Visual Analytics

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8 – Perceptual issues

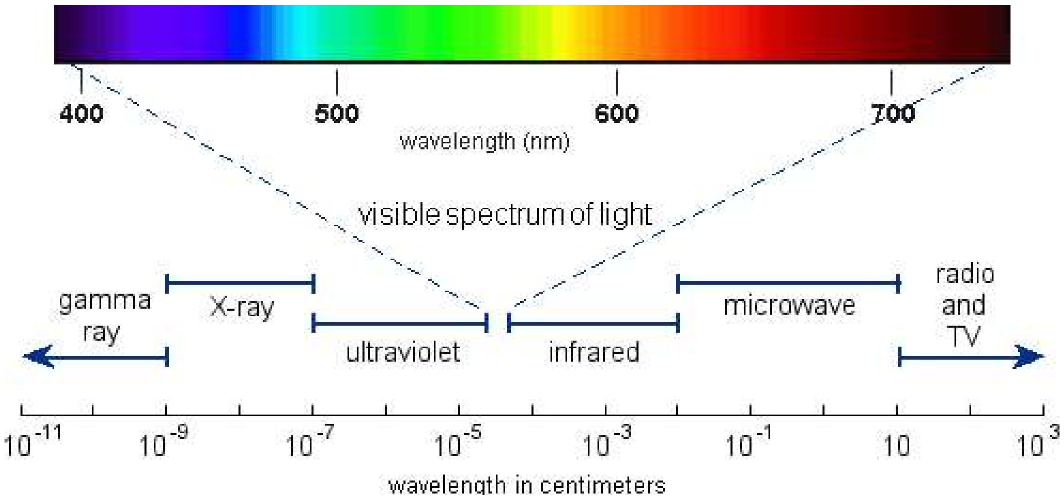
Thanks to Colin Ware, John Stasko, Robert Spence, Ross Ihaka, Marti Hearst, Kent Wittemburg

Outline

- Visible Light & Eyes
- Luminance
- Hue
- Brightness
- Lightness
- Chromaticity
- Saturation
- Trichromacy and Color Opponent Theory
- Color & Information Visualization
- Pre-attentive processing

Visible light and pure colors

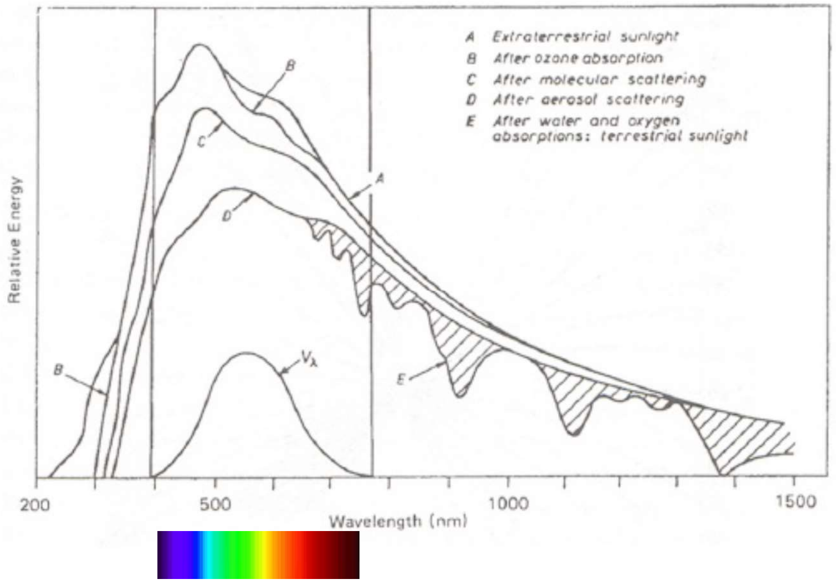
- Let's start with the basic stuff : the visible light (for human beings)
- It is a tiny part of the whole spectrum
- The usual unit is the nanometer, 10^{-9} m, and the visible range is from 400 (violet) to 700 nm (red)
- Light consisting of a single wavelength is monochromatic light, which looks to the eye as a pure color

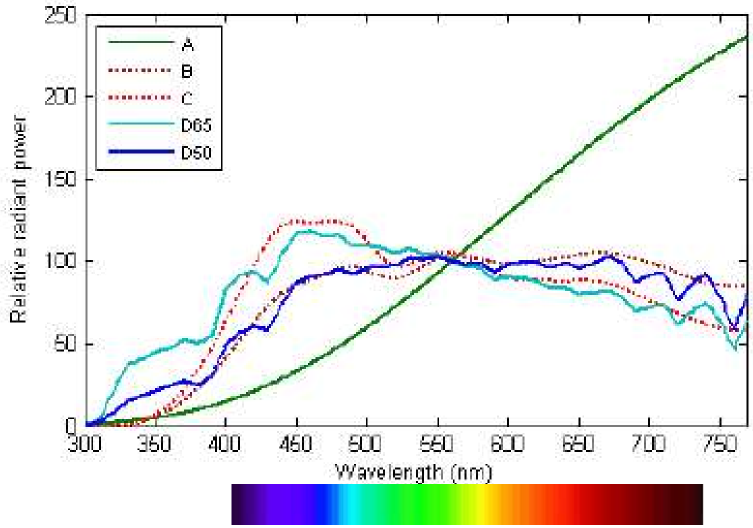


Color	Wavelength interval (nm)
Violet	$\sim$ 400–440
Blue	$\sim$ 440–500
Green	$\sim$ 500–570
Yellow	$\sim$ 570–590
Orange	$\sim$ 590–610
Red	$\sim$ 610–700

Light sources

- Usual light sources are not monochromatic and are characterized by their spectral power distribution



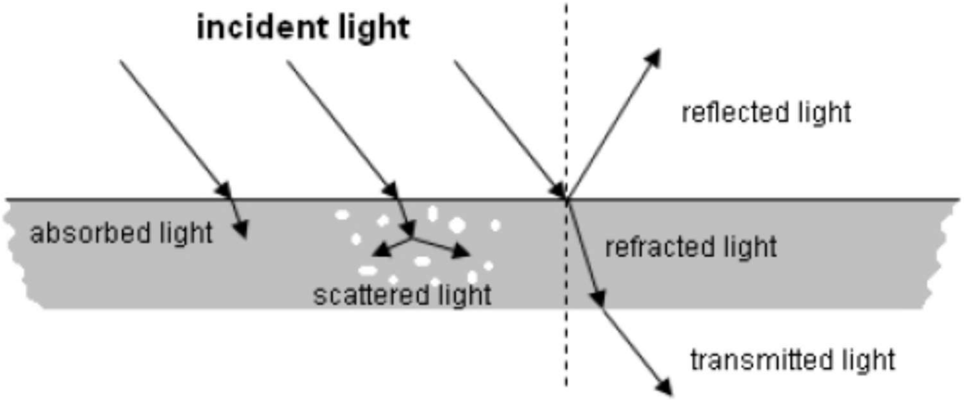


Sun spectral power distributions

A Incandescent light source
D50 and D65 statistical representations of average day light
B standard CIE definition of direct sunlight
C standard CIE definition of average daylight

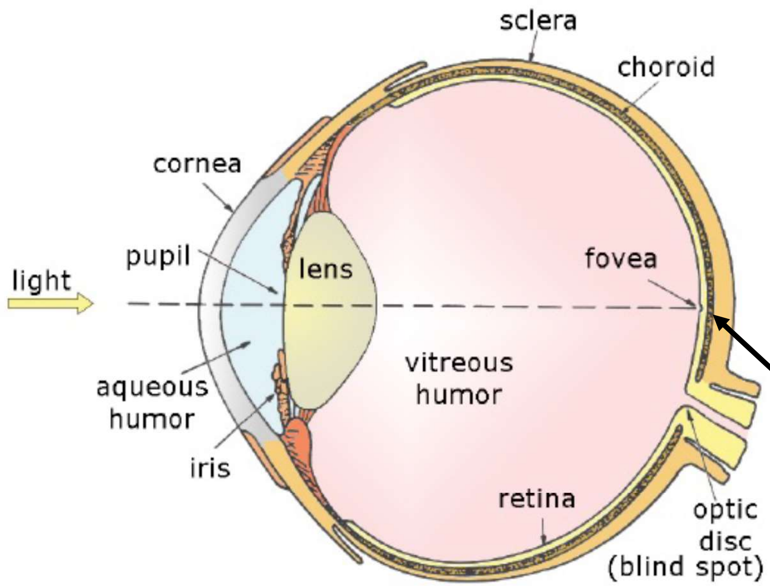
Light, objects, and perceived colors

- Perceived color of an object depends on the light source, the properties of visual system, and how light interacts with the object
- Light can be
  - Refracted and then transmitted through it (if the object is transparent)
  - Absorbed by it (transforming in to heat)
  - Scattered inside the object if it is not completely transparent, because of the collision of photons with the molecules of the object (like sunlight scattering in the atmosphere)
  - Reflected
- Color = reflected light (same of light source) + scattered (depends on the object)



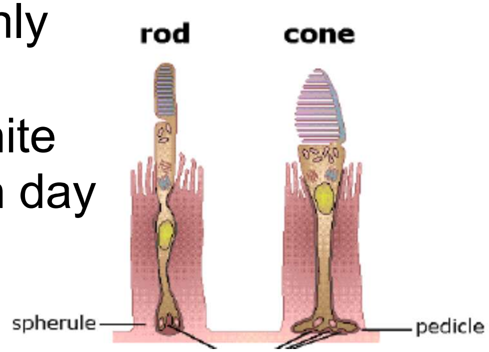
The eye

- it is like a camera (focal length = 17 mm)
  - or is a camera like the eye?
- high resolution only in the very little fovea area
- two basic sensors **rods** (bastoncelli) and **cones** (coni)

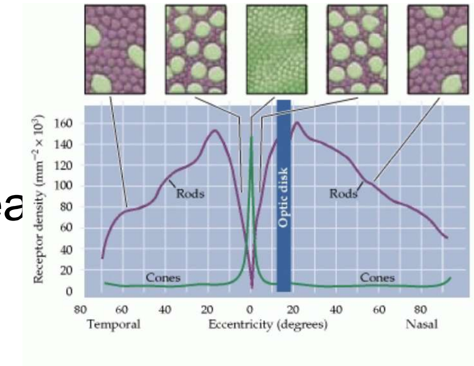


Rods work only
in low light
Black and white
Disabled with day
light

Cones work with high light
Photopic vision
Colors

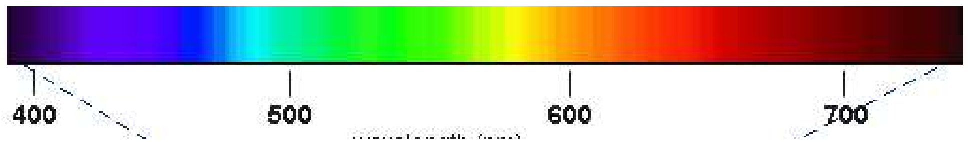


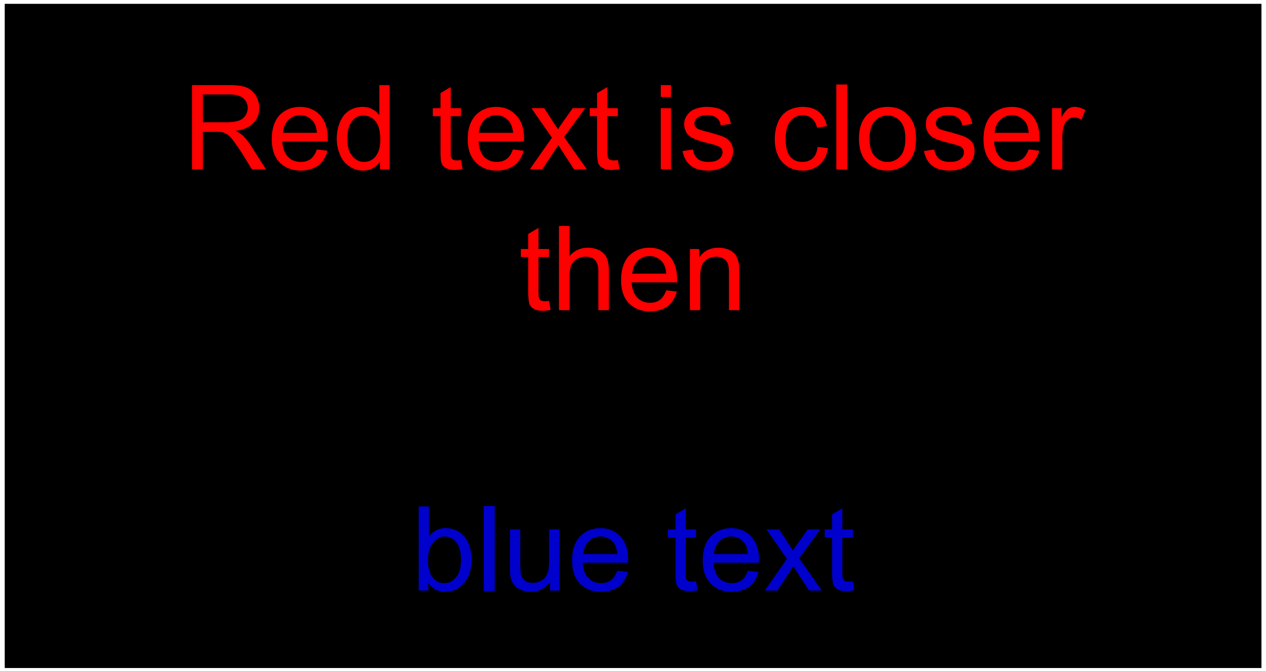
About 100.000
cones in the fovea
180 cones per
degree



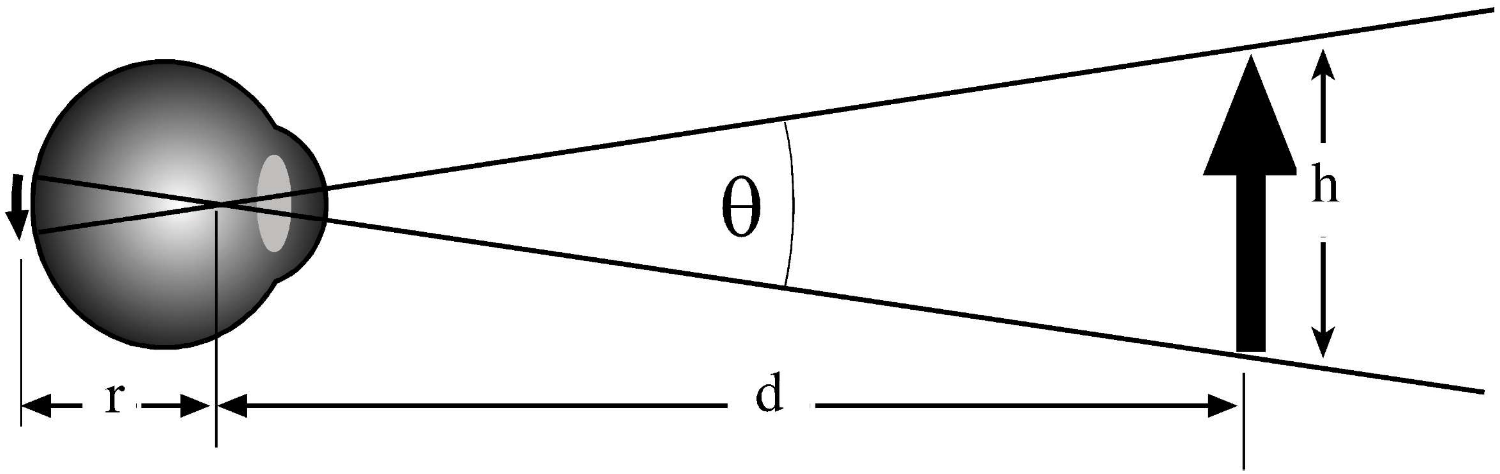
Chromatic aberration

- Different wavelengths are focused at different distance
  - diffraction depends on wavelength
- If we use in the same image two far pure colors the eye is not able to focus both of them





Visual angle (degrees, minutes, seconds)

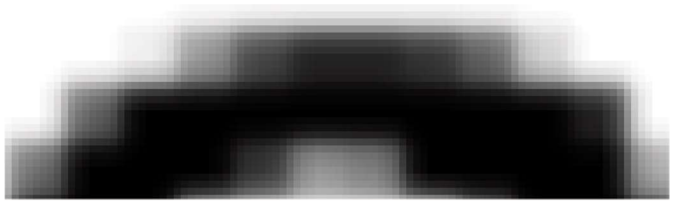


θ=2 arctan (h/2d)

1 cm tall object viewed at 57 cm has **1 degree** angle
57 cm is a good approximation of the distance at which we view a computer monitor
That roughly corresponds to the fovea visual angle

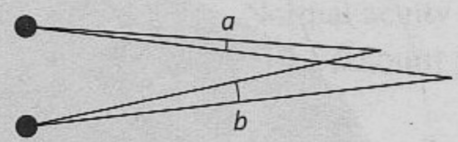
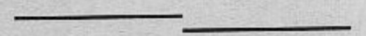
Simple acuity

- Acuity : ability to see details (pixels should be below our acuity)

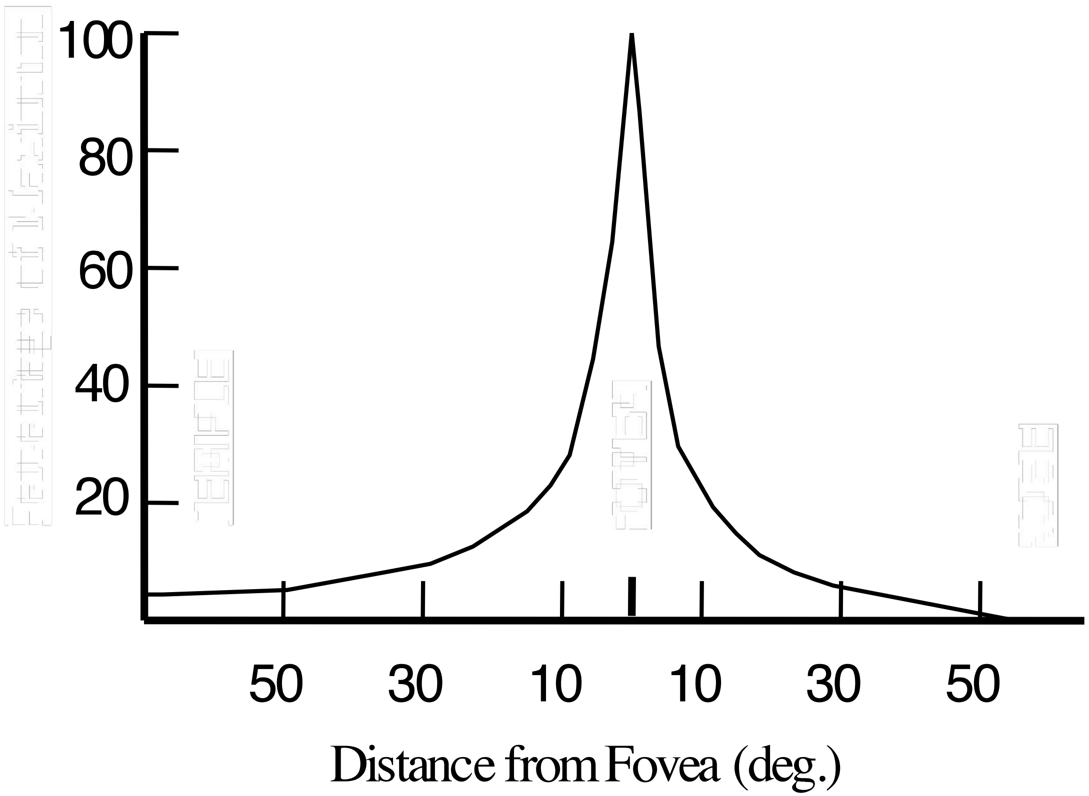


degrees, minutes, seconds

°, ', "

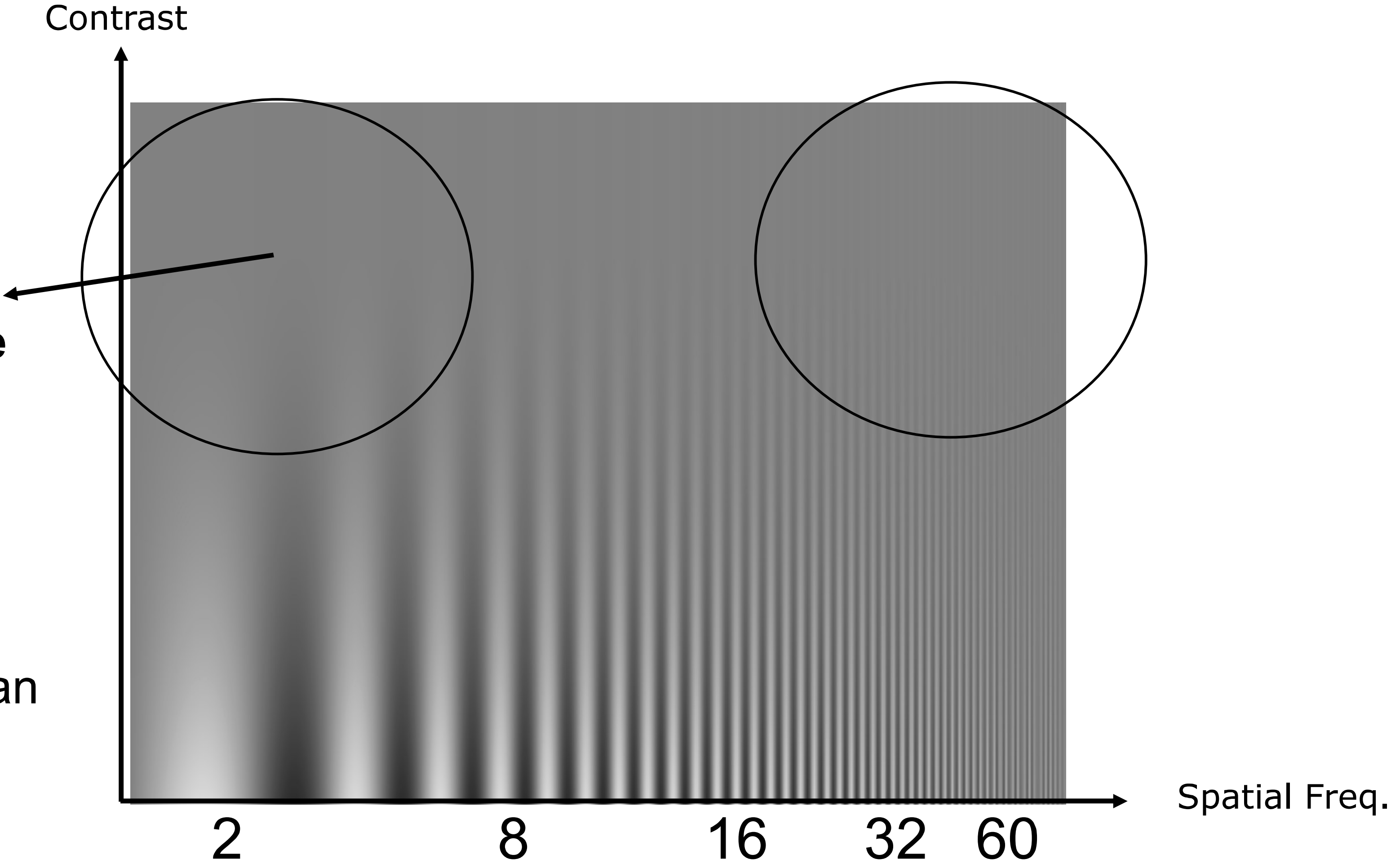
Point acuity (1 minute of arc): The ability to resolve two distinct point targets.	
Grating acuity (1–2 minutes of arc): The ability to distinguish a pattern of bright and dark bars from a uniform gray patch.	
Letter acuity (5 minutes of arc): The ability to resolve letters. The Snellen eye chart is a standard way of measuring this ability. 20/20 vision means that a 5-minute letter target can be seen 90% of the time.	E
Stereo acuity (10 seconds of arc): The ability to resolve objects in depth. The acuity is measured as the difference between two angles (*a* and *b*) for a just-detectable depth difference.	
Vernier acuity (10 seconds of arc): The ability to see if two line segments are collinear.	

