

Lecture 2

Principles + Best Practices

DSCI 532, Data Visualization II

January 7, 2019

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Choosing a visual encoding

How to map your data into a visual form

Topics

- Marks + Channels
- Colour
- Applying the Principles

Marks + Channels

Material and figures primarily from
Visualization Analysis and Design | Ch 5

Tamara Munzner

Marks + Channels

Mark

- geometric primitive

→ Points



→ Lines



→ Areas



Channel

- appearance of mark

→ Position

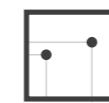
→ Horizontal



→ Vertical



→ Both



→ Color



→ Shape



→ Tilt



→ Size

→ Length



→ Area



→ Volume



Marks + Channels | Examples

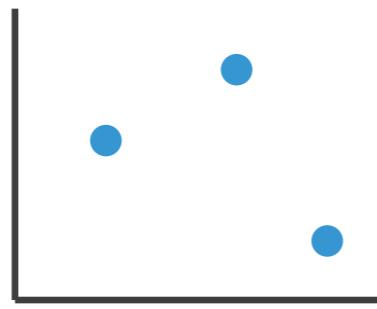


Mark

point

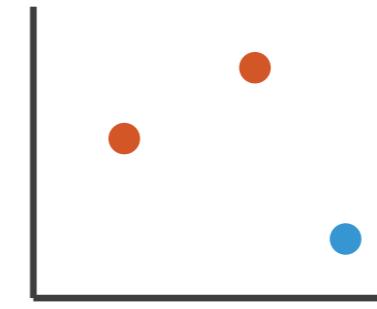
Channel

horizontal position



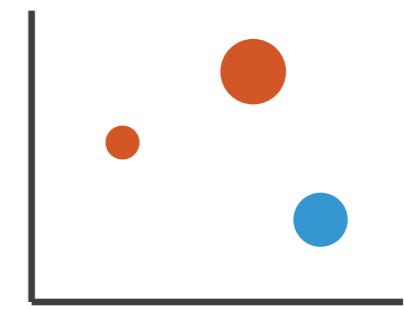
point

horizontal position
vertical position



point

horizontal position
vertical position
colour hue



point

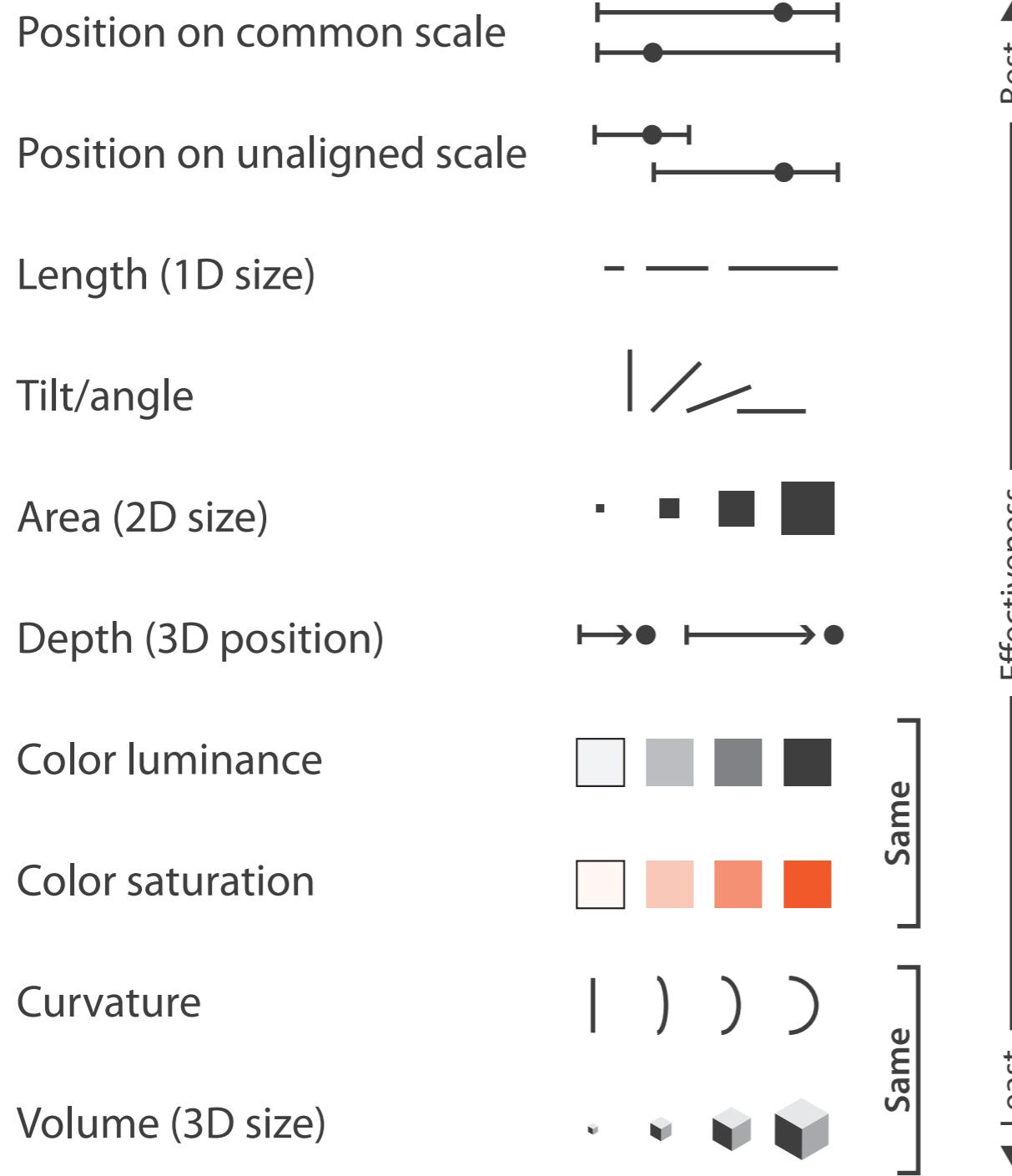
horizontal position
vertical position
colour hue
size (area)

Can express different dimensions of your data with different visual channels

Visualizing quantitative values

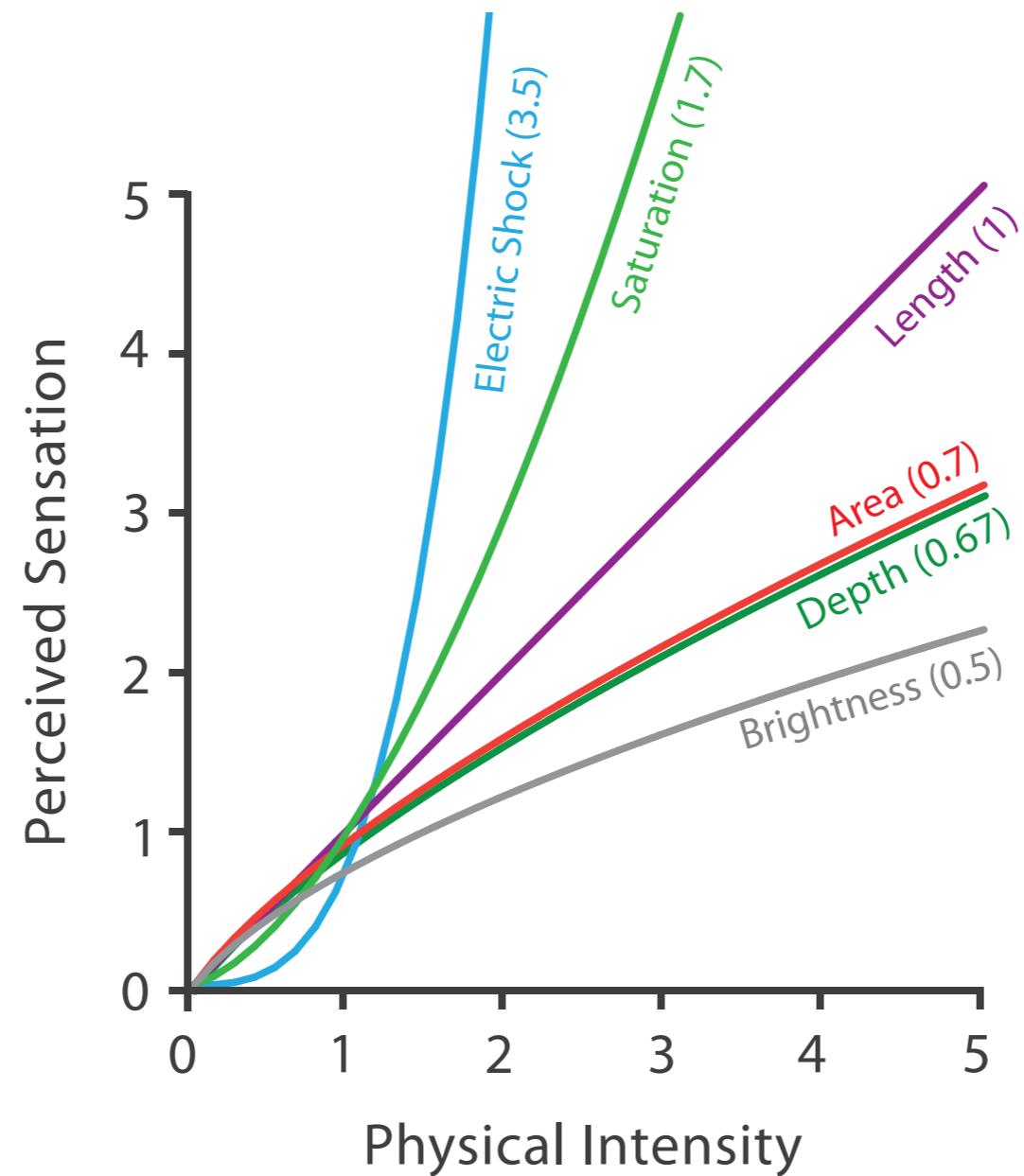
Best practices | Visualizing quantitative values

④ Magnitude Channels: Ordered Attributes



Accuracy

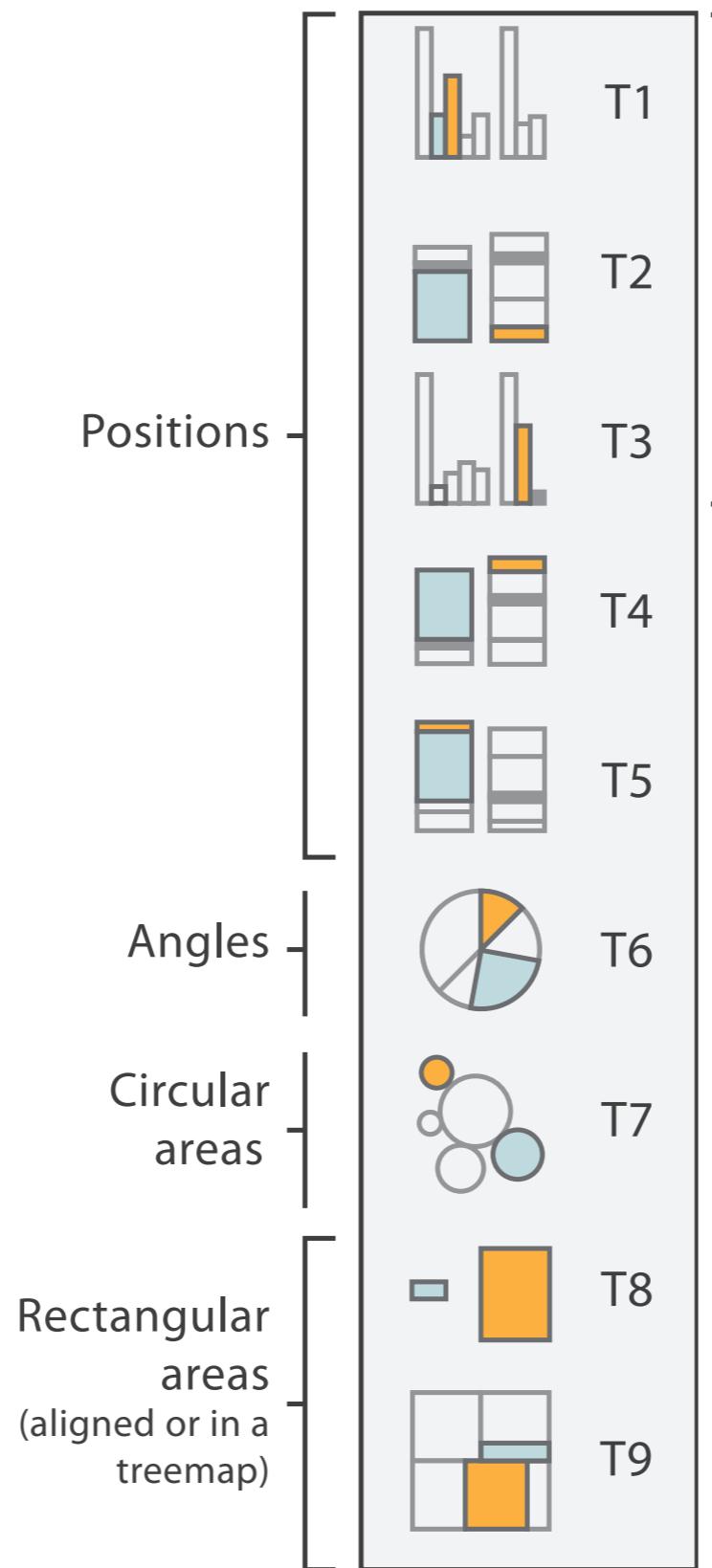
Steven's Psychophysical Power Law: $S = I^n$



Accuracy

Tasks

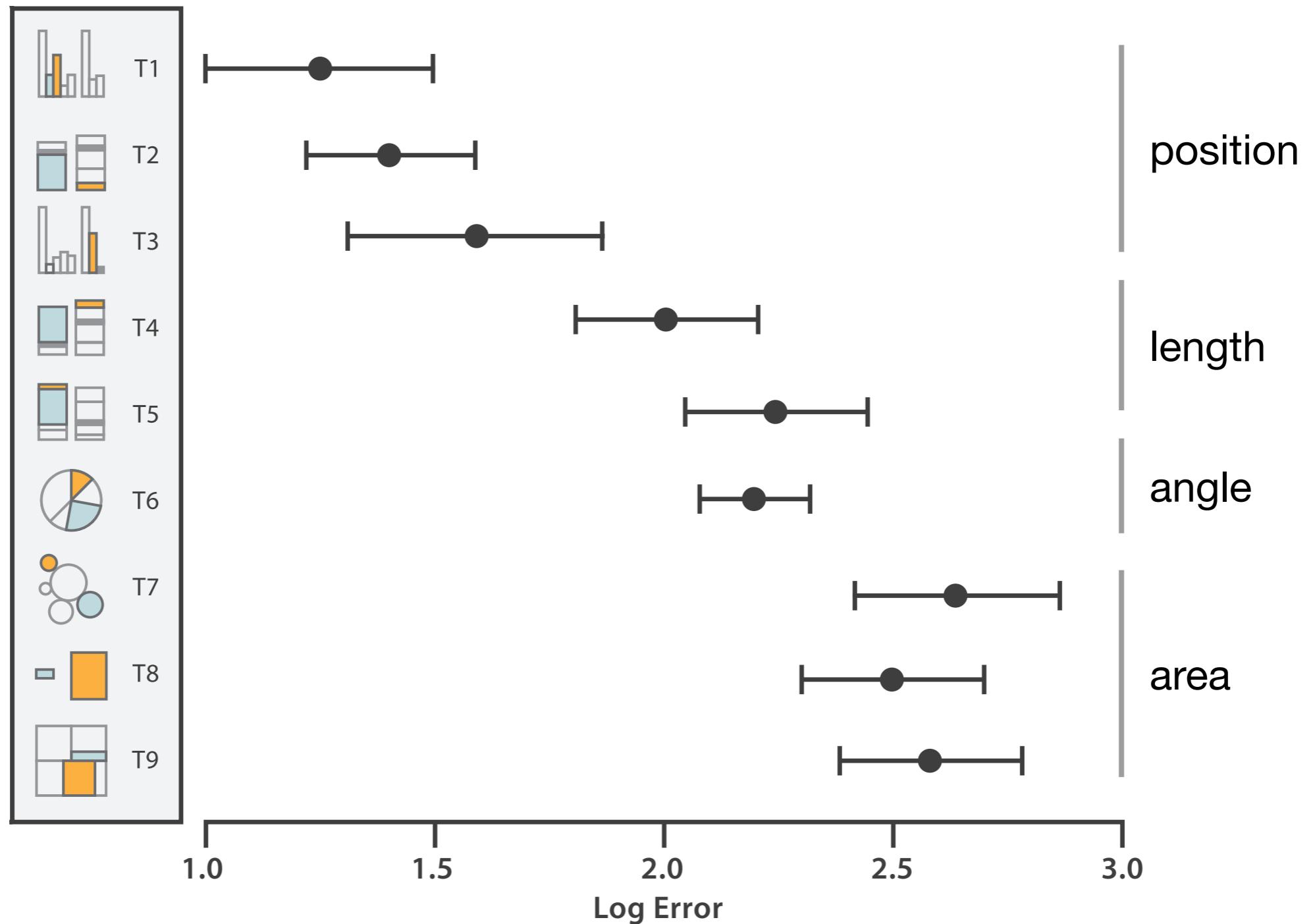
- identify the smaller of two marked values
- estimate what percentage the smaller is of the larger



