Marks + Channels

Cmpt 767

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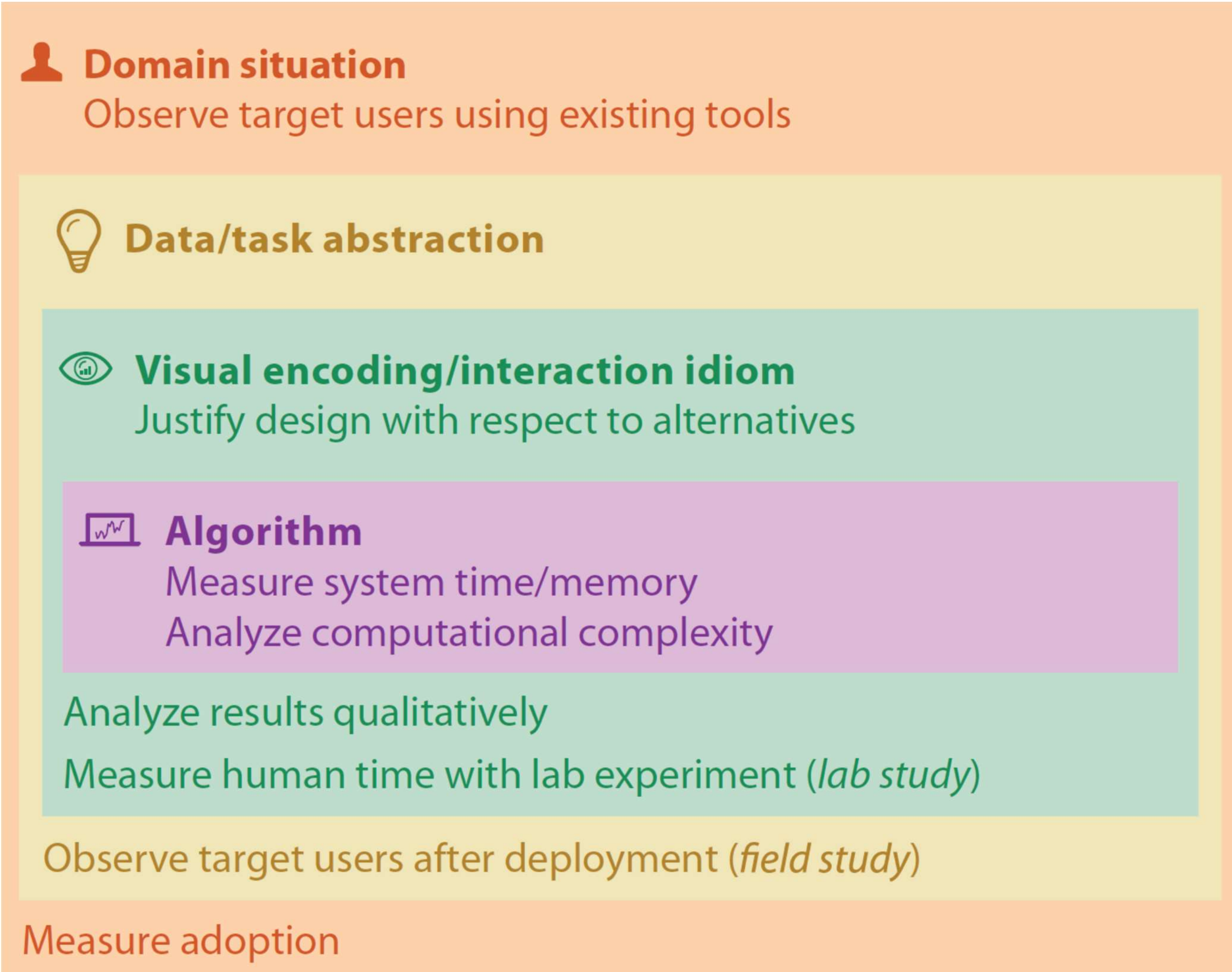
[Munzner/Möller]


Domain situation
Observe target users using existing tools
Data/task abstraction
Visual encoding/interaction idiom
Justify design with respect to alternatives
Algorithm
Measure system time/memory
Analyze computational complexity
Analyze results qualitatively
Measure human time with lab experiment (*lab study*)
Observe target users after deployment (*field study*)
Measure adoption

Overview

- Effectiveness of mappings
- Mapping to positional quantities
- Mapping to shape
- Mapping to color
- Mapping to texture
- Other mappings
- Glyphs

Overview

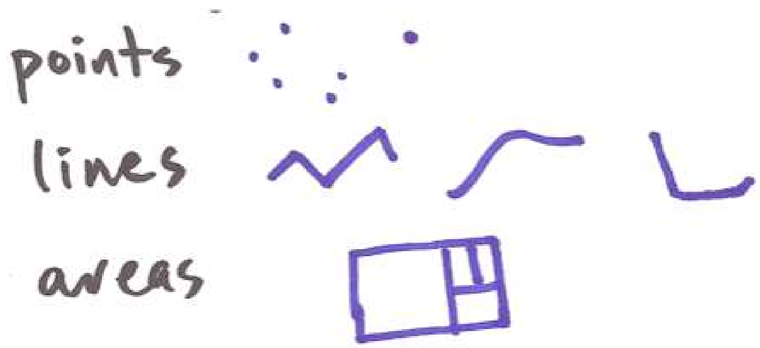
- Marks + channels
- Channel effectiveness
  - Accuracy
  - Discriminability
  - Separability
  - Popout
- Channel characteristics
  - Spatial position
  - Colour
  - Size
  - Tilt (angle)
  - Shape (glyph)
  - Stipple (texture)
  - Curvature
  - Motion

Readings

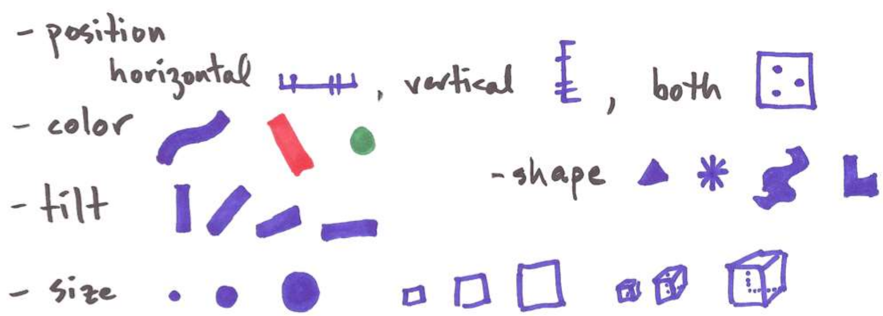
- Munzner, “Visualization Analysis and Design”:
  – Chapter 5 (Marks and Channels)
- Colin Ware:
  – Chapter 4 (Color)
  – Chapter 5 (Visual Attention and Information that Pops Out)
- The Visualization Handbook:
  – Chapter 1 (Overview of Visualization)
- Additional (background) reading
  – J. Mackinlay: 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 ...

Marks

Points Lines Areas

Channels

Position

Size

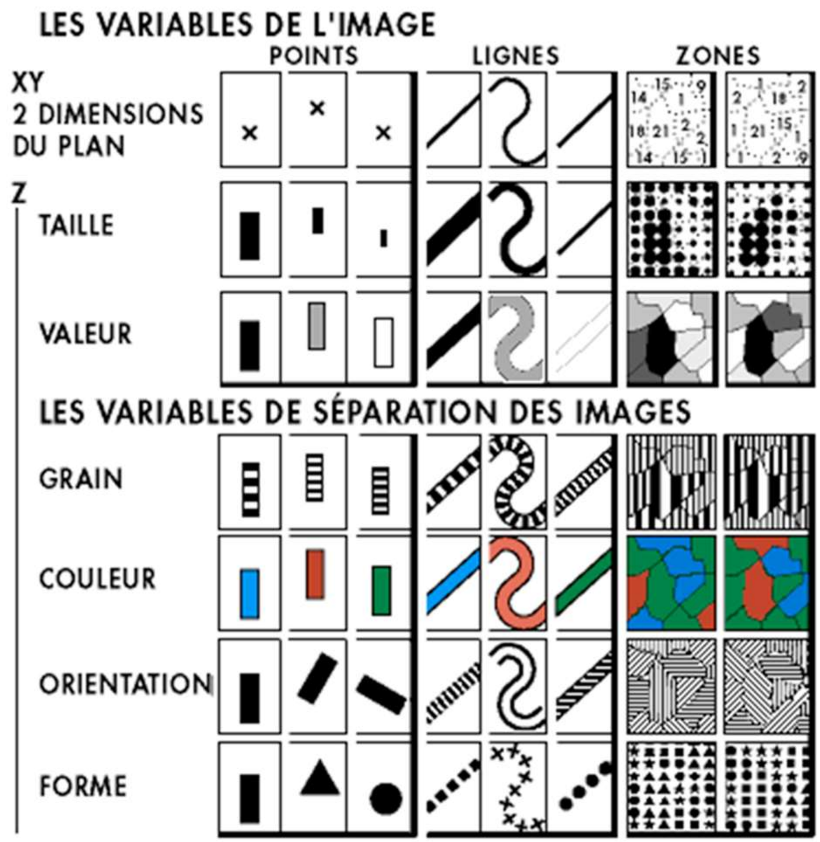
(Grey)Value

Texture

Color

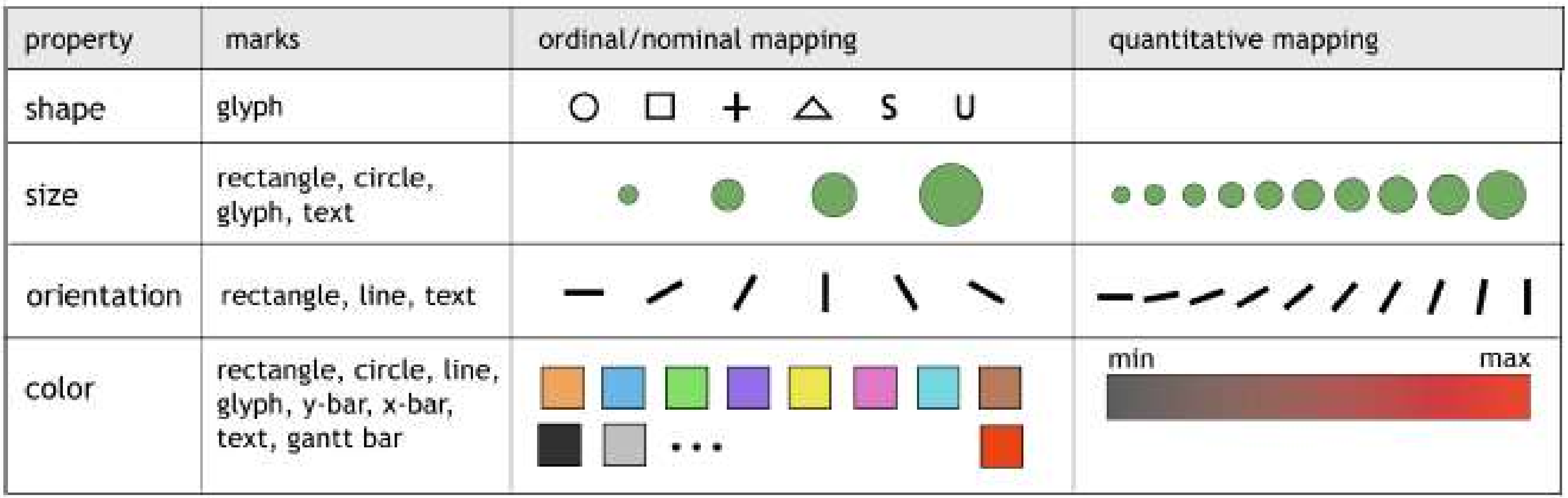
Orientation

Shape



Semiology of Graphics [J. Bertin, 67]

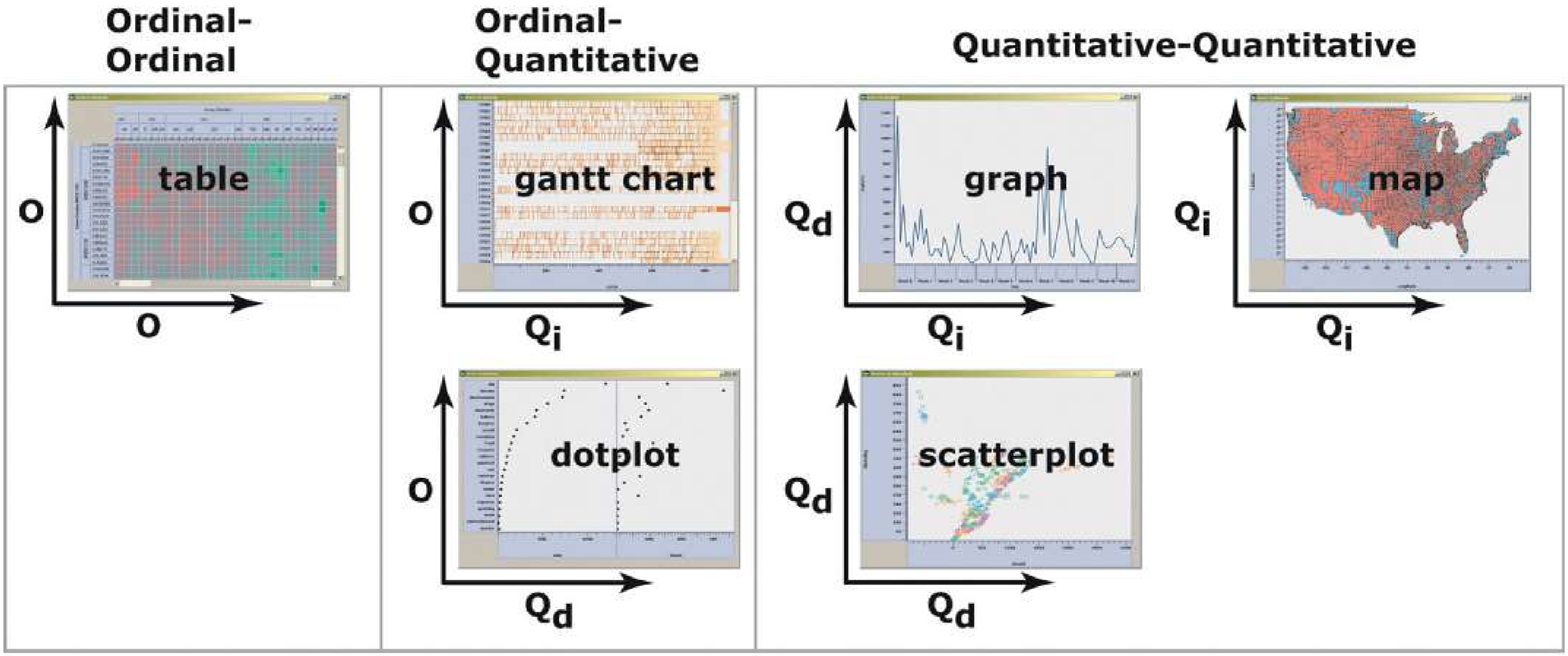
Stolte / Hanrahan



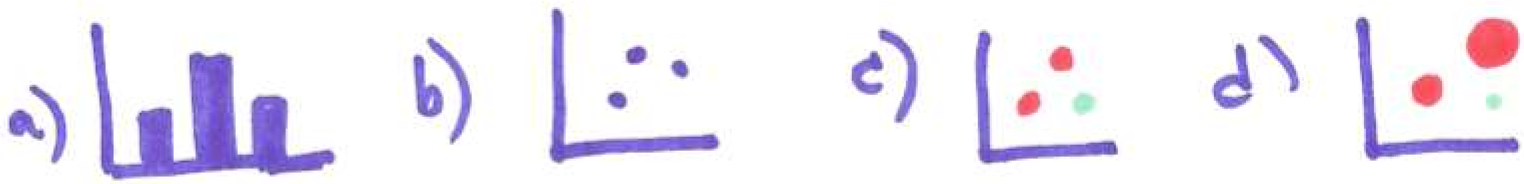
property	marks	ordinal/nominal mapping	quantitative mapping
shape	glyph	○ □ + △ S U	
size	rectangle, circle, glyph, text		
orientation	rectangle, line, text		
color	rectangle, circle, line, glyph, y-bar, x-bar, text, gantt bar	. . .	min max

