Visual Encoding Principles

Visualization
Torsten Möller

Overview

- Marks + channels
- Channel effectiveness
  - Accuracy
  - Discriminality
  - Separability
  - Popout
- Channel characteristics
  - Planar position
  - Colour
  - Size
  - Tilt (angle)
  - Shape (glyph)
  - Stipple (texture)
  - Curvature
  - Motion

Readings

- Munzner, “Visualization Design and Analysis”:
  - Chapter 5 (Visual Encoding Principles)
- Colin Ware:
  - Chapter 4 (Color)
  - Chapter 5 (Visual Attention and Information that Pops Out)
- The Visualization Handbook:
  - Chapter 1 (Overview of Visualization)
- Additional (background) reading
  - J. Mackinlay: Automating the design of graphical presentations of relational information. ACM ToG, 5(2), 110-141, 1986

Marks + Channels

- Mark: basic graphical element / geometric primitive:
  - point (0D)
  - line (1D)
  - area (2D)
  - volume (3D)
- Channel: control appearance (of a mark)
  - position
  - size
  - shape
  - orientation
  - hue, saturation, lightness
  - etc.

According to Bertin ...

Channels

Position

Size

(Grey)Value

Texture

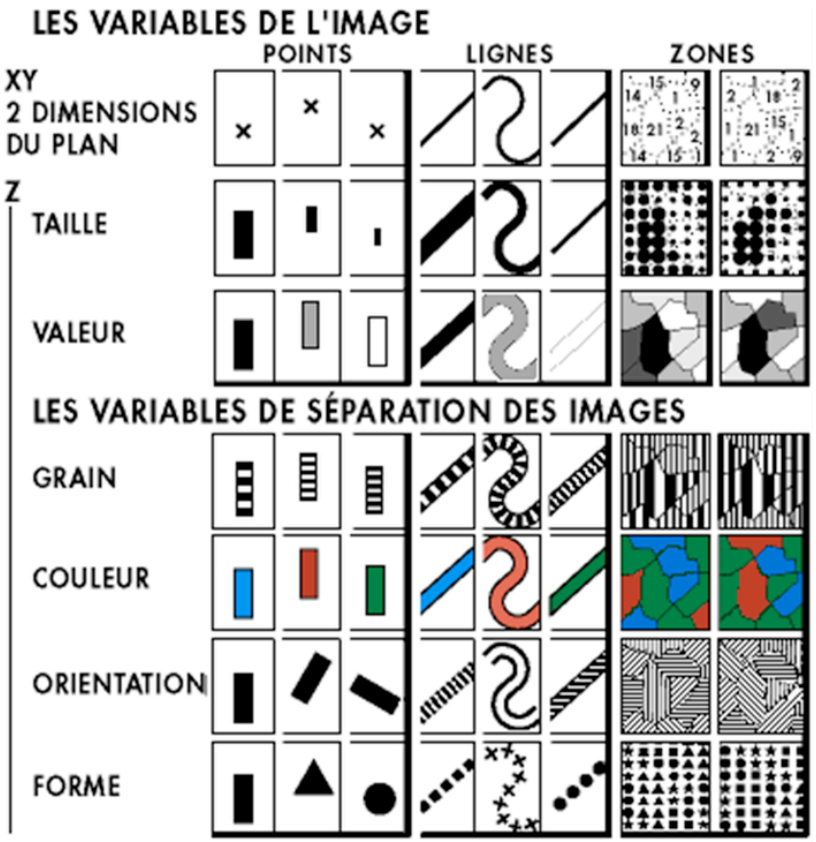
Color

Orientation

Shape

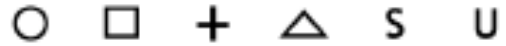
Marks

Points Lines Areas



Semiology of Graphics [J. Bertin, 67]

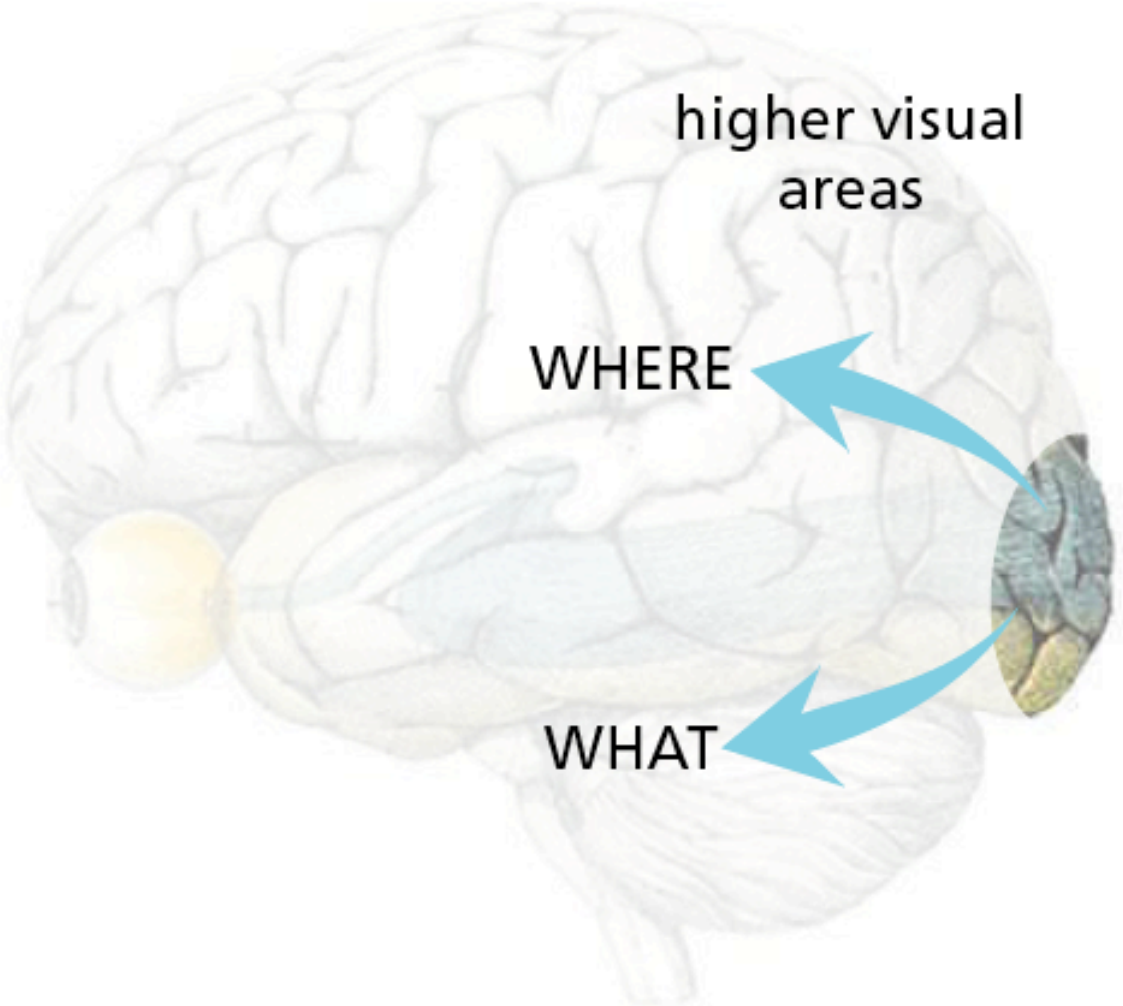
Stolte / Hanrahan

property	marks	ordinal/nominal mapping	quantitative mapping
shape	glyph		
size	rectangle, circle, glyph, text		
orientation	rectangle, line, text		
color	rectangle, circle, line, glyph, y-bar, x-bar, text, gantt bar		

"Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases", Chris Stolte and Pat Hanrahan

