Shaping our digital future

Institute for Informatics & Digital Innovation

Principles of Information Visualization Tutorial – Part 1 Design Principles

Prof Jessie Kennedy
Institute for Informatics & Digital Innovation

Edinburgh Napier UNIVERSITY

Overview

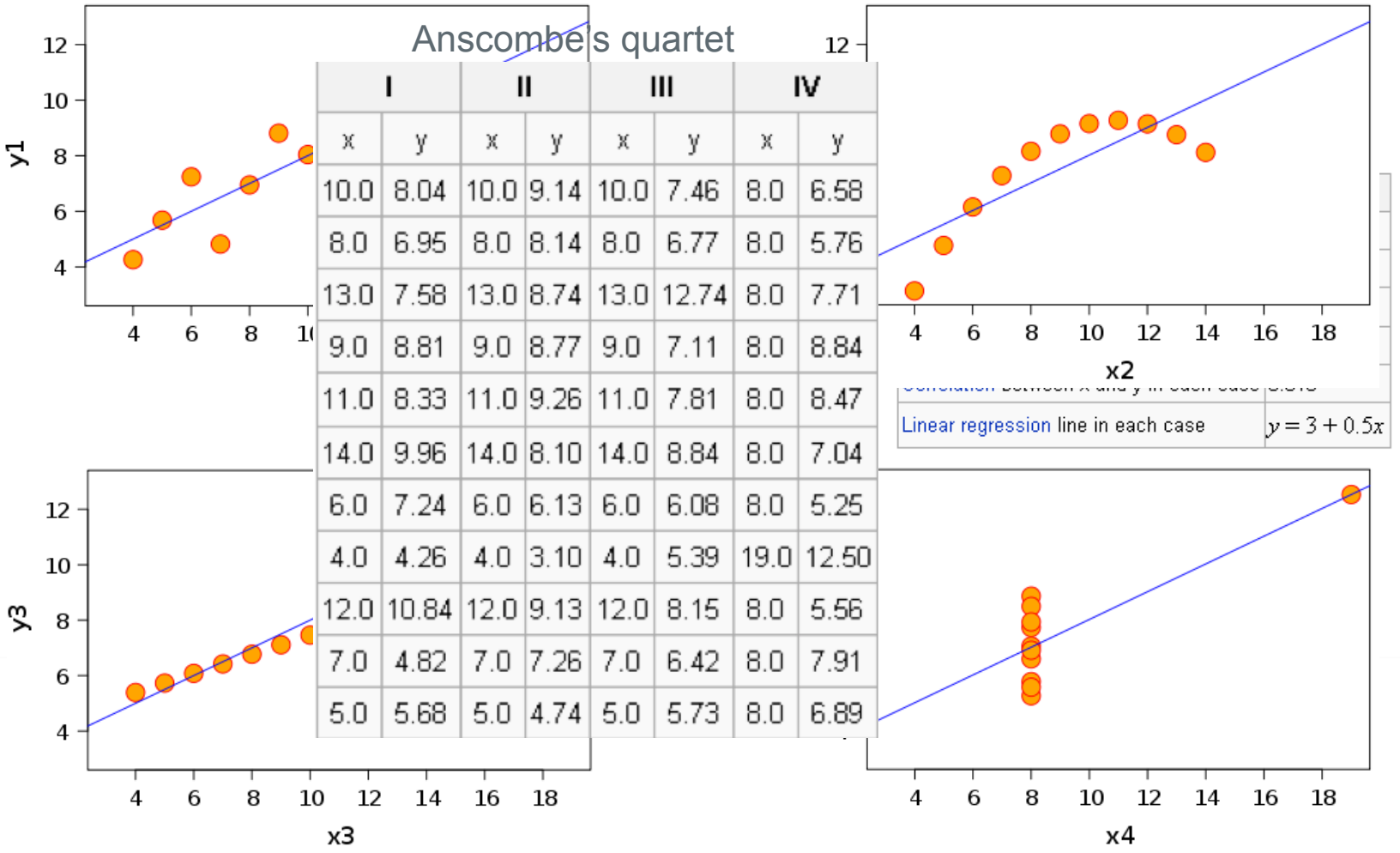
- Fundamental principles of graphic design and visual communication
  - help you create more effective information visualizations.

- Use of salience, colour, consistency and layout
  - communicate large data sets and complex ideas with greater immediacy and clarity.

Why Visualise? To see what's in the data

Anscombe's quartet

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89



Information Visualization

- 2 main objectives
- Data analysis
  - understand the data
  - derive information from them
  - involves comprehensivity
- Communication
  - of information
  - involves simplification

J Bertin, Semiology of Graphics, - Brief Presentation of Graphics, 2004

How do we get from Data to Visualization?

- Need to understand
  - the properties of the data or information
  - the properties of the image
  - the rules mapping data to images

How do we get from Data to Visualization?

- Need to understand
  - the properties of the data or information
  - the properties of the image
  - the rules mapping data to images

Types of Data

- Nominal (labels or types)
  - Sex: Male, Female,,
  - Genotype: AA, AT, AG…
- Ordinal
  - Days: Mon, Tue, Wed, Thu, Fri, Sat, Sun
  - Abundance: abundant - common – rare
- Quantitative
  - Physical measurements: temperature, expression level

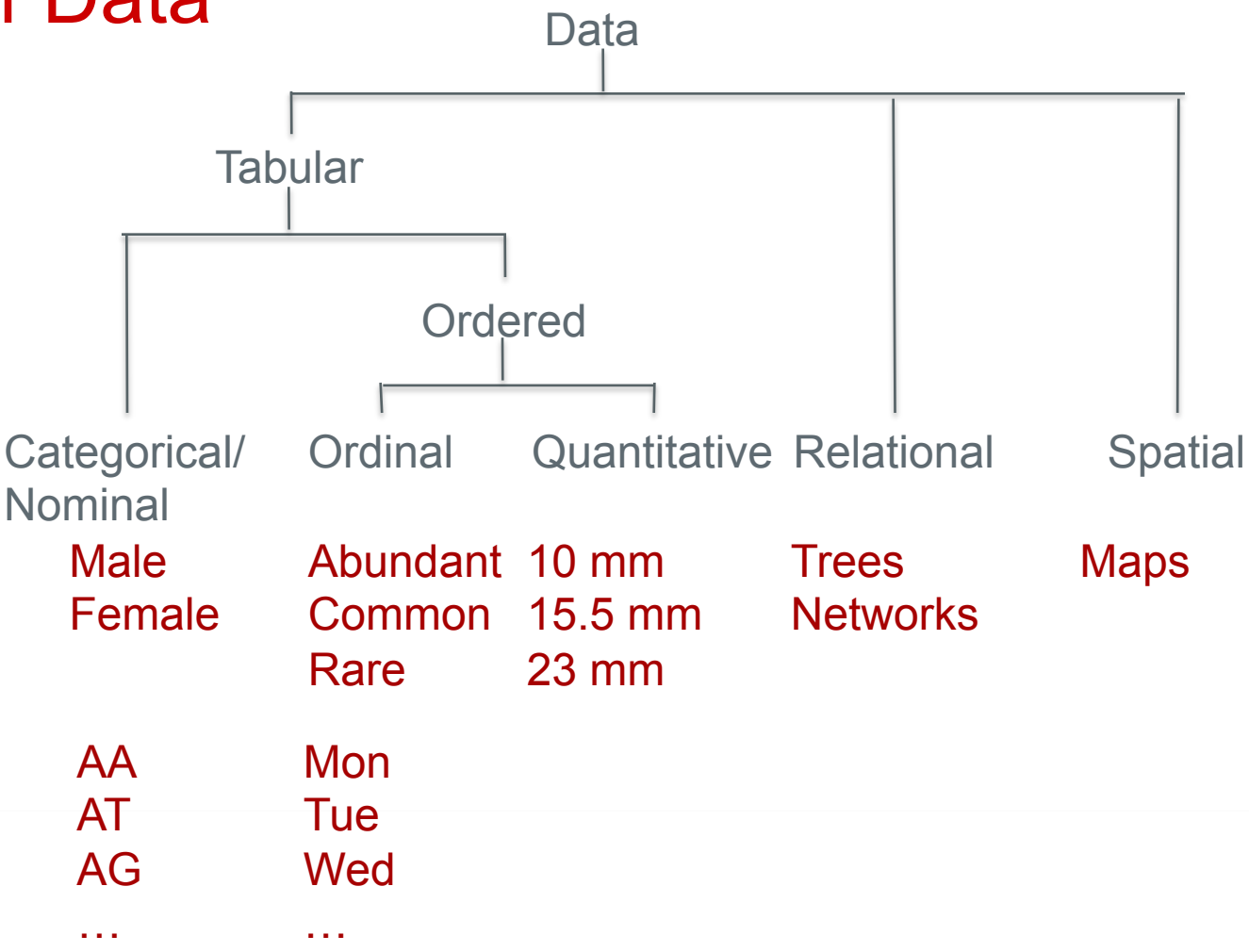
S. S. Stevens, On the theory of scales of measurements, 1946

Data Type Taxonomy

- 1D e.g. DNA sequences
- Temporal e.g. time series microarray expression
- 2D e.g. distribution maps
- 3D e.g. Anatomical structures
- nD e.g. Fisher's Iris data set
- Trees e.g Linnean taxonomies, phylogenies
- Networks e.g. Metabolic pathways
- Text and documents e.g. publications

B. Shneiderman, The eyes have it: A task by data type taxonomy for information visualization, 1996

Types of Data



slide adapted from Munzner 2011, Visualization Principles

How do we get from Data to Visualization?

- Need to understand
  - the properties of the data or information
  - the properties of the image
  - the rules mapping data to images

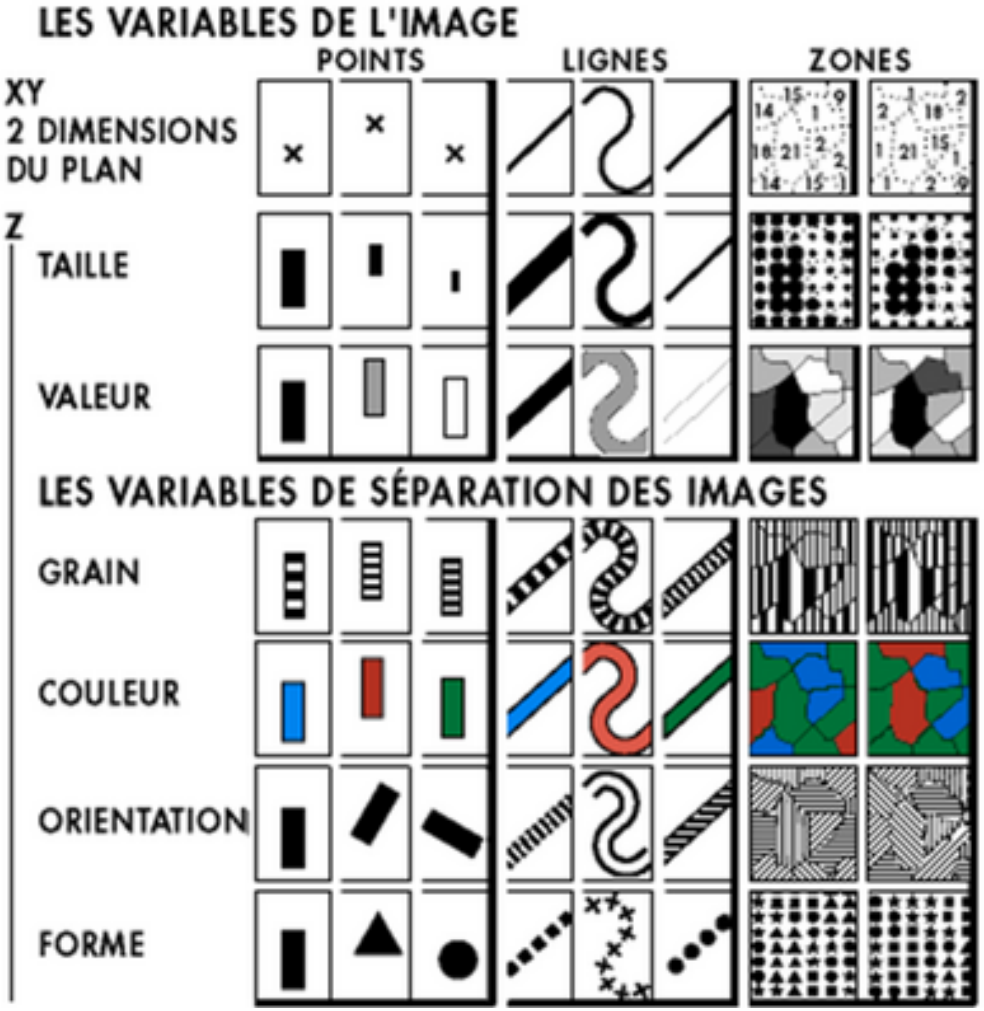
Theory of Graphics

- Application of human perception
  - understand and memorize forms in an image
  - XY dimensions of the plane and variation in Z dimension
- Correspondence between data and image
- Level of perception required by objective
- Mobility or immobility of the image