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

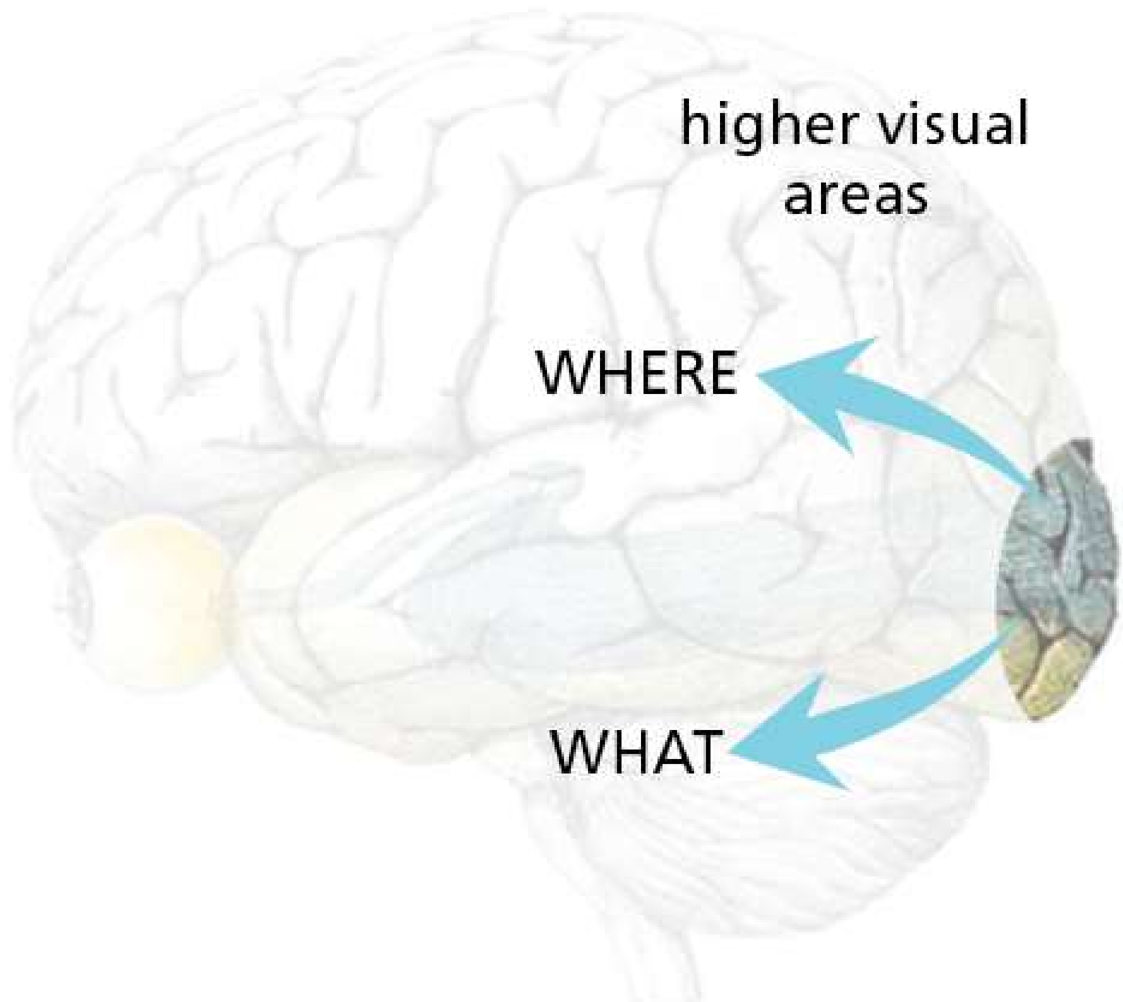
Visualization Families



Progression



Channel types: 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

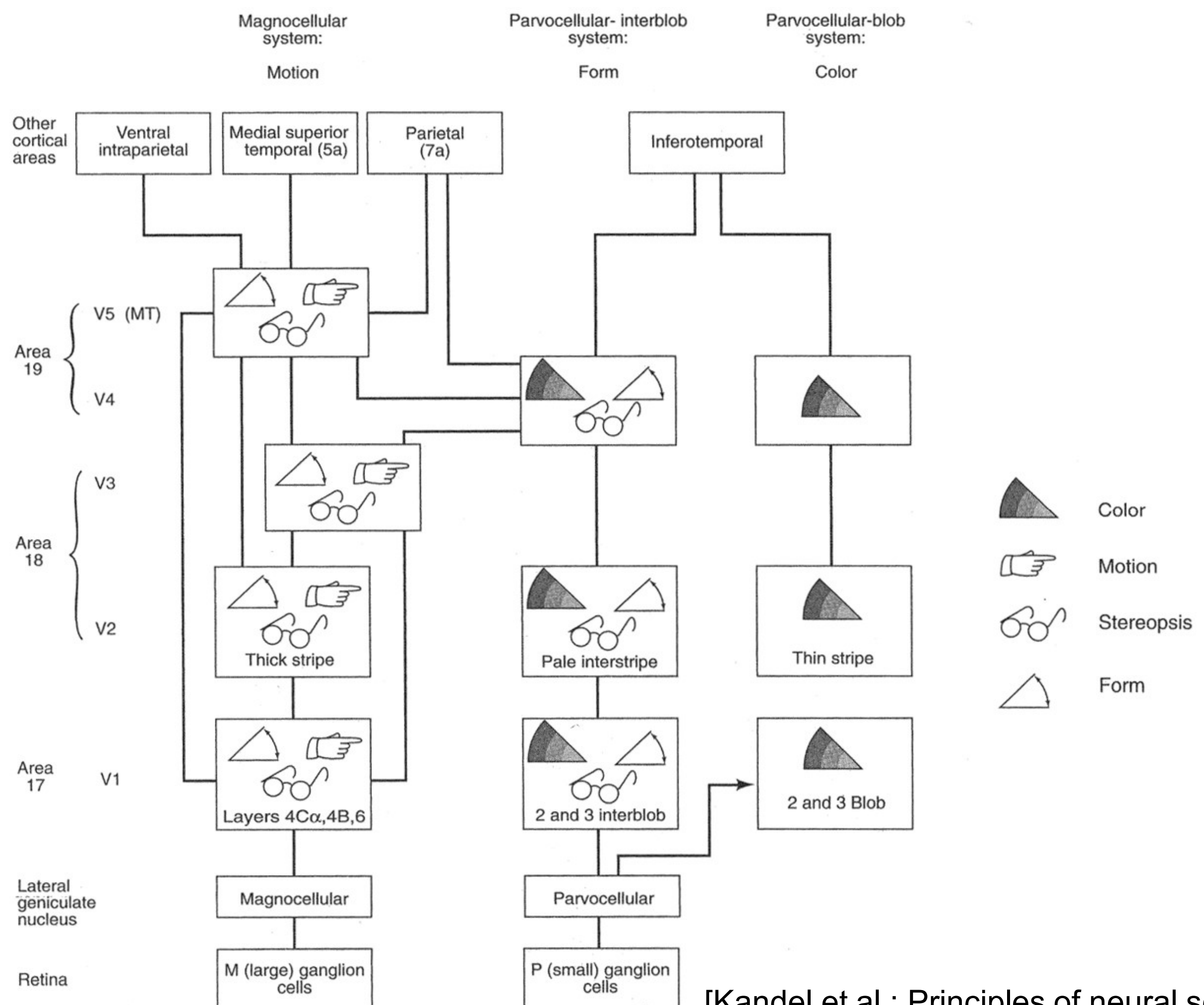
Expressiveness + Effectiveness

- 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

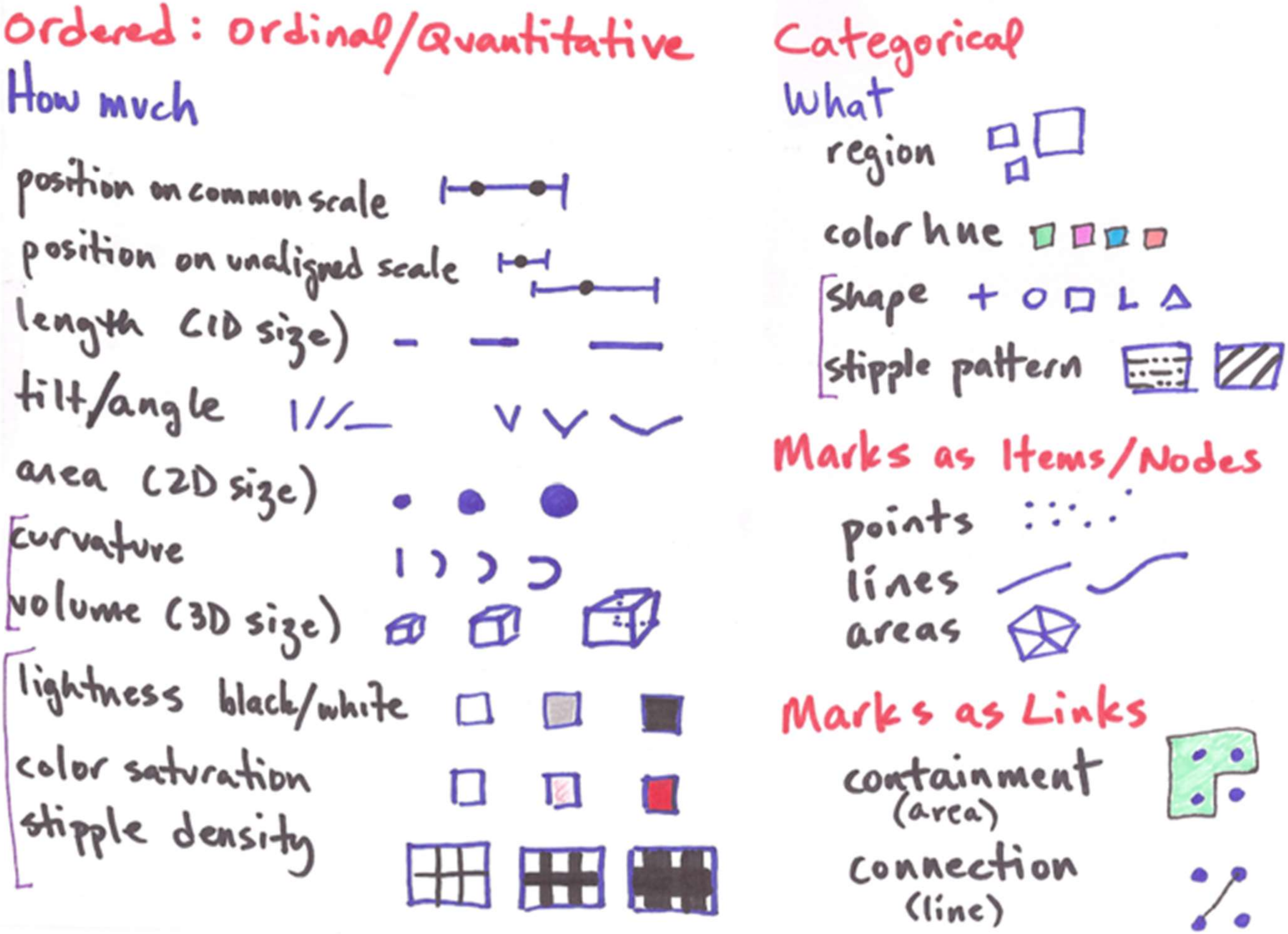
- Effectiveness according to neurophysiology
- Cells in Visual Areas 1 and 2 differentially tuned to each of the following properties:
  - Orientation and size (with luminance)
  - Color (two types of signal)
  - Stereoscopic depth
  - Motion

Effectiveness of Mappings



[Kandel et al.: Principles of neural science]

Channels and Marks: Types and Ranks



Visual Language is a Sign System

- Image perceived as a set of signs
- Sender encodes information in signs
- Receiver decodes information from signs

- Jacques Bertin
  - French cartographer [1918-2010]
  - Semiology of Graphics [1967]
  - Theoretical principles for visual encodings

Semiology of Graphics [J. Bertin, 83]

Effectiveness of Mappings

- Mapping from (filtered) data to renderable representation
- Most important part of visualization
- Possible visual representations:
  - Position
  - Size
  - Orientation
  - Shape
  - Brightness
  - Color (hue, saturation)
  - ….

Effectiveness of Mappings

- Efficiency and effectiveness depends on input data:
  - Nominal
  - Ordinal
  - Quantitative
- Good visual design
  - Based on psychology and psychophysics
- Psychological investigations to evaluate the appropriateness of mapping approaches

Bertin's Retinal Variables

Position	N	O	Q
Size	N	O	Q
Value	N	O	Q
Texture	N	O	
Color	N		
Orientation	N		
Shape	N		

Based on slide from Agrawala

Mapping to Data Types

	Nominal	Ordinal	Quantitative
Position			
Size			
(Grey)Value			
Texture			
Color			
Orientation			
Shape			

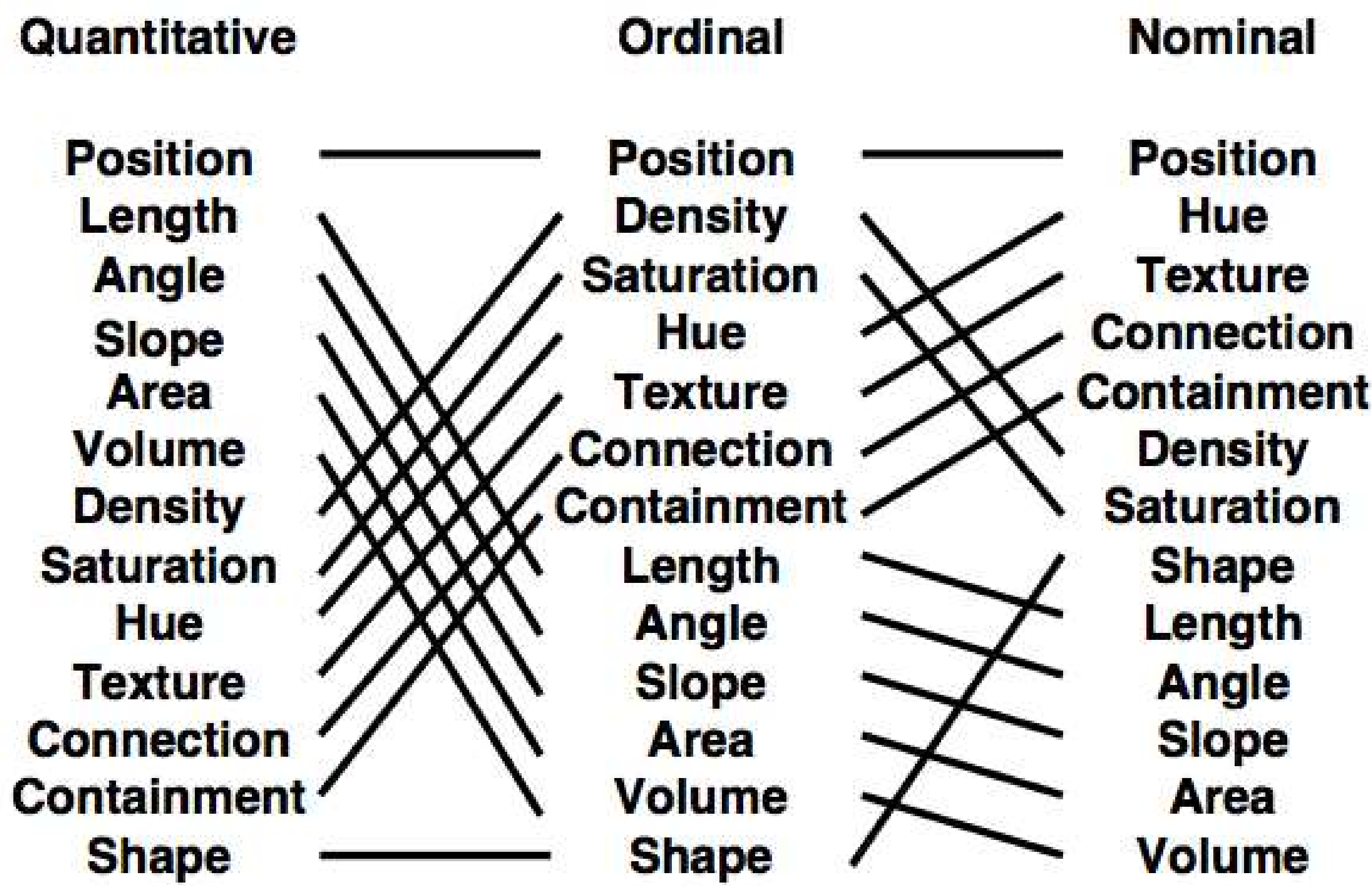
✔ = Good
~ = OK
✘ = Bad

Mapping to Data Types

	Nominal	Ordinal	Quantitative
Position	✓	✓	✓
Size	✓	✓	✓
(Grey)Value	✓	✓	~
Texture	✓	~	✗
Color	✓	✗	✗
Orientation	✓	✗	✗
Shape	✓	✗	✗

