Visual Perception

Ware, C. “Information VIsualisation, Perception for Design”, Elsevier, 2021
Archambault, D. “Visual Analytics: an Introduction”, Swansea University, 2020
Kerren, A. “Information Visualisation: Perception”, Linnaeus University, 2020

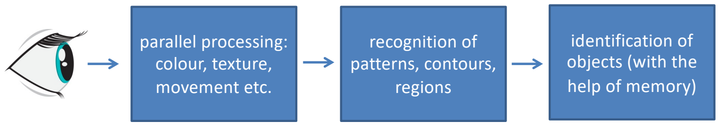
Visual perception

How the eye and mind work together so that we can perceive and interpret what we see, before we act on it

Perceptual model

Three levels to perceiving a scene:

- Level 1: processing low-level properties (parallel)
- Level 2: pattern recognition (sequential)
- Level 3: target-oriented search (sequential)



adapted from Ware (2021), p20

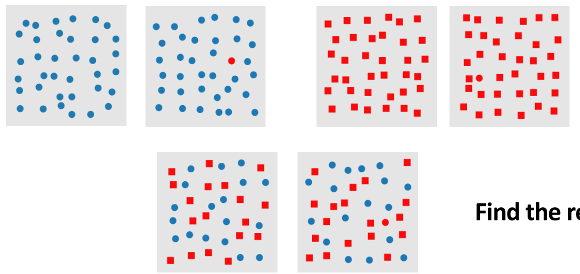
- **Level 1:**
  - rapid, parallel extraction of features
  - *e.g. edges, orientation, colour, texture, movement*
  - bottom-up, data-driven
  - pre-attentive, held very briefly
- **Level 2:**
  - slow, serial detection of patterns
  - *e.g. contours, regions*
  - combination of bottom-up and top-down
  - needs attention, uses memory (working and long-term)
- **Level 3:**
  - slow, serial identification of objects
  - *e.g. a handle to turn, a data point to focus on*
  - related to action, purpose, concentration
  - uses memory

Ware (2021), pg 21ff

Topics in Visual Perception

- **Level 1 (bottom-up)**
  - pre-attention
  - colour
- **Level 2 (bottom-up & top-down)**
  - pattern identification
  - Gestalt laws
- **Level 3 (top-down)**
  - object identification
- Interference between levels

Level 1: Pre-attention



Find the red circle

https://www.csc2.ncsu.edu/faculty/healey/PP/

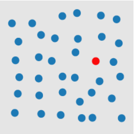
Healey & Enns (2012), Attention and Visual Memory in Visualization and Computer Graphics, TVCG, 18(7)

absent on the left, present on the right
colour is preattentive; shape is preattentive; the combination is not

boundary detection

Pre-attention experiments

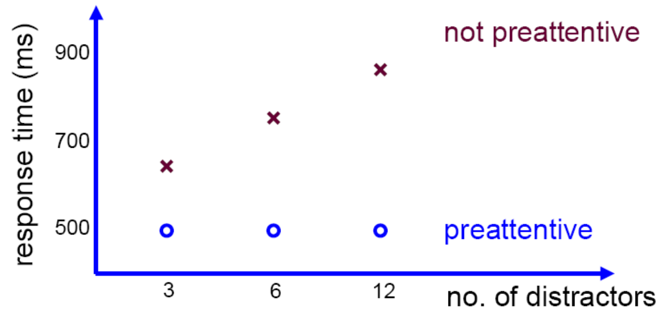
- Stimulus:
  - one unique target amongst several identical distractors
  - the target represents a feature (or features) that is absent in the distractors
- Task: identify the target
- Data collected: response time



If the response time does not depend on the number of distractors, the feature is pre-attentive

Kerren, A. “Information Visualisation: Perception”, Linnaeus University, 2020 (inspired by Hauser, 2005)