Progression

Where / What



Based on slide from Mazur

What vs. How Much channels

- What: **categorical**
  - shape
  - spatial region
  - colour (hue)
- How Much: **ordered** (ordinal, quantitative)
  - length (1D)
  - area (2D)
  - volume (3D)
  - tilt
  - position
  - colour (lightness)

Mark types

- tables: item = point
- network: node+link
- link types:
  - **connection**: relationship btw. two nodes
  - **containment**: hierarchy

Expressiveness + Effectiveness

- expressiveness principle:
  - visual encoding should express all of, and only, the information in the dataset attributes
  - lie factor
- effectiveness principle:
  - importance of the attribute should match the salience of the channel
  - data-ink ratio

Effectiveness of Mappings

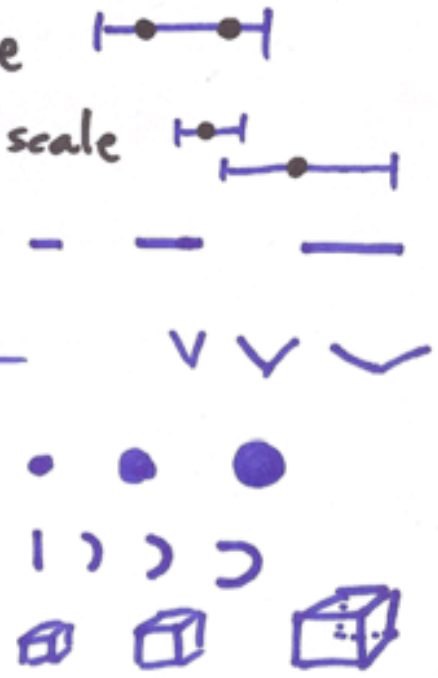
- Effectiveness according to neurophysiology
- Cells in Visual Areas 1 and 2 differentially tuned to each of the following properties:
  - Orientation and size (with luminance)
  - Color (two types of signal)
  - Stereoscopic depth
  - Motion

Channels and Marks: Types and Ranks

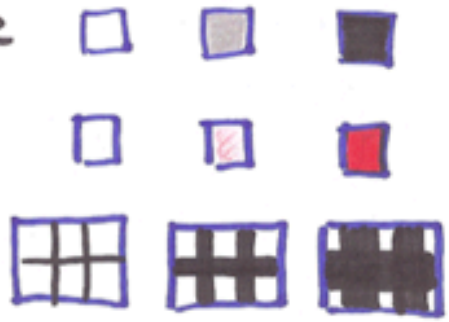
Ordered: Ordinal/Quantitative

How much

- position on common scale
- position on unaligned scale
- length (1D size)
- tilt/angle
- area (2D size)
- curvature
- volume (3D size)



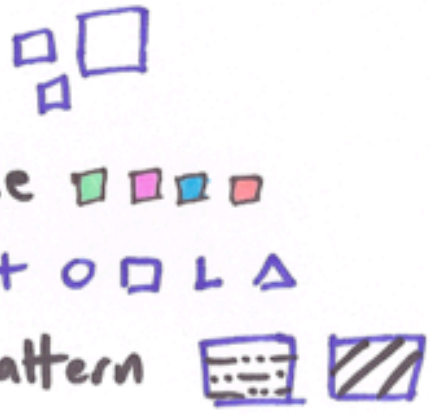
- lightness black/white
- color saturation
- stipple density



Categorical

What

- region
- color hue
- shape
- stipple pattern

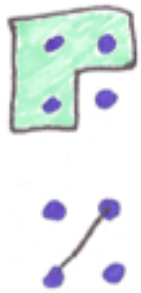


Marks as Items/Nodes

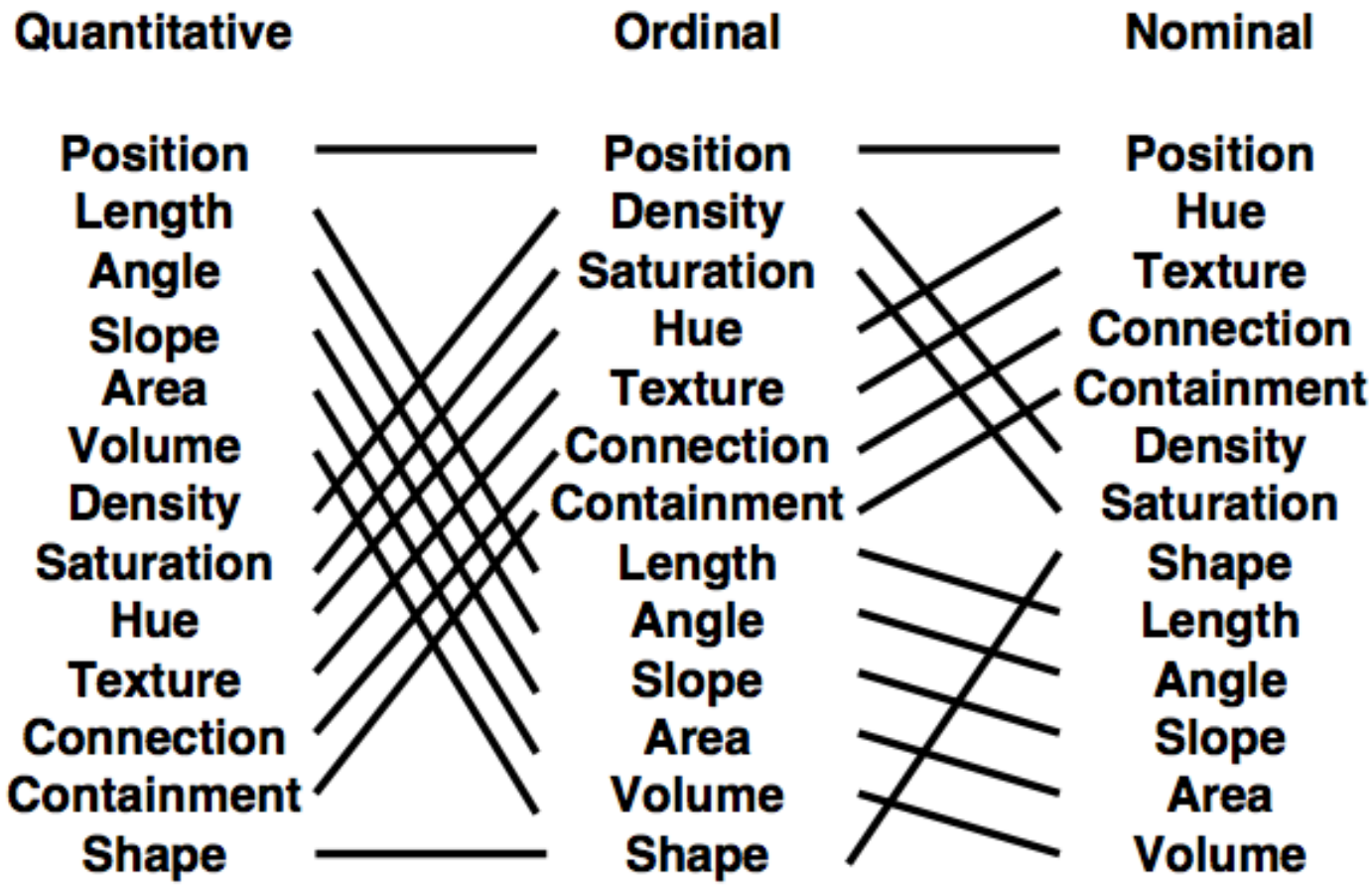
- points
- lines
- areas

Marks as Links

- containment (area)
- connection (line)