✓ = Good
~ = OK
✗ = Bad

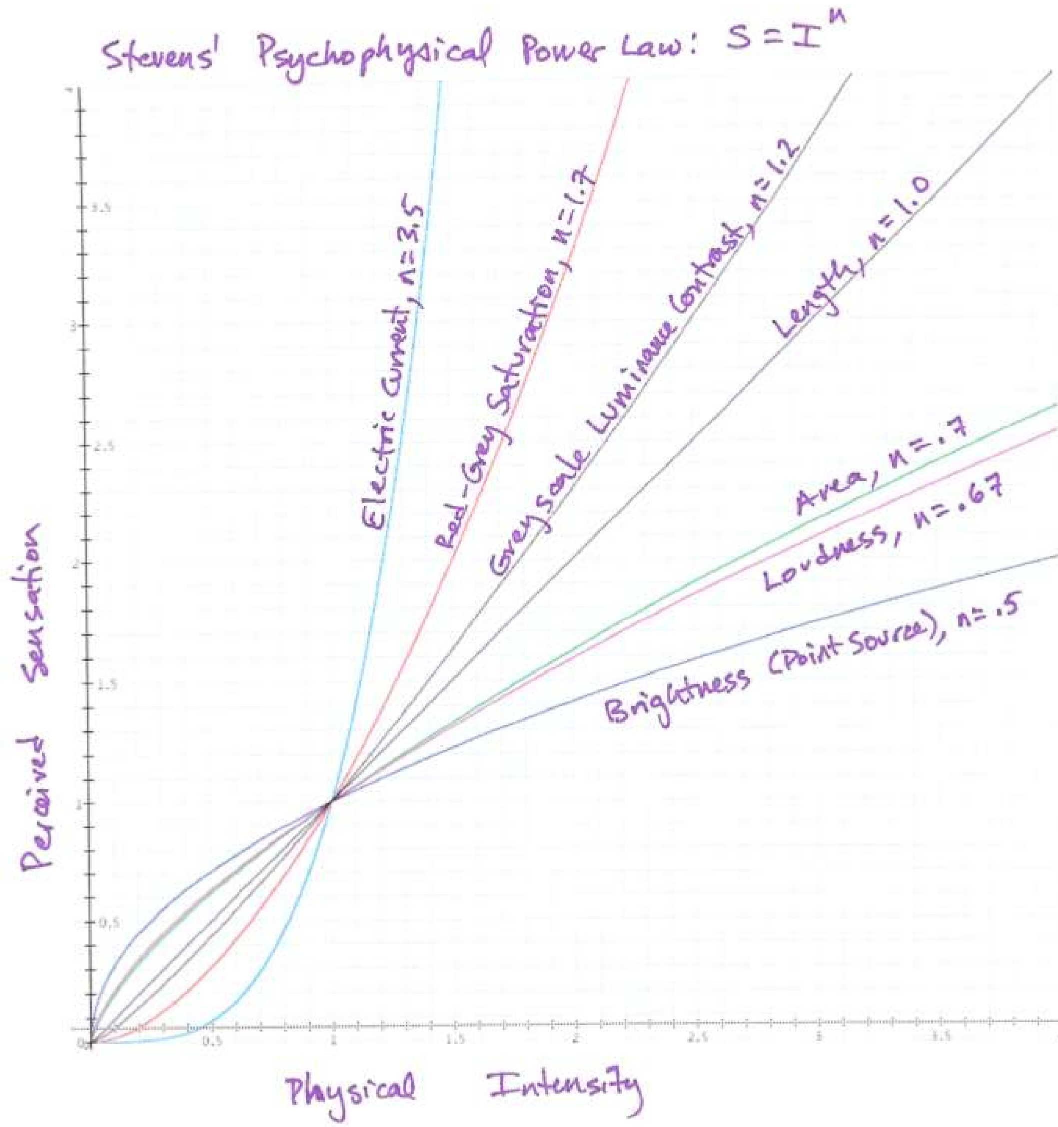
Mackinlay's Retinal Variables



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

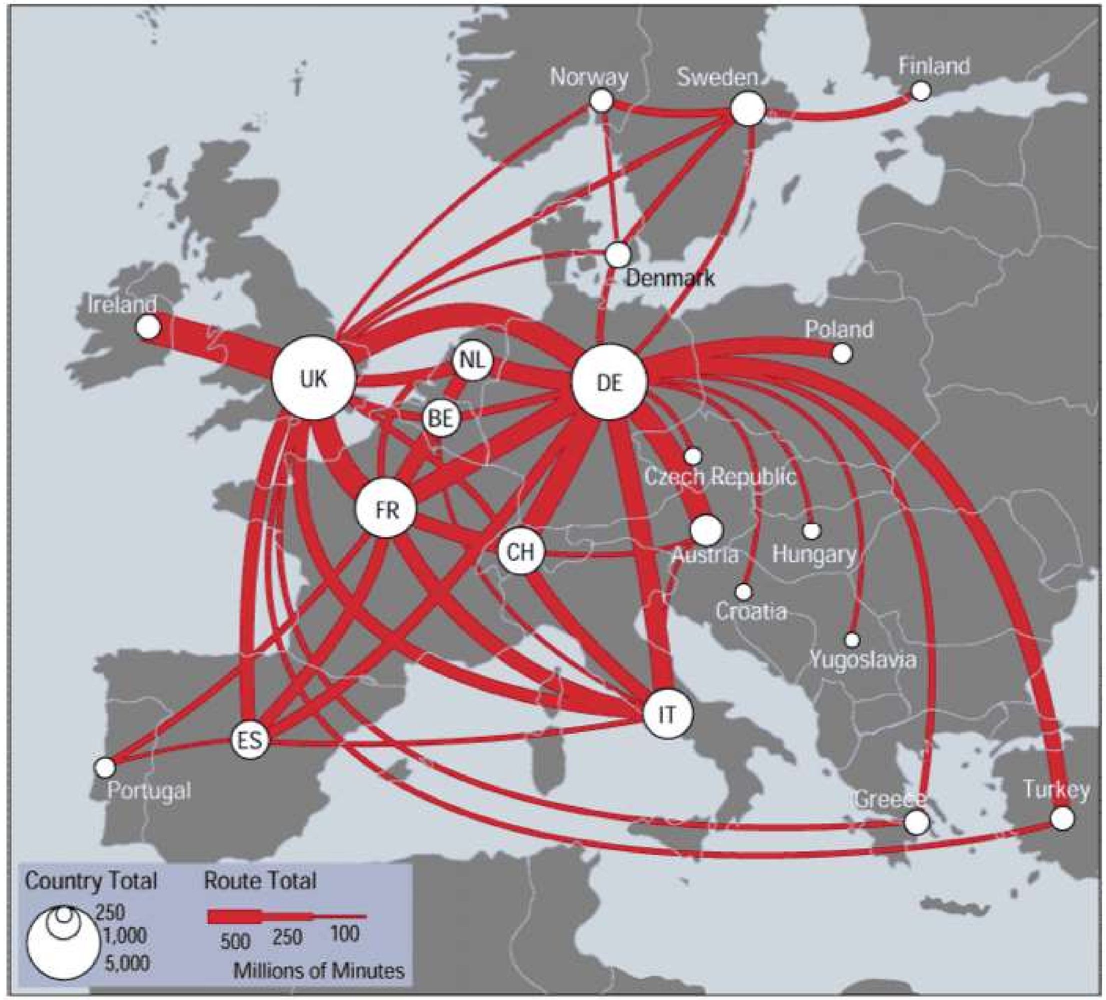
Effectiveness -- Accuracy

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



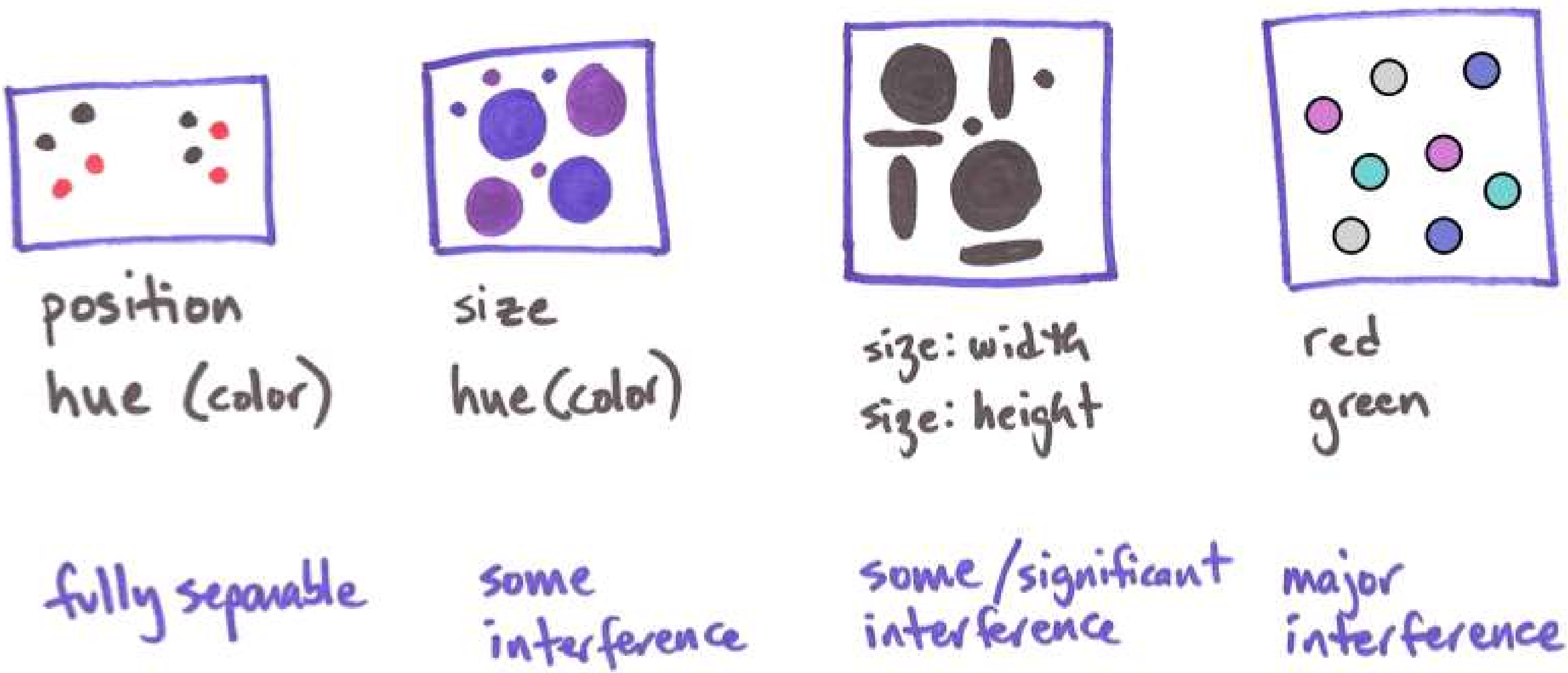
Effectiveness -- Discriminability

- 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 ...

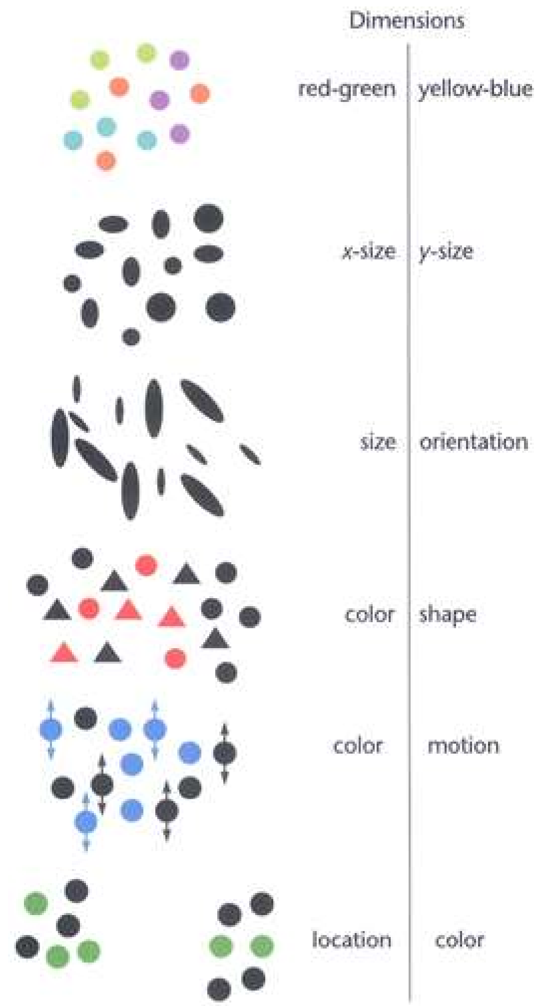
- **Integral** display dimensions
  – Two or more attributes perceived holistically
- **Separable** dimensions
  – Separate judgments about each graphical dimension
- Simplistic classification, with a large number of exceptions and asymmetries

Integral dimension pairs

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

Separable dimension pairs

More integral coding pairs

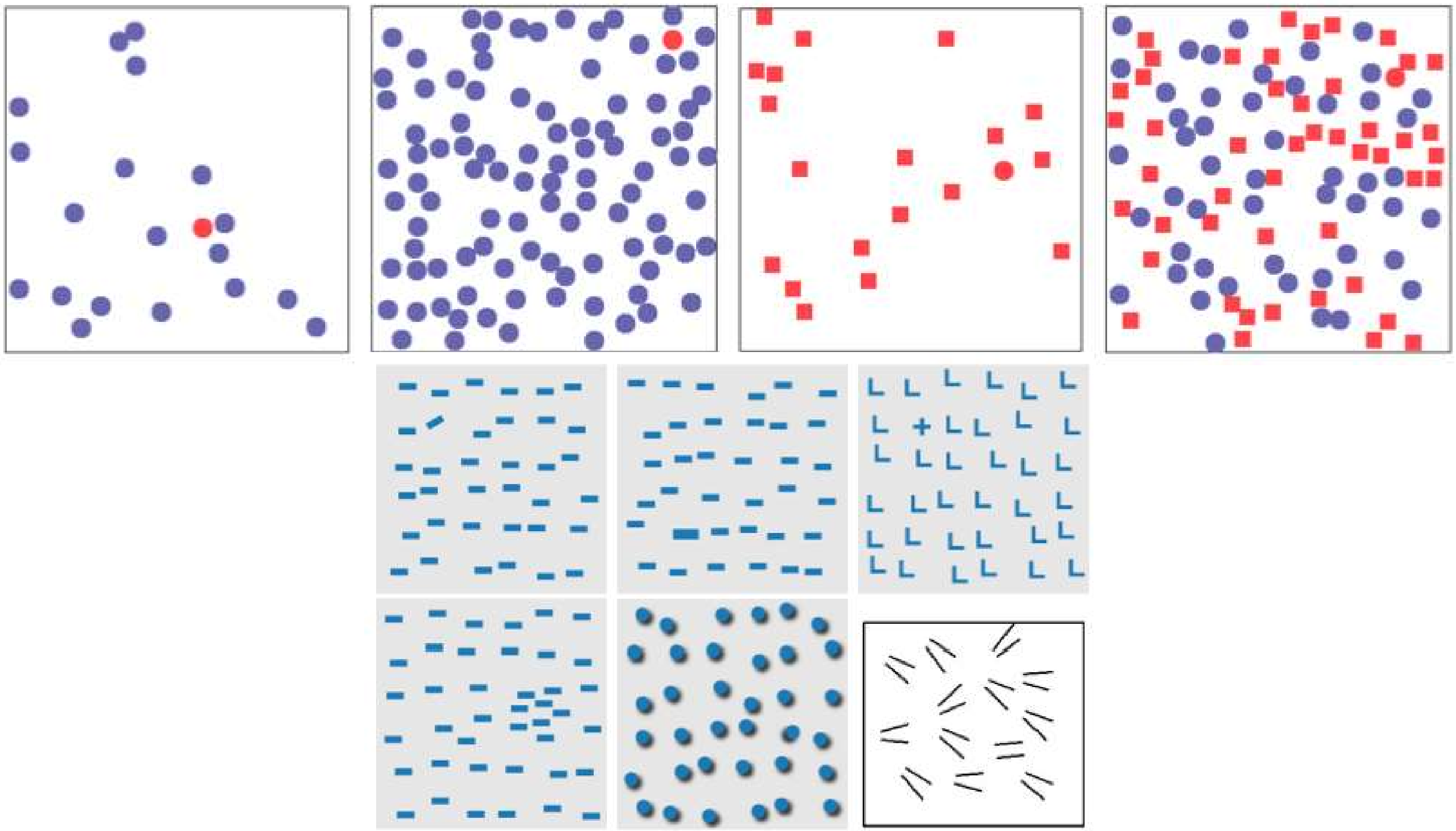


More separable coding pairs

[C. Ware, Information Visualization]

Popout - Preattentive processing

- parallel (visual processing)



