

Visual Perception and Principles of Design

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Agenda

- Visual Queries
 - Implications for visualization
- What can we easily see?
- Color
- Interactive Plots with Shiny (if time permits)

Next Lecture

Intro to Tableau

Class at 12:30pm-2pm

Everyone together!

Install Tableau, upload file from Canvas

Attention

When we awake we have
the impression that we
see the world vividly,
completely and in detail.
Wrong!

The "Door" Study
from Simons & Levin (1998)

50% of people did not detect the substitution

- Experiment in which we tested people's ability to detect unexpected visual changes in the real world.
- 50% of people did not detect a the sudden substitution of one conversation partner for another.

Simons, D.J., & Levin, D.T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin and Review*, 5, 644-649.

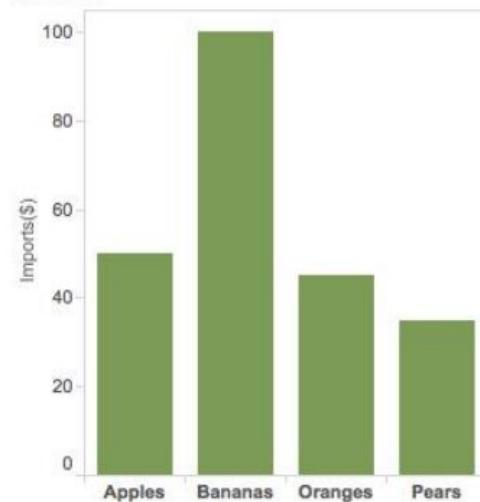
How we see

- We see very little at any given instant.
- We allocate “working memory” to retain information that are likely to be useful (to the task of the moment).
 - Looking at the map.
 - The person’s face was not critical for this task.
- The “working memory” has a small capacity
- Why is this is useful for visualization?
 - Design visualization based on our understanding of visual attention and pattern perception.

Visual Queries

“Visual thinking consists of a series of **acts of attention**, driving eye movements and tuning our pattern-finding circuits.”

Example: To find which fruit import is largest by dollar value we make a visual query to find the tallest bar, then we read the label.



Goal of Viz Design

*Design displays so that **visual queries** are processed both rapidly and correctly for every cognitive task that the display is intended to support.*

Implications for Viz Design

How well does a visualization design support likely visual queries of user?

What tasks does user need to accomplish? As a result what visual queries should a design support?

What visual queries are easily executed?

How to map data to colors, marks, space to efficiently service those queries?



London Underground Map

Which visual queries is supposed to support? (Suppose you are in hotel near station A and want to go to a pub near station B)

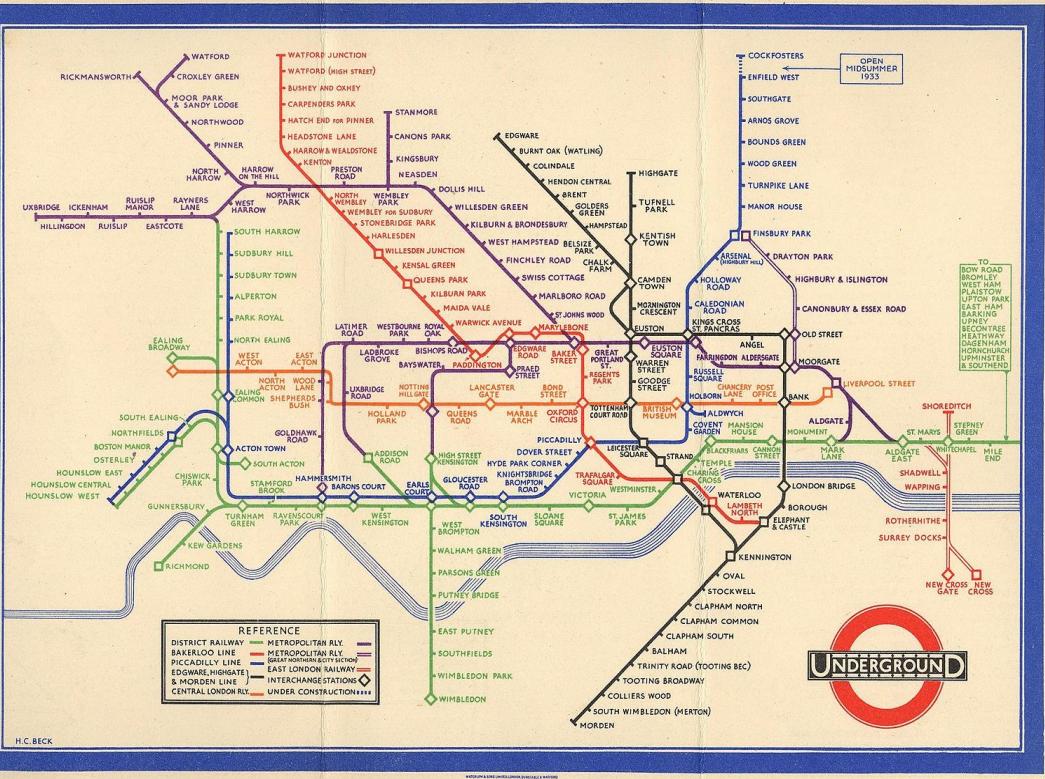
- Which combinations of lines will get us to the pub?
- Is there more than one route, which is the shortest?
- What is the distance between the hotel and station A?
- How much it will cost?
- How long it going to take?

Visual Queries for London Underground Map

Which visual queries is supposed to support? (Suppose you are in hotel near station A and want to go to a pub near station B)

- Which combinations of lines will get us to the pub? 
- Is there more than one route, which is the shortest? 
- ~~What is the distance between the hotel and station A?~~
- ~~How much it will cost?~~
- ~~How long it going to take?~~

Becks Concept



He believed that
Underground
passengers were not
concerned with
geographical accuracy
and were more
interested in **how to get**
from one station to
another and where to
change trains.

What can we easily see?

How can we make a graphic symbol that can be found rapidly?
How can something be highlighted?

Evolution has fine-tune our vision to find the Lyon



Discriminate between
background and
foreground; fining
boundaries

“Preattentive” Features

- **Preattentive process:** Automatic processes in brain that occur before attention is tuned in.
- **Preattentive features:** features process before to conscious attention.
- Pop out effect see in a single eye fixation (< 10ms)
- Enables very quick visual search rather than slow serial searching

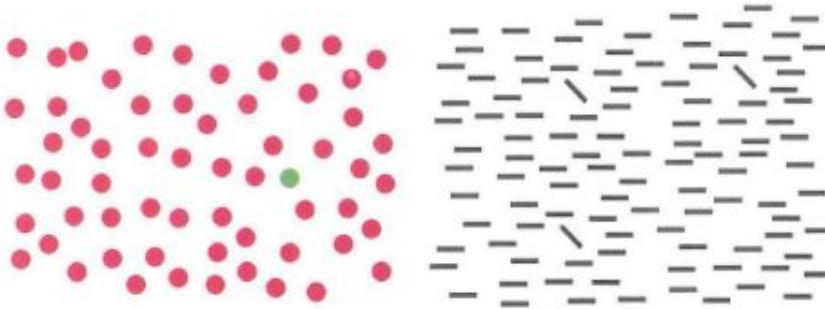
“Preattentive” Features

Distinctness

Is it different than its environment / context
Does it contrast

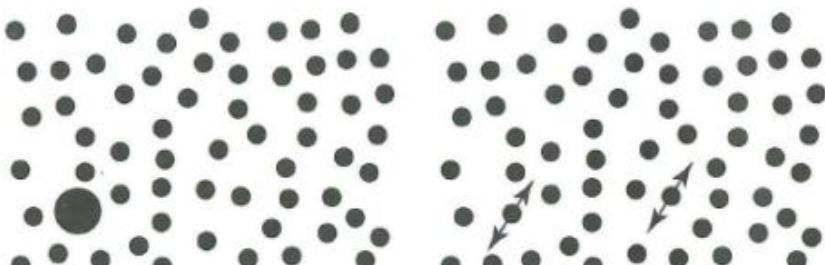
Features

Color, orientation, size, motion, depth



The green dot pops out

The oblique lines pop out



The large circle pops out

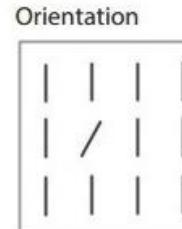
If two dots were to oscillate as shown they would pop out

“Preattentive” Features

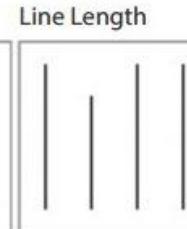
Effective visualizations
make intentional use of
preattentive features

Form

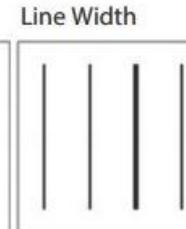
Orientation



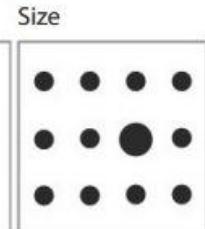
Line Length



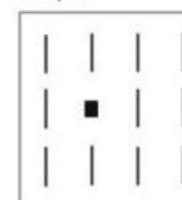
Line Width



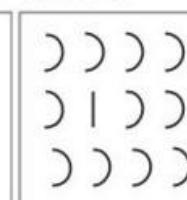
Size



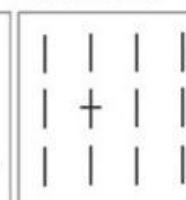
Shape



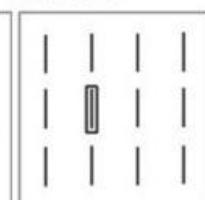
Curvature



Added Marks

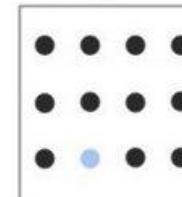


Enclosure

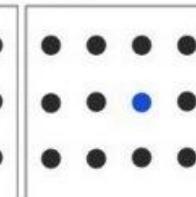


Color

Intensity

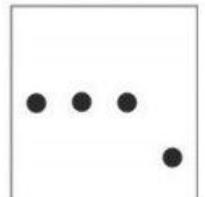


Hue



Spatial Position

2-D Position



Preattentive features can increase performance of tasks

- Target detection
- Boundary detection
- Region tracking
- Counting and estimation

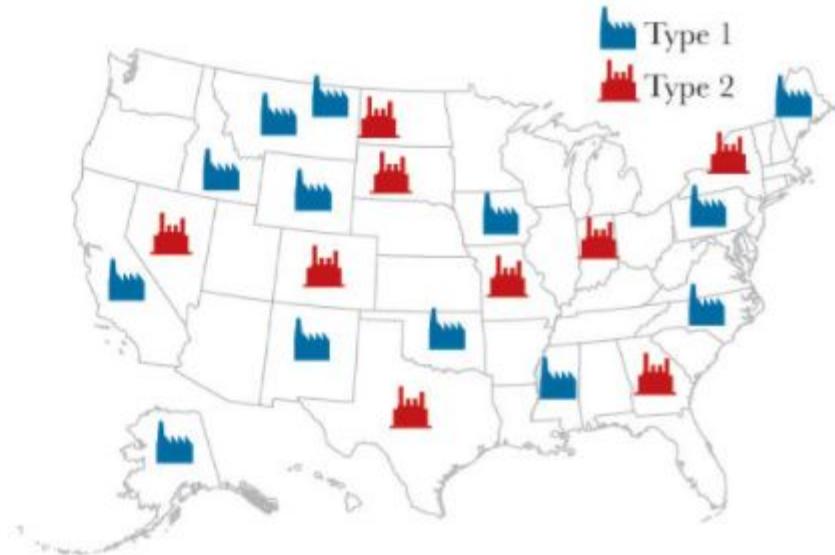
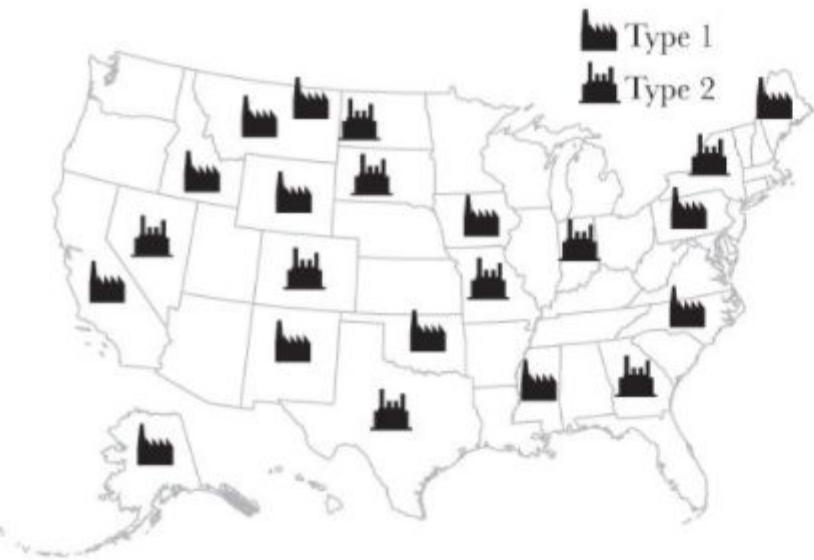
How many 6's?