position on a common scale

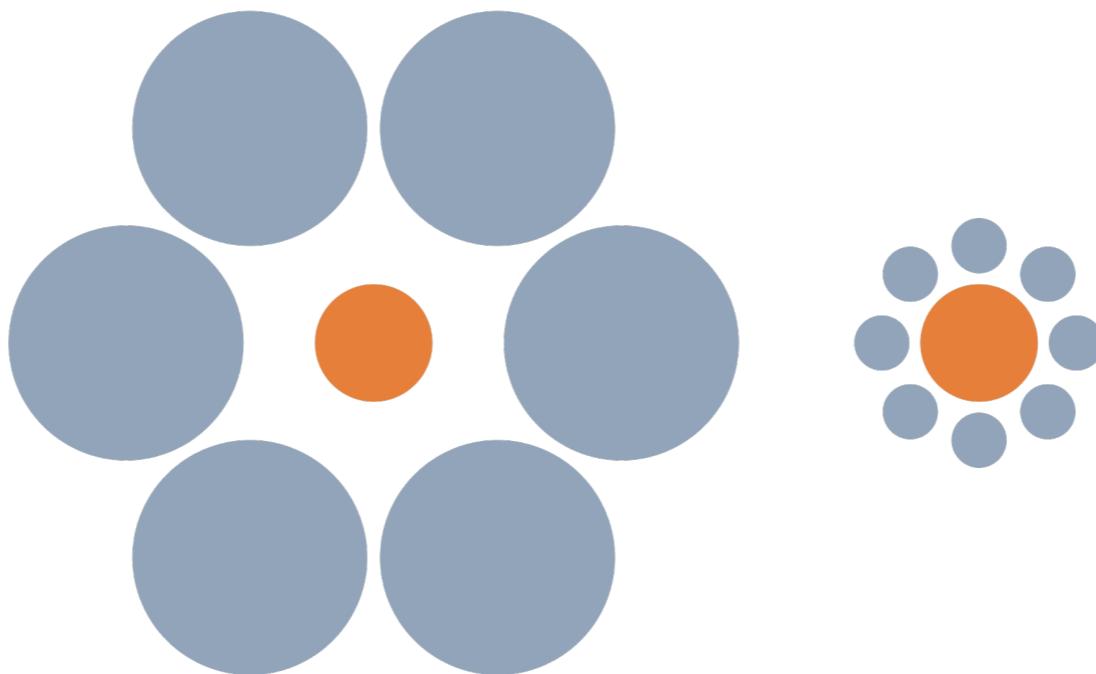
length comparison

Position better than angle better than area

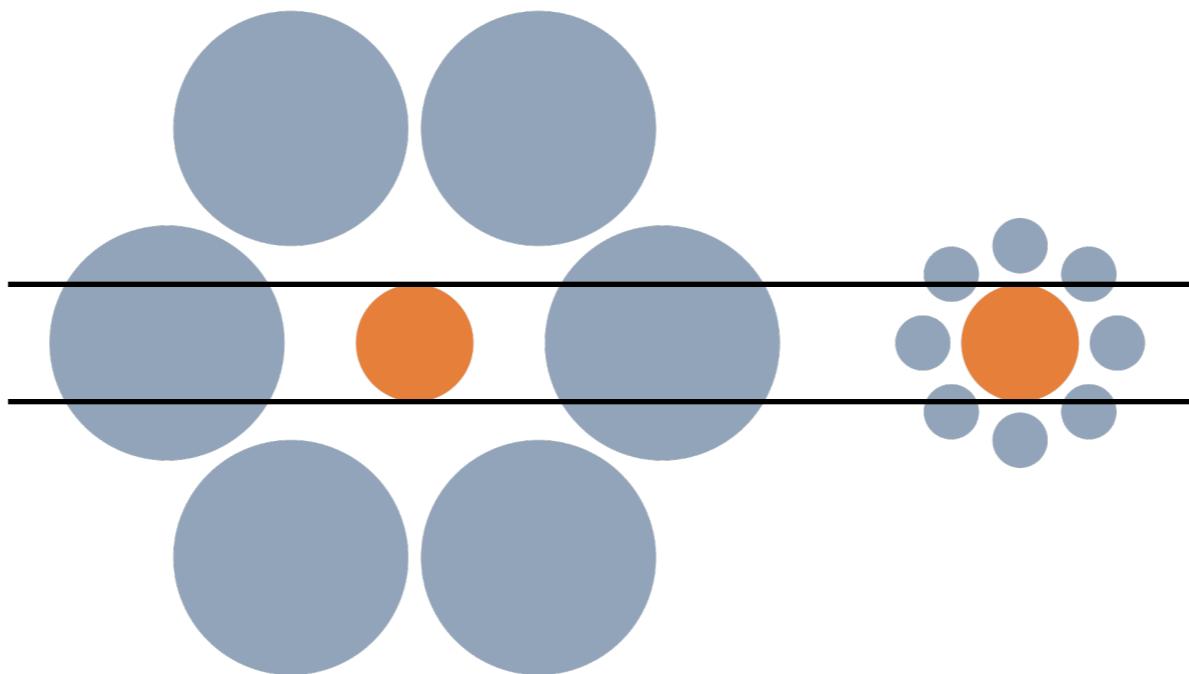




Context matters



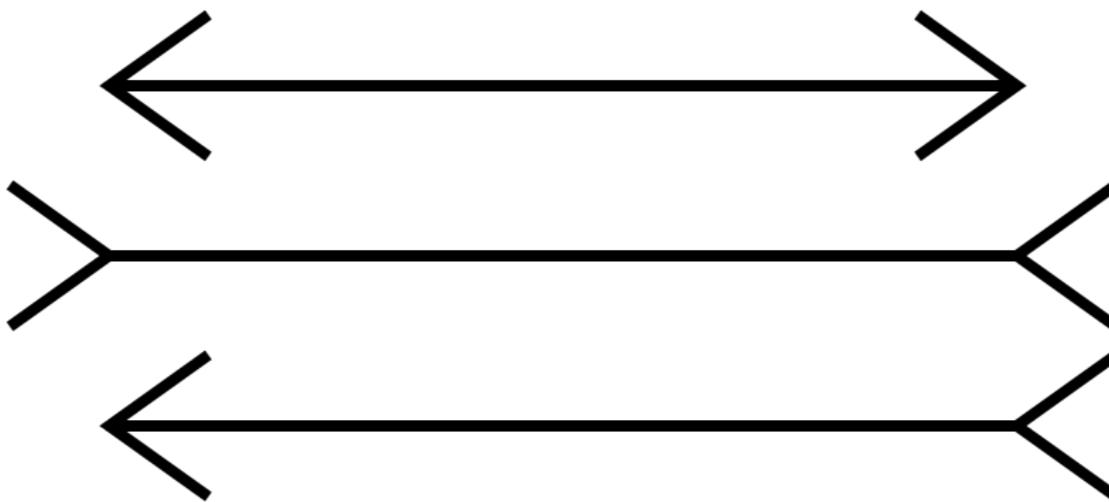
Context matters



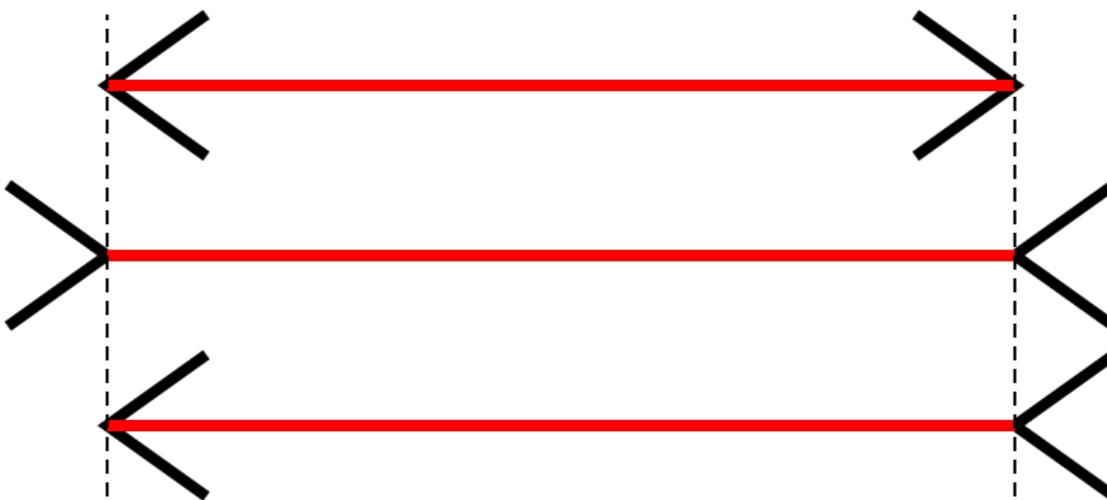
Ebbinghaus illusion

https://en.wikipedia.org/wiki/Ebbinghaus_illusion

Context matters



Context matters

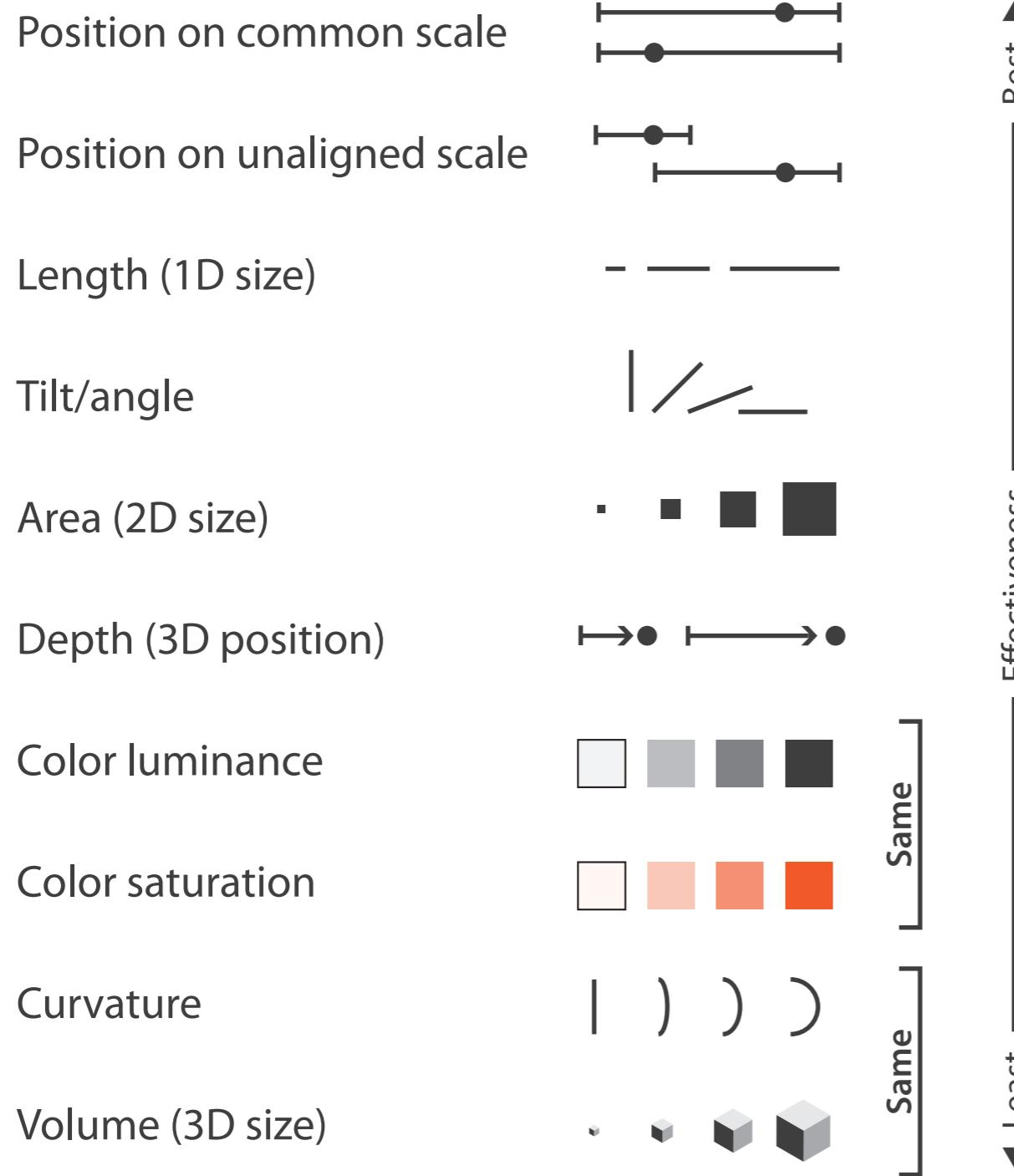


Müller-Lyer illusion

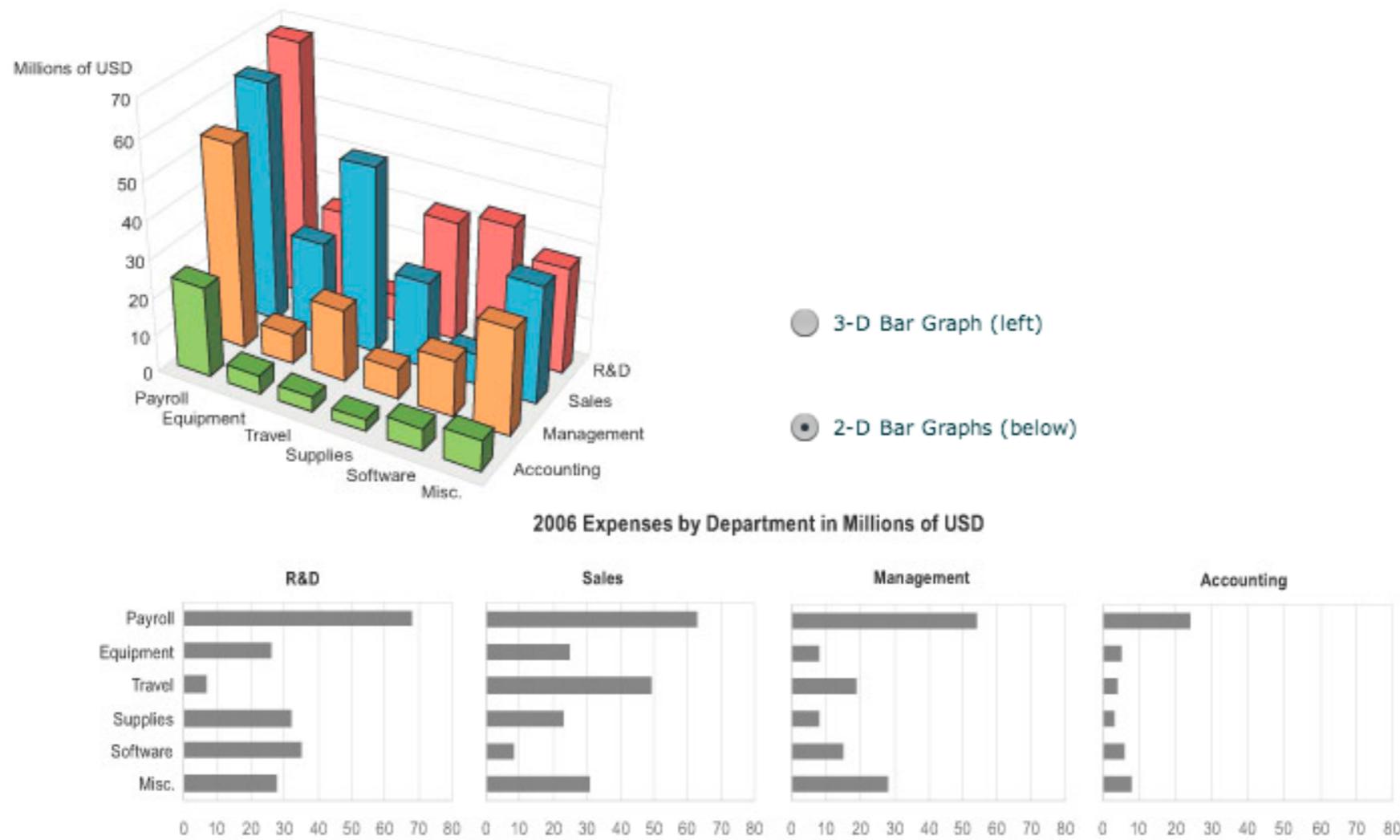
https://en.wikipedia.org/wiki/M%C3%BCller-Lyer_illusion

Best practices | Visualizing quantitative values

④ Magnitude Channels: Ordered Attributes



Avoid unnecessary 3D



3D bars have several limitations

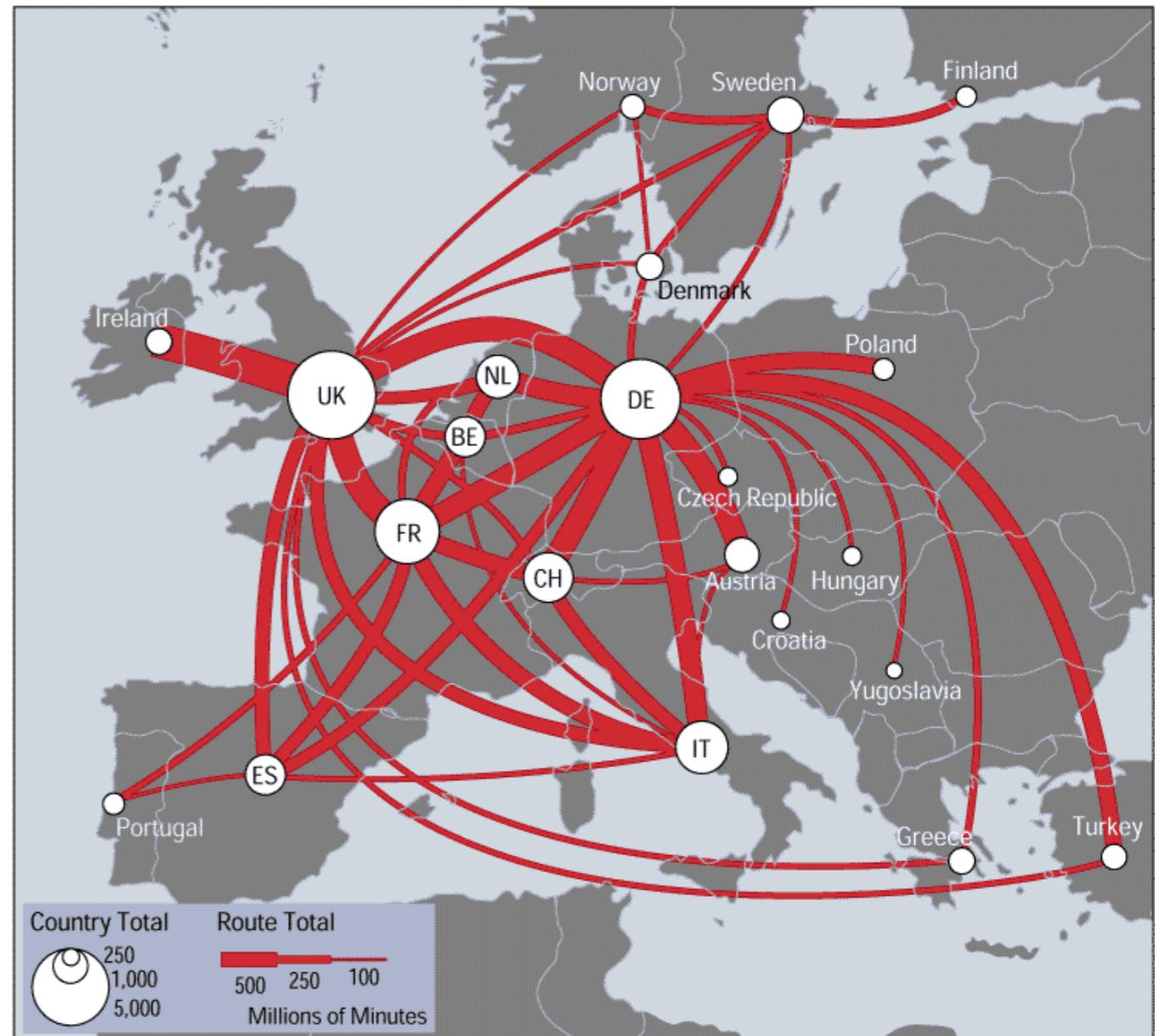
- Perspective distortion
- Occlusion

Faceting into 2D almost always better

Other considerations in ranking channels

How many usable steps?

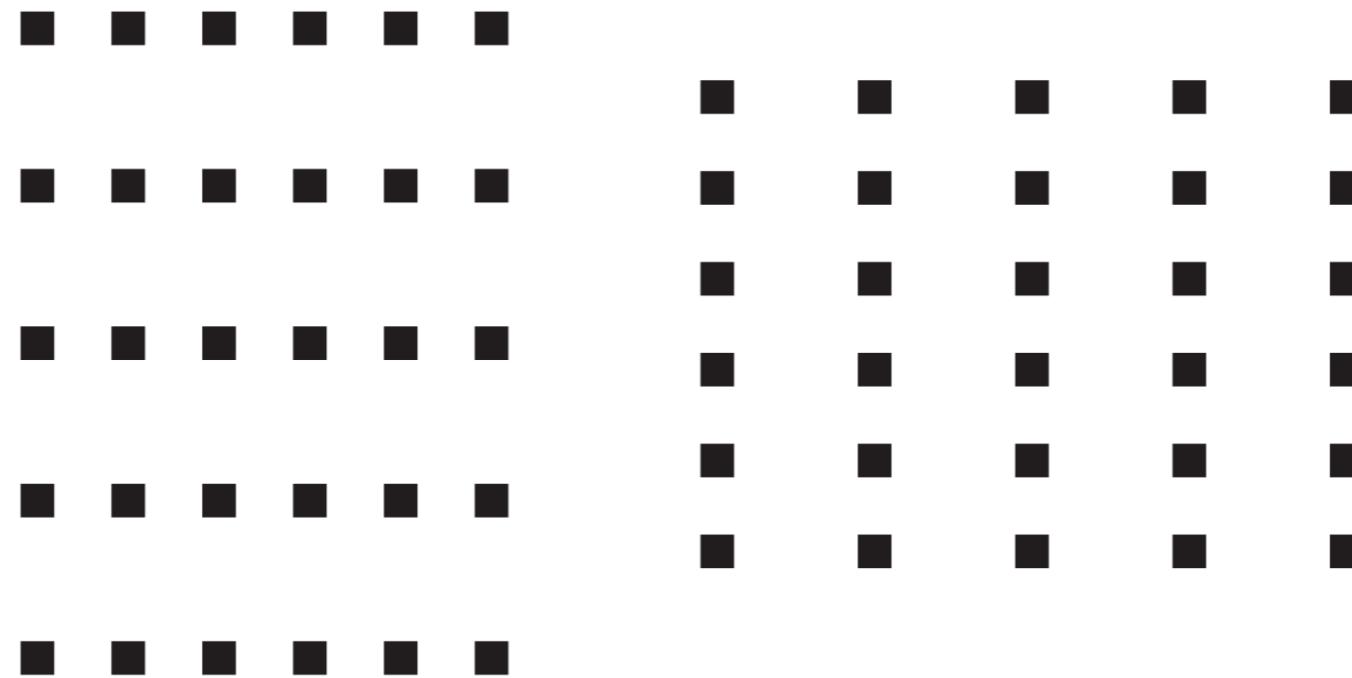
- Linewidth: few bins but salient



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

Visualizing groups

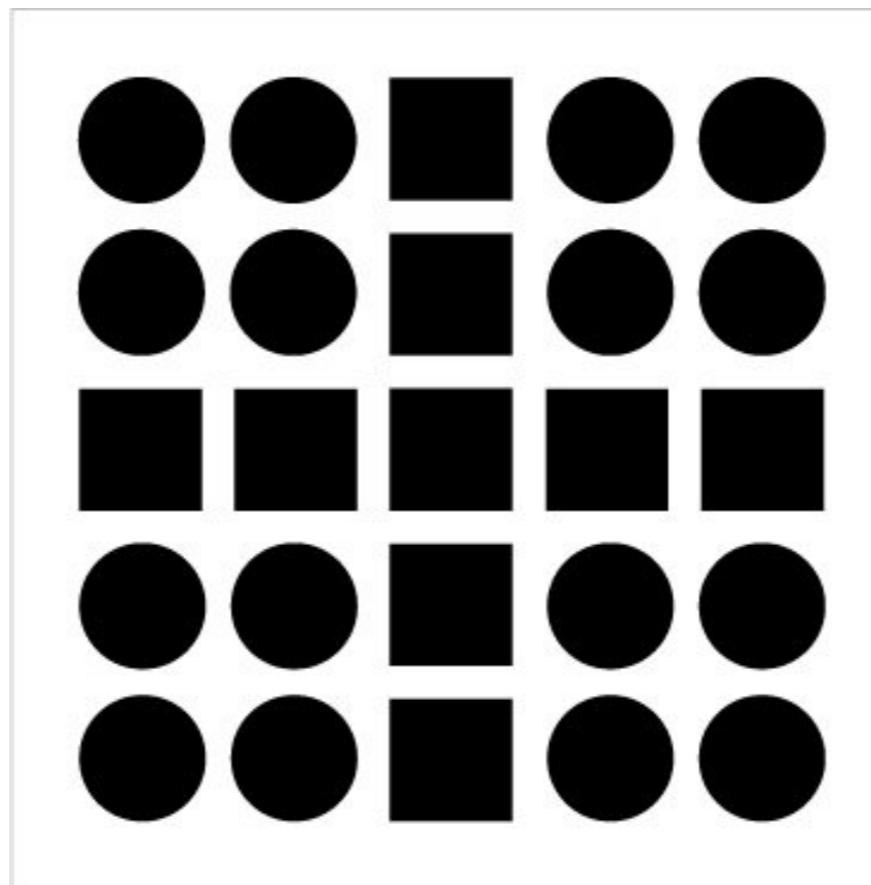
Perceiving Groups | Gestalt Principles



Proximity

Graphic from Bang Wong's Points of View column, Nature Methods, 2010

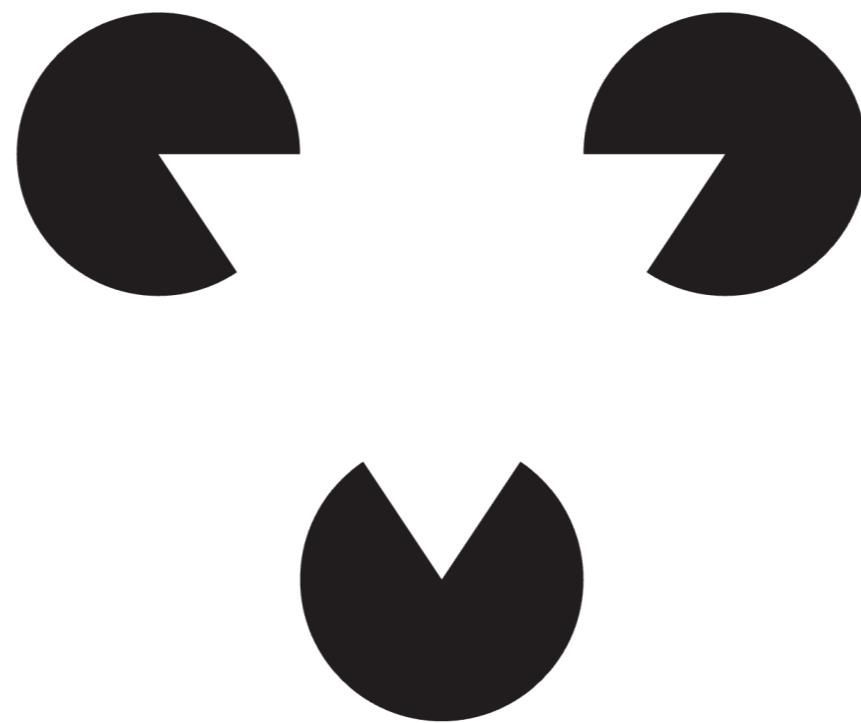
Perceiving Groups | Gestalt Principles



Similarity

Graphic from Bang Wong's Points of View column, Nature Methods, 2010

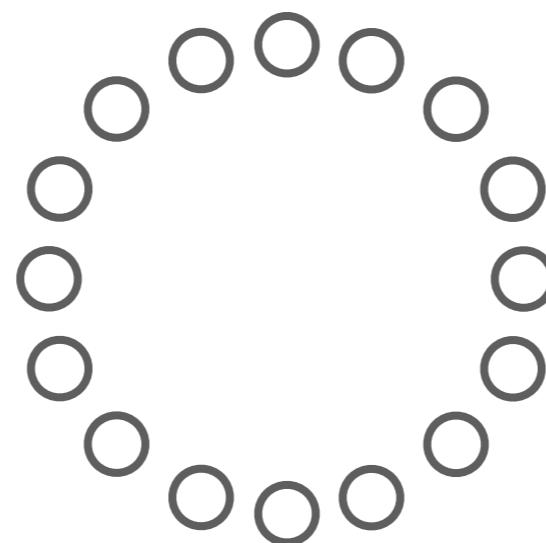
Perceiving Groups | Gestalt Principles



Closure

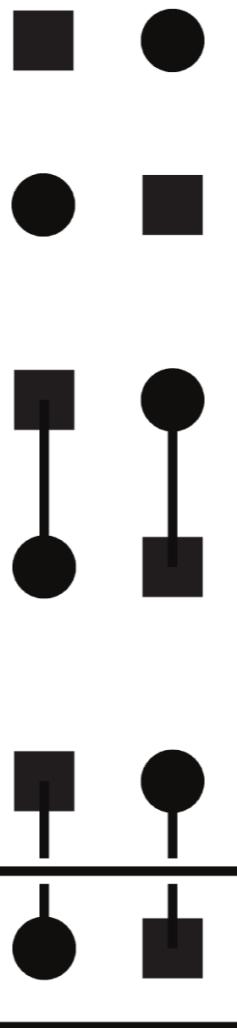
Graphic from Bang Wong's Points of View column, Nature Methods, 2010