Identifying a single target amongst a set of distractors



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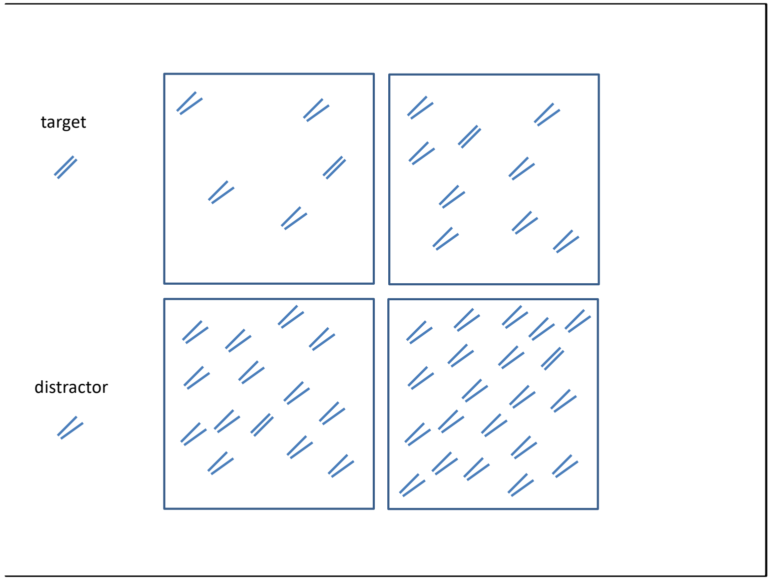
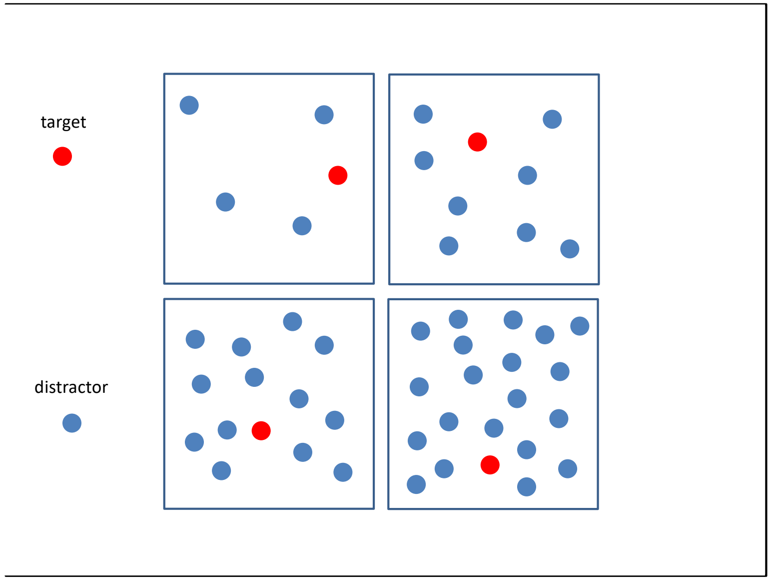

target
distractor


target
distractor

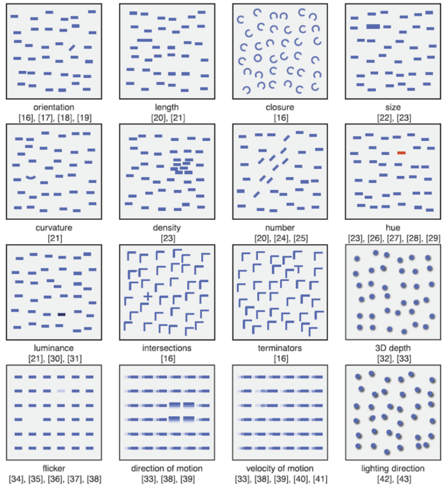


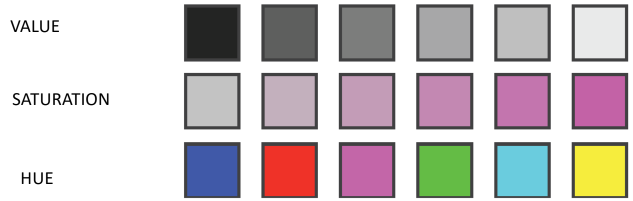
Fig. 2. Examples of preattentive visual features, with references to papers that investigated each feature's capabilities.