Acuity falls off rapidly from fovea



Spatial contrast sensitivity
how we do perceive luminance differences

This allows for producing monitors with high **difference in luminance** that is not perceived (center till 30 % brighter than borders)



We need high contrast for **both** low and high frequencies

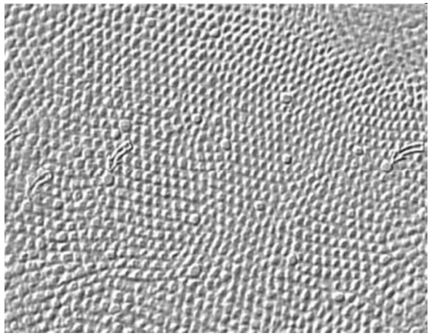
The optimal display

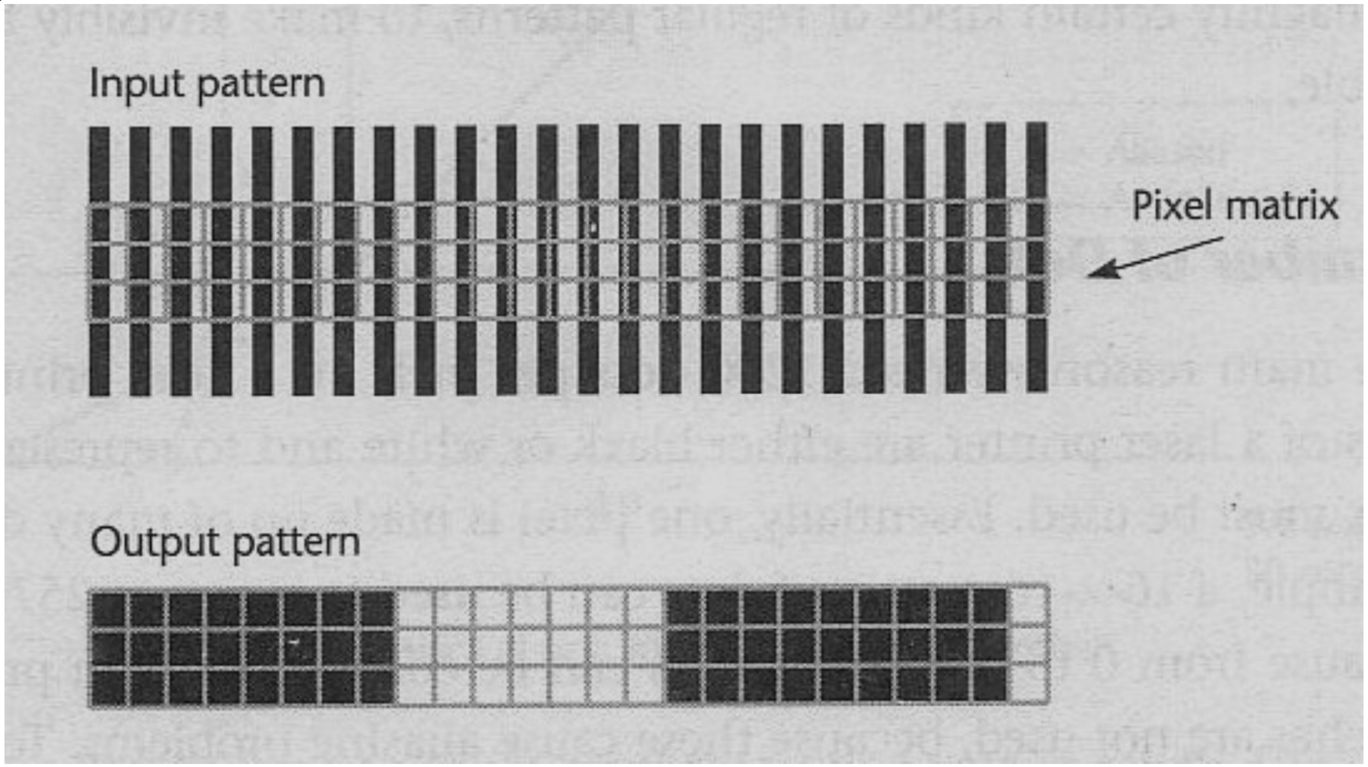
- A modern display has about 40 pixels per cm (~100 dpi)
- 1 cm at 57 cm of view corresponds to 1 degree
- The fovea is equipped with 180 cones per degree and we are are able to distinguish about 60 cycles per degree
- And (sampling theory) we need to sample at twice so, 120 pixels per cm should be enough (~300 dpi)
- A monitor should be be about 4000x4000
- We are still a bit far away (2,560×1,600) from a monitor as good as our eyes
  - But the iphone 4 with its Retina display?
    - 960x640 8x5cm → 326 dpi…. But from 30 cm you need 600/dpi…
    - With 300 dpi you just makes pixels not distinguishable (no so bad…)
  - Mac Pro retina? 220 dpi...
- So why we have laser printers capable of 1200 dots per inch (460 dots per centimeter)?

1200 dpi laser printer ?

- **Aliasing.** From a fundamental theorem of signal transmission we know that we have to sample a signal at least twice the highest frequency
- Aliasing occurs when we sample a **regular** pattern by another **regular** pattern at different frequency

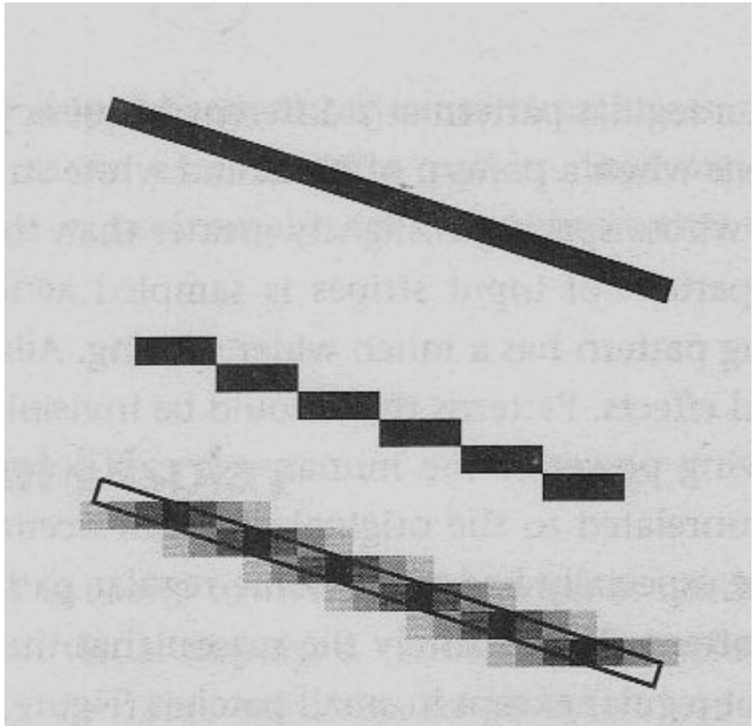
Cones in the fovea follow **non regular** patterns

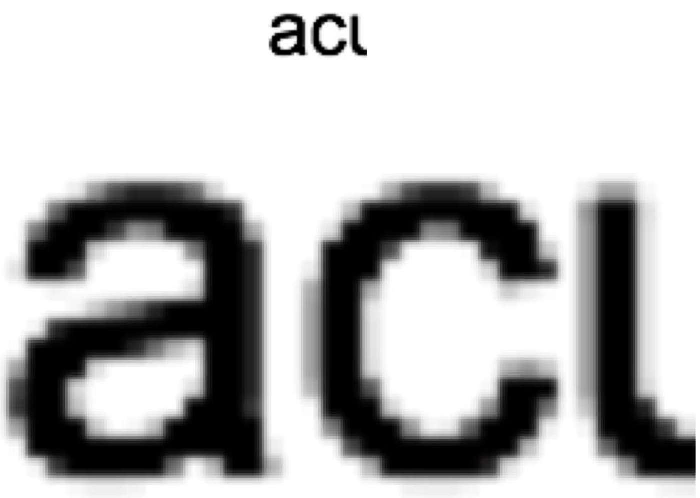




1200 dpi laser printer can help

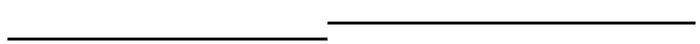
- **Antialiasing** Computing the average of the light pattern can mitigate the problem in a cost-effective way than simply increasing the pixel number
- It requires additional computation that further increases with colors





Superacuity and displays

- Vernier acuity applies also at monitor lines
- Appropriate **antialising** techniques result in a Vernier acuity better than pixel resolution !



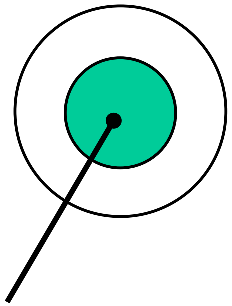
Vernier Super Acuity = 15 sec vs 30 sec pixel separation

1200 dpi laser needed for gray !

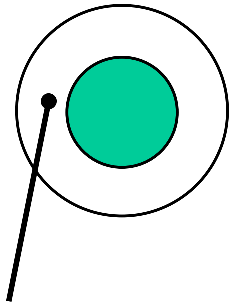
- The dots of a laser print are either black or white
- So a pixel is made of several dots:
  - A 16x16 dots matrix can implement a pixel with 256 gray levels
- Square pixels are not used (aliasing again)
- Patterns of dots are randomized
- A 1200 dpi laser print is 1200 only for black & white
- For a gray image it scales to about 120 dpi or less

Back to receptive fields

- **Receptive field** Disregarding several details we can concentrate on the visual area that responds to the light intensity, i.e., luminance



If the light is on the center
the corresponding neuronal
activity **increases**



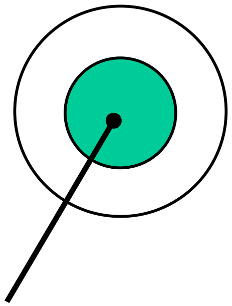
If the light is on the border the corresponding neuronal activity **decreases**
The receptive field is inhibited

Luminance ?

- The jargon used by people dealing with light and color is very complex and often used in a confused way
  - It refer to **perceived** stimuli
- The CIE (Commission Internationale de L'Eclarage) has published in 2011 the Standard CIE S 017/E:2011 ILV: International Lighting Vocabulary (www.cie.co.at/publications/international-lighting-vocabulary)
  - It contains **1448** entries ! → http://eilv.cie.co.at/termlist
- We will see a formal definition of luminance
- Now it is enough to say that it is a a **physical value** (measurable using a photometer)

Back to receptive fields

- **Receptive field** Disregarding several details we can concentrate on the visual area that responds to the light intensity, i.e., luminance



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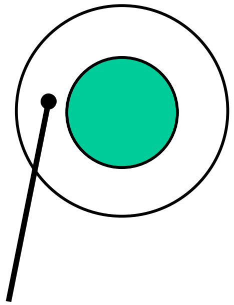
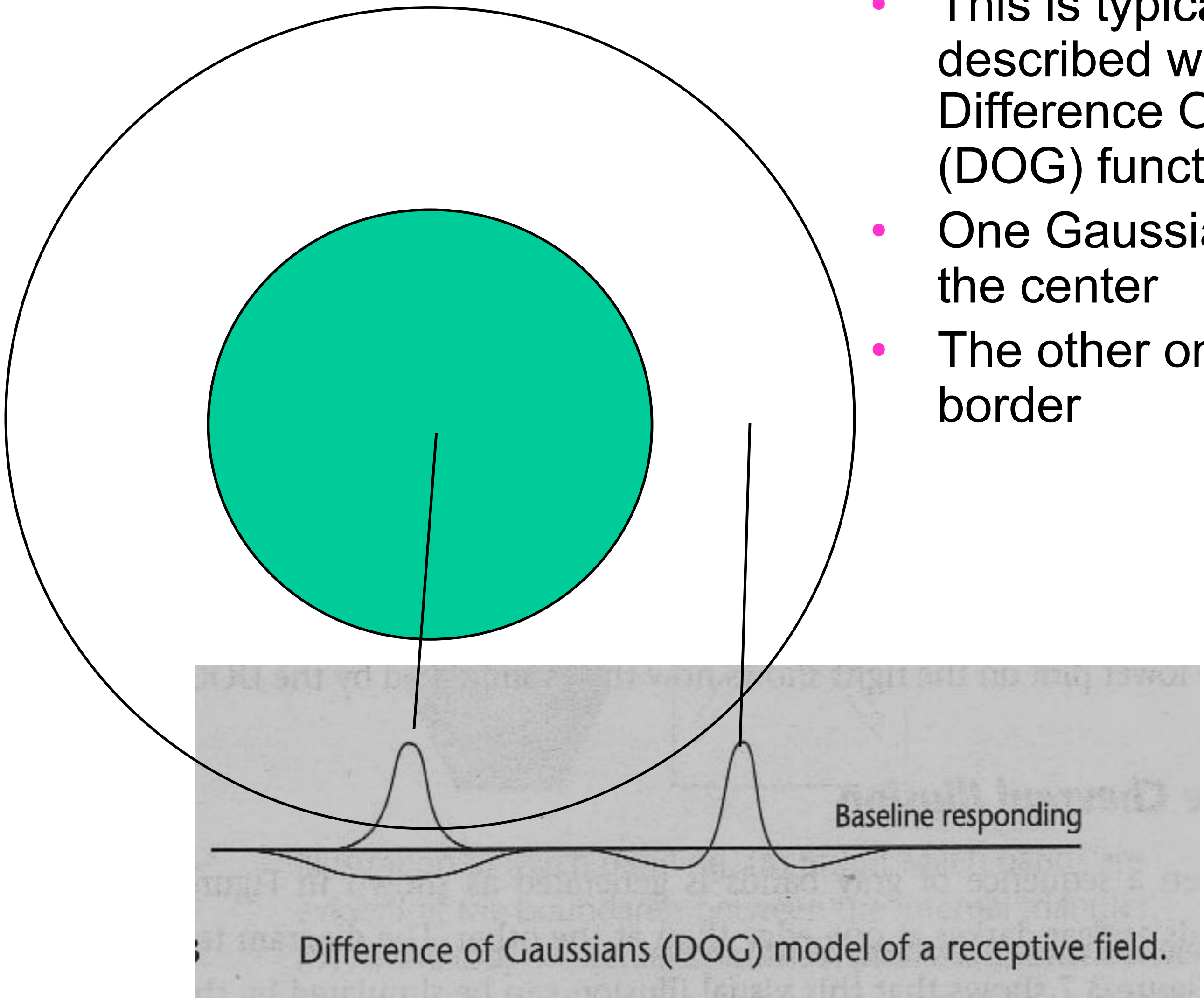


If the light is on the border the corresponding neuronal activity **decreases**
The receptive field is inhibited

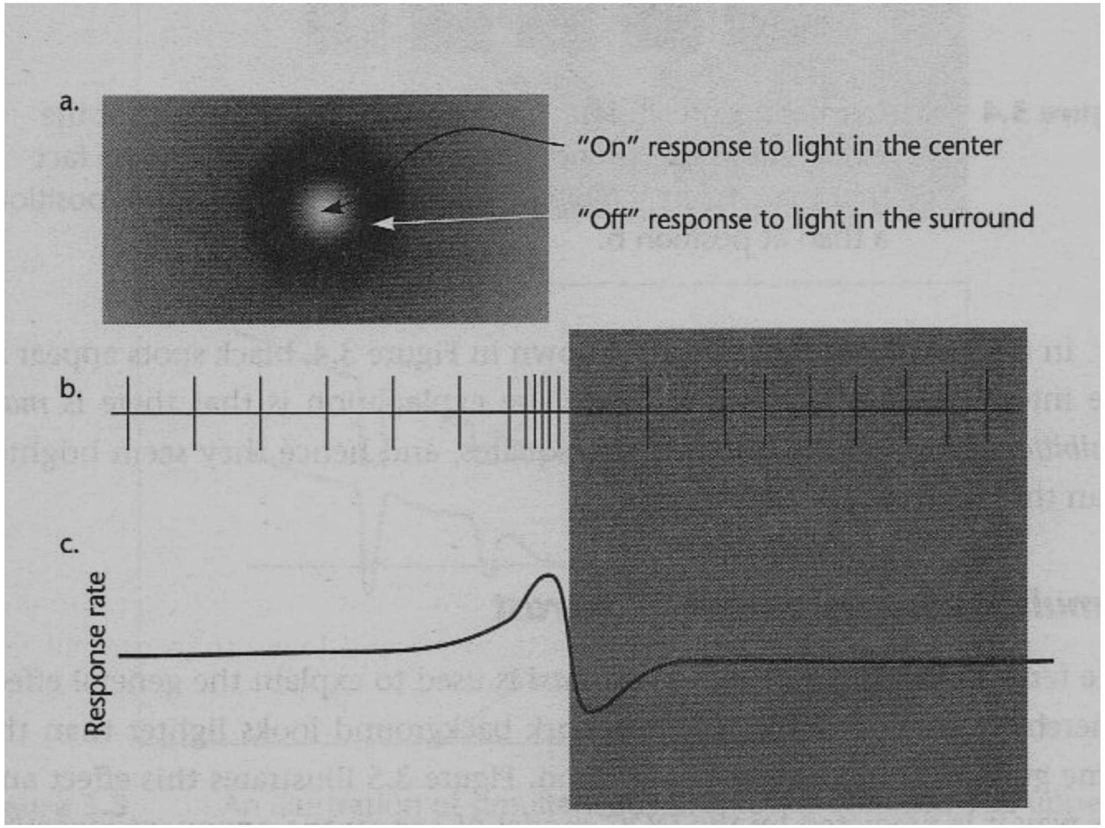
The DOG function



Difference of Gaussians (DOG) model of a receptive field.

- This is typically described with a Difference Of Gaussians (DOG) function
- One Gaussian represent the center
- The other one the border

Receptive field

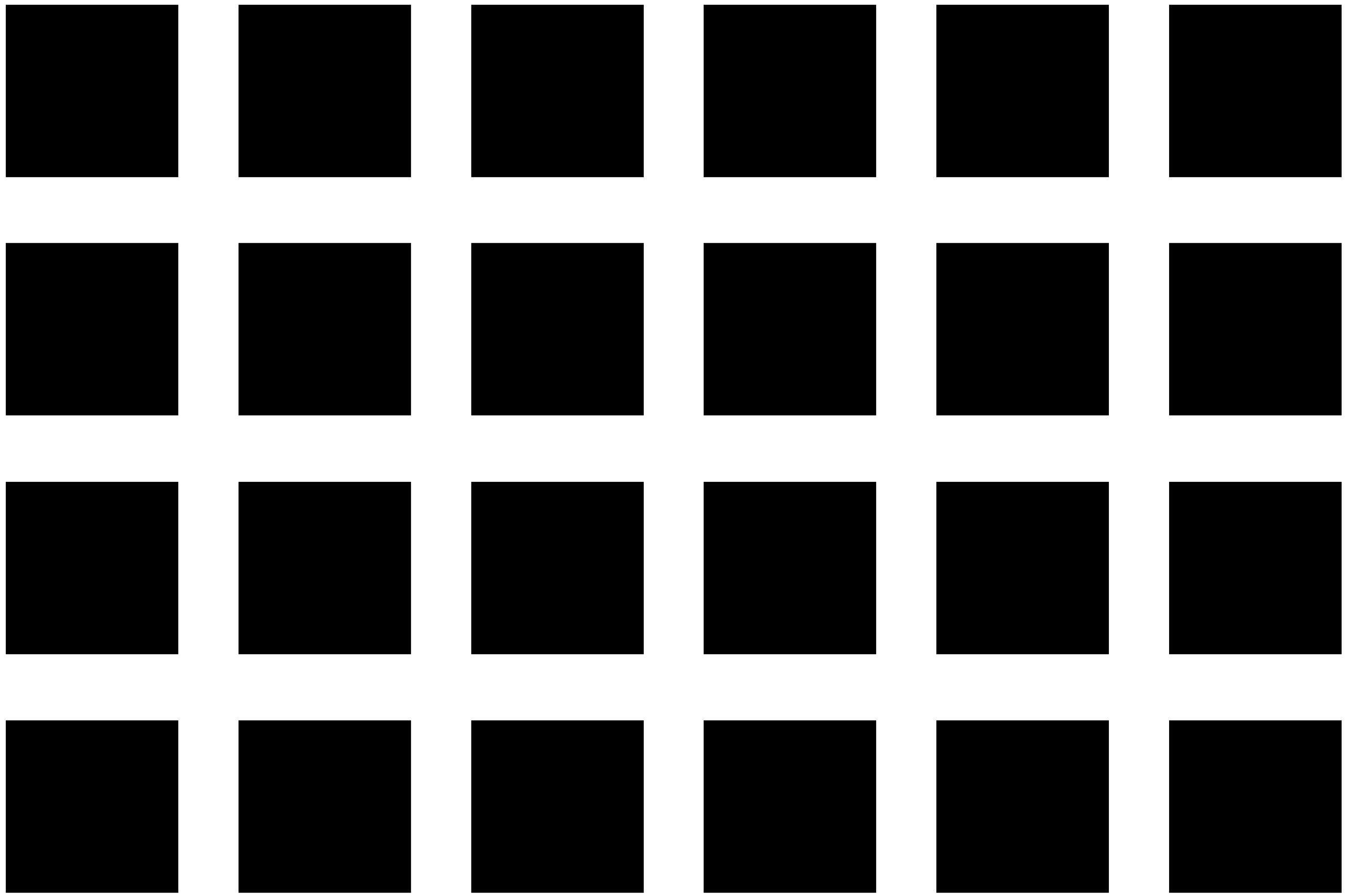


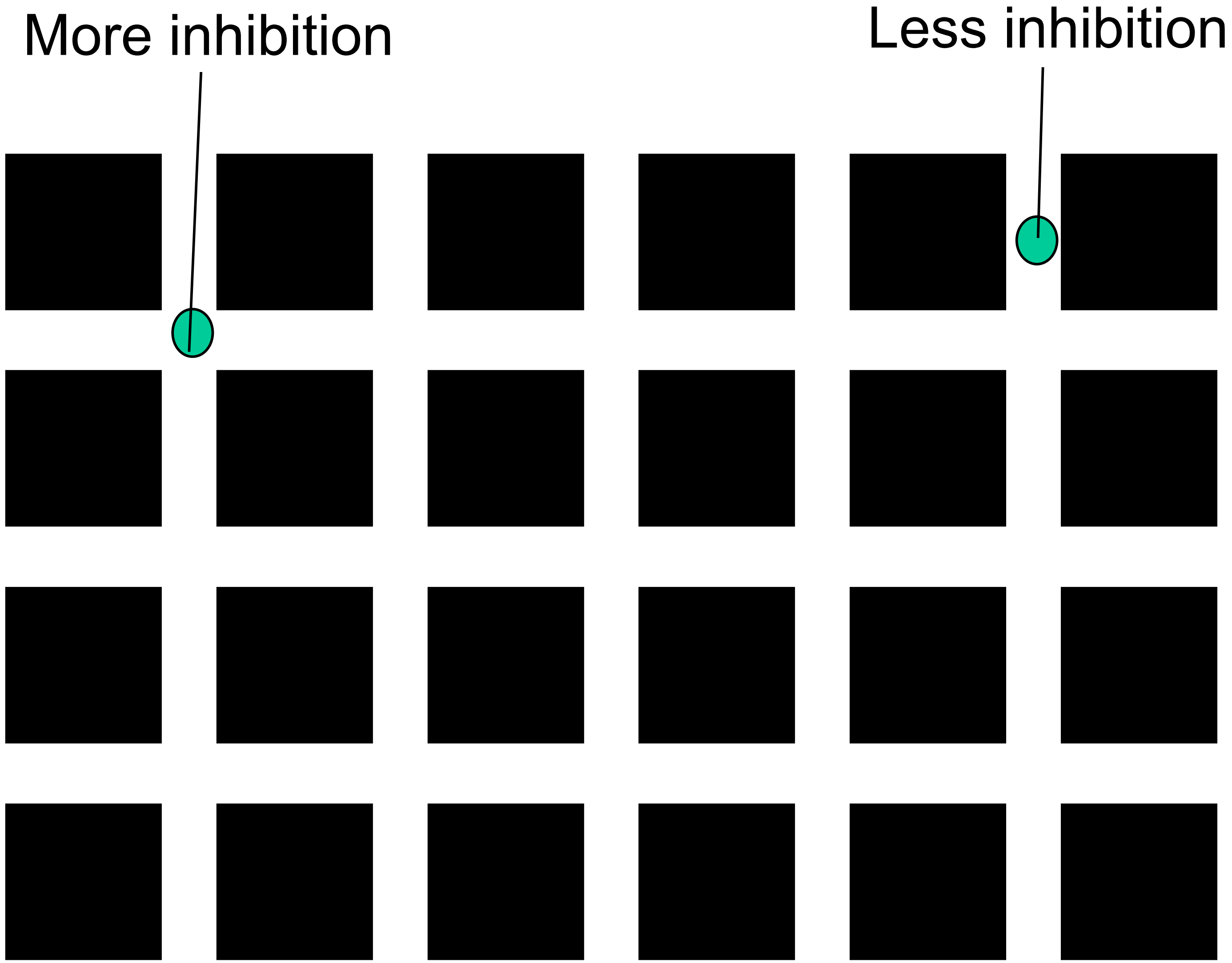
Maximum: the center is illuminated and the border is in the dark

Minimum: the center is dark and the border is illuminated

It is a perfect edge detection function!

A proof



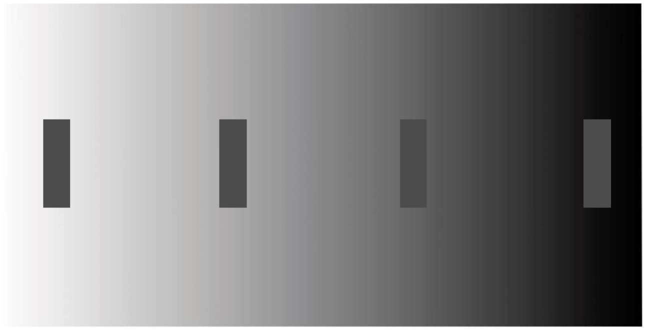

More inhibition
Less inhibition

Consequences to be aware of (DOG)

- Simultaneous Brightness Contrast

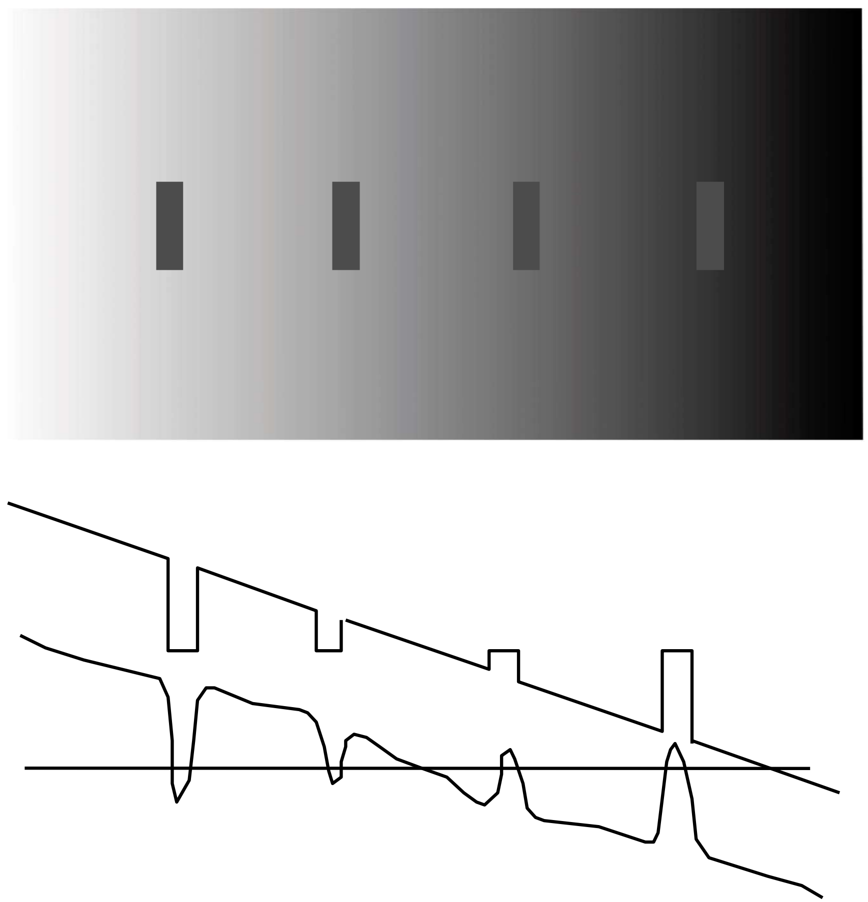
Consequences to be aware of (DOG)

- Simultaneous Brightness Contrast



Consequences to be aware of (DOG)

- Simultaneous Brightness Contrast

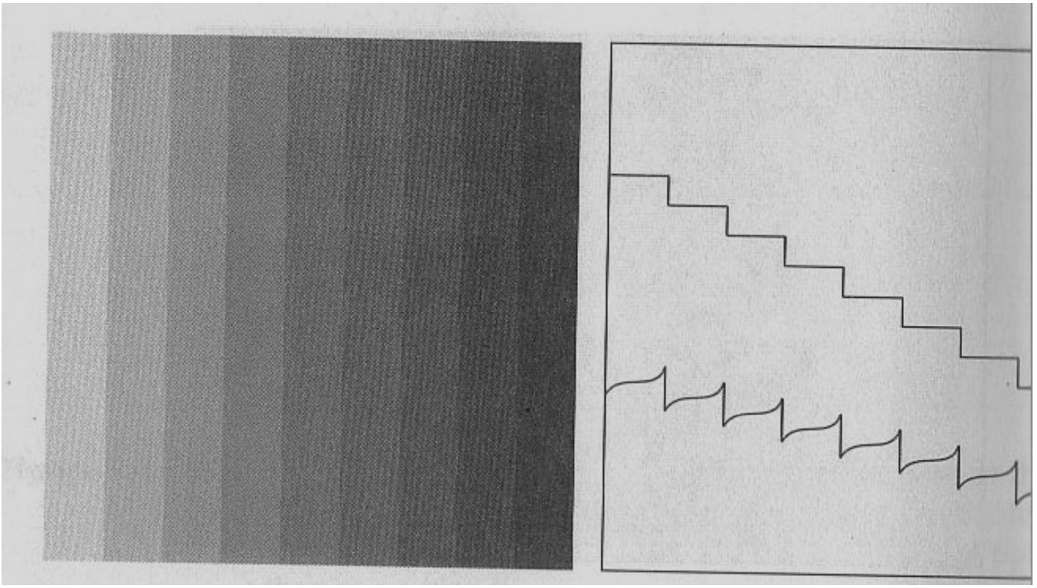


Watch the DOG !