4 3 6 7 9 8 1 2 5 5 1 1 5 6 1 1 5 8 1 3 4 1 5 9 1 5
1 5 3 4 5 1 1 5 2 5 1 3 1 9 2 5 1 2 1 8 9 1 4 1 1 6
5 2 1 6 1 1 6 1 2 4 1 8 1 6 1 5 8 2 4 1 4 1 5 1 9 1
1 4 1 8 1 9 5 1 2 8 1 9 1 1 5 1 1 5 1 6 1 8 2 6 1 2
2 6 1 9 1 5 1 2 2 1 4 1 1 8 2 1 4 1 2 4 4 1 1 9 1 2
3 1 2 5 1 1 6 1 5 3 1 8 2 1 3 8 1 1 8 1 4 1 3 1 6 1

How many 6 s?

4 3 **6** 7 9 8 1 2 5 5 1 1 5 **6** 1 1 5 8 1 3 4 1 5 9 1 5
1 5 3 4 5 1 1 5 2 5 1 3 1 9 2 5 1 2 1 8 9 1 4 1 1 **6**
5 2 1 **6** 1 1 **6** 1 2 4 1 8 1 **6** 1 5 8 2 4 1 4 1 5 1 9 1
1 4 1 8 1 9 5 1 2 8 1 9 1 1 5 1 1 5 1 **6** 1 8 2 **6** 1 2
2 **6** 1 9 1 5 1 2 2 1 4 1 1 8 2 1 4 1 2 4 4 1 1 9 1 2
3 1 2 5 1 1 **6** 1 5 3 1 8 2 1 3 8 1 1 8 1 4 1 3 1 **6** 1

The brain is much better at quickly detecting shade variations than shape differences.

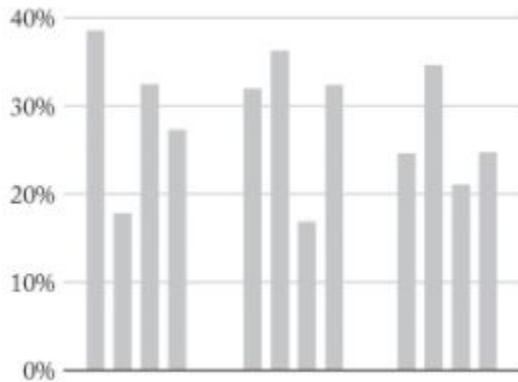


On which map is easier to identify the number of factories of each type?

The Gestalt Principles

- Theory of visual perception developed by German psychologists in the 1920s.
- People **tend to organize visual elements into groups** or unified wholes when certain principles are applied
- Principles:
 - SIMILARITY / CONTINUATION / CLOSURE / PROXIMITY / FIGURE & GROUND

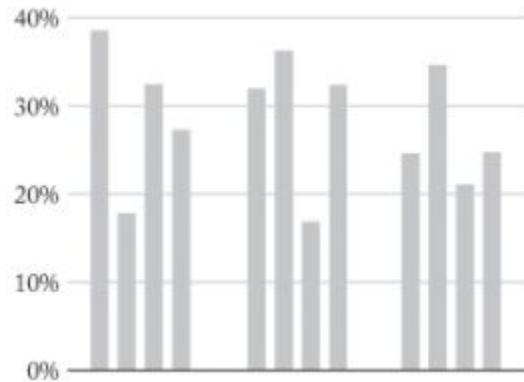
Proximity principle



4	3	6	7	9	8	1	2	5	5	1	1	8
4	6	9	1	5	1	8	4	6	9	1	5	1
1	5	3	4	5	1	1	5	2	5	1	2	1
1	3	5	1	6	2	1	1	6	2	1	1	1
5	1	1	6	2	1	1	1	6	2	1	1	1
1	4	1	8	1	9	5	1	2	8	1	9	9
1	1	1	5	2	1	1	1	5	2	1	1	9
2	1	1	1	1	1	1	1	1	2	4	5	
3	1	2	5	1	1	6	1	5	3	1	8	1
3	2	1	6	5	1	1	1	1	2	4	5	

Objects close to each other will be perceived as belonging to a group

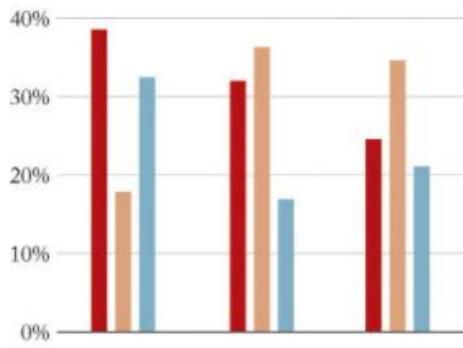
Applying Proximity principle



4	3	6	7	9	8	1	2	5	5	1	1	8	4	6	9	1	5	1	8
1	5	3	4	5	1	1	5	2	5	1	3	1	1	3	5	1	2	1	1
1	4	1	8	1	9	5	1	2	8	1	9	9	1	1	1	5	2	1	9
3	1	2	5	1	1	6	1	5	3	1	8	1	3	2	1	6	5	1	1

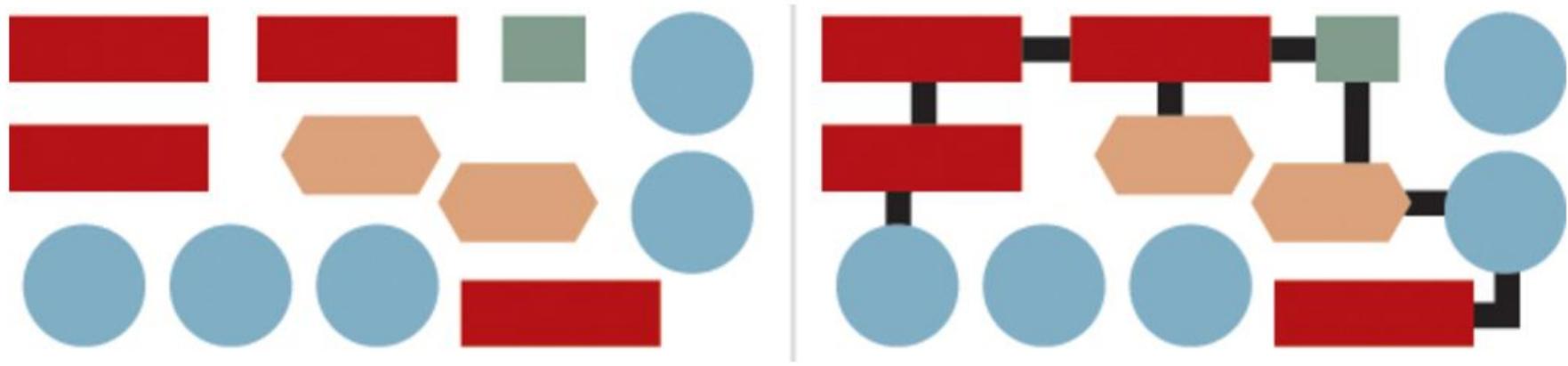
Objects that are related should be near each other in your composition.

Similarity principle



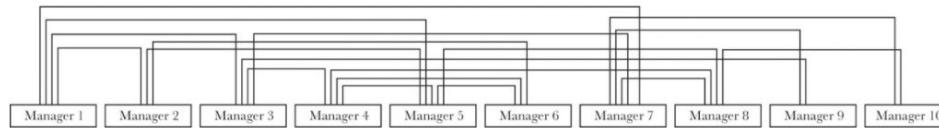
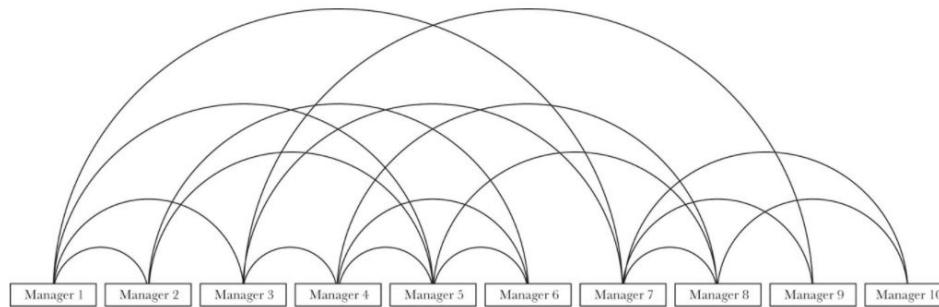
Objects that look alike will be perceived as belonging to a group.

Connectedness principle



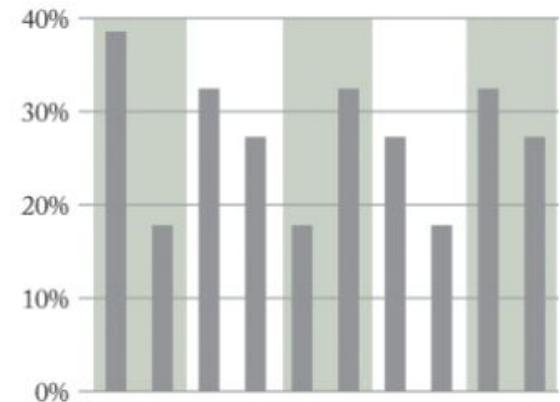
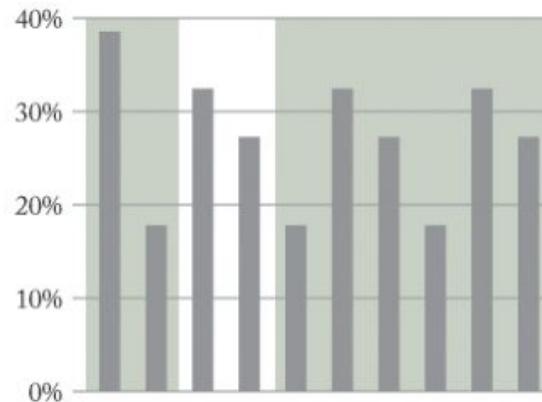
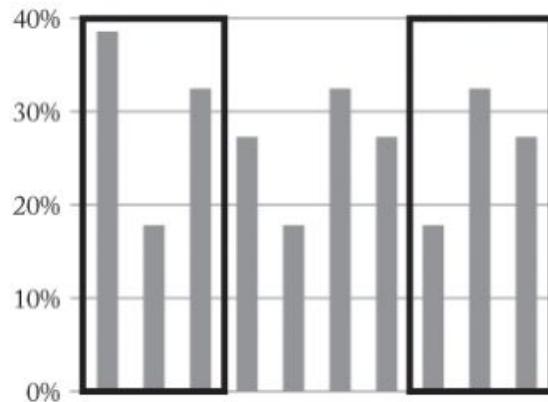
Objects linked by means of a graphics artifice (e.g. line)
will be perceived as members of a natural group.