Healy & Enns (2012), Attention and Visual Memory in Visualization and Computer Graphics, TVCG, 18(7)

Level 1: Colour

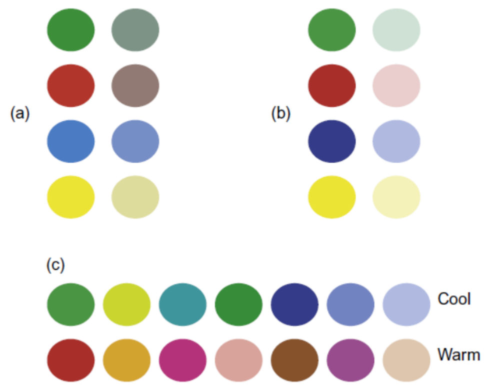
- Objective measures
  - Hue
    - the ‘basic’ colour itself
  - Saturation
    - intensity of the colour
    - Intense/pure vs dull/diffuse
  - Lightness/Value
    - light vs. dark
    - varying amounts of black or white in the colour
- Subjective assessment
  - Brightness (Luminance?)

Colour



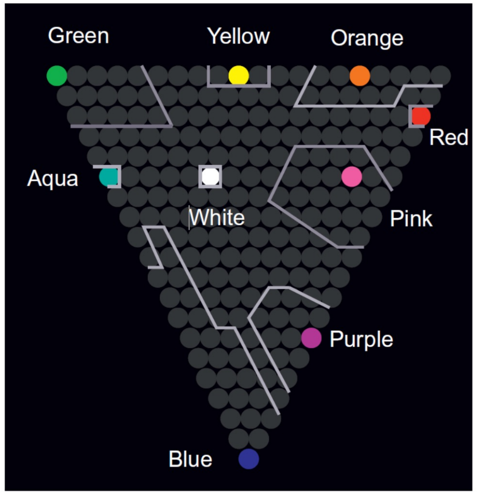
Human perception of ‘just noticeable difference’ implies a finite number of values

Archambault, D. “Visual Analytics: an Introduction”, Swansea University, 2020



(a) same hue, different saturation
(b) same hue, different saturation, different value
(c) cool hues and warm hues

Ware (2021), p127



“Name the colour” experiment

Darkened room, computer monitor

210 different colours computationally generated, on black background

12 participants, daily for 10 days

Free-form text answers

Outlined regions show the colors given the same name with better than 75% probability.

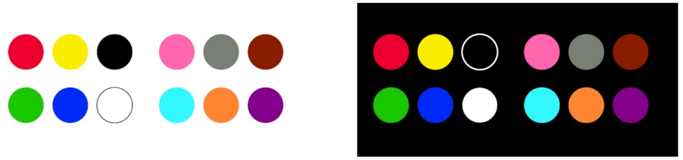
Ware (2021), p111, adapted from D.Post, F.Greene, *Color naming as a function of stimulus luminance* (1985)

Observations

- Only eight colours, plus white, consistently named
  - green, yellow, orange, red, aqua, pink, purple, blue, white
- The pure monitor ‘red’ was named orange most of the time
- Data obtained with a black background; different results expected with white background

Ware (2021), p111, adapted from D.Post, F.Greene, *Color naming as a function of stimulus luminance* (1985)

Colour hues for encoding nominal data



Set 1 (left): red, green, yellow, blue, black, white
(the unique colors that mark the ends of the opponent color axes)

Set 2 (right): pink, cyan, gray, orange, brown, purple

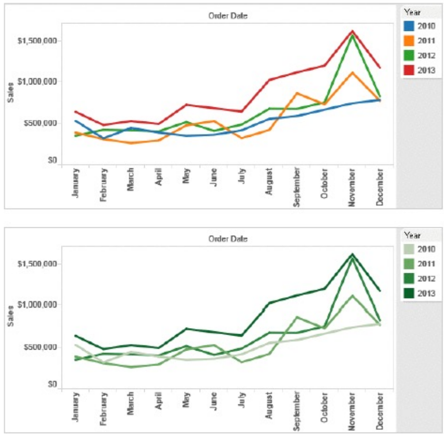
Most common colour names in cross-cultural study (+cyan)
[Berlin&Kay, 1969]

