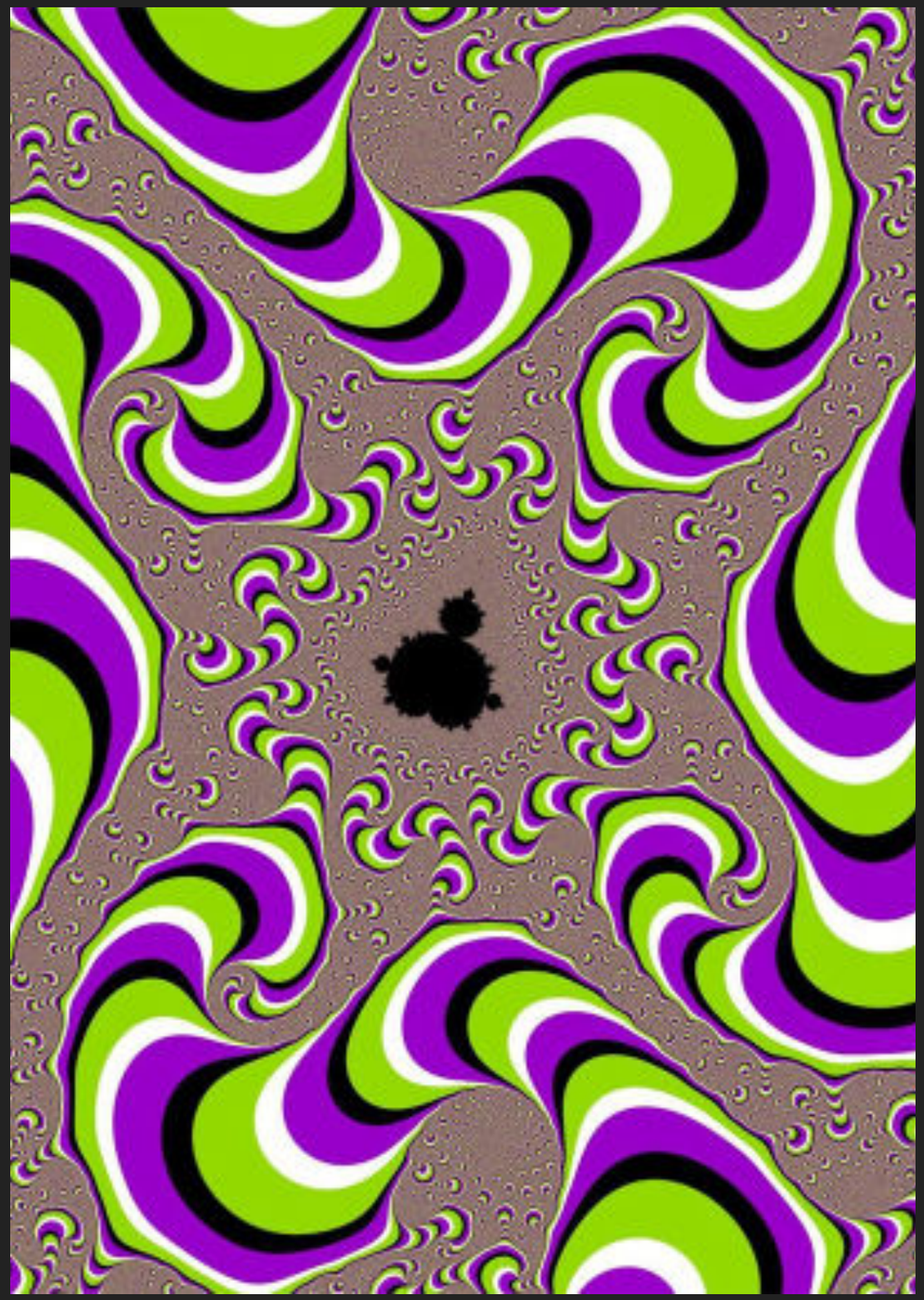
5.1 SENSATION AND PERCEPTION

At the end of this topic you should be able to:

- Understand the difference between sensation and perception
- Appreciate the effect of context on perception
- Give some examples of how context influences what is perceived

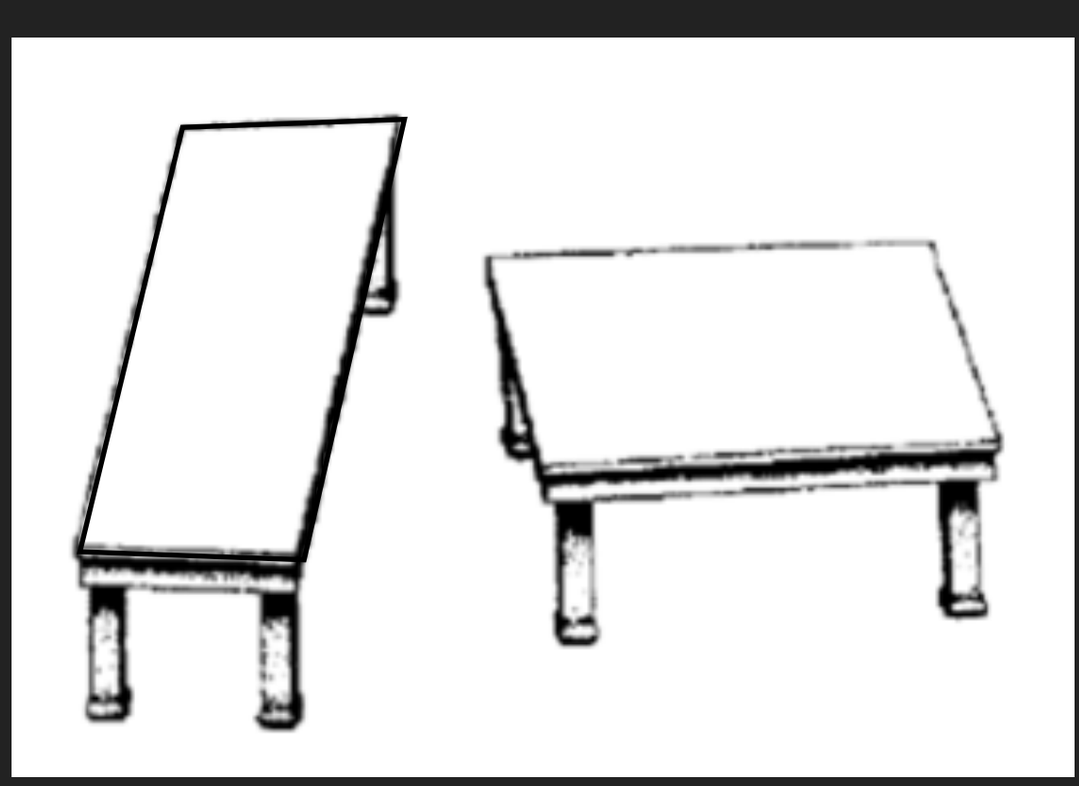
SENSATION AND PERCEPTION

- Sensation
  - receiving physical stimulation and encoding it into the nervous system
- Perception
  - the process of interpreting and recognising sensory information, the act of understanding what the sensation was

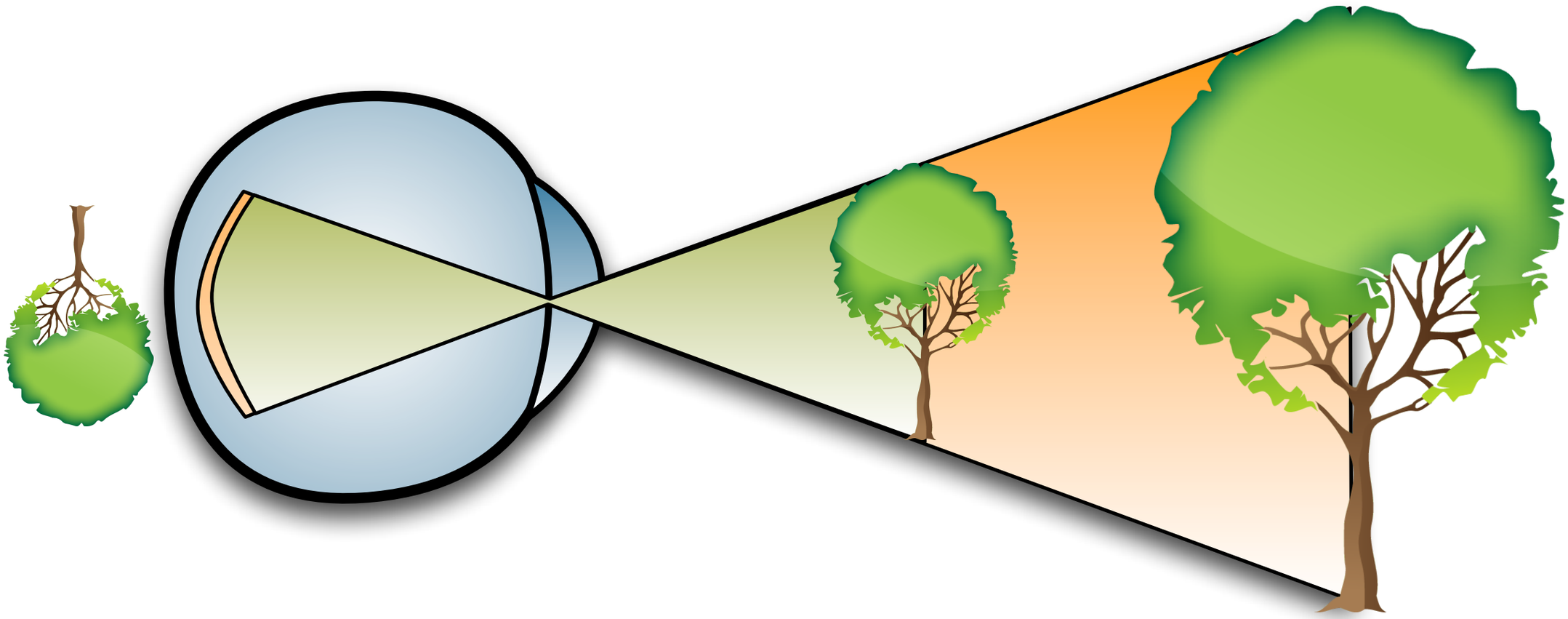


PERCEPTION

- Perception
  - not a true depiction of the world
  - biased by
    - our past experience
    - the current context
    - our future goals



Johnson (201)



small near object and

large far object cast

same size image on retina

However, we do not perceive these objects to be the same size...

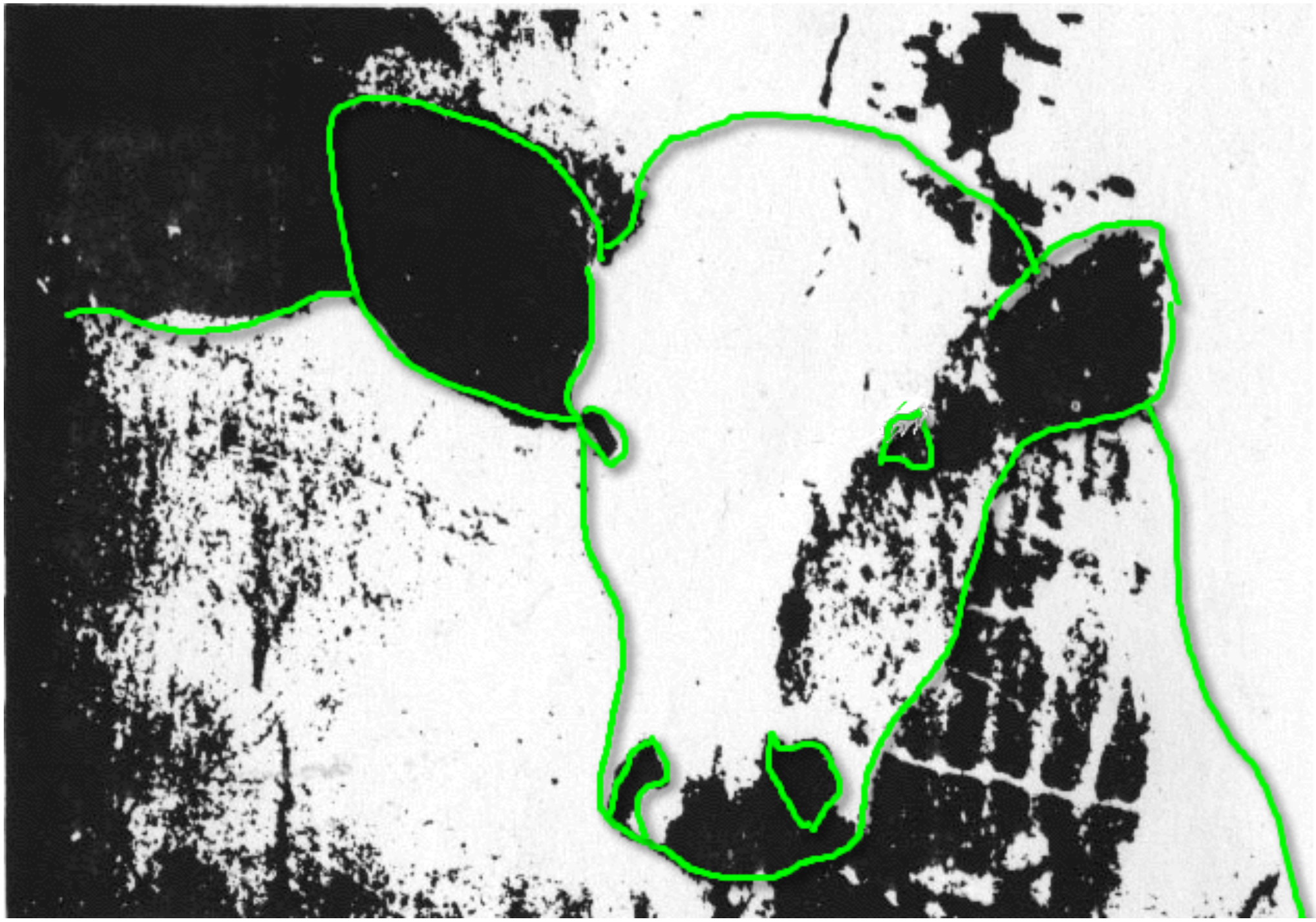
Karola von Baggo
Swinburne University of Technology

SIZE CONSTANCY

SIZE CONSTANCY

SENSORY EXPERIENCE AND PERCEPTION

SENSORY EXPERIENCE AND PERCEPTION



PERCEPTION AND CONTEXT

- Current context

Fold napkins. *Polish silverware*. Wash dishes.

French napkins. *Polish silverware*. German dishes.

Johnson (201)

5.1 SENSATION AND PERCEPTION

Now you should be able to:

- Understand the difference between sensation and perception
- Appreciate the effect of context on perception
- Give some examples of how context influences what is perceived

SWINBURNE UNIVERSITY OF TECHNOLOGY

COS30045

DATA VISUALISATION

TOPIC 05.2: ATTENTION

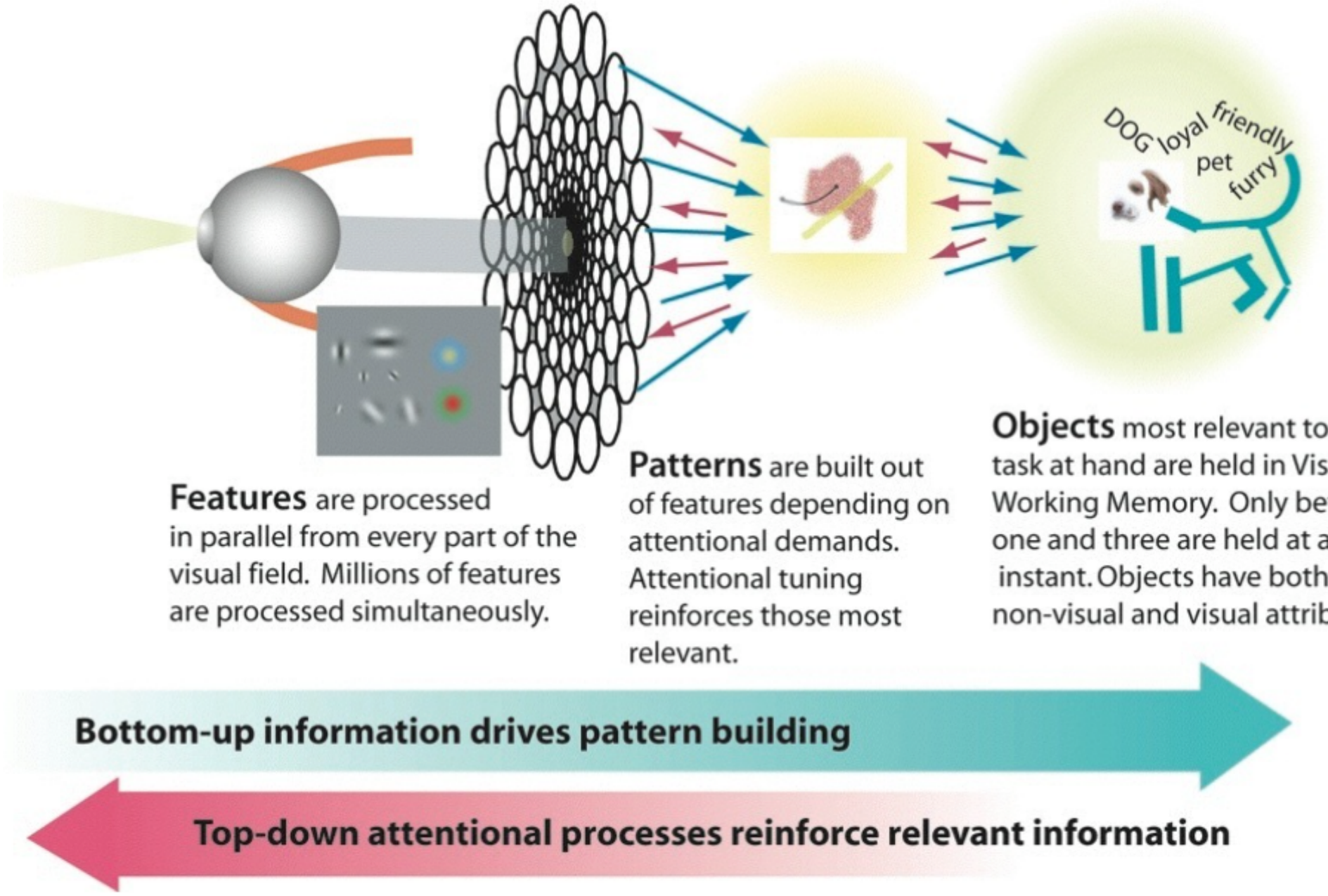
Karola von Baggo

5.2 ATTENTION

At the end of this topic you should be able to:

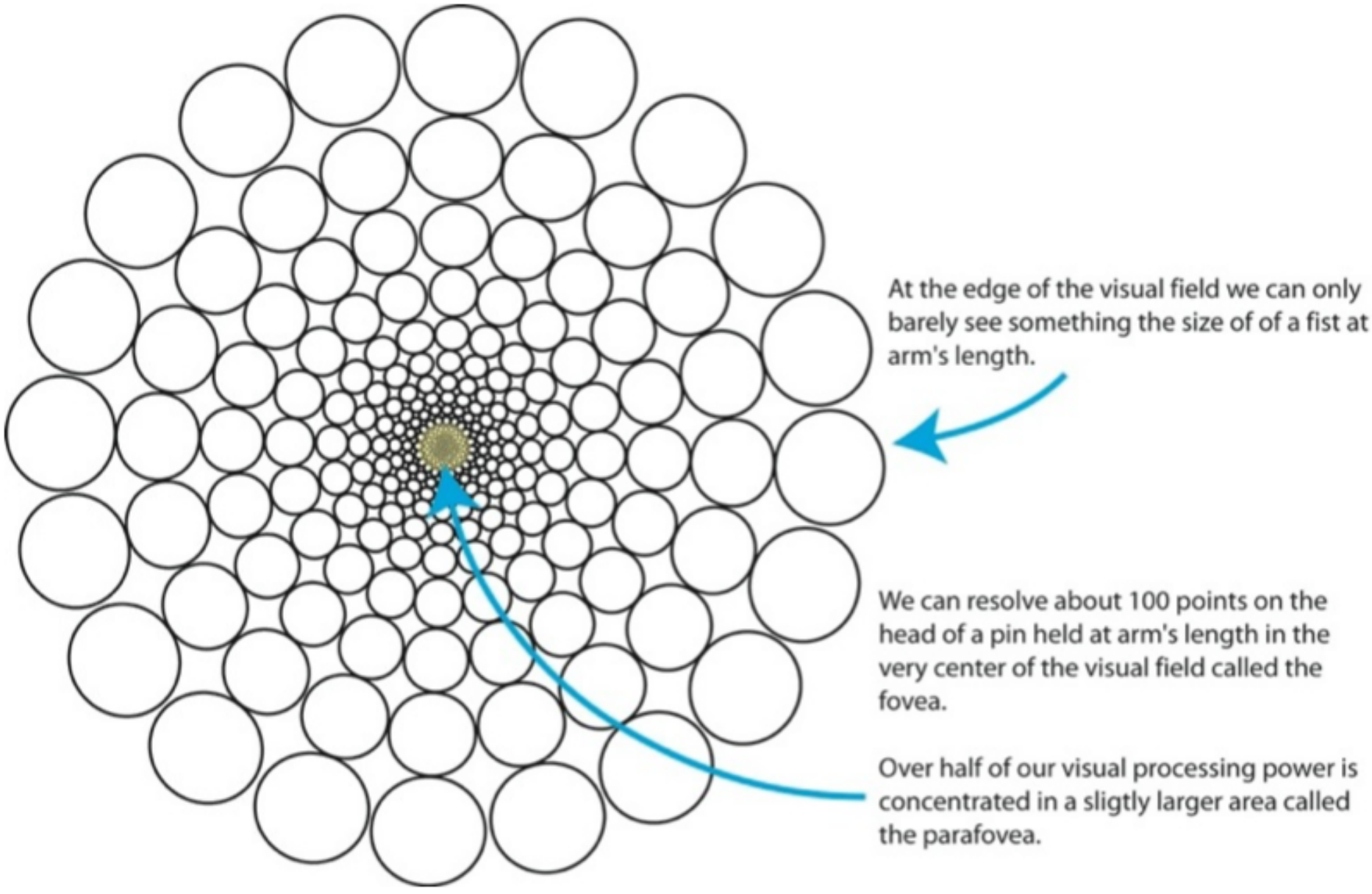
- Explain the role of attention in perception in terms of Ware's model of perceptual processing
- List and use a variety of pop-out channels to draw user's attention
- Identify separable and integral visual channel combinations

PERCEPTUAL PROCESSING

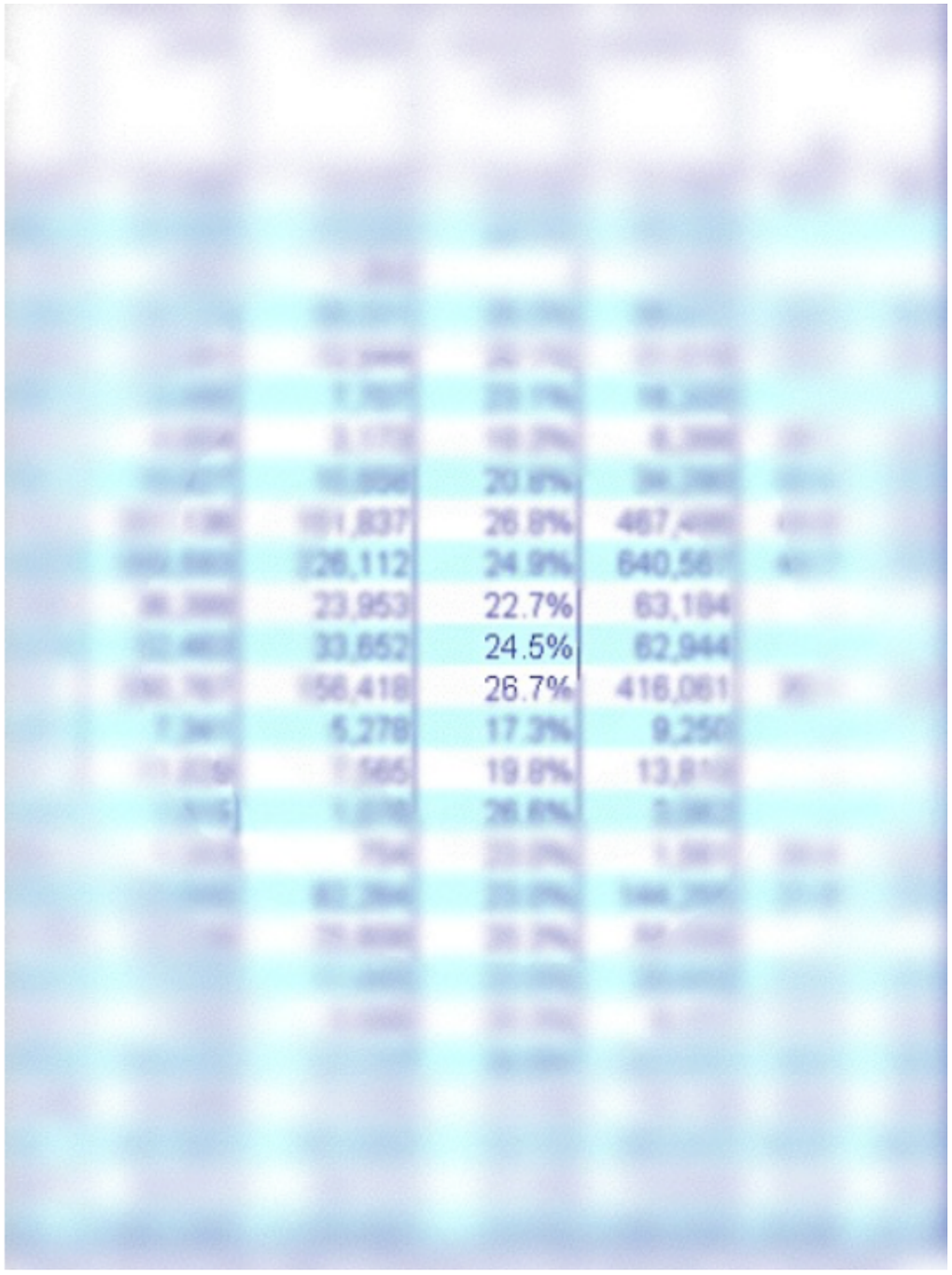


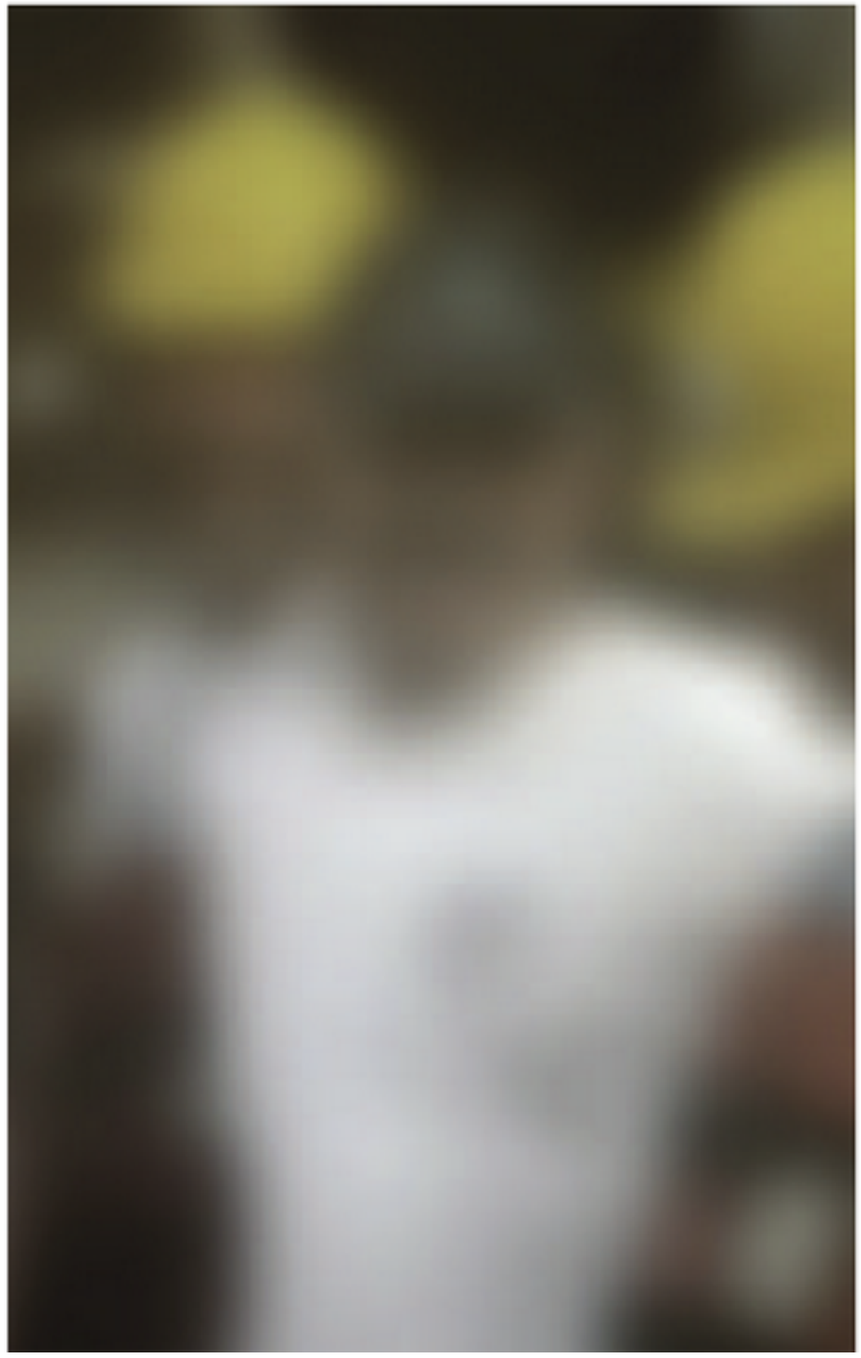
Ware (2008)

VISUAL PHYSIOLOGY: VISUAL FIELD



VISUAL PHYSIOLOGY: FOVEA

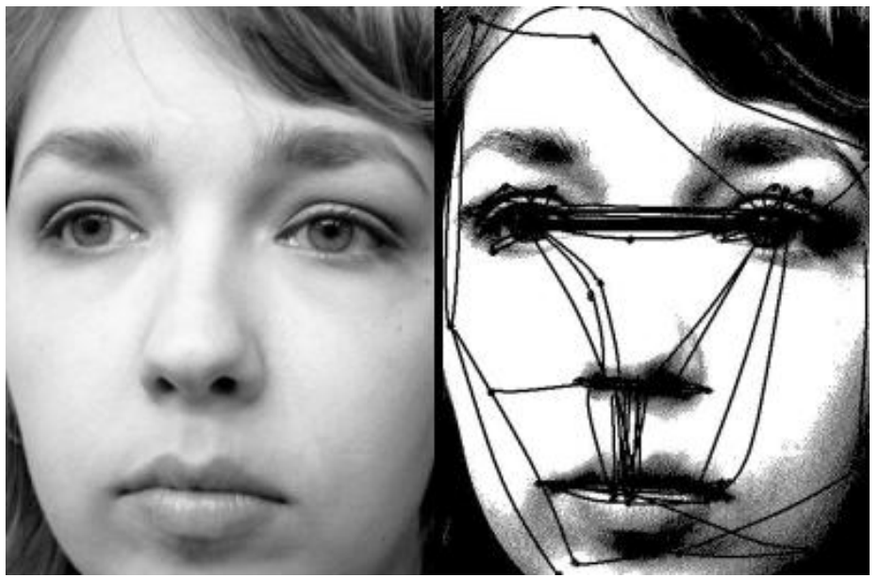




Ware (2008)

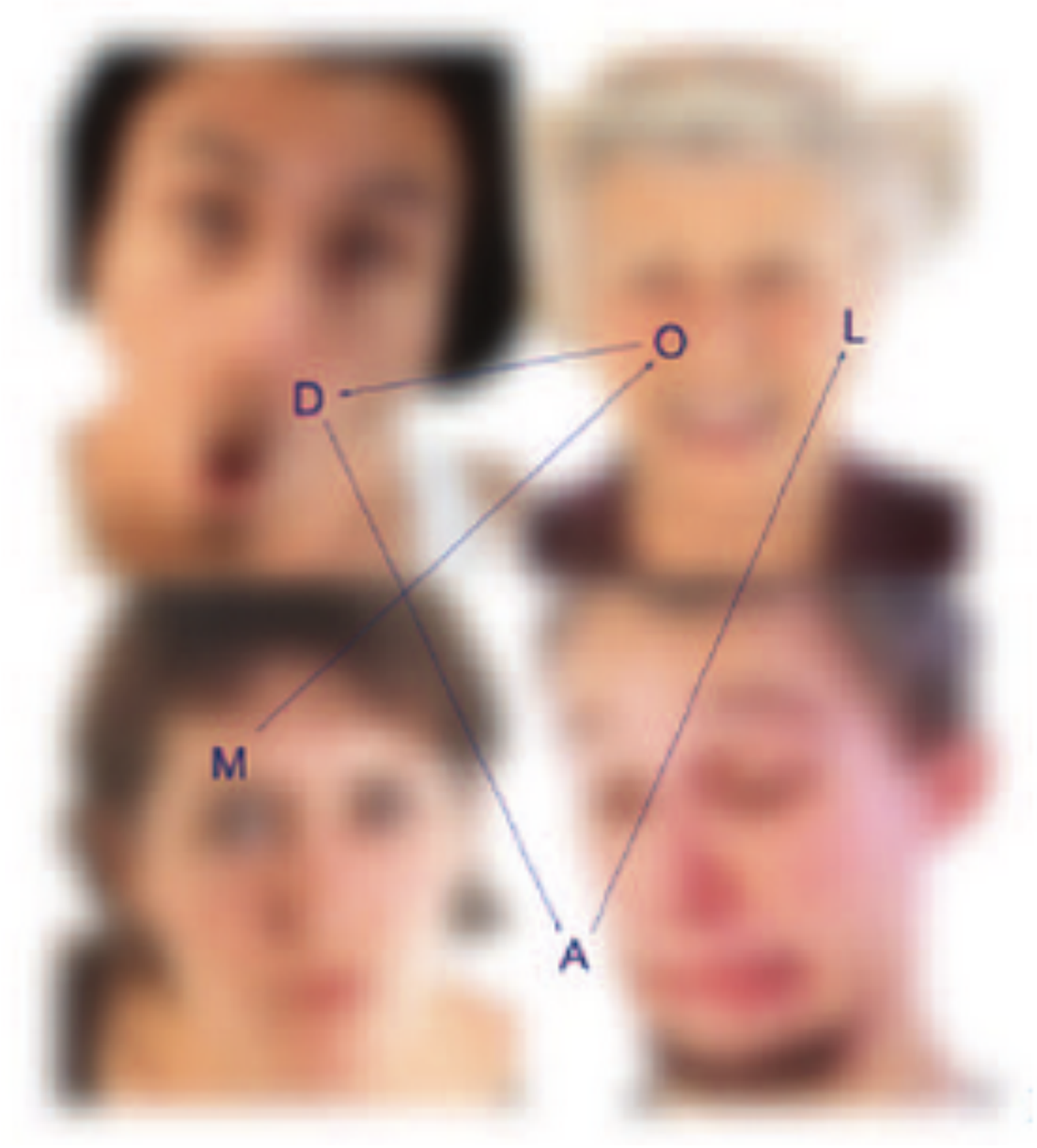
PERCEPTION AND ATTENTION

- Scanning of visual environment
  - sequence of saccades (rapid (20-200 ms), involuntary eye movement), and
  - fixation points (200-600 ms long)
- Not like the panning of a camera



