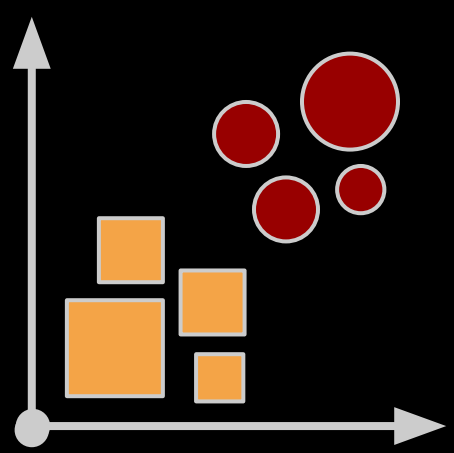
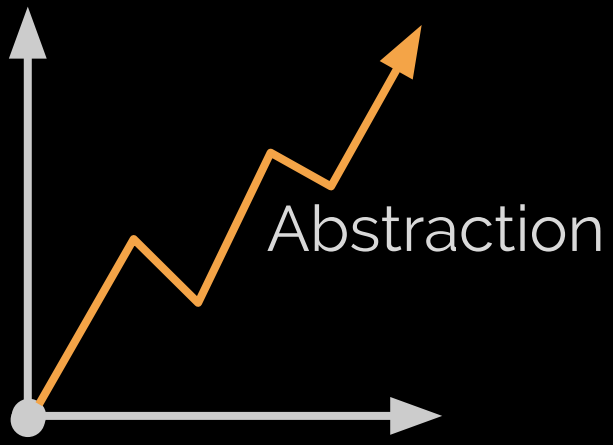
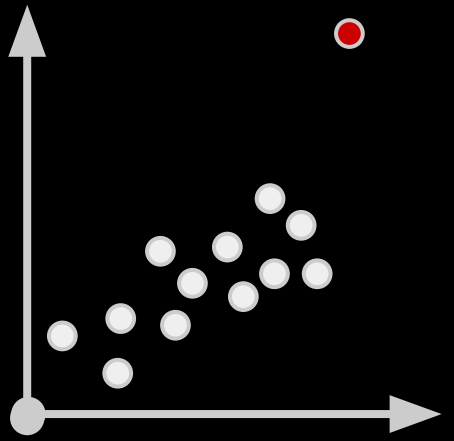
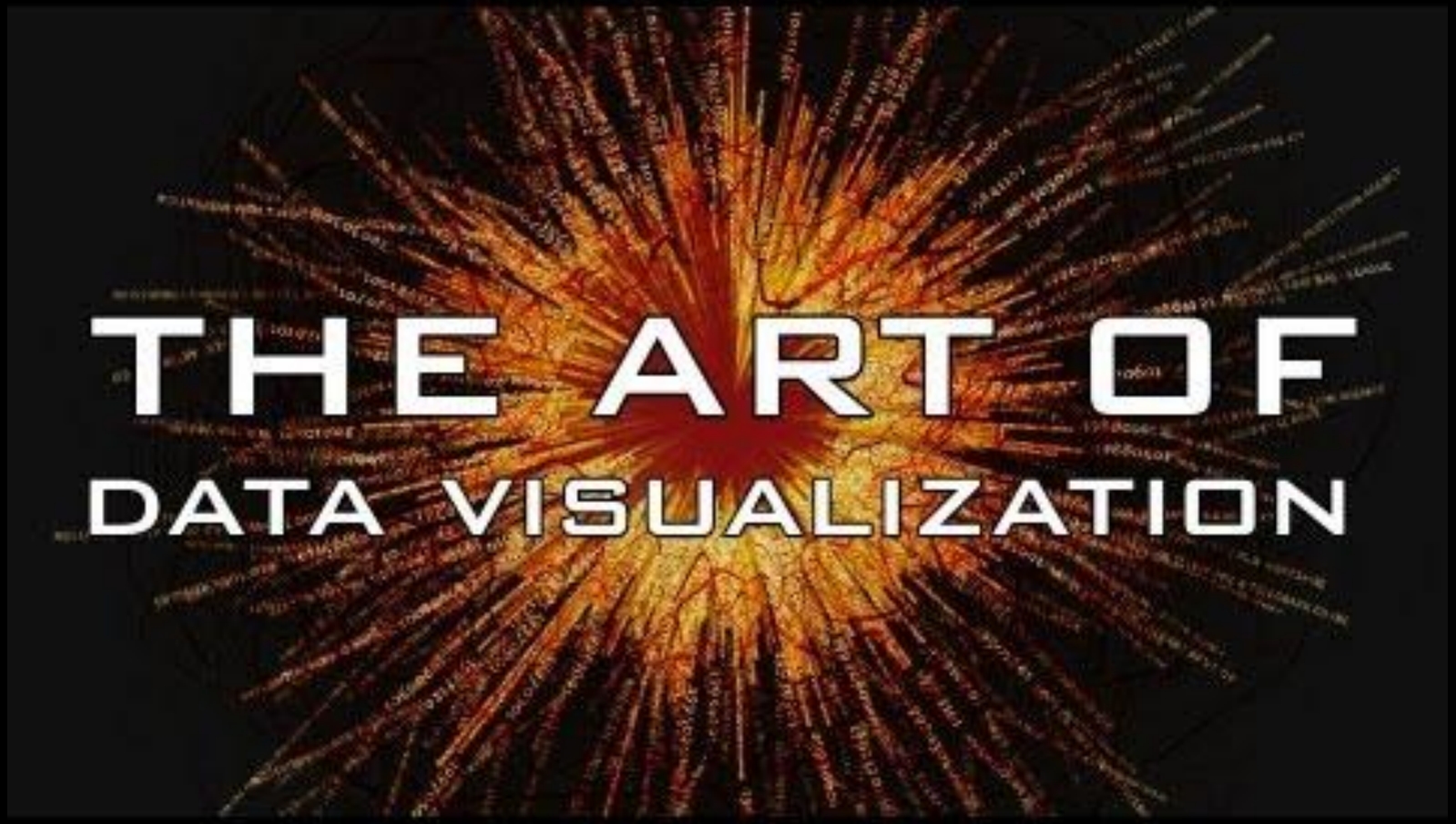
③ Aesthetics





Representation
& Aesthetics





Source: The Art of Data Visualization

How many 5's can you find?

14253678925136478924536917841935672849512678314935672842369851749512678314935672842369851745762938451672938359164782145762938451672938359164782431567298459163782431567298

Proximity

142 5 367892 5 136478924 5 369178
4193 5 672849 5 1267831493 5 6728
24 5 36917814 5 67289314 5 672938
49 5 1267831493 5 6728423698 5 17
3 5 916478214 5 6729384 5 1672938
46 5 132978423698 5 174 5 9163782
14 5 7629384 5 16729383 5 9164782
431 5 672984 5 9163782431 5 67298

Alignment

```
555 142367892136478924369178
555 419367284912678314936728
555 243691781467289314672938
555 491267831493672842369817
555 391647821467293841672938
555 461329784236981749163782
555 147629384167293839164782
555 431672984916378243167298
```

Repetition

123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789
123456789 123456789 123456789

Enclosure

142 5 367892 5 136478924 5 369178

4193 5 672849 5 1267831493 5 6728

24 5 36917814 5 67289314 5 672938

49 5 1267831493 5 6728423698 5 17

3 5 916478214 5 6729384 5 1672938

46 5 132978423698 5 174 5 9163782

14 5 7629384 5 16729383 5 9164782

431 5 672984 5 9163782431 5 67298

Contrast

1425367892513647892453691784193567284951267831493567283245369178145672893145672938495126783149356728423698517359164782145672938451672938465132978423698517459163782145762938451672938359164782431567298459163782431567298

Subtraction

Preattentive Process

Subtraction

Contrast

Repetition

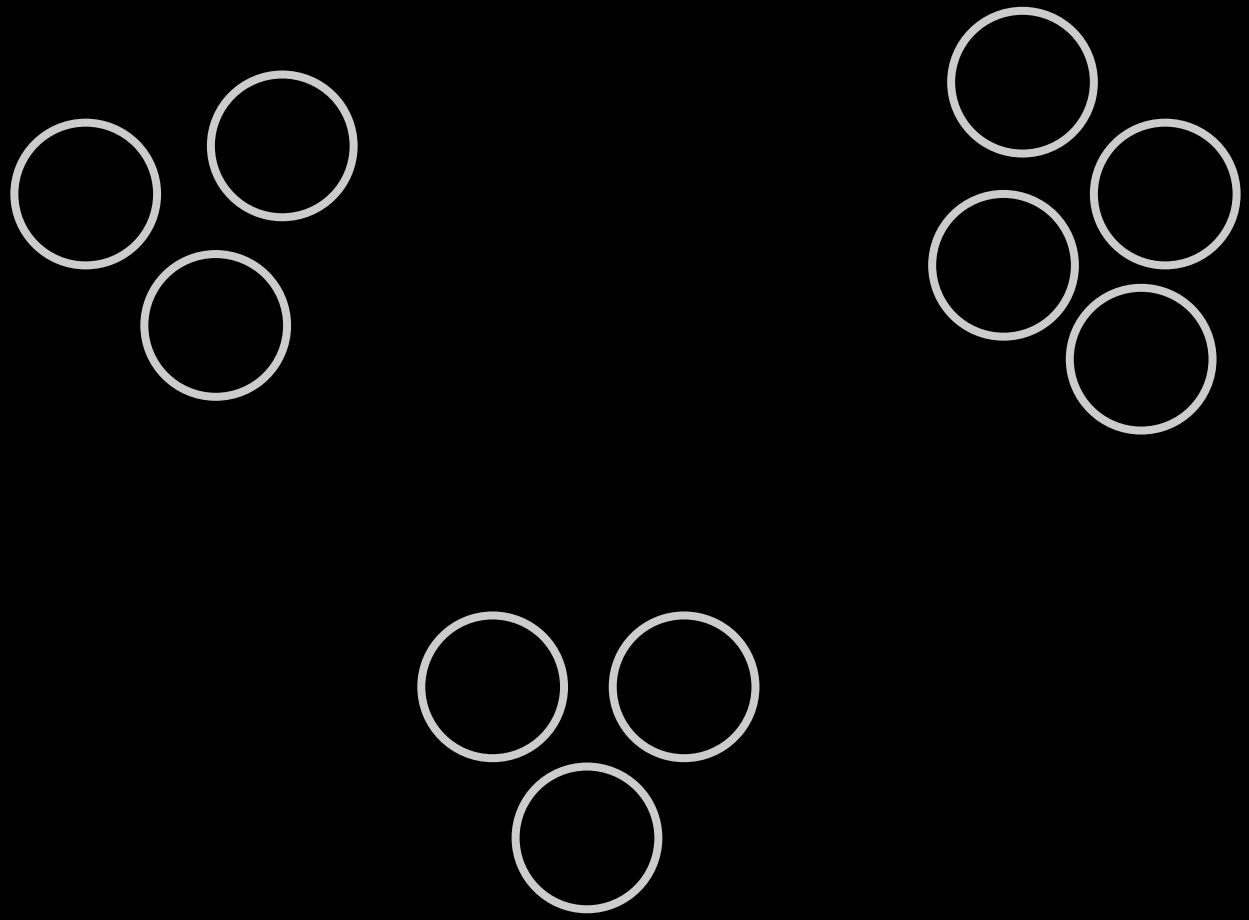
Alignment

Proximity

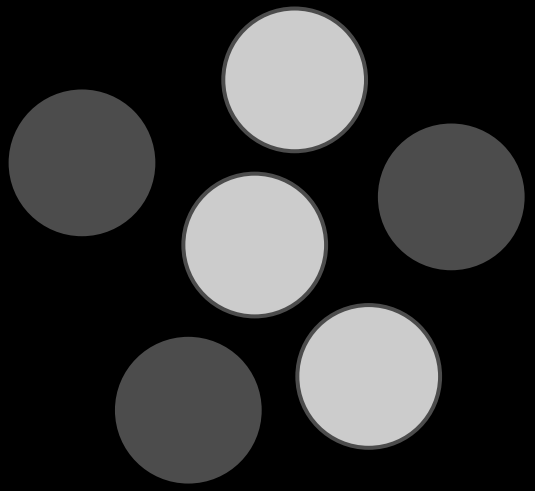
Enclosure

Gestalt Principles of Visual Perception

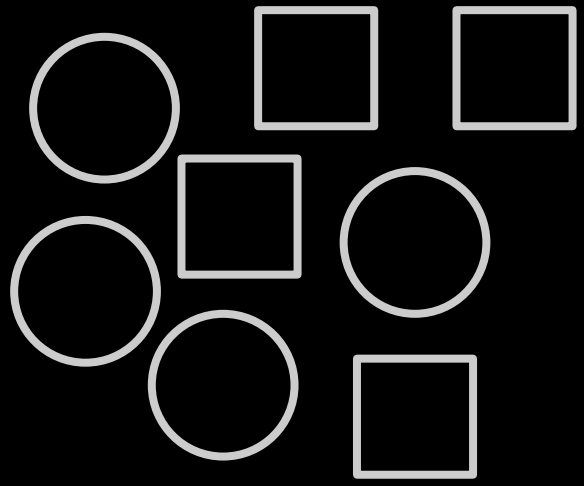
Proximity



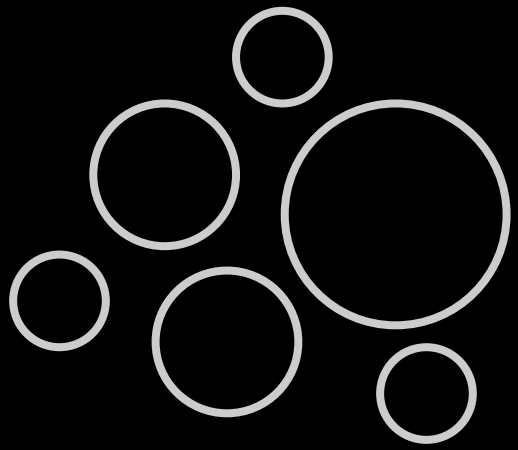
Similarity



Colour

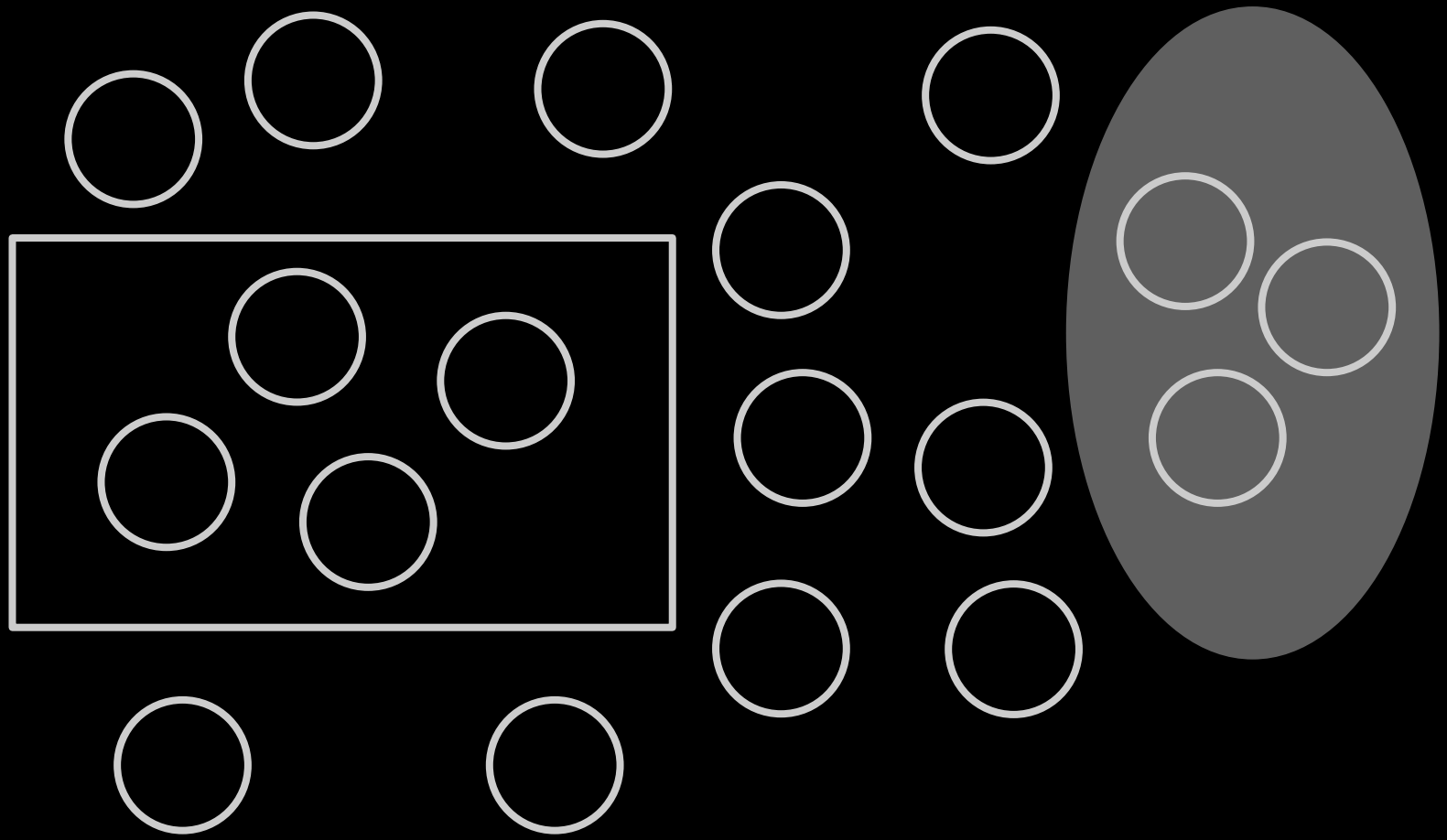


Shape

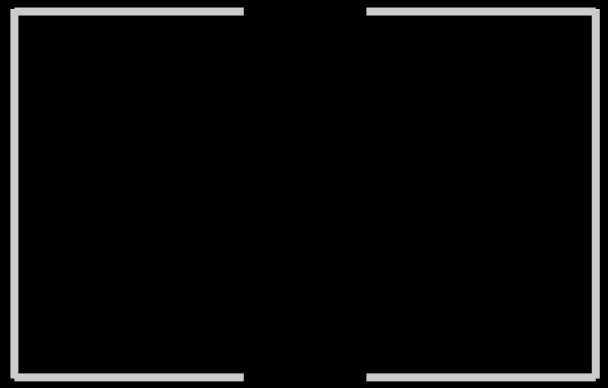


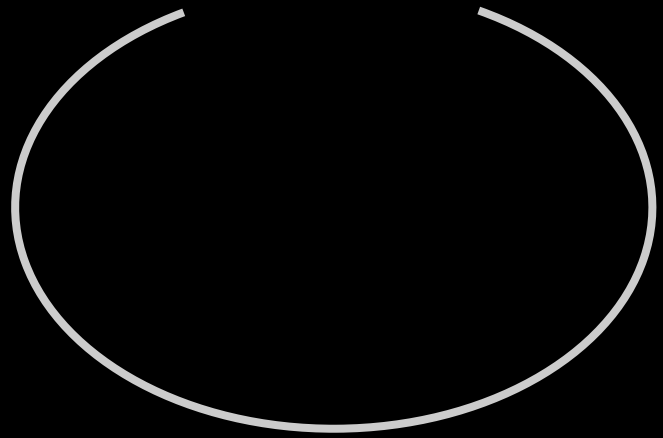
Size

Enclosure

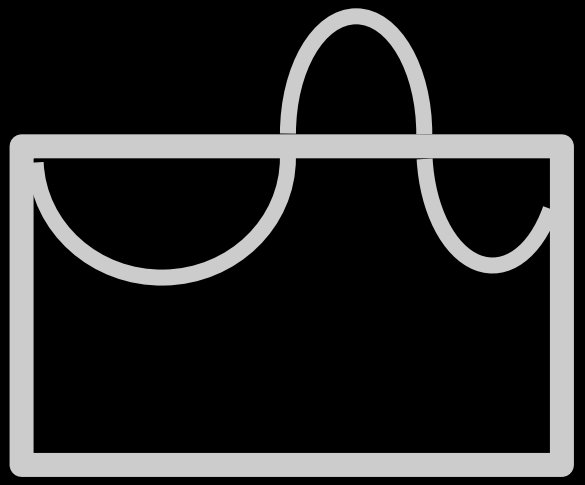


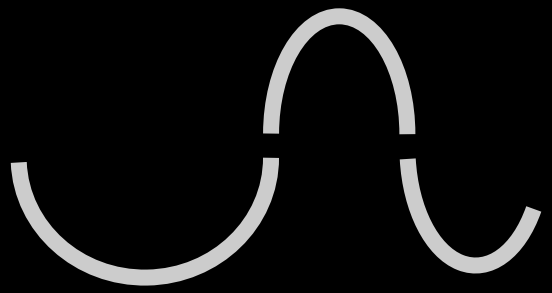
Closure



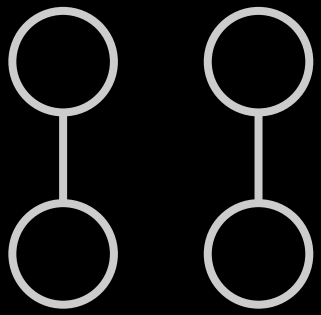


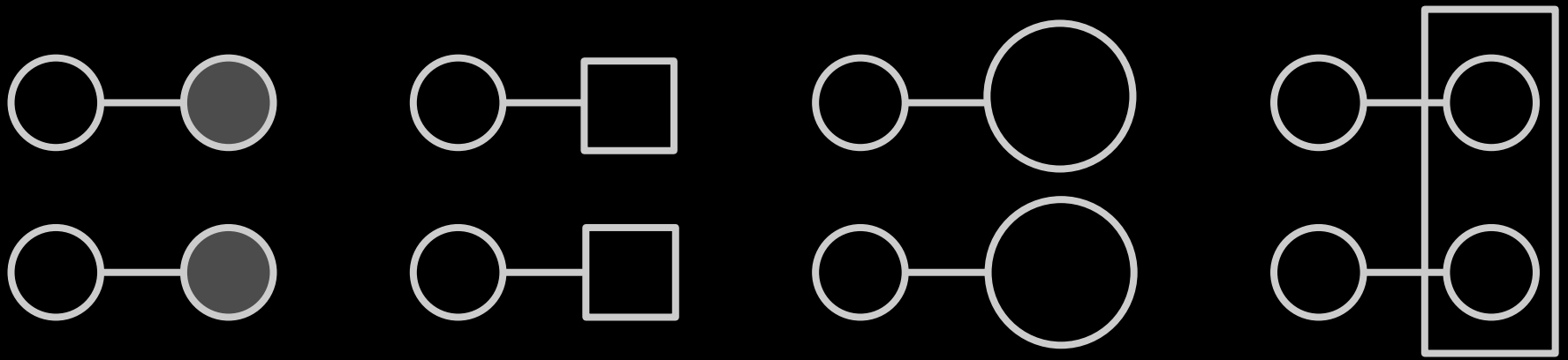
Continuity





Connection





Visual Language

Visual Language is a Sign Language

"... finding the artificial memory that best supports our natural means of perception." - Bertin

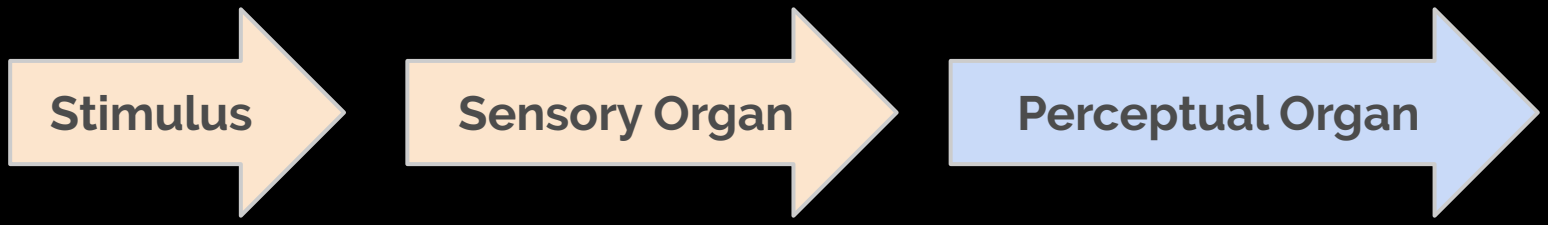
Graphical Perception

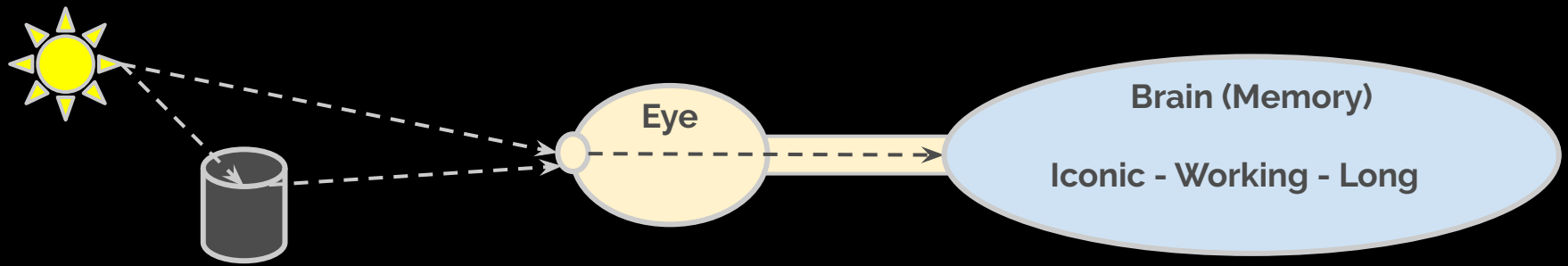
The ability of viewers to interpret visual (graphical) encodings of information and therefore decode information in graphs

Perception

Sensation
(Physical Process)

Perception
(Cognitive Process)





