POLITECNICO DI MILANO

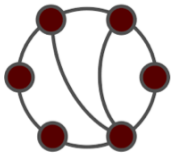
Unit 2

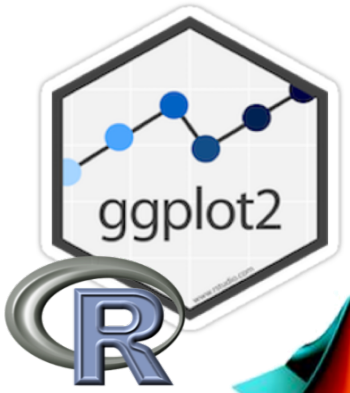
Data and Results Visualization

Daniele Loiacono

VISUALIZATION TOOLS

Overview



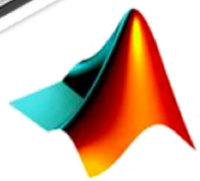


Seaborn

NetworkX

graph-tool

plotly

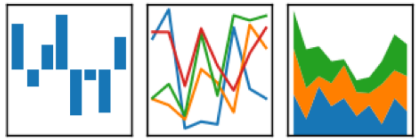


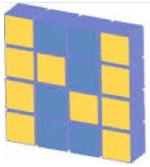
MATLAB

matplotlib

pandas

$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$

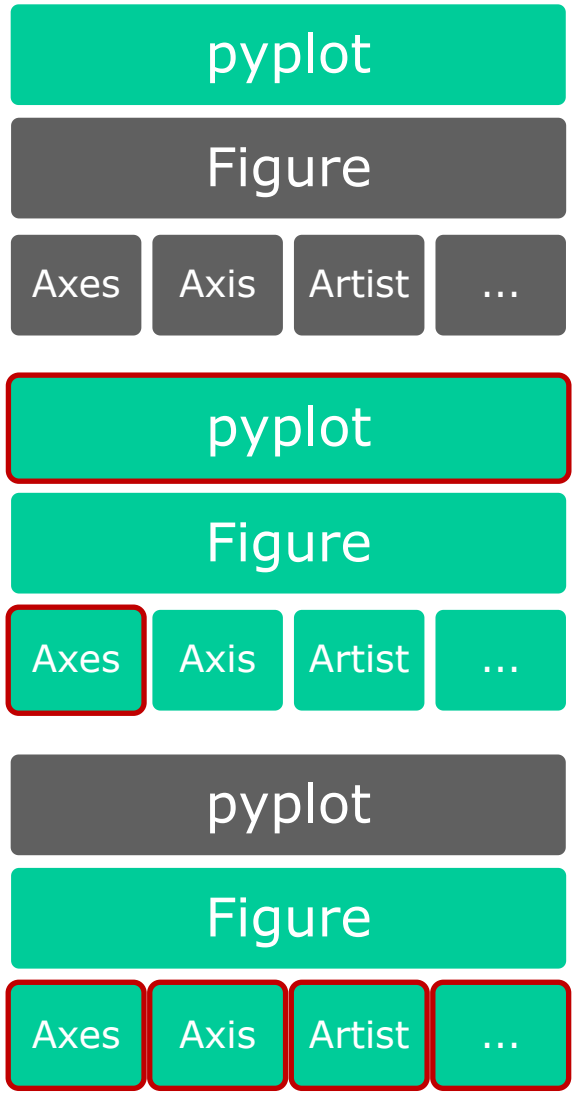




NumPy

Matplotlib and Seaborn

Using Matplotlib



Higher level
(state-machine)

Intermediate level
(state-machine + OO)

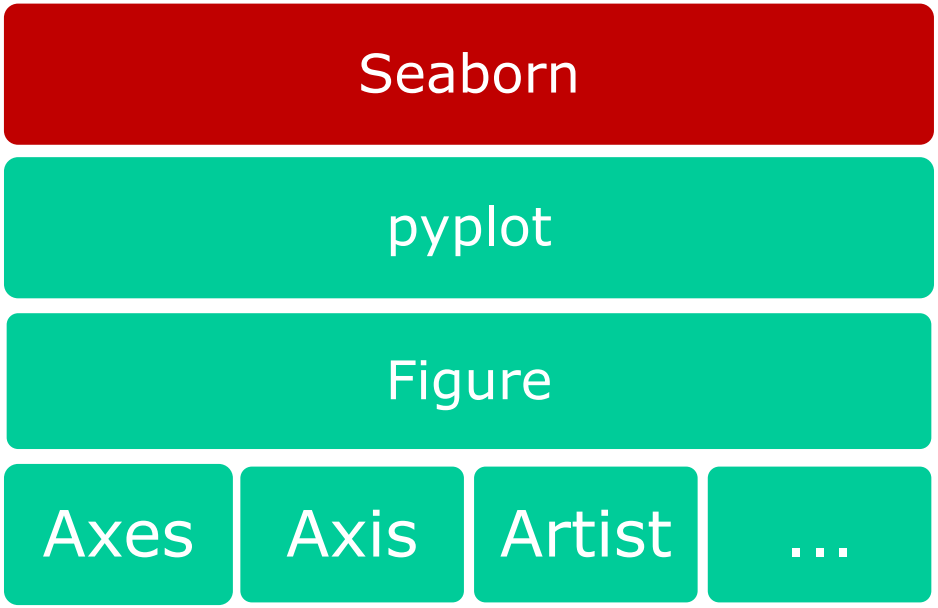
Lower level
(pure OO)

Abstraction

Flexibility

Seaborn

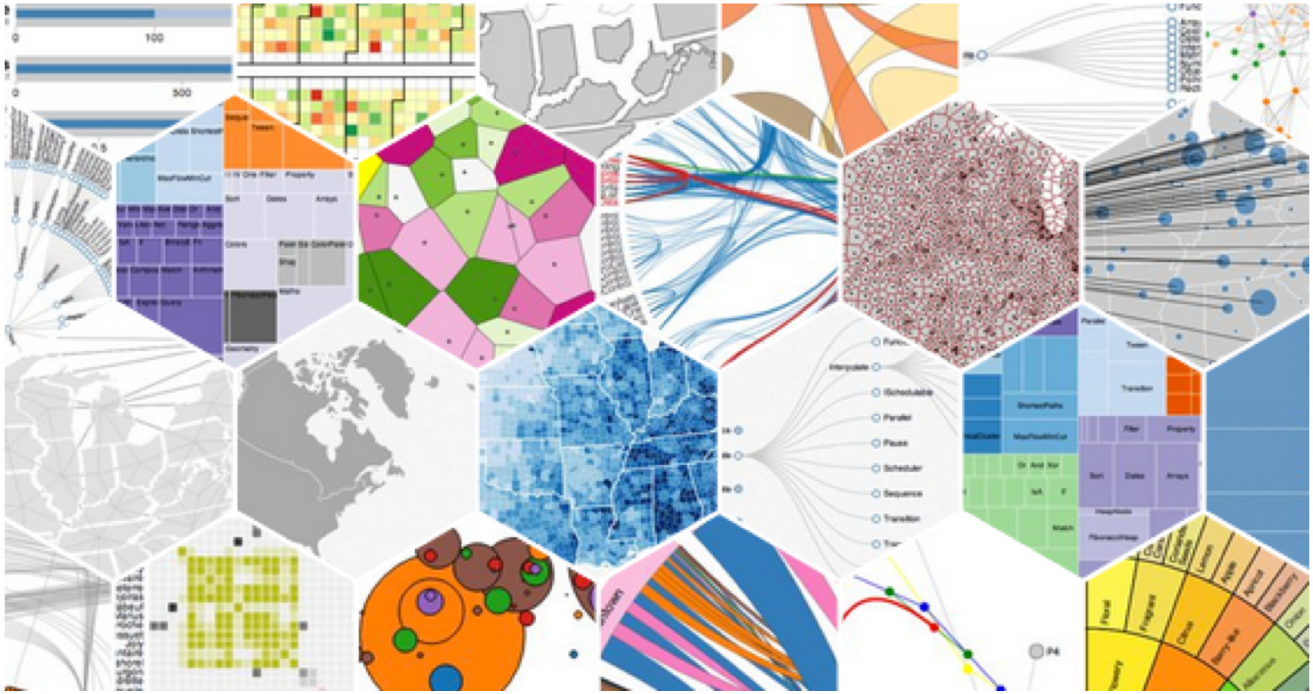
- Built on top of Matplotlib
- Integrate with Pandas
- Allows to use Matplotlib functions to customize the outcome



Alternatives

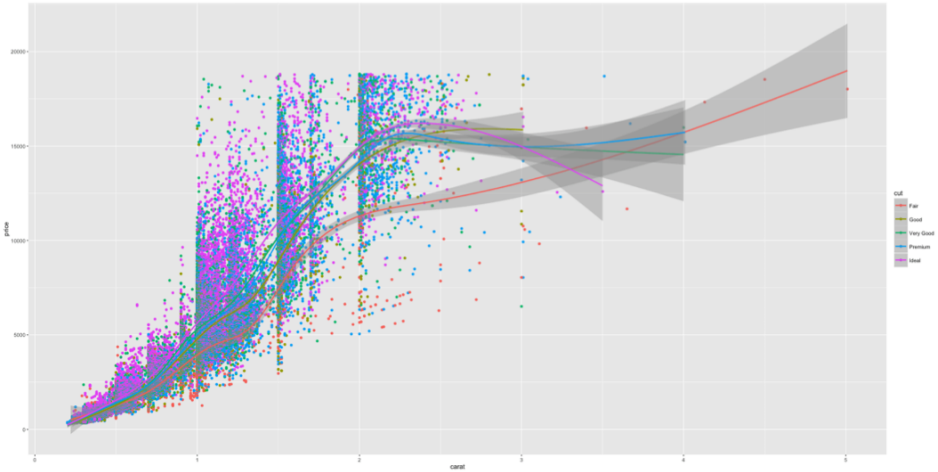
D3.js

- JavaScript library for manipulating documents based on data
- Uses Web standards HTML, SVG, CSS
- Has powerful visualization components
- Suitable for interactive design



ggplot2

- It is a package for R, a scripting language widely used for data and statistical analysis.
- It produces high-quality (statistical) graphics, using a sort of "grammar" to design graphs component-by-component rather than providing standard graphs.
- It allows to build a graph from concepts rather than recall of commands and options.



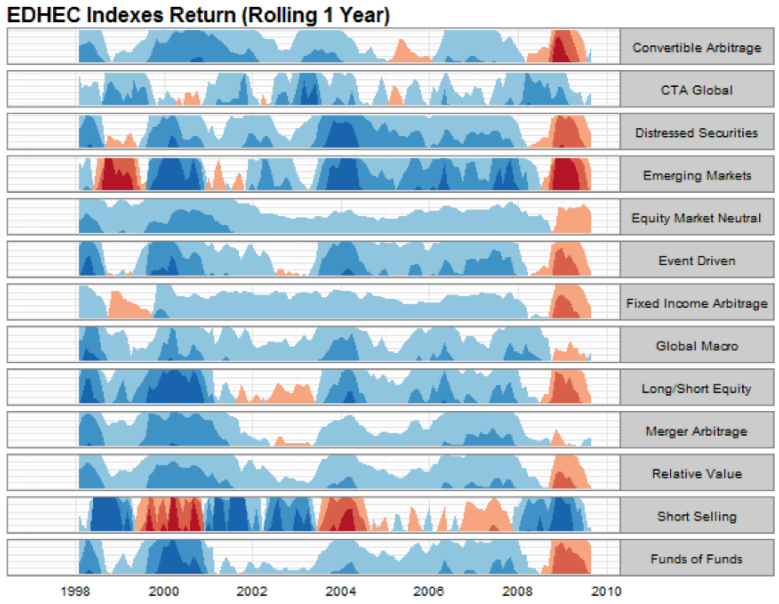
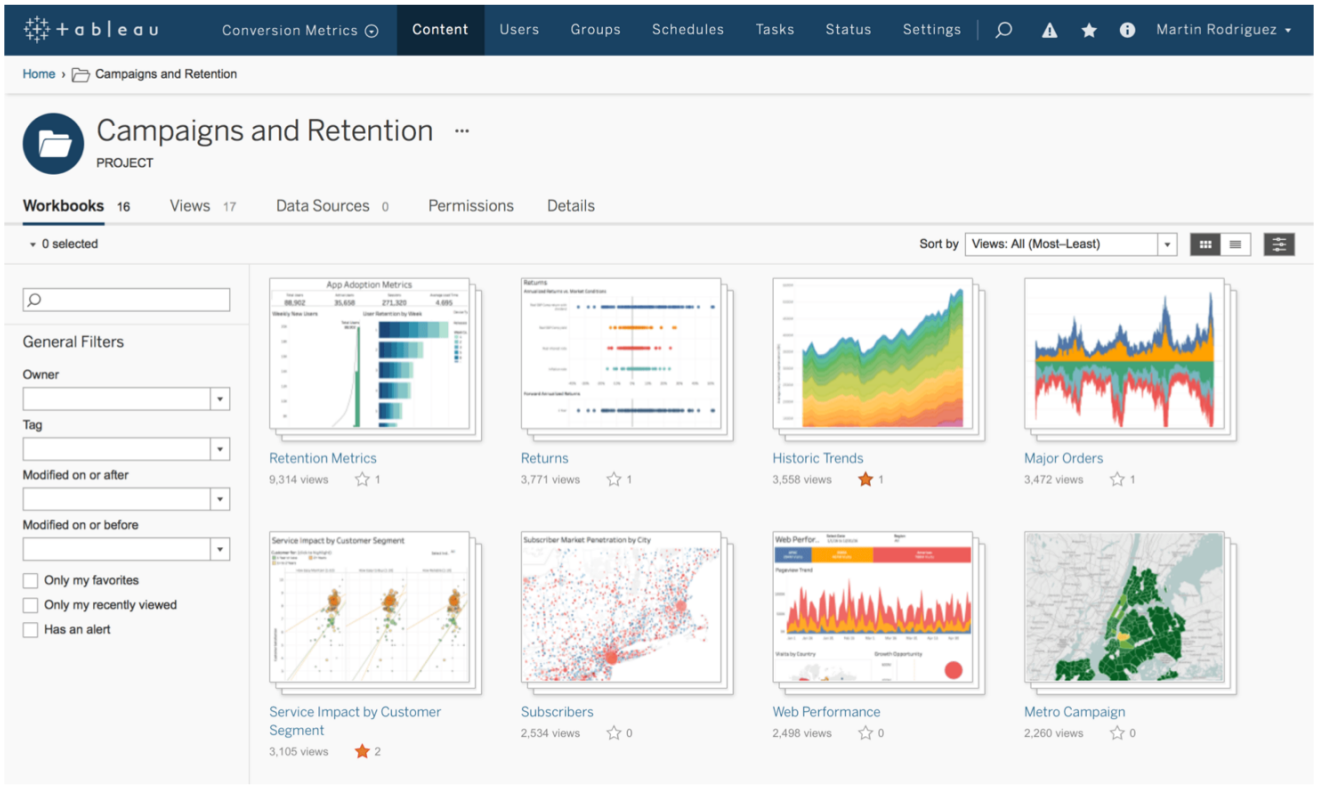


Tableau and Powerbi

- Commercial integrated solutions.
- Does not require programming.
- Allow to create good visualization (also interactive) but not fully customizable.