J Bertin, Semiology of Graphics, - Brief Presentation of Graphics, 2004

Semiology of Graphics

- visual encoding
  - points, lines, areas
    - patterns, trees/networks, grids
  - positional: XY
    - 1D, 2D, 3D
  - retinal: Z
    - size, lightness, texture,
    - colour, orientation, shape,
  - temporal:
    - animation

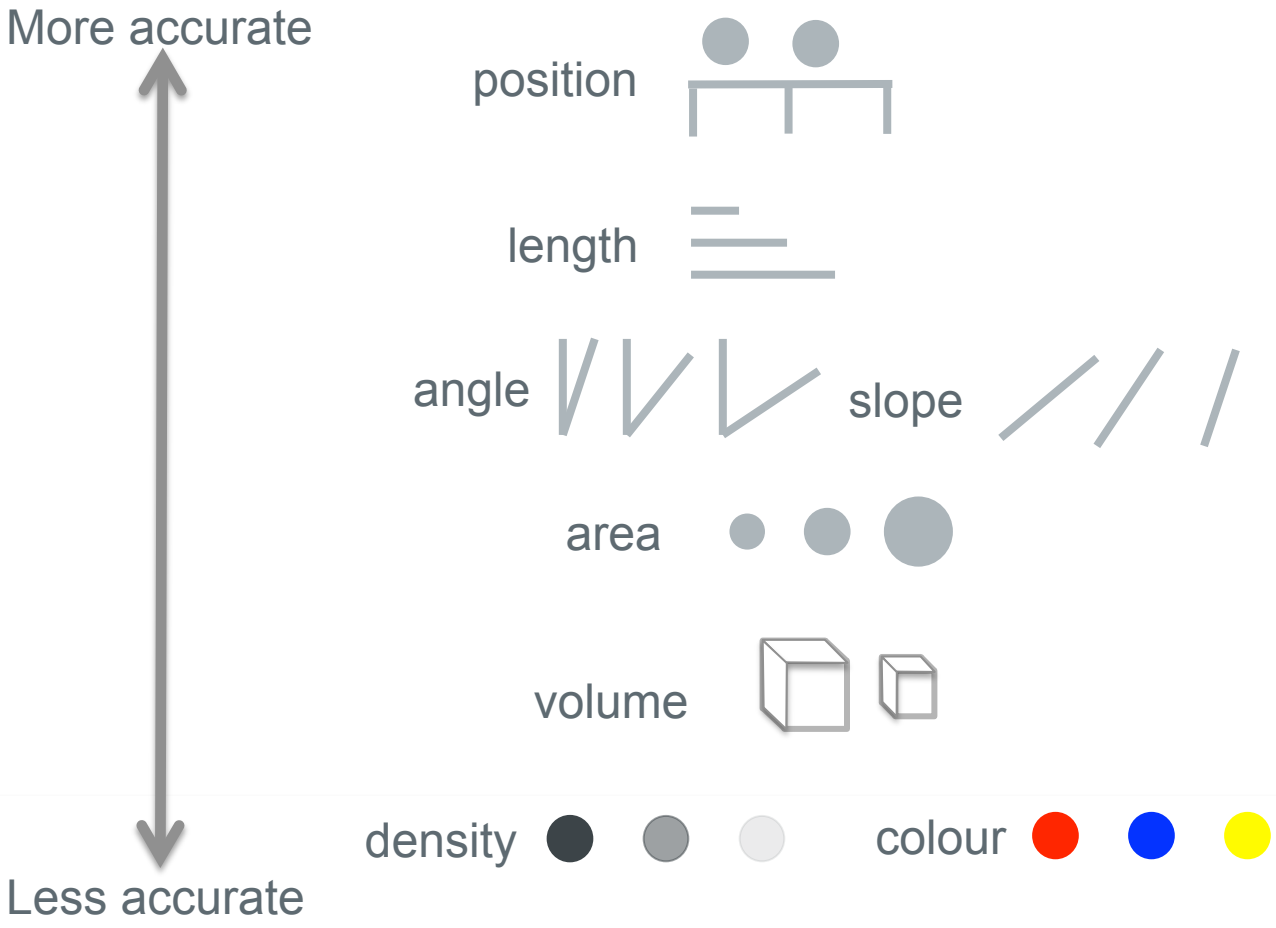


Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

Language of Graphics

- Graphics can be thought of as forming a sign system:
  - Each mark (point, line, or area) represents a data element.
  - Choose visual variables to encode relationships between data elements
    - difference, similarity, order, proportion
    - only position supports all relationships
- Huge range of alternatives for data with many attributes
  - find images that express and effectively convey the information.

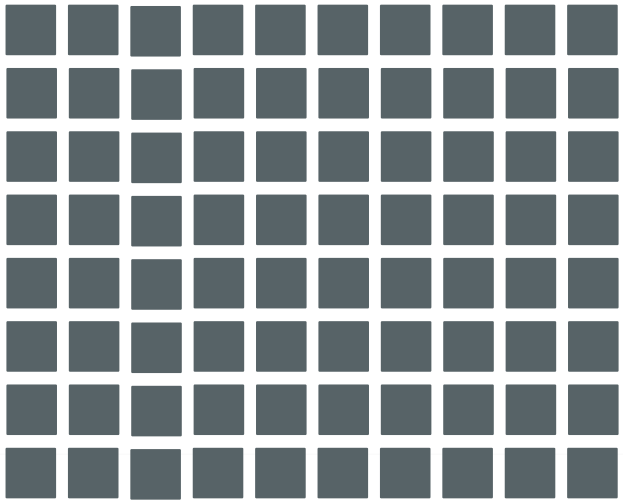
Accuracy of Quantitative Perceptual Tasks



Cleveland, W.S. & McGill, R. Science 229, 828–833 (1985).

Gestalt Effects

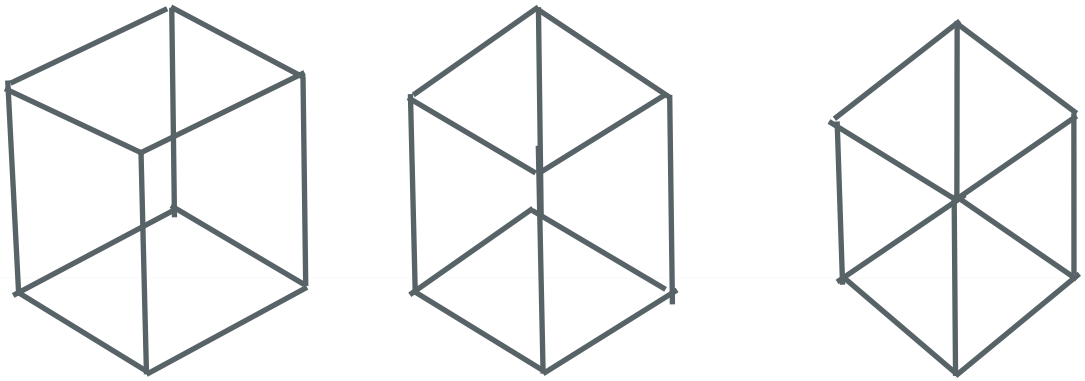
- Visual system tries to structure what we see into patterns
- Gestalt is the interplay between the parts and the whole
  - "The whole is 'other' than the sum of its parts." – Kurt Koffka



- Gestalt Laws/Principles

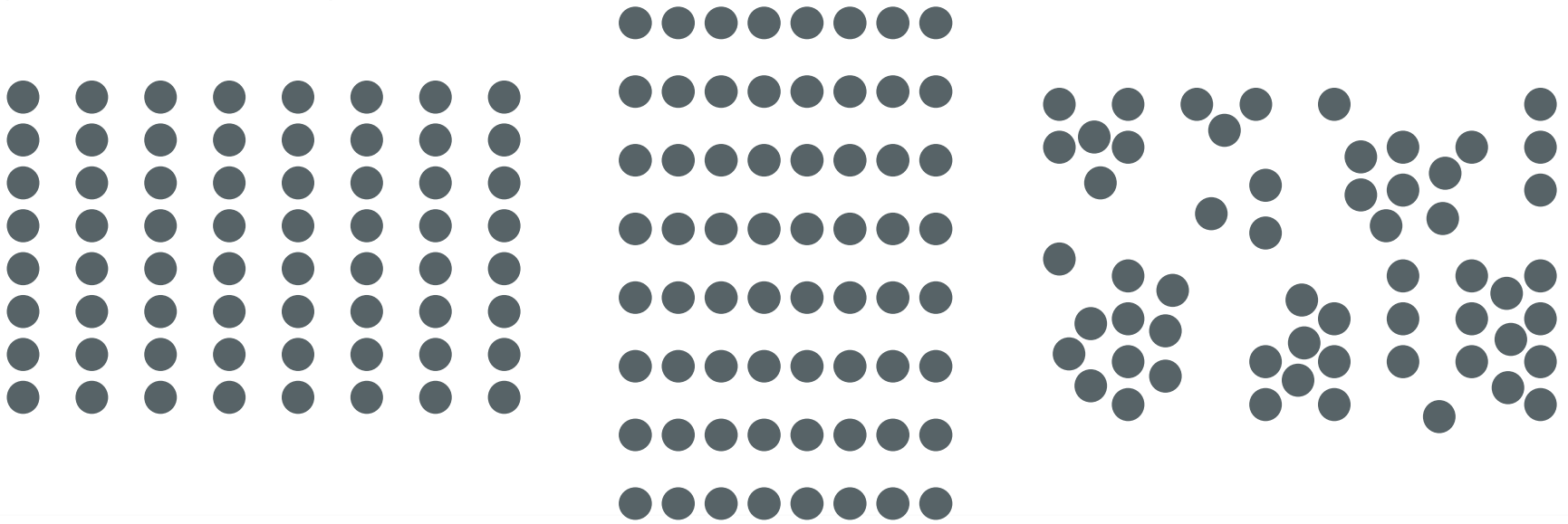
Principle of Simplicity

- Every pattern is seen such that the resulting structure is as simple as possible
  - Different projections of same cube
  - Perceived as 2 or 3 D
  - Depending on the simpler interpretation