Sensation - Eye

Fovea

Small focus, blurry outside

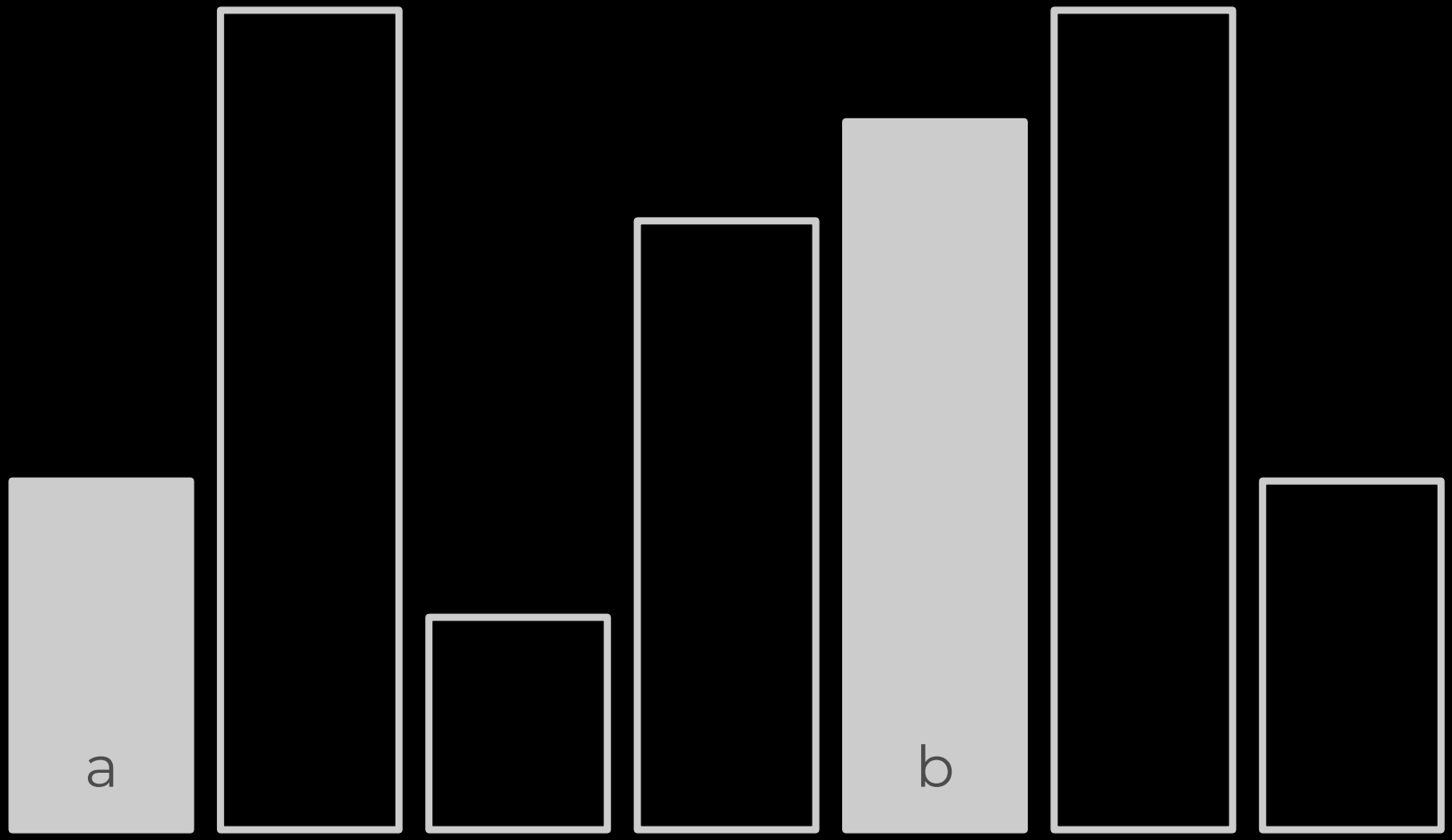
Saccadic Eye Movement

Eyes jump from one place to another (Saccades)

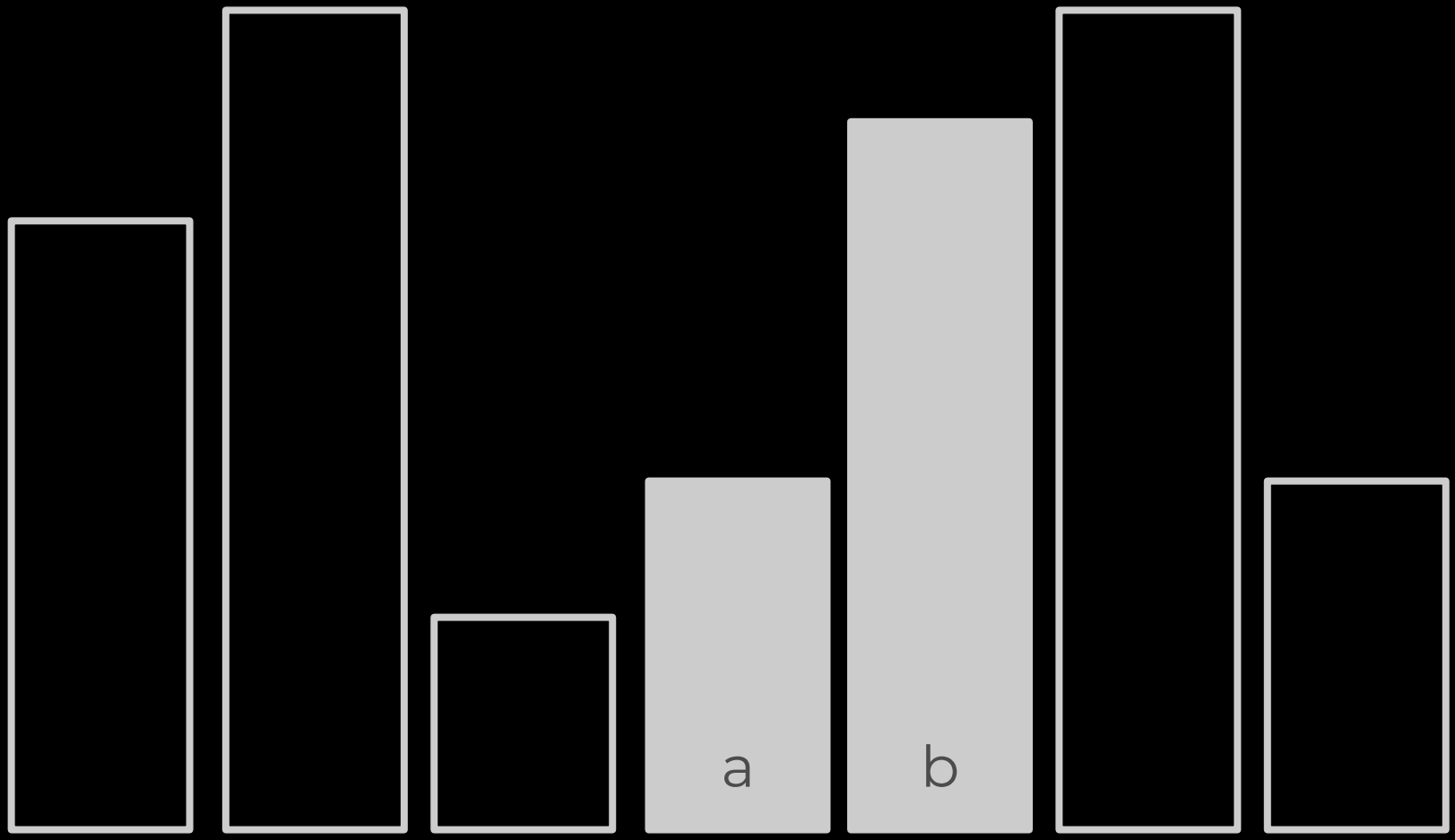
Perception - Memory

Iconic	Working	Long Term
Pre-attentive	Attentive	Attentive
< 1s - Fast	1-3s - Medium	Long
Temporary	Temporary	Permanent
Unconscious	Conscious	Deliberate
In-device	RAM	SSD

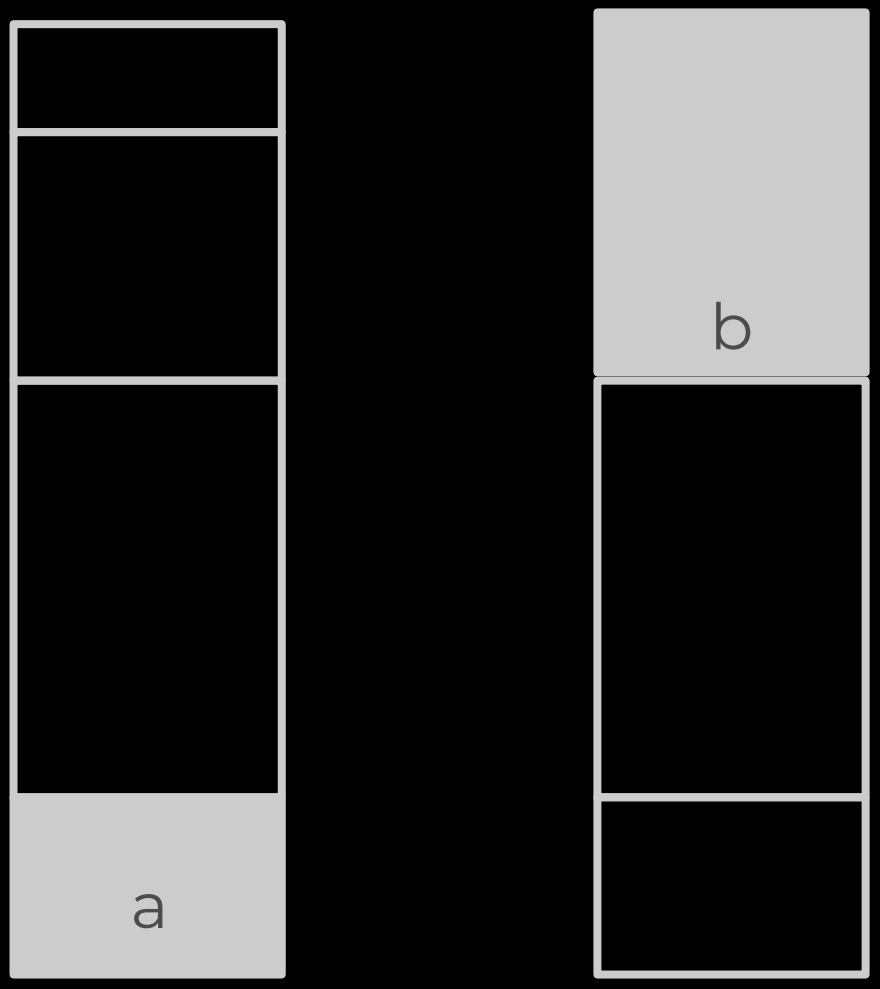
We compare relatively



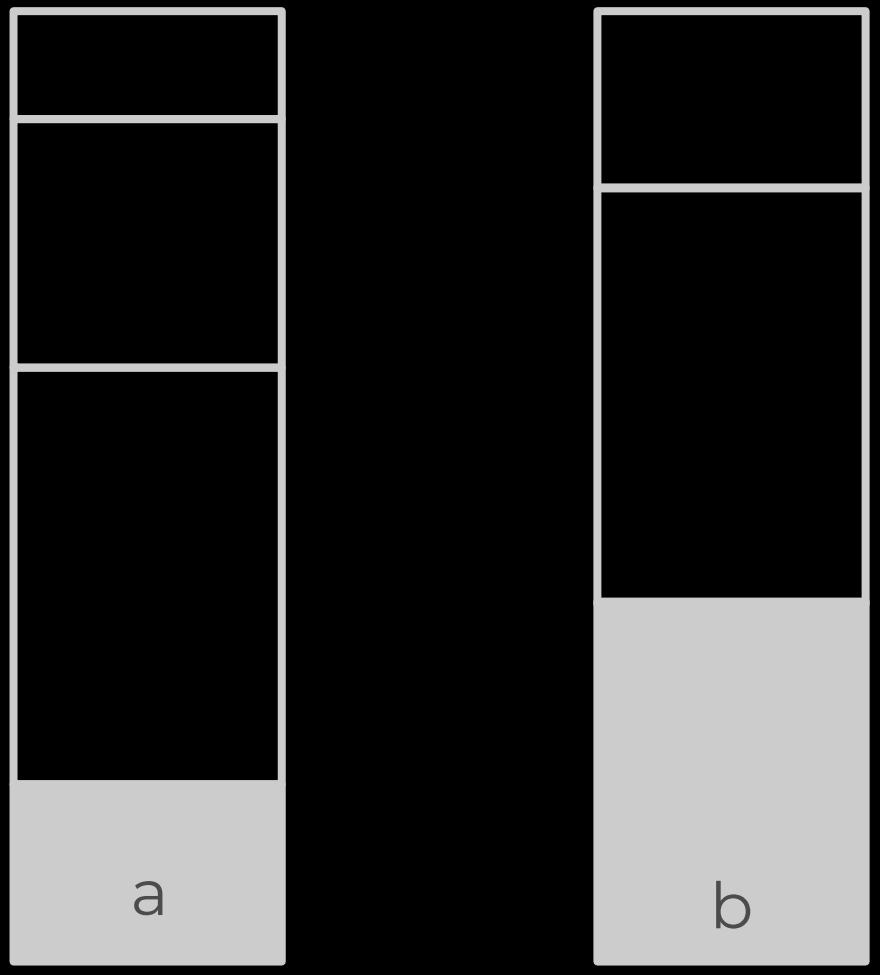
Proximity helps



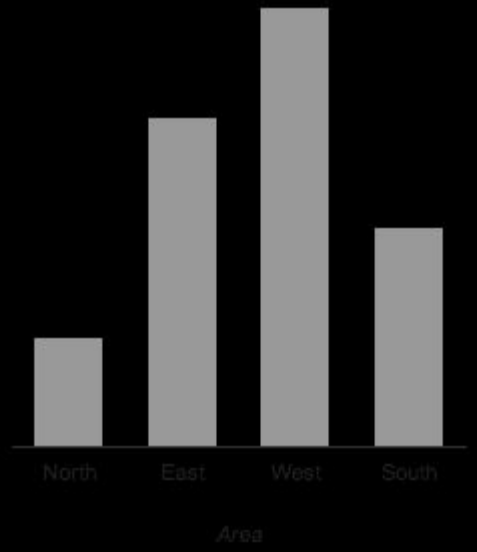
This is hard



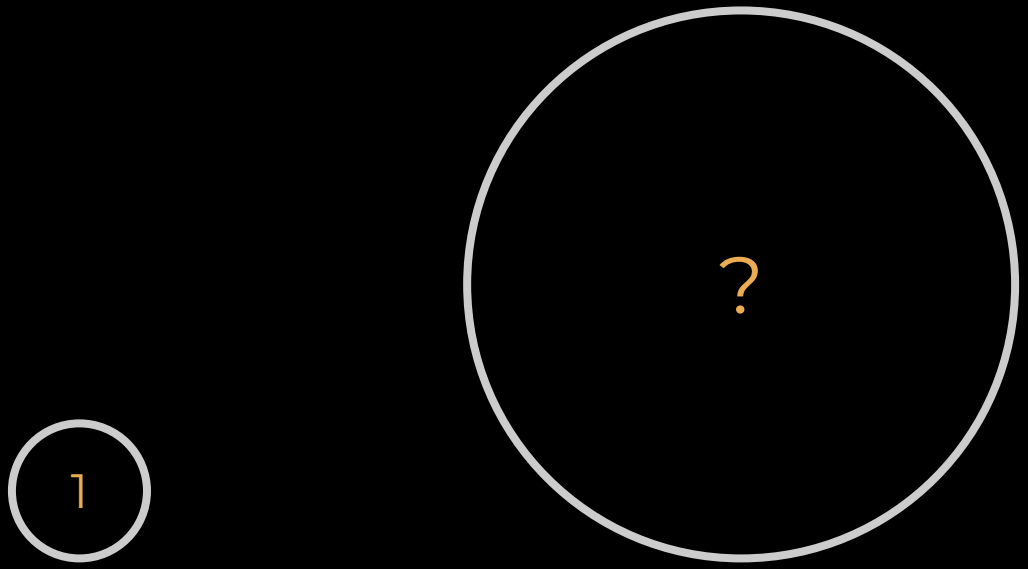
Make comparisons easy



Angles vs. Length



Area Comparison



Preattentive Attributes

Form

Length, Width, Orientation,
Shape, Size, Enclosure

Color

Hue, Intensity

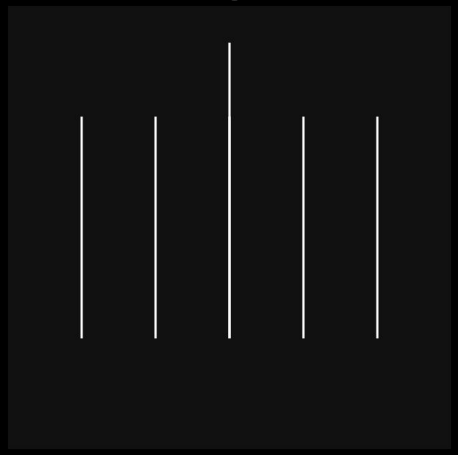
Spatial

2d position

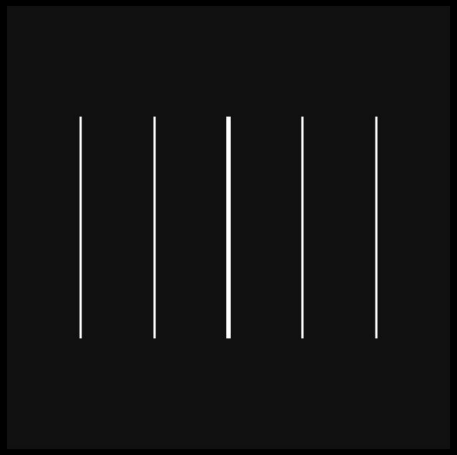
Motion

Preattentive - Form

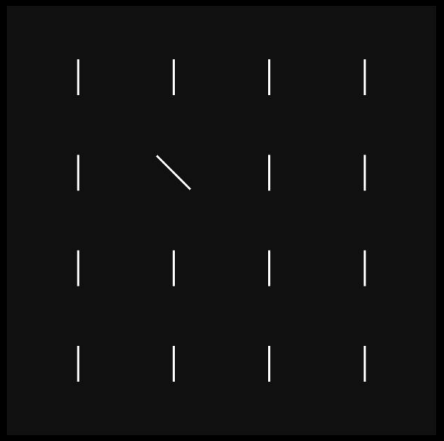
Length



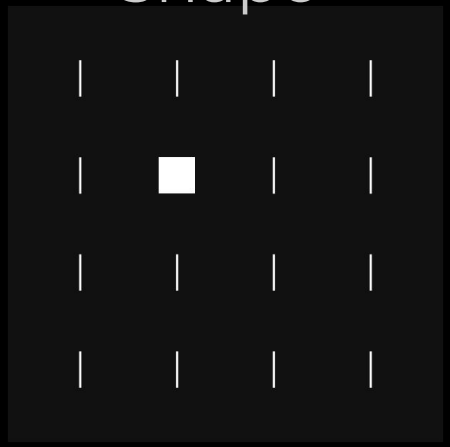
Width



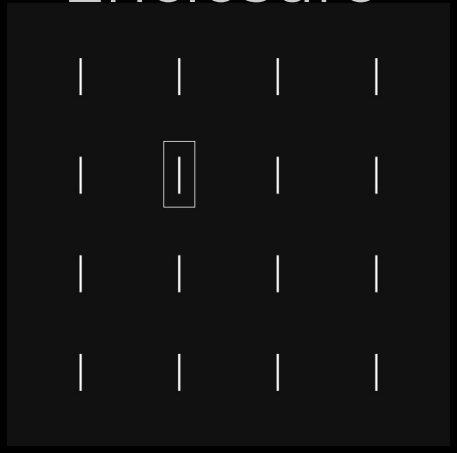
Orientation



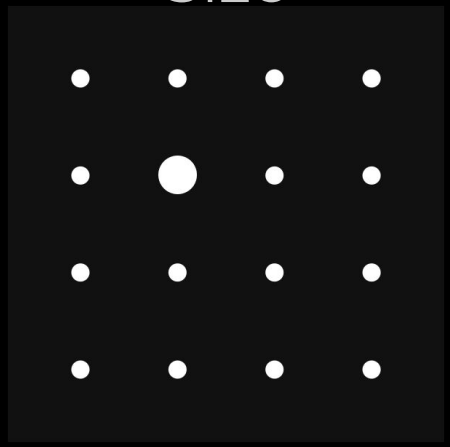
Shape



Enclosure

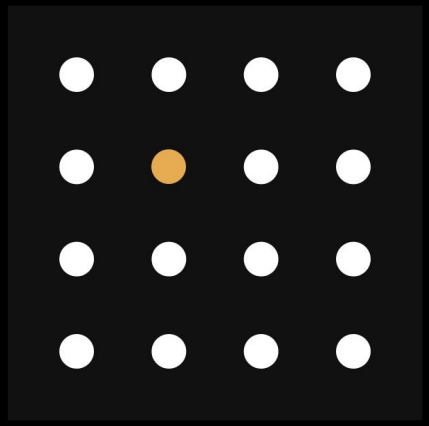


Size

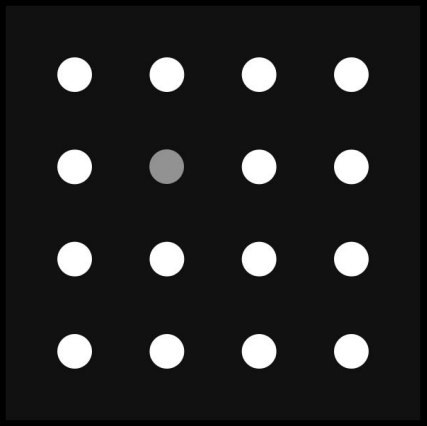


Preattentive - Color

Hue

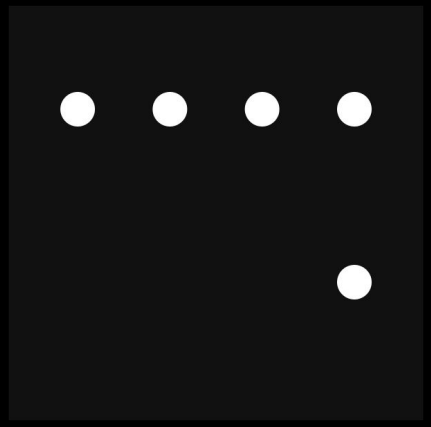


Saturation



Preattentive - Spatial

2D Position



3D Position
vs.
2.05D Vision

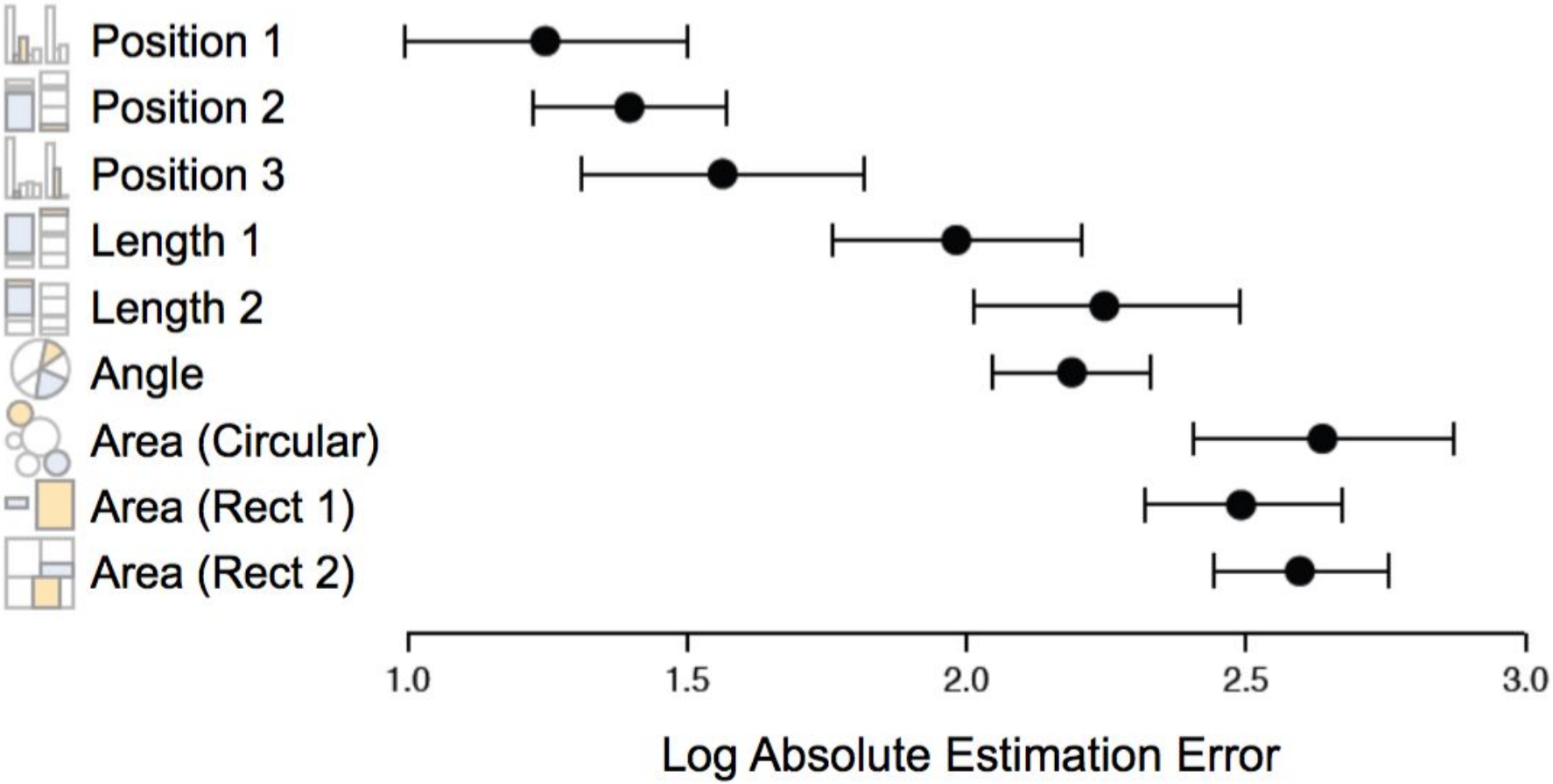
Preattentive - Motion

Ranking of Encoding

Quantitative	Ordinal	Nominal
Position	**Position**	**Position**
Length	**Color Saturation**	**Color Hue**
Angle	**Color Hue**	**Connection**
Slope	**Connection**	**Enclosure**
Size	**Enclosure**	**Color Saturation**
Volume	**Length**	**Shape**
Color Saturation	**Angle**	**Length**
Color Hue	**Slope**	**Angle**
Connection	**Size**	**Slope**
Enclosure	**Volume**	**Area**
Shape	**Shape**	**Volume**

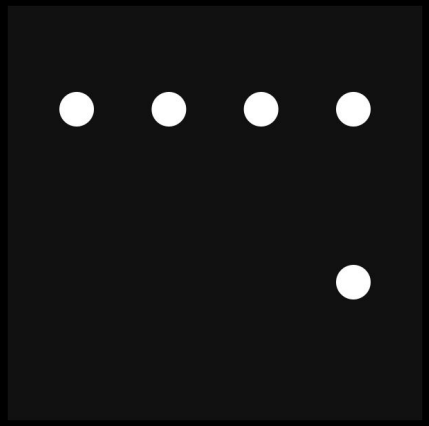
Ranking of Encoding

Quantitative	Ordinal	Nominal
Position	**Position**	**Position**
Length	**Color Saturation**	**Color Hue**
Angle	**Color Hue**	**Connection**
Slope	**Connection**	**Enclosure**
Size	**Enclosure**	**Color Saturation**
Volume	**Length**	**Shape**
Color Saturation	**Angle**	**Length**
Color Hue	**Slope**	**Angle**
Connection	**Size**	**Slope**
Enclosure	**Volume**	**Area**
Shape	**Shape**	**Volume**

