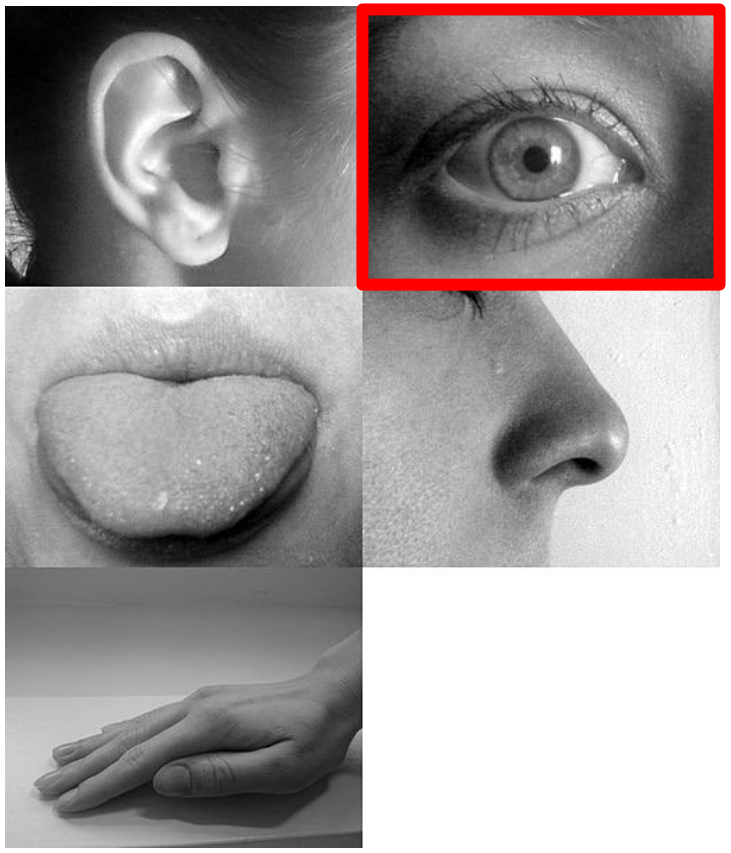
PERCEPTION AND INFORMATION PROCESSING

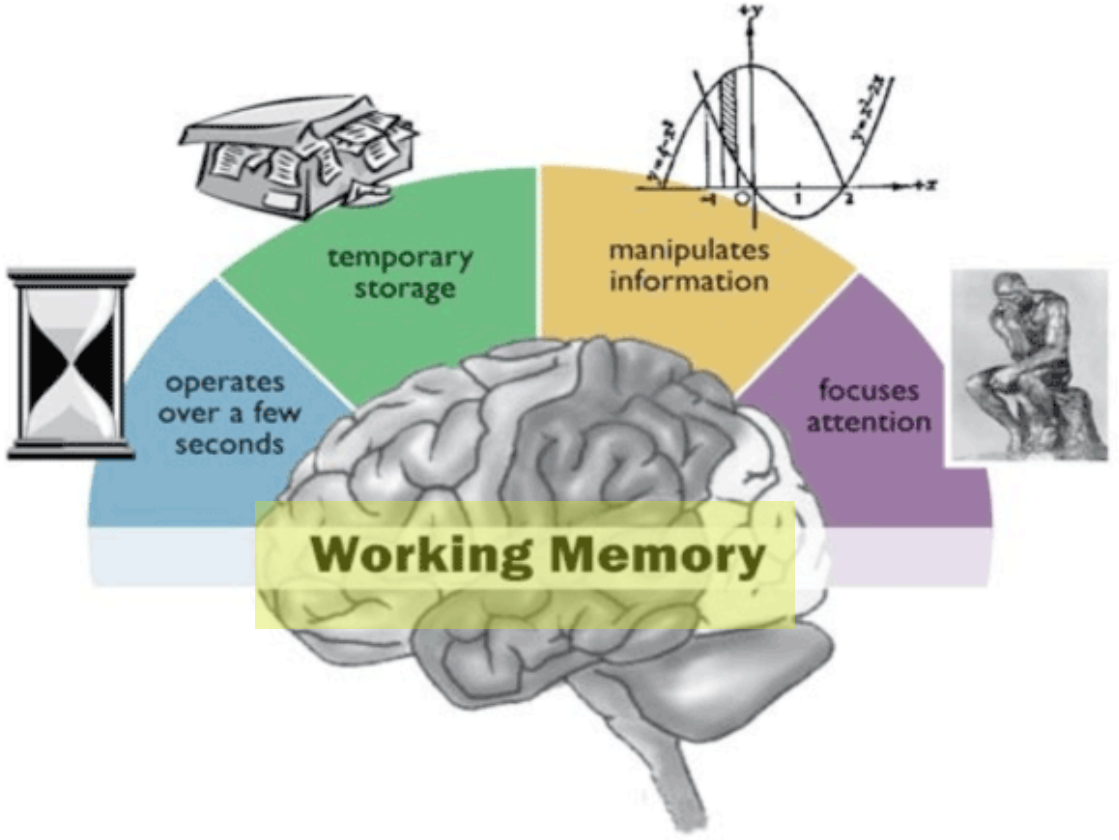
PRESENTATION AND VISUALIZATION – MIREIA RIBERA

FOUNDATIONS OF DATA SCIENCE MASTER DEGREE

INFORMATION PROCESSING

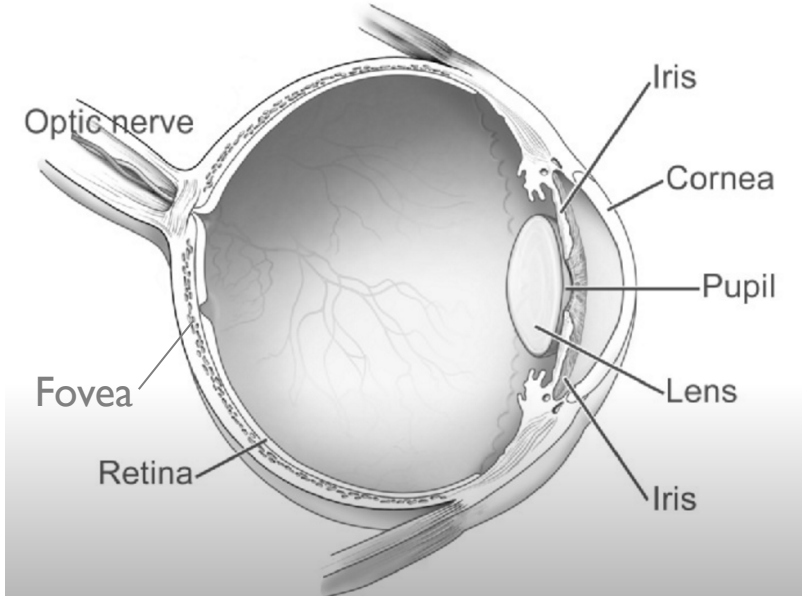
OUR INFORMATION PROCESSING CAPABILITIES

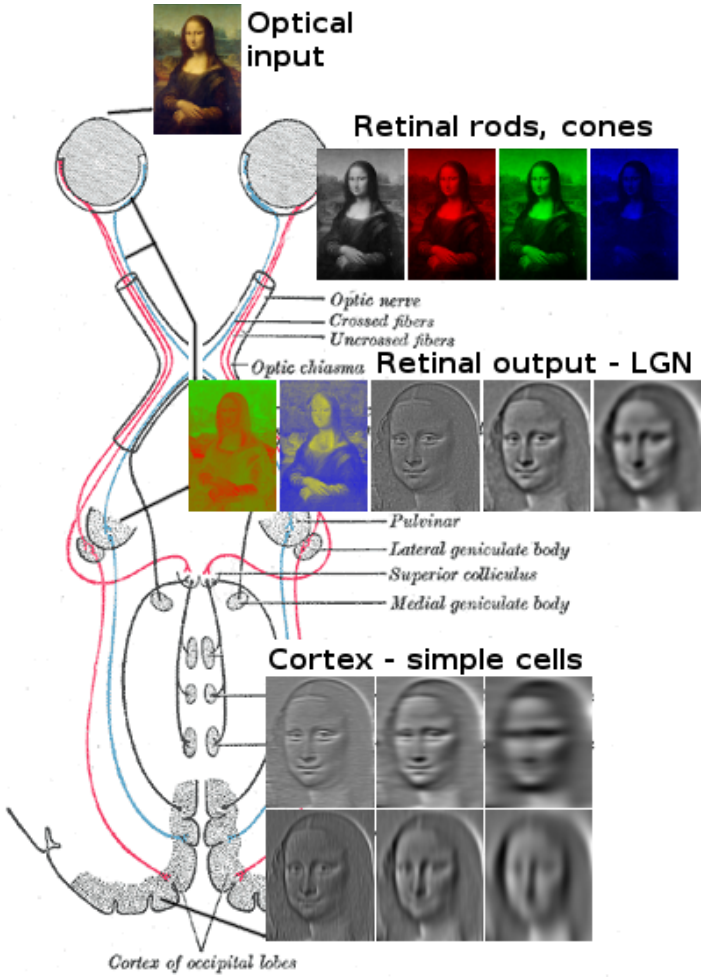




Source: Allan-Hermann Pool (Own work) [CC BY-SA 4.0 (http://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons
http://usablealgebra.landmark.edu/instructor-training/working-memory-attention-executive-function/

THE VISUAL SYSTEM



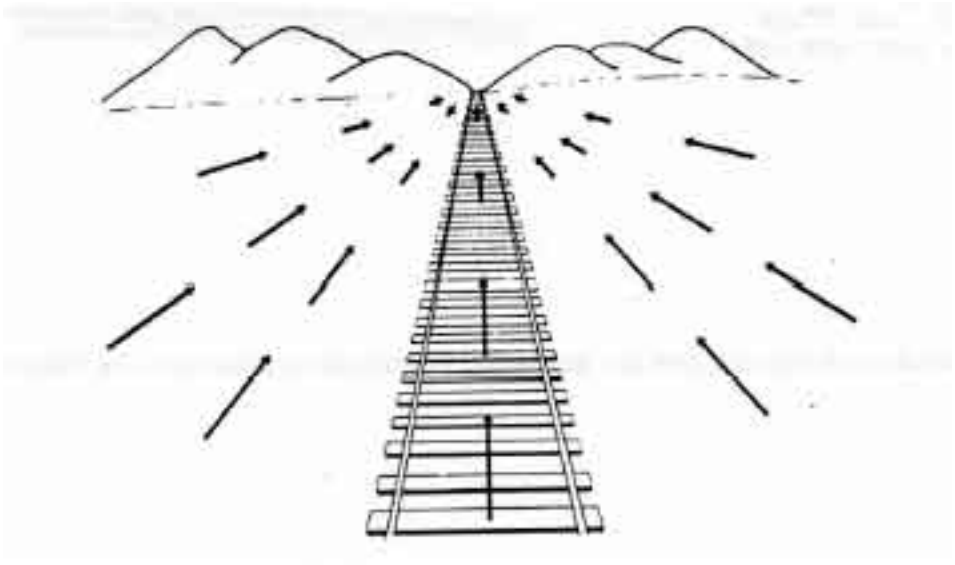


WHAT DO YOU READ HERE?