Continuity principle



Continuity is better perceived in curves than in lines with sharp angles.

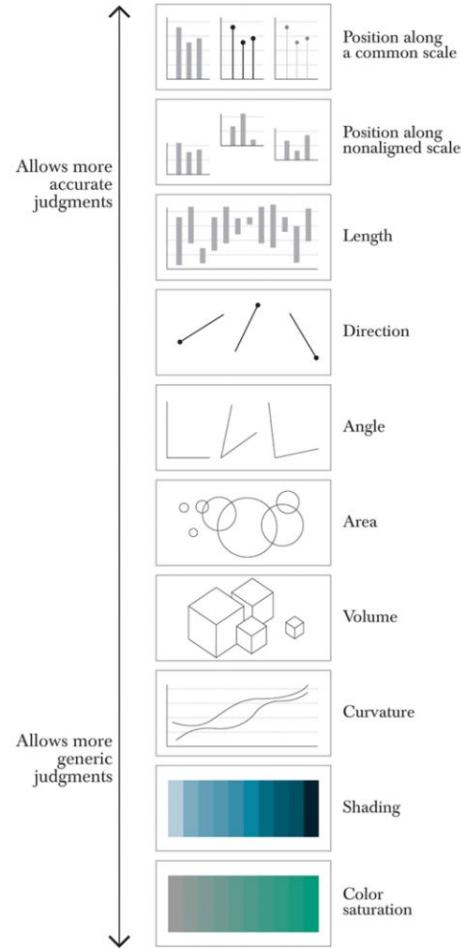
Closure principle



Objects inside an area with crisp, clear boundaries will be perceived as belonging to a group.

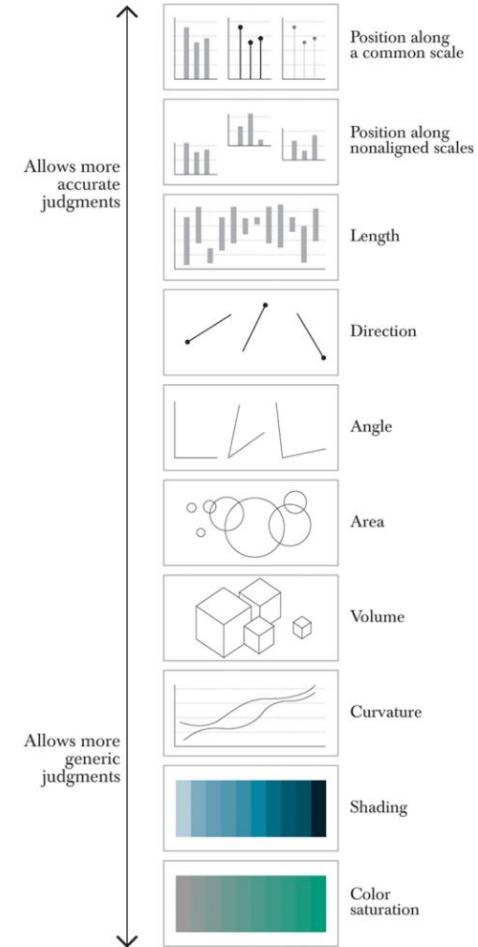
Choosing Graphics Forms Based on How Vision Works

Ranking data representation methods on accuracy



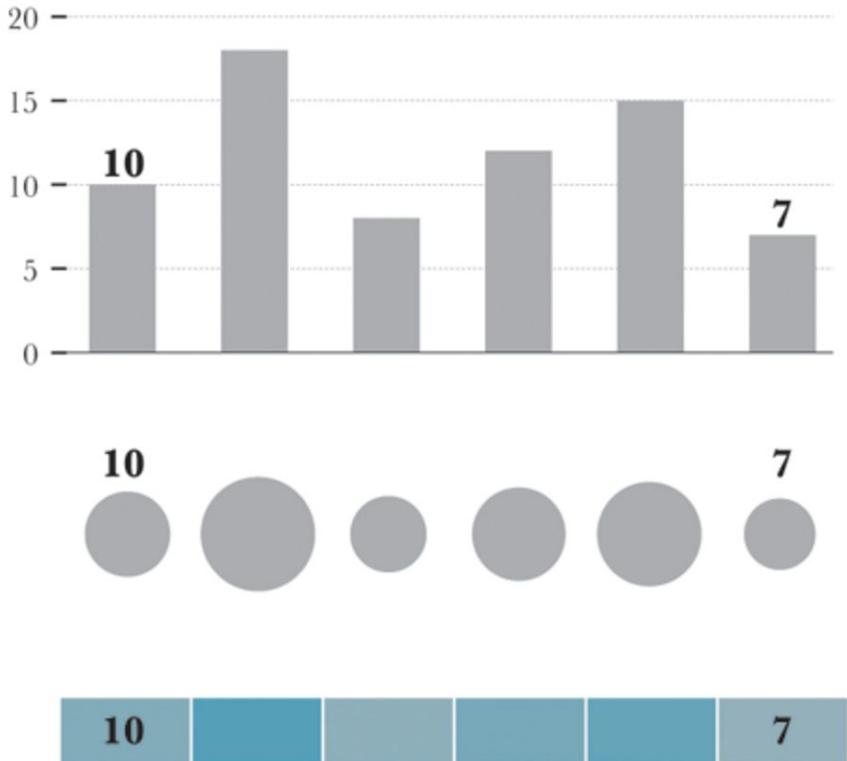
Ranking data representation methods on accuracy

- Based on experiments
- Summary: a bar chart is always superior to a bubble chart or a heat map if the goal of the graphics is precise comparisons



Bar chart is the King

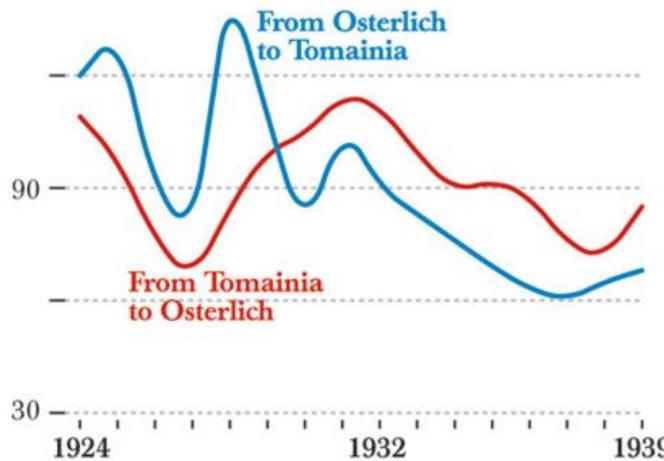
When the goal is to allow readers to make accurate comparisons, a chart based on bars or lines sitting on a single horizontal or vertical axis beats other representations.



Exports between Tomainia and Osterlich

In millions of Tomainian reichsmarks a year

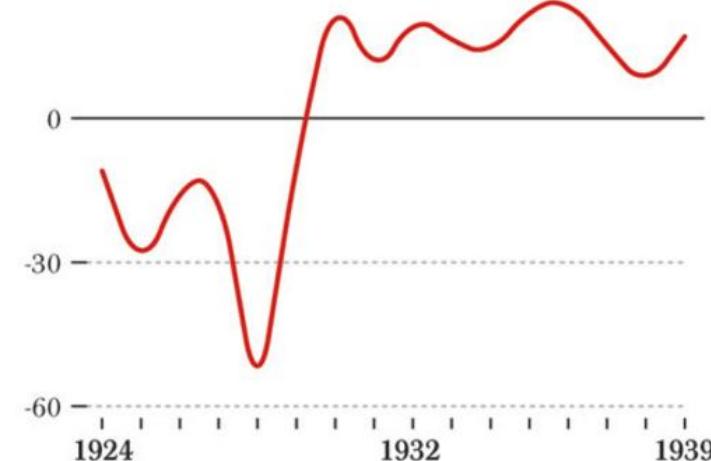
150 —



Trade balance in favor of Tomainia

In millions of Tomainian reichsmarks a year

30 —

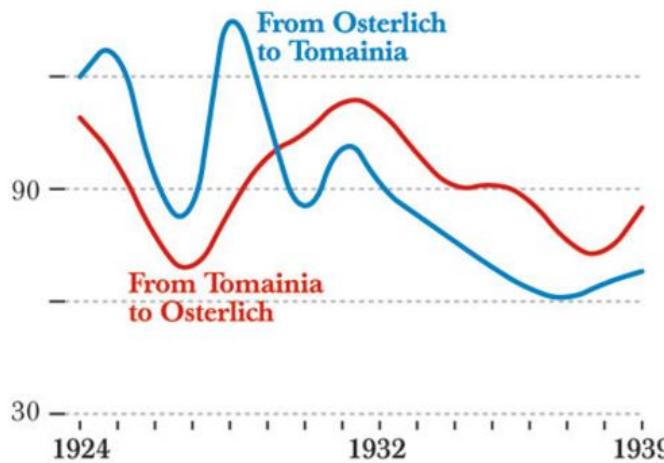


Which one is best?

Exports between Tomainia and Osterlich

In millions of Tomainian reichsmarks a year

150 —



Trade balance in favor of Tomainia

In millions of Tomainian reichsmarks a year

30 —

0 —

-30 —

-60 —

1924

1932

1939

Version one: how much each nation exports to the other.

Version two: Display the trade balance between the two nations.