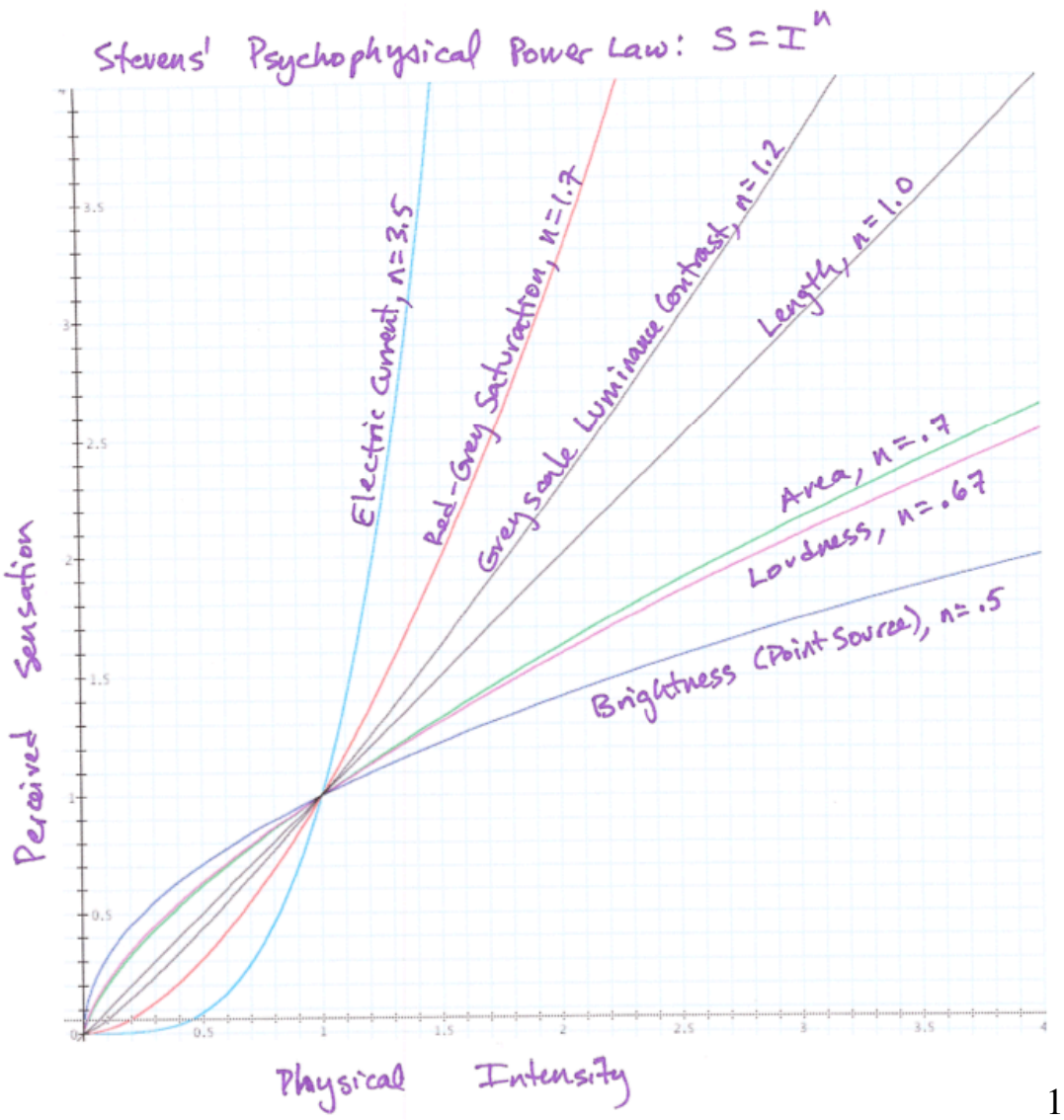
Mackinlay's Retinal Variables



[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

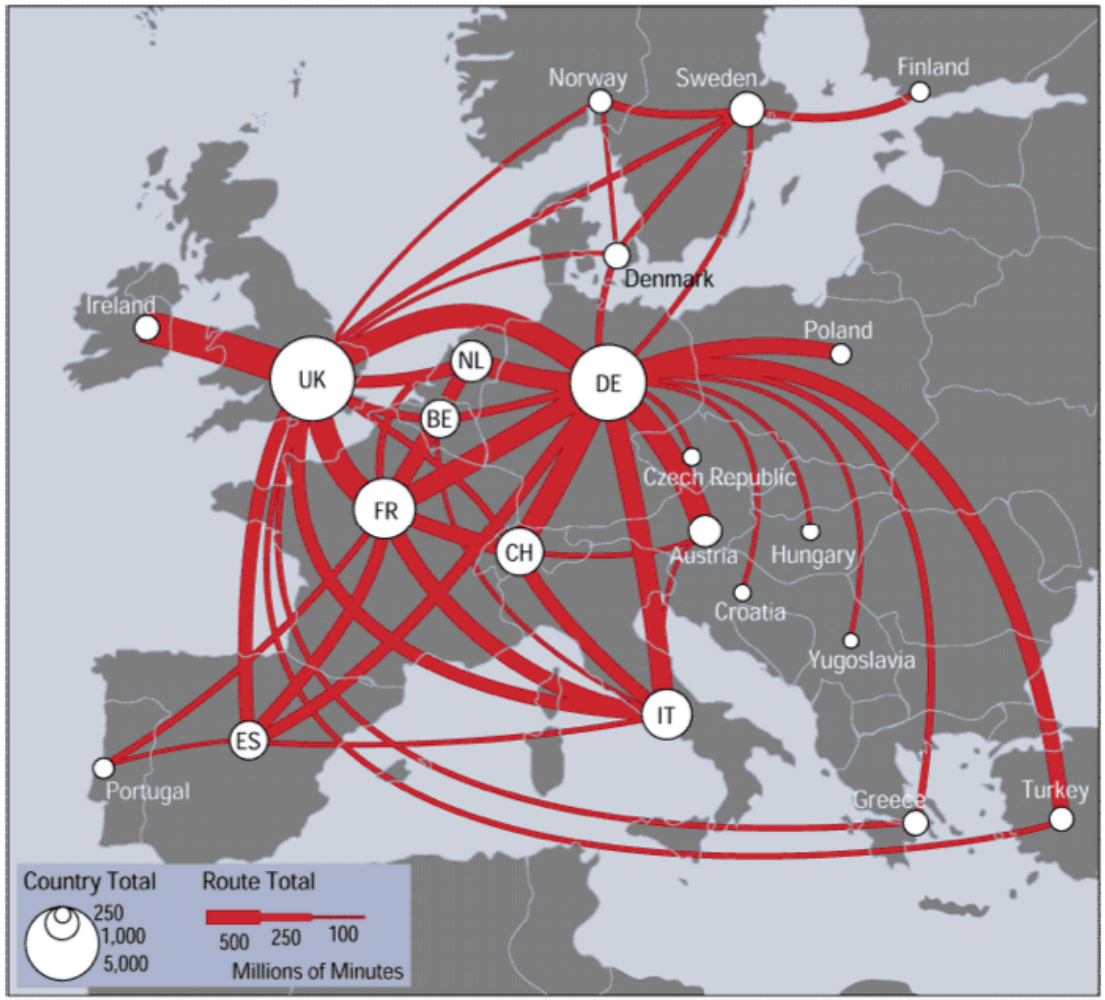
Effectiveness -- Accuracy

- perceptual judgement vs. stimulus
- Weber's law: $S = I^n$



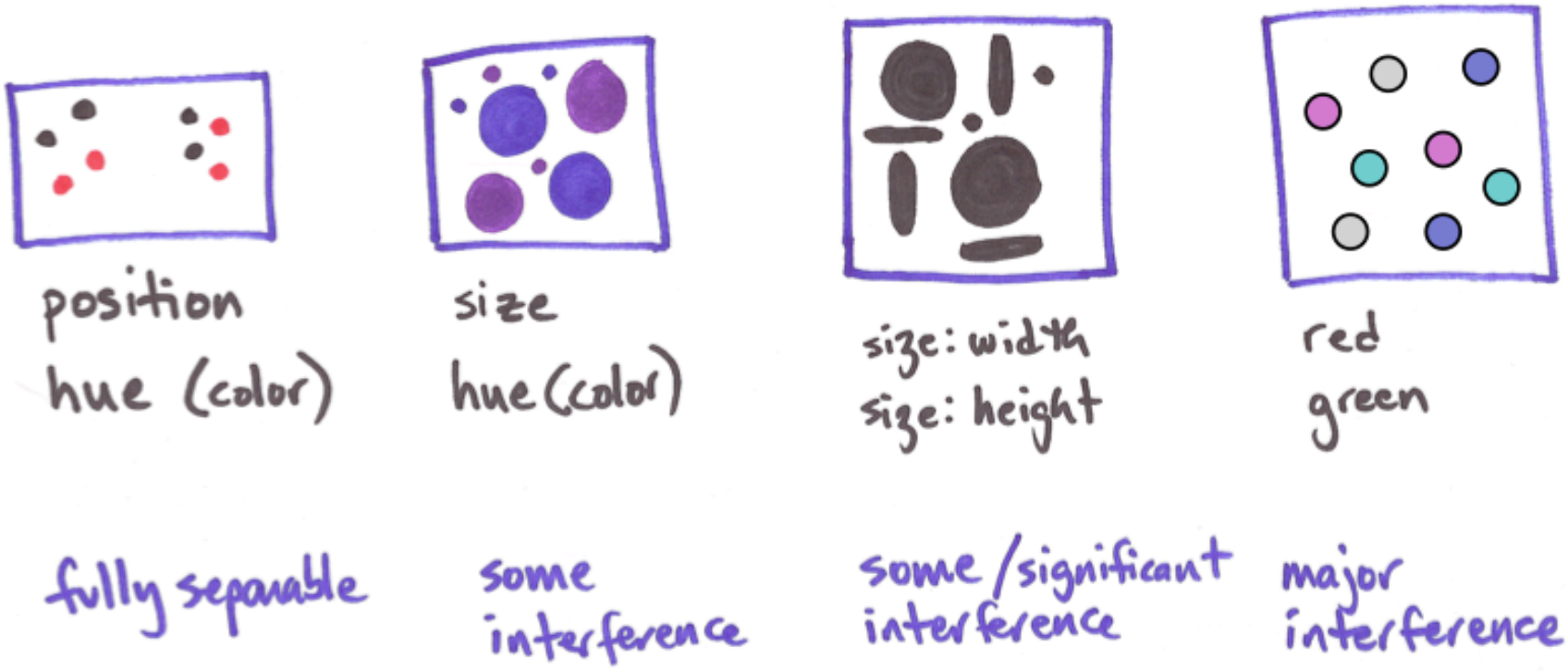
Effectiveness -- Discriminality

- how many colours can I tell apart?
- how many levels of grey etc.
- Ex: line width



Effectiveness -- Separability

- separable vs. integral channels



According to Ware ...

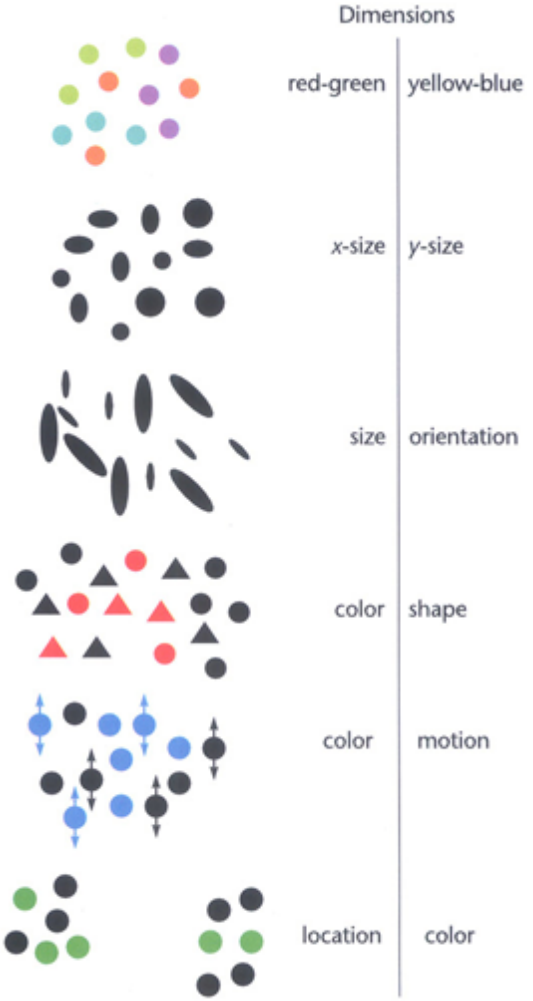
- **Integral** display dimensions