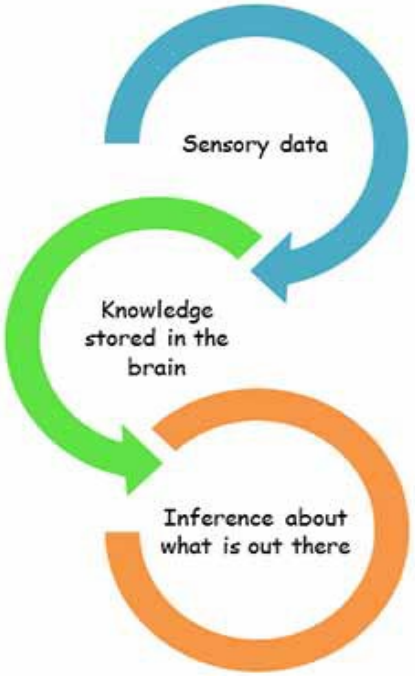
THE CHT

TWO THEORIES OF PERCEPTION PROCESSING

BOTTOM-UP APPROACH

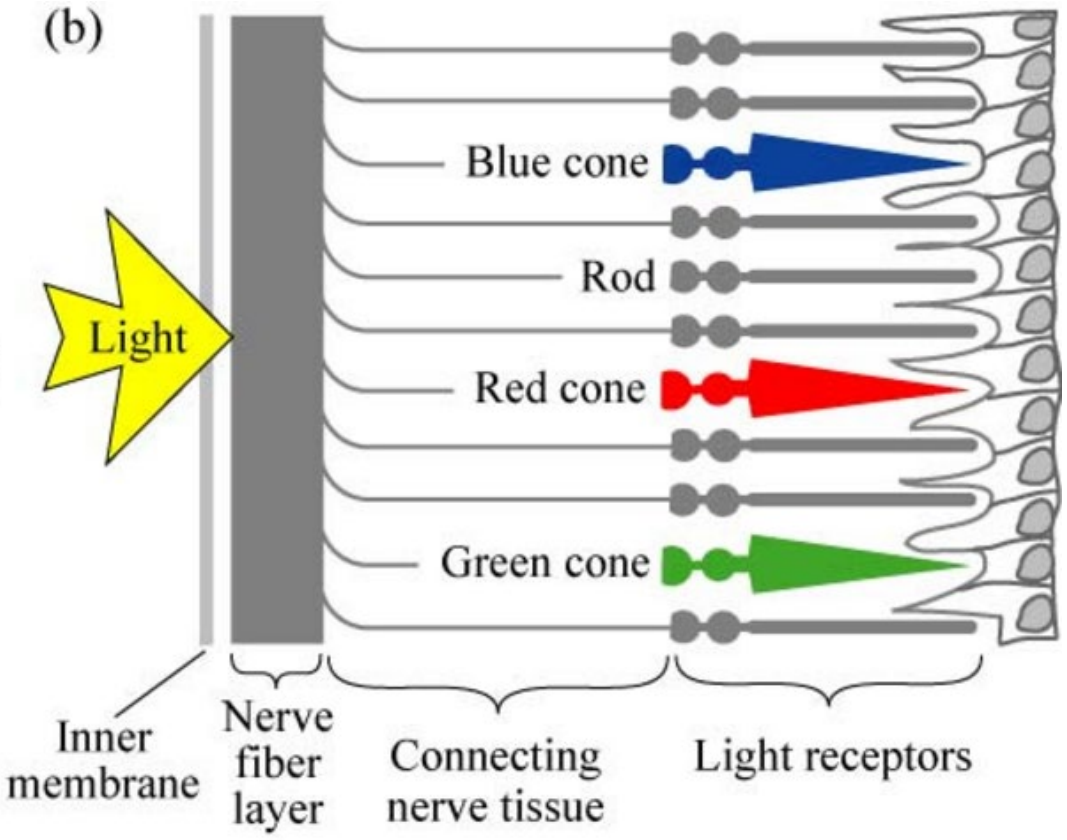


TOP-DOWN APPROACH



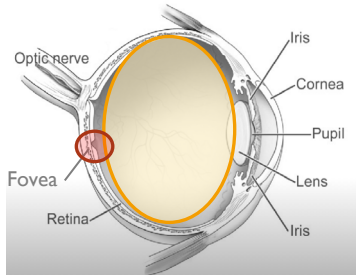
SENSATION

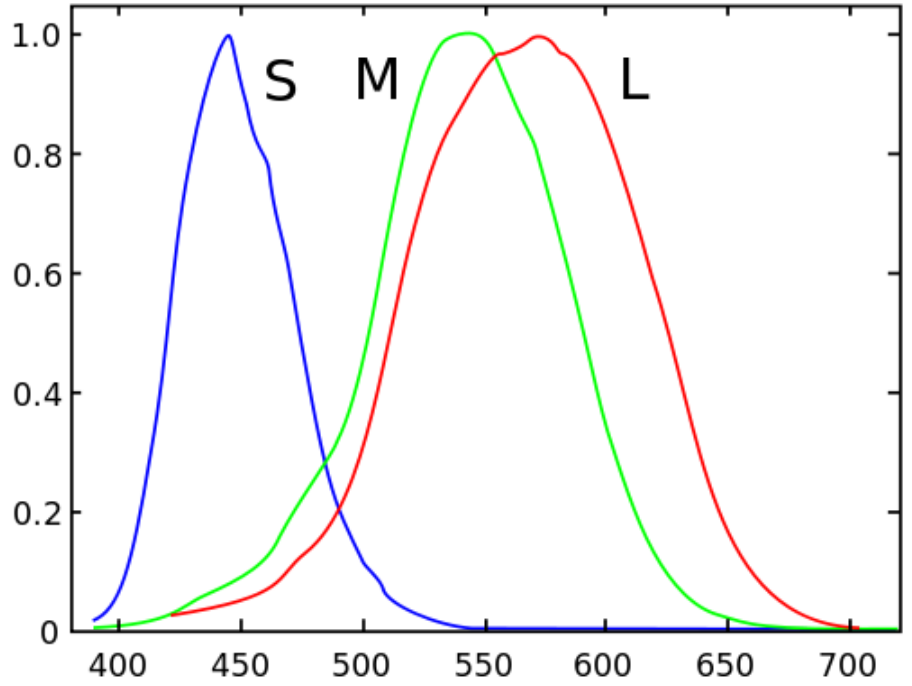
RETINA, RODS AND CONES



Rods (120 million) detect low light level. Periphery

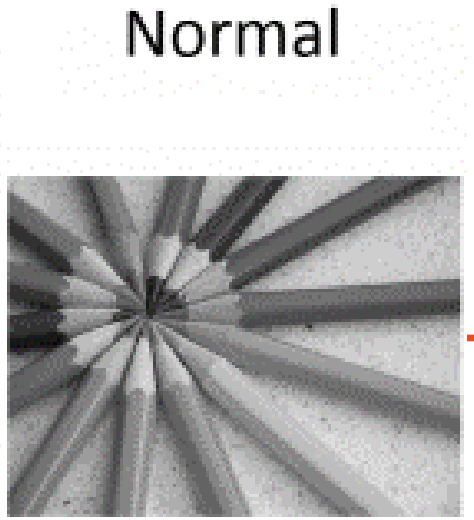
Cones (6.4 million) detect hue. Fovea



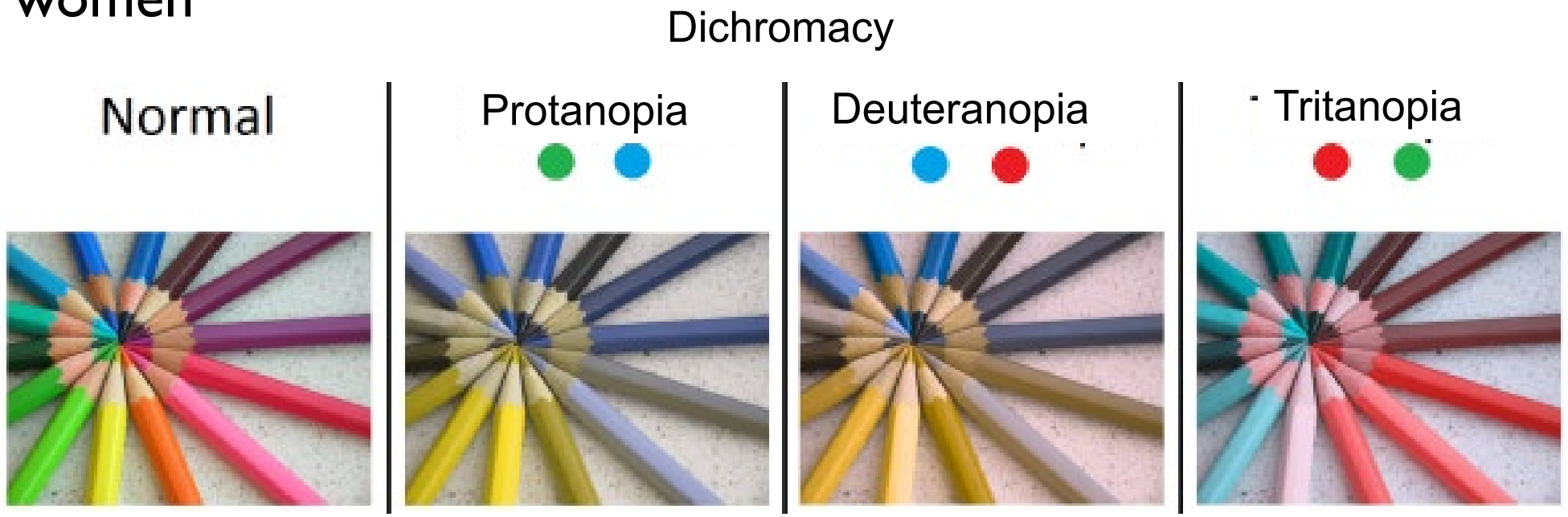


S – Short wavelength cones (blue)
M – Medium wavelength cones (green)
L – Long wavelength cones (red)

COLOUR DEFICIENCY



- 10% men
- 1% women



Colour blindness: Protanopia (lack of L cones), Deuteranopia (lack of M cones)

CLASS ACTIVITY

- The Hue-test challenge

http://www.xrite.com/hue-test/ try to pass the test with maximum qualification

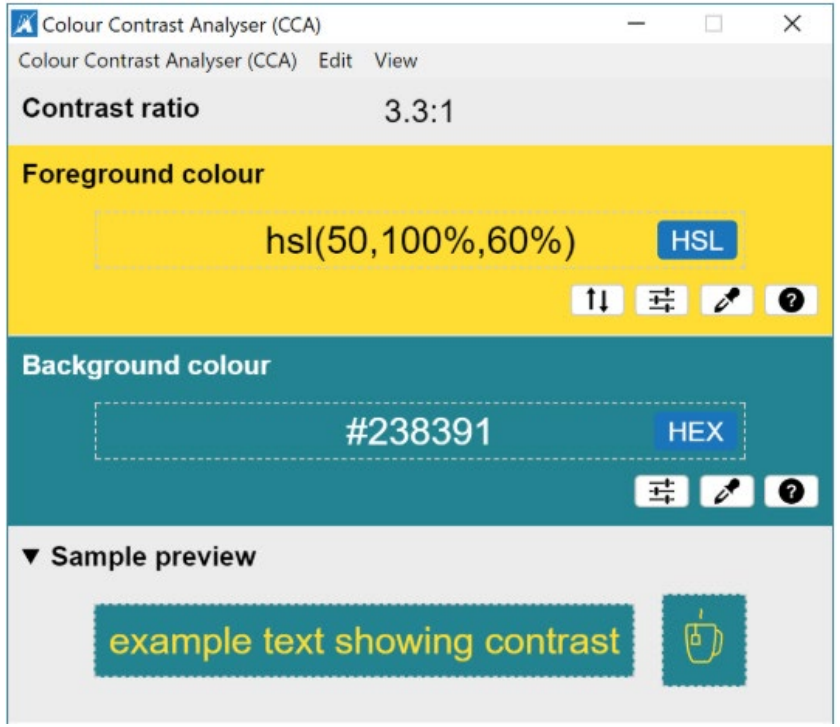
- Silktide disability simulator

Install the extension. Visit a colourful web you use to go. Try colour deficiency options of the extension

AGE, COLOUR BLINDNESS AND CONTRAST

- Colour perception decreases with age
- Sight decrease affects both rods and cones
- As we have many more rods, elders perceive much better luminance differences than hue differences.
- It is therefore important to keep contrast differences in every colour system.

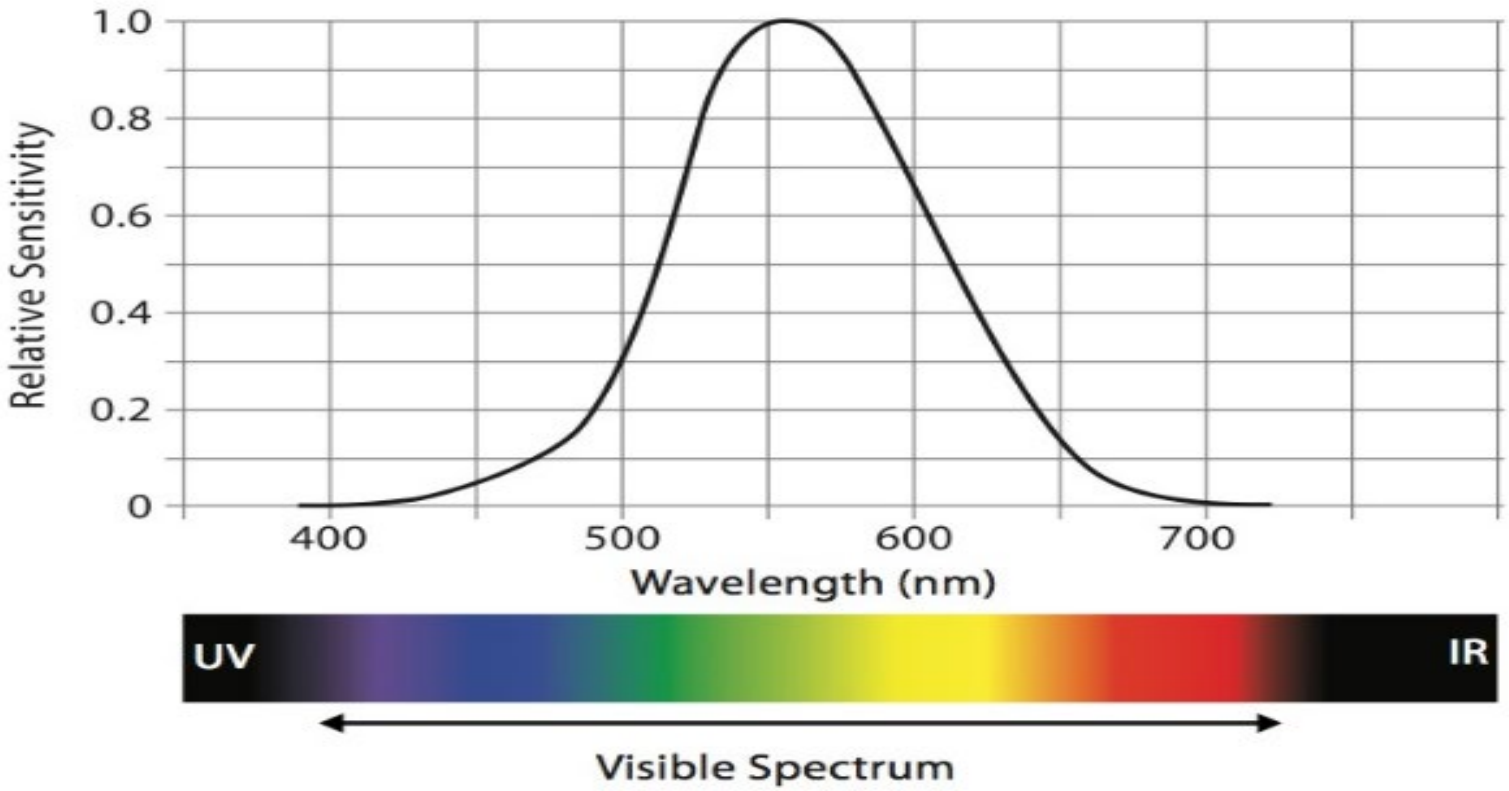
CONTRAST: SOME TOOLS

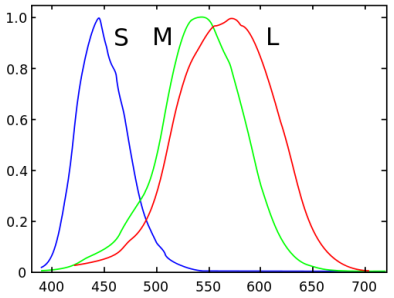


LINUX: https://contrast-ratio.com

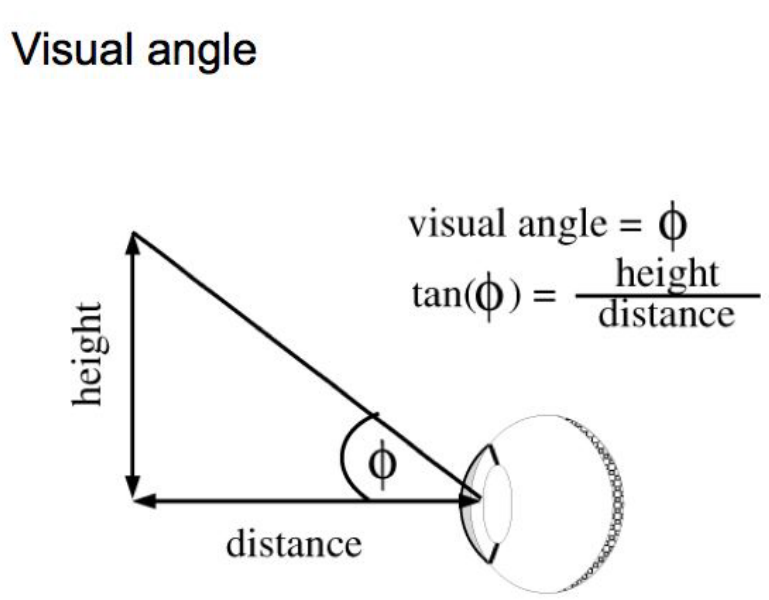
Carbon IBM's Design System: Accessible colour palettes for information visualization

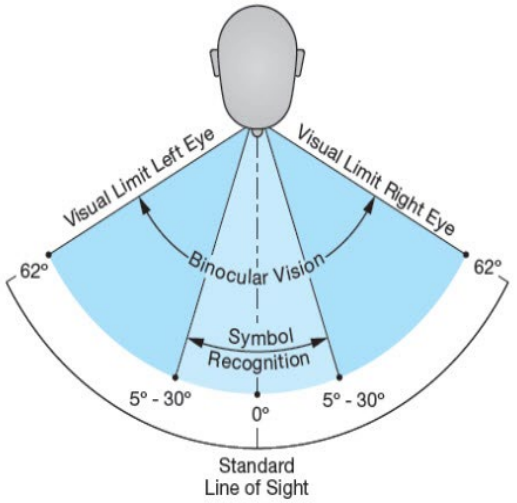
EYES SENSITIVITY

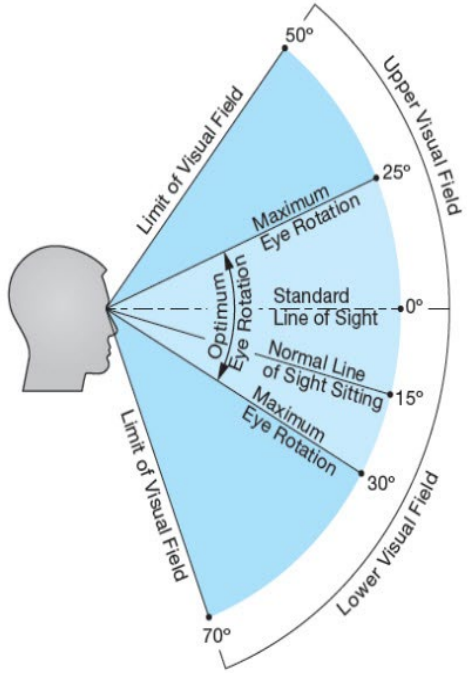




VISUAL ANGLE AND USEFUL FIELD OF VIEW (UFOV)







Source: http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/eye/eye.html

DESIGN PRINCIPLE

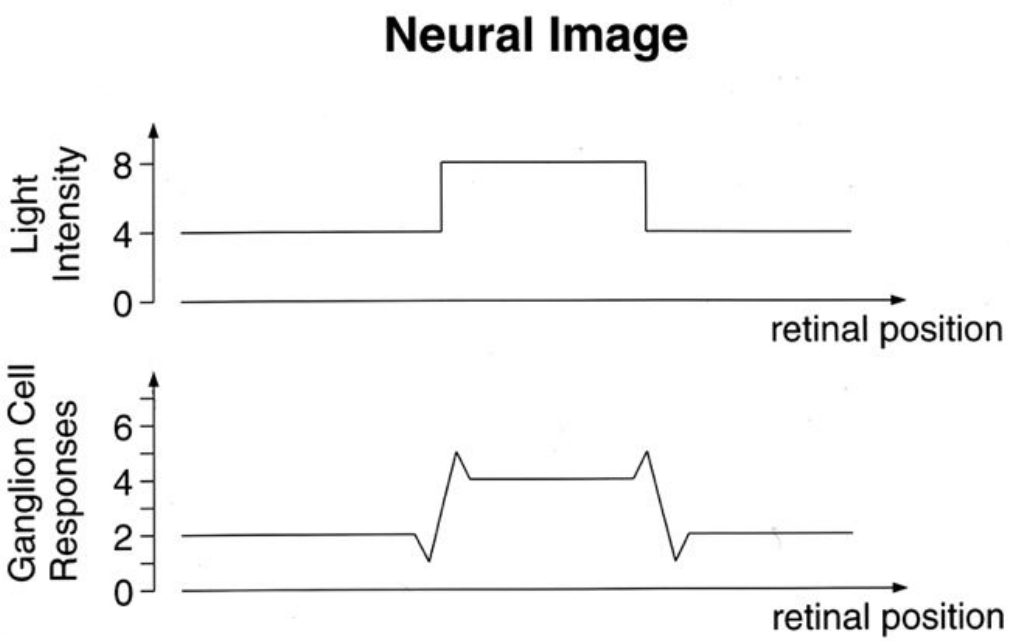
- G5.1 'To minimize the cost of visual searches, make visualization displays as compact as possible, compatible with visual clarity. For efficiency, information nodes should be arranged so that the average saccade is 5 degrees or less'

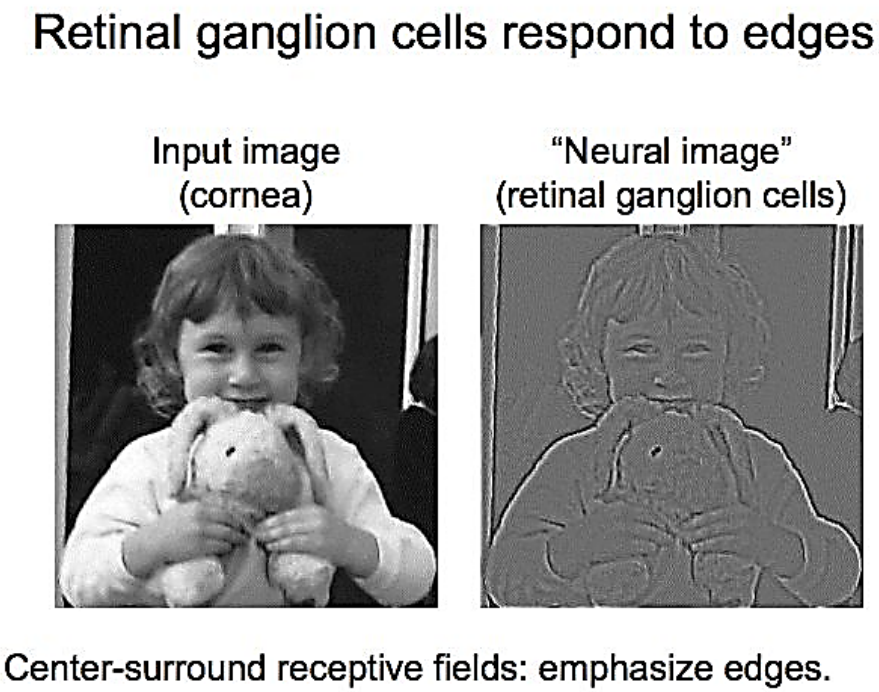
Source (of this and posterior G principles): Colin Ware, *Perception for design*