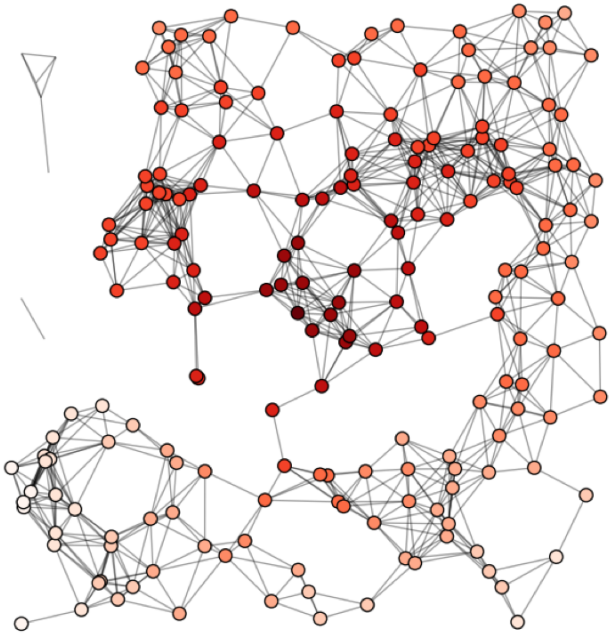


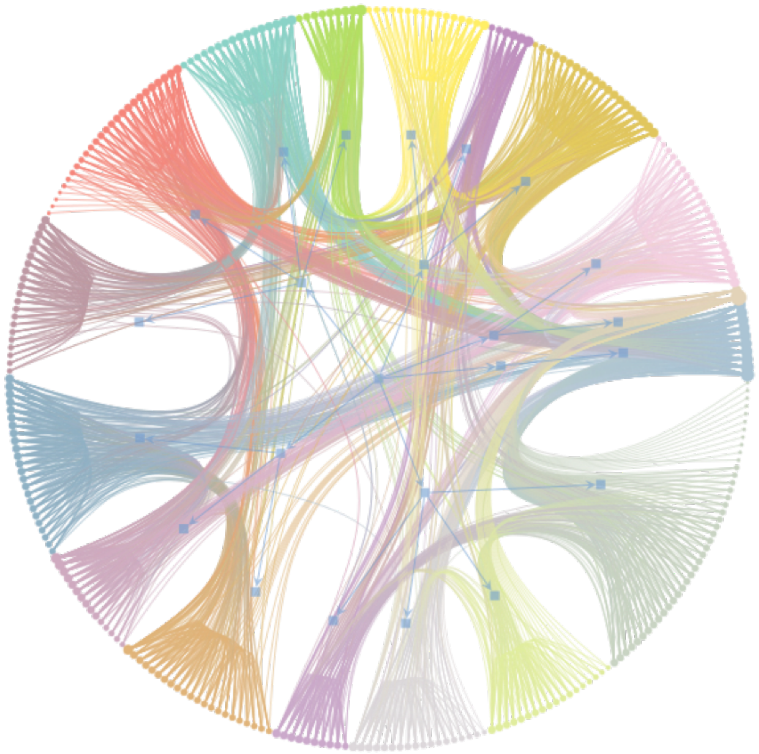
Plotly

- Premium cloud-based platform for commercial and integrated solutions.
- Open source libraries in different languages (js, python, R).
- Solutions for interactive visualization and dashboards.

Networkx and graph-tool

- Popular graph libraries in Python.
- Networkx is based on Matplotlib.





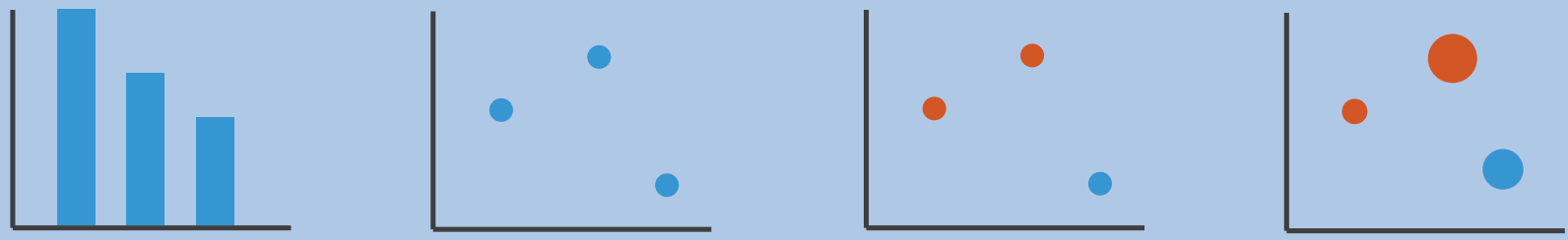
Hands-On

Introduction to Pandas

Introduction to Matplotlib

Introduction to Seaborn

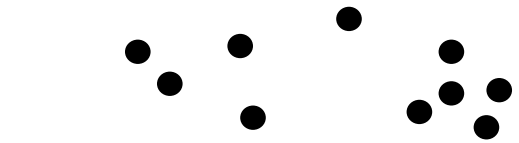
MARKS AND CHANNELS

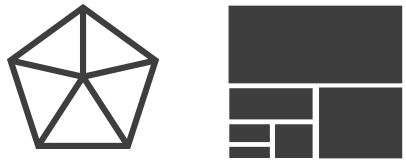


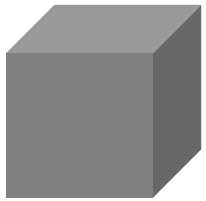
Elements of visual encodings

Definition: marks

- **Marks** are the geometric primitives used to visualize data:
  - Points (0-D)
  - Lines (1-D)
  - Areas (2-D)
  - Volumes (3-D)
- Marks are used to represent items and links

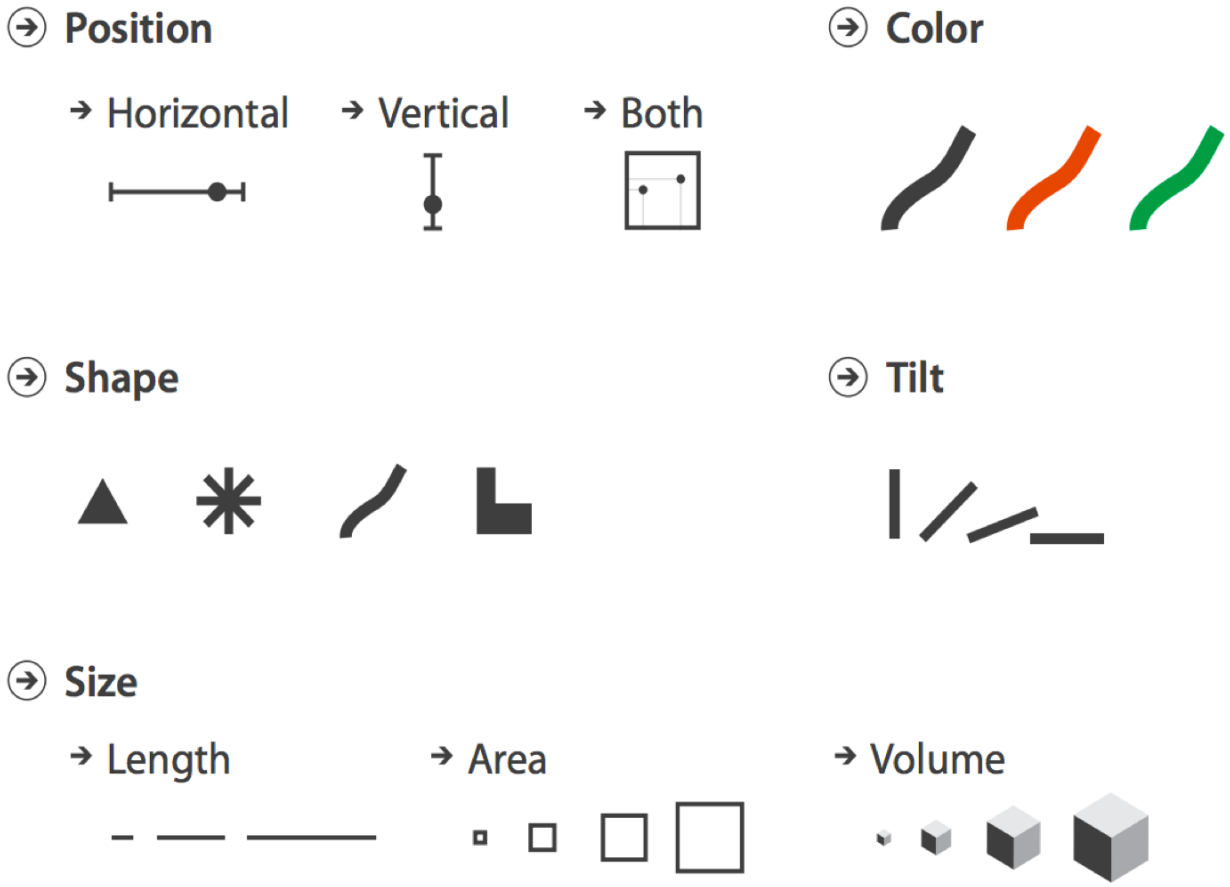






Definition: channels

- **Visual channels** are visual variables that allow to control the appearance of the marks:

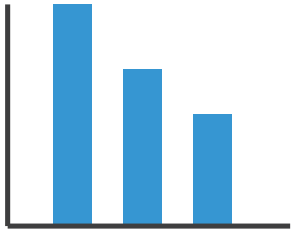


Visual encoding with marks and channels

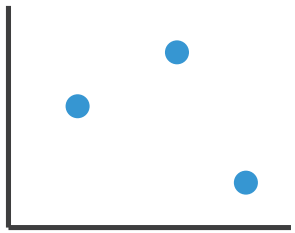
- Marks are used to encode **items, nodes, grids,** and **links.**
- Channels are used to encode **attributes** and **positions.**
- We distinguish two types of visual channels:
  - **identity channels** encode categorical attributes and positions
  - **magnitude channels** encode ordered attributes

A simple example of analysis

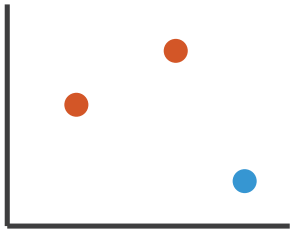
- Identify
  - Marks used for items
  - Channels of categorical and ordered attributes



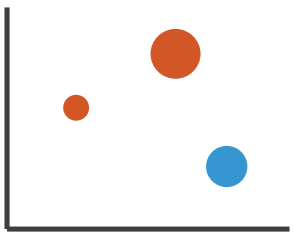
lines
horiz. position
vert. position



points
horiz. position
vert. position



points
horiz. position
vert. position
color

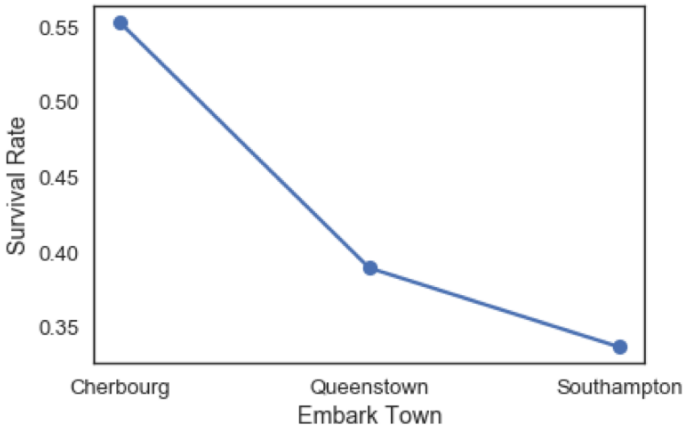


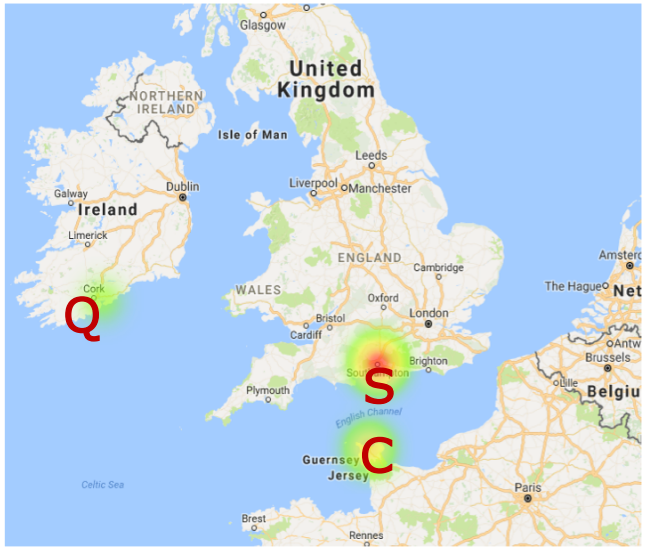
points
horiz. position
vert. position
color
size (area)

Visual encoding principles

Expressiveness

- Visual encoding should express all and **only** the information in the data.





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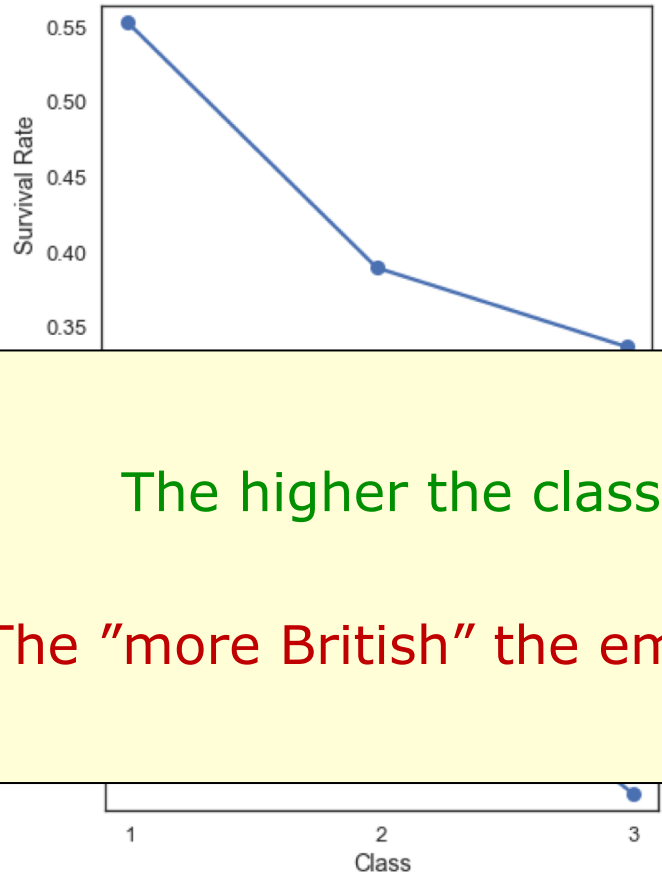

