

The Science of Information Visualization

Houston Data Visualization Meetup

October 2015

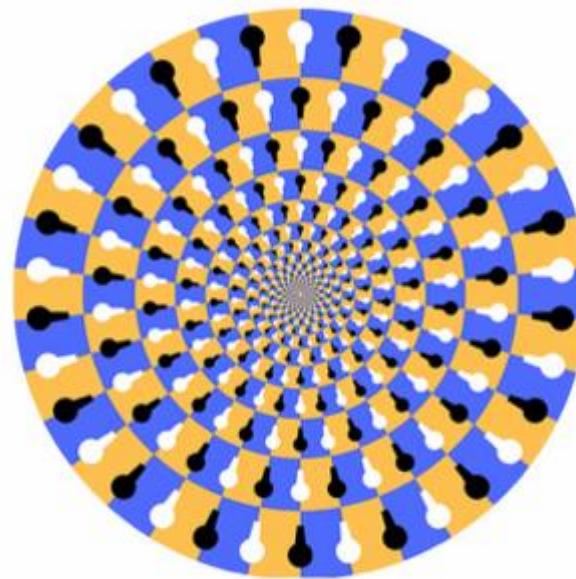
Overview

Visual Perception

- 70% of the body's sense receptors reside in our eyes
- “The eye and visual cortex of the brain form a massively parallel processor that provides the highest-bandwidth channel into human cognitive centers.” Colin Ware, *Information Visualization*, 2004
- Important to understand how visual perception works in order to effectively design visualizations

How the Eye Works

- The eye is not a camera!
- Better metaphor for vision: “dynamic and ongoing construction project” – Healey, 95
- Attention is selective (filtering)



Eyes vs. Cameras

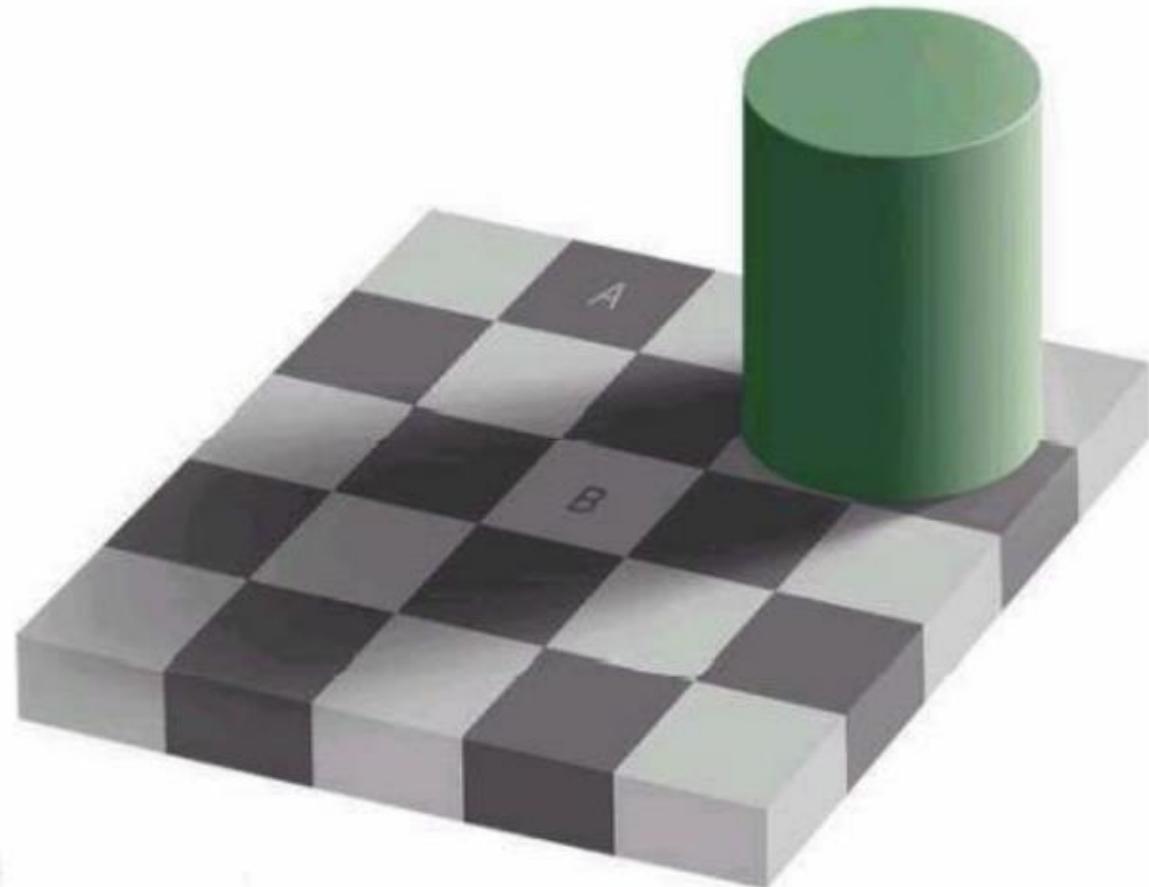
- Cameras
 - Good optics
 - Single focus, white balance, exposure
 - “Full image capture”



- Eyes
 - Relatively poor optics
 - Constantly scanning
 - Constantly adjusting focus
 - Constantly adapting (white balance, exposure)
 - Mental reconstruction of image (sort of)

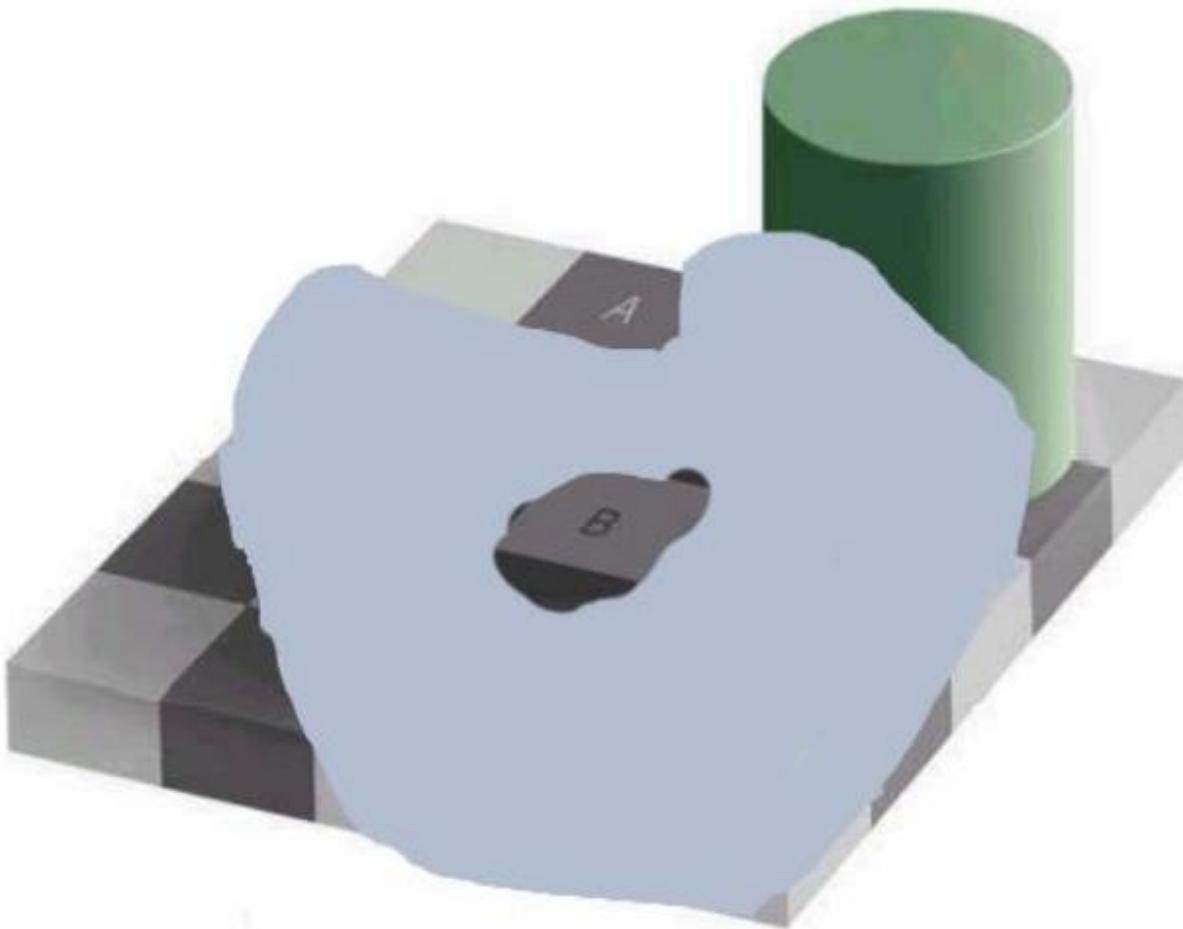


Visual perception is not just camera work



Square A is darker than B, right?

Visual perception is not just camera work



Square A is darker than B, right?