Perceiving Groups | Gestalt Principles



Closure

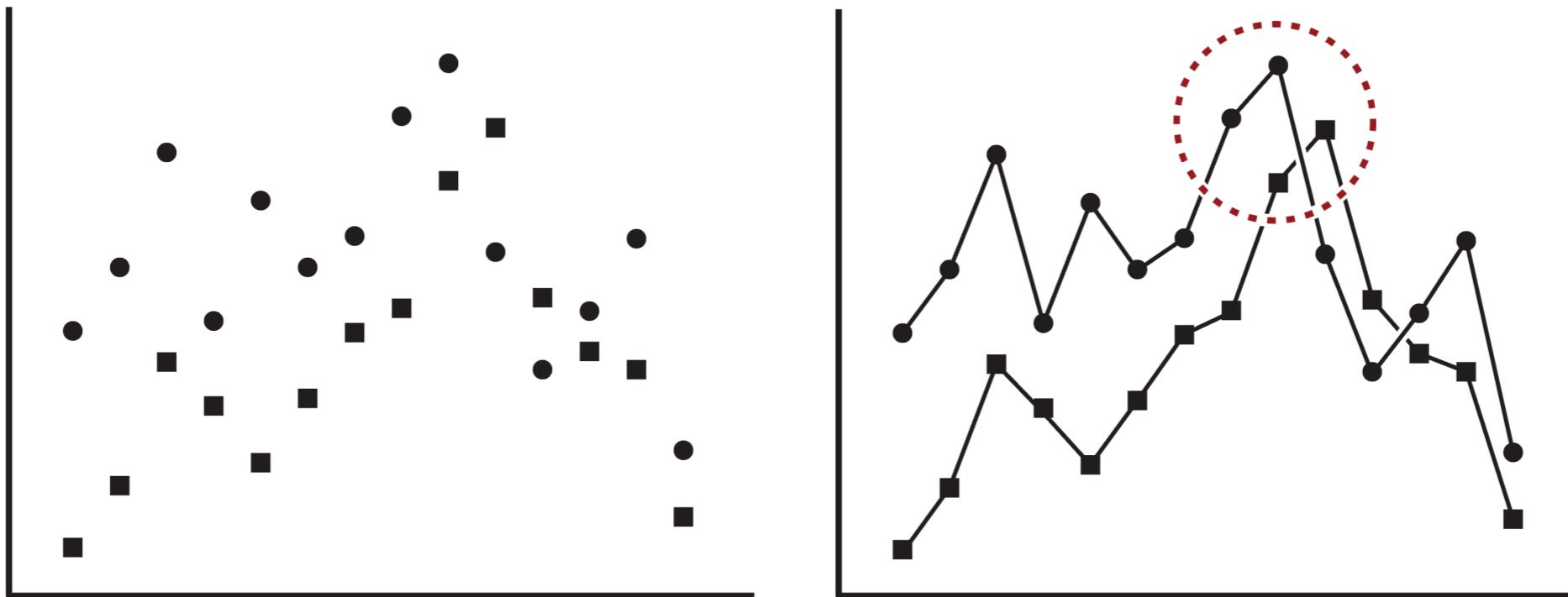
Perceiving Groups | Gestalt Principles



Connection + Containment

Graphic from Bang Wong's Points of View column, Nature Methods, 2010

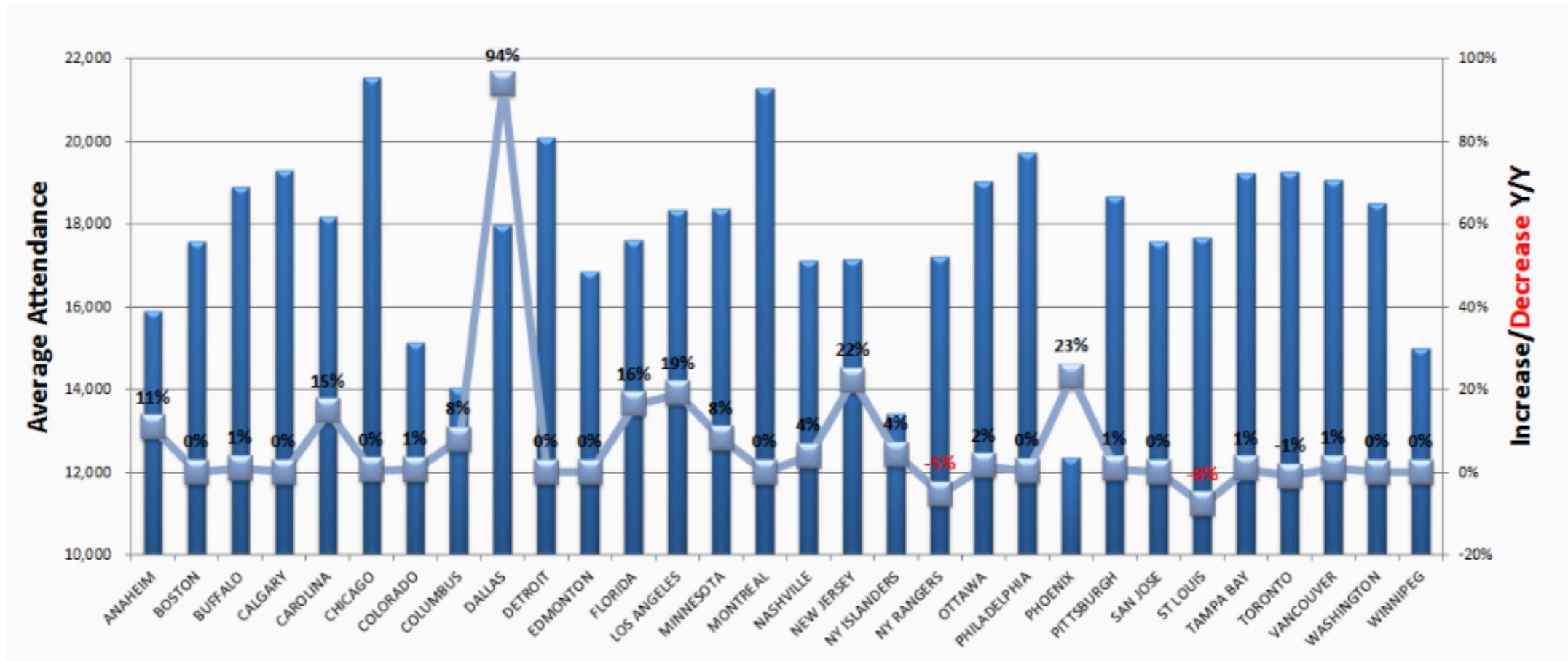
Perceiving Groups | Gestalt Principles



Connection + Containment

Graphic from Bang Wong's Points of View column, Nature Methods, 2010

Use caution in connecting the dots



<http://www.vizwiz.com/2018/12/nhl-attendance.html>

- Connecting points in a plot implies a sequence
 - If the slope of the line is meaningless or misleading, don't use a line!

Best practices | Visualizing groups

Containment	Best	Marks as Links	Connection
Connection		Containment	Connection
Proximity		Identity Channels: Categorical Attributes	
Similarity		Spatial region	
	Effectiveness	Color hue	
	Least	Motion	
		Shape	

Containment

Connection

Proximity

Similarity

Effectiveness

Least

Marks as Links

Containment

Connection

Identity Channels: Categorical Attributes

Spatial region

Color hue

Motion

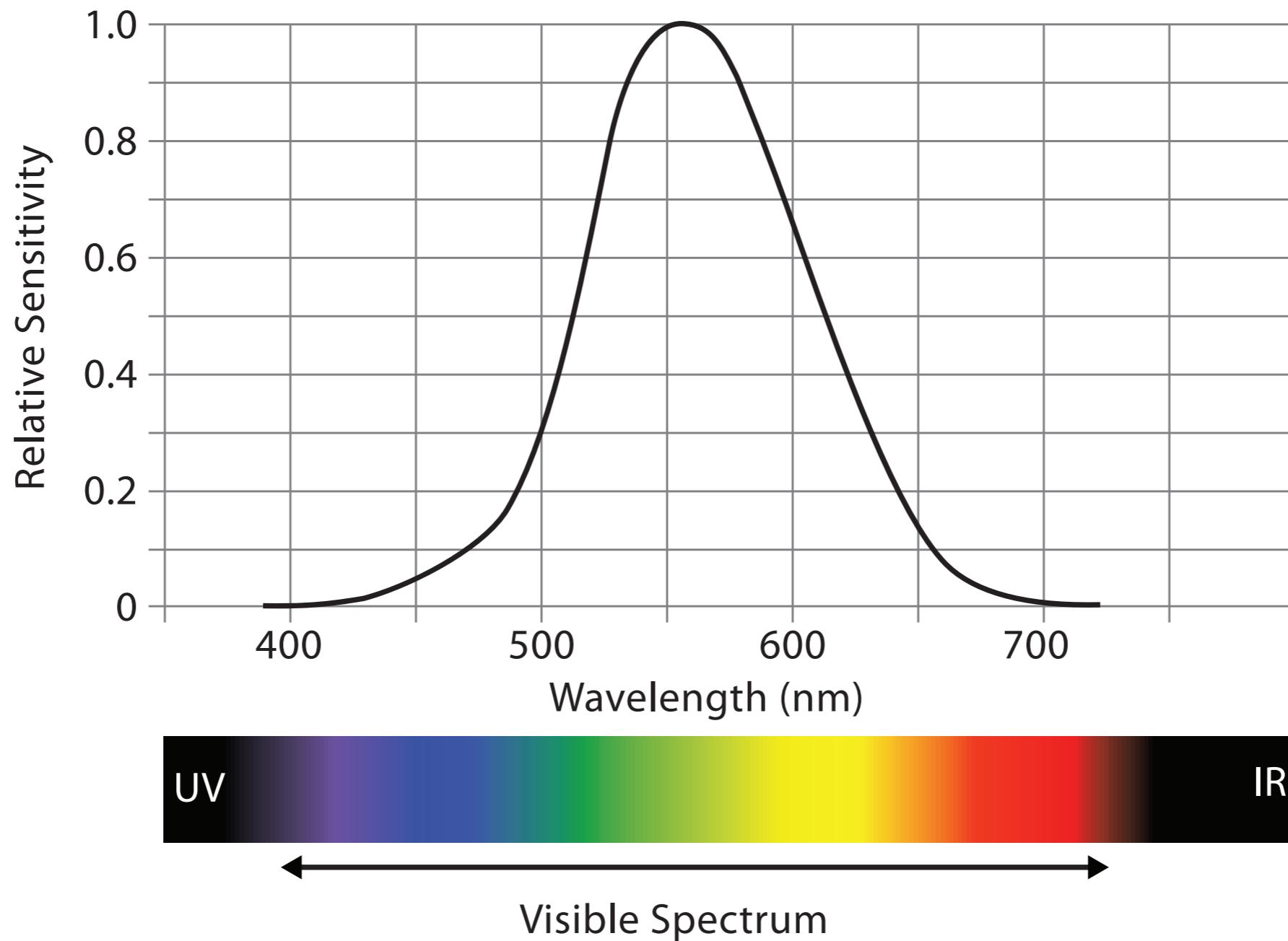
Shape

The diagram illustrates best practices for visualizing groups across five levels of effectiveness. At the top (Best) is 'Containment' with 'Marks as Links' (Containment and Connection) and 'Identity Channels: Categorical Attributes'. Below it is 'Connection' with 'Containment' and 'Connection'. The middle row includes 'Proximity' with 'Identity Channels: Categorical Attributes' and 'Similarity' with 'Spatial region', 'Color hue', 'Motion', and 'Shape'. The bottom row, labeled 'Least', shows 'Effectiveness' and 'Least'.

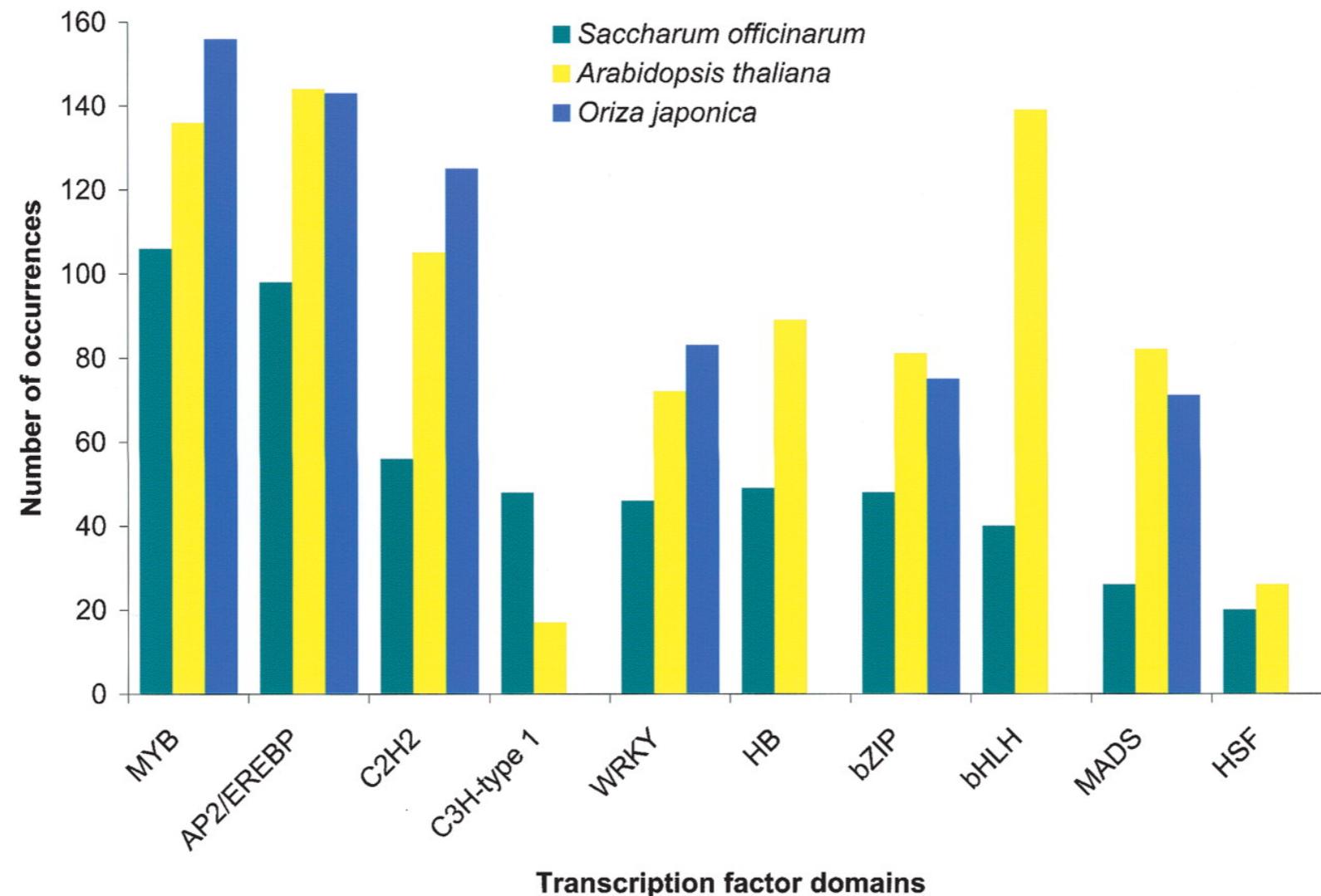
Colour

Choosing colours for your visualization

Not all colours are equal



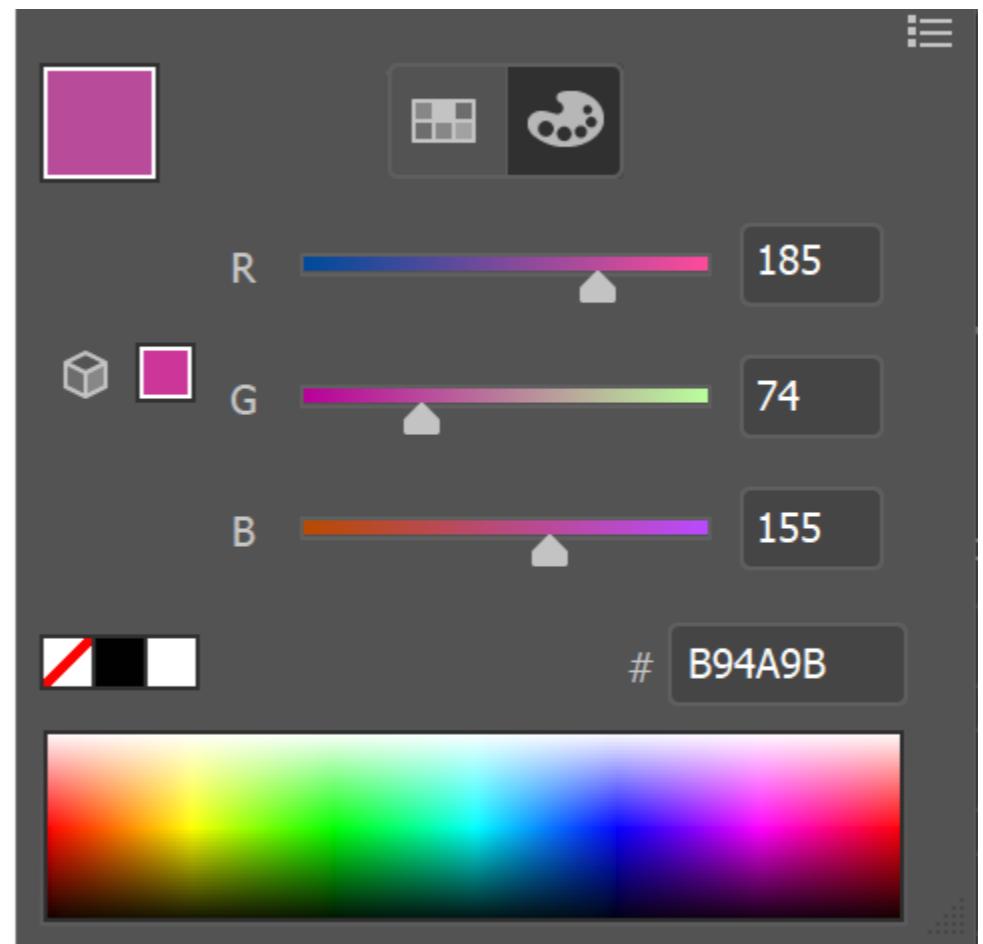
Yellow is bright and catches your attention



From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>

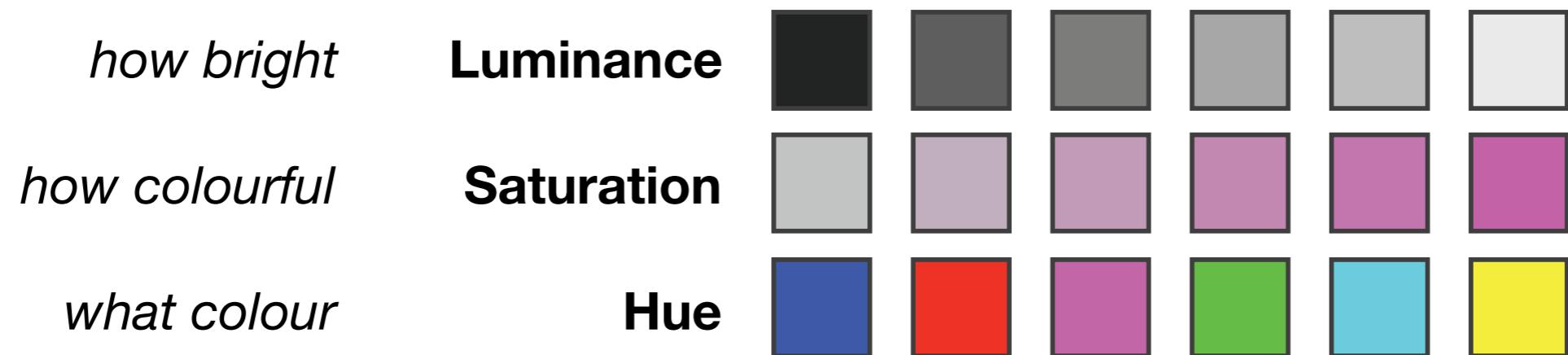
RGB colour space

- **Commonly used colour space**
- **But not intuitive**
 - We cannot easily decompose colours into red, green, and blue components



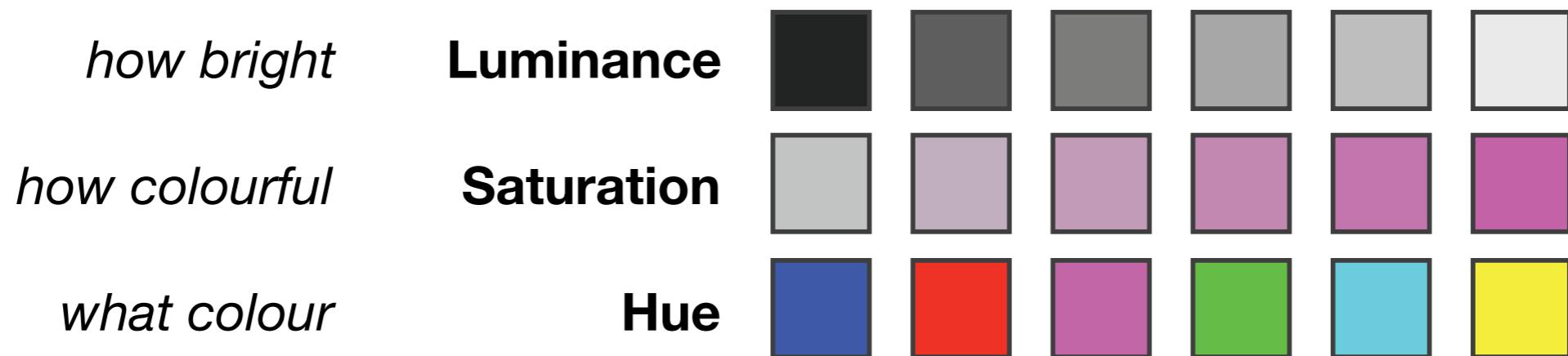
Adobe Illustrator colour picker

HSL colour space



HSV is very similar, where V stands for grayscale value and is linearly related to L

HSL colour space



- **More intuitive for selecting colours than RGB**
- **But not perceptually uniform**
 - Distances between colours in the space are not proportional to their perceived differences

HSL colour space

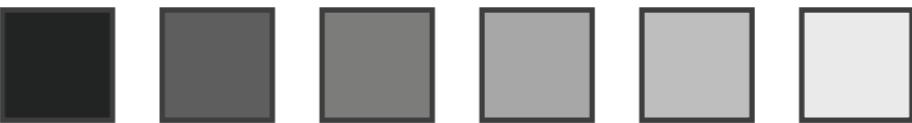
Corners of the RGB
color cube



L from HLS
All the same

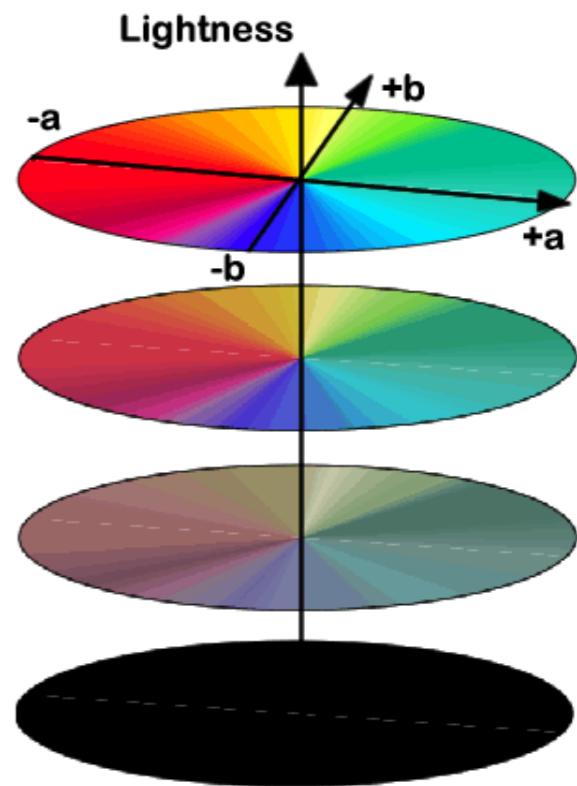


Luminance values



$L^*a^*b^*$ colour space (Lab)

- Single black-white luminance channel L^*
- Two colour axes a^* and b^* (not very intuitive)
- But axes are designed to be perceptually linear, so that equally sized steps appear equal to our visual system