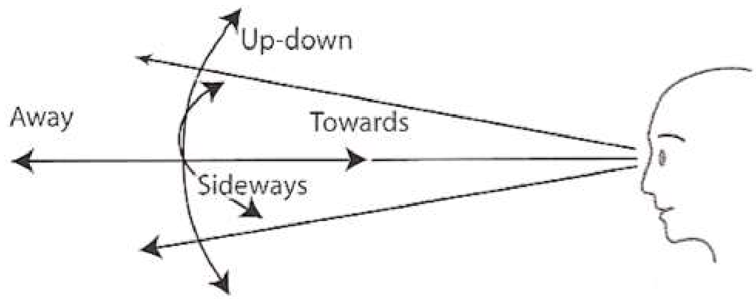
Overview

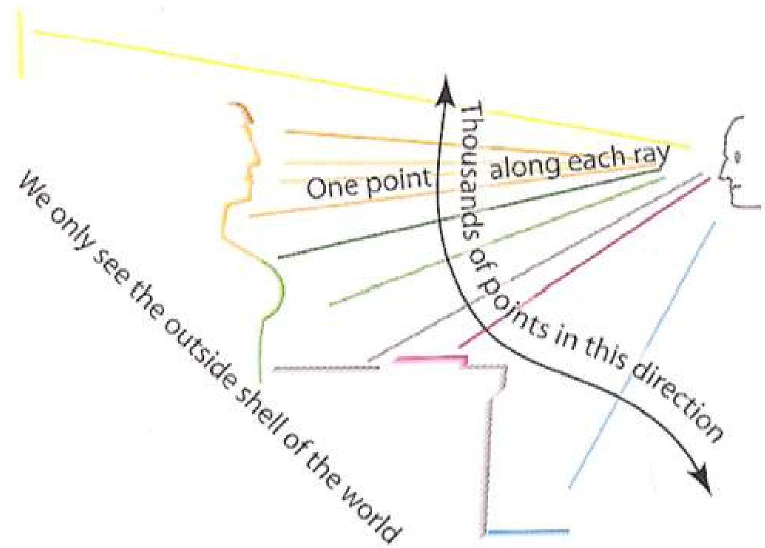
- Marks + channels
- Channel effectiveness
- Channel characteristics
  - Spatial position
  - Color
    - visual system
    - color models
    - color deficiency
  - Size
  - Tilt (angle)
  - Shape (glyph)
  - Stipple (texture)
  - Curvature
  - Motion