PERCEPTION AND ATTENTION

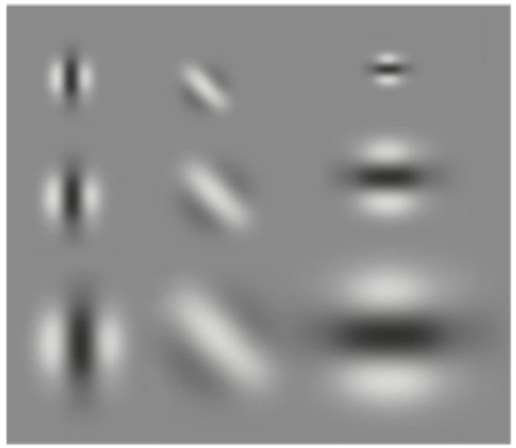
- attentional focus
  - bottom-up (perception of shapes and colours to identify patterns)
  - top-down (looking for specific features)



Ware (2008)

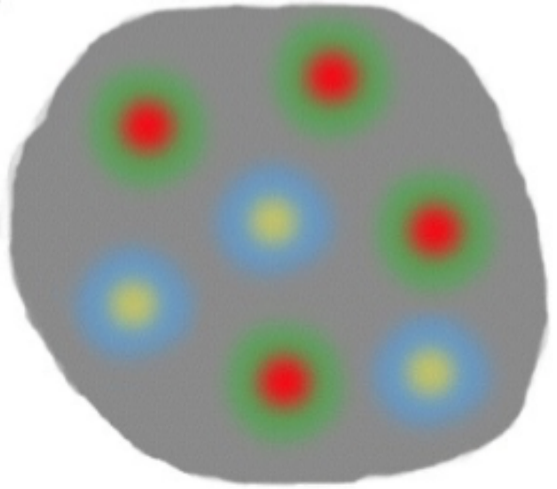
BOTTOM-UP PROCESSING

- feature detection
- pattern recognition
- object recognition



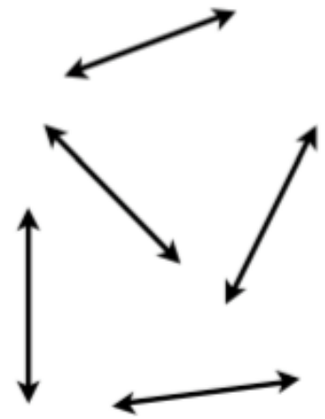
Orientation

some sensitivity to colour



Colour

R/G and Y/B channels



Movement

insensitive to colour

Ware (2008)

TOP-DOWN PROCESSING

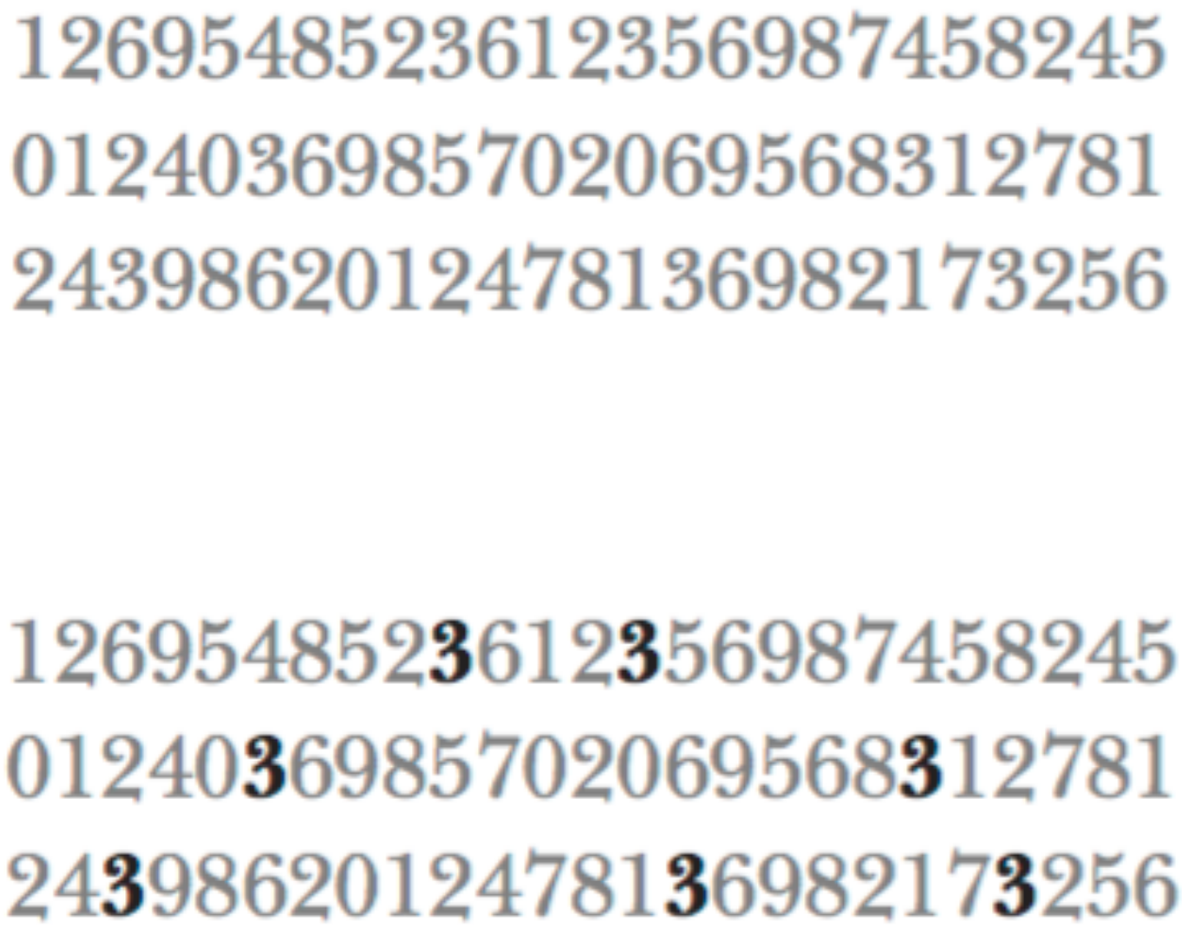
How affluent?

What are their ages?

Ware (2008)

POP-OUT EFFECT – ATTENTIONAL TUNING

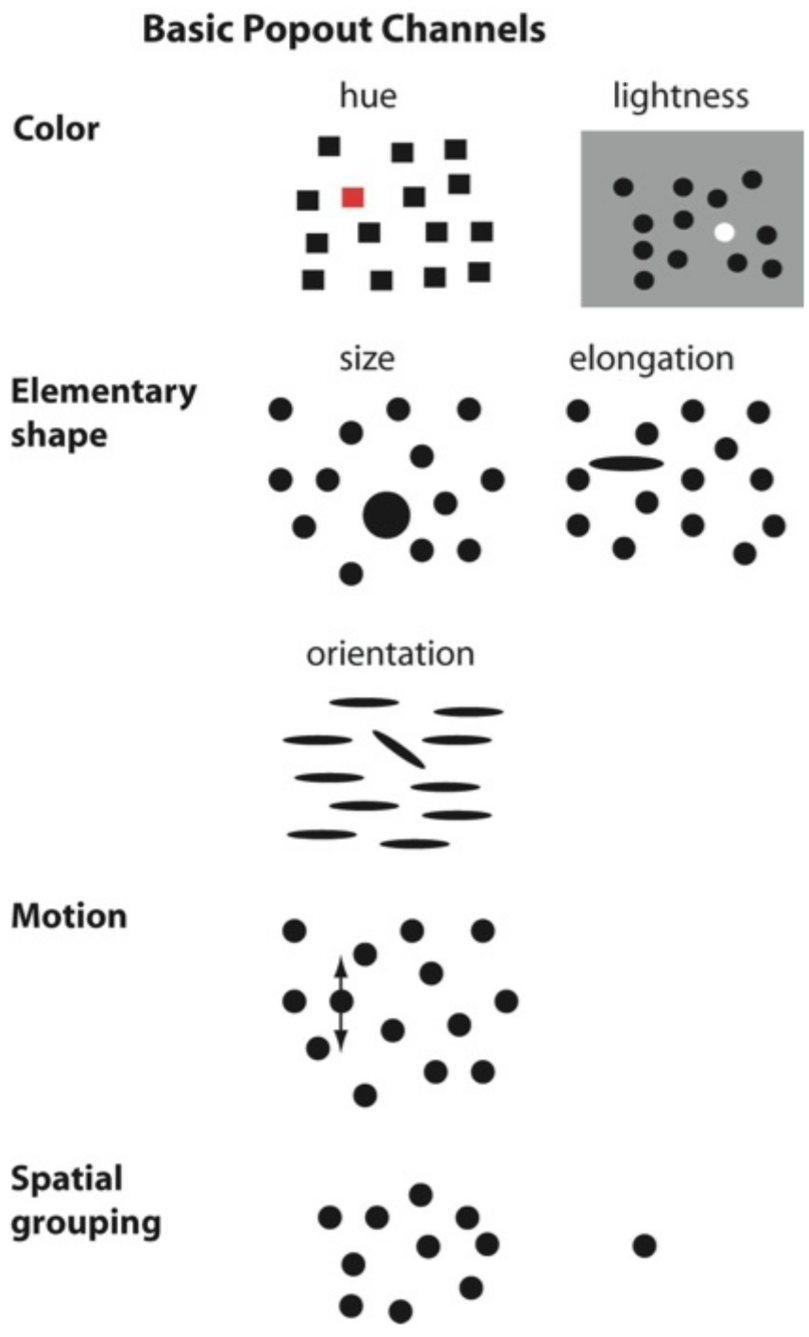
- Very fast < 200-250 ms
- Targets processed in parallel
- Picks up on contrast between features
- Independent of number of distractors



Schwabish (2014) An Economist's Guide to Visualizing Data

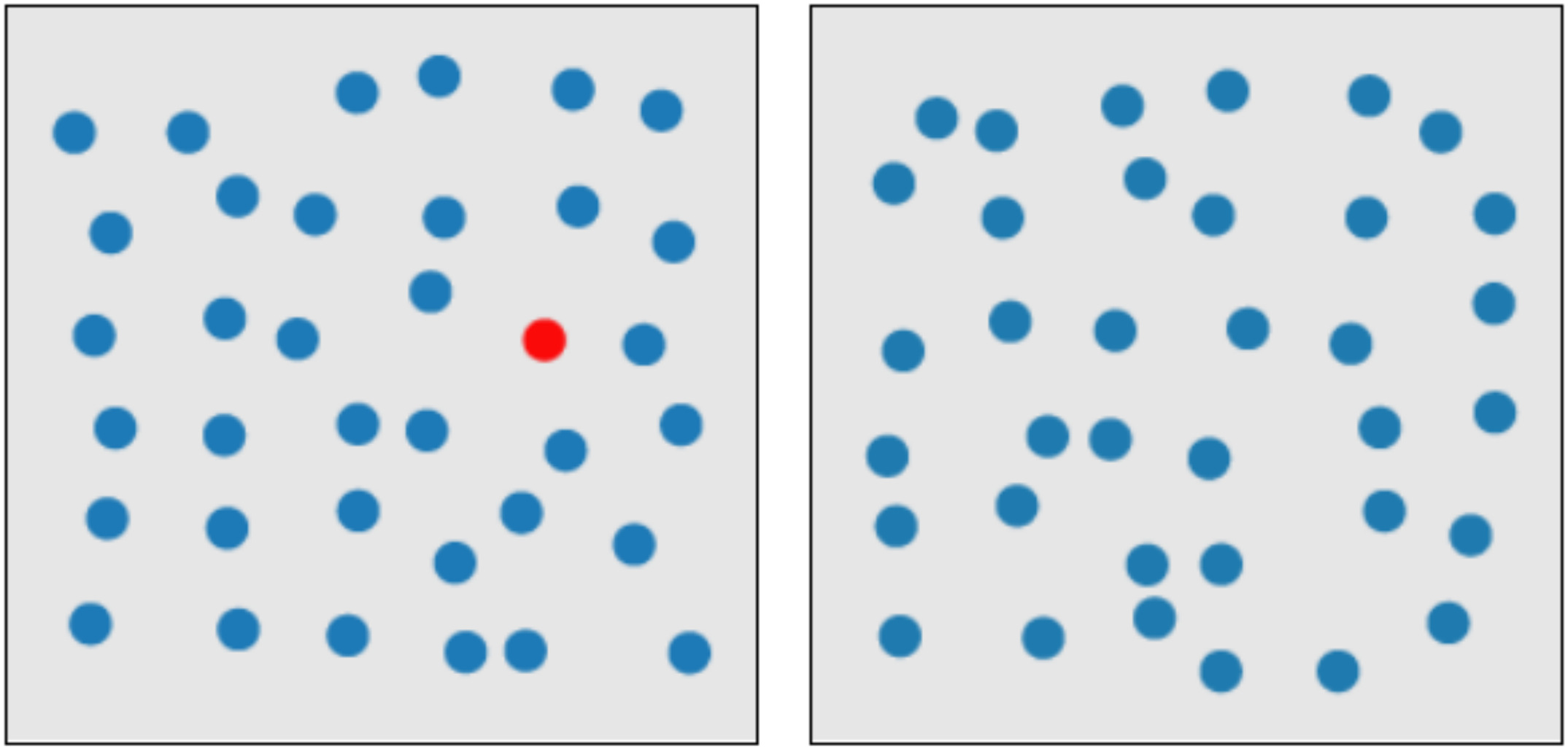
POP-OUT CHANNELS

- Colour
- Shape
- Orientation
- Motion
- Spatial grouping
- Limits: conjunction, separability and integral

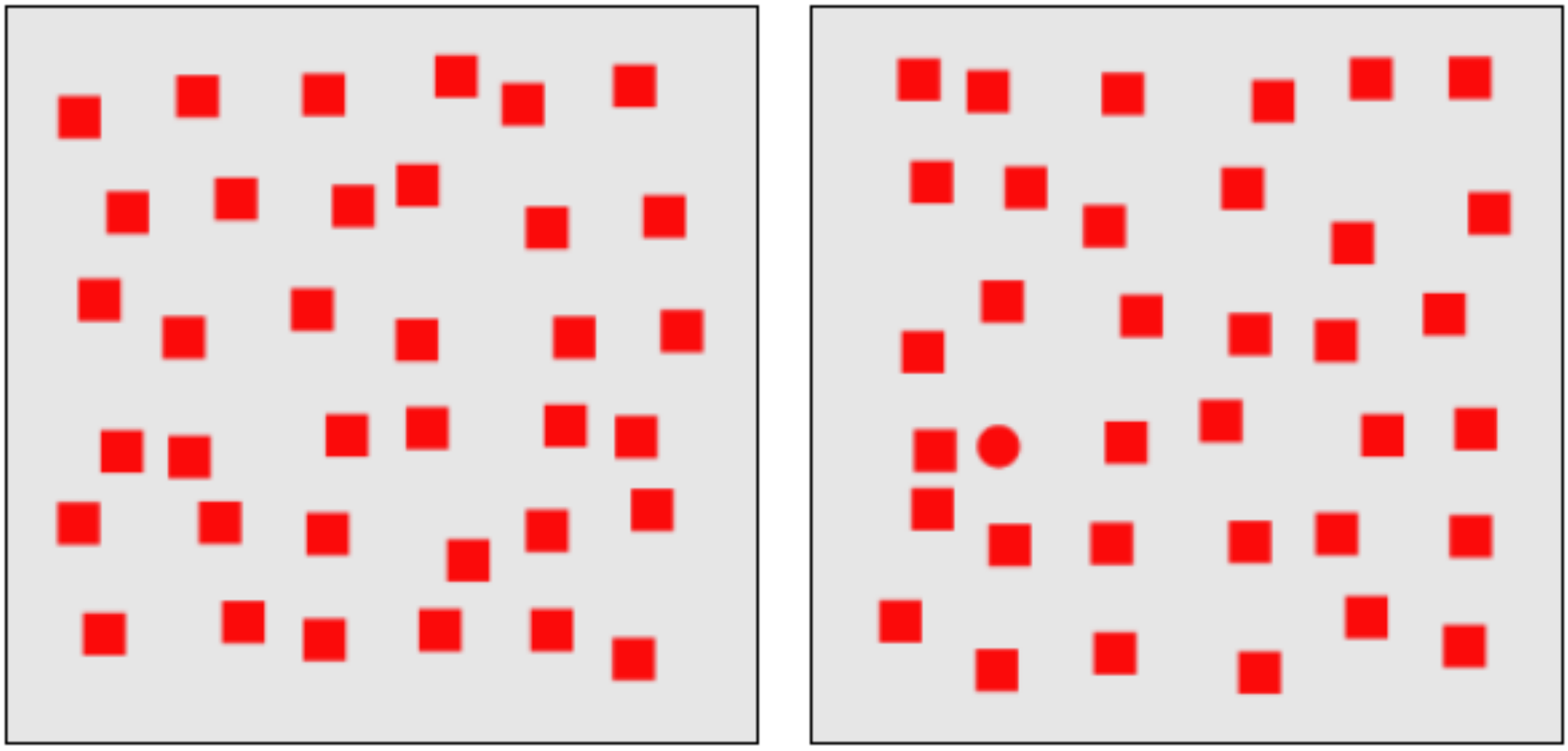


Ware (2008)

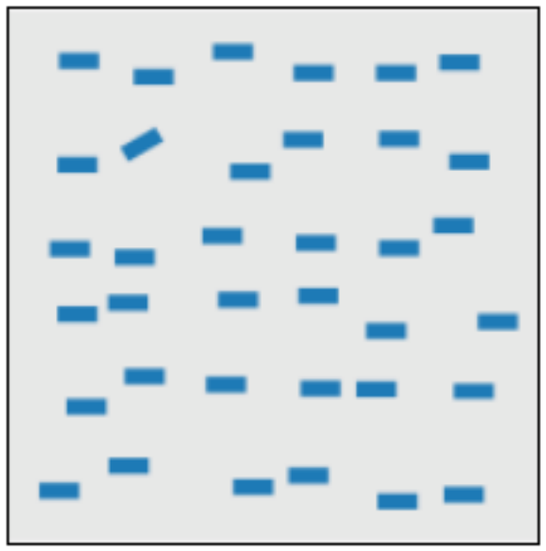
POP-OUT: COLOUR



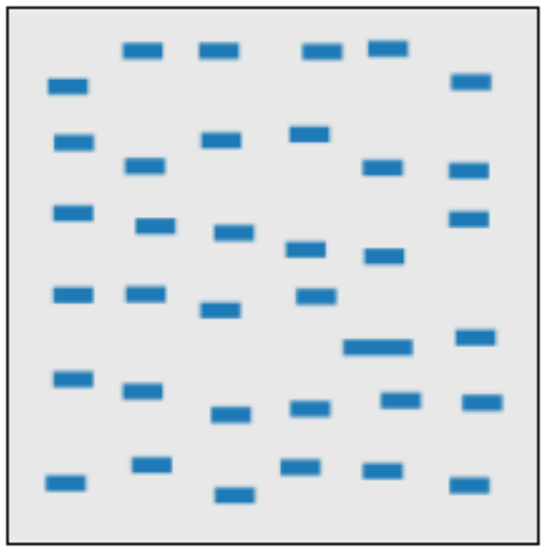
POP-OUT: SHAPE



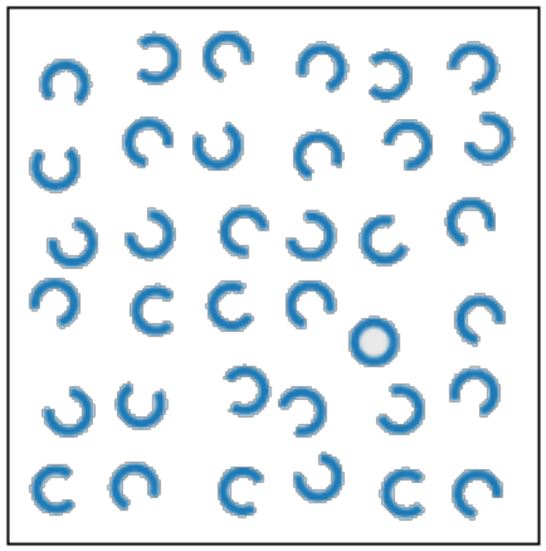
MORE POP-OUT FEATURE COMBINATIONS . . .



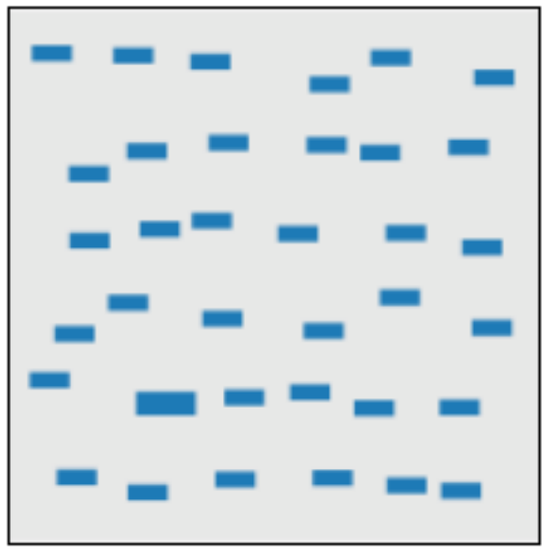
line (blob) orientation



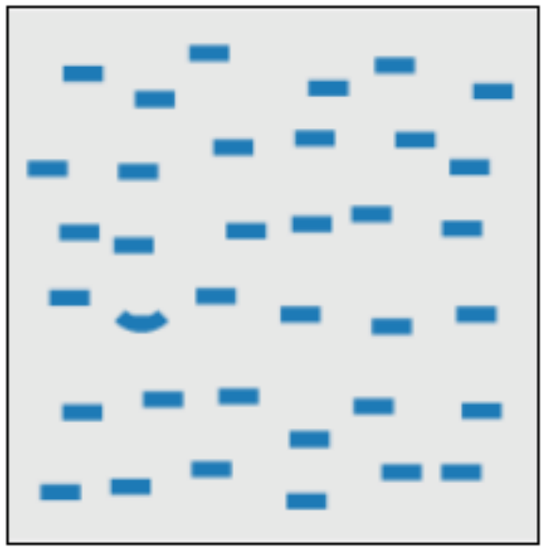
length, width



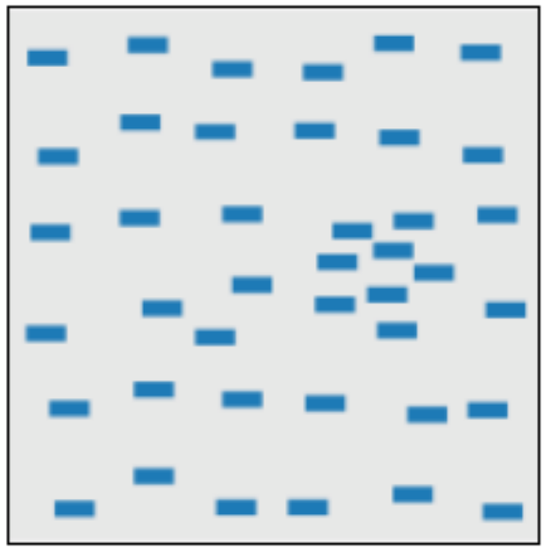
closure



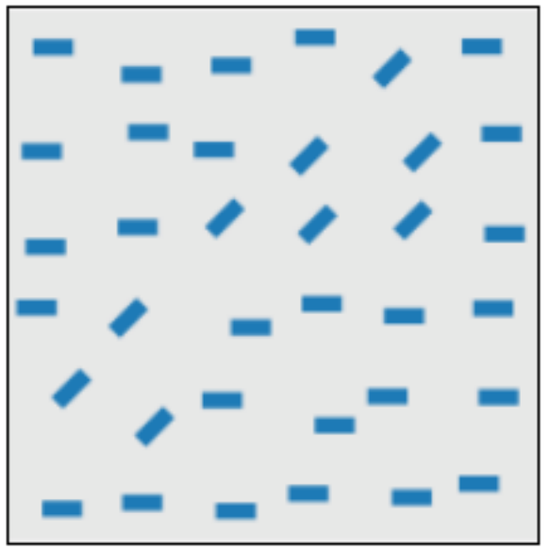
size



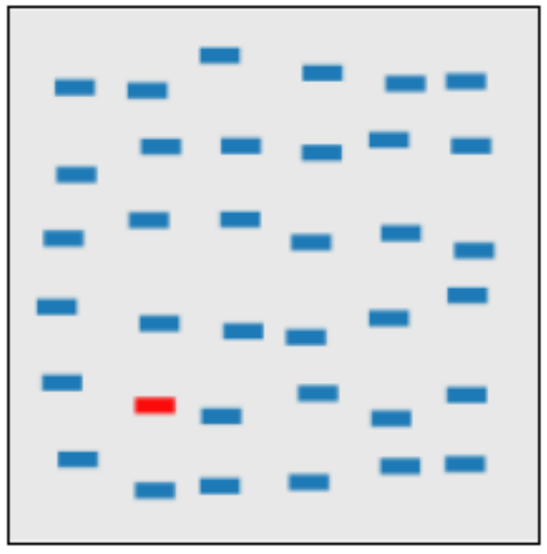
curvature



density, contrast

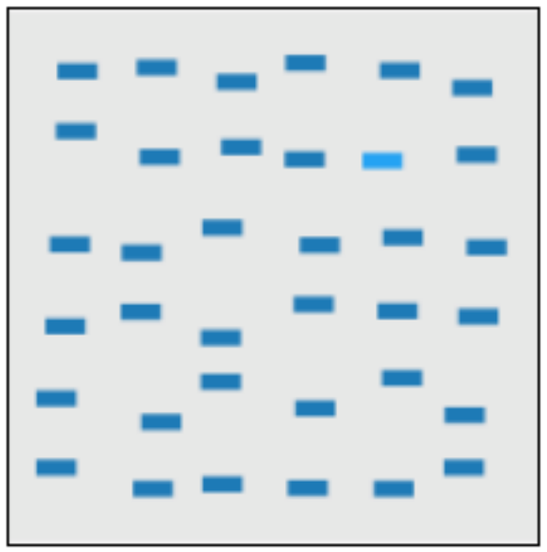


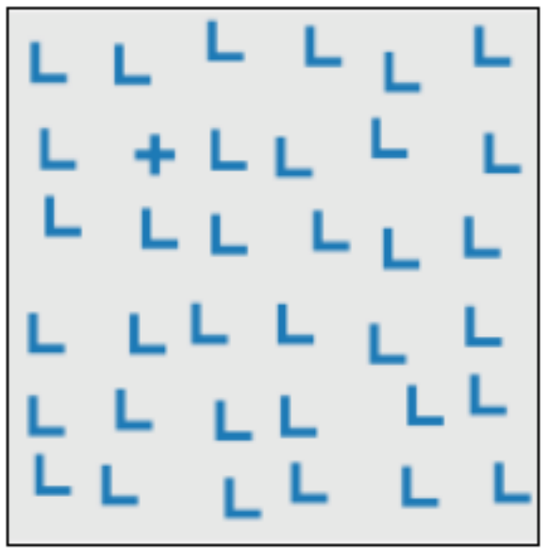
number, estimation

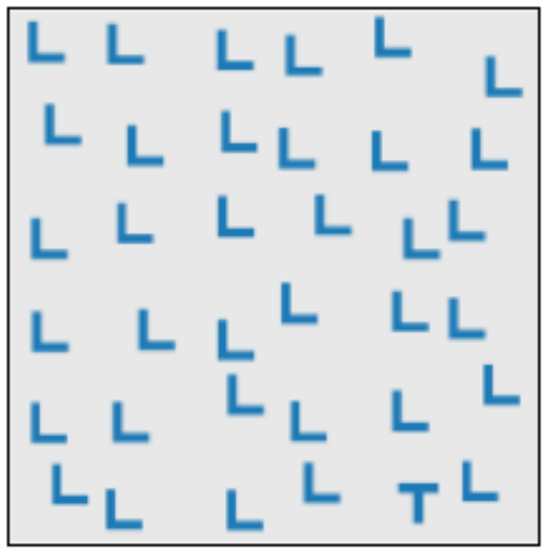


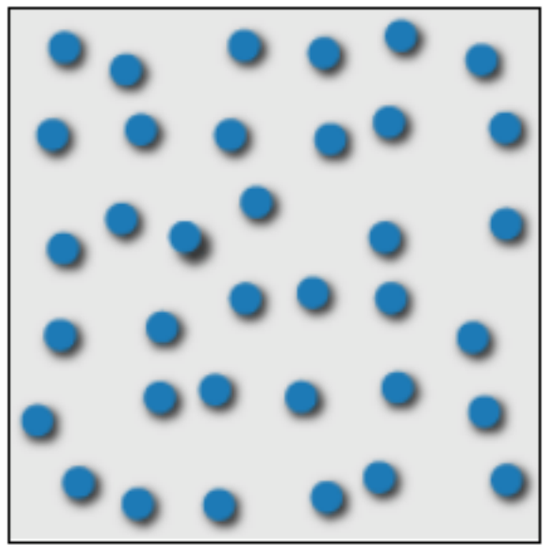
colour (hue)

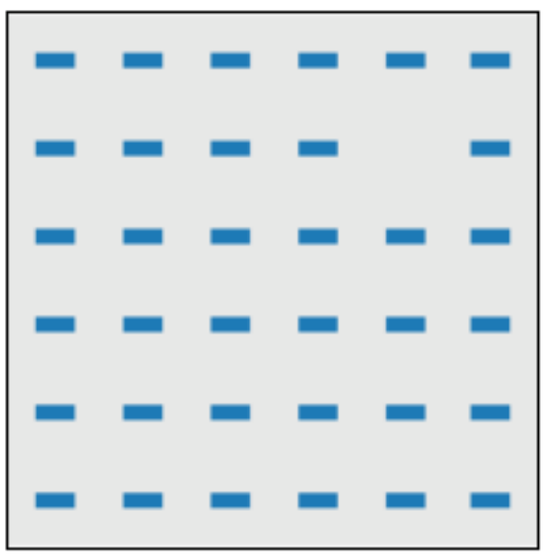
MORE POP-OUT FEATURE COMBINATIONS . . .