PERCEPTION

RETINAL GANGLION CELLS

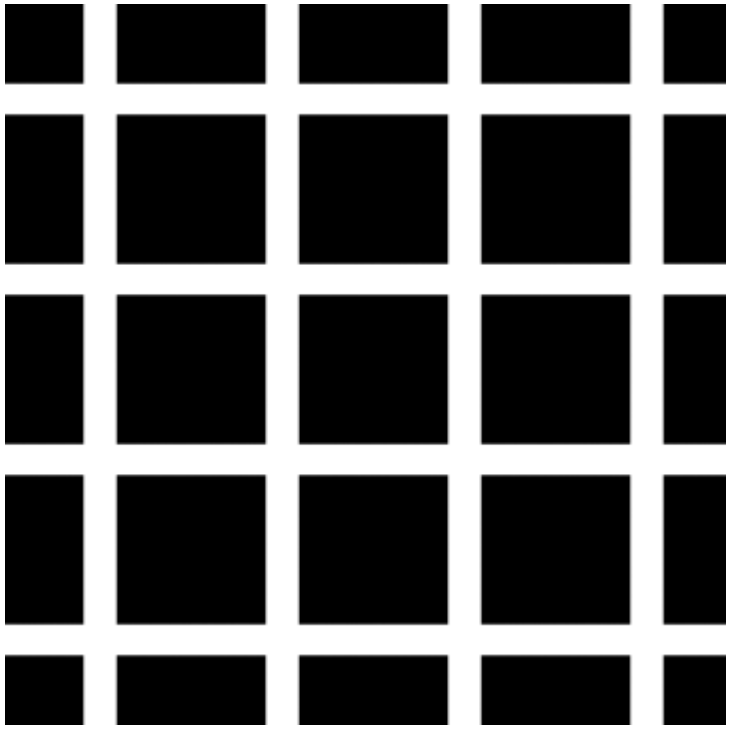
Rods (120 million) detect low light level. Periphery
Cones (6.4 million) detect hue. Fovea

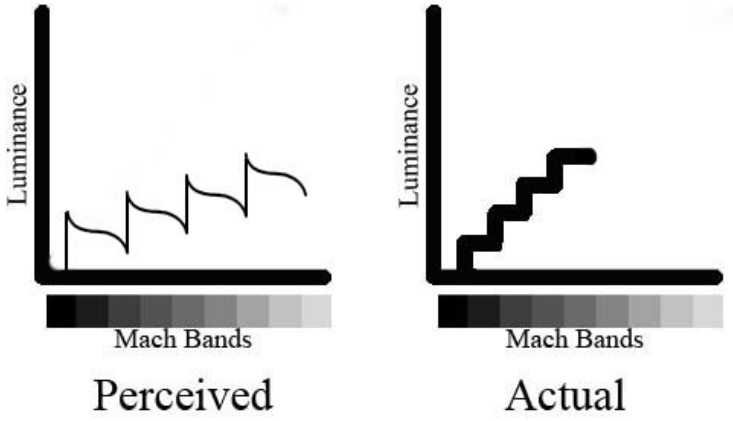




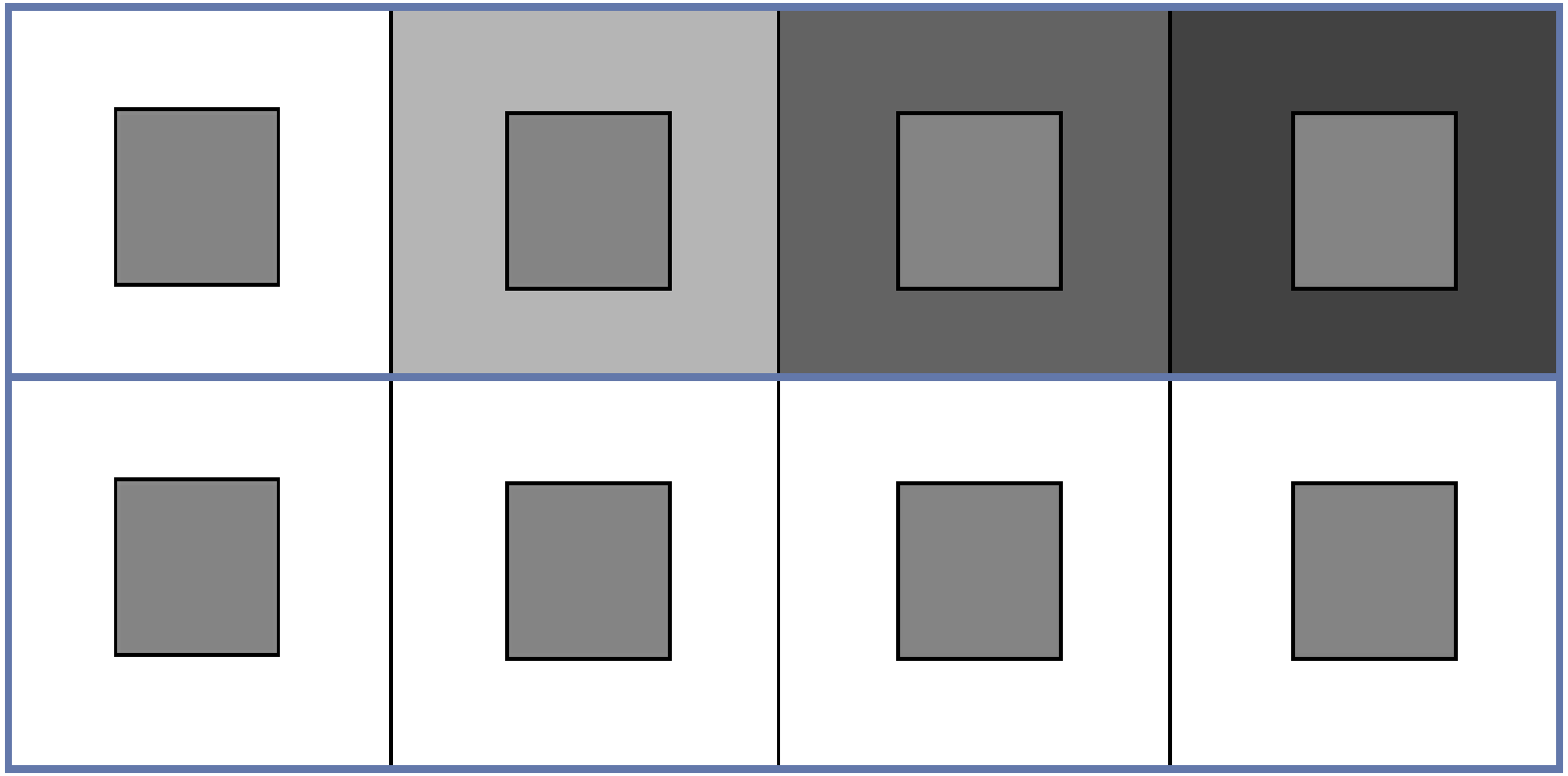
Source: http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/ganglion/ganglion.html

BIASED SIGNALS SENT TO NEURONS

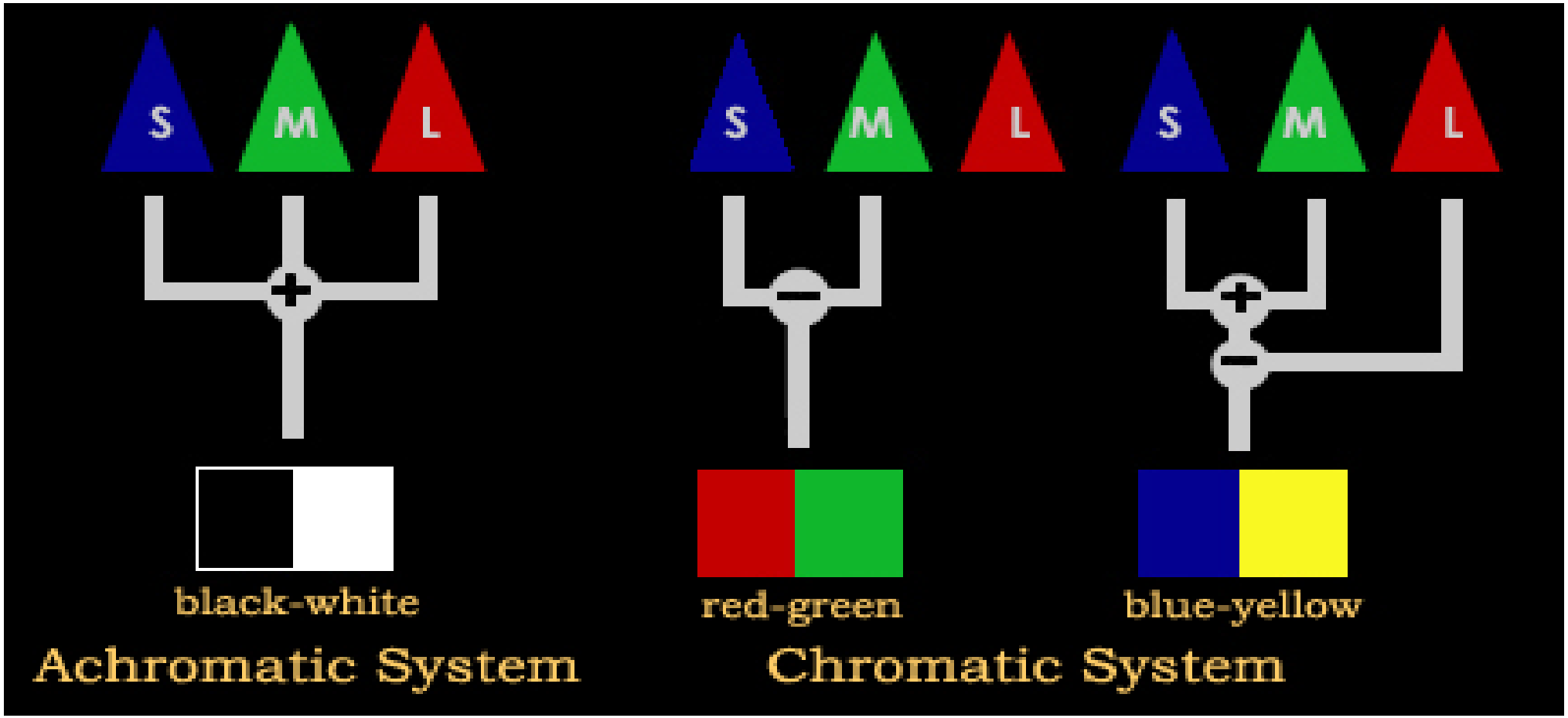




PERCEPTION IS RELATIVE

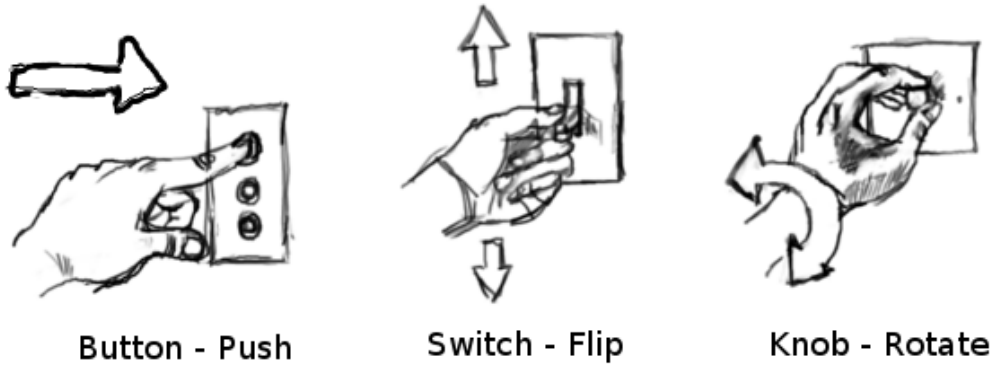


THE OPPONENT-PROCESS THEORY



PERCEPTION THEORIES

AFFORDANCES



Source: http://paaralan.blogspot.com.es/2010/09/affordance-and-educational-games.html;
https://www.slideshare.net/Tzec/affordances-constraints-and-feedback-in-user-experience-design

HOW MANY 5s?

385720939823728196837293827

382912358383492730122894839

909020102032893759273091428

938309762965817431869241024

HOW MANY 5s?

385720939823728196837293827

3829123583834927301228948 39

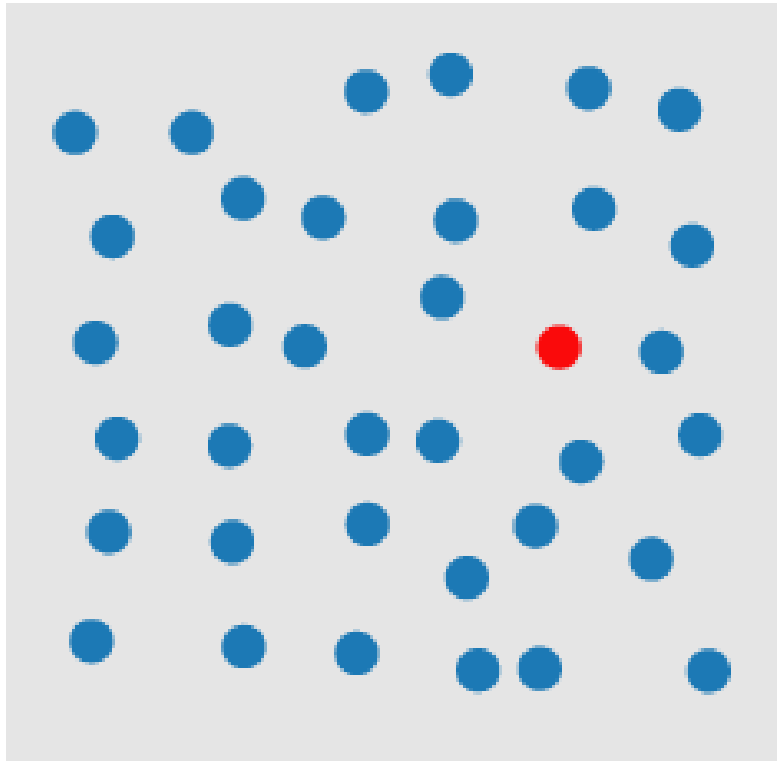
9090201020328937592730914 28

9383097629658174318692410 24

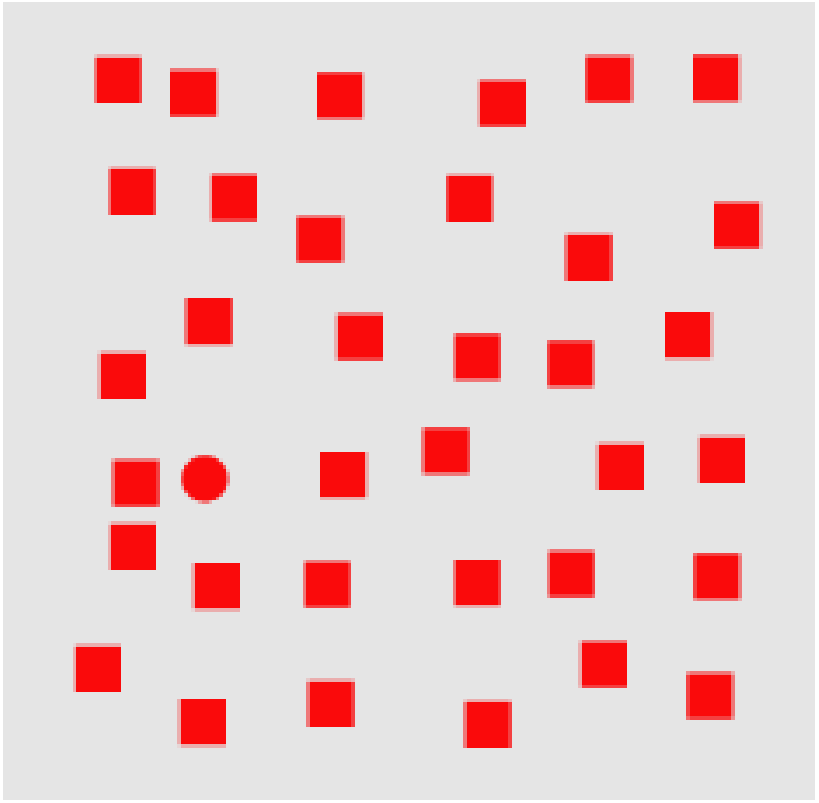
PREATTENTIVE PROPERTIES

- Certain visual properties are detected immediately by low-level visual system
  - Immediately is <200-250 ms
- They "pop-out" without requiring serial search
- Not affected by distractors

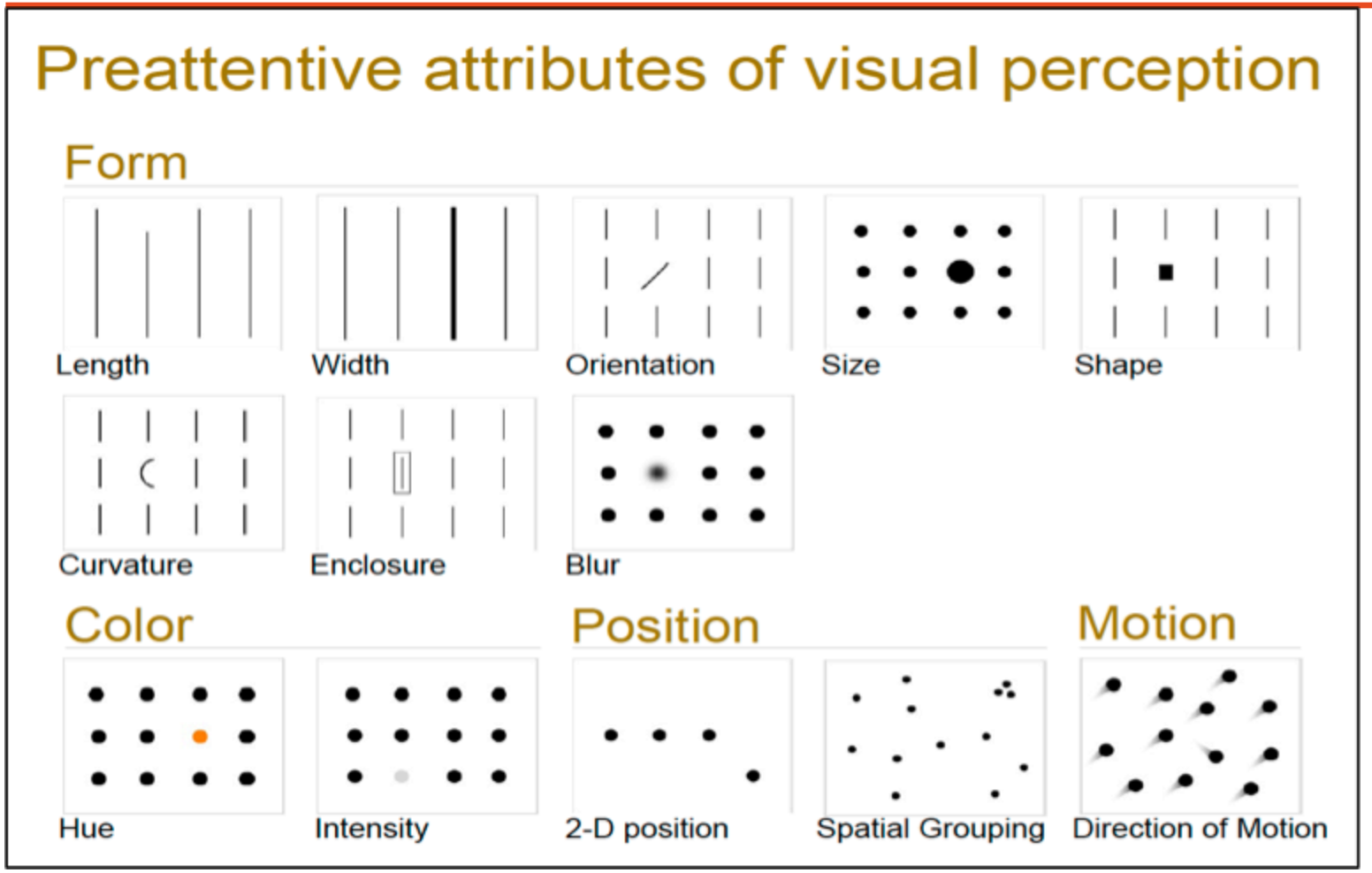
TEST YOUR ABILITIES: WHERE IS THE RED CIRCLE?