Gray coding + Simultaneous Brightness Contrast
can produce very large errors!

Consequences to be aware of (DOG)

- The Chevreul illusion



Adjacent pattern of different intensity create edges

A perfect edge detection !

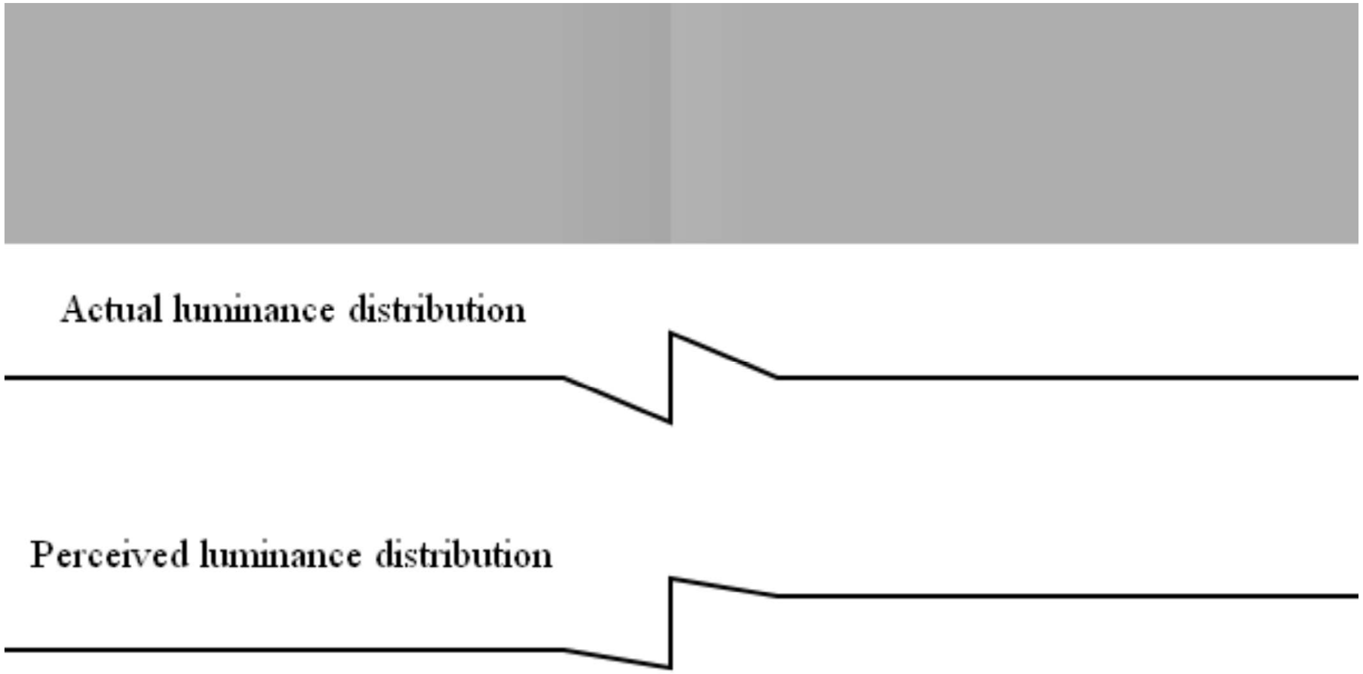
Cornsweet effect

- Suitable shading creates edges and difference in lightness
- What is the darker side?

Cornsweet effect

- No one…

Be aware of DOG



Be aware or use it, like Seurat

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- Chromaticity
- Saturation
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Luminance (physical value)

17-711 luminance (in a given direction, at a given point of a real or imaginary surface) [L_v; L]

quantity defined by the formula:

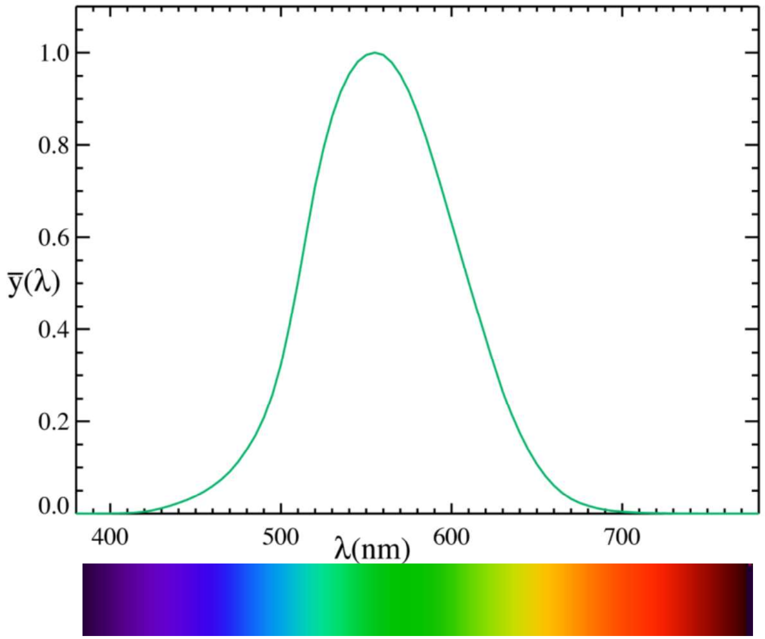
$$L_v = \frac{d\Phi_v}{dA \cos\theta \, d\Omega}$$

$d\Phi_v$ is the luminous flux transmitted by an elementary beam
dA is the area
Θ is the angle between the normal to that section and the direction of the beam

- Luminance is the amount of visible light coming from a region of space or a surface
- It is a **physical value** (measurable using a photometer)
- Unit: candelas per square meter

The CIE V(λ) function

- The CIE (Commision Internationale de L'Eclairage) standardized the V(λ) function (averaging 200 people)

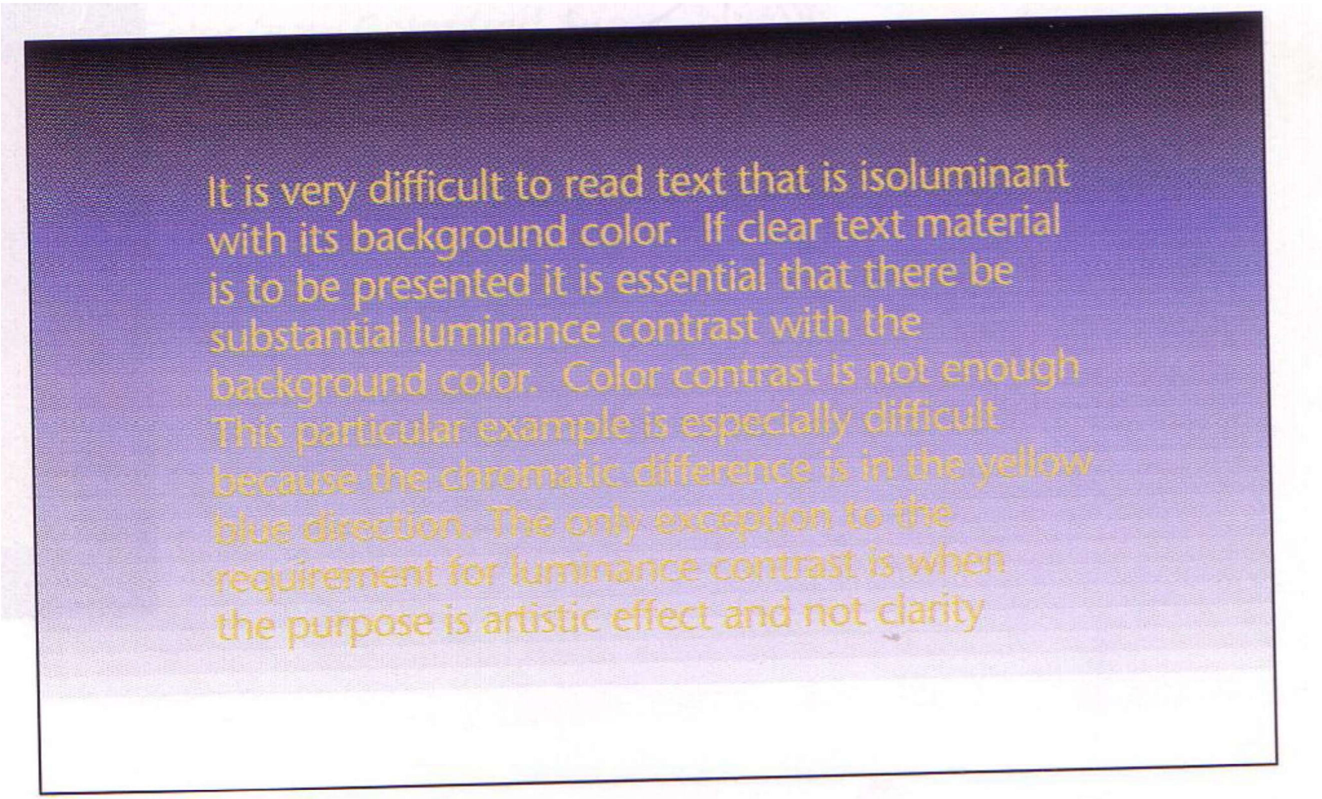


Wavelength (nanometers)	Relative Sensitivity	Wavelength (nanometers)	Relative Sensitivity	Wavelength (nanometers)	Relative Sensitivity
400	.0004	510	.5030	620	.3810
410	.0012	520	.7100	630	.2650
420	.0040	530	.8620	640	.1750
430	.0116	540	.9540	650	.1070
440	.0230	550	.9950	660	.0610
450	.0380	560	.9950	670	.0320
460	.0600	570	.9520	680	.0170
470	.0910	580	.8700	690	.0082
480	.1390	590	.7570	700	.0041
490	.4652	600	.6310	710	.0010
500	.3230	610	.5030	720	.0005

$$L = \int V_\lambda \, E_\lambda \, \delta \lambda$$

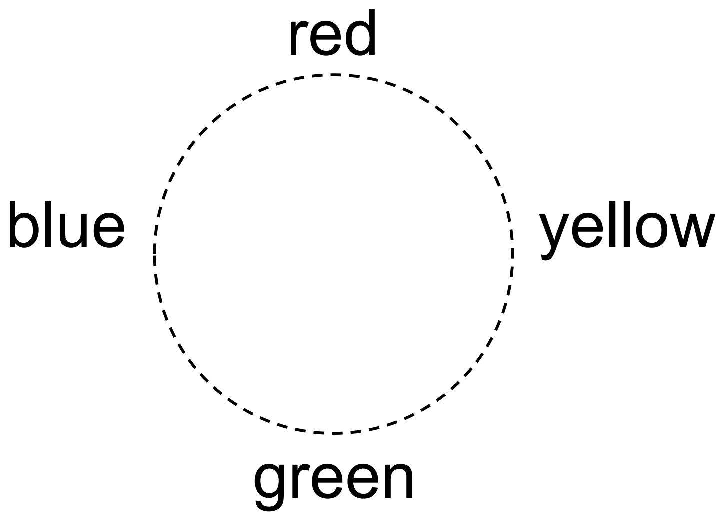
Practical usage of luminance

- Text background contrast: ISO and W3C specify a minimum level of luminance difference (1:3)



Hue (perceptual value)

17-542 hue: attribute of a visual perception according to which an area appears to be similar to one of the colours: red, yellow, green, and blue, or to a combination of adjacent pairs of these colours considered in a closed ring



yellowish green gialloverde
greenish blue verdeblu
bluish red rossoblu
yellowish red giallorosso

what about
reddish green rossoverde?
yellowish blue gialloblu?

Brightness (perceived luminance)

17-111 brightness : attribute of a visual perception according to which an area appears to emit, or reflect, more or less light

- Brightness refers to the **perceived** amount of light coming from a source of light (reflected or generated)
- It is not linear with luminance and the usage of the **magnitude estimation** technique is quite popular:
  - Subject are experimentally asked to indicate when a perceived sensation is twice then a reference one
  - Most physical sensations follow a simple power law: $\mathbf{S=aI^n}$
  - S is the sensation, a is a constant and the stimulus intensity I is raised to a power n
- For large source of light (>5 degrees) the law is: Brightness = $\text{Luminance}^{0.333}$
  - in order to duplicate the perceived brightness it is needed to increase luminance by a 8 factor
- For point sources of light (e.g., stars) the law is: Brightness = $\text{Luminance}^{0.5}$
  - in order to duplicate the perceived brightness it is needed to increase luminance by a 4 factor

A well known example : star magnitude

- by Ipparco, 200 A.D. and published ☺ by Tolomeo 350 years later
- Magnitude 1   : the strongest stars visible in the sky
- Magnitude 2   : stars showing ½ brightness of magnitude 1
- ….
- Magnitude 6 : the faintest stars that are visible at naked eyes 1/64th
- Ipparco et al. star classification has been recently revised:
- Magnitude 6 is now 100 times less bright of 1 not 64
- So the real brightness ratio between two consecutive magnitudes was about 2.5
- But they did not have computers and photometers…

Monitor gamma ?

- Most visualizations are produced on a monitor
- Nowadays computer allows for setting the gamma value (ranging from 1.4 to 3.0)
- The relationship between physical luminance L and voltage V is:

$$L=V^{\gamma}$$

- A gamma value of 3 compensates the Brightness/Luminance law

$$\text{Brightness} = \text{Luminance}^{0.333}$$

resulting in a display characterized by a linear relationship between voltage and brightness

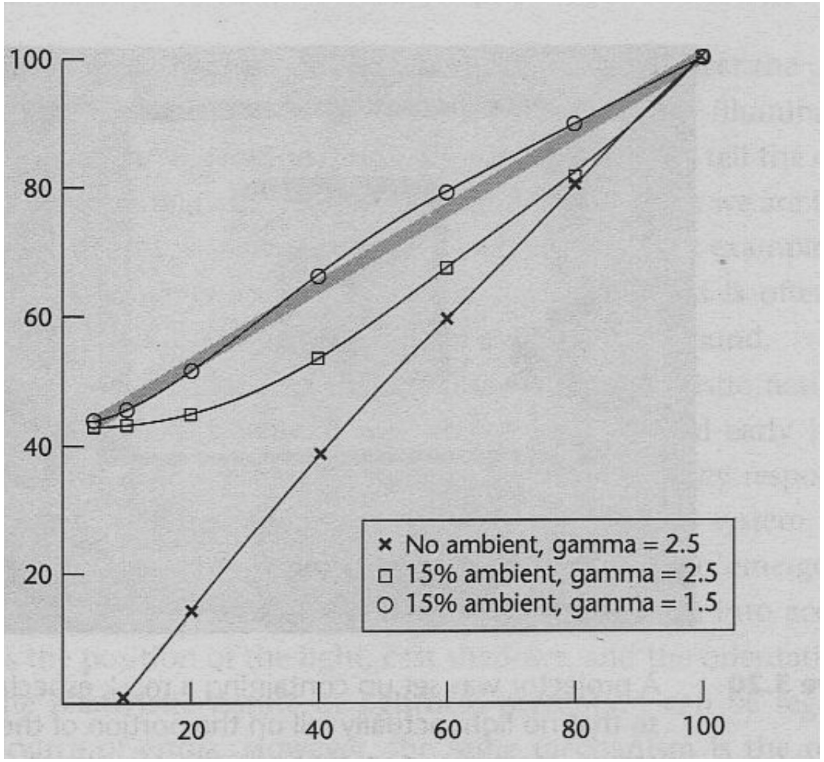
Monitor illumination and gamma

- Monitor are not used in dark rooms
- In normal usage about 15 – 40% of light comes from the ambient light A and not from the monitor
- We can take that in account adding a constant to the gamma equation:

$$L=A+V^{\gamma}$$

- In such a case a better linear relationship between brightness B and V is obtained with a lower gamma

B



V

Lightness (perceived color brightness)

17-680 lightness (of a related colour): brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be **white** or highly transmitting

NOTE **Only related colours exhibit lightness**

- Lightness refers to the perceived reflectance of a color surface
- White surfaces reflect about 90% of the light striking them. **They are light**
- Black surfaces reflect about 3%. **They are dark**
- **In colorimetry and color theory, lightness is the perception of a color brightness**. It is one of the color appearance parameters of any color appearance model and in some cases it is is called with different names (e.g., value in the Munsell color model)
- Some adaptive mechanism of the vision system allow for perceiving colors in a constant way:
  - A black object in a sunny day reflects about 1000 candelas per square
  - The same object in an office light reflects 50 candelas per square.
    - It is still perceived as black
  - A white paper in the same office reflects less light than the black object in the sun.
    - It is still perceived as white

Each row exhibits the same lightness

Chromaticity

17-144 chromaticity: property of a colour stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together

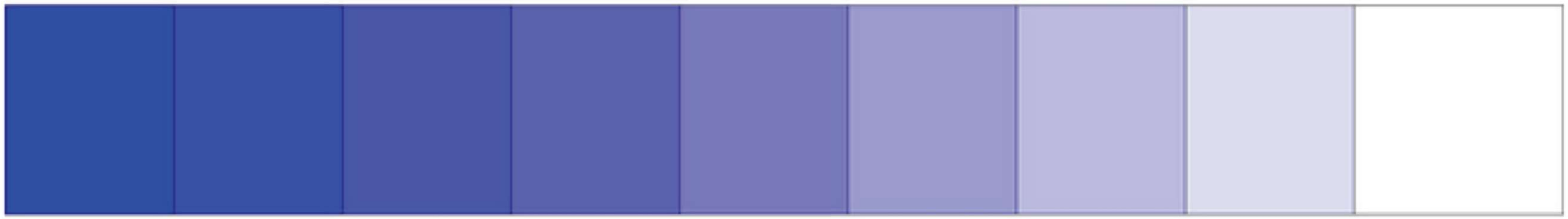
17-145 chromaticity coordinates ratio of each of a set of 3 tristimulus values to their sum

These concepts refer to the proportion of the three coordinates (e.g. **R**ed, **G**reen, **B**lue)

Saturation

17-1136 saturation: colourfulness of an area judged in proportion to its brightness

NOTE For given viewing conditions and at luminance levels within the range of photopic vision, a colour stimulus of a given chromaticity exhibits approximately constant saturation for all luminance levels, except when the brightness is very high.



Adaptation

- The iris of the eye opens and closes, modulating the incoming light
- More significant: photo pigment is bleached under high light and eyes became less sensitive
- When moving from strong light to dark photo pigment is regenerated, but it takes time
- That’s way entering in a dark room from a sunny day makes you blind for several seconds
- The fully regeneration process takes up to 30 minutes (as star observers perfectly know…)
- So the eye is not a photometer at all !!!

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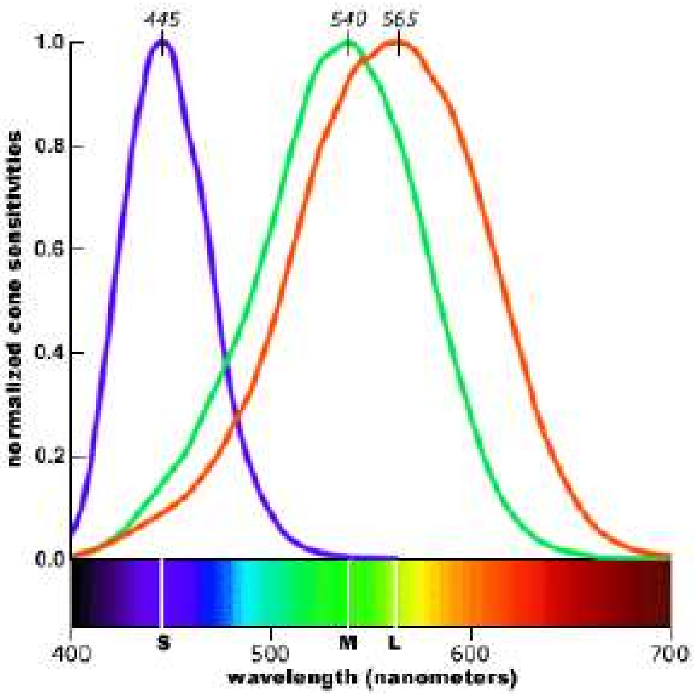
Trichromacy and Color Opponent Theory

Why red, green, and blue (RGB) and yellow?

And why a color like reddish green does not exist?

Trichromacy Theory

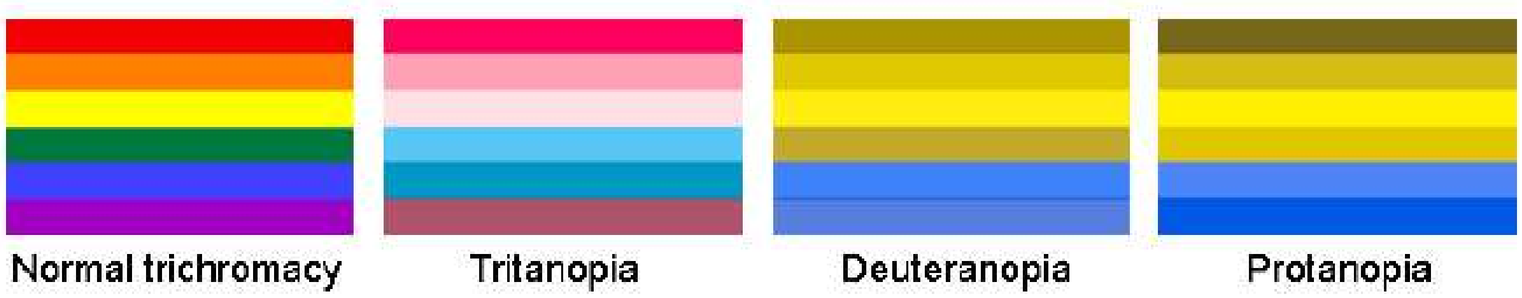
- We have three kinds of cones, sensible to different wavelengths LMS (Long, Medium, Short)
- That's is the reason why we generate colors using three primaries (e.g., RGB)
- Chicken engineers will became crazy in designing a monitor with 12 colored phosphors



- LMS cones spectral sensitivity curves

Color blindness

- About 7% of the male population and 1% of female population suffer from some color vision deficiency
- That correspond to a lack of one (most cases) of the three receptors
- A better comprehension of the matter allows for designing systems usable by both trichromats and dichromats