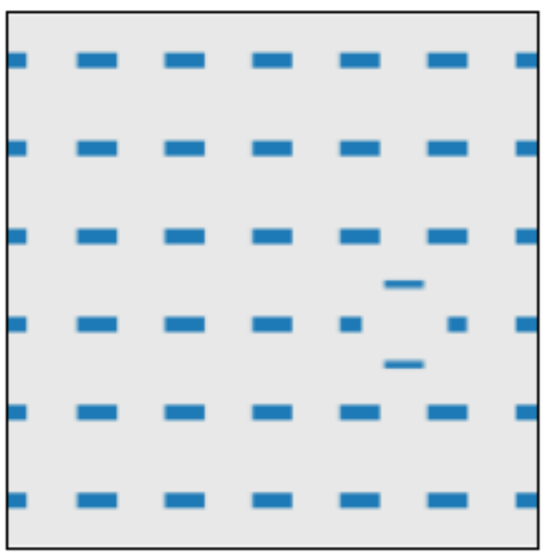




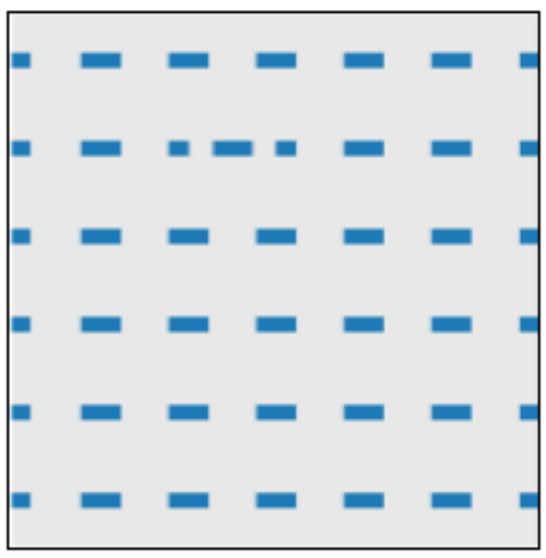




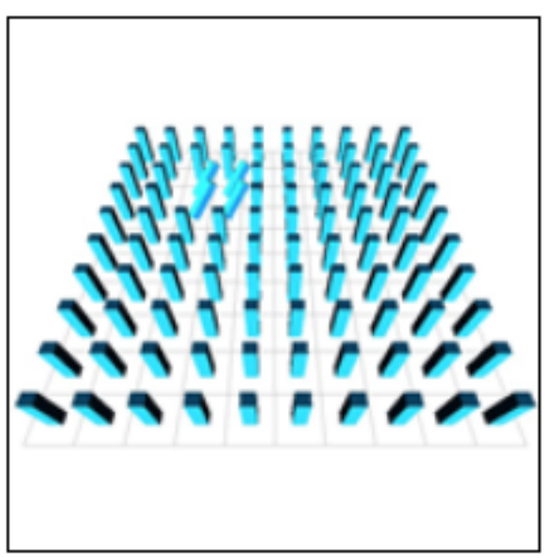
flicker



direction of motion

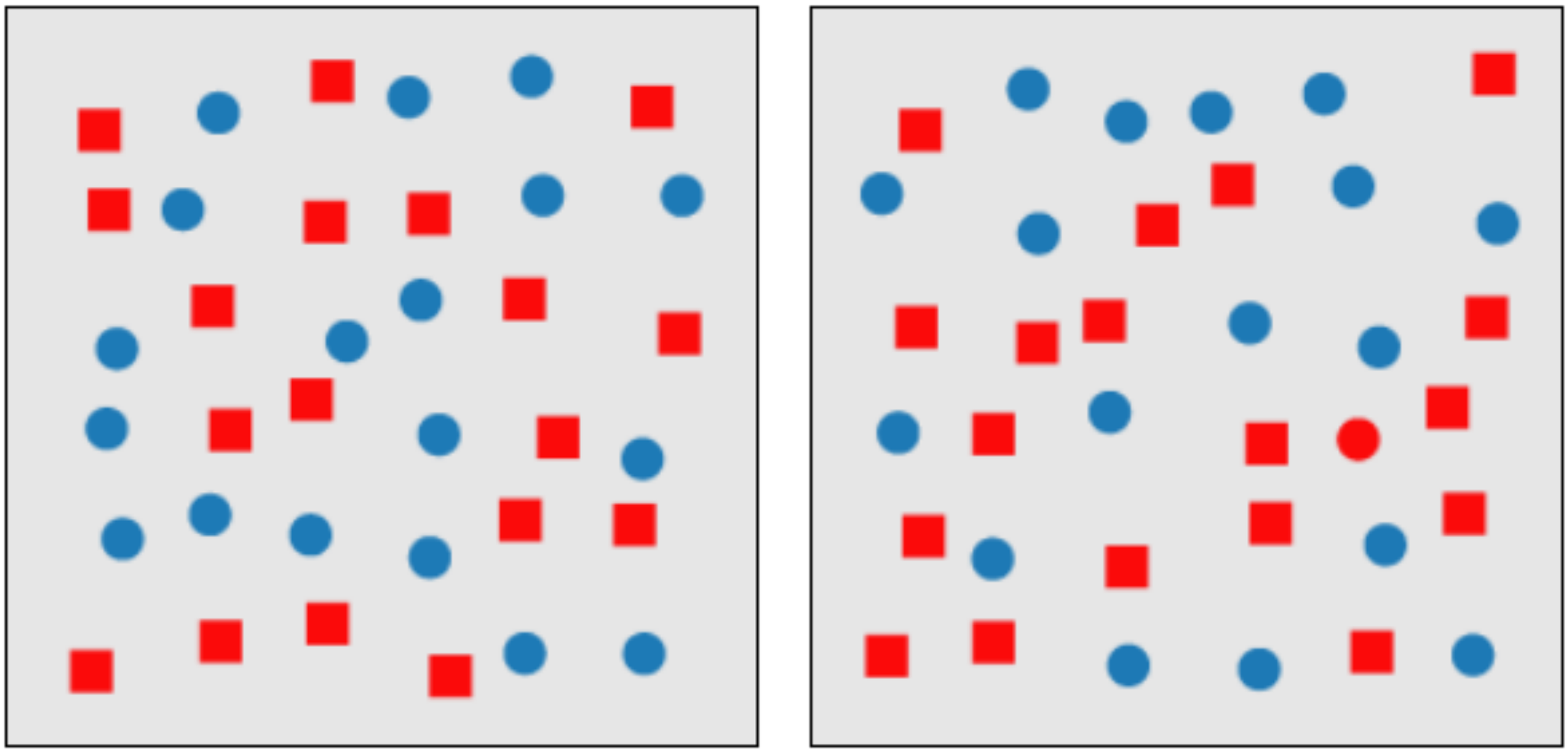


velocity of motion



3D orientation

~~POP-OUT~~: CONJUNCTION (COMBINATION OF NON-UNIQUE FEATURES)

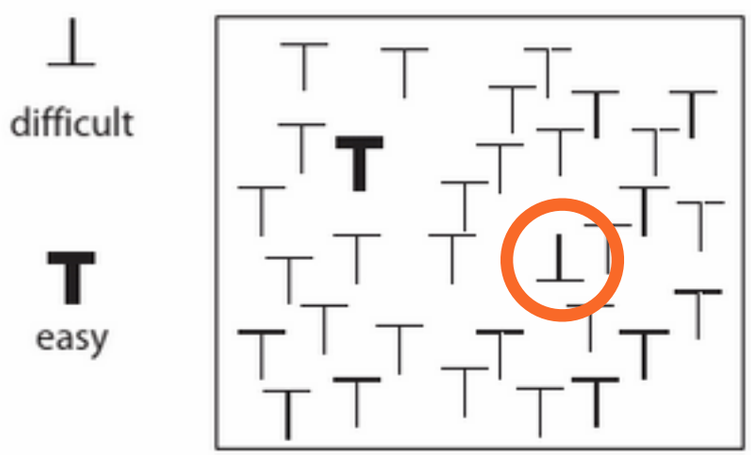


Red Circle Target - must be search for serially (time consuming)

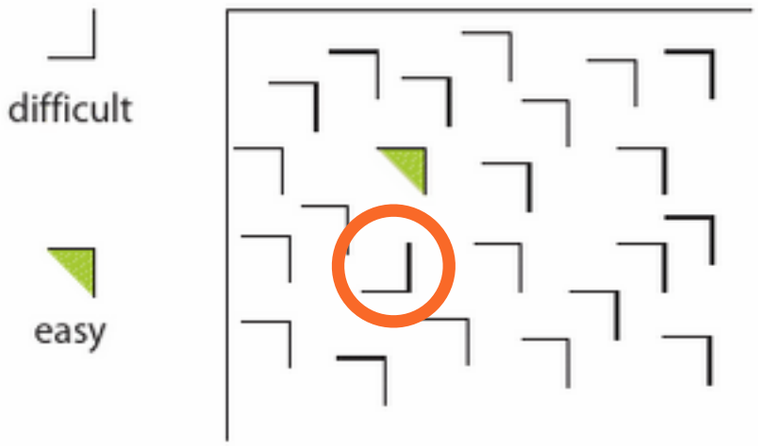
~~POP-OUT~~: CONJUNCTION (COMBINATION OF NON-UNIQUE FEATURES)

Green Square Target - must be search for serially (time consuming)

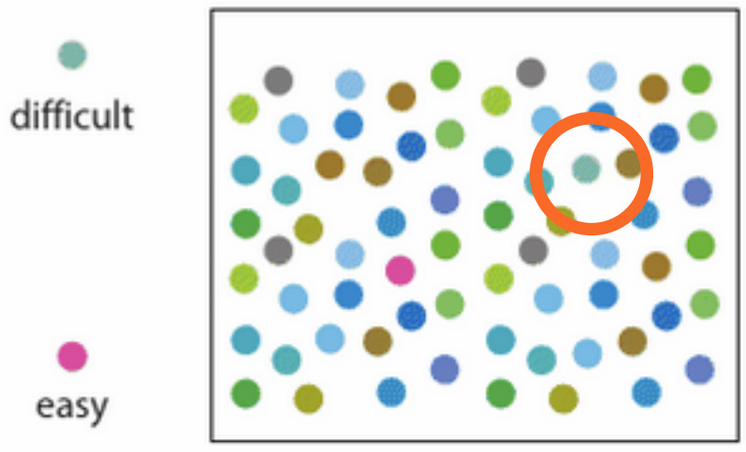
FEATURE COMBINATIONS – SOME WORK SOME DON'T



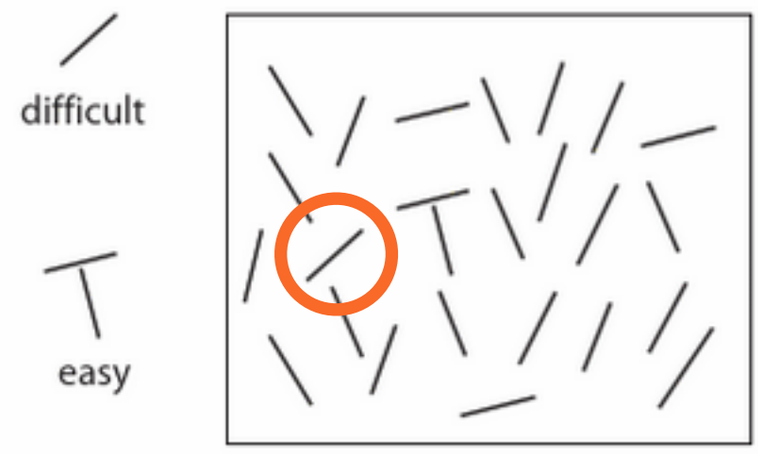
The inverted T has the same feature set as the right-side-up T and is difficult to see. But the bold T does support pop-out and is easy to find.



Similarly the backwards L has the same feature set as the other items, making it difficult to find. But the green triangle addition does pop out.



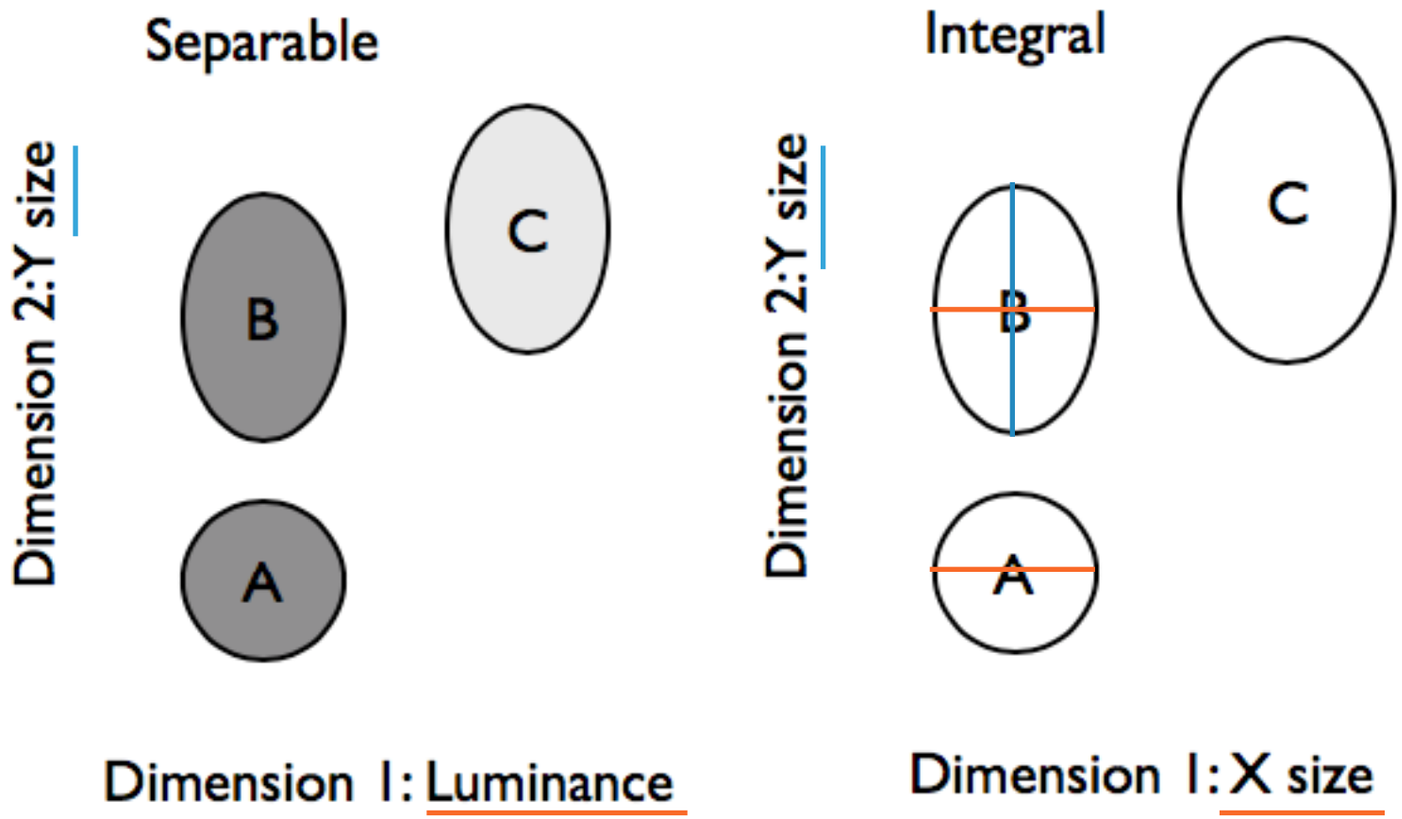
A color that is close to many other similarly colored dots cannot be tuned for and is difficult to find.



Similarly, if a line is surrounded by other lines of various similar orientations it will not stand out.

SEPARABLE AND INTEGRAL CHANNEL COMBINATIONS

- **Separable**:
  - Two channels that can be judged independently
- **Integral**:
  - Two channels are viewed holistically



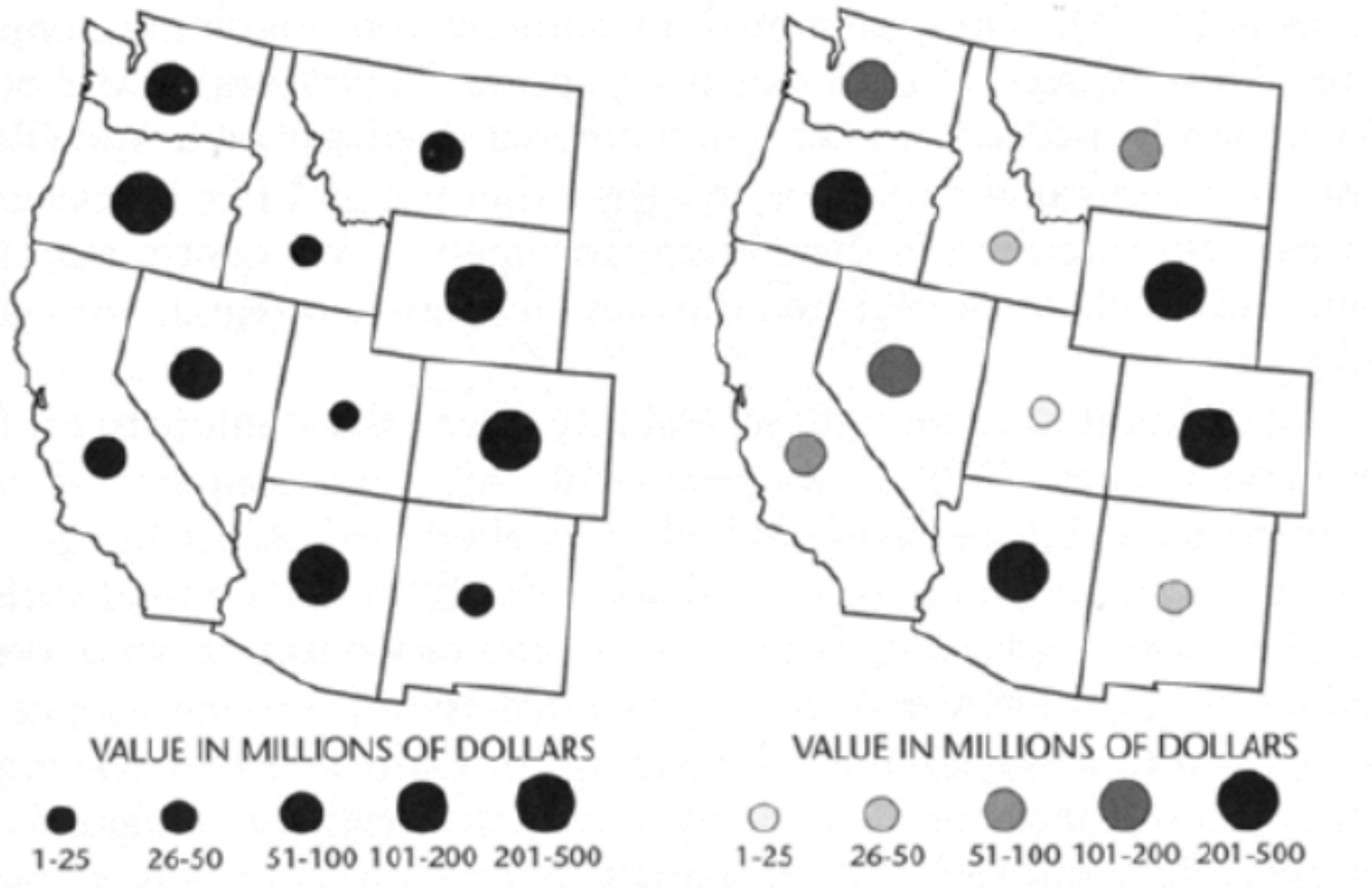
Two independent channels

Two 'dependent' channels

Ware (2008)

SEPARABLE CHANNEL COMBINATION

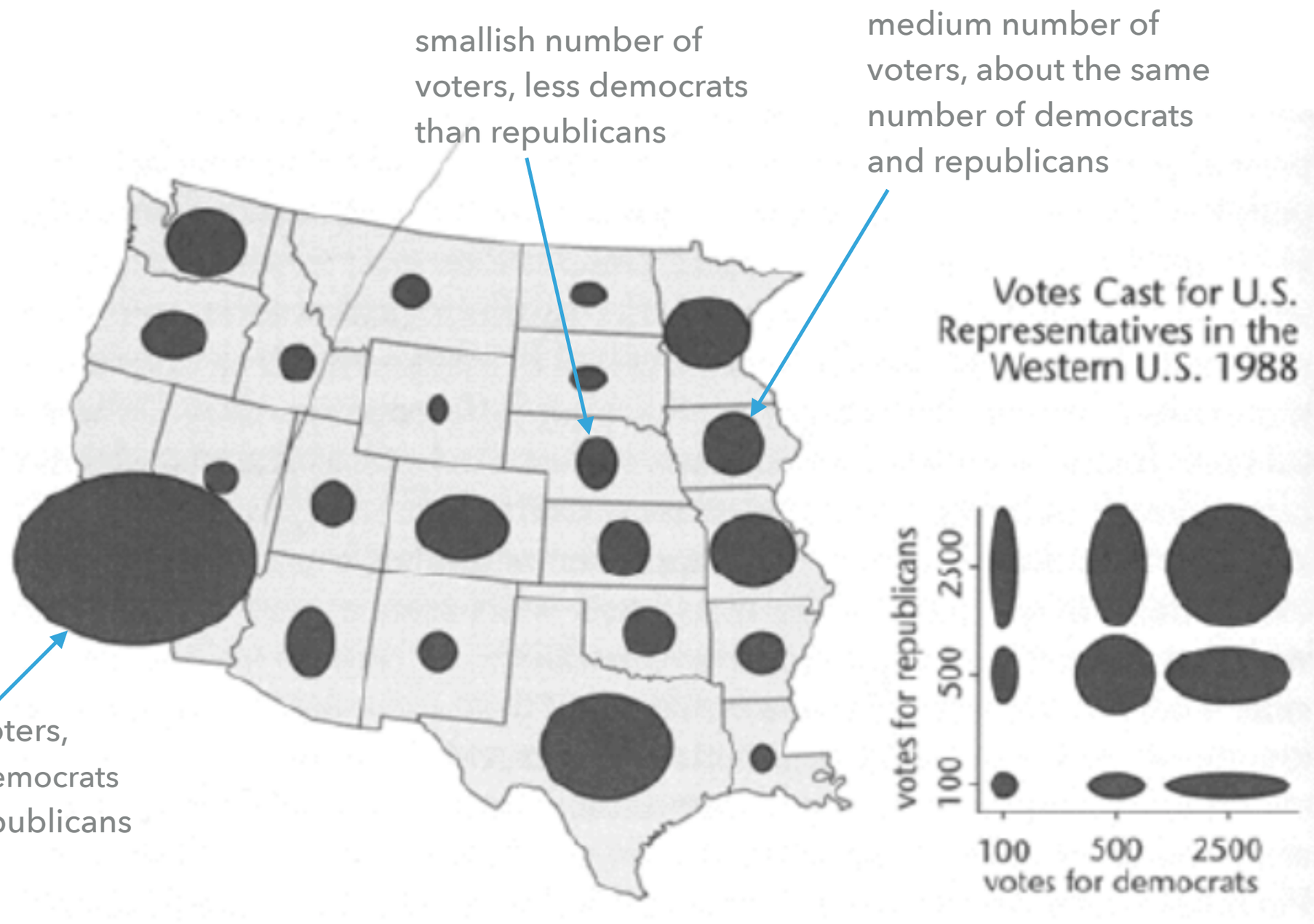
- size and luminance work together



Dobson,"Visual Information Processing and Cartographic Communication", 1983

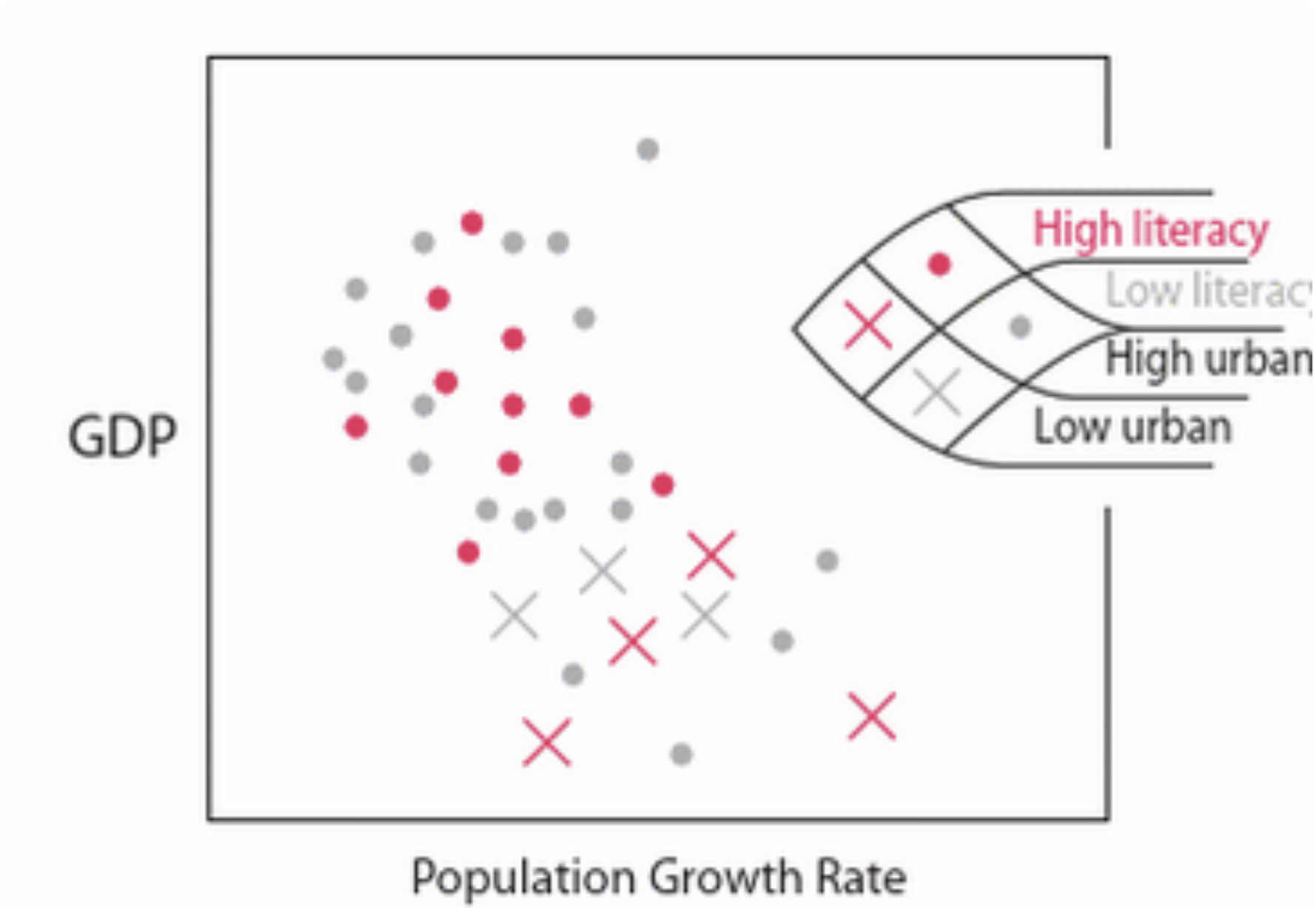
INTEGRAL CHANNEL COMBINATION

- x-size and y-size are difficult to discriminate separately



MacEachren, 1995

SEPARABLE CHANNEL COMBINATIONS



Ware (2008)

SEPARABLE AND INTEGRAL CHANNEL COMBINATIONS

Separable ⟷ Integral

colour and location	colour and motion	colour and shape	size and orientation	x-size and y-size	red-green and yellow-blue

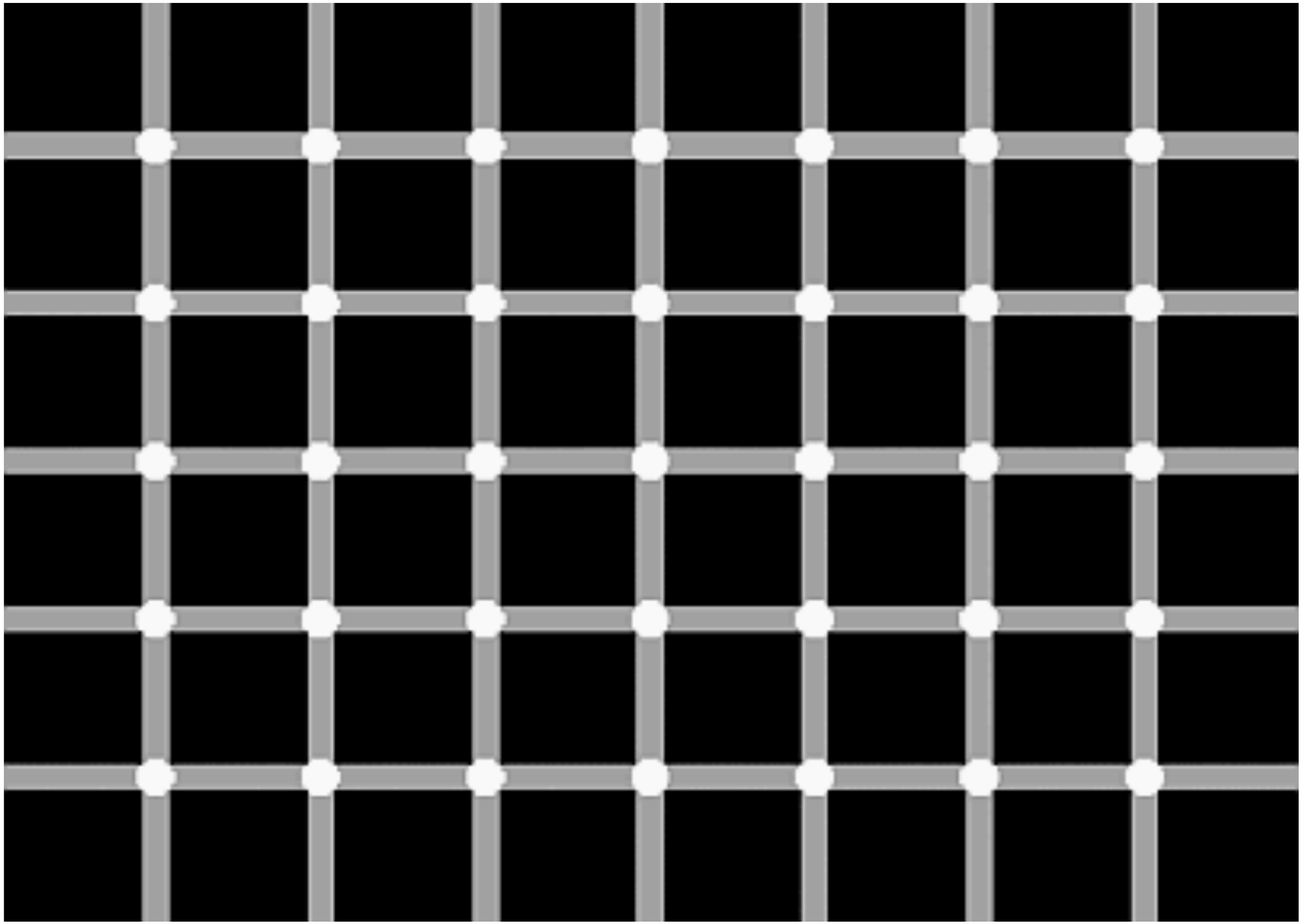
Ware (2008)

CHANGE BLINDNESS

- Details of an image cannot be remembered across separate scenes
  - except in areas with focused attention
- Interruption (e.g. a blink, eye saccade or blank screen) amplifies this effect
- Not failure of vision system
- Failure due to inappropriate attentional guidance

Lex

CHANGE BLINDNESS



Hermann Grid - completion between cells with different receptive fields

5.2 ATTENTION

You should now be able to:

- Explain the role of attention in perception in terms of Ware's model of perceptual processing
- List and use a variety of pop-out channels to draw user's attention
- Identify separable and integral visual channel combinations

SWINBURNE UNIVERSITY OF TECHNOLOGY

COS30045

DATA VISUALISATION

TOPIC 05.3: COLOUR

Karola von Baggo

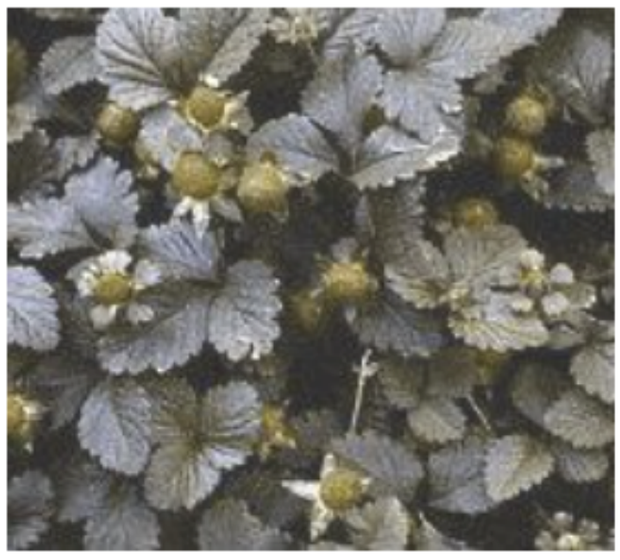
5.3 COLOUR

At the end of this topic you should be able to:

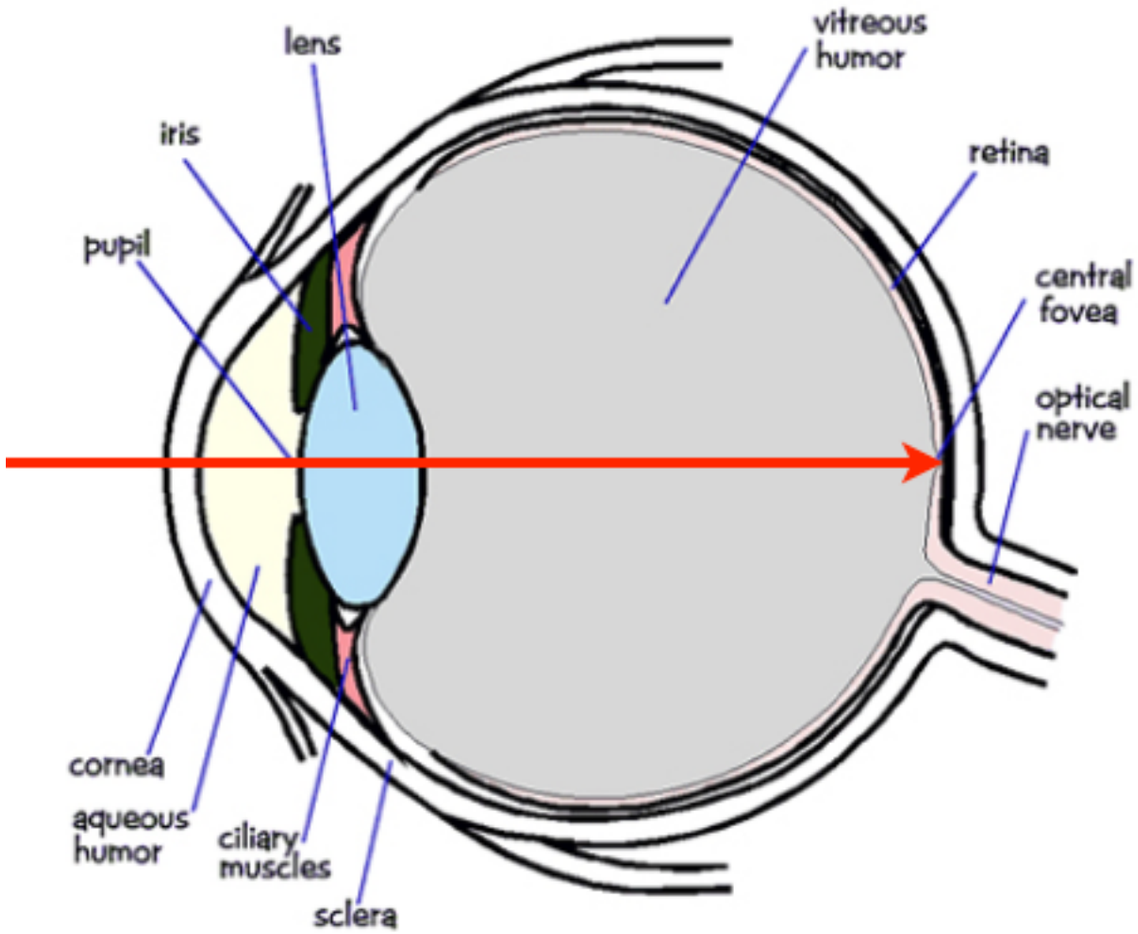
- Be familiar with the anatomy of the human eye and the difference between rod and cone cells
- Explain the difference between Hue, Saturation and Luminosity
- Be aware of design guidelines for use of colour
- Understand the effect of colour blindness on perception of colour and design strategies for colour blind users

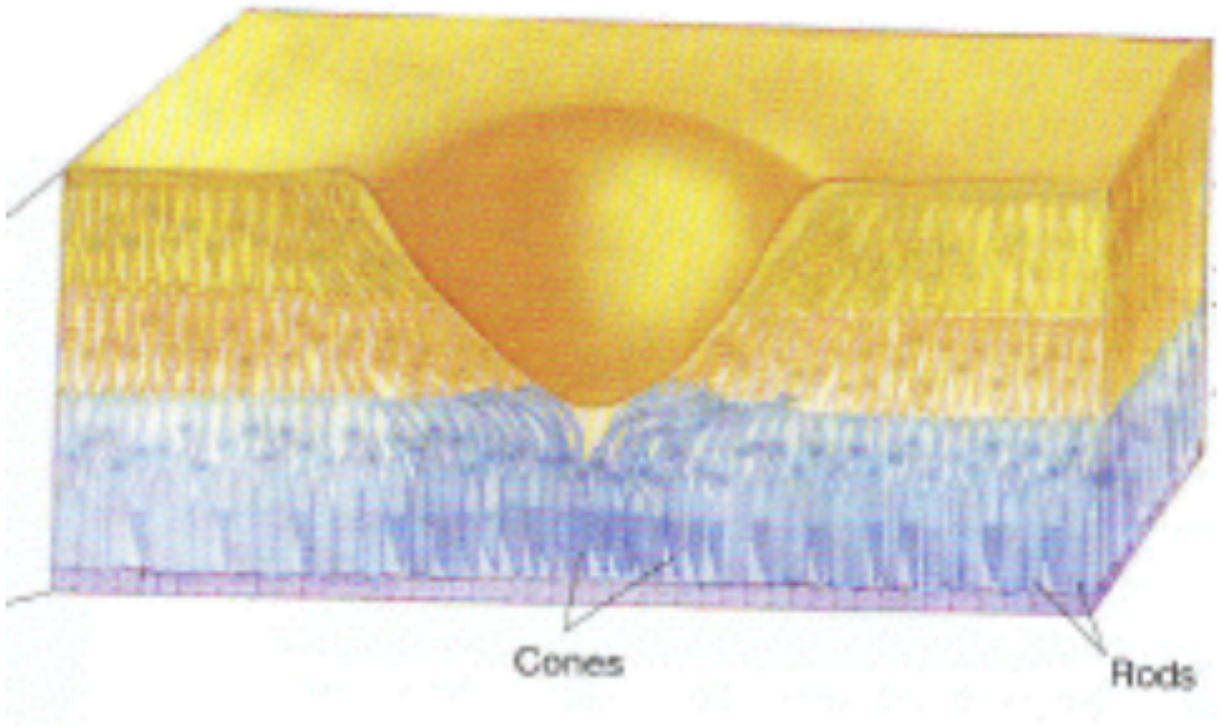
COLOUR

- not a big part of normal vision
- does not help us perceive layout
- does not show movement or shape
- helps us pick out elements in our environment (breaks camouflage)