How many 5's

385720939823728196837293827

382912358383492730122894839

909020102032893759273091428

938309762965817431869241024

How many 5's

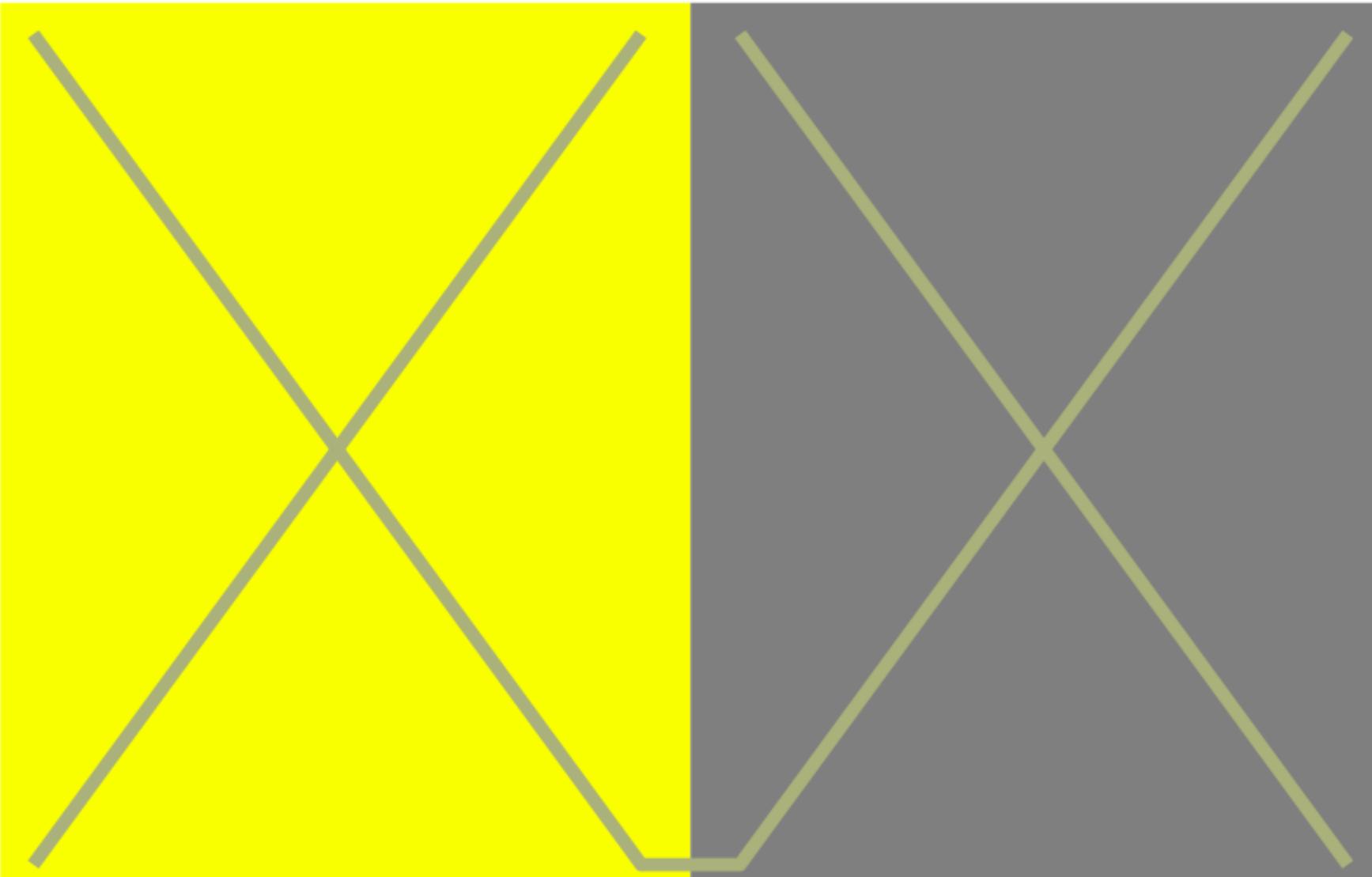
385720939823728196837293827

382912358383492730122894839

909020102032893759273091428

938309762965817431869241024

Color is relative



Visual Marks

Basic geometric elements

→ Points



0D

→ Lines



1D

→ Areas



2D

Visual Variables (aka Channels)