HSL colour space

Corners of the RGB
color cube



L from HLS
All the same

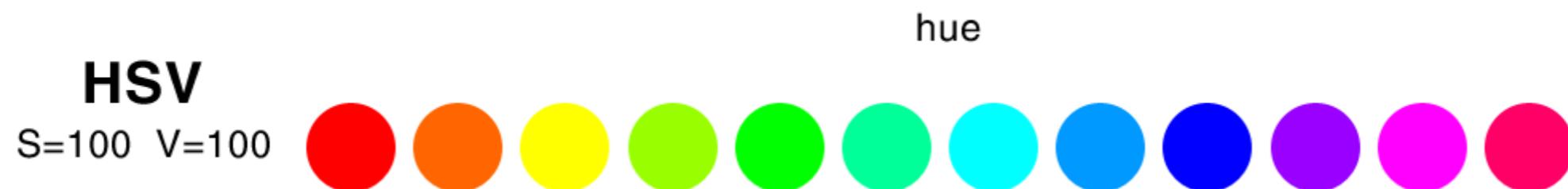


Luminance values

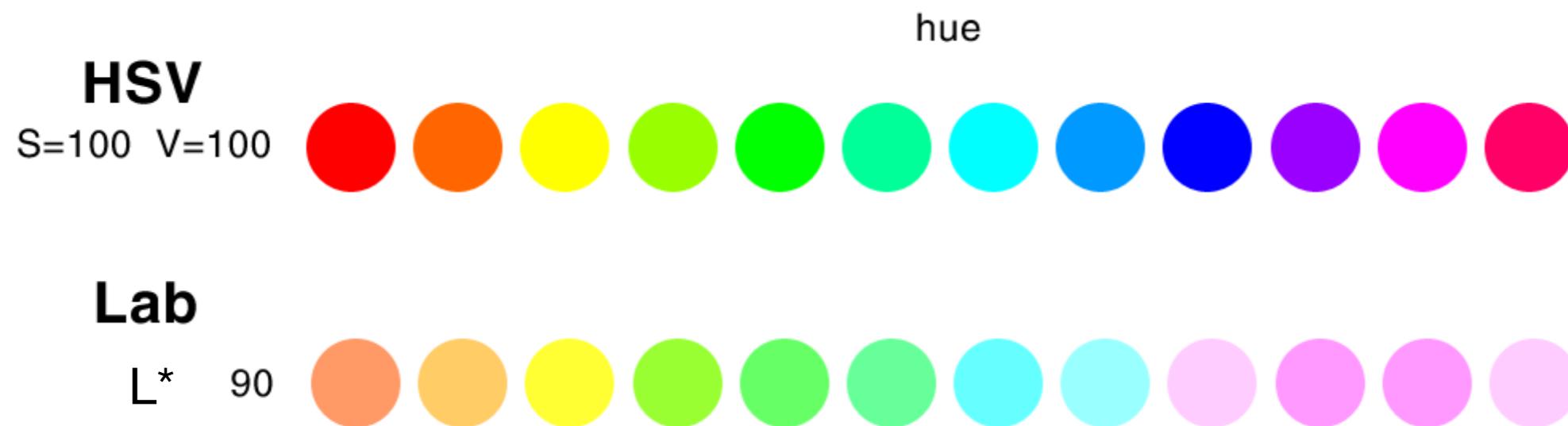


L* values

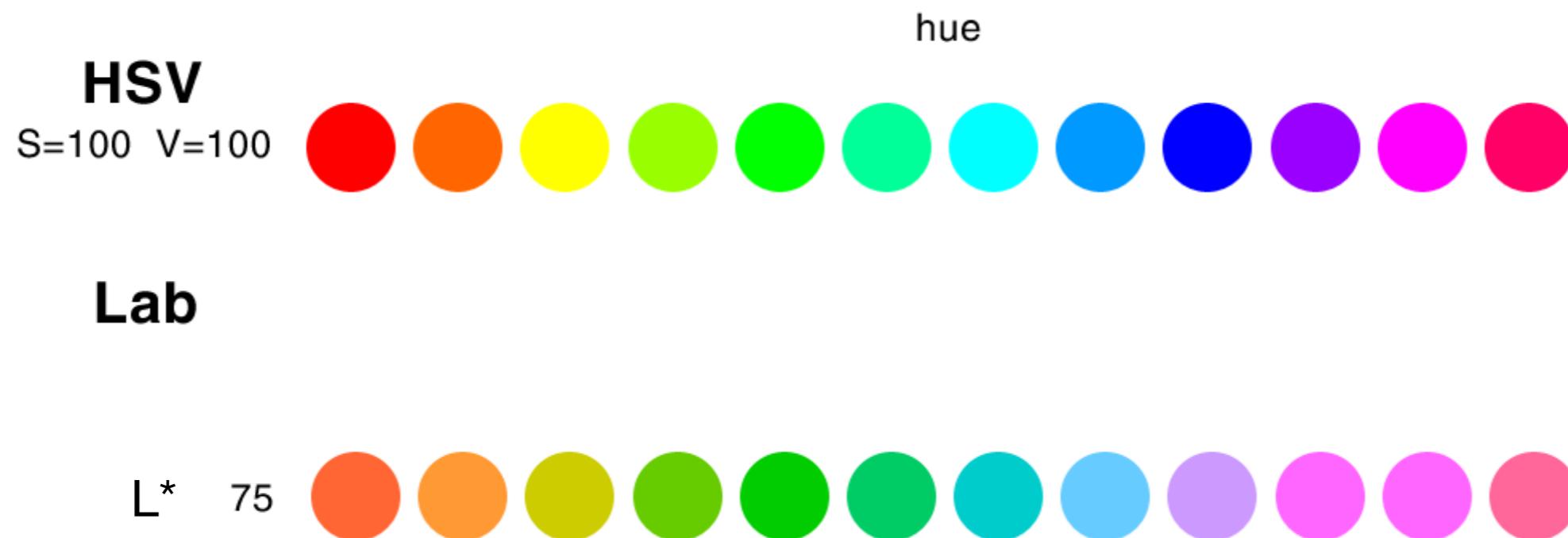




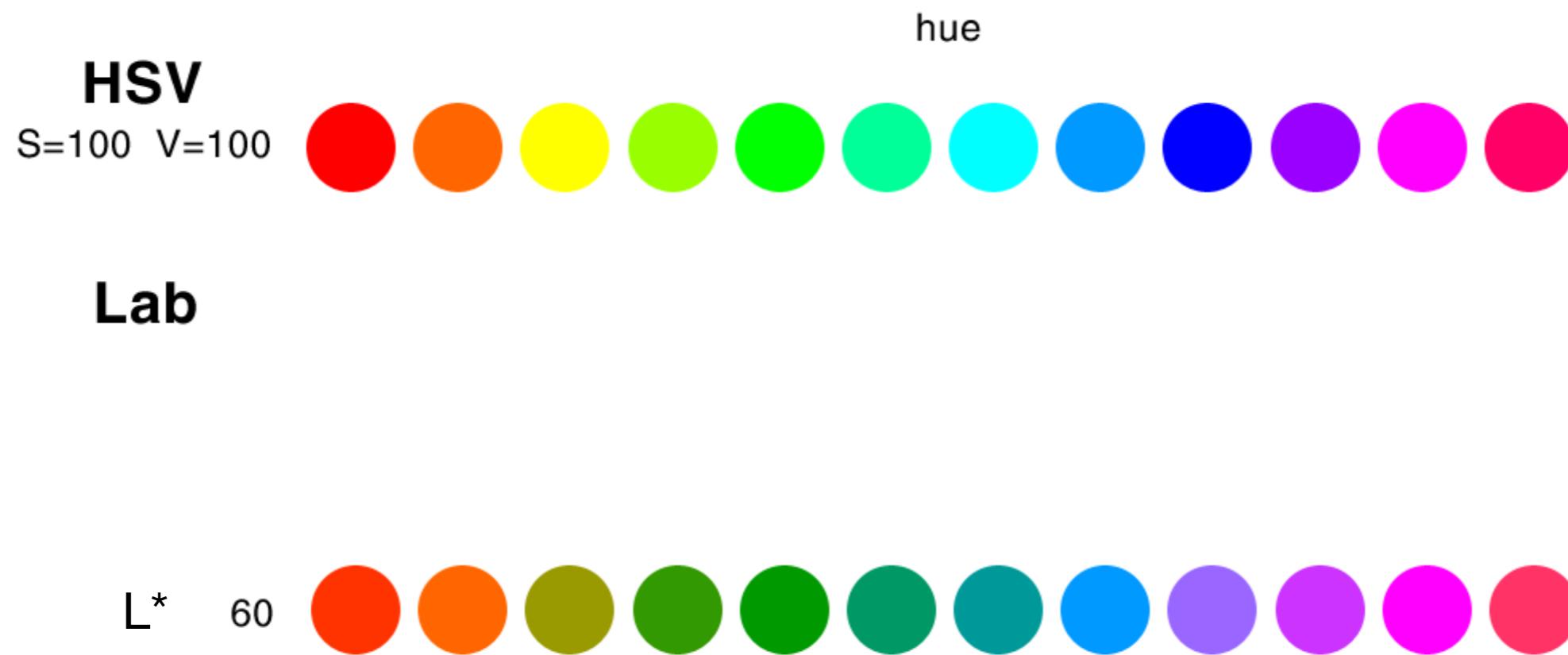
From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>



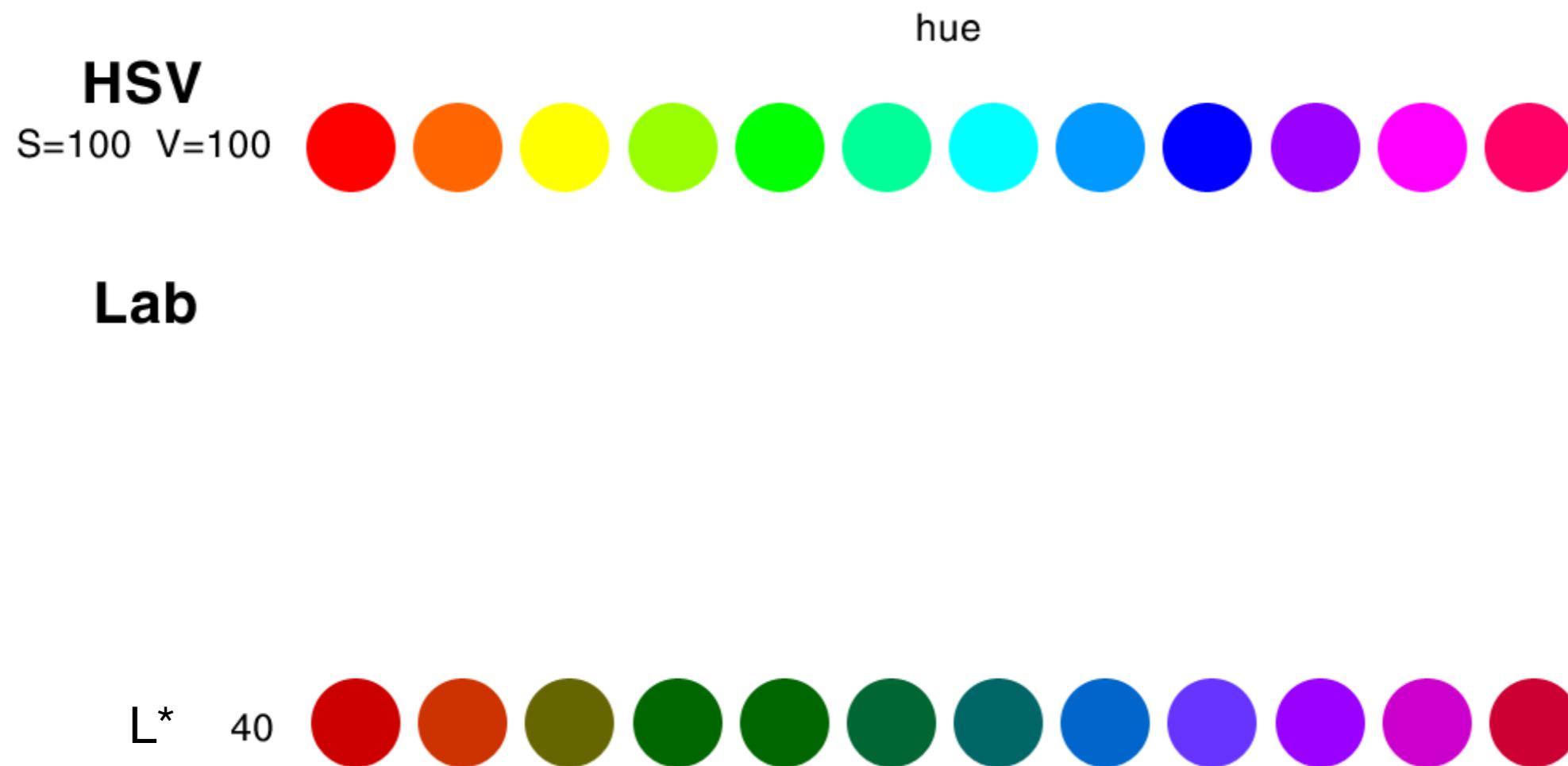
From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>



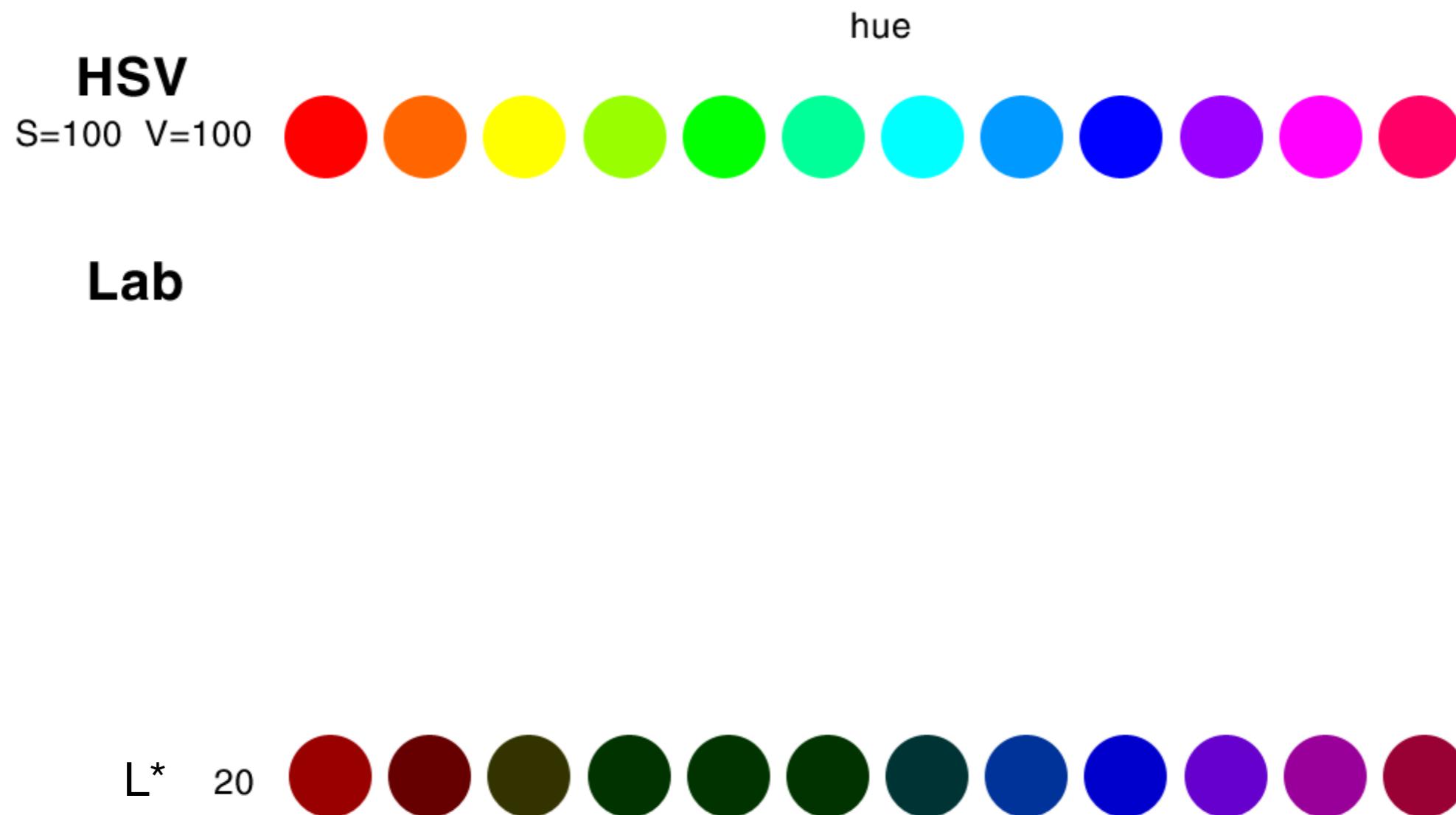
From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>



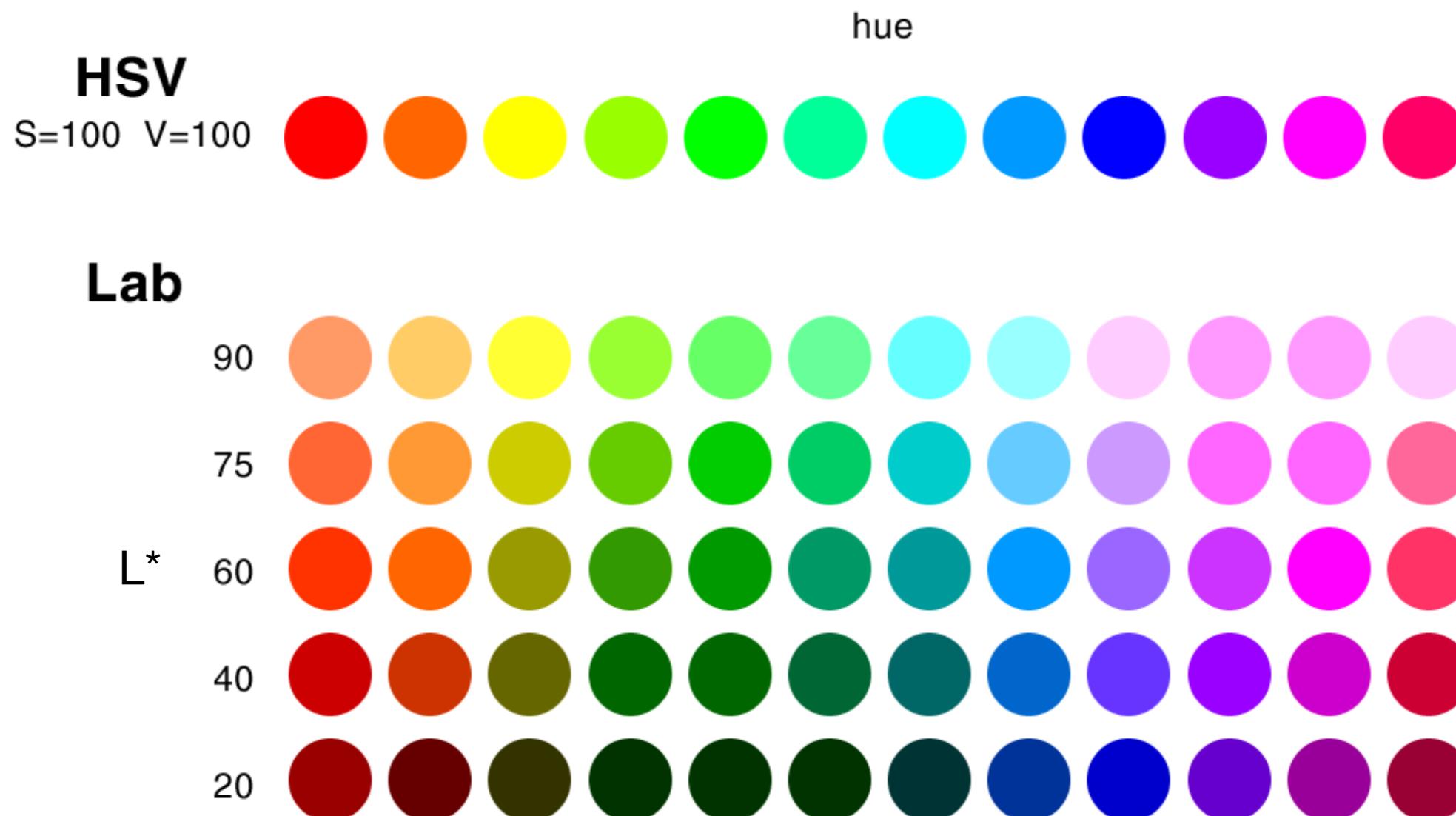
From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>



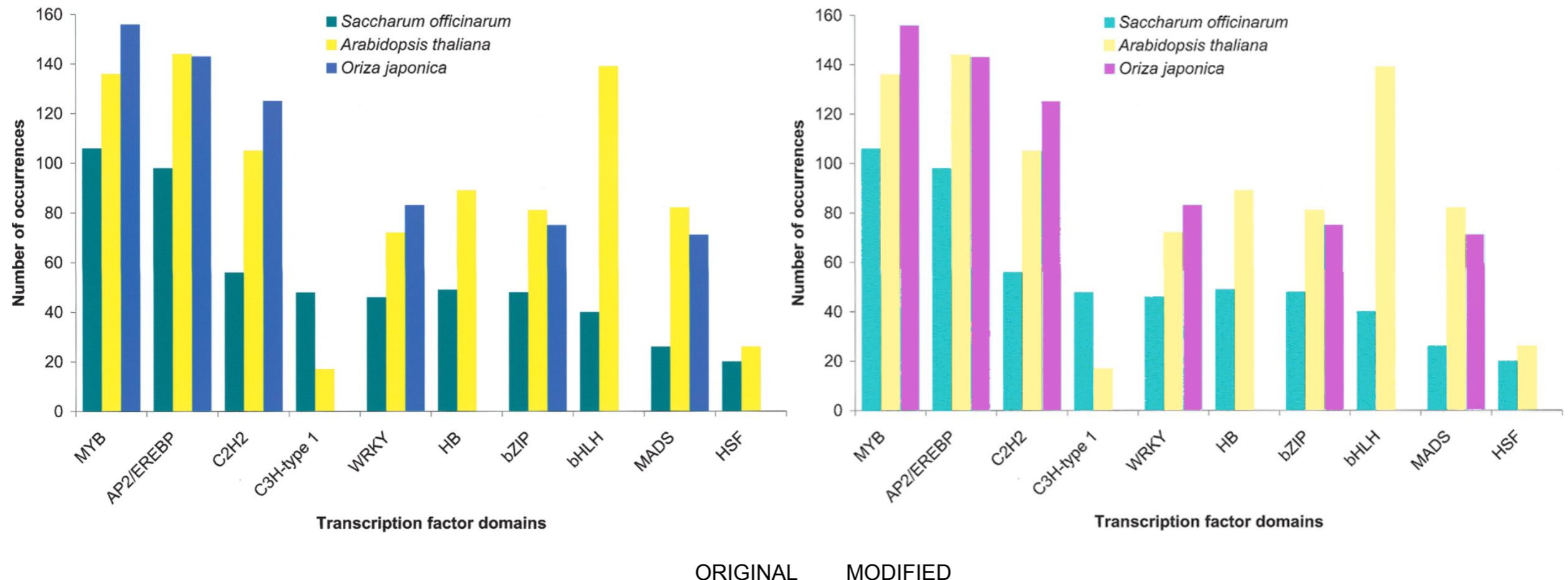
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From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>