Channels

- Spatial 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

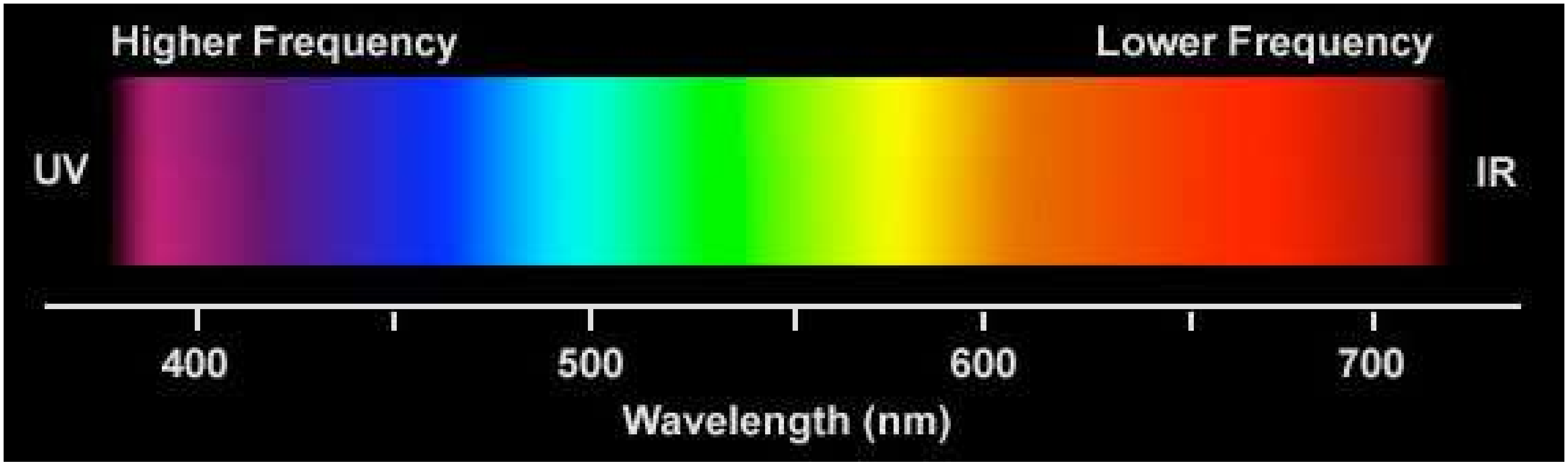
Spatial position





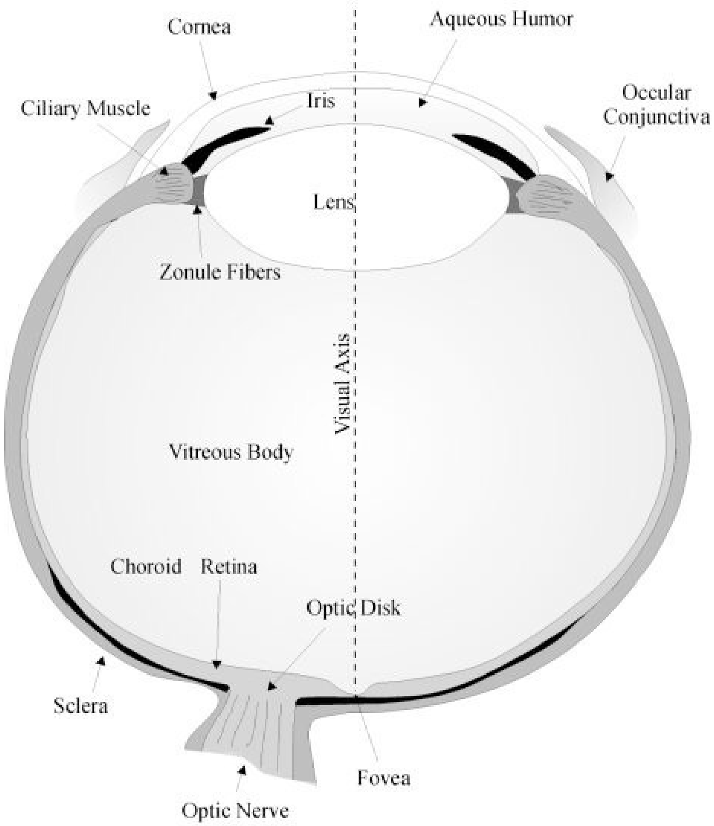
2.05D

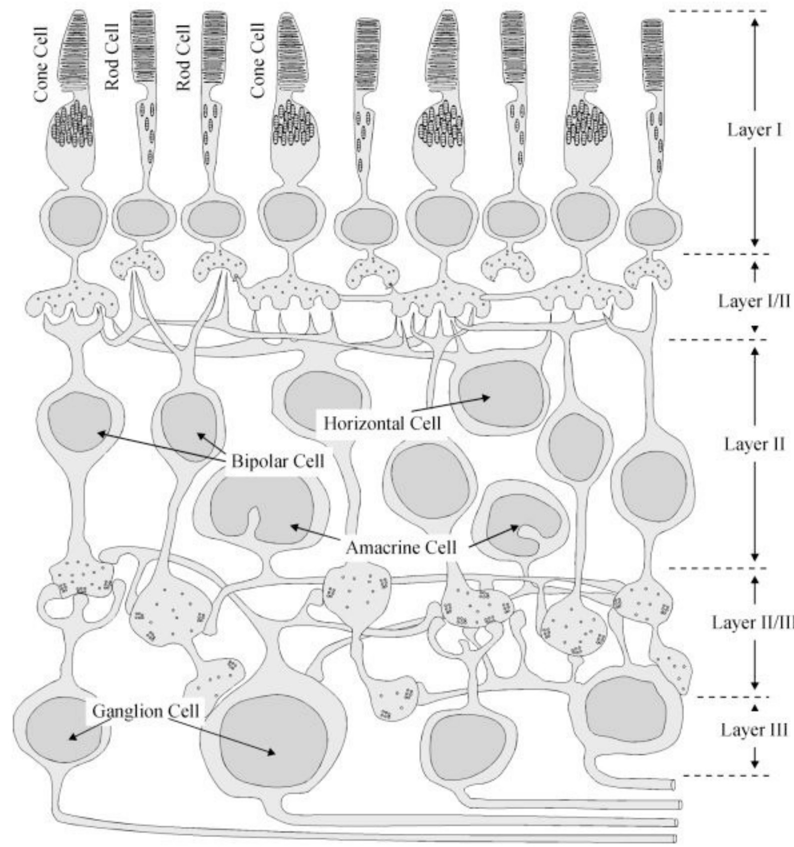
Colour


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

Visual System

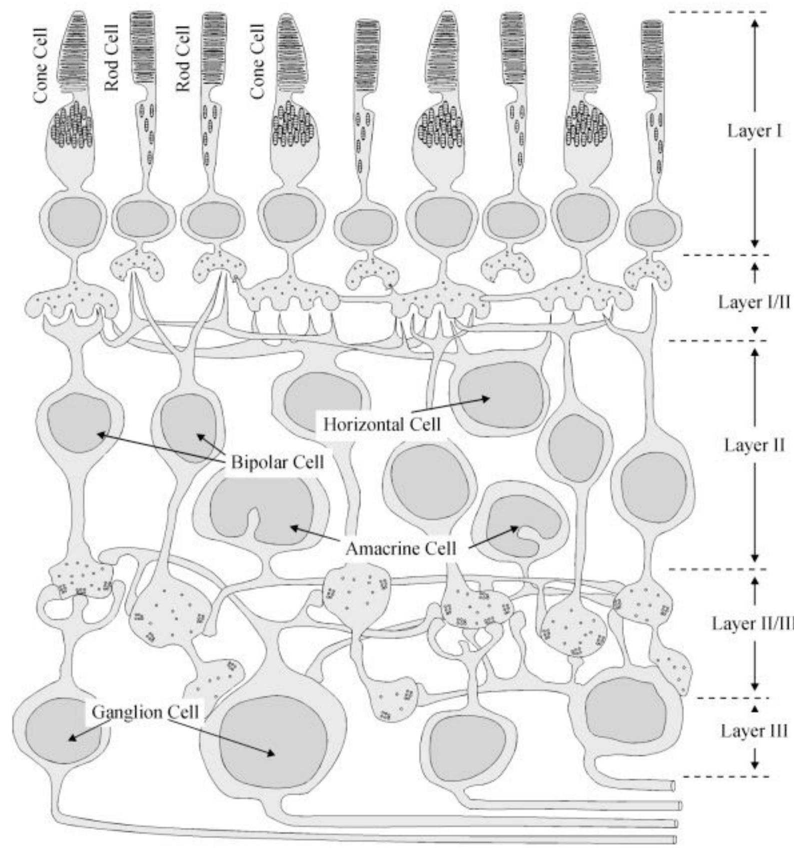
The eye and the retina





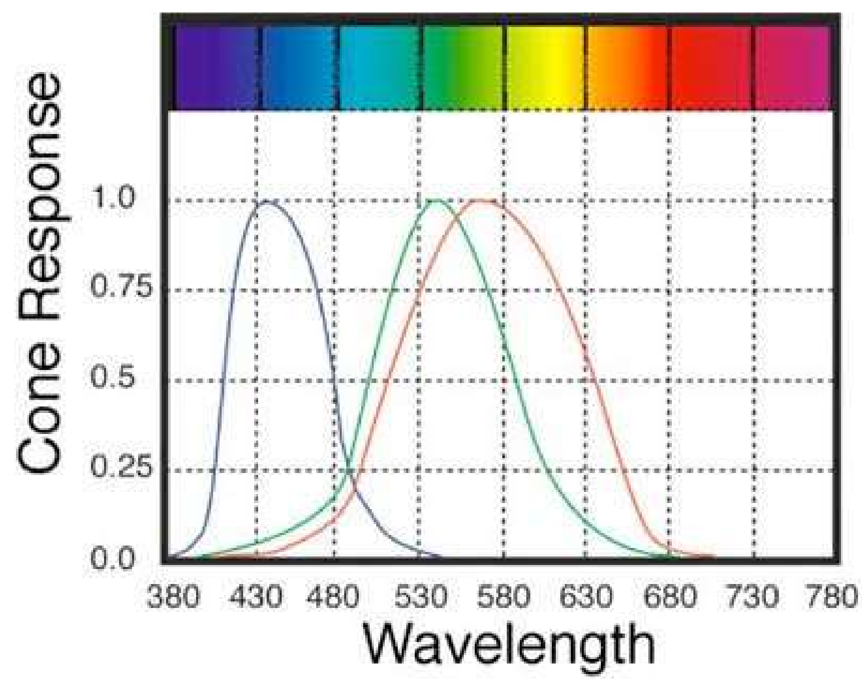
Retina detectors

- 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

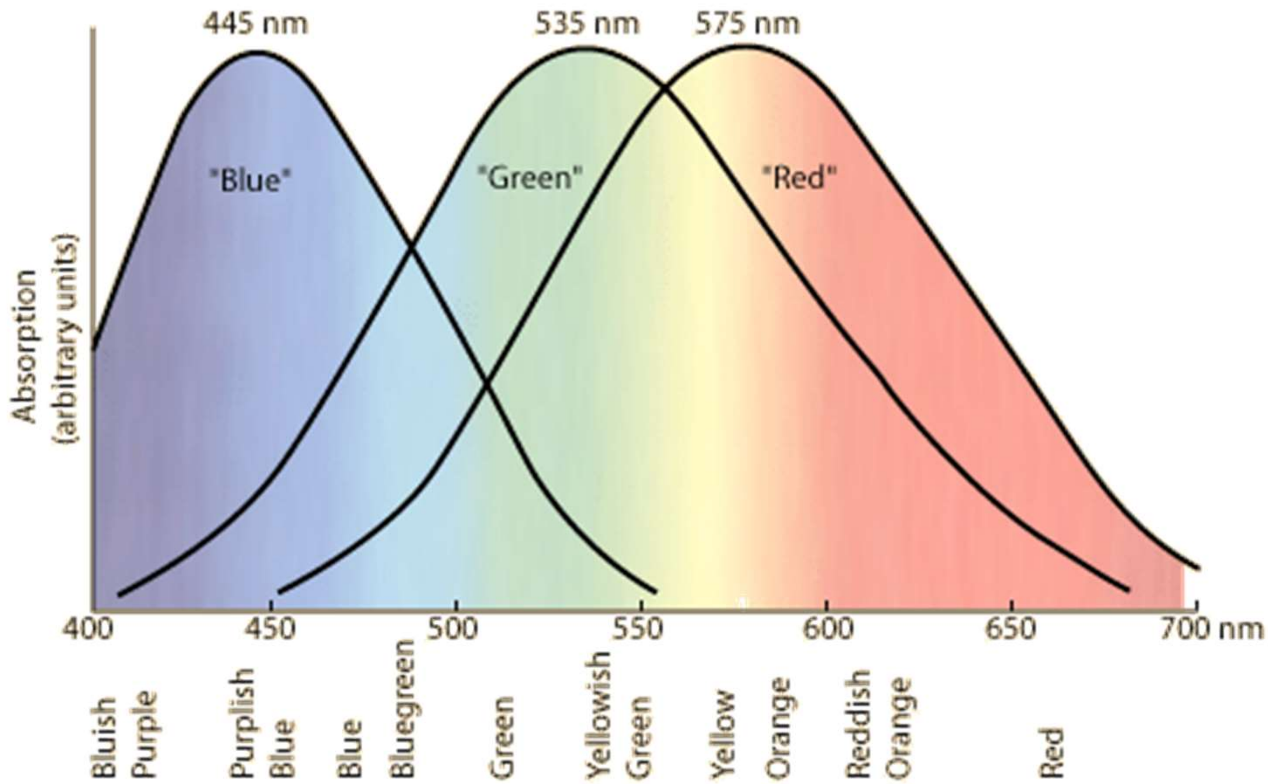


Retina detectors

- 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

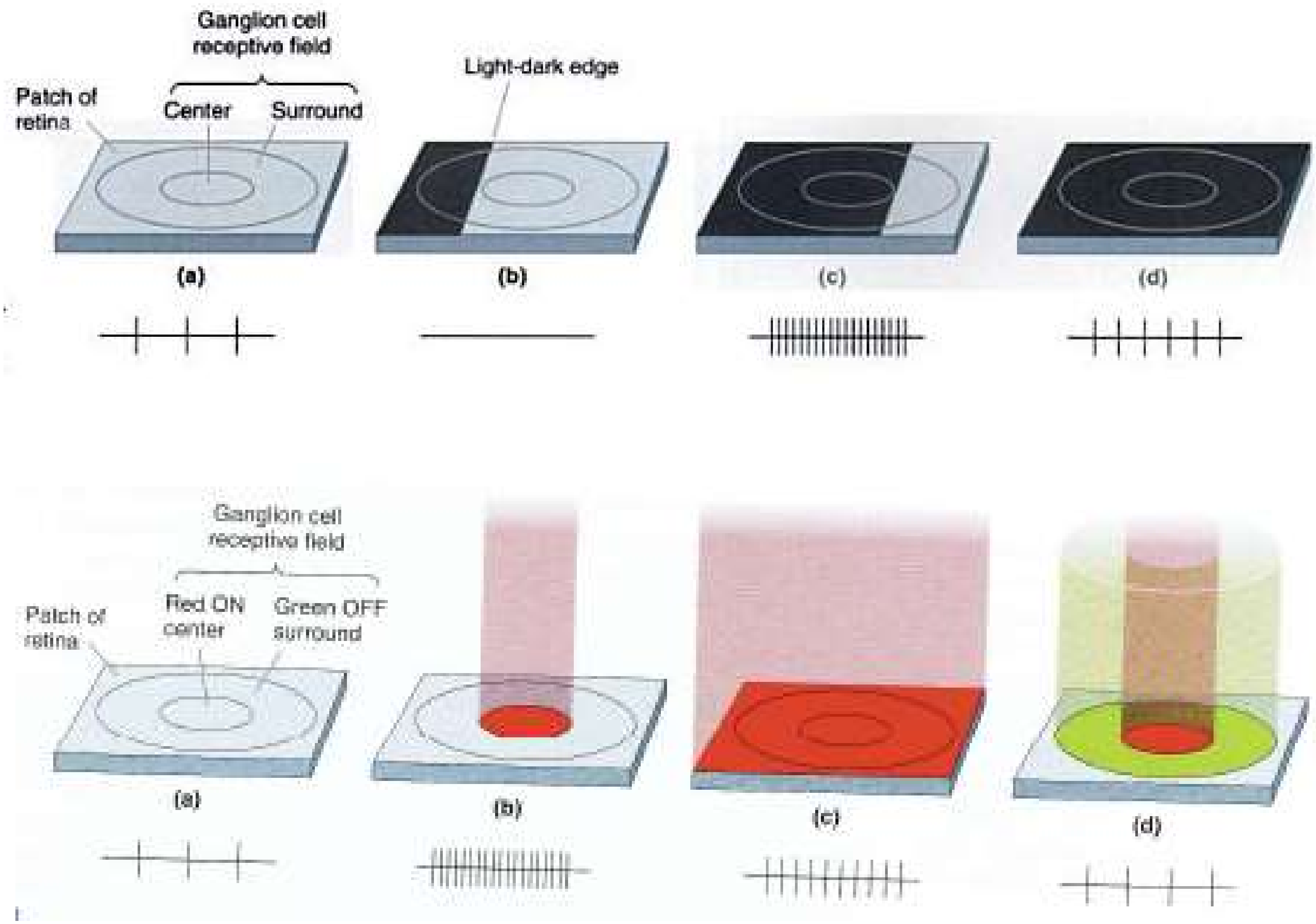


Cone Response



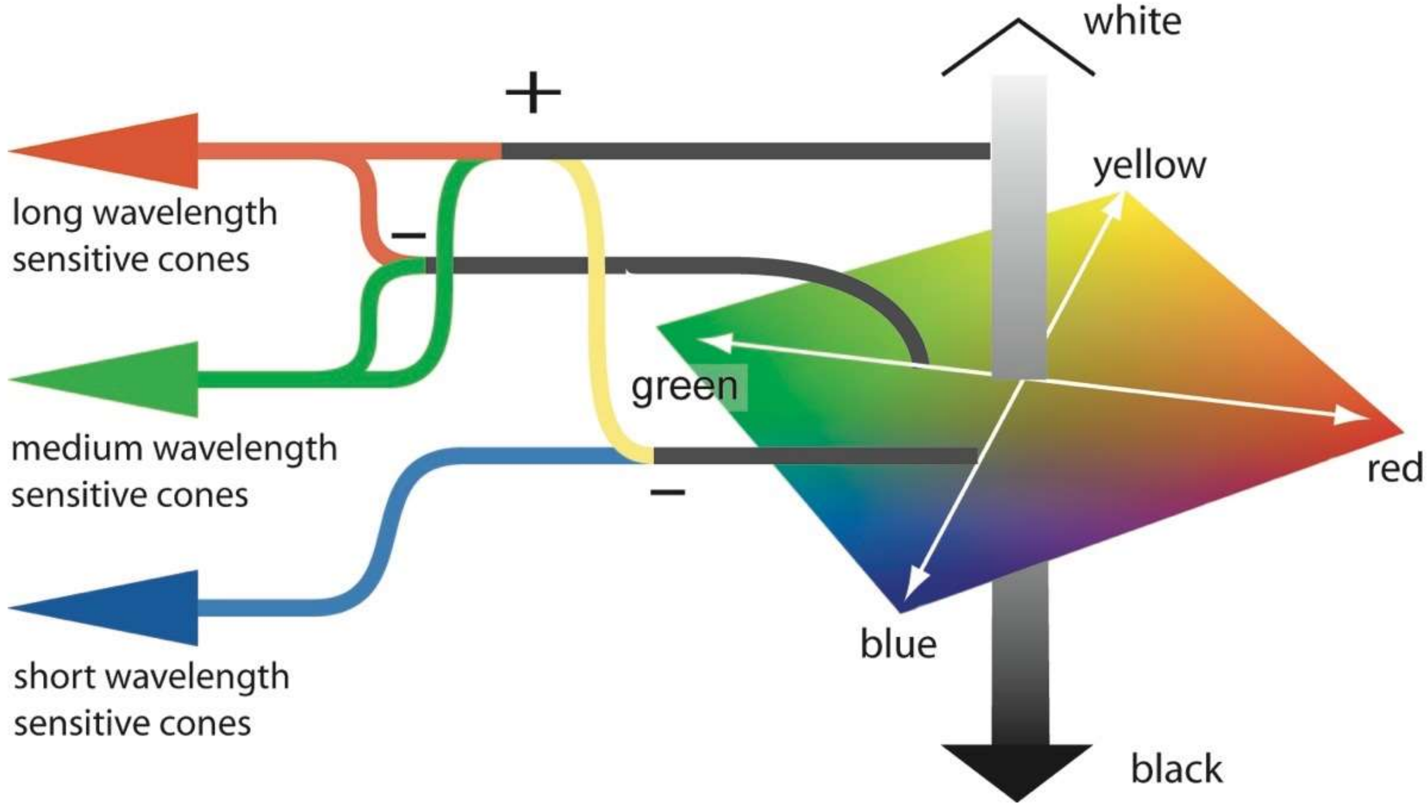
HyperPhysics, Georgia State University

Color-Opponent Cells



Bear, Connors, Paradiso, "Neuroscience"

Color Opponency

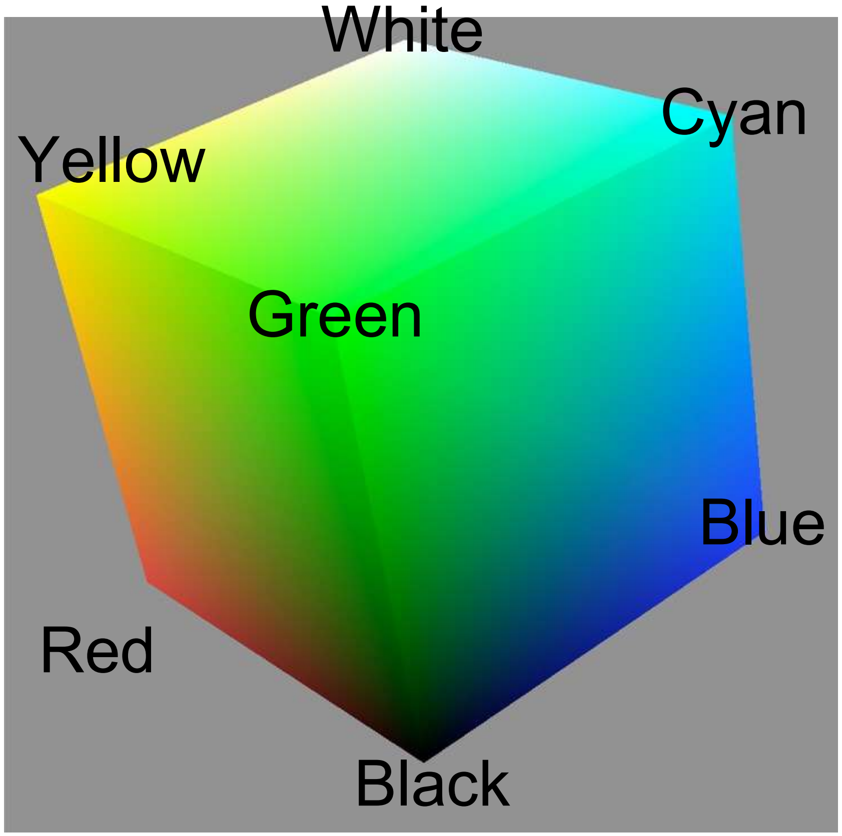


C. Ware, "Visual Thinking for Design"

Color Models

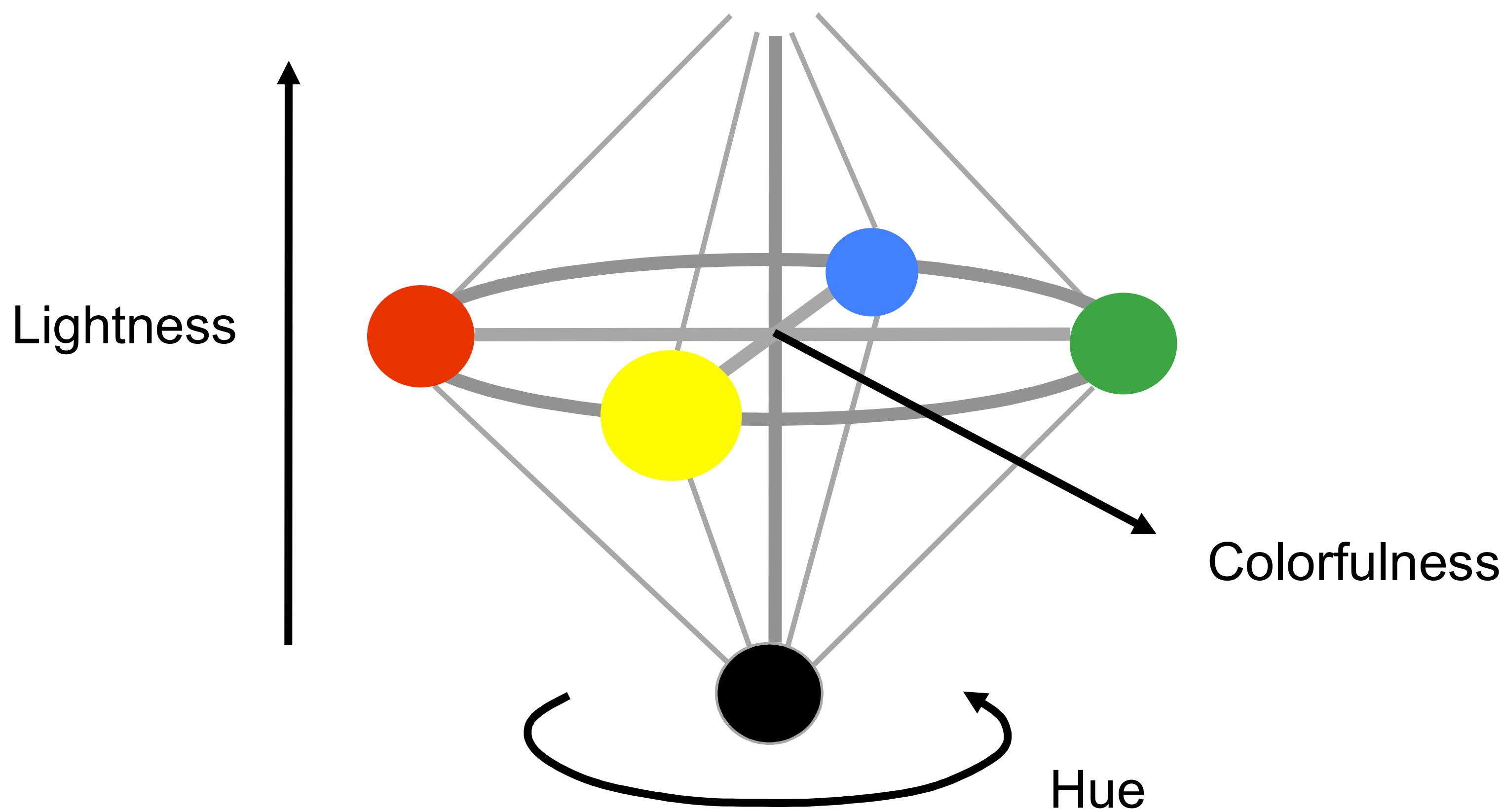
RGB Color Space

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



C. Ware, "Visual Thinking for Design"

Perceptual Color Spaces

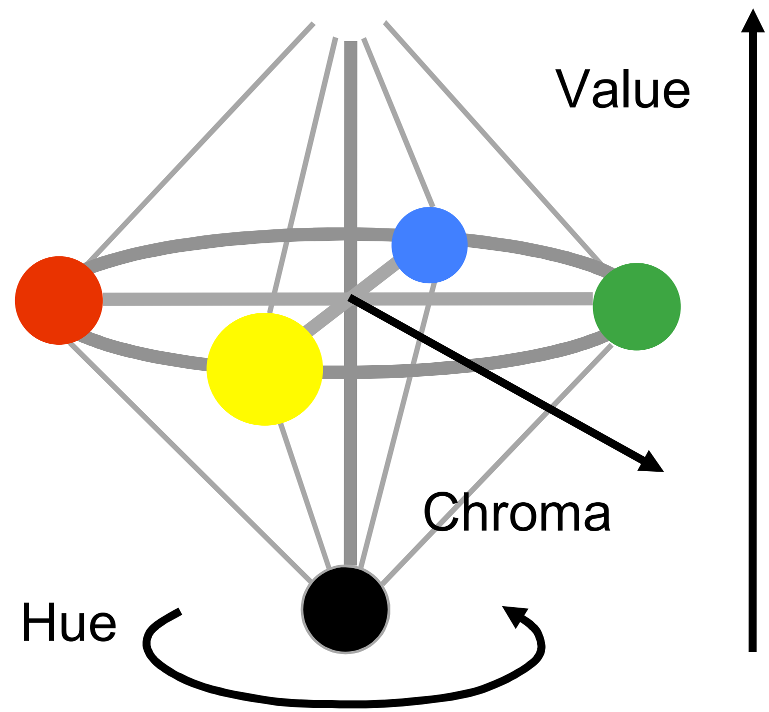


Unique black and white

Courtesy of Maureen Stone

Munsell Color

- Hue, Value, Chroma
  - 5 R 5/10 (bright red)
  - N 8 (light gray)
- Perceptually uniform