  - Two or more attributes perceived holistically
- **Separable** dimensions
  - Separate judgments about each graphical dimension
- Simplistic classification, with a large number of exceptions and asymmetries

Integral dimension pairs

Separable dimension pairs

red-green	yellow-blue
red-green	black-white
shape height	shape width
shape	size
color	size
direction of motion	shape
color	shape
color	direction of motion
x,y position	Size, shape, or color

More integral coding pairs

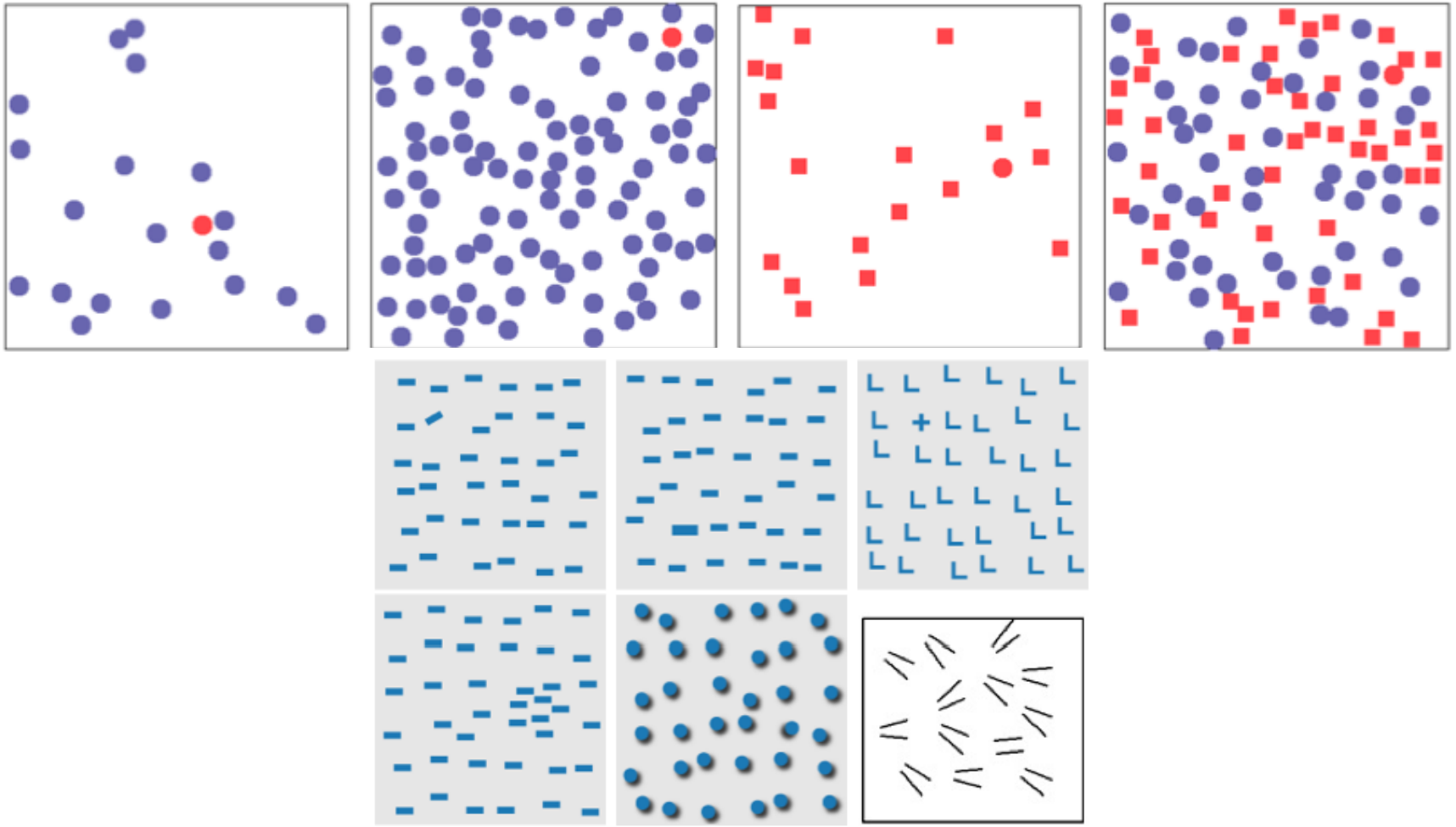


[C. Ware, Information Visualization]