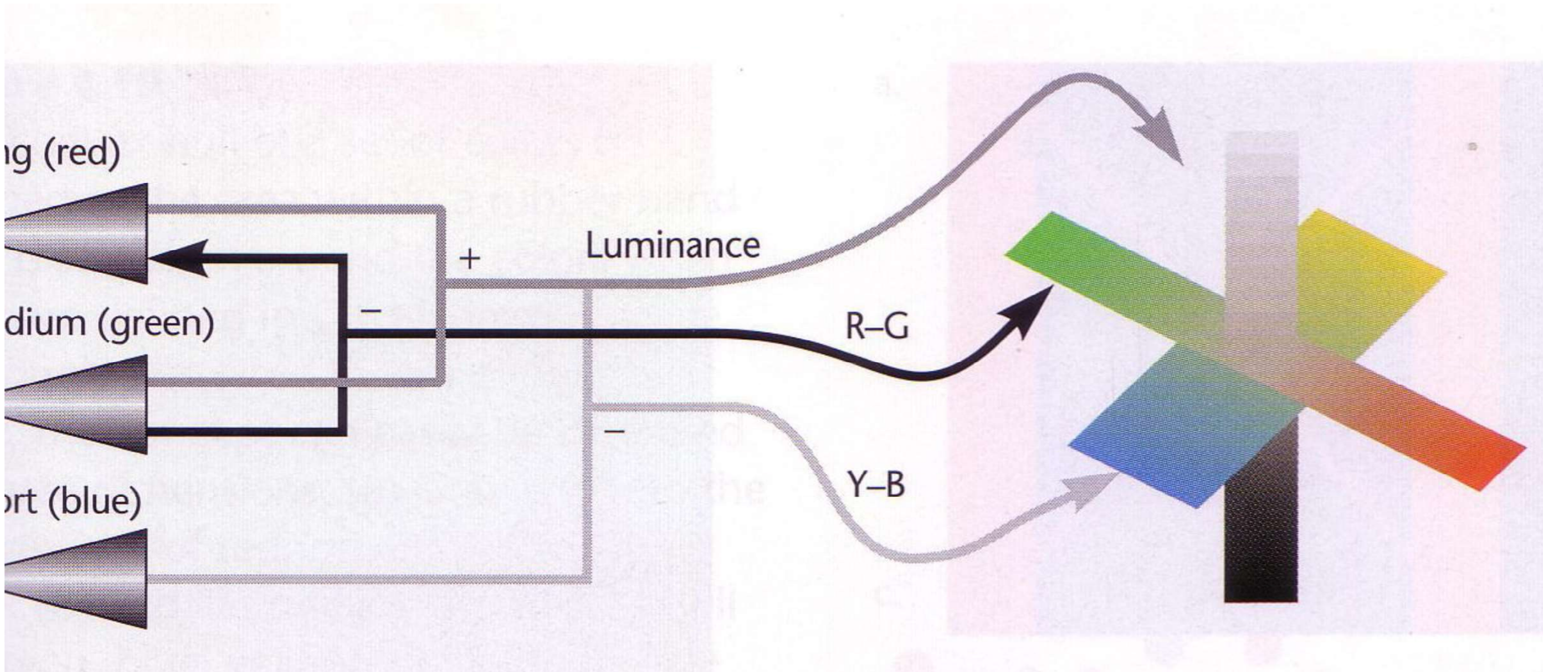


Missing S Missing M Missing L

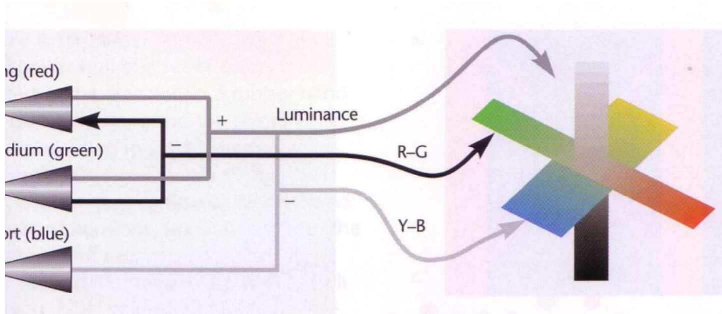
Color simulation

Color opponent process theory

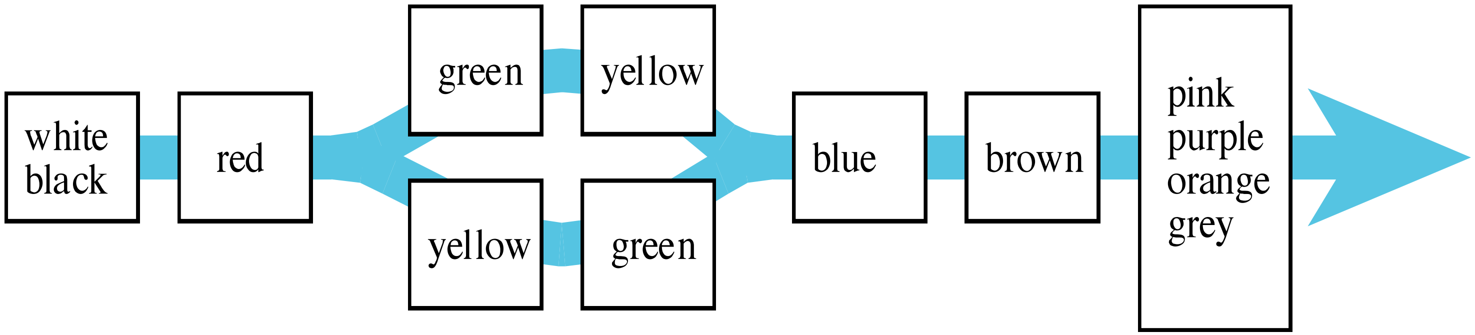
- The Hearing idea (1920) is that there are only 6 elementary colors arranged in three pairs
  - Black-White (luminance channel)
  - Red-Green
  - Yellow-Blue



Scientific evidence



- Naming: yellowish green or greenish blue are often used; reddish green or yellowish blue NOT
- Cross-cultural naming: an anthropological study on more than 100 languages shows that color naming definition order is the same as follows



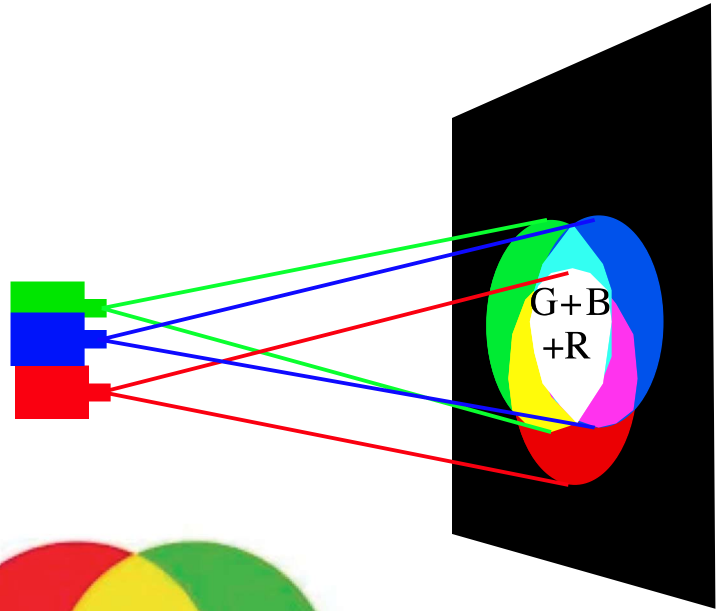
Now you know why...

Color measurement

- We are able to match any pure color C (single wavelength) with an **additive** mixture of no more than three hues (called primaries)

$$C \; \Xi \; rR+gG+bB$$

- Where Ξ denotes that the equation refers to a perceptual match
- Color appearance or Hue
- Two different spectral color distributions look the same (metameres) if they stimulate the three cones in the same way
- No physical reason but perceptual

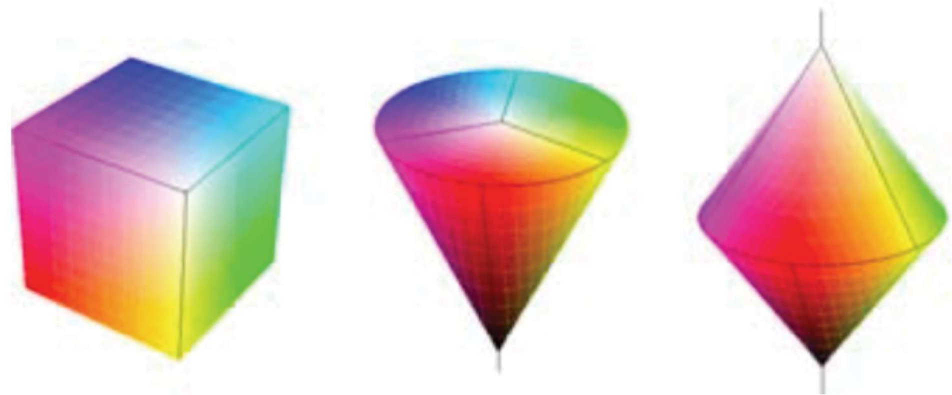


R G B

Change of primaries

- The amount of RGB required to “generate” a color has been determined by CIE through several experiments performed in 1931 that produced several standards
- The problem with RGB is that they are not able to cover all the perceivable colors and different primaries have been chosen for that
- Moreover the RGB standard is device-oriented and hard to use

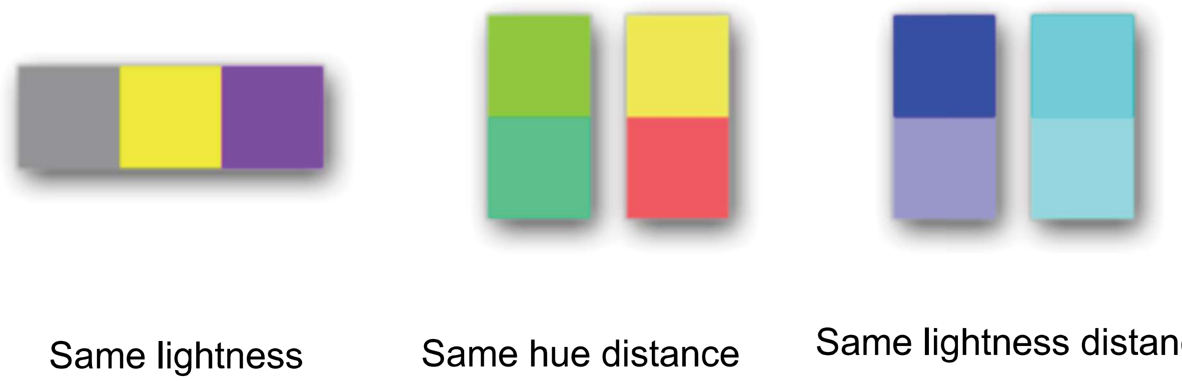
Alternative color spaces



RGB HSV HLS

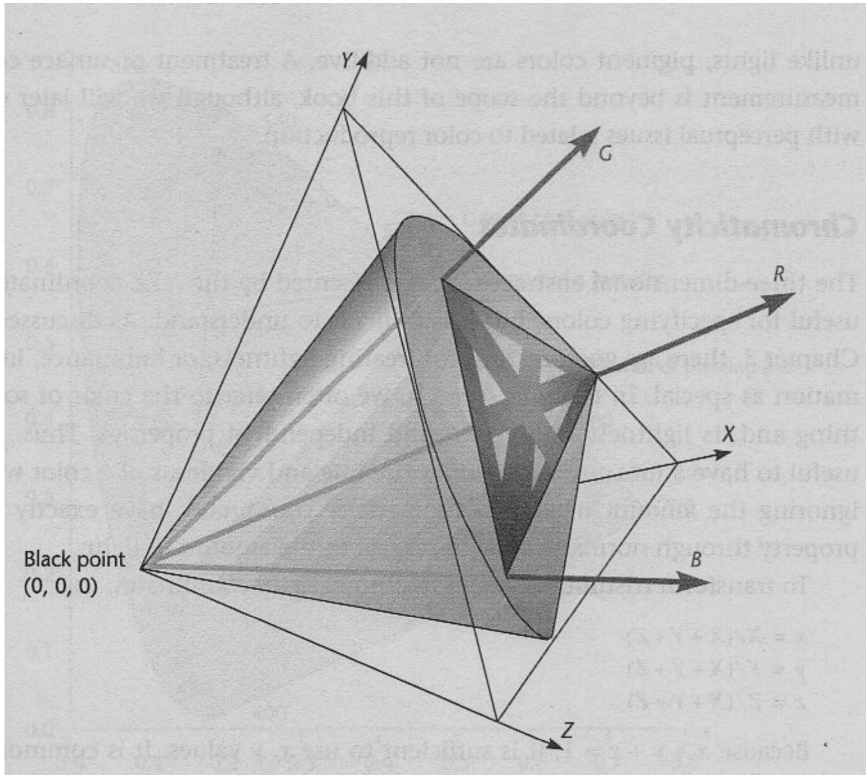
- **RGB** device-oriented color spaces => not easy to use
- Ease of use is enhanced with cylindrical color spaces directly handling color attributes such as hue, saturation and value (lightness) (**HSV**) and hue, lightness, and saturation (**HLS**)
- Easier to understand and interact with, but they have no connections with human color perception

Examples of problems in HLS

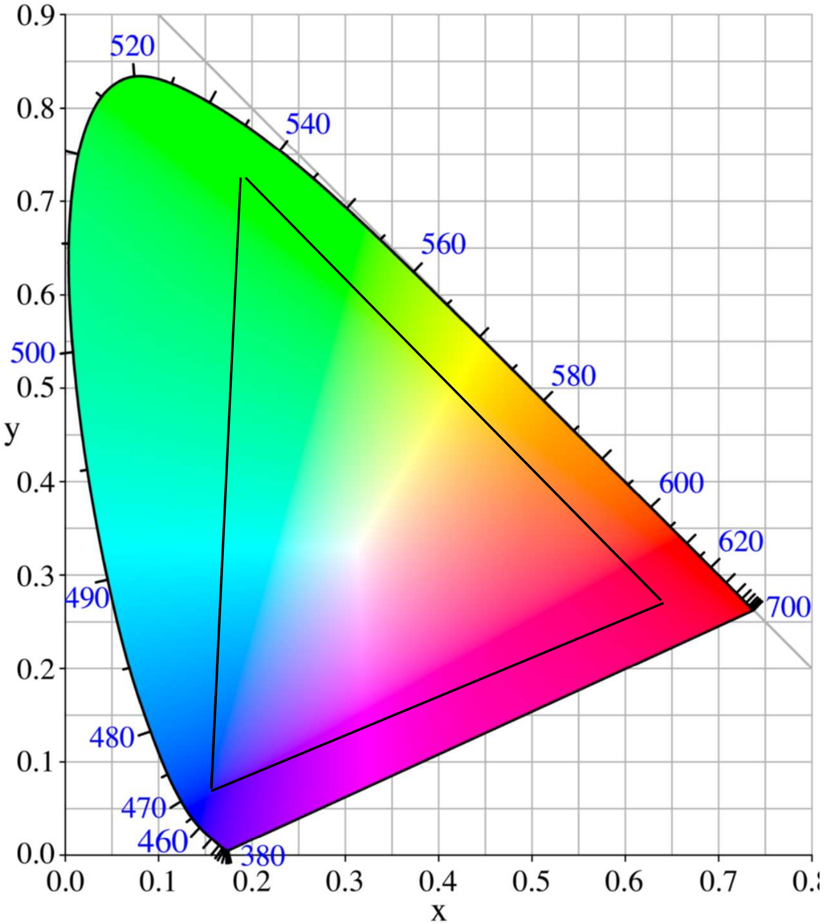


The CIE X,Y, and Z color space

- They selected three abstract primaries able to represent a wide color space that includes the visible color gamut (in gray)

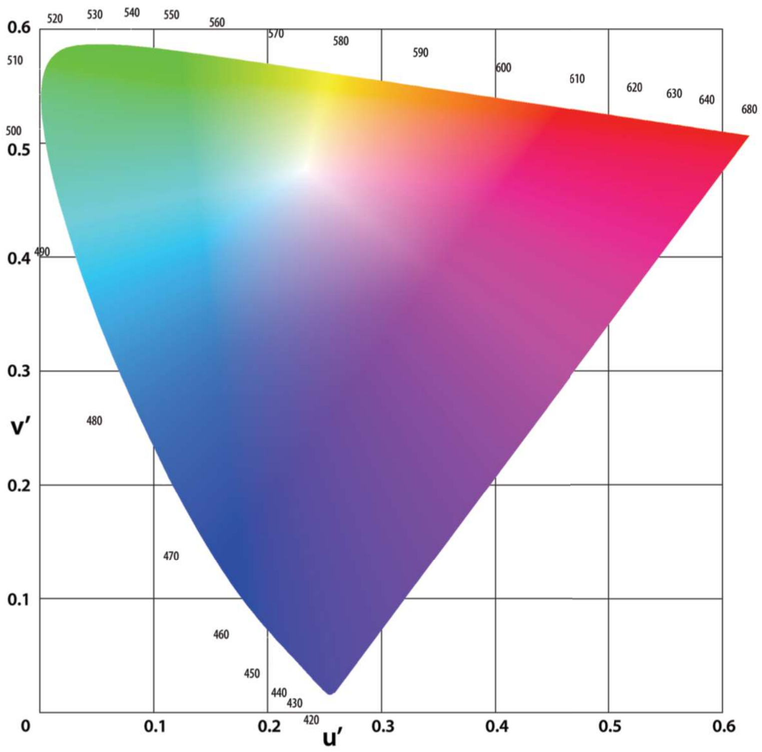


The normalized CIE X,Y, and Z

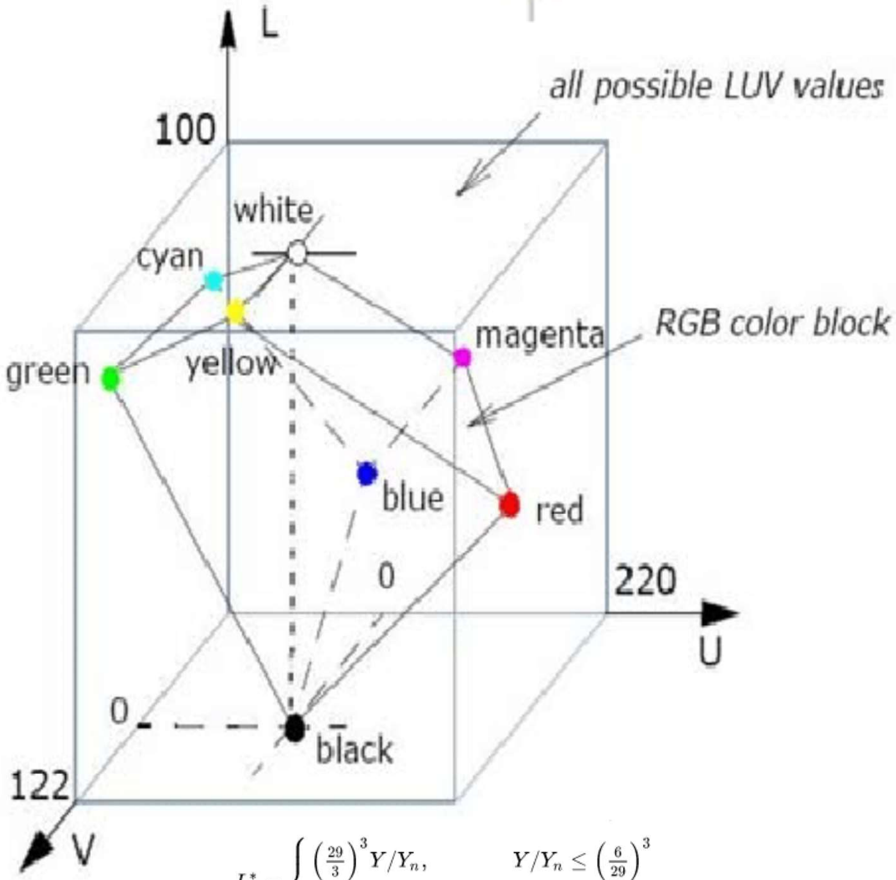


- Setting x+y+z=1, i.e., normalizing with respect luminance it becomes a 2D space
- Colors on the border are “pure” colors
- The white has x=y=z=0.333
- The distance from white point gives the color saturation
- The triangle represent the RGB space
- Given two colors, all the colors given by their mixture lie on the connecting line
- It is easy to specify a set of three primaries on it
- The complementary of a color is produced by drawing a line between that color and the white and extrapolating to the opposite locus. The mixture of the two colors produces white

The CIE LUV (perceptually uniform)
a simple-to-compute transformation of the CIE XYZ color space,
The distance between colors can be measured since the color spaces are roughly uniform
Natural (but not trivial) choice for controlling colors within a program

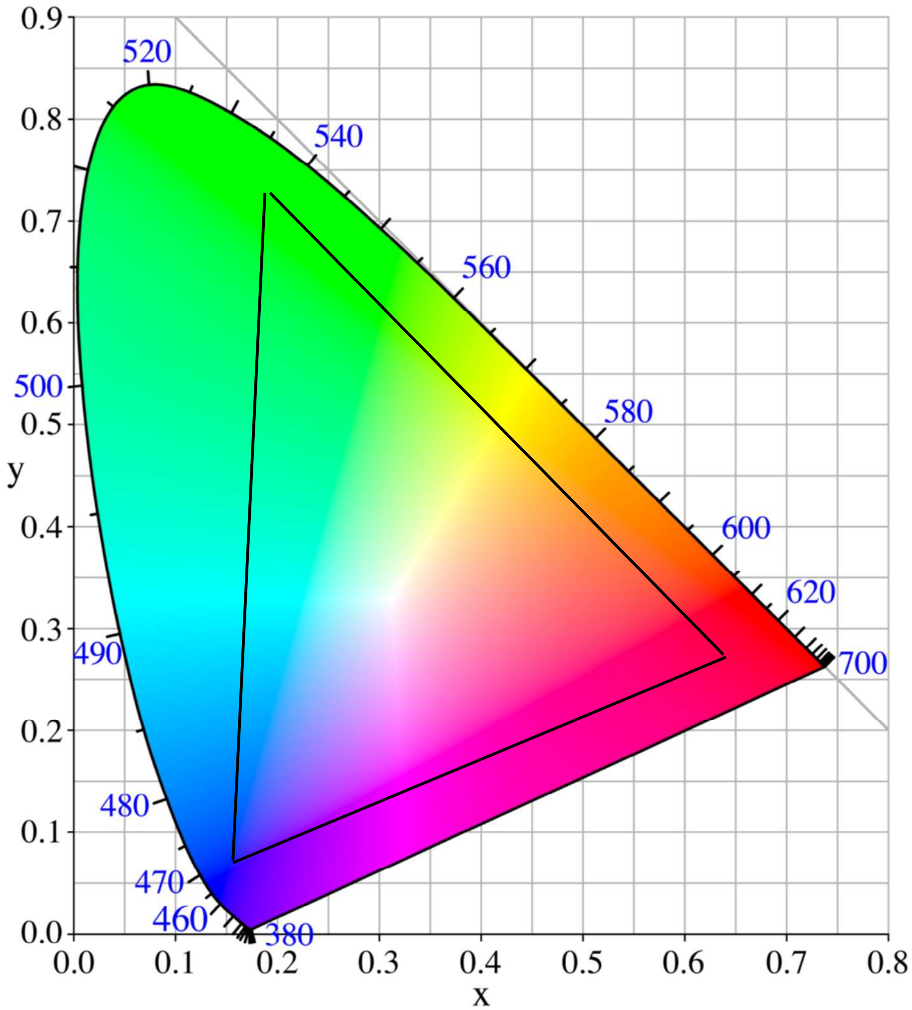


$$u' = \frac{4X}{X+15Y+3Z} = \frac{4x}{-2x+12y+3}$$
$$v' = \frac{9Y}{X+15Y+3Z} = \frac{9y}{-2x+12y+3}$$



$$L^* = \begin{cases} \left(\frac{29}{3}\right)^3 Y/Y_n, & Y/Y_n \le \left(\frac{6}{29}\right)^3 \\ 116(Y/Y_n)^{1/3} - 16, & Y/Y_n > \left(\frac{6}{29}\right)^3 \end{cases}$$
$$u^* = 13L^* \cdot (u' - u'_n)$$
$$v^* = 13L^* \cdot (v' - v'_n)$$

The CIE chromaticy diagram



- Being the X,Y, and Z space difficult to understand they defined a transformation from X, Y, and Z to a new coordinate system x,y, and z that, under the constraint that x+y+z=1, i.e., **normalizing with respect to the amount of light**, can be represented in a two dimensional space
- Colors on the border are “pure”colors
- The distance from the “white point” give the color saturation
- The triangle represent the RGB space

Outline

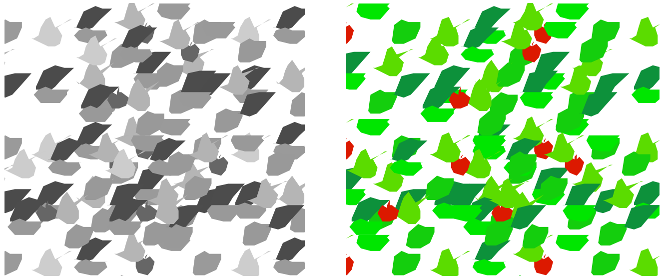
- Visible Light & Eyes
- Luminance
- Hue
- Brightness
- Lightness
- Chromaticity
- Saturation
- Trichromacy and Color Opponent Theory
- Color & Information Visualization
- Pre-attentive processing

Main learned issues

- Color Perception is relative
- Sensitive to small differences
  - hence need sixteen million colors
- Not sensitive to absolute values
  - hence we can only use < 10 colors for coding

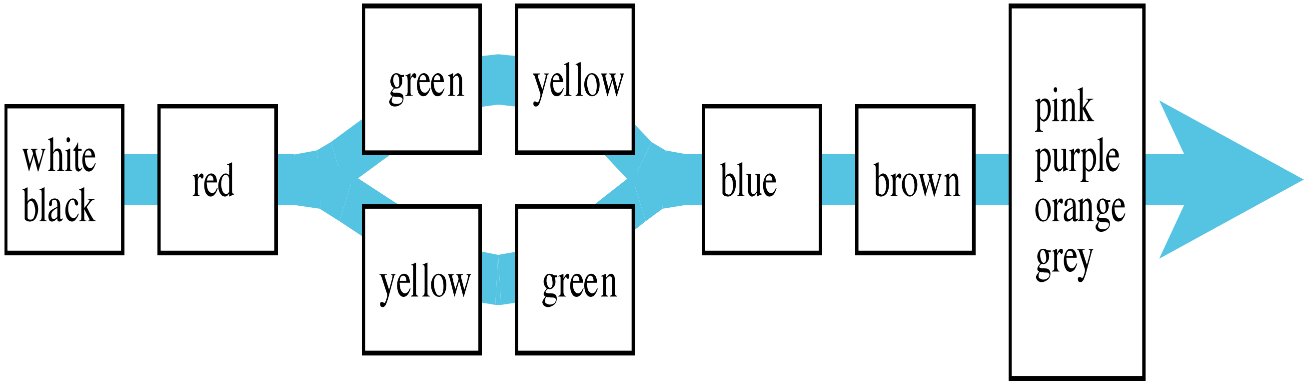
Color = Classification

Rapid Visual Segmentation



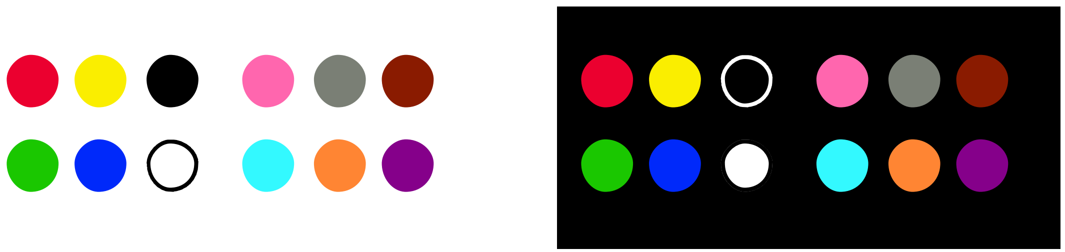
Color helps us to determine type

Only about six categories



Color for labeling

- Distinctness
- Unique hue (red, green, yellow, blue, black and white)
- Contrast with background
- Color blindness (mainly red-green direction)
- Conventions
- The bottom line 6 + 6 = 12



