Information Visualisation (3) Marks and Channels; Colour Mapping

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Course Outline

- Introduction to Information Visualisation
- Data, Task and Validation
- Marks and Channels; Color Mapping
- Tables, Spatial data, Networks and Trees
- Manipulating View, Facetting, Focus + Context
- Reduce Items and Attributes + Some Cases Analysis

Program for Today

- Marks
- Channels
  - Channels effectiveness
- Colour
  - Colour spaces
  - Colourmaps
- Other channels

Marks? Channels? Colour?

- Finding the right visual notation for your data/attribute
- Dependent on human perception

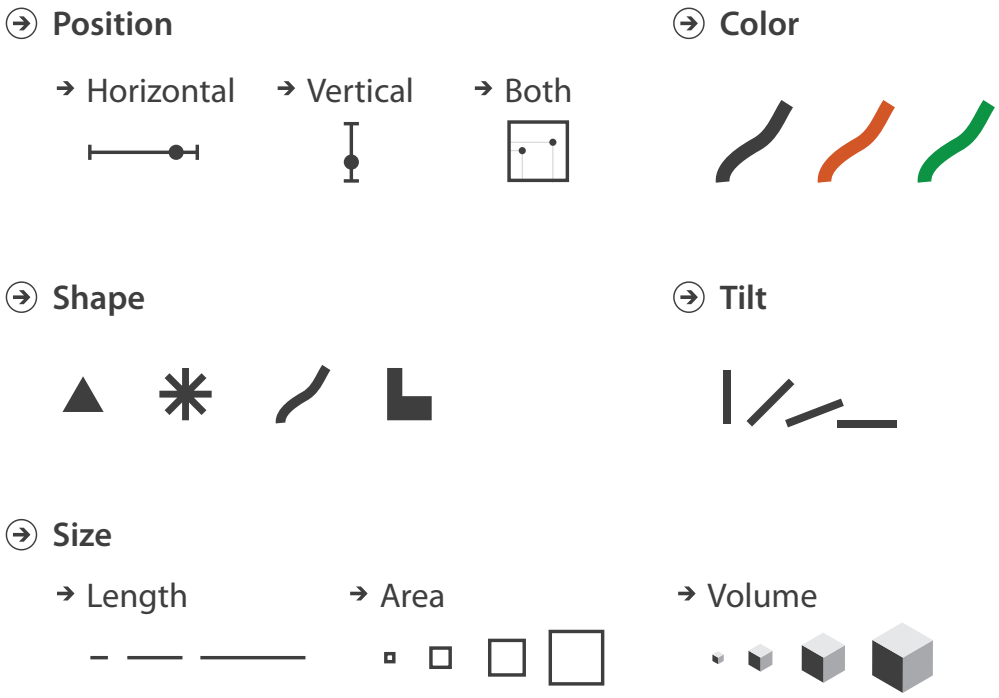
Marks?

- Mark:
  - Basic graphical element in an image
  - Geometric primitive object
  - 0D -> point, 1D -> line, 2D -> area, 3D -> volume

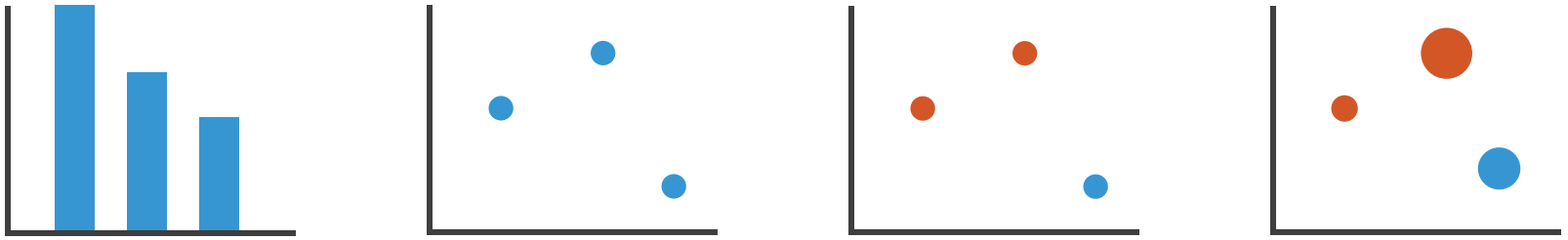
Points **Lines** **Areas**

Channel?

- (Visual) channel:
  - Way to control the appearance of marks, independent of the dimensionality of the geometric primitive
  - May pertain to spatial position, colour, size, motion, shape...



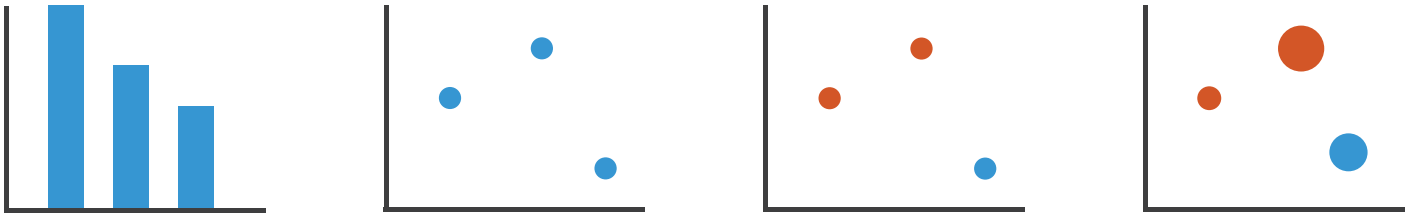
An Introductory Example



How many encoded attributes?

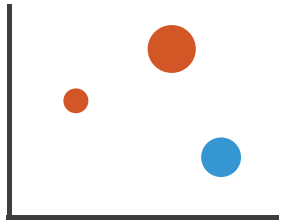
An Introductory Example

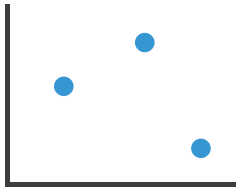
- In this example…
  - 1) Two attributes (X categorical/Y quantitative)
  - 2) Two attributes (X quantitative/Y quantitative)
  - 3) Three attributes (X quantitative/Y quantitative/colour)
  - 4) Four attributes (X quantitative/Y quantitative/colour/size)
- Each attribute can convey one dimension…
- … Or you can introduce redundancy between attributes…
- … Some channels are more efficient for certain attributes…
  - E.g. bars in bar chart convey a sense of size better than scatterplots

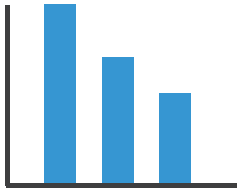


Channel Types

- Two main types of channels: identity and magnitude
  - Identity: tells us information about *what* something is or *where* it is
  - Magnitude: tells us *how much* of something there is
- Identity example: shapes, hue, motion pattern…
- Magnitude example: line length, luminance, size…
- Linked to how the human perceptual system works
- -> All channels are not equal!

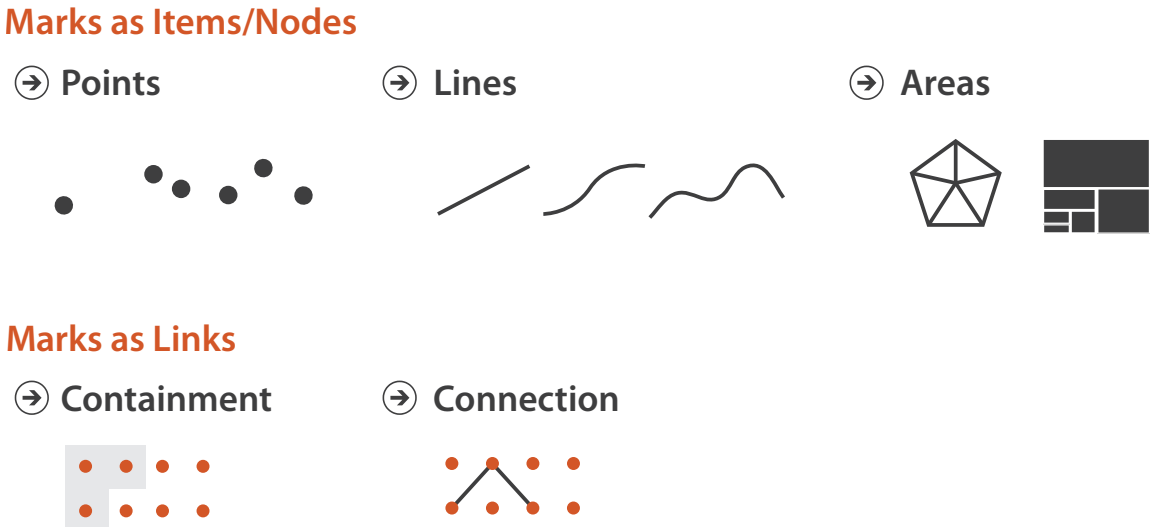






Mark Types

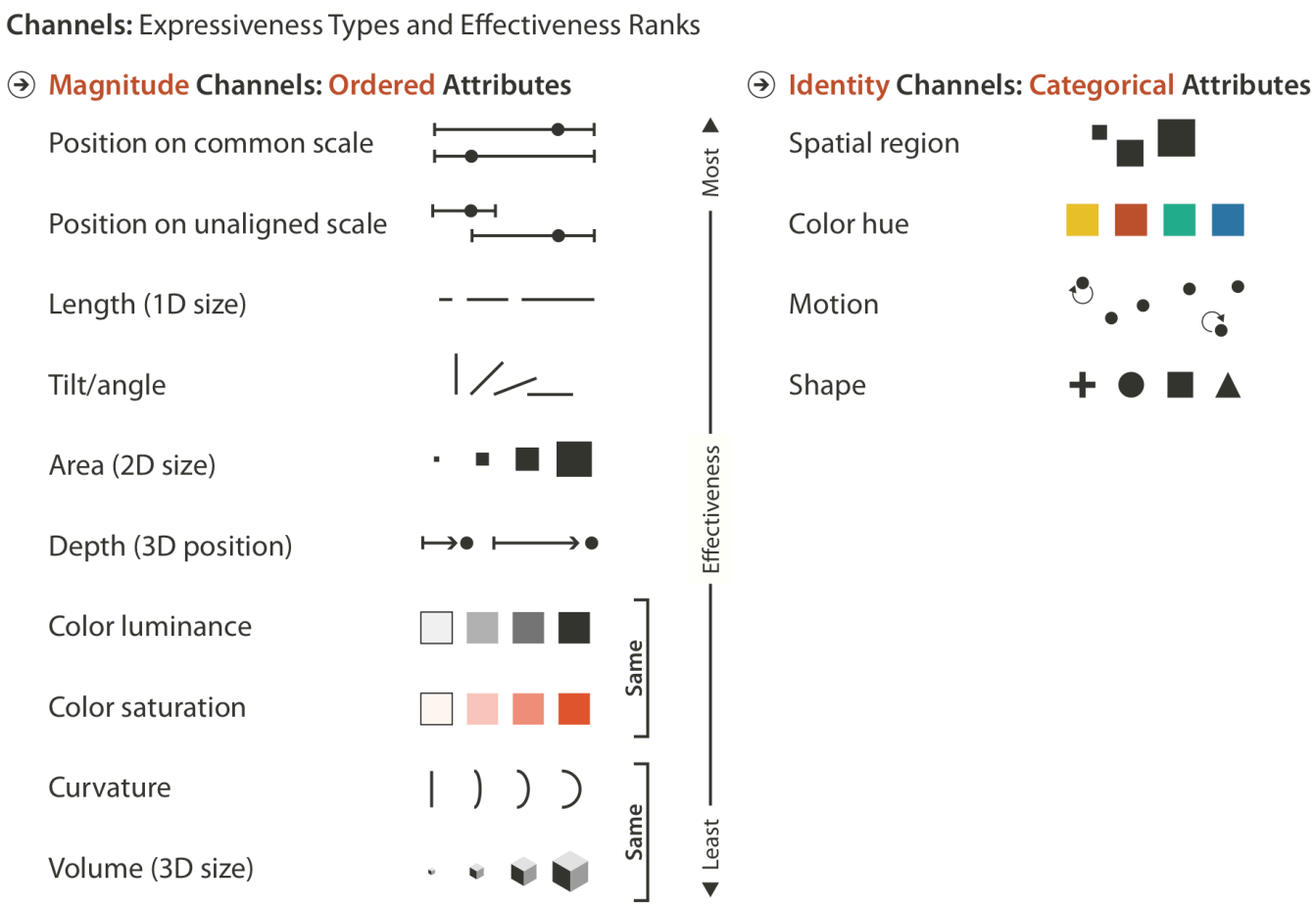
- Mark types:
  - For tables datasets: items
  - For networks and graphs: connections
  - For relationships: enclosures (using areas)