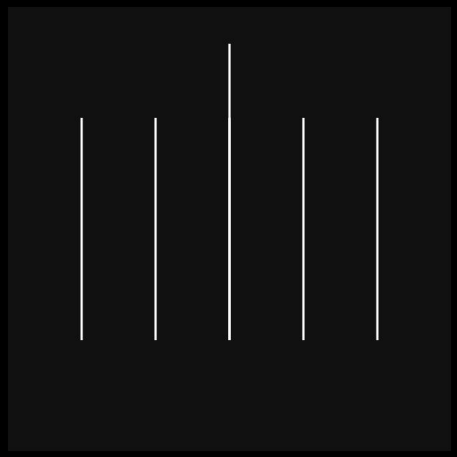

Position 1
Position 2
Position 3
Length 1
Length 2
Angle
Area (Circular)
Area (Rect 1)
Area (Rect 2)
1.0
1.5
2.0
2.5
3.0
Log Absolute Estimation Error

Quantitative Encoding

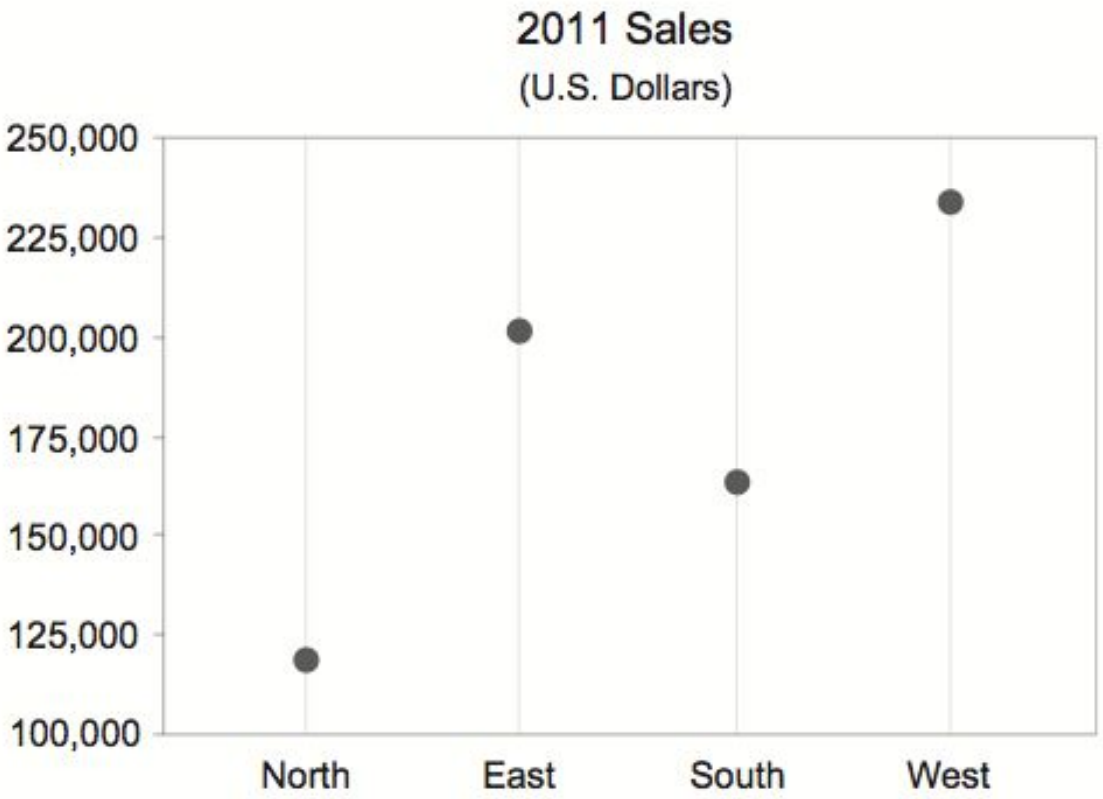
2D Position



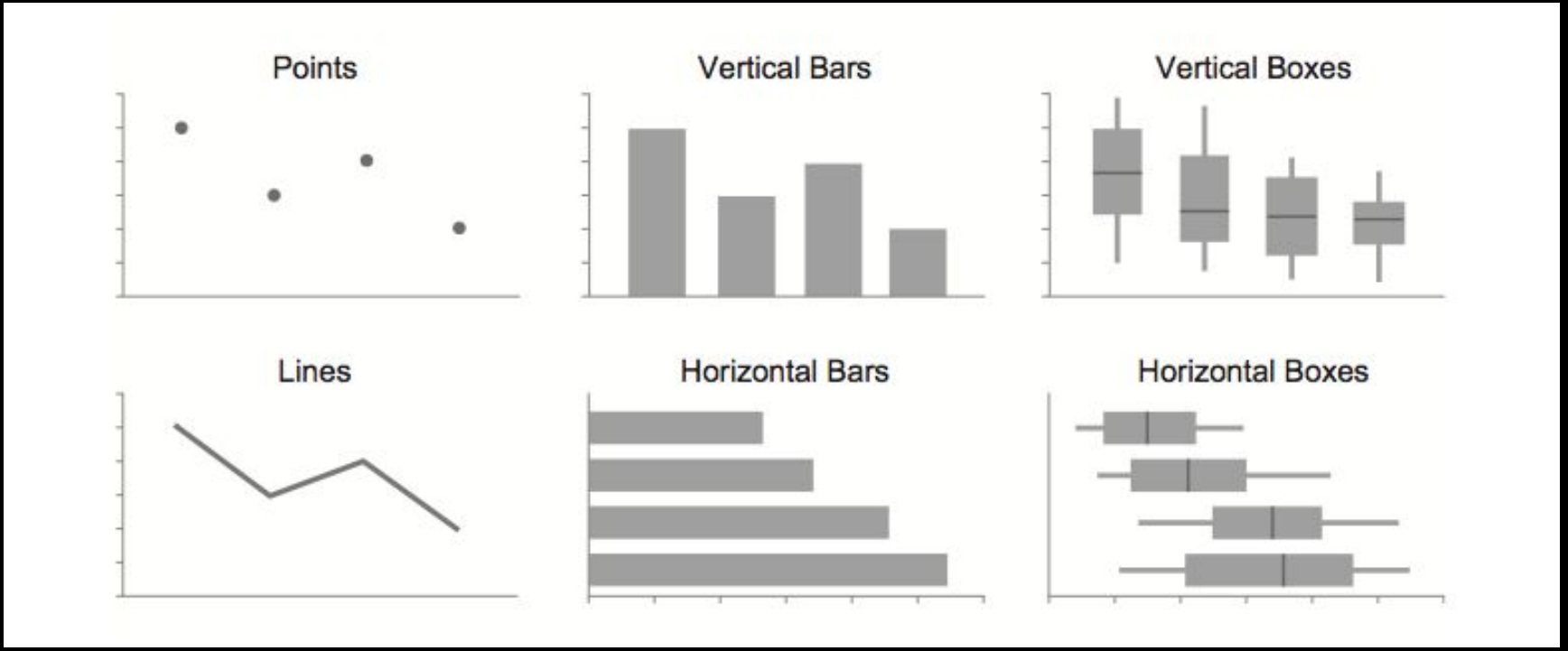
Length



Position can do it all

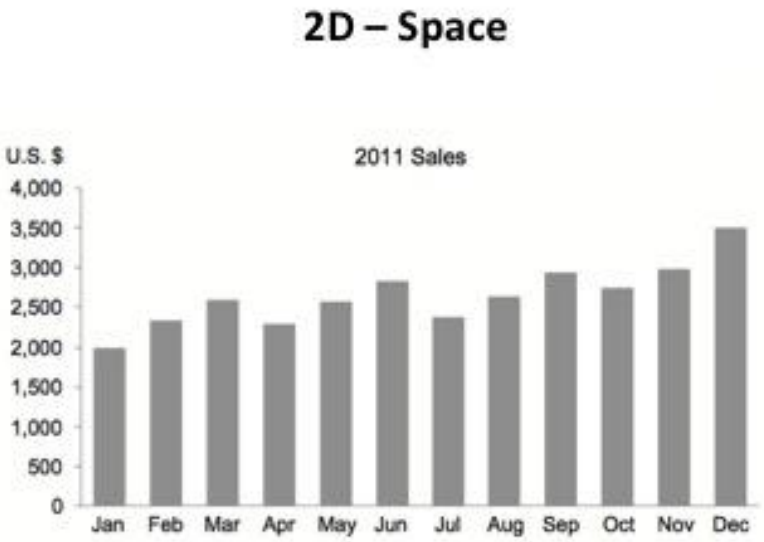


Quantitative Encoding

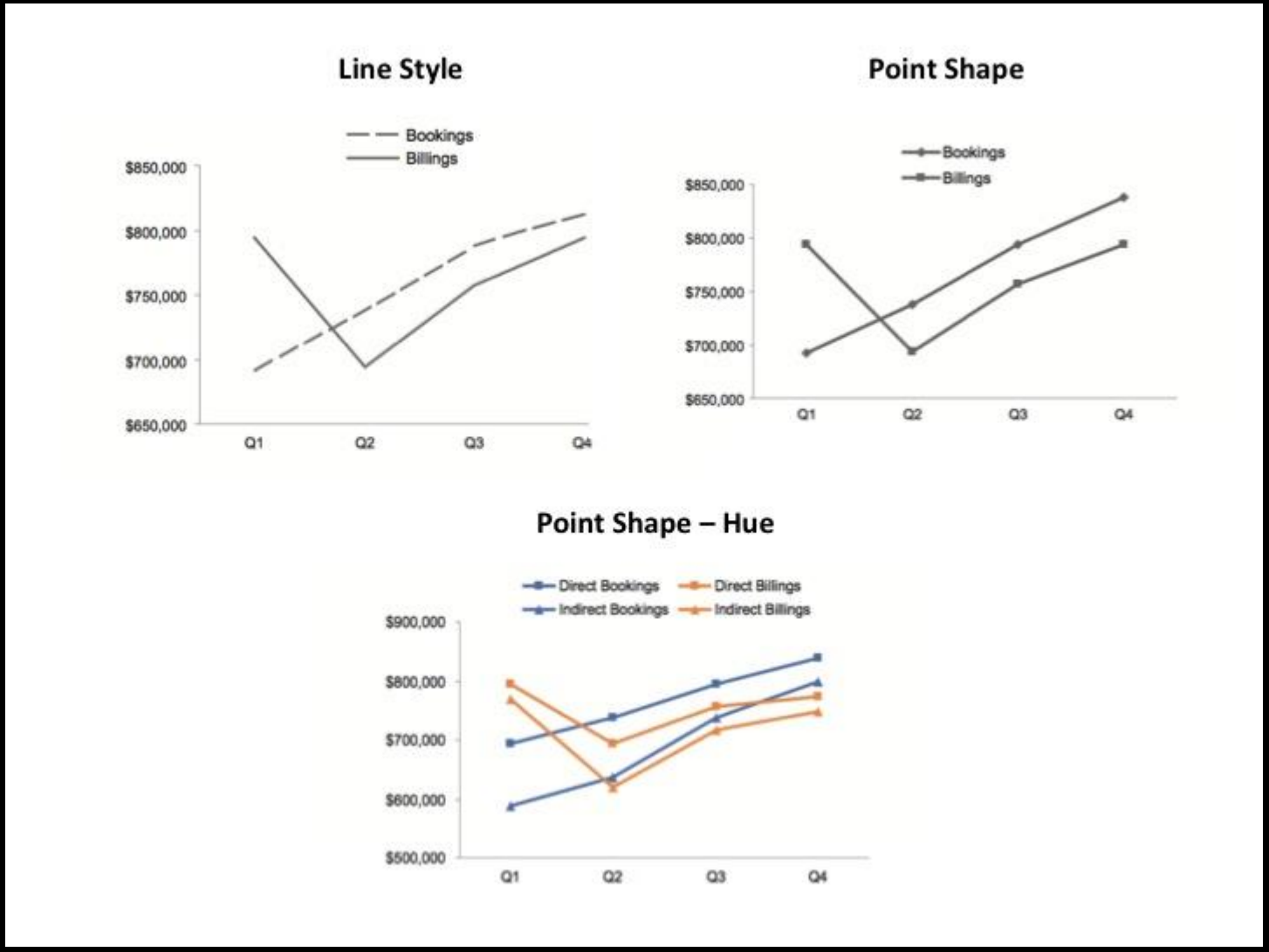


Use Position and Length mainly

Categorical Encoding

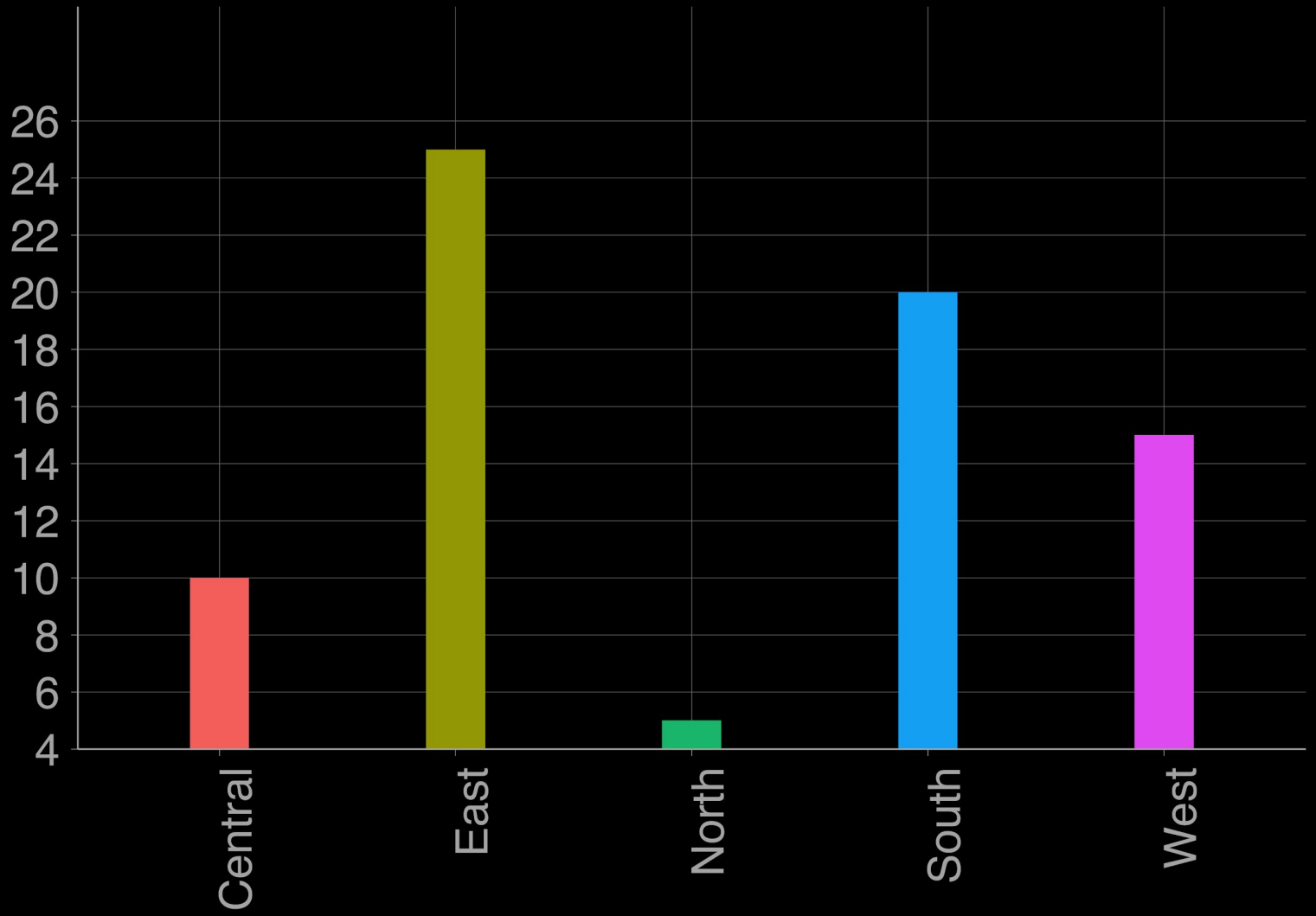


Categorical Encoding



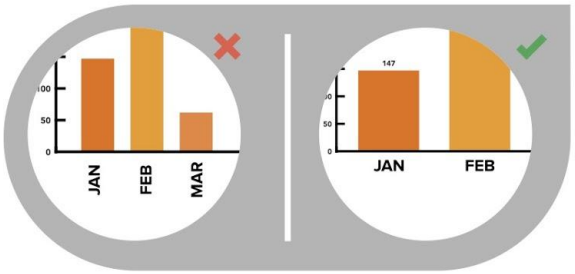
Aesthetic Best Practices

Review - Bar Chart

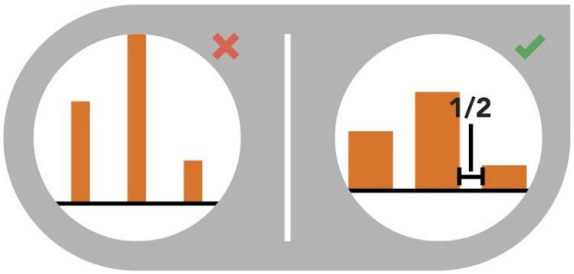


BAR CHART

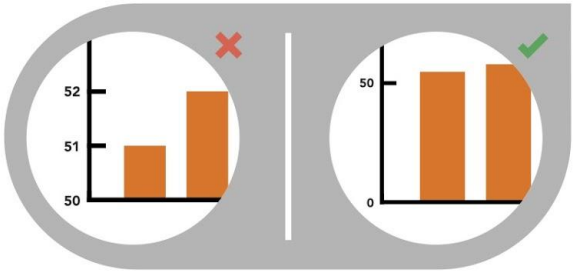
DESIGN BEST PRACTICES



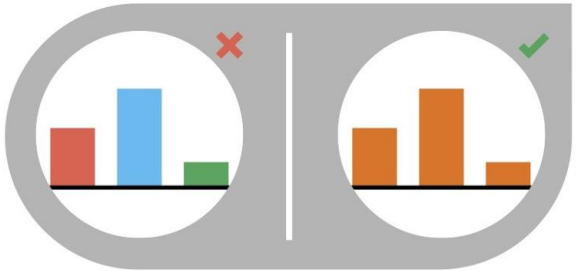
USE HORIZONTAL LABELS
Avoid steep diagonal or vertical type, as it can be difficult to read.



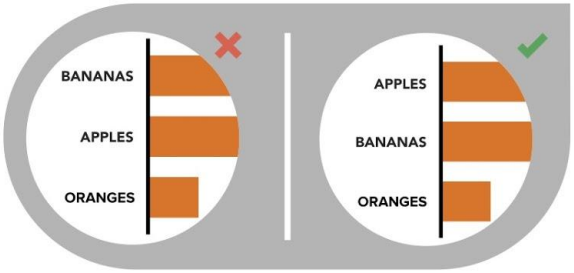
SPACE BARS APPROPRIATELY
Space between bars should be ½ bar width.



START THE Y-AXIS VALUE AT 0
Starting at a value above zero truncates the bars and doesn't accurately reflect the full value.

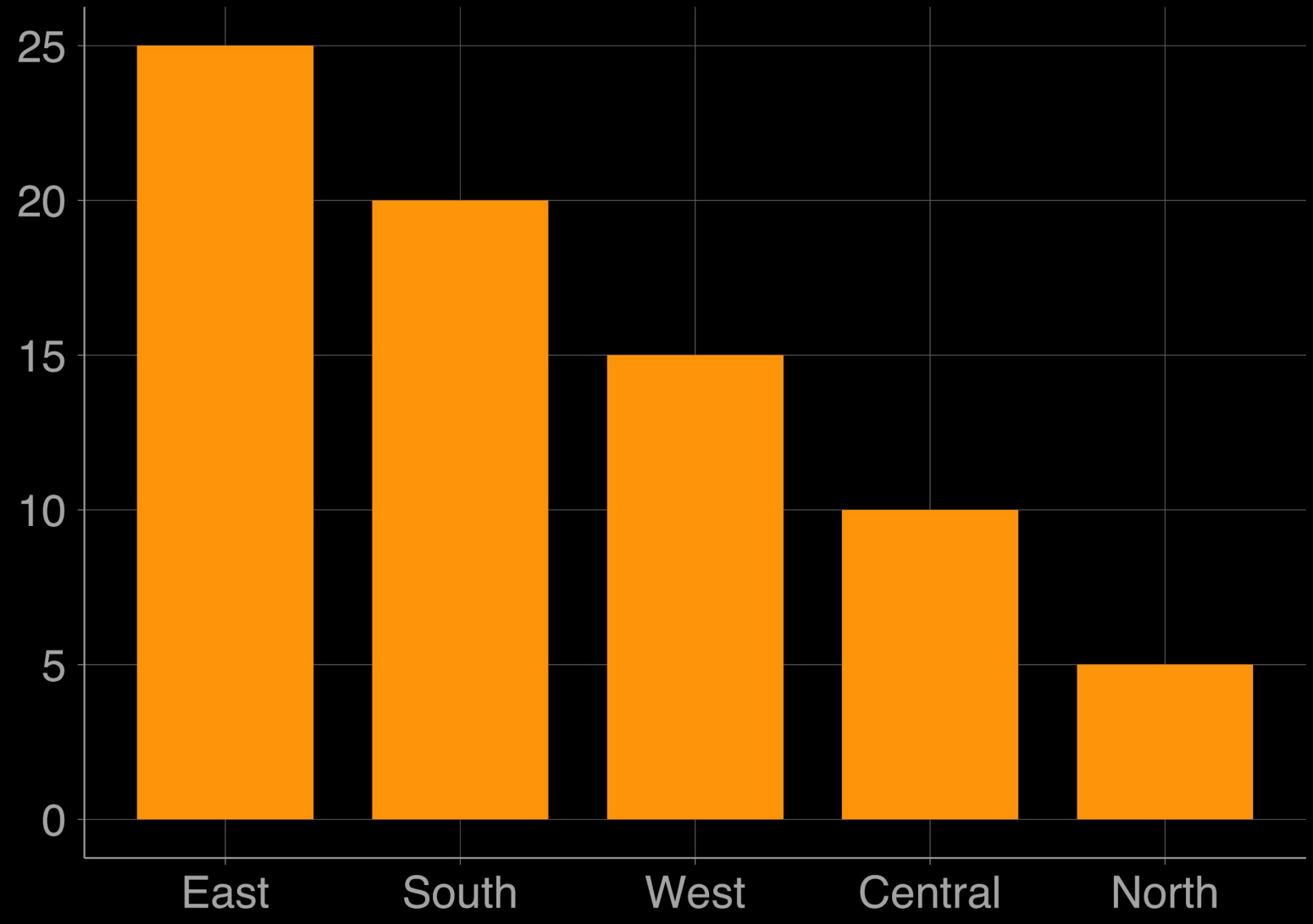


USE CONSISTENT COLORS
Use one color for bar charts. You may use an accent color to highlight a significant data point.

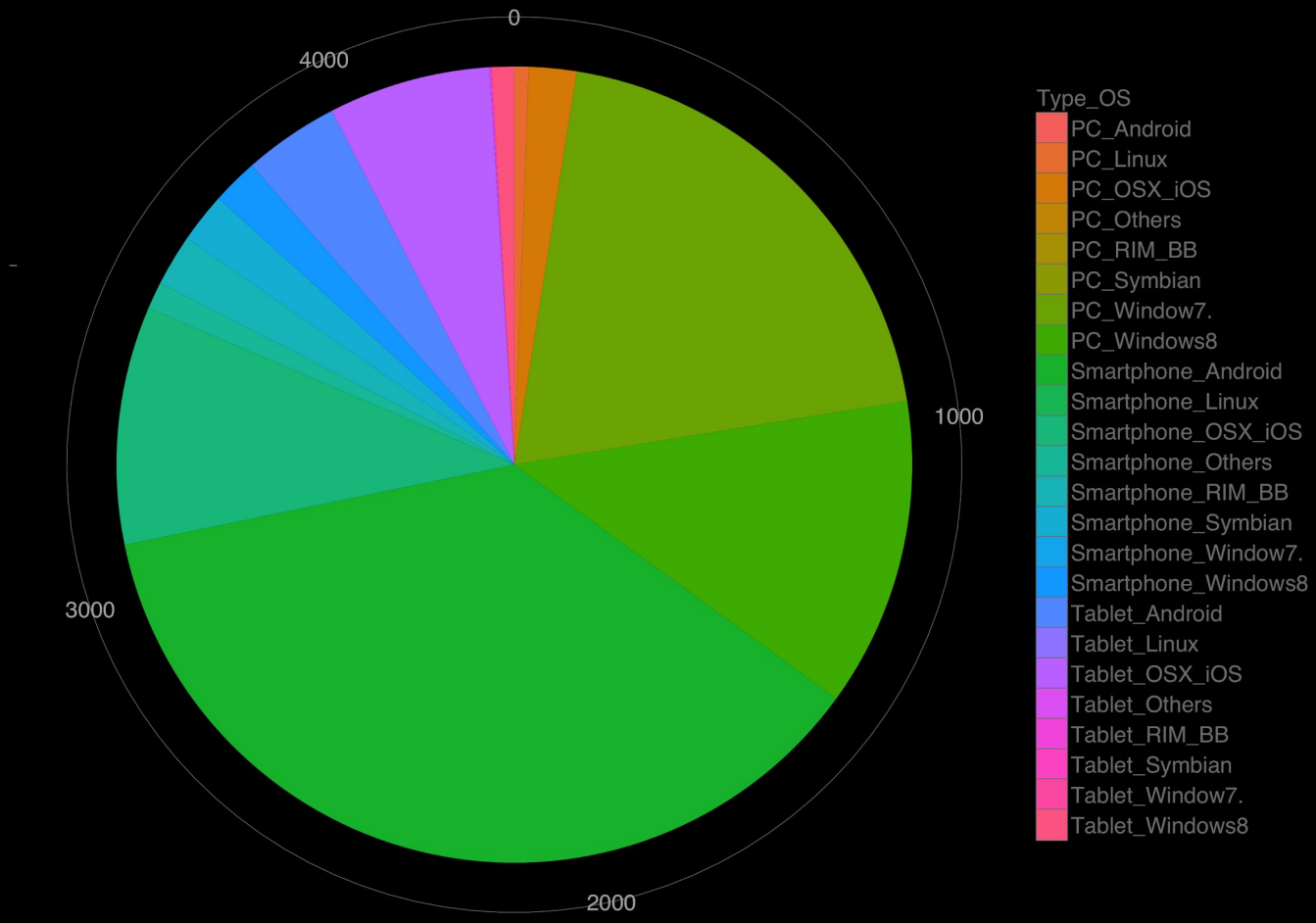


ORDER DATA APPROPRIATELY
Order categories alphabetically, sequentially, or by value.

Bar Chart - Aesthetics



Review - Pie Chart

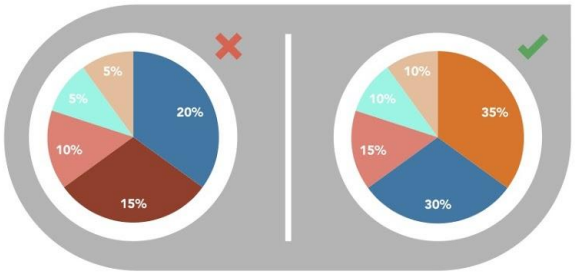


VISUALIZE NO MORE THAN 5 CATEGORIES PER CHART

It is difficult to differentiate between small values; depicting too many slices decreases the impact of the visualization. If needed, you can group smaller values into an “other” or “miscellaneous” category, but make sure it does not hide interesting or significant information.