Colour works very well for categories

→ Identity Channels: Categorical Attributes

Spatial region



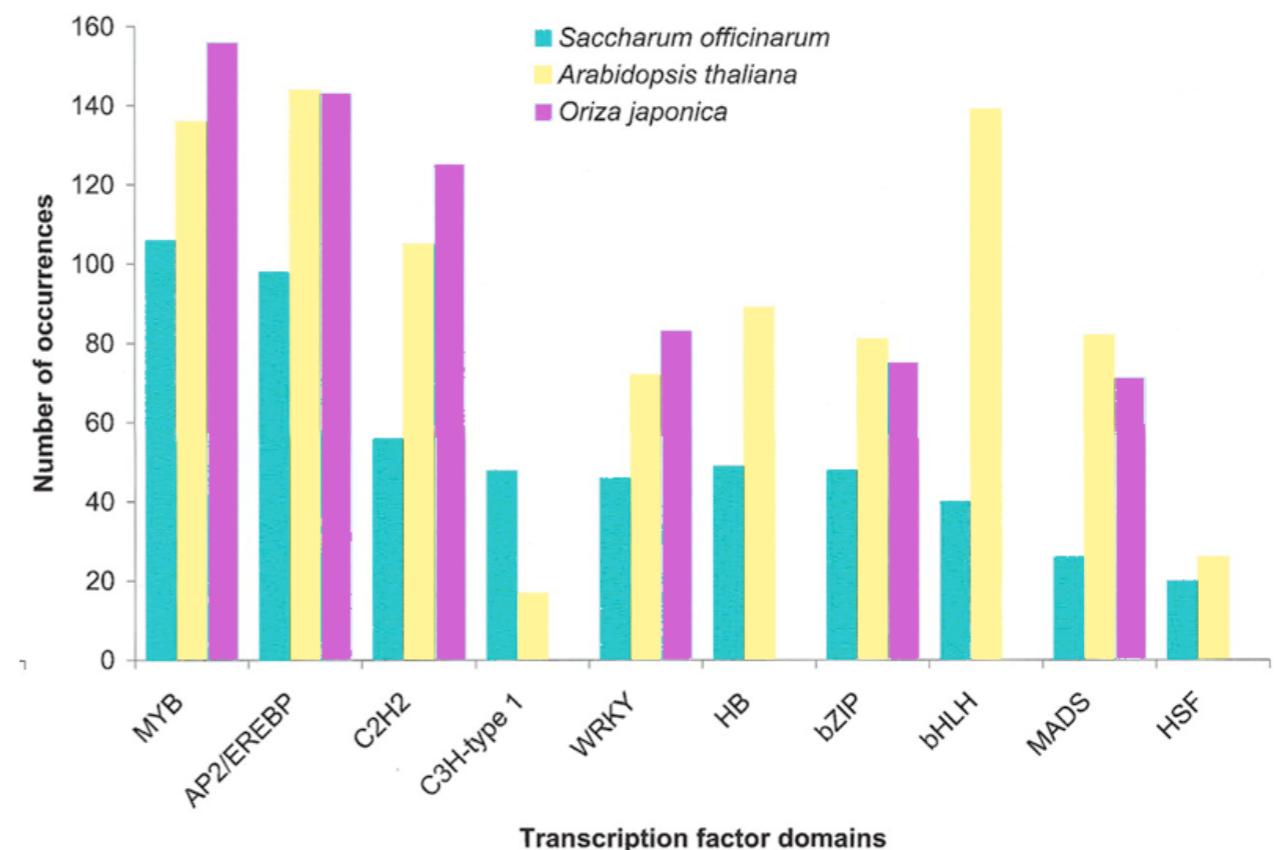
Color hue



Motion

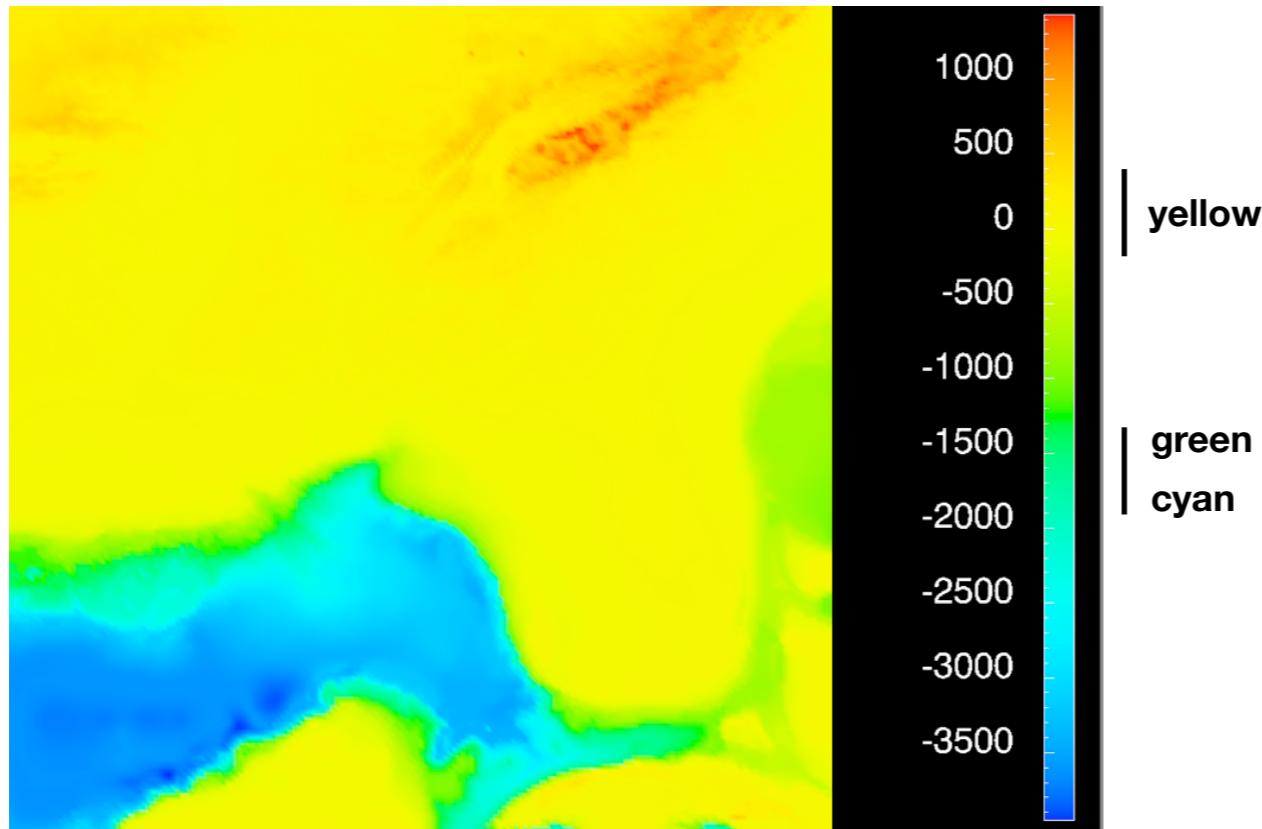


Shape



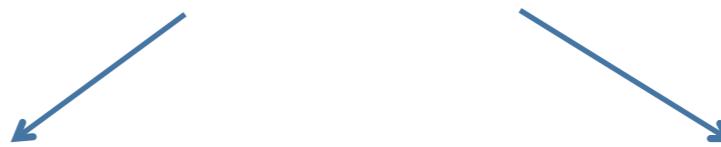
From Martin Krzywinski
<http://mkweb.bcgsc.ca/brewer/talks/color-palettes-brewer.pdf>

Continuous colourmaps for ordered data



- **Rainbow is a poor default**
 - Perceptually unordered
 - Perceptually nonlinear
 - There are places where the apparent colour changes quickly over a short range

Importance of luminance contrast



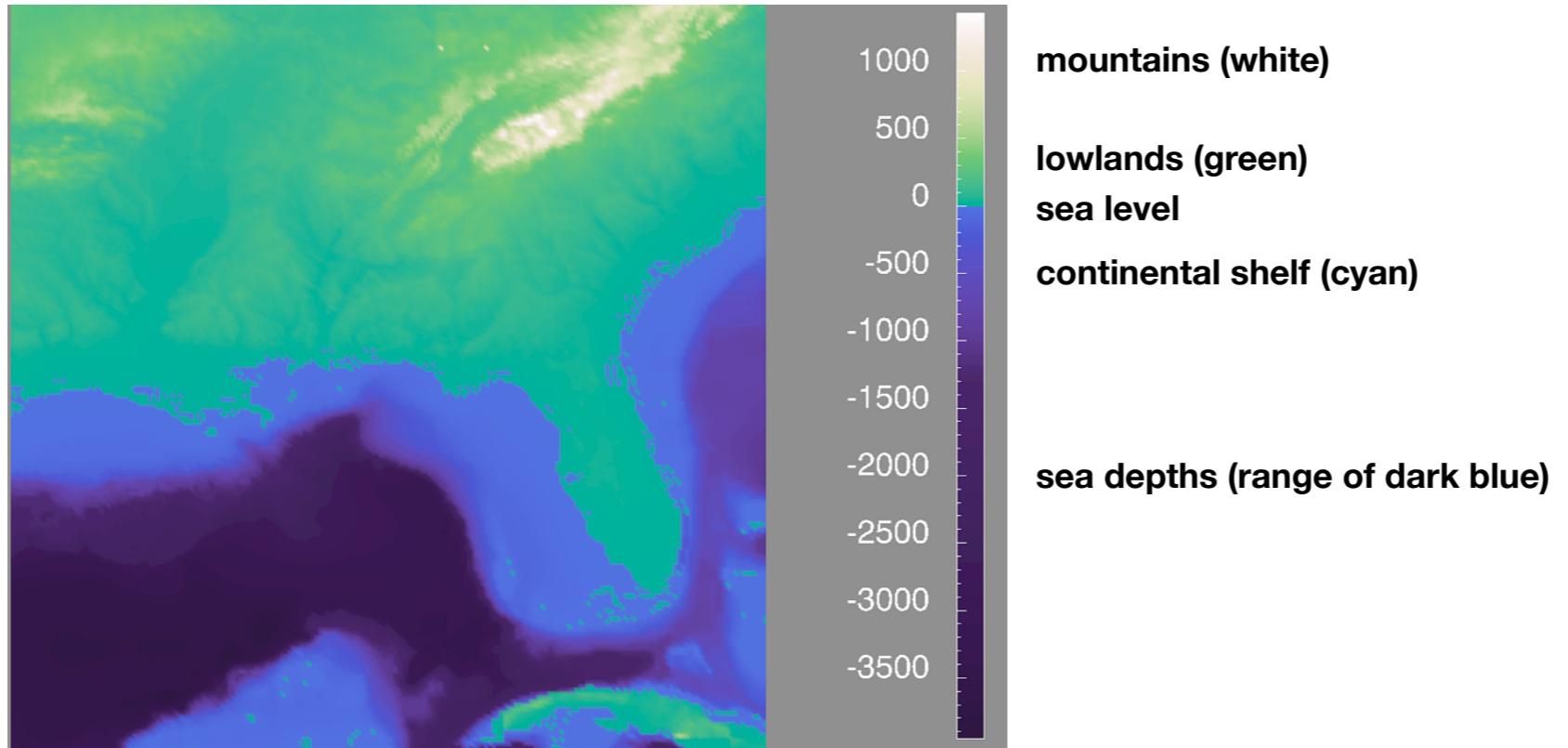
Luminance information



Chroma information

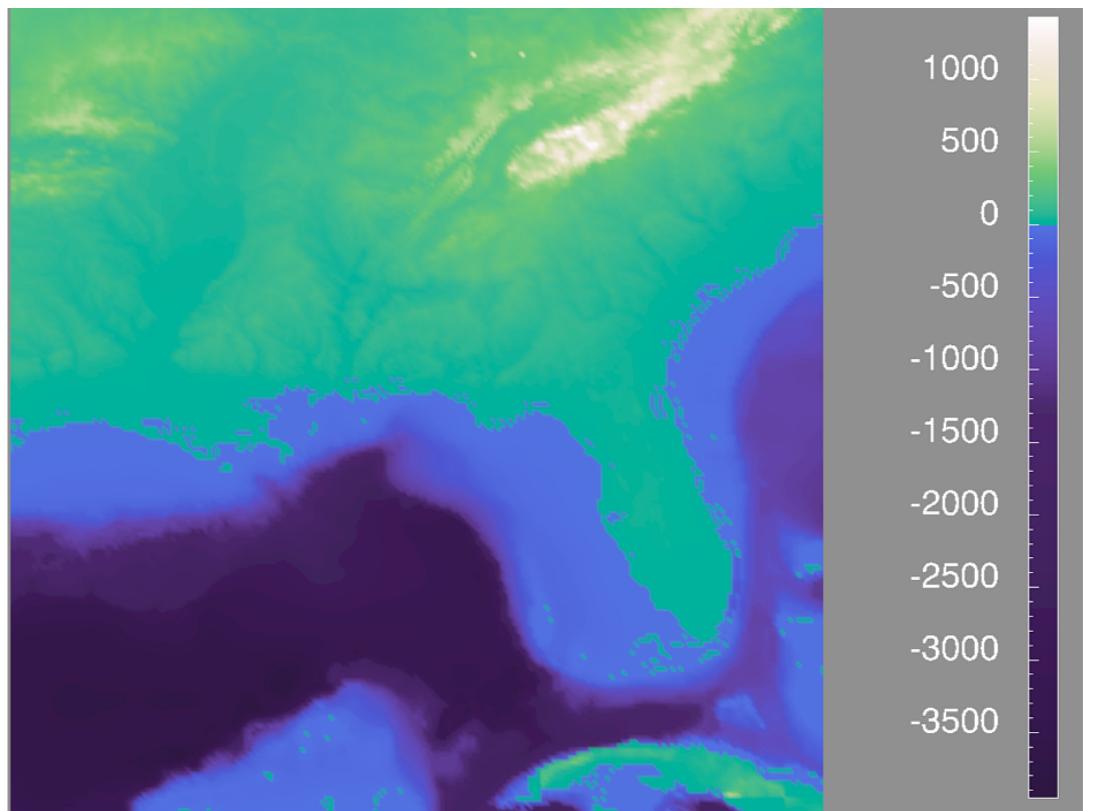
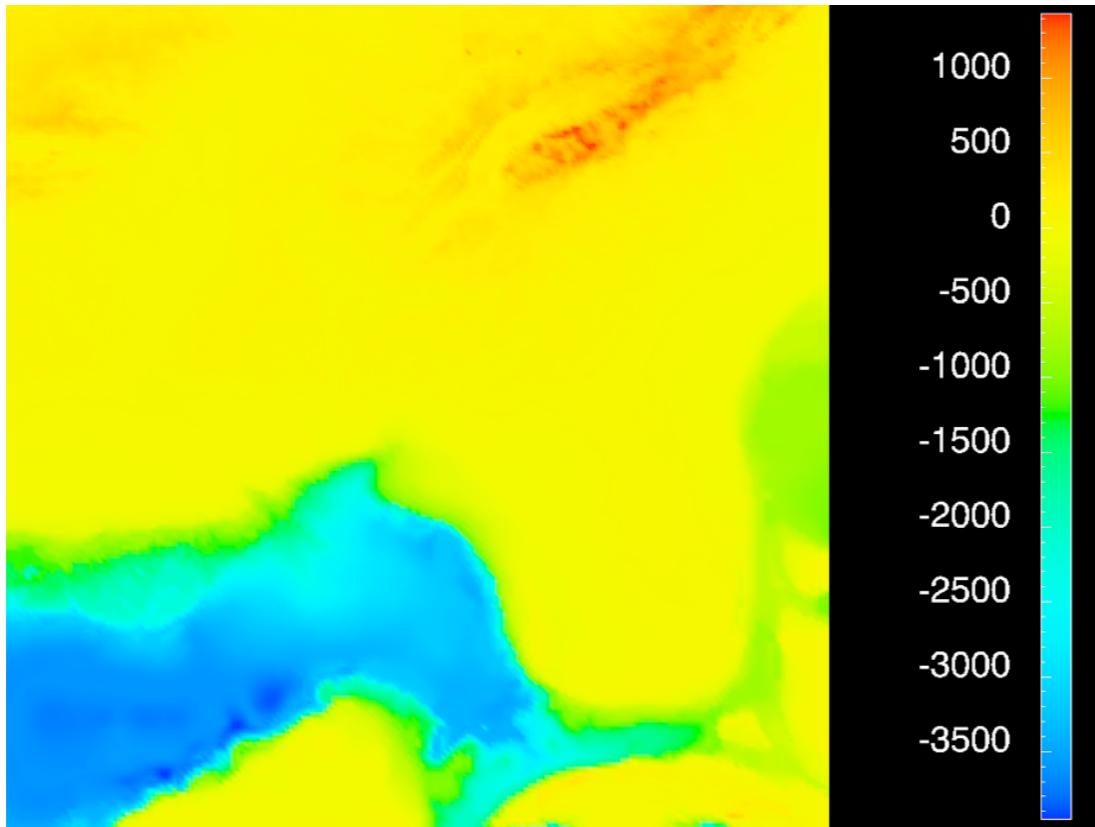


Continuous colourmaps for ordered data

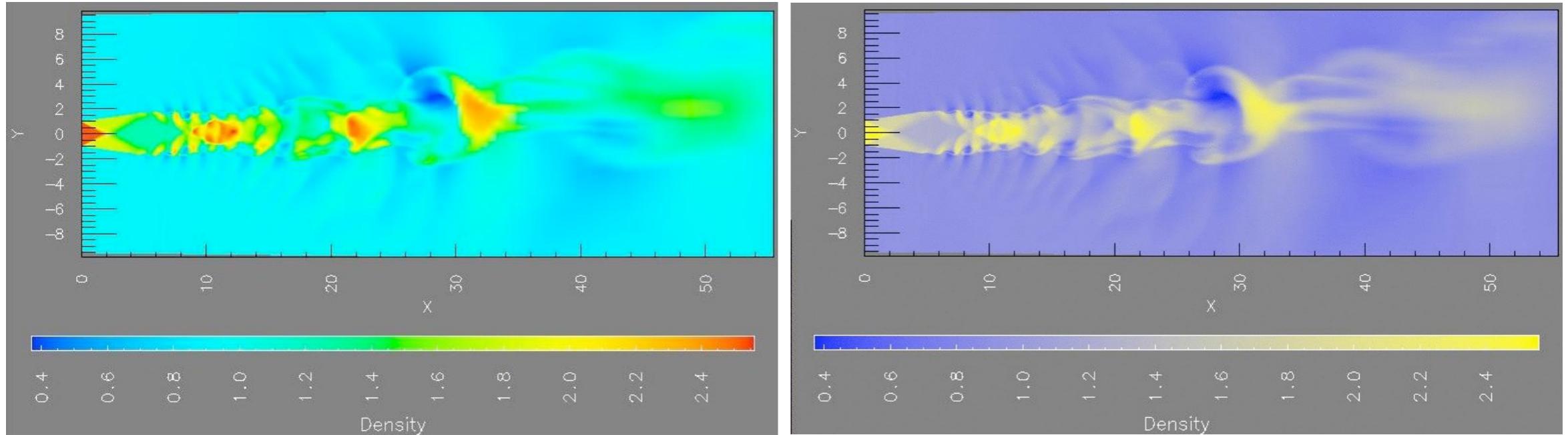


- **Alternative**
 - Hue to show meaningful categories
 - Monotonically increasing luminance to provide contrast for revealing detailed structures

Side by side comparison



Continuous colourmaps for ordered data



Colour Palette Resources | colorbrewer2.org

sequential

Number of data classes: 9 how to use | updates | downloads | credits

Nature of your data:
 sequential diverging qualitative

COLORBREWER 2.0
color advice for cartography

Pick a color scheme:
Multi-hue: Single hue:

Only show:
 colorblind safe
 print friendly
 photocopy safe

Context:
 roads
 cities
 borders

Background:
 solid color
 terrain

color transparency

9-class YIGnBu

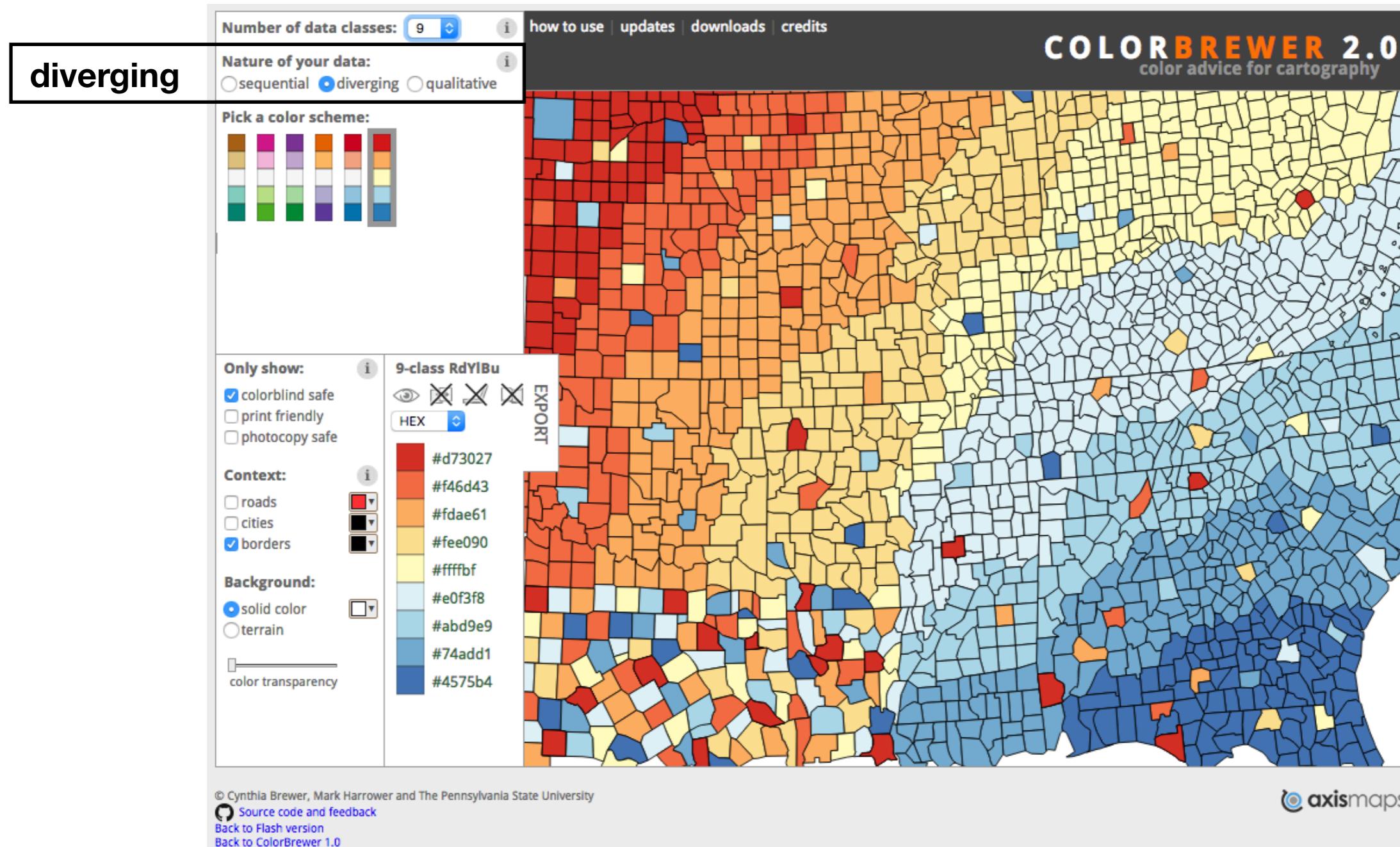
EXPORT

#ffffd9
#edf8b1
#c7e9b4
#7fcdbb
#41b6c4
#1d91c0
#225ea8
#253494
#081d58

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[Source code and feedback](#)
[Back to Flash version](#)
[Back to ColorBrewer 1.0](#)

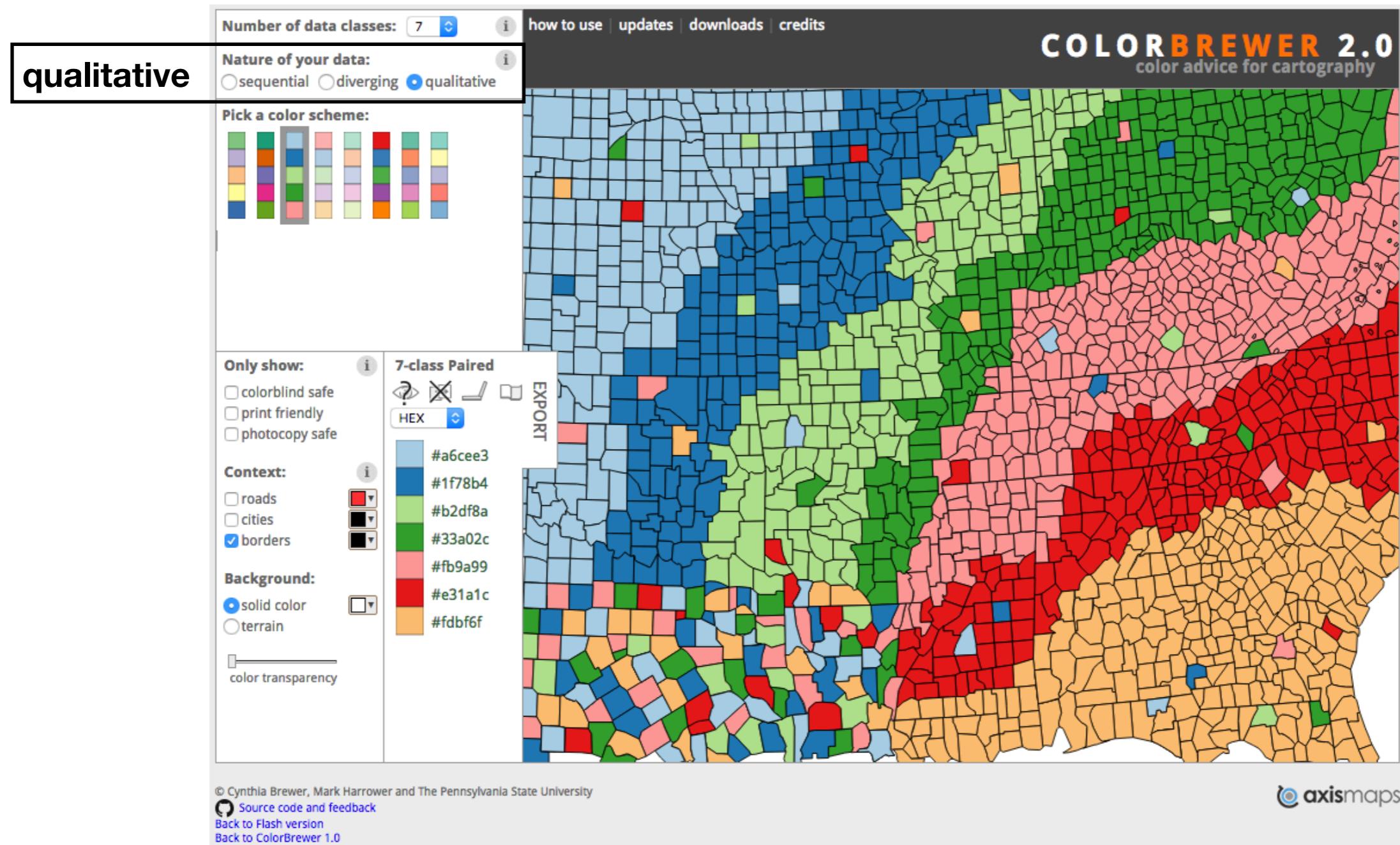
Hand picked by Cynthia Brewer for their perceptual properties

Colour Palette Resources | colorbrewer2.org



Hand picked by Cynthia Brewer for their perceptual properties

Colour Palette Resources | colorbrewer2.org



Hand picked by Cynthia Brewer for their perceptual properties

Colour Palette Resources | viridis palette



- **Viridis package for R (from matplotlib for python)**
- **Designed to be perceptually uniform**
 - Values close to each other have similar appearing colours
 - Values far away from each other have more different appearing colours