Channels Expressiveness and Effectiveness

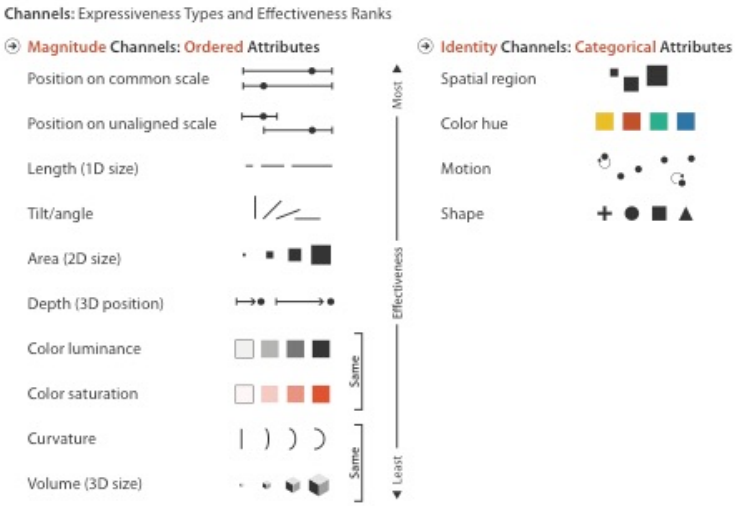
- Two principles
- Expressiveness principle: *the visual encoding should express all of, and only, the information in the dataset attributes*
  - Example: ordered data should be displayed in a way that our perceptual system considers as ordered
  - Follow-up example: unordered data should be displayed in a way that our perceptual systems does not consider as ordered...
- Effectiveness principle: *the importance of the channel should match the salience of the channel*
  - Salience = noticeability
  - E.g. the most important attributes should be encoded with the most effective channels
  - ... But what is an effective channel?...

Channel Effectiveness: Ranking of channels



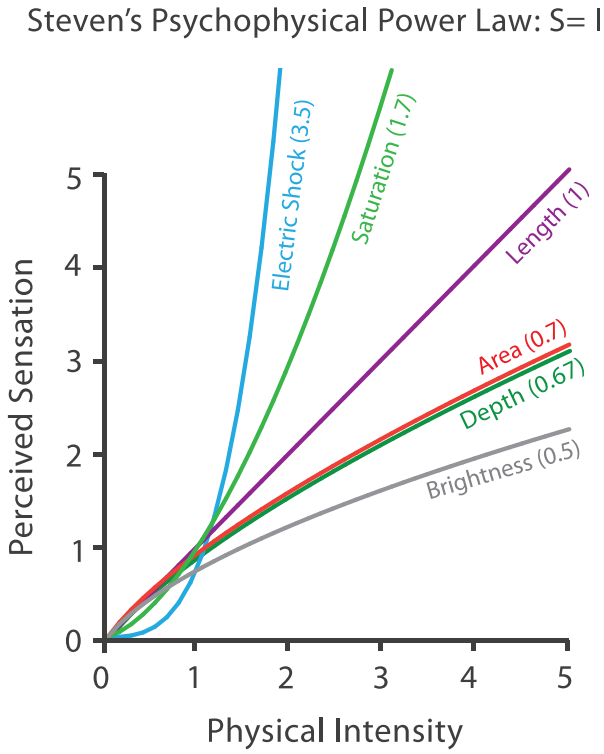
Channel Effectiveness: Ranking

- Some remarks on the rankings:
- Magnitude/ordered vs. Identity/categorical
  - You *can* use a magnitude channel for an identity attribute, but it's really (really) NOT advised
- Most effective channels are on top
- Most effective channels are spatial..
  - Primacy of spatial channel
  - Best linked to users' mental models
  - ... But it applies only for 2D.
    - 3D is strongly ill-advised for infovis



Channel Effectiveness: Accuracy

- Accuracy to assess channel effectiveness w.r.t. perception
- Demonstrated as exponential law

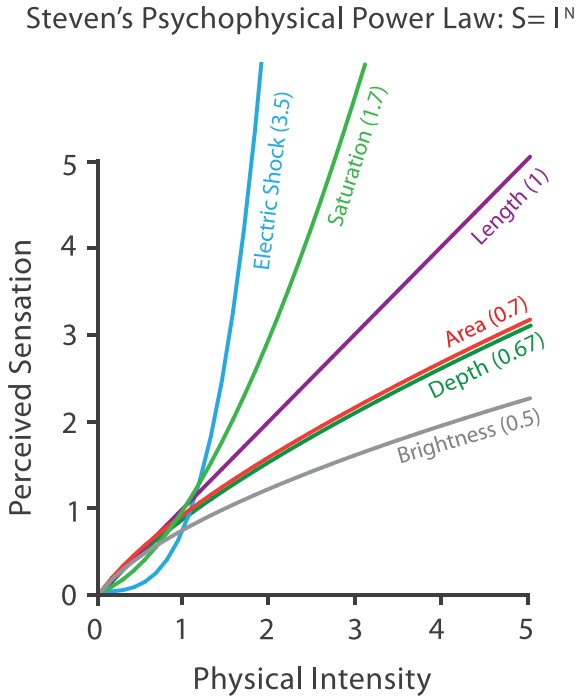


S: perceived sensation
I: physical intensity
N: dependent of channel

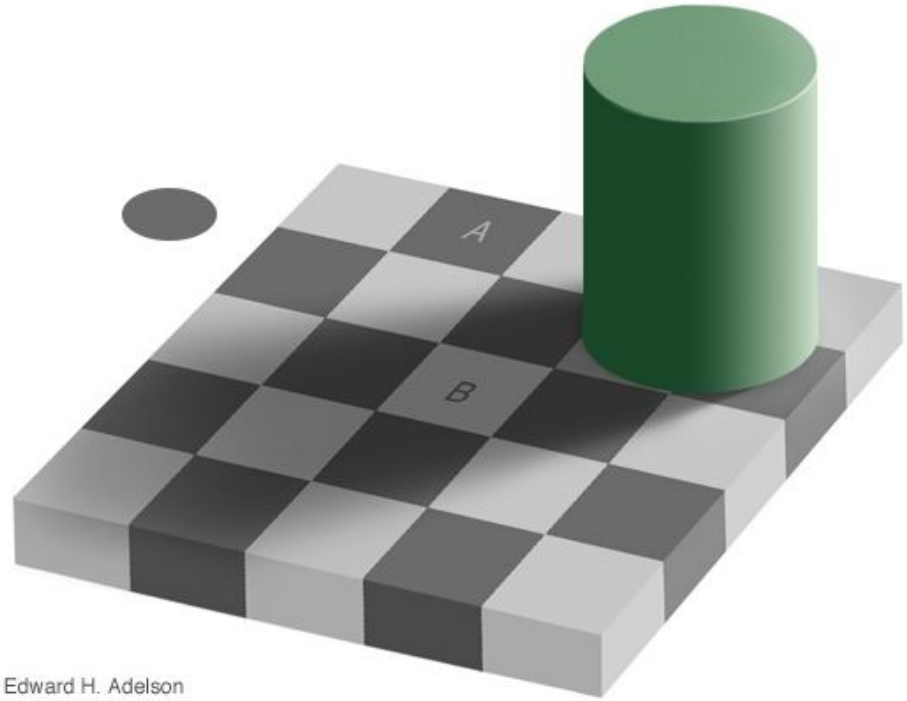
Stevens, S. S. (2017). Psychophysics: Introduction to its perceptual, neural and social prospects. Routledge.

Channel Effectiveness: Accuracy

- Observations:
- Some channels' perception is magnified…
  - E.g. doubling electrical shocks (much) more than doubles perception
- … While others' perception is compressed
  - E.g. doubling brightness is much less perceived
- One special case: length, with N = 1
  - Best accuracy in terms of perception