TEST YOUR ABILITIES (II): WHERE IS THE RED CIRCLE?



PREATTENTIVE PROCESSING AND PROCESSING CHANNELS



TEST YOUR ABILITIES (III)

- Perception in visualization / Christopher G. Healey
  https://www.csc2.ncsu.edu/faculty/healey/PP/index.html

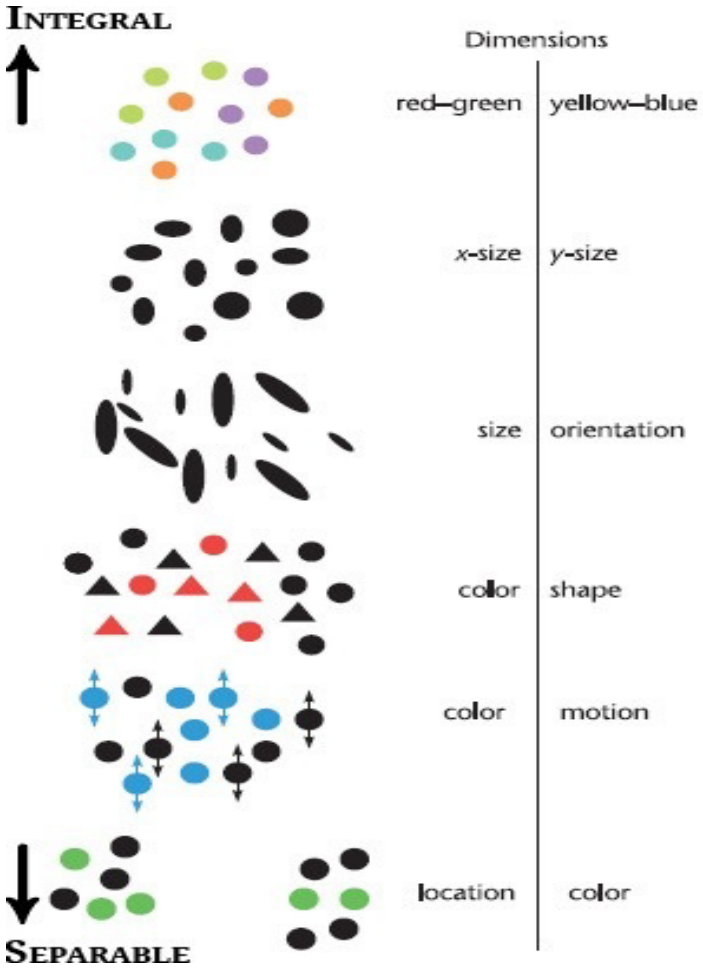
DESIGN PRINCIPLES

- G5.2 "Use different visual channels to display aspects of data so that they are visually distinct"
- G5-7 "For maximum pop out a symbol should be the only object in a display that is distinctive on a particular feature channel; for example, it might be the only item that is coloured in a display where everything else is black and white."

DESIGN PRINCIPLES

- G5-8 "Use positively asymmetric preattentive cues for highlighting"
- G5-9 "For highlighting, use whatever feature dimension is used least in other parts of the design"
- G5-10 "When colour and shape channels are already fully utilized, consider using motion or blink highlighting. Make the motion or blinking as subtle as possible, consistent with rapid visual search"

COMBINATION OF DIMENSIONS: INTEGRAL AND SEPARABLE

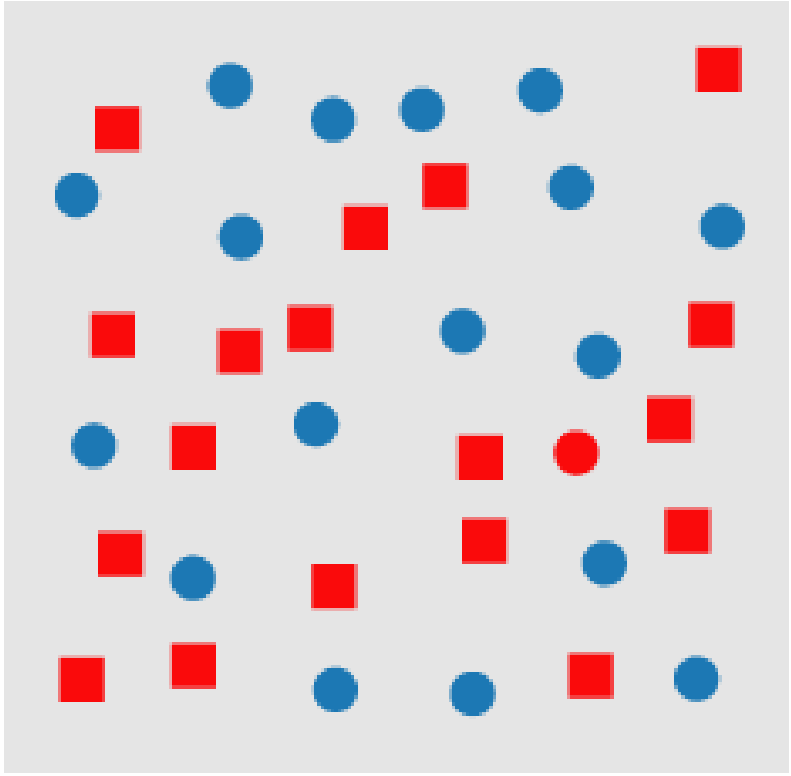


- Integral dimensions are seen together
- Separable dimensions are seen separately

DESIGN PRINCIPLES

- G5.14 "If it is important for people to respond holistically to a combination of two variables in a set of glyphs, map the variables to integral glyphs properties"
- G5.15 "If it is important for people to respond analytically to a combination of variables, making separate judgments on the basis of one variable or the other, map the variables to separable glyph properties"

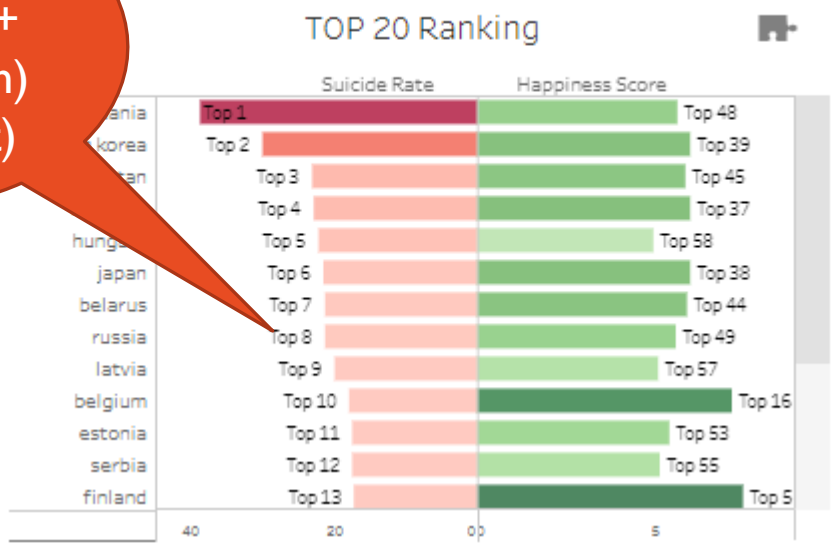
TEST YOUR ABILITIES (IV): WHERE IS THE RED CIRCLE?



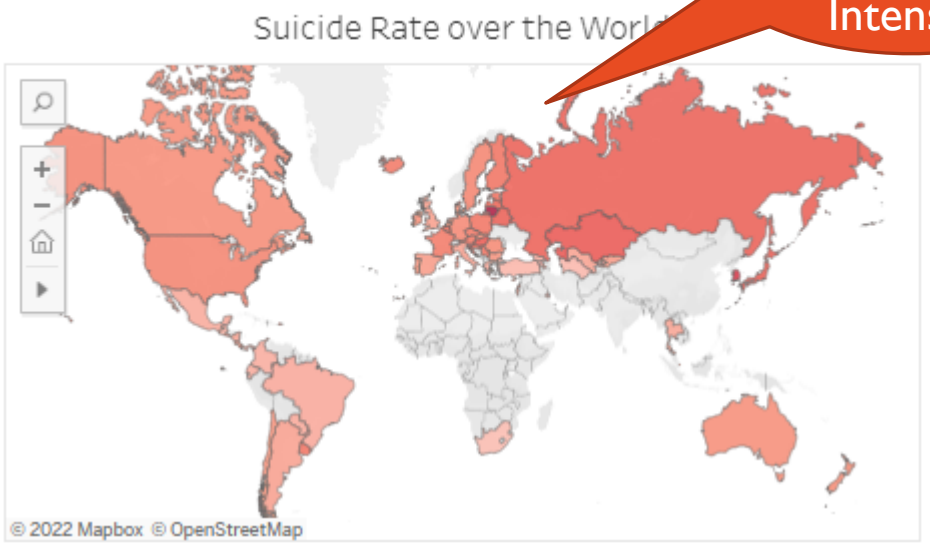
DESIGN PRINCIPLES

- G5.11 "To make symbols in a set maximally distinctive, use redundant coding wherever possible; for example, make symbols differ in both shape and color"
- When the visual query implies a conjunction query (searching for two attributes at the same time) G5.13 "consider coding one using motion or special grouping and the other using a property such as color or shape"

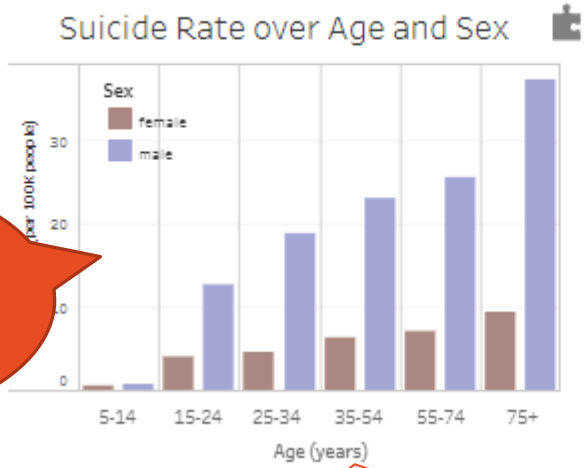
Color (Hue + Intensity) + length(Form) (redundant)

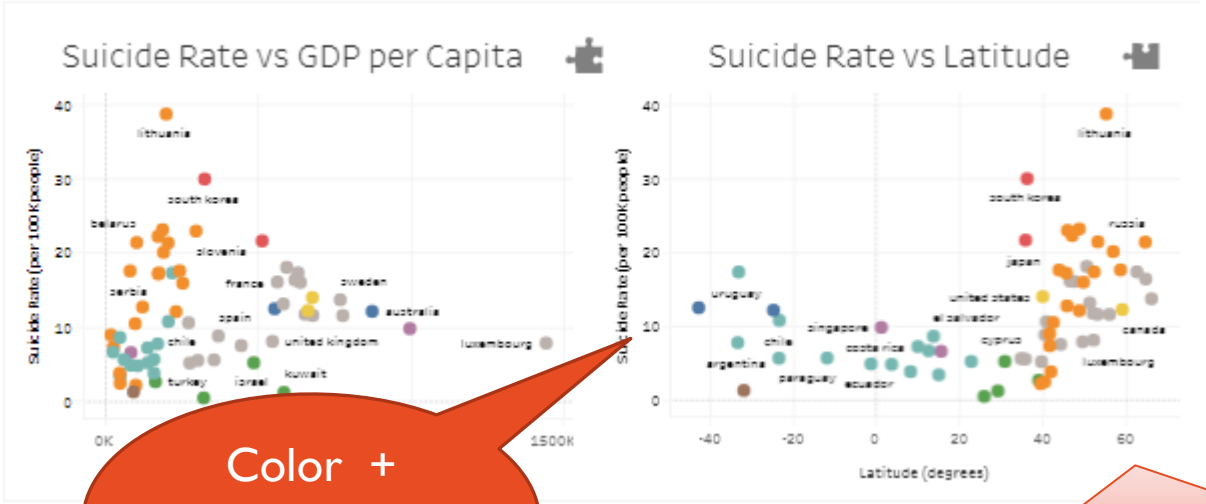


Color (Saturation + Luminosity) = Intensity



Color + length (Form) (separable)





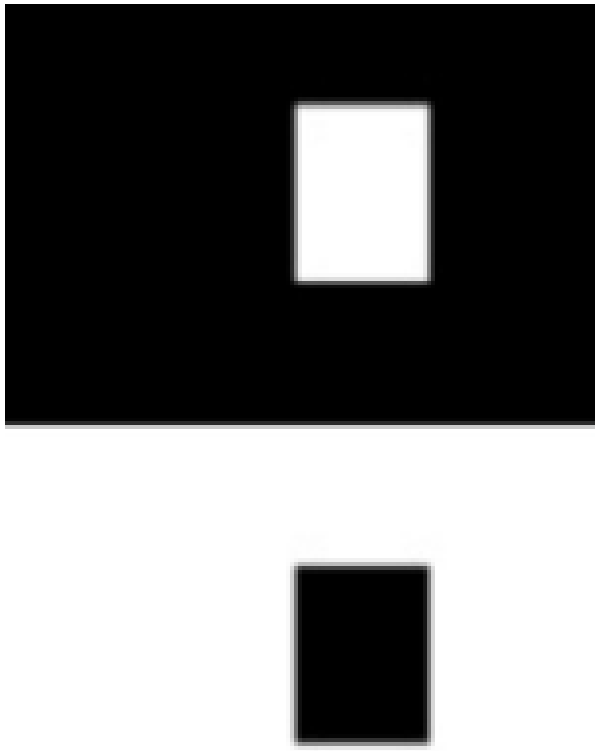
Color + Position (separable)

What do women…? What age …?

How is Central and Eastern Europe GDP and suicide rate?

GESTALT LAWS: SIMPLEST FORMS

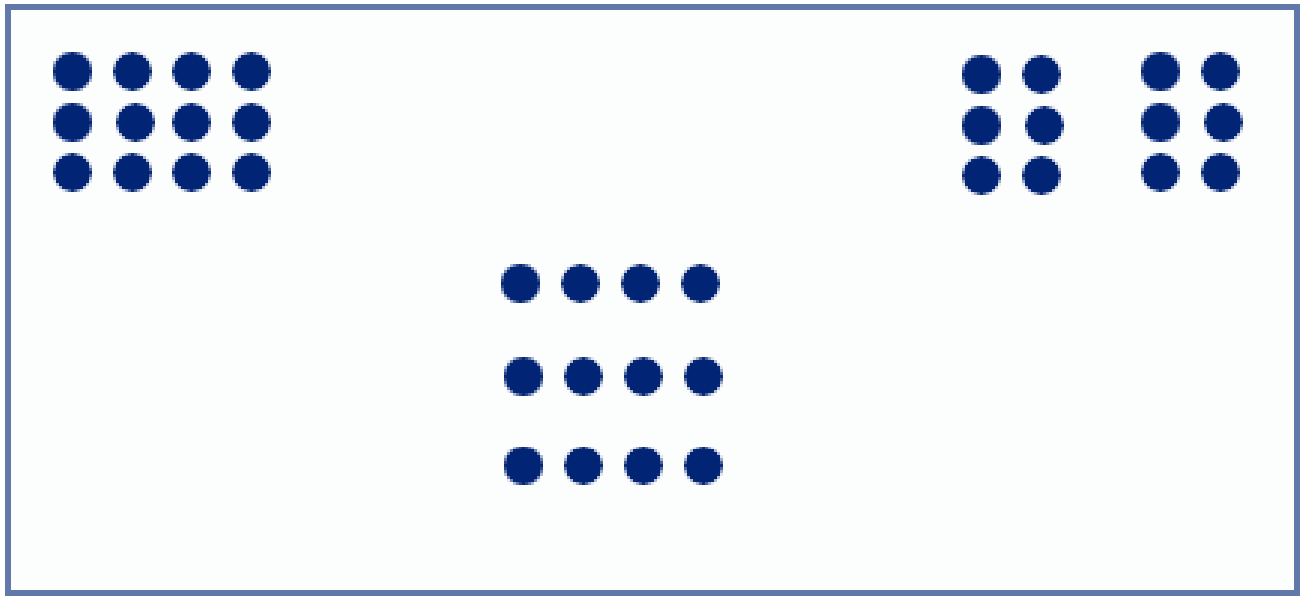
FIGURE AND GROUND



DESIGN PRINCIPLE

- G5.3 "To make symbols easy to find, make them distinct from their background and from other symbols".