VISUAL PHYSIOLOGY: FOVEA





- high cell density (27 times)
- responsible for sharp, central vision
- only cone cells -> colour vision

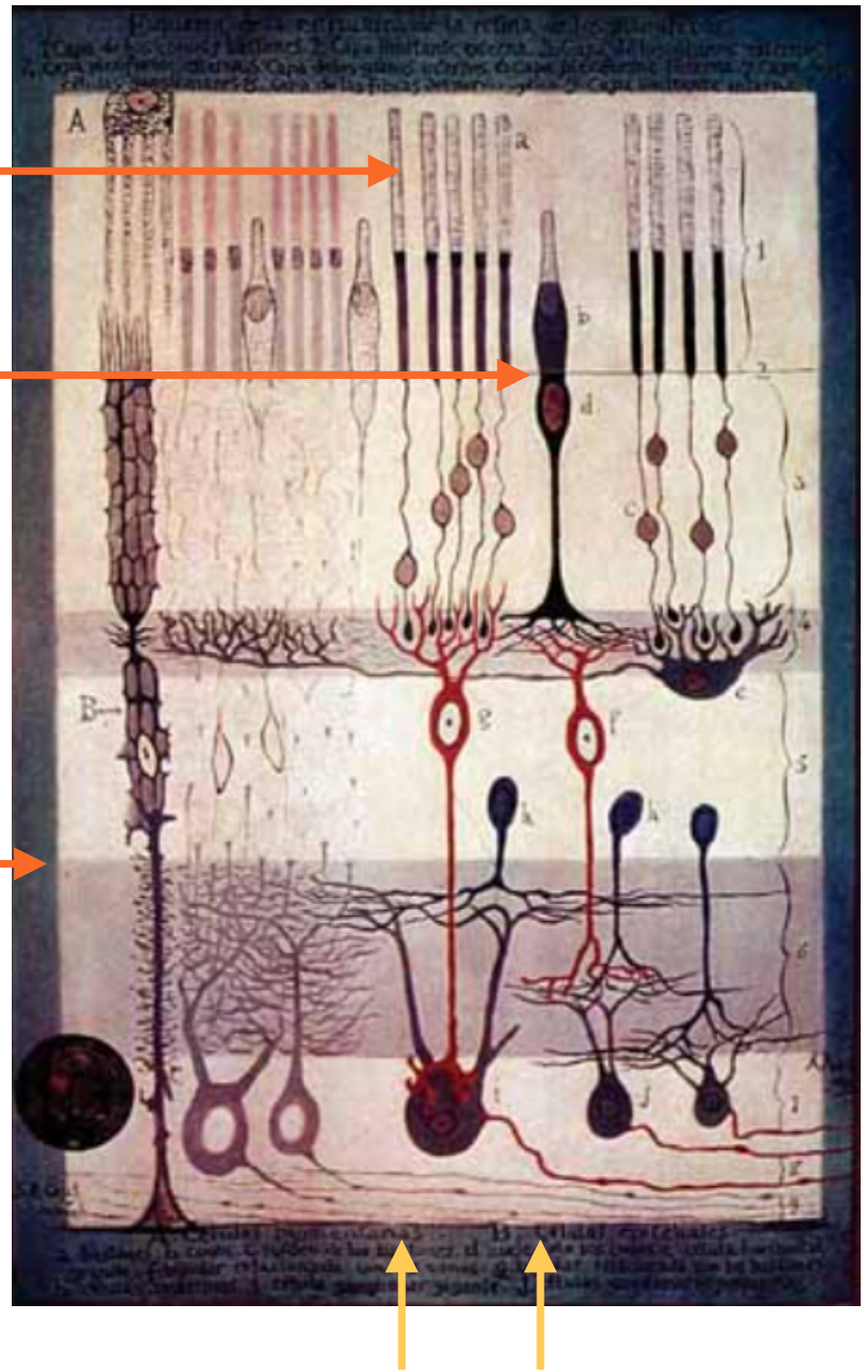
VISUAL PHYSIOLOGY: STRUCTURE OF RETINA

- 120 million rods
- 5-6 million cones

Rod

Cone

Nerve cells - exit retina at optic nerve (blind spot)

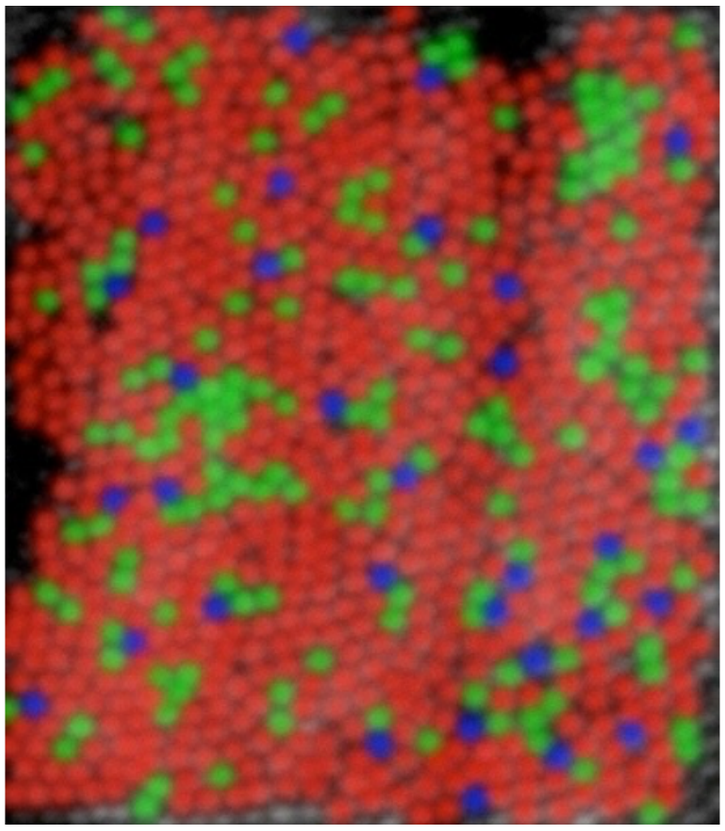


Light

S. Ramnon y Cajal, Structure of the Mammalian Retina, 1900

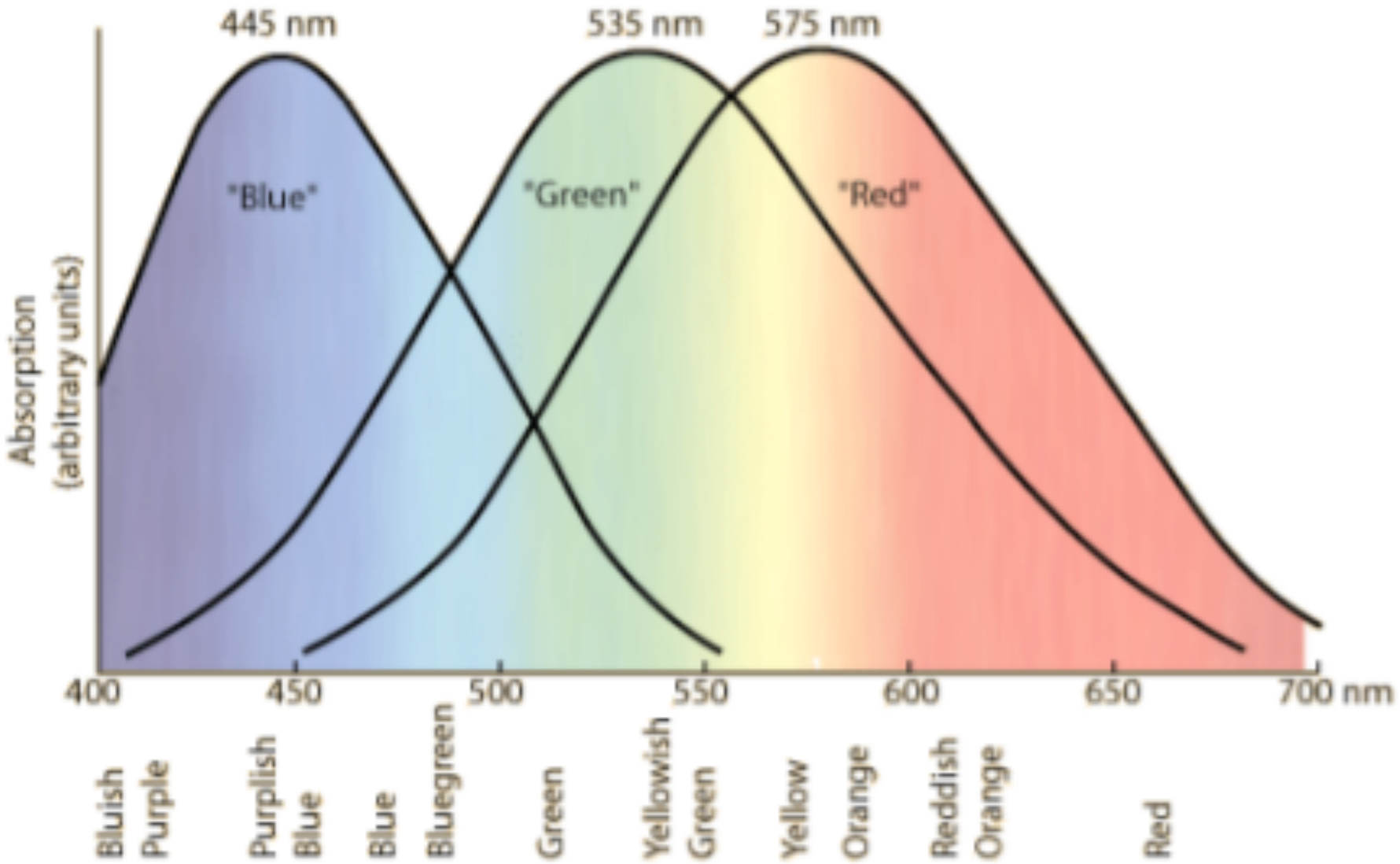
VISUAL PHYSIOLOGY: CONES

- Cones
  - daytime vision
  - three different kinds
    - short wavelength (blue) 6%
    - medium wavelength (green) 31%
    - long wavelength (red) 63%



Distribution of red, green and blue cone cells

VISUAL PHYSIOLOGY: CONE WAVELENGTH RESPONSE



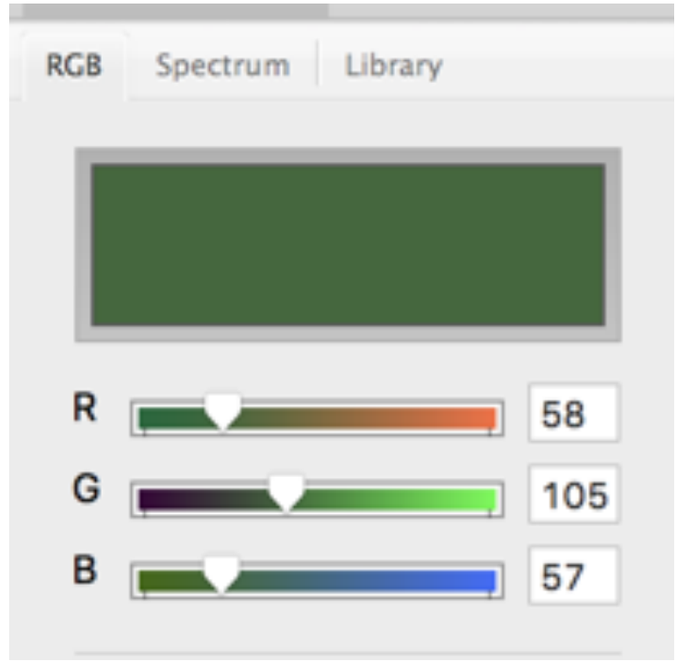
OPPONENT PROCESS THEORY

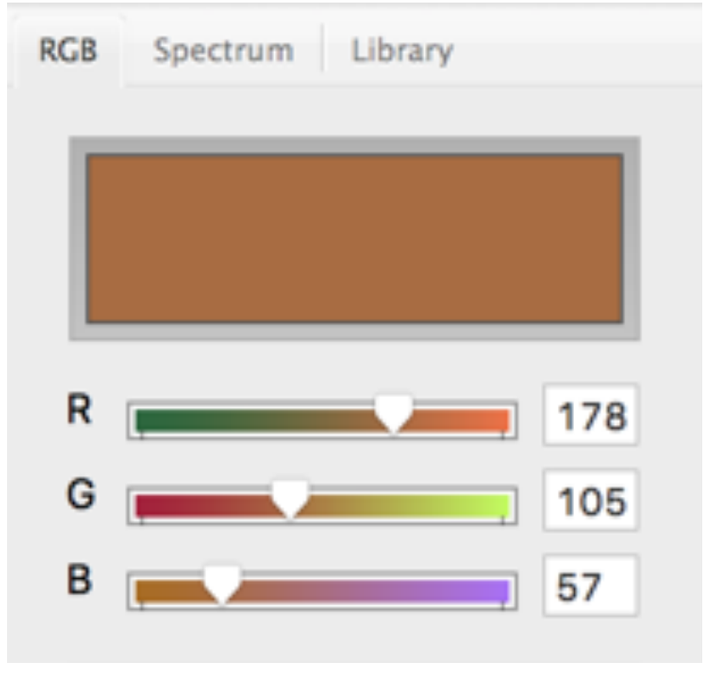
- Receptor cells the respond to one colour are inhibited by another colour (cells can only detect one colour at a time)
- Opponent process channels
  - red-green - lower resolution
  - blue-yellow - lower resolution
  - black-white (luminance) - high resolution edge information

For example, neurones excited by red are inhibited by green - people never see reddish-green, but do see greenish-blue

RGB (RED-GREEN-BLUE)

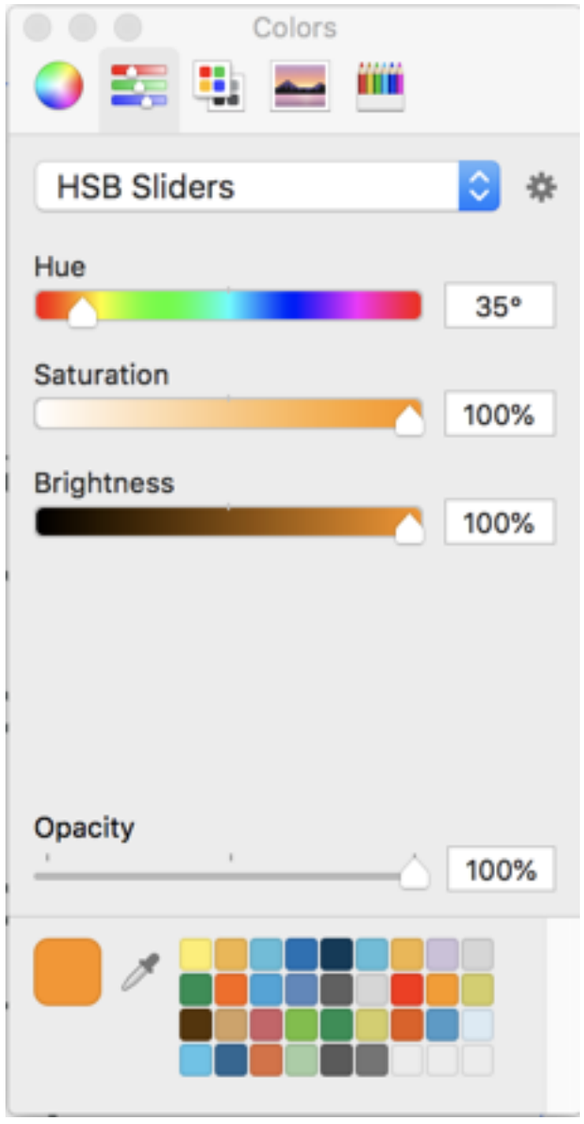
- Commonly used in computer displays
- Alter the 'amount' of red, green and blue to make colour
- Difficult to make adjustments for lighter/ darker or paler/richer (e.g., saturation)

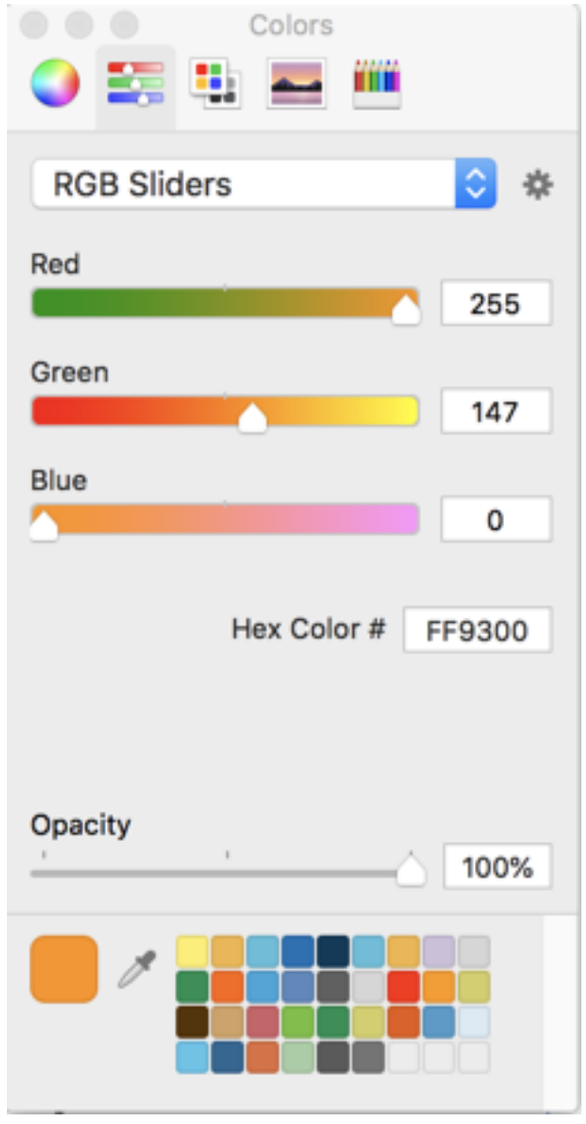




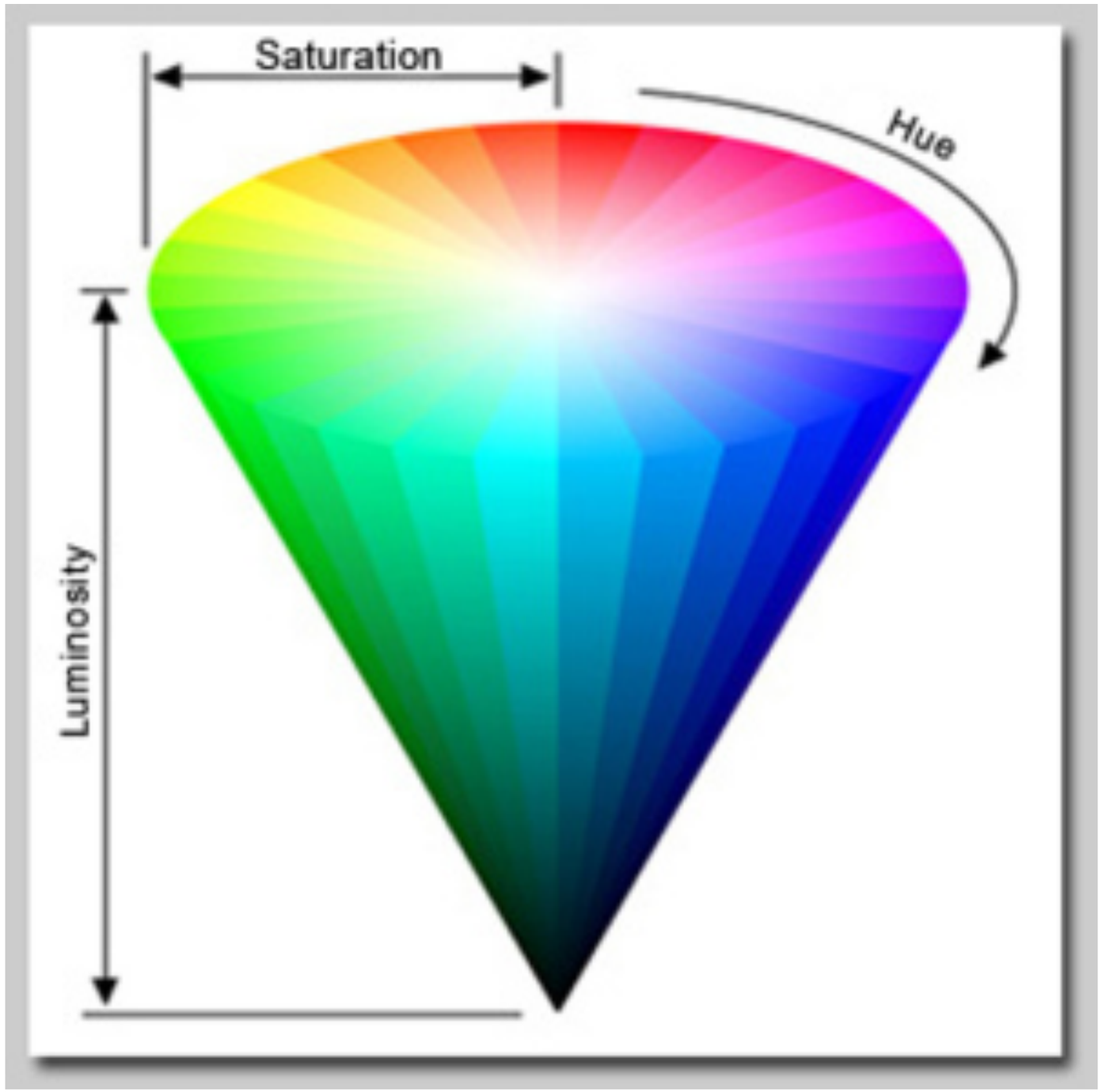
HSL (HUE-SATURATION-LUMINOSITY)

- More human friendly way of presented colour
  - Hue - pure colour
  - Saturation - amount of white (pale to vivid)
  - Luminosity (brightness) - amount of black (light to dark)
- easier to manipulate saturation (key vis channel)



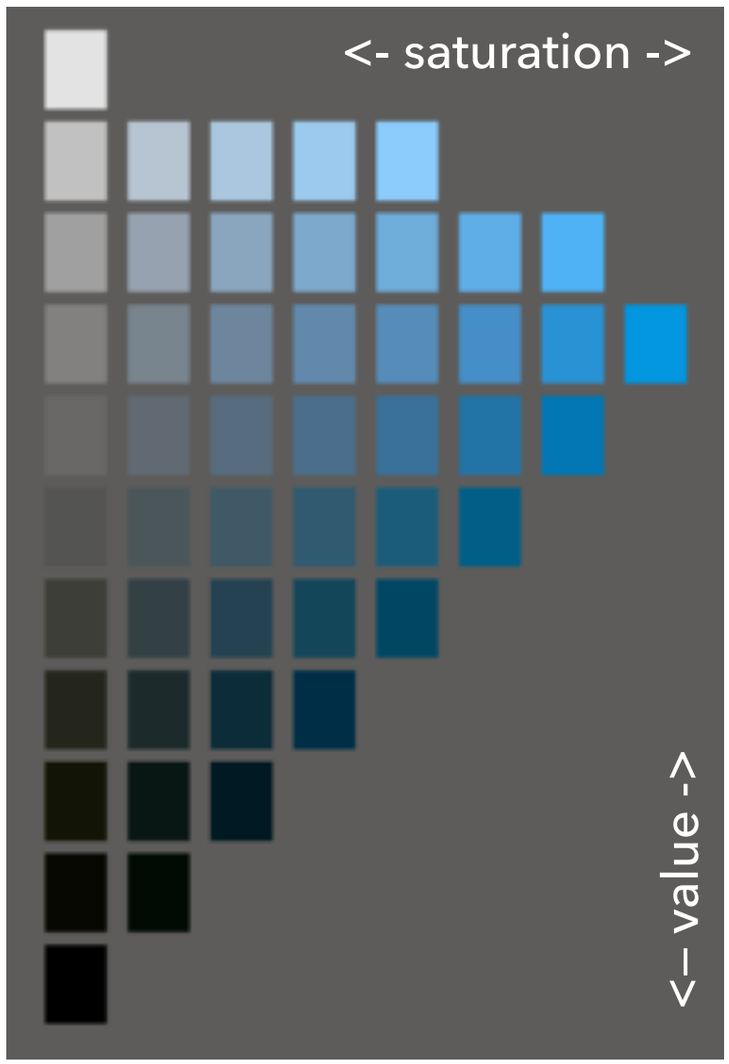


HSL COLOUR SPACE



DIMENSIONS OF COLOUR

- Hue
  - what most people call ‘colour’
- Saturation
  - purity of a colour (pale to vivid)
- Luminance
  - lightness of a colour (light to dark)



CHANNEL DISCRIMINABILITY

- Perceptual ordering
  - luminance - very good
  - saturation - good
  - hue - poor

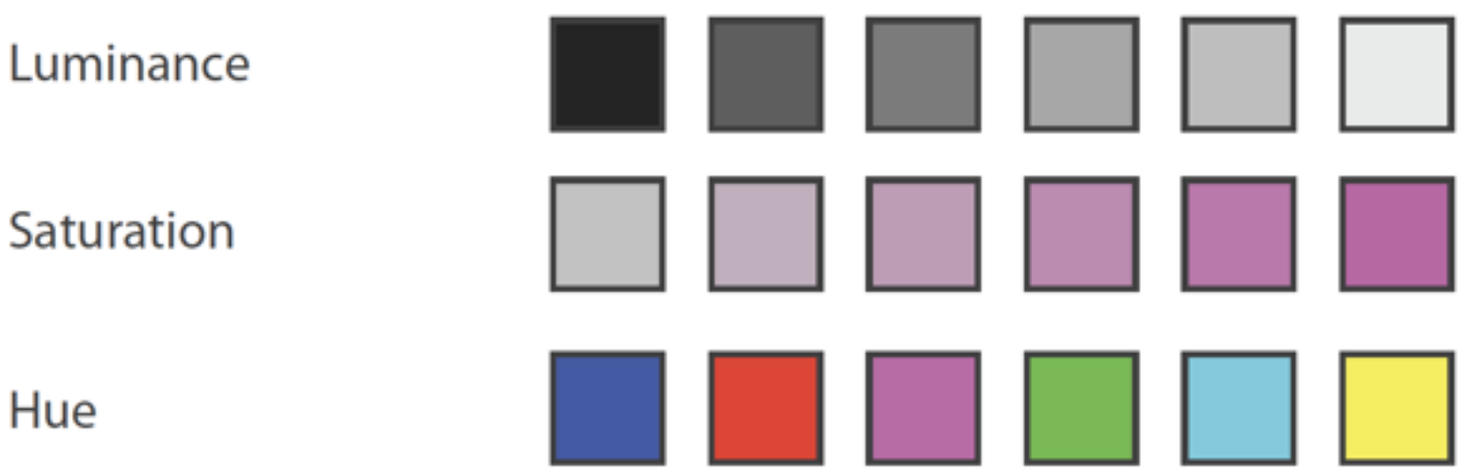
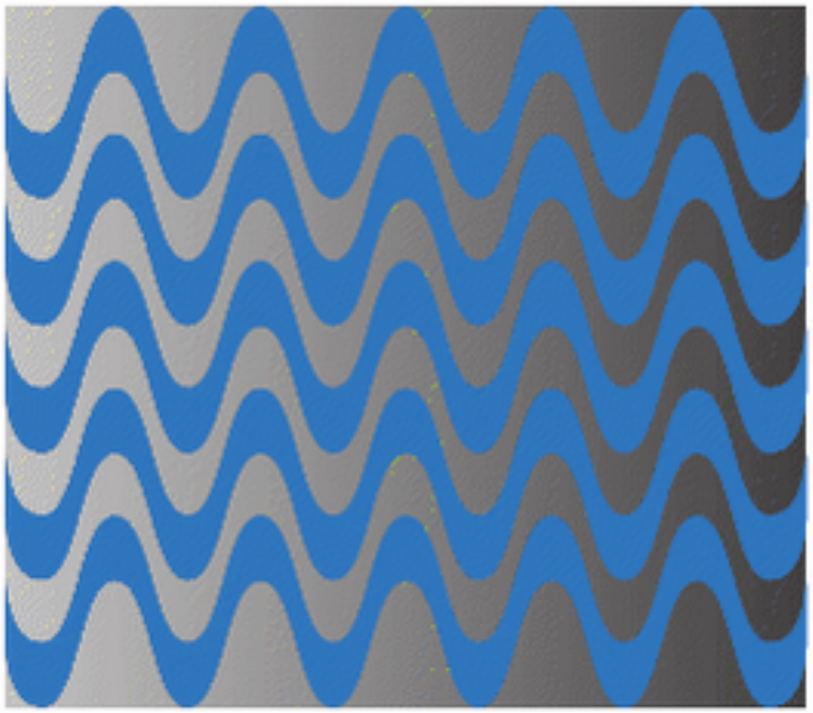
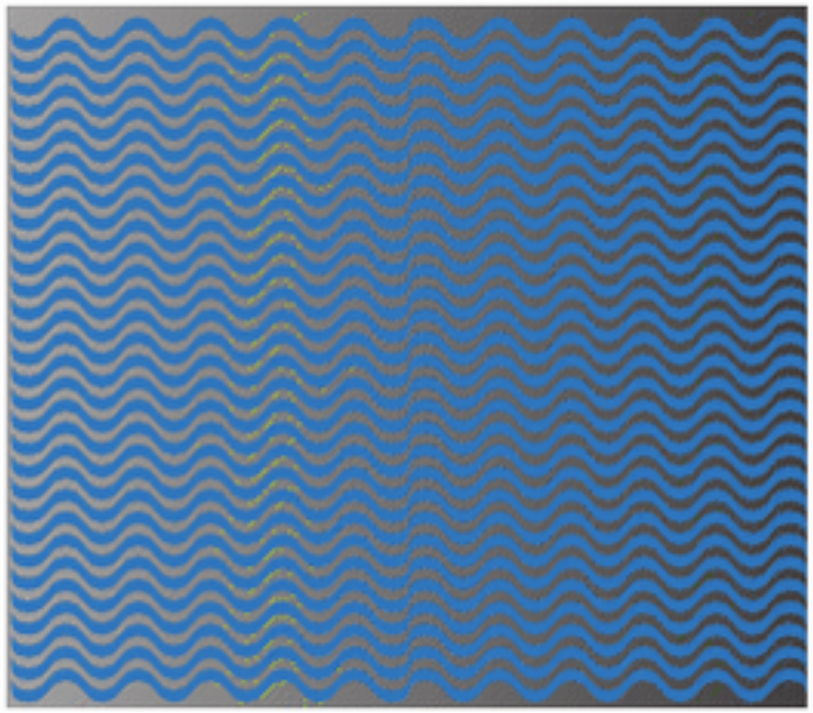
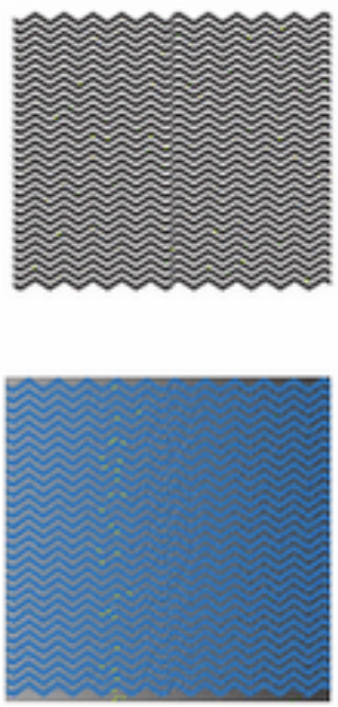


Figure 10.5. The luminance and saturation channels are automatically interpreted as ordered by our perceptual system, but the hue channel is not. Munzner