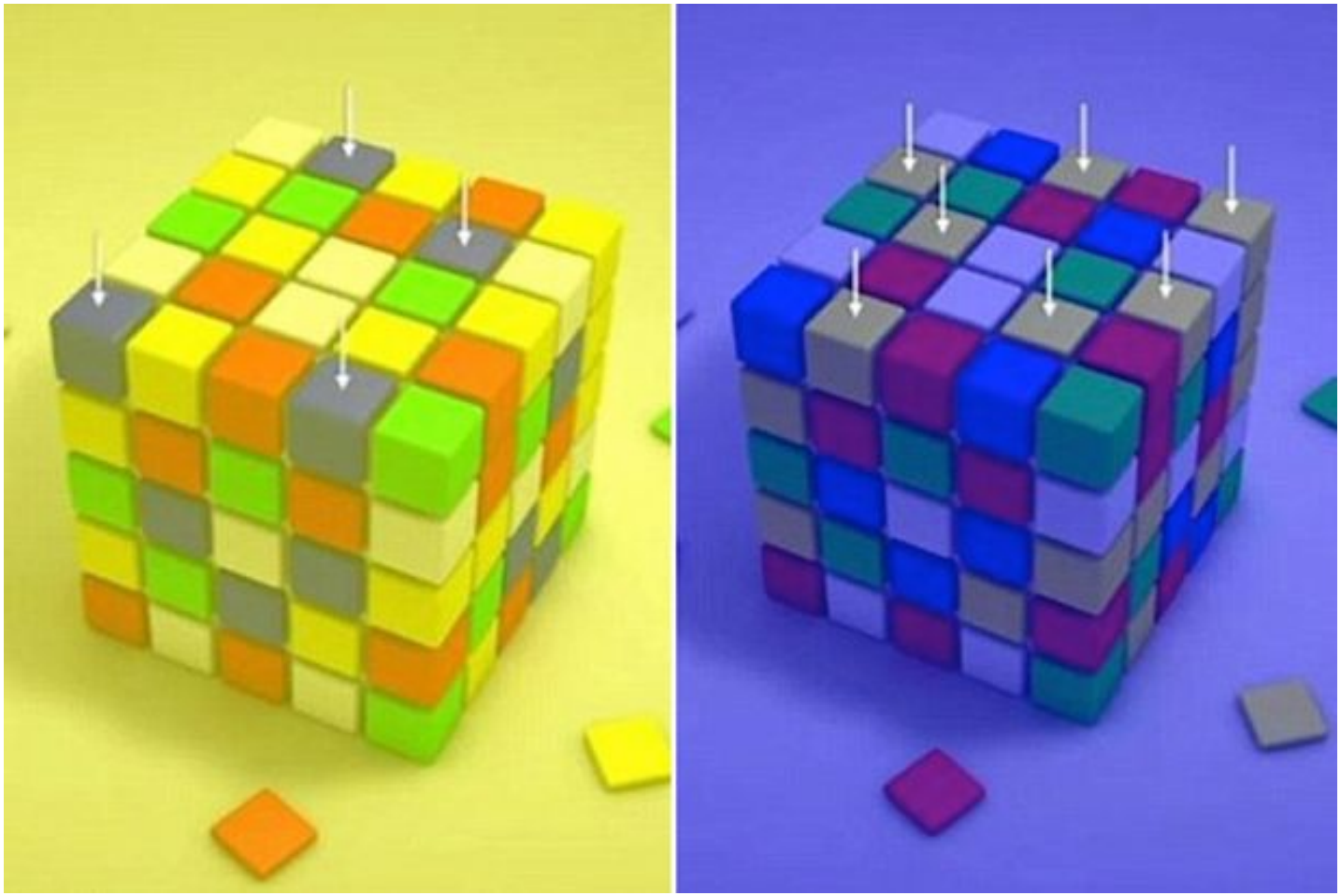


Break: A Small Brightness Test…



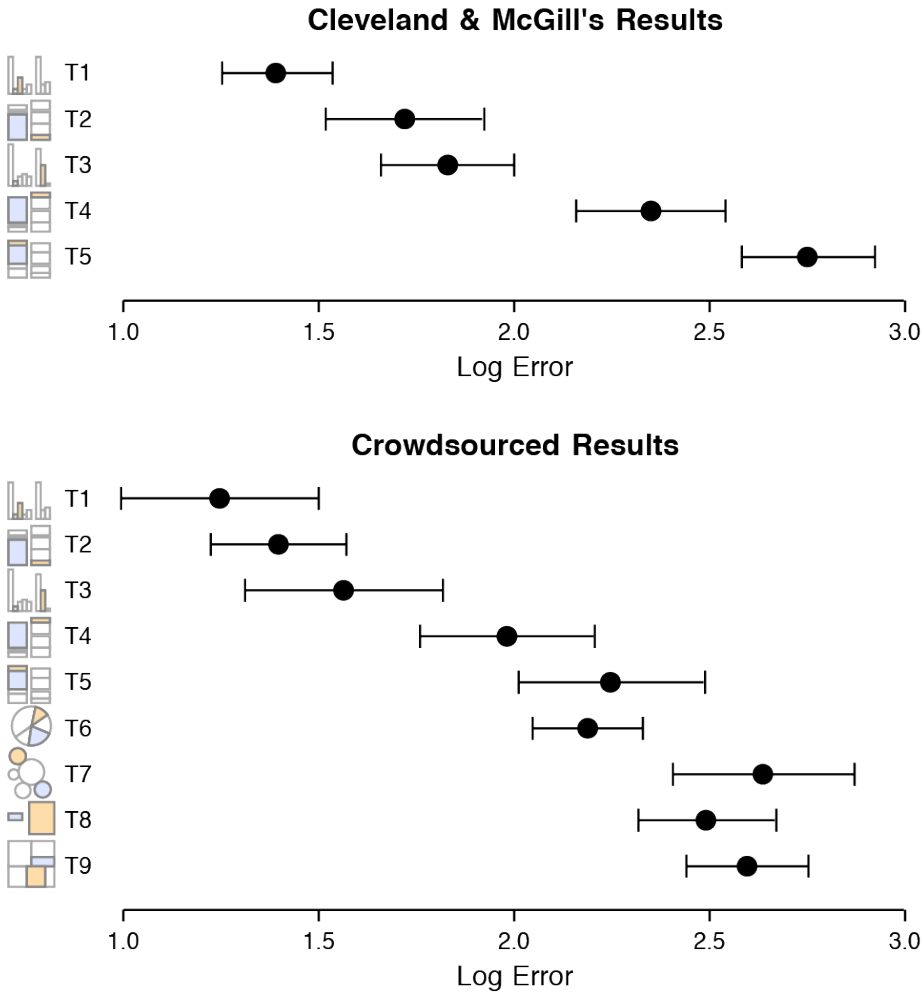
Edward H. Adelson

Break: A Small Hue Test…



Channel Effectiveness: Accuracy

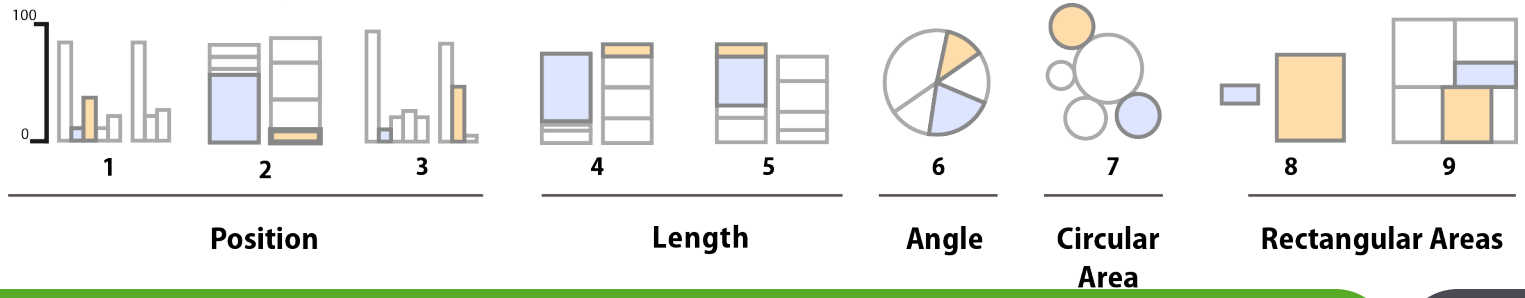
T1-T5: positions
T6: angles
T7: circular areas
T8-T9: rectangular areas



Heer, J., & Bostock, M. (2010, April). Crowdsourcing graphical perception: using mechanical turk to assess visualization design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 203-212). ACM.

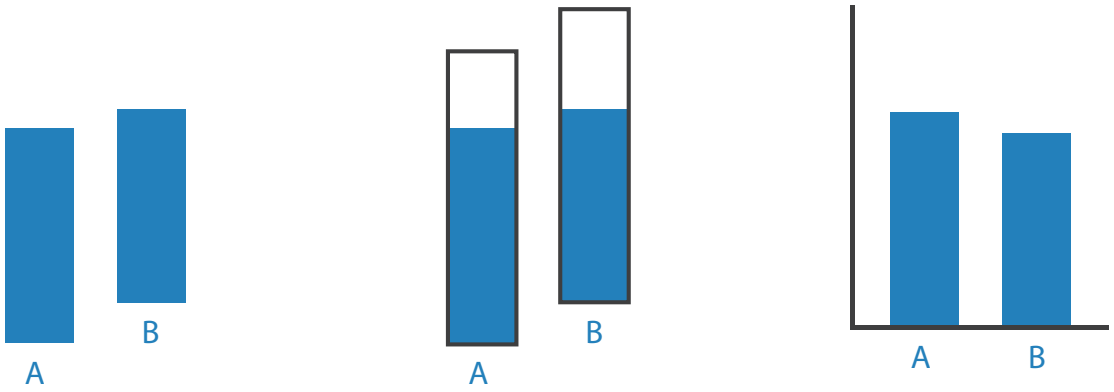
Channel Effectiveness: Accuracy

- Aligned position against a common scale is #1
- Follows:
  - Unaligned position against identical scale (#2-3)
  - Length (#4-5)
  - Angle (#6)
- Area judgements are much worse…
  - Circular and rectangular areas (#7-8-9)
- Untested: volume, curvature, luminance would be #10-11-12
- Hue (*as magnitude channel*) would be last



Channel Effectiveness: Accuracy

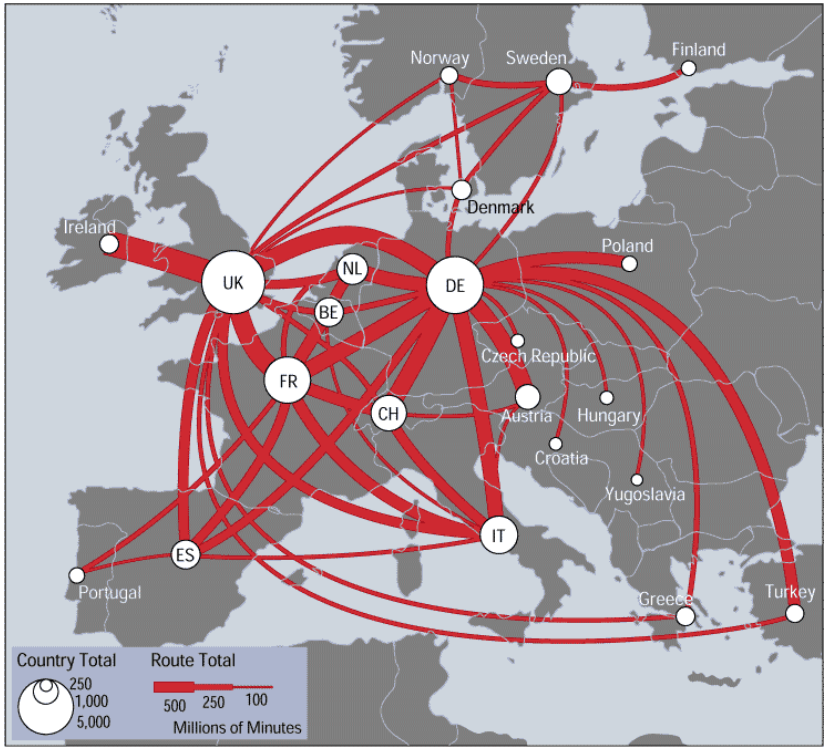
- Example: unaligned vs. reference frame vs. aligned
- Human perceptual system is based on relative judgements
  - *Weber's Law*
  - As an aside, true for all modalities
  - Explains the two (brightness/hue) examples before



Unframed Unaligned | Framed Unaligned | Unframed Aligned

Channel Effectiveness: Discriminability

- Discrimanibility: are the differences between items perceptible to the user?
- Concept of bin = distinguishable level within a visual channel
  - Exemple with line width: how many levels can you spot on this image?



https://mappa.mundi.net/maps/maps_014/telegeography.html

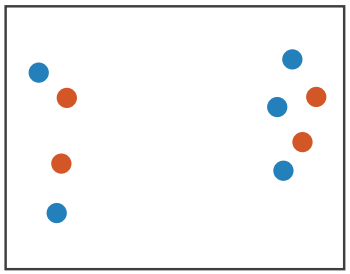
Channel Effectiveness: Separability

- Different channels on a visualisation are not independant one from the other
- Separable channels integral channels

Orthogonal, independant combined

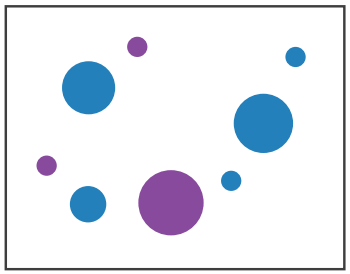
- Let us consider four examples:

Position
+ Hue (Color)



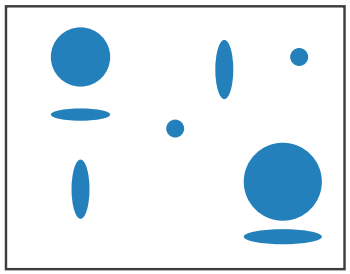
Fully separable

Size
+ Hue (Color)