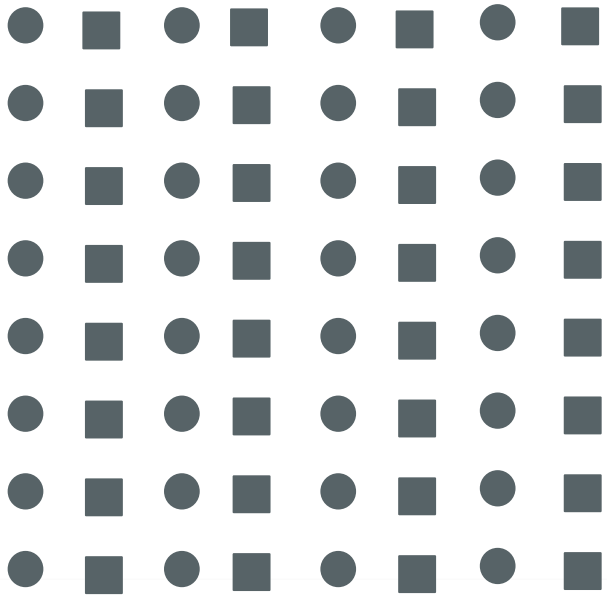
Principle of Proximity

- Things that are near to each other appear to be grouped together



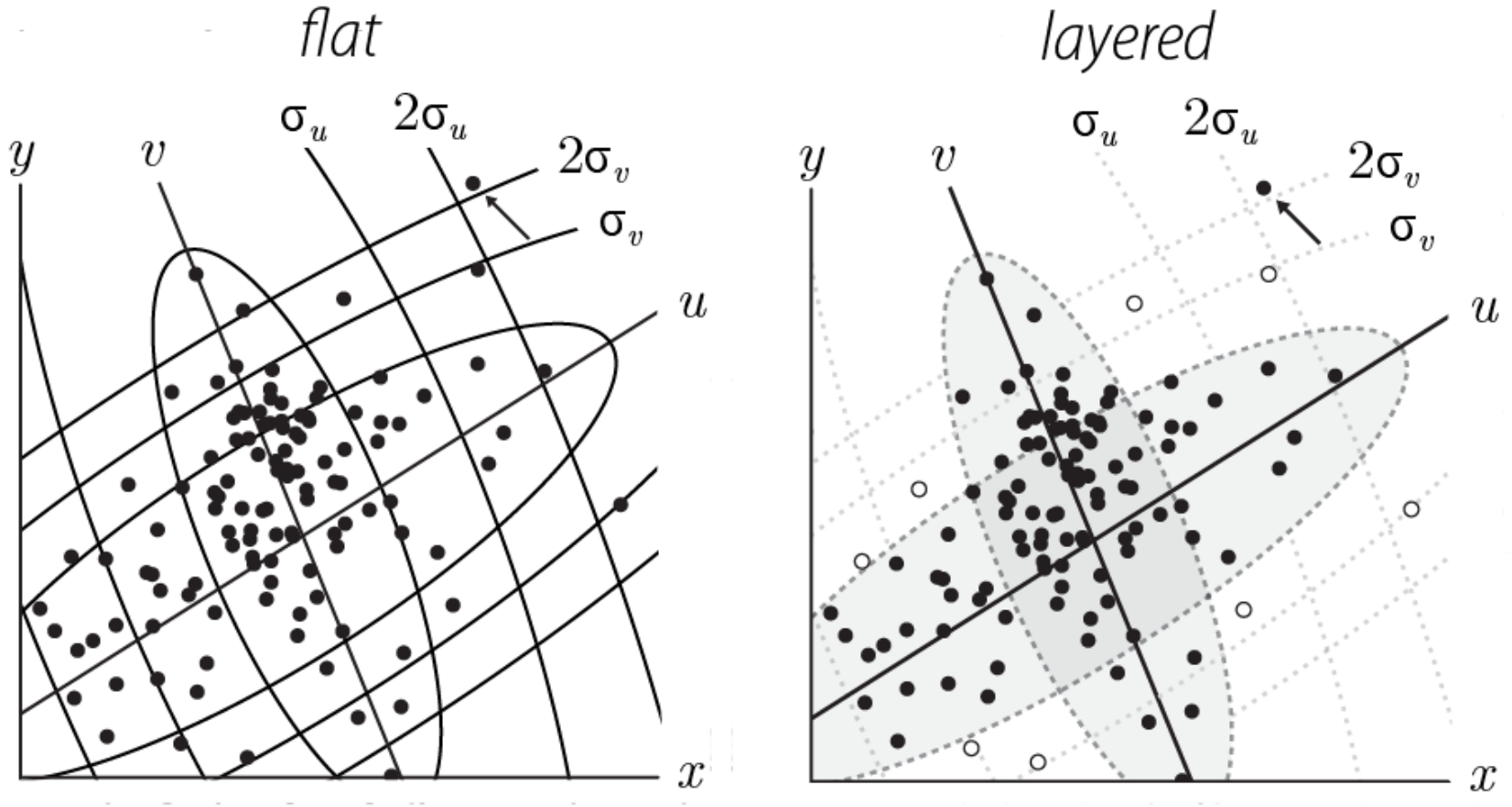
Principle of Similarity

- Similar things appear to be grouped together



Variable Opacity for Clarity

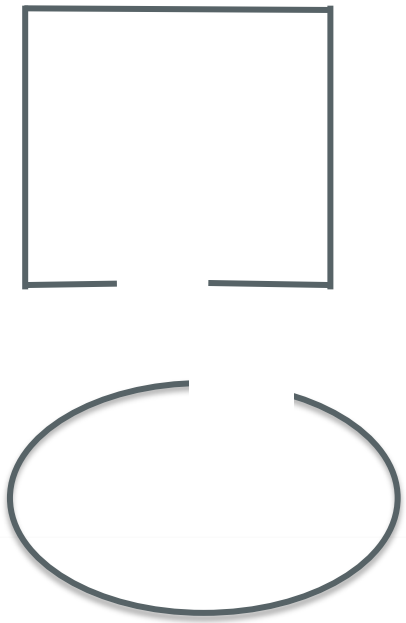
- Use of similarity of stroke and opacity to clarify image
  - Layers in the image

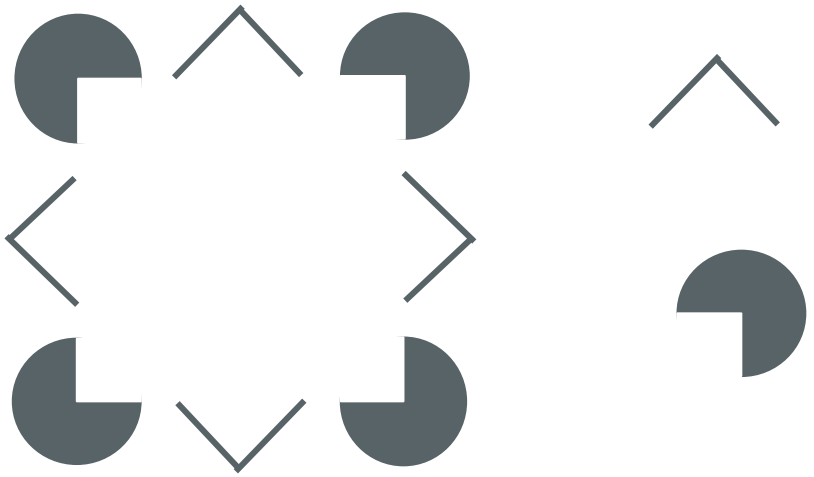


M. Krzwinski, behind every great visualization is a design principle, 2012

Principle of Closure

- The law of closure posits that we perceptually close up, or complete, objects that are not, in fact, complete

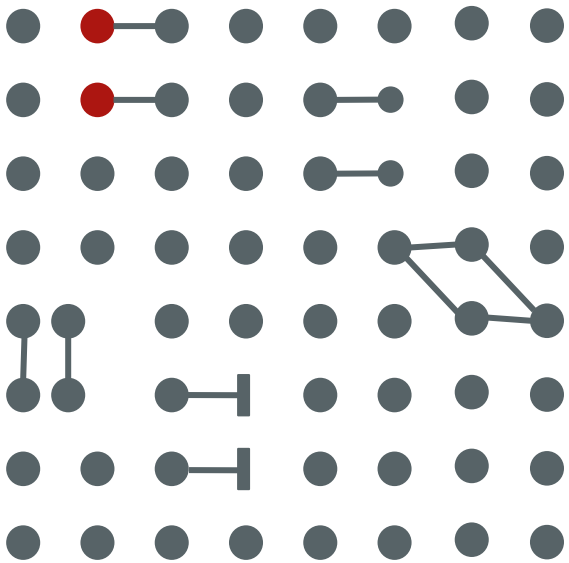




Illusory

Principle of Connectedness

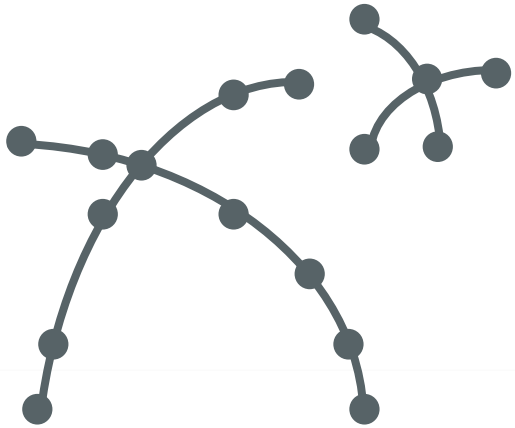
- Things that are physically connected are perceived as a unit

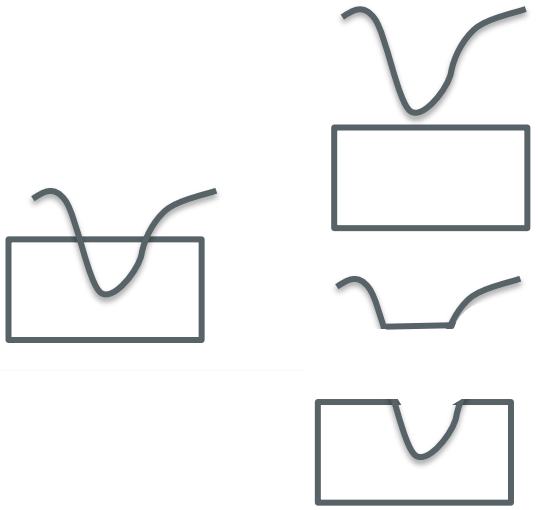


- Stronger than colour, shape, proximity, size

Principle of Good Continuation

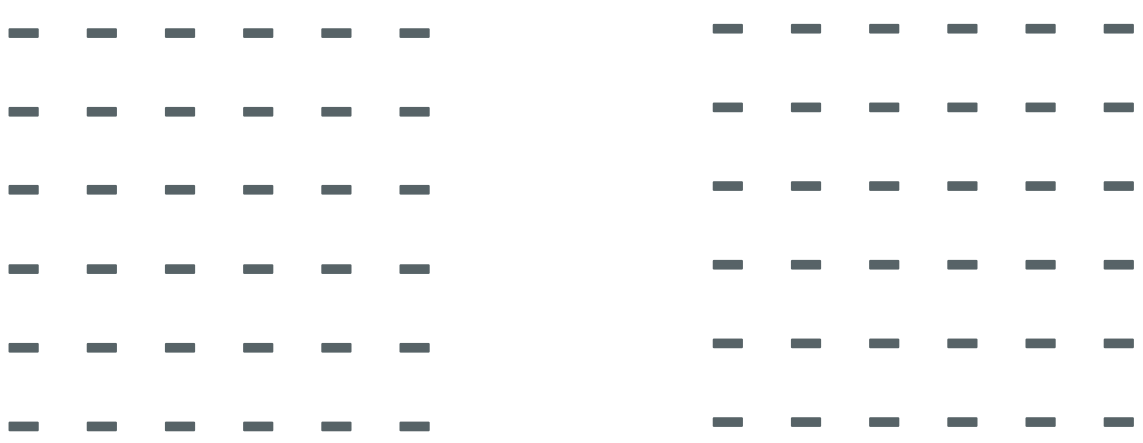
- Points connected in a straight or smoothly curving line are seen as belonging together
  - lines tend to be seen as to follow the smoothest path





Principle of Common Fate

- Things that are moving in the same direction appear to be grouped together



Principle of Familiarity

- Things are more likely to form groups if the groups appear familiar or meaningful

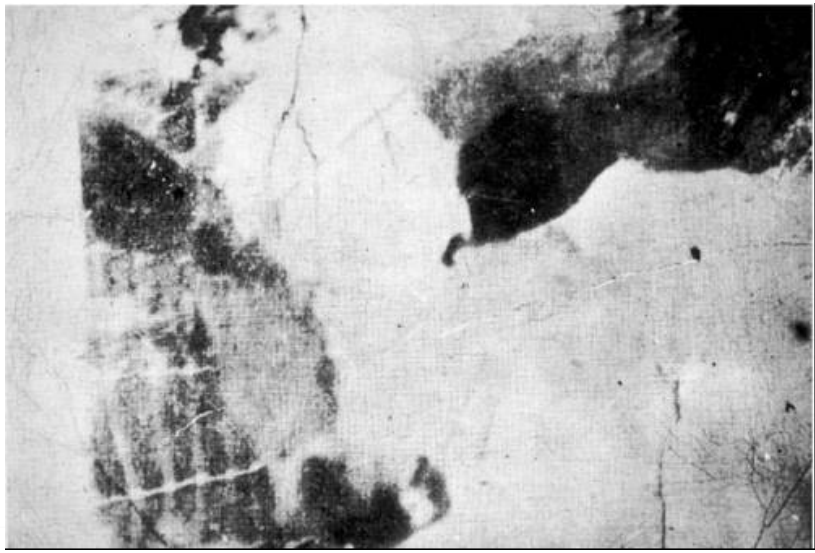
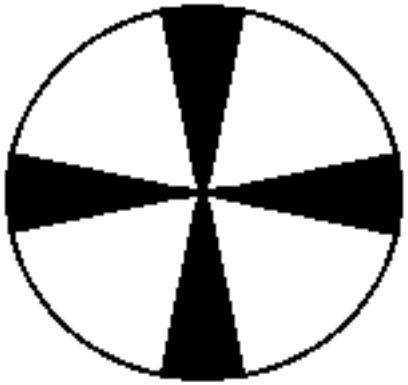
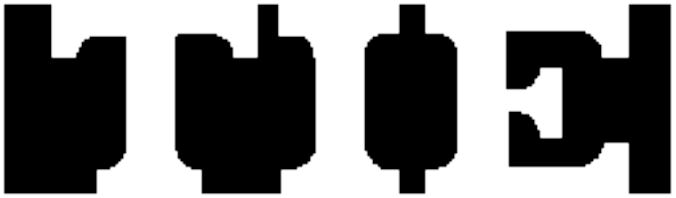