HUE VS LUMINANCE

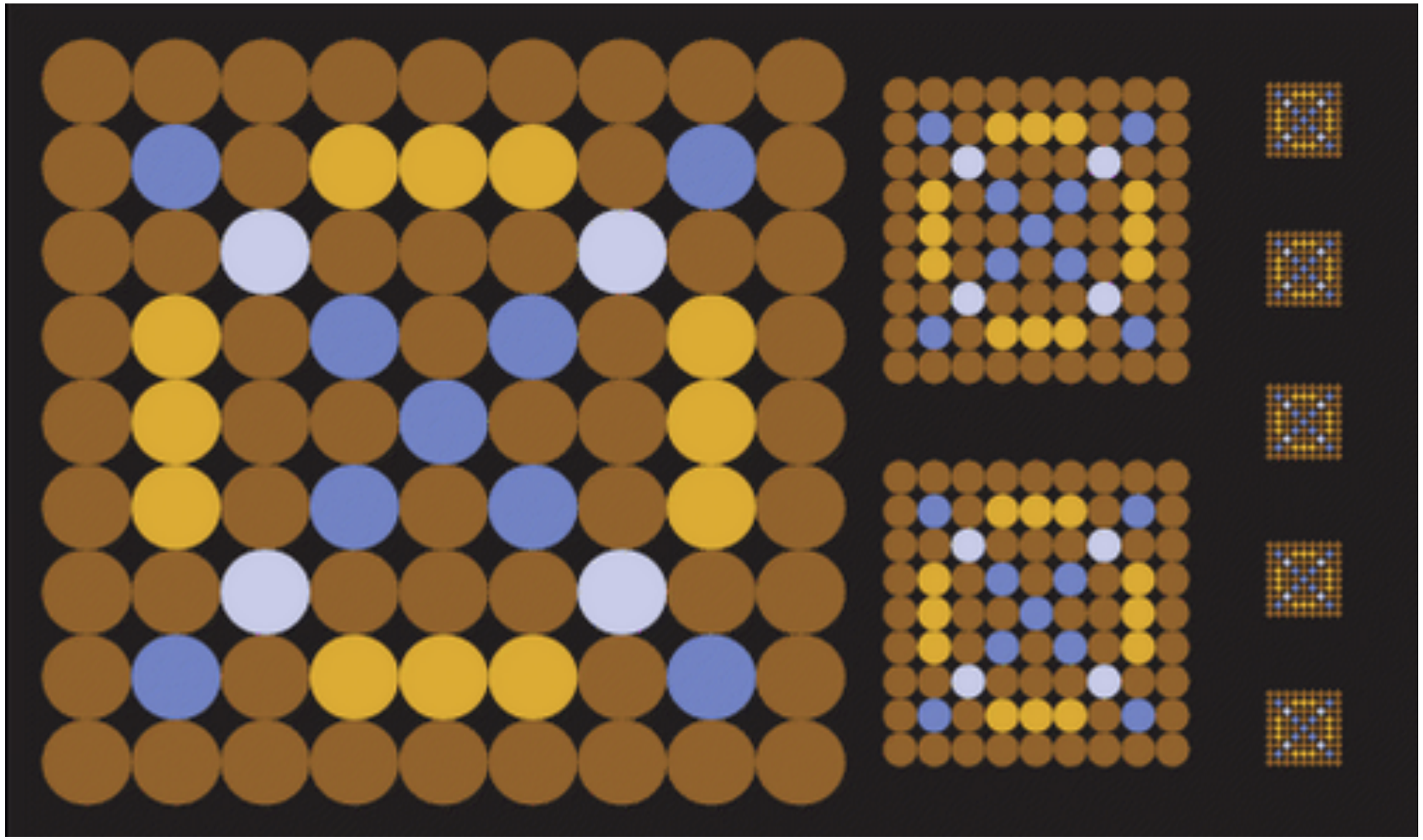






Ware (2008)

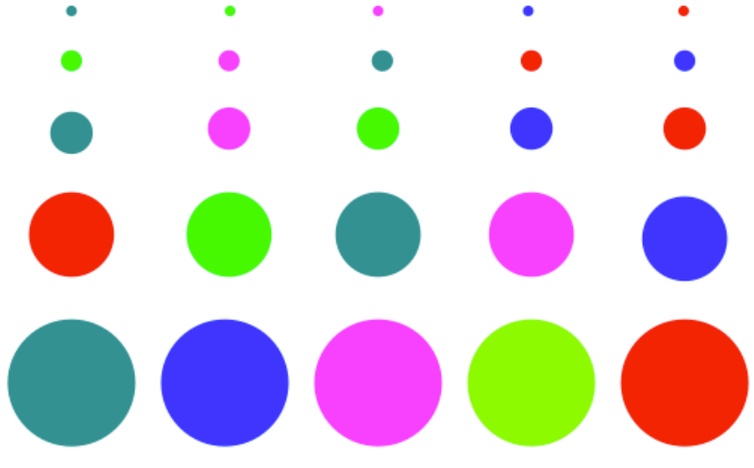
HUE VS SATURATION



Ware (2008)

COLOUR GUIDELINES

- Use luminance and saturation for **magnitude** channels
- Use hue for **categories**
- Watch out for saturation
- Harder to see colour on smaller items



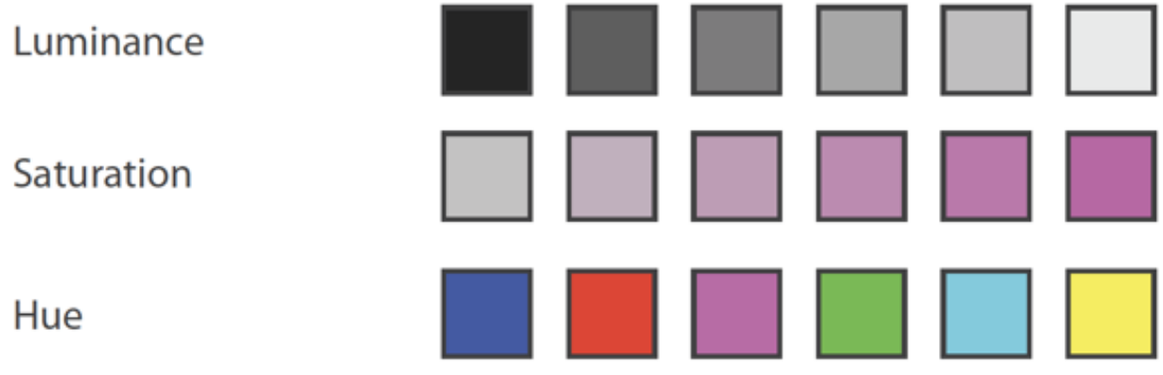
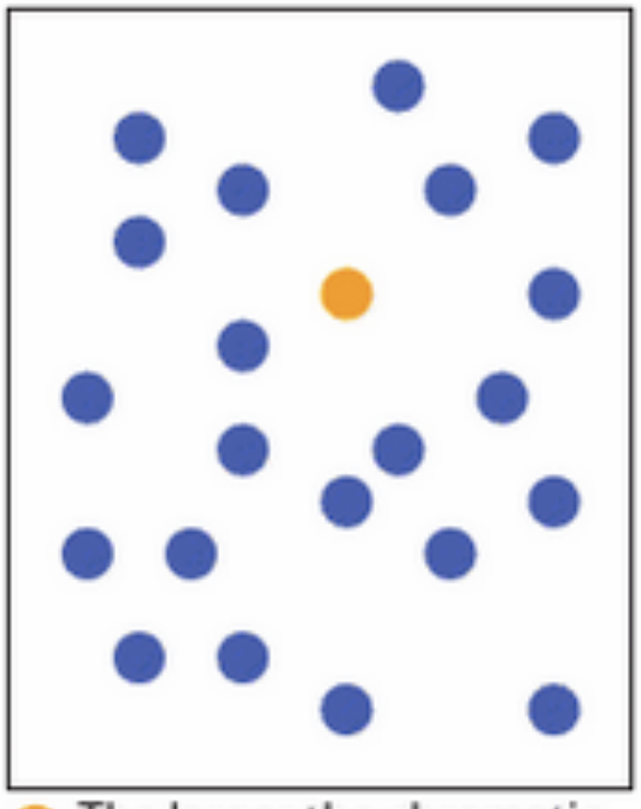
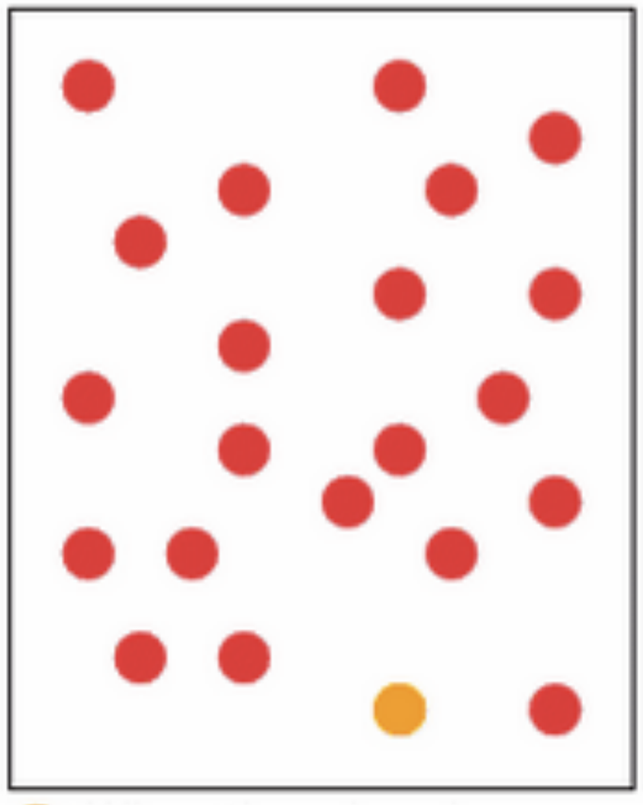


Figure 10.5. The luminance and saturation channels are automatically interpreted as ordered by our perceptual system, but the hue channel is not.

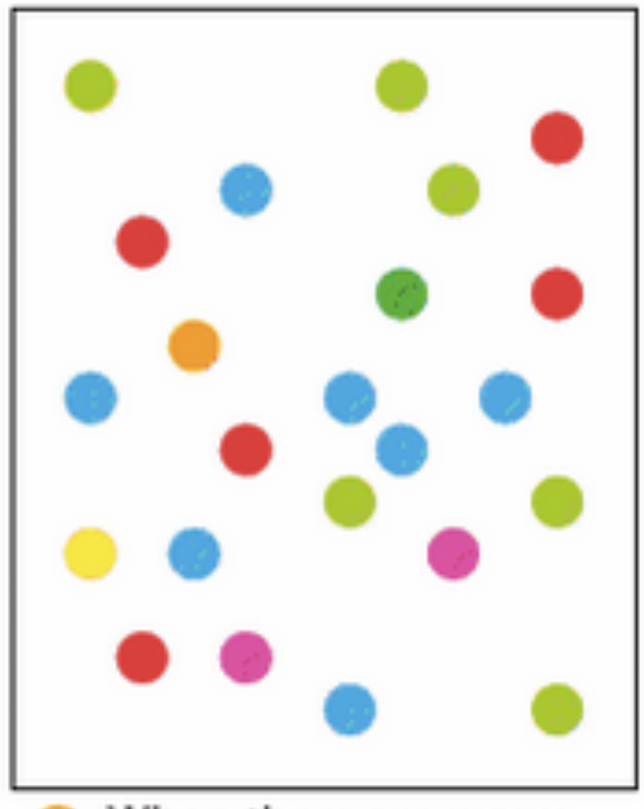
POP-OUT EFFECT AND COLOUR



The larger the chromatic difference between the target symbol and the other symbols, the easier the search.



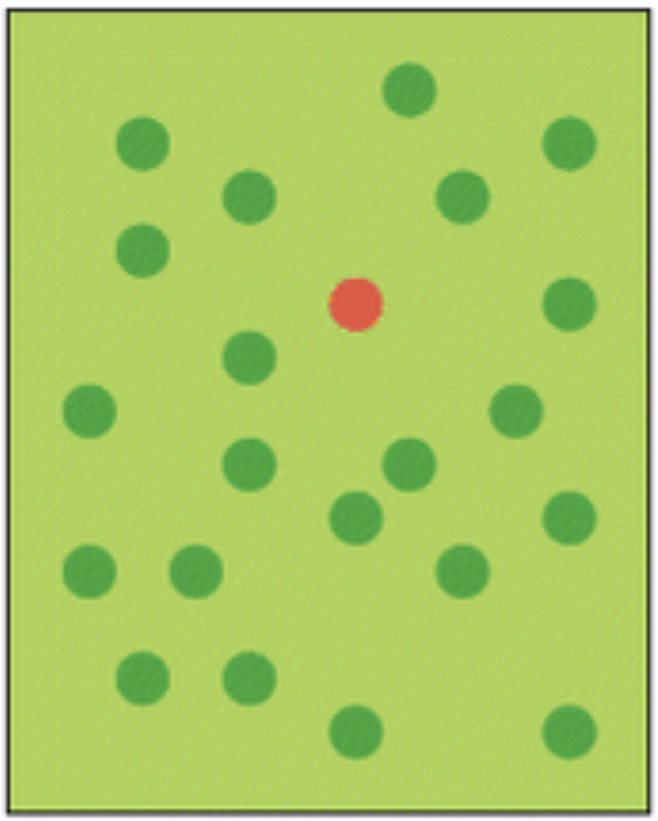
When there is only a small color difference from non-target symbols, the search is difficult.



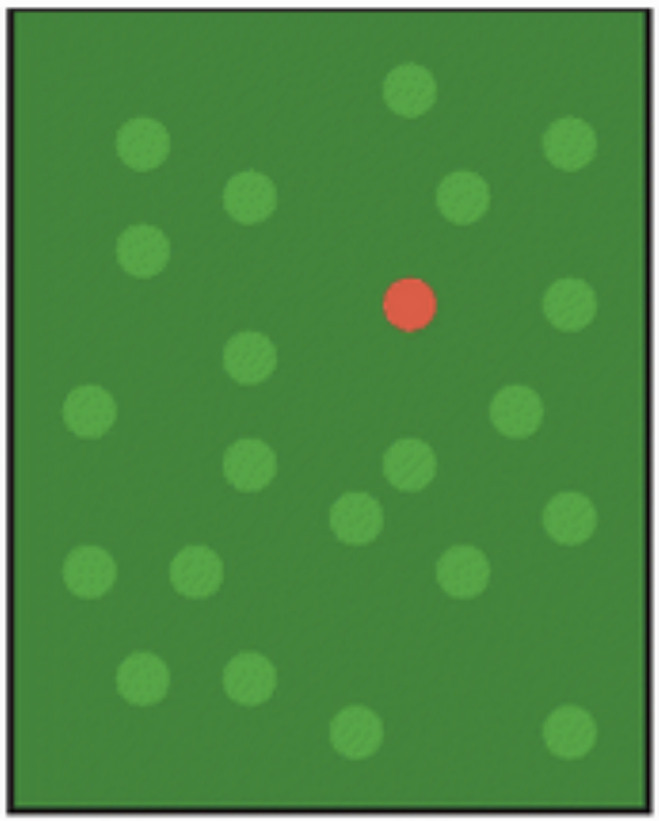
When there are many non-target symbol colors, the search is the most difficult.

Ware (2008)

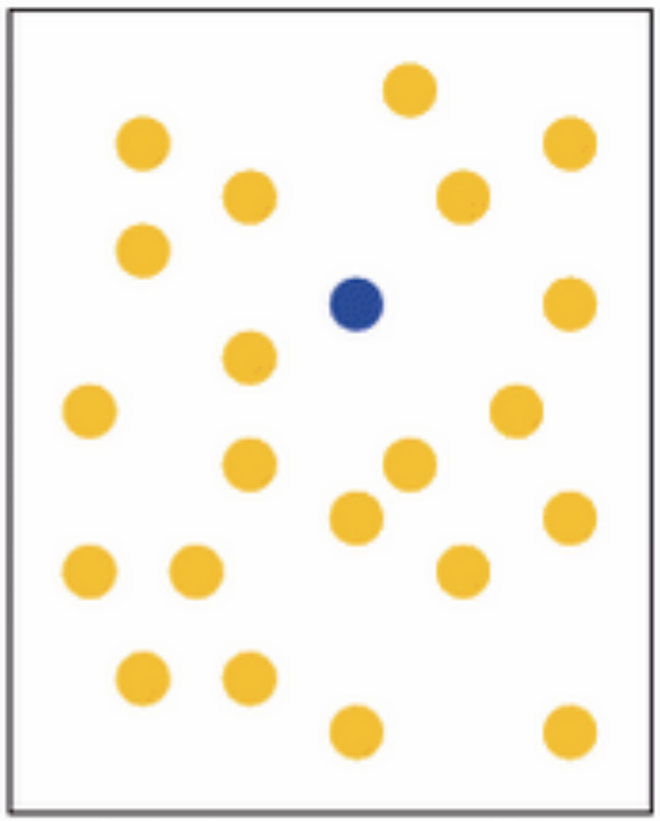
POP-OUT EFFECT AND COLOUR



If non-target symbols are similar to the background, they are easy to exclude from the visual search.



A luminance difference plus a chromatic difference from other symbols and the background leads to the easiest search.

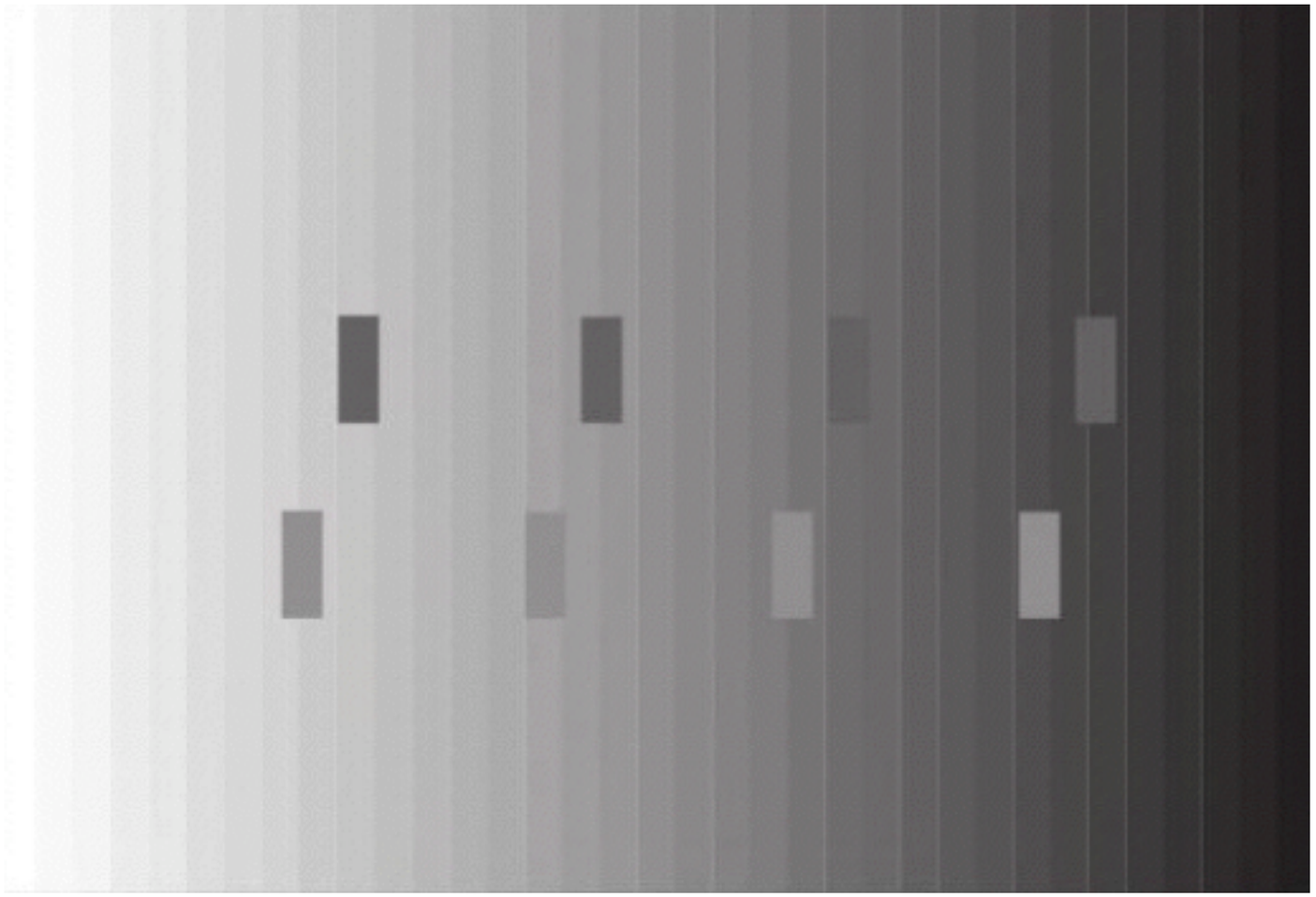


A dark target on a light background with light non-target symbols can be as effective as the reverse.

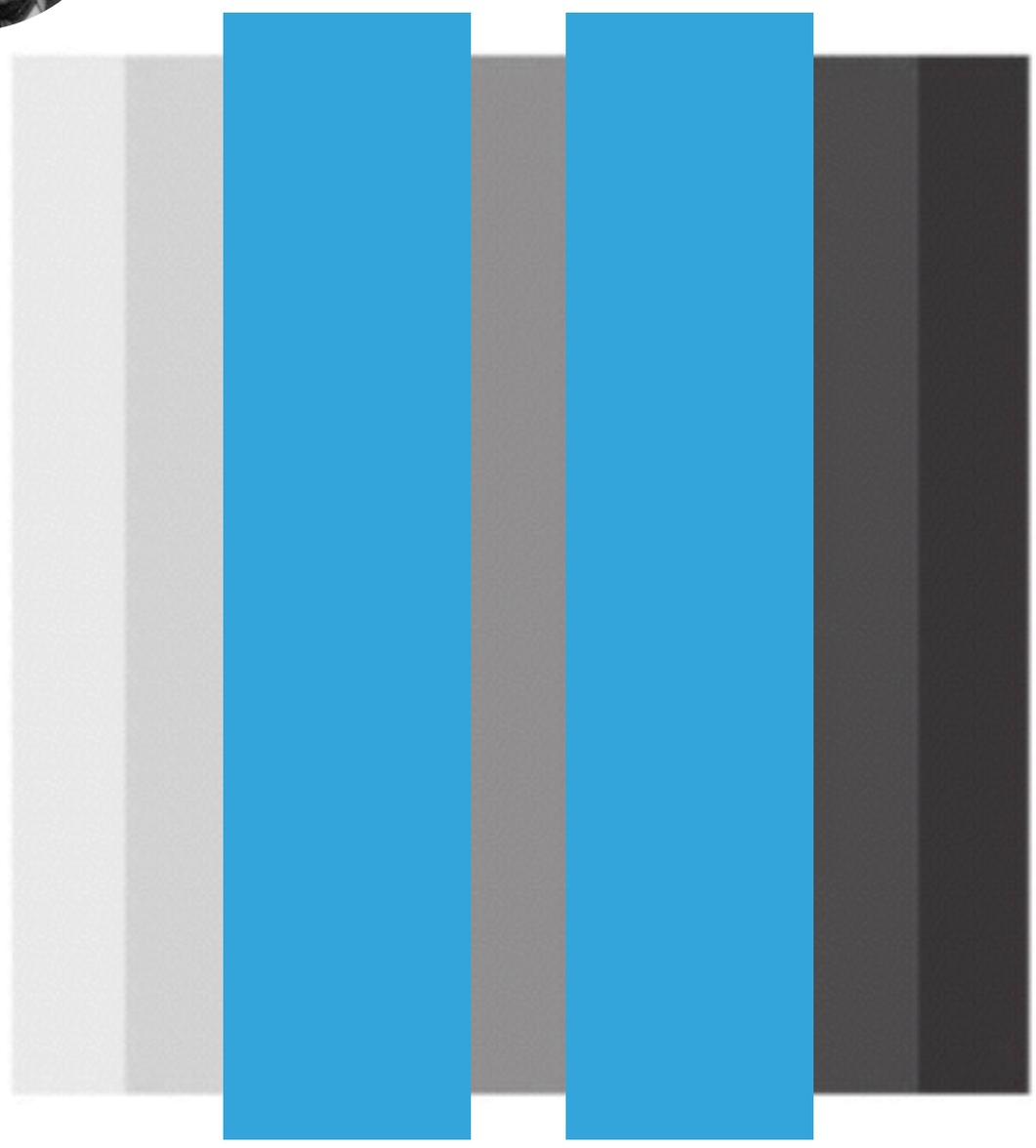
Ware (2008)

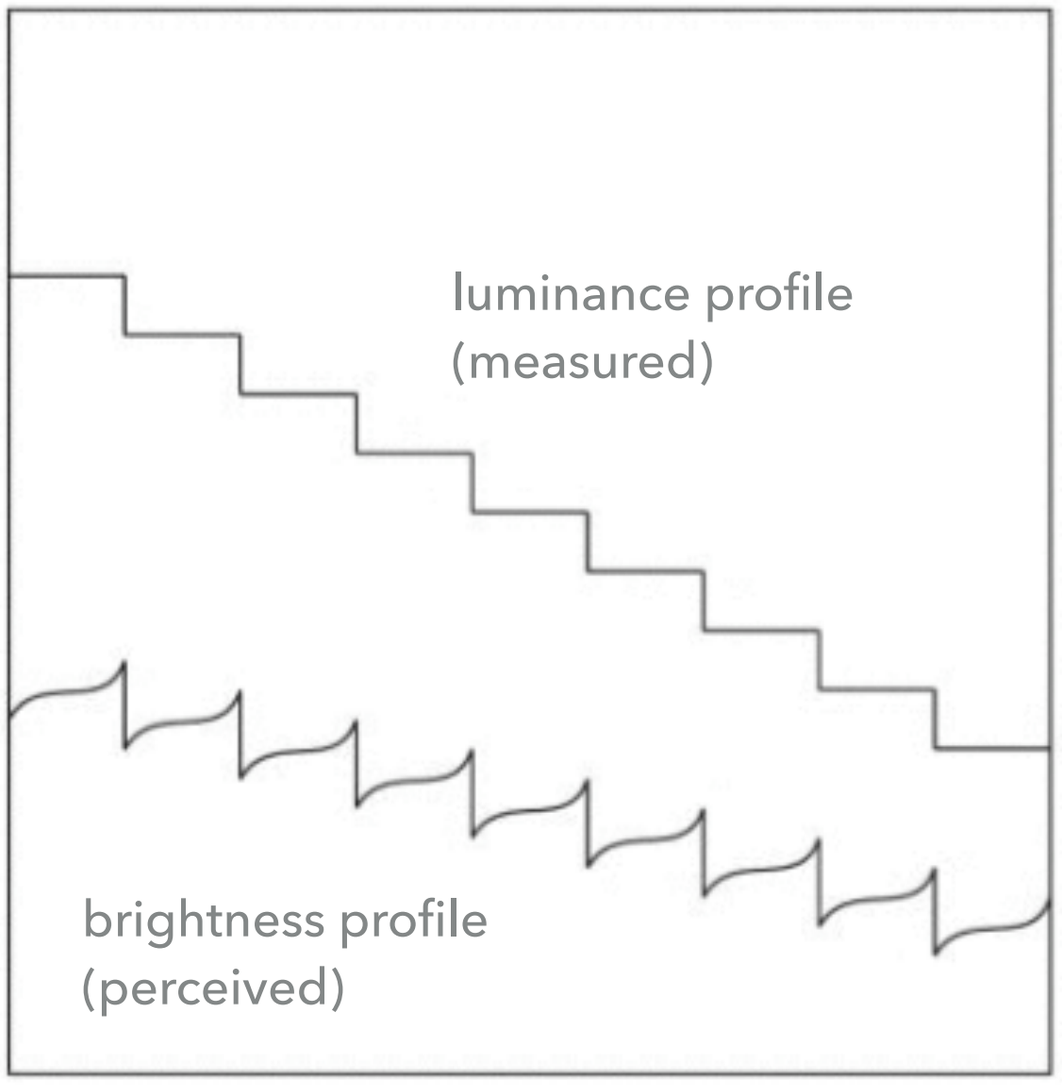
PERCEIVED BRIGHTNESS

- Perceived brightness is relative to background



CHEVREULL ILLUSION

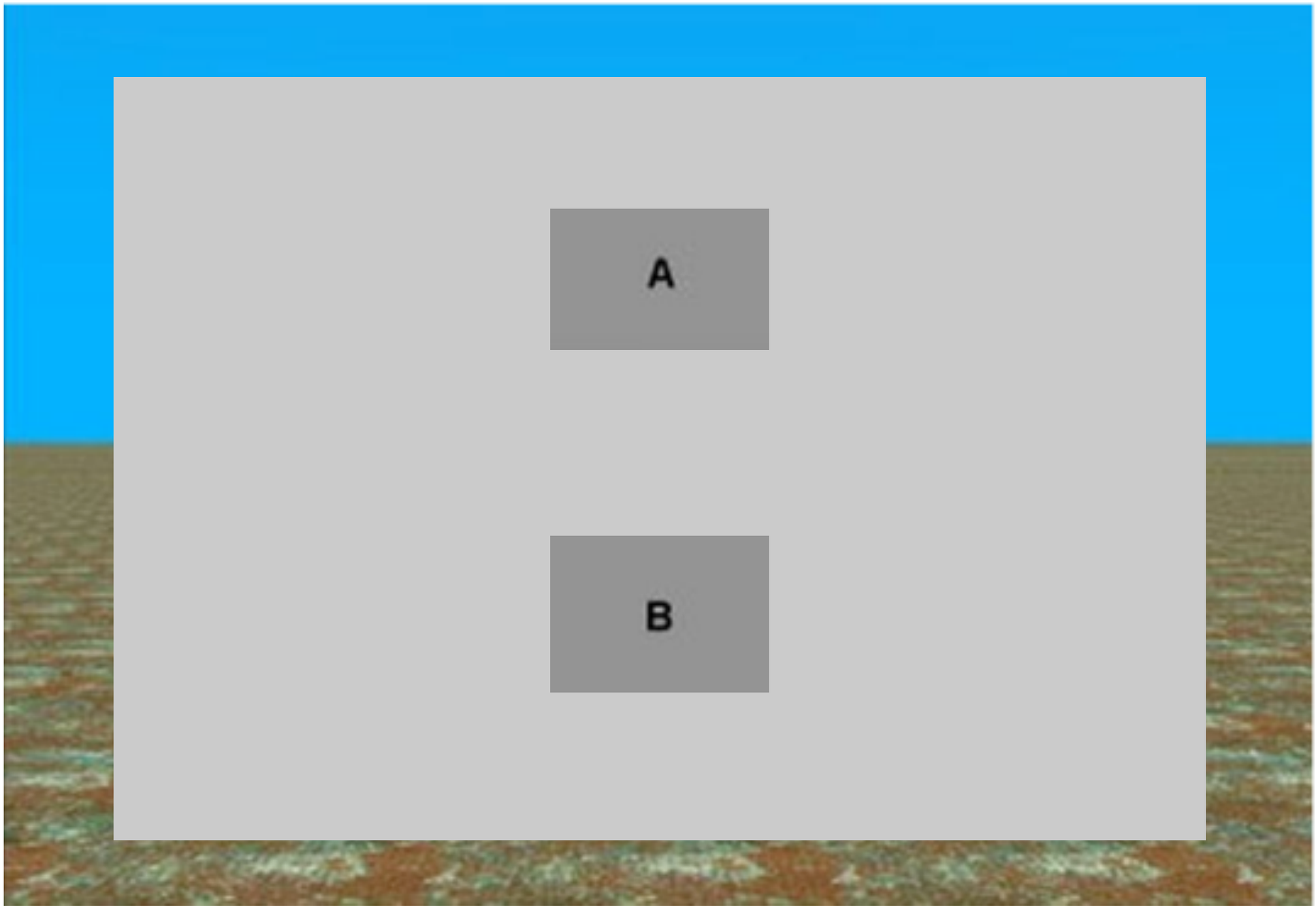




Can result in errors of judgement

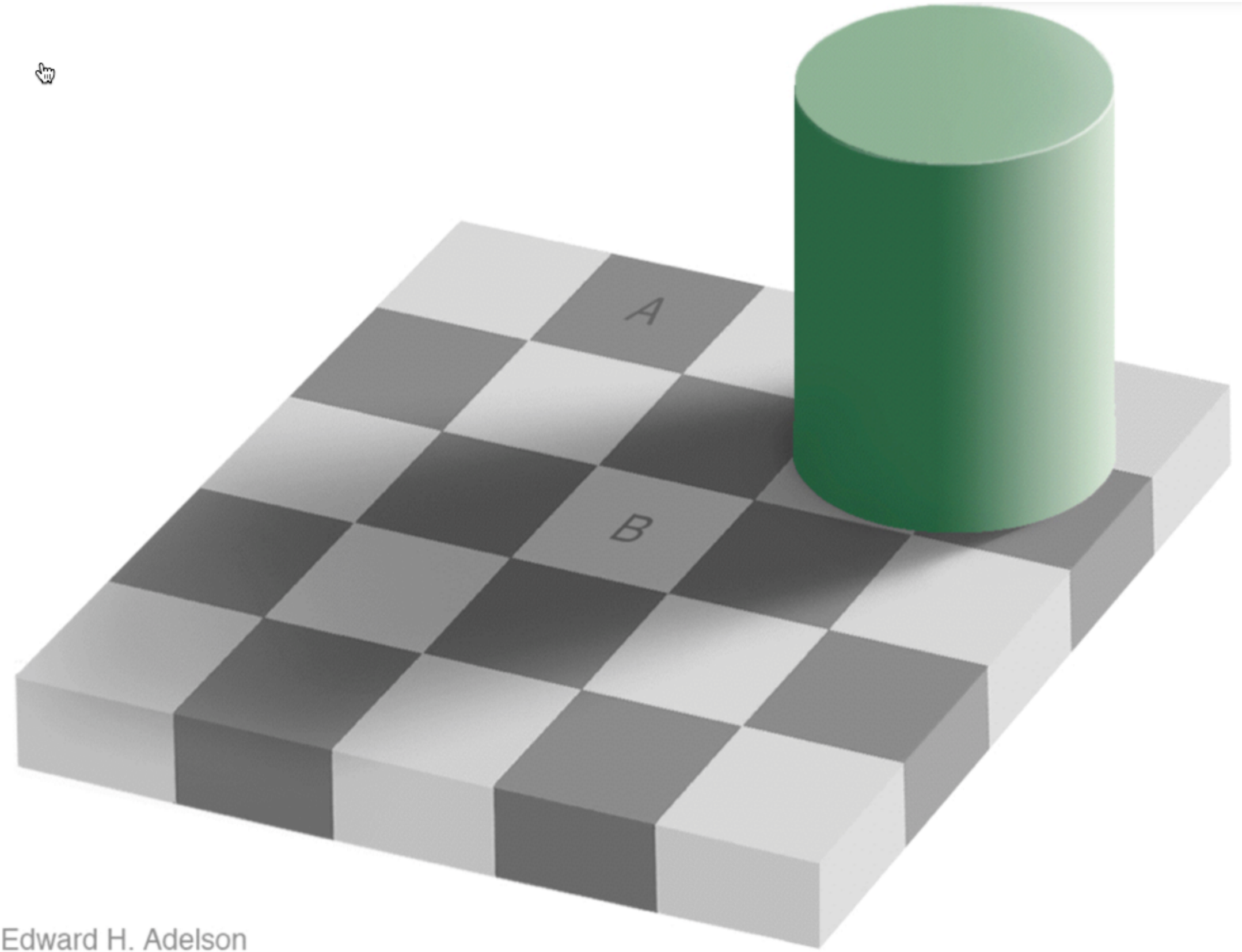
Amplifies artefacts in computer graphic shading