The higher the class, the lower the survival rate

The ”more British” the embark, the lower the survival rate

Expressiveness

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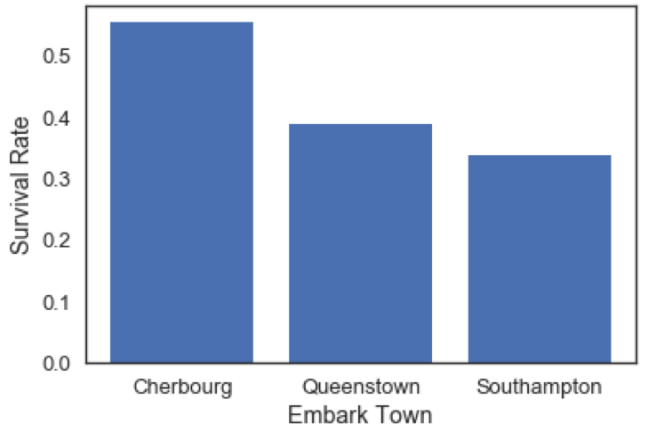
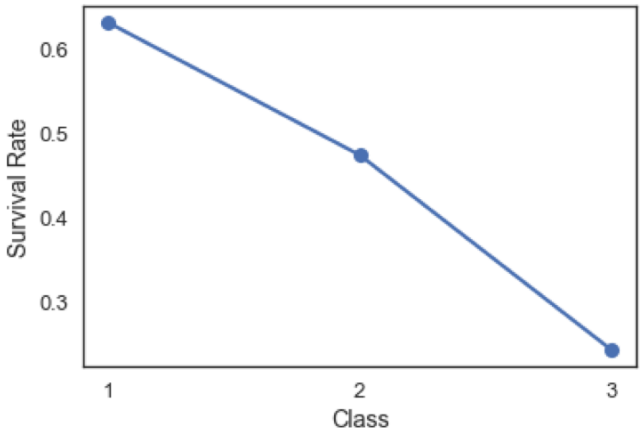
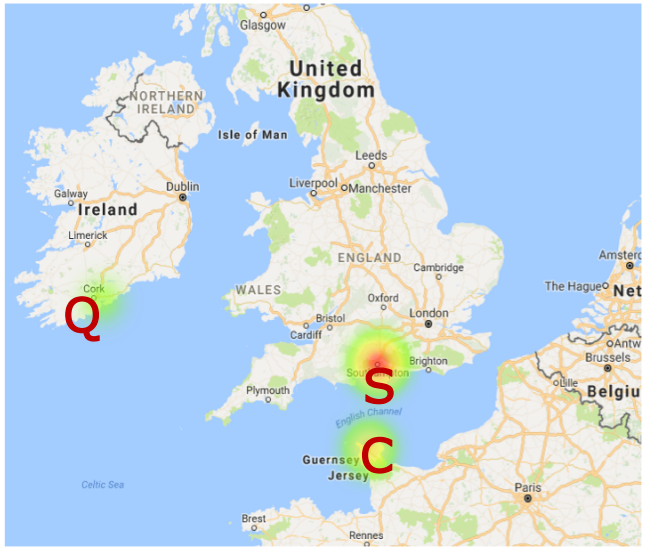
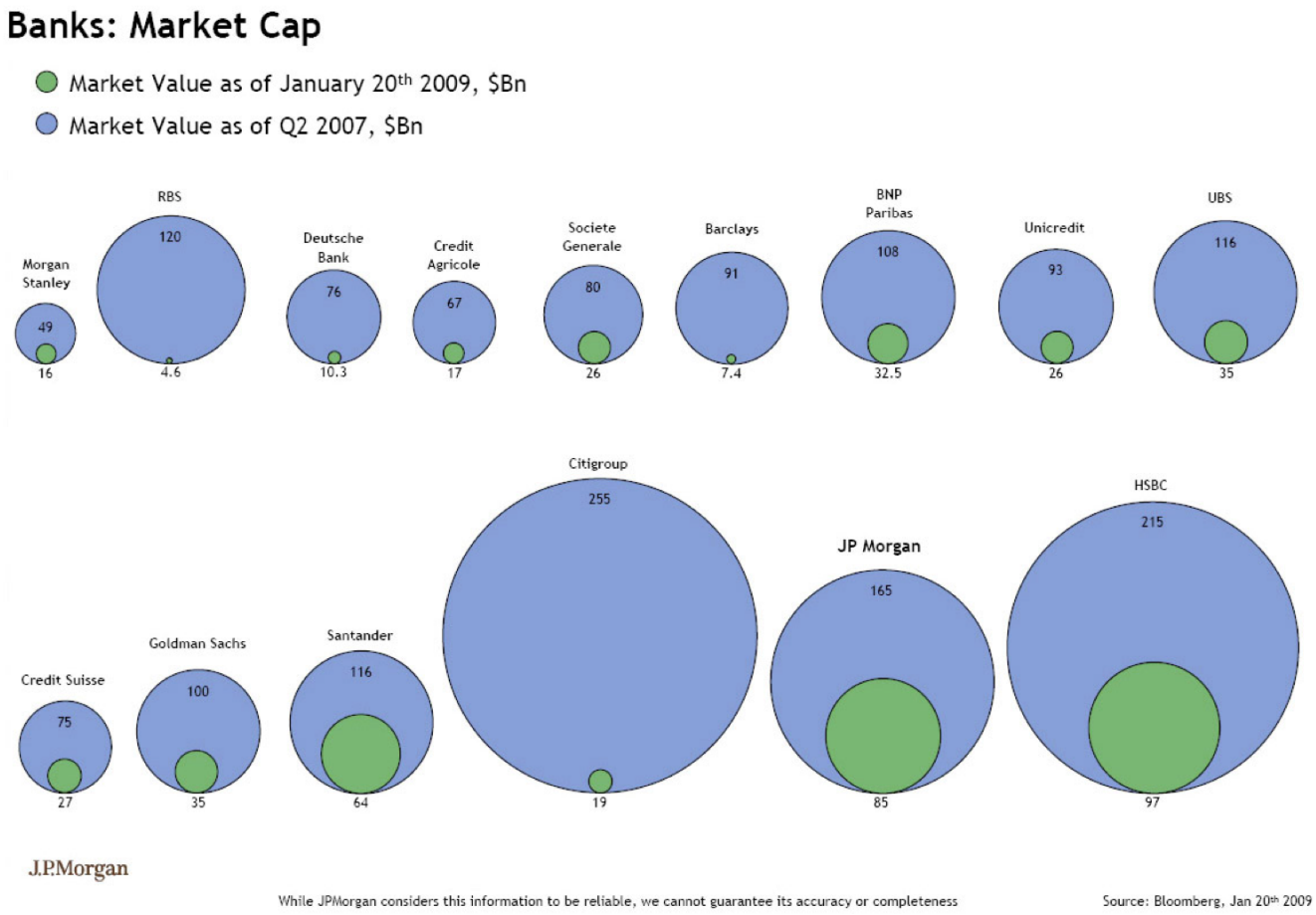






Effectiveness

- The importance of attributes should match the **salience** of the channels used to encode them!



Effectiveness

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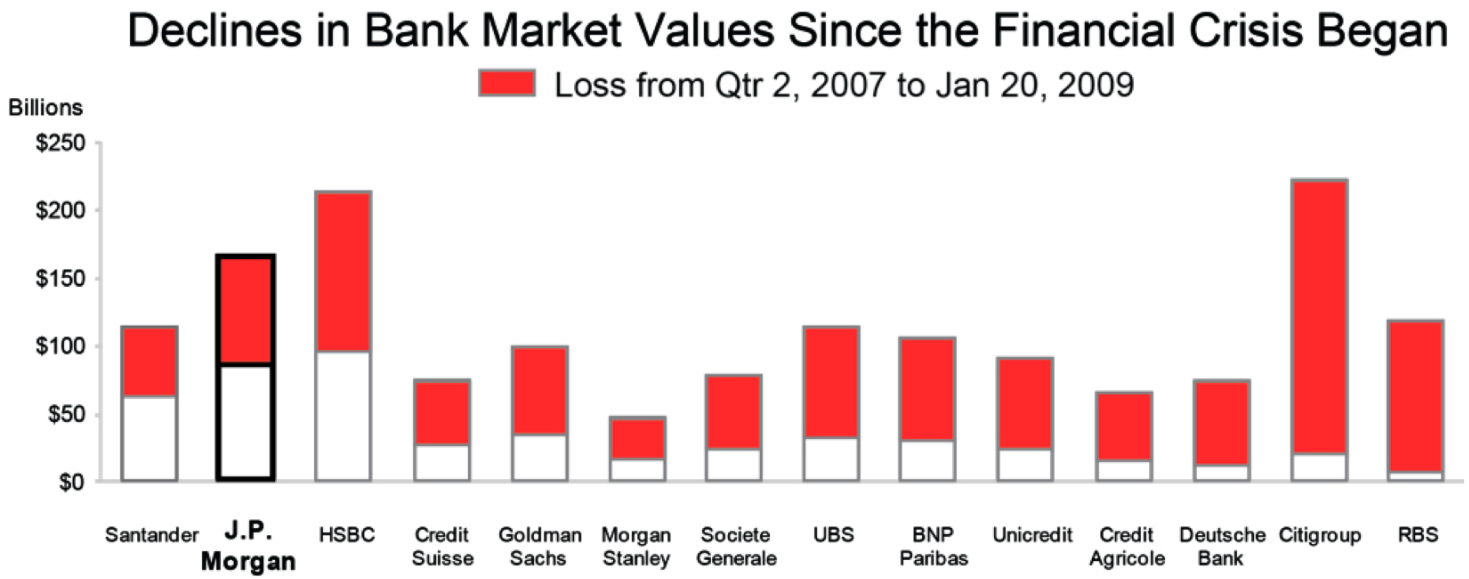


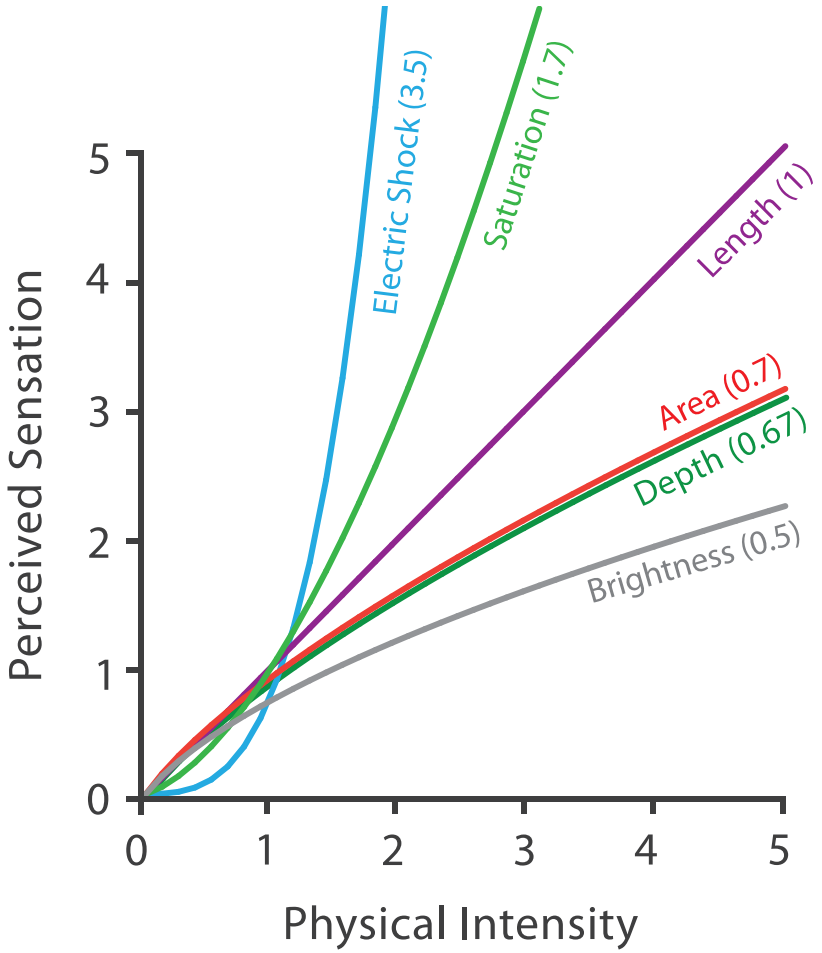
How to measure effectiveness?

Channel Effectiveness

- **Accuracy**: How accurately values can be estimated.
- **Discriminability**: How many different values can be perceived.
- **Separability**: How much interaction there is with multiple encodings.
- **Popout**: How easy it is to spot some values from the rest.
- **Grouping**: How good a channel is in conveying groups.

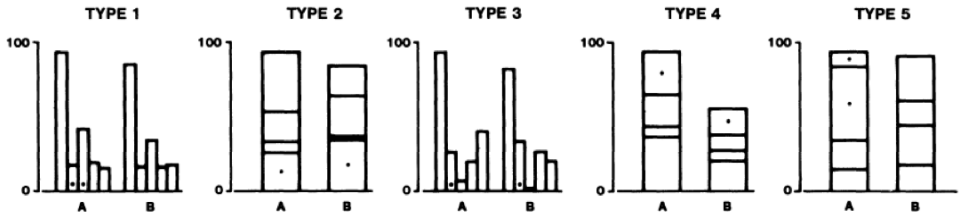
Accuracy

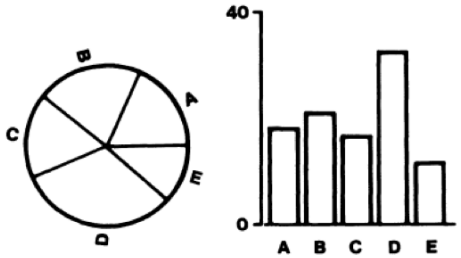
- How do we perceive magnitude through different channels?