12 Colors
for labeling

Color sequences for maps

- Next class will deal better with these issues…

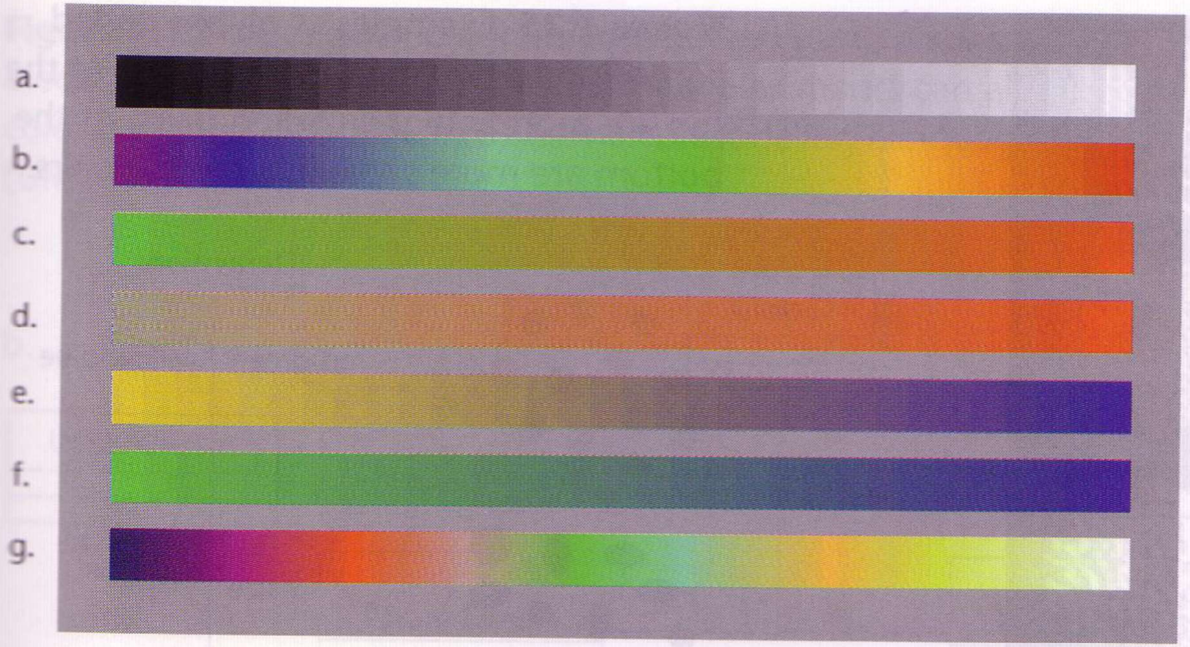
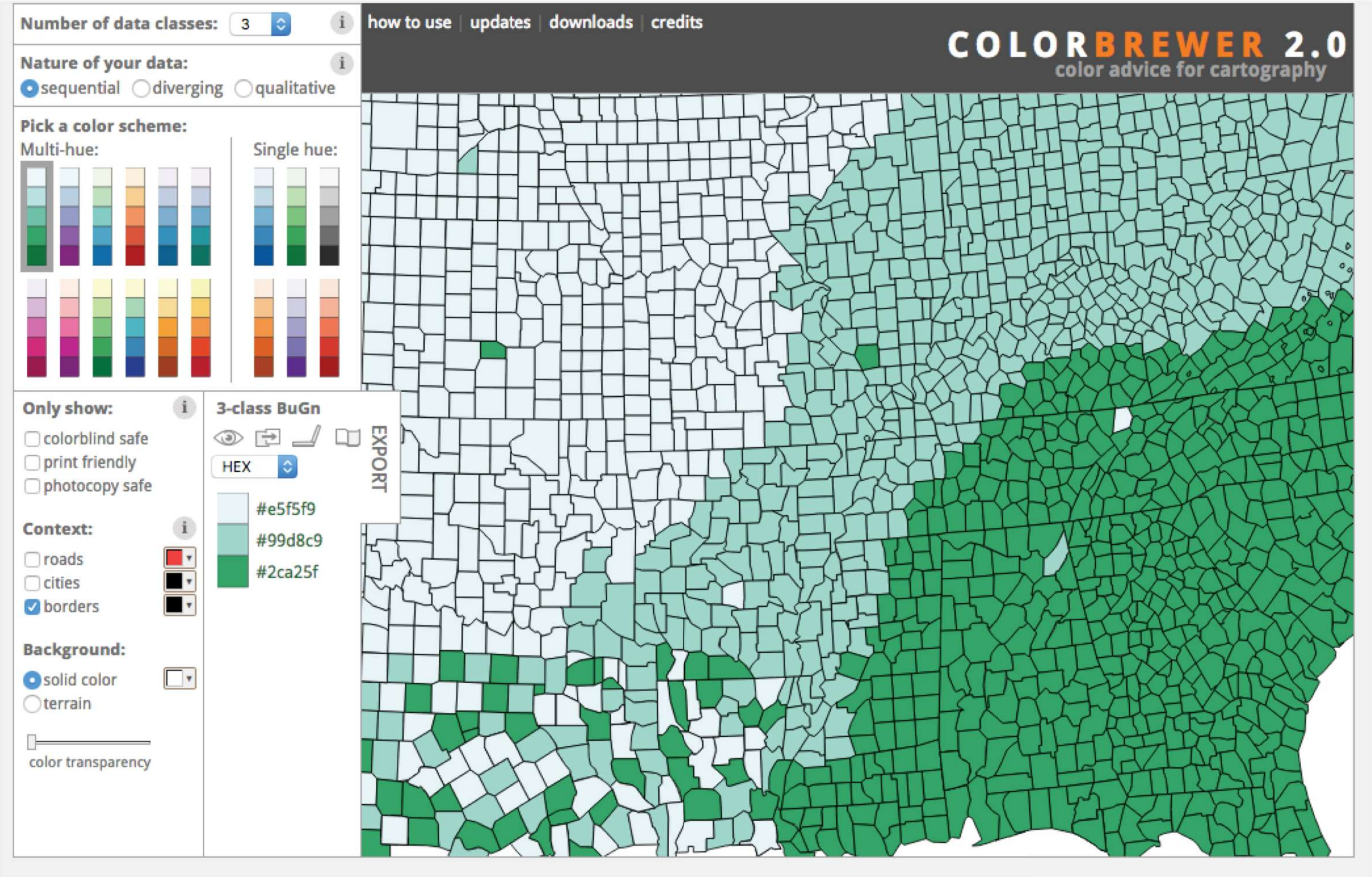


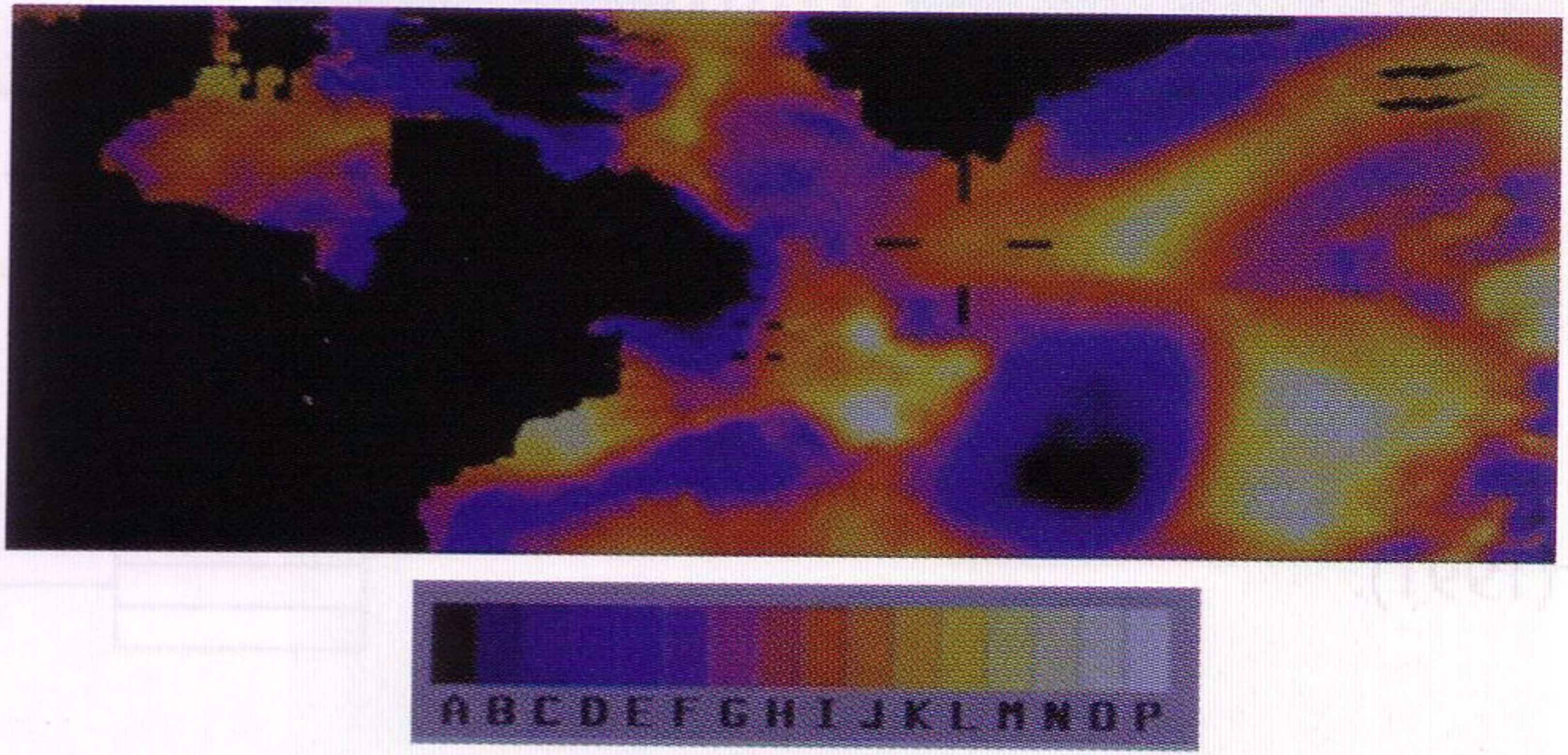
Figure 4.24
Seven different color sequences: (a) Gray scale. (b) Spectrum approximation. (c) Red-green. (d) Saturation. (e) and (f) Two sequences that will be perceived by people suffering from the most common forms of color blindness. (g) A sequence of colors in which each color is lighter than the previous one.

Color brewer (colorbrewer2.org/)




A B C D E F G H I J K L M N O P

The revised gravity gray map



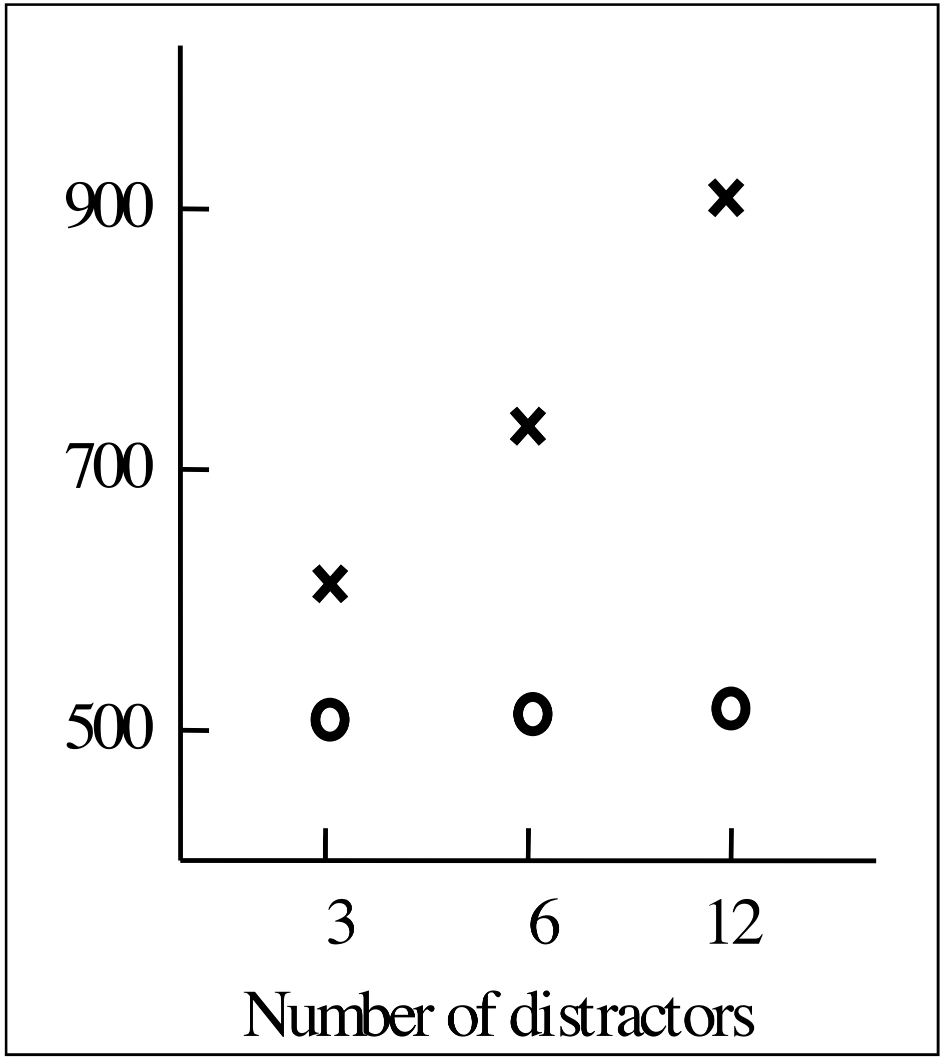
Outline

- Visible Light & Eyes
- Luminance
- Hue
- Brightness
- Lightness
- Chromaticity
- Saturation
- Trichromacy and Color Opponent Theory
- Color & Information Visualization
- Pre-attentive processing

Pre-Attentive Processing

- **Some Visual Properties Processed Pre-Attentively**
  - No need to focus attention nor reasoning
- **Pre-Attentive Properties -> Design of Visualizations**
  - Can be perceived immediately
- < 200 - 250ms
  - Eye movements = at least 200ms
  - Some processing can be done very quickly
    - ➔ Implies low-level processing in **parallel**

Pre-Attentive Experiment

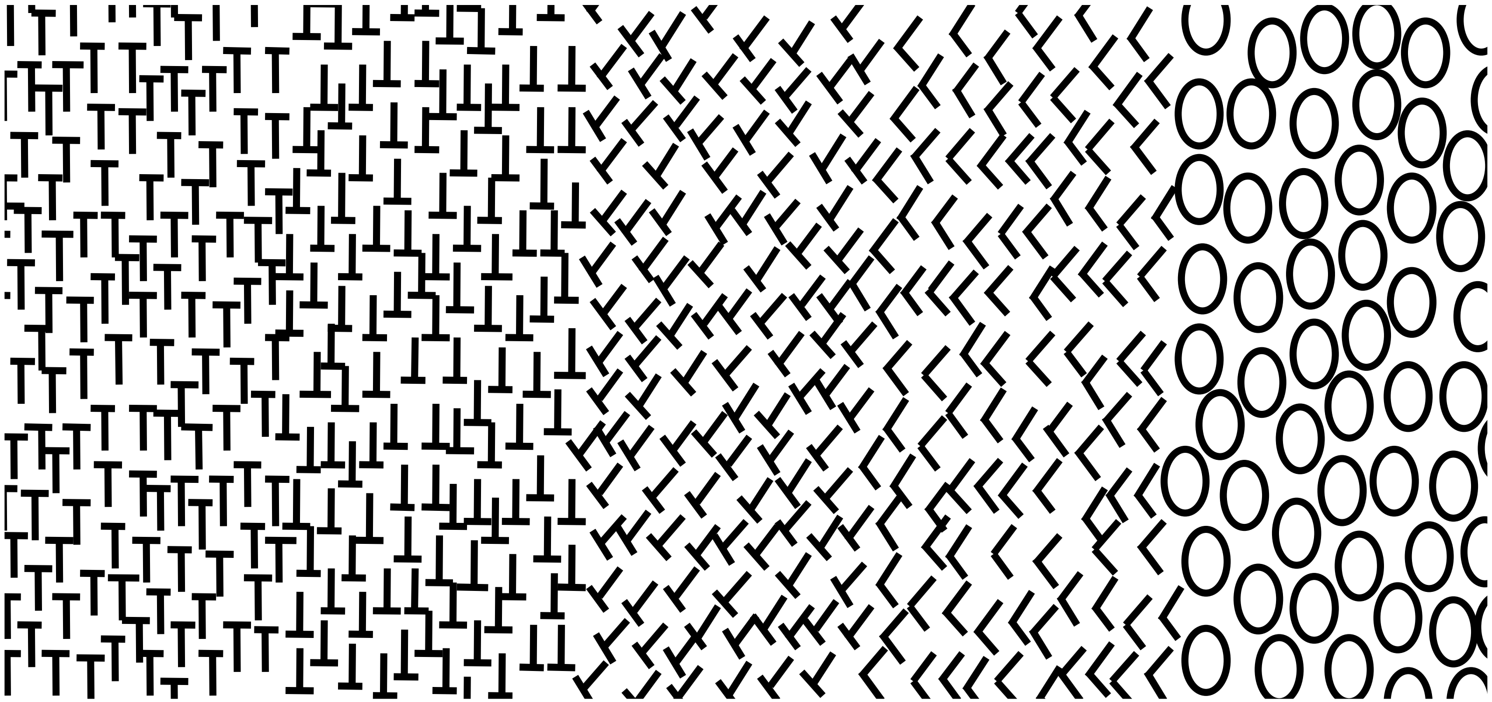


- Number of irrelevant items (distractors) varies
- Pre-attentive 10 msec per item or better.

- Decision = Fixed Time
  regardless of the number of distractors
  ➔ Preattentive

Segmentation by Primitive Features

- How many areas ?



Pre-Attentive Processing - lightness

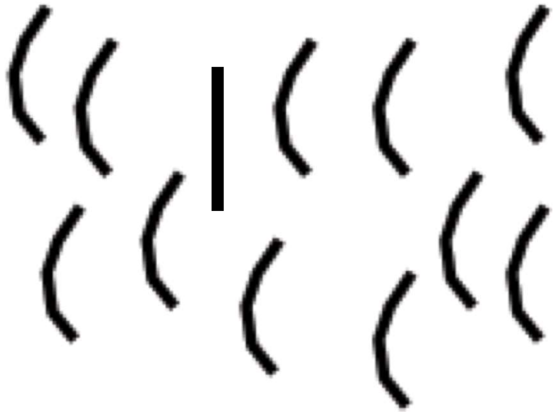
- **How many 3s ?**

0802808508083080280985O–802808
567847298872ty4582020947577200
217898438900r4557904560992721 88
897594797902855892594573979209

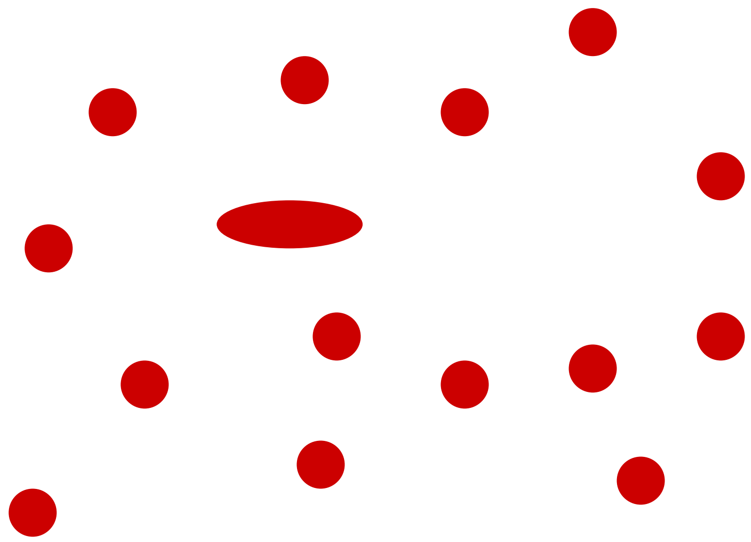
Pre-Attentive Channels

- Form
  - Orientation
  - Size / Length
  - Curvature
  - Spatial grouping
- Color
  - Hue
  - Intensity
- Motion
  - Blinking
  - Direction of motion
- Spatial/Position
  - 2D position
  - Stereoscopic depth
  - Convex/concave for shading

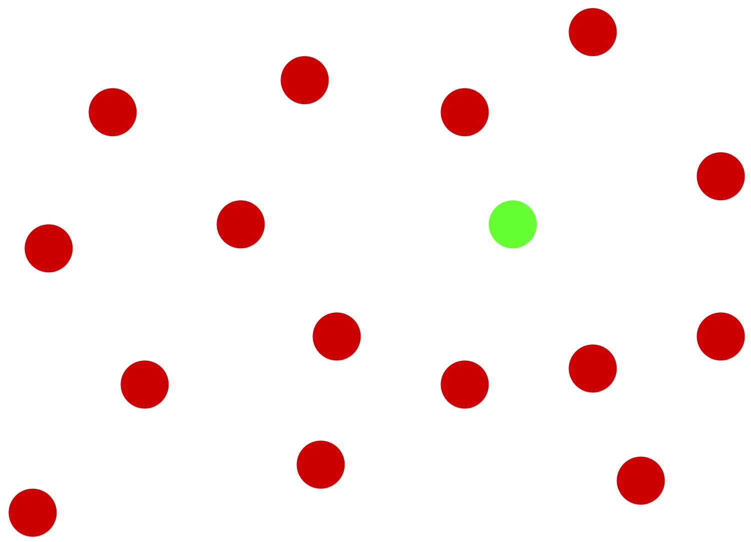
Pre-Attentive Processing - **Curvature**



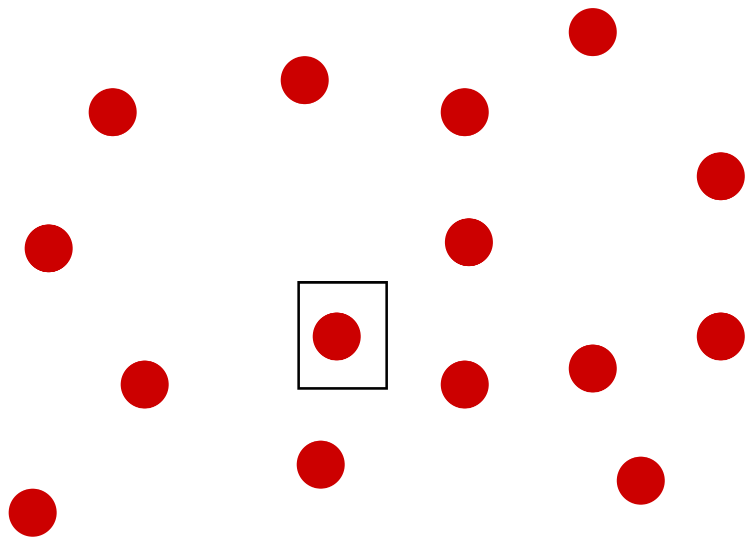
Pre-Attentive Processing - **Shape**



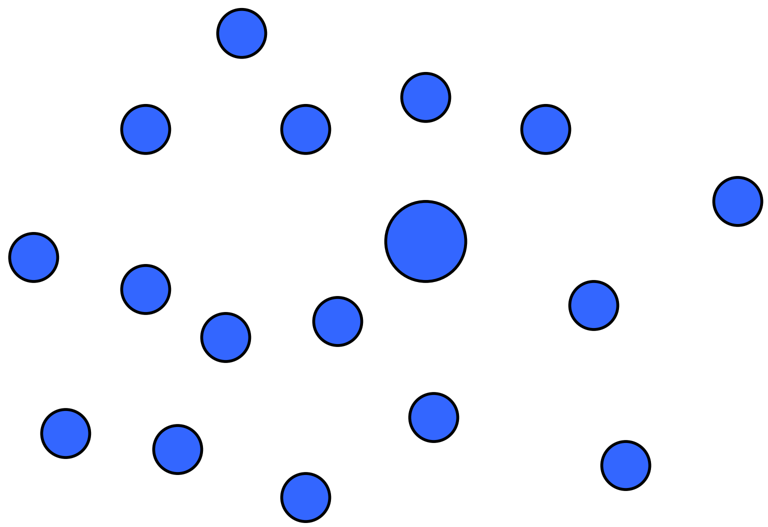
Pre-Attentive Processing **- Color**



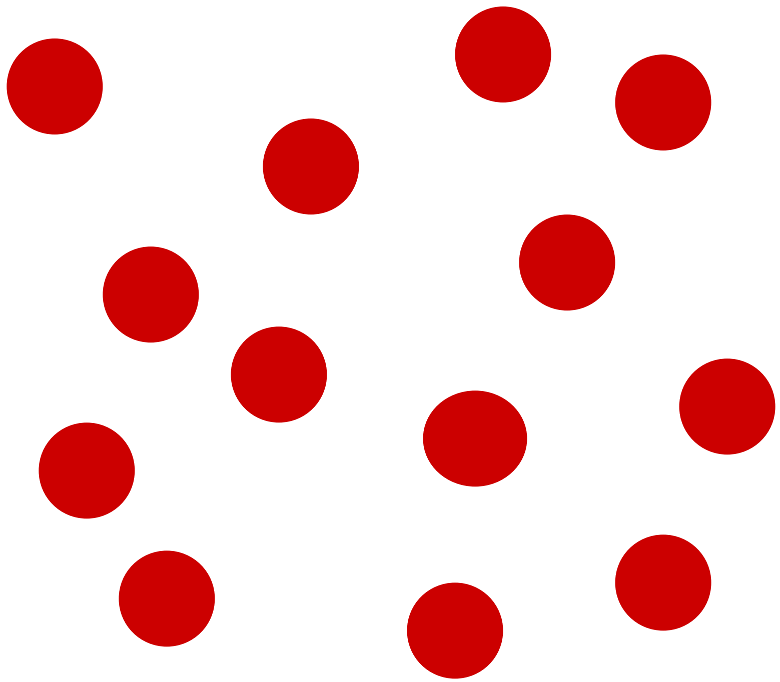
Pre-Attentive Processing - **Enclosure**