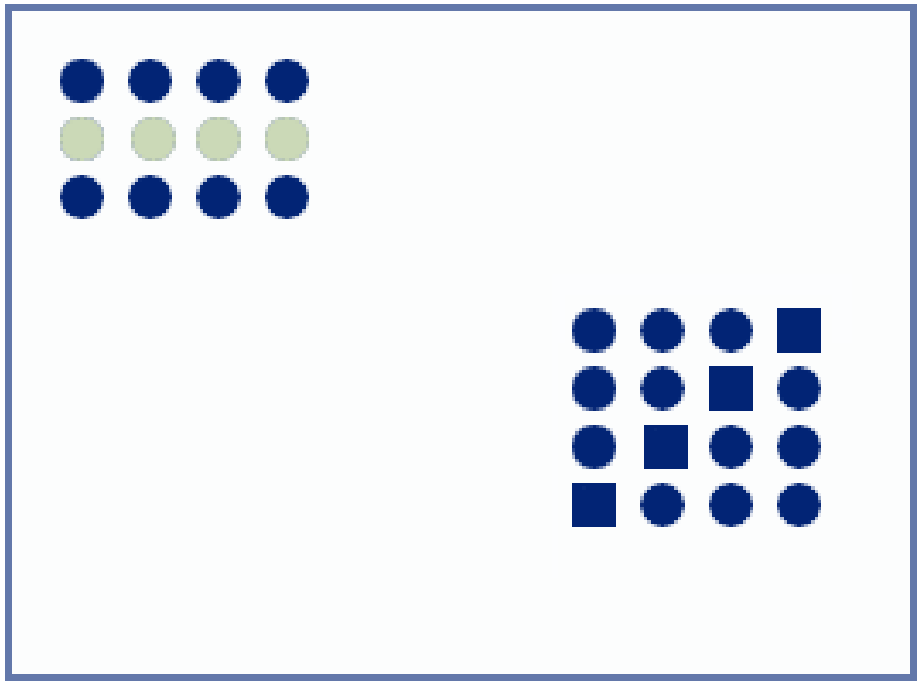
PROXIMITY

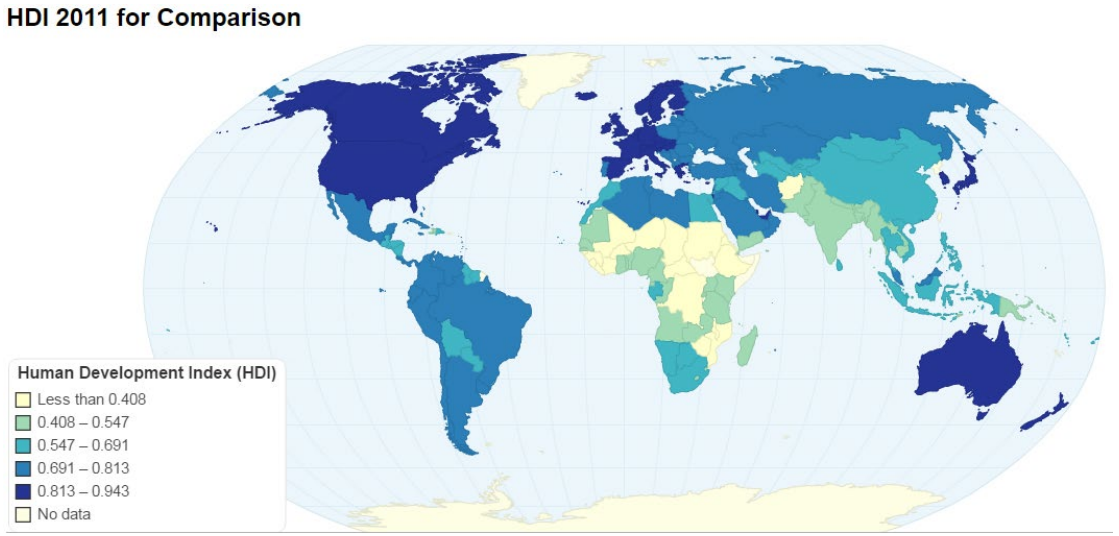


DESIGN PRINCIPLE

- G6. 1 “Place symbols and glyphs representing related information close together”

SIMILARITY

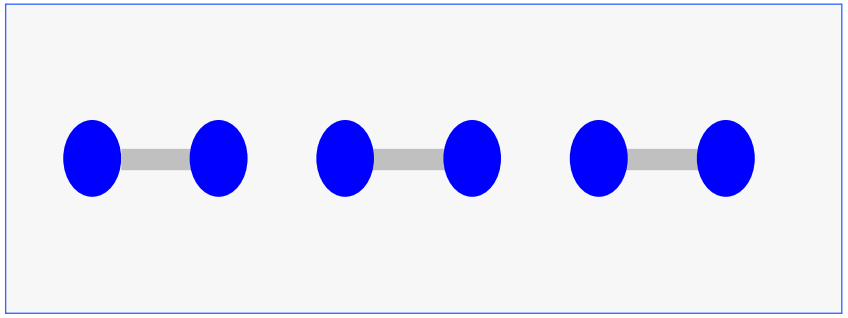


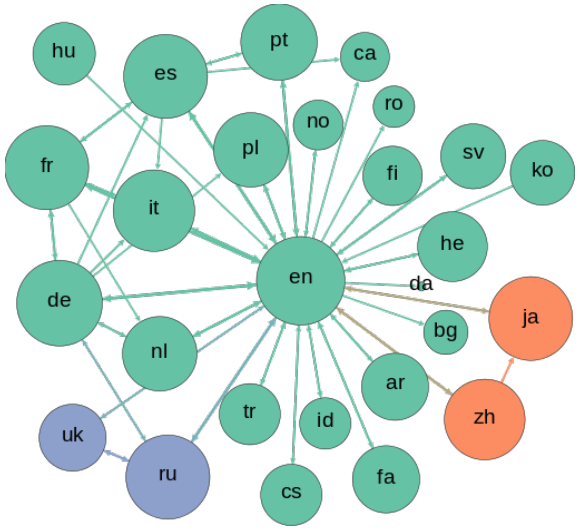

HDI 2011 for Comparison
Human Development Index (HDI)
Less than 0.408
0.408 – 0.547
0.547 – 0.691
0.691 – 0.813
0.813 – 0.943
No data

DESIGN PRINCIPLE

- G6.2 "When designing a grid layout of a data set, consider coding rows and/or columns using low-level visual channel properties, such as colour and texture"

CONNECTEDNESS





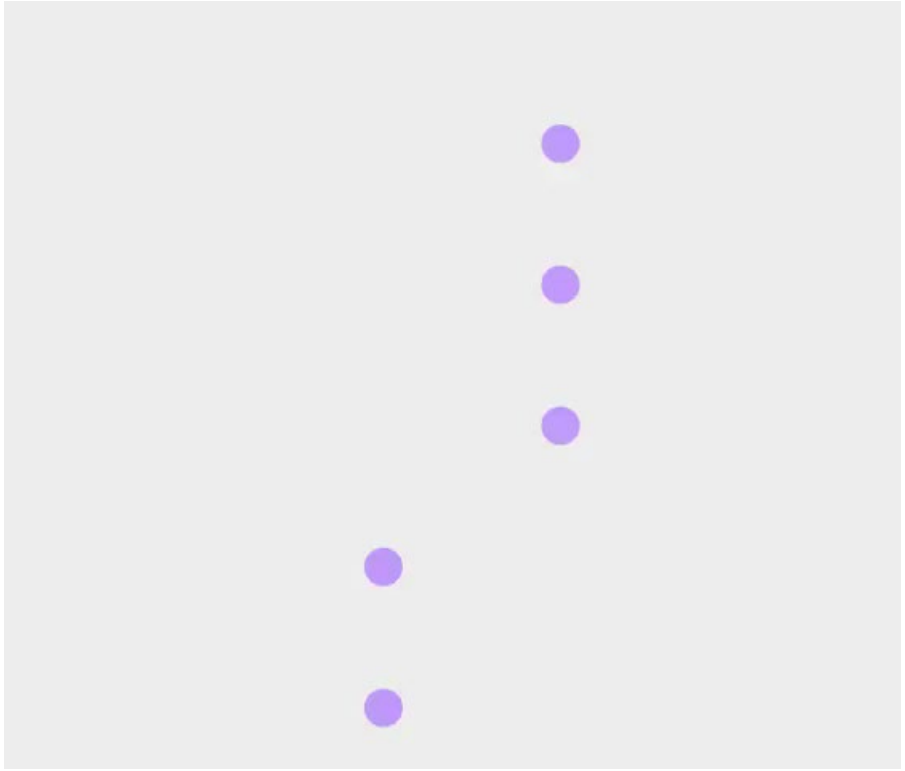
Source: Computermacgyver (Own work)
[CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

DESIGN PRINCIPLE

- G6.3 "To show relationships between entities, consider linking graphical representations of data objects using lines or ribbons of colour"

CONTINUITY: HOW WILL YOU SEPARATE THESE LINES?

COMMON FATE (SYNCHRONY)



Source: https://emeeks.github.io/gestaltdataviz/section3.html

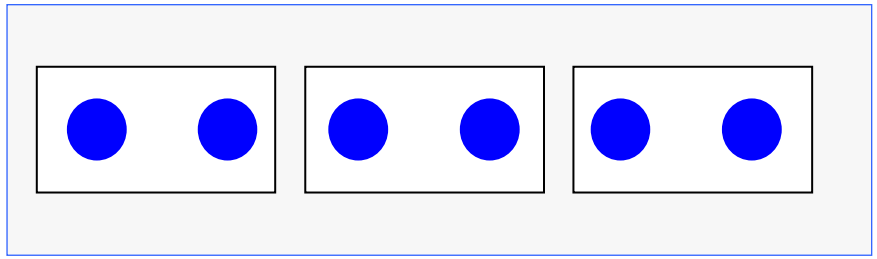
SYMMETRY

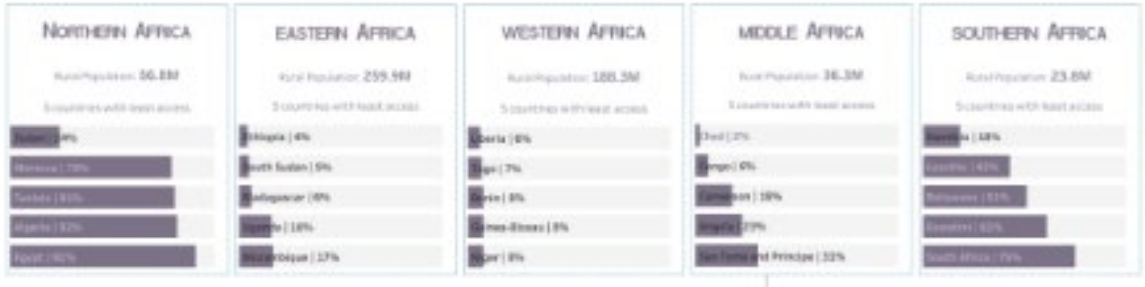
{ }[ ]( )

DESIGN PRINCIPLE

- G6.4 Consider using symmetry to make pattern comparisons easier but be sure that the patterns to be compared are small in terms of visual angle (<1 degree horizontally and <2 degrees vertically).
  Symmetrical relations should be arranged on horizontal or vertical axes unless some framing pattern is used.

CLOSURE AND COMMON REGION



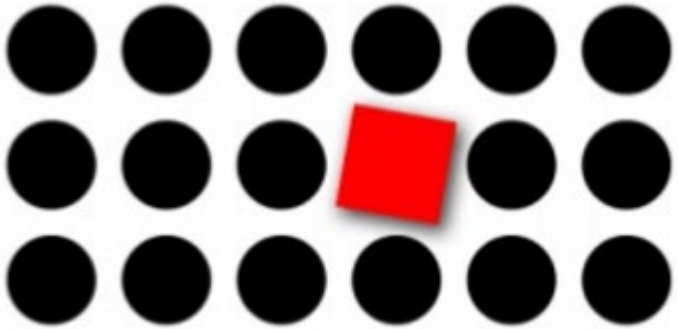


Example vis

DESIGN PRINCIPLE

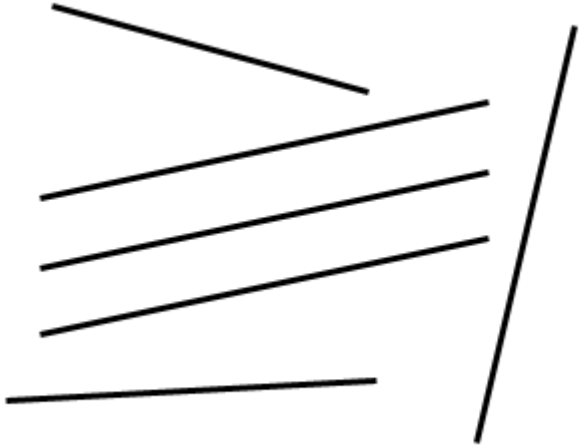
- G6.5 "Consider putting related information inside a closed contour. A line is adequate for regions having a simple shape. Colour or texture can be used to define regions that have more complex shapes".
- G6.6 "To define multiple overlapping regions, consider using a combination of line contour, colour, texture, and sweet contours"

FOCAL POINT



Source: https://www.slideshare.net/Lobelia10/gestalt-principles-of-form-perception