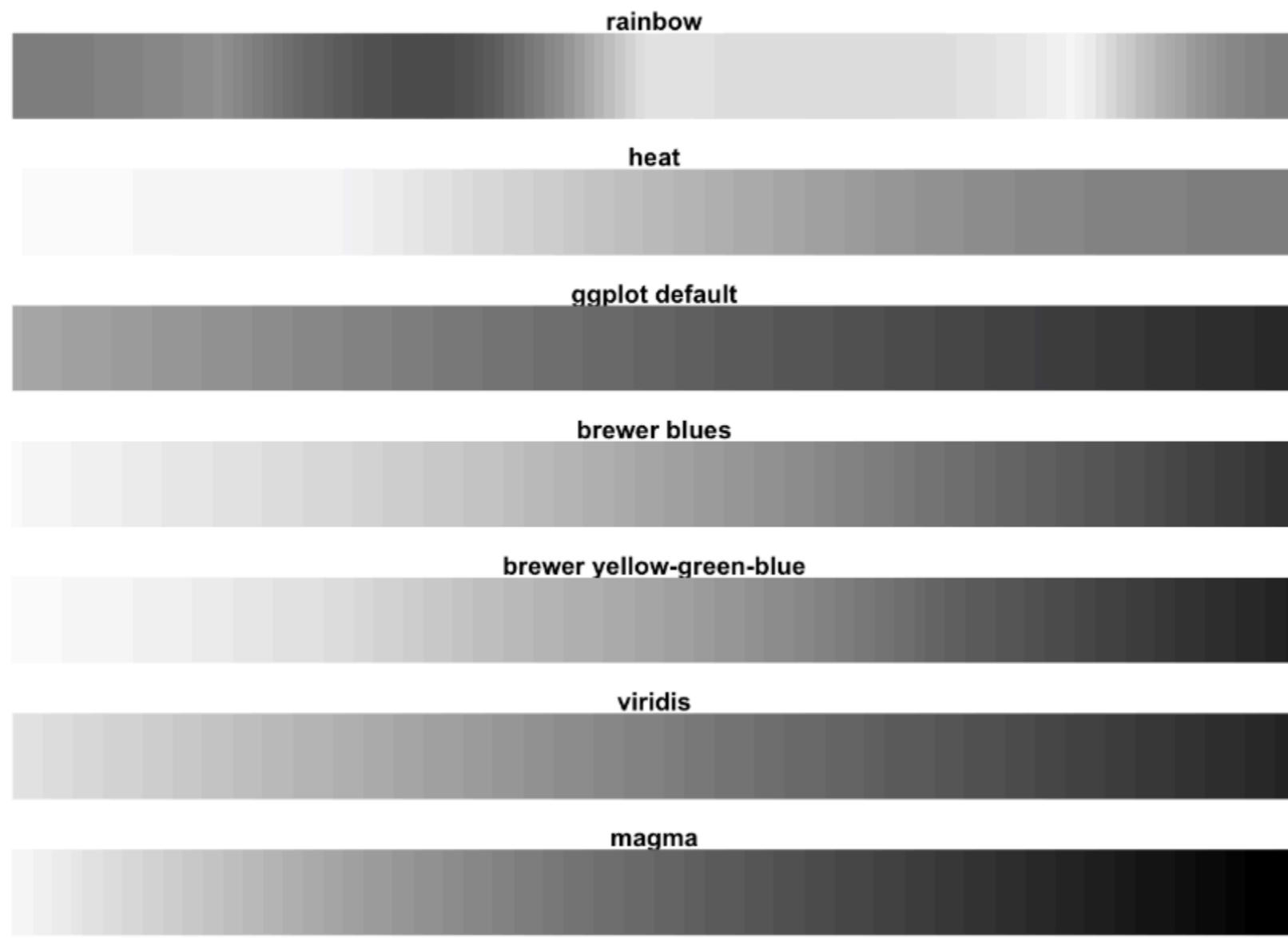
Colour Palette Resources | viridis palette

Comparison to other palettes



Colour Palette Resources | viridis palette

Comparison to other palettes (desaturated)

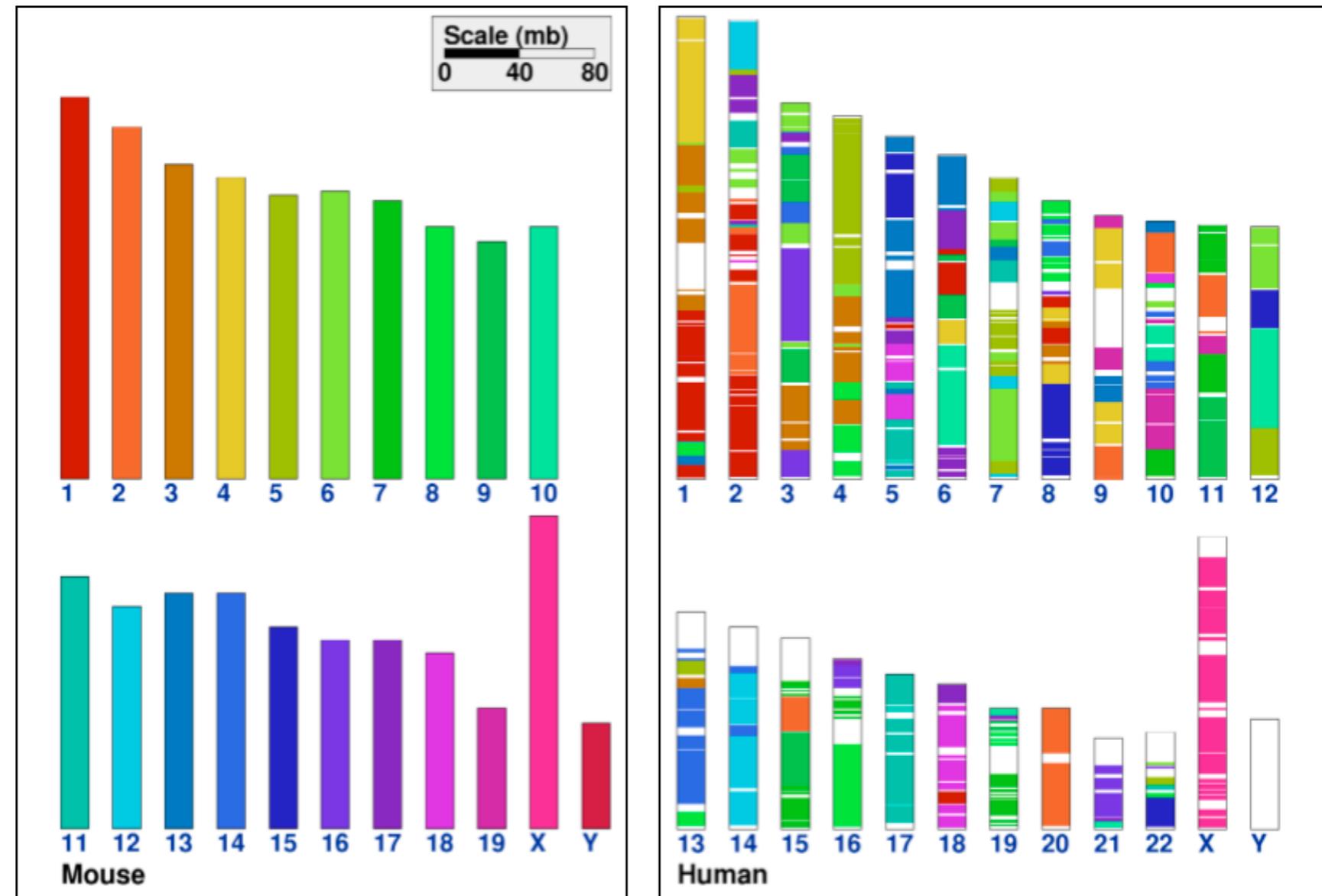


Viridis palettes
work well in
grey scale

**A few more things that
are good to know**

How many colours to use?

- **human perception built on relative comparisons**
 - great if colour is contiguous
 - surprisingly bad for absolute comparisons
- **noncontiguous small regions of colour**
 - **rule of thumb:** 6-12 bins, including background and highlights



Colour Palette Resources | colorbrewer2.org

**built-in
guidance
on number
of colours**

The screenshot shows the ColorBrewer 2.0 interface. On the left, there's a sidebar with the following settings:

- Number of data classes:** A dropdown menu set to 3, with other options like 4, 5, 6, 7, 8, 9, 10, 11, and 12 available.
- Nature of your data:** Radio buttons for "sequential" and "diverging".
- Pick a color scheme:** A grid of color palette swatches.
- Only show:** Checkboxes for "colorblind safe", "print friendly", and "photocopy safe".
- Context:** Checkboxes for "roads", "cities", and "borders".
- Background:** Radio buttons for "solid color" (selected) and "terrain". A "color transparency" slider is also present.

In the center, the main area displays a map of the United States where states are colored according to a 3-class Paired scheme. The colors used are #a6cee3 (light blue), #1f78b4 (dark blue), and #b2df8a (light green). The map is overlaid with state borders. On the right side of the map, there's an "EXPORT" button and a color palette panel showing the three selected colors with their hex codes: #a6cee3, #1f78b4, and #b2df8a.

At the bottom of the page, there's footer information:

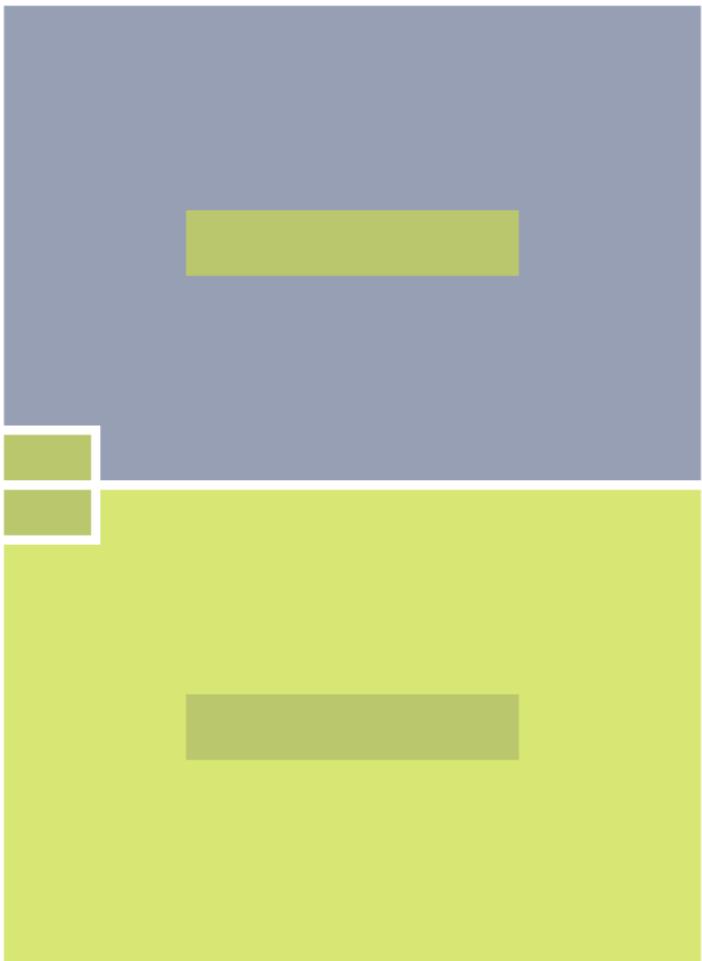
- © Cynthia Brewer, Mark Harrower and The Pennsylvania State University
- [Source code and feedback](#)
- [Back to Flash version](#)
- [Back to ColorBrewer 1.0](#)

COLORBREWER 2.0
color advice for cartography

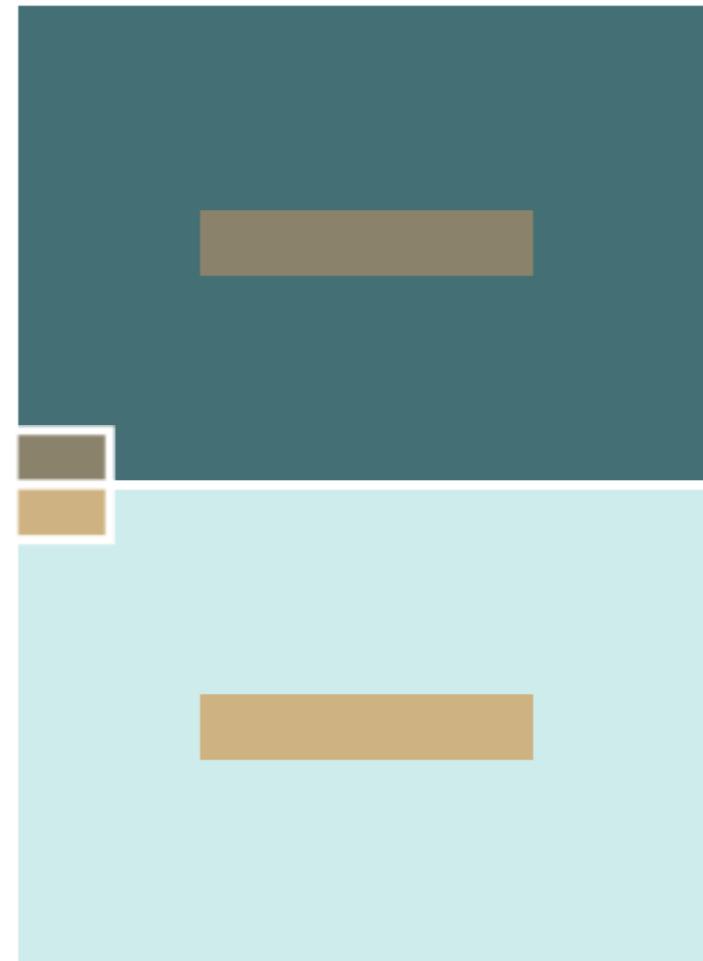
axismaps

If you need more than 12 colours
find another way

Context matters



Same colour can look different



Different colours can look the same

Context matters

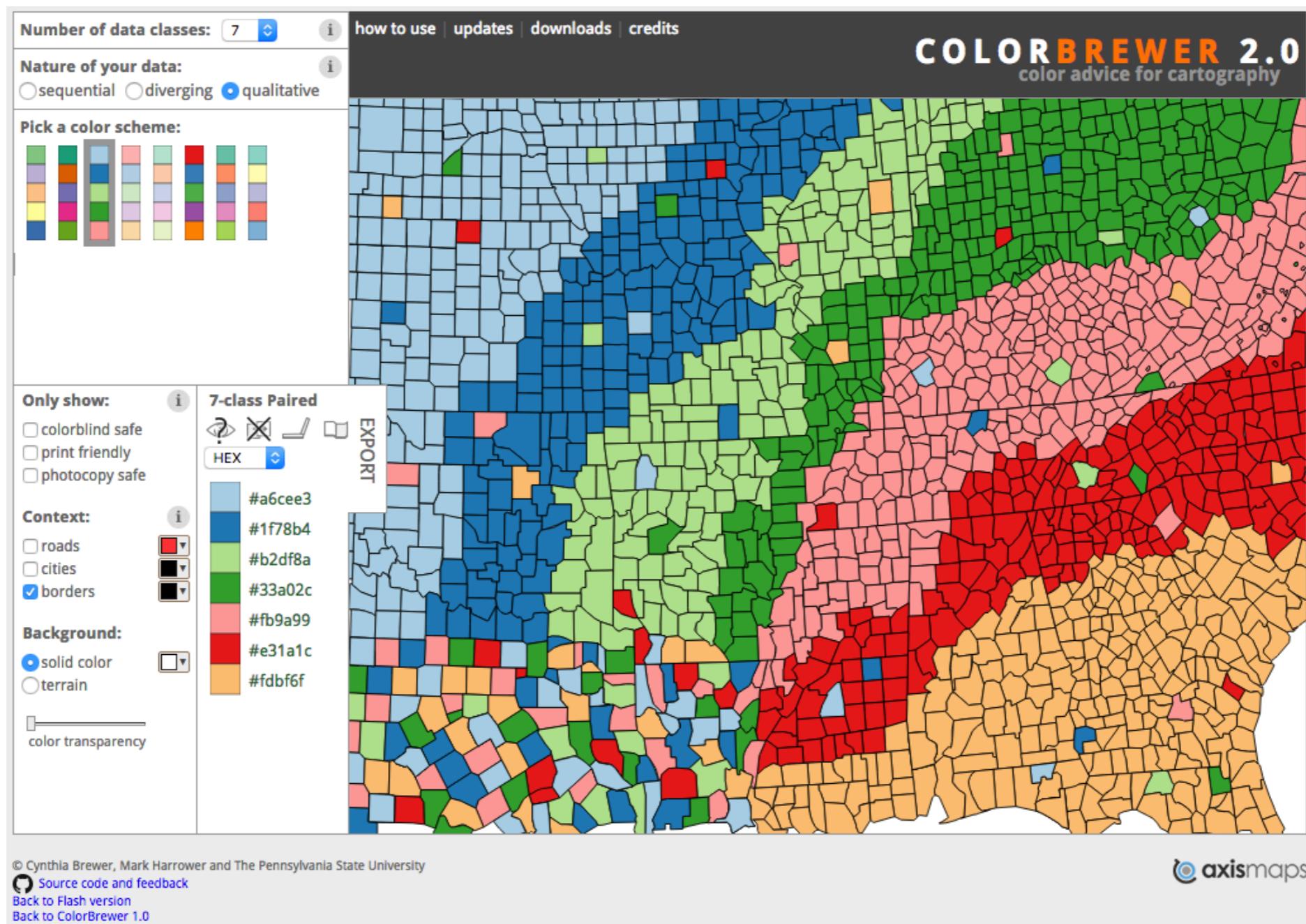


Bezold Effect: Outlines matter

Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014

What can you do about it?

- Use trusted colour palettes | e.g. colorbrewer2.org



What can you do about it?

- **Use trusted colour palettes** | e.g. colorbrewer2.org
- **Make actual data values available on demand**
 - On hover / tool-tip
 - In a linked tabular view

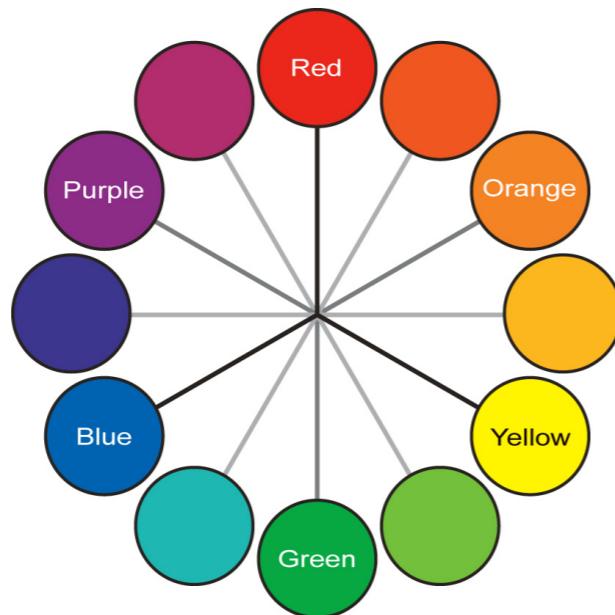
Colour accessibility

- **Color blindness**

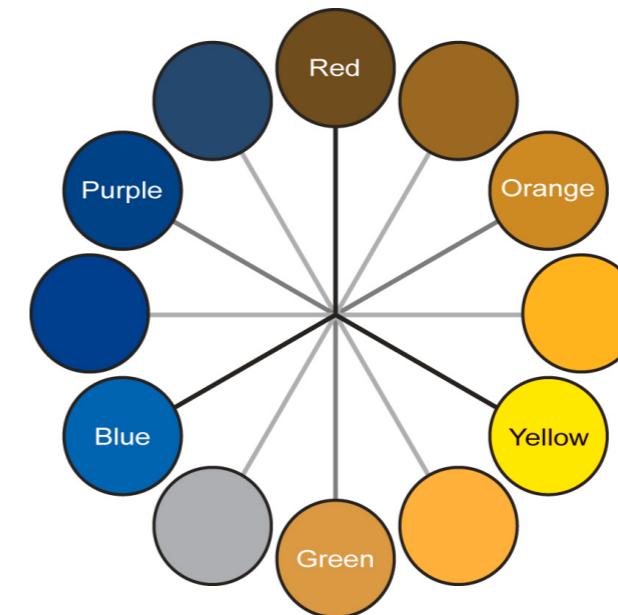
- Affects approximately every 1 in 12 men (8%) and 1 in 200 women (0.5%)
- The most common form called red-green color blindness is encoded on the x-chromosome and therefore sex-linked.

<http://www.color-blindness.com>

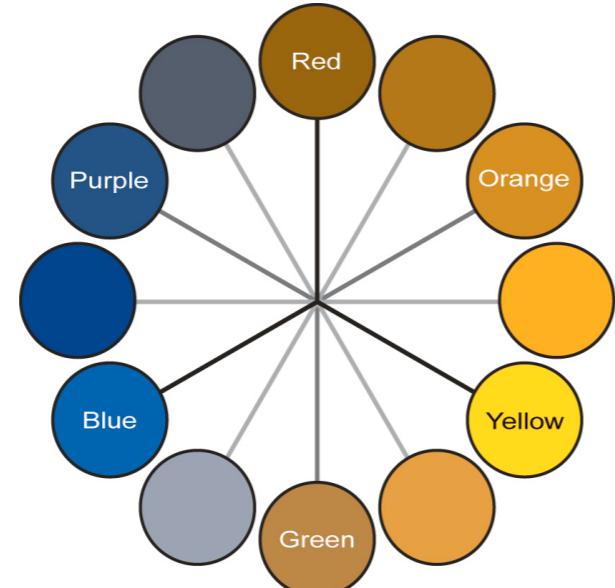
Colour deficiency | Reduces colour to 2 dimensions