Figure-Ground & Smallness

- Smaller areas seen as figures against larger background

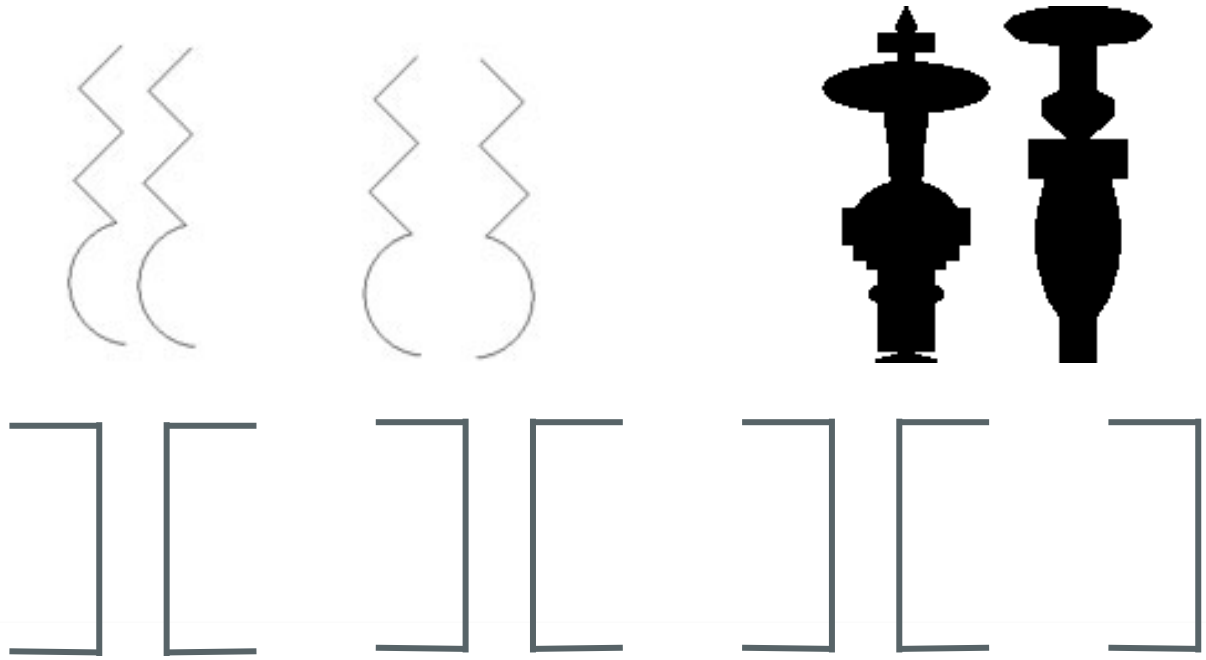


- Surroundedness

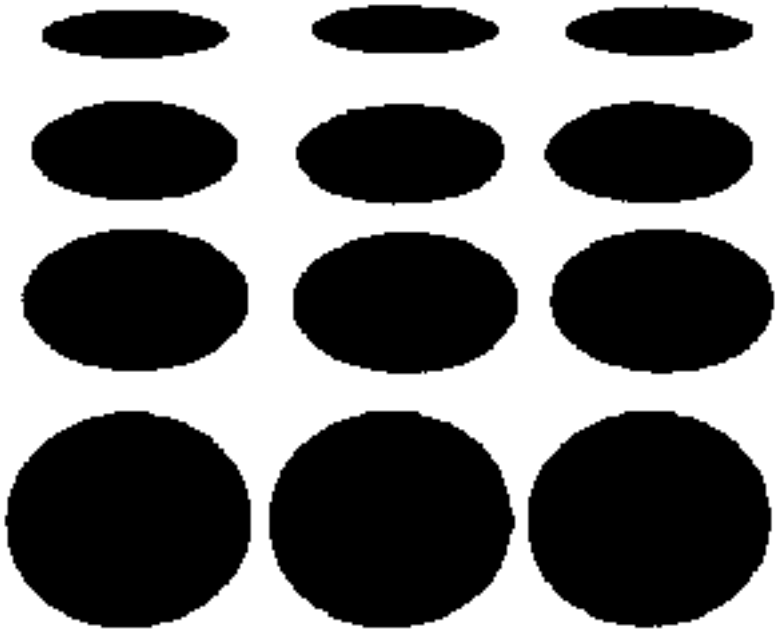


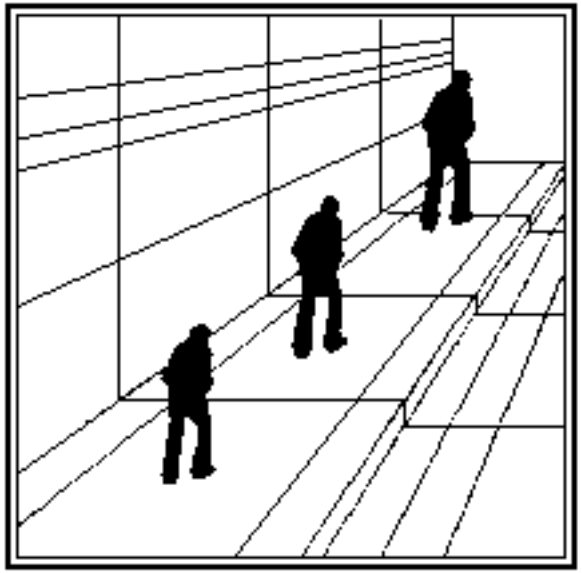
Principle of Symmetry

- The principle of symmetry is that, the symmetrical areas tend to be seen as figures against the asymmetrical background.



3D Effect

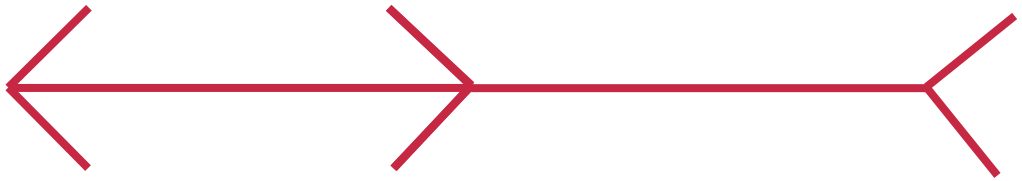




Context affects perceptual tasks

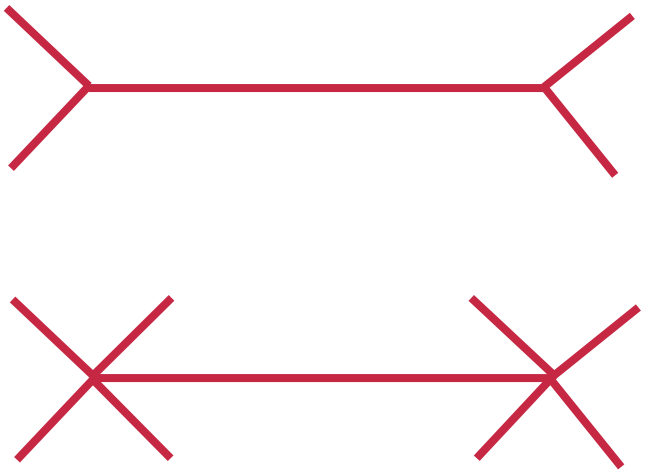
- Comparing values
  - Length
  - Curvature
  - Area
  - 2.5D shape
  - Position in 2.5D

Ambiguous Information: Length



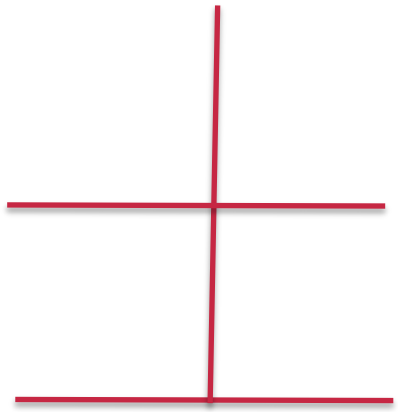
Muller-Lyer

Ambiguous Information: Length



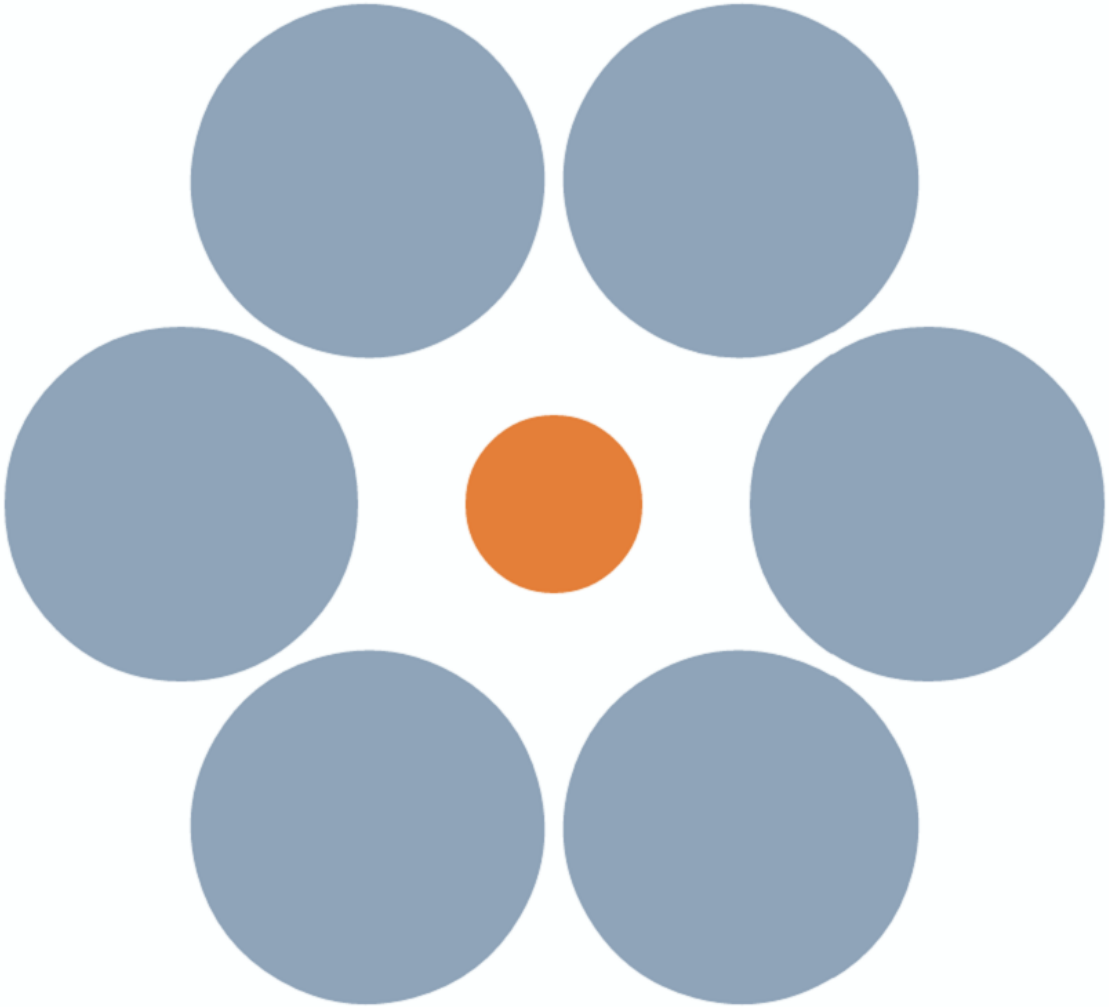
Muller-Lyer

Horizontal-Vertical Illusion



Ambiguous Information: Curvature

Ambiguous Information: Area (Context)



Ebbinghaus

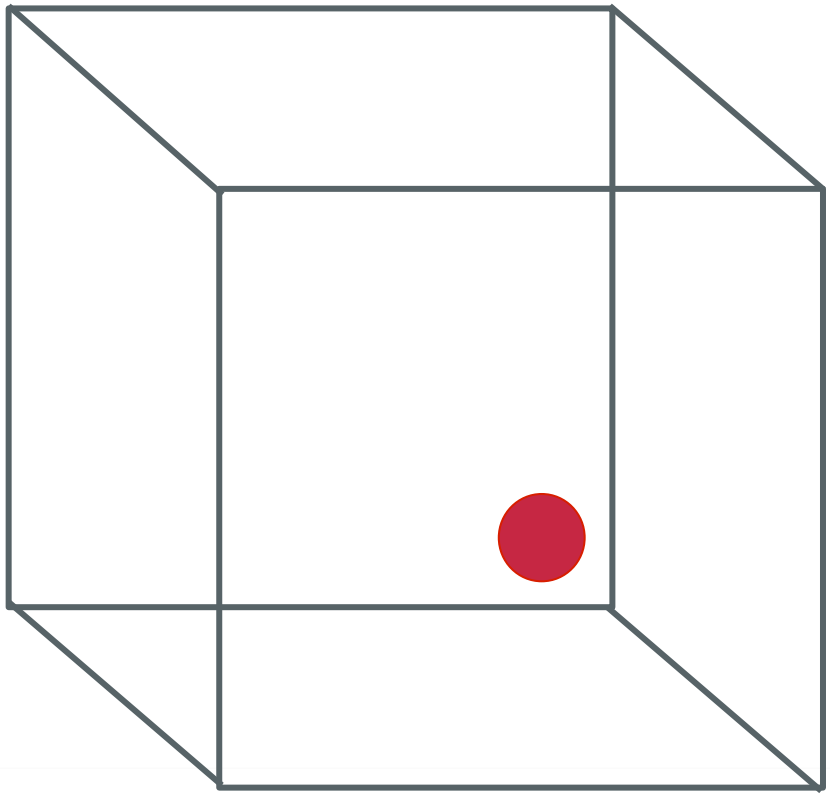
2.5D Shape

Adapted from Shepard R N, 1990 Mind Sights: Original Visual Illusions, Ambiguities, and other Anomalies (