More separable coding pairs

Popout - Preattentive processing

- parallel (visual processing)



Overview

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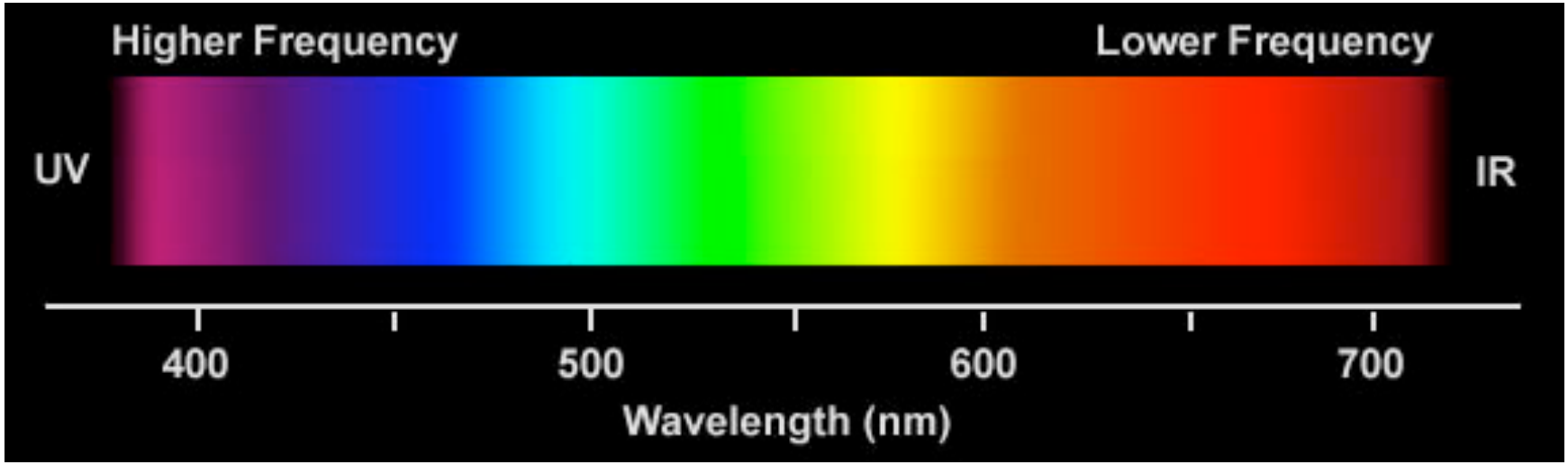
- Channel effectiveness
- **Channel characteristics**
  - Planar position
  - Colour
  - Size
  - Tilt (angle)
  - Shape (glyph)
  - Stipple (texture)
  - Curvature
  - Motion

Channels

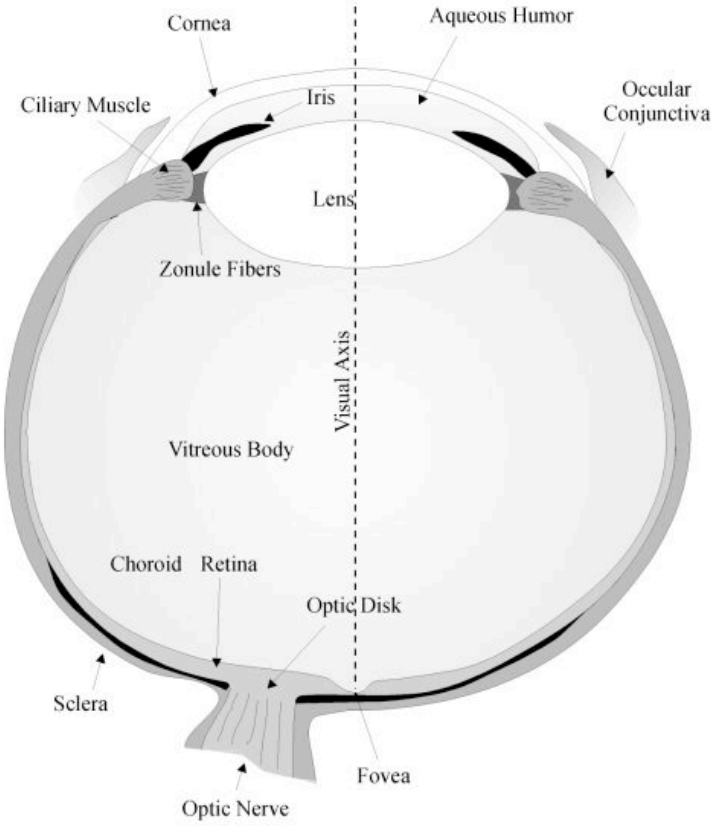
- Planar position: most effective for all data types (remember the power of the plane)
- Size: ‘how much’, interacts with others
- Shape/Glyph: ‘what channel’
- Stipple/texture: less popular today
- Curvature
- Motion: large popout effect

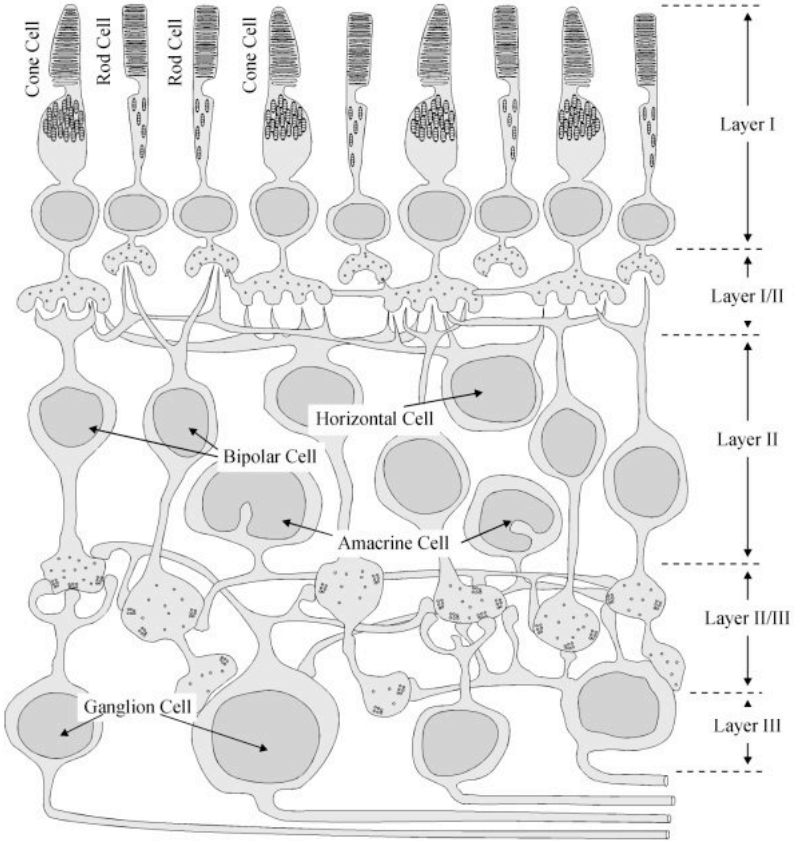
Colour


Higher Frequency
Lower Frequency
UV
IR
400
500
600
700
Wavelength (nm)