DON’T USE MULTIPLE PIE CHARTS FOR COMPARISON

Slice sizes are very difficult to compare side-by-side. Use a stacked bar chart instead.



MAKE SURE ALL DATA ADDS UP TO 100%

Verify that values total 100% and that pie slices are sized proportionate to their corresponding value.

PIE CHART

DESIGN BEST PRACTICES

ORDER SLICES CORRECTLY

There are two ways to order sections, both of which are meant to aid comprehension:

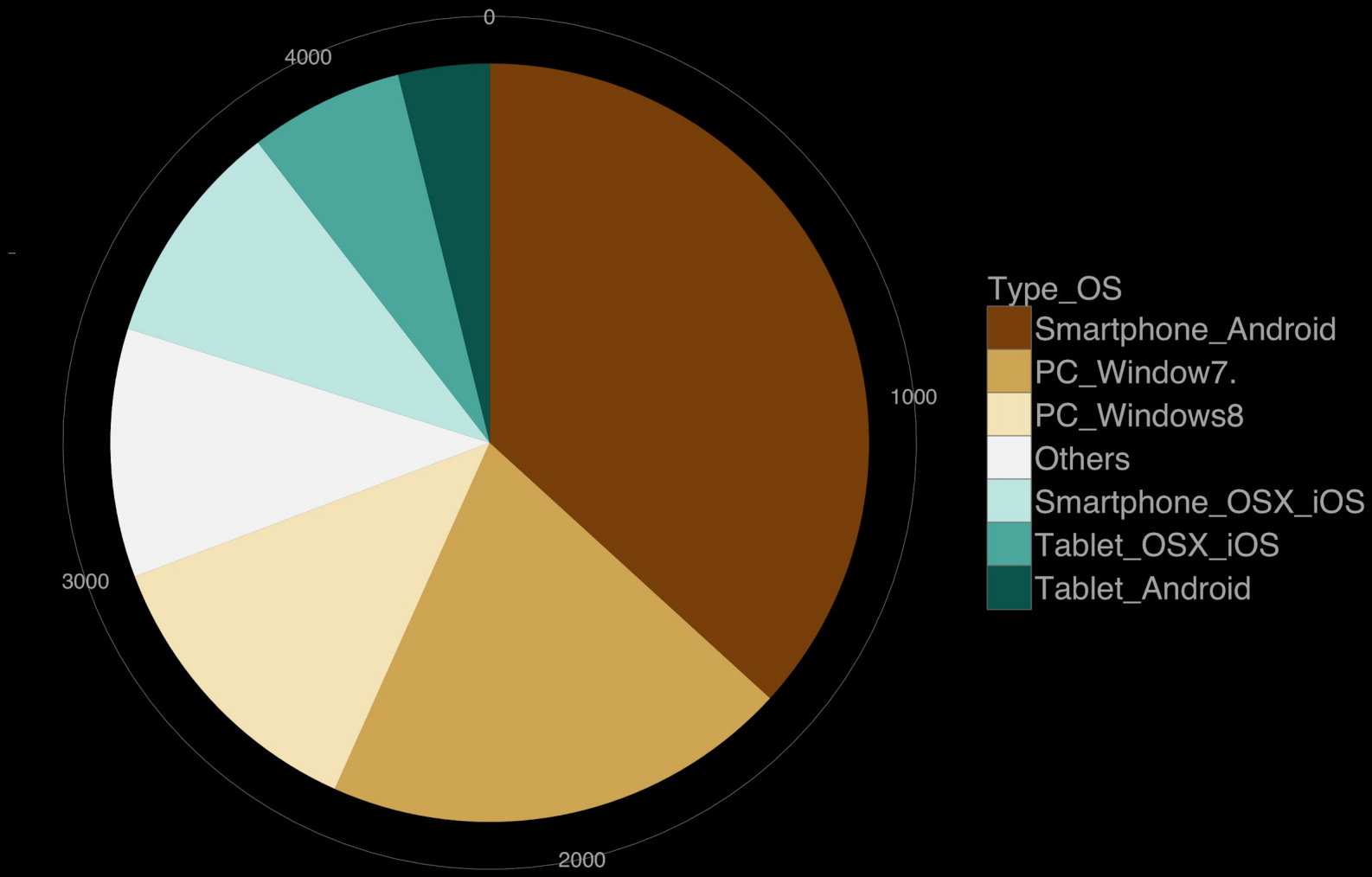
OPTION 1

Place the largest section at 12 o’clock, going clockwise. Place the second largest section at 12 o’clock, going counterclockwise. The remaining sections can be placed below, continuing counterclockwise.

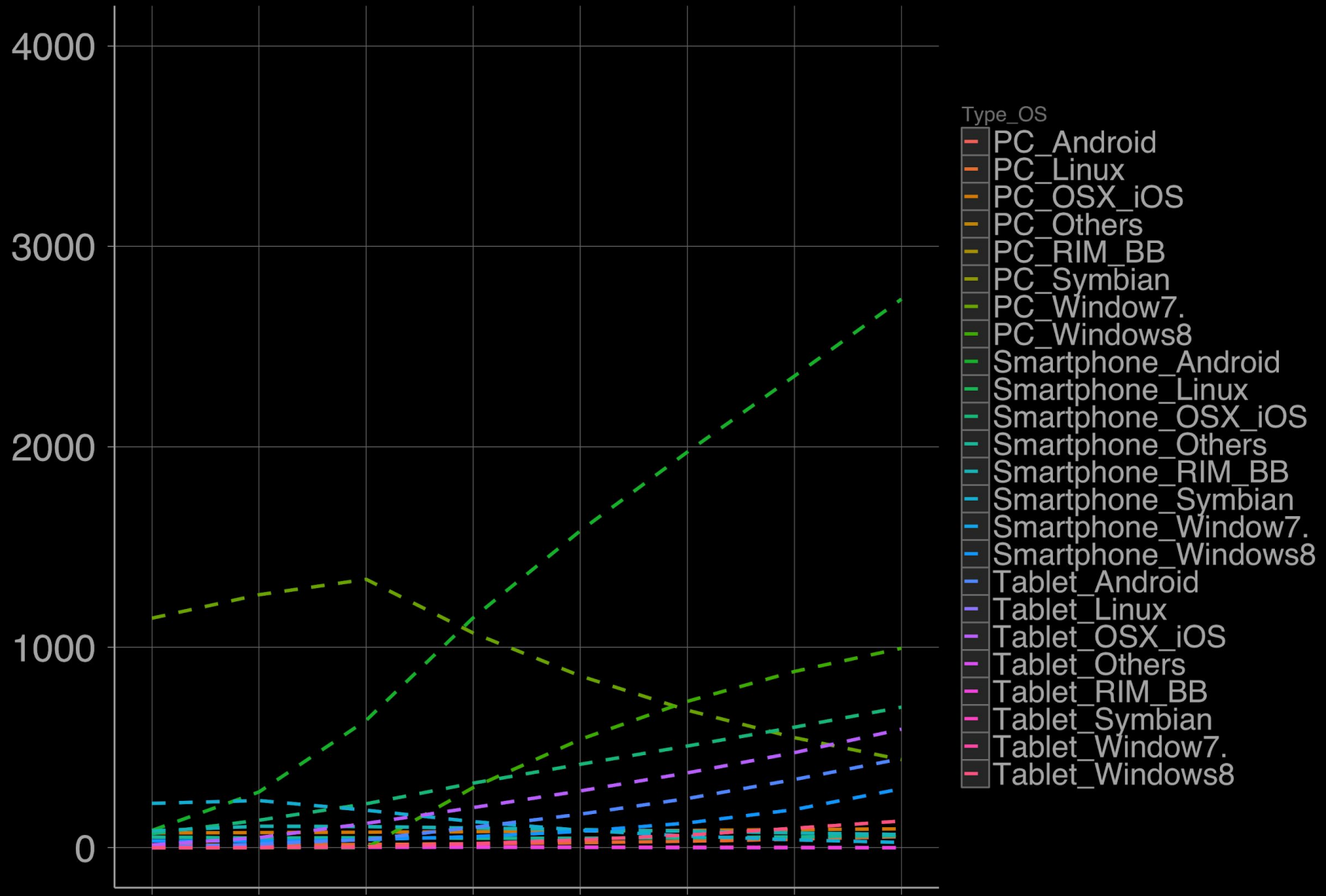
OPTION 2

Start the largest section at 12 o’clock, going clockwise. Place remaining sections in descending order, going clockwise.

Pie Chart - Aesthetics

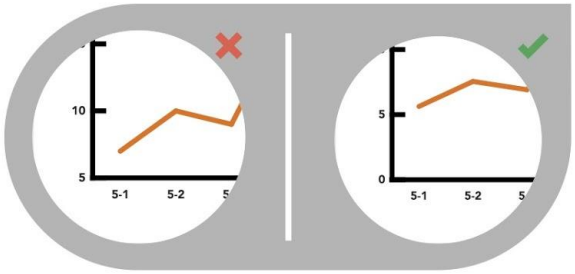


Review - Line Chart

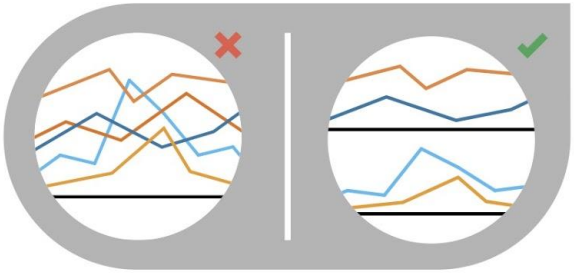


LINE CHART

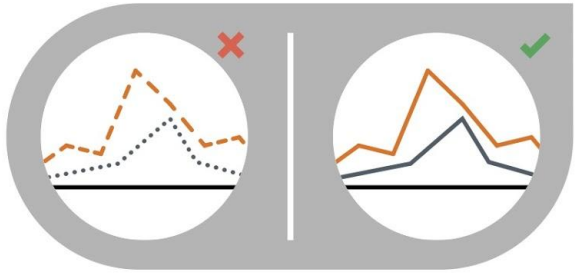
DESIGN BEST PRACTICES



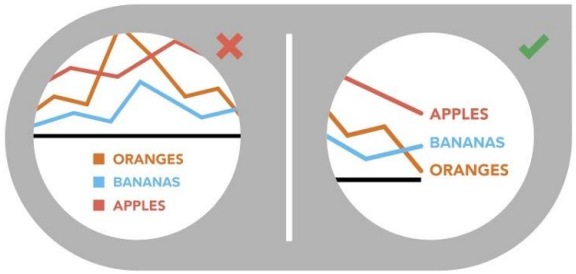
INCLUDE A ZERO BASELINE IF POSSIBLE
Although a line chart does not have to start at a zero baseline, it should be included if possible. If relatively small fluctuations in data are meaningful (e.g., in stock market data), you may truncate the scale to showcase these variances.



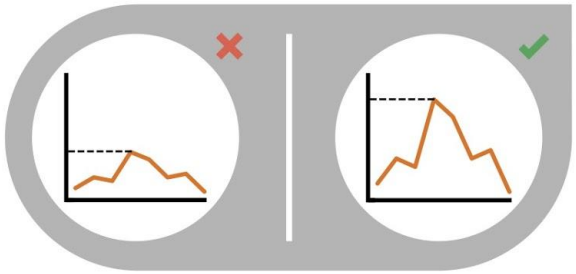
DON'T PLOT MORE THAN 4 LINES
If you need to display more, break them out into separate charts for better comparison.



USE SOLID LINES ONLY
Dashed and dotted lines can be distracting.

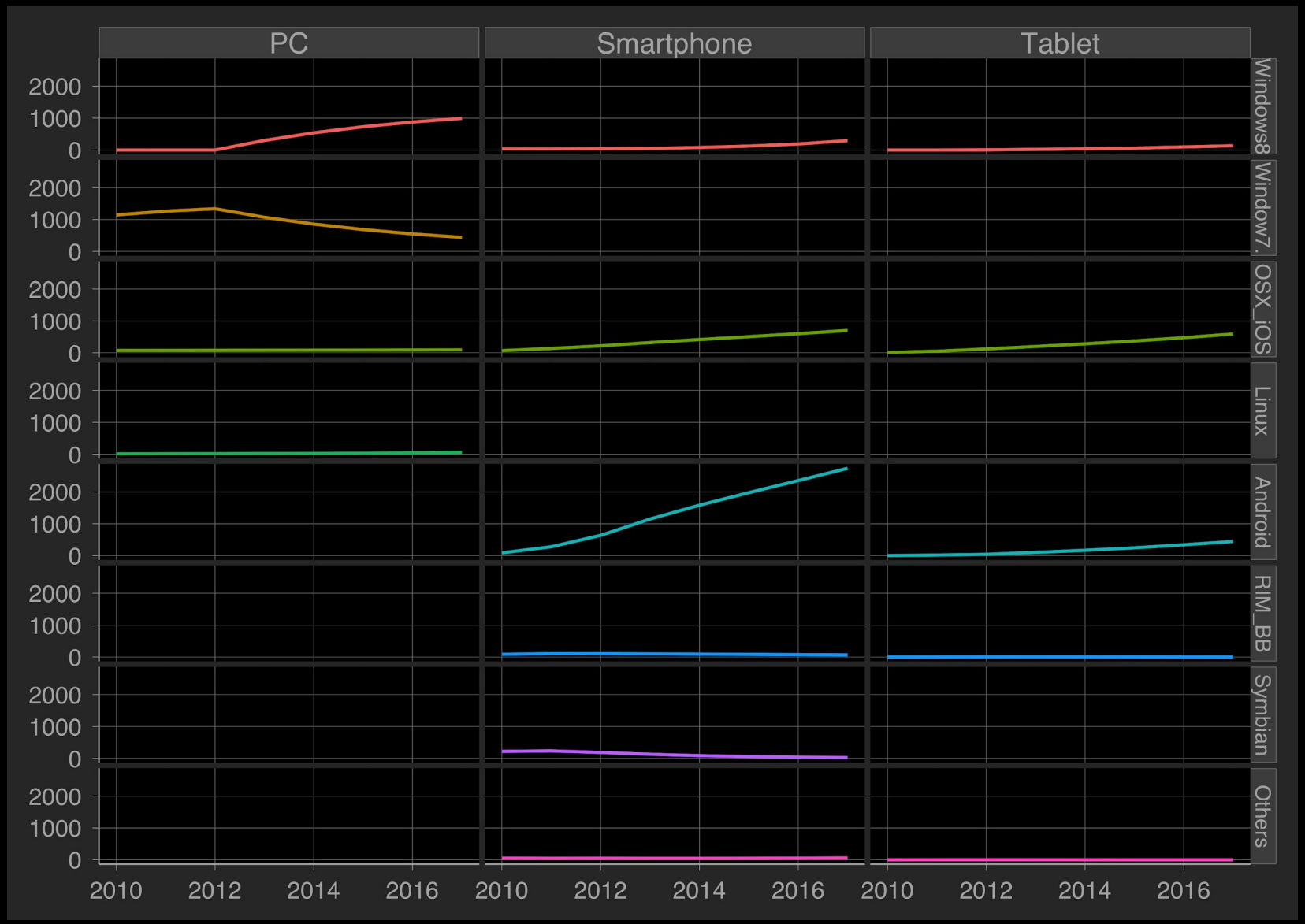


LABEL THE LINES DIRECTLY
This lets readers quickly identify lines and corresponding labels instead of referencing a legend.

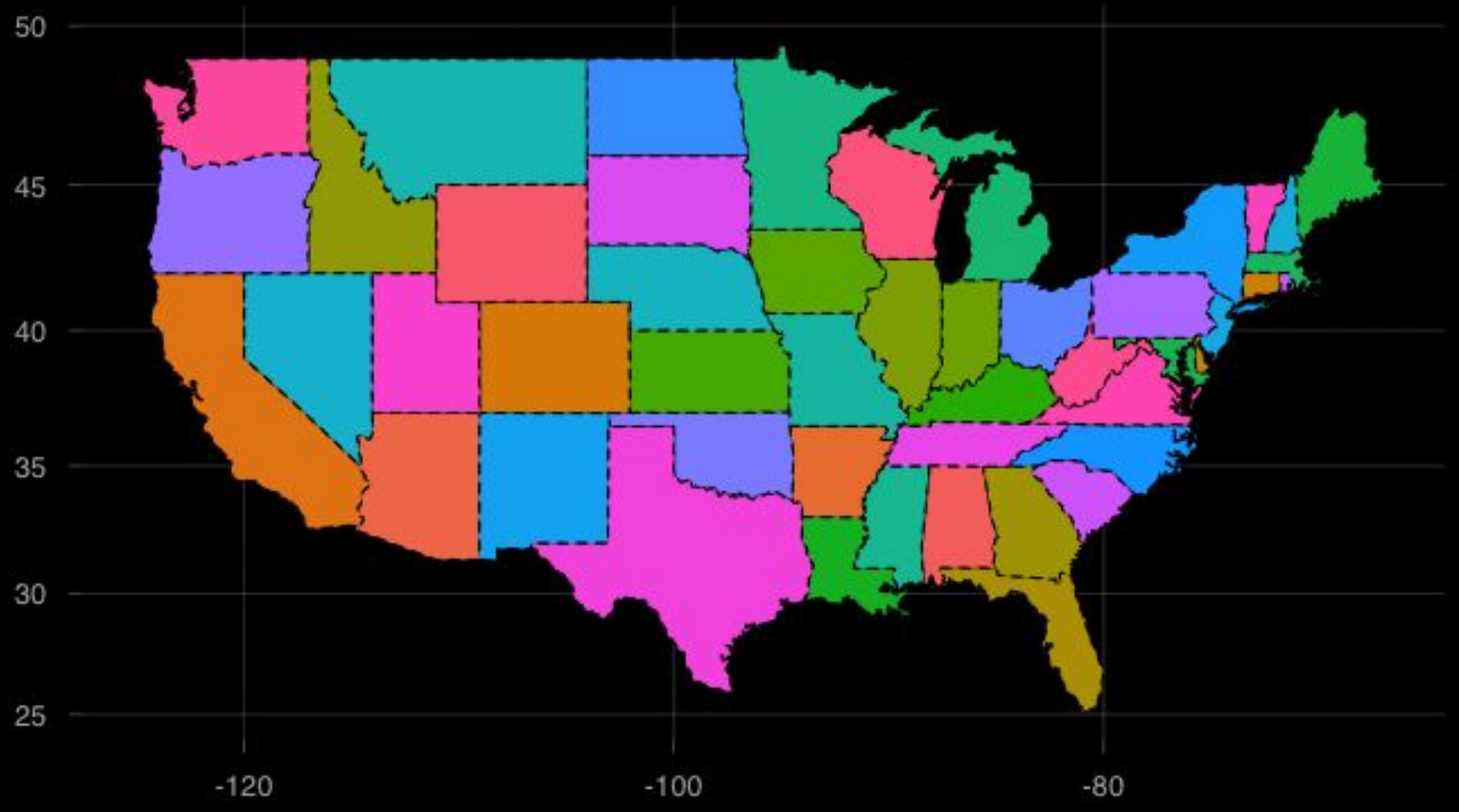


USE THE RIGHT HEIGHT
Plot all data points so that the line chart takes up approximately two-thirds of the y-axis' total scale.

Line Chart - Aesthetics

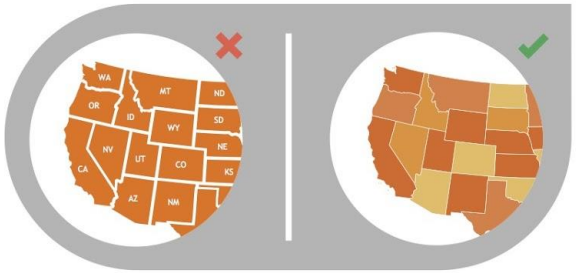


Review - Choropleth

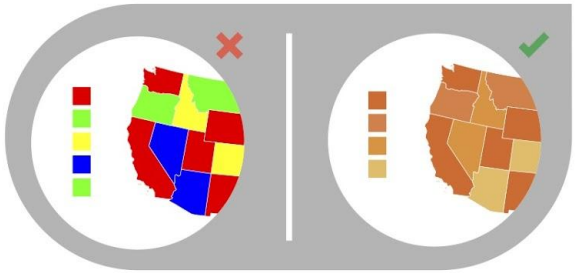


HEAT MAP

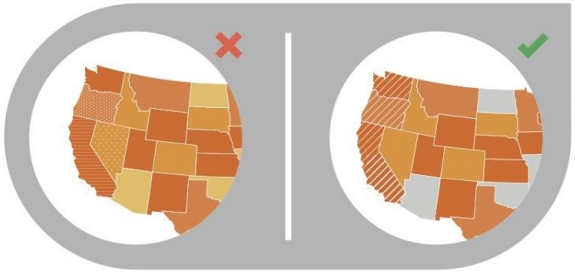
DESIGN BEST PRACTICES



USE A SIMPLE MAP OUTLINE
These lines are meant to frame the data, not distract.



SELECT COLORS APPROPRIATELY
Some colors stand out more than others, giving unnecessary weight to that data. Instead, use a single color with varying shade or a spectrum between two analogous colors to show intensity. Also remember to intuitively code color intensity according to values.



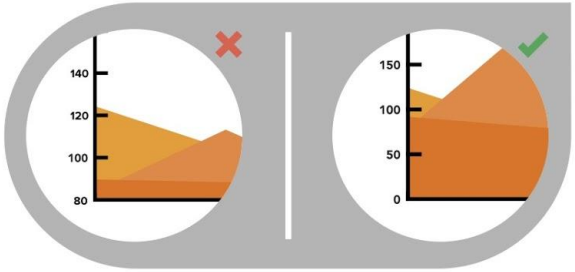
USE PATTERNS SPARINGLY
A pattern overlay that indicates a second variable is acceptable, but using multiple is overwhelming and distracting.

CHOOSE APPROPRIATE DATA RANGES
Select 3-5 numerical ranges that enable fairly even distribution of data between them. Use +/- signs to extend high and low ranges.

AREA CHART

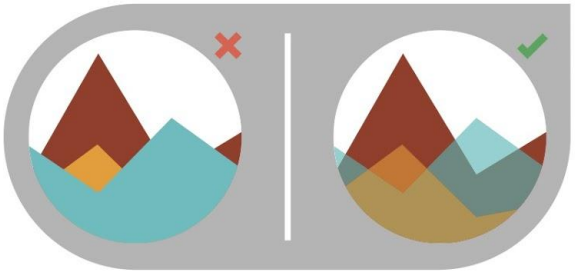
DESIGN BEST PRACTICES

MAKE IT EASY TO READ
In stacked area charts, arrange data to position categories with highly variable data on the top of the chart and low variability on the bottom.

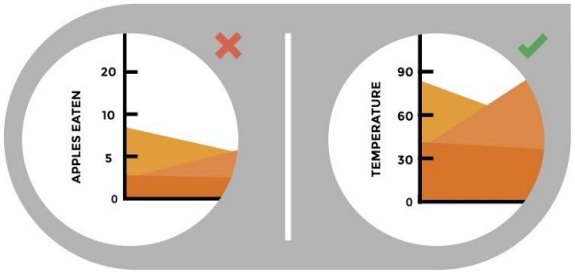


START Y-AXIS VALUE AT 0
Starting the axis above zero truncates the visualization of values.

DON'T DISPLAY MORE THAN 4 DATA CATEGORIES
Too many will result in a cluttered visual that is difficult to decipher.



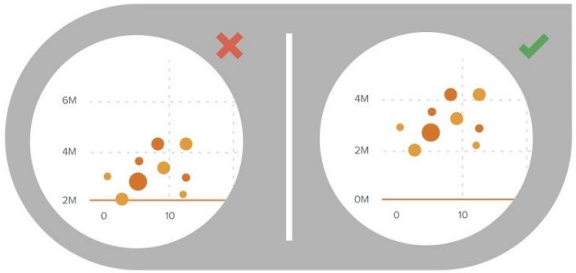
USE TRANSPARENT COLORS
In standard area charts, ensure data isn't obscured in the background by ordering thoughtfully and using transparency.



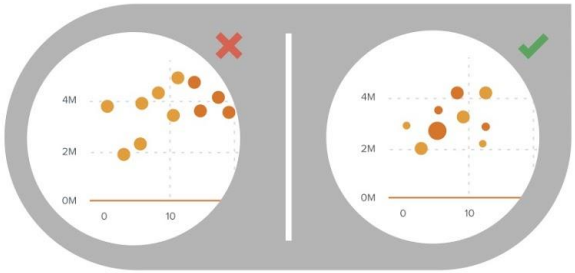
DON'T USE AREA CHARTS TO DISPLAY DISCRETE DATA
The connected lines imply intermediate values, which only exist with continuous data.

SCATTER PLOT

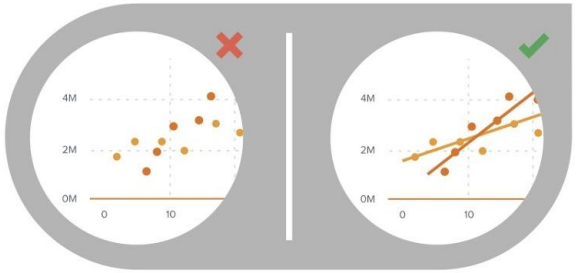
DESIGN BEST PRACTICES



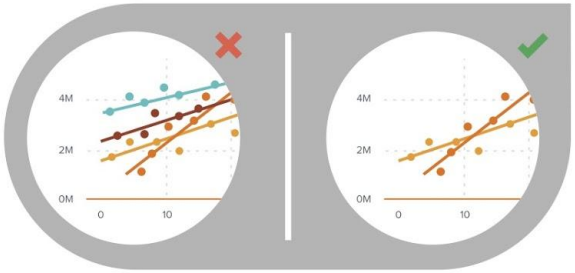
START Y-AXIS VALUE AT 0
Starting the axis above zero truncates the visualization of values.



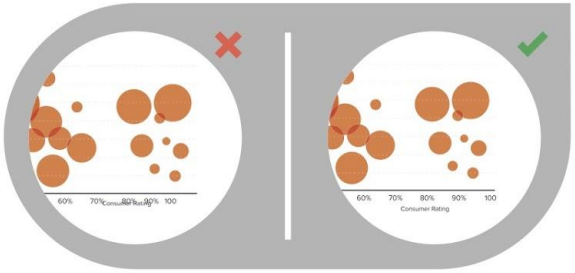
INCLUDE MORE VARIABLES
Use size and dot color to encode additional data variables.



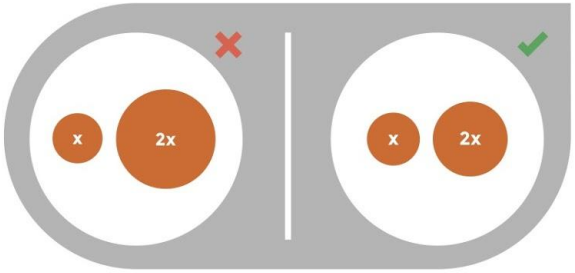
USE TREND LINES
These help draw correlation between the variables to show trends.