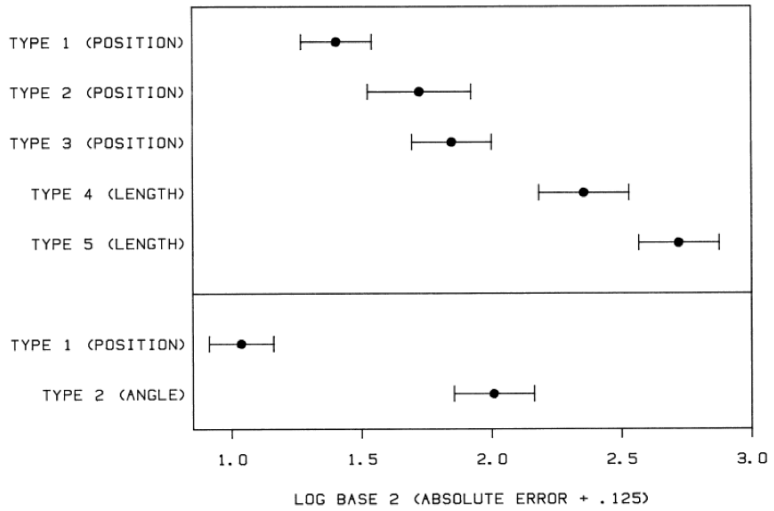


Accuracy: experimental results

Cleveland, William S., and Robert McGill. "Graphical perception: Theory, experimentation, and application to the development of graphical methods." (1984)

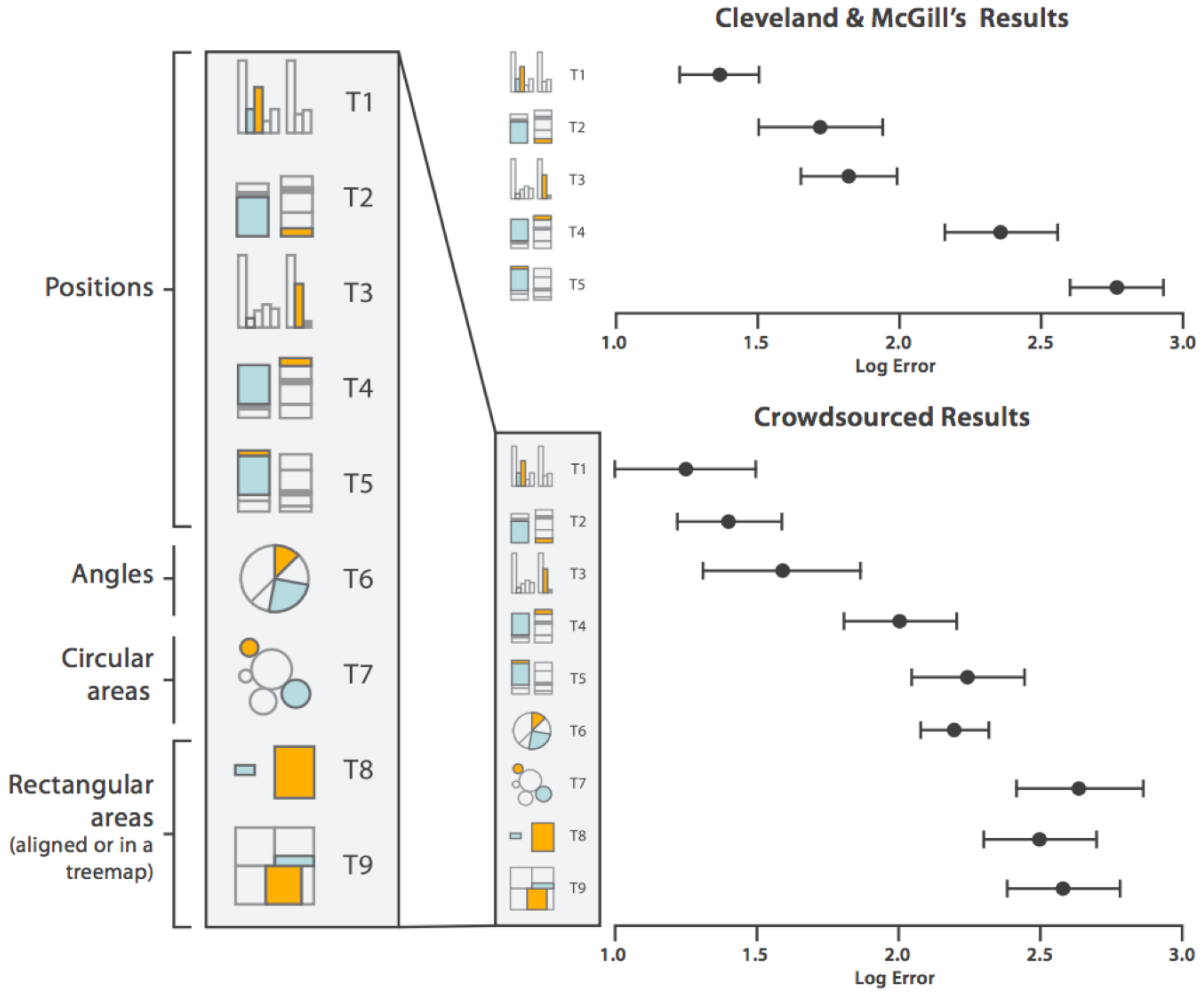






Accuracy: experimental results

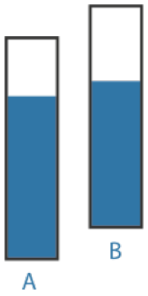
Jeffrey Heer and Michael Bostock. "Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design." (2010)



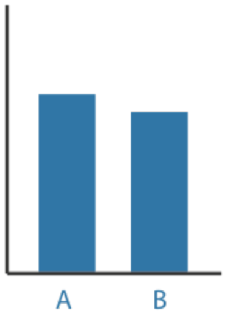
Accuracy: an example

accuracy

length



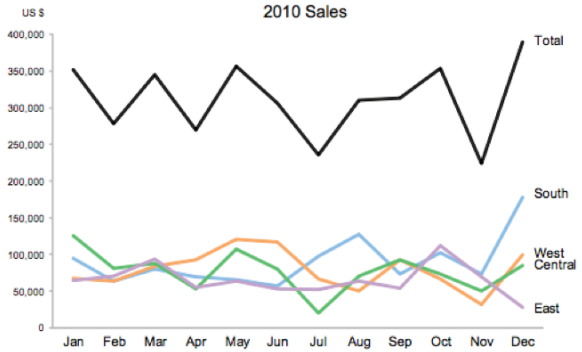
position
(unaligned)

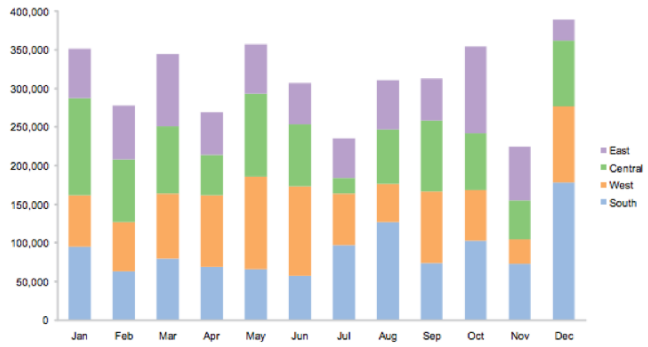


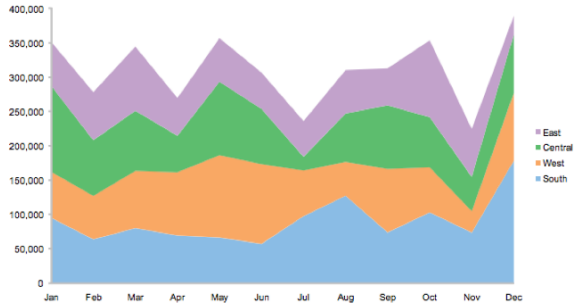
position
(aligned)

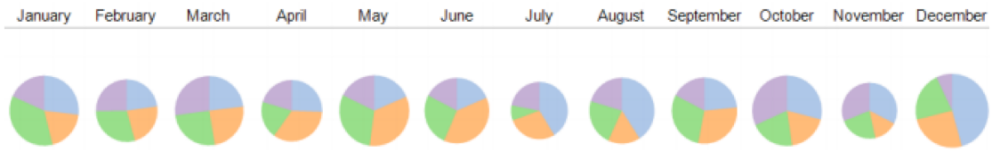
Accuracy: an example

- Which one is more effective to compare sale trends across regions?





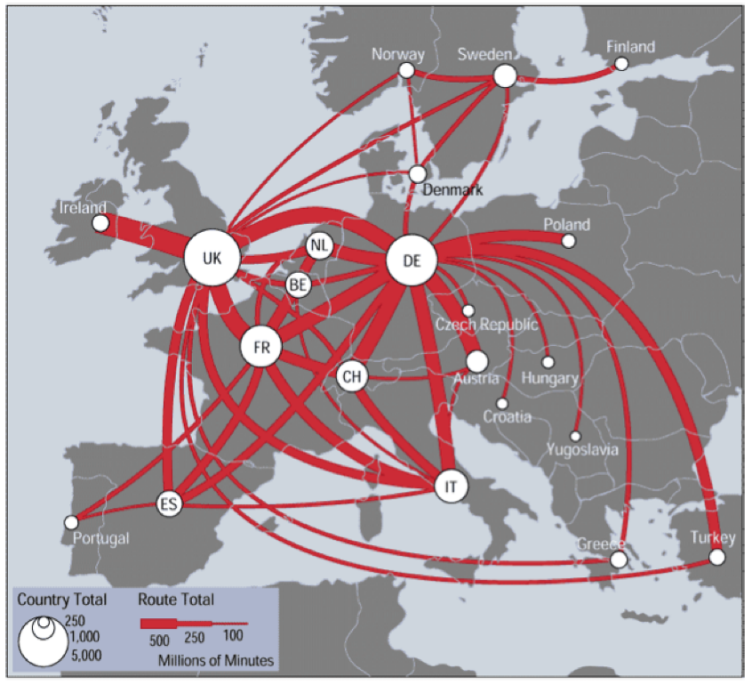




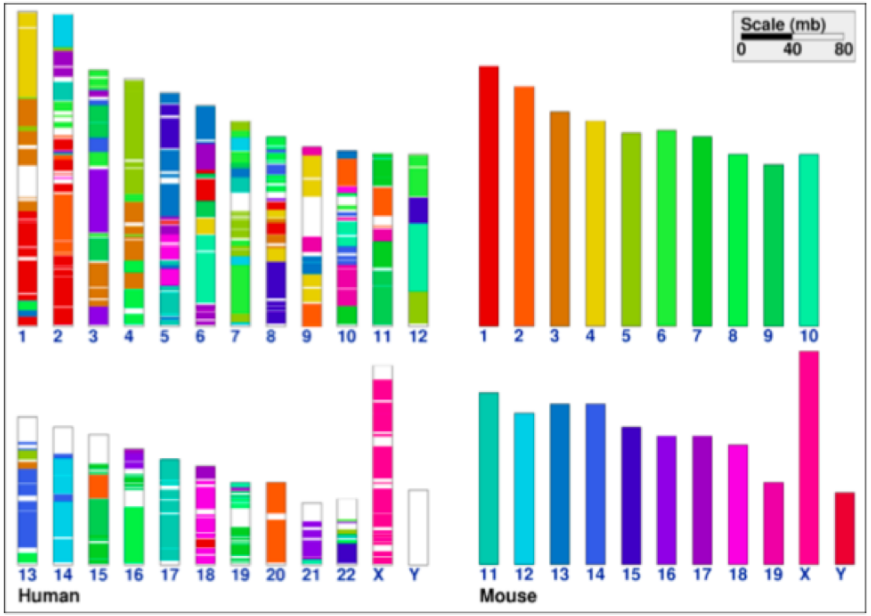
Example taken from Stephen Few: link

Discriminability

- How many values (or bins) can we distinguish for any given channel?



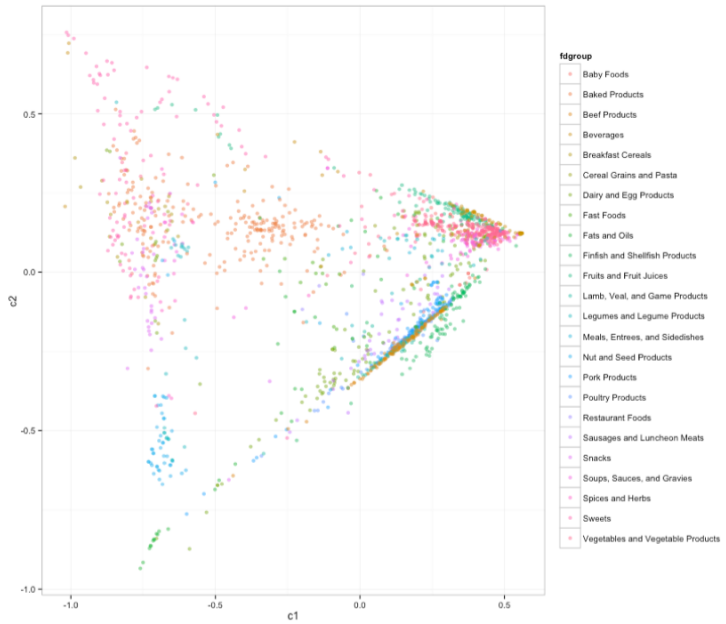
Line width

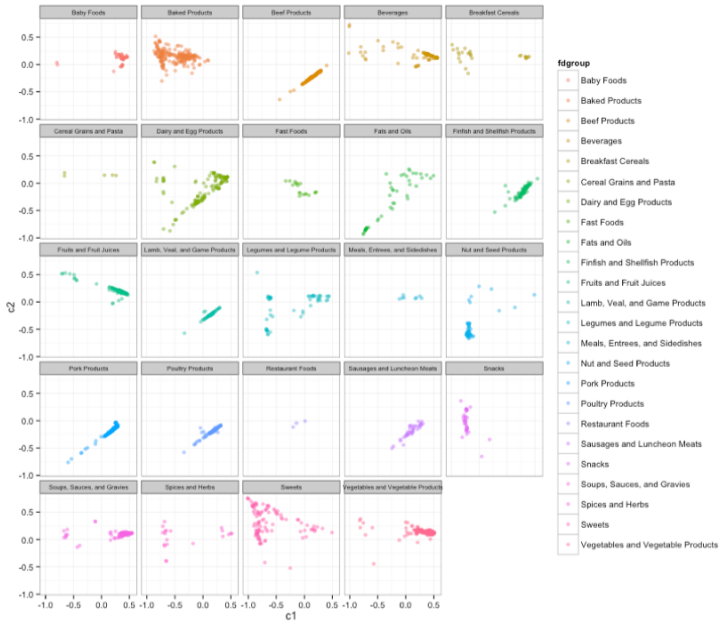


Color (hue)

Discriminability: guidelines

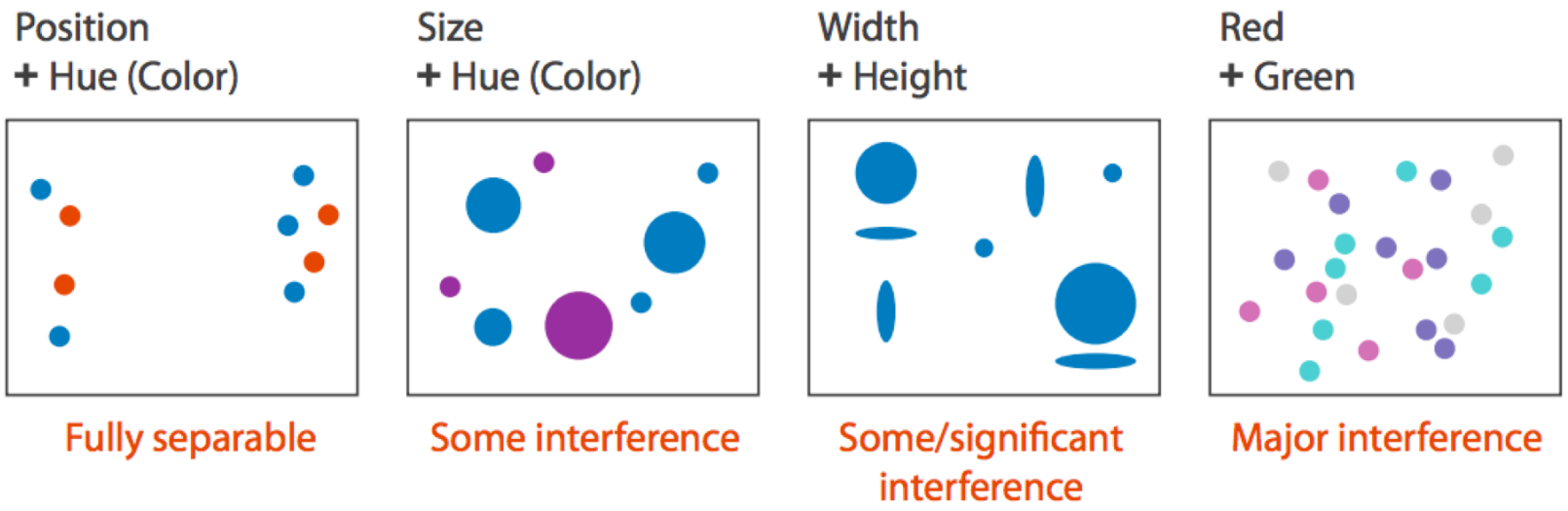
- Most channels can deal with a **very low** number of bins.
- If you have too many bins
  - group data further
  - change channel
  - trade-off space with other channels