PARALLELISM



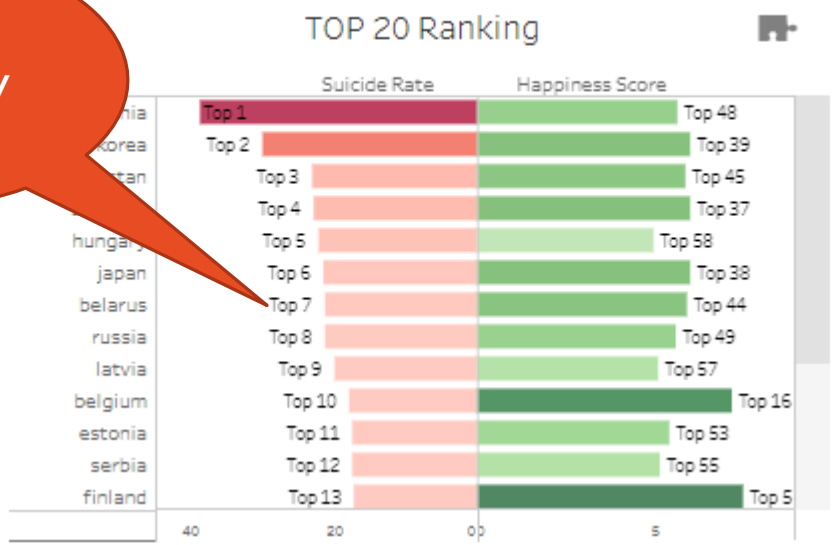
Symmetry

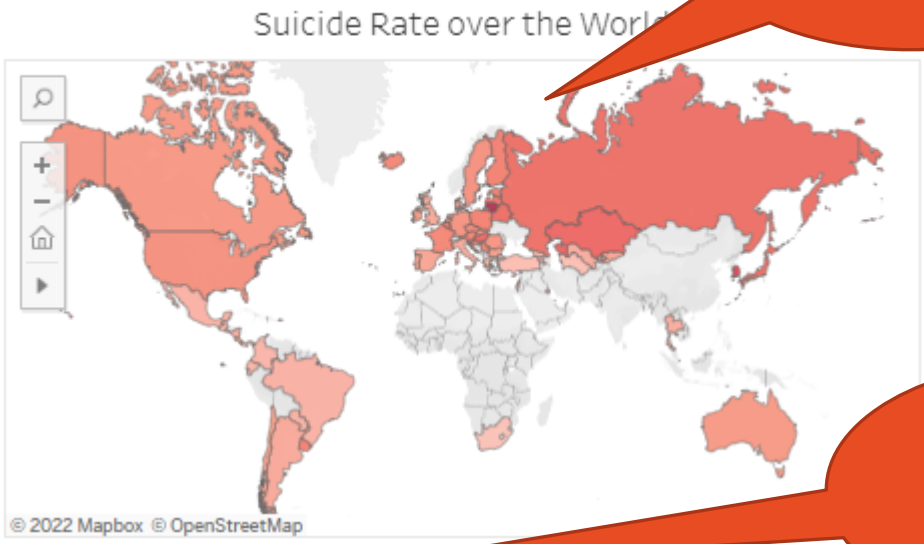
Similarity

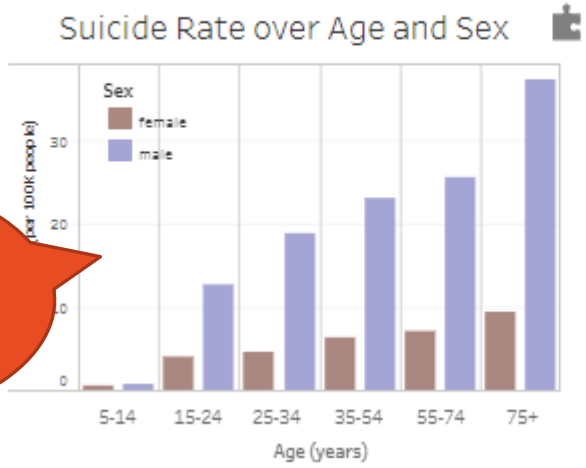
Closure

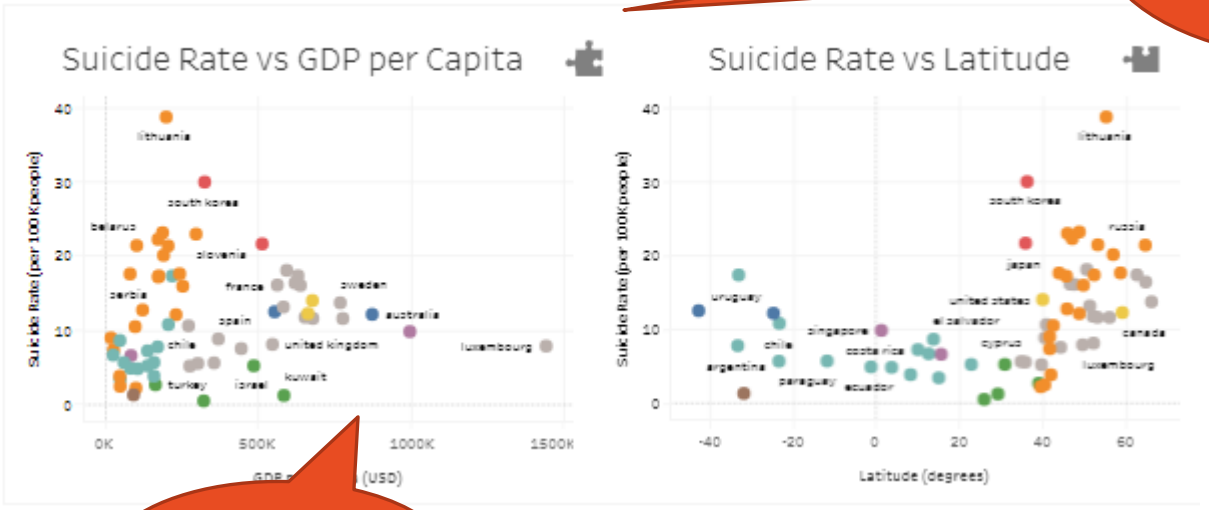
Similarity

Proximity









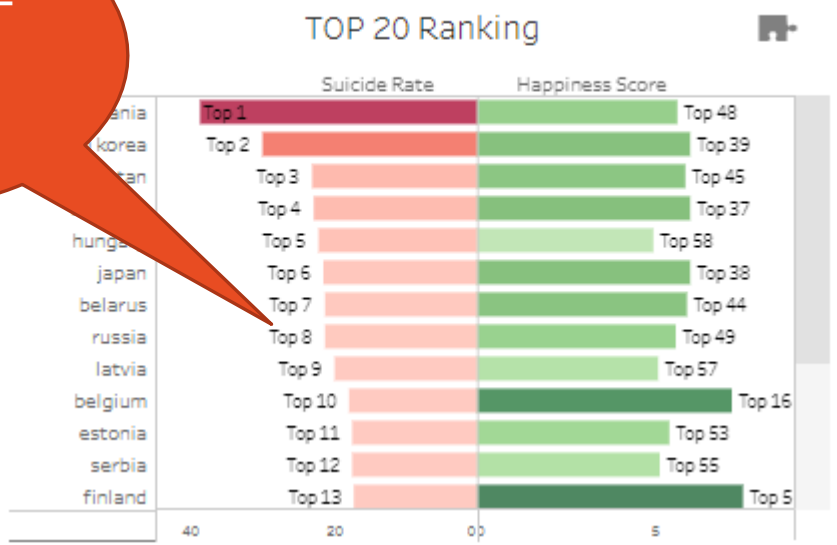
DESIGN PRINCIPLE

- *Combining preattentive processing properties and Gestalt laws we can derive best practices to represent quantity, intensity or to provide visual salience*

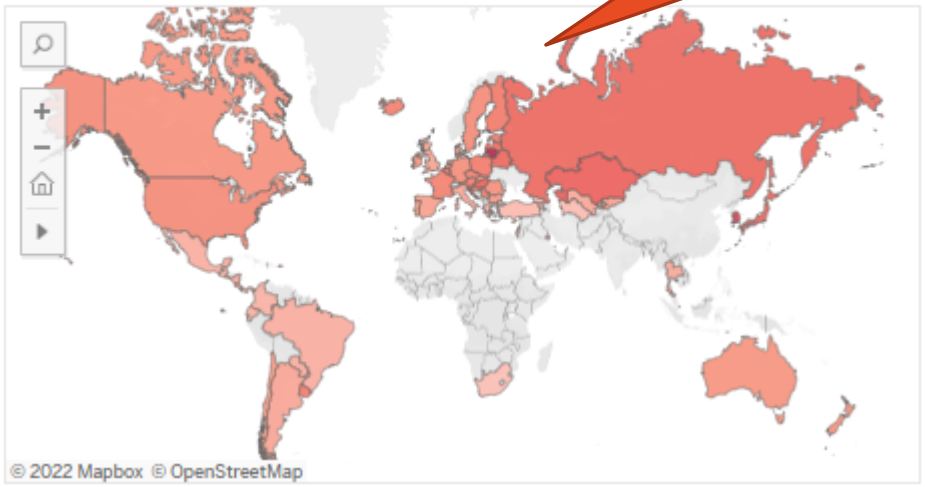
COMBINING PREATTENTIVE PROPERTIES + GESTALT TO REPRESENT QUANTITY

- size:
  - *length or height,*
  - *area* (radius),
  - never *volume*
- lightness, darker = bigger
- hue saturation, saturated = bigger
- vertical position, higher = bigger

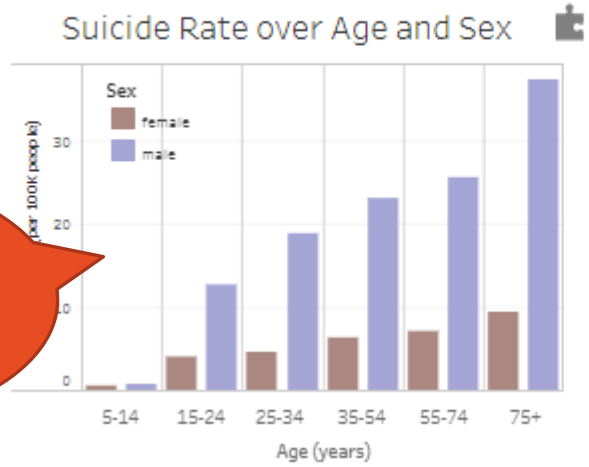
More saturated = bigger Larger = bigger

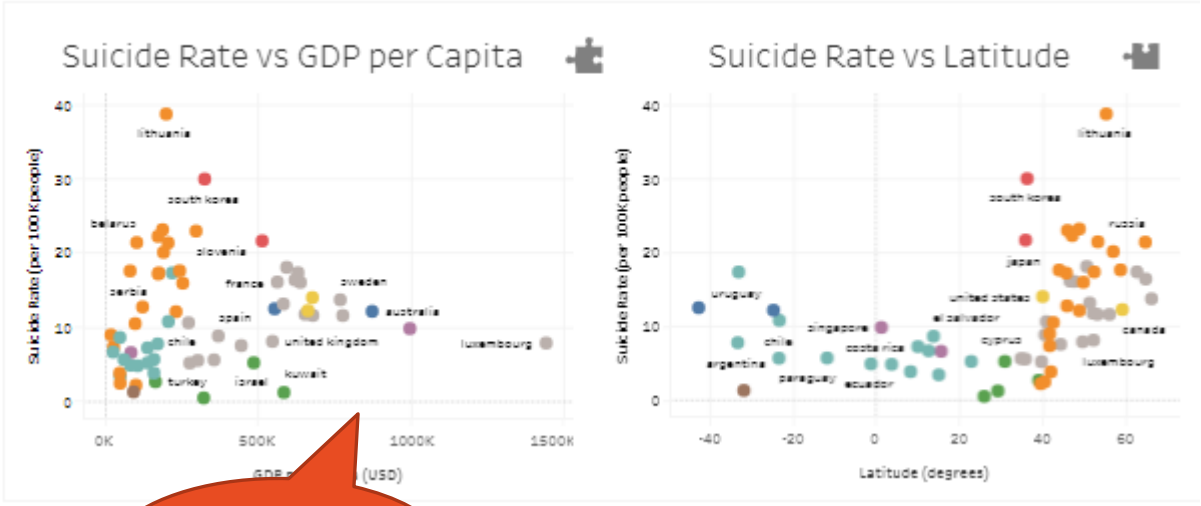


More saturated = bigger



Larger = bigger





Higher = bigger

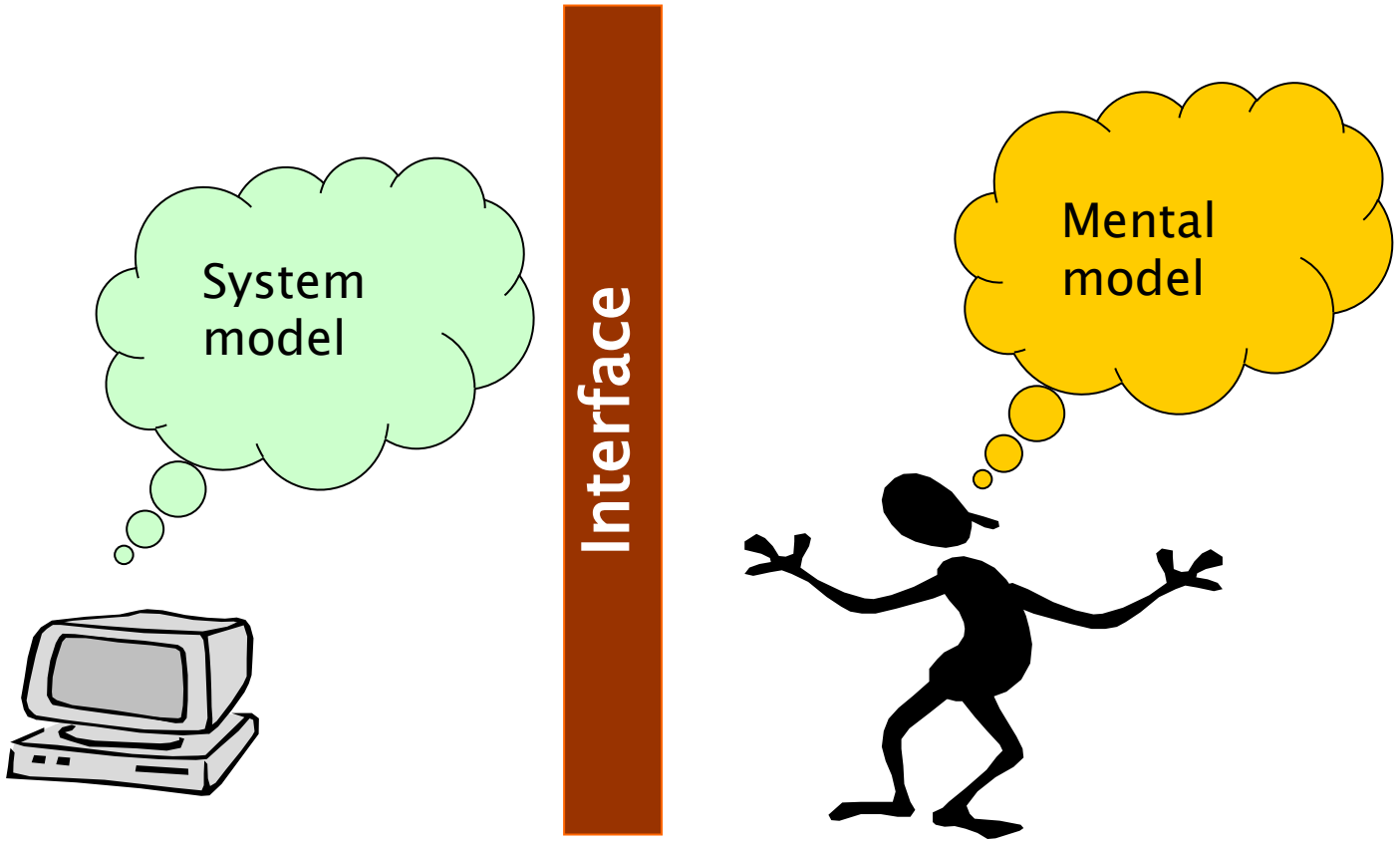
COMBINING PREATTENTIVE PROPERTIES + GESTALT TO REPRESENT INTENSITY

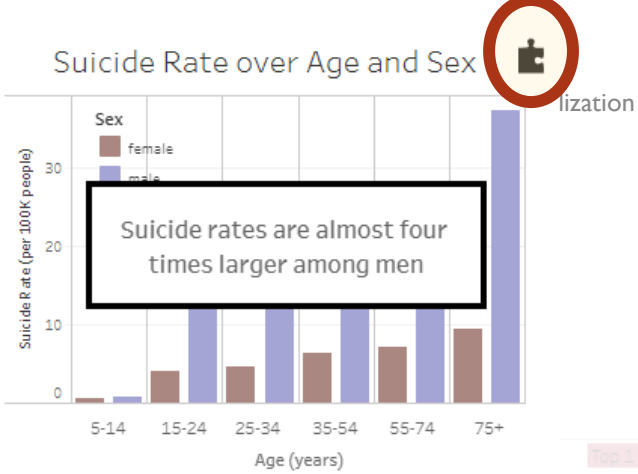
- Darker or more saturated,
- Bigger,
- Thicker

COMBINING PREATTENTIVE PROPERTIES + GESTALT TO REPRESENT VISUAL SALIENCE

- Distinct from the norm: in hue, orientation,
- Enclosure: by line or background colour,
- Added marks

MENTAL MODELS





Suicide Insights

Close Help

TOP 20 Ranking

Suicide Rate

Happiness Score

Top 1
Top 2
Top 3
Top 4
Top 48
Top 39
Top 45
Top 37
south korea
kazakhstan
slovenia
hungary
japan
belarus
finland
Top 53
Top 55
Top 13

Happier countries do not have the lowest suicide

Belgium

Slide to the leftmost part to see the average of all years

Click to order countries by their suicide ranking

Click to order countries by their happiness ranking

Select a country

Suicide Rate (per 100K people)
21.11
38.66
Happiness Score
(Cantril ladder 0-10)
7.501

Exploration

Year
2013

Country
(Todo)
argentina
armenia
australia
austria
bahrain

© 2022 Mapbox © OpenStreetMap

Suicide Rate over Age and Sex

Suicide Rate vs GDP per Capita

Suicide Rate vs Latitude

Click on a puzzle piece for data insight

Select a region

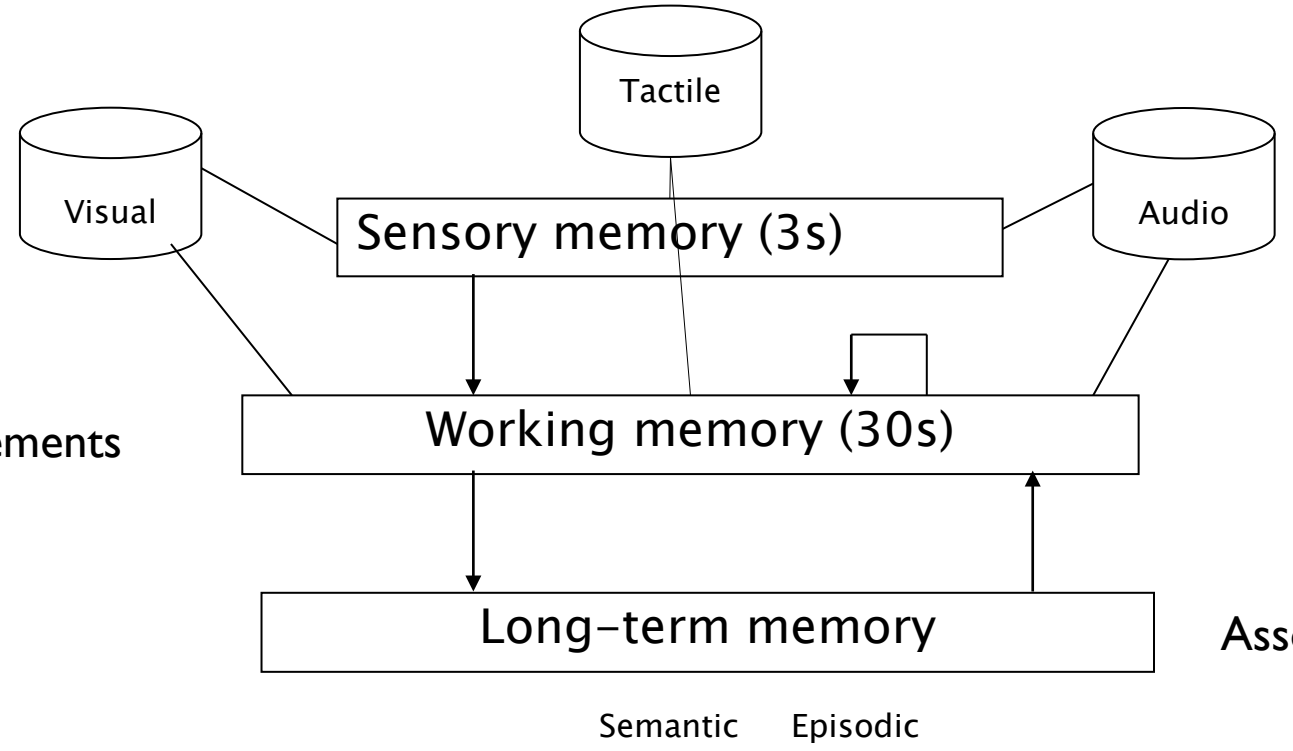
Region
Australia and New Zealand
Central and Eastern Europe
Eastern Asia
Latin America and Caribbean
Middle East and Northern Africa
North America
Southeastern Asia
Sub-Saharan Africa
Western Europe

GDP per Capita (USD)

Latitude (degrees)

COGNITIVE PROCESSING

MEMORY



9 elements

7 active elements

Sounds
2 or 3 words

Associated to emotions

Source: Cañas

TRY TO REMEMBER

724103582910643512 90

724 103 582 910 643 512 90

AUTOMATIC TELLER MACHINE (ATM)

- What do you have to take first: money or card?

WHY?