Correlating percentage obesity and education

Percentage of people with a
BA degree or higher



Percentage of
obese people



Correlating percentage obesity and education

Percentage of people with a
BA degree or higher



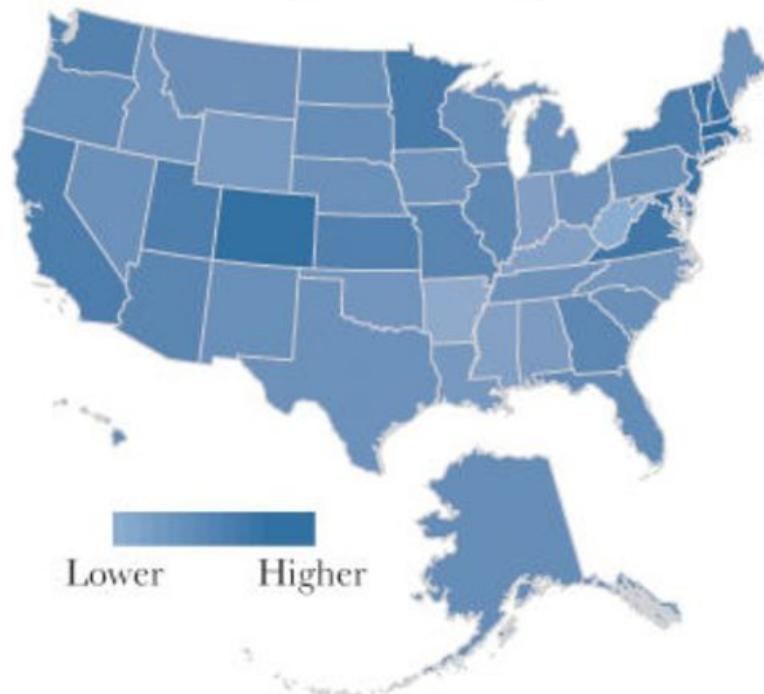
Percentage of
obese people



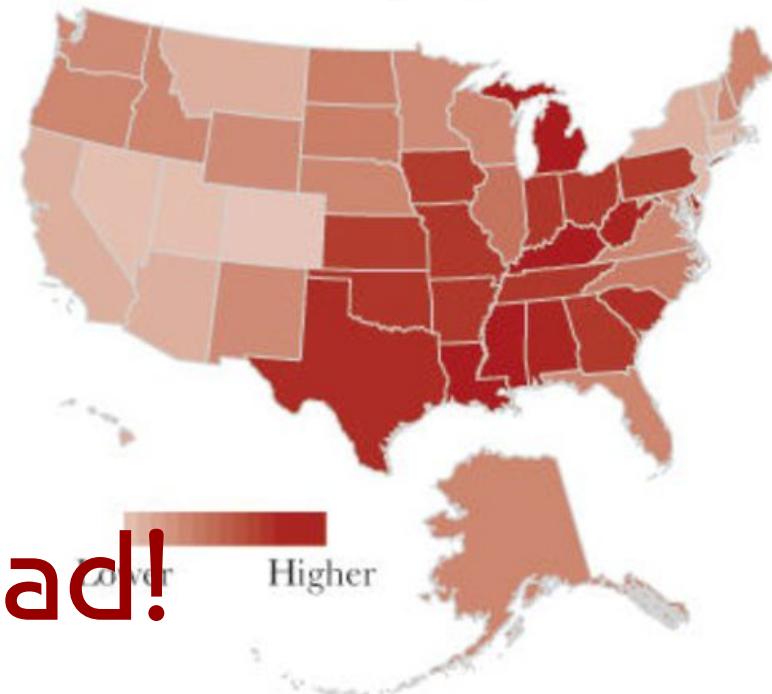
Bad!

Correlating percentage obesity and education

Percentage of people with a
BA degree or higher

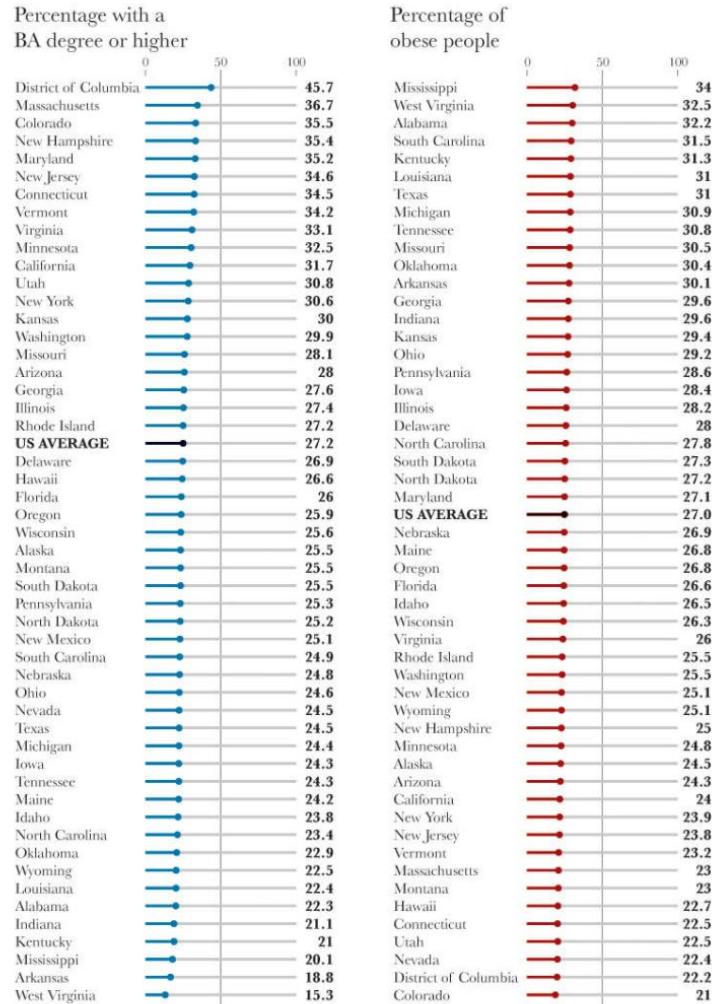


Percentage of
obese people

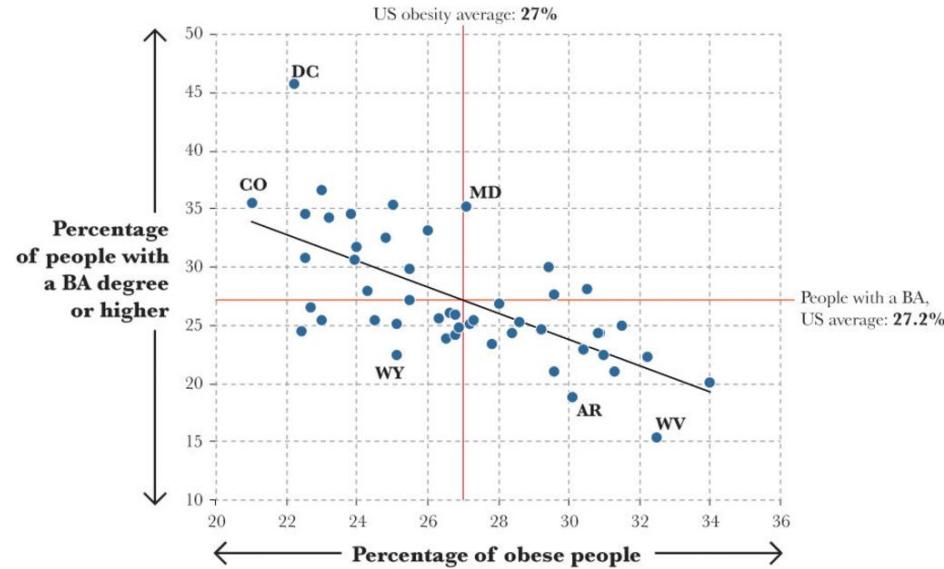


Obesity & Education: Dot chart

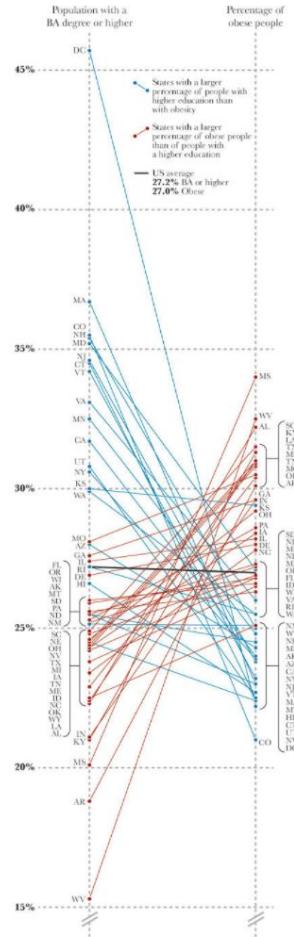
A dot chart is equal to a bar chart for estimation proportions



Obesity & Education: scatter-plot

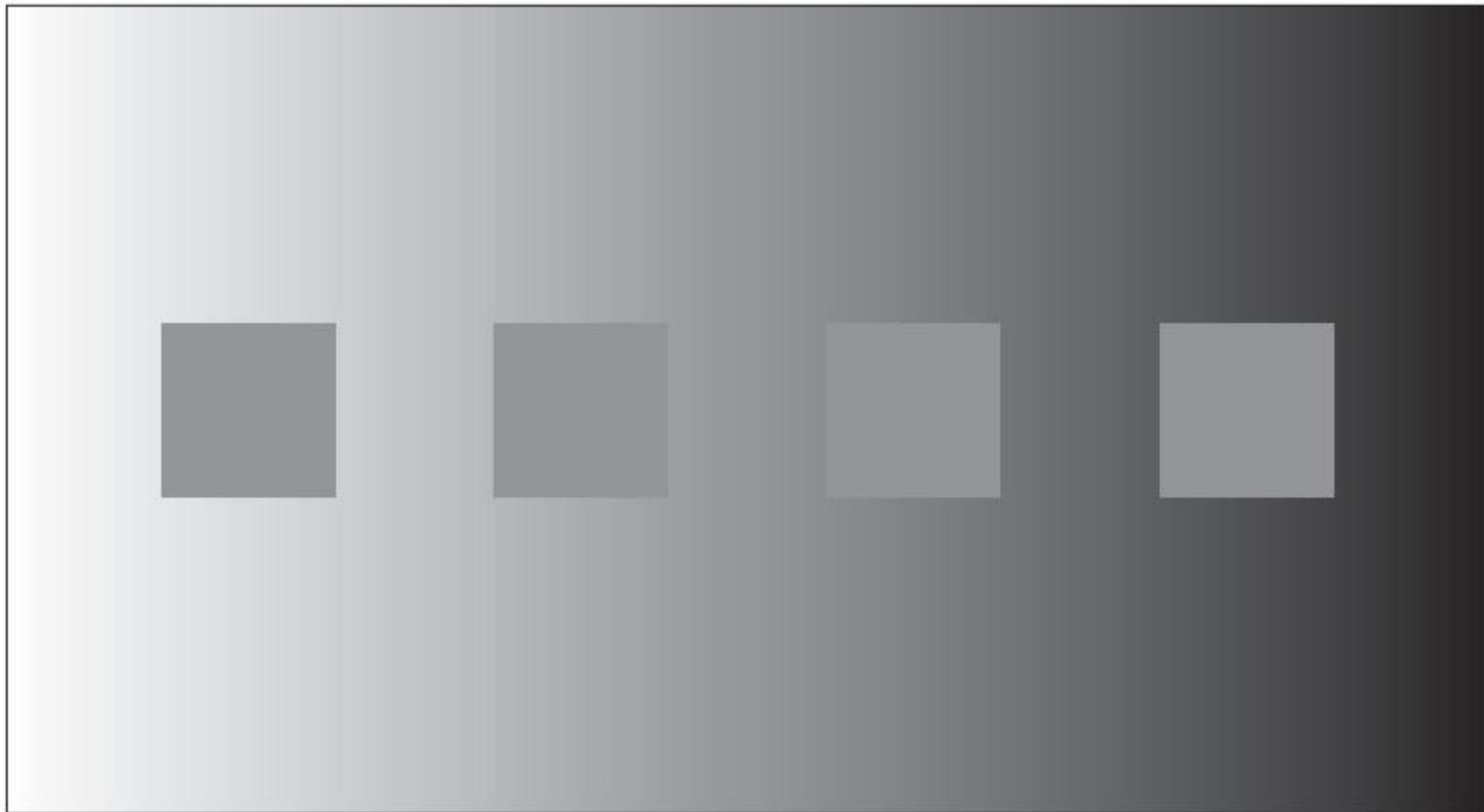


Obesity & Education: slopegraph



Color

Same square different background



Stephen Few's Rules for Color

Rule #1 If you want different objects of the same color in a table or graph to look the same, make sure that the background—the color that surrounds them—is consistent.

Rule #2 If you want objects in a table or graph to be easily seen, use a background color that contrasts sufficiently with the object.