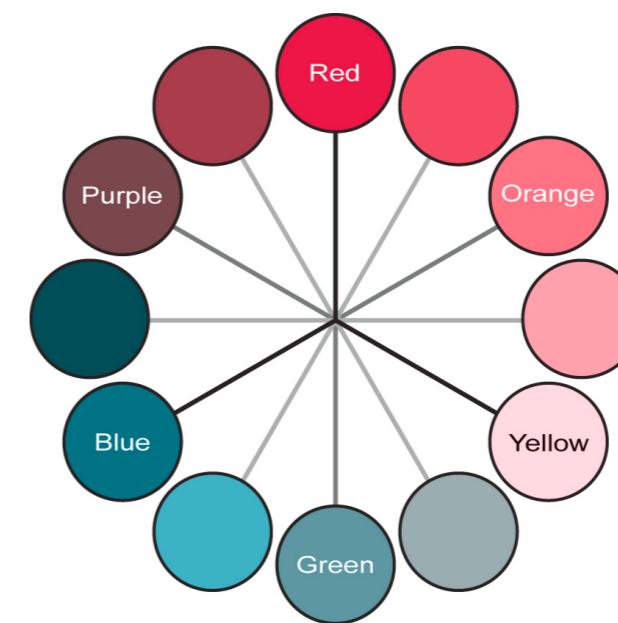
Normal



Protanope



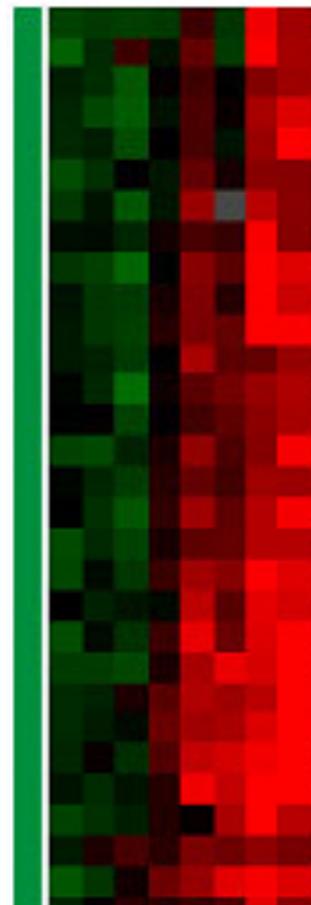
Deutanope



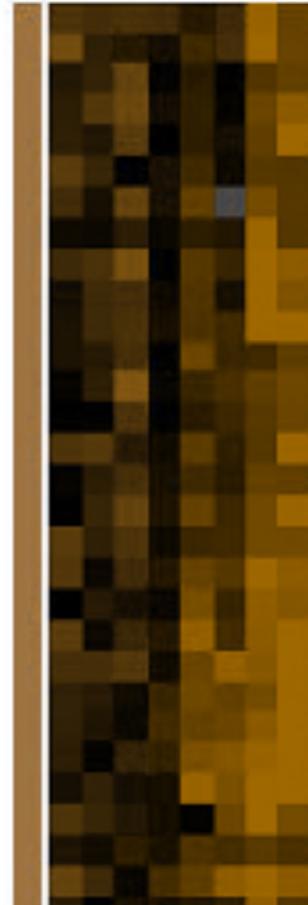
Tritanope

Check your visualization with a simulator

<http://rehue.net>



Normal

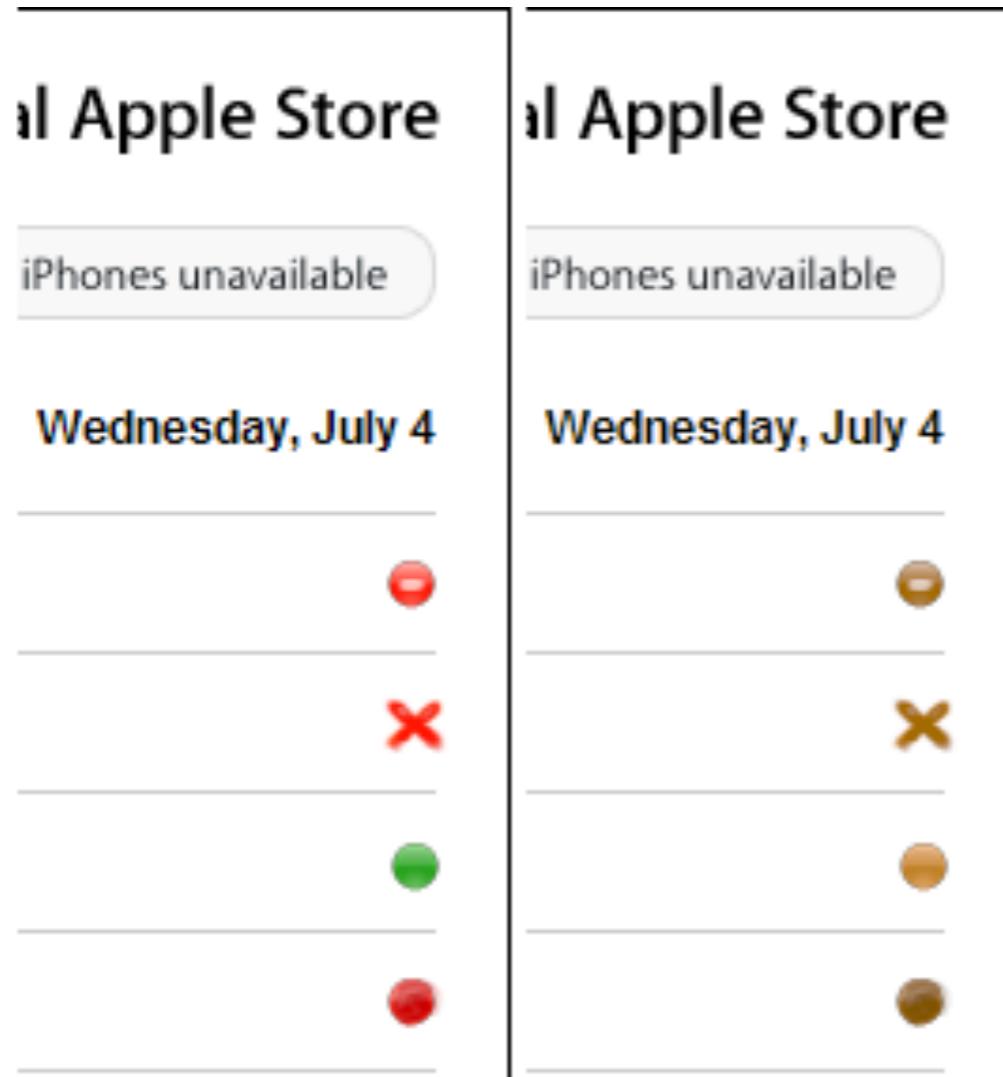


Deutanope



Protanope

Avoid encoding with hue alone



- Change the shape
- Vary luminance

Use trusted colour palettes

Deutanope



Use trusted colour palettes

Number of data classes: 9

Nature of your data:
 sequential diverging qualitative

Pick a color scheme:


Only show:
 colorblind safe print friendly photocopy safe

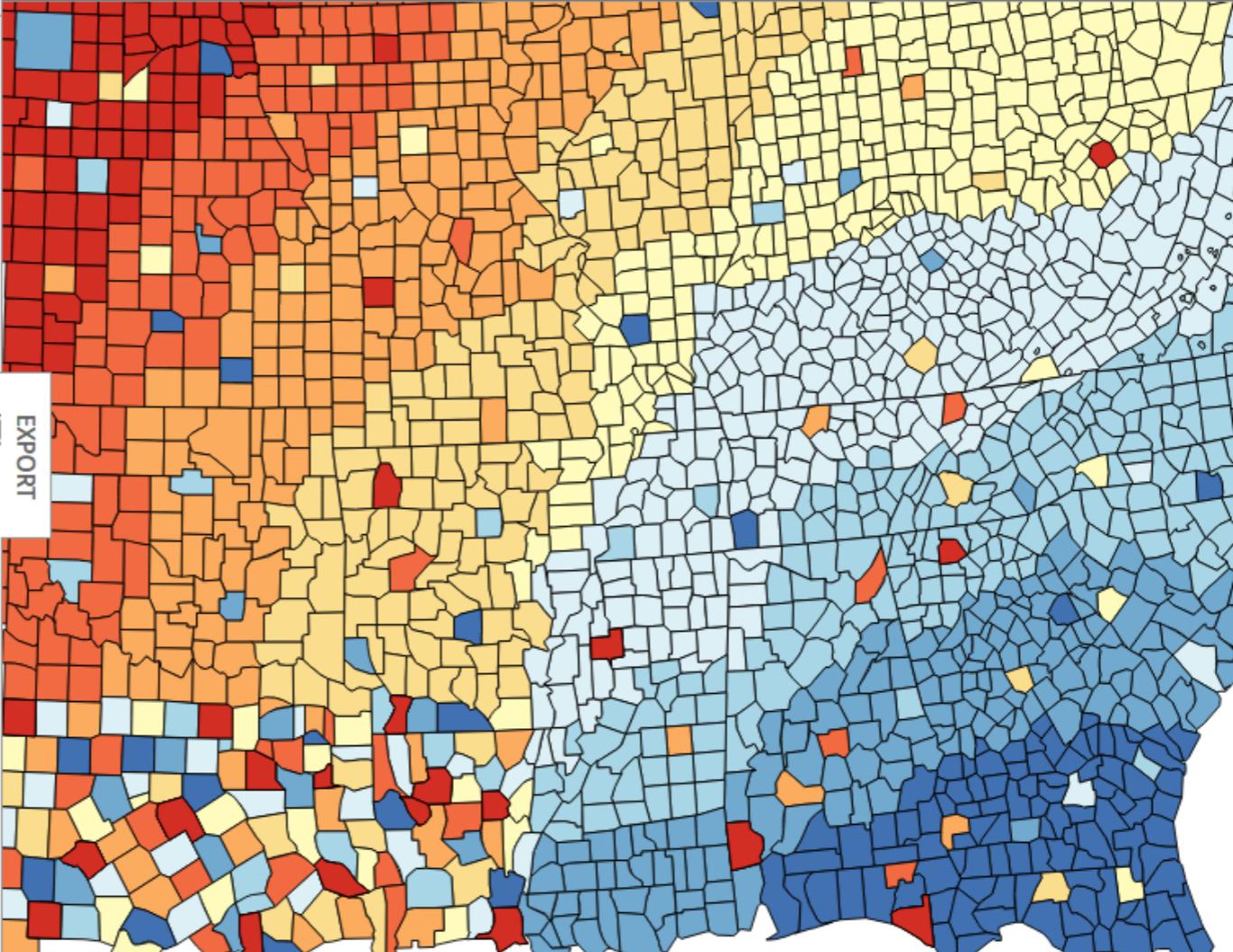
Context:
 roads 
 cities 
 borders 
Background:
 solid color 
 terrain 
color transparency 

9-class RdYIbu

#d73027
#f46d43
#fdae61
#fee090
#ffffbf
#e0f3f8
#abd9e9
#74add1
#4575b4

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 [Source code and feedback](#)
[Back to Flash version](#)
[Back to ColorBrewer 1.0](#)





<http://colorbrewer2.org>

Key Points

Key points

- **Representing quantitative values**
 - Position on common scale is most accurate
 - Position > Length > Angle > Area
 - Avoid 3D charts (bars, lines, scatterplots, etc.)
- **Representing groups**
 - Containment and Connection are the strongest visual cues (Containment > Connection)
 - Position > Colour hue > Motion > Shape
- **Use trusted colour palettes**
 - Choose palettes that are appropriate for your data (categorical, diverging, sequential)
- **If you are trying to use more than 12 colours, stop!**
 - Try aggregating categories into logical groups; expose details interactively
- **Design for colour-blindness**
 - Choose colour-blind safe palettes and test with a simulator
- **Plot responsibly**

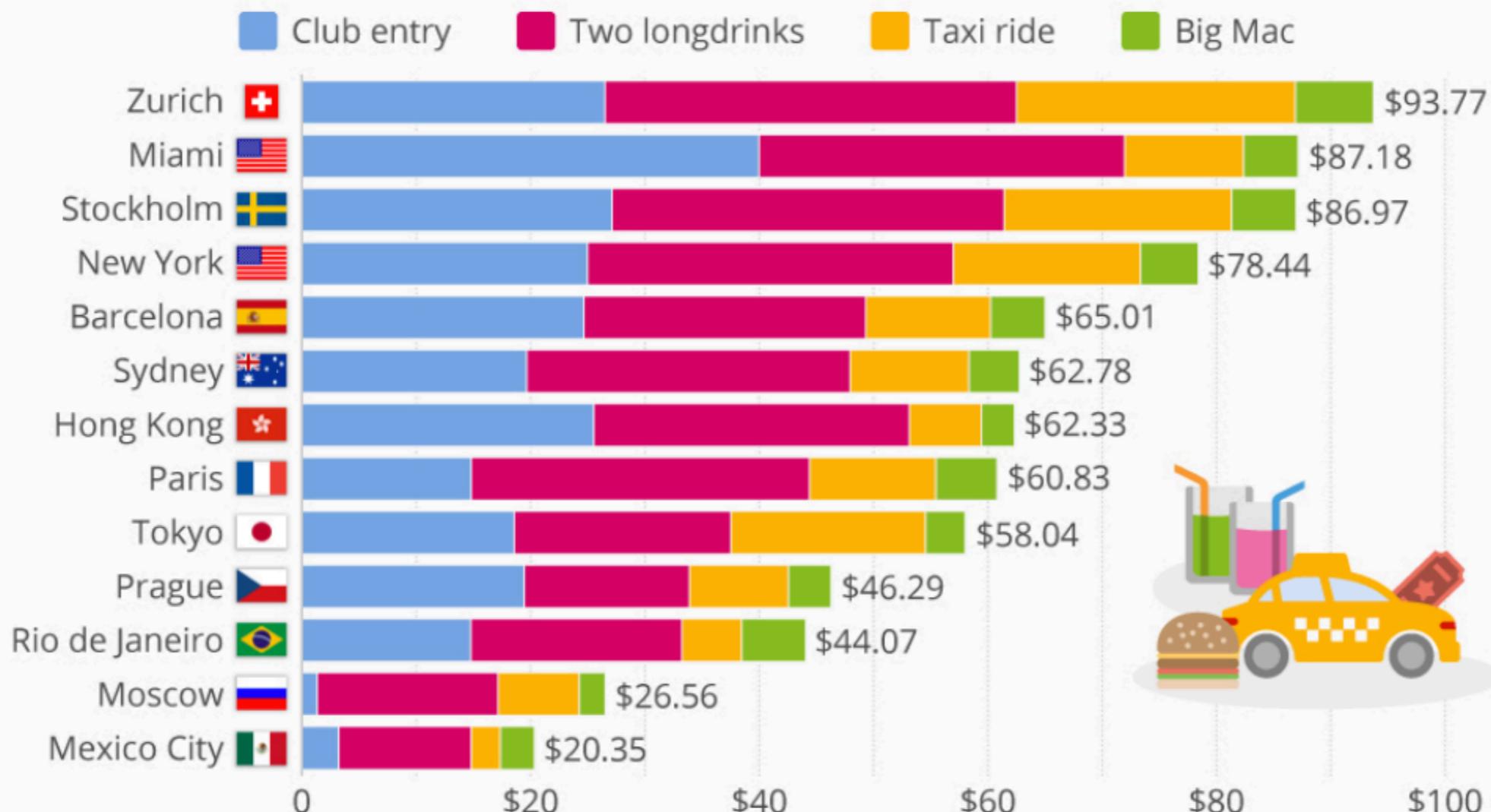
Applying the Principles

All examples from Makeover Monday
<http://www.makeovermonday.co.uk>

Example 1

The Cost of a Night Out Around the World

Average price of a late night out in selected cities in 2018



@StatistaCharts

Source: UBS

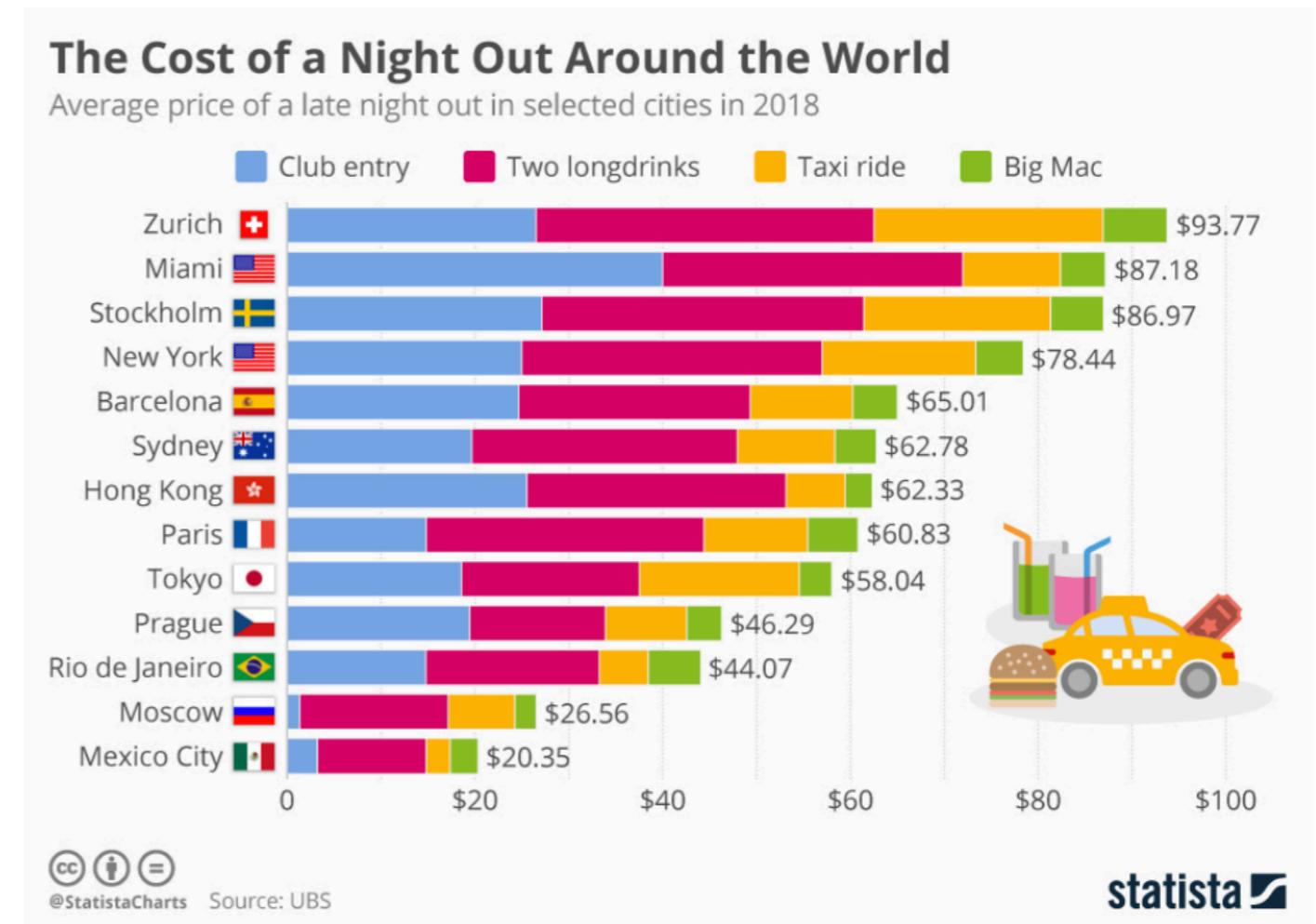
statista

What do we want to learn from the data?

What works well? What could be improved?

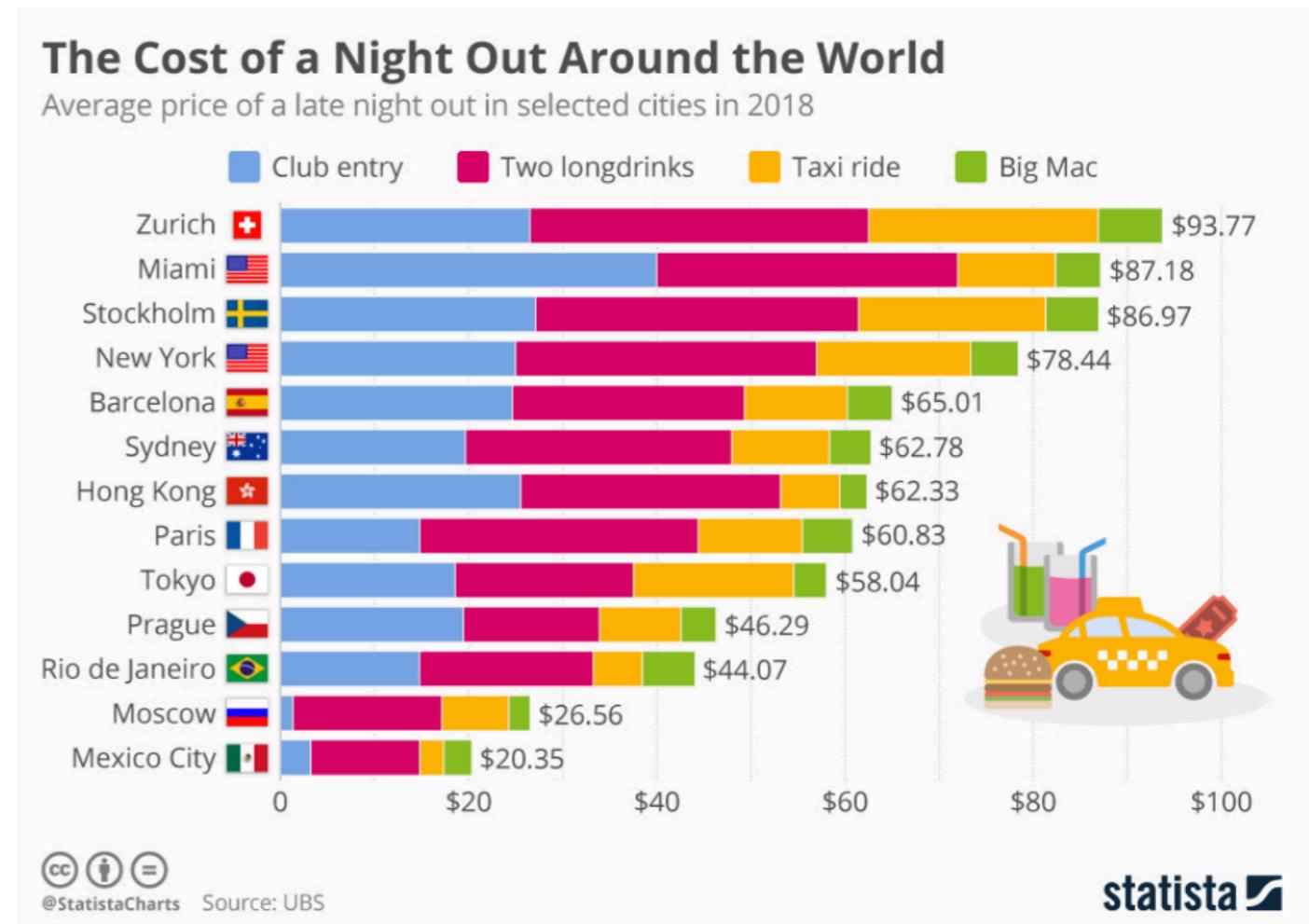
What do we want to learn from the data?

- Which of these cities has the highest/lowest cost?
- Which city has the highest/lowest cost per category?
- Is the category ranking the same as the total cost ranking?



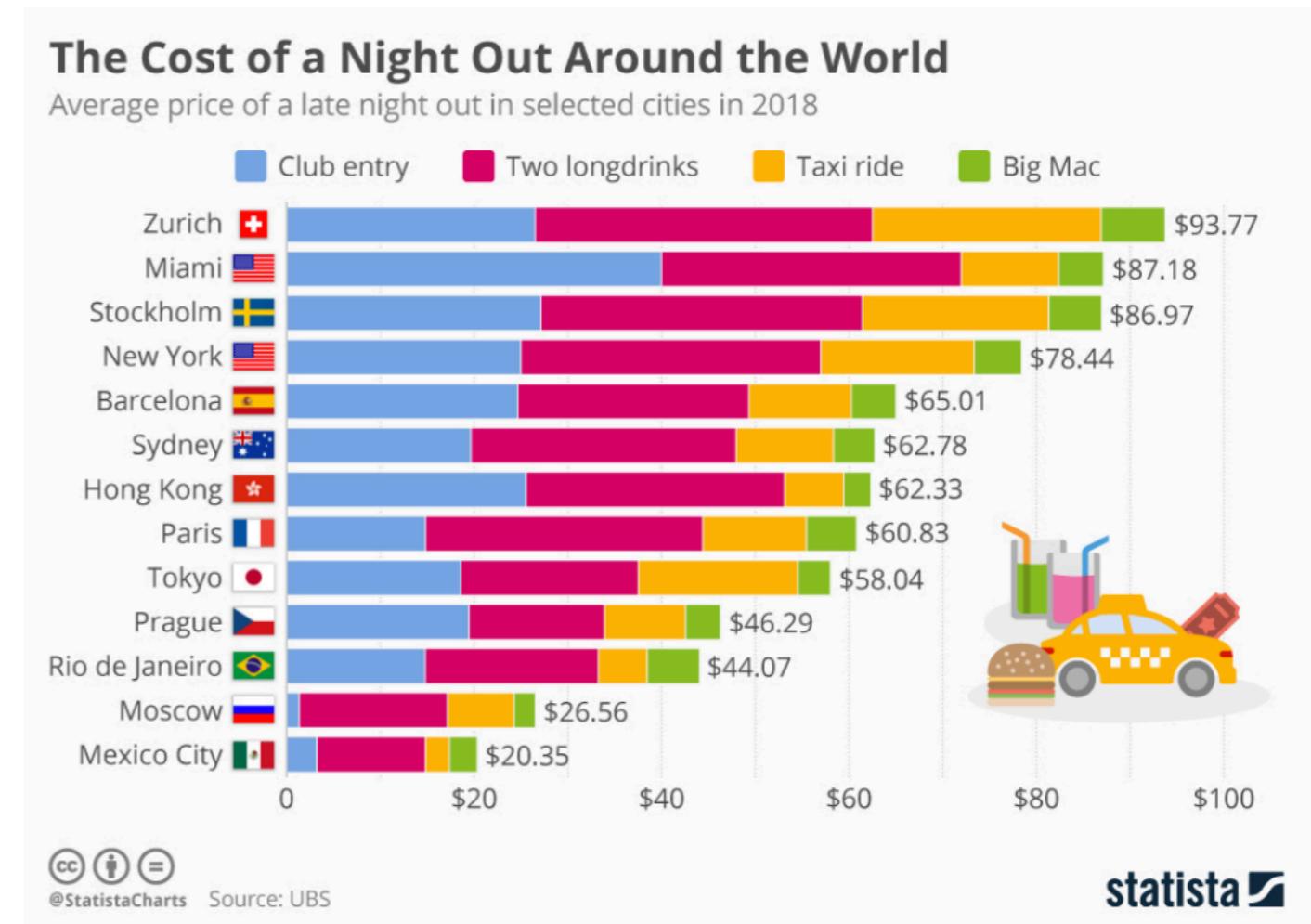
What works well?