Munsell Renotation System maps between HVC and XYZ

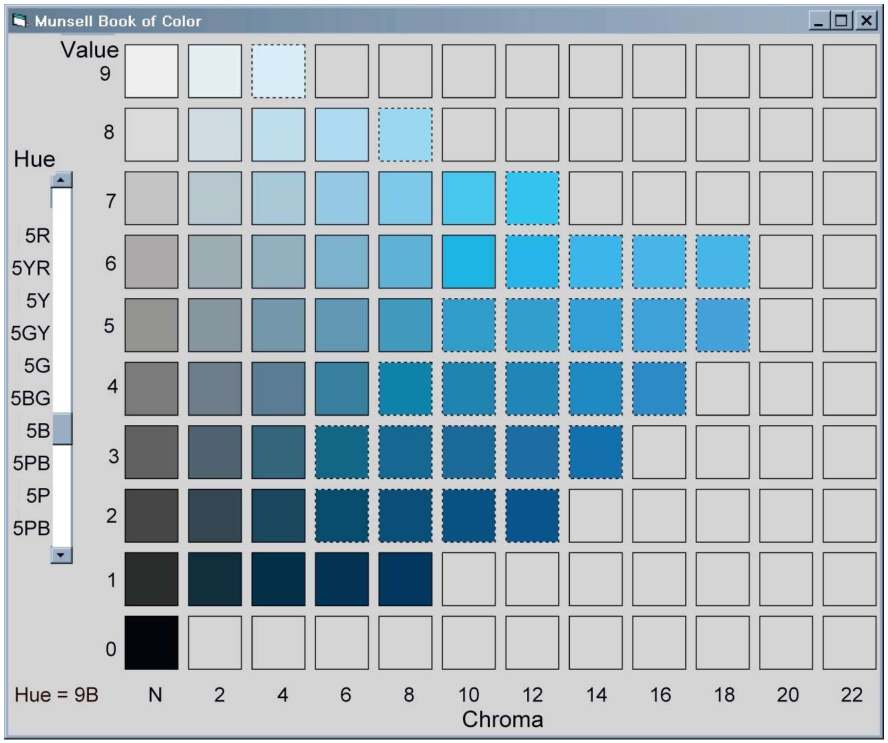
Courtesy of Maureen Stone

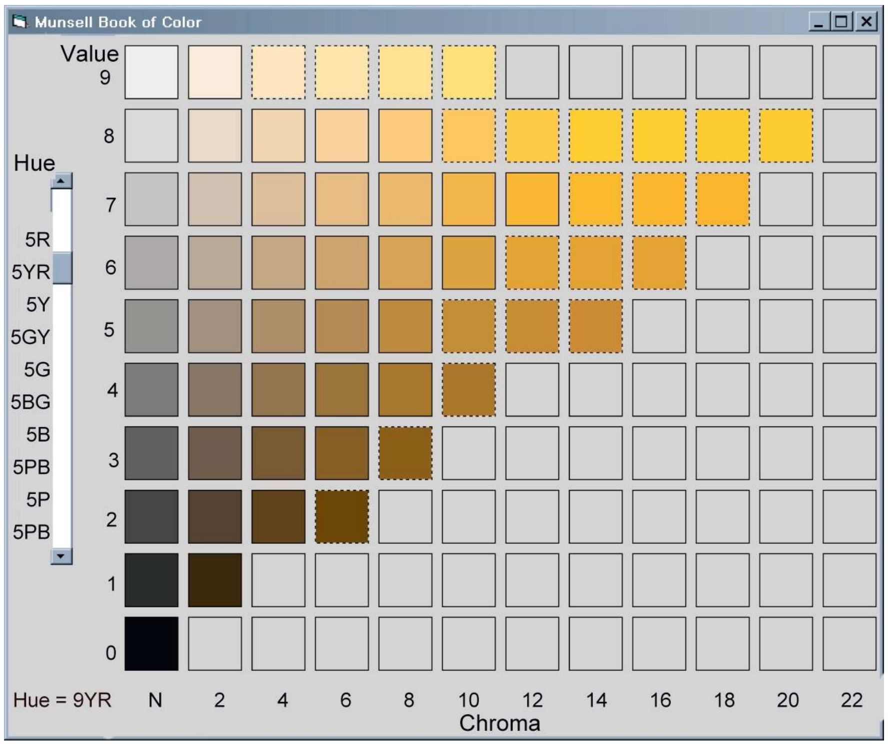
Munsell Atlas

Courtesy Gretag-Macbeth

Interactive Munsell Tool

- From www.munsell.com

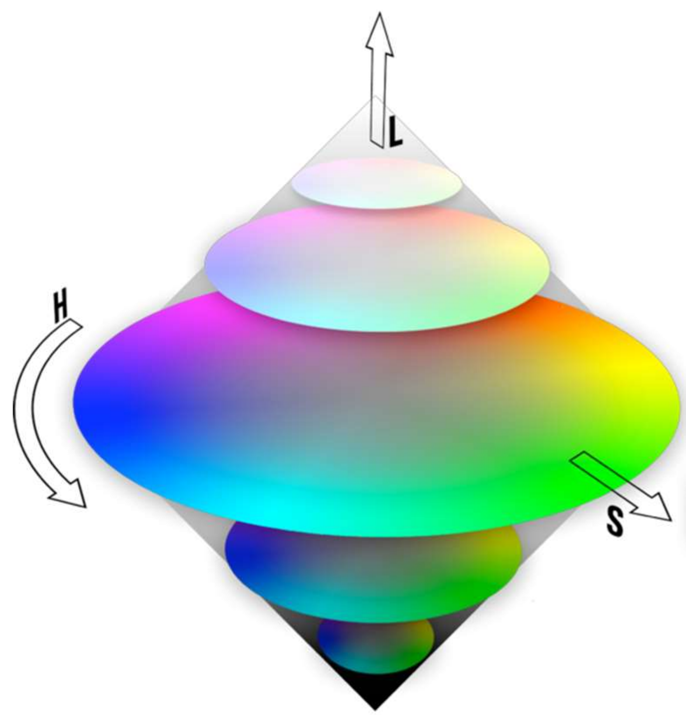




Courtesy of Maureen Stone

HSL Color Space

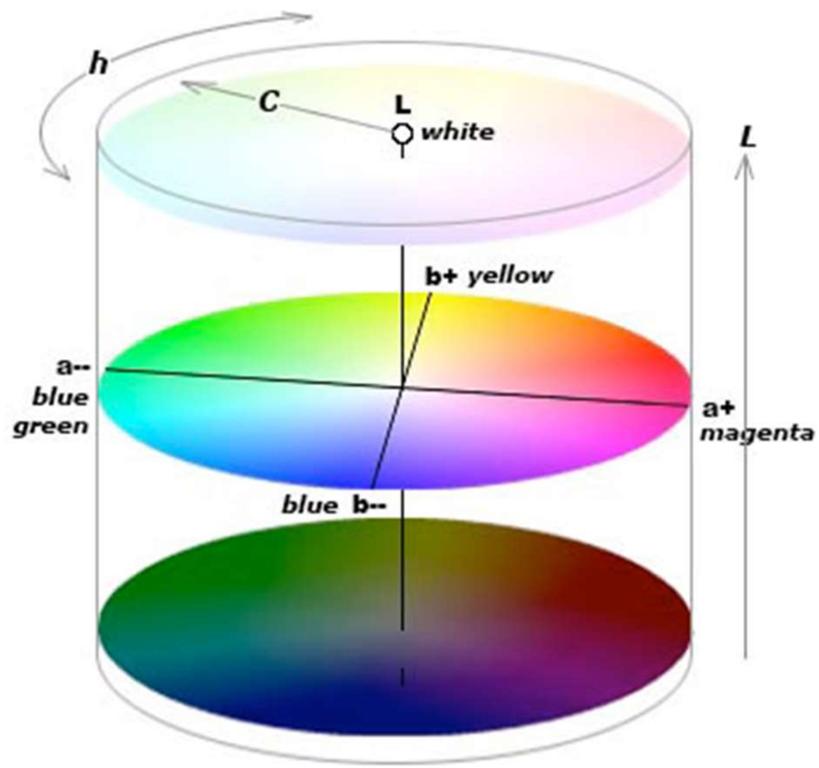
- Hue - what people think of color
- Saturation - purity, distance from grey
- Lightness - from dark to light
- Not perceptually uniform



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



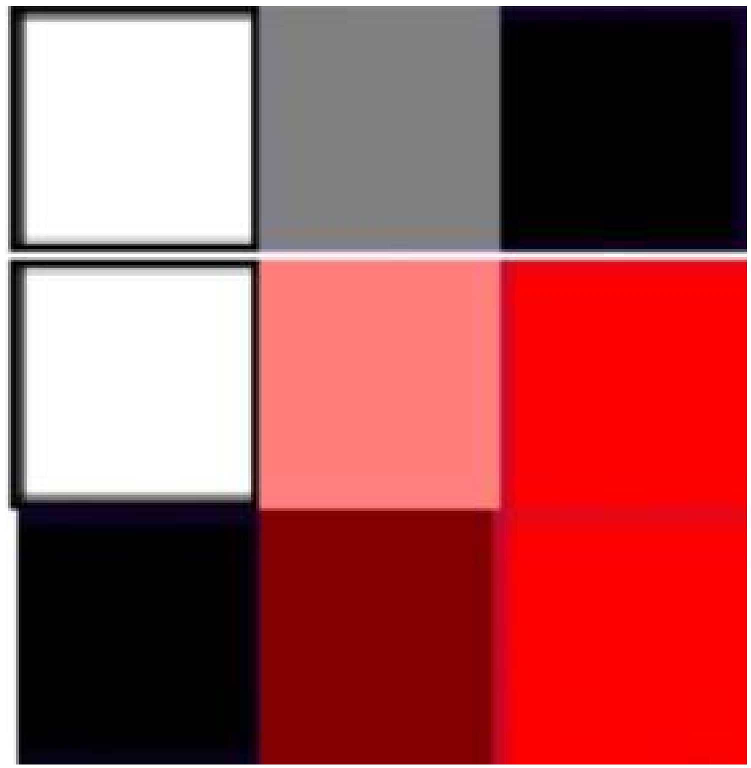
CIELAB 1976

Luminance, Saturation, Hue

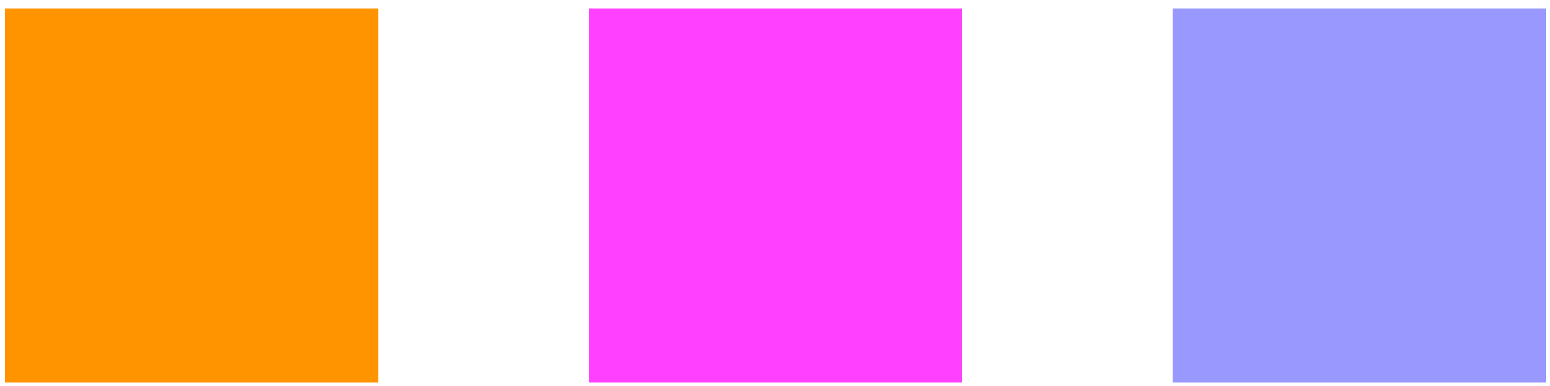
- Luminance
  - *How-much* channel
  - discriminability: ~2-4 bins
  - contrast important
- Saturation
  - *How-much* channel
  - discriminability: ~3 bins
- Hue
  - *What* channel
  - discriminability: ~6-12

Ordered Data

- Luminance
- Saturation
- Brightness



- Rainbow is a learned order!



Thanks to Moritz Wustinger



Thanks to Moritz Wustinger

Thanks to Moritz Wustinger
Smiley based on http://upload.wikimedia.org/wikipedia/commons/b/bd/A_Smiley.jpg

Thanks to Moritz Wustinger

Color deficiency

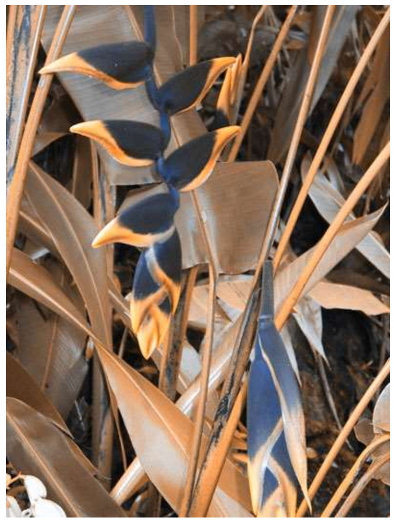
Source: M. Stone

Model "Color blindness"

- Flaw in opponent processing
  - Red-green common (deuteranope, protanope)
  - Blue-yellow possible (tritanope -- most common)
  - Luminance channel almost "normal"
- 8% of all men, 0.5% of all women
- Effect is 2D color vision model
  - Flatten color space
  - Can be simulated (Brettel et. al.)
  - http://colorfilter.wickline.org
  - http://www.colblindor.com/coblis-color-blindness-simulator/

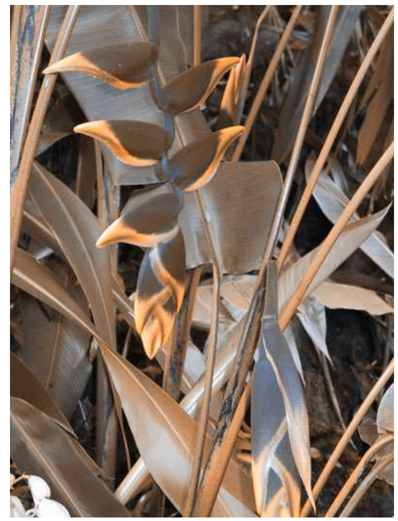
Source: M. Stone

Color Blindness



Protanope

No L cones



Deuteranope

No M cones

Tritanope

No S cones

Red / green deficiencies

Blue / Yellow deficiency

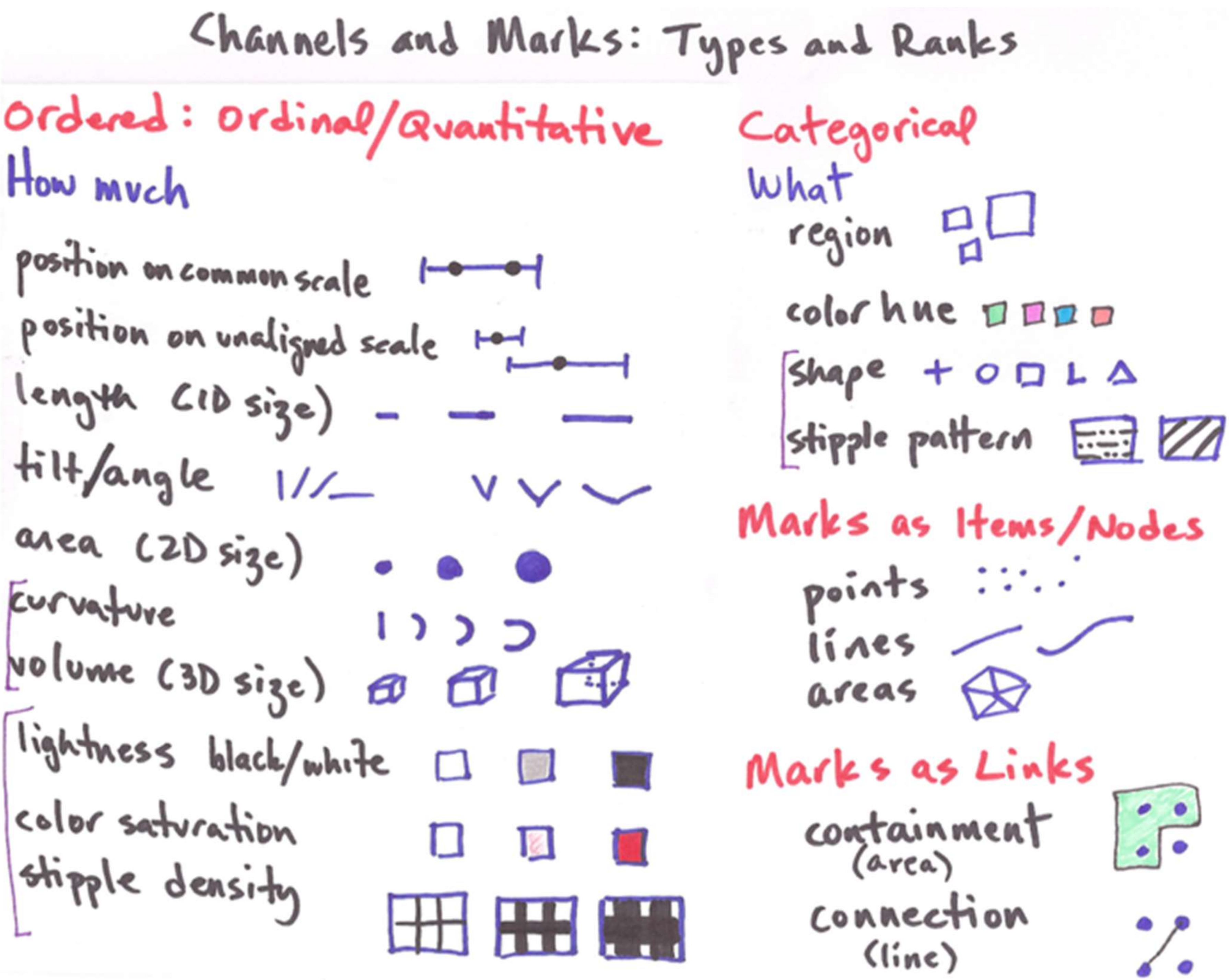
Source: M. Stone

Color-Blindness

Normal Protanope Deuteranope Lightness

Overview

- Marks + channels
- Channel effectiveness
- Channel characteristics
  - Spatial position
  - Color
- Other channels:
  - Size
  - Tilt (angle)
  - Shape (glyph)
  - Stipple (texture)
  - Curvature
  - Motion