④ Position

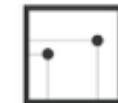
→ Horizontal



→ Vertical



→ Both



④ Color



④ Shape



④ Tilt

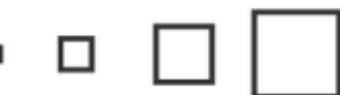


④ Size

→ Length



→ Area



→ Volume



Using Marks and Attributes



Length



Position



Color



Size

Most
Efficient



Least
Efficient

Position



Length



Slope



Angle



Area



Intensity



Color



Shape



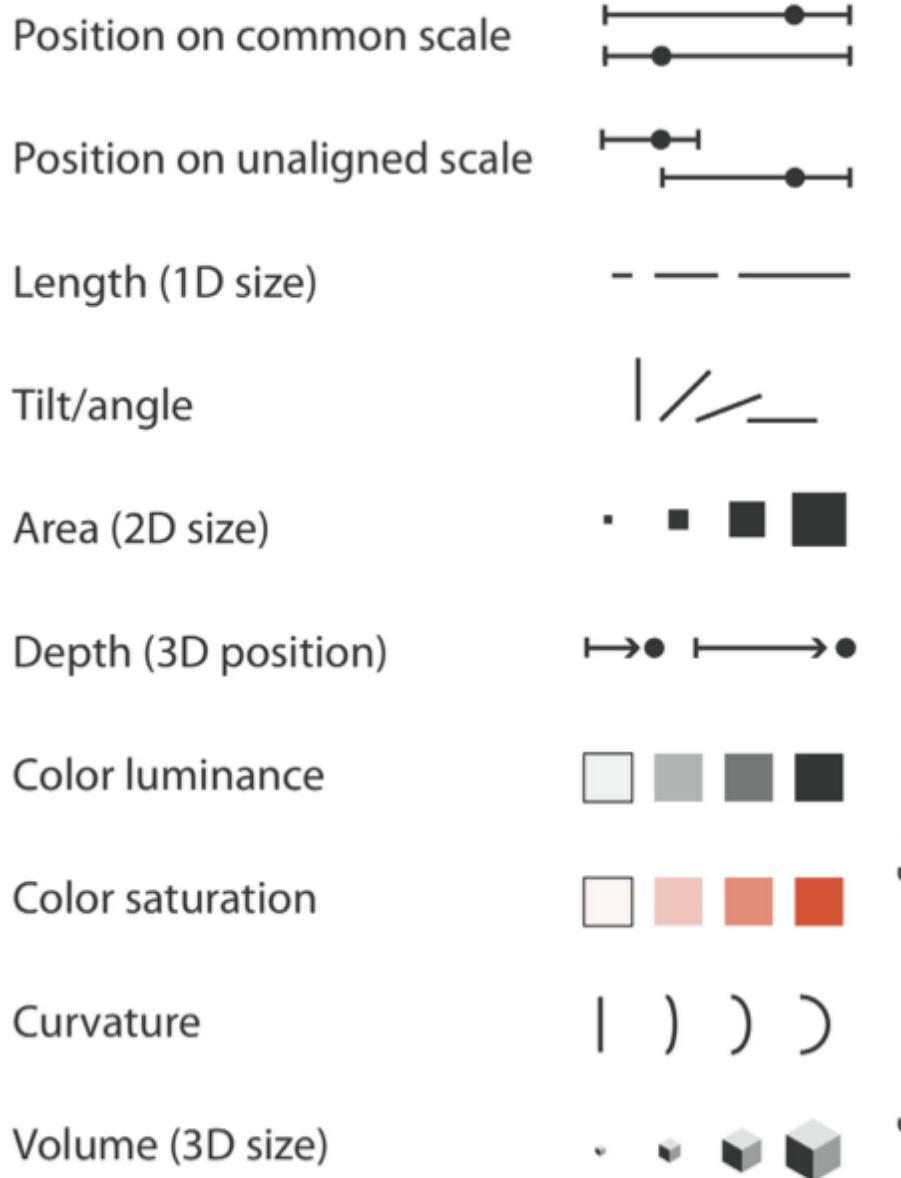
Quantitative

Ordinal

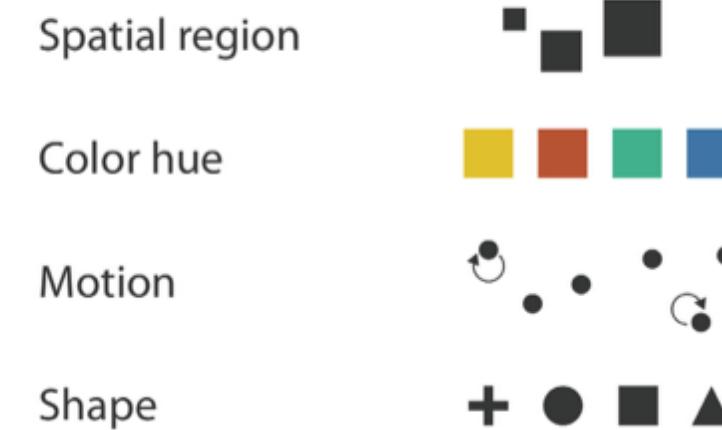
Nominal



→ **Magnitude Channels: Ordered Attributes**

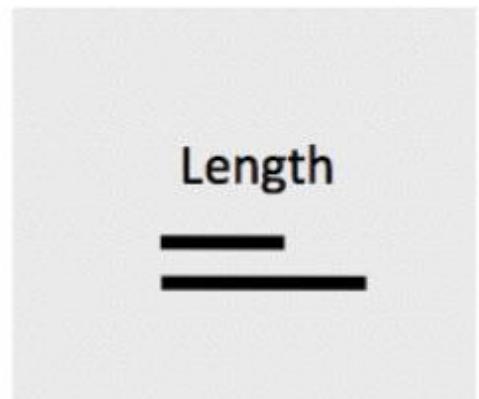
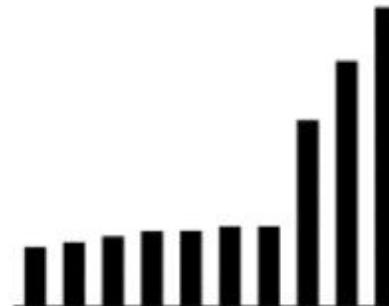
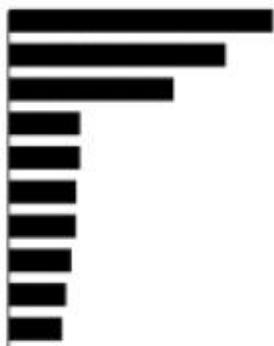
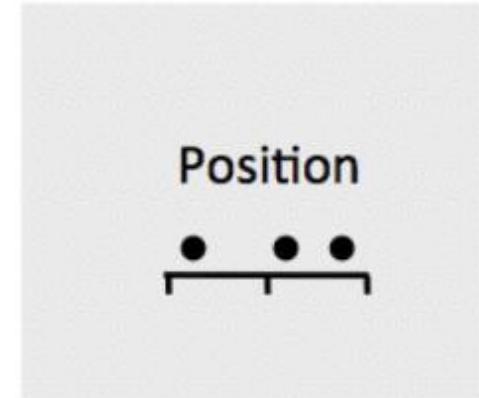
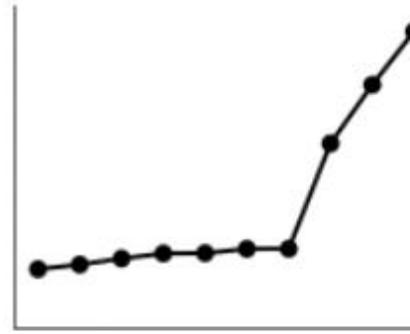


→ **Identity Channels: Categorical Attributes**

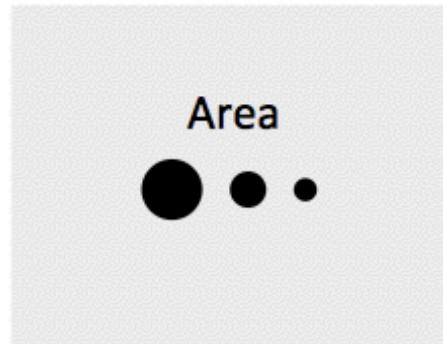
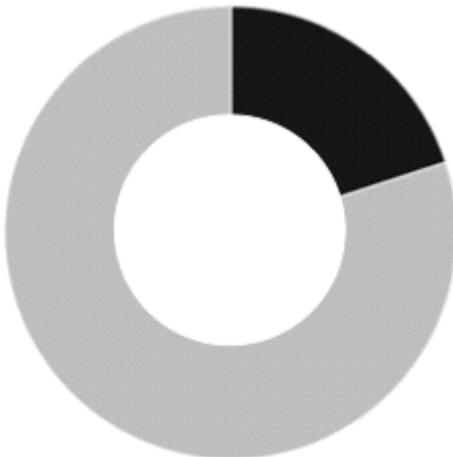
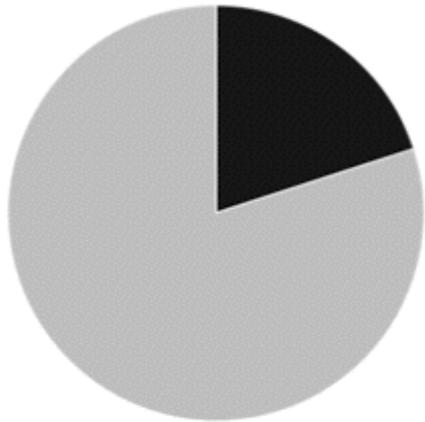


▲ Most
Effectiveness
▼ Least
Effectiveness
Same

Most Effective For Quantitative/Ordinal Data



Less Effective For Quantitative/Ordinal Data



Least Effective: Color For Quantitative/Ordinal Data

SANFORD AND SELNICK

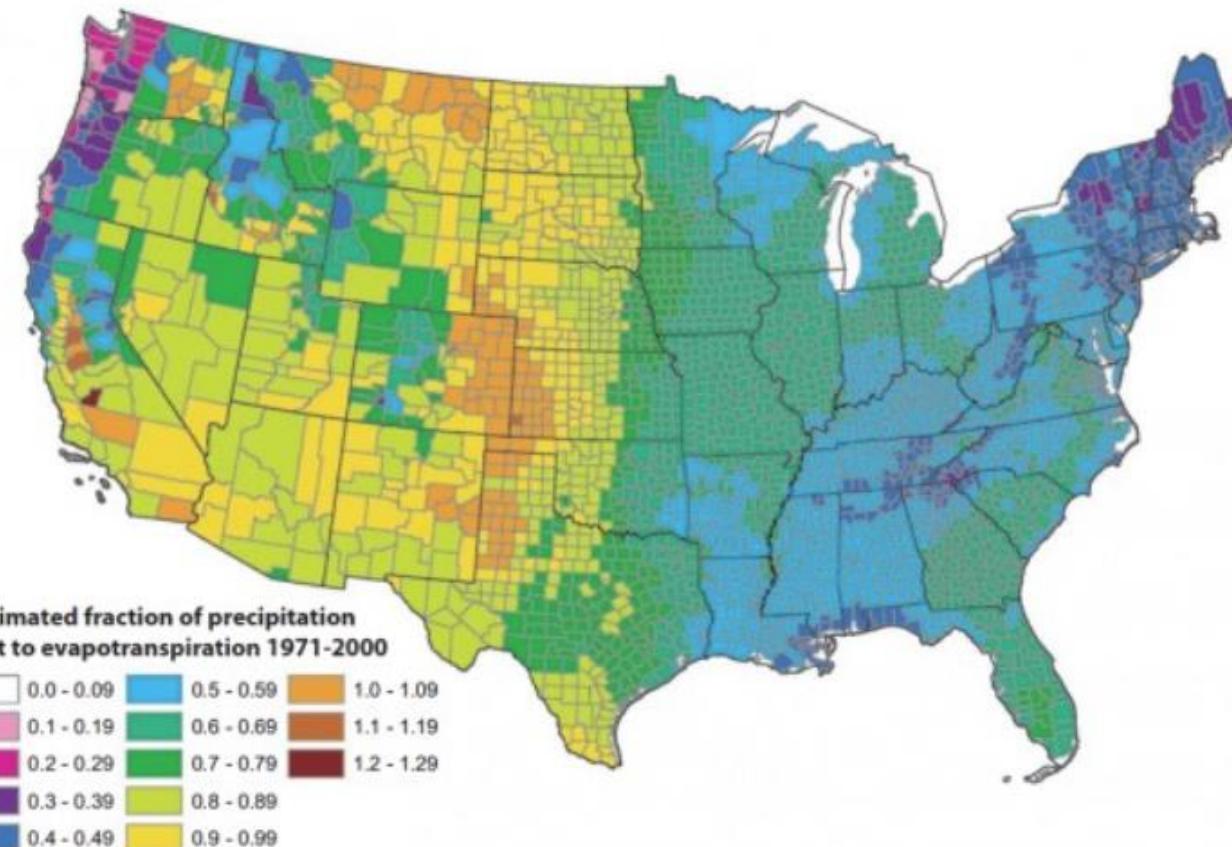


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM 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.

Bertin's Visual Attributes

Jacques Bertin

- French cartographer (1918 – 2010)
- Semiology of Graphics (1967)
- Theoretical principles for visual encodings



Bertin's Visual Variables

Bertin's Original Visual Variables	
Position changes in the x, y location	
Size change in length, area or repetition	
Shape infinite number of shapes	
Value changes from light to dark	
Colour changes in hue at a given value	
Orientation changes in alignment	
Texture variation in 'grain'	