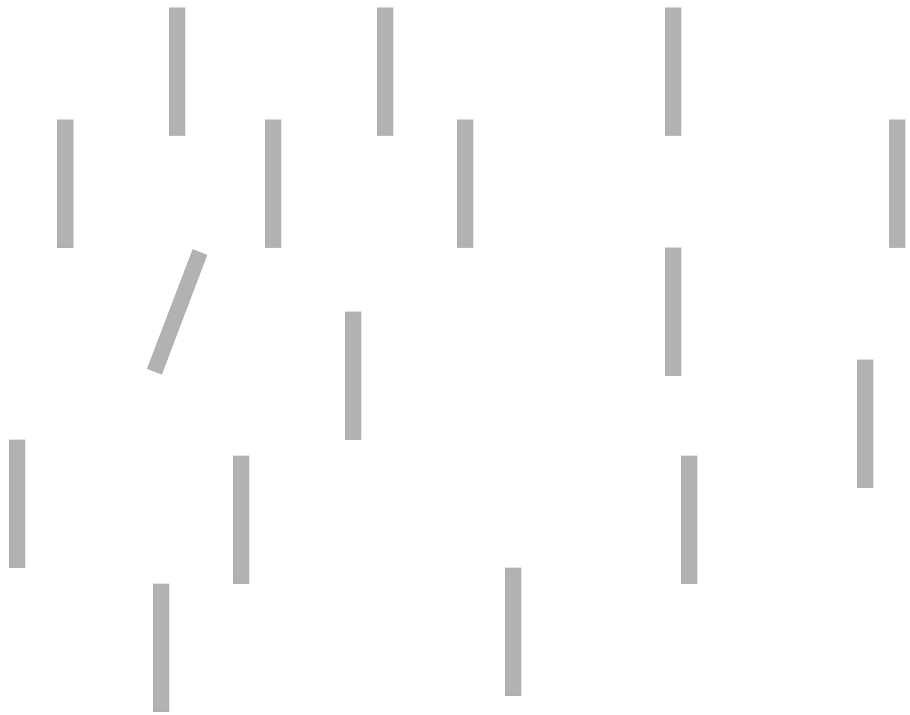
Pre-Attentive Processing - **Size**



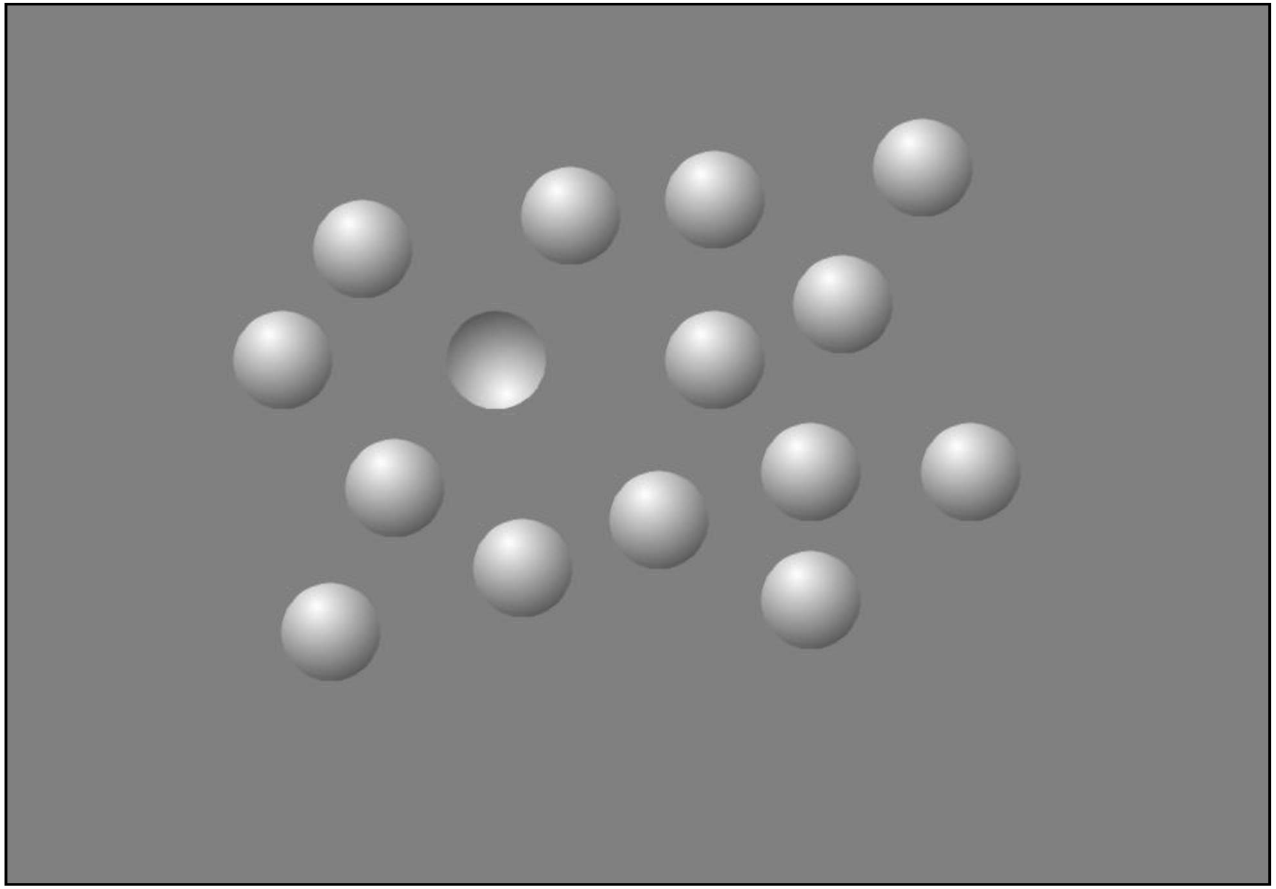
Pre-Attentive Processing - **Motion**



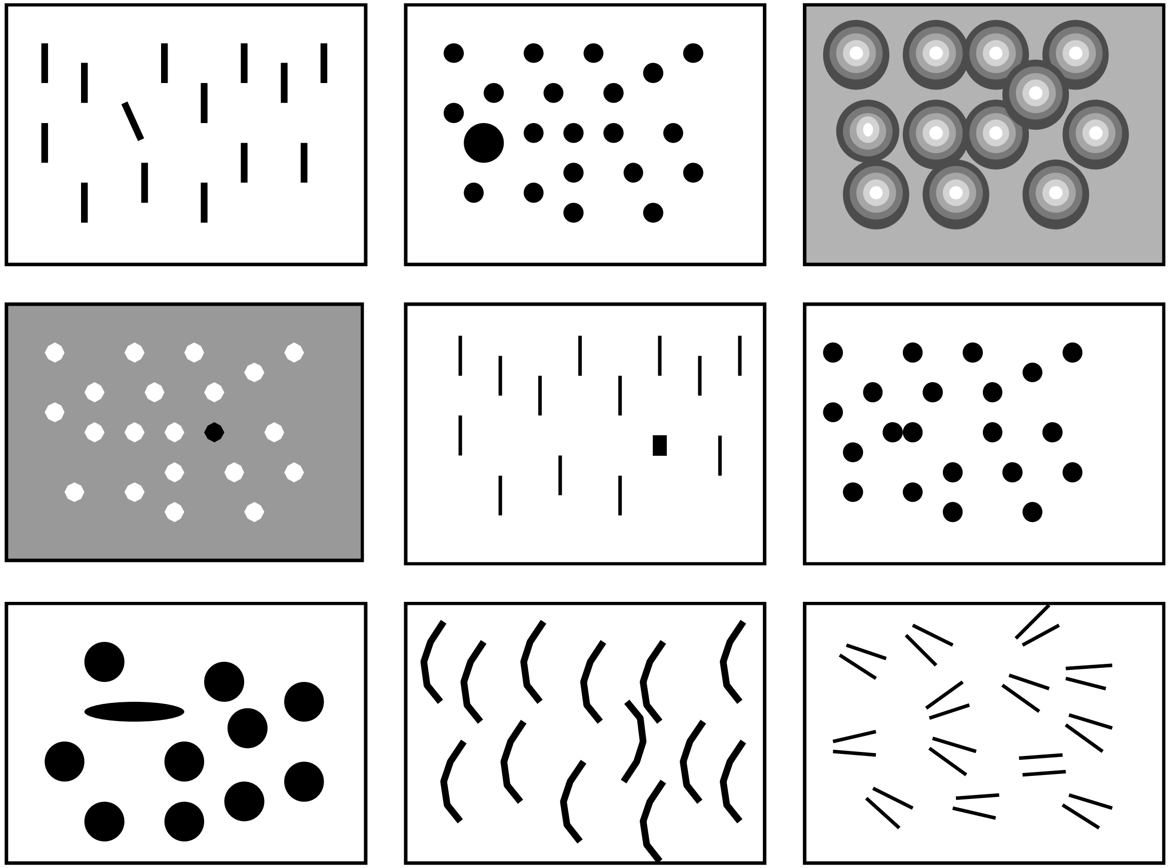
Pre-Attentive Processing - **Orientation**



Pre-Attentive Processing - **Simple shading**



Pre-Attentive – Summary



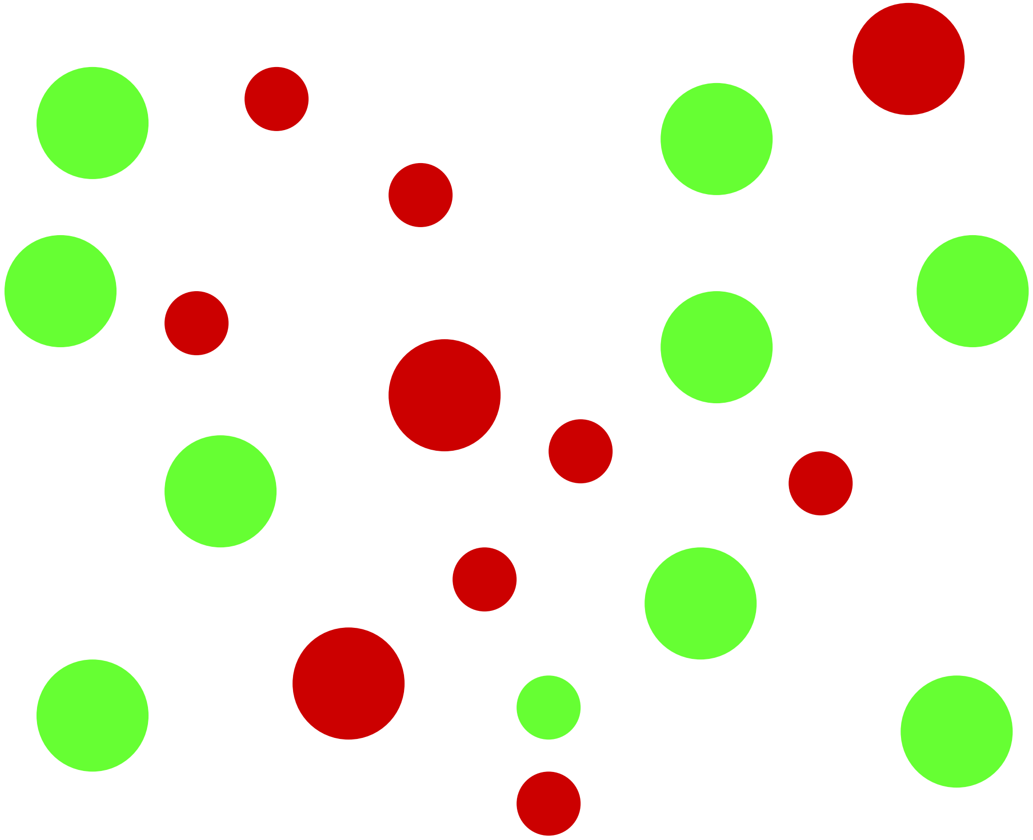
Problem solved?

- No!
- Cojunction of pre-attentive features is often NOT pre-attentive!

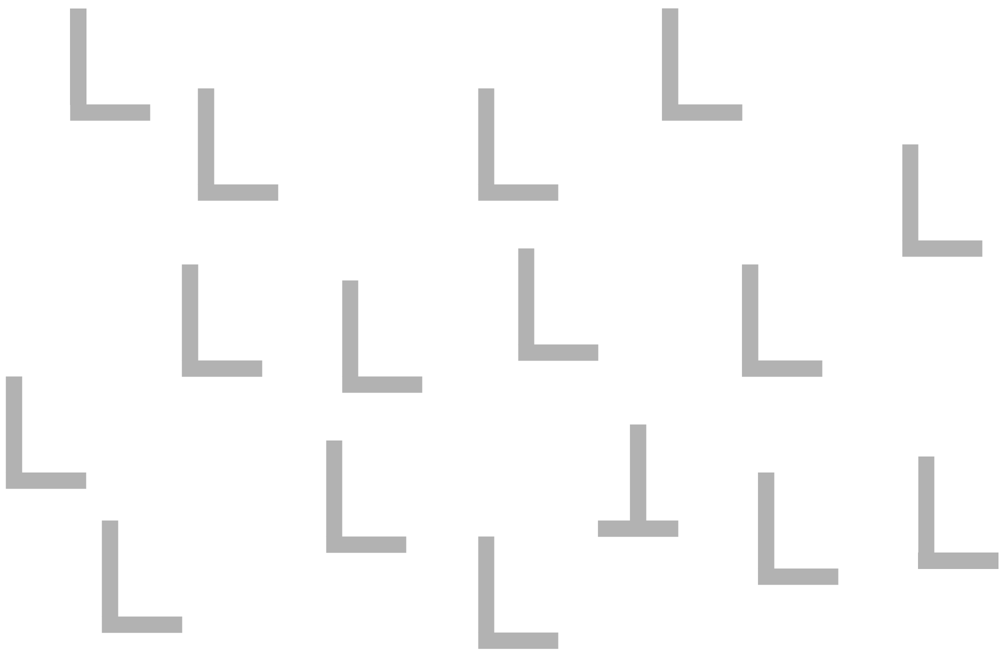
Pre-Attentive Conjunctions

- Position + Color
- Size + Color
- Position + Shape
- Color + Motion
- ...

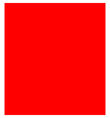
Color+size conjunction (does not pop out)



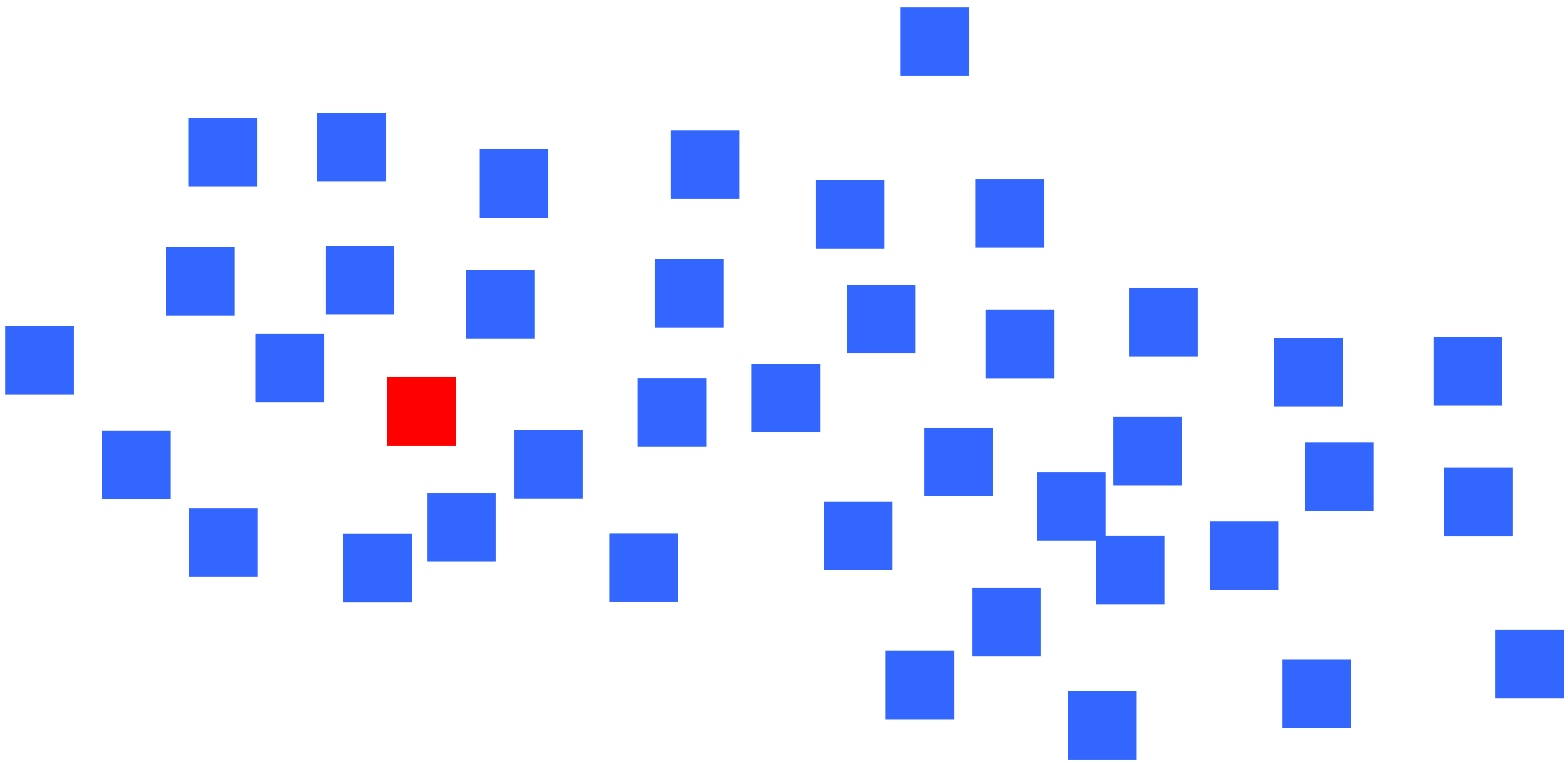
Compound features (do not pop out)



Pre-Attentive Demo

- **Pre-Attentive Demo by Christopher Healey**
- **Target =** Red square 

Go!

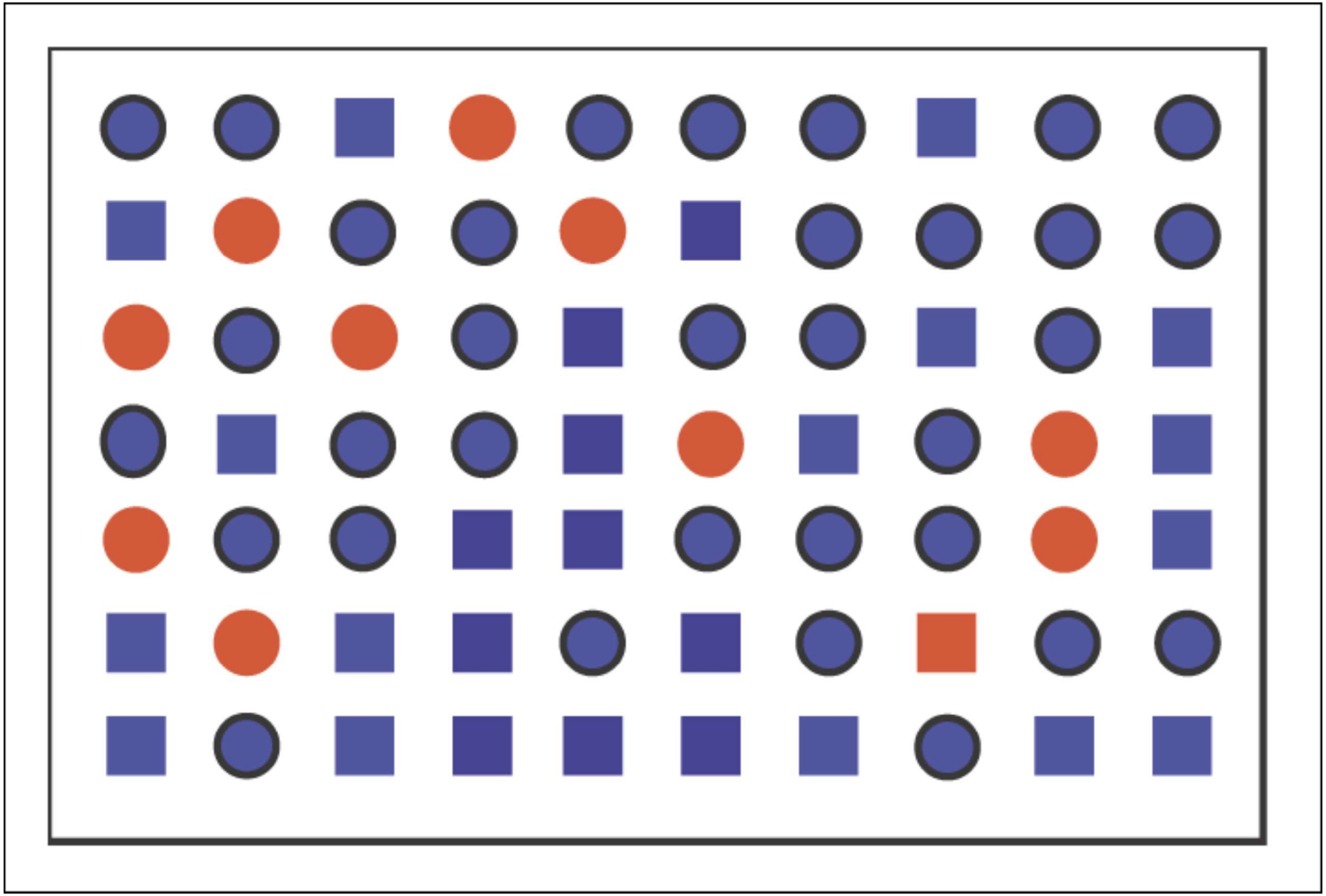


Viewer *cannot* rapidly and accurately determine if target (**red square**) is present or absent when target has two or more features, each of which are present in the distractors.
Viewer must search sequentially.

- **Target =** Red square

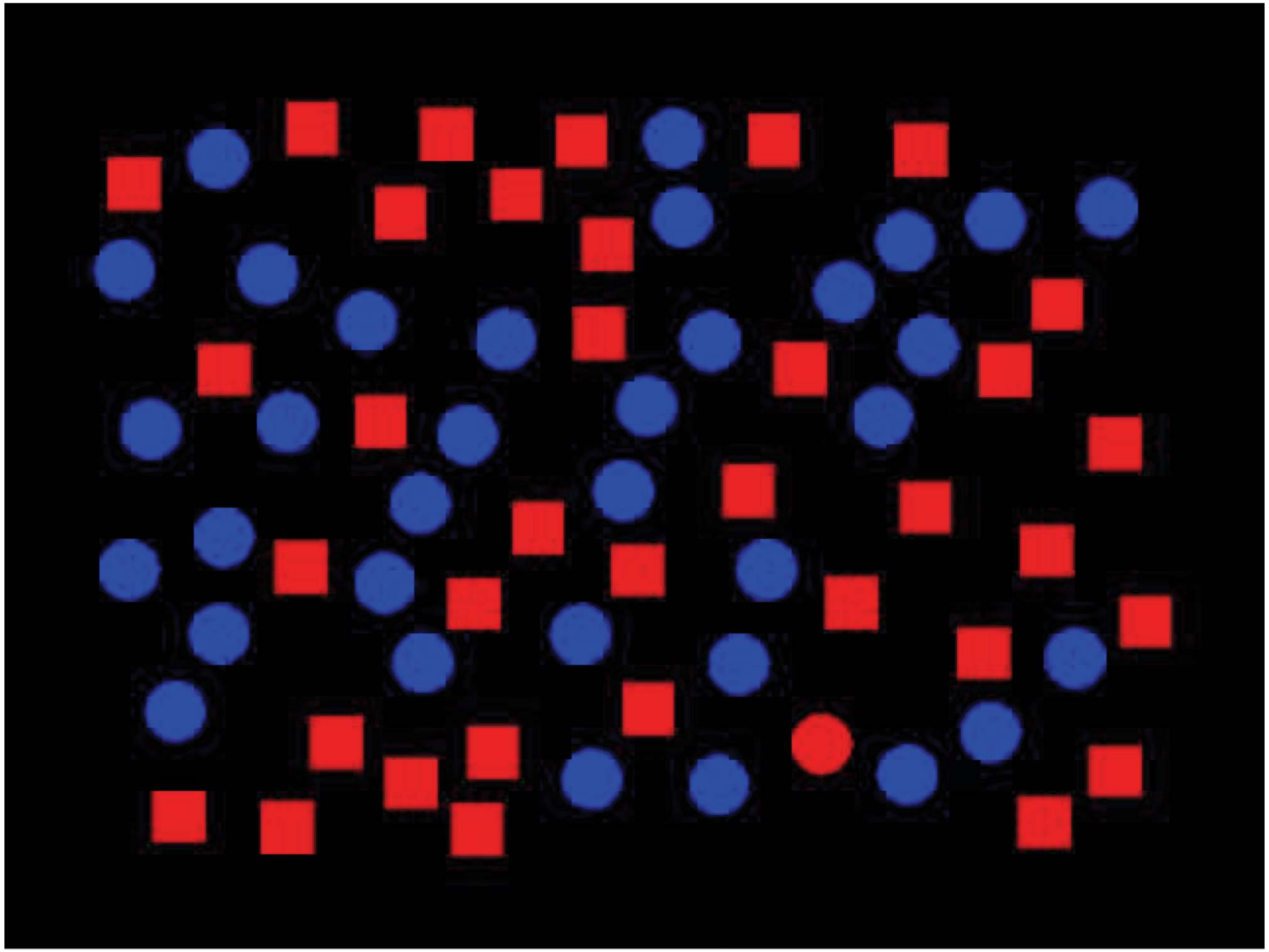
Pre-Attentive Demo

- **Distractors**
  - – blue squares (color search)
  - – red circles (shape search)
  - – blue circles and red squares (conjunction search)



With conjunction encoding the red square is not pre-attentively identified.