DESIGN PRINCIPLES

- Design based on recognition, not recall
- 7 ± 2
- Long tasks in small steps
- Avoid interferences within a channel, enrich with different channels

ATTENTION

- Focused attention
  - All our attention in one event
- Divided attention
  - Our attention shifts between two or more events
  - Be careful with balance and interferences

DESIGN PRINCIPLES

- Important information should receive focused attention, it shall appear in preeminent locations and have visual salience
- Secondary information may be on secondary locations or hidden, only visible on demand

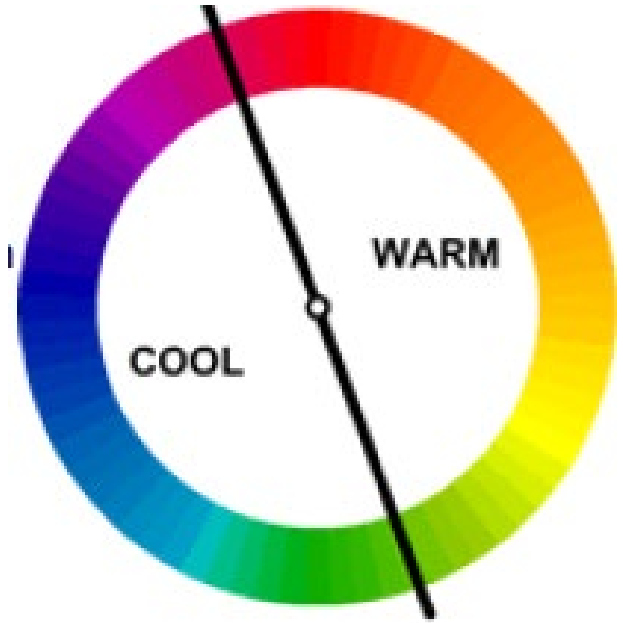
SELECTIVE ATTENTION

Source: https://www.nngroup.com/articles/banner-blindness-old-and-new-findings/

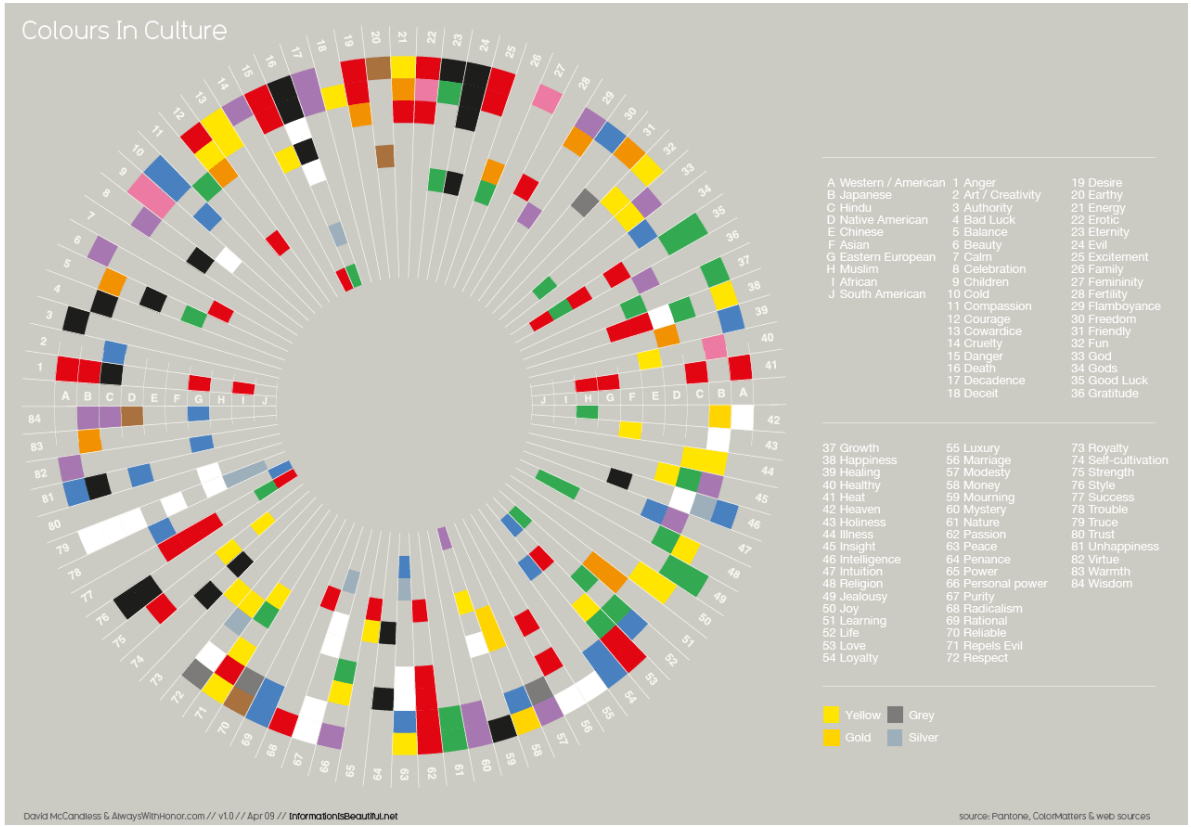
COLOUR

COLOURS AFFECT OUR MOODS

- Colours affect us in numerous ways, both mentally and physically
- We can divide colours into warm and cool
  - Warm colours are energetic, and tend to advance in space.
  - Cool colours give calm, and tend to work better as background.

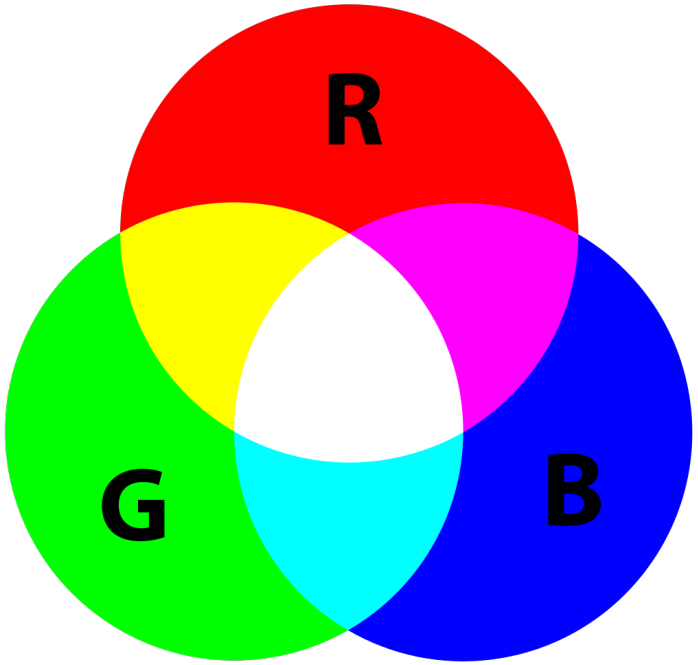


COLOUR MEANING IS A CULTURAL ISSUE

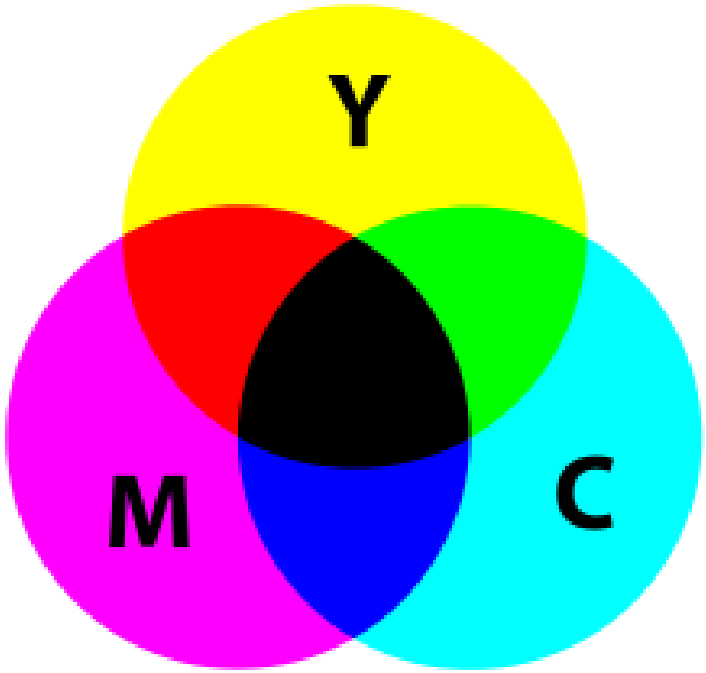


SPECIFICATION OF A COLOUR: SCREENS AND PRINTING

ADDITIVE MODEL



SUBTRACTIVE MODEL

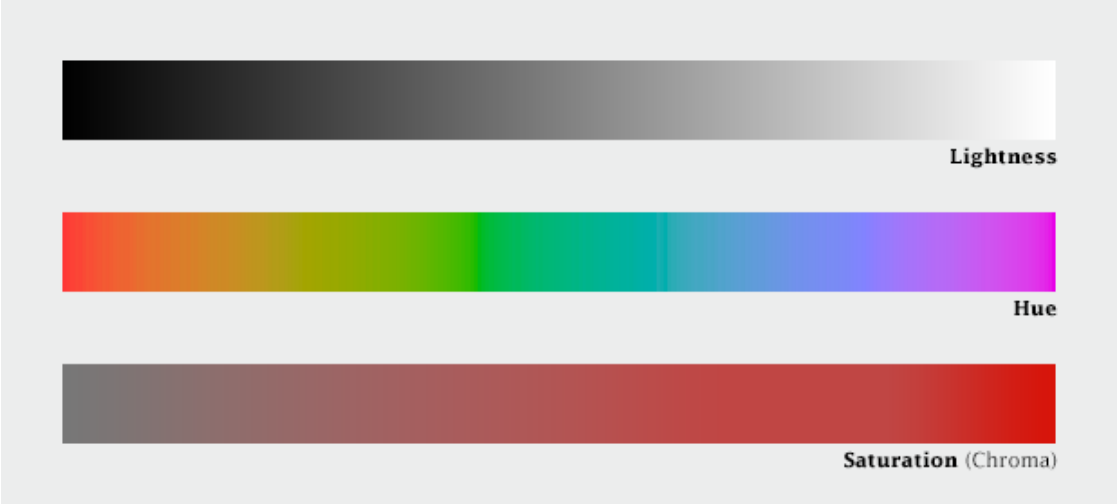


SPECIFICATION OF A COLOUR: PERCEPTUAL DIMENSIONS

HSL: Hue Saturation Lightness

- Luminance / Lightness / Value : (it is relative) how much light appears to reflect an object in relation to the White on the scene
- Hue : what we associate to colour names
- Saturation (Chroma): Purity of the colour (vividness)

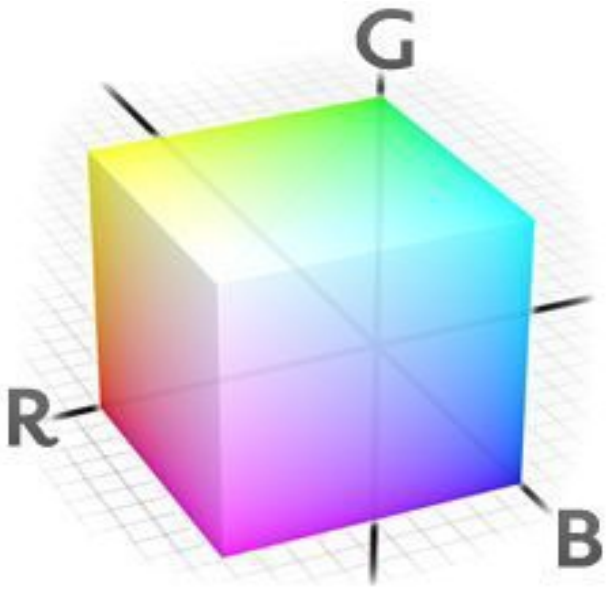
HSV or HSB (Value / Brightness)



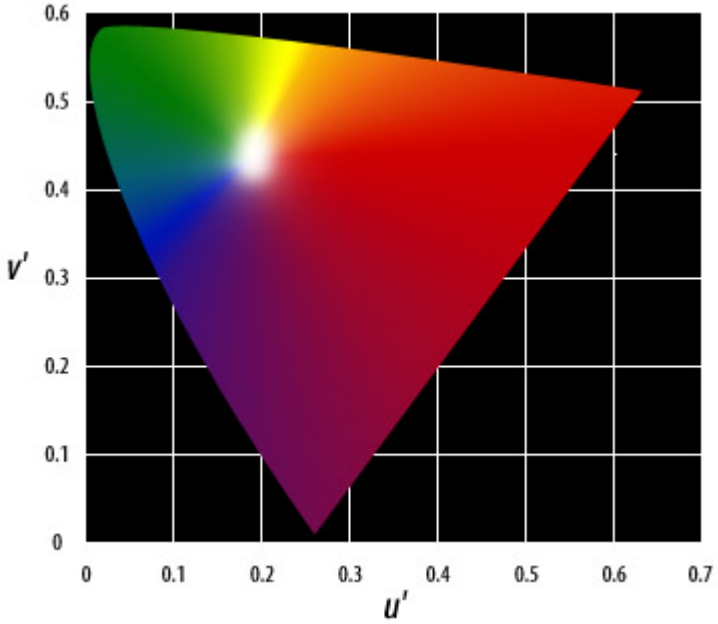
http://hslpicker.com/

http://colorizer.org/

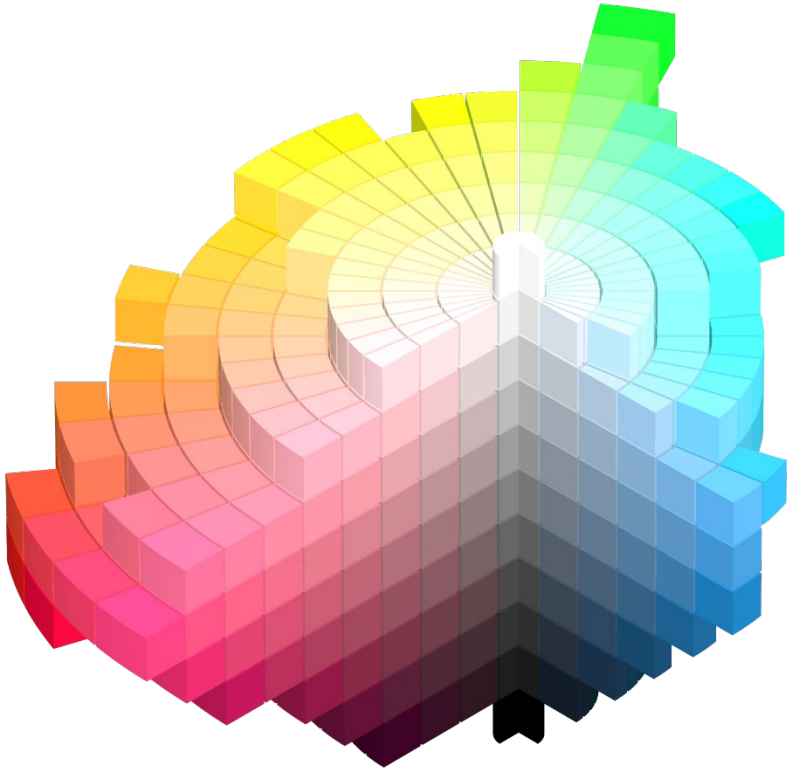
COLOUR SPACES AND PERCEPTUAL UNIFORMITY



RGB

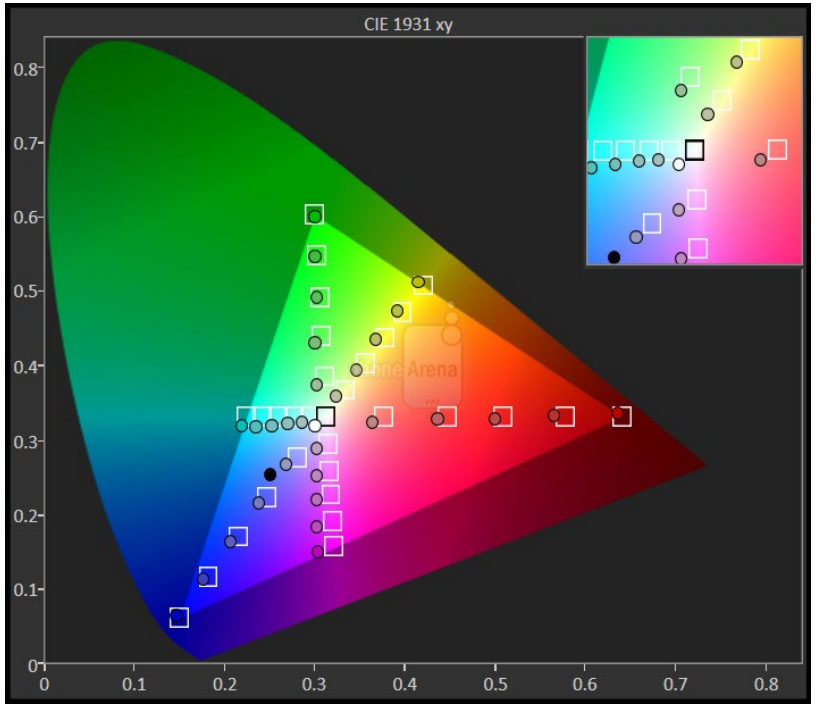


CIE LUV 1975



MUNSELL COLOUR SPACE

COLOUR GAMUT



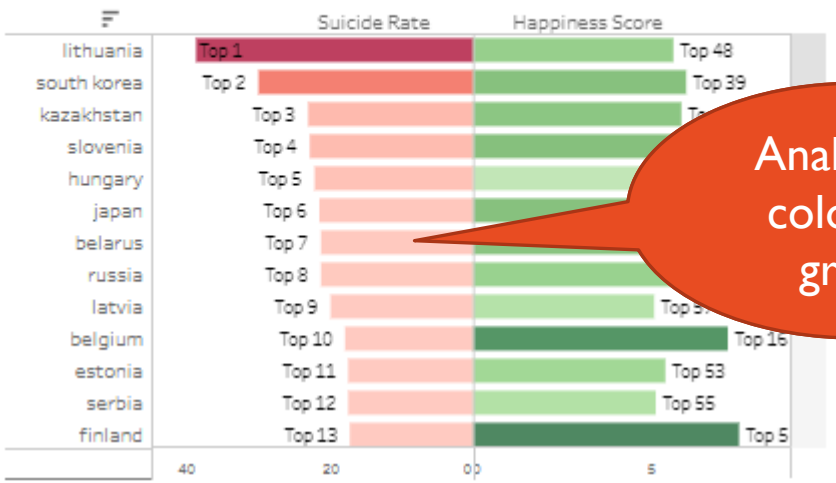
http://www.phonearena.com/phones/benchmarks