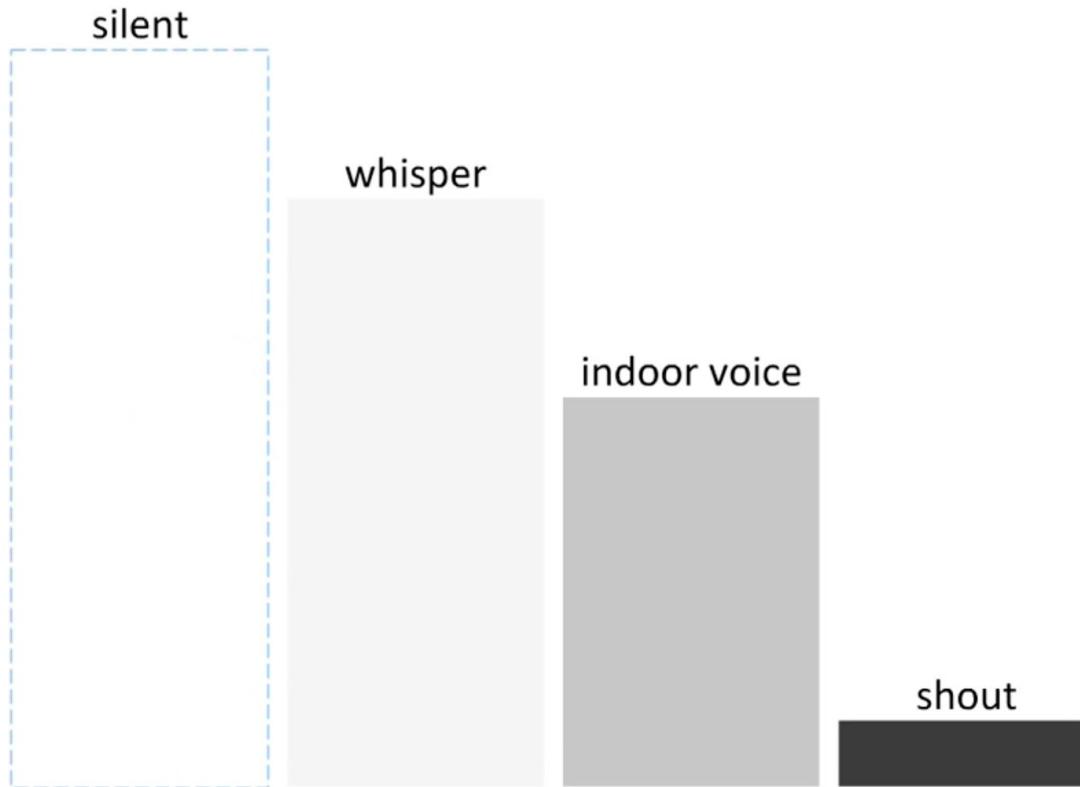
The interesting numbers are hard to read

	Laptops	Desktop PCs	Harddisks	Flash Memory	Screens	Keyboards	Printers	Scanners	PDAs	Projectors	Cameras
California	-2,216	4,497	884	3,252	8,564	3,418	6,582	-3,891	2,333	1,356	5,450
Colorado	3,410	0	2,338	2,676	1,567	367	1,361	3,249	828	1,272	-141
Connecticut	0	0	4	0	2,998	1,219	673	0	0	610	989
Florida	0	0	583	765	2,305	940	1,737	2,727	0	1,344	497
Illinois	0	0	9,384	3,405	4,362	2,331	4,495	3,464	1,366	0	1,569
Iowa	377	0	412	6,577	210	4,487	872	189	5,622	0	3,466
Louisiana	0	2	1,455	1,501	1,138	0	920	1,349	0	0	991
Massachusetts	0	0	-297	0	12,489	707	0	0	0	492	367
Missouri	0	0	1,224	-169	986	367	1,011	1,125	-210	-45	-685
Nevada	0	875	374	884	-45	11,934	410	210	4,497	-10,978	4,355
New Hampshire	1,009	0	-166	0	897	376	0	0	0	882	-43
New Mexico	0	-208	-161	377	902	0	369	-683	0	0	202
New York	0	0	-17,034	0	8,564	3,254	0	0	3,405	2,326	7,589
Ohio	820	0	2,671	495	827	2,305	355	-134	2,724	0	705
Oklahoma	0	2,722	492	495	1,274	0	2,305	700	-15,034	0	571
Oregon	-139	357	818	708	395	487	2,671	834	2,310	2,727	1,269
Texas	0	1,356	3,415	808	5,452	0	2,336	1,567	0	0	829
Utah	1,130	1,006	1,501	1,009	678	-156	1,222	979	367	-208	904
Washington	0	768	488	2,998	1,661	1,452	1,418	564	918	-5	1,141
Wisconsin	497	0	1,418	1,450	576	916	767	1,740	2	0	1,337

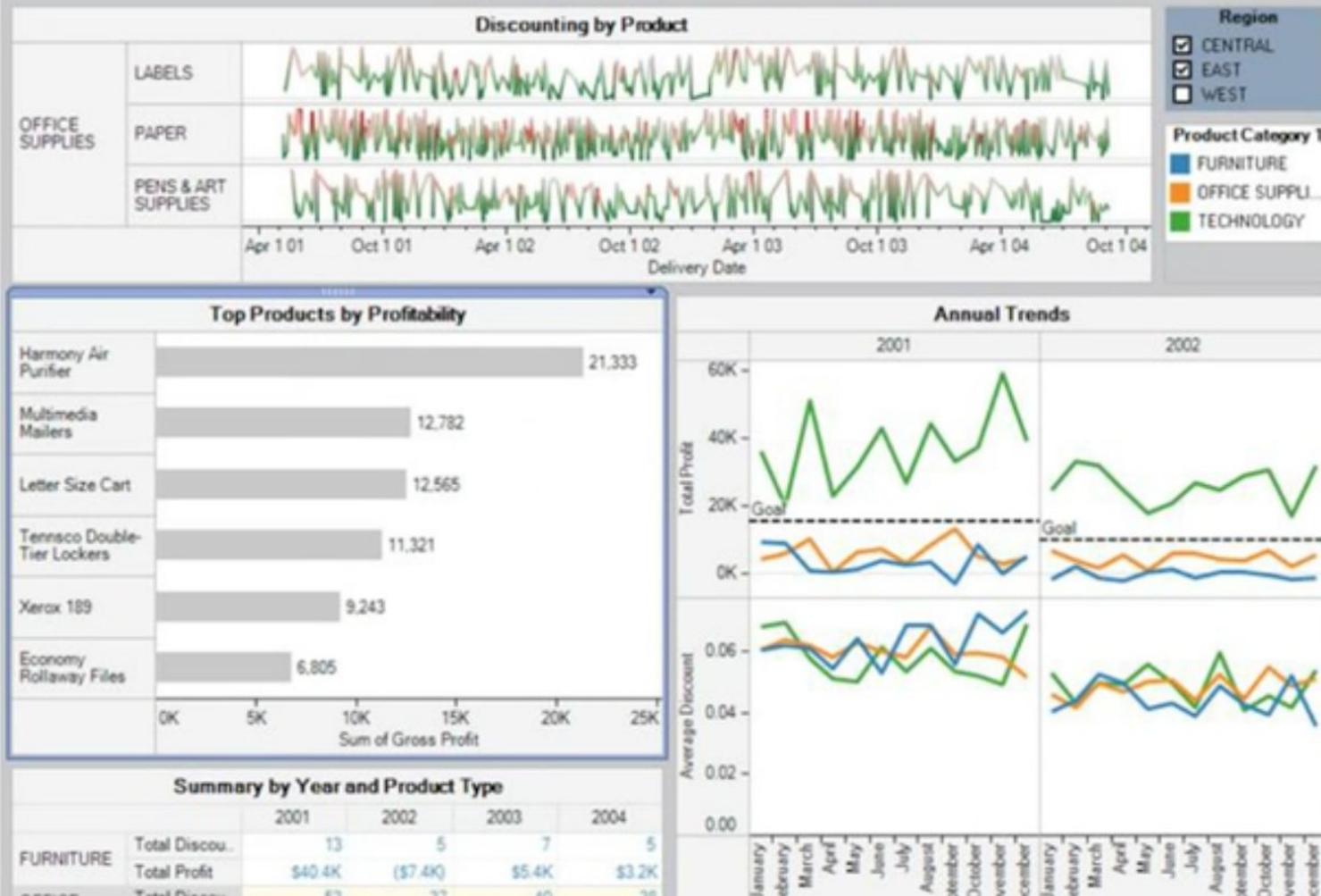
Rule #3 Use color only when needed to serve a particular communication goal.

Don't use color to decorate the display

Create a clear visual hierarchy



Monitor Data in Analytical Dashboards



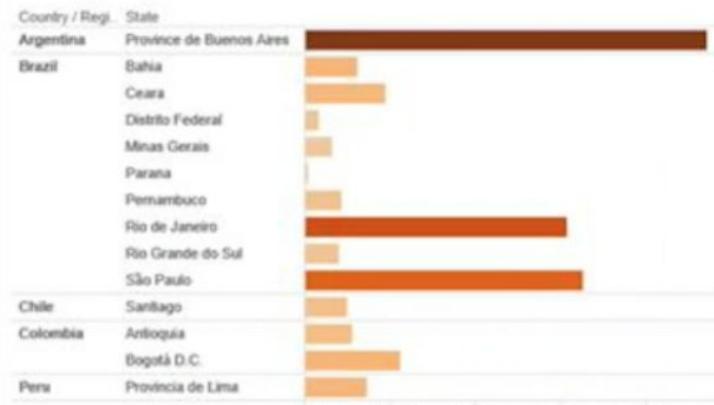
Order Quantity by Country



Sales



Order Quantity South America



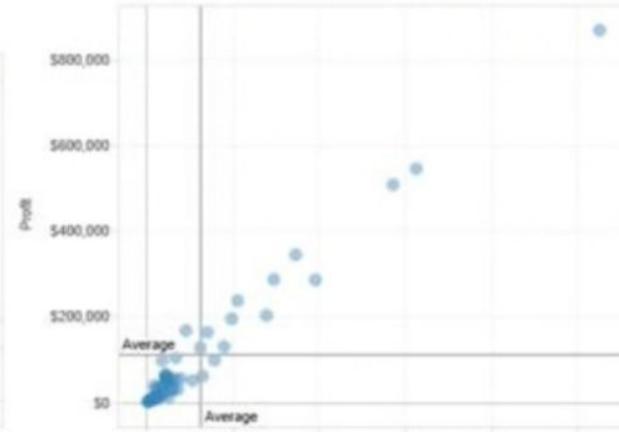
Profit and Sales by Region

Department	Category	Region				
		Central	East	Internatio...	South	West
Furniture	Bookcases	(\$21,335)	(\$3,120)	\$152,158	\$8,698	\$8,049
	Chairs & Chai...	\$65,017	\$55,151	\$547,020	\$8,730	\$36,451
	Office Furnish...	\$28,795	\$19,403	\$263,311	\$10,771	\$33,241
	Tables	(\$17,255)	(\$45,218)	\$251,291	(\$11,216)	\$1,194
Office Supplies	Appliances	\$57,125	\$21,907	\$371,776	\$27,399	\$15,220
	Binders and B...	\$83,273	\$80,413	\$622,809	\$17,237	\$35,650
	Envelopes	\$12,226	\$16,990	\$93,299	\$382	\$16,534
	Labels	\$2,829	\$2,469	\$24,135	\$10,201	\$2,276
	Paper	\$12,641	\$8,136	\$182,482	\$7,079	\$7,506
	Pens & Art Su...	\$3,018	\$3,185	\$39,805	(\$6,982)	\$1,975
	Rubber Bands	\$334	(\$14)	\$3,700	(\$3,140)	(\$21)
	Scissors, Rule	(\$4,027)	(\$1,214)	(\$377)	\$3,266	\$39
	Storage & Org...	(\$234)	\$921	\$221,388	\$3,010	\$4,383
Technology	Computer Peri...	\$26,020	\$20,517	\$255,244	\$24,814	\$16,567
	Copiers and F...	\$46,449	\$44,957	\$447,752	\$1,883	\$35,668