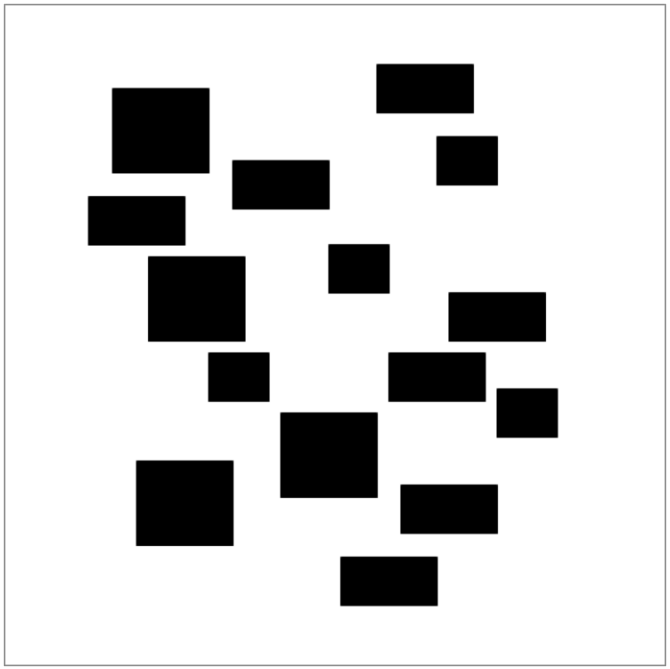
Separability

- Visual channels are not independent: they can be fully **separable** or almost **integral.**
- Designer must take into account dependencies between channels.
- Examples:



Separability: example

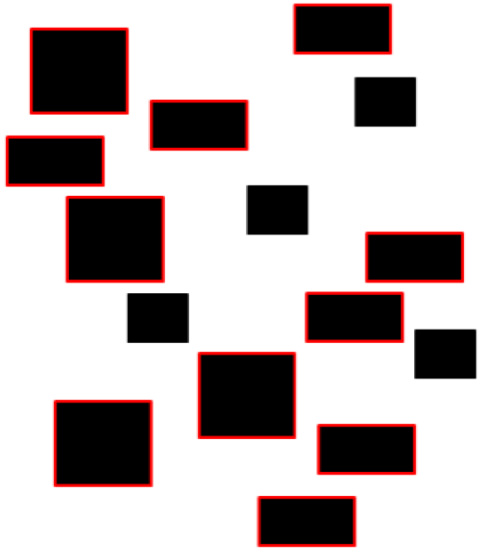
Try group these by same width or height ...



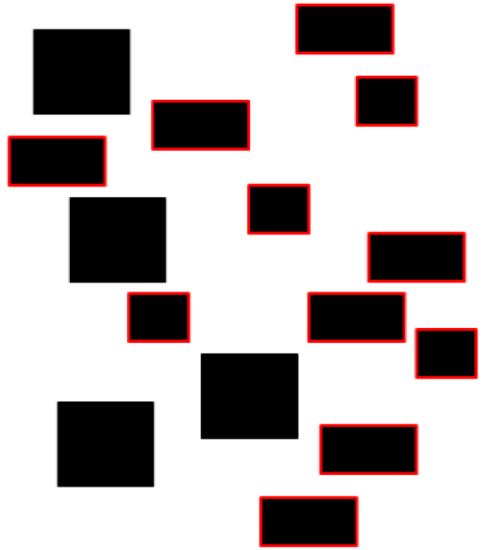
It’s hard! Because width and height interfere one to another

Separability: example

Same Width

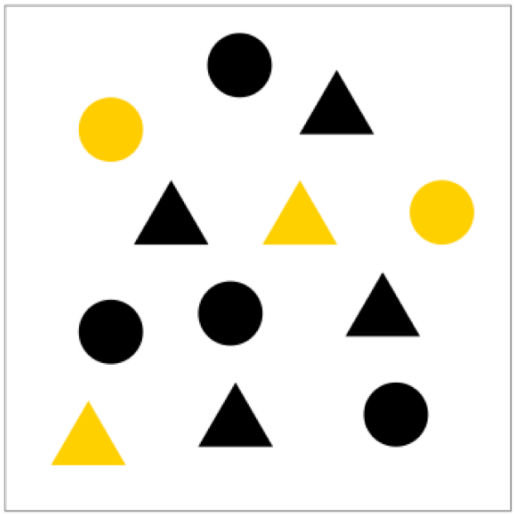


Same Height

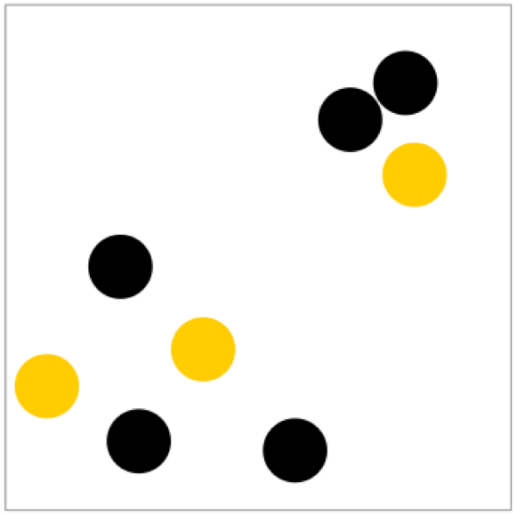


Separability: example

Color and Shape

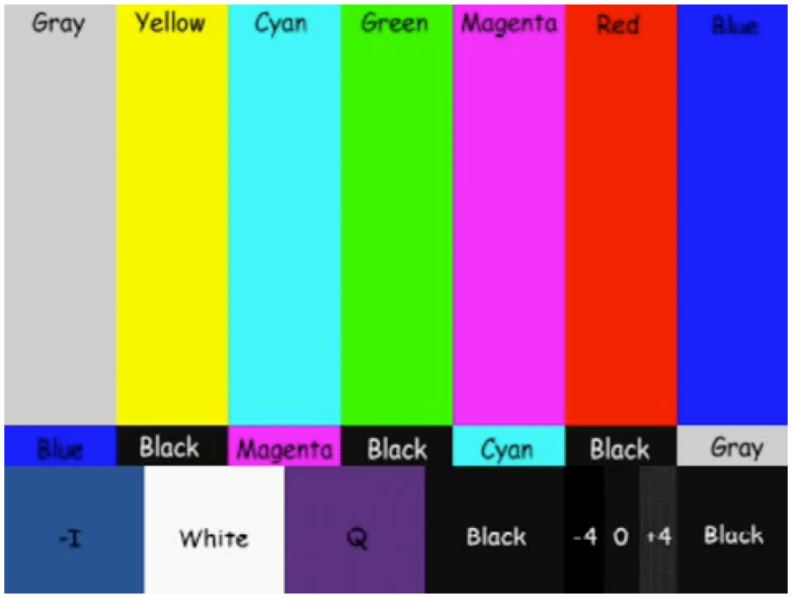


Position and Color



Popout

- Some channels provide a visual **popout**: makes a distinct item standing out from others.



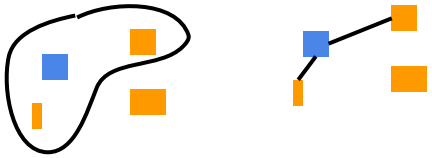
http://www.csc.ncsu.edu/faculty/healey/PP/

Separability and popout: guidelines

- Do not encode data with too many non-spatial visual channels (3/4 at max).
- Integral vs separable channels:
  - Use separable channels to encode different attributes.
  - Use integral channels to encode values of a single attribute (in a more effective way).
- To direct attention (e.g., selection) use channels that provide a good visual popout.

Grouping

- The perception of **grouping** is visually represented with three major approaches:
  - Containment and Connection **(marks)**



  - Proximity **(spatial channels)**

  - Similarity (**identity channels**)

More about colors

How do we perceive color?

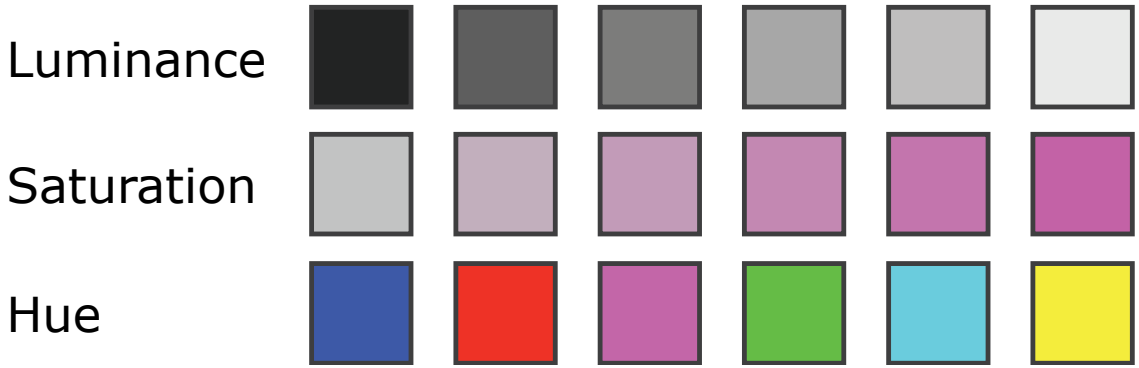
- Our visual system process signals into **3 opponent color channels**:
  - Red-Green
  - Blue-Yellow

  } chromaticity

  - Black-White — luminance
- Luminance channel conveys more information than chromaticity channels.
  - Chromaticity is what we informally call **color**.
  - Luminance allows **edge** detection.
- People with color deficiency (**color blindness**) has reduced perception of Red-Green or (more rarely) Blue-Yellow channels.

Encoding data with colors

- We decompose colors in three channels:
  - Luminance: how bright is?
  - Saturation: how *colorful* is?
  - Hue: which *color* is?

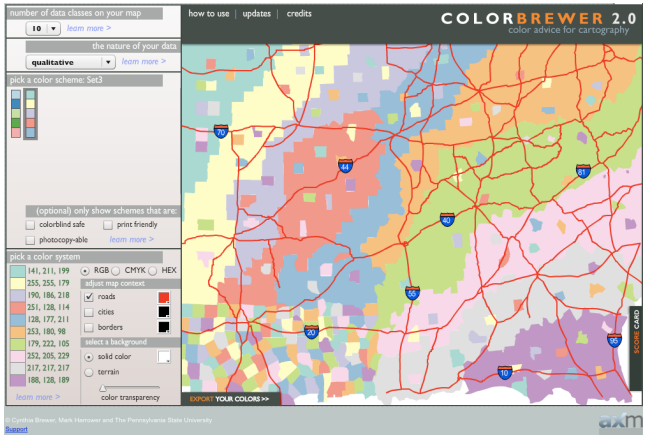


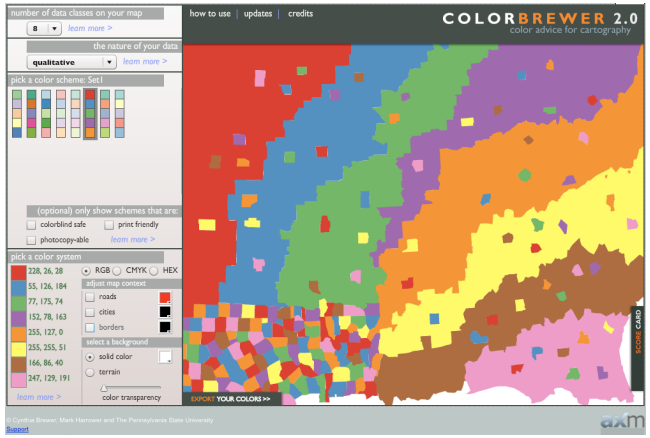
Encoding with luminance

- It is a **magnitude** channel suitable to encode **ordered** data.
- It allows to **discriminate** about 5 different (non-contiguous) values.
- When used to encode data, it might not be used to provide enough contrast to detect edges.
  - Luminance is the most important channel to provide contrast.
  - E.g., for making text readable standard guideline is a 10:1 ratio (where 3:1 is the minimum).

Encoding with saturation

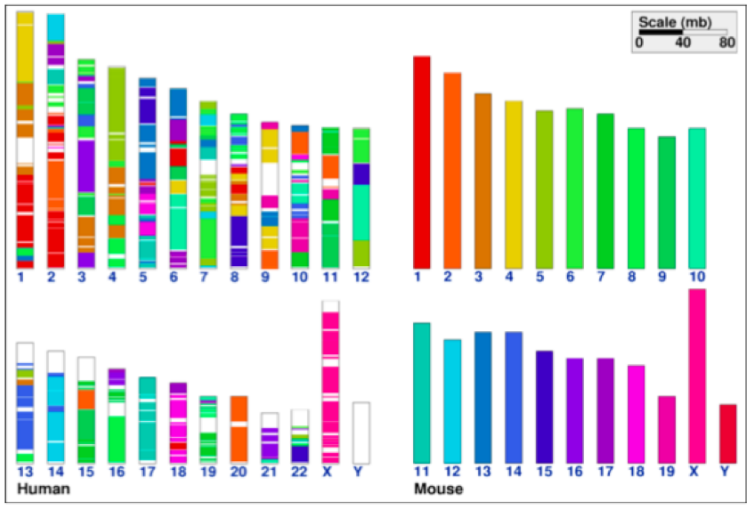
- It is a **magnitude** channel suitable to encode **ordered** data.
- It is less accurate than luminance and allows to **discriminate** about 3 different (non-contiguous) values.
- Separability issues
  - Difficult to perceive in small areas.
  - Hue and saturation are not well separable.
- Guidelines
  - Use high-saturated colors for small areas.
  - Use low-saturated colors suits better large areas.