Visual System

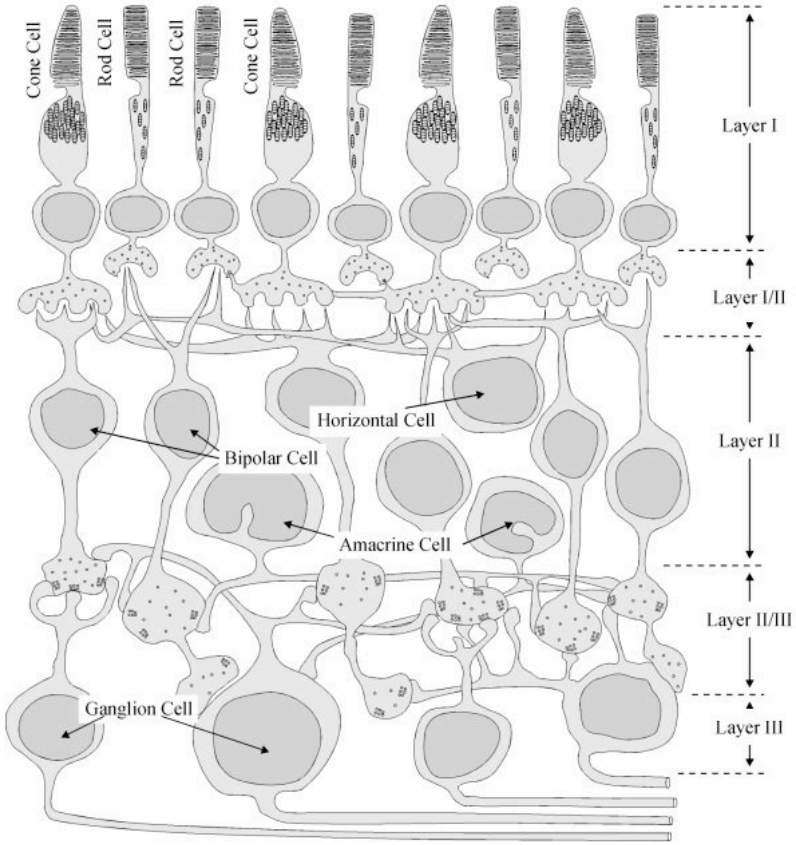
The eye and the retina





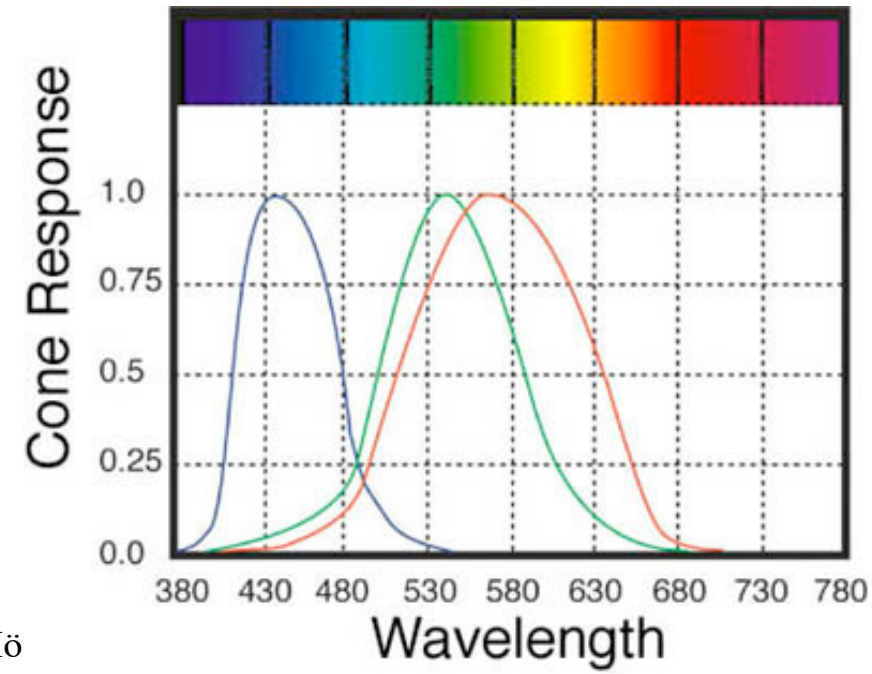
Retina detectors

- 1 type of monochrome sensor (rods)
  - Important at low light
- Next level: lots of specialized cells
  - Detect edges, corners, etc.
- Sensitive to contrast
  - Weber's law: DL ~ L

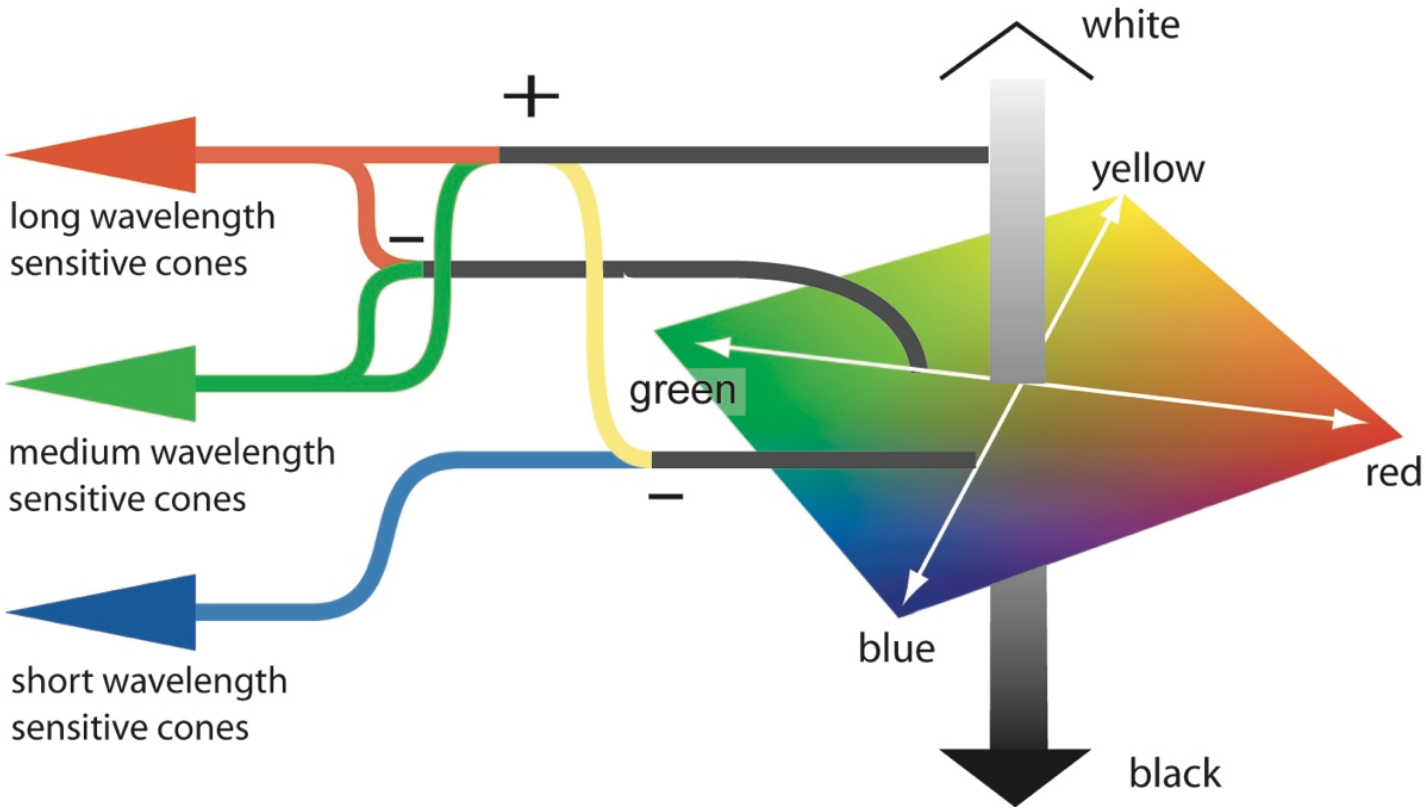


Retina detectors

- 3 types of color sensors - S, M, L (cones)
  - Works for bright light
  - Peak sensitivities located at approx. 430nm, 560nm, and 610nm for "average" observer.
  - Roughly equivalent to blue, green, and red sensors