2.5D Shape

Adapted from Shepard R N, 1990 Mind Sights: Original Visual Illusions, Ambiguities, and other Anomalies (

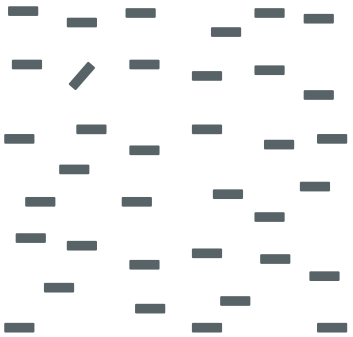
Ambiguous Information: Position in 2.5D space



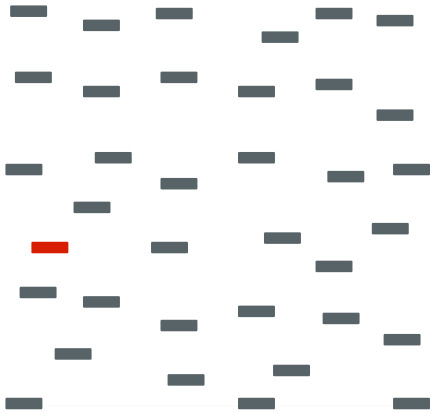
Necker Cube

Preattentive Visual Features

- the ability of the low-level human visual system to rapidly identify certain basic visual properties
- a unique visual property e.g., colour red allows it to "pop out"
- aids visual searching



orientation



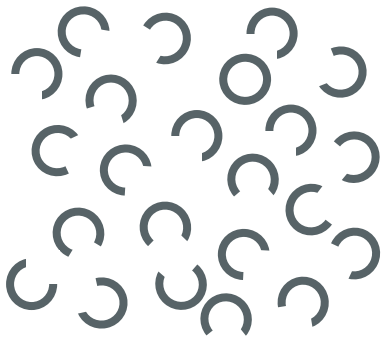
colour

size

Adapted from Perception in visualization C. Healey, : http://www.csc.ncsu.edu/faculty/healey/PP/

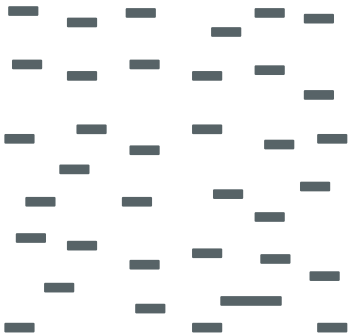
Preattentive Visual Features

- Some more effective than others



closure

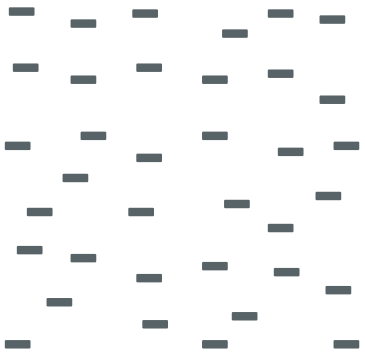
curvature



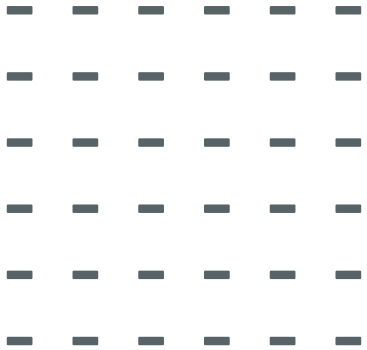
length

Adapted from Perception in visualization C. Healey, : http://www.csc.ncsu.edu/faculty/healey/PP/

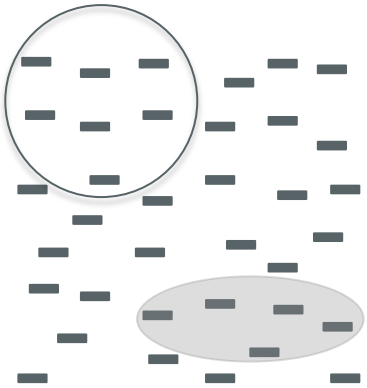
Preattentive Visual Features



flicker



direction of movement

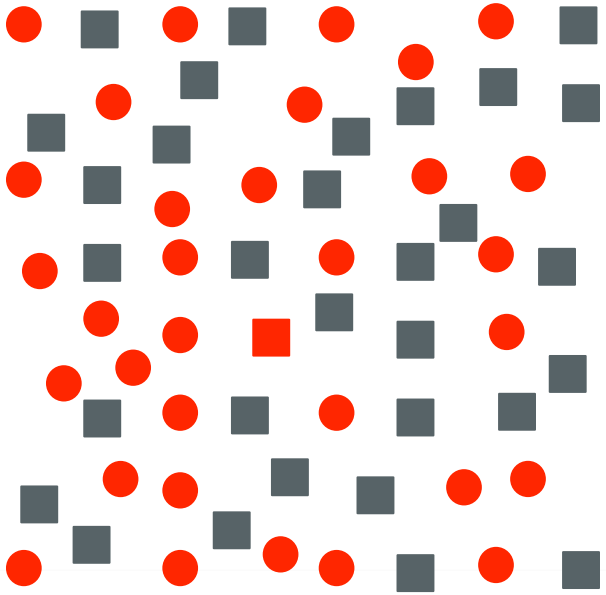


enclosure/containment

Adapted from Perception in visualization C. Healey, : http://www.csc.ncsu.edu/faculty/healey/PP/

More than 2 Preattentive visual features

- A target made up of a combination of non-unique features normally cannot be detected preattentively

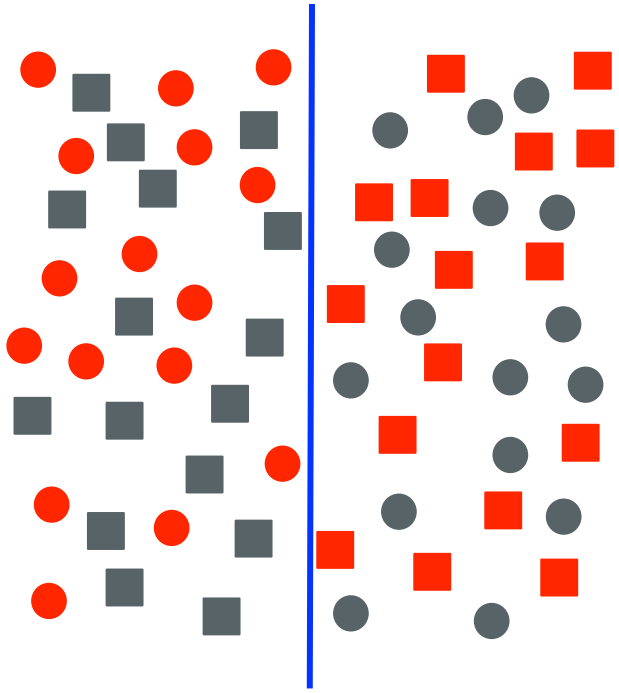


- spot the red square
- difficult to detect
- serial search required

Adapted from Perception in visualization C. Healey, : http://www.csc.ncsu.edu/faculty/healey/PP/

Boundary detection

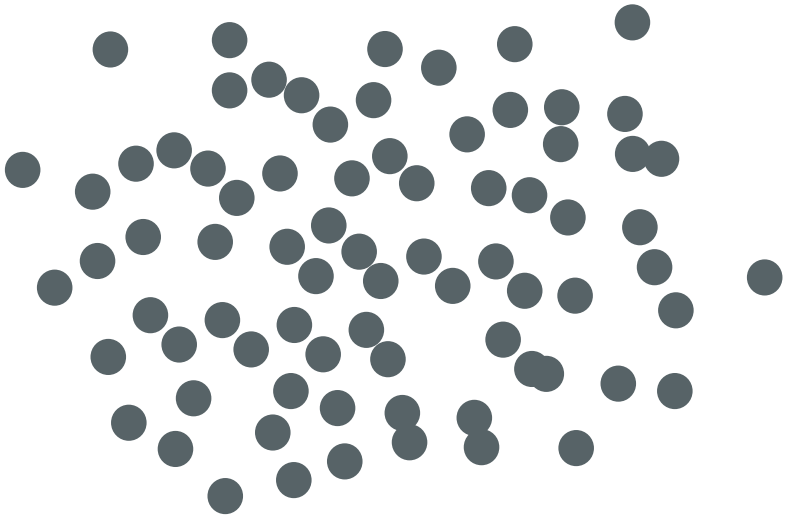
Horizontal boundary



Vertical boundary

Adapted from Perception in visualization C. Healey, : http://www.csc.ncsu.edu/faculty/healey/PP/

Region tracking



Use of preattentive features

- target detection:
  - users rapidly and accurately detect the presence or absence of a "target" element with a unique visual feature within a field of distractor elements
- boundary detection:
  - users rapidly and accurately detect a texture boundary between two groups of elements, where all of the elements in each group have a common visual property
- region tracking:
  - users track one or more elements with a unique visual feature as they move in time and space, and
- counting and estimation:
  - users count or estimate the number of elements with a unique visual feature.

COLOURCO

LOURCOLO

URCOLOUR

COLOURCO

Colour

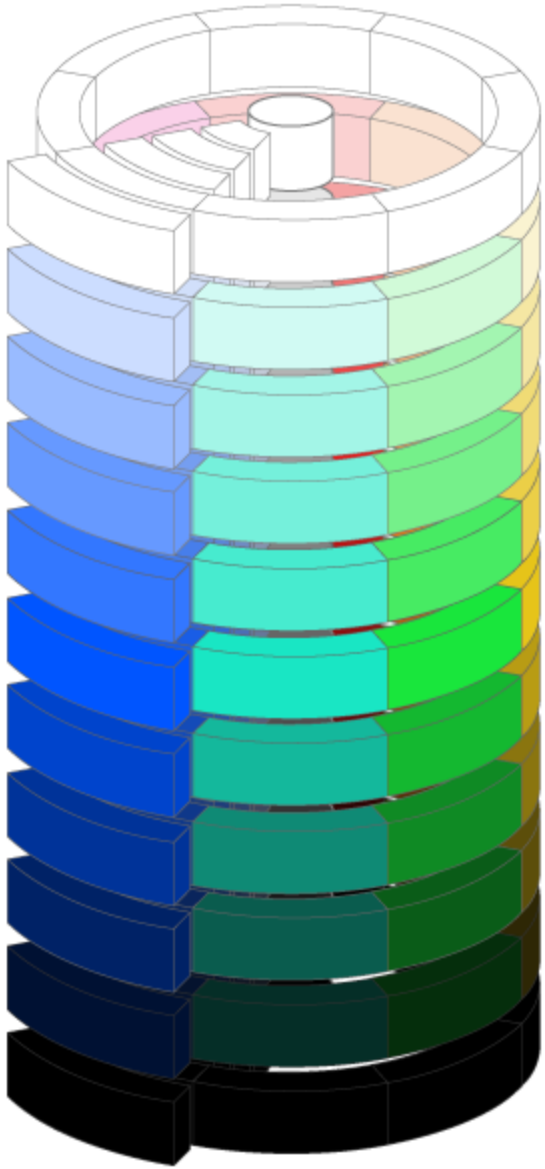
- "Colour used poorly is worse than no colour at all" - Edward Tufte
  - "Above all, do no harm"
  - colour can cause the wrong information to stand out and
  - make meaningful information difficult to see.