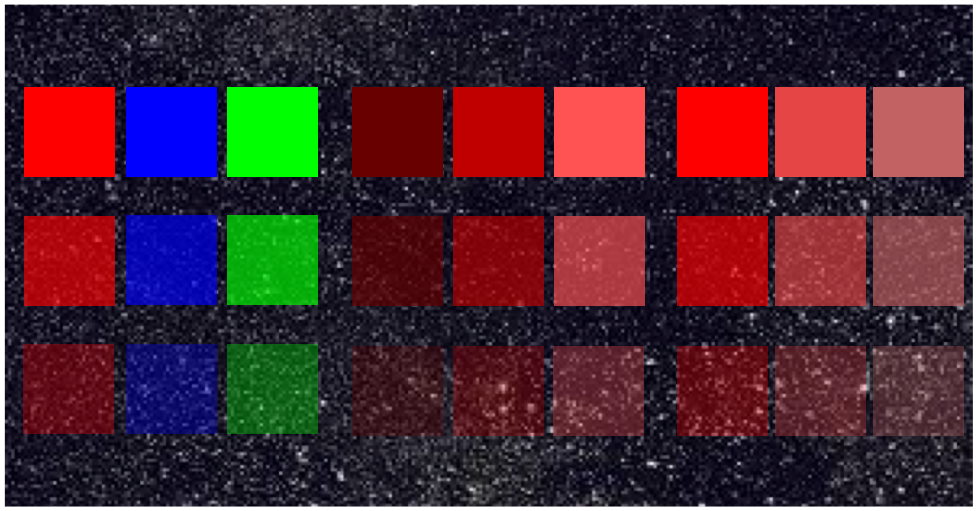




Encoding with hue

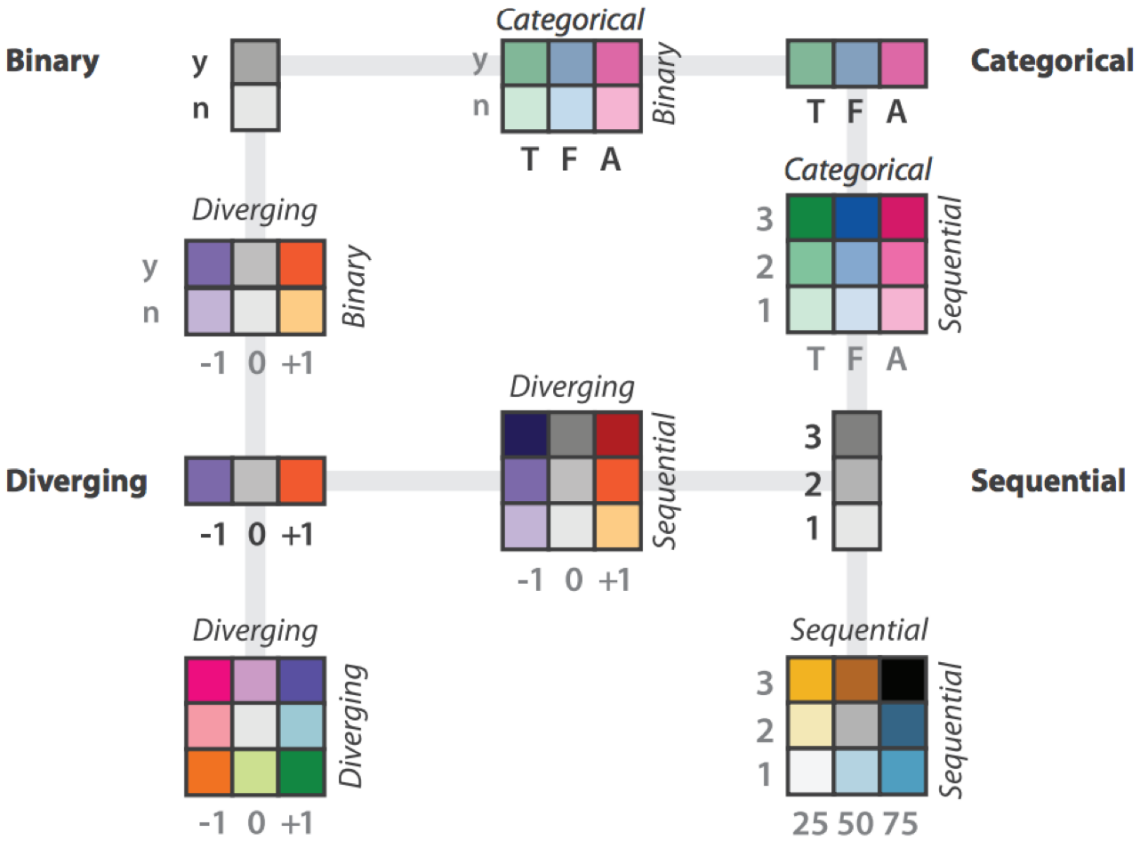
- Hue is an effective **identity** channels to encode **categorical** values but it does provide any implicit perceptual ordering.
- It allows to **discriminate** about 7 different (non-contiguous) values.
- It can be used with **transparency**, which is instead has strong interaction with luminance and saturation.





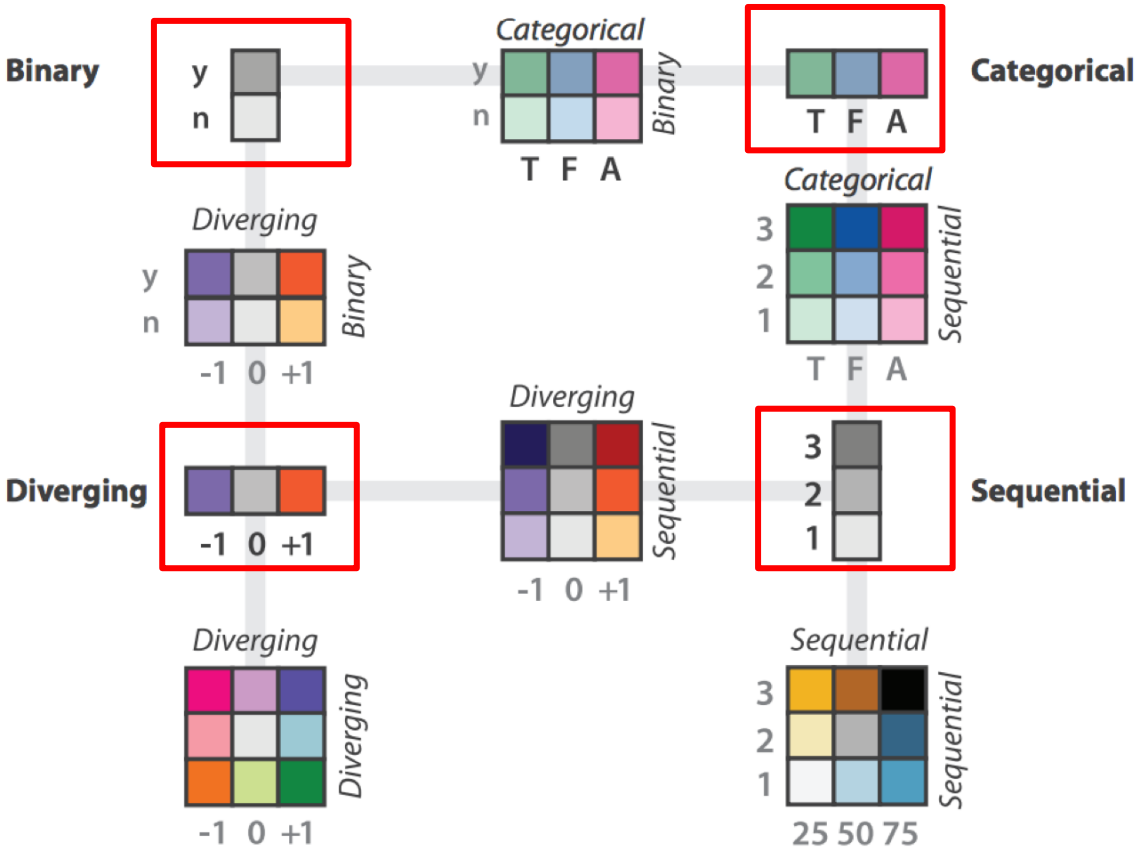
Colormaps

- A colormap is the mapping chosen to encode one (or two) attributes with color.



Colormaps

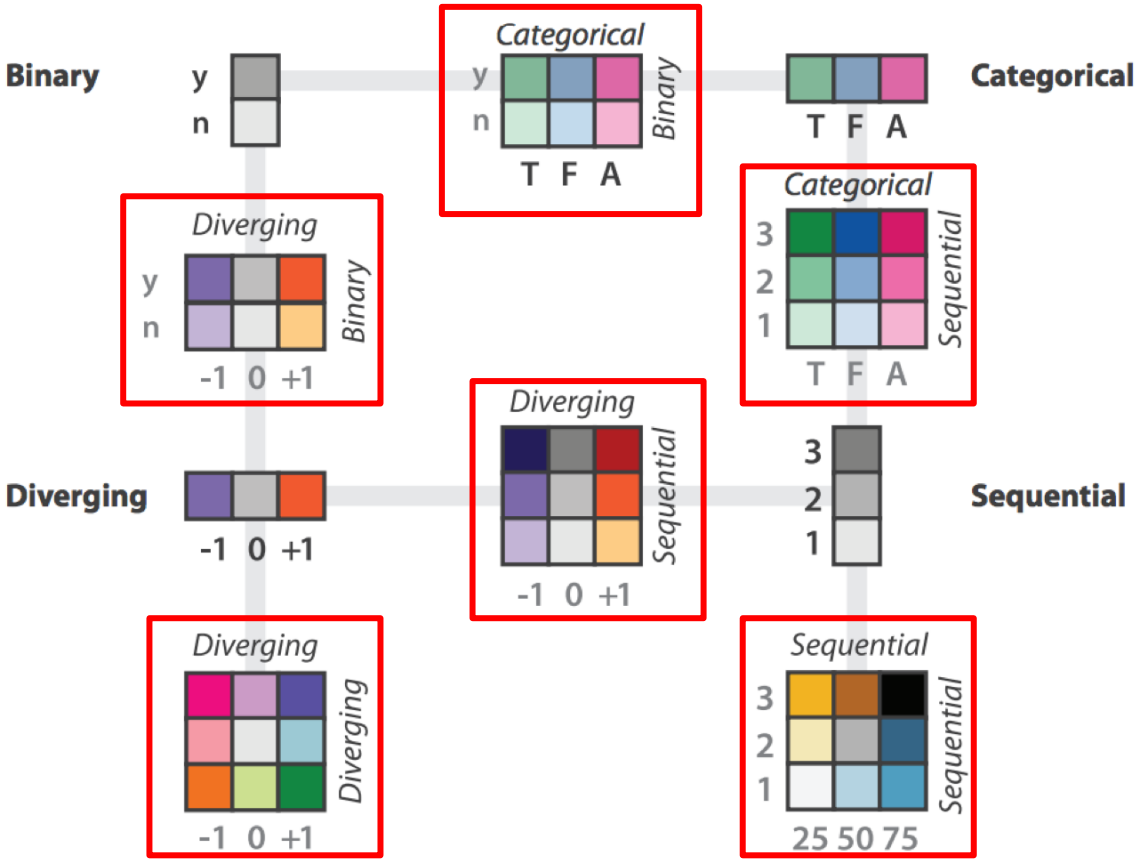
- A colormap is the mapping chosen to encode one (or two) attributes with color.



Univariate mappings encode one attribute.

Colormaps

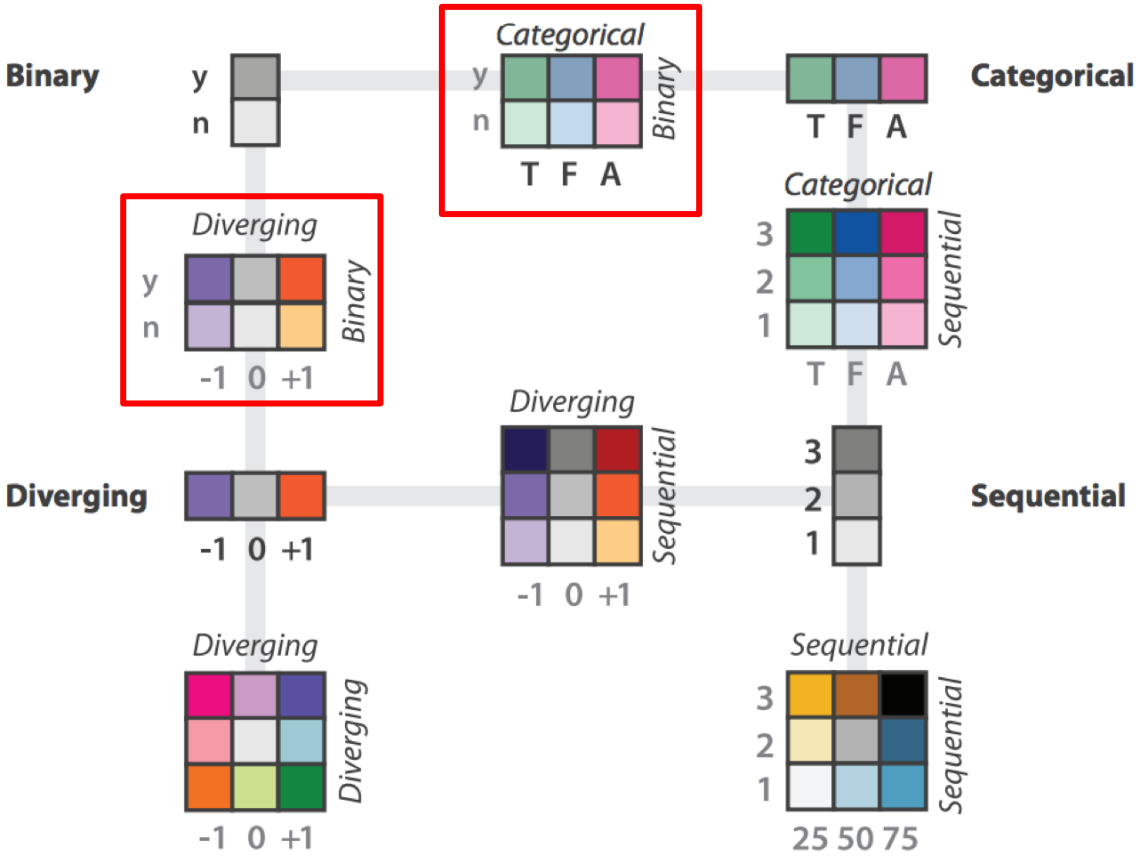
- A colormap is the mapping chosen to encode one (or two) attributes with color.



Bivariate mappings encode two attributes.

Colormaps

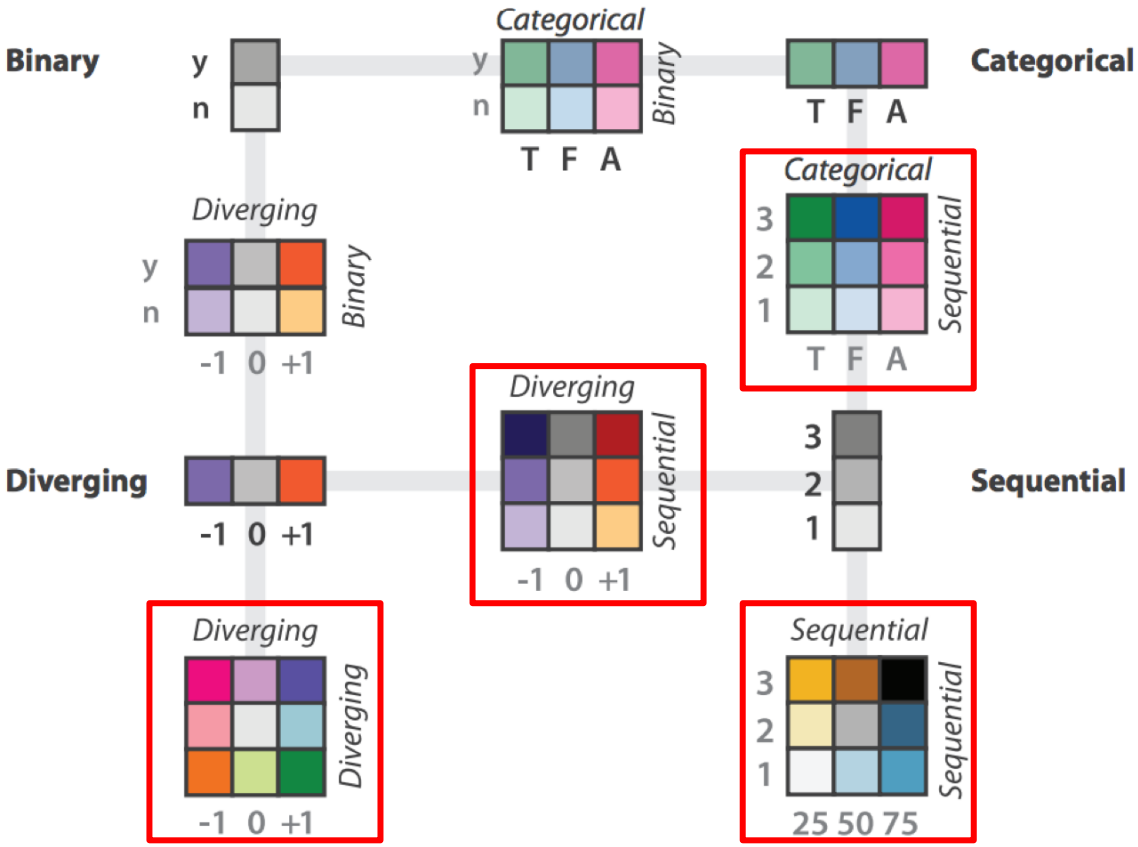
- A colormap is the mapping chosen to encode one (or two) attributes with color.