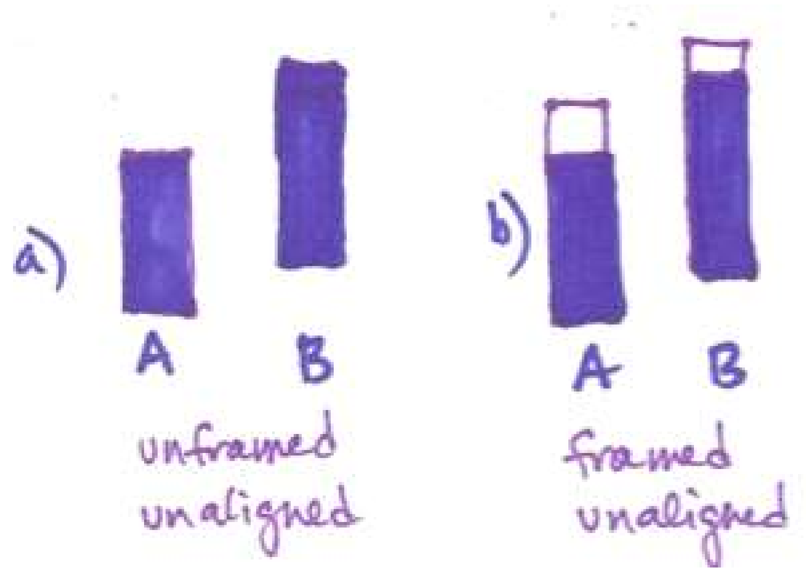

Channels and Marks: Types and Ranks
Ordered: Ordinal/Quantitative
How much
position on common scale
position on unaligned scale
length (1D size)
tilt/angle
area (2D size)
curvature
volume (3D size)
lightness black/white
color saturation
stipple density
Categorical
What
region
color hue
shape
stipple pattern
Marks as Items/Nodes
points
lines
areas
Marks as Links
containment (area)
connection (line)

Relative vs. absolute judgement

- Weber's law says that everything is relative, i.e. the "intensity" depends on the background signal

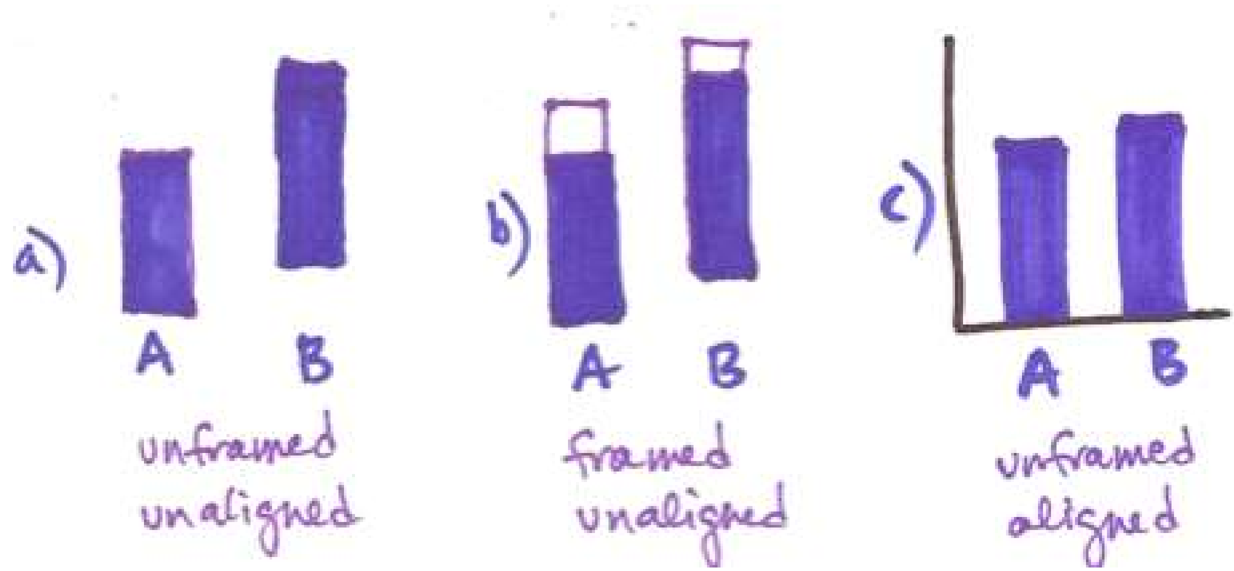
Relativ vs. absolute judgement

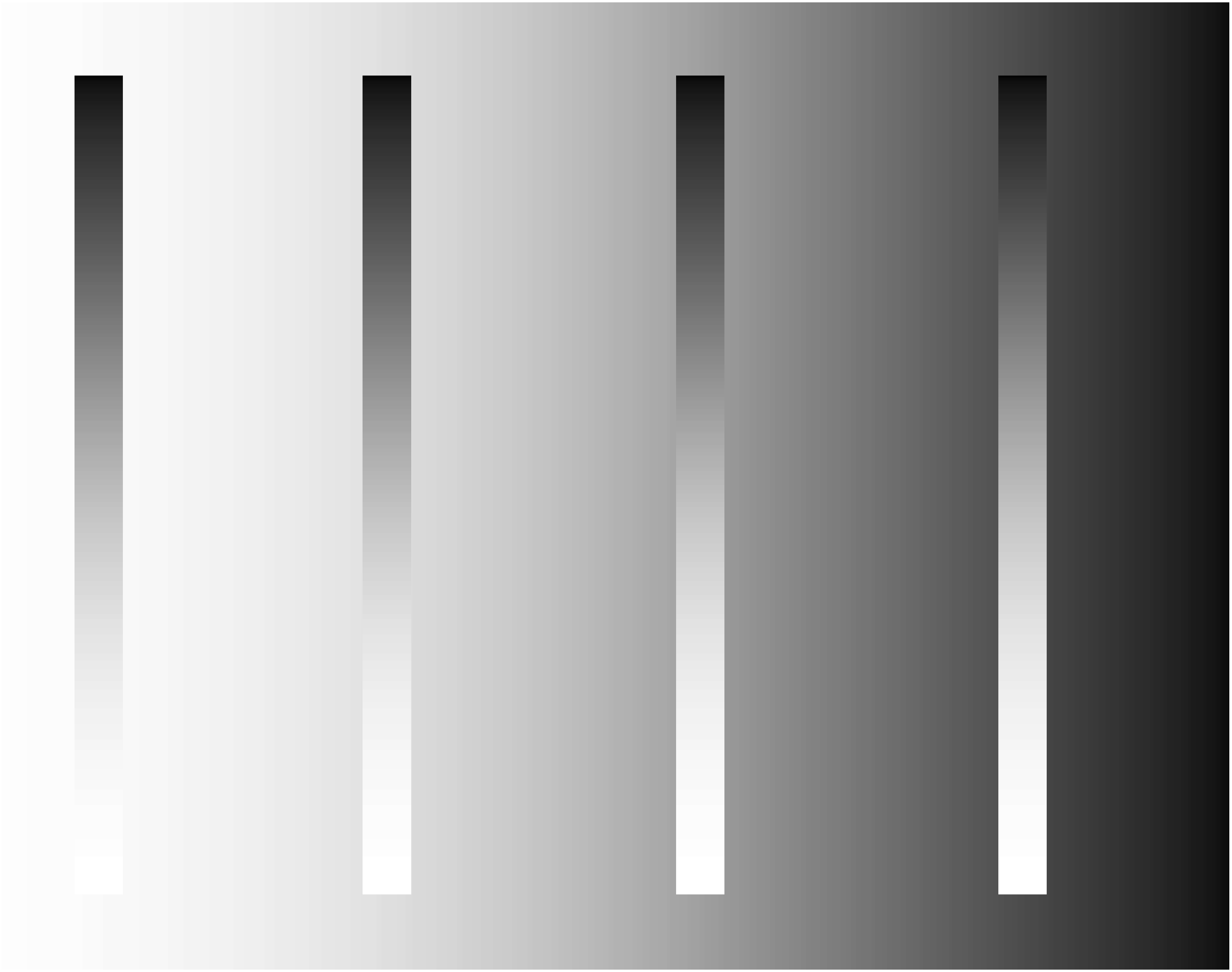
- Weber's law says that everything is relative, i.e. the "intensity" depends on the background signal

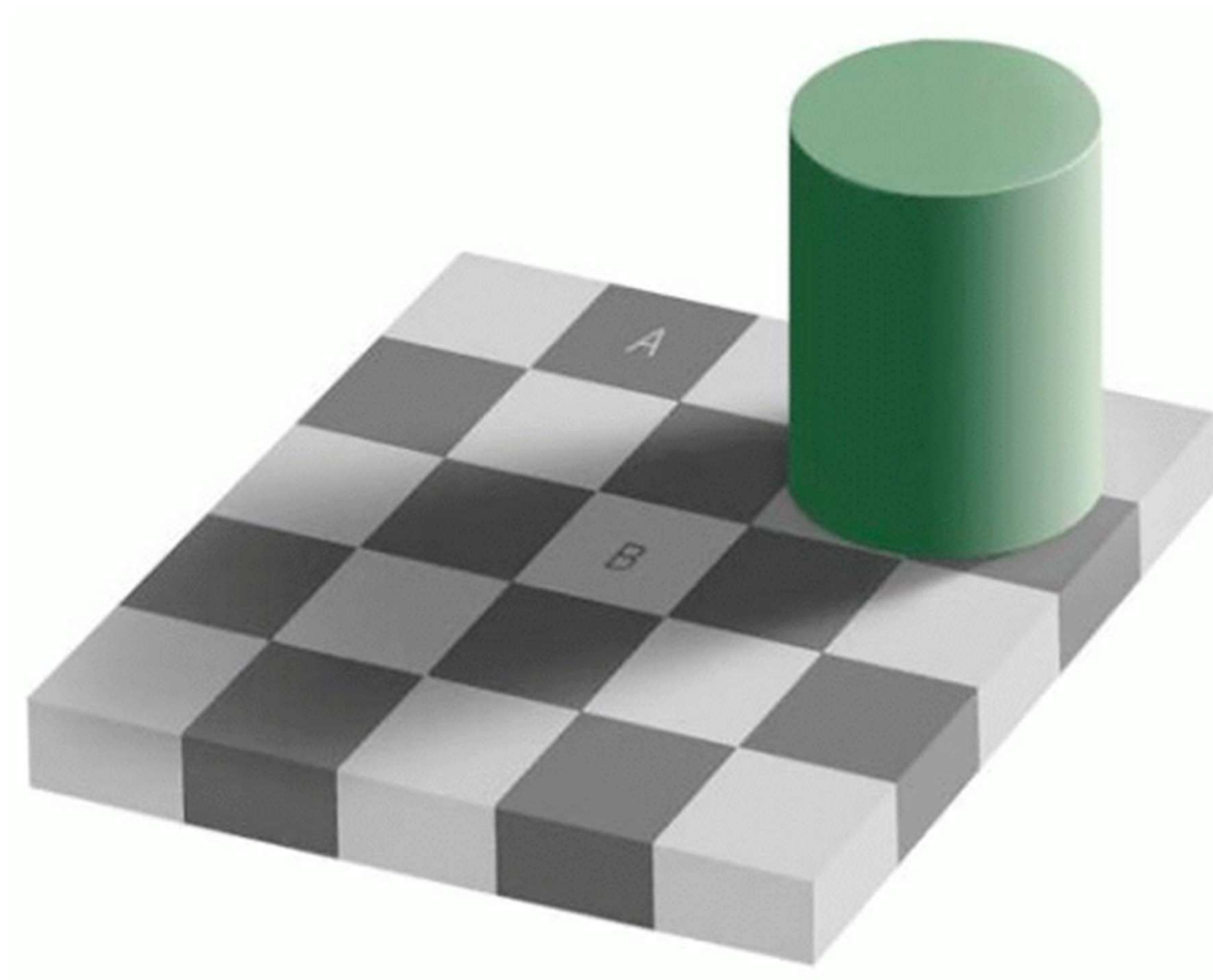


Relativ vs. absolute judgement

- Weber's law says that everything is relative, i.e. the "intensity" depends on the background signal



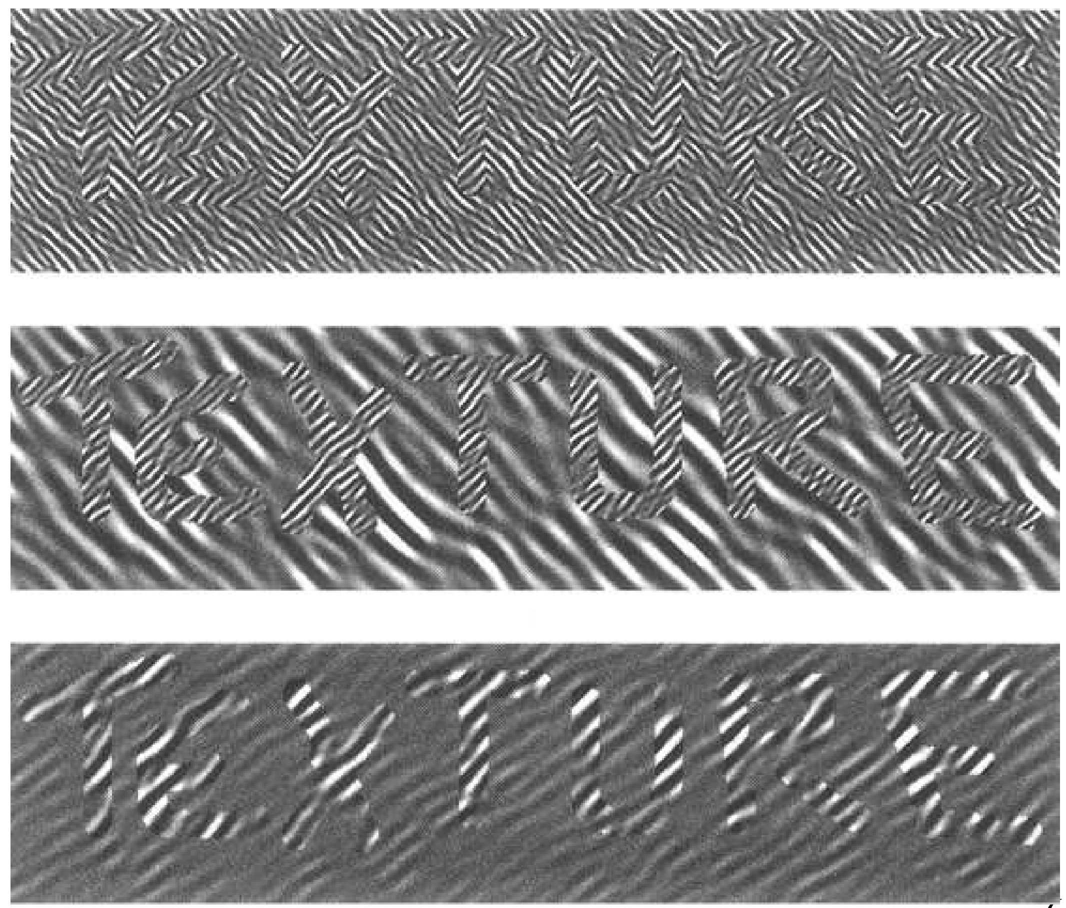




http://de.wikipedia.org/wiki/Optische_Täuschung

Mapping to Texture

- Main parameters for texture
  - Orientation
  - Size
  - Contrast
- Alternatively [Tamura 78]:
  - Coarseness
  - Roughness
  - Contrast
  - Directionality
  - Line-likeness
  - Regularity



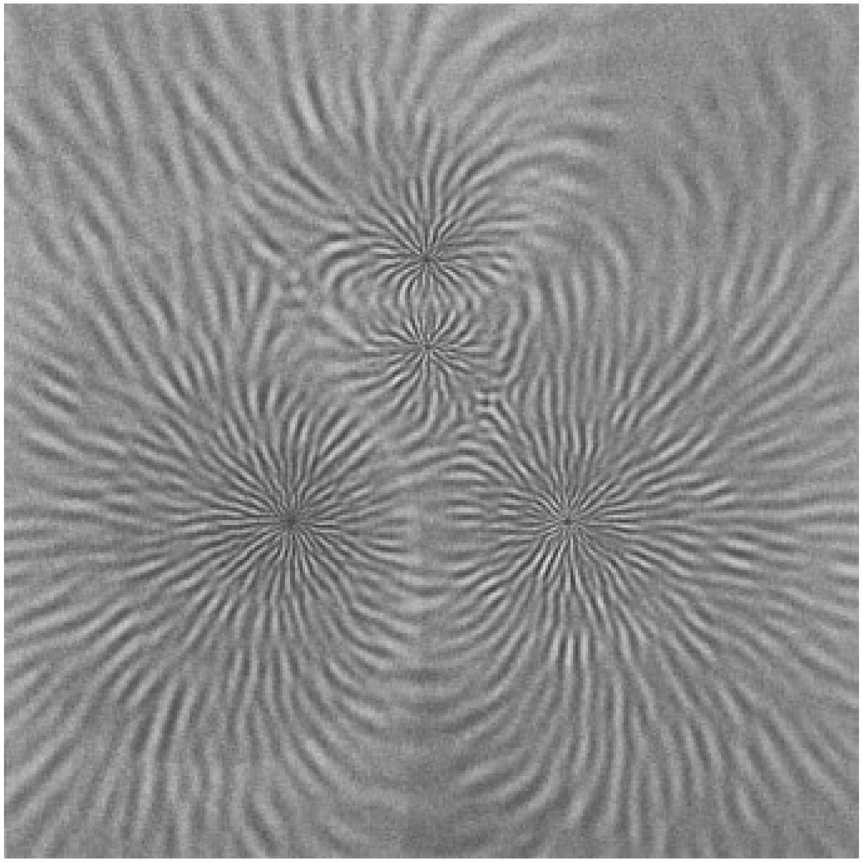
[C. Ware, Information Visualization]