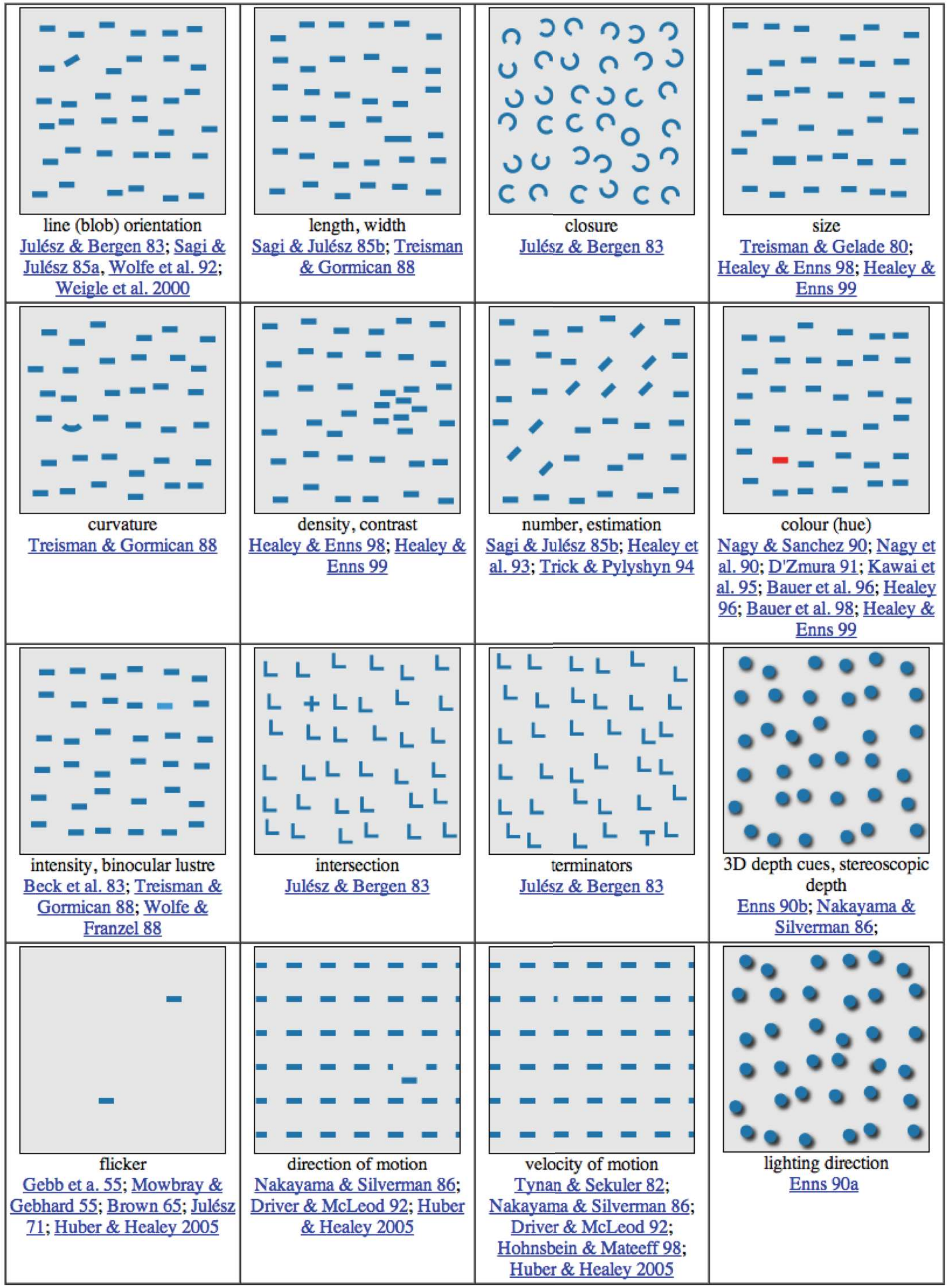
Preattentive Processing



Perception in Visualization:
http://www.csc.ncsu.edu/faculty/healey/PP/

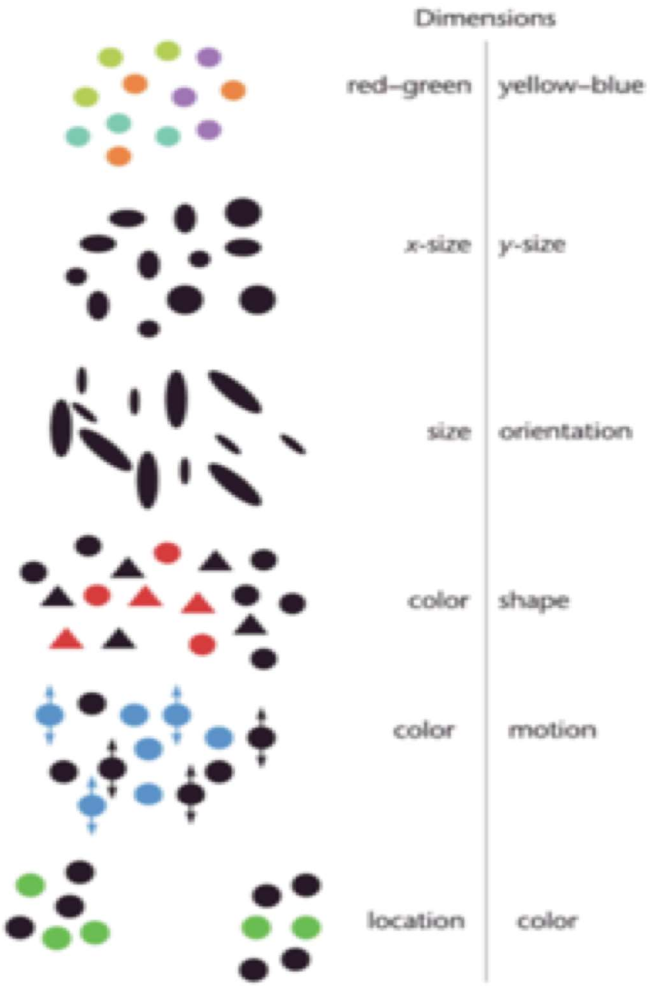
Preattentive Features

http://www.csc.ncsu.edu/faculty/healey/PP/



Integral-Separable Dimensions Theory (Colin Ware)

most integral

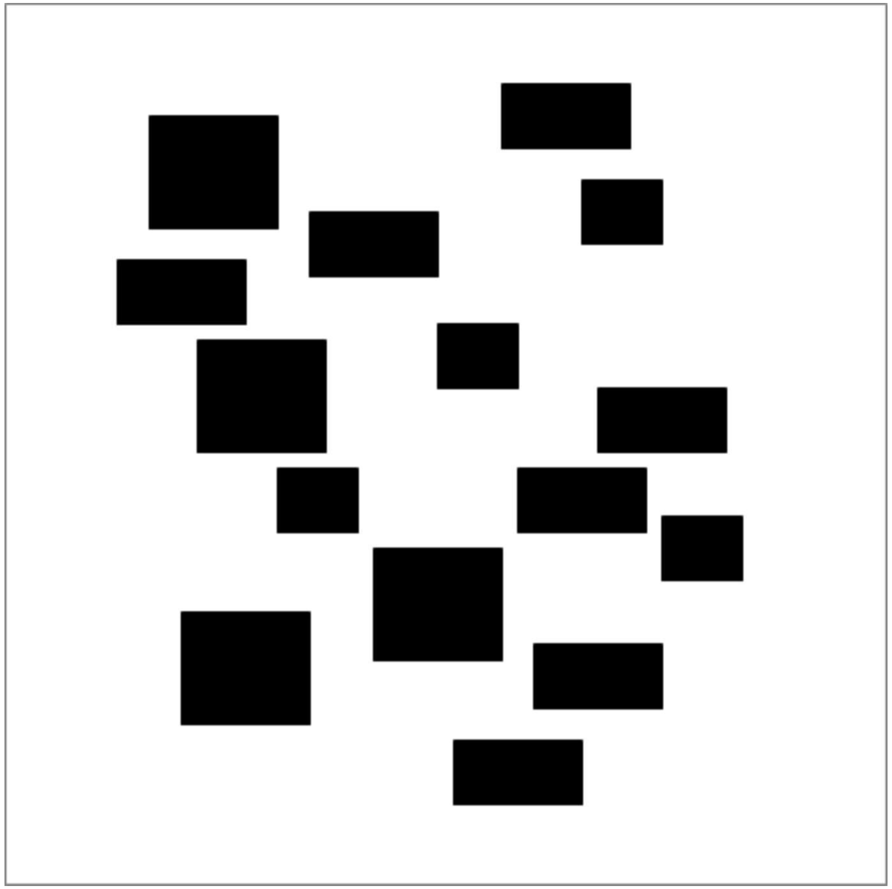


most

All features influence each other to some extent but some more than others. For instance, if you use *color* and *size* to encode two data features, the way color is perceived will be affected by the size of the object

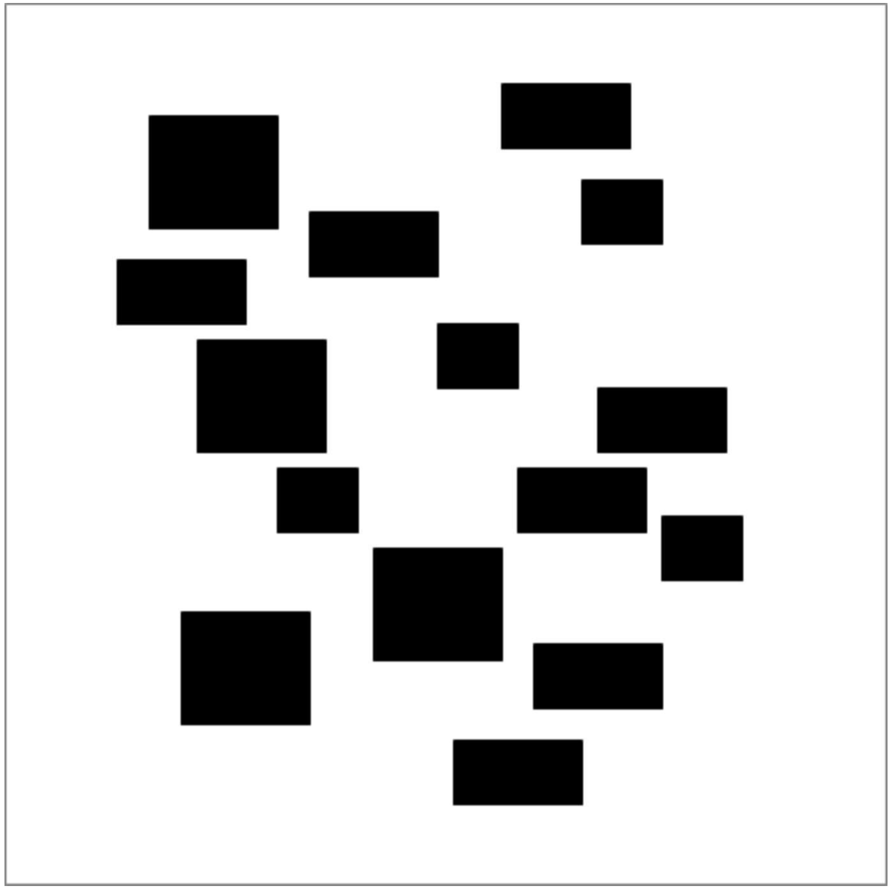
when encoding different data attributes with different visual features, there are good combinations that make them separable, there are also combinations that make them not separable

Get rectangle of same **w i d t h** ?



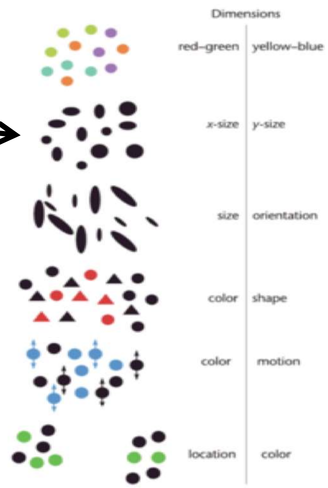
Two variables
are encoded using
width and height

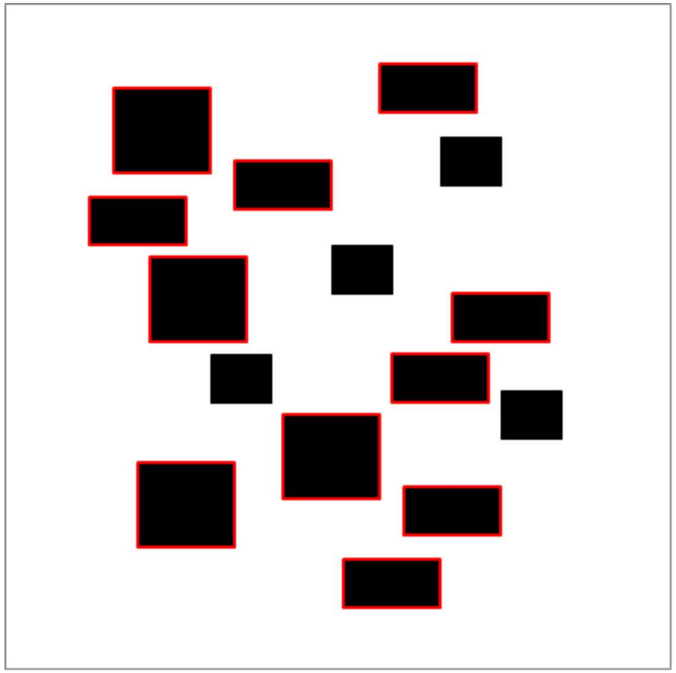
Get rectangle of same height?



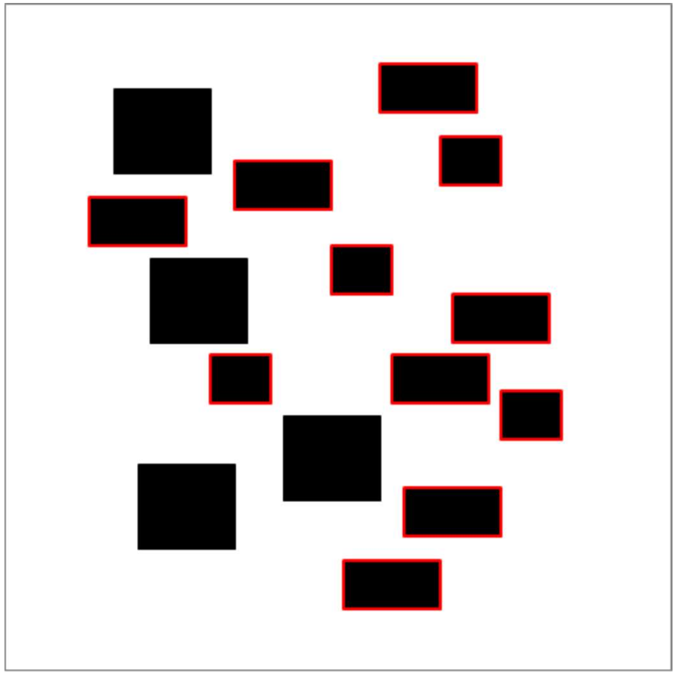
Two variables
are encoded using
width and height

Not so easy...



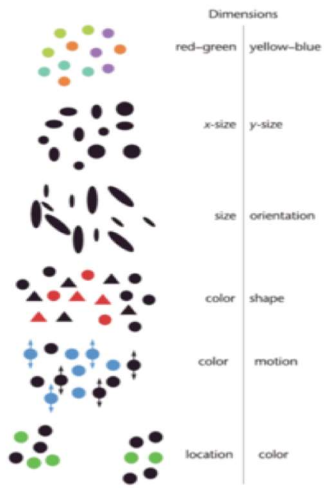


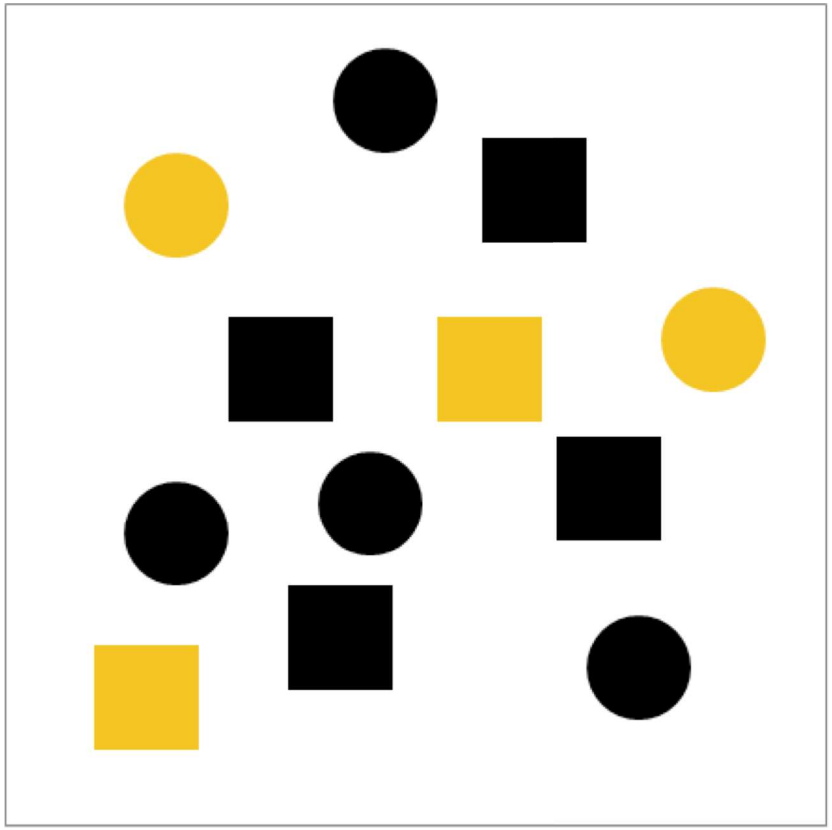
same width



same height...

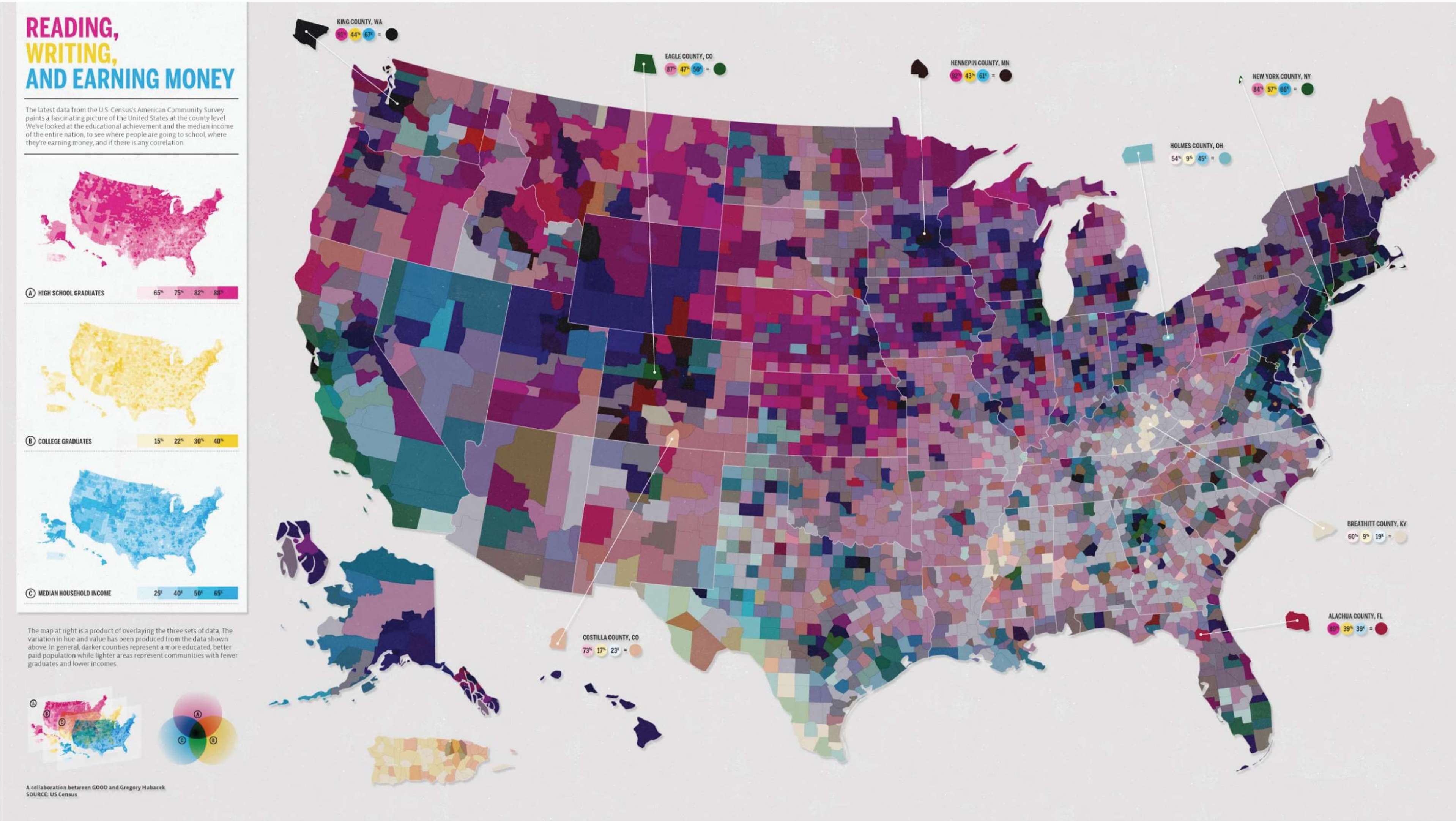
Much better !





Shape and color are more separable than width and height!

Cargo cult visualizations! Thanks to Enrico Bertini...



See discussion here:
http://fellinlovewithdata.com/reflections/demystifying-cargo-cult-visualization-you-cannot-visualize-3-variables-by-mixing-3-colors

cargo cult science in a famous lecture … (source Wikipedia)

- to negatively characterize research in the soft sciences (psychology and psychiatry in particular) – arguing that they have the semblance of being scientific, but are missing “a kind of scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty”.

Cargo cult visualization

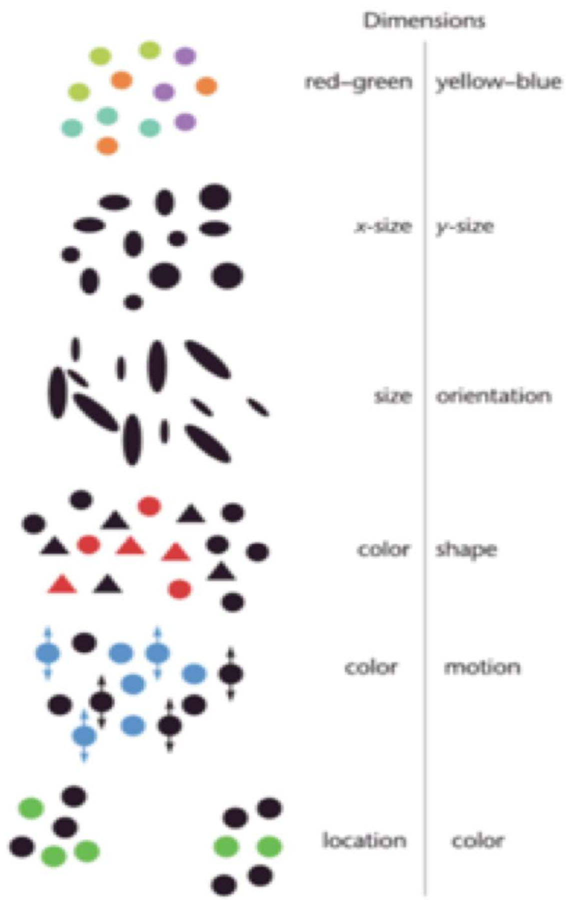
- Cargo cult vis is not just junk charts, it’s more insidious. In chart junks there is “only” the bad or creative use of standard charts in ways that basically hide the message behind the glitter. But here we have a more courageous step: a method proposed like if it was new when in fact it is not new at all and it’s badly executed

- **Cargo cult visualization is trying to invent new techniques without having any minimal knowledge of the basics**

- That’s dangerous and can deceive novices who are interested in visualization

you cannot visualize 3 variables combining 3 colors

- You are on the top of the scale: most integral!



What are the general implications of these perceptual processes in visualization design and use?

(details about colors will be discussed in a more specific class)

Highlighting (Pop-Out Effect)

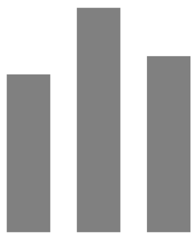
- use pre-attentive features and separable values (e.g. green and red) to stand out

Encoding

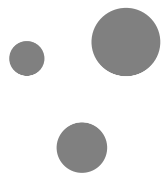
- limit the number of features
- limit number of levels
- remember perceptive issues
- reduce interference between channels

Representation of Quantitative Information

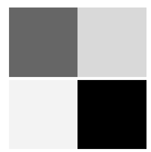
Visual features can be used to encode quantitative information (to answer “how much” questions). For instance ...



Bar Height



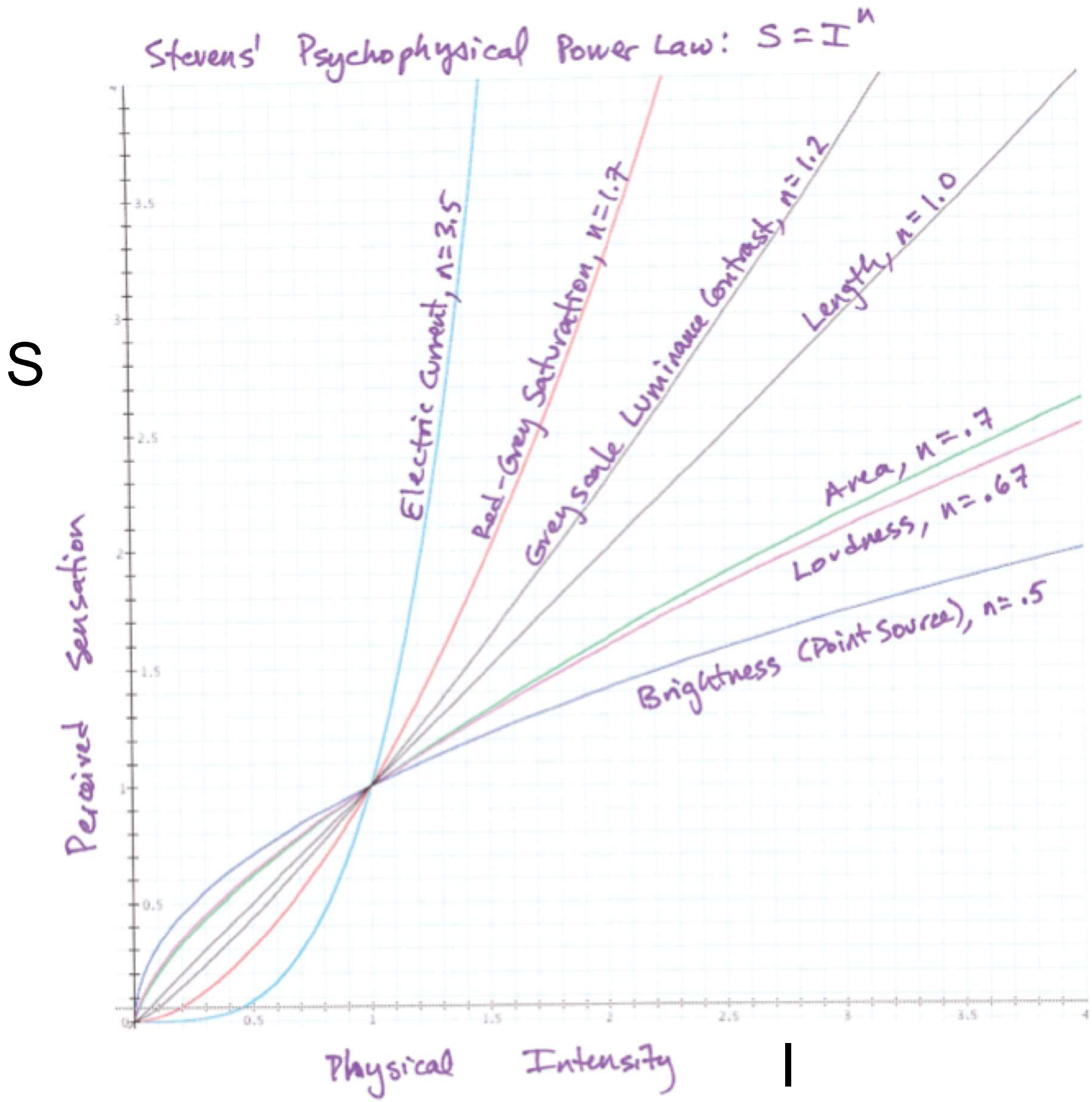
Symbol Size



Color Intensity

How are they perceived? Are they equally effective?