Bivariate mappings with a binary attribute works well.

Colormaps

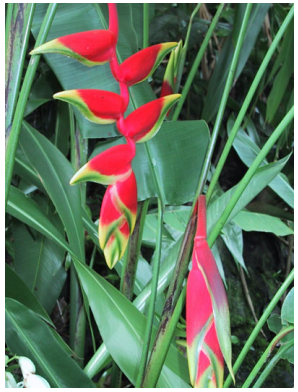
- A colormap is the mapping chosen to encode one (or two) attributes with color.

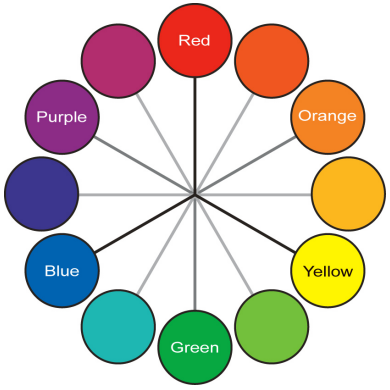


Other bivariate mappings are possible but less effective

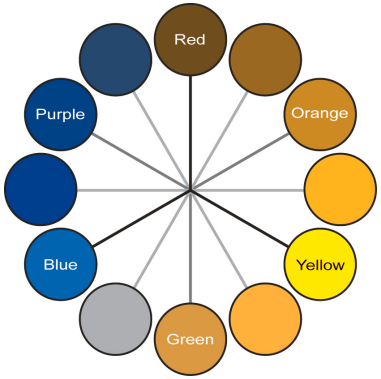
Dealing with color deficiency

- Use only two channels

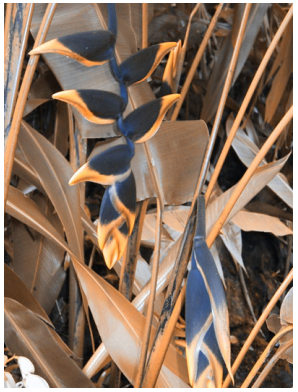


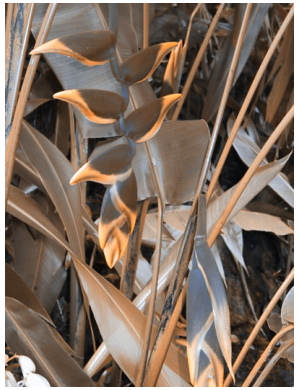


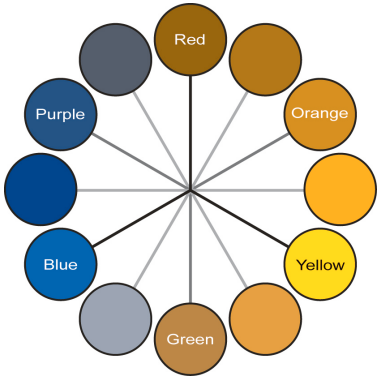
Normal



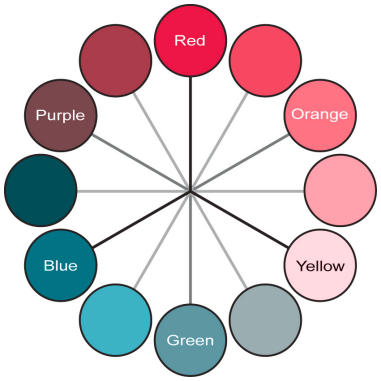
Protanope







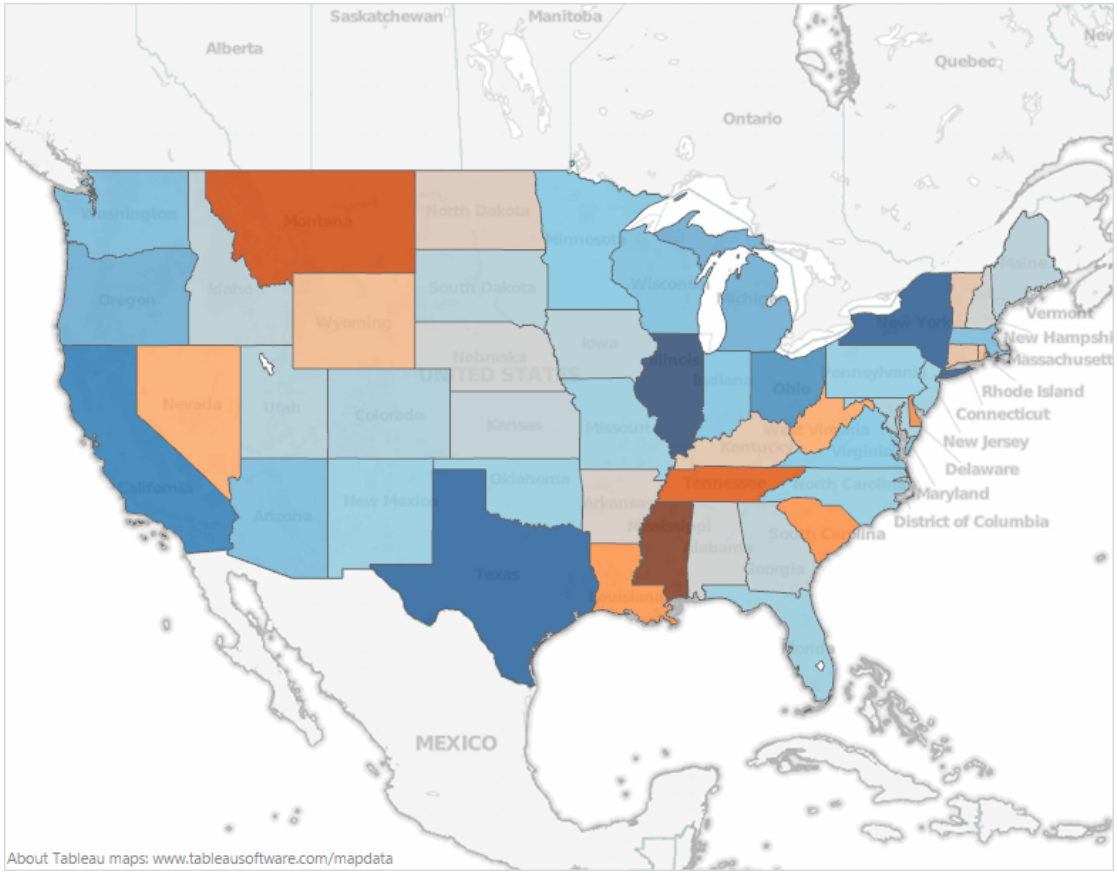
Deuteranope



Tritanope

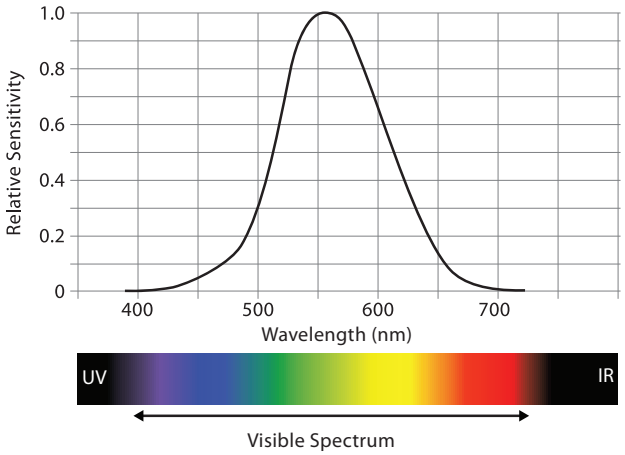
Dealing with color deficiency (2)

- Use colorblind-safe mappings



Design colormaps: the color space

- RGB
  - red, green, blue channels
  - good for display hardware but not useful for encoding
- HSL/HSV
  - hue, saturation and lightness/value channel
  - much better for encoding…
  - … but lightness/value ≠ luminance

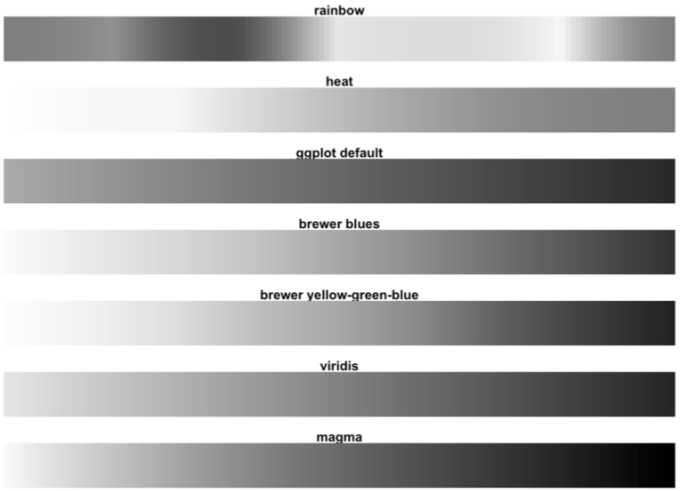


Colors with same L/V converted to grayscale

Infact…

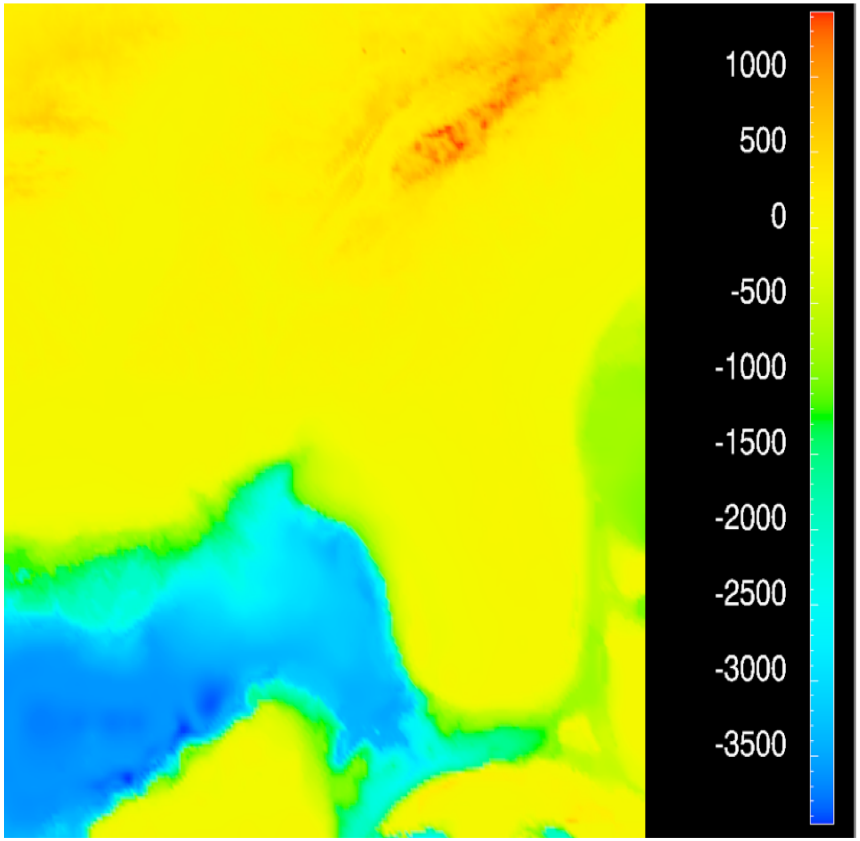
- Some standard mappings (e.g., rainbow) are not perceptually uniform and might not be effective to encode ordered attributes.

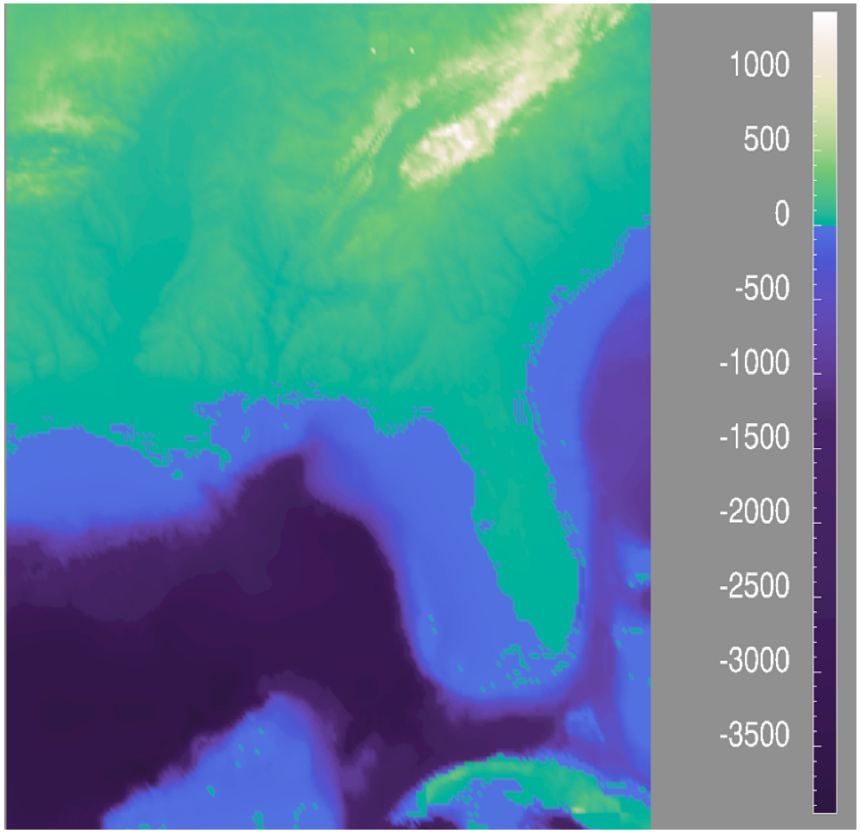
Colormaps



Converted to grayscale

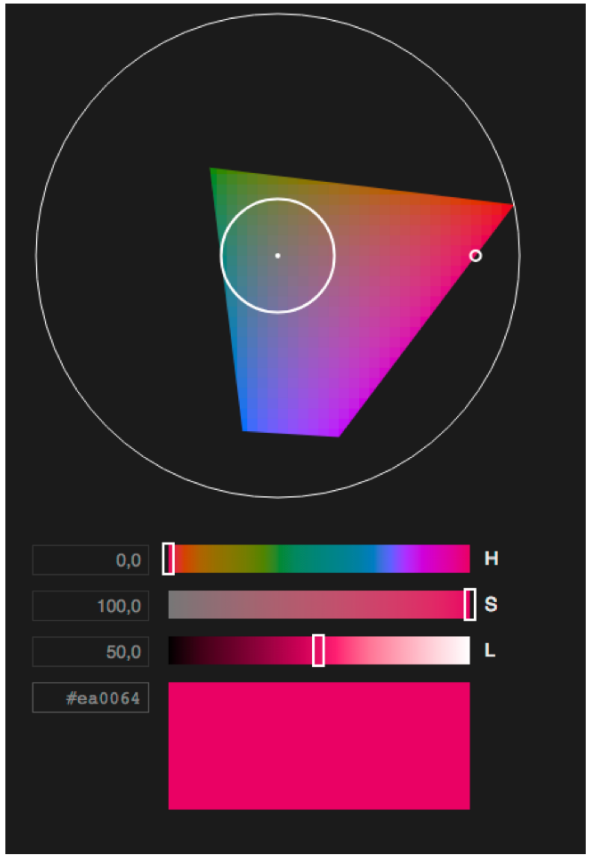
An example: design of diverging colormap