Bertin's Visual Attributes

Channels

Position

Size

(Grey) Value

Texture

Color

Orientation

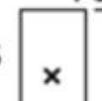
Shape

Marks Points Lines Areas

LES VARIABLES DE L'IMAGE

XY
2 DIMENSIONS
DU PLAN

POINTS



LIGNES



ZONES



Z
TAILLE

VALEUR

LES VARIABLES DE SÉPARATION DES IMAGES

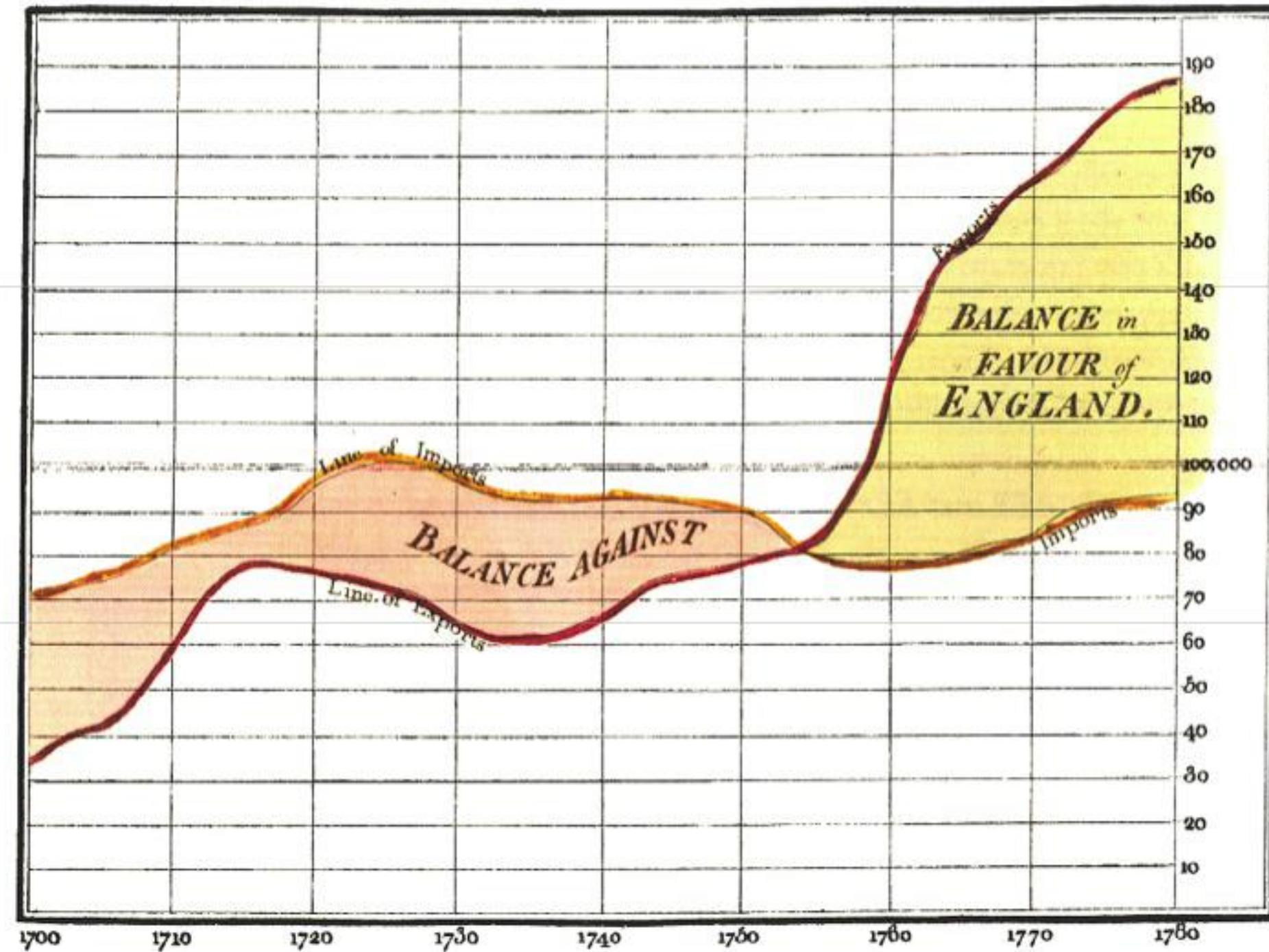
GRAIN

COULEUR

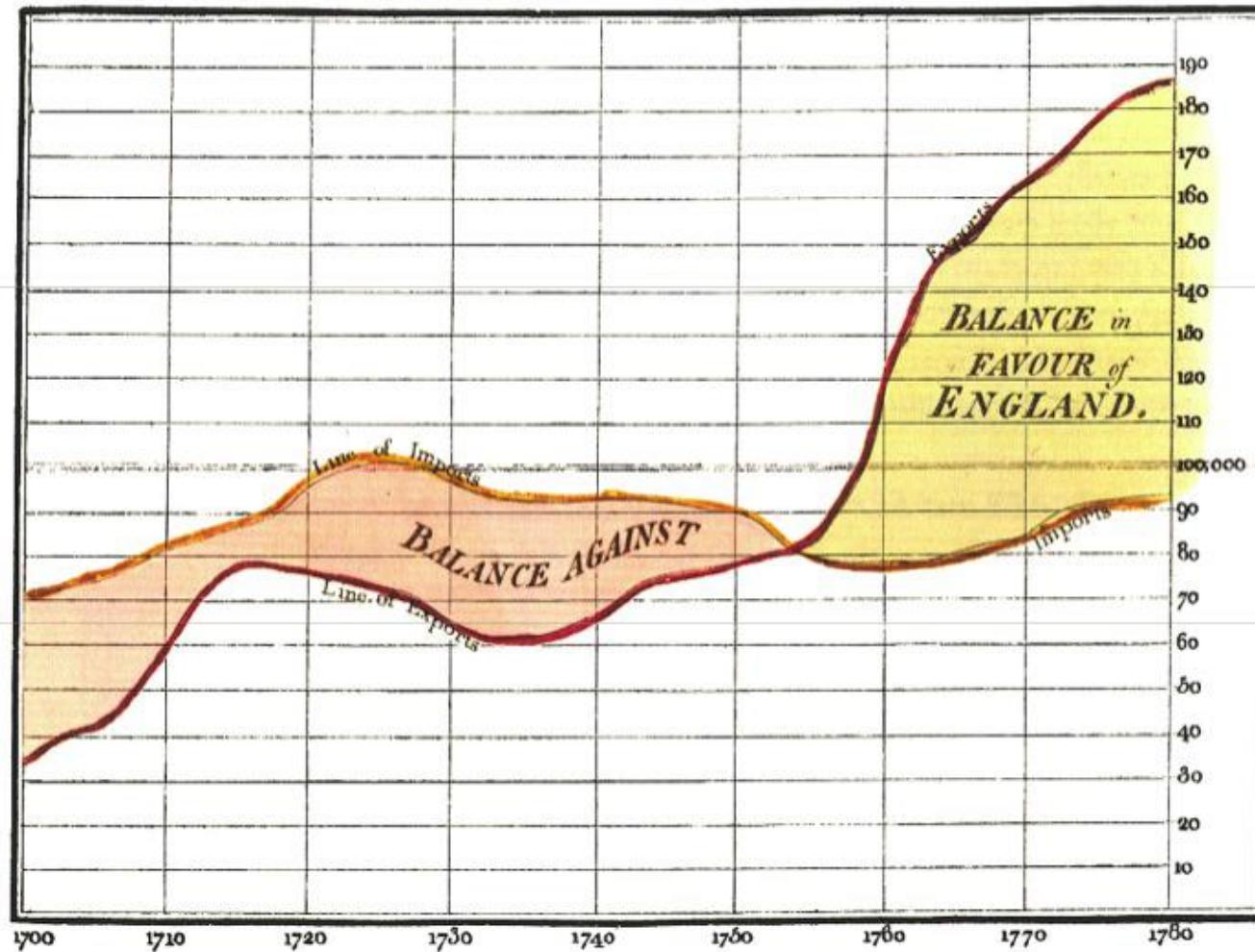
ORIENTATION

FORME

Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



x-axis: Year (Q)uantity

y-axis: Currency (Q)uantity

Color: Imports / Exports (N)ominal

Color: Positive / Negative (O)rdered

Bertin's Visual Attributes (1967)

	Categories	Ordinal	Quantitative
Position	✓	✓	✓
Length	✓	✓	✓
Brightness	✓	✓	~
Texture	✓	~	✗
Color	✓	~	✗
Angle	✓	✗	✗
Shape	✓	✗	✗

✓ = Good

~ = OK

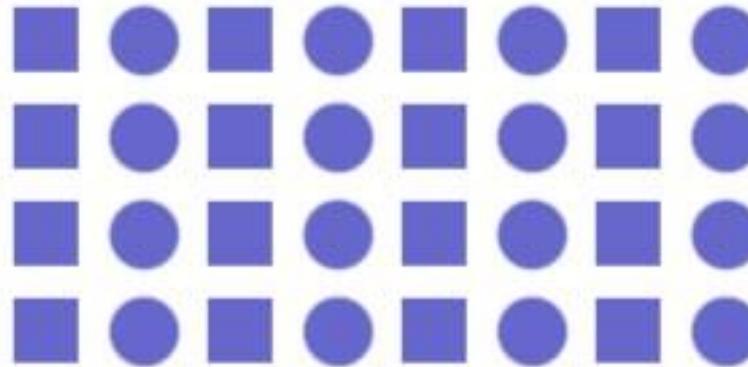
✗ = Bad

Gestalt's Laws of Perceptual Organization

Gestalt's Laws of Perceptual Organization

1. Similarity
2. Pragnanz
3. Proximity
4. Continuity
5. Closure

Gestalt's Laws of Perceptual Organization

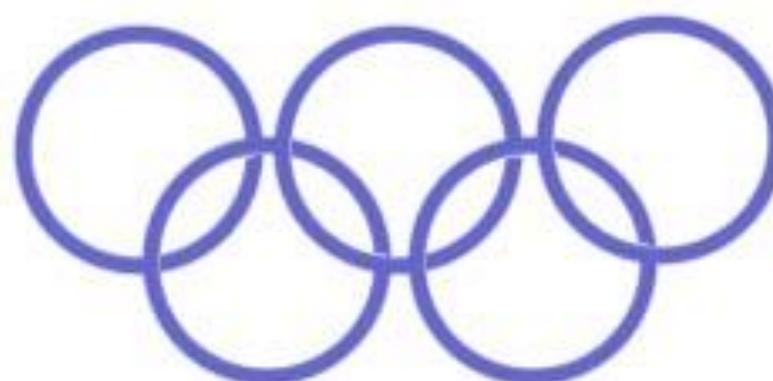


Law of Similarity:

Items that are similar tend to be grouped together.