Accuracy: Steven's Power Law



Relative Vs. Absolute Judgments

Psychophysics: physical stimulus vs. perceived sensation

Human perception based on relative judgments not absolute readings of physical stimuli

The same physical stimulus may lead to different perceptions when context changes

Just Noticeable Difference (JND)

"*The smallest detectable difference between a starting and secondary level of a particular sensory stimulus*"

Weber's Law

"*The just-noticeable difference between two stimuli is proportional to the magnitude of the stimuli*"

Example: Weight

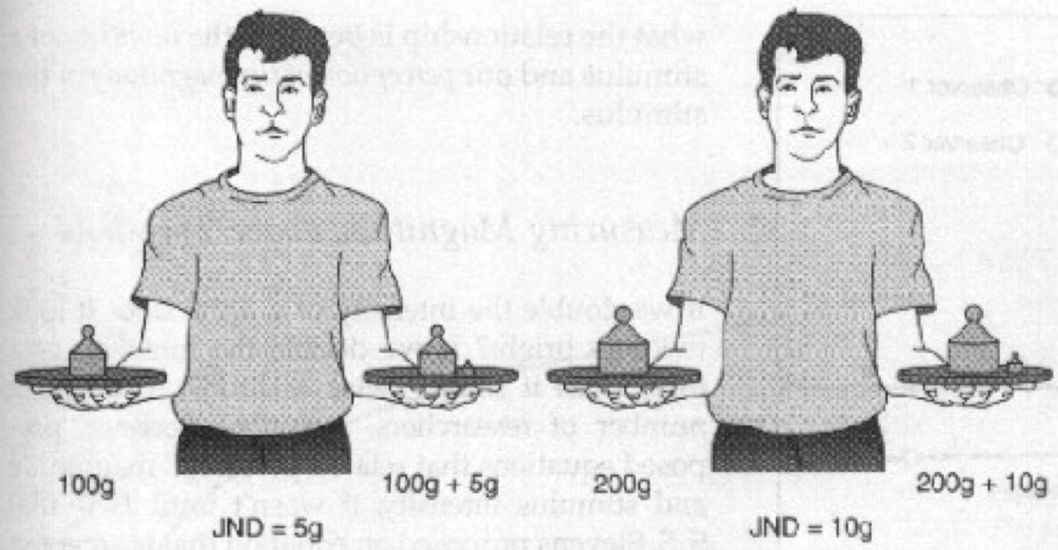


Figure 1.17

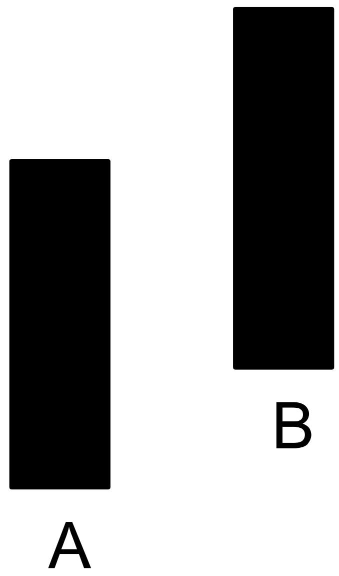
The just noticeable difference (JND). The person can detect the difference between a 100-gram weight and a 105-gram comparison weight but cannot detect a smaller difference, so the JND is 5 grams. With a 200-gram weight, the comparison weight must be 210 grams before the person can detect the difference, so the JND is 10 grams. Note that for both the 100- and 200-gram weights, the ratio of JND to weight is the same. This ratio is the Weber fraction.

Just Noticeable Differences

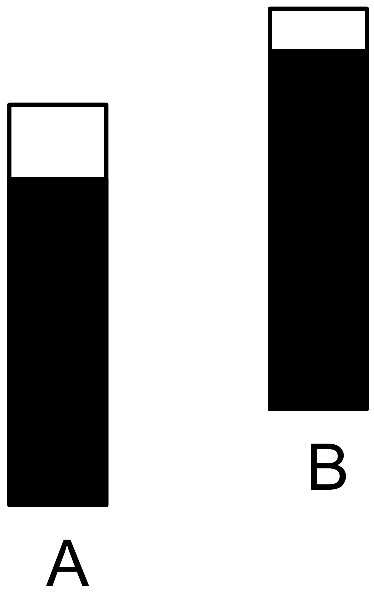
Which one is brighter?

(130,130,130) (140,140,140)

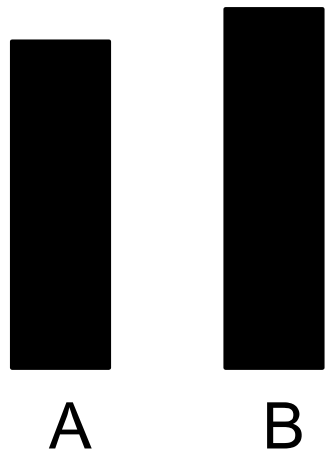
Which one is bigger?



Framed

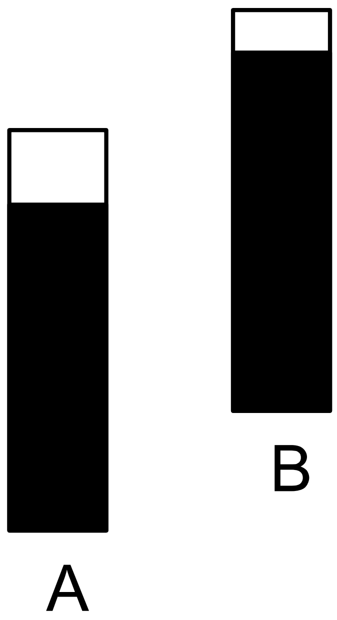


Aligned

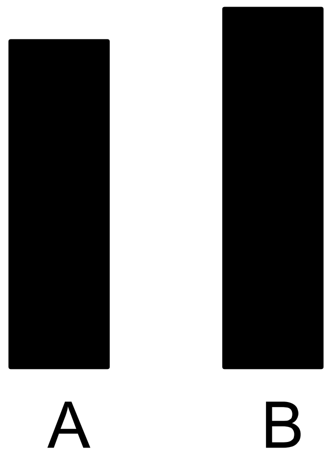


Why framed and aligned are easier to detect?

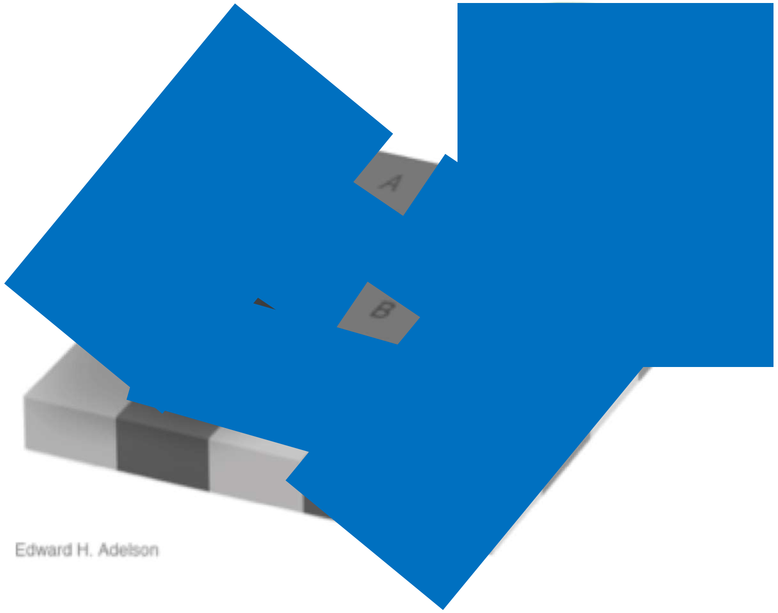
Weber’s law!

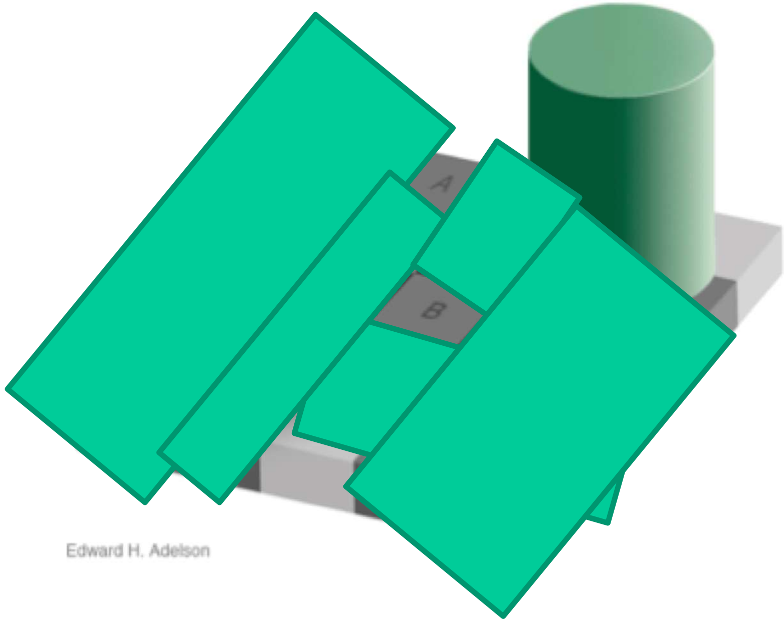


Position is more accurate than length!



A and B?




A
B
Edward H. Adelson


BEWARE
OF
DOG!

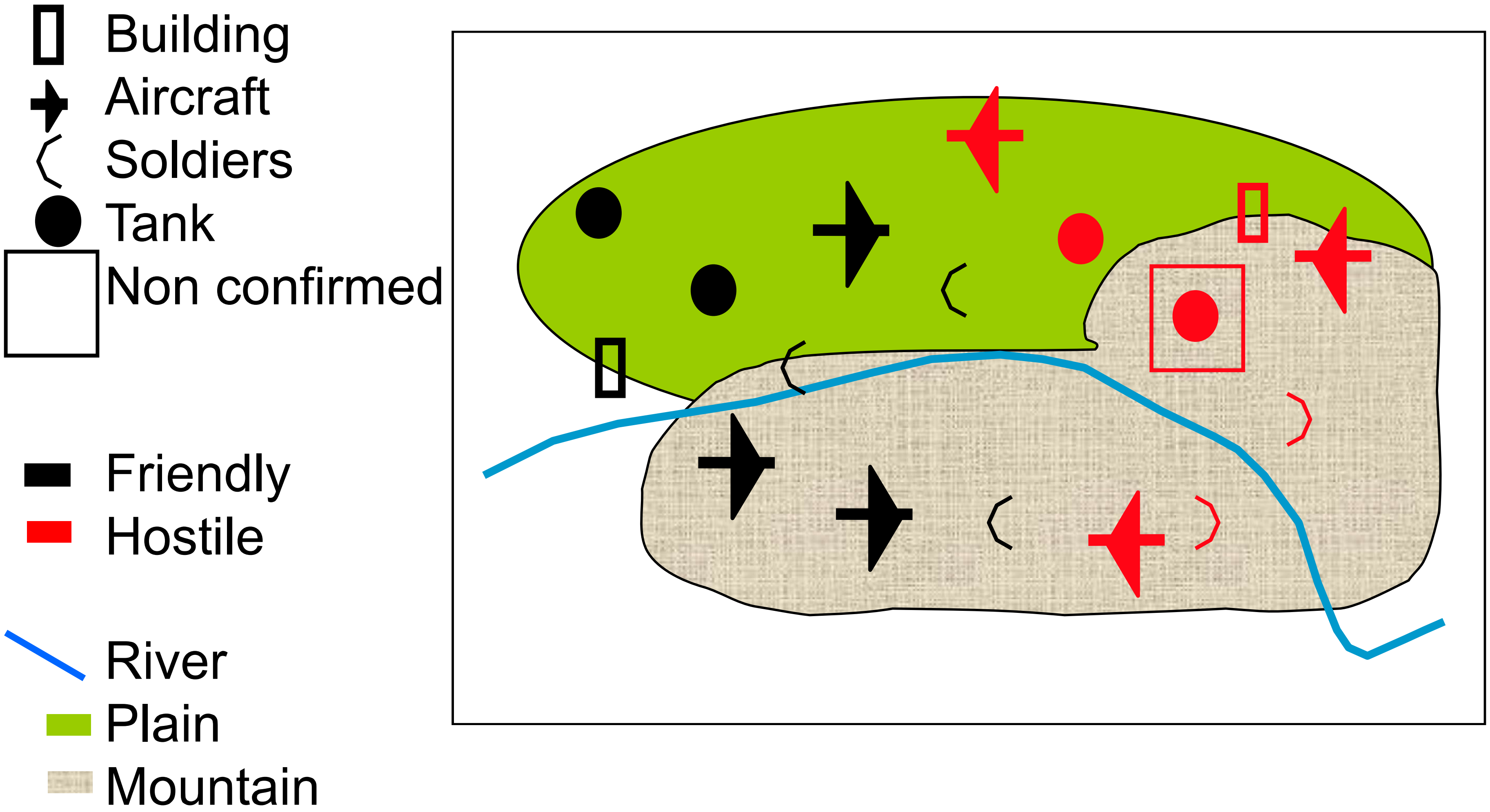
A didactical example:
A symbol set for a tactical map

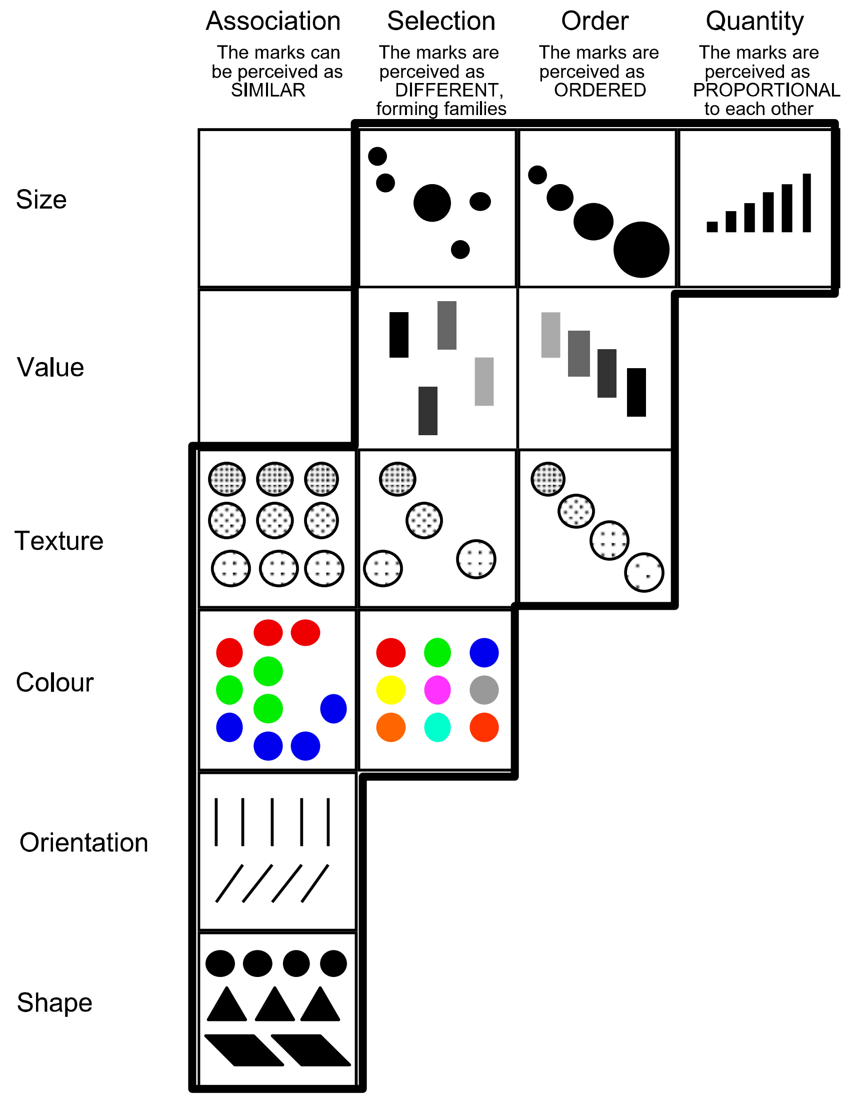
- Aircrafts
- Tanks
- Buildings
- Soldiers
- +
- Stress during decision
- Each item can be classified as friendly or hostile
- Some items exists whose presence is just suspected but not confirmed
- Terrain

A symbol set for a tactical map

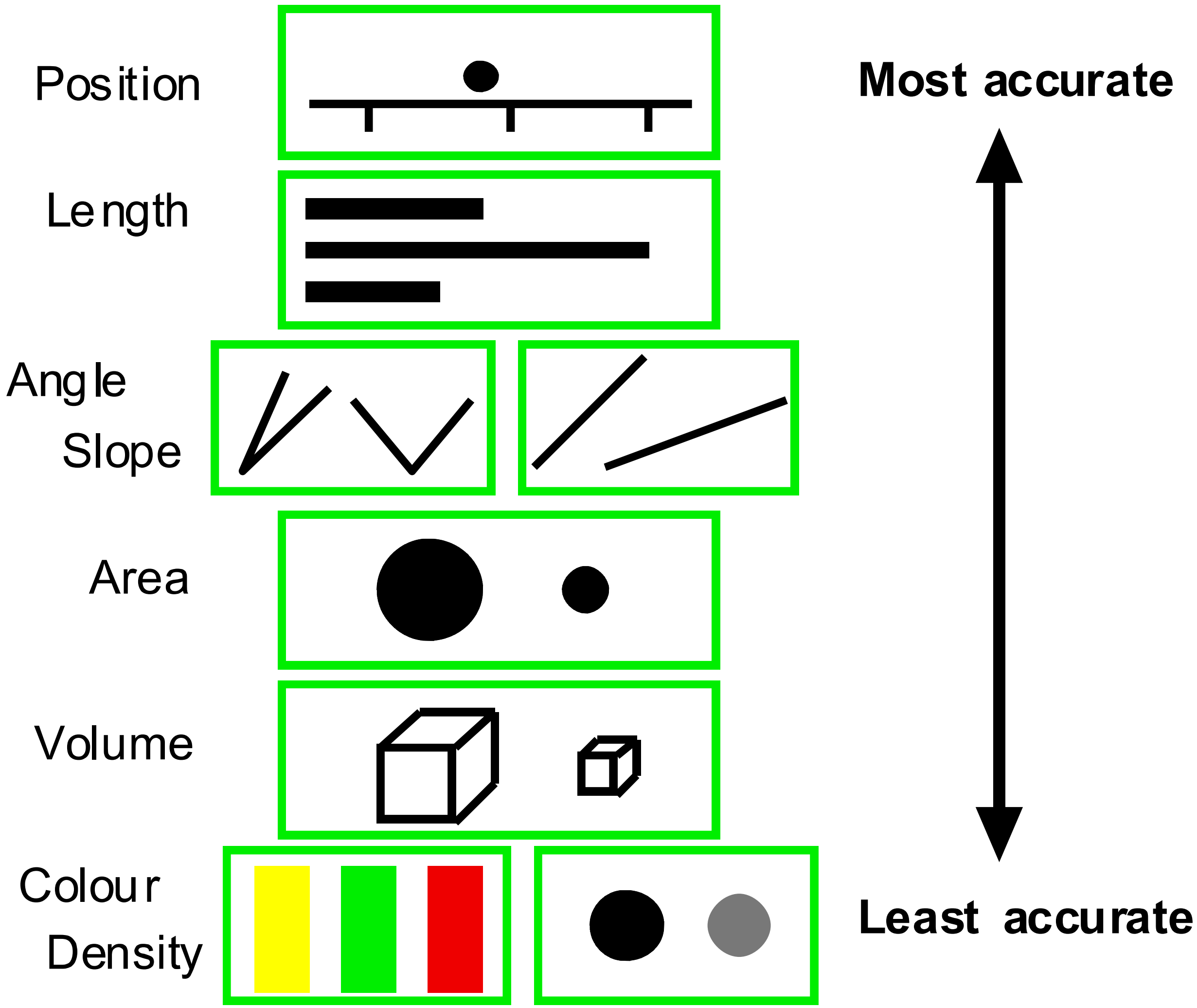
- Aircrafts Tanks Buildings Soldiers
  - Different using **pre-attentive shapes**
- Each item can be classified as friendly or hostile
  - Labeled with **two well separable colors and using cultural interpretation (red=danger)**
- Some items exists whose presence is just suspected but not confirmed
  - Made different with **pre-attentive enclosure**
- Terrain
  - Rendered through **simplified shapes and interpretable colors**

Example

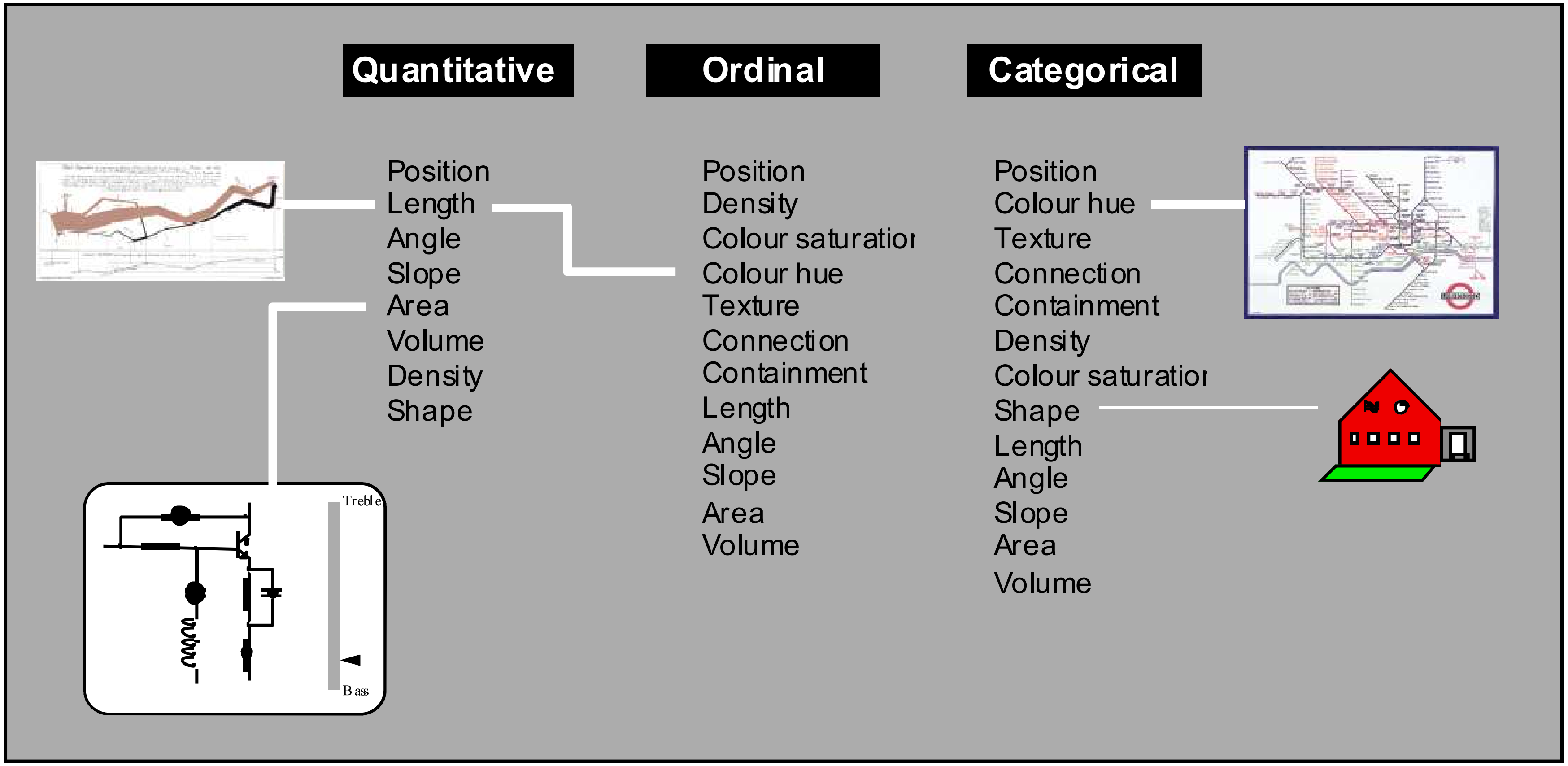

Building
Aircraft
Soldiers
Tank
Non confirmed
Friendly
Hostile
River
Plain
Mountain



Interpretation of Bertin's guidance regarding the suitability of various encoding methods to support common tasks



The relative difficulty of assessing **quantitative** value as a function of encoding mechanism, as established by Cleveland and McGill



Mackinlay’s guidance for the encoding of quantitative, ordinal and categorical data