Use all the colours in Set 1 before choosing any in Set 2

Ware (2021), p126

Watch out for red-green colour blindness, though

Ordered vs Categorical



Archambault, D. "Visual Analytics: an Introduction", Swansea University, 2020

The year is an ordered data attribute, and so it might be better to encode it with an ordered visual attribute… like saturation… as in the lower figure

Some rules on colour

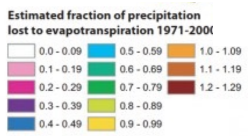
- Less is more! Try to use minimal and low-intensity colours. Save strong colours for highlighted or extreme data.
- Don't use blue for thin lines, rather use it for large areas
- *Use red and green in the centre of the field of view*
- Use black, white, yellow in the periphery
- For large regions, don't use highly saturated colours
- Don't use adjacent colours that vary in the amount of blue
- Use colour for grouping and to assist search
- Use a neutral tone to encode the number 0
- Positive and negative numbers should be encoded with the saturation of contrary colours (e.g. purple/yellow; blue/orange)
- Errors in contrast can be avoided by drawing boundaries around selected areas

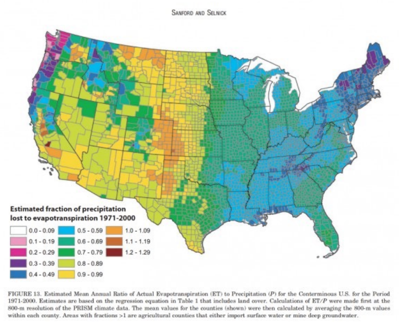
- Also: see ColorBrewer2.org for good colour maps and code downloads

Kerren, A. "Information Visualisation: Perception", Linnaeus University, 2020, inspired by J.Stasko

Italics for those which might be problematic for colour blind people

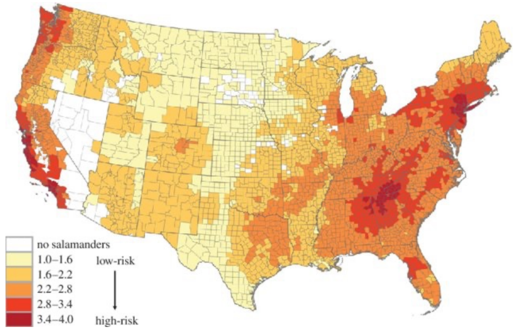
It is tempting to use the ‘Rainbow Colour Map’ for ordered data – forgetting that hue is not appropriate for representing order





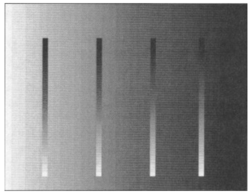
R.Kosara, *How The Rainbow Color Map Misleads*, eagereyes, 2013

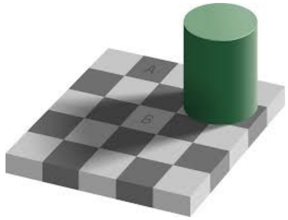
Better to use saturation of the same hue

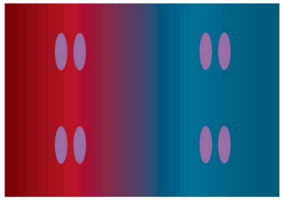


Russell et. al (2016), Royal Society Open Science 3(2)

Beware of contrast!