DON'T COMPARE MORE THAN 2 TREND LINES
Too many lines make data difficult to interpret.



MAKE SURE LABELS ARE VISIBLE
All labels should be unobstructed and easily identified with the corresponding bubble.



SIZE BUBBLES APPROPRIATELY
Bubbles should be scaled according to area, not diameter.

DON'T USE ODD SHAPES
Avoid adding too much detail or using shapes that are not entirely circular; this can lead to inaccuracies.

BUBBLE CHART

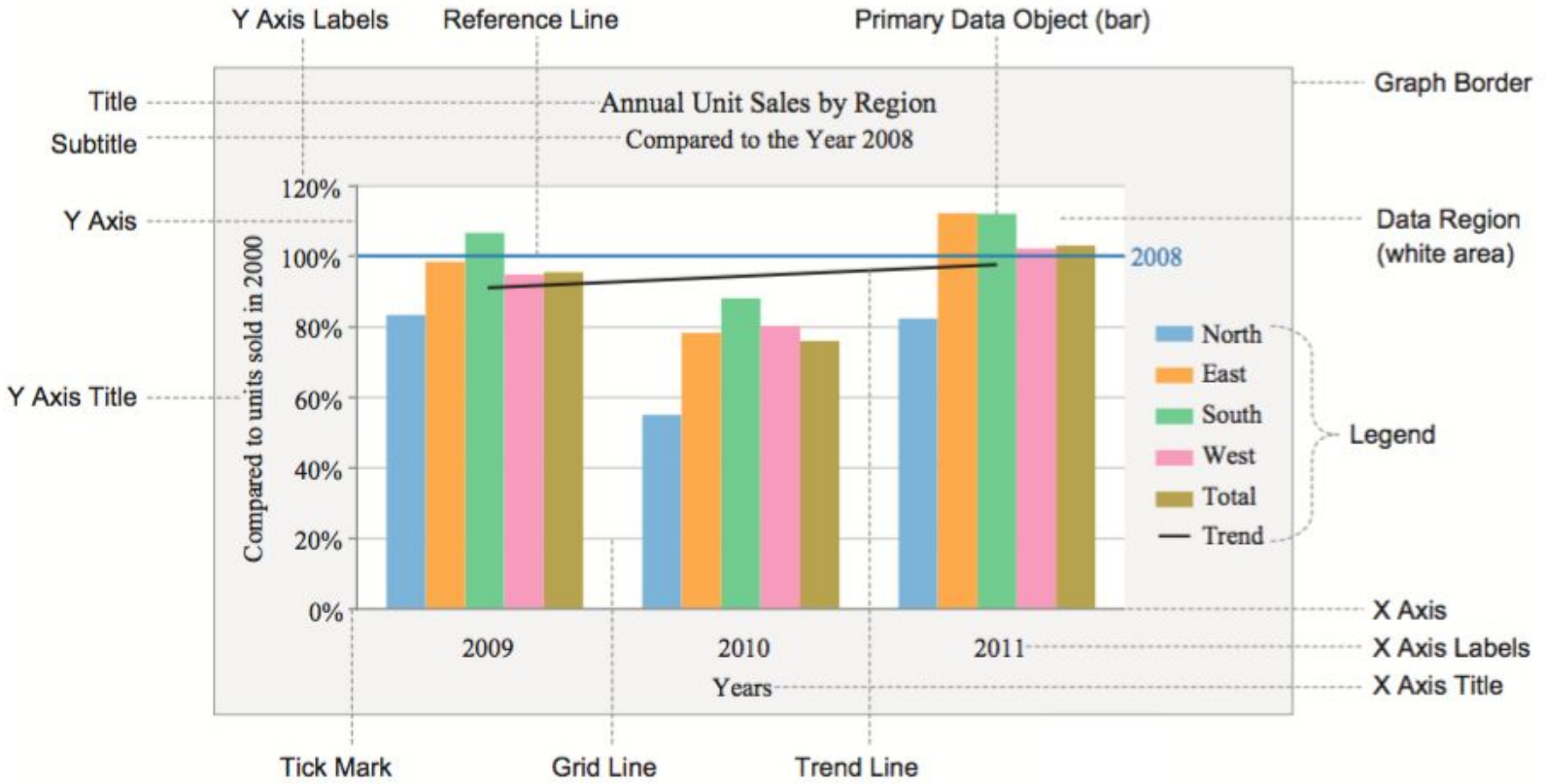
DESIGN BEST PRACTICES

Data-Ink & Chart Junk Principles

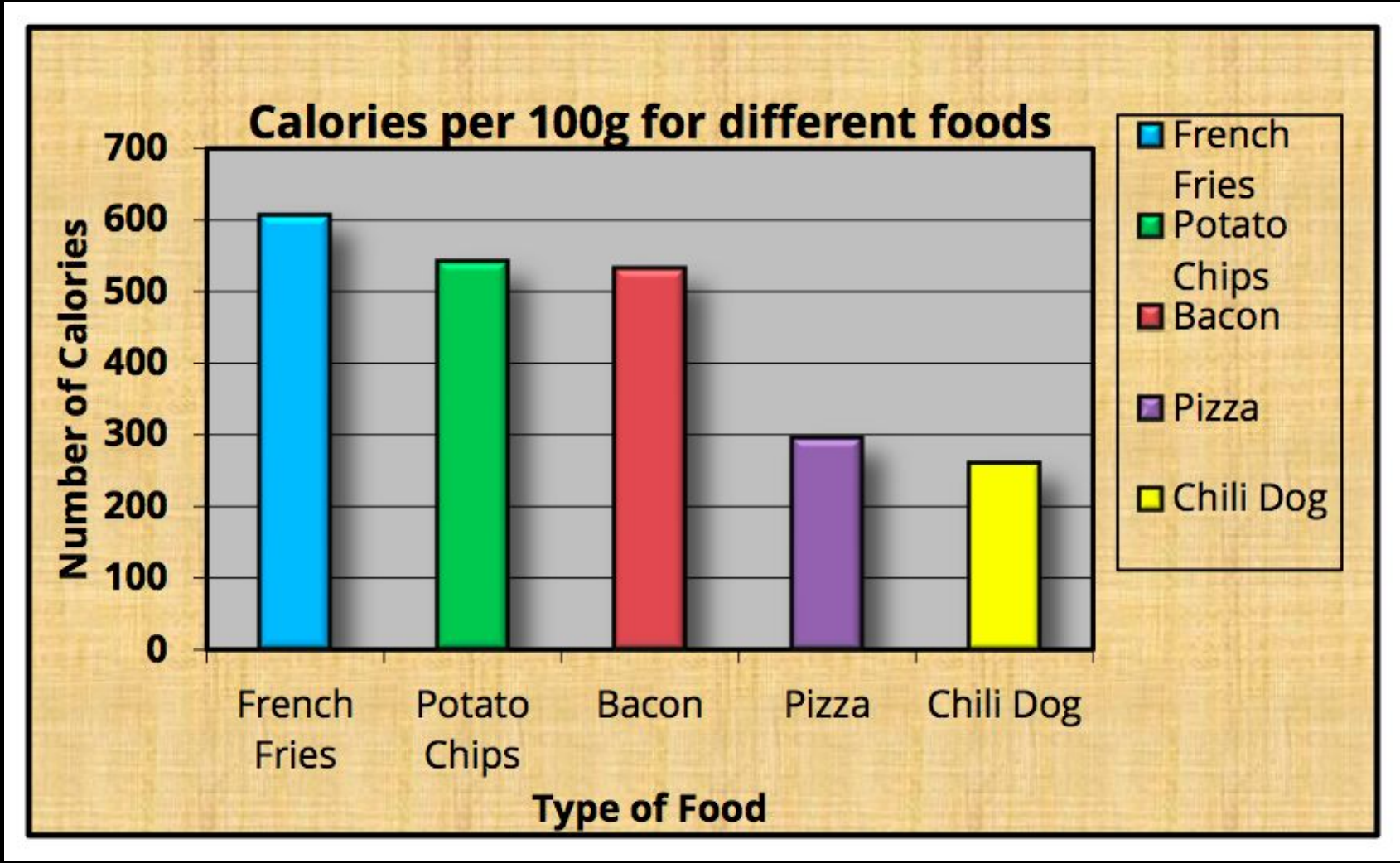
“Above all else show the data”

- Edward Tufte

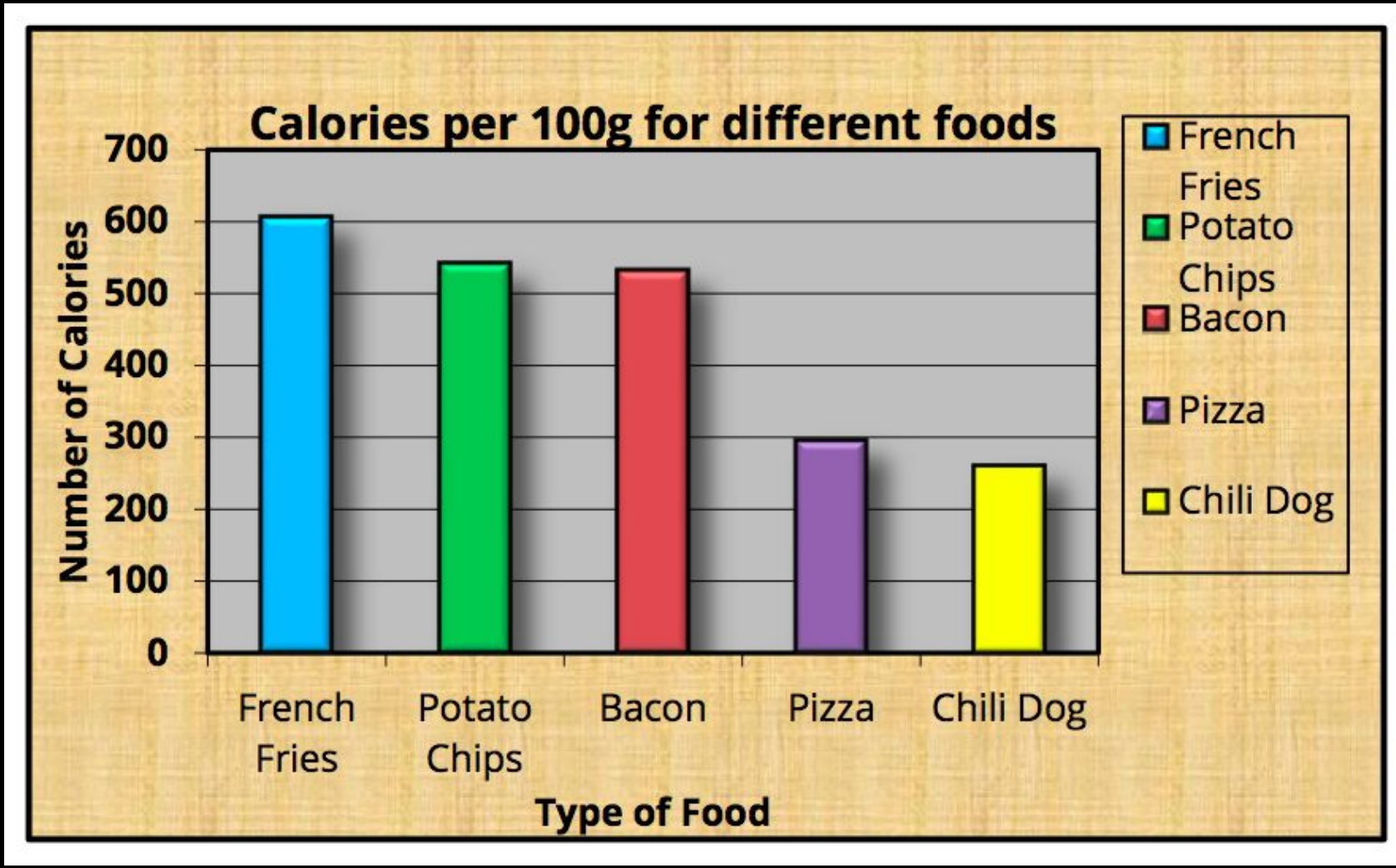
Anatomy of a Chart

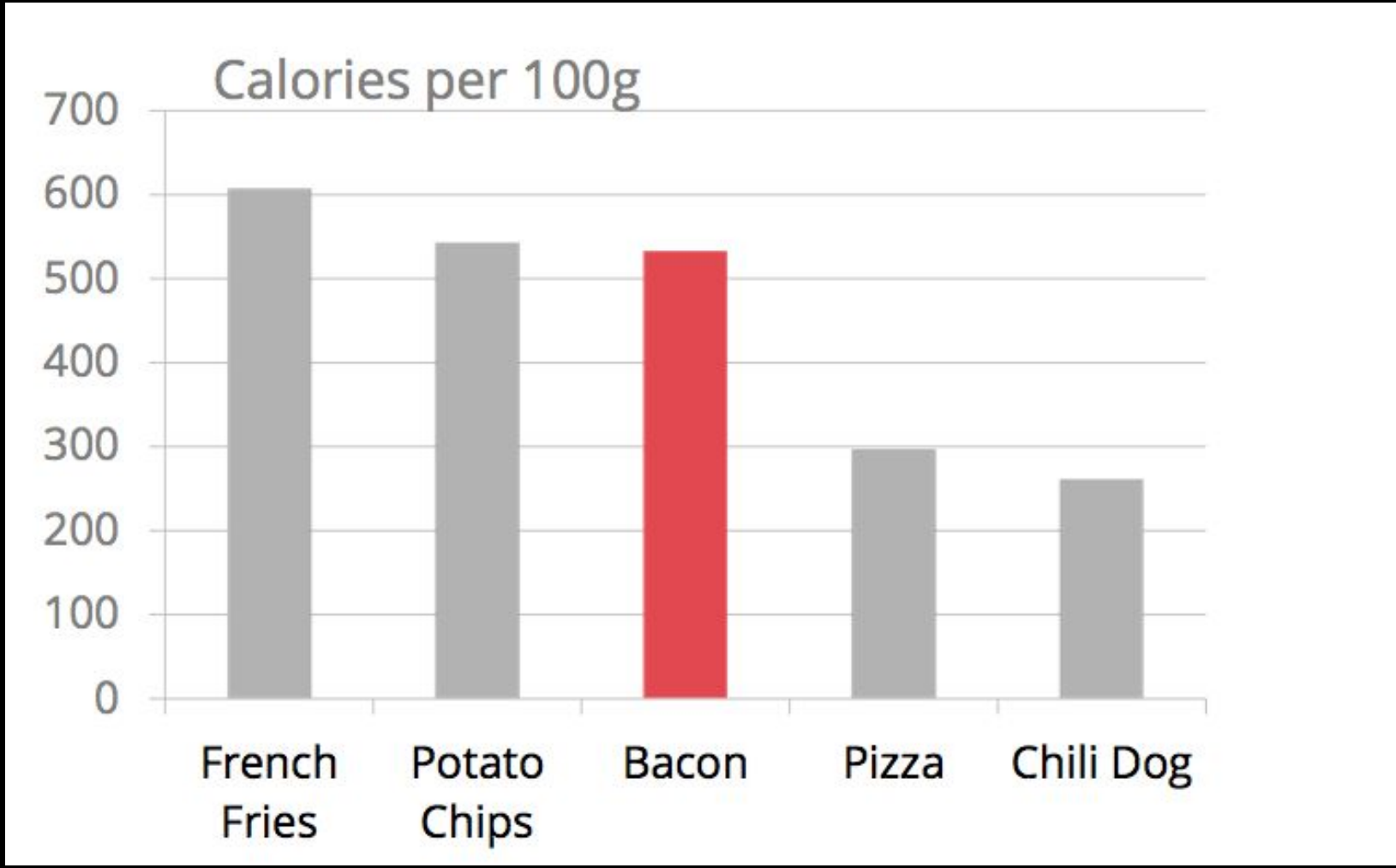


How can we improve this?

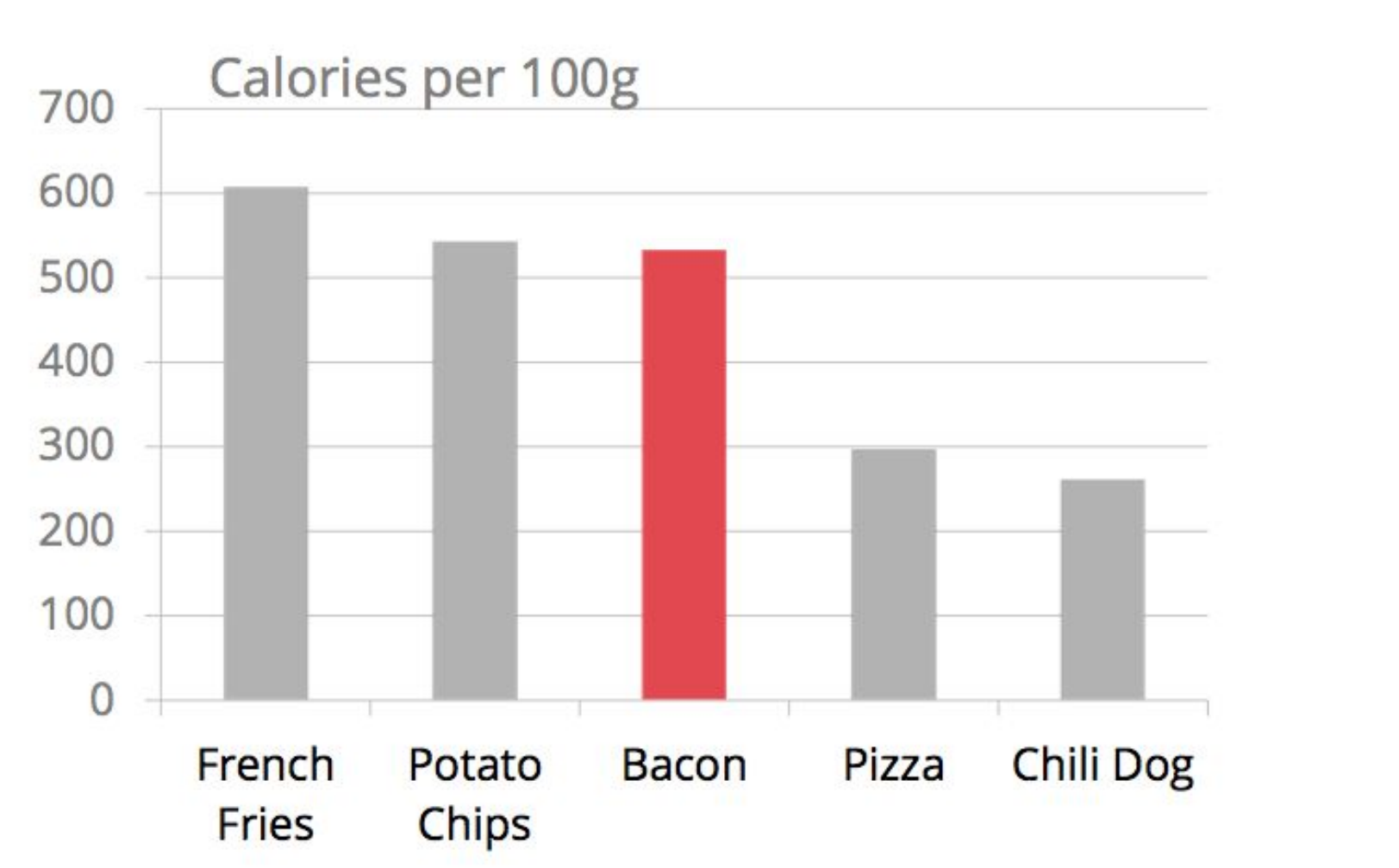


Source: Darkhorse Analytics

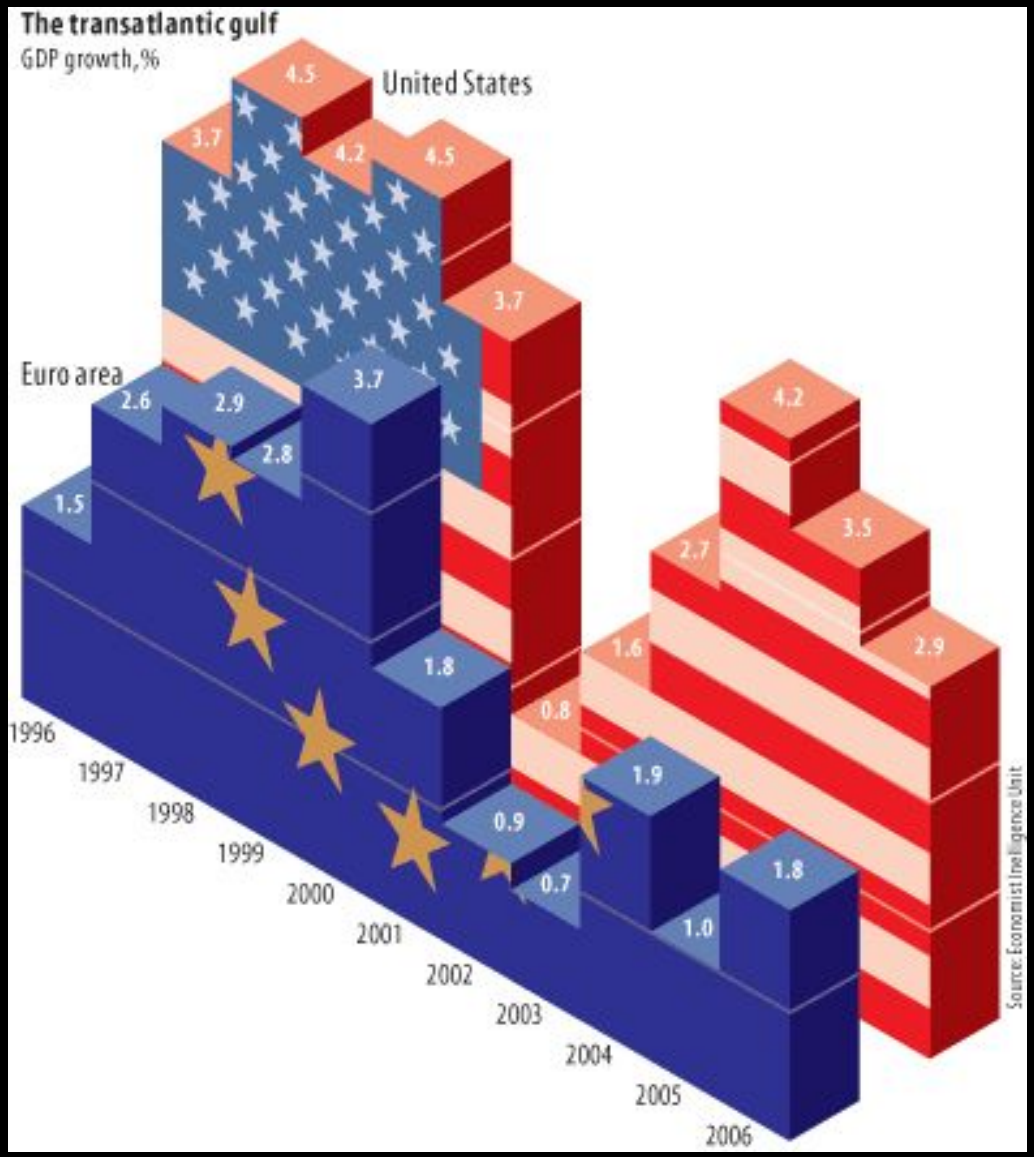

Calories per 100g for different foods
Number of Calories
700
600
500
400
300
200
100
0
French Fries
Potato Chips
Bacon
Pizza
Chili Dog
Type of Food
French Fries
Potato Chips
Bacon
Pizza
Chili Dog


Calories per 100g
700
600
500
400
300
200
100
0
French Fries
Potato Chips
Bacon
Pizza
Chili Dog