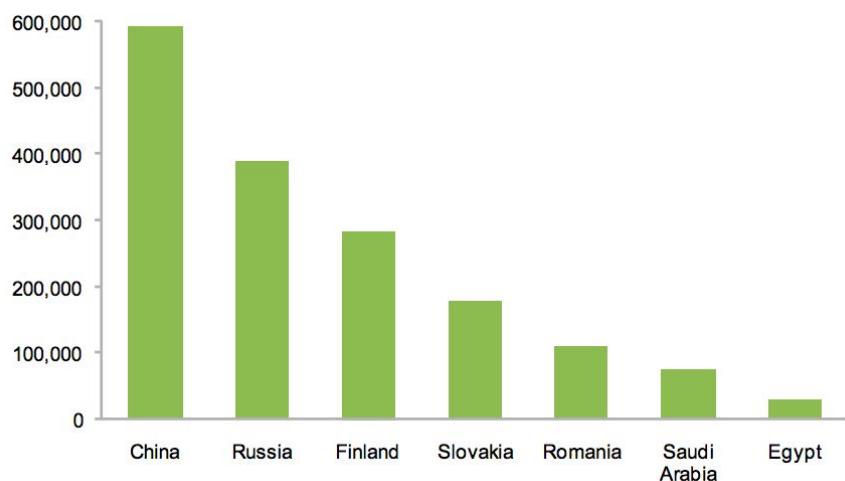
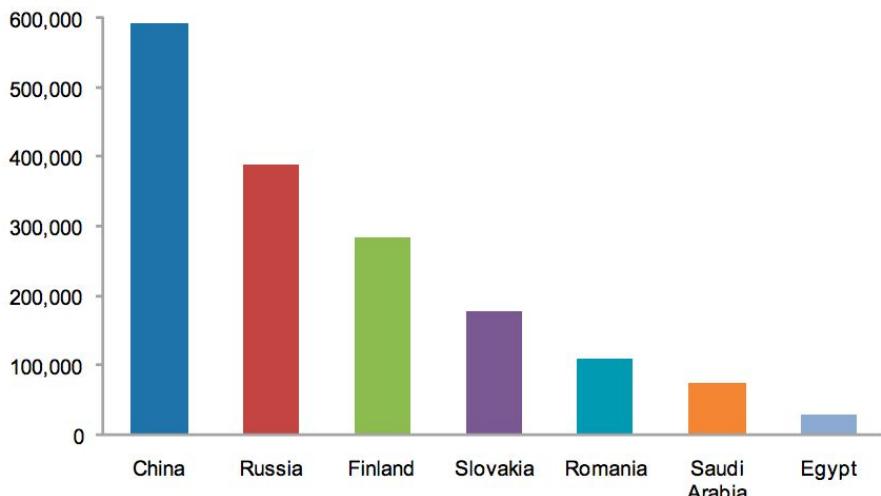
Profit



Distribution by region



Rule #4 Use different colors only when they correspond to differences of meaning in the data



Rule #5 Use soft, natural colors to display most information and bright and/or dark colors to highlight information that requires greater attention.

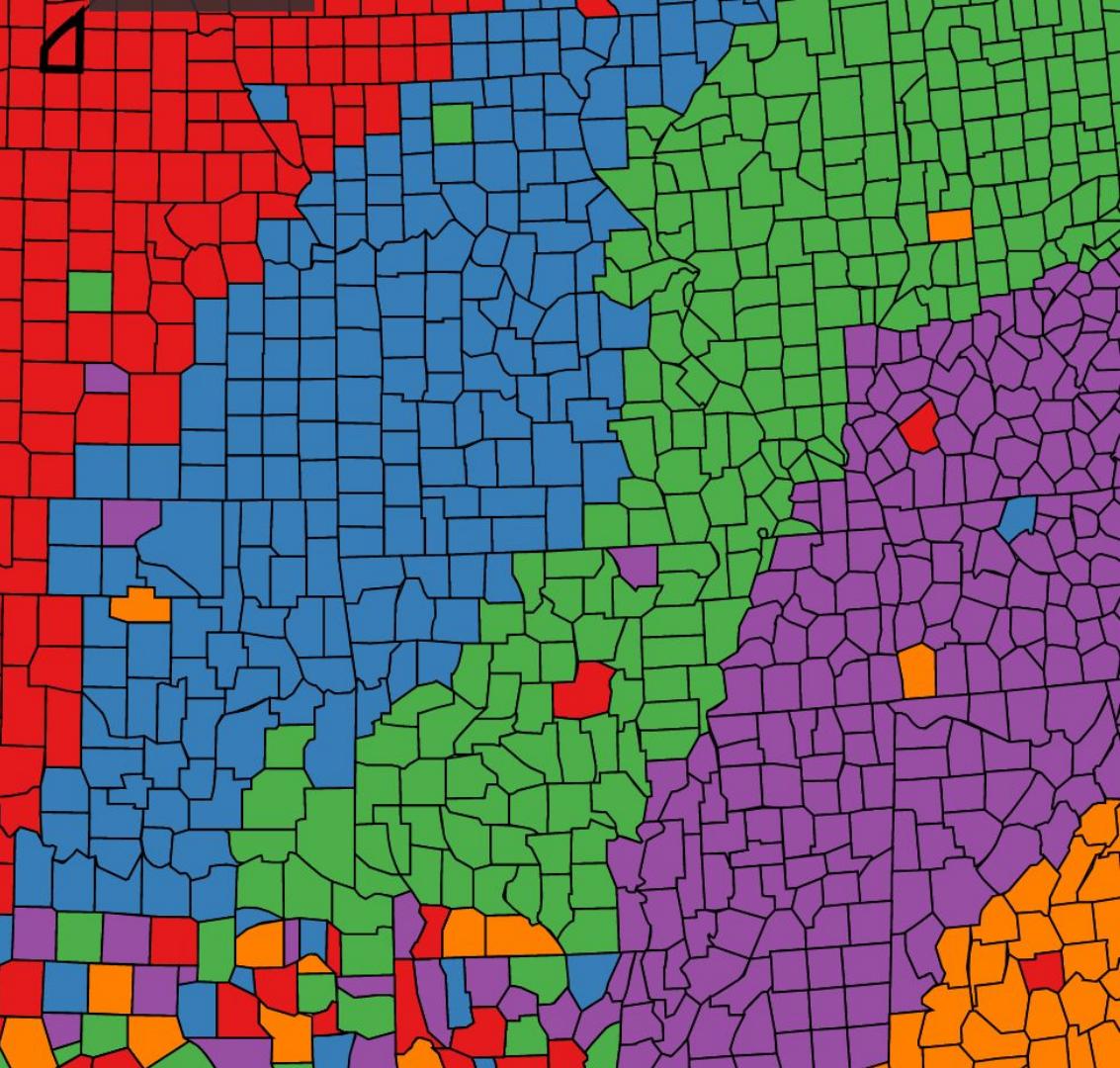
Rule #6 When using color to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colors for low values to increasingly darker and brighter colors for high values