All four lines are identical (top left)
A and B are the same colour grey (top right)
All 8 purple discs are the same (below)

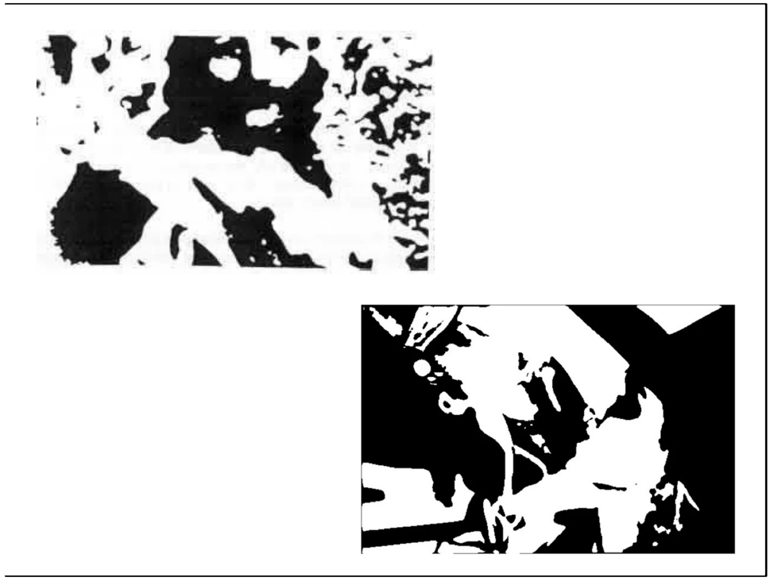
So… keep background colours plain and uniform. No changing fields or bands or regions of colour, as in the problematic examples above

Level 2: Pattern identification

Level 2: 'interim' level using bottom-up and top-down processing

- bottom-up: uses the actual features that are physically perceived
- top-down: uses other contextual information – e.g. from the environment, from memory

the first time you see this, you will use bottom-up processing only to try to interpret it.
once you are told what it is, you will use top-down processing to interpret it
and after that, you will never be able to see it as a simply a whole load of black dots again, as the top-down processing will take over the bottom-up processing



Top: The face is looking straight ahead and is in the top half of the picture in the center. The figure is strongly lit from the side and has long hair and a beard.
Bottom: on the right is a woman, wearing a cowboy hat, with her face tilted back and also up close to a horse's face (on the left)

Level 2: Gestalt laws

Rules describing how we see patterns in a visual display...
In particular, how we see visual objects form *groups*

- proximity
- similarity
- connectedness
- continuity
- symmetry
- closure
- figure and ground
- common fate

- Ware (2021) provides example design principles for each

Note that these design principles are not the only things that can be learned from these rules

Proximity

Elements that are physically close together are perceptually grouped together

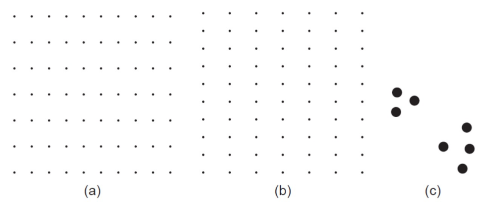


Figure 6.2 Spatial proximity is a powerful cue for perceptual organization. A matrix of dots is perceived as rows on the left (a) and columns on the right (b). In (c) we perceive two groups of dots because of proximity relationships.

So: symbols representing related information should be placed together

Ware (2021), p186

Similarity

Similar elements tend be to be grouped together

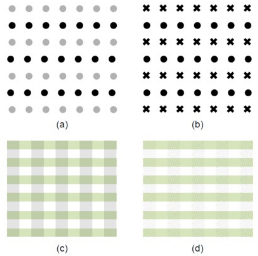


Figure 6.4 (a, b) According to the Gestalt psychologists, similarity between the elements in alternate rows causes the row percept to dominate. (c) Integral dimensions are used to delineate rows and columns. (d) When separable dimensions (color and texture) are used, it is easier to attend separately to either the rows or the columns.

So: use different colours to encode rows/columns in a grid data set

Ware (2021), p187

Connectedness

Elements connected by lines form groups

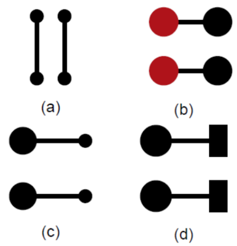


Figure 6.5 Connectedness is a powerful grouping principle that is stronger than (a) proximity, (b) color, (c) size, or (d) shape.