Color Opponency

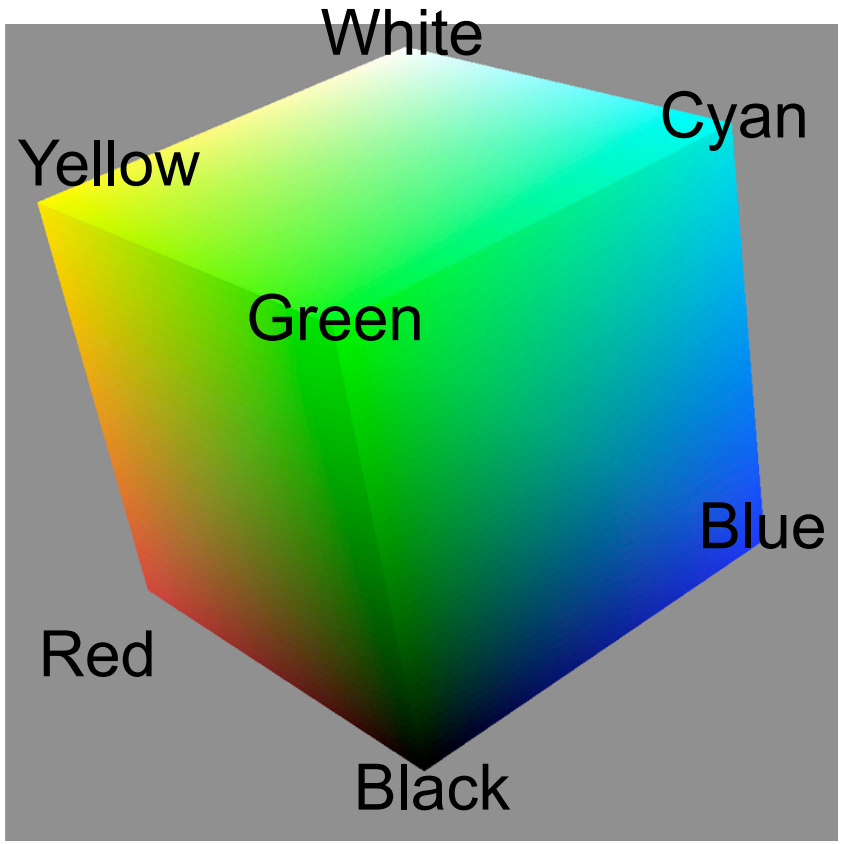


C. Ware, "Visual Thinking for Design"

Color Models

RGB Color Space

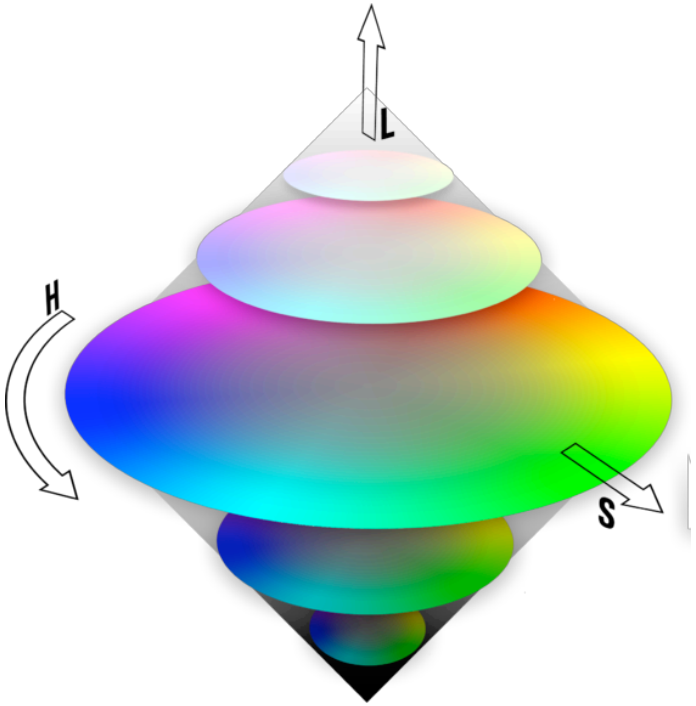
- Additive system
- Colors that can be represented by computer monitors
- Not perceptually uniform



C. Ware, "Visual Thinking for Design"

HSL Color Space

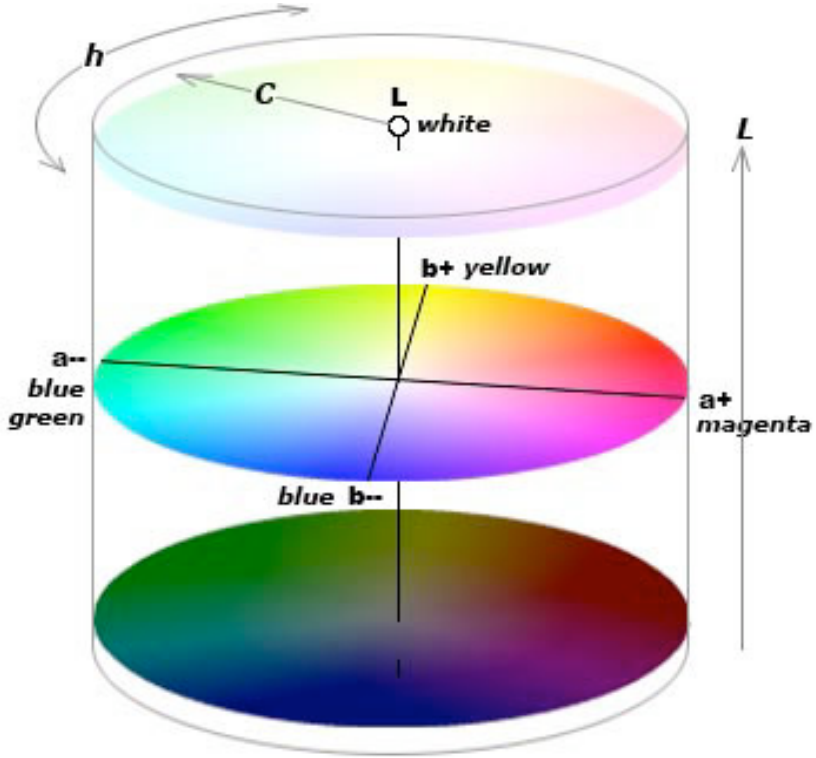
- Hue - what people think of color
- Saturation - purity, distance from grey
- Lightness - from dark to light
- Not perceptually uniform



wikipedia.org

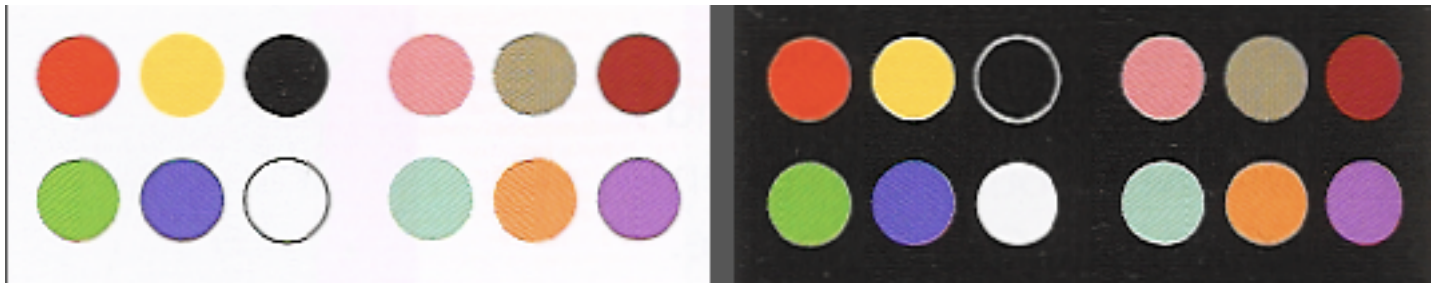
Lab Color Space

- Perceptually uniform
- L approximates human perception of lightness
- a, b approximate R/G and Y/B channels
- a, b called chroma