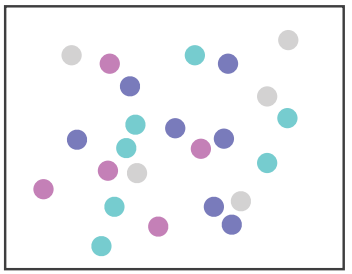
Some interference

Width
+ Height



Some/significant interference

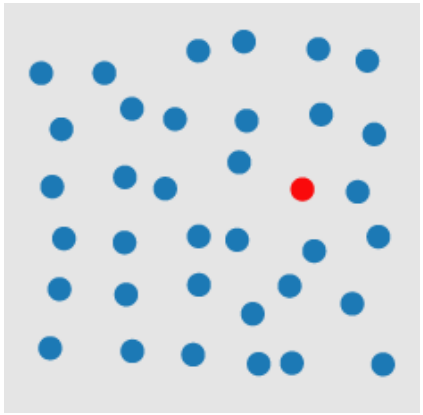
Red
+ Green

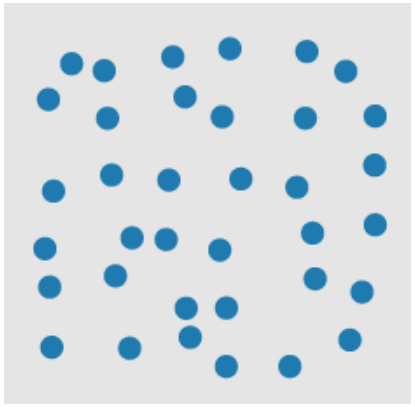


Major interference

Channel Effectiveness: Popout

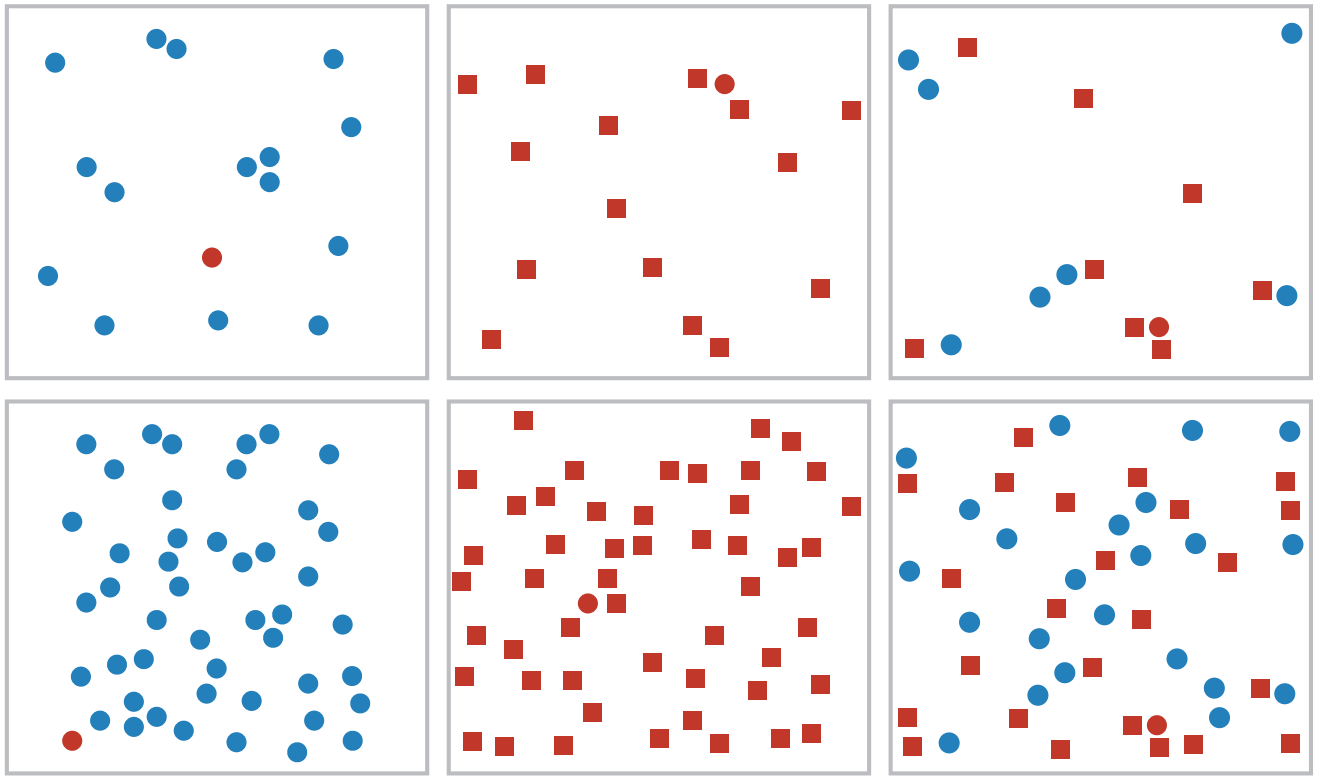
- Eye movements take at least 200 msec. to initiate
- Tasks performed in less than 200-250 msec. are considered preattentive
- A limited set of visual properties are detected very rapidly by the low-level visual system





Channel Effectiveness: Popout

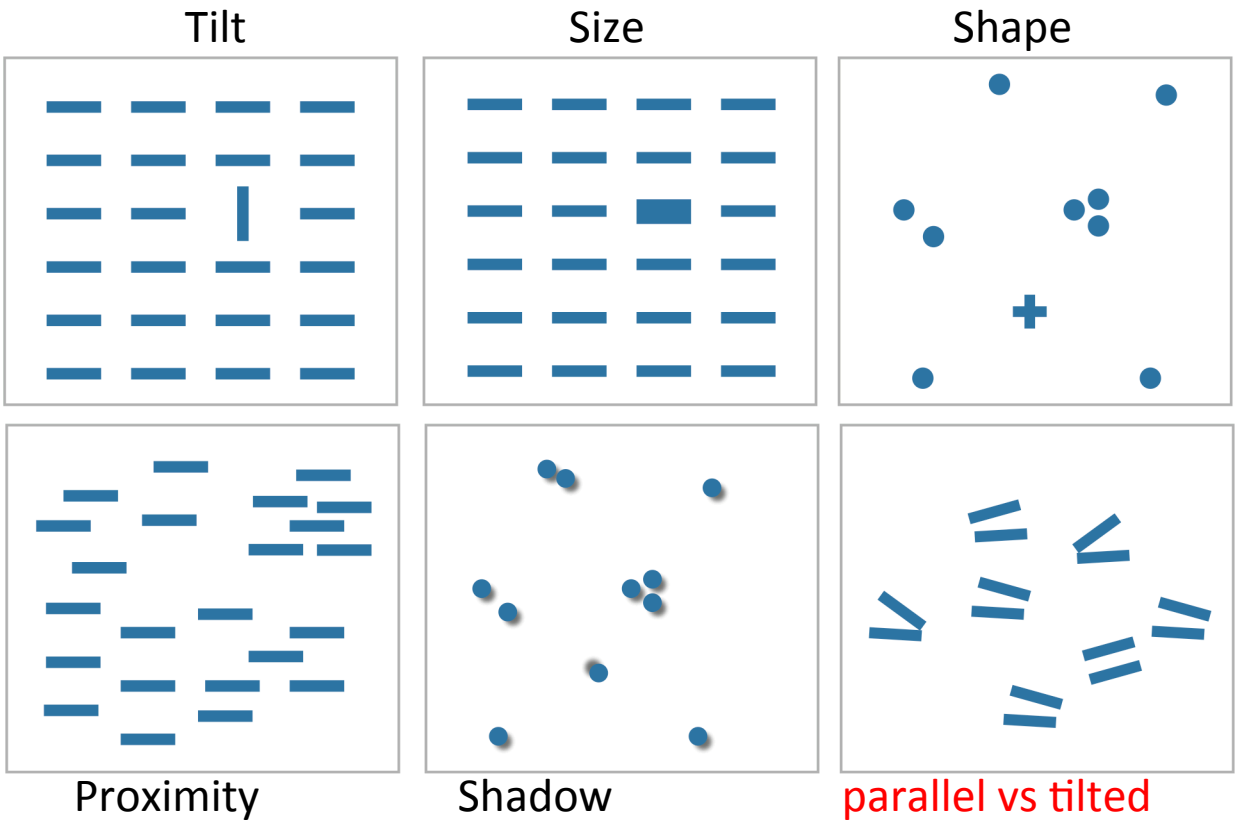
- Popout is not an all-or-nothing phenomenon
- Some examples (again): find the red circle !



Only serial search can help detect it!