In the image above, most people see vertical columns of circles and squares.

Gestalt's Laws of Perceptual Organization

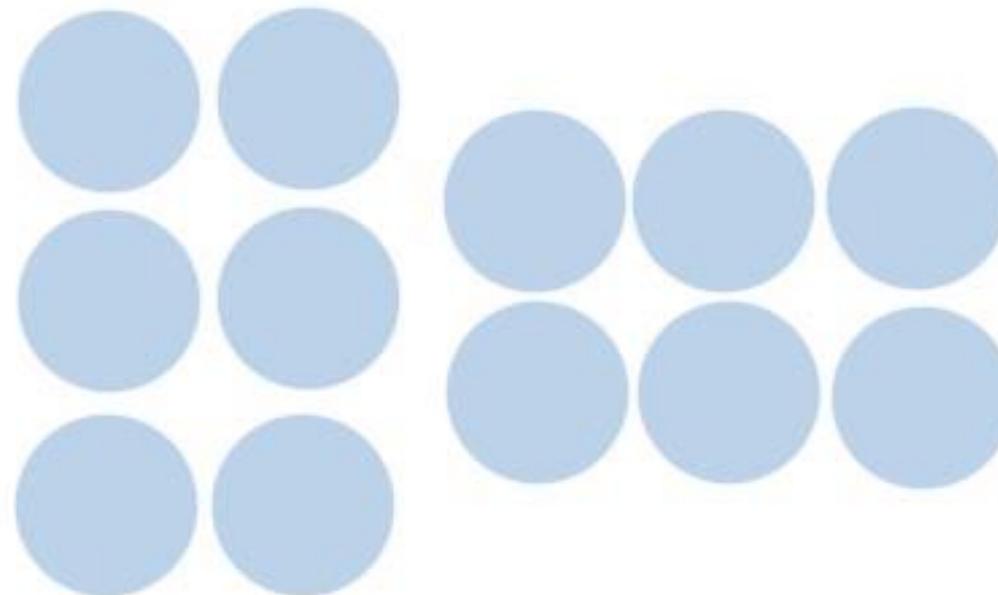


Law of Pragnanz:

Reality is organized or reduced to the simplest form possible.

For example, we see the image above as a series of circles rather than as many much more complicated shapes.

Gestalt's Laws of Perceptual Organization

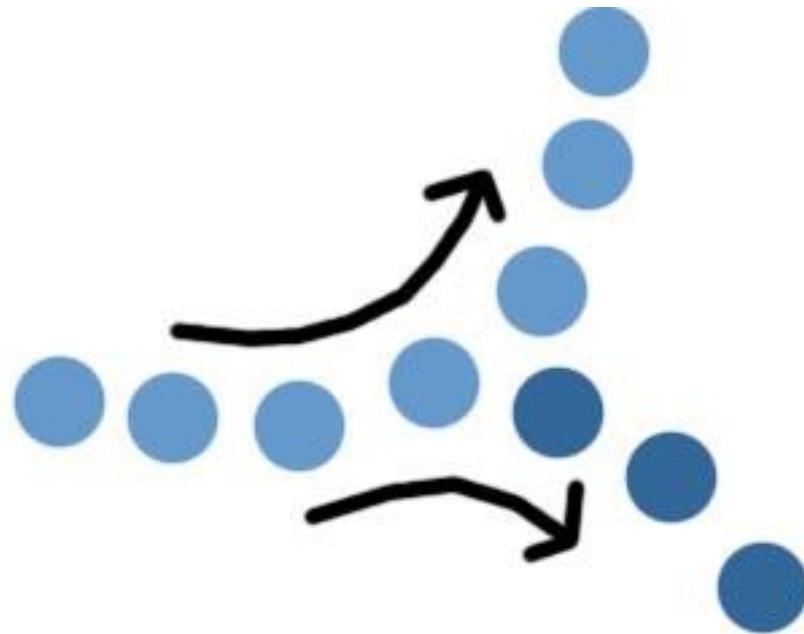


Law of Proximity:

Objects near each other tend to be grouped together.

The circles on the left appear to be grouped in vertical columns, while those on the right appear to be grouped in horizontal rows.

Gestalt's Laws of Perceptual Organization

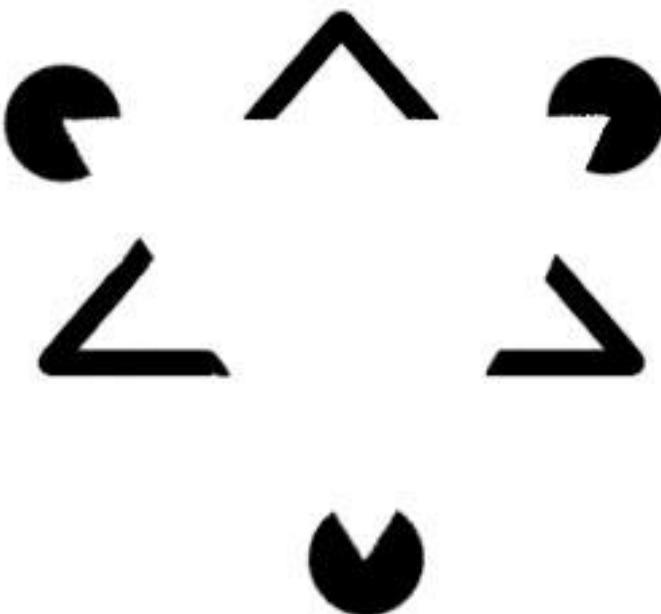


Law of Continuity:

Lines are seen as following the smoothest path.

In the image above, the top branch is seen as continuing the first segment of the line. This allows us to see things as flowing smoothly without breaking lines up into multiple parts.

Gestalt's Laws of Perceptual Organization



Law of Closure:

Objects grouped together are seen as a whole.

We tend to ignore gaps and complete contour lines. In the image above, there are no triangles or circles, but our minds fill in the missing information to create familiar shapes and images.

Graphical Perception

Graphical Perception

- Some visual processing takes place without any conscious effort on our part
- This is termed *preattentive vision*
- Graphical perception derives from preattentive vision to extract information from graphs
- Graphs which convey their information at this unconscious level allow us to extract the information without any considered effort on our part

Preattentive Processing

- A limited set of visual properties are processed preattentively
 - (without need for focusing attention)
- This is important for design of visualizations
 - What can be perceived immediately?
 - Which properties are good discriminators?
 - What can mislead viewers?

Preattentive Attributes (Ranked)

Journal of the American Statistical Association, September 1984

1. Position on common scale
2. Position on non-aligned scale
3. Length
4. Direction
5. Angle
6. Area
7. Volume
8. Curvature
9. Shading