- Colours for categories
- Clear legend
- Bars for quantitative values
- Sorting by total bar height
 - Can easily identify most/least expensive

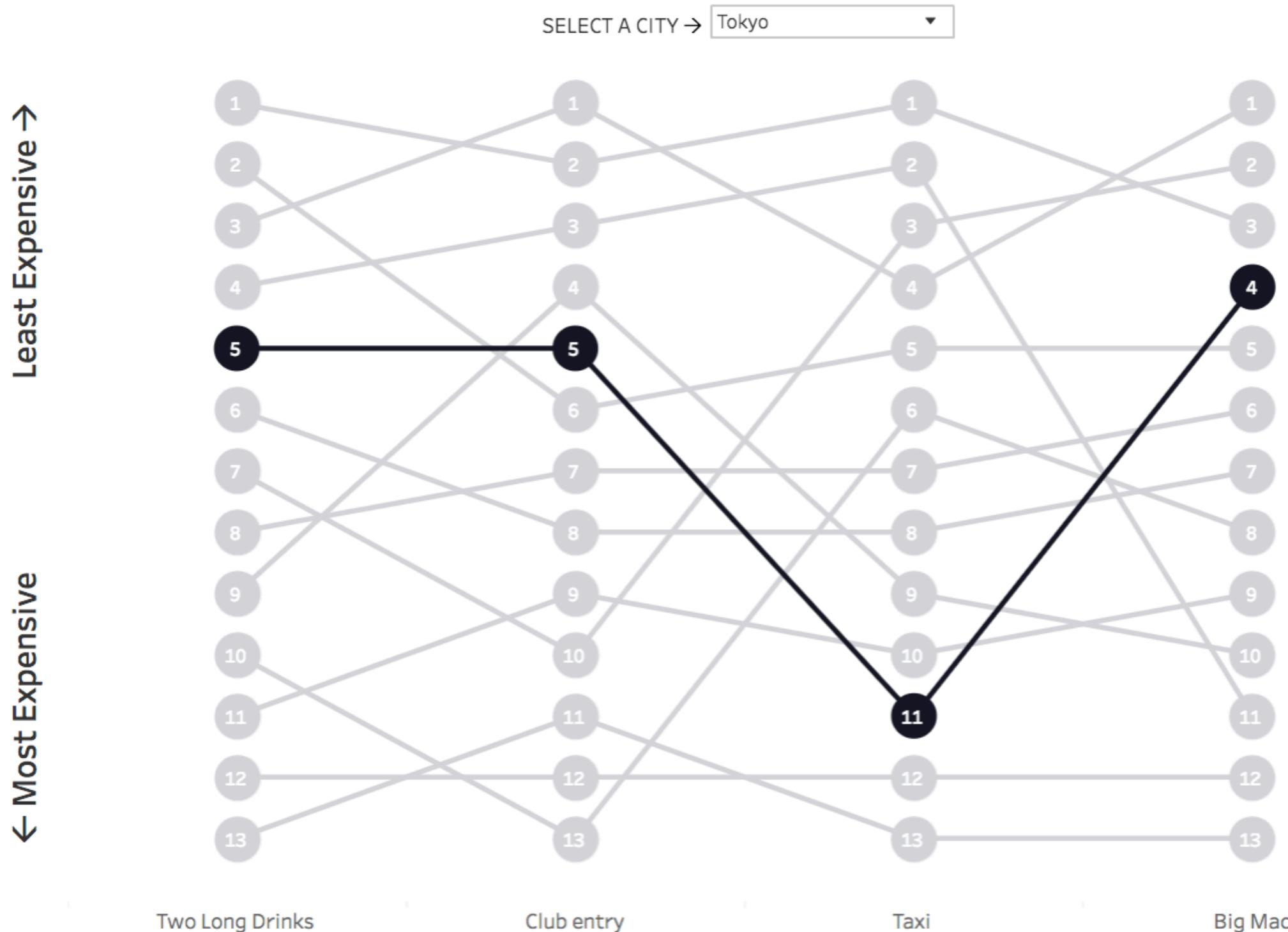


What could be improved?

- Unnecessary art
 - Flags and graphic add no value
- What are the units?
- Stacked bar chart makes comparisons across items difficult
- Exact price label at end of each bar seems unnecessary

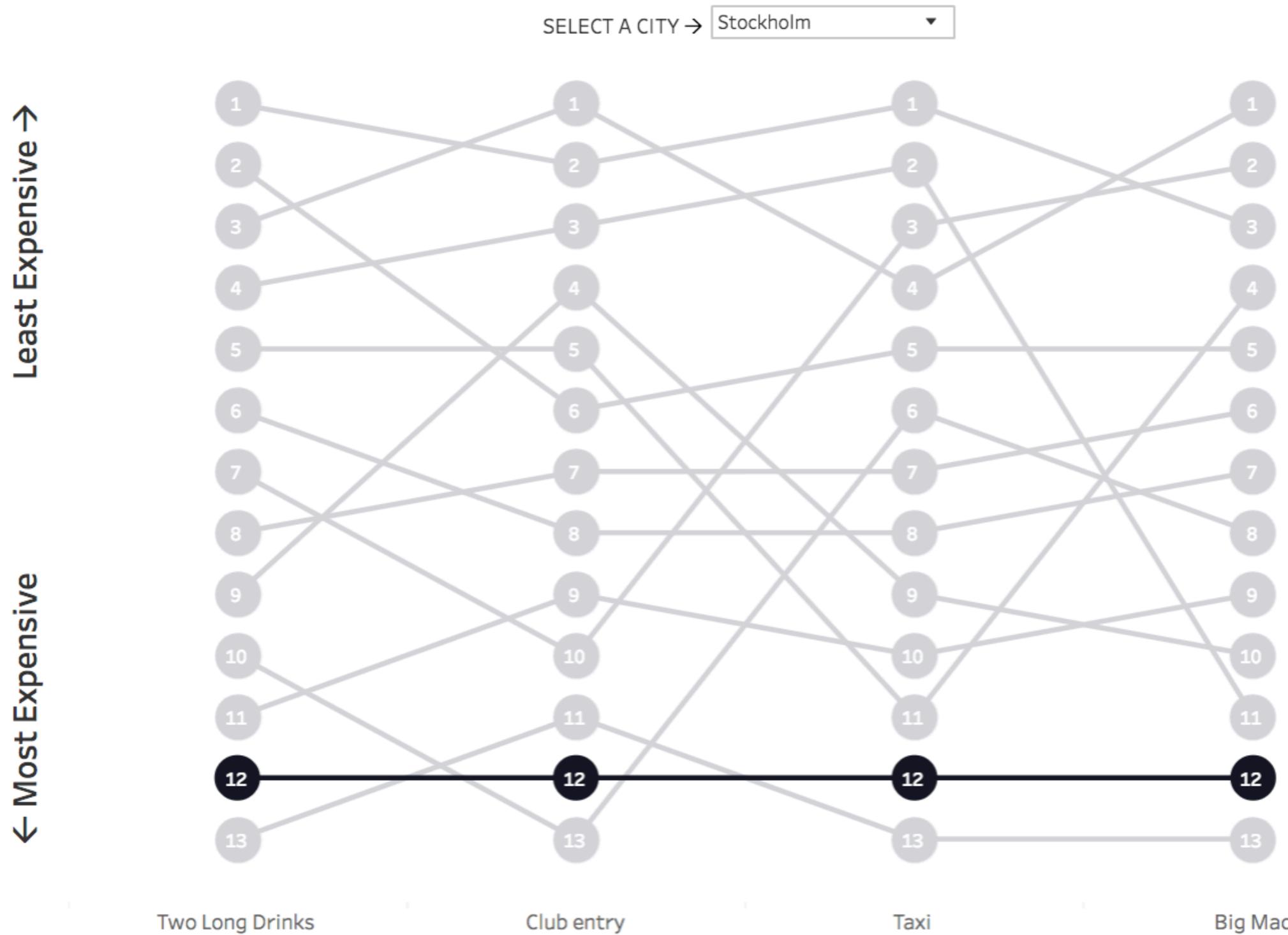


How does the cost of a night out rank across a selection of cities?



DATA SOURCE: UBS •••• CREATED BY: Andy Kriebel | @VizWizBI

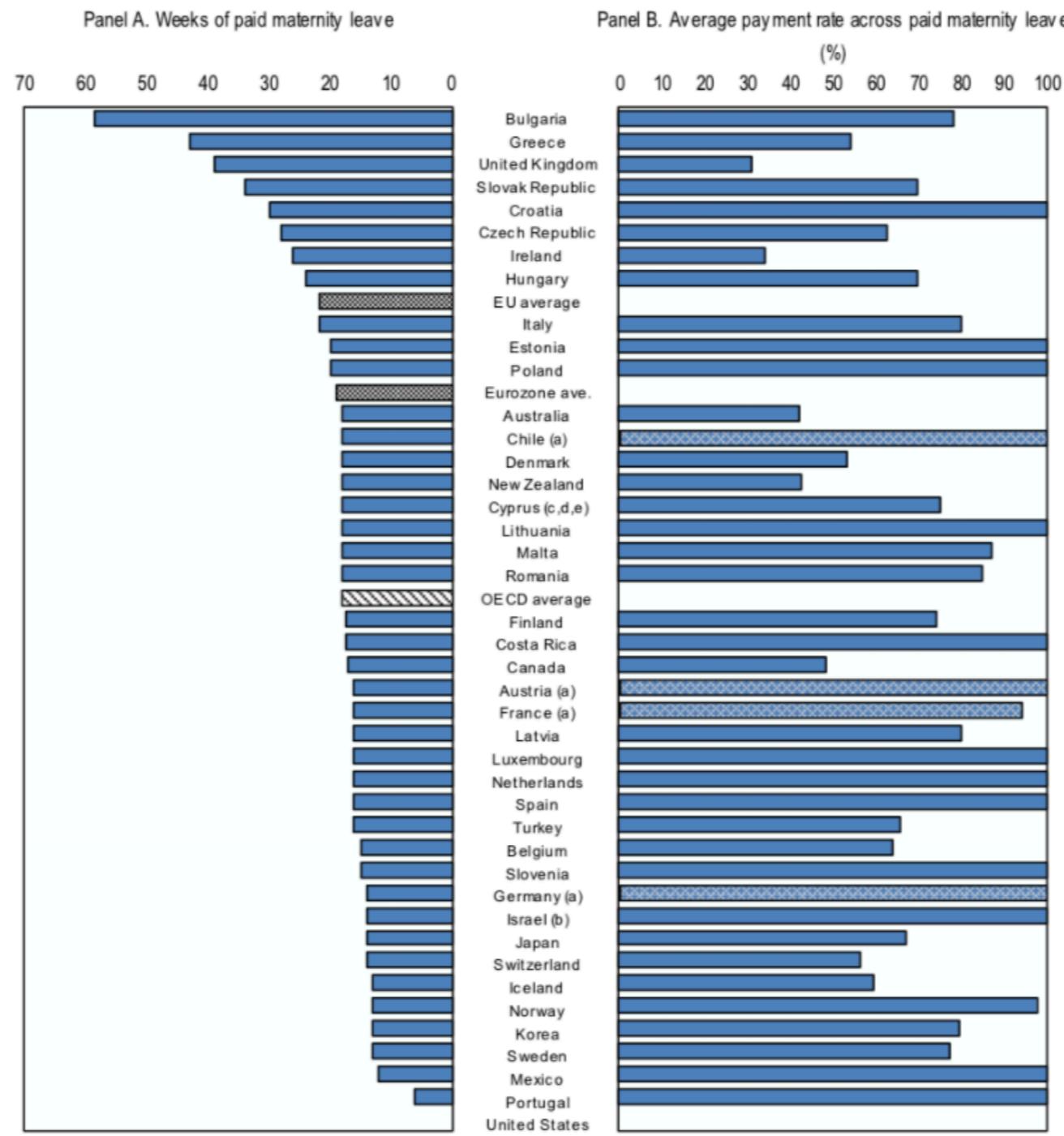
How does the cost of a night out rank across a selection of cities?



DATA SOURCE: UBS •••• CREATED BY: Andy Kriebel | @VizWizBI

Example 2

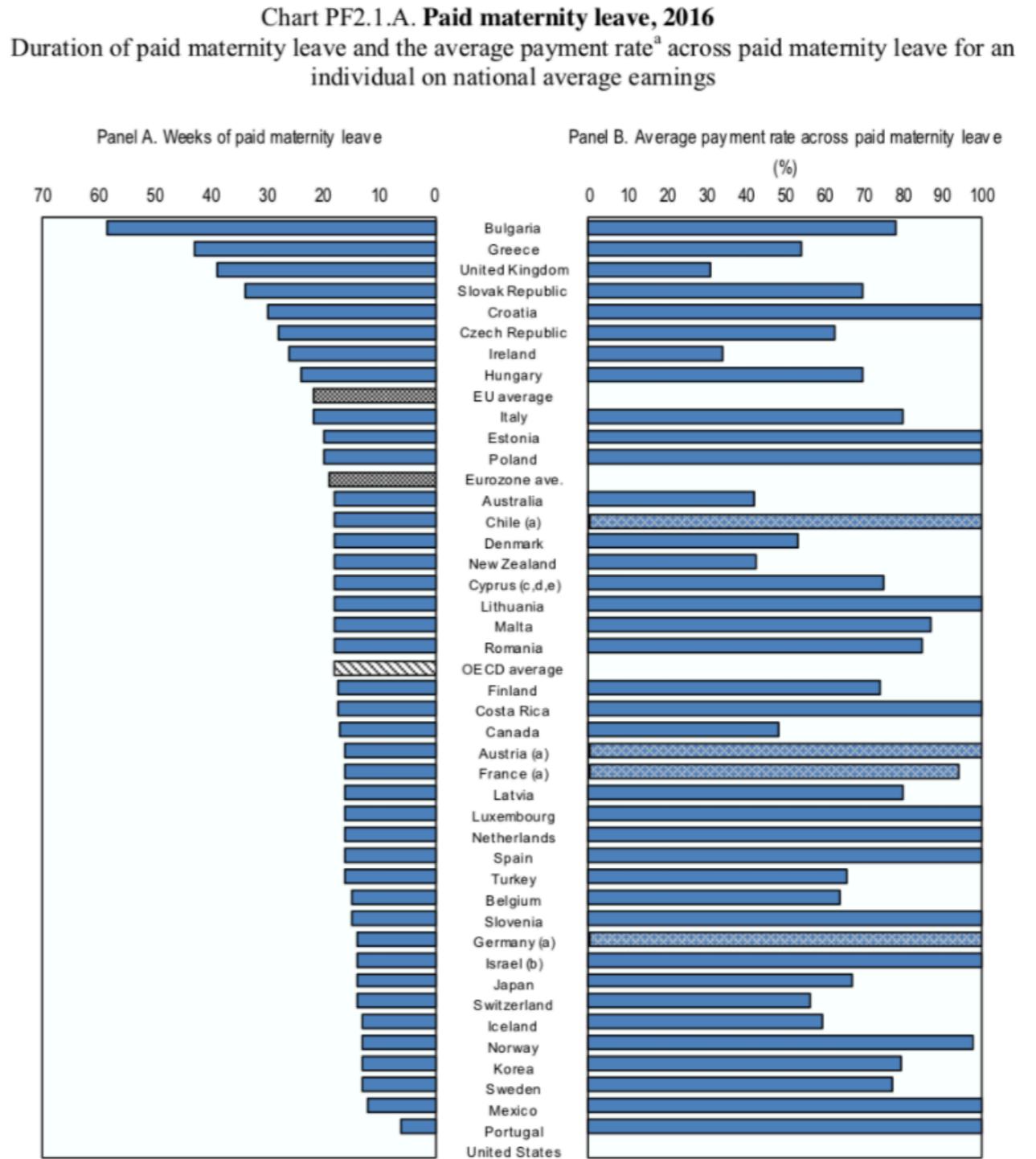
Chart PF2.1.A. Paid maternity leave, 2016
Duration of paid maternity leave and the average payment rate^a across paid maternity leave for an individual on national average earnings



What do we want to learn from the data?
What works well? What could be improved?

What do we want to learn from the data?

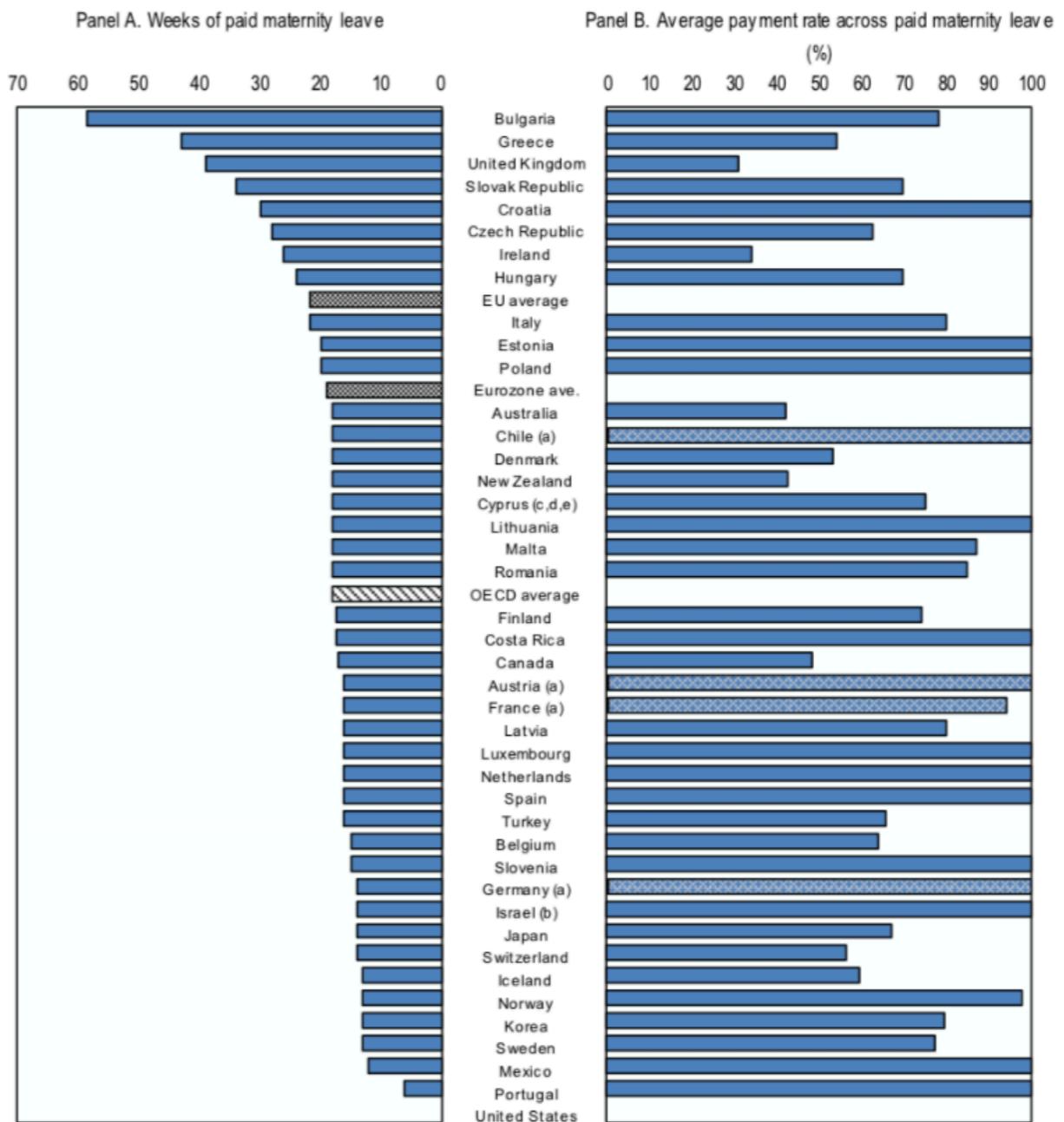
- Which country has the highest/lowest weeks of paid leave?
- Which country has the highest/lowest average pay rate?
- Is there any relationship between weeks of paid maternity leave and average pay rate?



What works well?

- Bars for quantitative values
- Countries sorted by weeks of paid leave, so can easily identify lowest/highest in this dimension
- No excessive colour

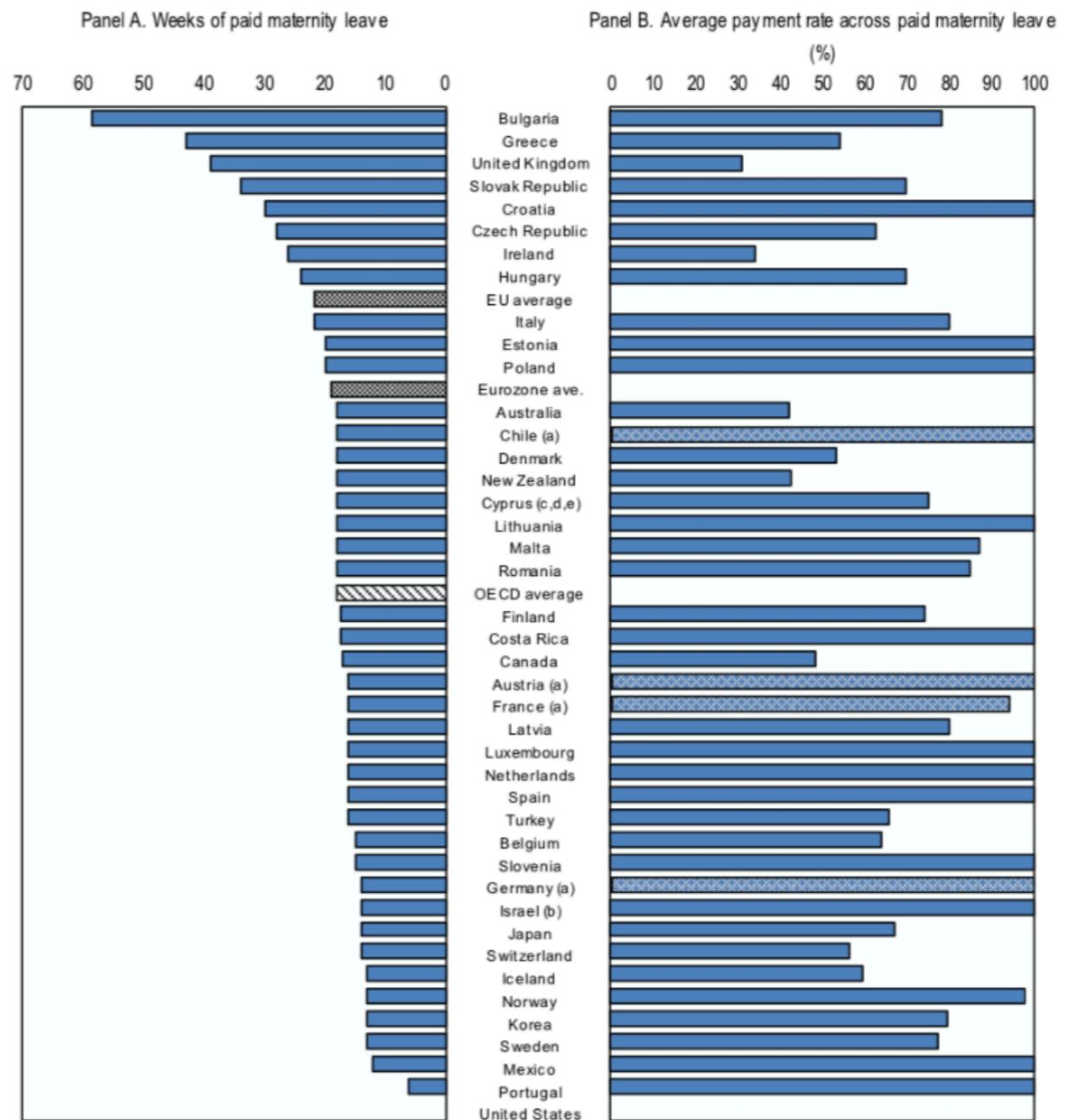
Chart PF2.1.A. Paid maternity leave, 2016
Duration of paid maternity leave and the average payment rate^a across paid maternity leave for an individual on national average earnings



What could be improved?

- Very difficult to find the highest/lowest pay rate in unordered bar chart
- Very difficult to see the relationship between the two dimensions
- Averages are displayed as bars, which makes themmistakable for countries

Chart PF2.1.A. Paid maternity leave, 2016
Duration of paid maternity leave and the average payment rate^a across paid maternity leave for an individual on national average earnings



The **United States** is the only OECD country that does not guarantee employment-protected leave of absence for mothers.



SOURCE: OECD • DESIGNED BY: Andy Kriebel | @VizWizBI

Resources

- **Visualization Analysis & Design | Tamara Munzner**
 - Chapter 5 - Marks and Channels
 - Chapter 10 - Map Color and Other Channels
- **Colour palettes**
 - viridis | <https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>
 - colorbrewer | <http://colorbrewer2.org>
- **Test for colour blindness simulator**
 - <http://rehue.net>
- **Makeover Monday**
 - For inspiration | <http://www.makeovermonday.co.uk/>

What I've been listening to...

**DATA
STORIES**

Visualization podcast
by Enrico Bertini and Moritz Stefaner

<http://datastori.es>