Lex

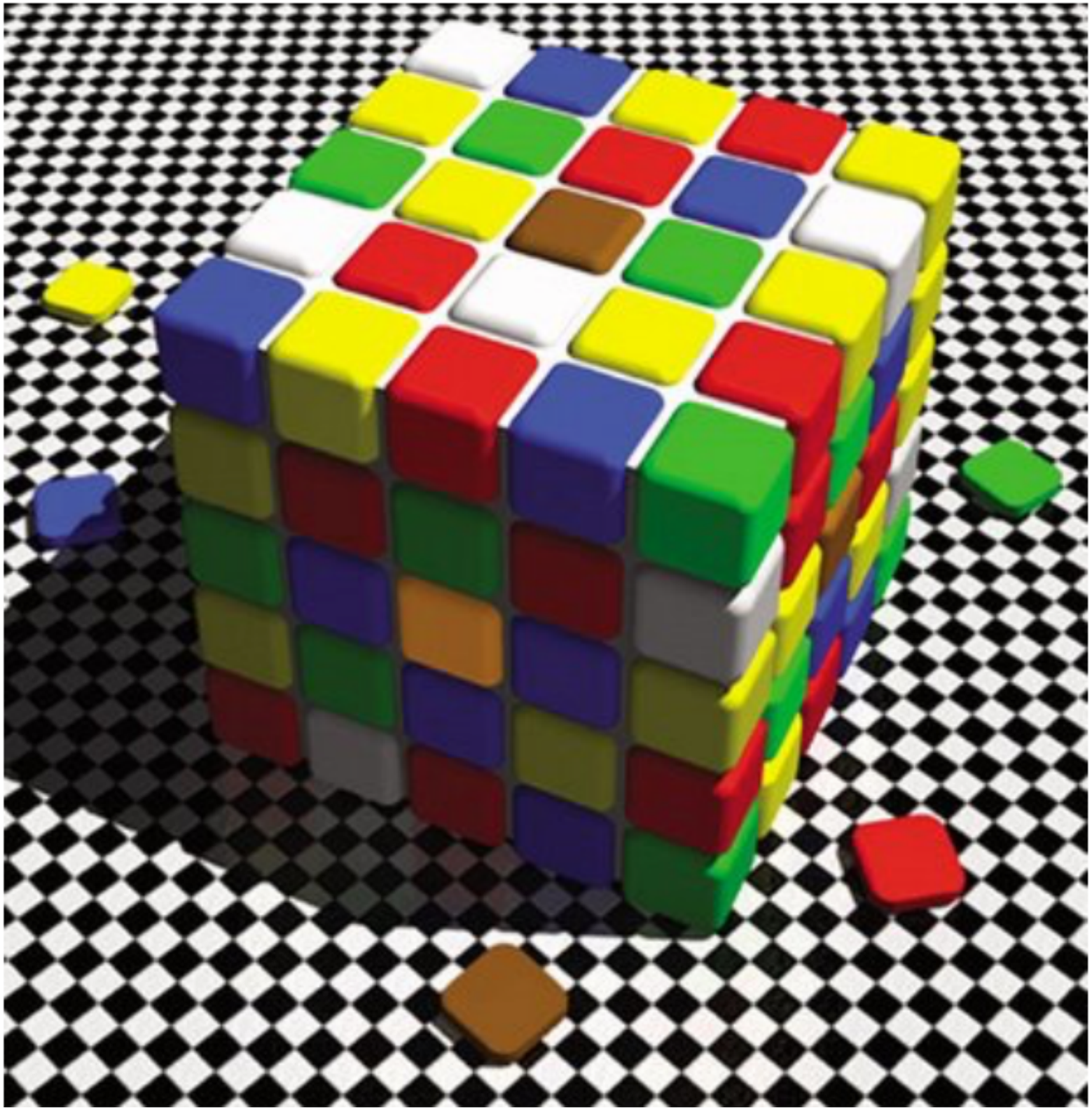


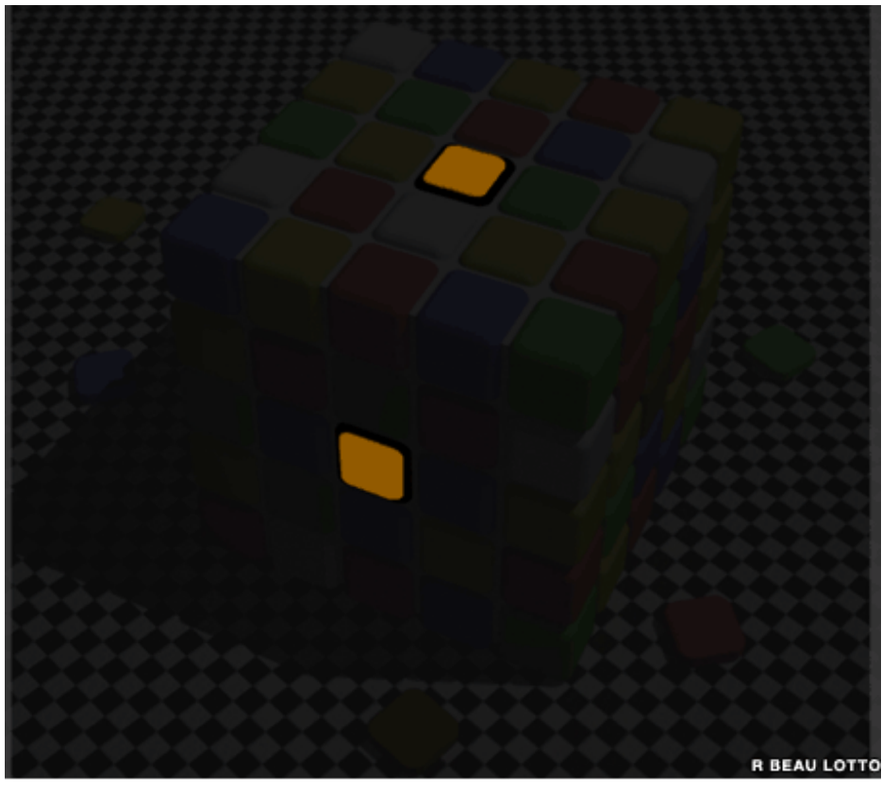
Cornsweet Illusion - A and B are the same colour

Visual system operates on relative differences, not absolute differences



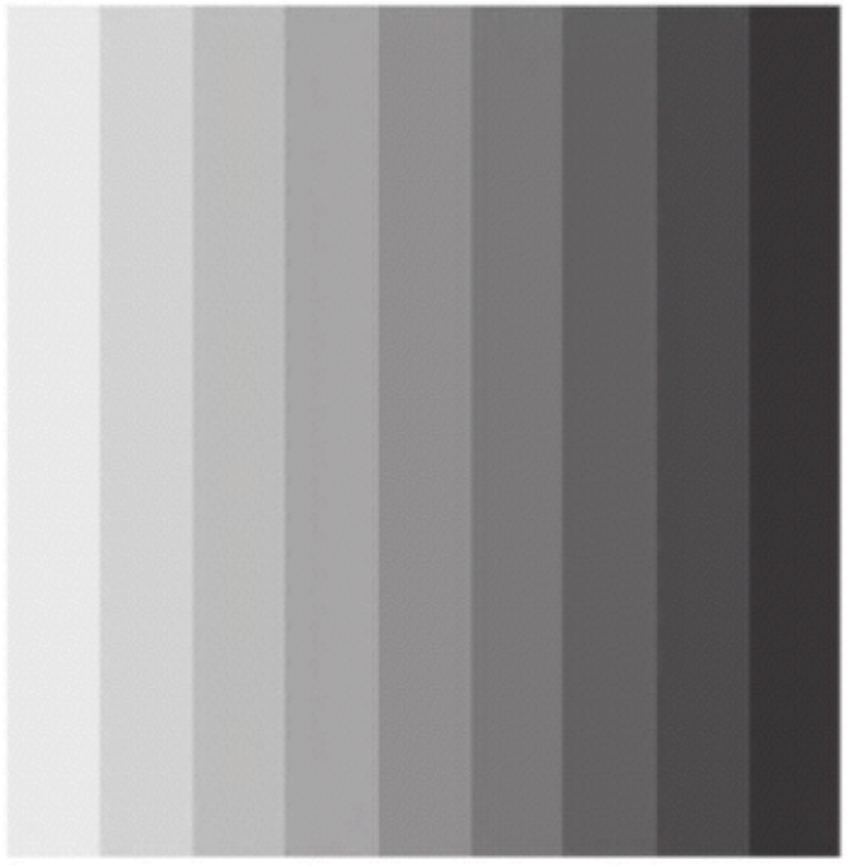
Edward H. Adelson




R BEAU LOTTO

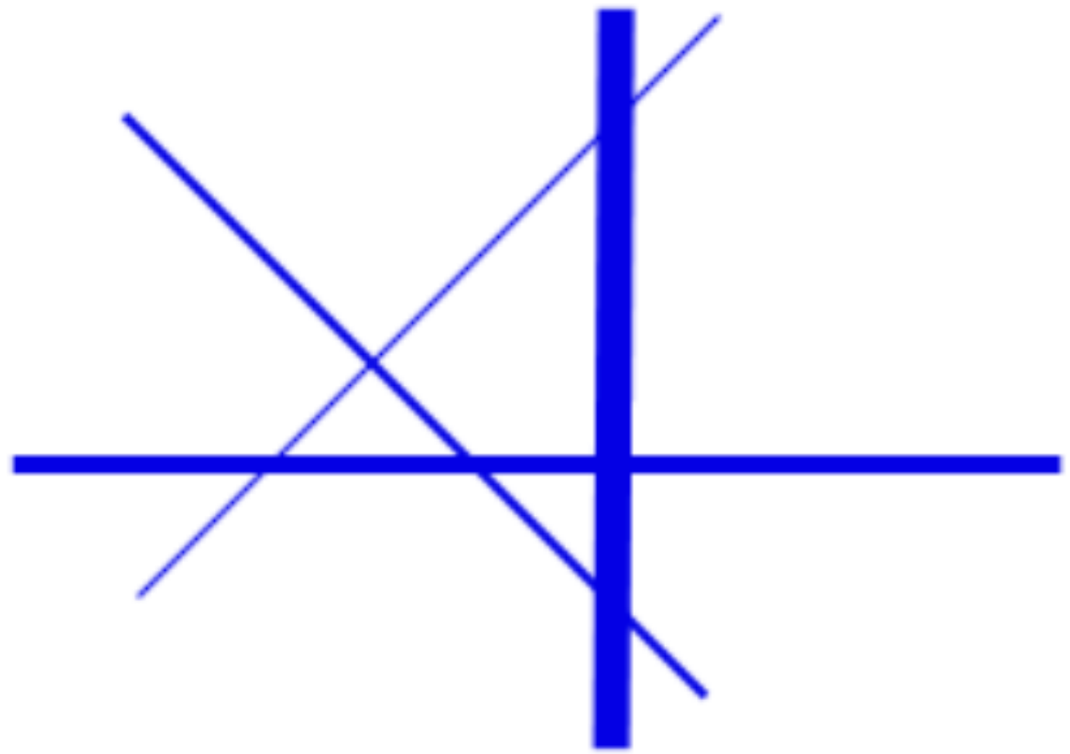
COLOUR GUIDELINES

- Perception of luminance affected by context
- Avoid grey scale when more than four ‘bins’ required (Ware)



LINE WEIGHT AND ITEM SIZE

- Wide lines:
  - have higher brightness contrast
  - more salient
  - line width used a lot in map making



CONTRAST AND LAYERING

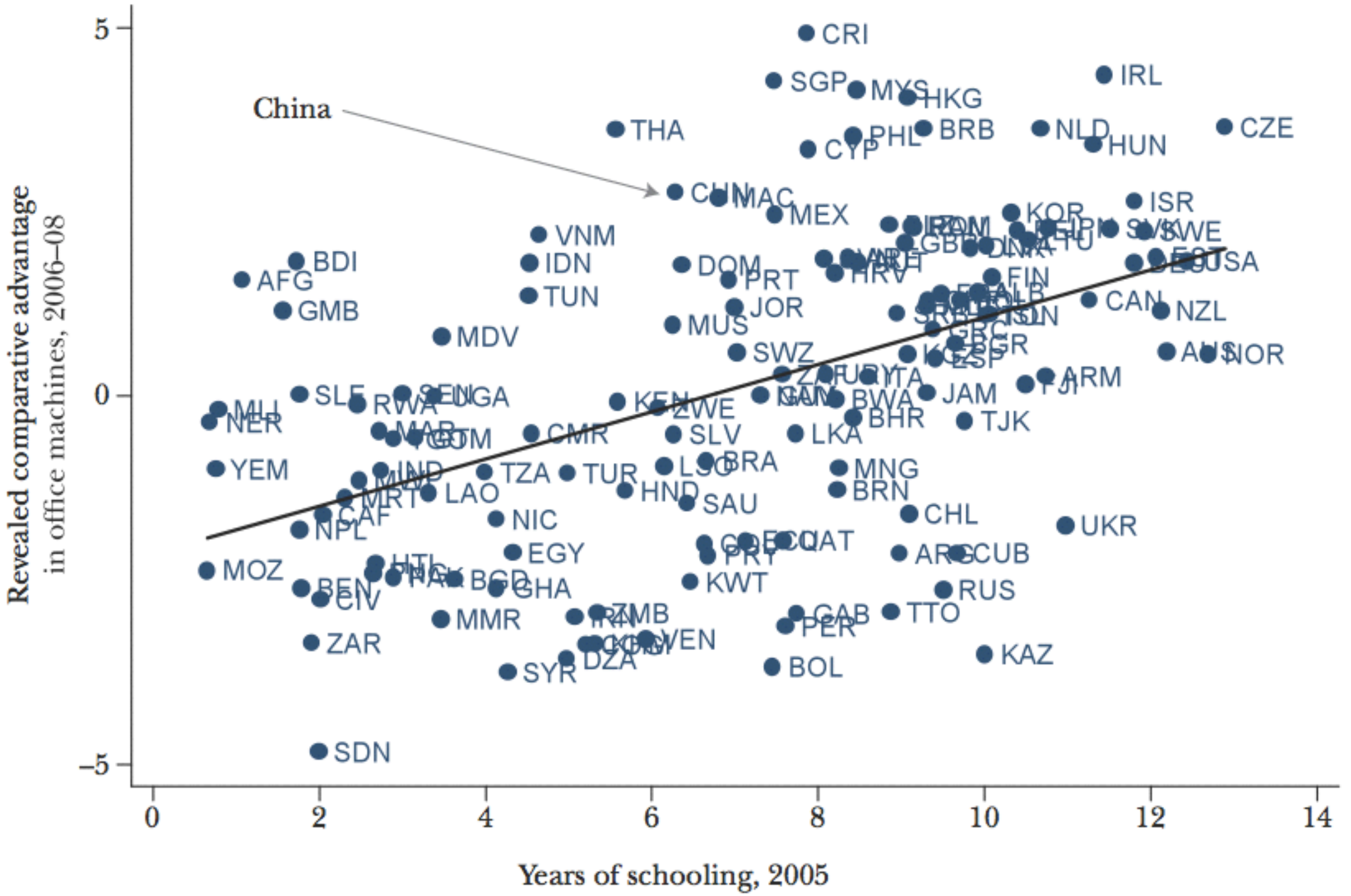
- differences im luminosity used to give contrast and to layer visual elements

Grid sits unobtrusively in the background

Grid sits in foreground, obscuring map

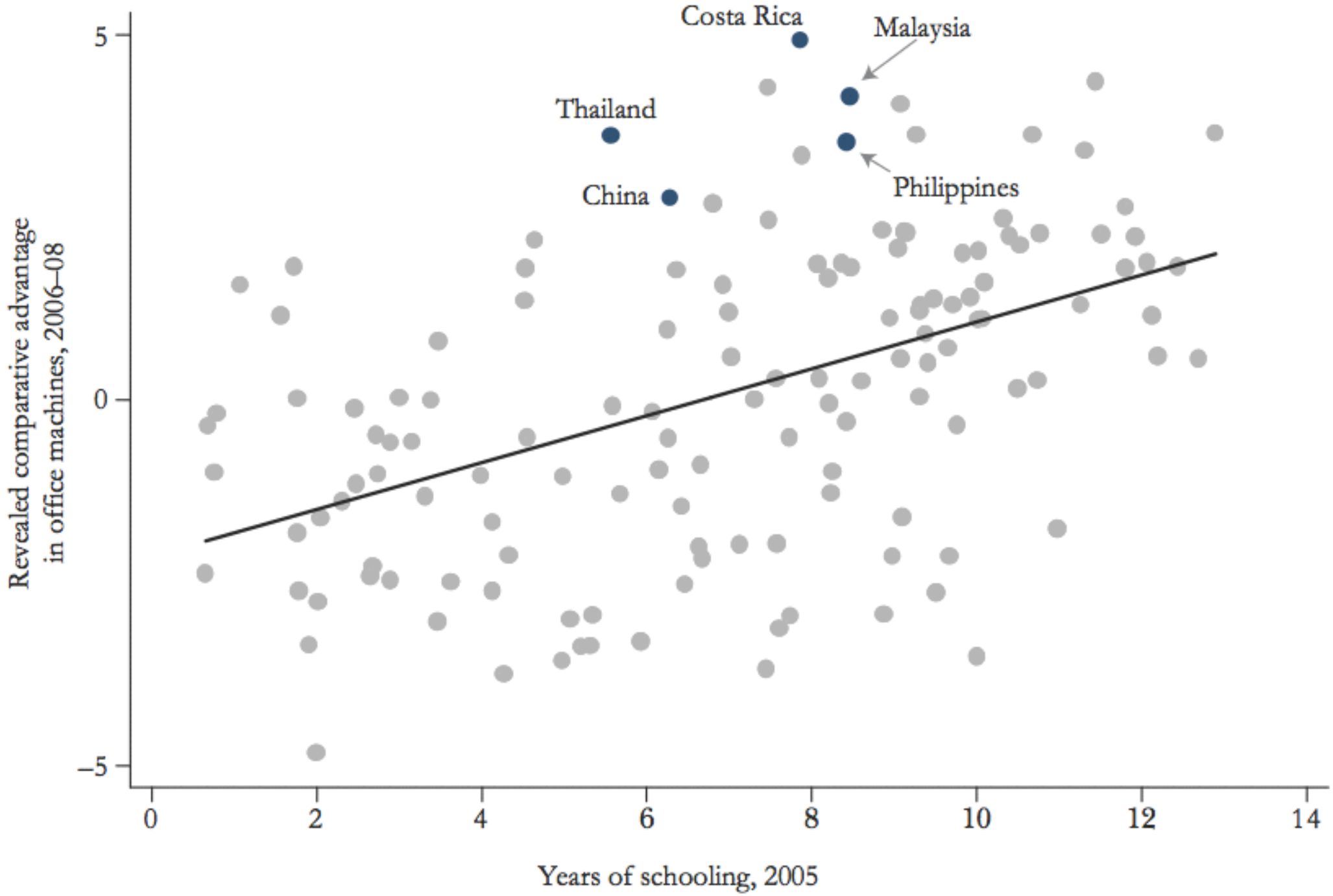
Great Grids: How and Why? (APGV06 and SIGGRAPH poster) Maureen Stone, Lyn Bartram and Diane Gromala

Education and Exports of Office Machines



Schwabish (2014) An Economist's Guide to Visualizing Data

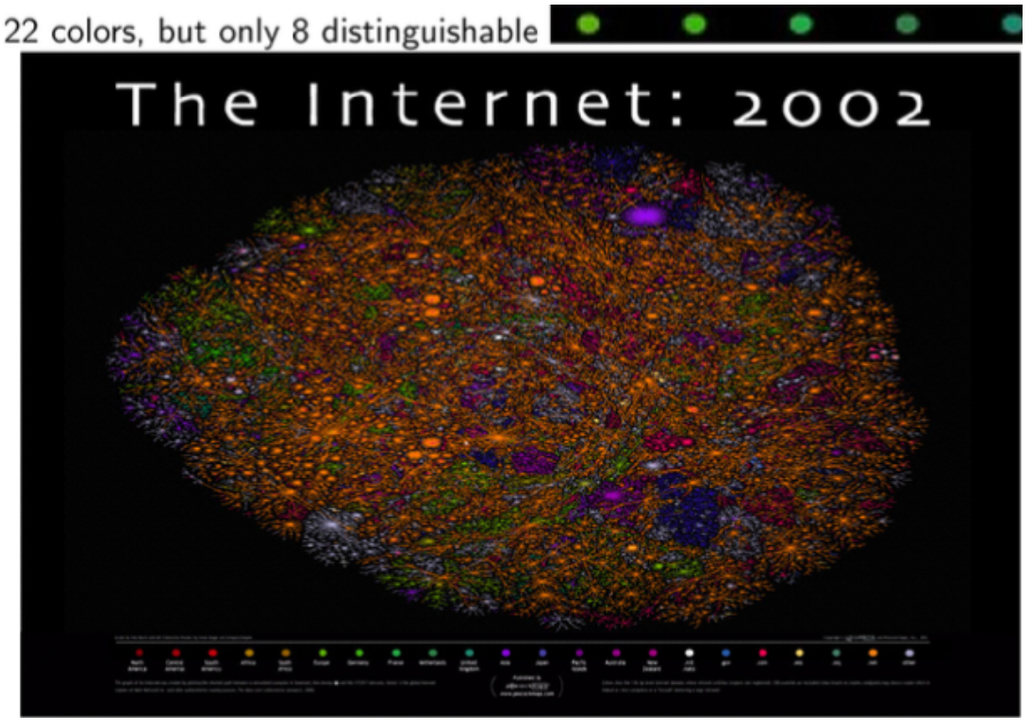
Education and Exports of Office Machines

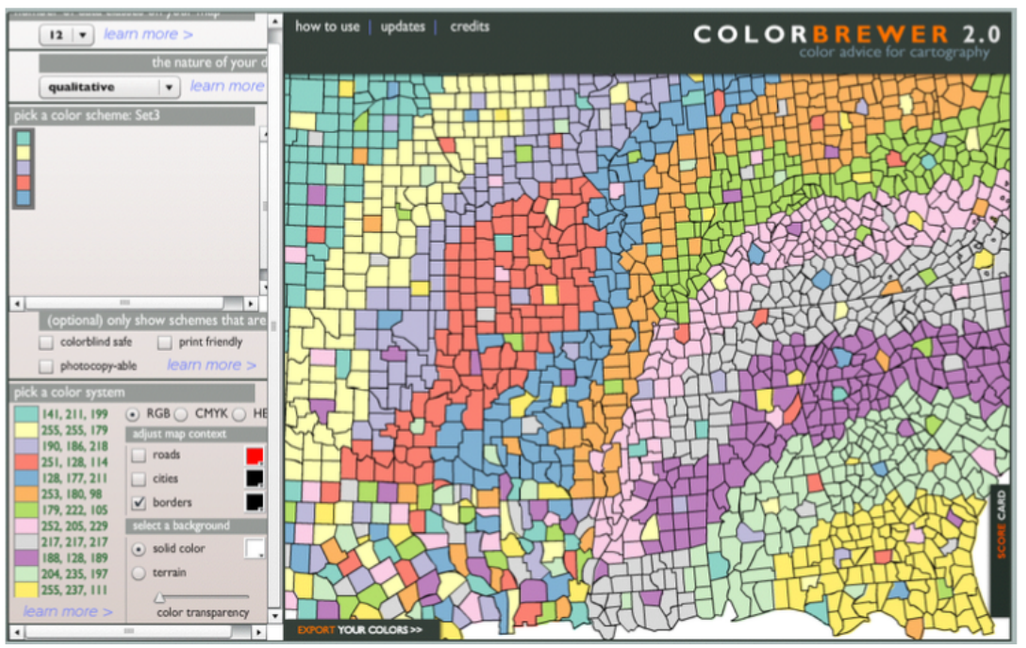


Schwabish (2014) An Economist's Guide to Visualizing Data

COLOUR GUIDELINES

- Hue
  - qualitative (nominal) data
  - around 6 variables (no more than 10)
  - more becomes difficult to discriminate between colours
  - although see colorbrewer for large workable colour schemes





COLOUR GUIDELINES

Quantitative data

- Hue, not good…
  - **avoid** rainbow colour map
- differences in luminance misleading
- the steps between hues is not equal

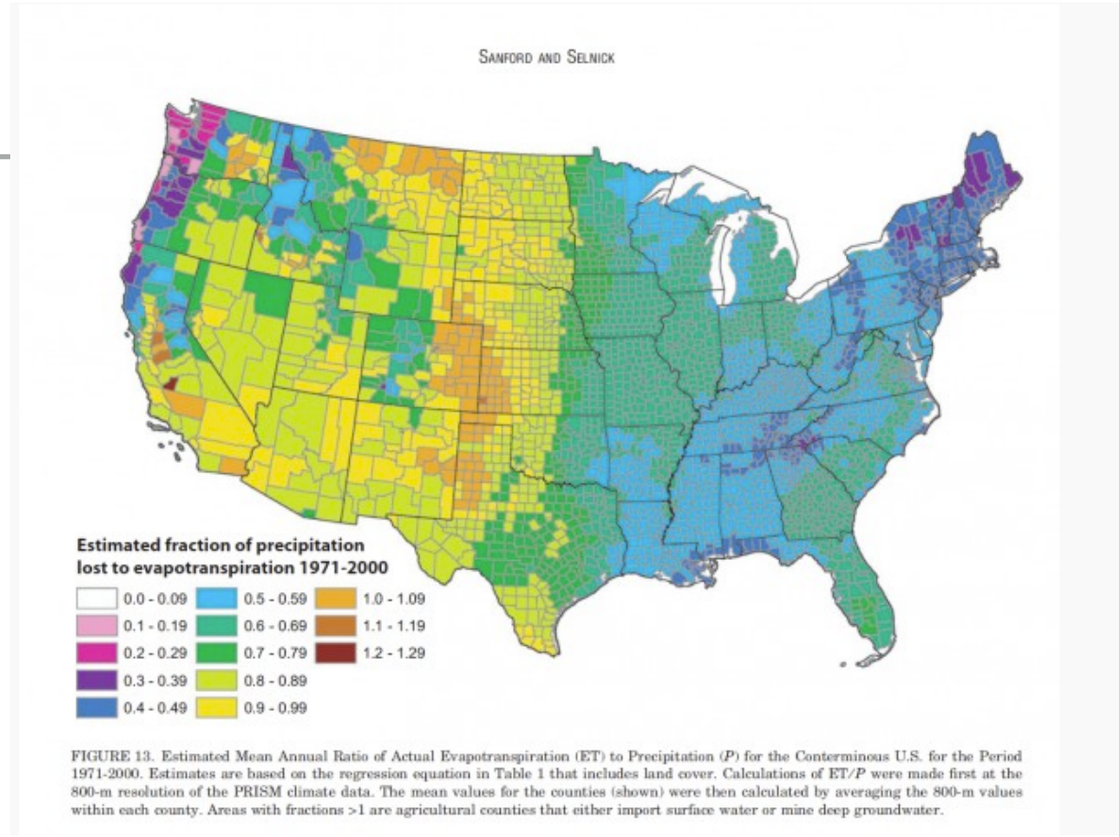
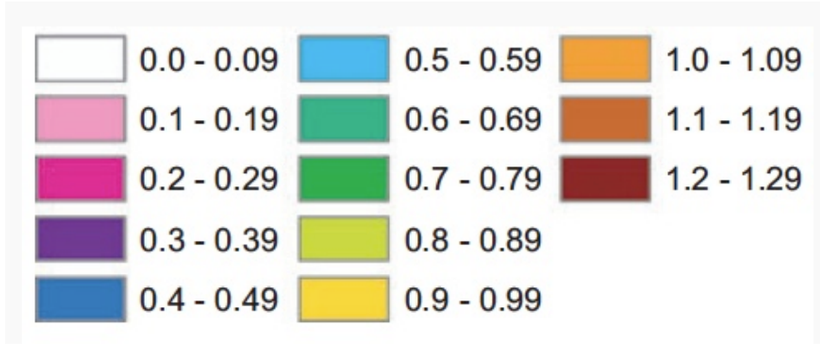
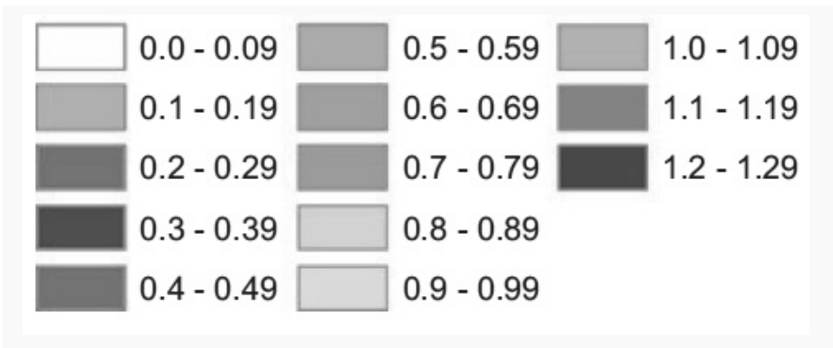
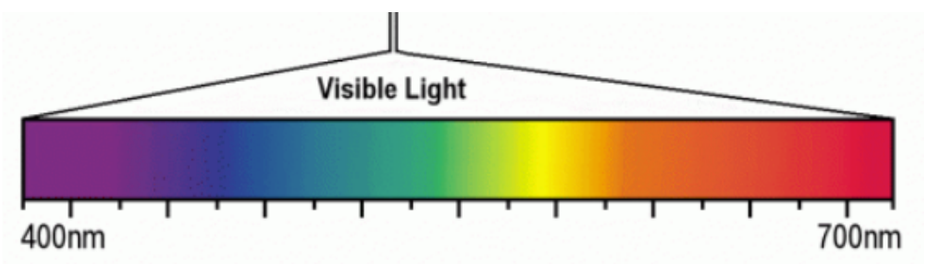
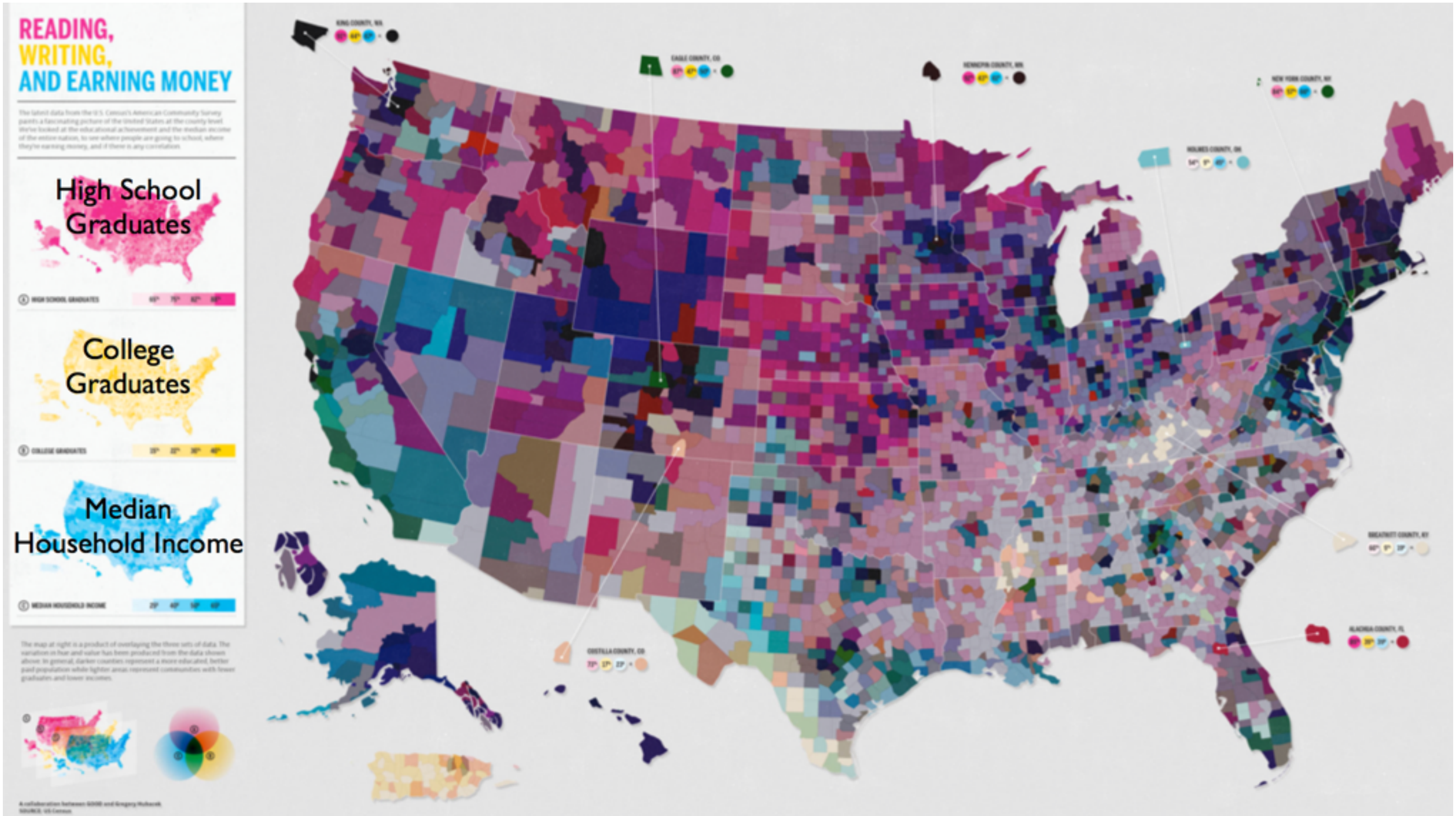


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (*P*) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/*P* were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.