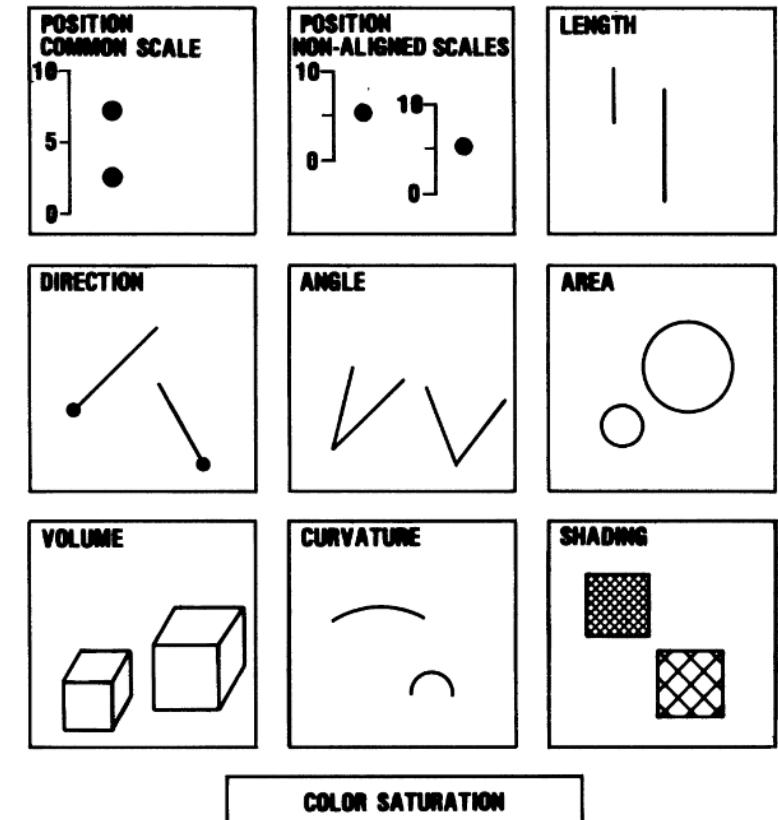
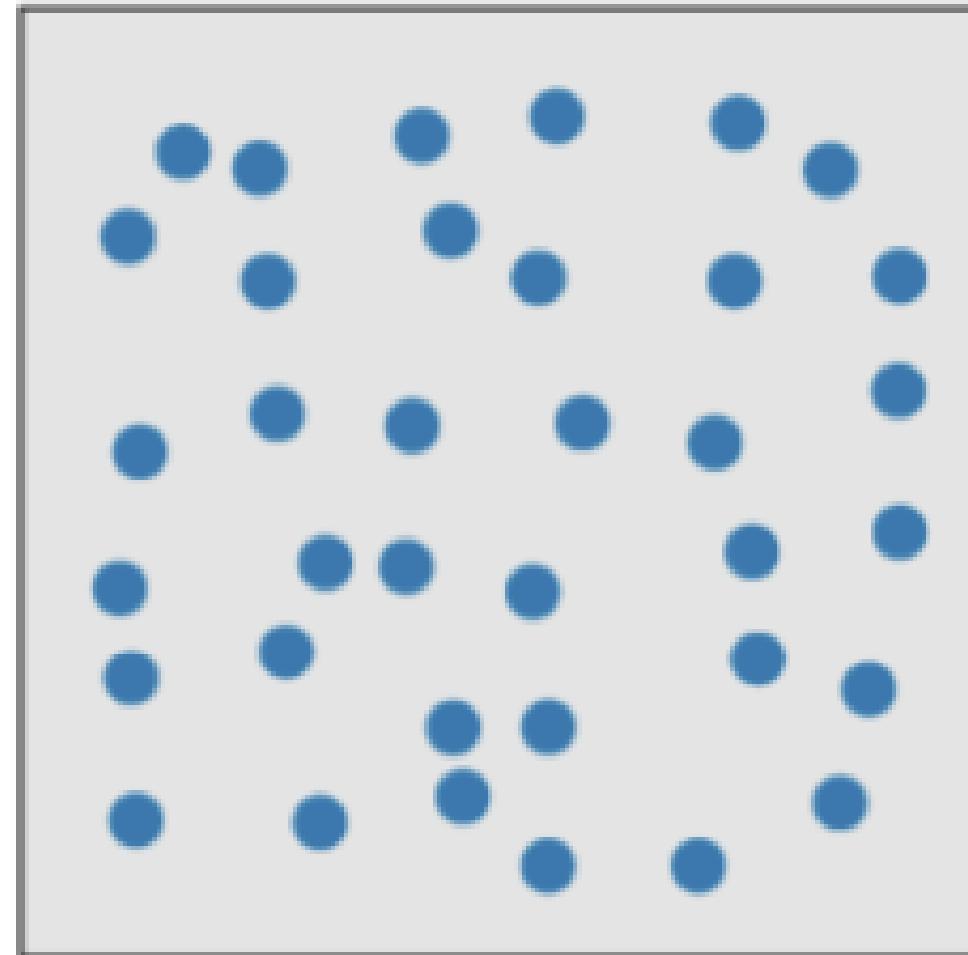
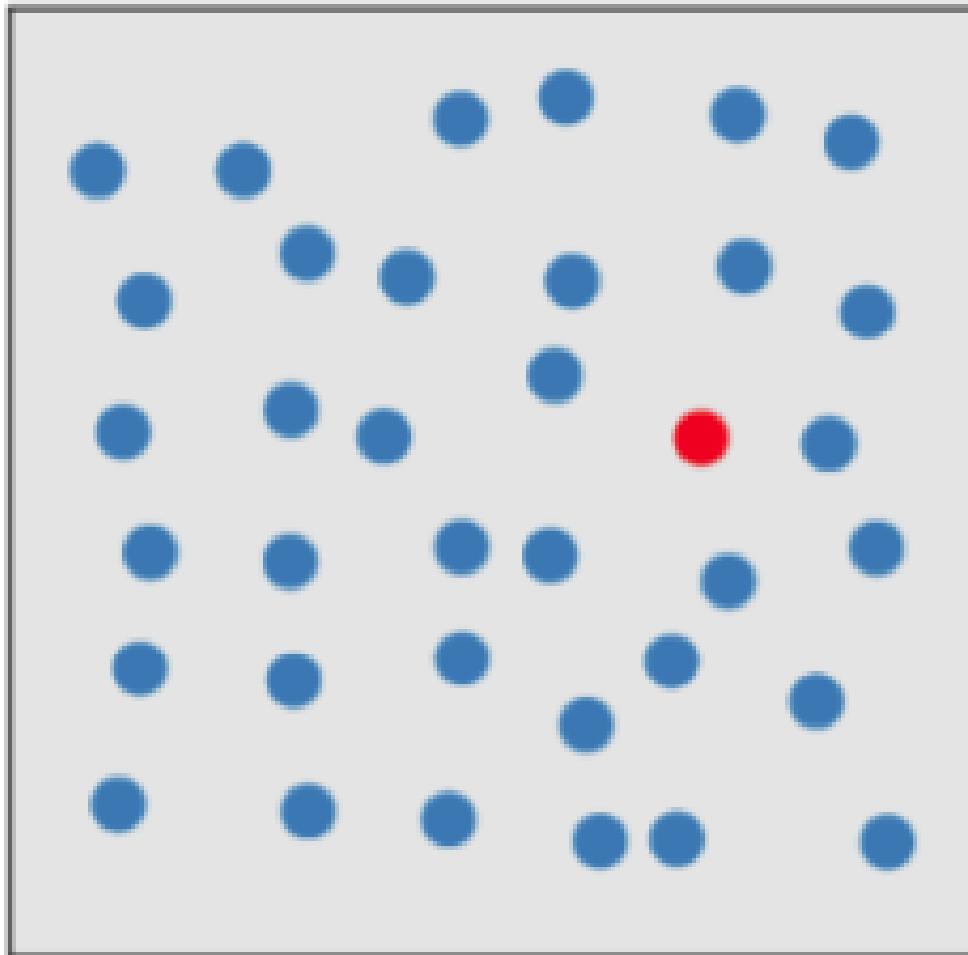
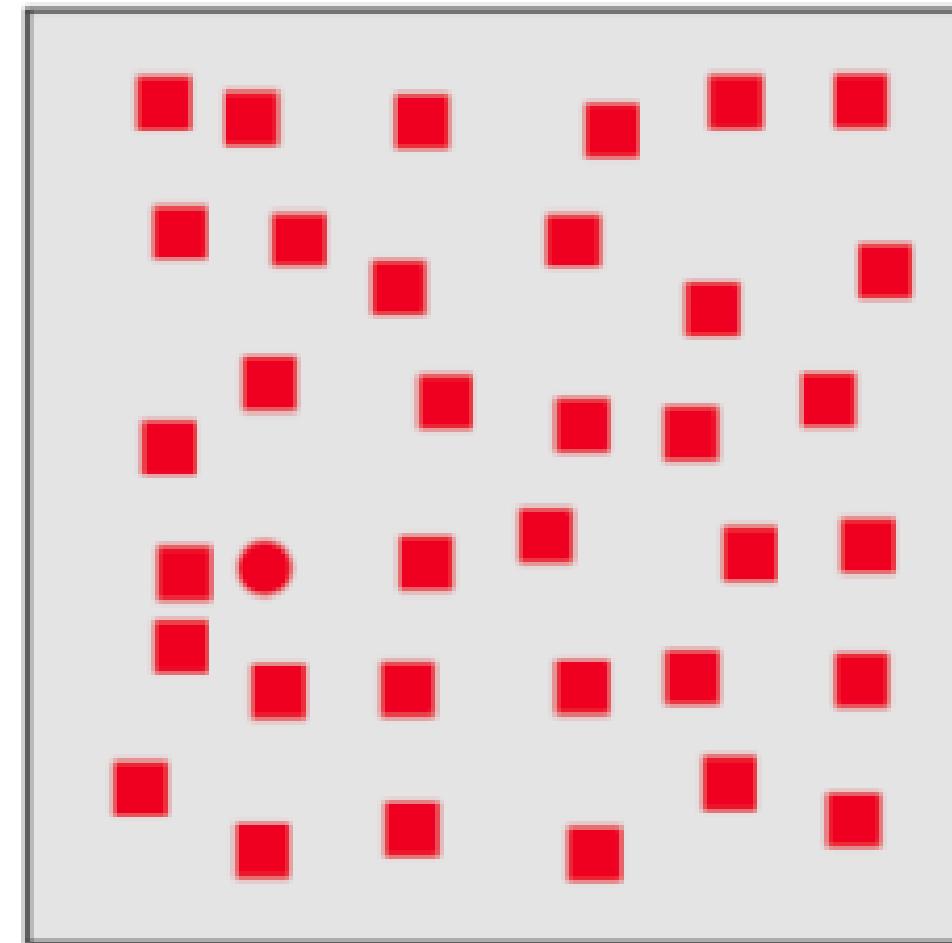
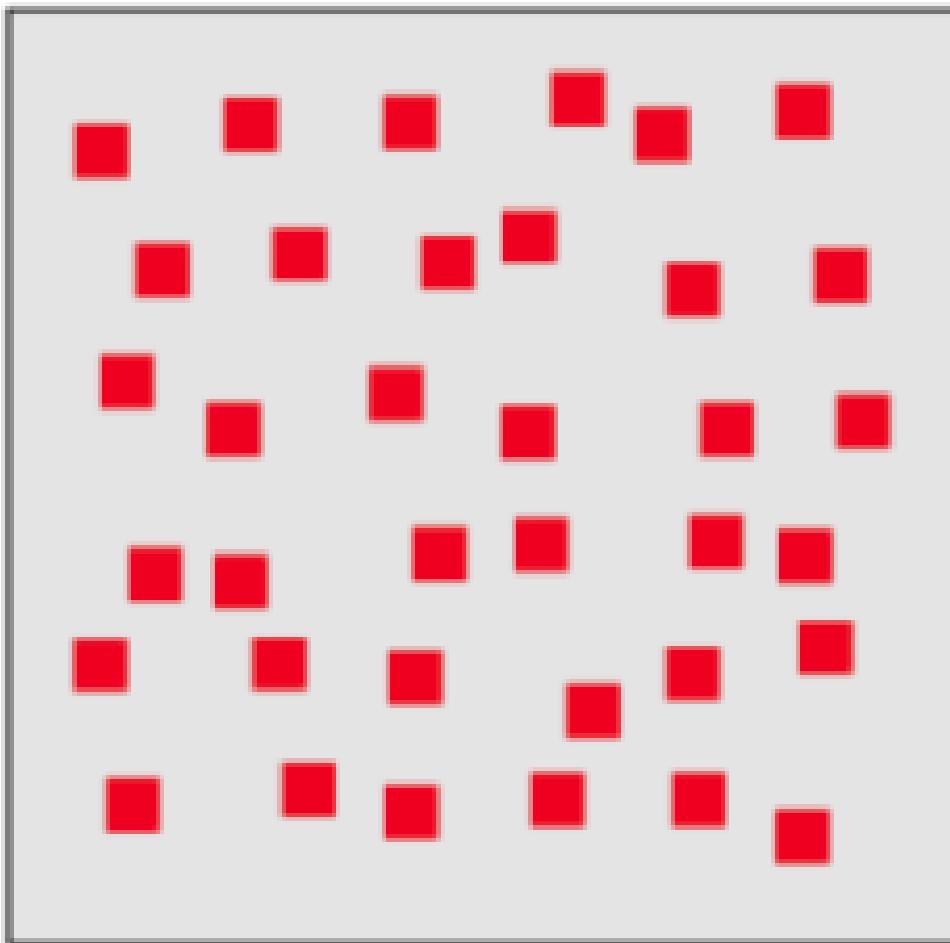