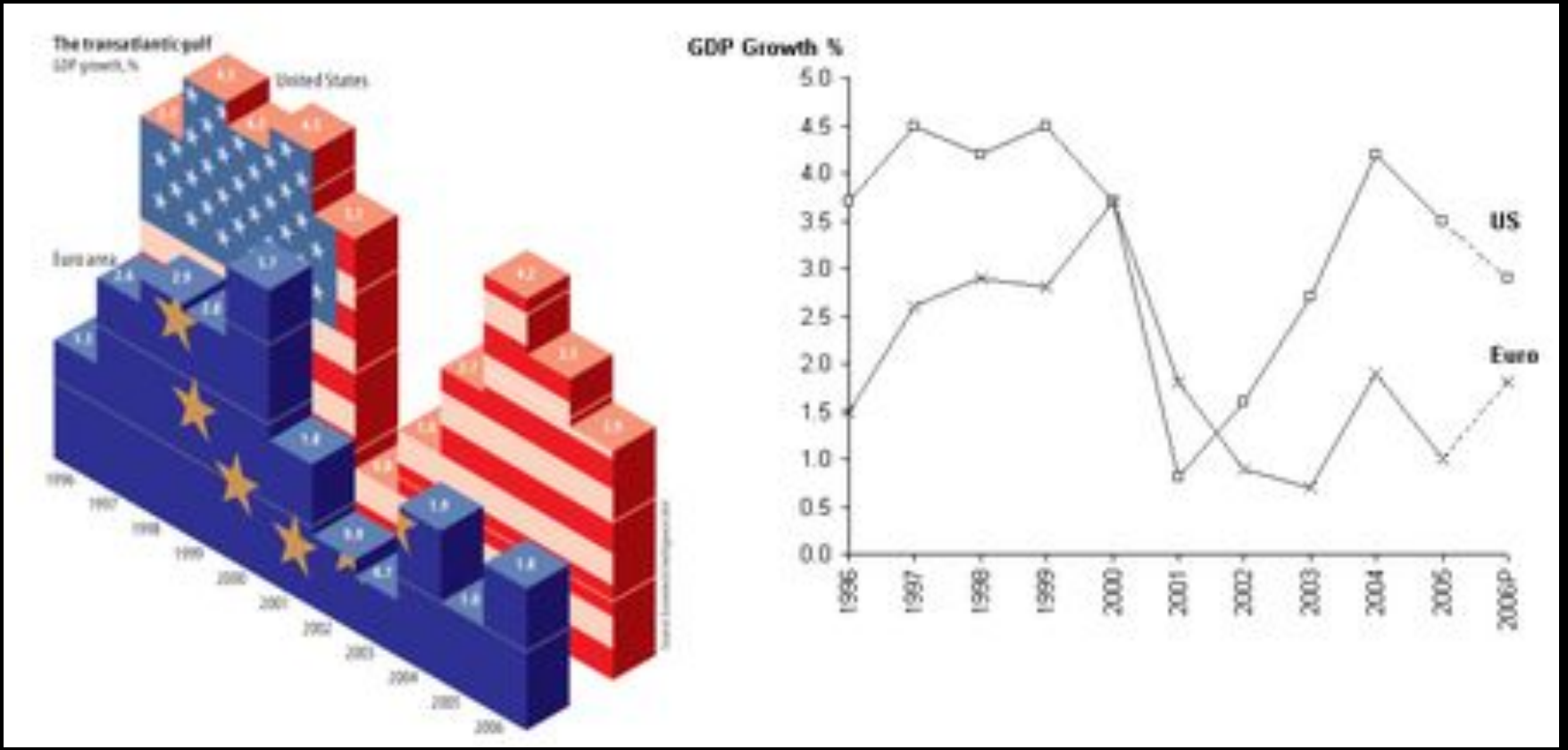
Data-Ink Improved



Avoid Chart Junk

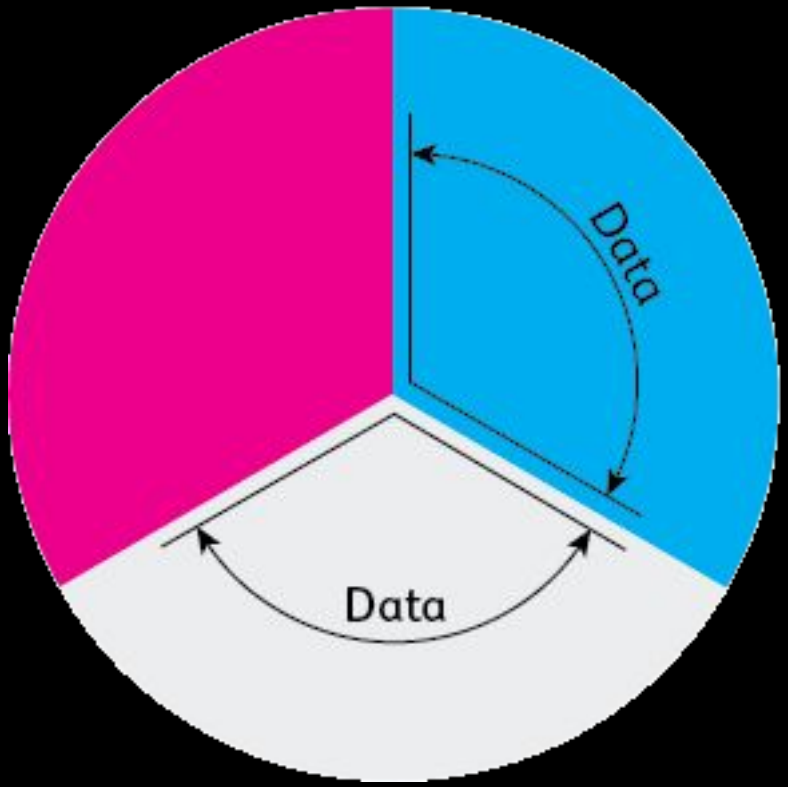


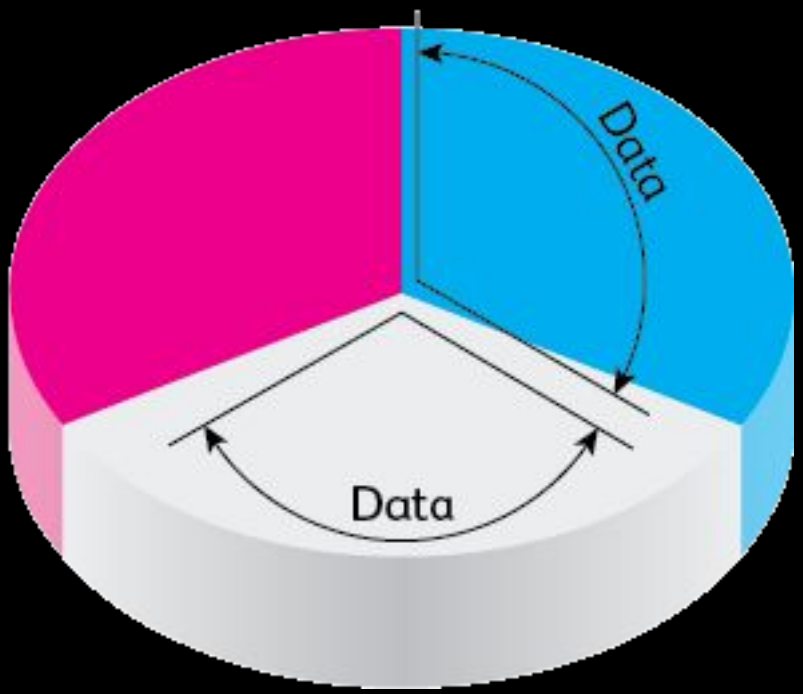
Avoid Chart Junk



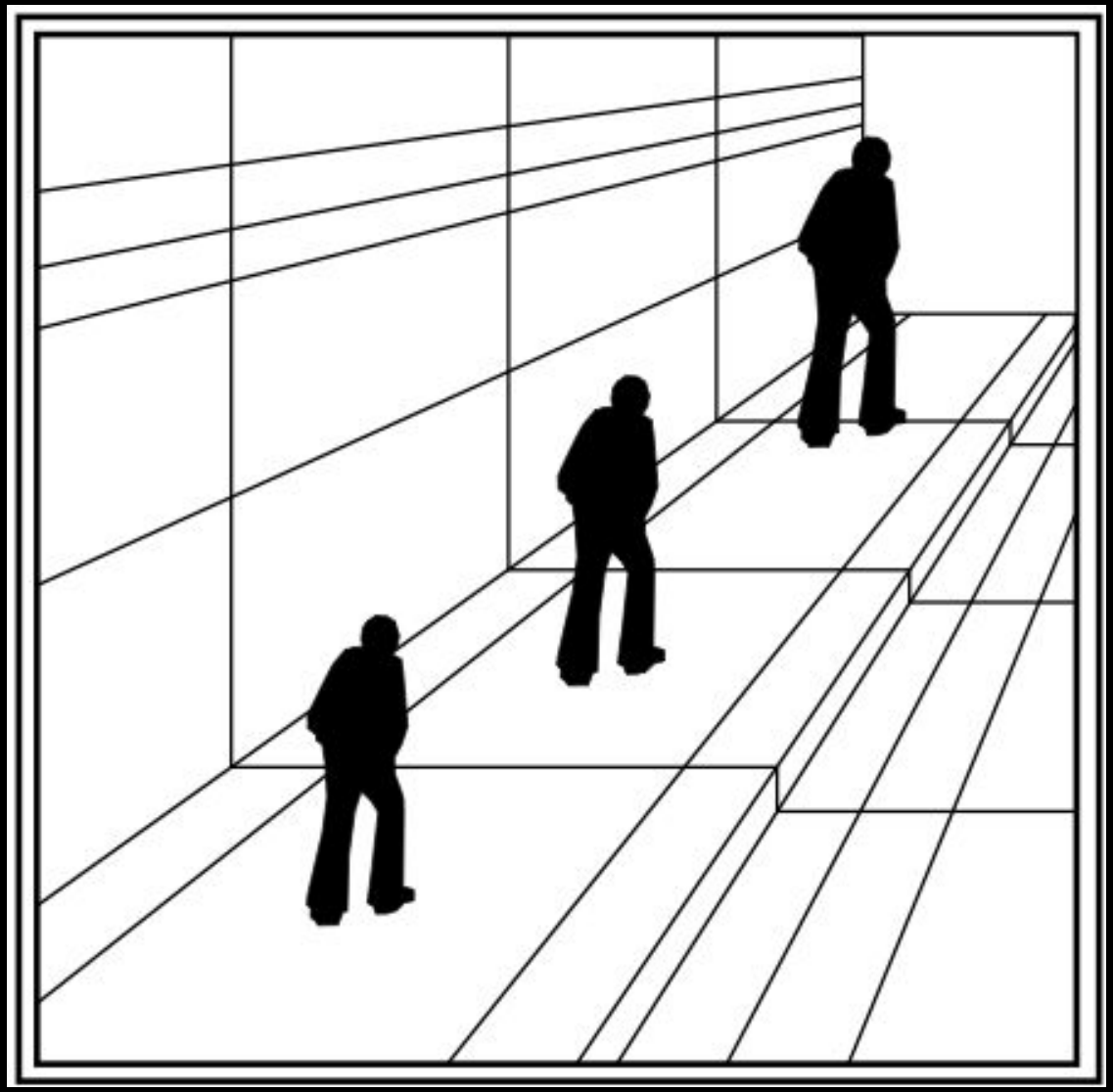
Avoid Chart Junk

Avoid 3D Distortion

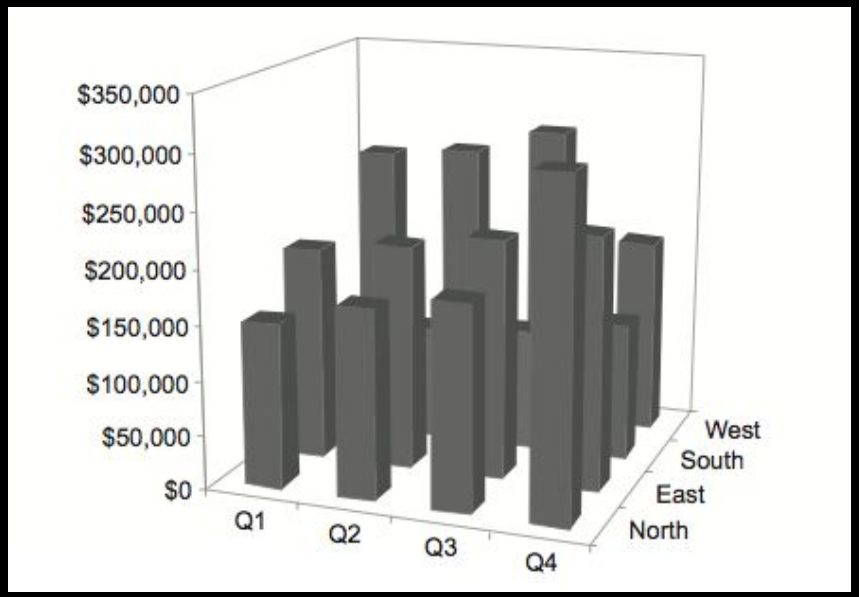




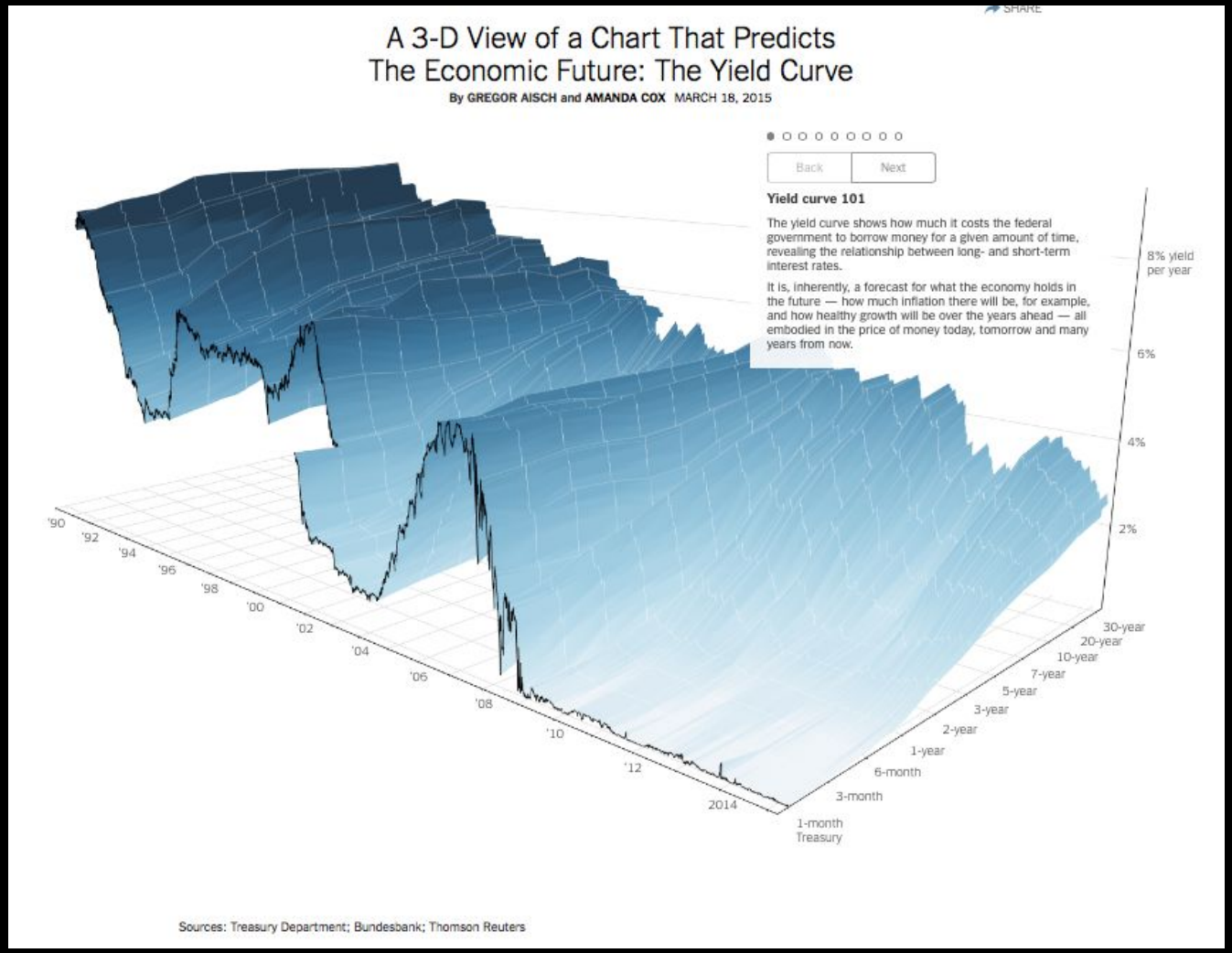
3D vs 2.05D



You do not need 3D



Interactive 3D can work

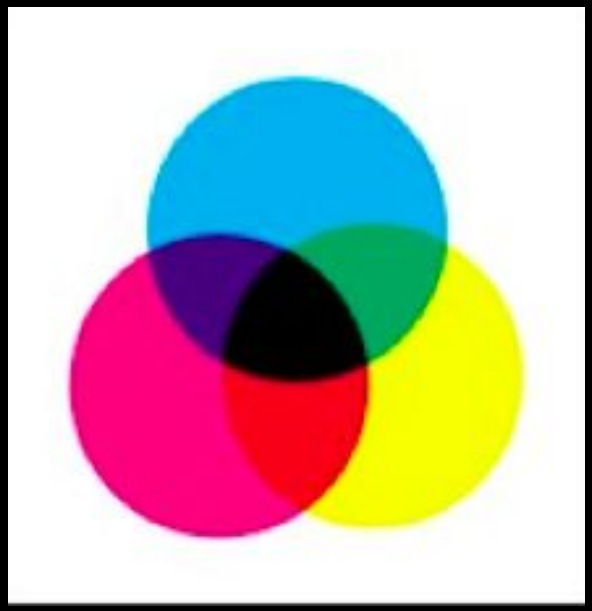


Source: [NYTimes Upshot]

Color

Color - RGB / CMYK

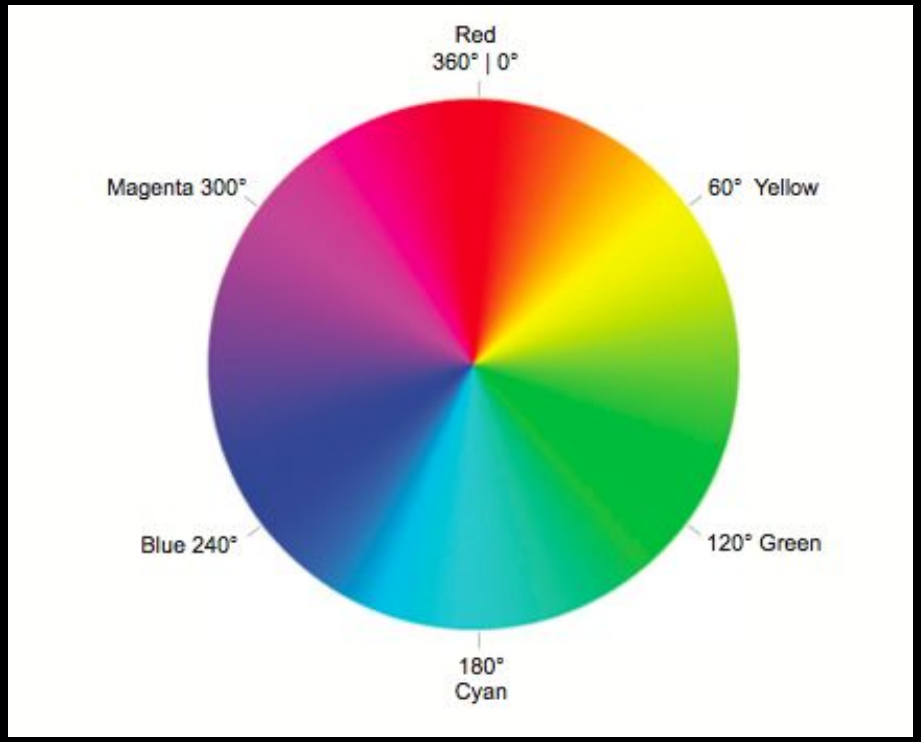
Additive
(Digital Display)



Subtractive
(Print)

Color Perceptual

Hue



Saturation

Lightness

Use of Color

To label

To measure

To represent and imitate

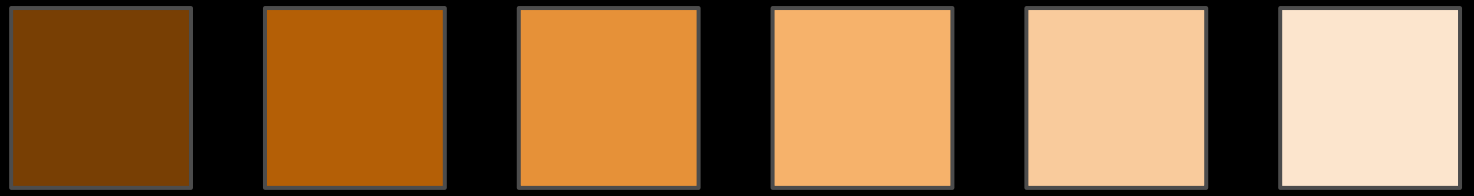
To enliven and decorate

“Above all, do no harm” - Tufte

“Position is everything, Color is difficult” - Stefaner

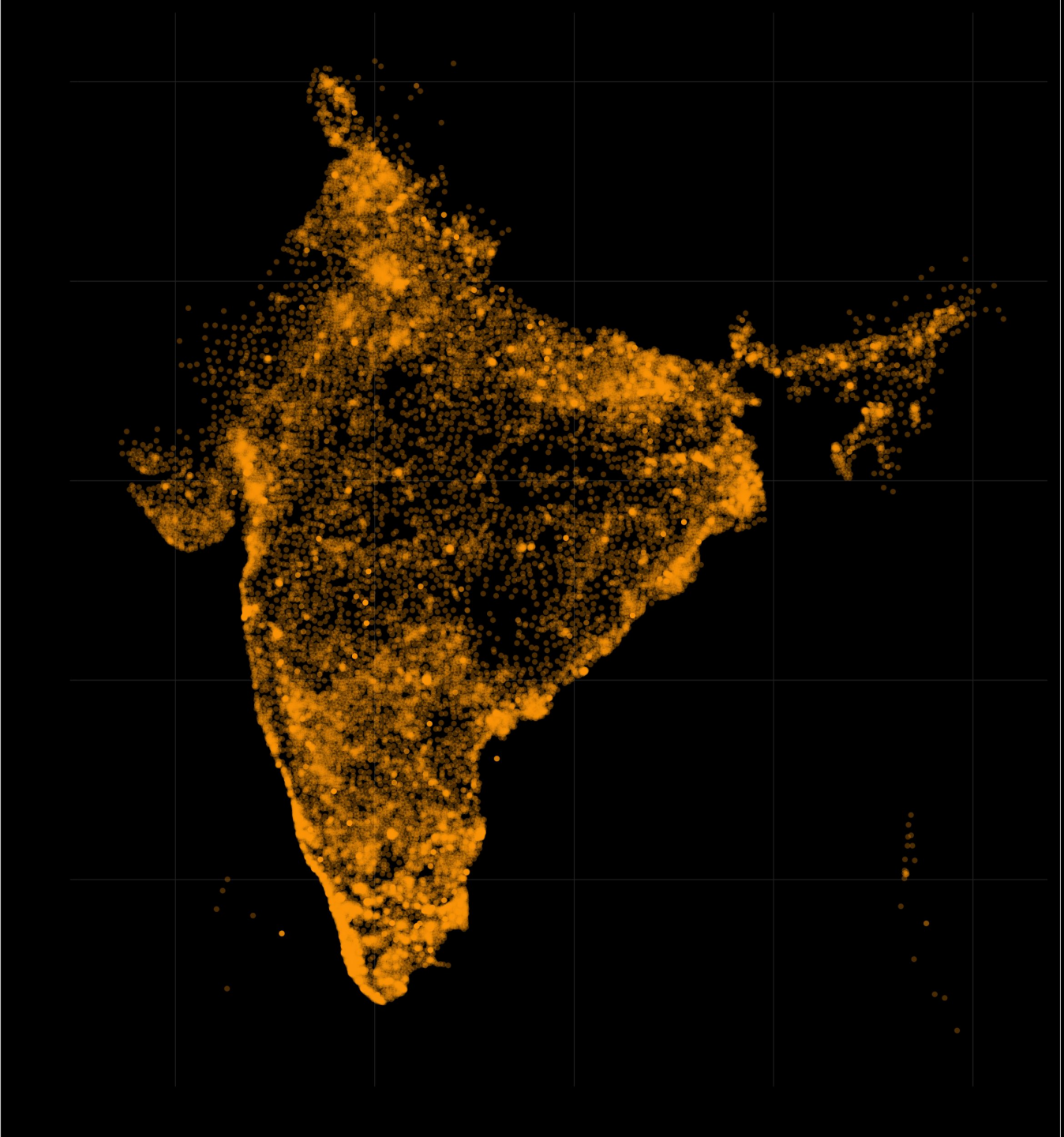
Color

Saturation for Ordinal / Nominal



Hues for Nominal only

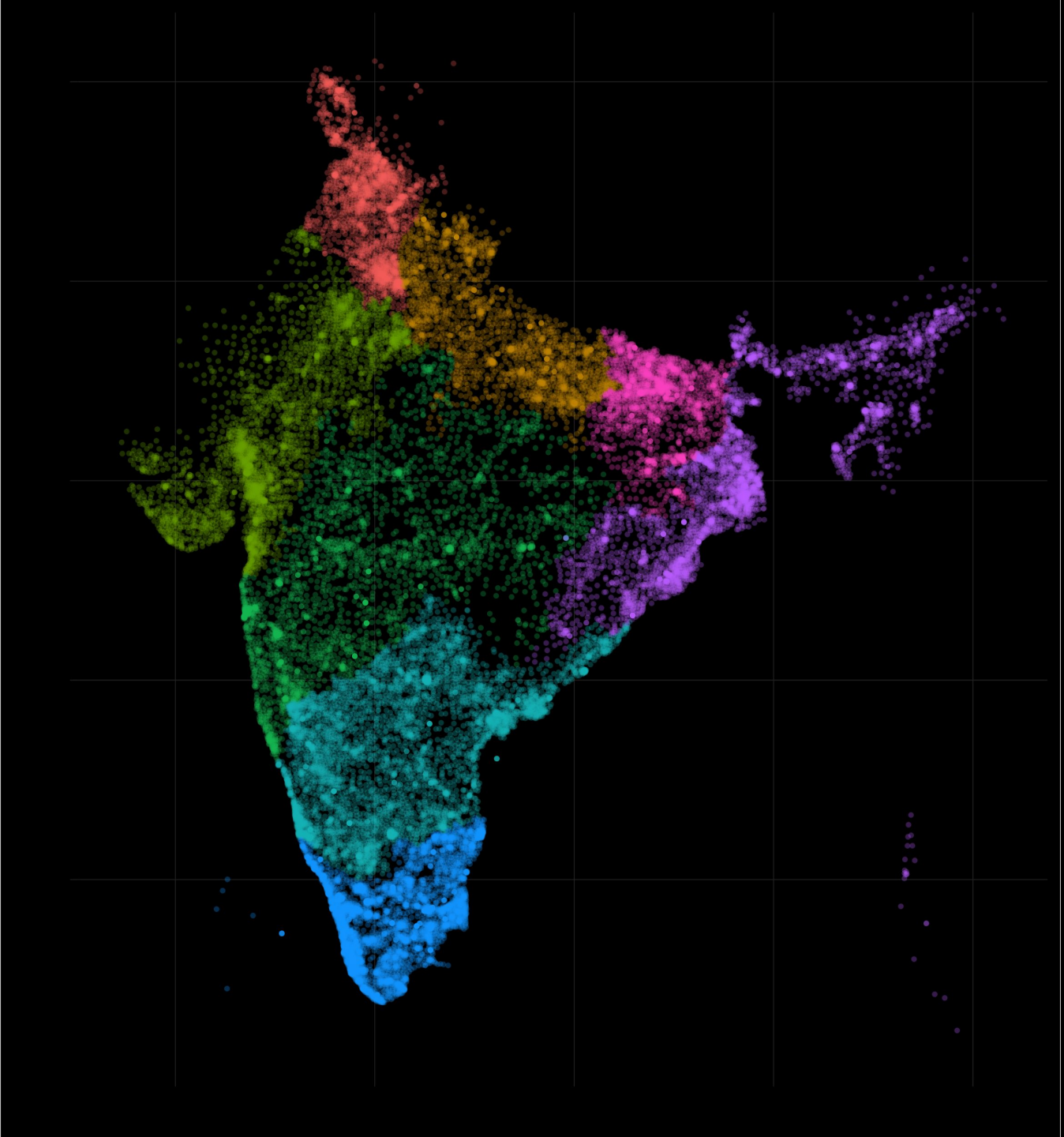
Grey Blue Orange Green Pink Brown Purple Yellow Red