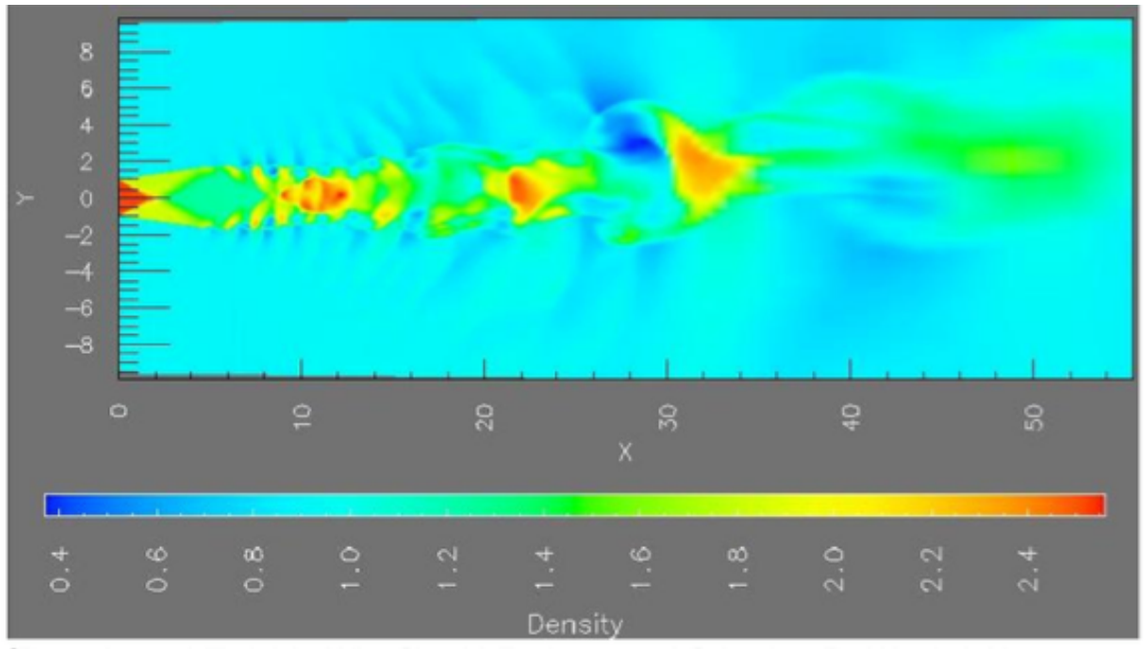






Good Magazine, Jan 2011

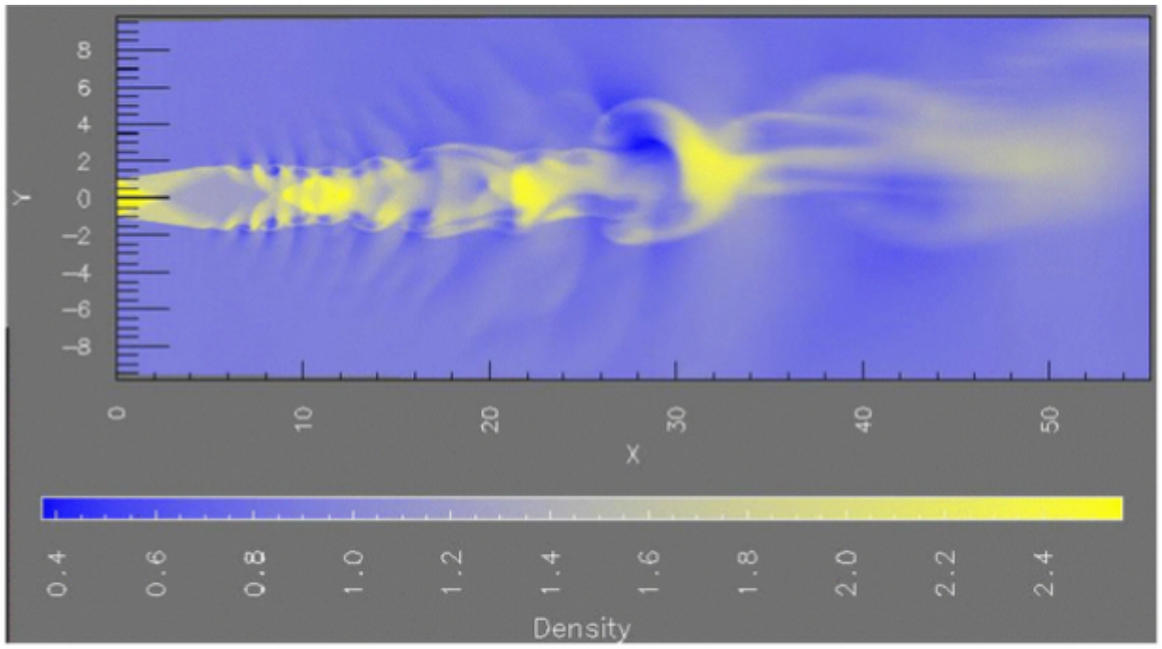
COLOUR GUIDELINES



[Rogowitz and Treinish, Why Should Engineers and Scientists Be Worried About Color? http://www.research.ibm.com/people/l/lloydt/color/color.HTM]

Hue - Rainbow map

difficult to see all features of data



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm]

Saturation - Divergent scale (blue/yellow)

easier to see features of data

COLOUR BLINDNESS

Normal

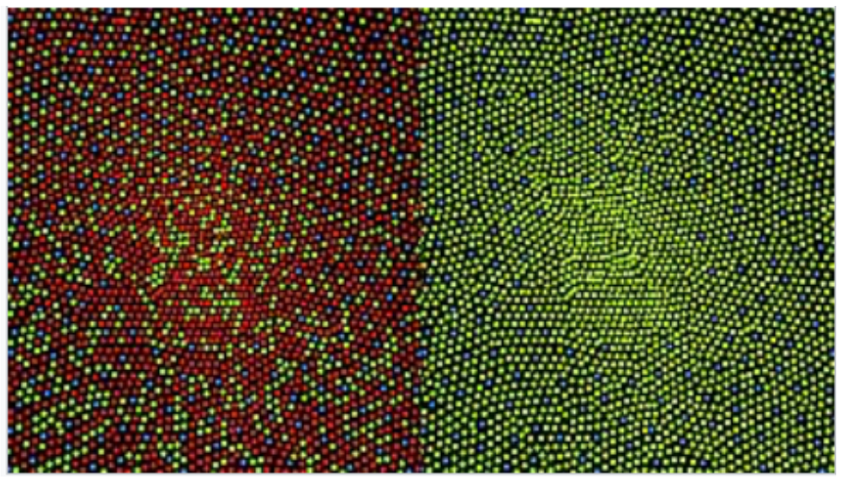
Deuteranopia

no green receptors

Protanopia

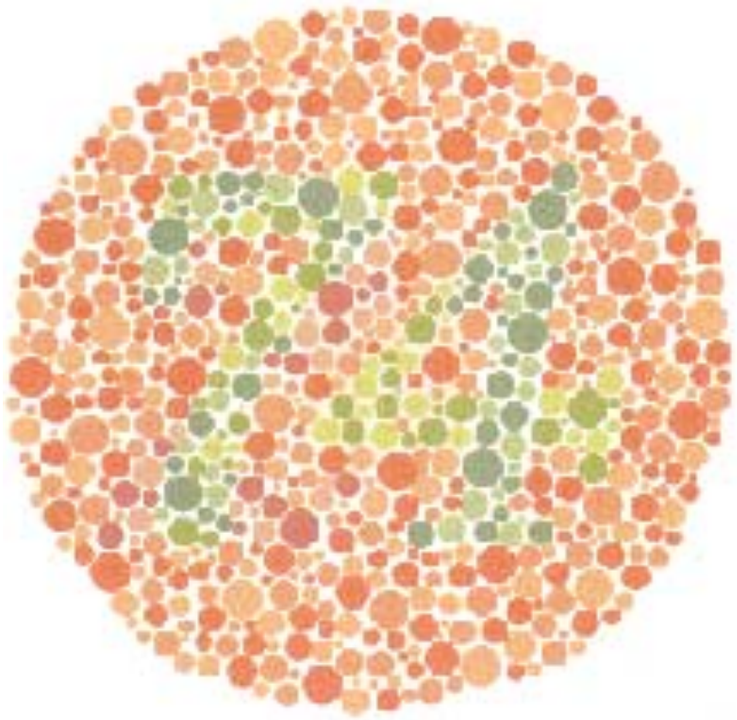
no red receptors

- approx. 10% Male (x chromosome recessive)
- approx. 1% Female
- red/green (deuteranopia) most common

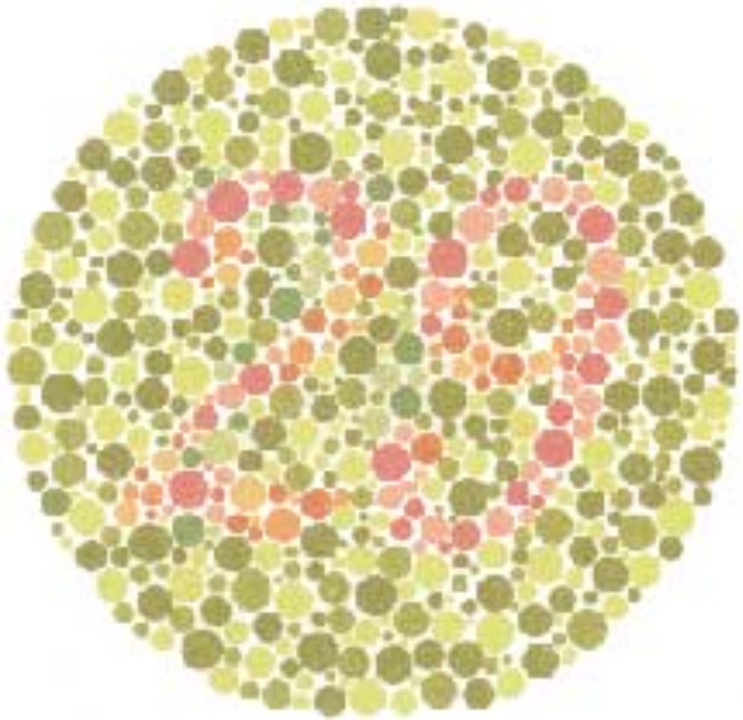


Normal fovea

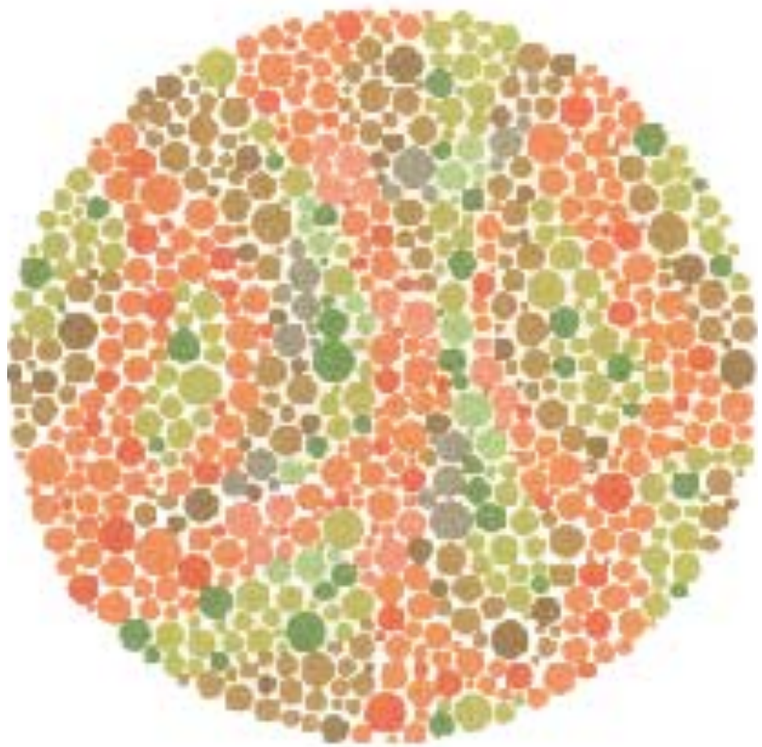
Protanopia



Normal - 74



Normal - 29
Red-Green - 70

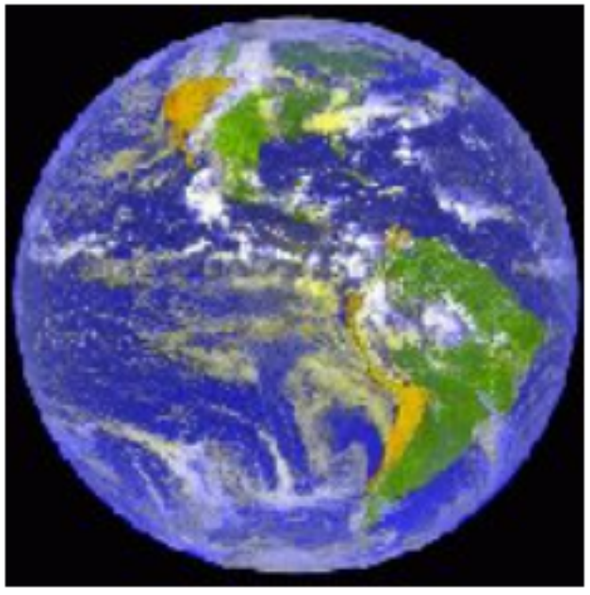


Normal - NA
Red-Green - 5

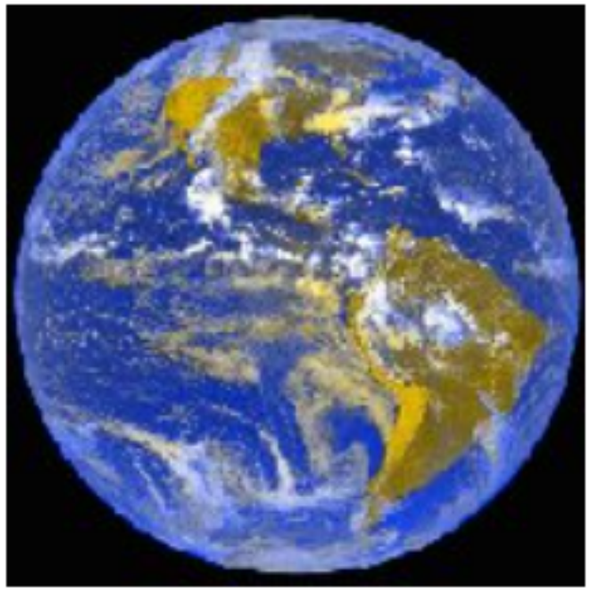
Ishihara plates - for diagnosing colour blindness

COLOUR BLINDNESS

Normal

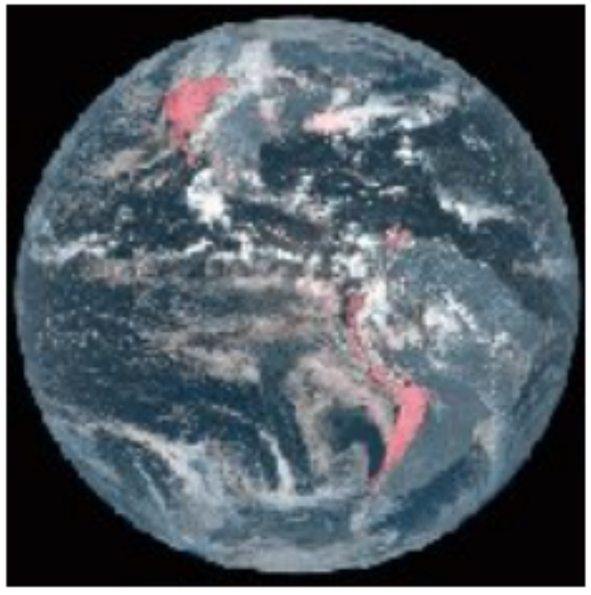


Deuteranopia

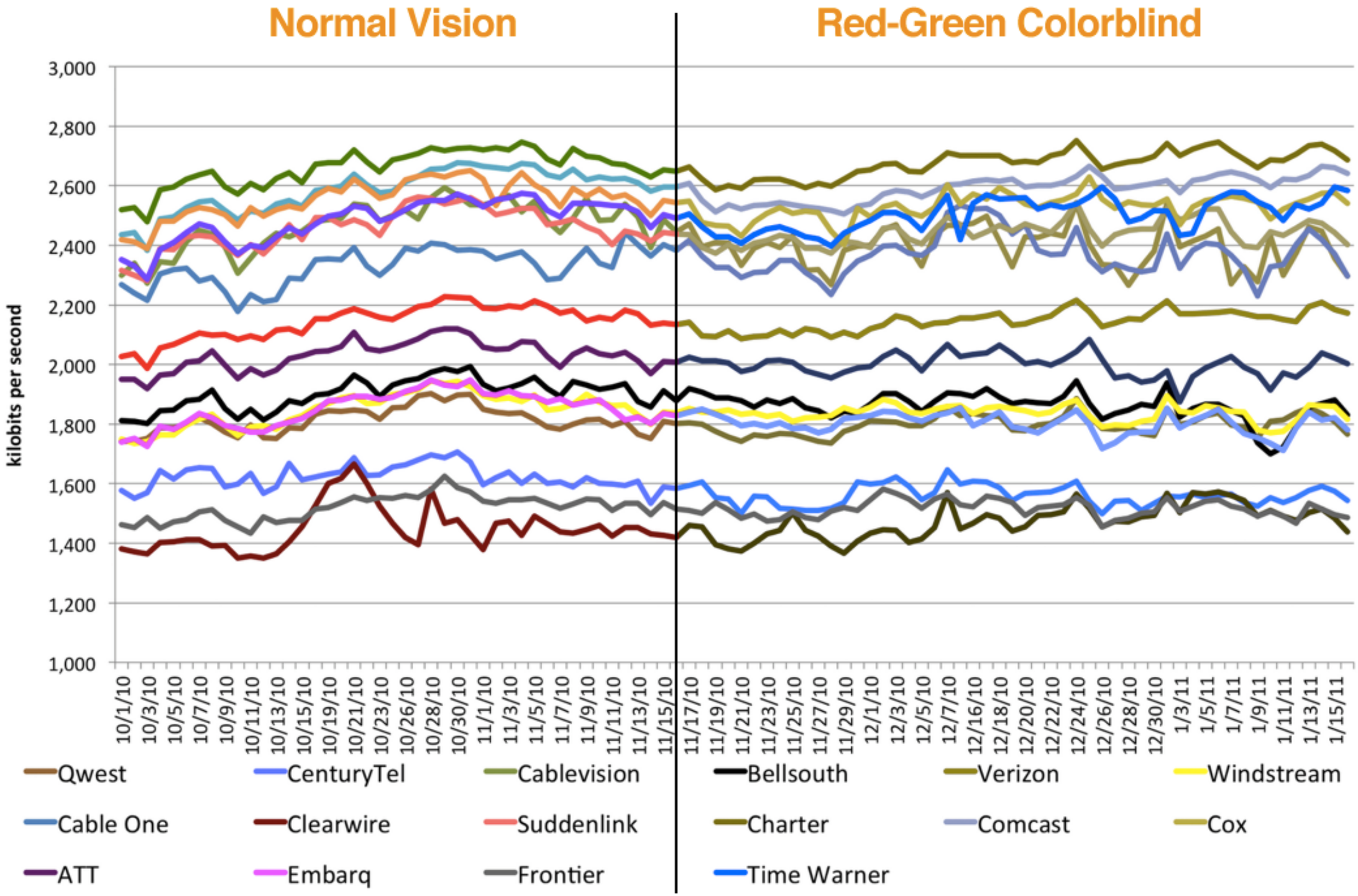


red/green
colour deficit

Tritanopia

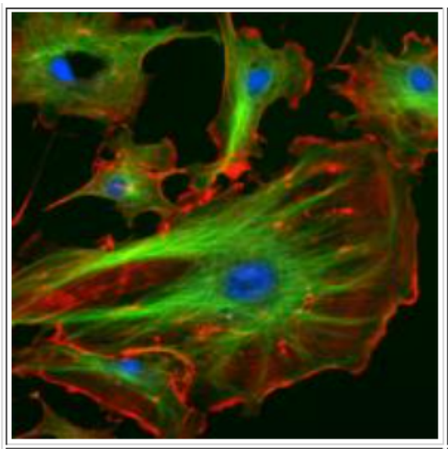


blue/yellow
colour deficit

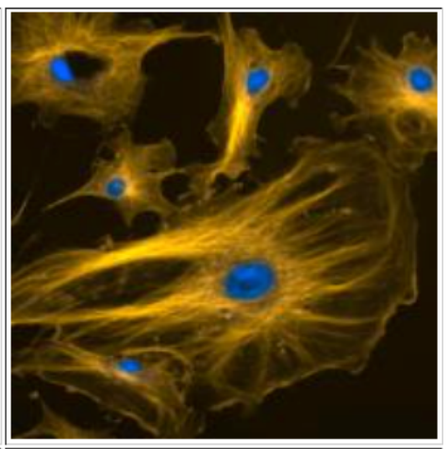

Normal Vision
Red-Green Colorblind
kilobits per second
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
10/1/10
10/3/10
10/5/10
10/7/10
10/9/10
10/11/10
10/13/10
10/15/10
10/19/10
10/21/10
10/23/10
10/26/10
10/28/10
10/30/10
11/1/10
11/3/10
11/5/10
11/7/10
11/9/10
11/11/10
11/13/10
11/15/10
11/17/10
11/19/10
11/21/10
11/23/10
11/25/10
11/27/10
11/29/10
12/1/10
12/3/10
12/5/10
12/7/10
12/16/10
12/18/10
12/20/10
12/22/10
12/24/10
12/26/10
12/28/10
12/30/10
1/3/11
1/5/11
1/7/11
1/9/11
1/11/11
1/13/11
1/15/11
Qwest
CenturyTel
Cablevision
Bellsouth
Verizon
Windstream
Cable One
Clearwire
Suddenlink
Charter
Comcast
Cox
ATT
Embarq
Frontier
Time Warner

VALIDATION TOOLS

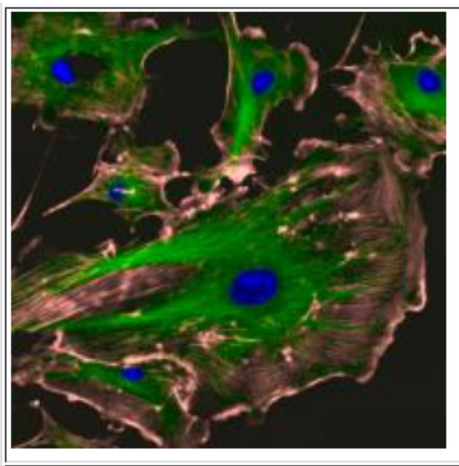
- Tools for checking what your website or image looks like to colour blind people
- Where true colour not as important as information conveyed by colour difference -> Daltonization - map colour variants to colours colourblind people can see



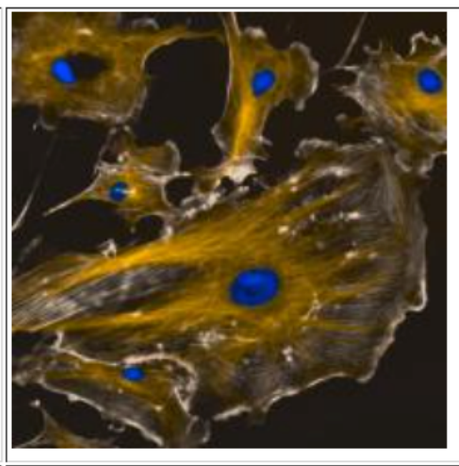
1) Cells labelled with three types of fluorescent markers to show up three different structures.



2) Red/green color blind simulation of fluorescent cell picture.



3) Daltonized version of three-color-labelled fluorescent cells.



4) Dichromat (red/green color blind) simulation of the Daltonized image.

5.3 COLOUR

You should now be able to:

- Be familiar with the anatomy of the human eye and the difference between rod and cone cells
- Describe the difference between Hue, Saturation and Luminosity
- Be aware of design guidelines for use of colour
- Understand the effect of colour blindness on perception of colour and design strategies for colour blind users

SWINBURNE UNIVERSITY OF TECHNOLOGY

COS30045

DATA VISUALISATION

TOPIC 05.4 PSYCHOLOGY – GESTALT

Karola von Baggo

5.4 GESTALT

At the end of this topic you should be able to:

- Identify a range of Gestalt principles
- Consider how to use gestalt principles to manipulate perception of relationships between objects in your design

GESTALT PRINCIPLES

*The whole is **other** than the sum of the parts-* Kurt Koffka

- Perception is more than the sum of the parts

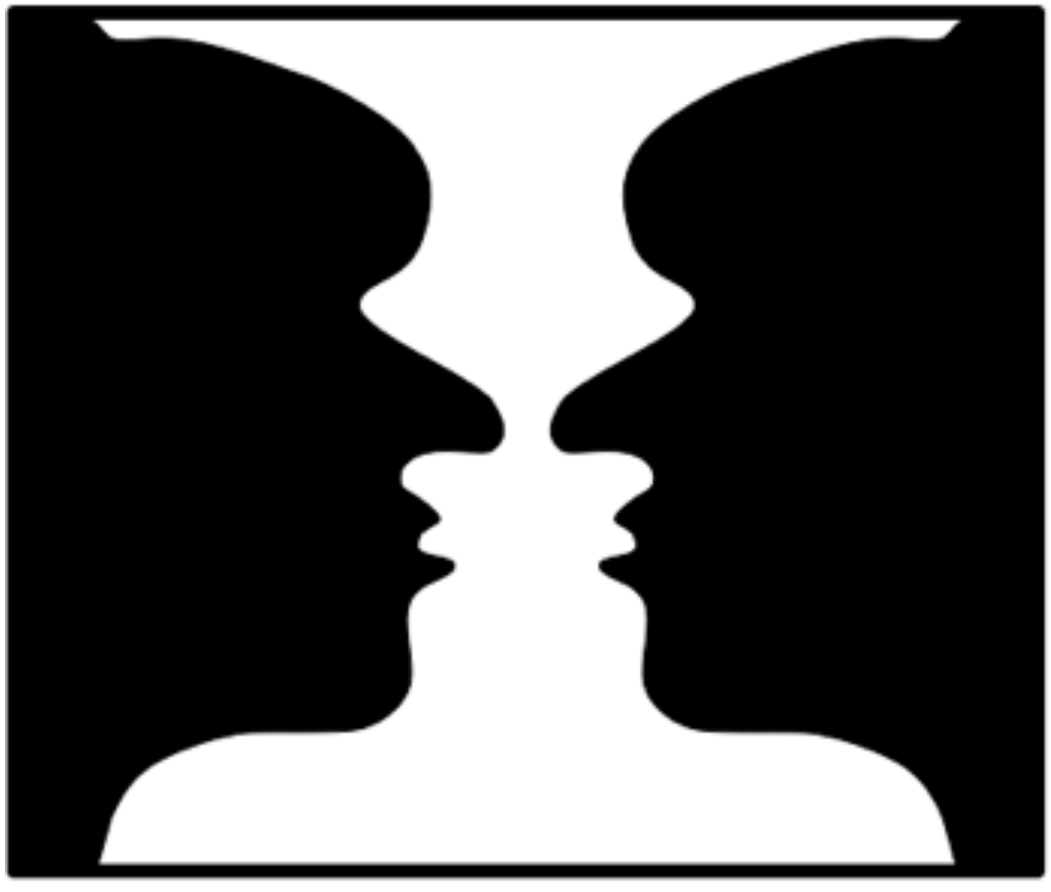


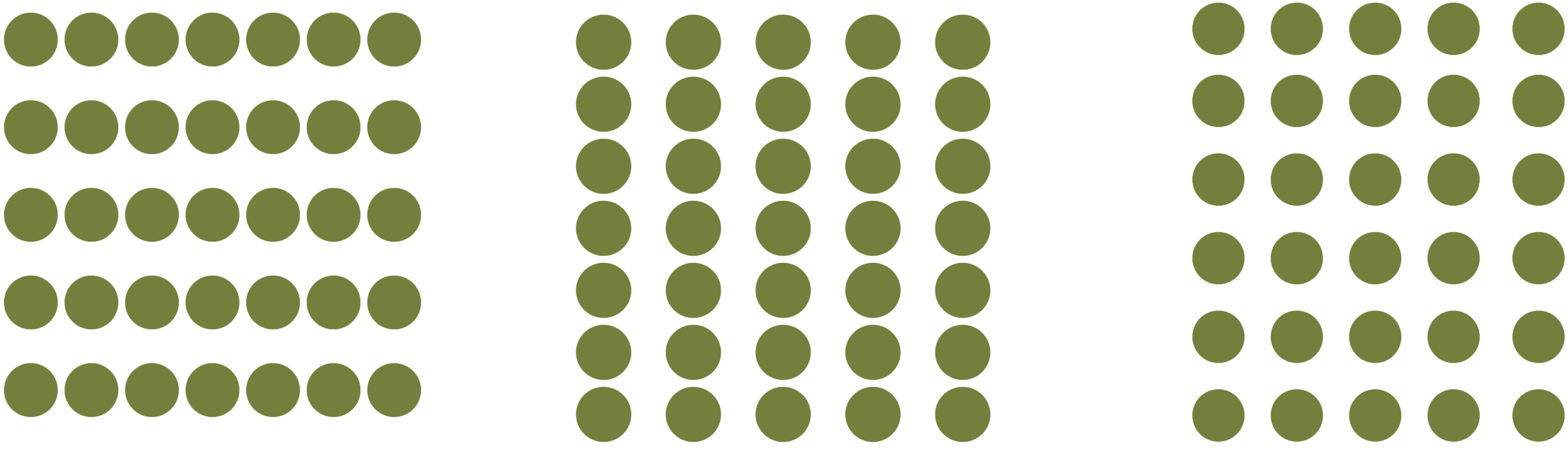
Figure- ground - the object doesn't change, but our perception of it does

Kurt Koffka

Gestalt Psychologist

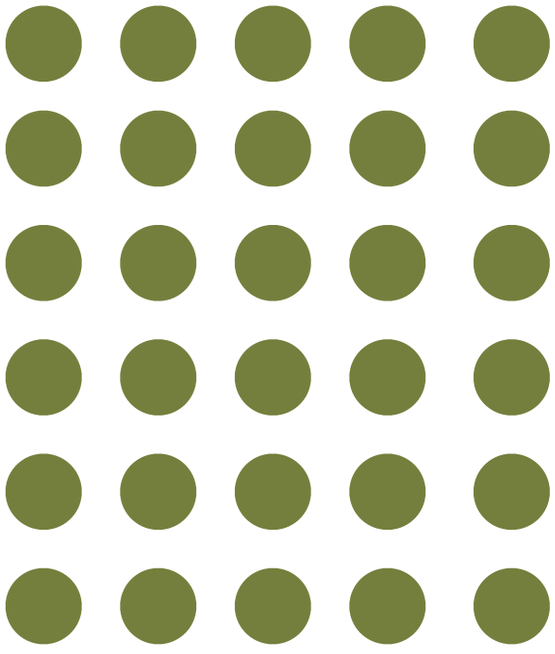
GESTALT: PROXIMITY

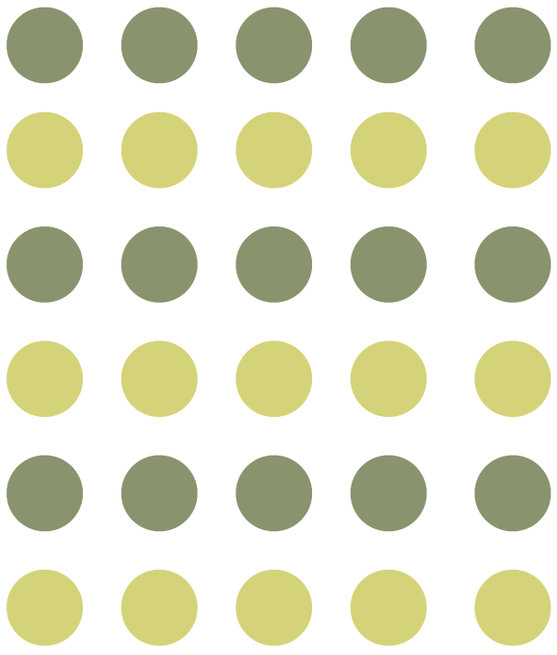
- Objects that are close together are perceived to be more related than those that are far away

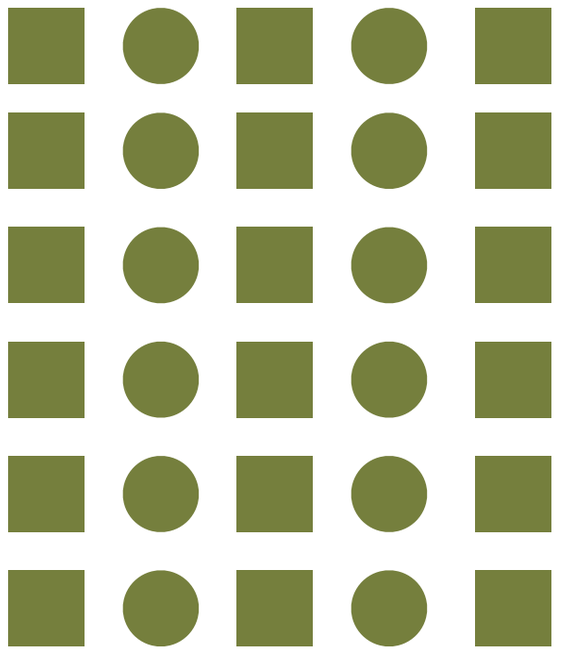


GESTALT: SIMILARITY

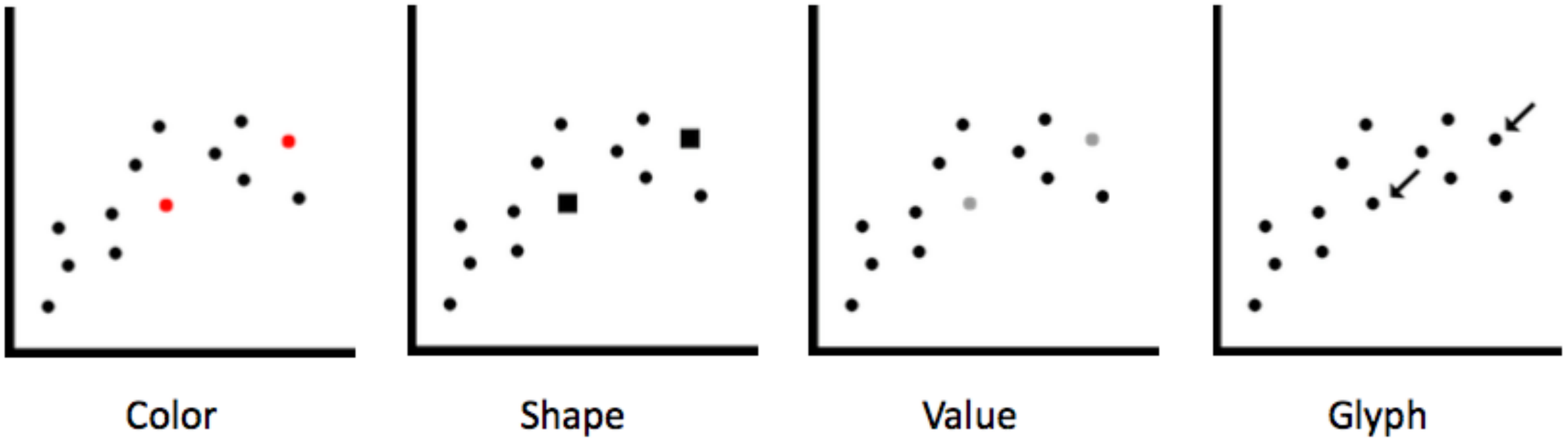
- Objects that share characteristics are perceived to be related than those that don’t