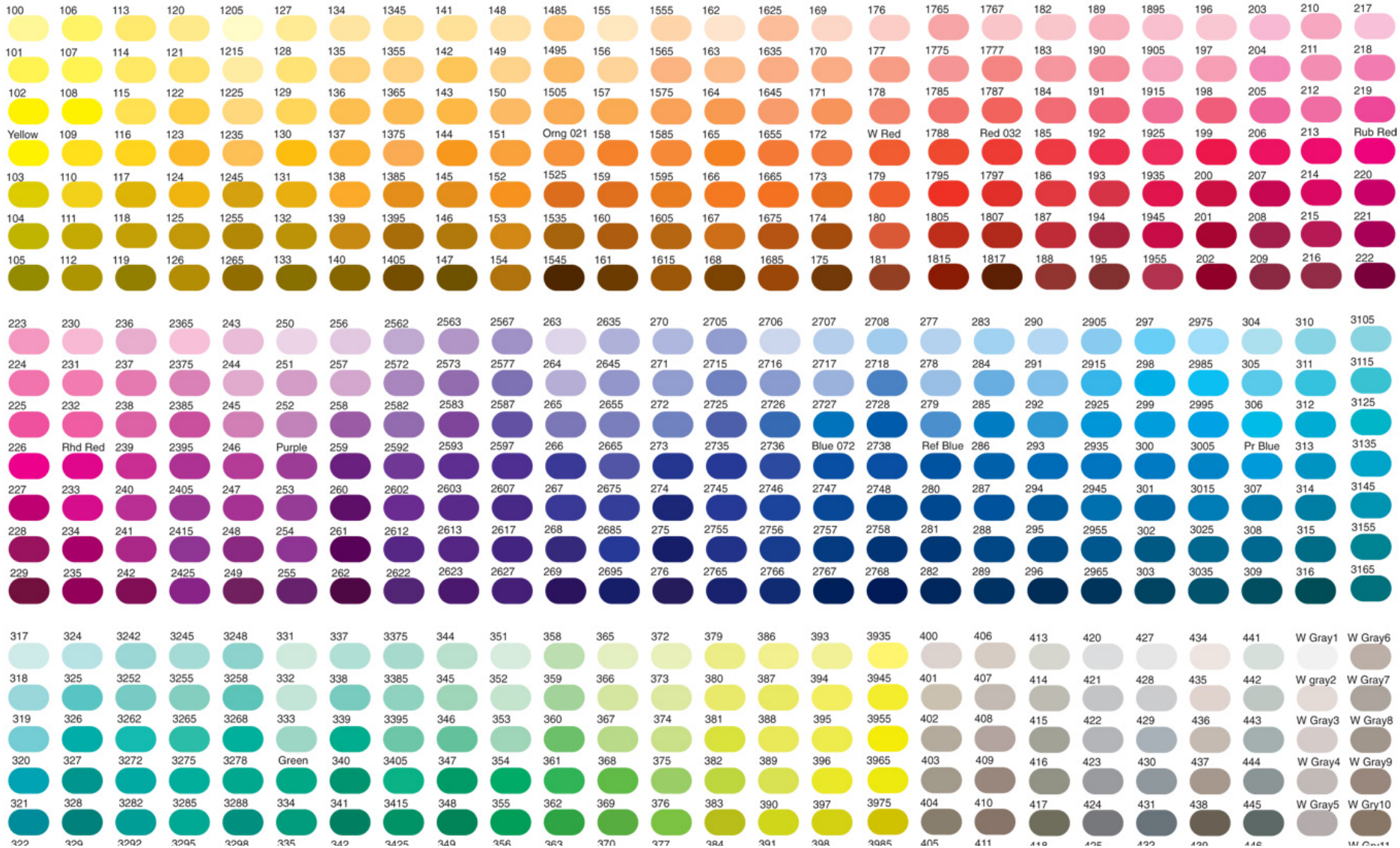
Channel Effectiveness: Popout

- Some channels are very good, others less, for popout



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

Colour Mapping

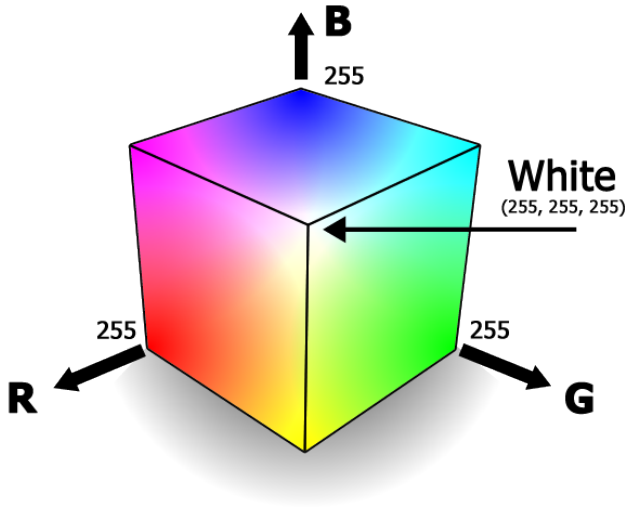


Colour Vision

- Two different kind of receptors in the human eye:
  - Rods -> low-light settings, provide low-resolution black and white info
  - Cones -> three types, each sensitive to different wavelengths
  - Information from cones processed in three opponent colour channels
    - Red to green (medium resolution)
    - Blue to yellow (medium resolution)
    - Black to white luminance (very high resolution)
  - Strong impact of opponent colour channels on visual encoding design
  - Opponent colour channels help explain colour blindness

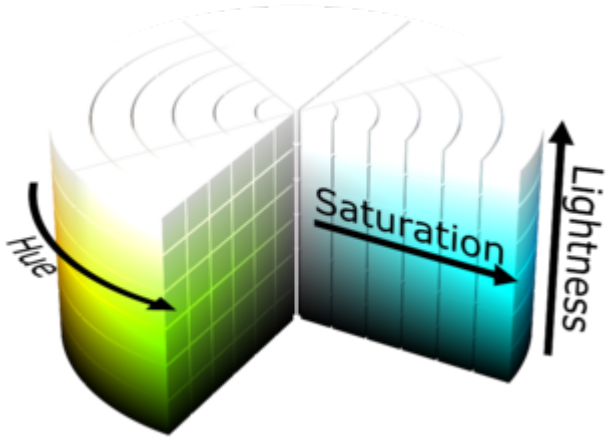
Colour Spaces

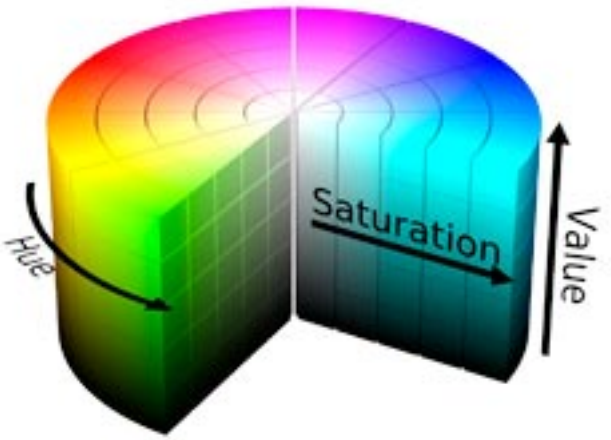
- Multiple descriptions of the colour space that humans can detect
- Most common colour space in computer systems: RGB (red-green-blue)
  - Red 0 – Green 0 – Blue 0 -> **Black**
  - Red 255 – Green 255 – Blue 255 -> White
  - Red 255– Green 255 – Blue 0 -> Yellow
- Computationally convenient...
  - ... But not very useful for infovis
  - Red, green and blue axes are not good as separable channels



Colour Spaces

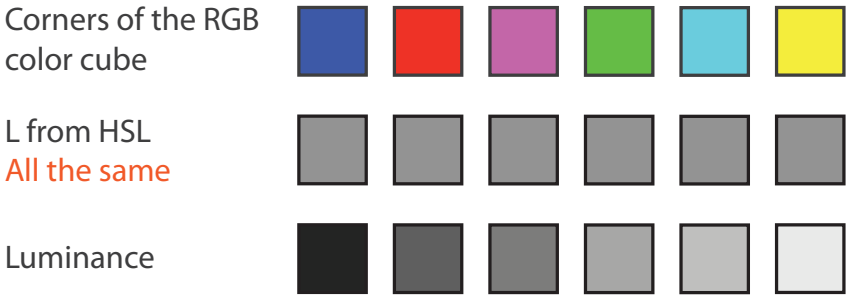
- A better colour space for information visualisation (well, two): Hue-Saturation-Lightness (HSL) / Hue-Saturation-Value (HSV)
  - Heavily used by artists and designers
  - Hue: pure colors, except black and white
  - Saturation: amount of white (or black) mixed with the pure color
  - Lightness/Value: gray scale

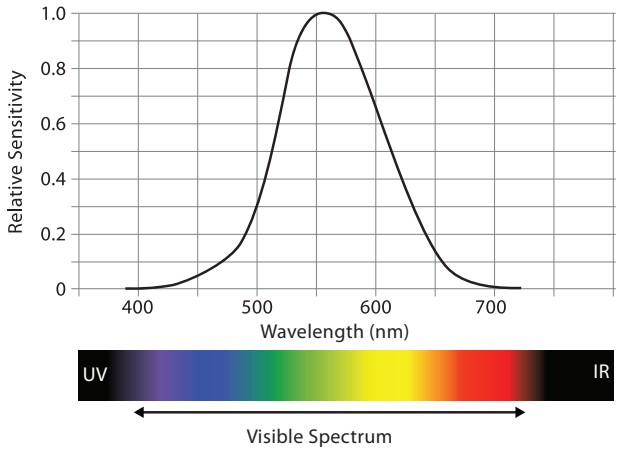




Colour Spaces

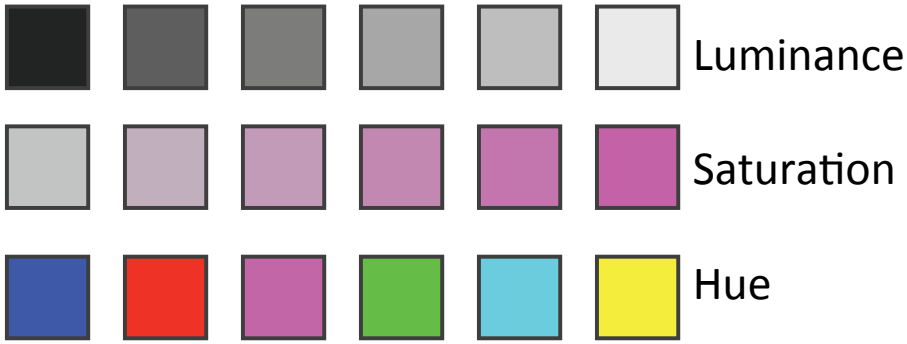
- HSL/HSV is only *pseudoperceptual*: it does not truly reflect how we perceive colour
- Theoretical luminance all the same for « pure colours » while actual luminance is wildly different
- Amount of luminance humans perceive linked to wavelength
  - Spectral sensitivity





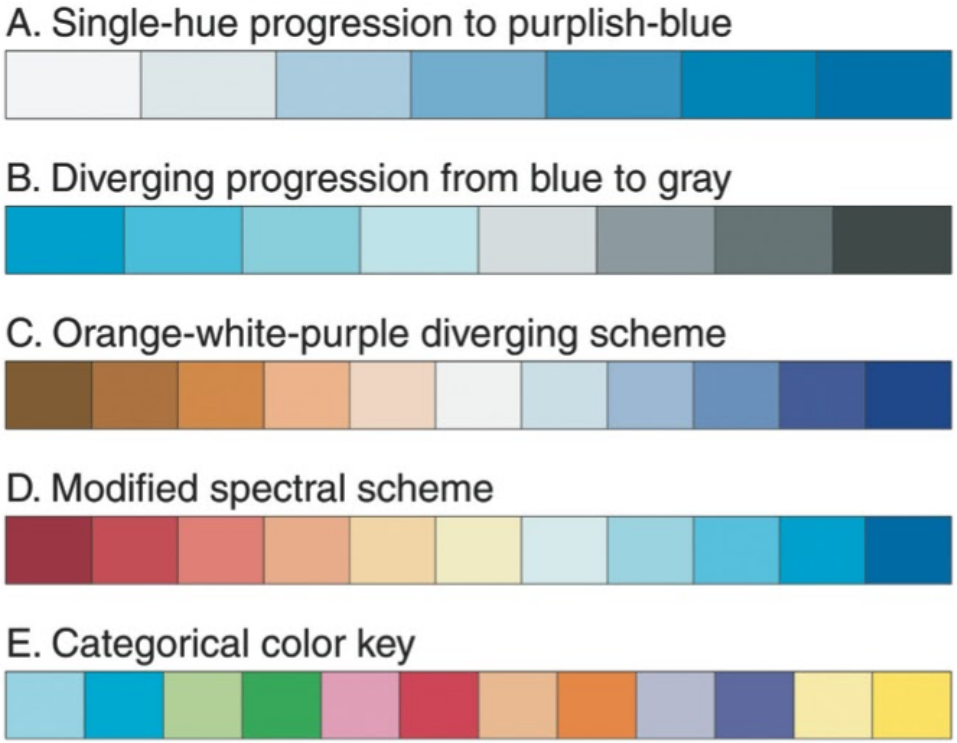
Colour Spaces: Luminance, Saturation and Hue

- Luminance (aka lightness/value): magnitude channel
  - Suitable for ordered data, but small number of bins available (< 5)
  - Also, luminance is frequently used for fine detail and crisp edges
    - Typical case: text reading needing a contrast ratio of 10:1
- Saturation: magnitude channel
  - Also suitable for ordered data, also suffers from small bin number (~3)
  - Saturation interacts strongly with size: the smaller the item, the more difficult saturation is perceived
- Hue: identity channel
  - Extremely effective for categorical data
  - No implicit ordering
  - Around 6-12 bins discriminable