Mapping to Texture

- Goal:
  - Avoid visual "crosstalk“
  - “Orthogonal” perceptual channels
- Restricts range of parameters
  - E.g. approximately 30 degrees difference in orientation needed to distinguish textures
- Main application for textures: nominal data
- Some applications for direct visualization of orientations

Mapping to Texture

- Generate texture
- Gabor func. as primitives
- Parameters:
  - Orientation
  - Size
  - Contrast
- Randomly splatter down Gabor functions
  - Blending yields continuous coverage
  - Stochastic texture model

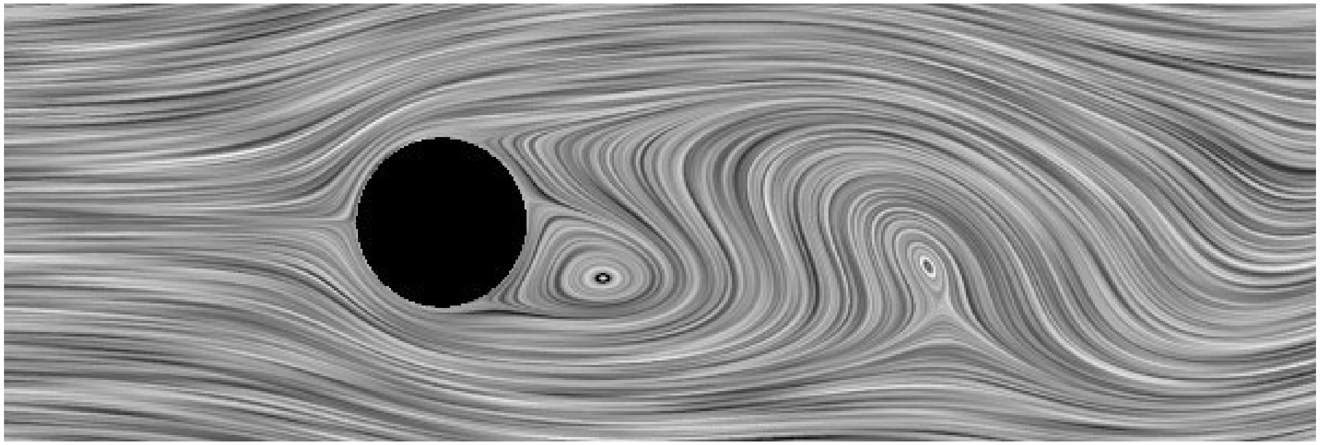


[C. Ware, Information Visualization]

Visualization of a magnetic field

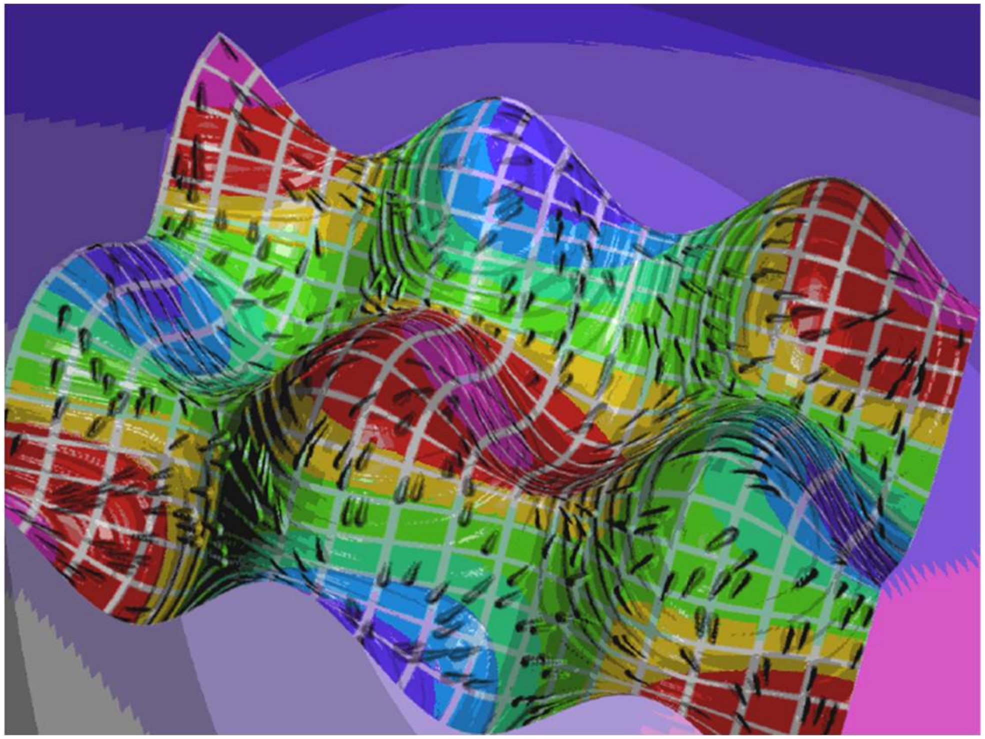
Mapping to Texture

- Other stochastic texture models:
  - LIC (Line integral convolution) for vector field visualization
- Structural models
  - Procedural description of texture generation
  - E.g. Lindenmayer systems (L-systems)



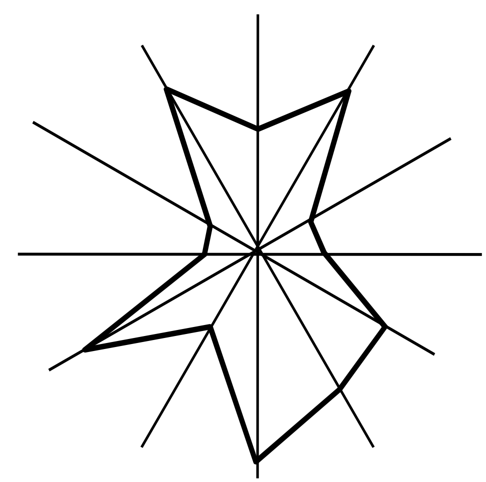
Other Mappings

- More advanced mappings possible
- Examples for other visual variables
  - Motion
  - Blink coding
  - Explicit use of 3D
- Multiple attributes
- Typical combination of attributes:
  - Geometric position, e.g., height field
  - Color: saturation, intensity, tone
  - Texture
- Issue: Interference?



Glyphs

- Glyphs and icons
  – Consist of several components
- Features should be easy to distinguish and combine
- Icons should be separated from each other
- Mainly used for multivariate *discrete* data

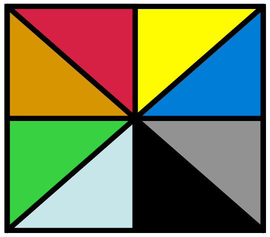


Glyphs

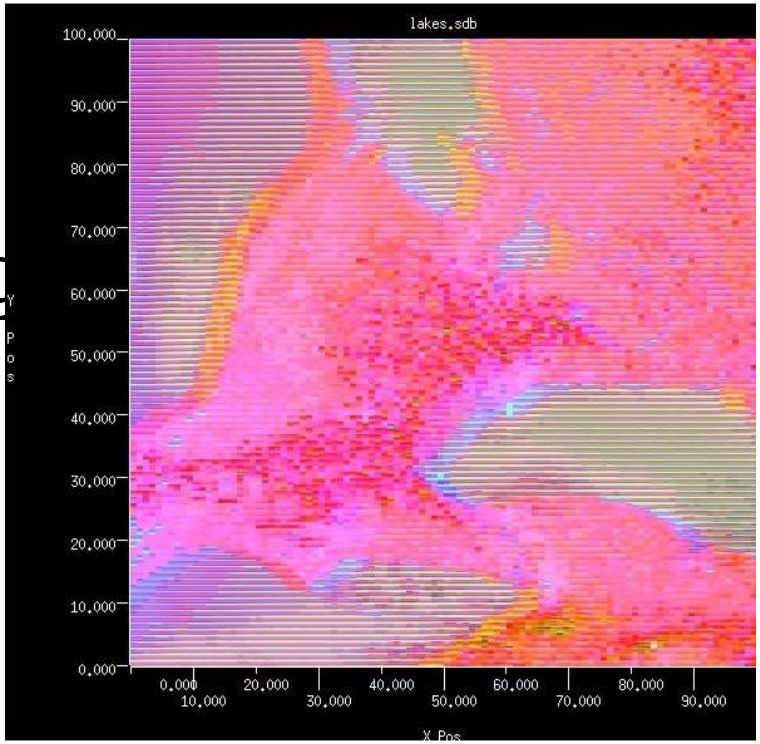
- Interesting graphical attributes for basic glyph design [according to C. Ware, Information Visualization]

Visual variable	***Dimensionality***
Spatial position of glyph	3 dimensions: X, Y, Z
Color of glyph	3 dimensions: defined by color opponent theory
Shape	2–3? dimensions unknown
Orientation	3 dimensions: corresponding to orientation about each of the primary axes
Surface texture	3 dimensions: orientation, size, and contrast
Motion coding	2–3? Dimensions largely unknown, but phase may be useful
Blink coding: The glyph blinks on and off at some rate	1 dimension

Glyphs

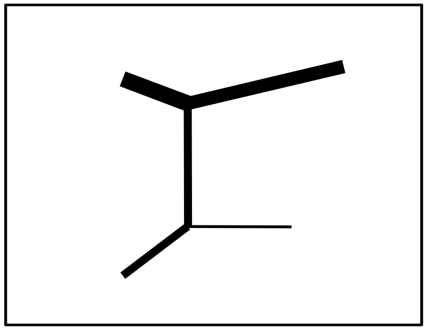


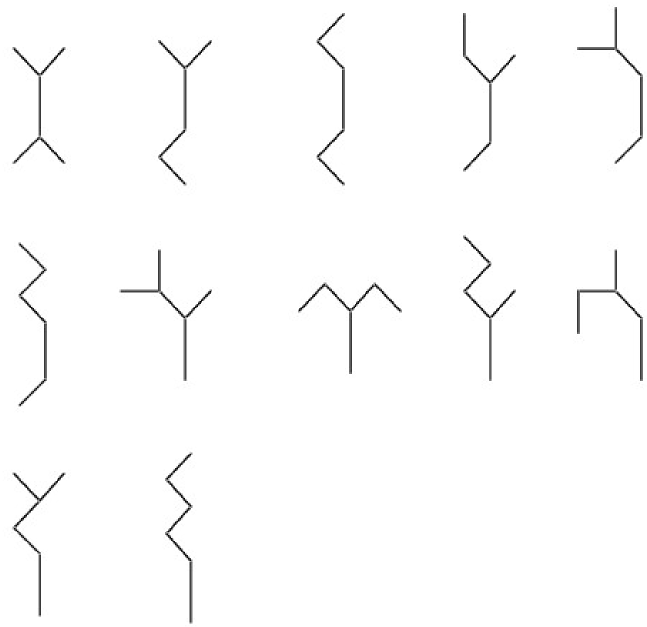
- Color icons [Levkowitz 91]
- Subdivision of a basic figure (triangle, square, …) into edges and faces
- Mapping of data to faces via color tables
- Grouping by emphasizing edges or faces



Glyphs

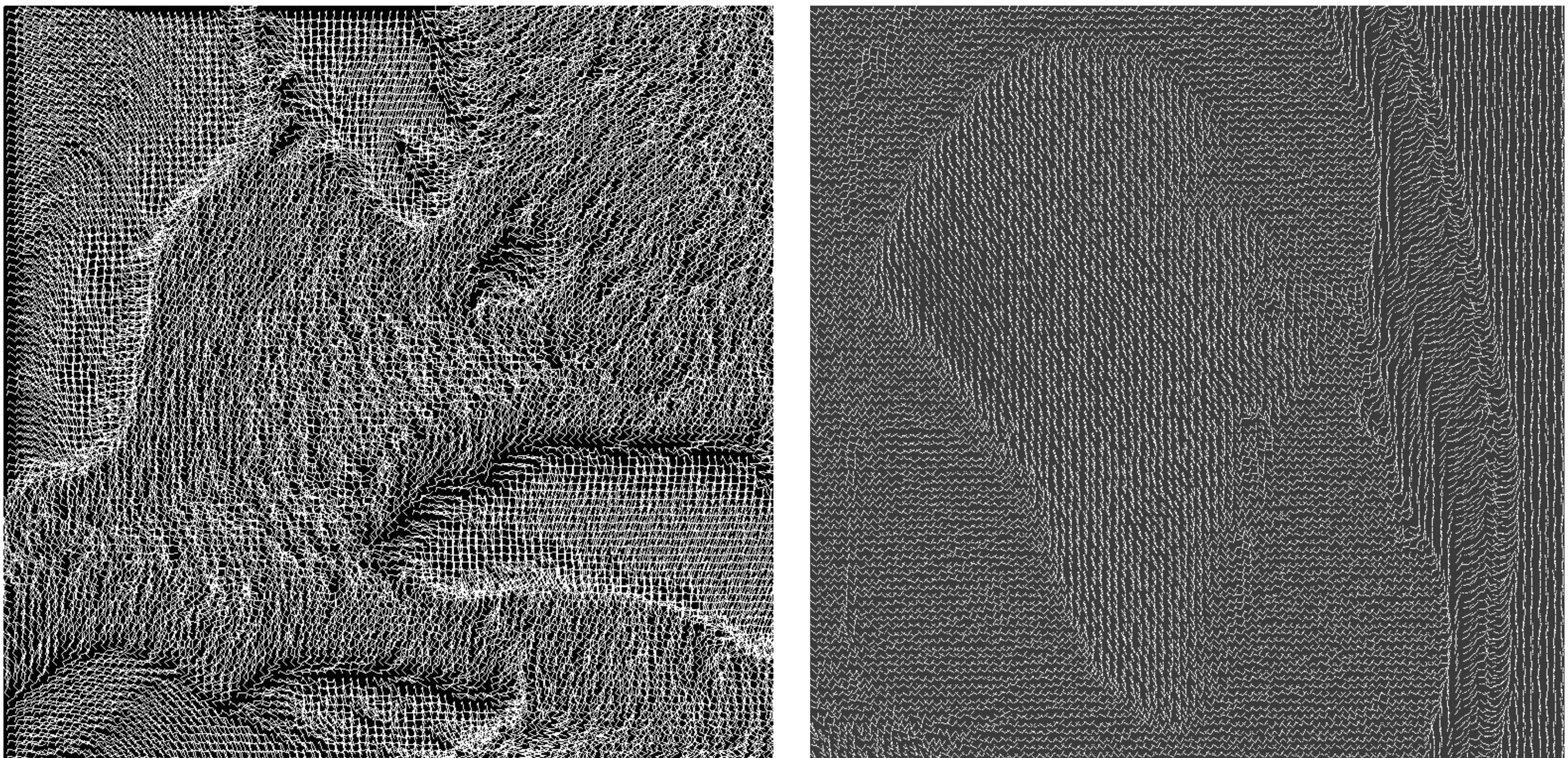
- Stick-figure icon [Picket & Grinstein 88]
- 2D figure with 4 limbs
- Coding of data via
  - Length
  - Thickness
  - Angle with vertical axis
- 12 attributes
- Exploits the human capability to recognize patterns/textures





Glyphs

- Stick-figure icon



Glyphs

- Circular icon plots:
  - Star plots
  - Sun ray plots
  - etc…
- Follow a "spoked wheel" format
- Values of variables are represented by distances between the center ("hub") of the icon and its edges

Glyphs

- Star glyphs
  [S. E. Fienberg: Graphical methods in statistics.
  The American Statistician, 33:165-178, 1979]
  - A star is composed of equally spaced radii, stemming from the center
  - The length of the spike is proportional to the value of the respective attribute
  - The first spike/attribute is to the right
  - Subsequent spikes are counter-clockwise
  - The ends of the rays are connected by a line