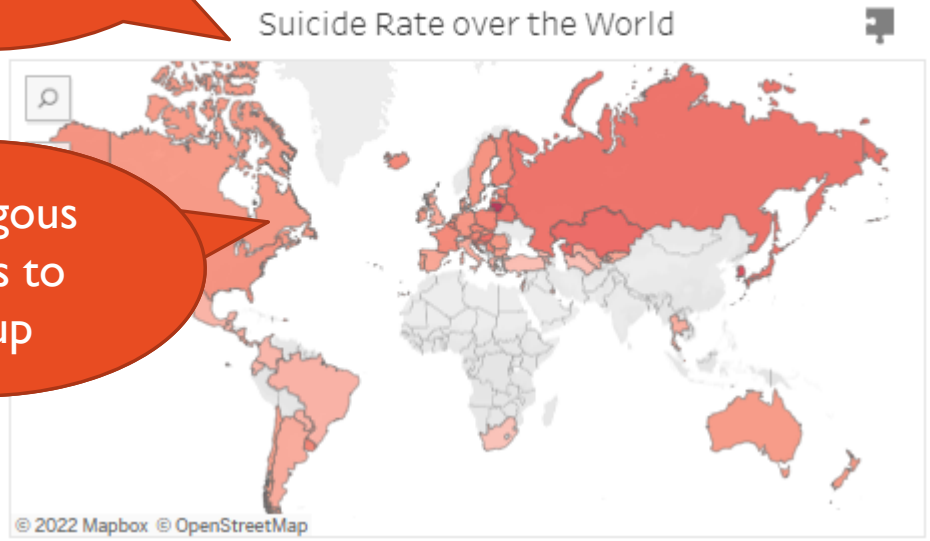
COLOURS FOR CHARTS

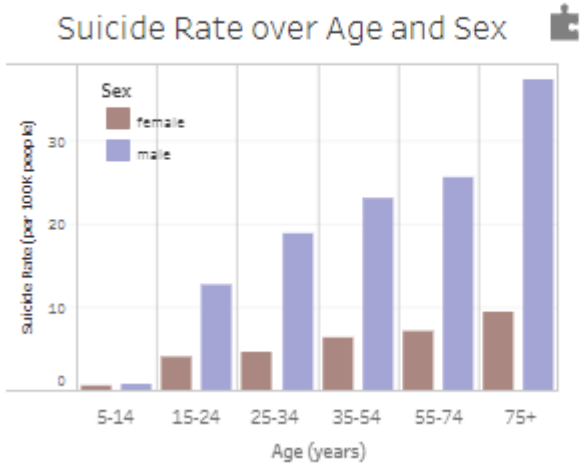
- Assign colour according to function:
  - Use contrast to highlight
  - Analogous colours to group
  - Use greys for context and axis when labelling with colour

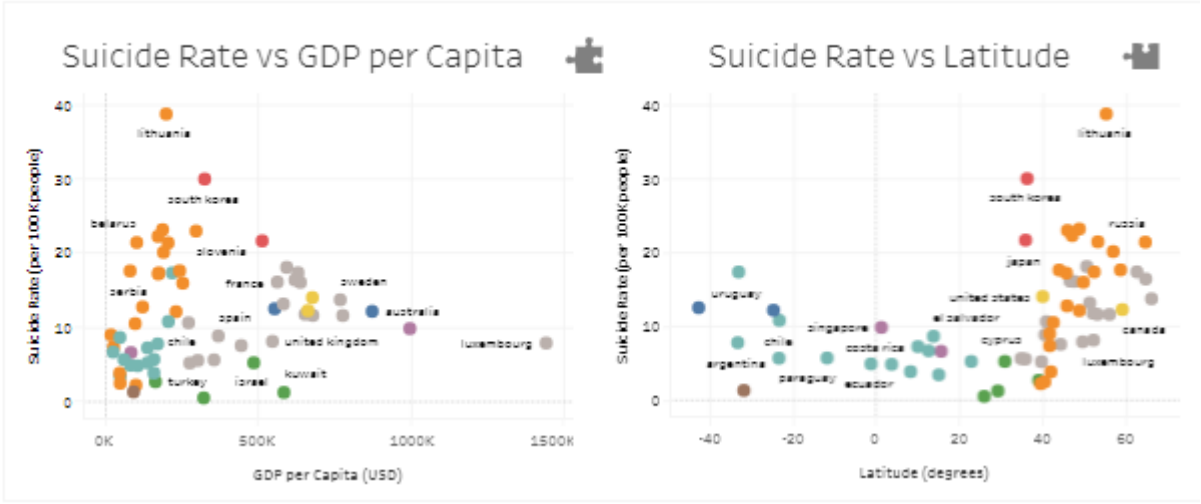
Greys for context

Analogous colors to group









COLOUR PRINCIPLES

- G4.7 If using colour saturation to encode numerical quantity, use greater saturation to represent greater numerical quantities. Avoid using a saturation sequence to encode more than three values.

COLOUR PRINCIPLES

- G4.16 Use low-saturation colours to colour code large areas. Generally, light colours will be best because there is more room in colour space in the high-lightness region than in the low-lightness region.

COLOUR PRINCIPLES

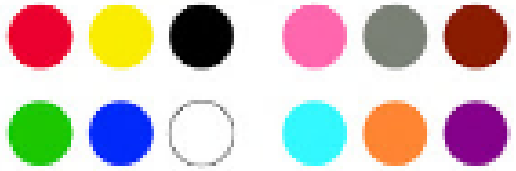
- G4.17 When colour coding large background areas overlaid with small coloured symbols, consider using all low-saturation, high-value (pastel) colours for the background, together with high-saturation symbols on the foreground.

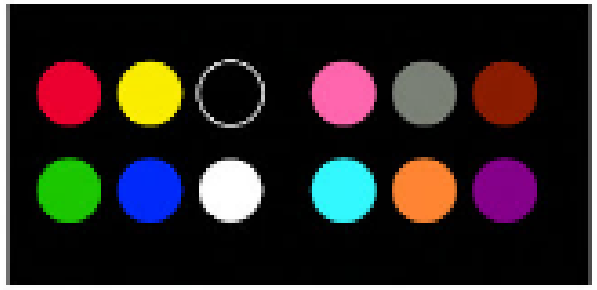
COLOUR PRINCIPLES

- G4.18 When highlighting text by changing the colour of the font, it is important to maintain luminance contrast with the background.

COLOURS FOR LABELLING. QUALITATIVE

- Small set: based on opponent theory, red, green, yellow, blue
- 12 cross-cultural safe colours: Red, Green, Yellow, Blue, Black, White, Pink, Cyan, Grey, Orange, Brown, Purple

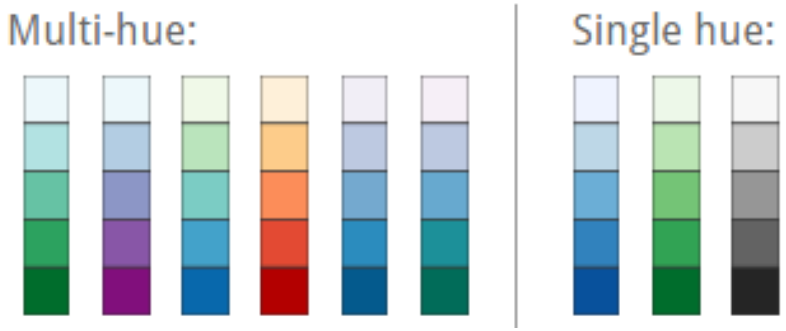




Different hues have no order

COLOURS FOR LABELLING. QUANTITATIVE SCALES

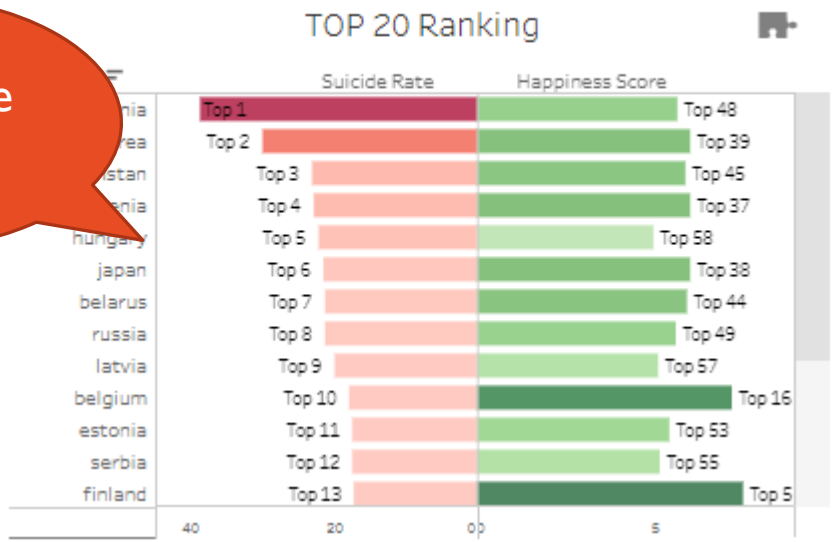
- Sequential: each step differs in saturation or in saturation and lightness



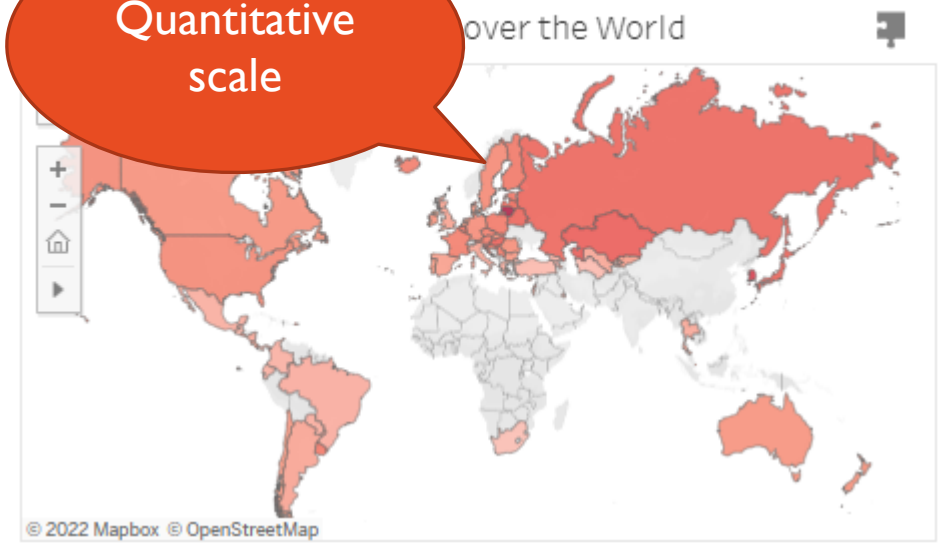
+ Saturation => Higher quantity

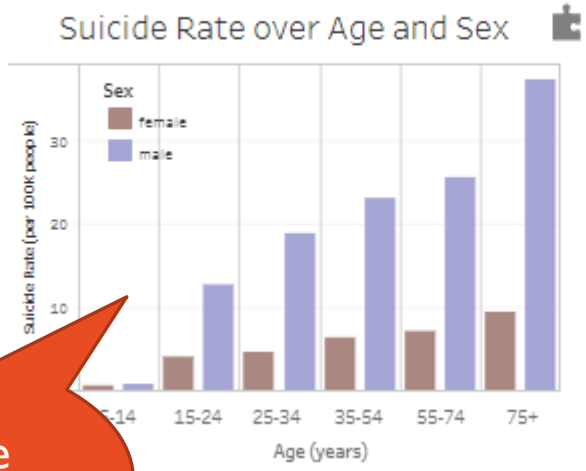
- Diverging: two hues, a neutral hue in the middle

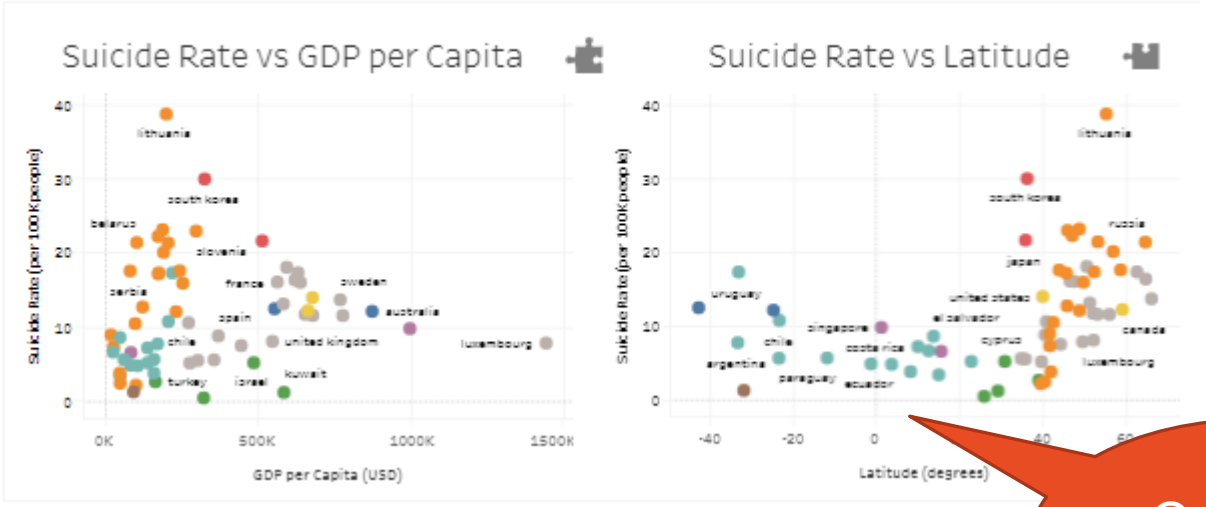
Quantitative scale



Quantitative scale



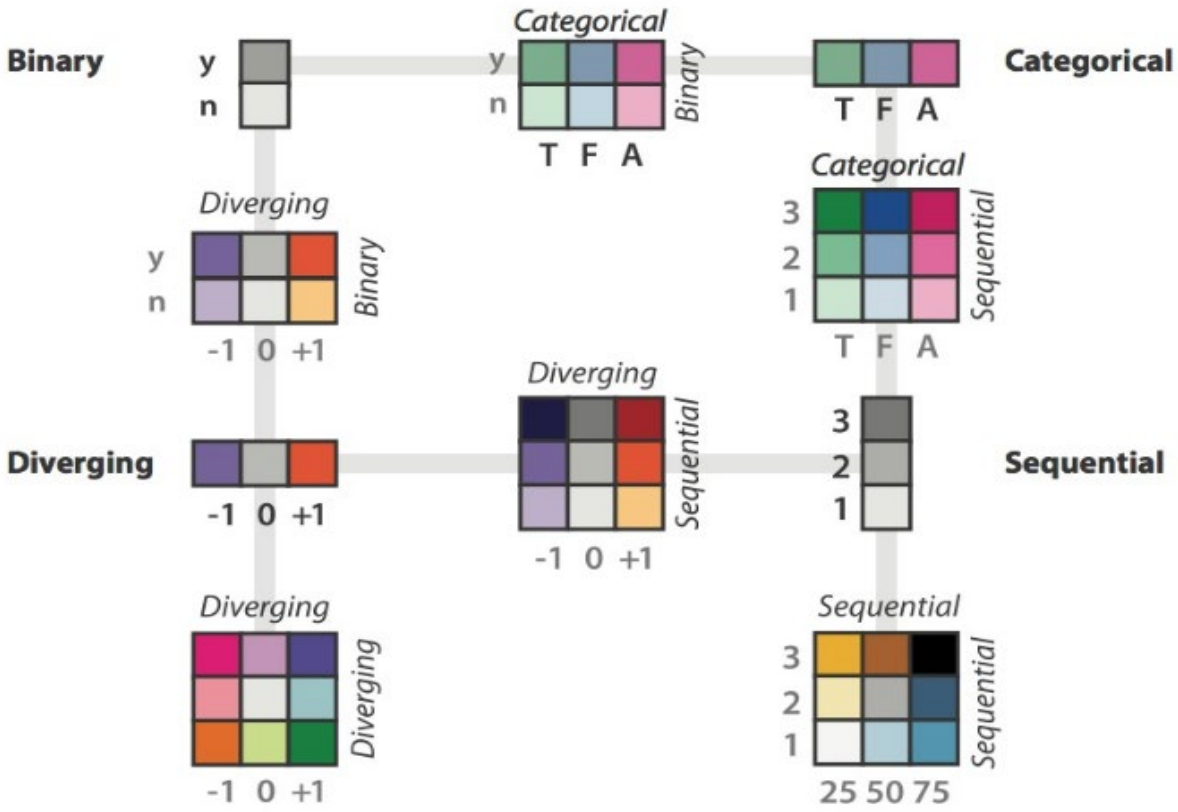




Qualitative scale

Qualitative scale

COLOUR MAPPING: ENCODING VALUES WITH COLOUR



After [Brewer 99]. Source Munzer

COLOURS FOR MAPS

- Big areas: low saturation; Small areas: highly saturated
- Ensure hue and luminance contrast with the background (use a border if needed)
- For colour-blindness assure yellow-blue distinction
- See Cynthia Brewer ColorBrewer tool

ACKNOWLEDGEMENTS

- The example Dashboard on the slides, is made by Muriel Rovira, Jael Freixanet, Emilio Tylson as last course (2021-2022) task.