Colourmaps

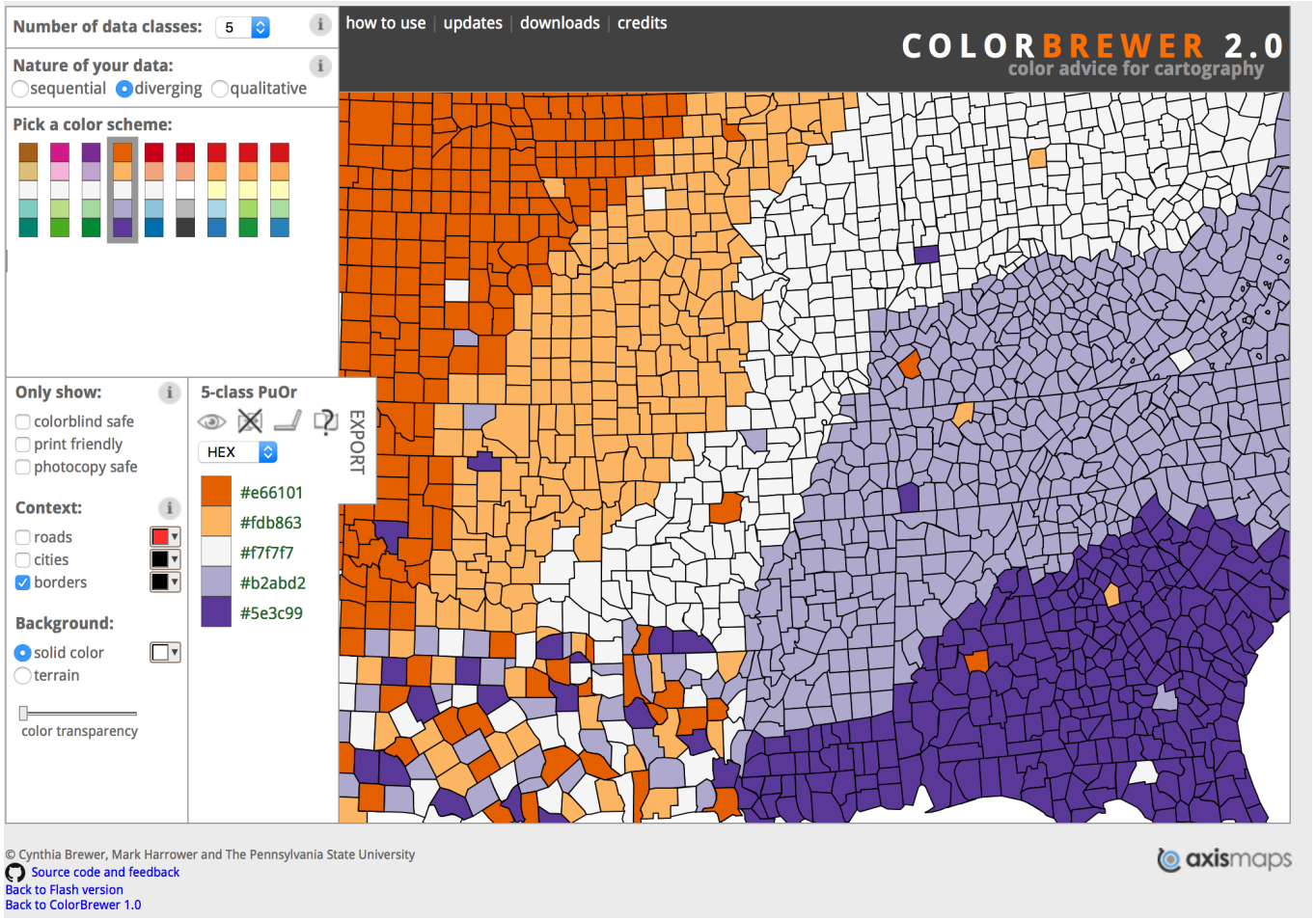
- Colourmap = mapping between colours and data values
  - ~ visual encoding with colour



Categorical Colourmaps

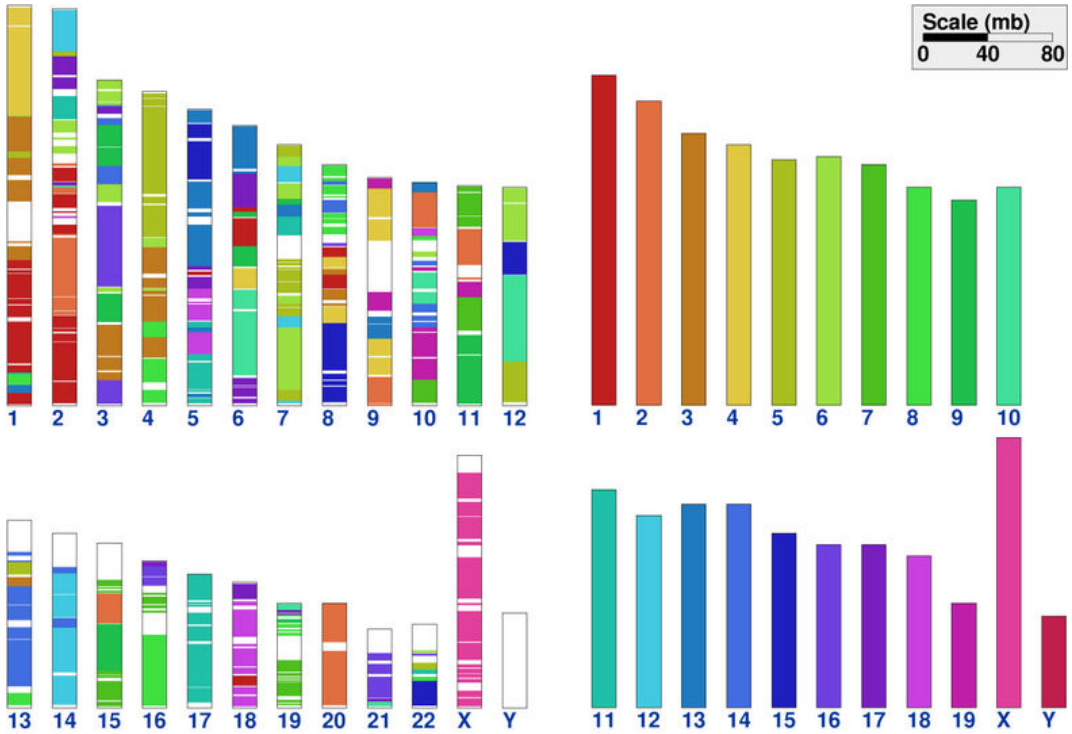
- Categorical (aka qualitative) colourmaps
- Best next channel for categorical data (after spatial position)
- 6-12 bins discriminable (with background colour!)
- Careful attention must be paid to luminance and saturation
- Multiple categorical colourmaps available on the web

Categorical Colourmaps: Colorbrewer



http://colorbrewer2.org/

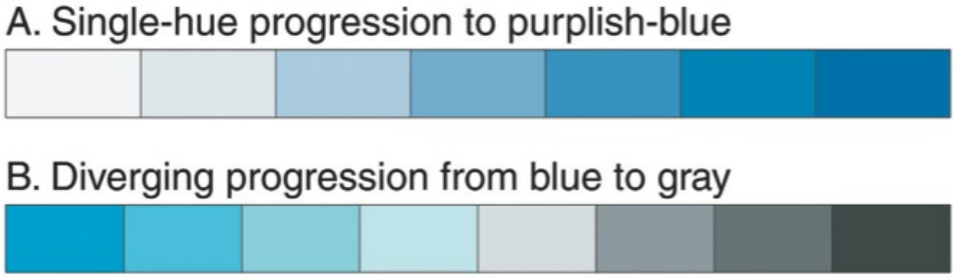
Categorical Colourmaps: Bad Example



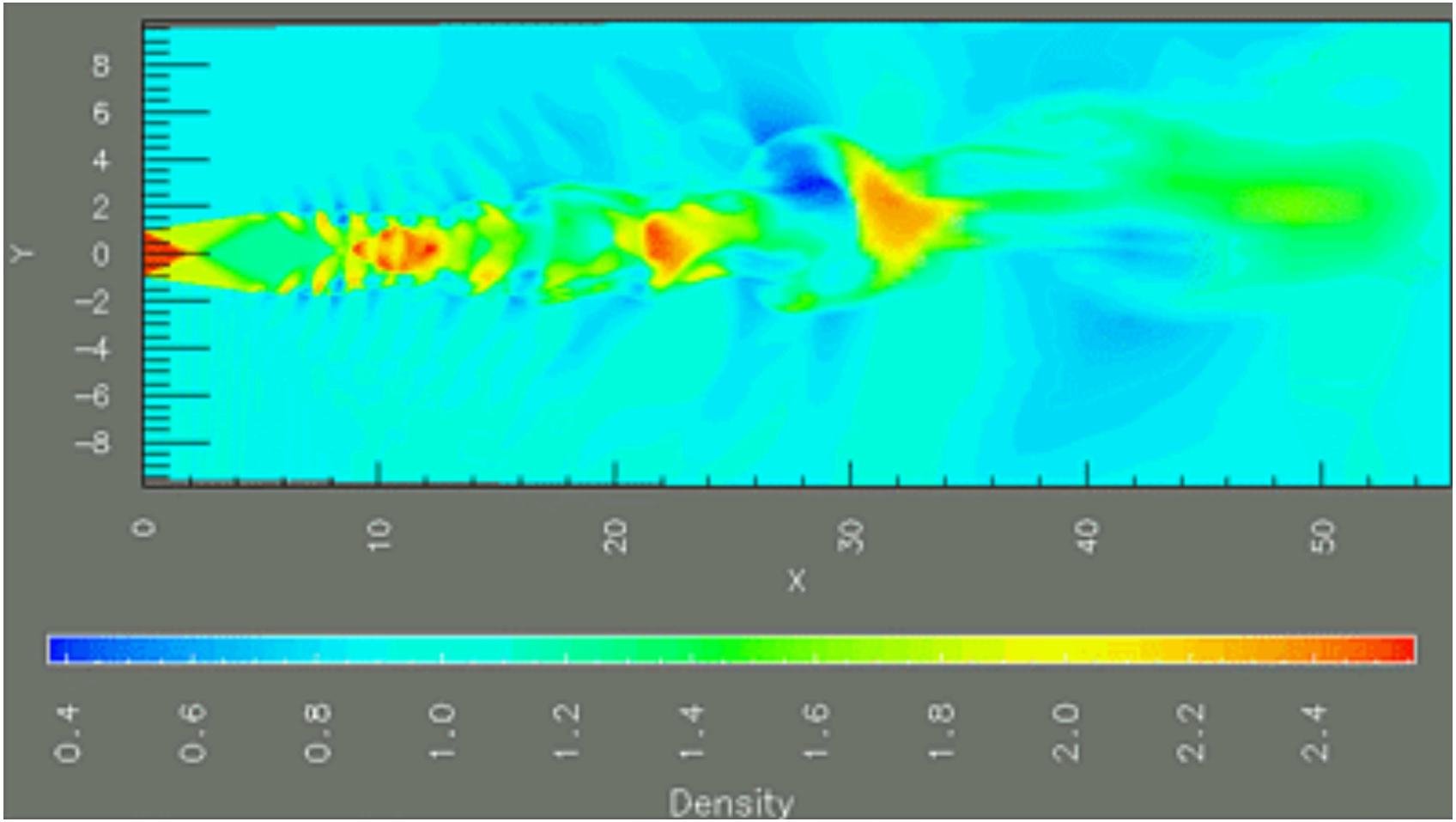
- Too many colour bins, especially considering the size of the smaller regions on the right side
  - An alternative: use a different visual encoding idiom in complement
  - Shape, texture, length...