So: use lines to show relationships between objects

Ware (2021), p187

Continuity

We perceive elements as smooth and continuous
(rather than with abrupt change in direction)

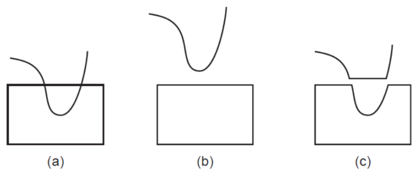


Figure 6.6 The pattern on the left (a) is perceived as a smoothly curved line overlapping a rectangle (b) rather than as the more angular components shown in (c).

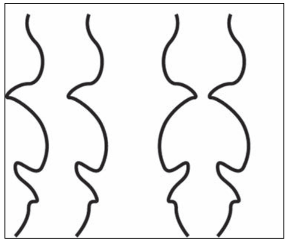
Consider continuity when showing overlapping objects

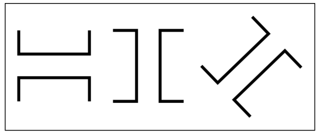
Ware (2021), p188

A bigger aim here is not to have overlapping objects, or to reduce overlaps, so as to avoid image complexity. An example is bubble charts, which uses the size of a bubble or dot, to convey a magnitude.

Symmetry

Symmetric elements tend to be grouped together





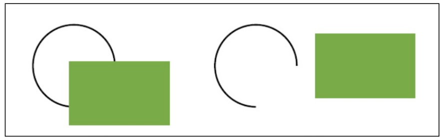
So: use symmetry to make pattern comparisons easier

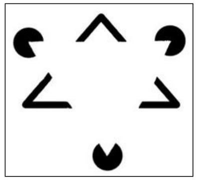
Ware (2021), p189, 191

This (roughly) applies to the use of 'small multiples' of scatterplots and similar charts… having several such charts alongside each other makes it easy to see symmetries and similarities… as well as asymmetries and differences

Closure

Contours with gaps tend to be perceptually 'closed'





So: put related information in a closed contour – defined by line, colour or texture

Ware (2021), p191

Figure and Ground

Small areas tend to be seen as ‘figure’

Context may affect figure/ground interpretation

So: Use closure, symmetry, layout etc. to ensure objects will be perceived as figures, not ground.

Ware (2021), p195

We see a black propeller, not a white one
Ambiguity: between the symmetry and the closure that favours the vase, and the prior knowledge recognitiion of faces (which are very important in real-world context) => competition between mid-level (gestalt) and high-level (contextual object identification) processes.

Common Fate

Things that move together are grouped together

We see a black propeller, not a white one
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Common Fate

Things that move together are grouped together

https://www.youtube.com/watch?v=nuH6dIcgaoU

Don't use concurrent animation on unrelated objects

Issue here is that if you use animation or dynamics in a visualisation, then it should match with the semantics of the data. Don't move things together unless they are related.

Level 3: Object identification

Top-down identification of objects

Often led by a query, task or intention

Supported by memory and context

Crossing the road

What objects would I recognise if I were about to cross this road?
If I were looking for a supermarket, I might see the ASDA sign… but if I were not, then I wouldn’t see it

Interaction between bottom-up and top-down processing

Interaction between bottom-up and top-down processing

Say out loud the **font colour** of the following words

Red Green Purple
Brown Blue Red

Purple Red Brown
Red Green Blue

The Stroop Effect

- The top-down processing (reading the words) interferes with the bottom-up processing (identifying the colours)… so the second row of words is usually read more slowly
- Effect found to be reduced in young children learning to read, but increased in older children with dyslexia

Every word was shown for exactly the same amount of time!

Summary

- **Level 1 (bottom-up)**
  - pre-attention
  - colour
- **Level 2 (bottom-up & top-down)**
  - pattern identification
  - Gestalt laws
- **Level 3 (top-down)**
  - object identification
- Interference between levels

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