Colour space

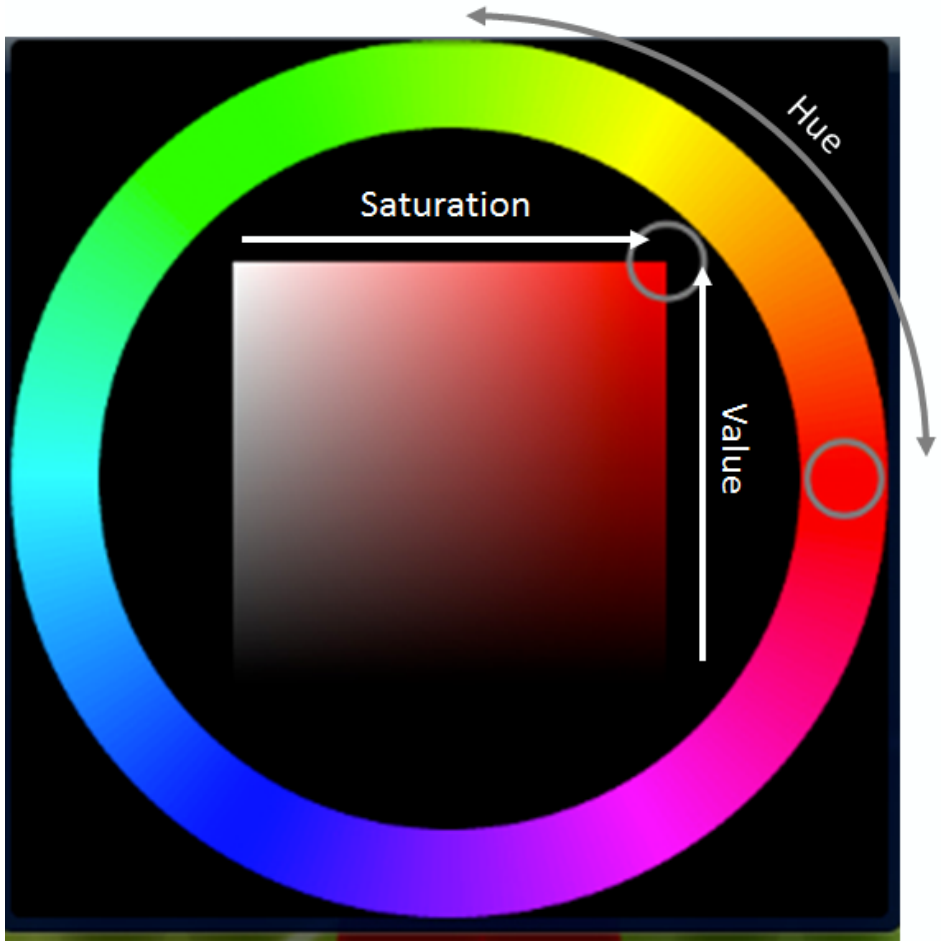
- A *colour space* is mathematical model for describing colour.
  - RGB, HSB, HSL, Lab and LCH
- RGB is the most common in computer use,
  - but least useful for design
  - our eyes do not decompose colours into RGB constituents
- HSV, describes a colour in terms of its hue, saturation and value (lightness),
  - models colour based on intuitive parameters
  - more useful.

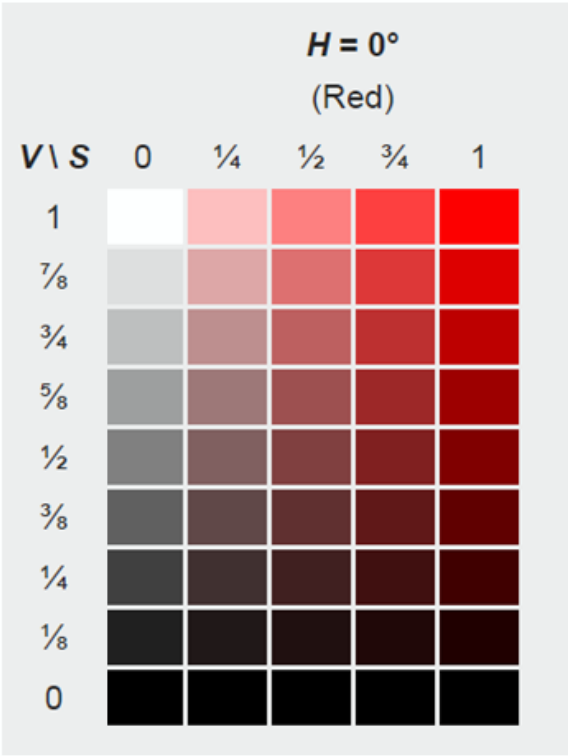
Colourimetry

- Hue (colour)
  - around the circle
- Saturation
  - Inside to outside
  - Colour to grey scale
- Lightness (value)
  - top to bottom



Figs. Courtesy of S Rogers, ONS


Hue
Saturation
Value


H = 0°
(Red)
V \ S
0
¼
½
¾
1
1
⅞
¾
⅝
½
⅜
¼
⅛
0

Brewer Palettes

- Brewer palettes (colorbrewer.org) provide a range of palettes based on HSV model which make life easier for us….

Avoid the use of hue to encode quantitative variables

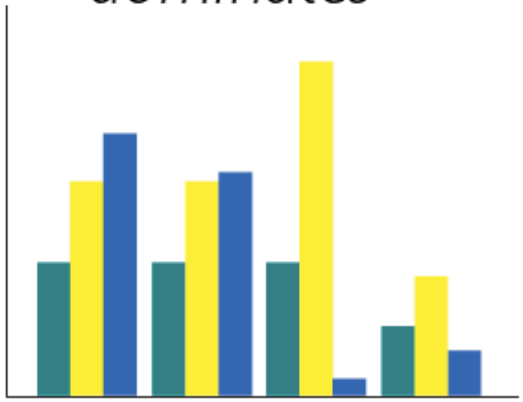
Quantitative encoding e.g. heat maps

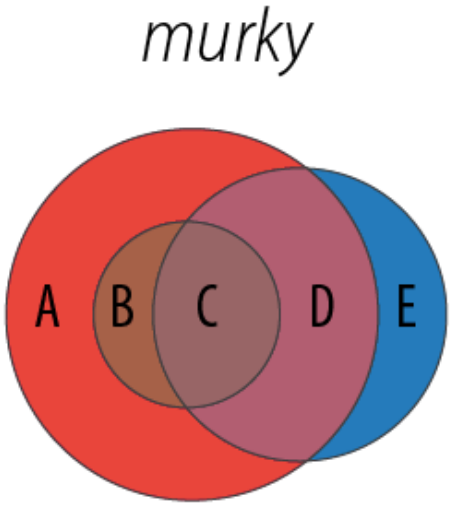
Two-sided quantitative encodings

Fig. Courtesy of M. Krzwinski,

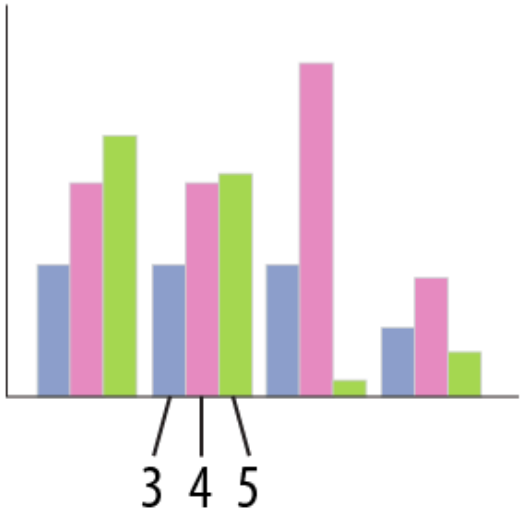
Examples

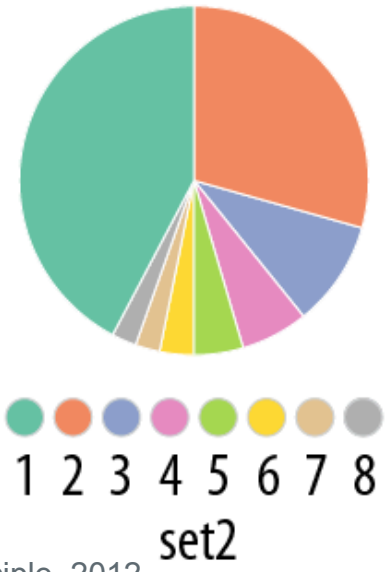
Poor use of colour

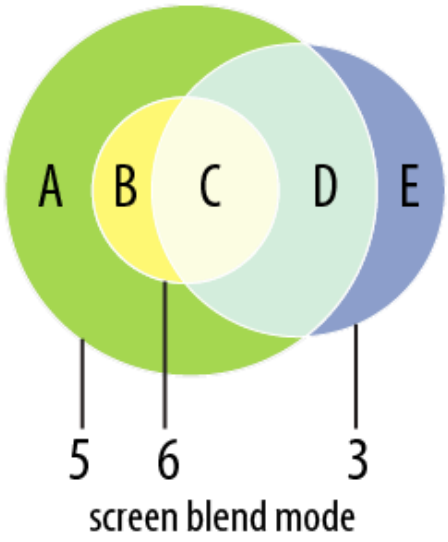




Brewer colours







M. Krzwinski, behind every great visualization is a design principle, 2012

Conversion to Grey scale

- Ensure chosen colour set works well in grey scale
  - Sequential palette works well here

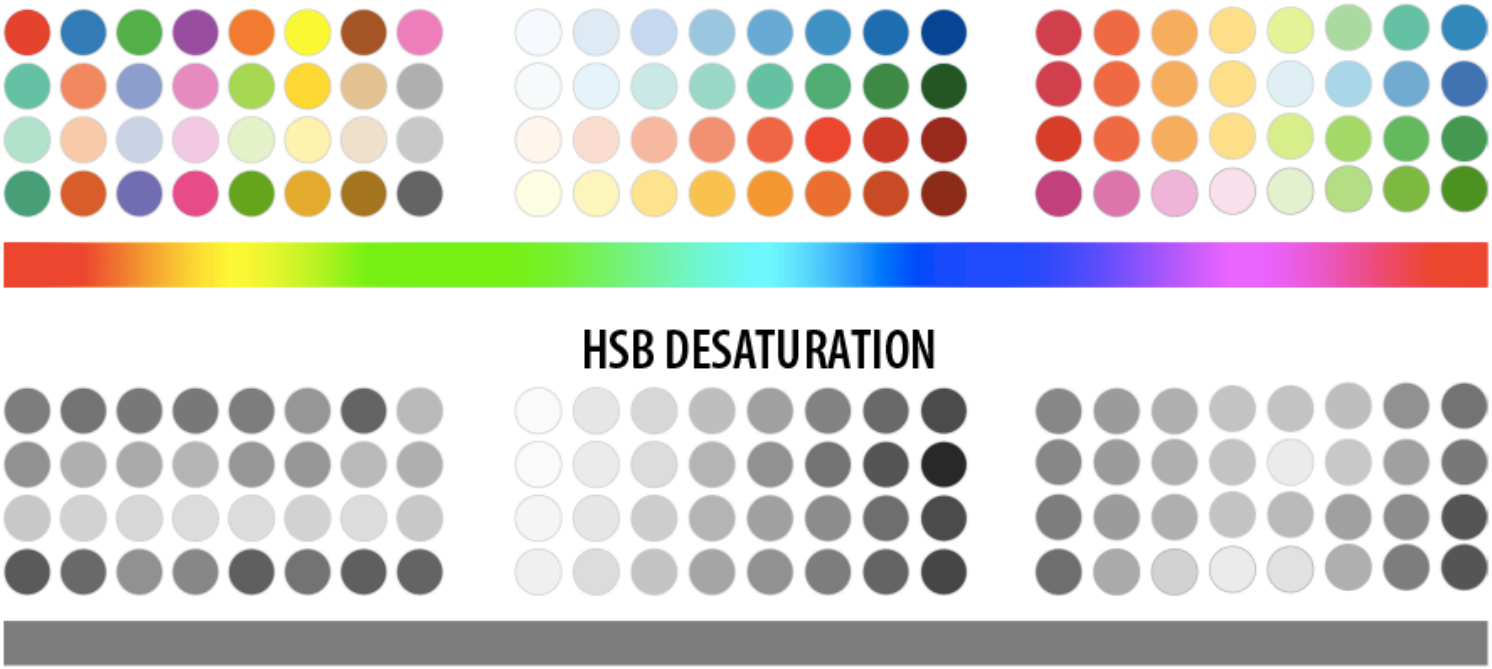
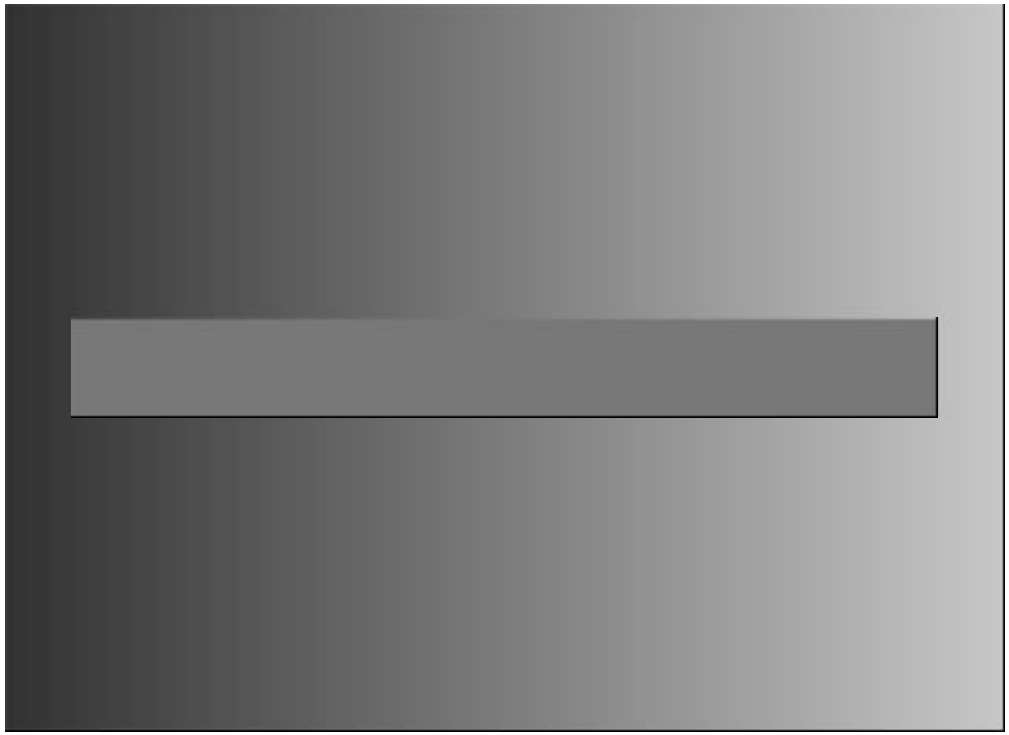