Pincode Map

Scatter plot, play with alpha to show density

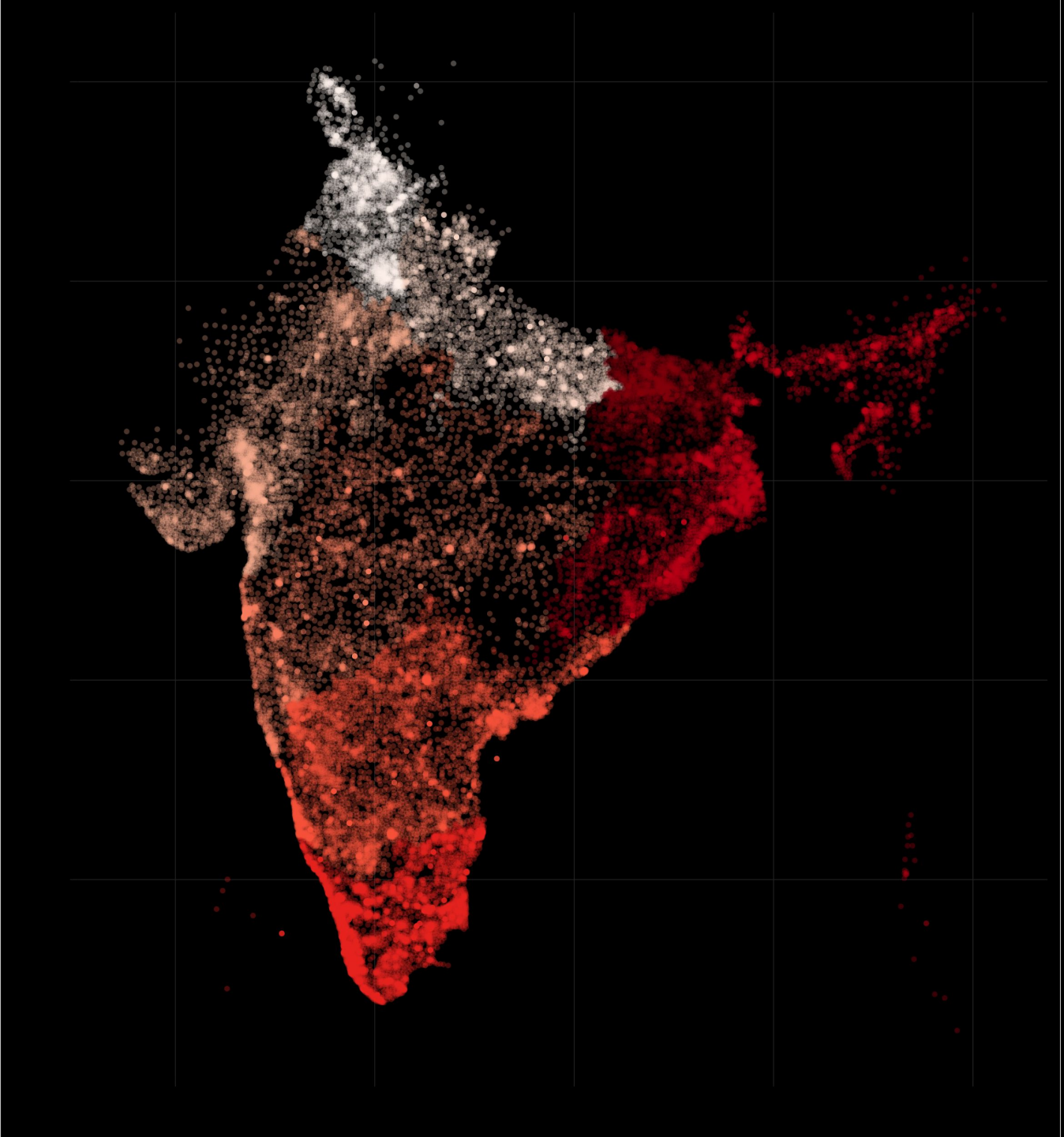
Single Color



Pincode Map ++

Scatter plot, play with alpha to show density

Hue for each starting pincode digit



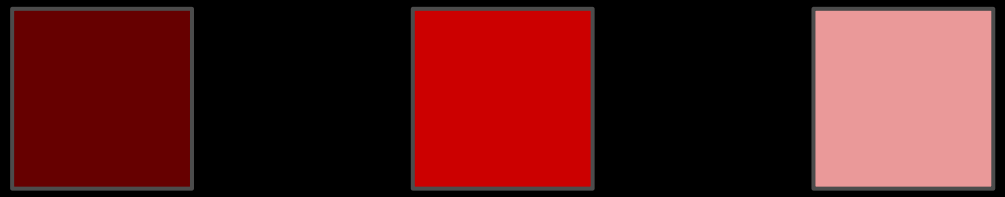
Pincode Map ++

Scatter plot, play with alpha to show density

Saturation for each starting pincode digit

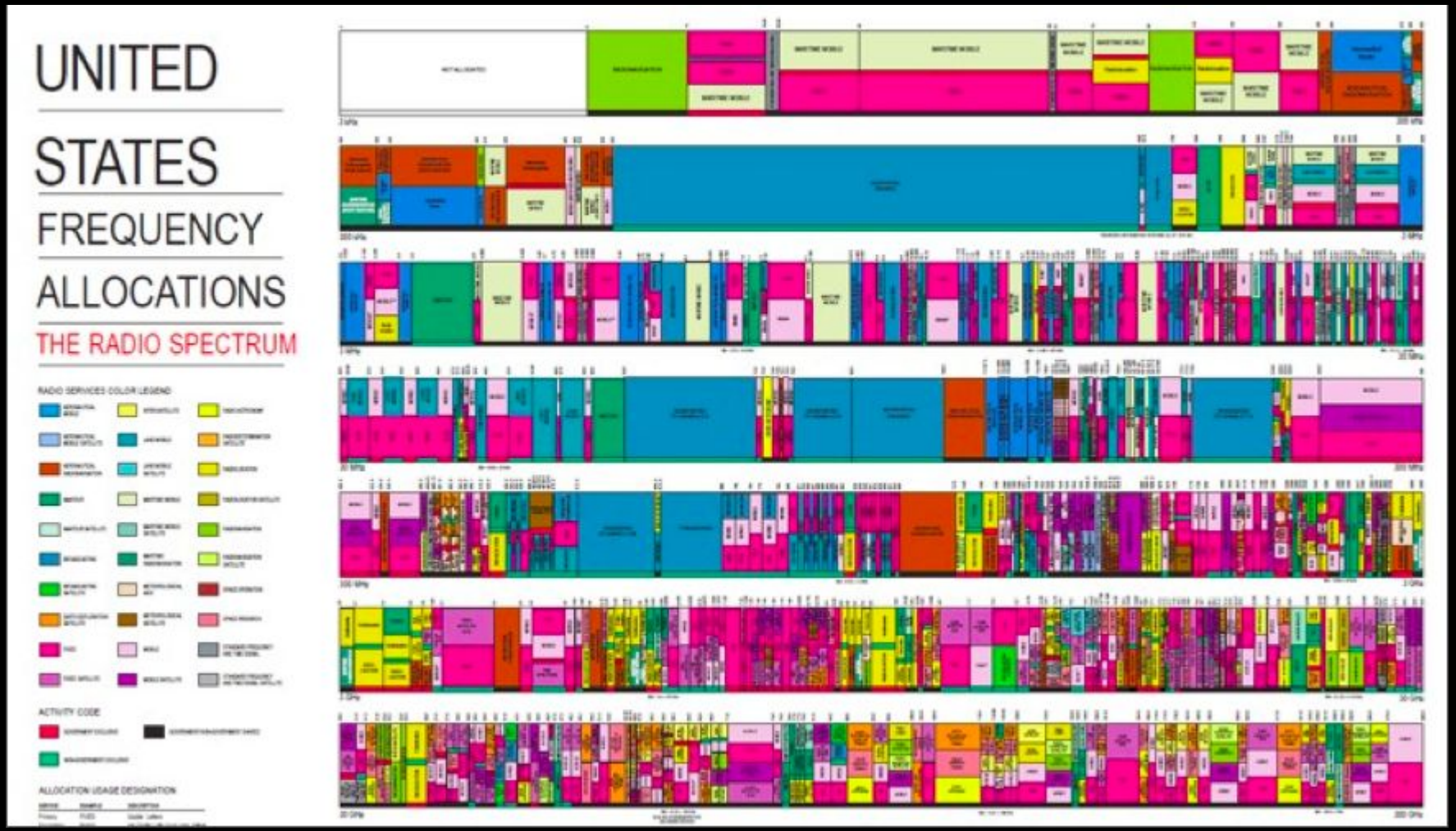
Perception Limit

Too Close

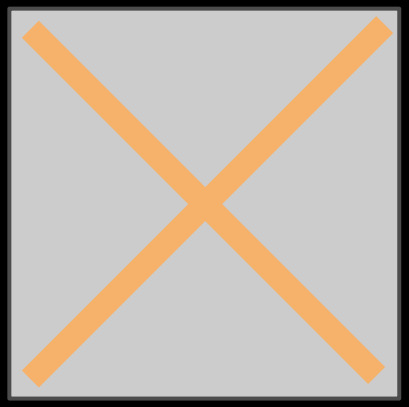


Distinct

Limit the number of colors

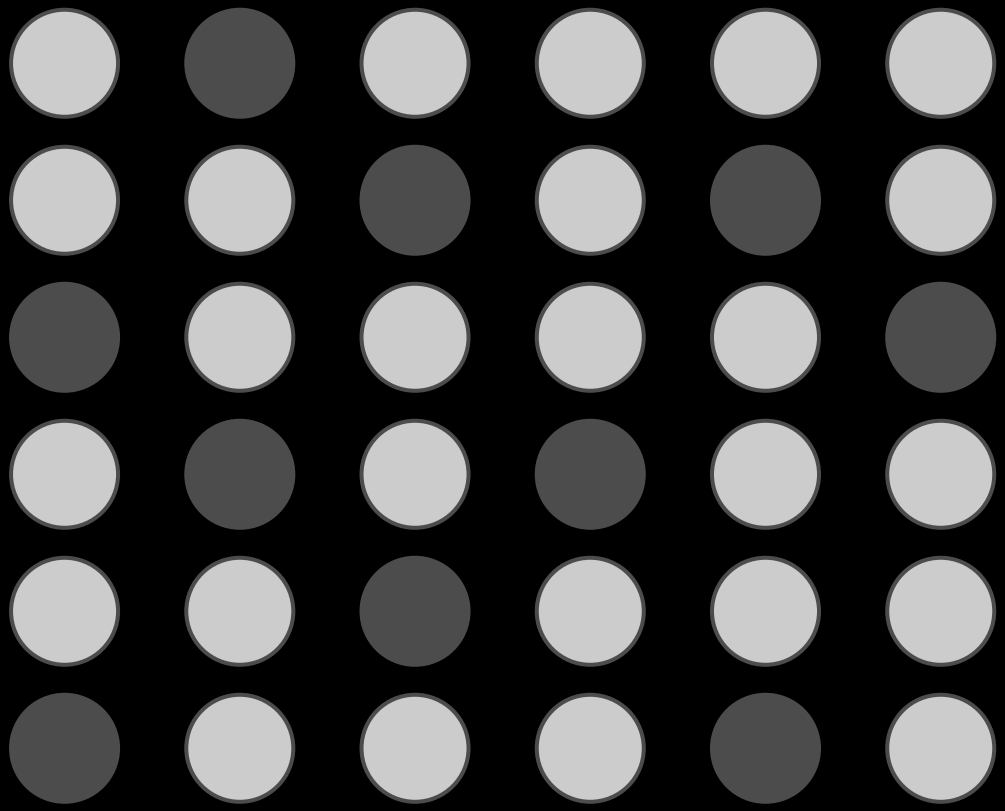


Context Matters



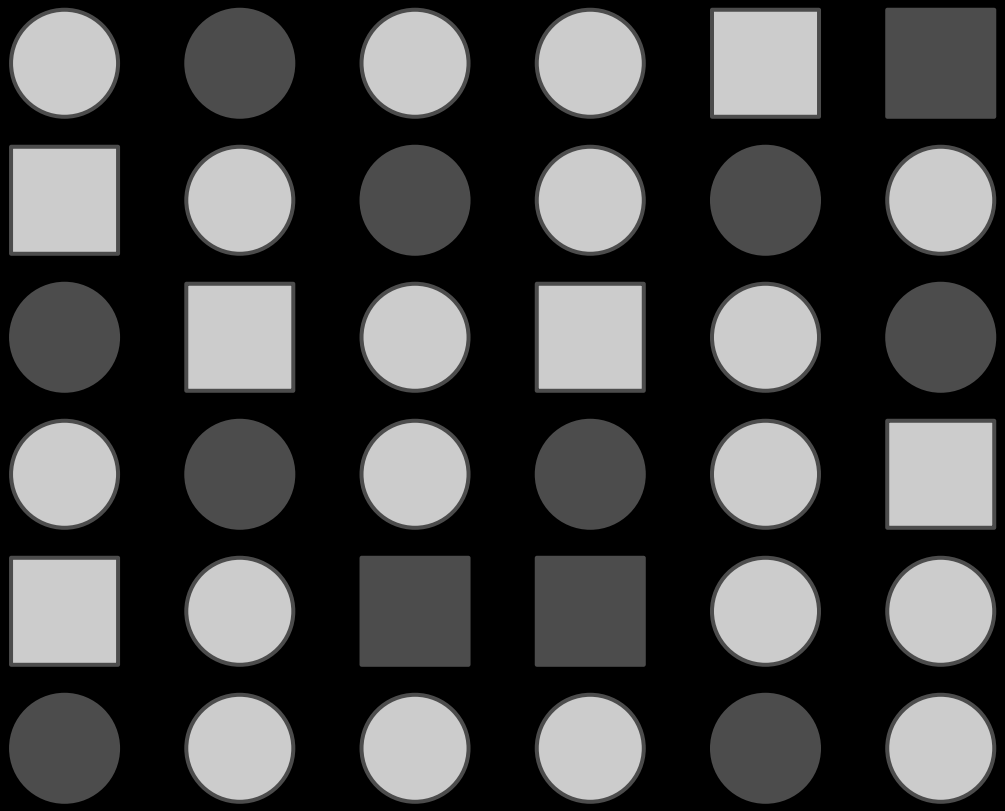
Context Matters

Perception Limit



Intensity: One is distinct

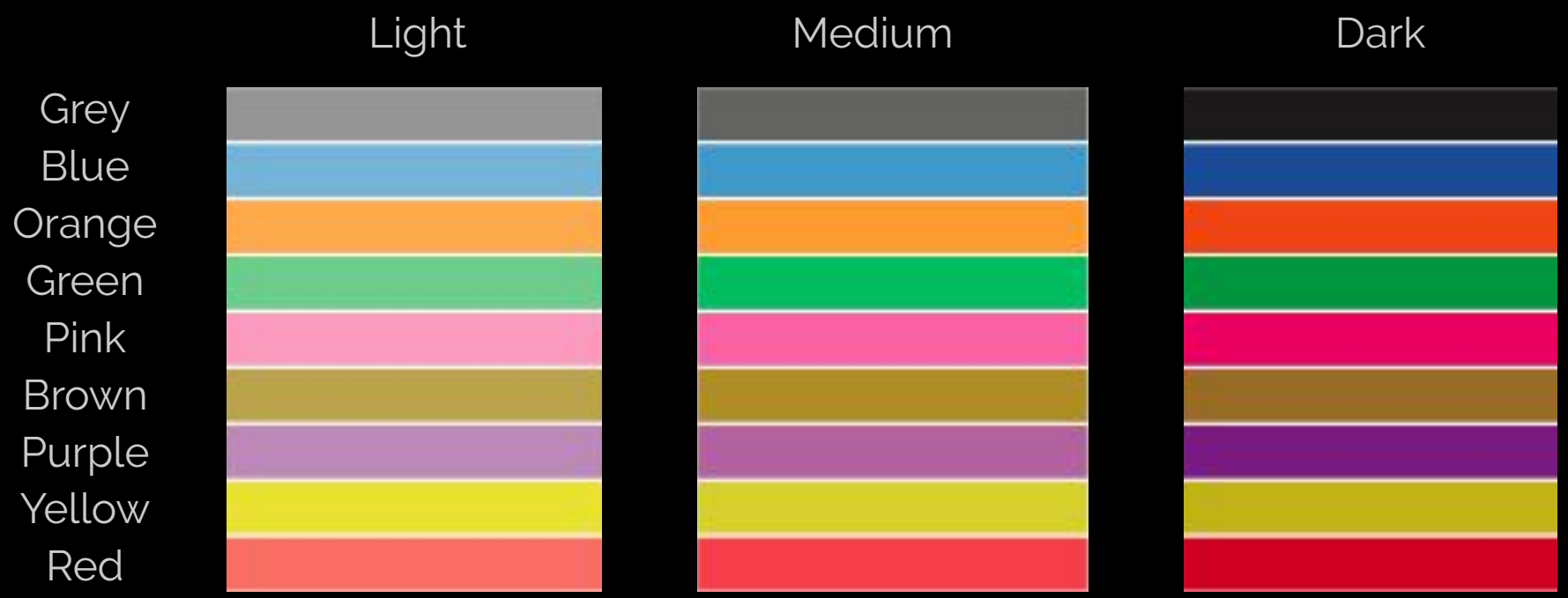
Perception Limits



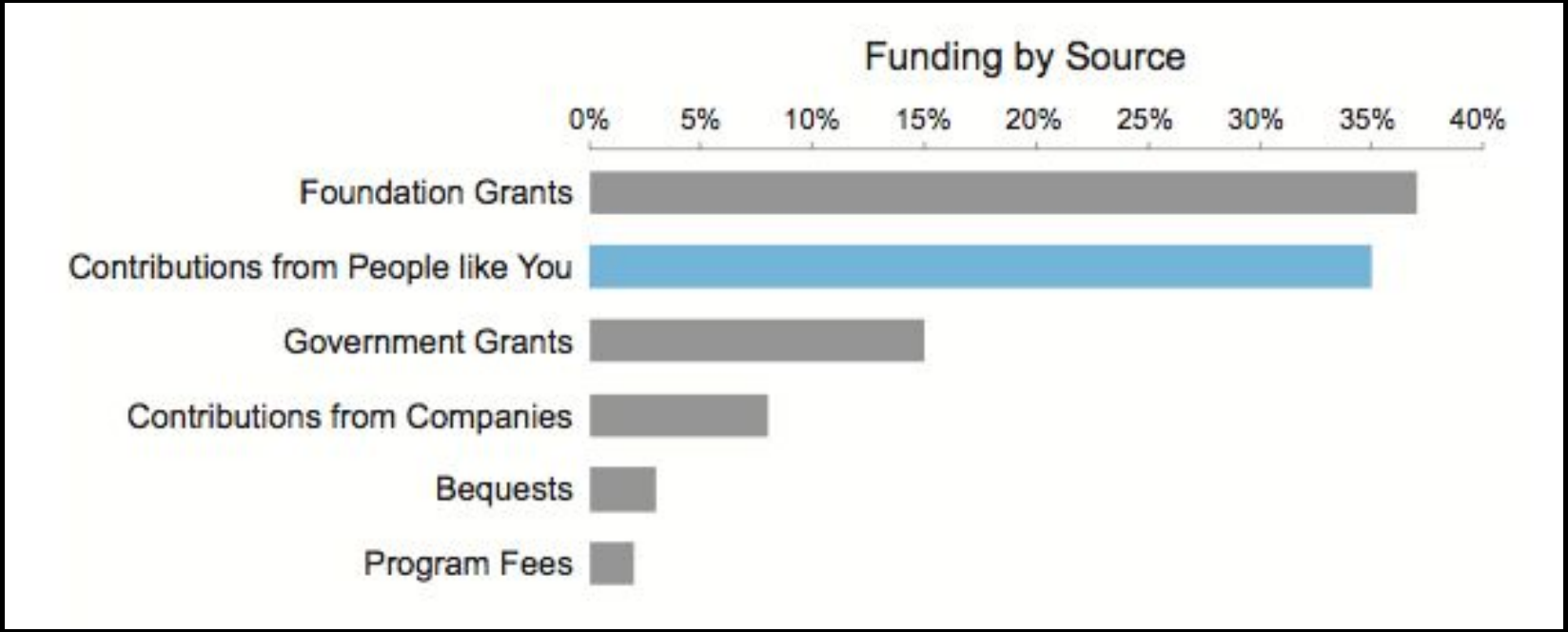
Intensity + Shape: Two is too many

Harmony - Natural Colors

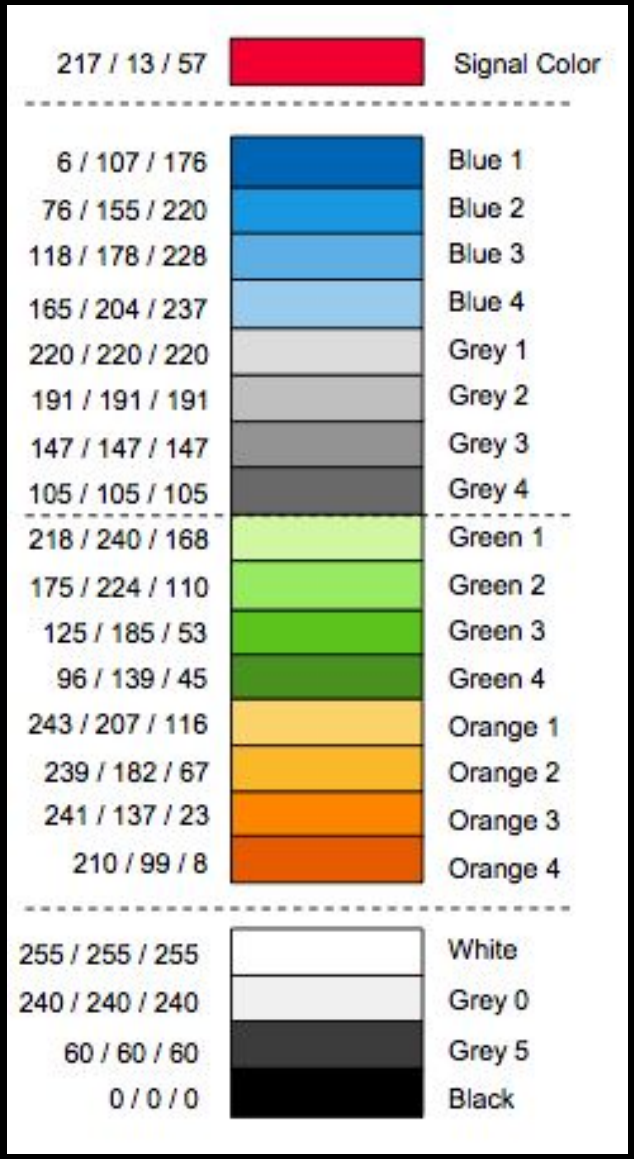
Use Distinct & Named



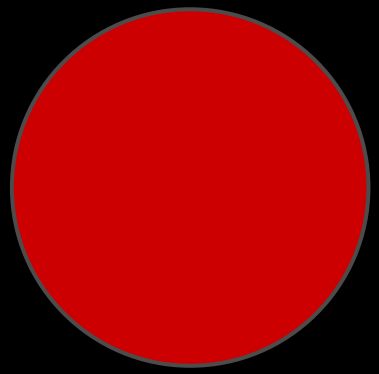
One Contrast Color



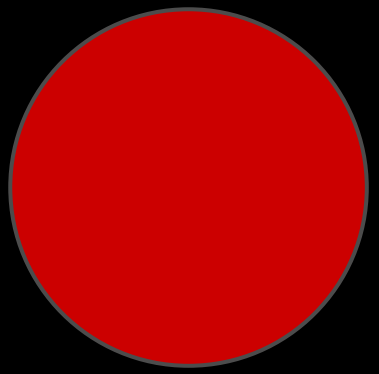
Example Pallette



Cultural Convention

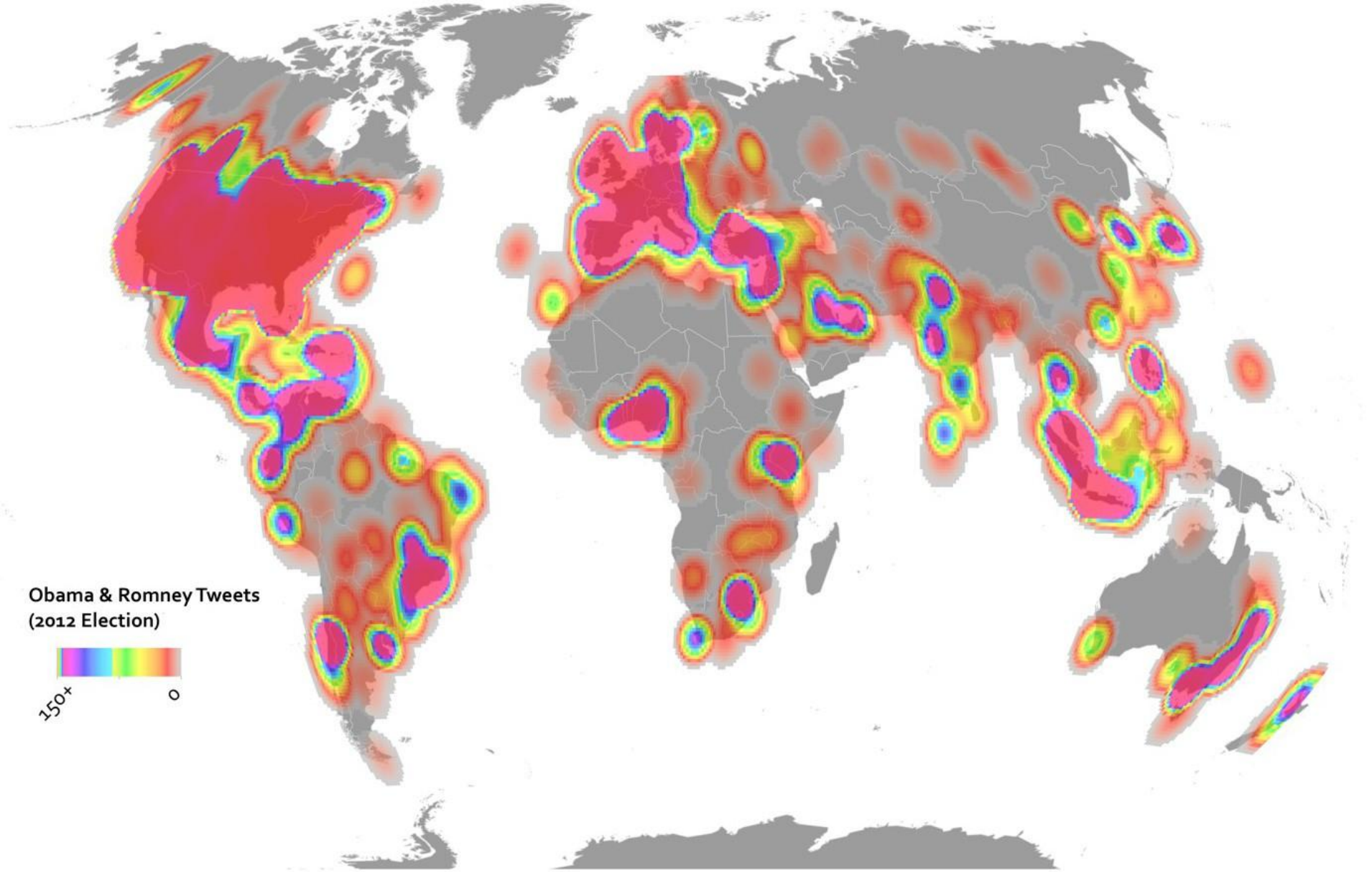


Danger
(West)