Type of palettes

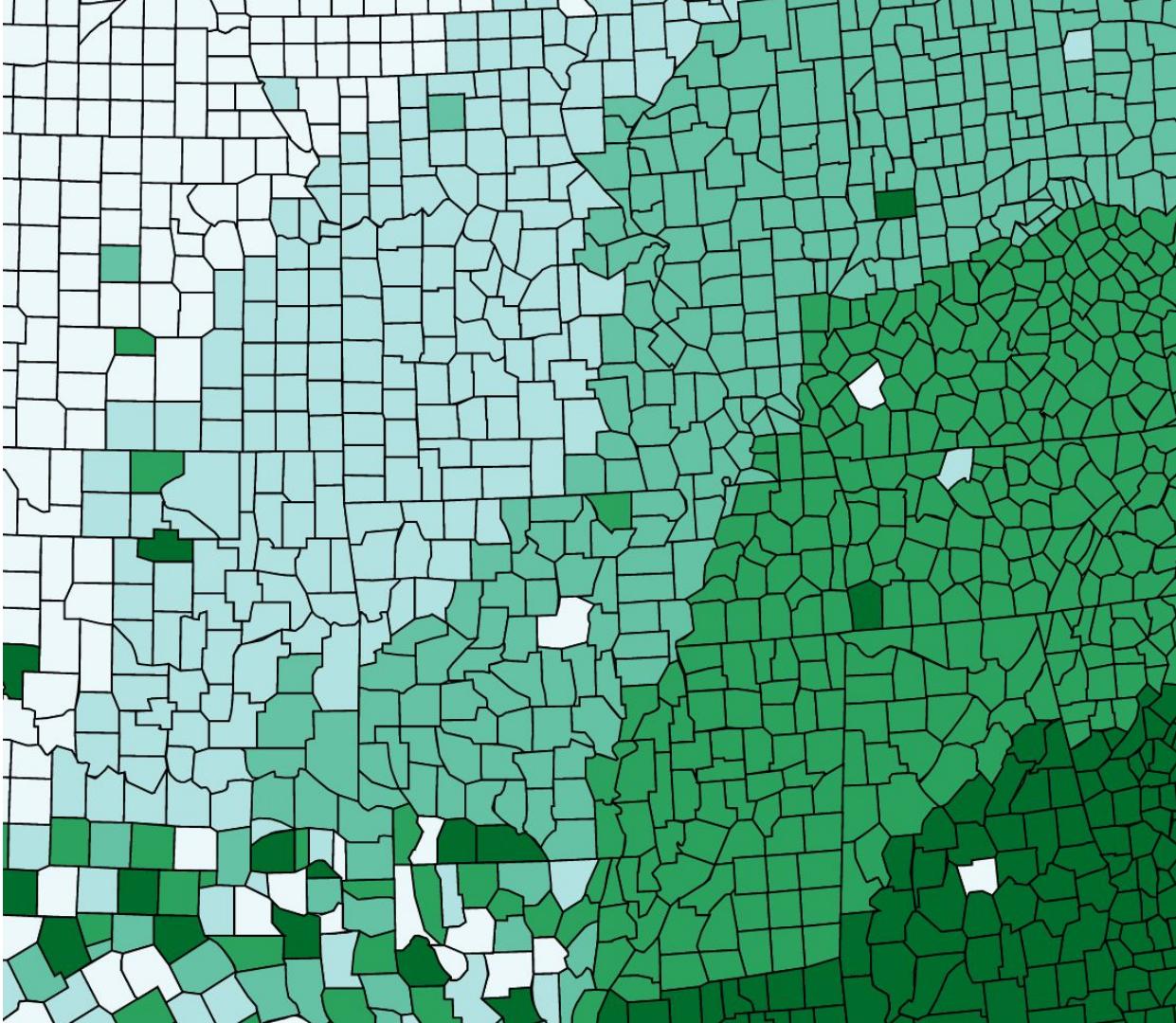
- Categorical
- Sequential
- Diverging

Demo <http://colorbrewer2.org/>

Categorical

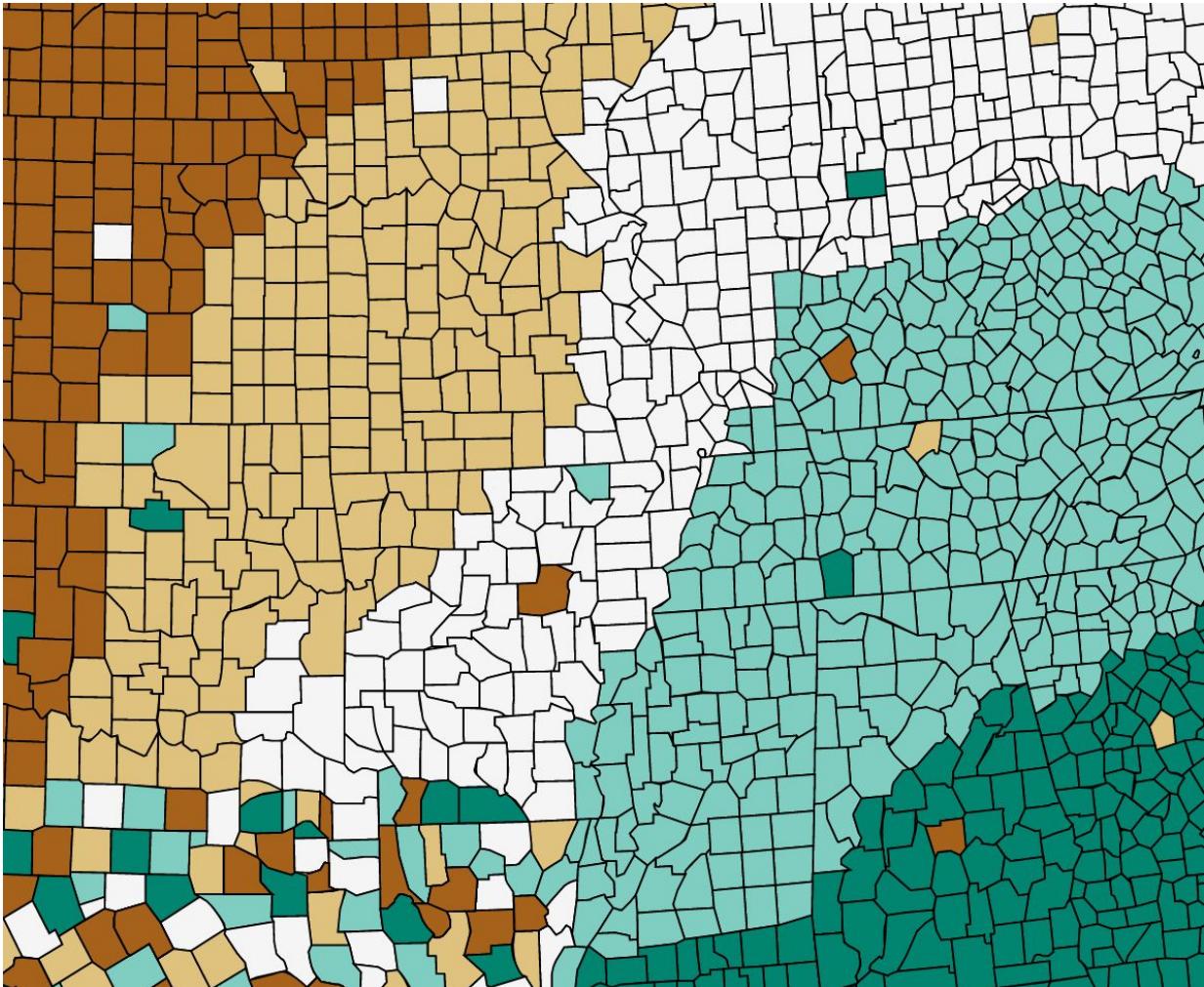


Sequential



<http://colorbrewer2.org/>

Diverging



What not to do: Rainbow colors

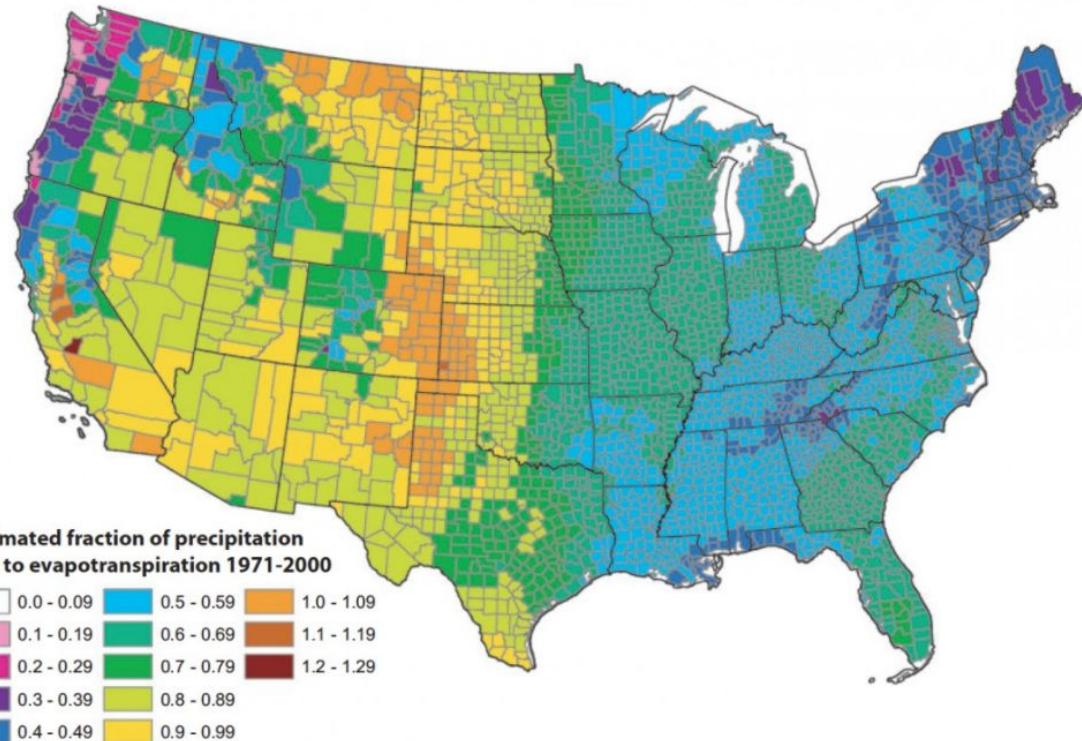
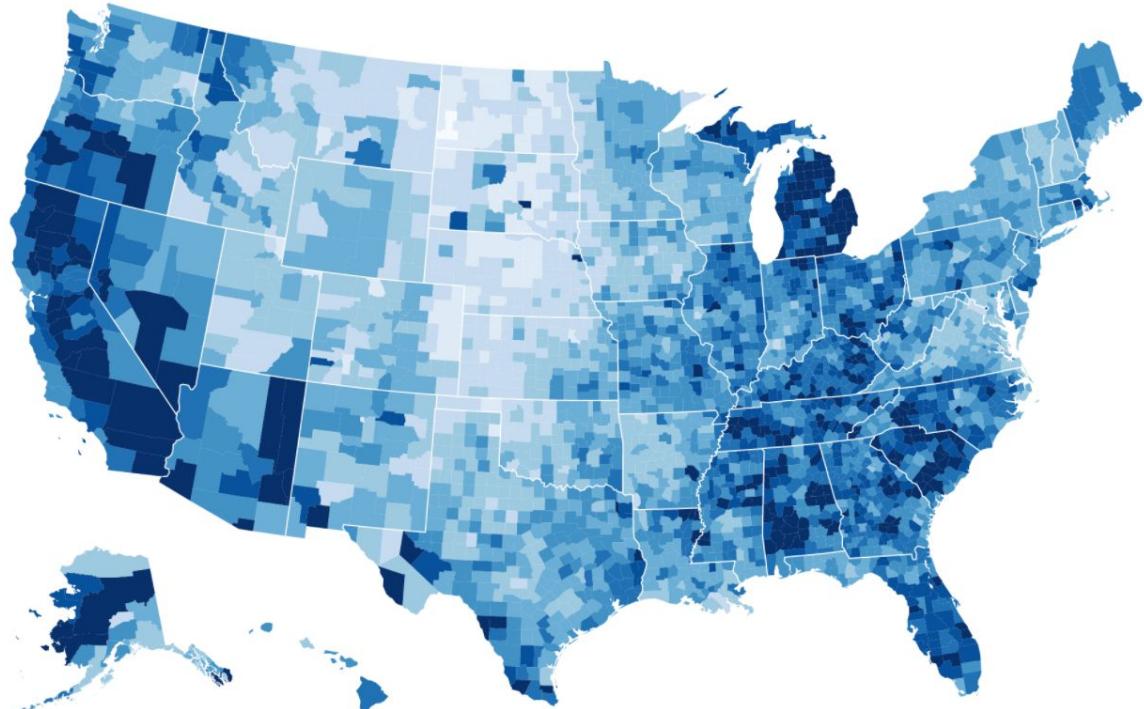


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

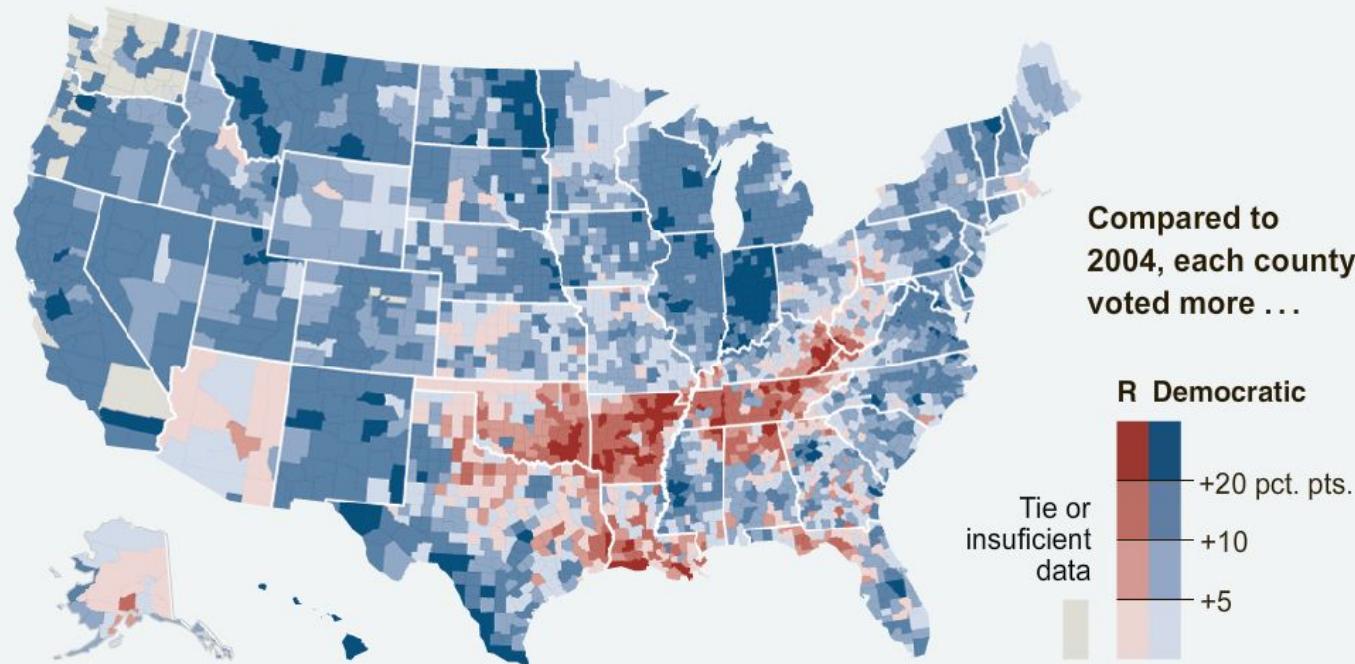
Choropleth

Areas are colored or patterned proportionally to the category or value of one or more variables being represented.