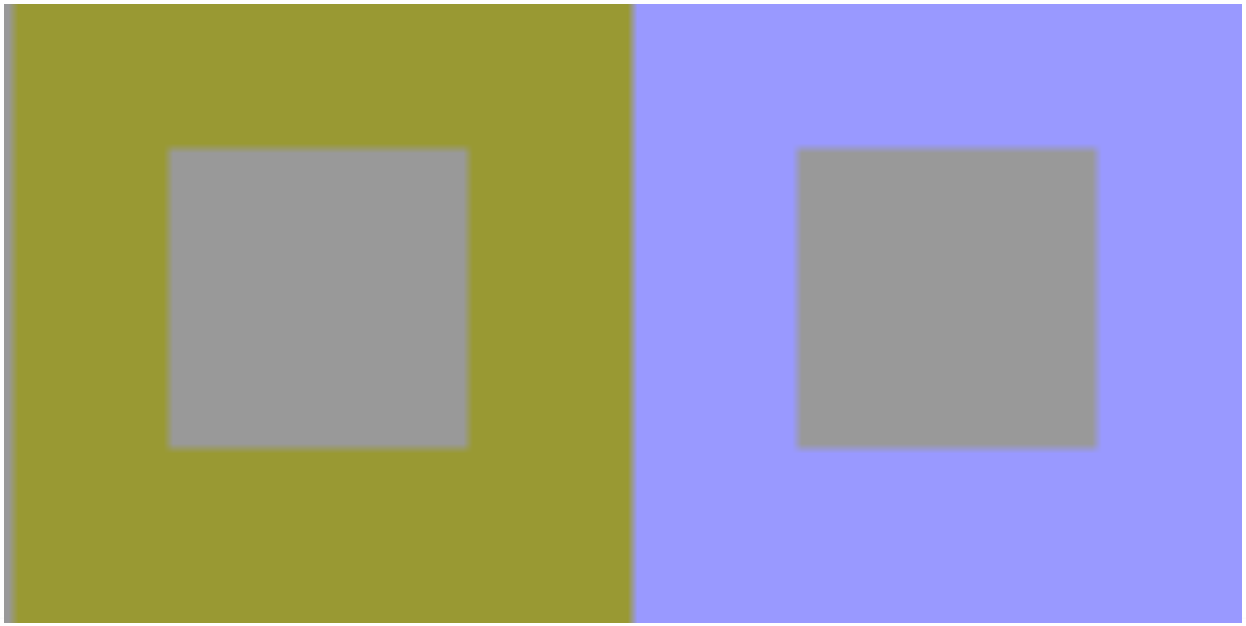
Fig. Courtesy of M Krzywinski

Trouble with perceptual colour….



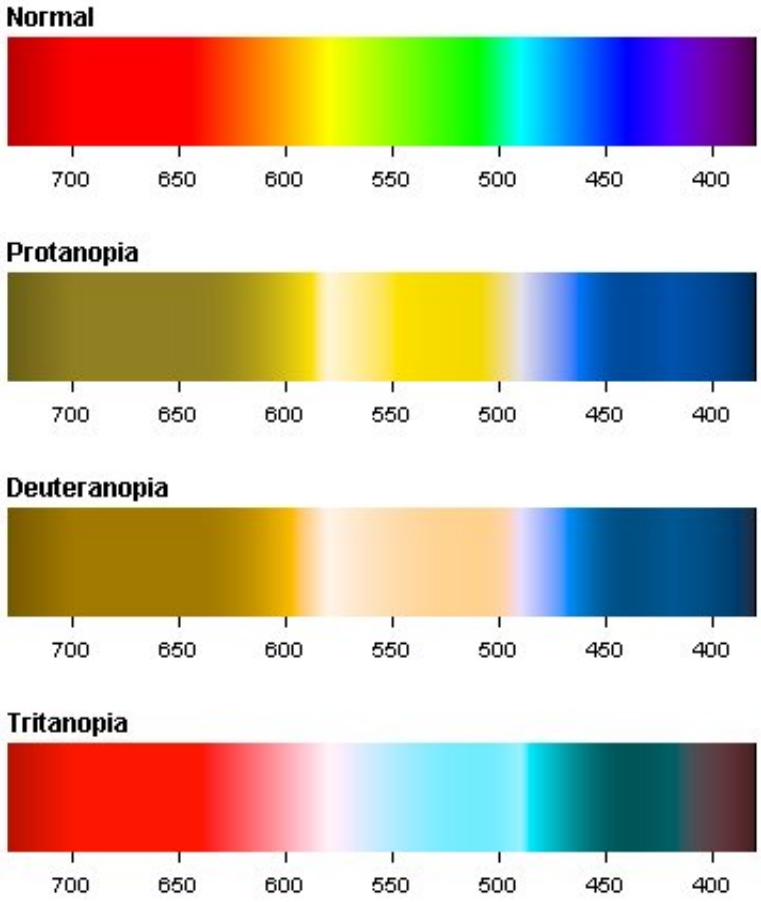
Figs. Courtesy of S Rogers, ONS

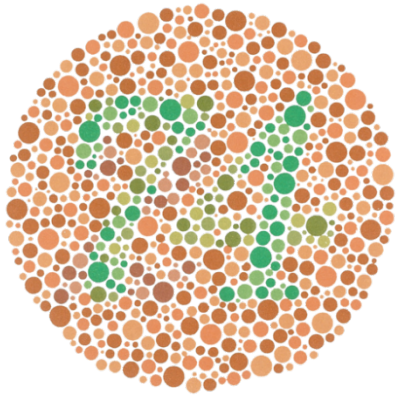
Context Affects Perceived Colour



Figs. Courtesy of S Rogers, ONS

Colour & Accessibility….





Accessibility (W3C):

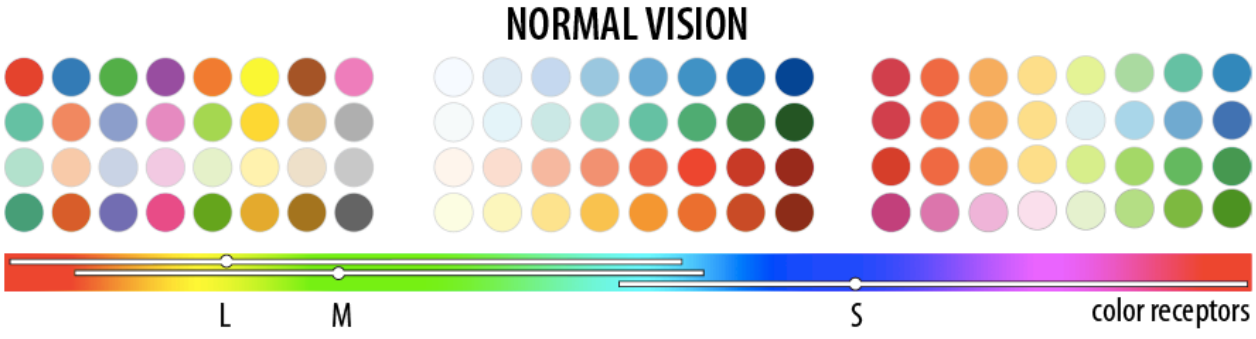
10-20% of population are red/green colour blind.

(74? 21? No number at all?)….

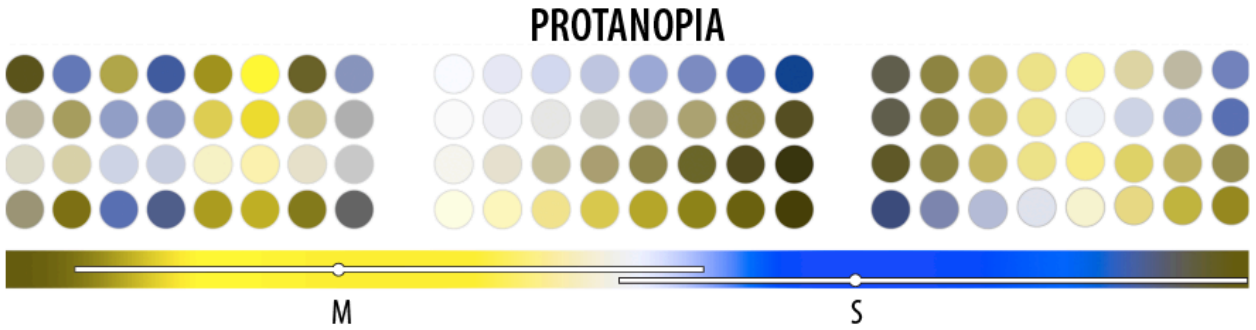
Figs. Courtesy of S Rogers, ONS

Colour Blindness

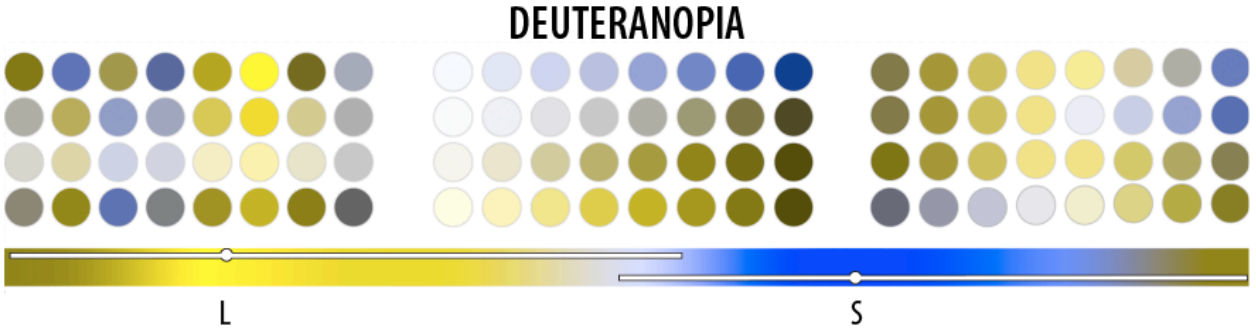
8% males of
USA descent



Red-green



Red-green



Blue-yellow

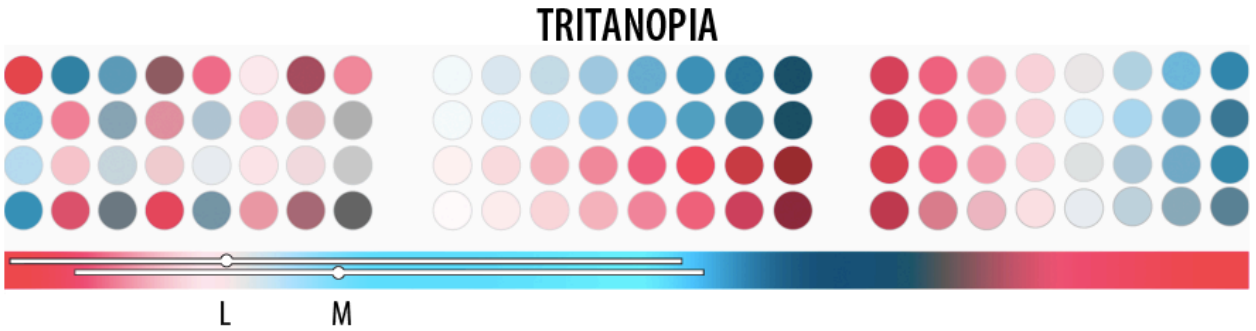


Fig. Courtesy of M Krzywinski

Shaping our digital future

BioVis Example: Immunofluorescence images

red-green image of P2Y1 receptor and migrating granule neurons,

effectively remapped to magenta-green using the channel mixing method.