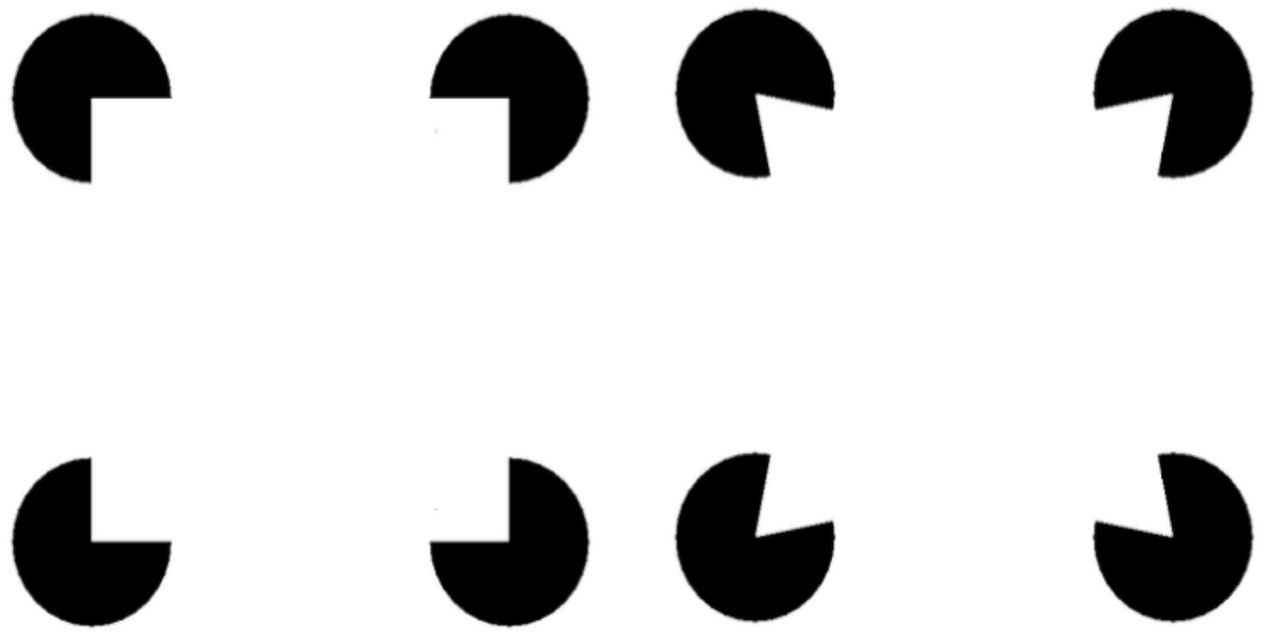


GESTALT: SIMILARITY



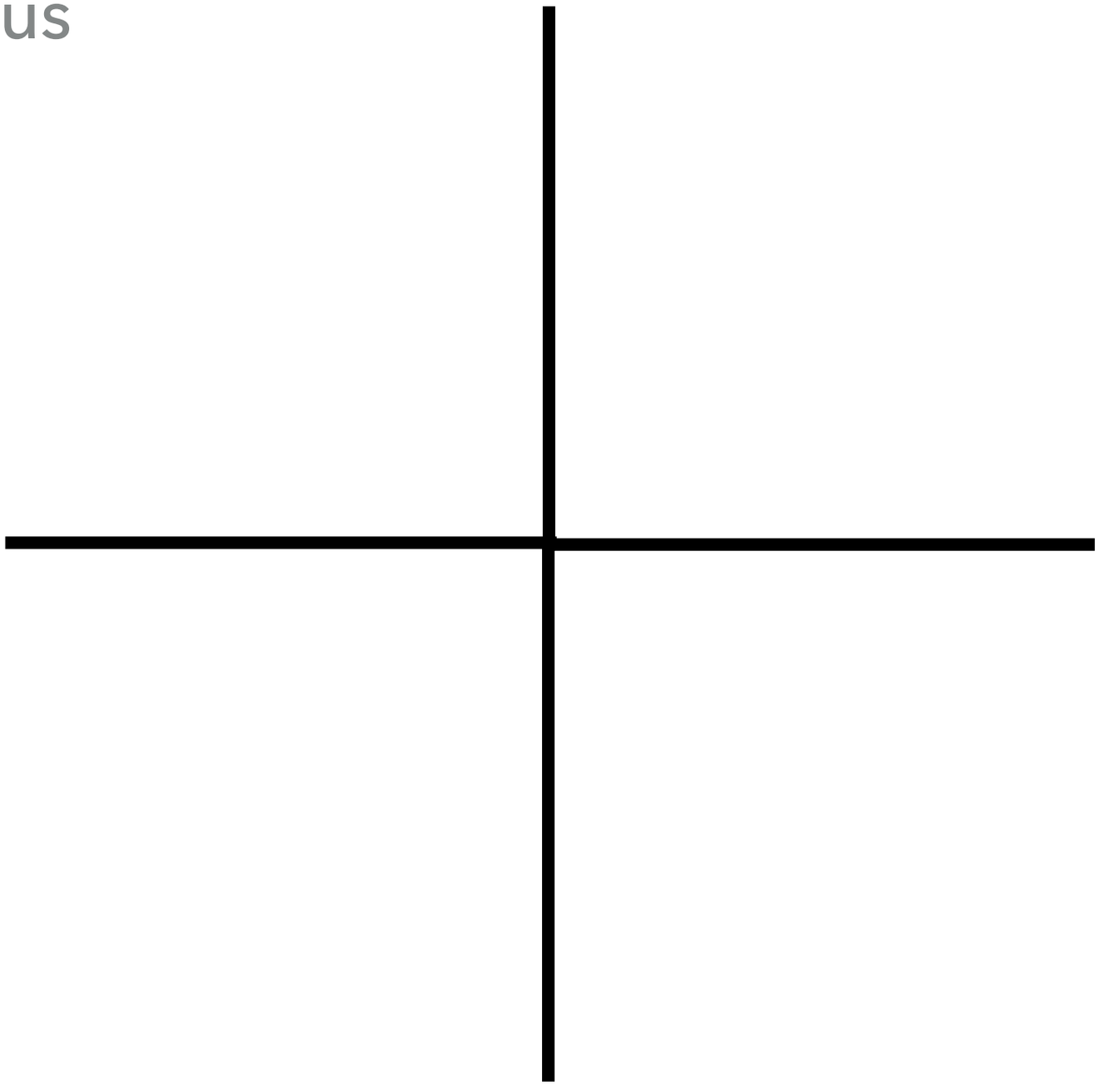
GESTALT: CLOSURE

- Closure of gaps to perceive a familiar form

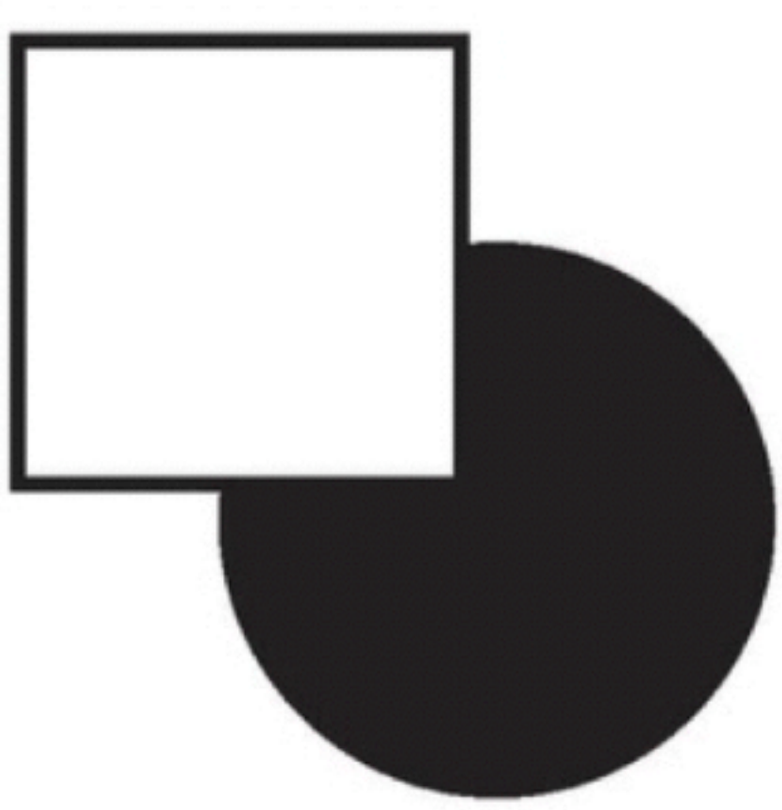


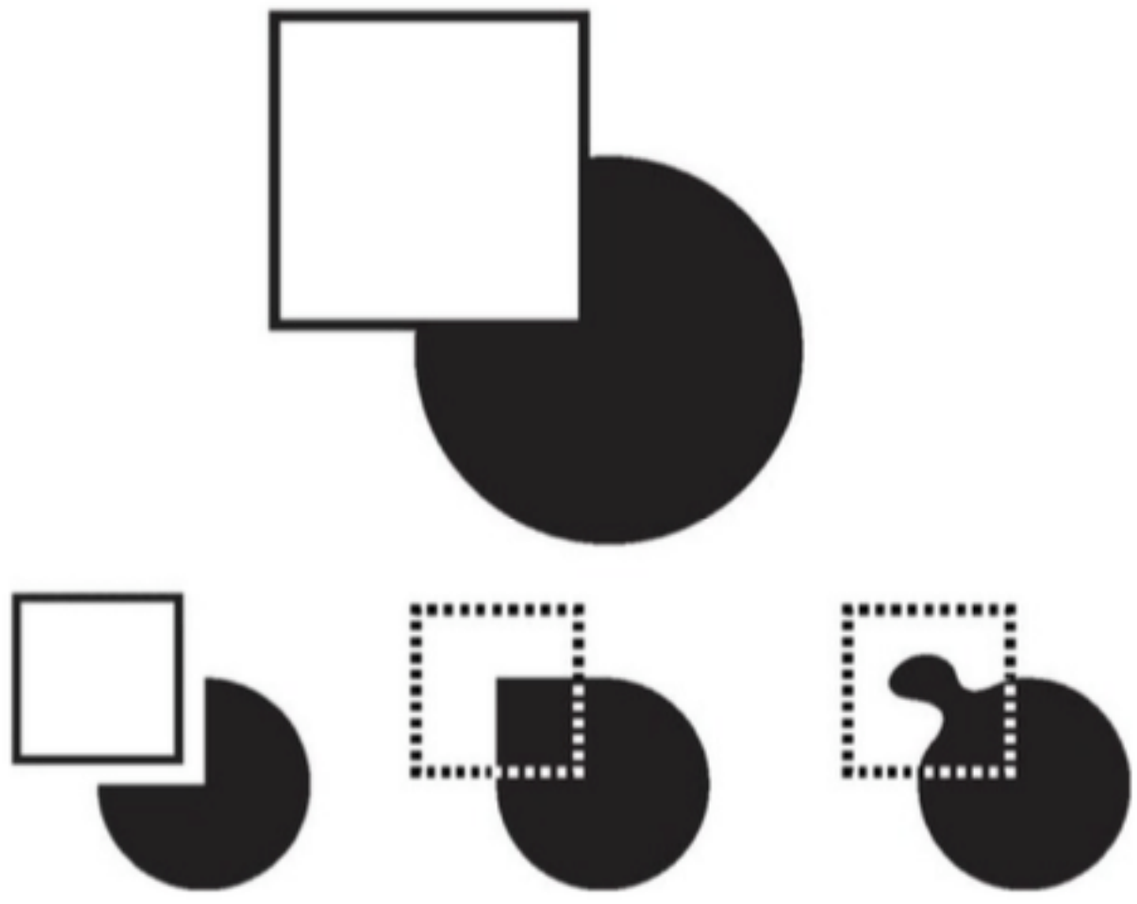
GESTALT: CONTINUITY

- Tendency to perceive objects as continuous rather than discontinuous

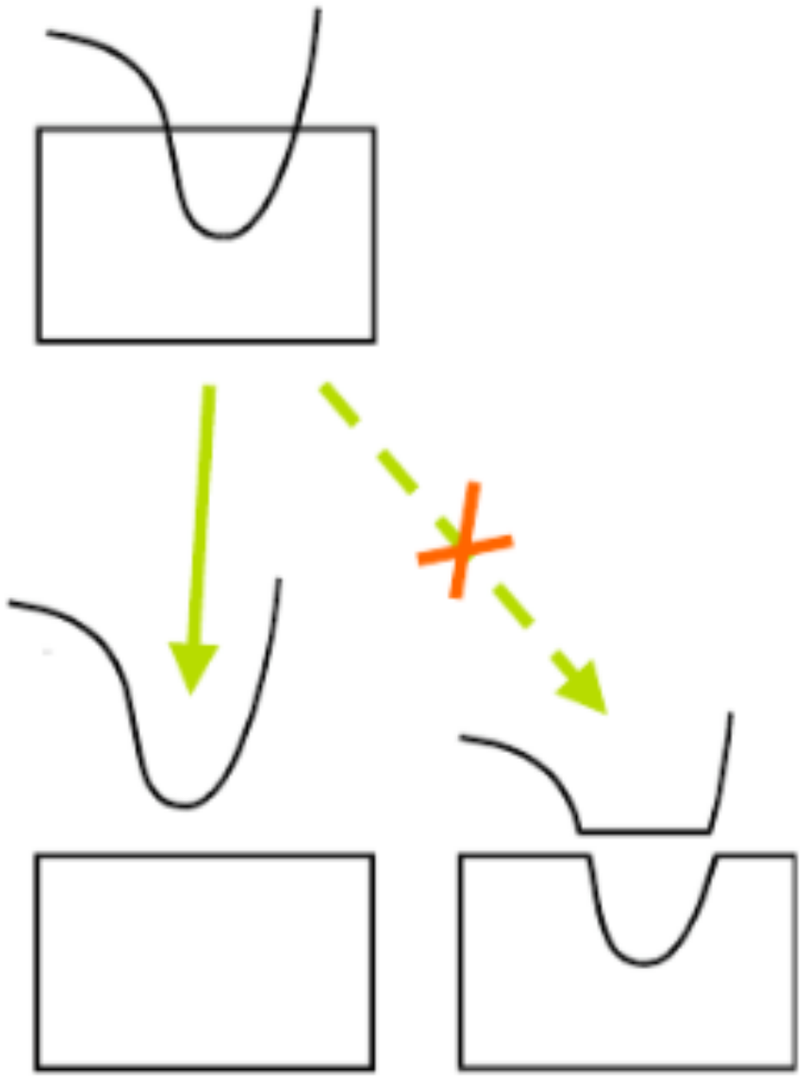


GESTALT: CONTINUITY



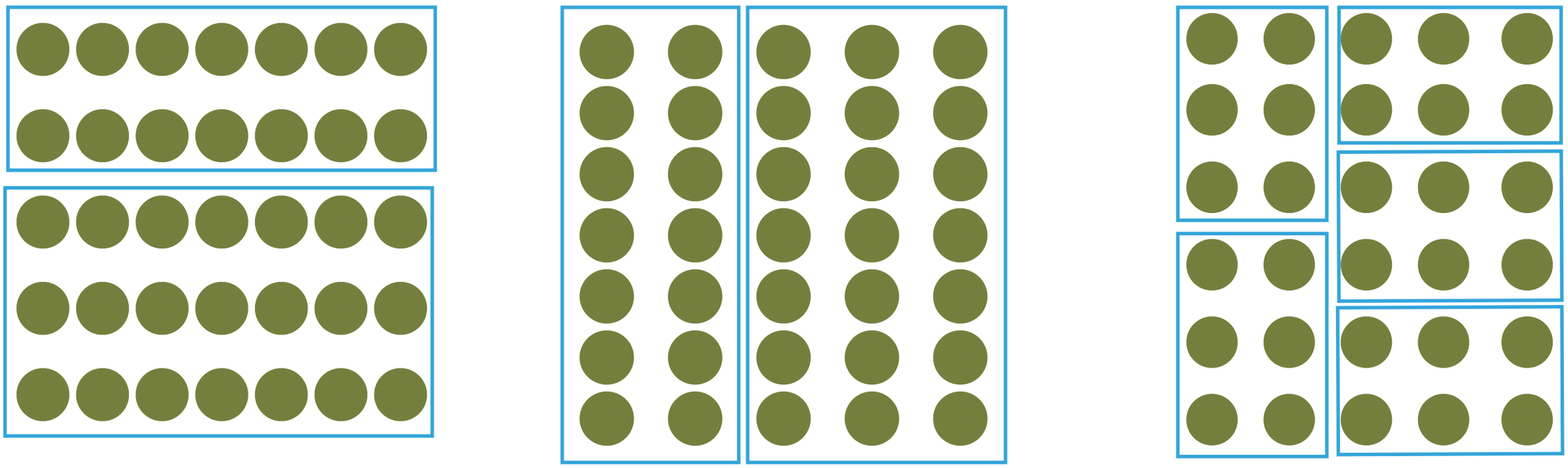


GESTALT: CONTINUITY

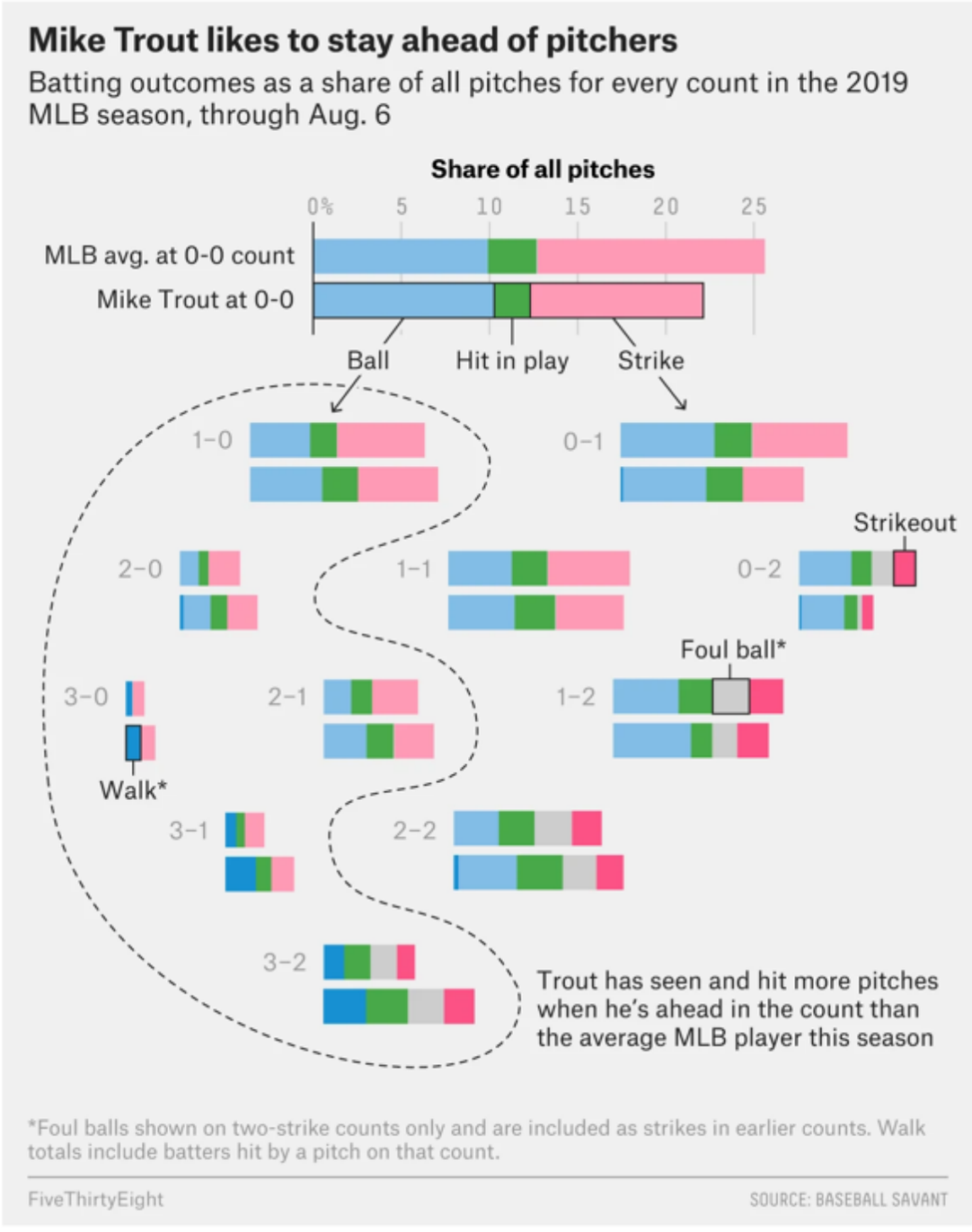


GESTALT: ENCLOSURE (COMMON REGION)

- Objects that are perceived to be in a group if they share an area with a clearly defined boundary



DESIGN PRINCIPLES IN ACTION



DESIGN PRINCIPLES IN ACTION

How many people might the census miss?

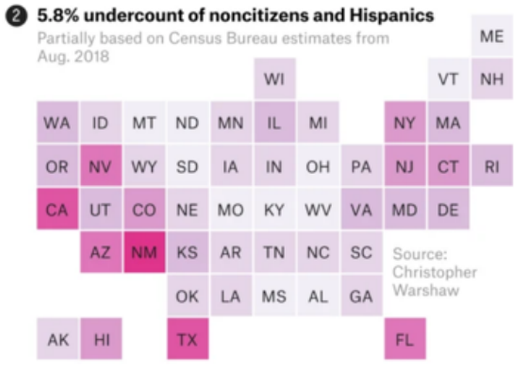
Estimated share of the projected population that would not be counted in the 2020 census if a citizenship question is added, based on five scenarios from researchers

1 5.8% undercount of noncitizens

Based on Census Bureau estimates from Aug. 2018

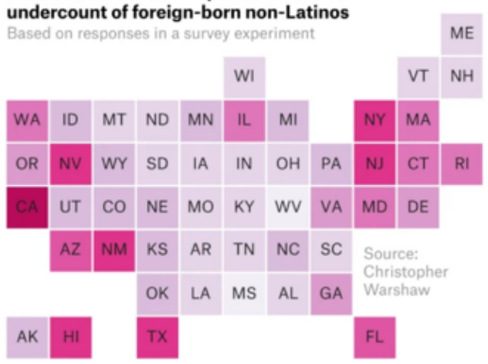
2 5.8% undercount of noncitizens and Hispanics

Partially based on Census Bureau estimates from Aug. 2018



3 5.9% undercount of Hispanics and 11.3% undercount of foreign-born non-Latinos

Based on responses in a survey experiment

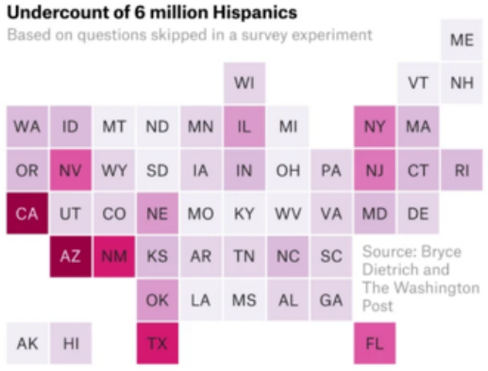


4 Poorly conducted census and a 10% undercount of households with undocumented immigrants

Partially based on the undercount in the 1990 census

5 Undercount of 6 million Hispanics

Based on questions skipped in a survey experiment

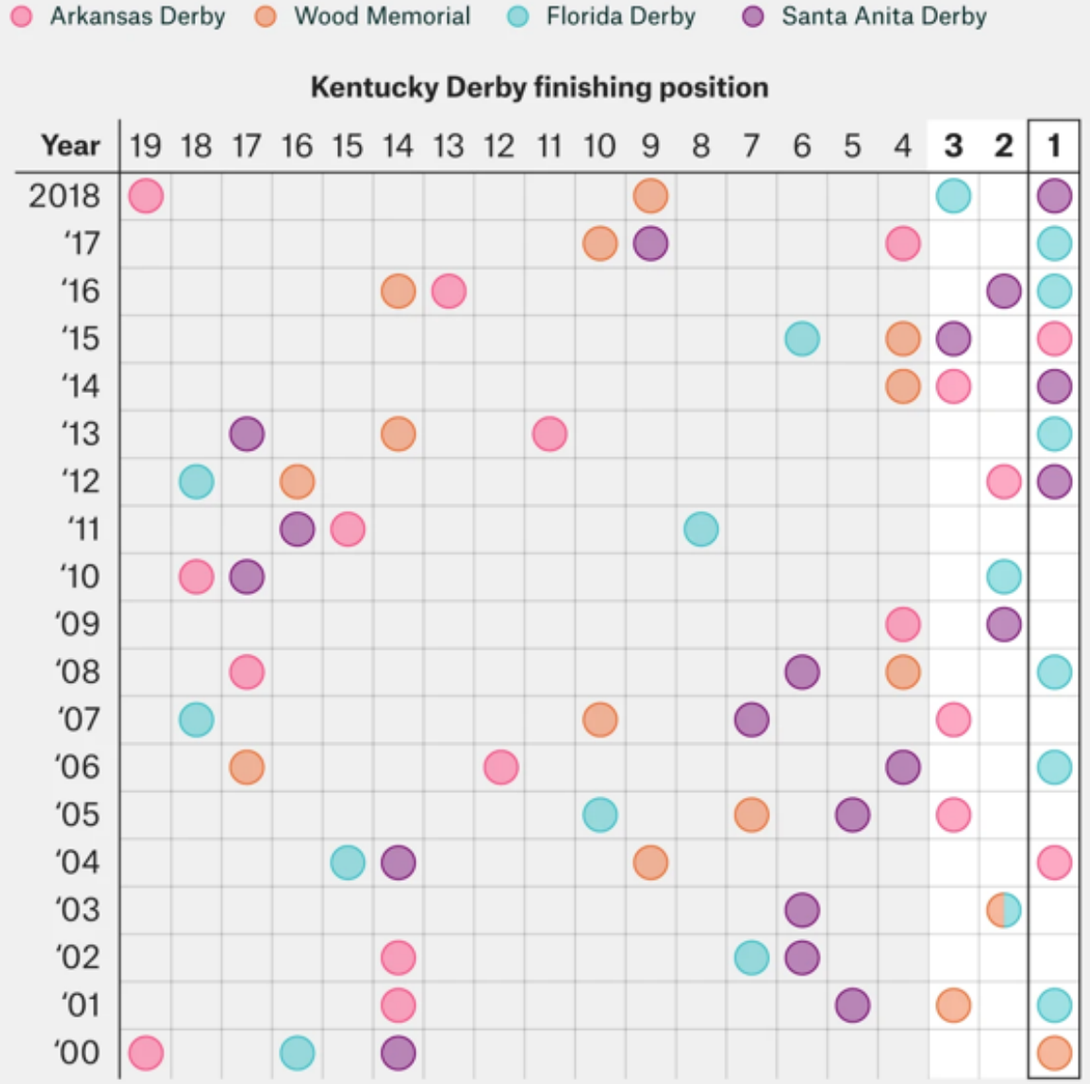


Scenario 3 is based on a survey experiment that tested how much less likely respondents were to say they would return the census form if the citizenship question was included. Scenario 5 is based on a survey experiment that tested how much less likely respondents were to respond to individual questions on the form if the citizenship question was included.

FiveThirtyEight

The races that pick Derby favorites

Finishing position in the Kentucky Derby of the winner of four major prep races, by year

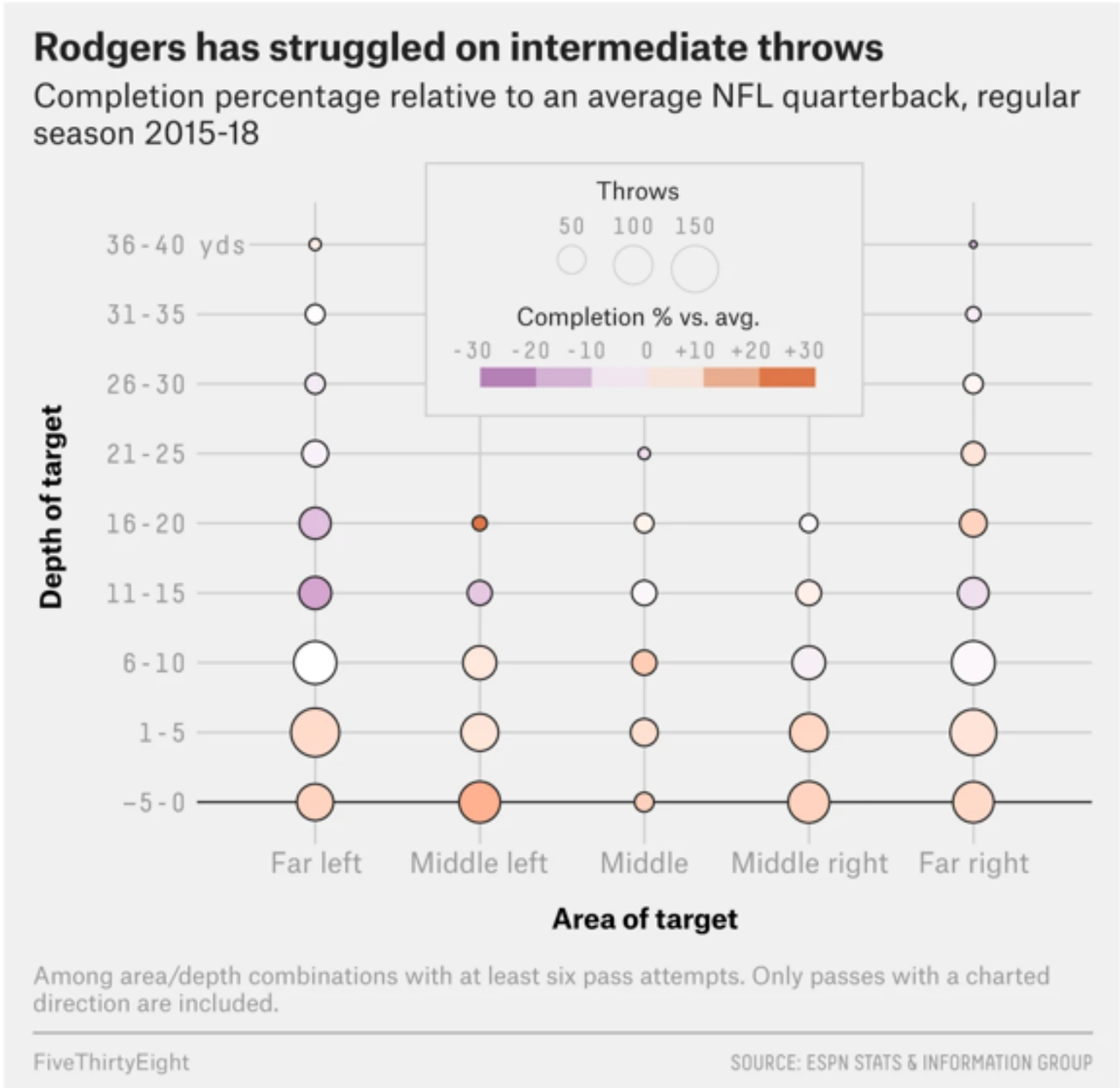


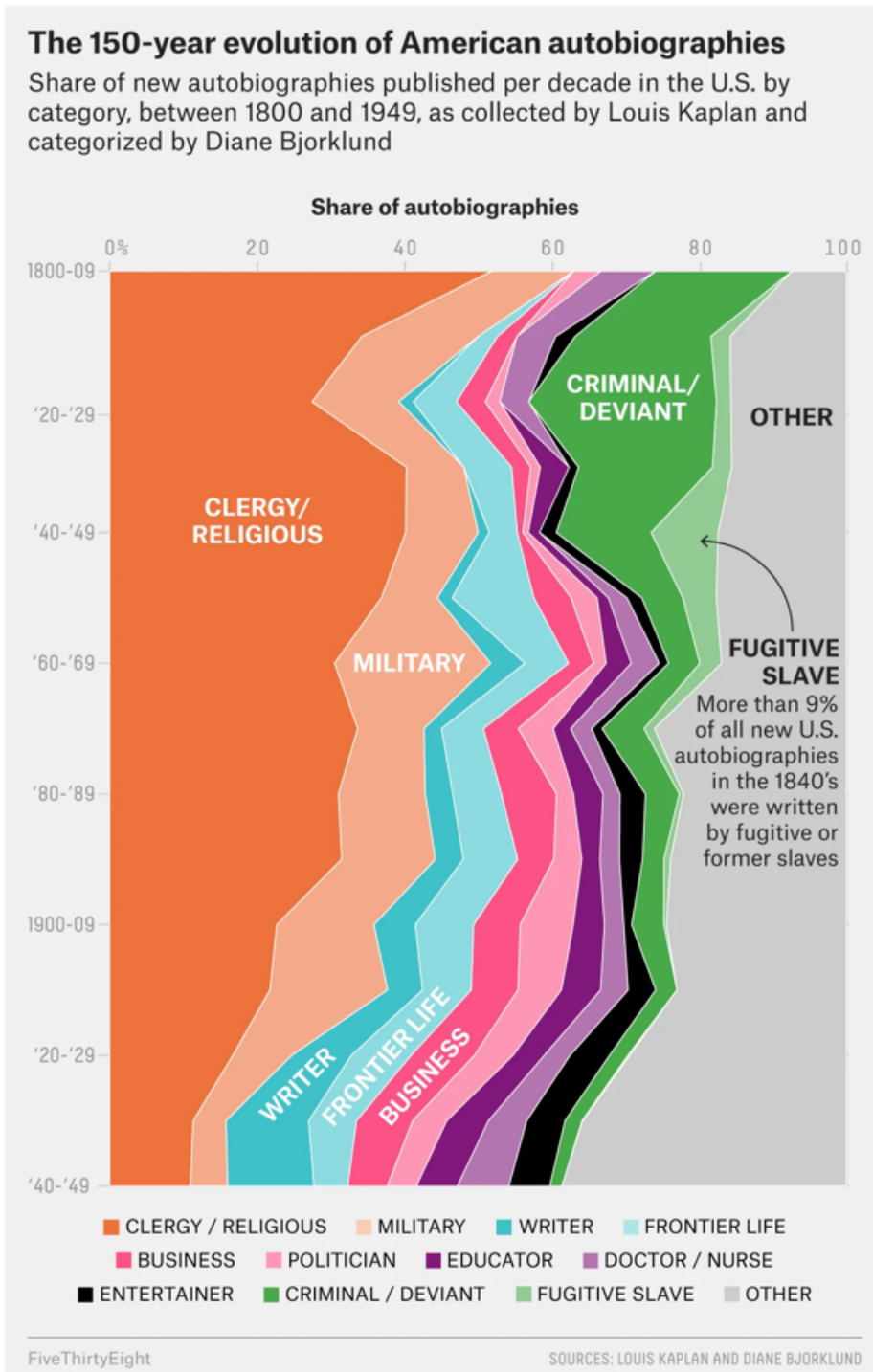
In 2003, Empire Maker won the Wood Memorial and the Florida Derby

FiveThirtyEight SOURCE: HORSE RACING NATION

https://fivethirtyeight.com/features/the-56-best-and-weirdest-charts-we-made-in-2019/

DESIGN PRINCIPLES IN ACTION





5.4 GESTALT

You should now be able to:

- Be aware of a range of Gestalt principles
- Consider how to use gestalt principles to manipulate perception of relationships between objects in your design

We see what we look for, not what we look at.

Ulrich Neisser

Cognitive Psychologist