Ordered Colourmaps

- Appropriate for encoding ordinal or quantitative attributes
  - Types of ordered colourmaps: sequential, diverging
- Sequential colourmap: ranges from minimum to maximum value of a single scale
  - Extreme case: only using luminance -> from black to white
- Diverging colourmap: two hues at the endpoints and a neutral colour (white, grey, some shades of yellow…) in the middle
  - Possibility to combine multiple continous colourmaps to put the focus on different aspects of the visualisation

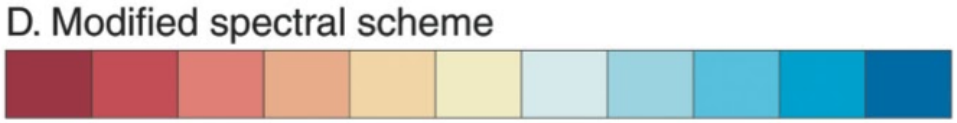


Ordered Colourmap Example

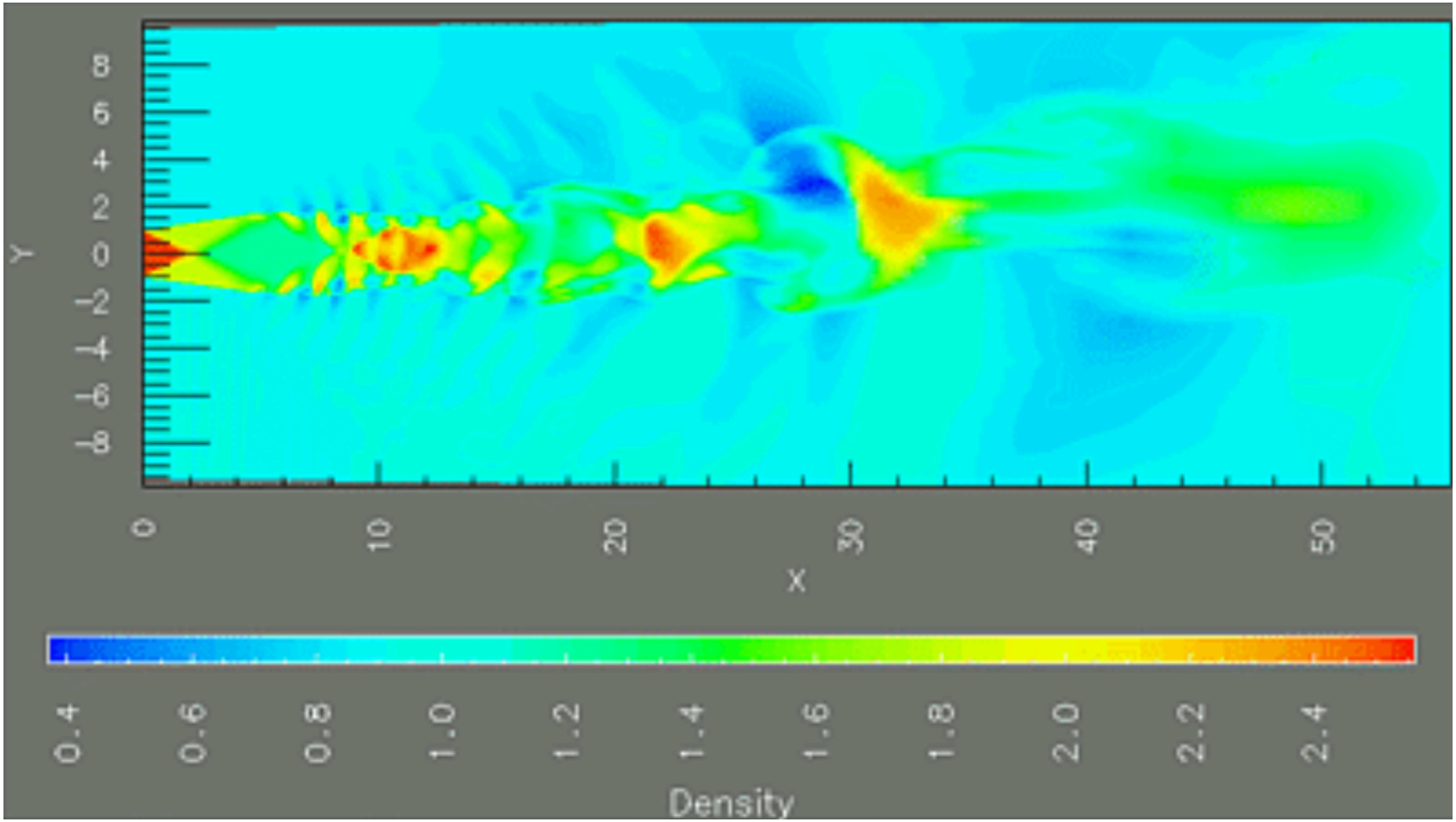


Colourmaps: the Case of Rainbows

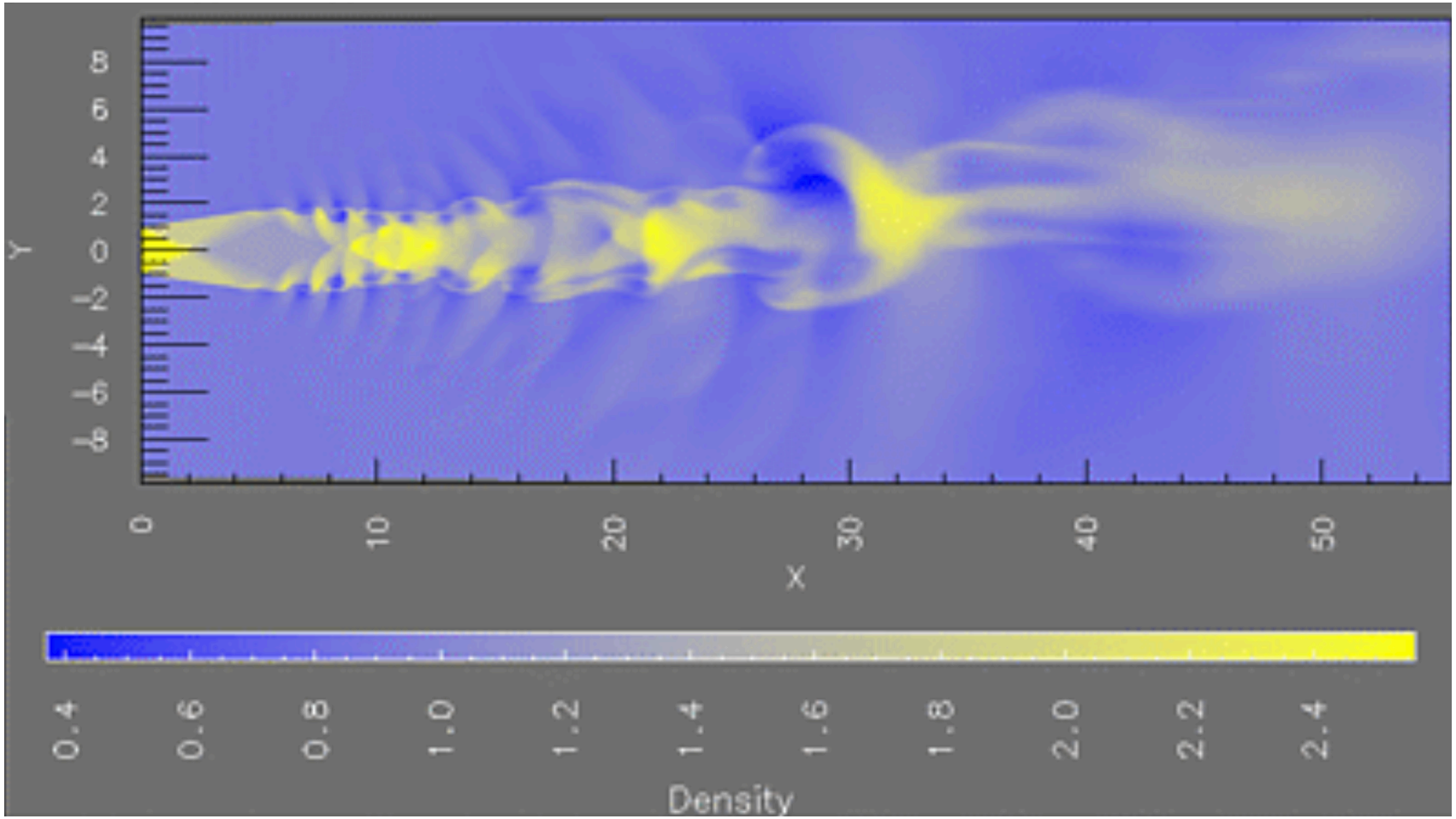
- Rainbow colourmaps are classic basic choice in many software packages
  - Sadly, not always (by far) the best choice
- Pro: easily distinguishable colour subranges
  - ... easily namable, too: « the red part versus the green part »
- Cons:
  - They are frequently used to indicate order, while hue is better suited as an identity channel
  - Scale is not perceptually linear
  - Fine detail can be hard to perceive
- Variant: work on luminance + hue