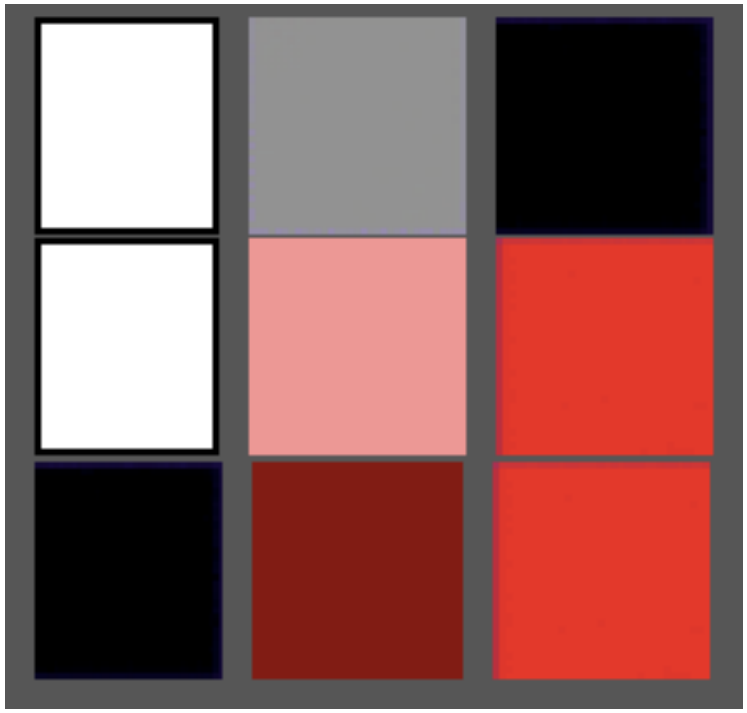
Categorical Data

- Limited distinguishability (8-14)
  - Best with Hue
  - Best choices from Ware:



Ordered Data

- Greyscale
- Saturation
- Brightness



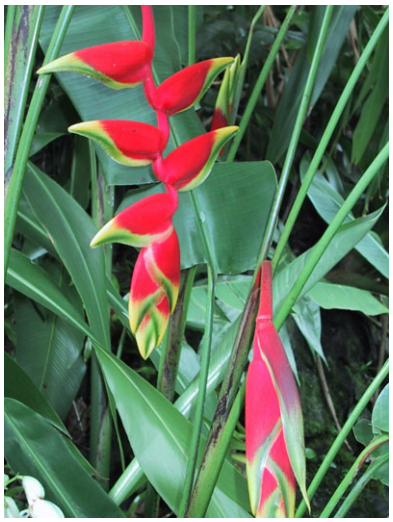
- Rainbow is a learned order!

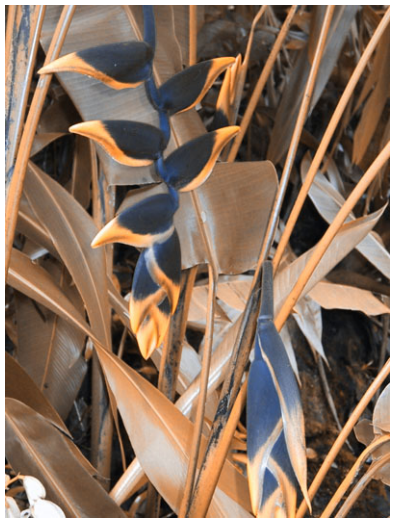
Model “Color blindness”

- Flaw in opponent processing
  - Red-green common (deuteranope, protanope)
  - Blue-yellow possible (tritanope)
  - Luminance channel almost “normal”
- Effect is 2D color vision model
  - Flatten color space
  - Can be simulated (Brettel et. al.)
  - Vischeck (www.vischeck.com)

Courtesy of Maureen Stone

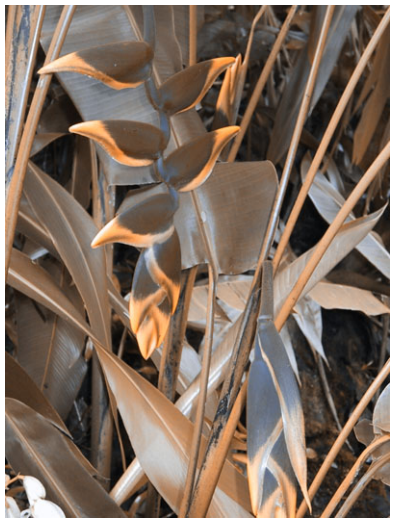
Color Blindness





Protanope

No L cones



Deuteranope

No M cones

Red / green deficiencies

Tritanope

No S cones

Blue / Yellow deficiency

Based on slide from Stone

Color-Blindness

Based on slide from Stone

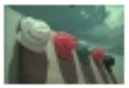
www.vischeck.com

Try Vischeck on a Webpage

Select the type of color vision to simulate:


(•) Deuteranope (a form of red/green color deficit)

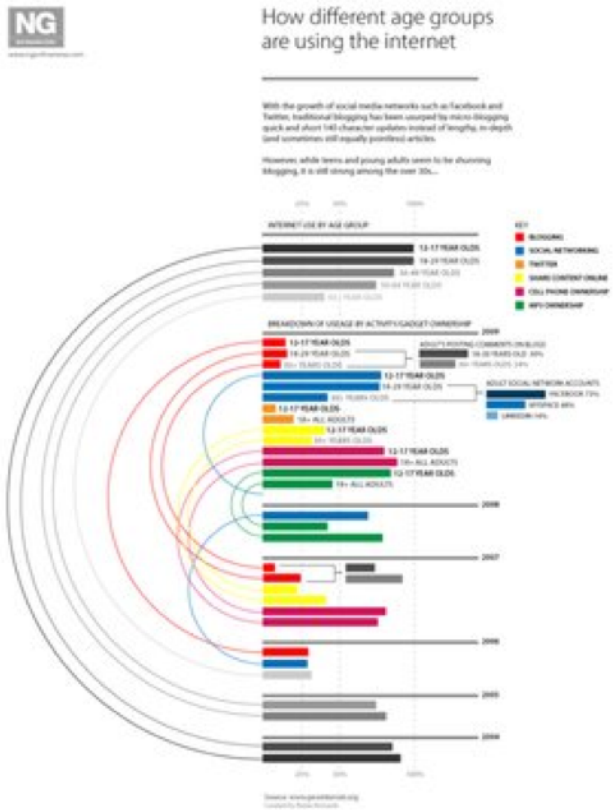

( ) Protanope (another form of red/green color deficit)


( ) Tritanope (a blue/yellow deficit- very rare)

Enter the URL of any webpage- eg. **www.google.com**.

URL: [ ] Run Vischeck!

Original Image



Deuteranope Simulation