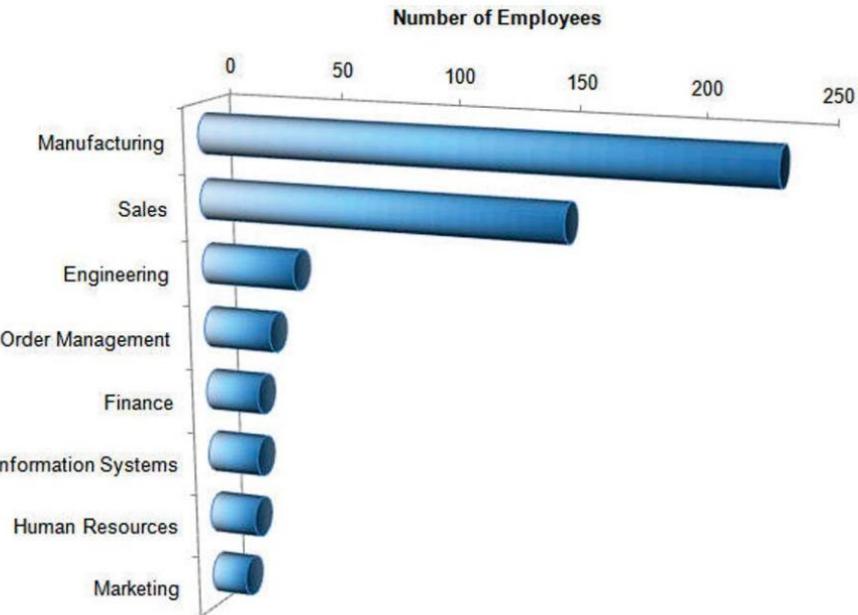
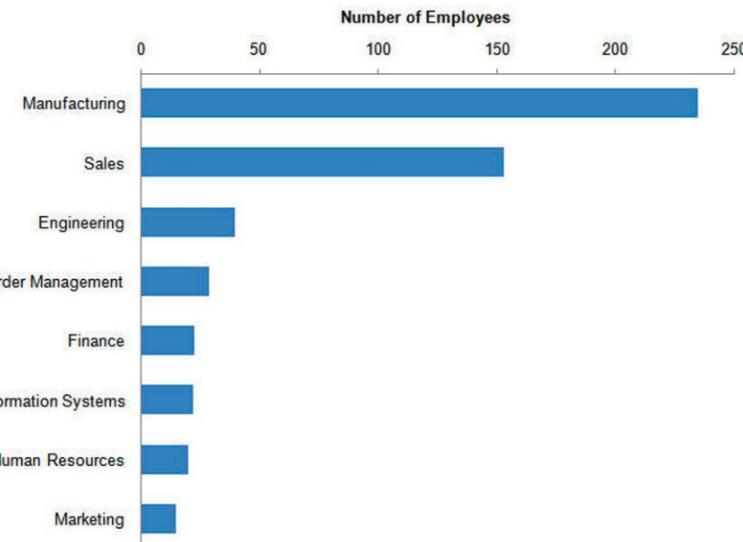
Choropleth with diverging palette

... while the rest of the nation shifted more Democratic.



Rule #8 To guarantee that most people who are colorblind can distinguish groups of data that are color coded, avoid using a combination of **red and green** in the same display.

Rule #9 Avoid using visual effects in graphs.

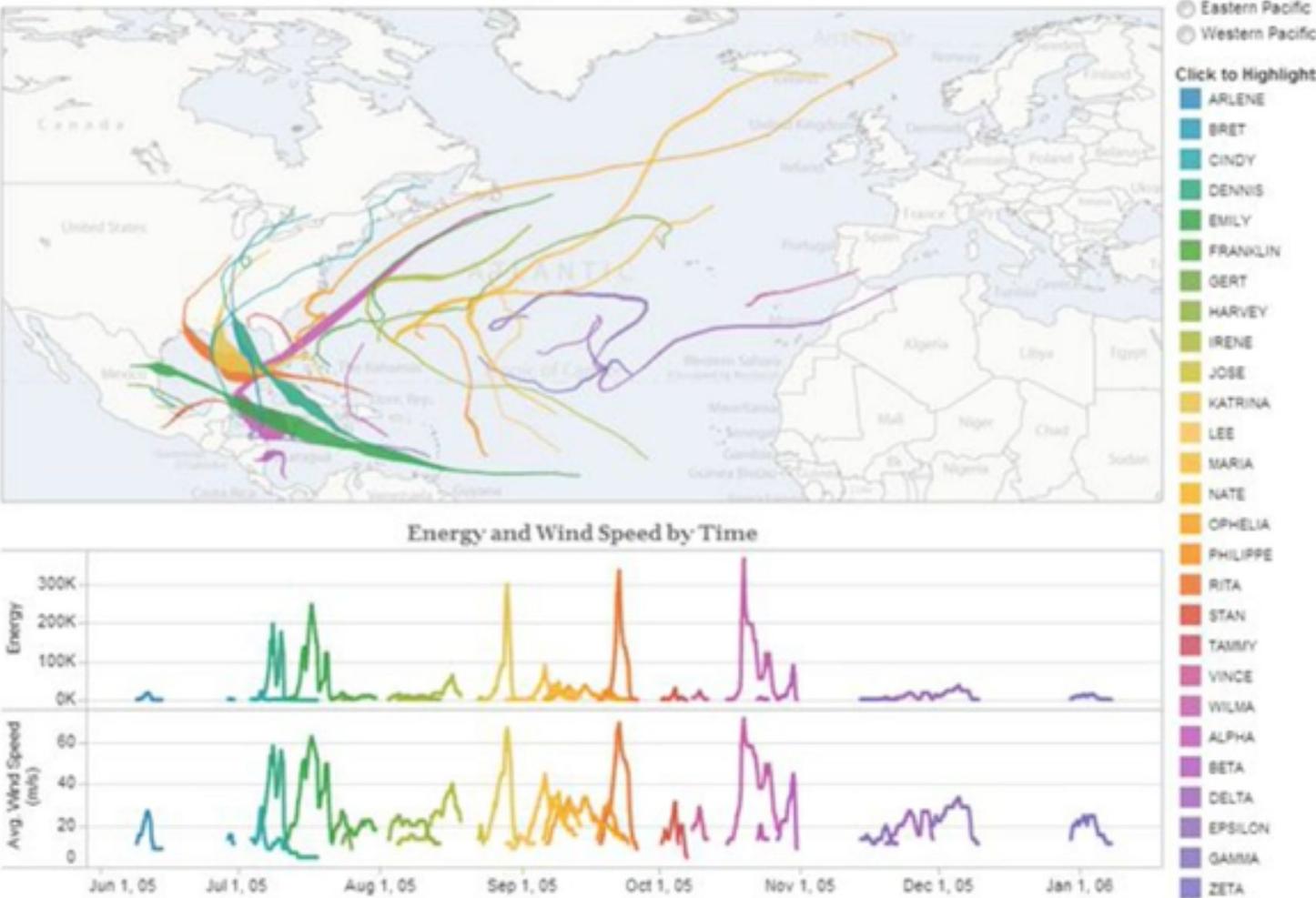


Tufte's fundamental use of color

- To label (identity or group)
- To measure (color to quantify, color scales)
- To represent or to imitate reality (semantic encoding)
- To decorate

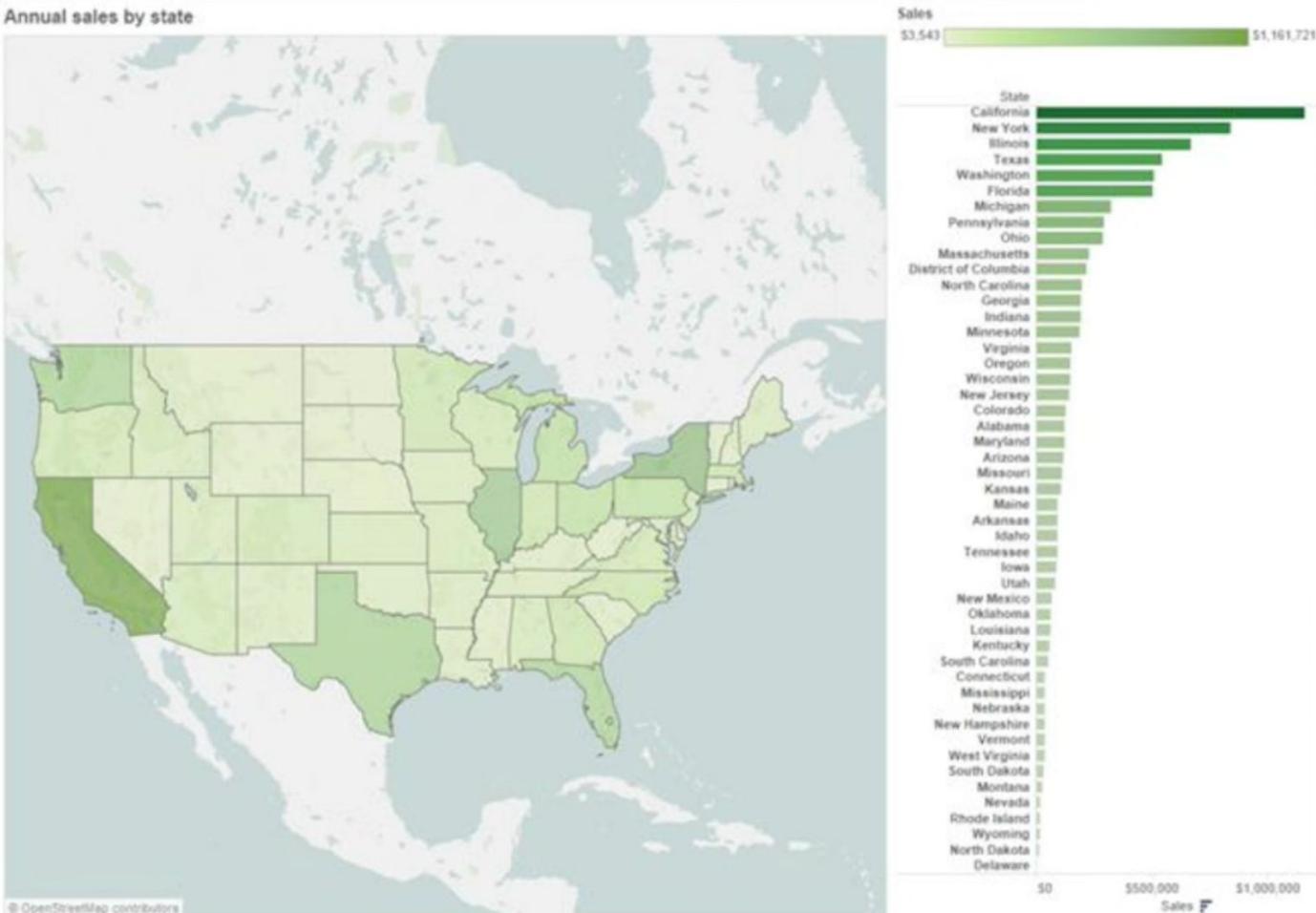
The 2005 Hurricane Season

To label



To measure

Annual sales by state



Semantic encoding

Sea → blue

Land → green

Roads → red



References

Visual thinking for design. Colin Ware (Chapters 1 and 2)

The functional art. Alberto Cairo (Chapter 6)

<https://www.tableau.com/learn/webinars/best-practices-using-color-data-visualizations-how-and-why>

http://www.perceptualedge.com/articles/visual_business_intelligence/rules_for_using_color.pdf

```
git clone git@github.com:usfviz/class-code.git
```

or

```
git pull
```