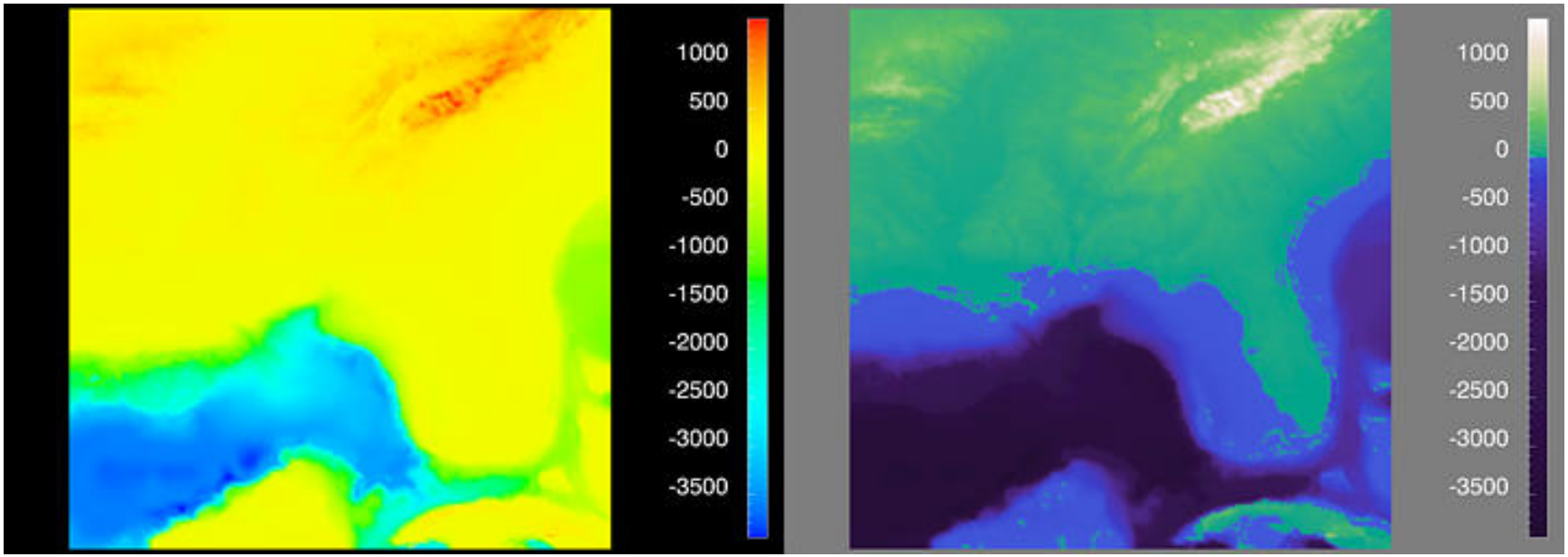
Ordered Colourmap Example



Alternative Colourmap for the Example Before

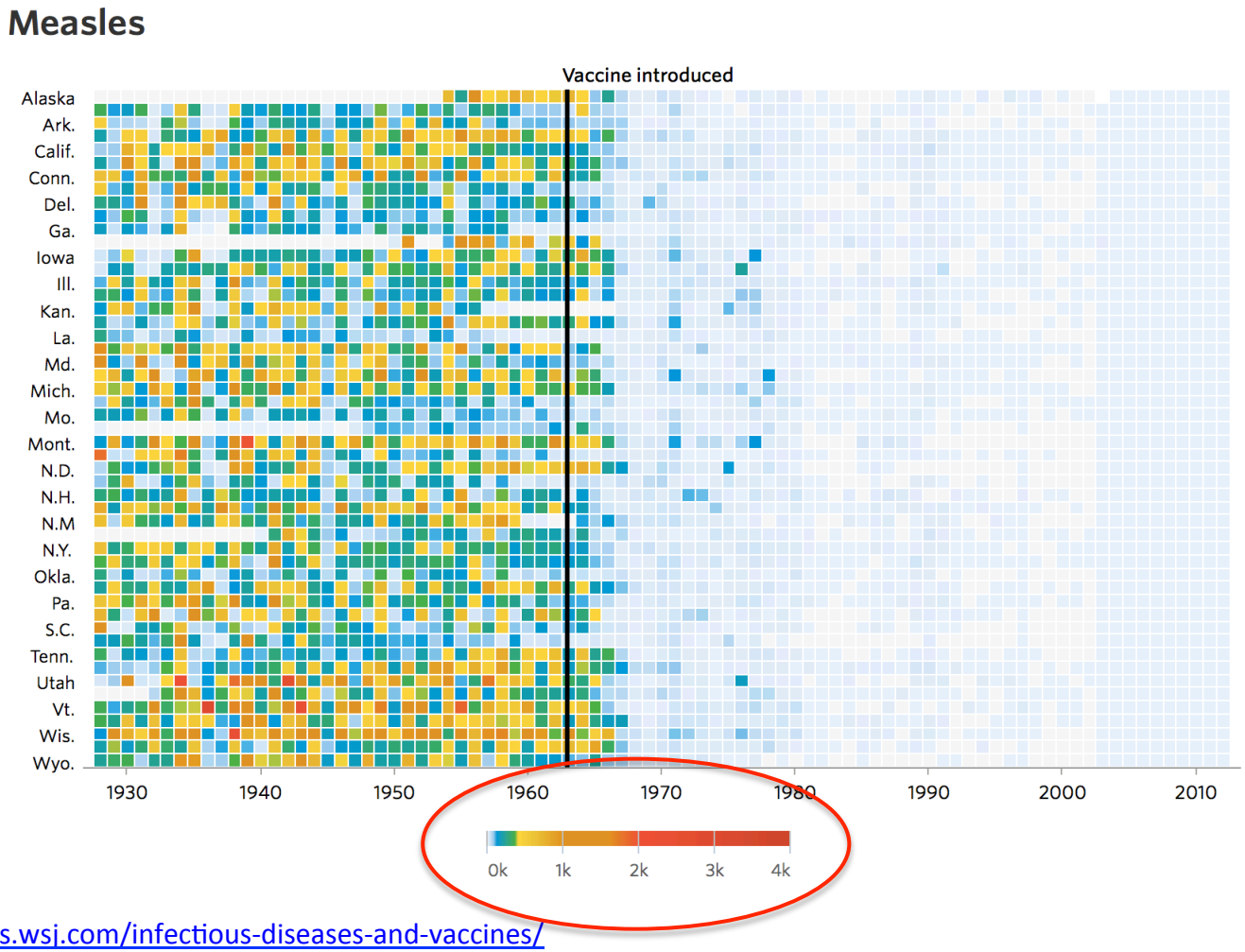


Ordered Colourmaps Example – Rainbow vs. Carefully Designed Colourmap



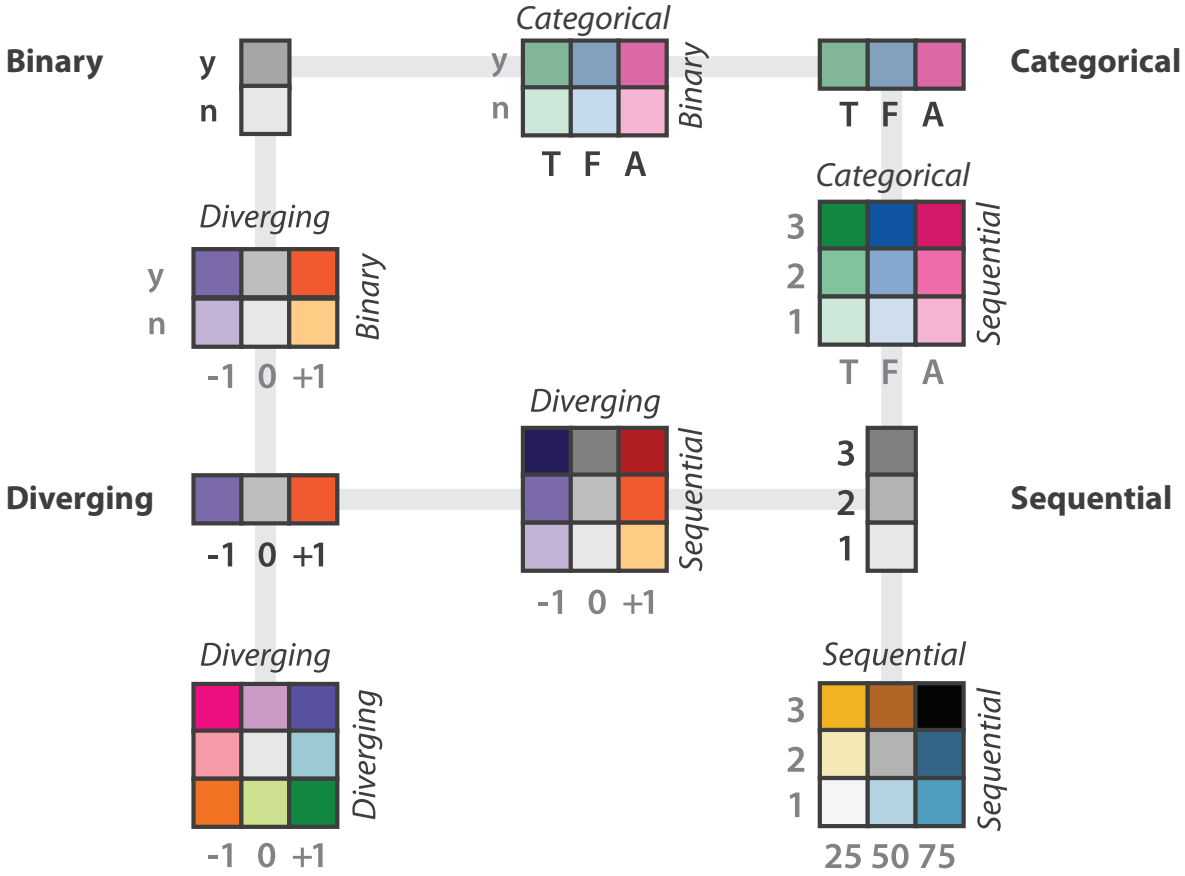
https://www.research.ibm.com/people/l/lloydt/color/color.HTM

Colourmaps: Remember This?



http://graphics.wsj.com/infectious-diseases-and-vaccines/

Taxonomy of Colourmaps

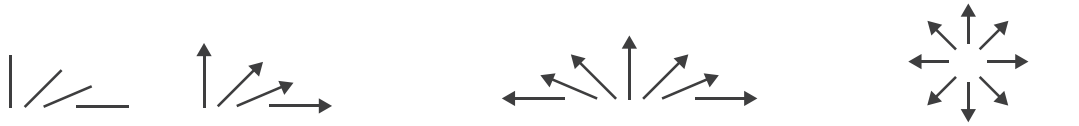


The Case of Colour Blindness

- Colour blindness: affects 8% of males, 0.5% of females
- How to make sure your vis is colourblind-friendly?
  - Best case: avoid using hue as a channel altogether
  - Common case: Avoid relying on red/green colourmaps
- Practical case: many tools available online to help you
  - http://rehue.net
  - http://www.color-blindness.com
  - http://www.etre.com/tools/colourblindsimulator/

Other Channels…

- Size channel for magnitude
  - Length extremely accurate (especially when a landmark is available)
  - Area less accurate
  - Volume quite inaccurate
- Angle channel for magnitude
  - Orientation/direction
  - Angle has cyclic properties
  - Perception of angle very good near horizontal, vertical and diagonal positions, less good everywhere else



Sequential ordered line mark or arrow glyph

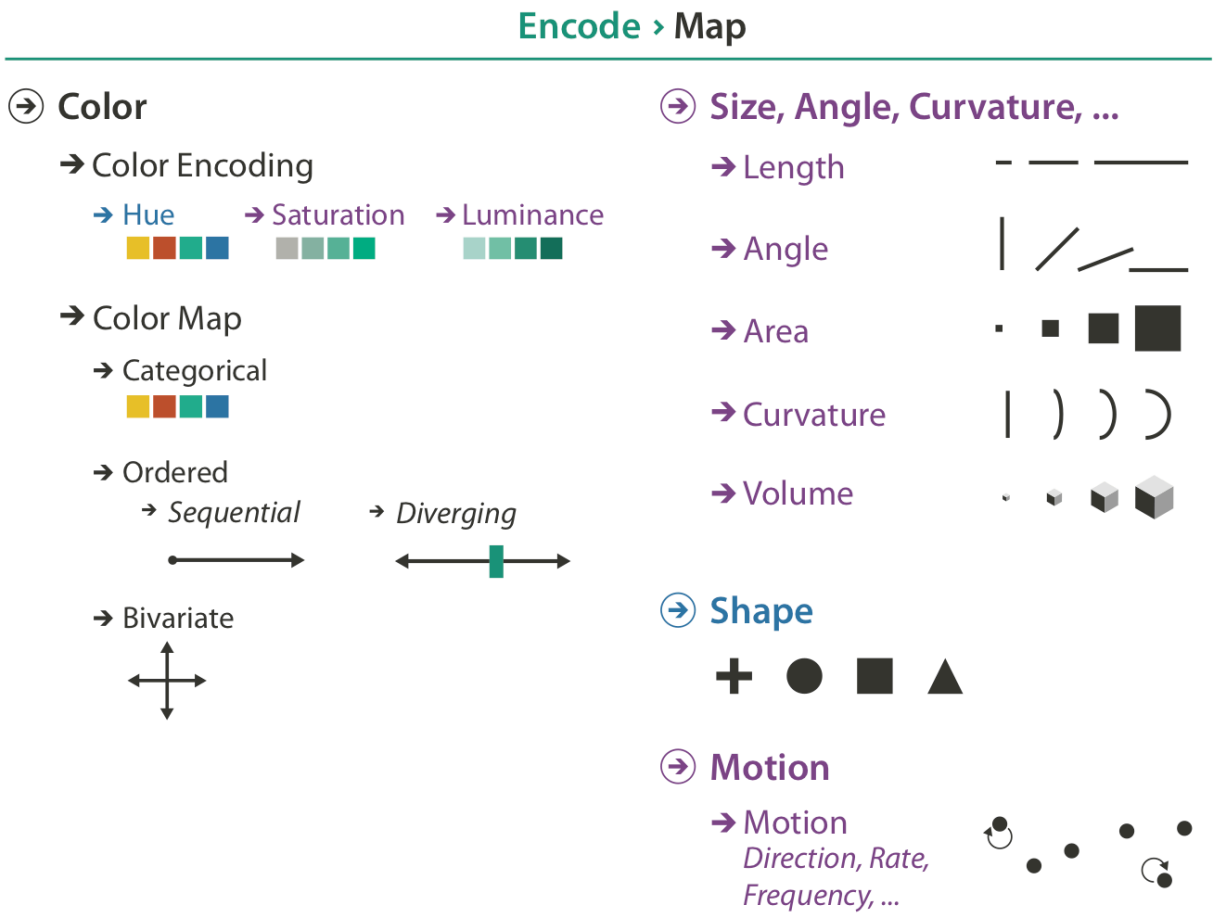
Diverging ordered arrow glyph

Cyclic ordered arrow glyph

Other Channels…

- Curvature channel
  - Not very accurate, needs to be used with line marks
- Shape channel for identity
  - At least dozens of discriminable bins, as long as the point size is sufficiently large
  - Strong interaction between shape and size
  - Shape channel can easily interfere with other channels
- Motion channel for identity
  - Direction of motion, velocity of motion, flicker frequency...
  - Typically, cyclic pattern
  - Very separable from all other cyclic patterns
  - Strongly draws attention (too much, sometimes!)

Channel Encoding Cheat Sheet



Next Week:

- Idioms !