Figure 1. Elementary perceptual tasks.

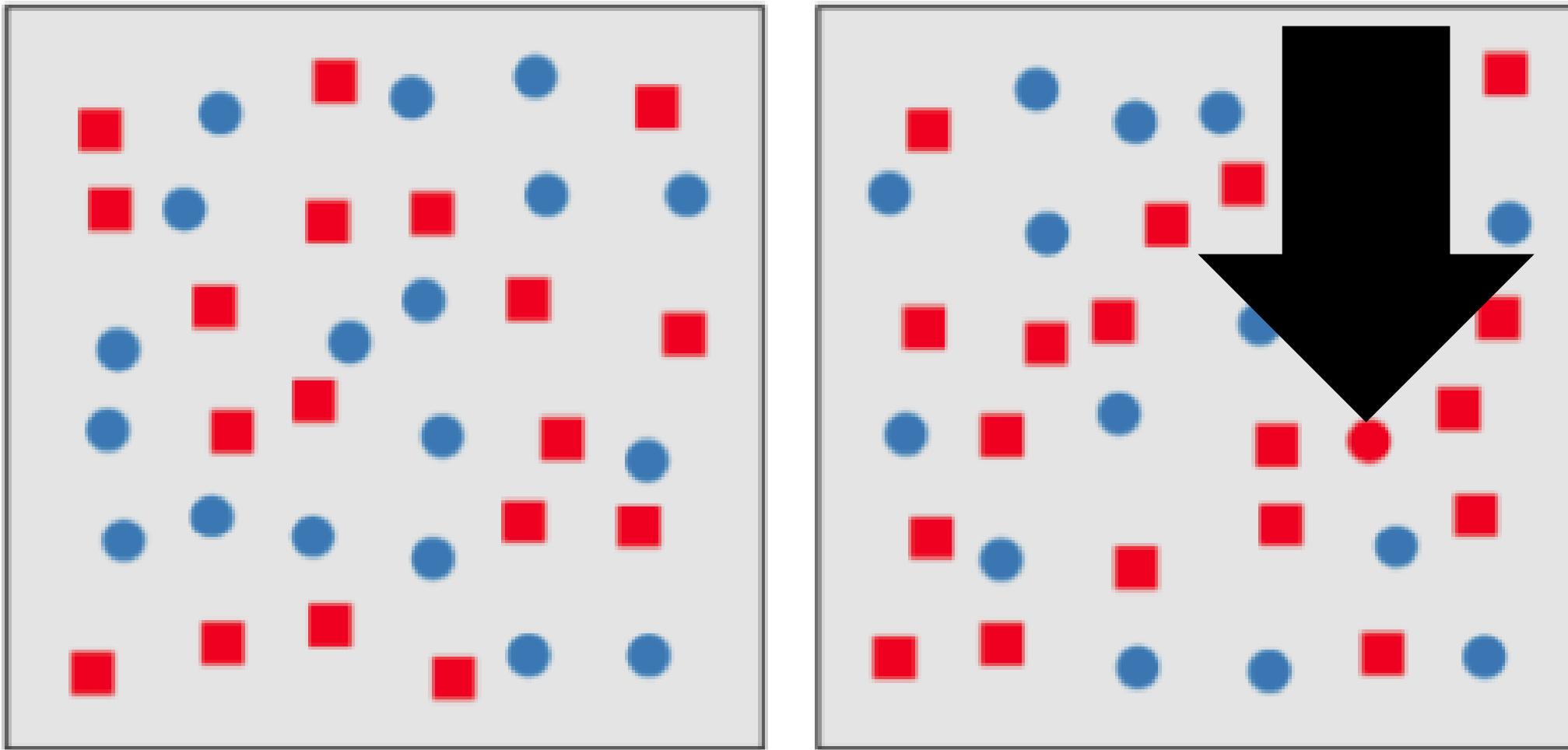
Preattentive Processing (Hue)



Preattentive Processing (Curvature)

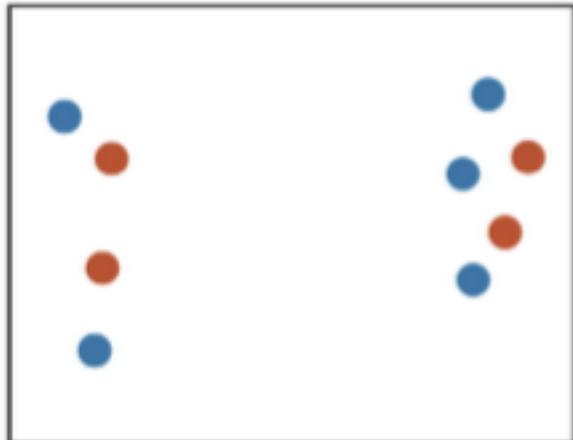


Preattentive Processing Limits (Conjunction of Attributes)



Separability of Attributes

Position
+ Hue (Color)



Fully separable

Size
+ Hue (Color)