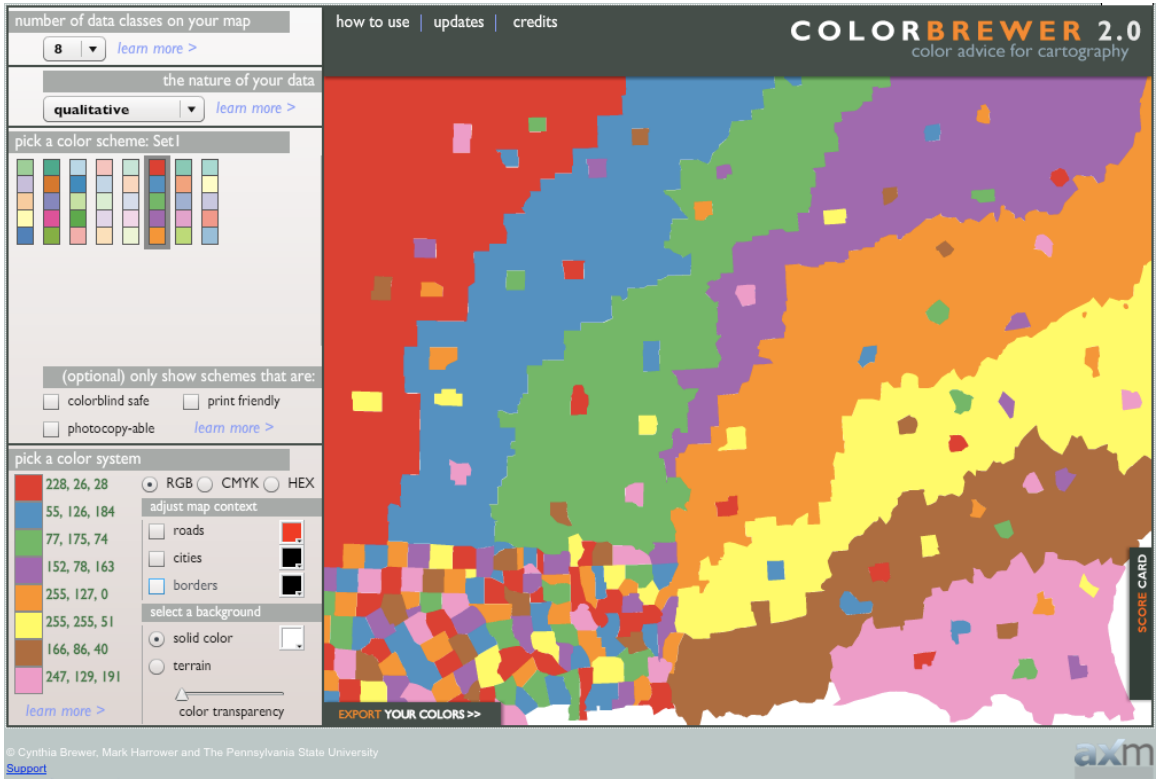
Design colormaps: get it right

- Use CIELab and CIELUV spaces that are perceptually uniform
  - Human friendly HSL (HSL_{uv}): http://www.hsluv.org/



Design colormaps: tools

- Use CIELab and CIELUV spaces that are perceptually uniform
  - Human friendly HSL (HSL_{uv}): http://www.hsluv.org/
  - Color Brewer: http://colorbrewer2.org



Design colormaps: tools

- Use CIELab and CIELUV spaces that are perceptually uniform
  - Human friendly HSL (HSL_{uv}): http://www.hsluv.org/
  - Color Brewer: http://colorbrewer2.org
  - Several libraries provide some helps (e.g., see https://seaborn.pydata.org/tutorial/color_palettes.html)

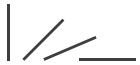
Additional visual channels

Size channel

- It is a magnitude channel
- Interacts with shape and color channels
- Accuracy depends on dimensionality:
  - length (1D size) is very accurate
  - area (2D size) is moderately accurate
  - volume (3D size) is not accurate

Angle/Tilt channel

- **Tilt** vs angle



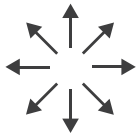
tilt

angle

- It is a magnitude channel

Sequential ordered
line mark or arrow glyph

Diverging ordered
arrow glyph



Cyclic ordered
arrow glyph

- Perceptual accuracy is not uniform
  - More accurate around 0°, 90°, and 45°

Shape channel

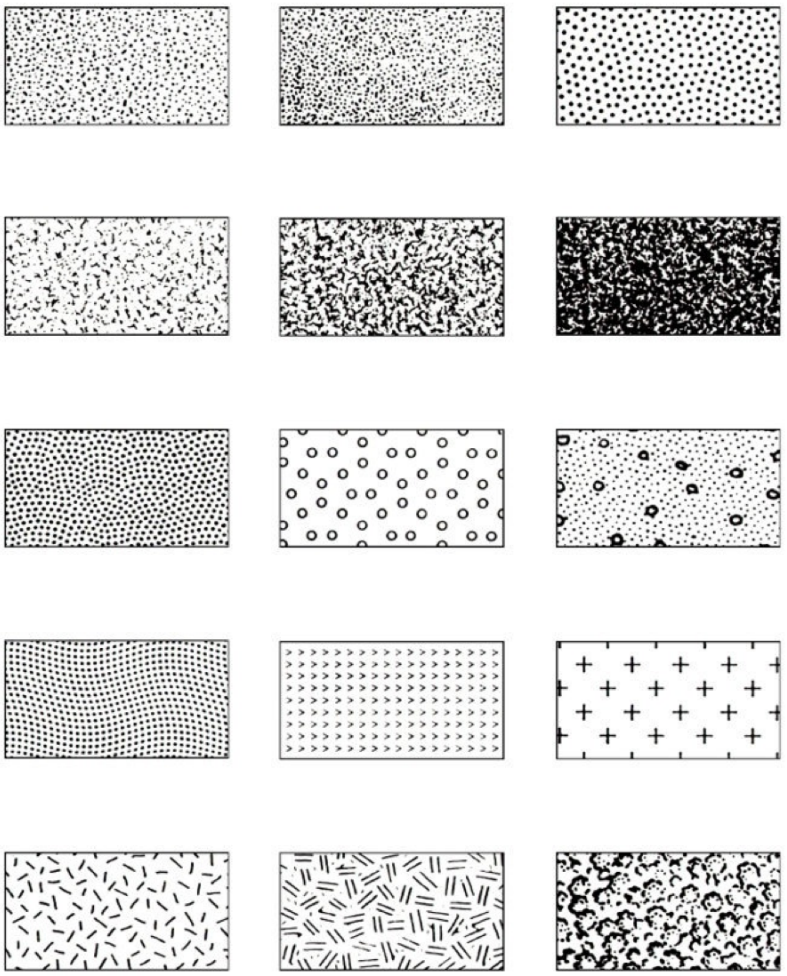
- It is an identity channel
- Generally used with point marks
- Major interaction with size and color channels

Curvature channel

- It is a magnitude channel.
- It can be used only with line marks.
- It is very inaccurate channel.

Texture/Stippling channels

- Encoding data with patterns based on three dimensions:
  - orientation
  - size
  - density
- Combined together, they can encode a categorical attribute.
- Otherwise, a dimension can be also used to encode an ordered attribute.
- Heavily used in the past (with older printing technologies) are now mainly used with **line marks**.

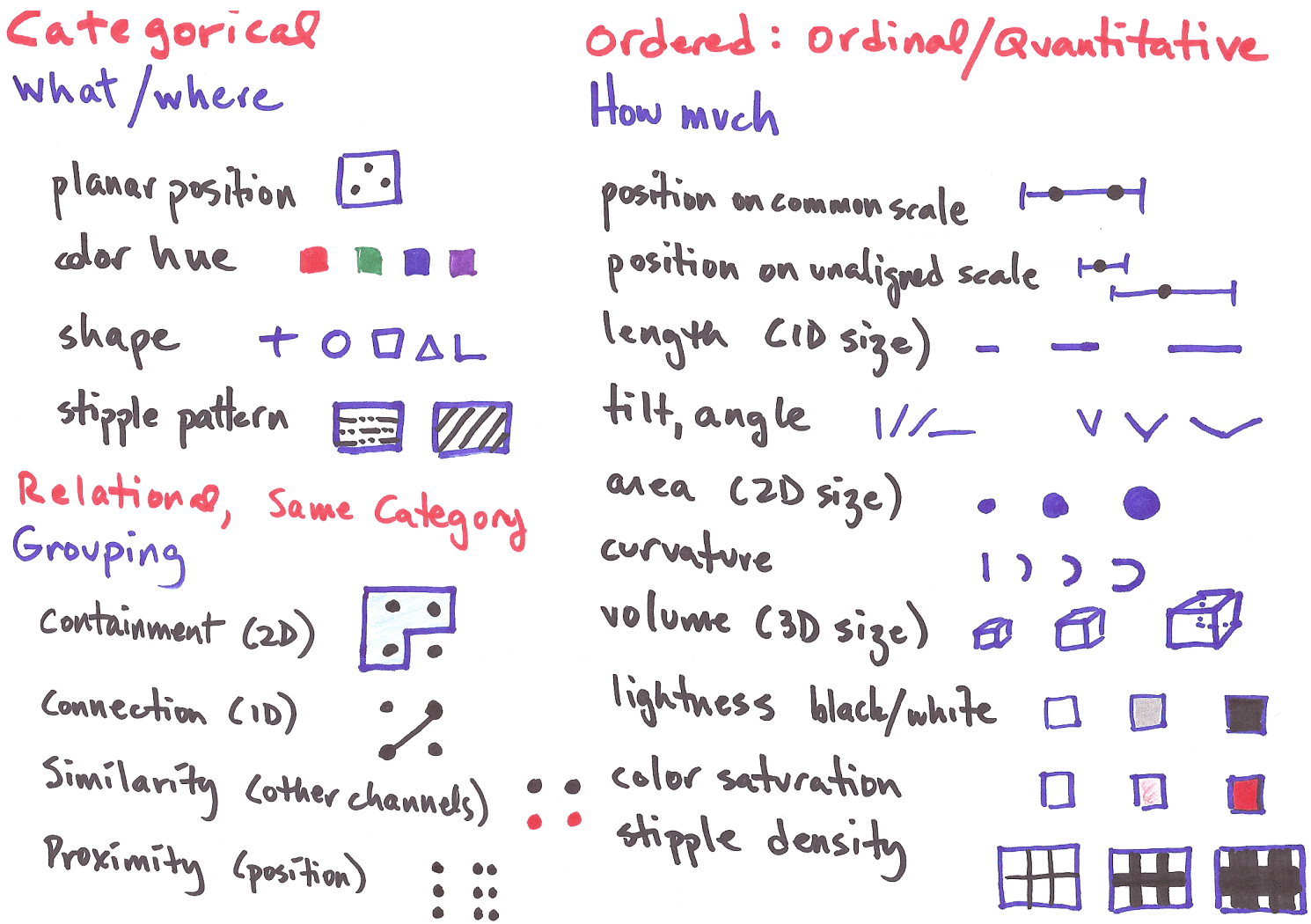


Motion channels

- They are identity channels that can be used for animated/interactive visualization:
  - Direction
  - Speed
  - Flickering
- Extremely salient and well **separable from static channels.**
- Separability of different motion channels as well the possibility to encode different values is not well studied.
- Often used to encode binary attribute or to highlight items in interactive visualization.

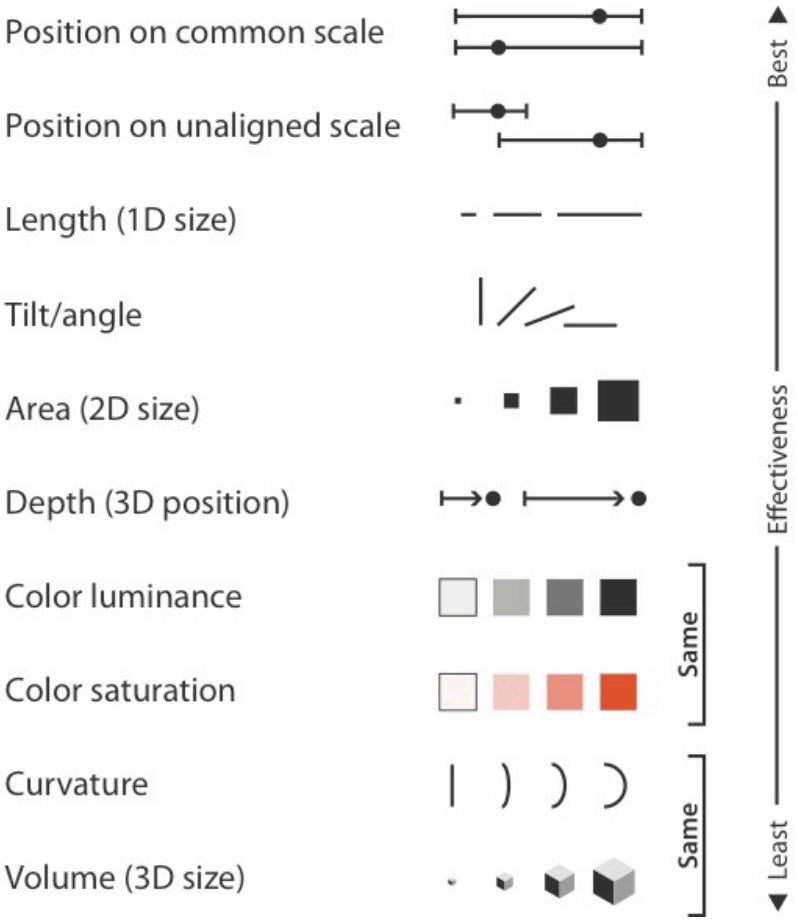
Summary on visual channels

A visual channels summary



Ranking

Magnitude channels



Identity channels

Hands-On

Working with Colors in Seaborn