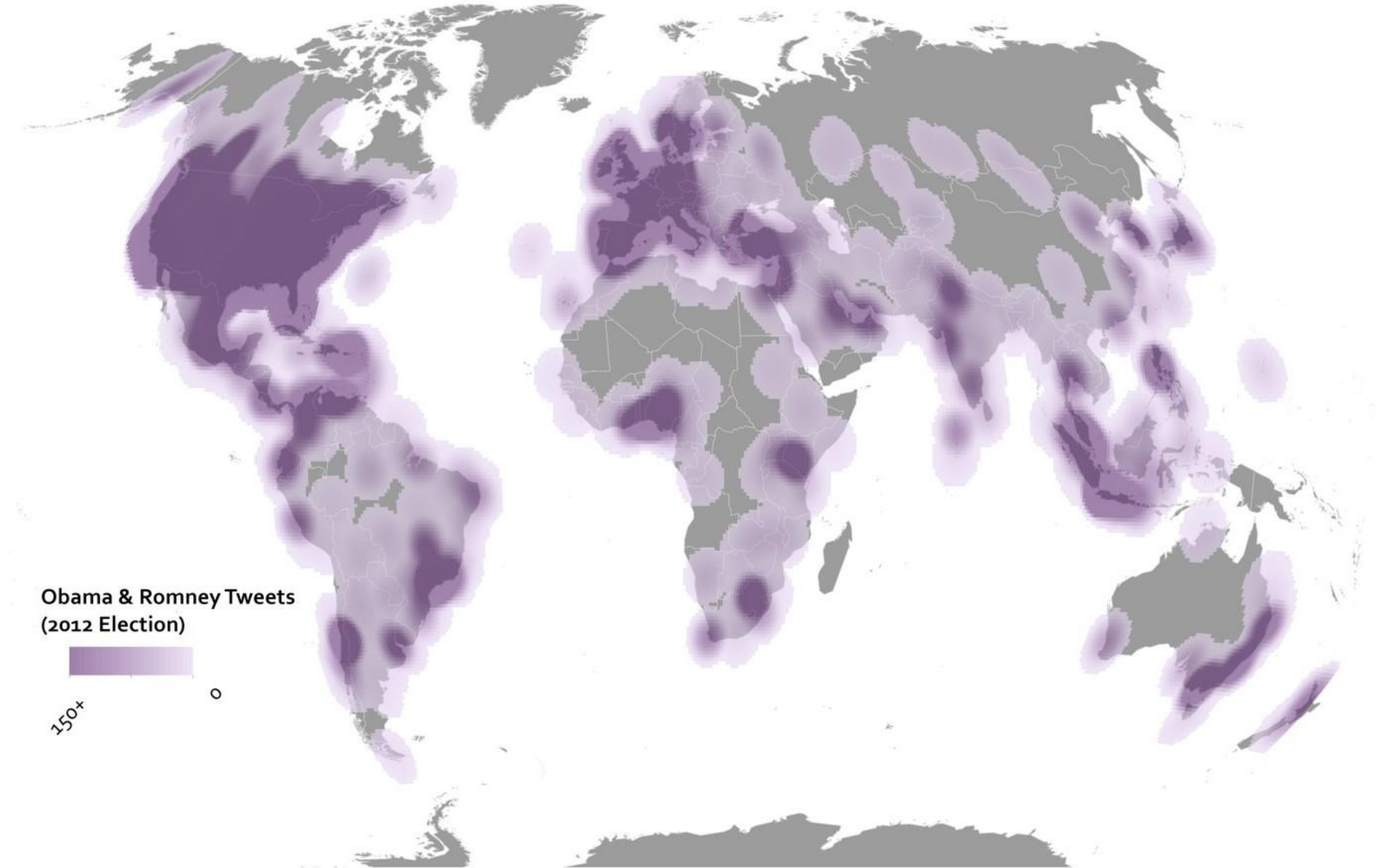


Fortune
(China)

Avoid Rainbow Colors



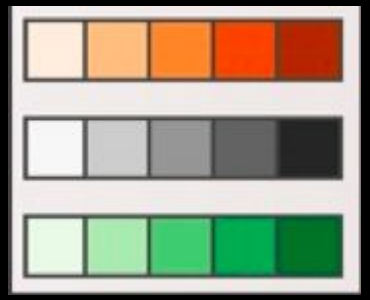
Avoid Rainbow Colors



Quantitative Encoding

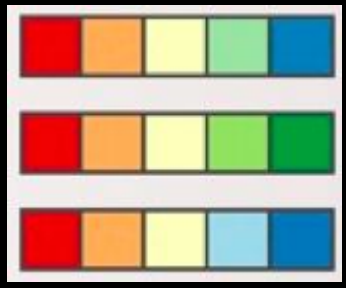
Sequential

- Constrain hue, change sat/lightness
- Map higher value to darker shade



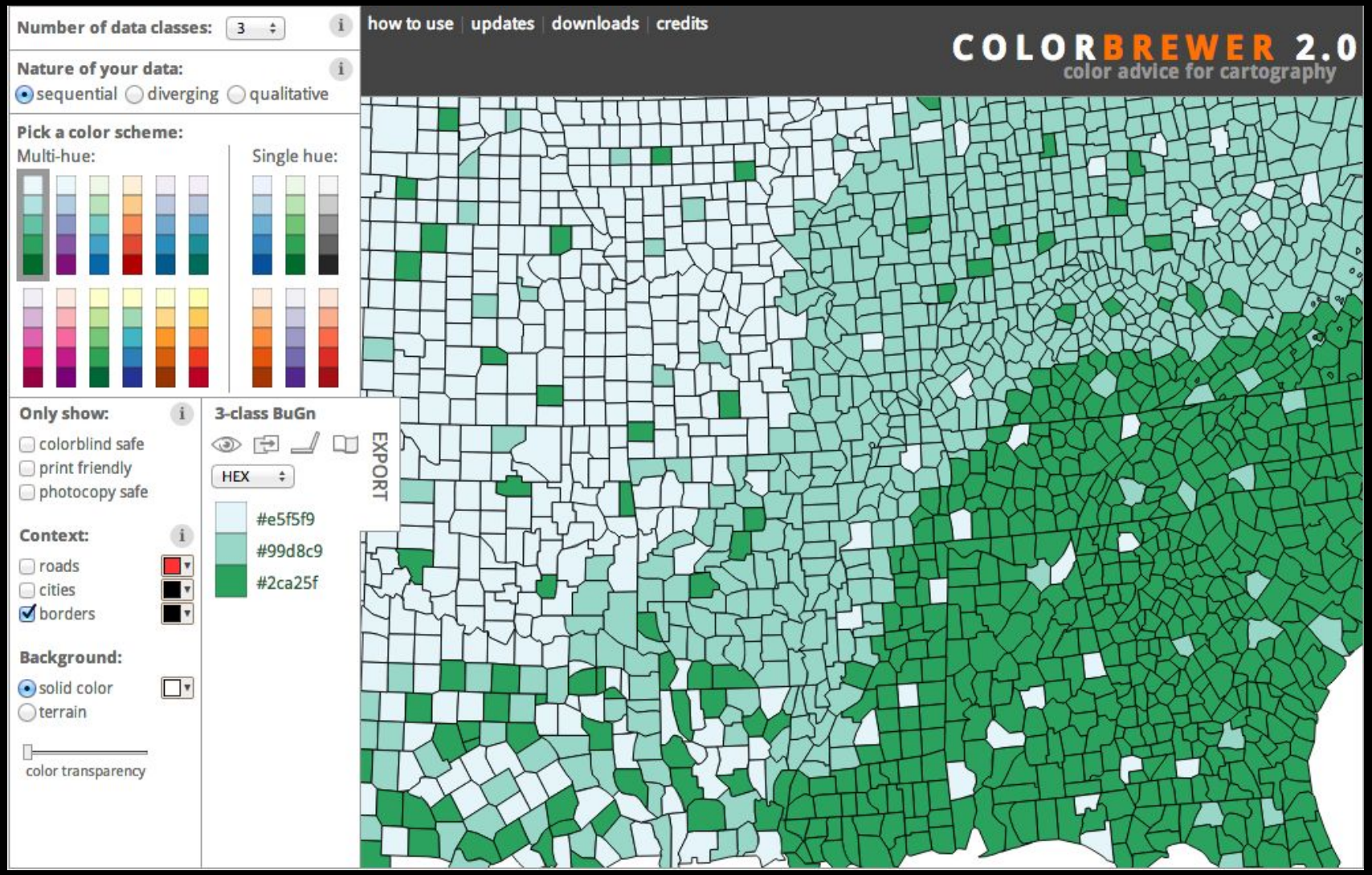
Divergent

- Used when data is a meaningful midpoint
- Use neutral color (grey) at midpoint
- Use saturated color at endpoint



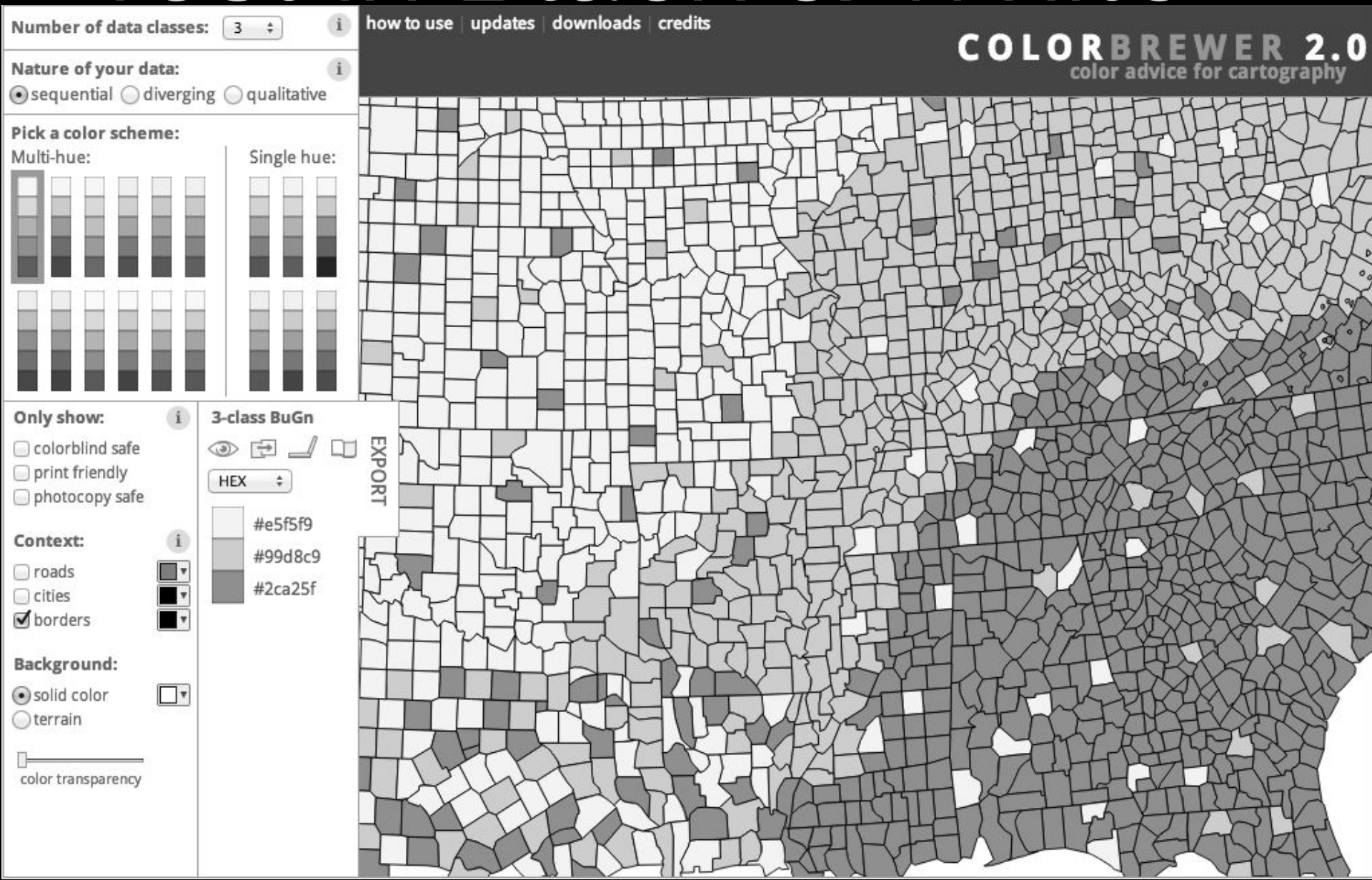
Limit the number of steps from 3 to 9

Tool - Color Brewer

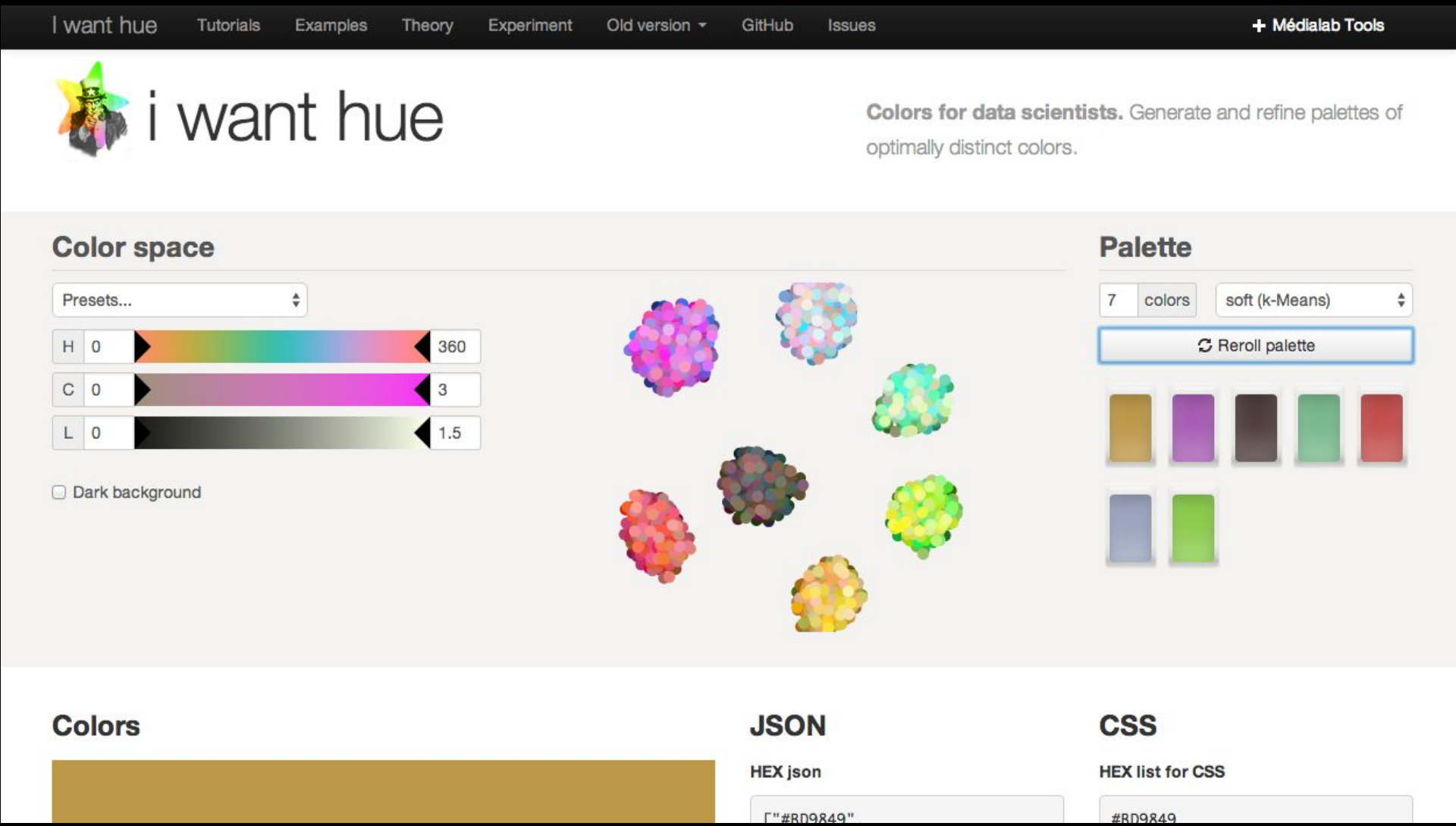


Source: [Color Brewer 2](#)

Test in Black & White

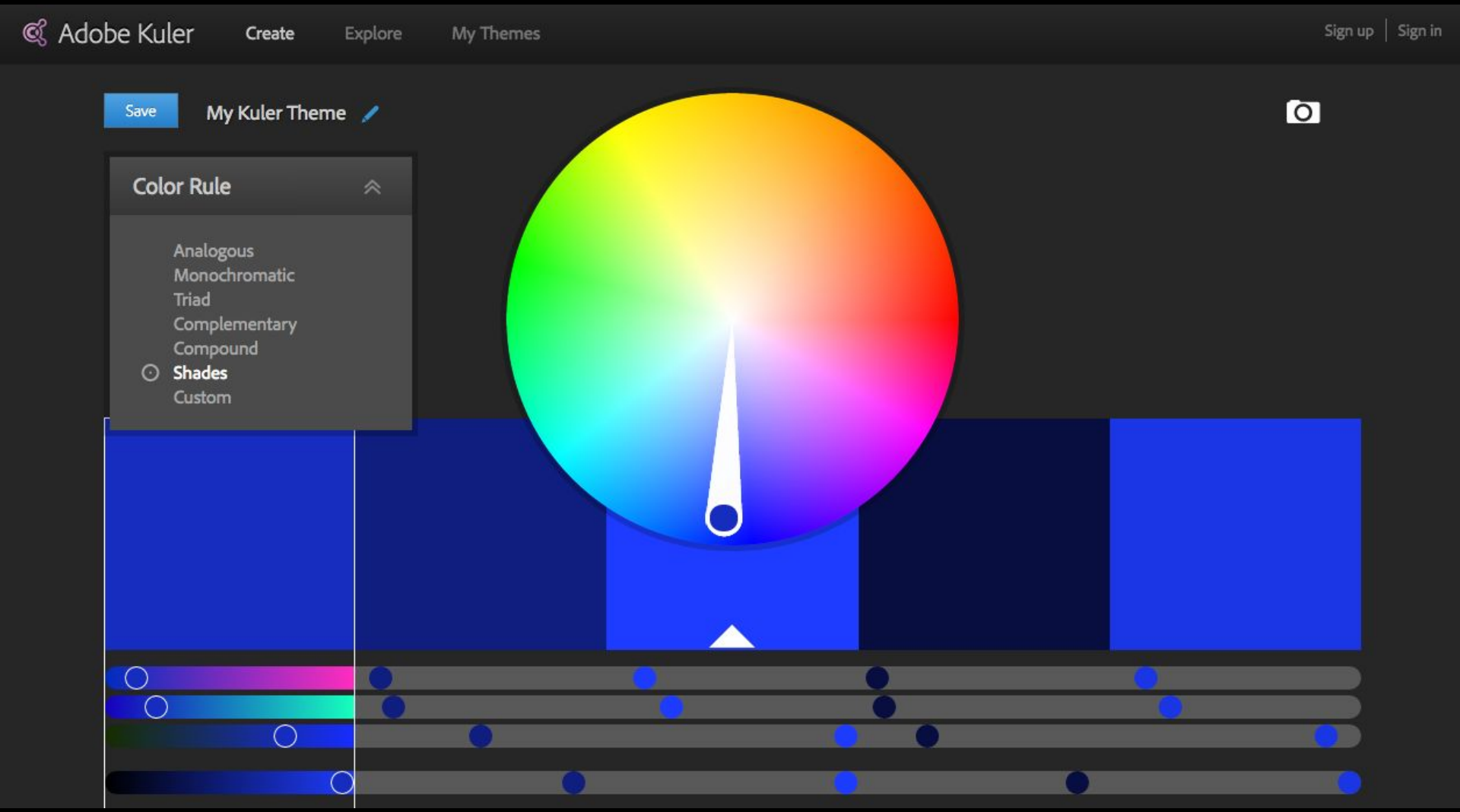


Tool - I want hue



Source: [I want hue]

Tool - Adobe Kuler



Source: [Kuler Adobe]

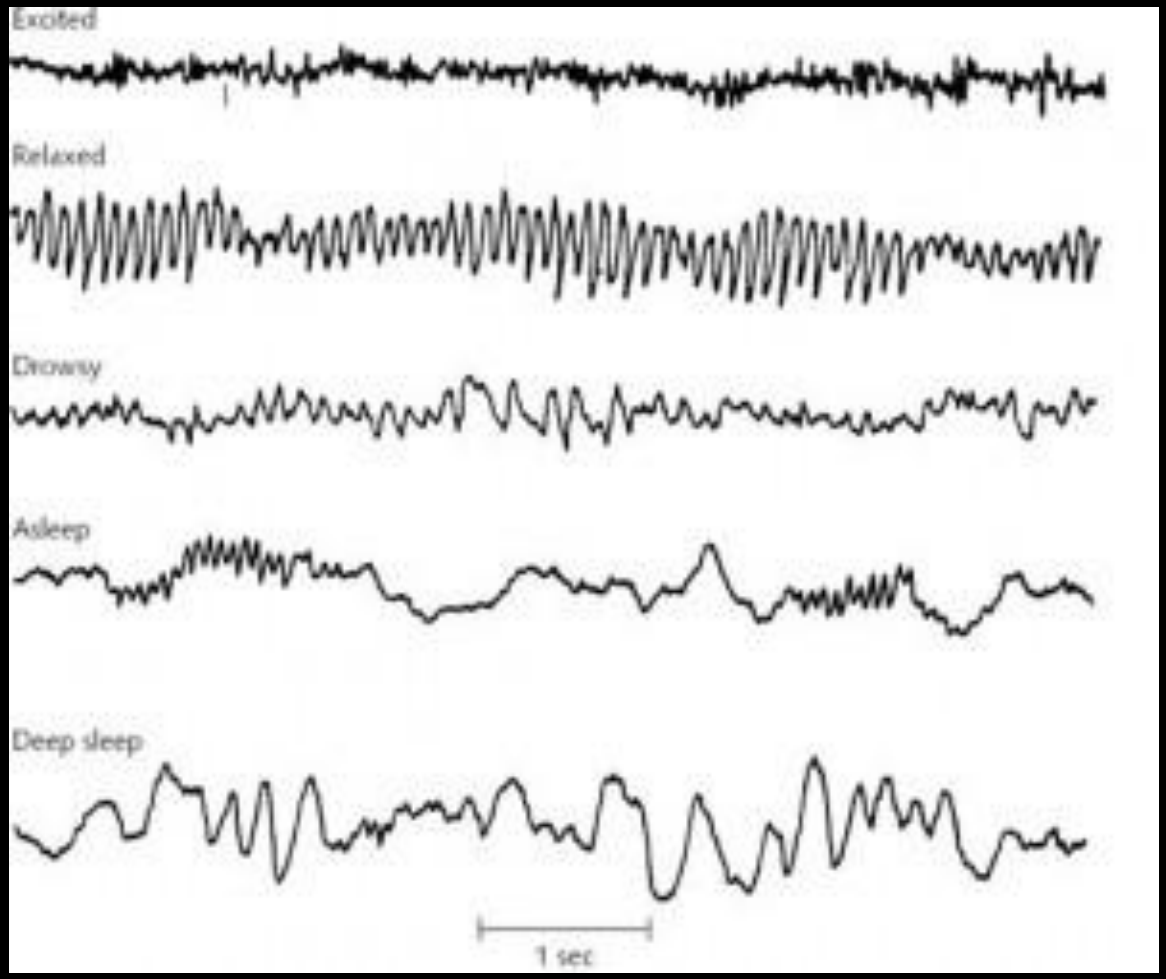
“In anything at all, perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away.”

- Antoine de Saint Exupery

Data-Ink Ratio

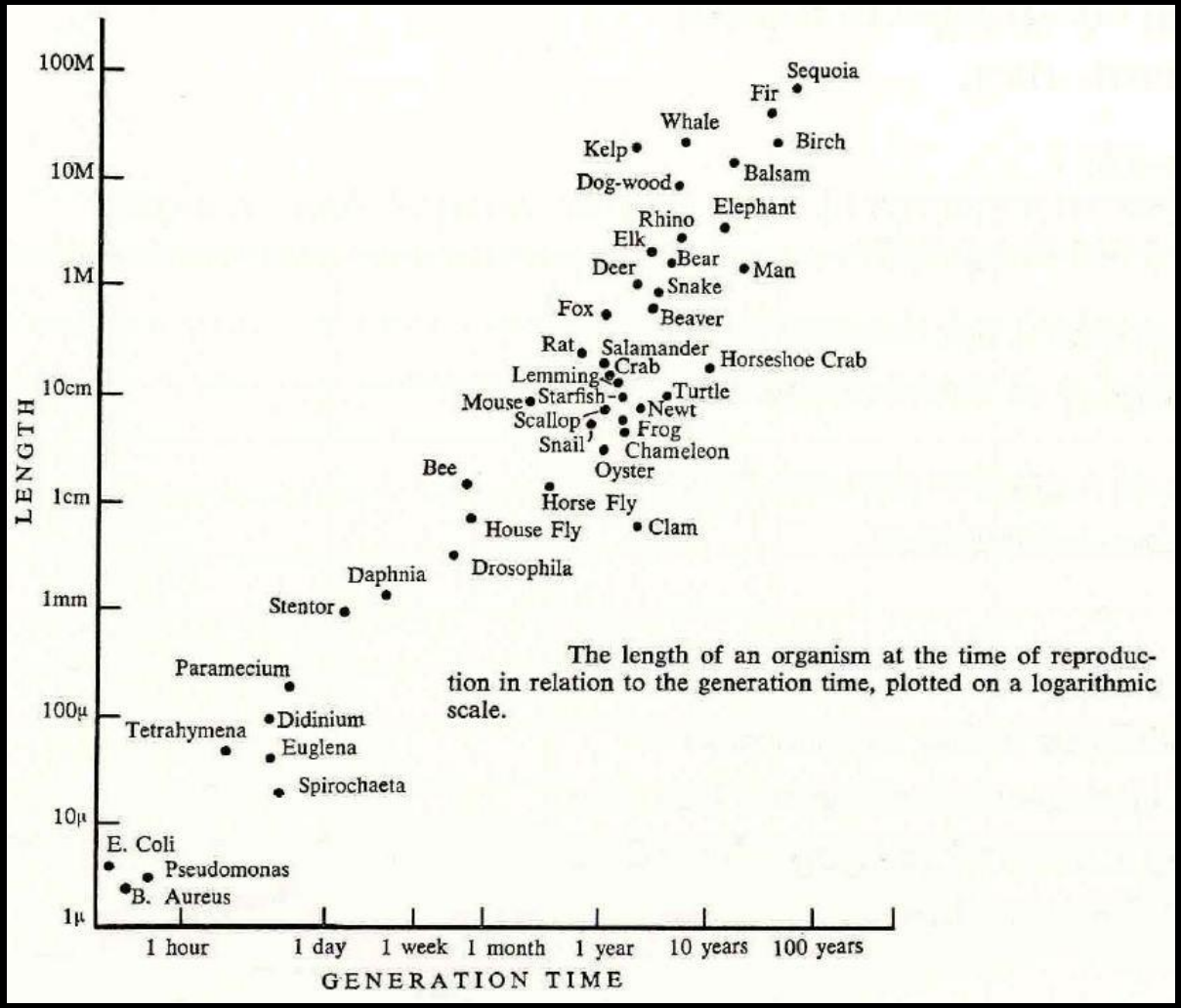
$$\frac{\text{Data-Ink}}{\text{Total Ink used to Print}}$$

Data-Ink ~ 1.0



Electroencephalogram

High Data-Ink ~ 0.8



Structure of Biology

Enhance Data-Ink

1. Above all else show the data
2. Maximize the data-ink ratio
3. Erase non-data ink
4. Erase redundant data-ink
5. Revise and Edit

Examples

Hans Rosling's 200 Countries, 200 Years, 4 Minutes - The Joy of Stats - BBC Four

3:19 / 4:47

3D Charts - Avoid!