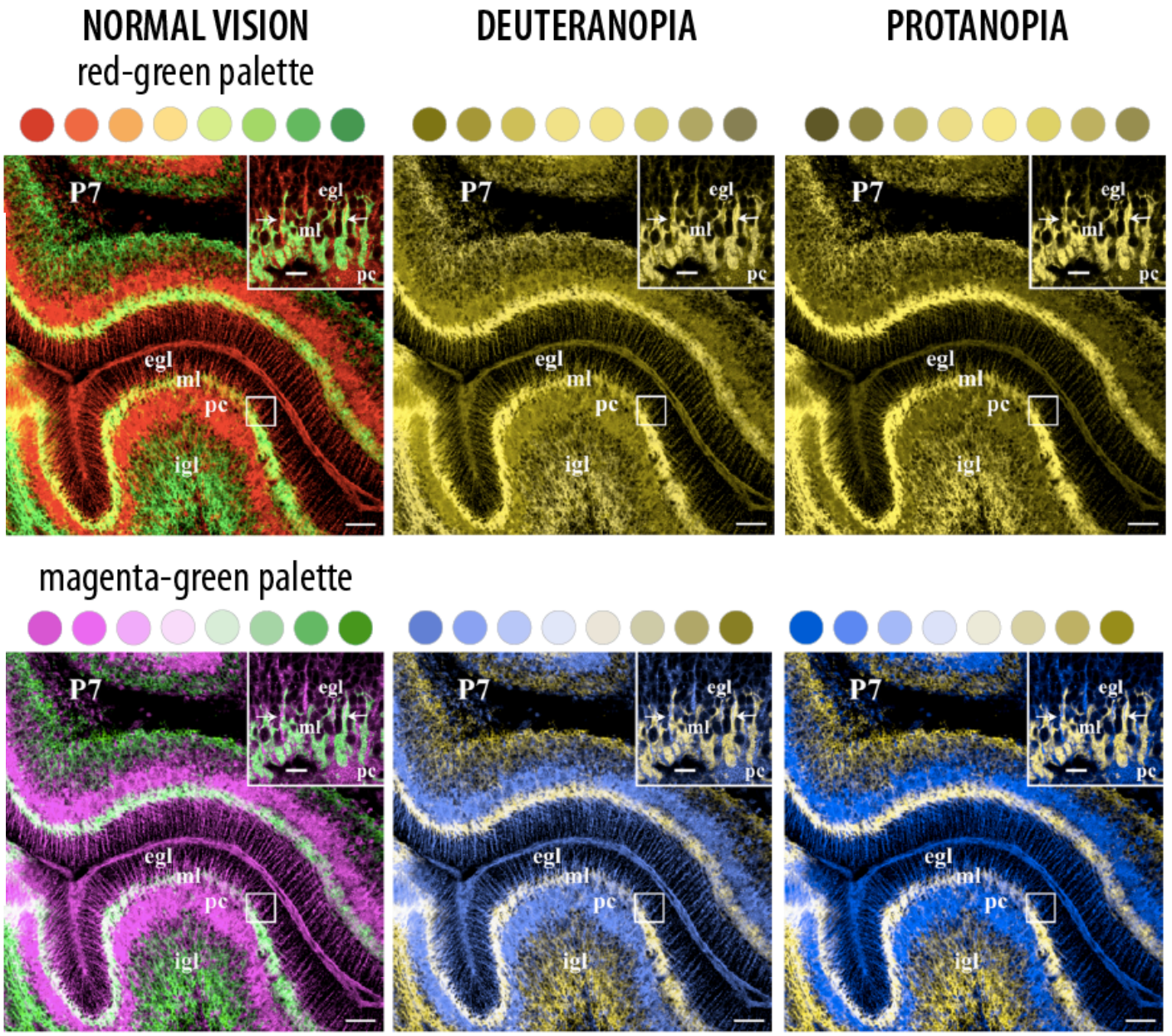
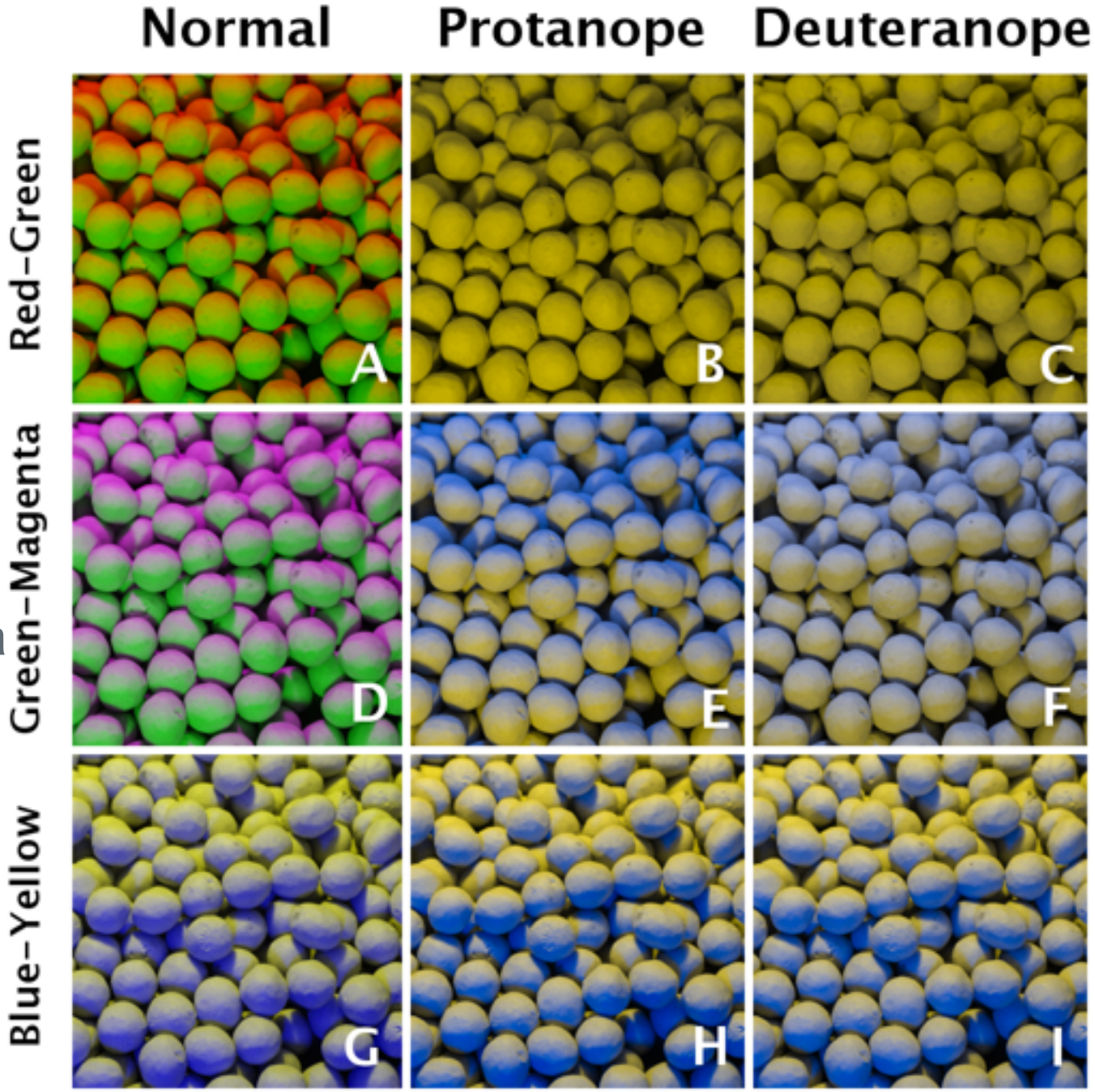


Fig. Courtesy of M Krzywinski

Shaping our digital future

- Blue-Yellow
  - might be better than
- Green-Magenta
  - talk about same colours



Gabriel Landini & D Giles Perryer, Image recolouring for colour blind observers

From Data to Visualization…

- The properties of the data or information
- The properties of the image
- The rules mapping data to images

Encoding Schemes

position

slope

density

length

area

saturation

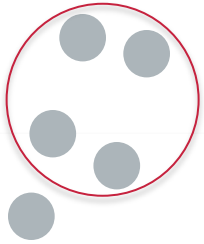
angle

shape

hue

connection

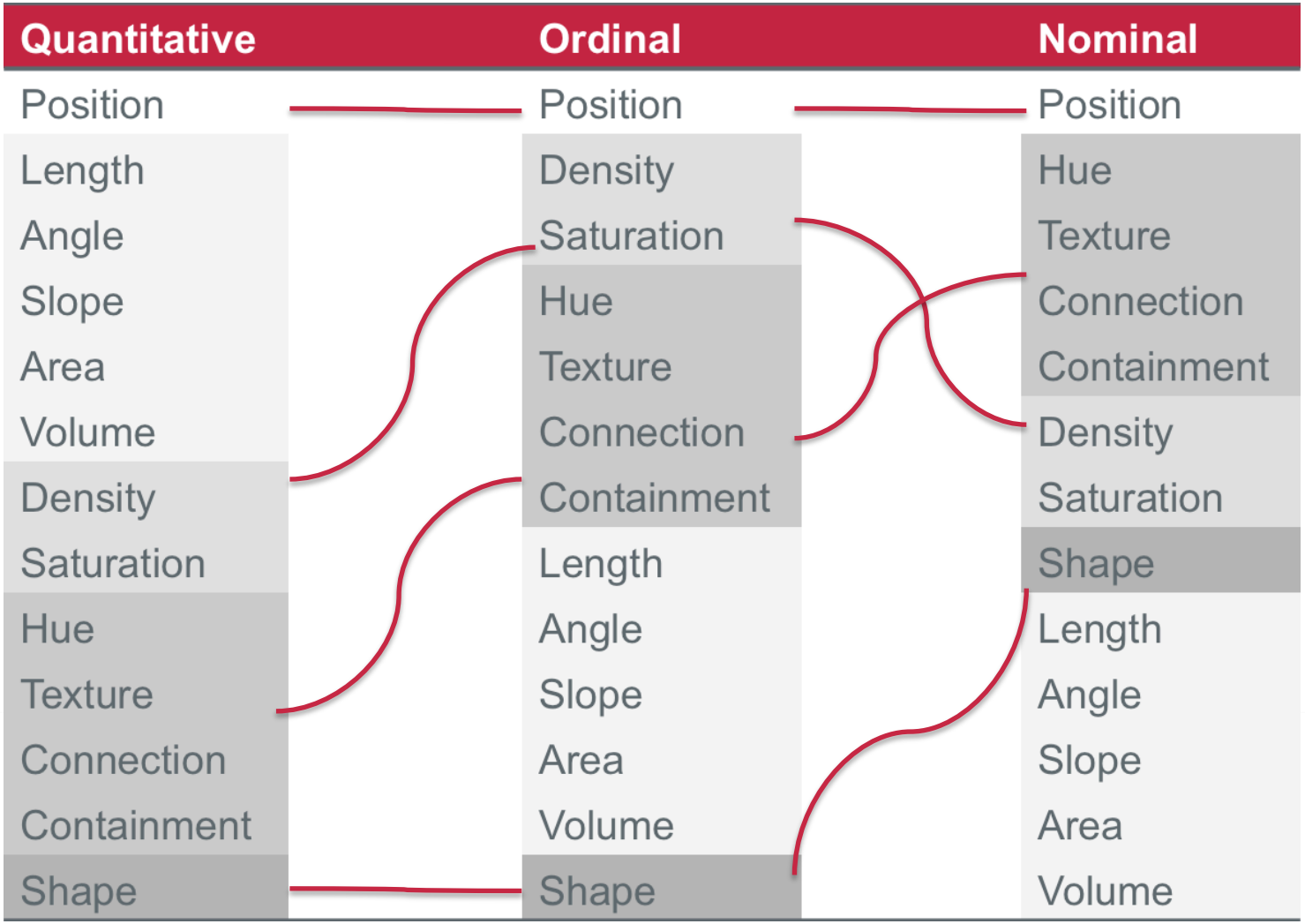
containment



texture

Adapted from Mackinlay J (1986) Automating the design of graphical presentations of relational information.

Mapping data types to encoding



Mackinlay J (1986) Automating the design of graphical presentations of relational information.