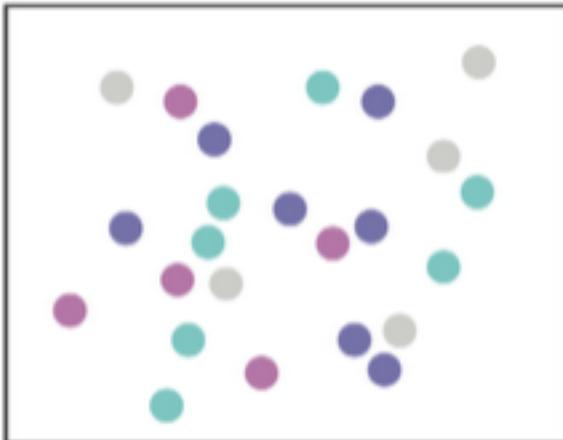
Some interference

Width
+ Height



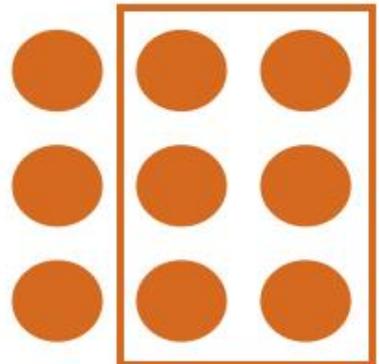
Some/significant
interference

Red
+ Green

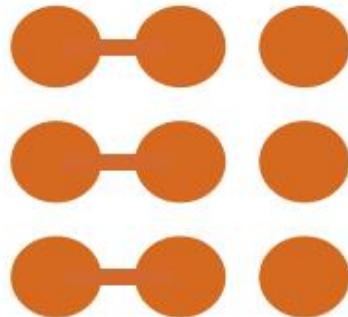


Major interference

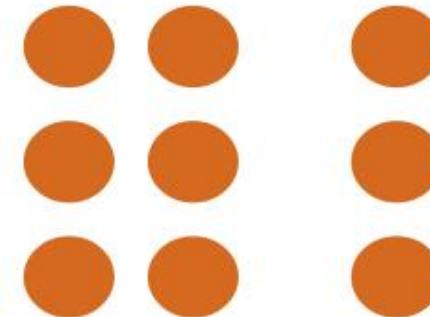
Grouping Principles



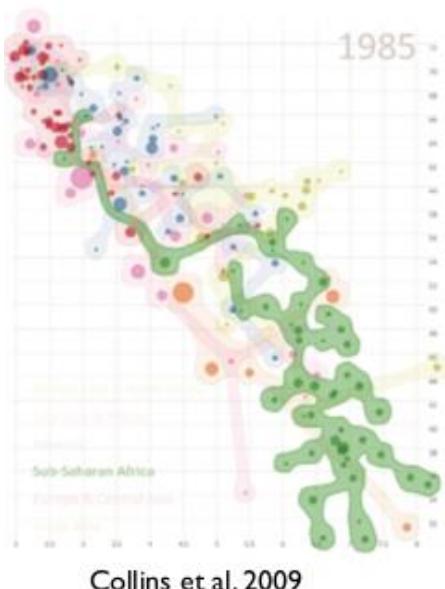
Containment



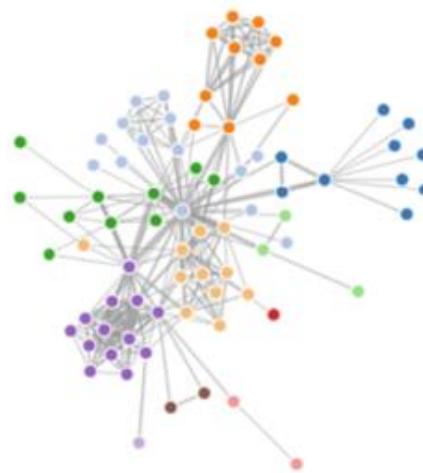
Connection



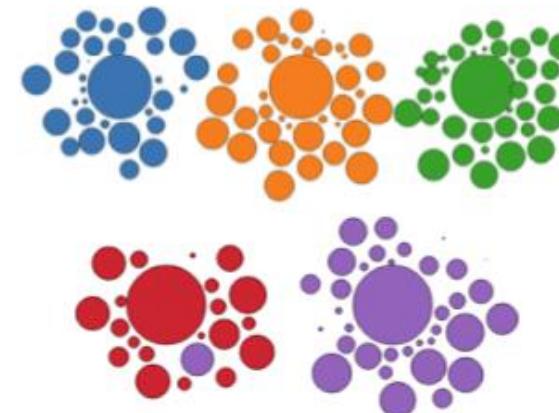
Proximity



Collins et al. 2009

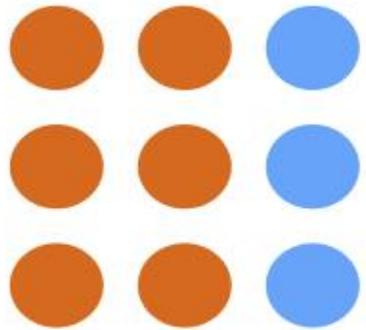


D3.js Example

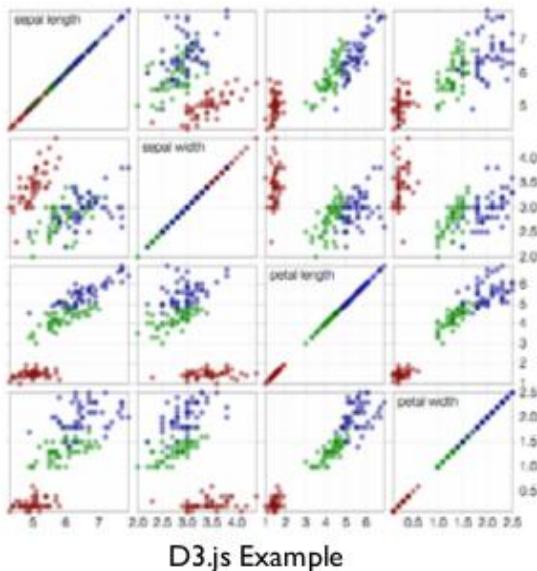


D3.js Example

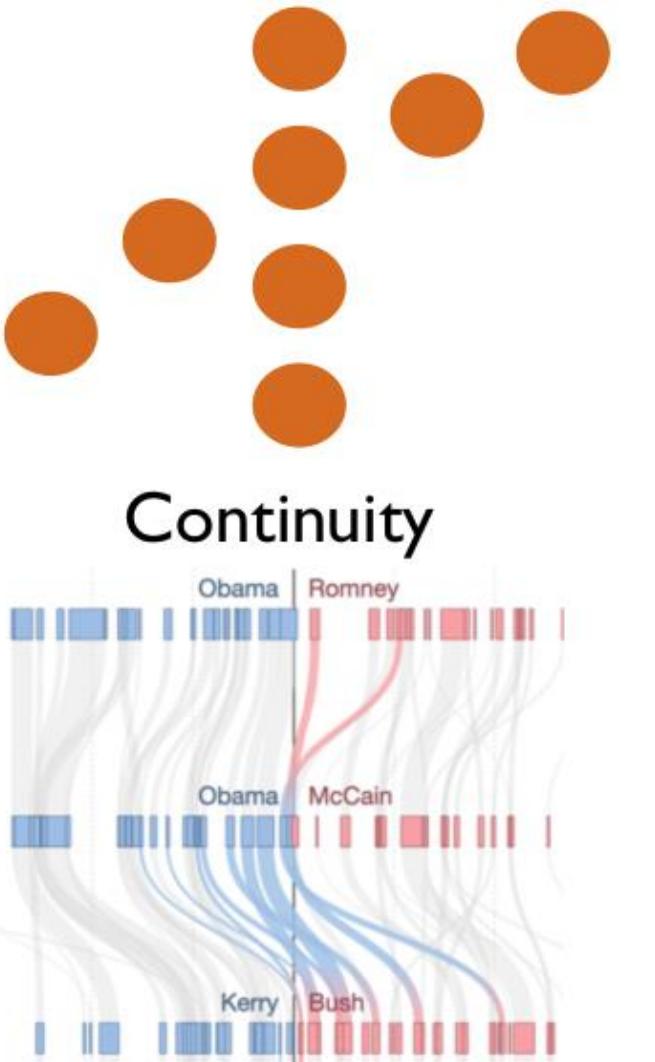
Grouping Principles



Similarity



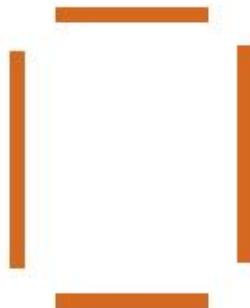
D3.js Example



NYT Swing States

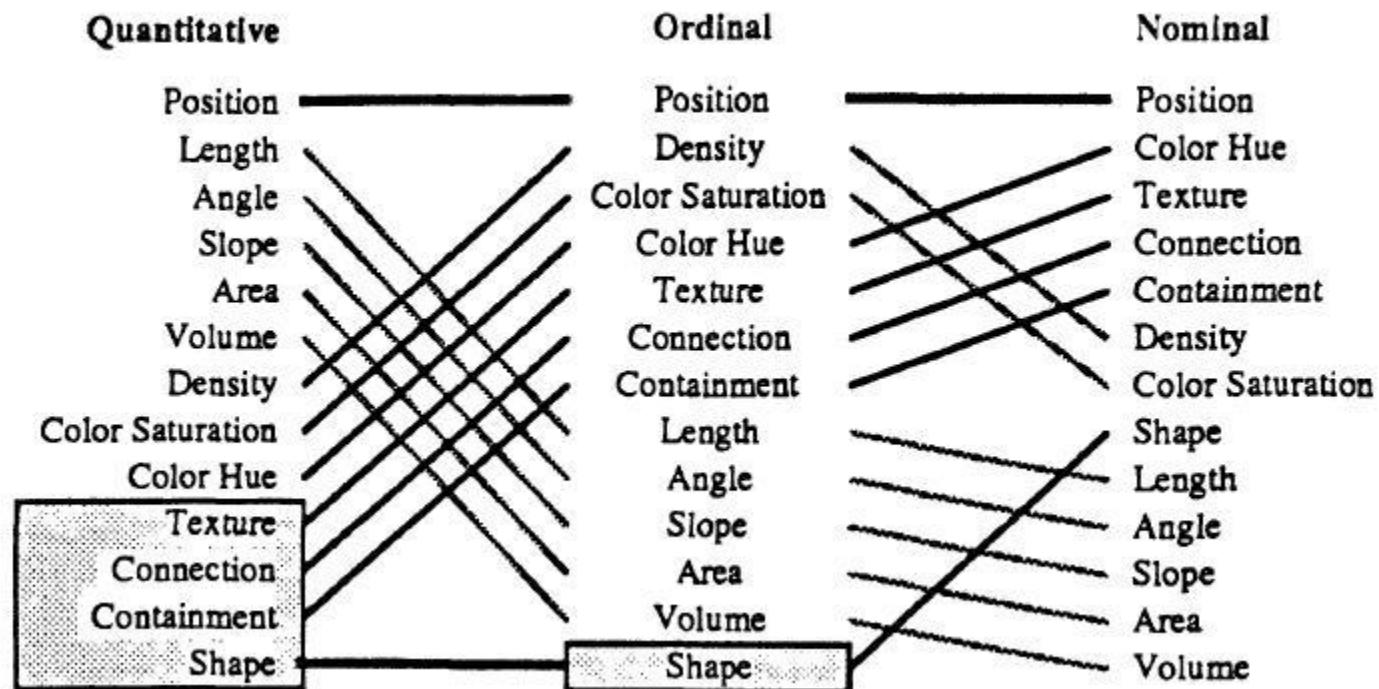


Common Fate

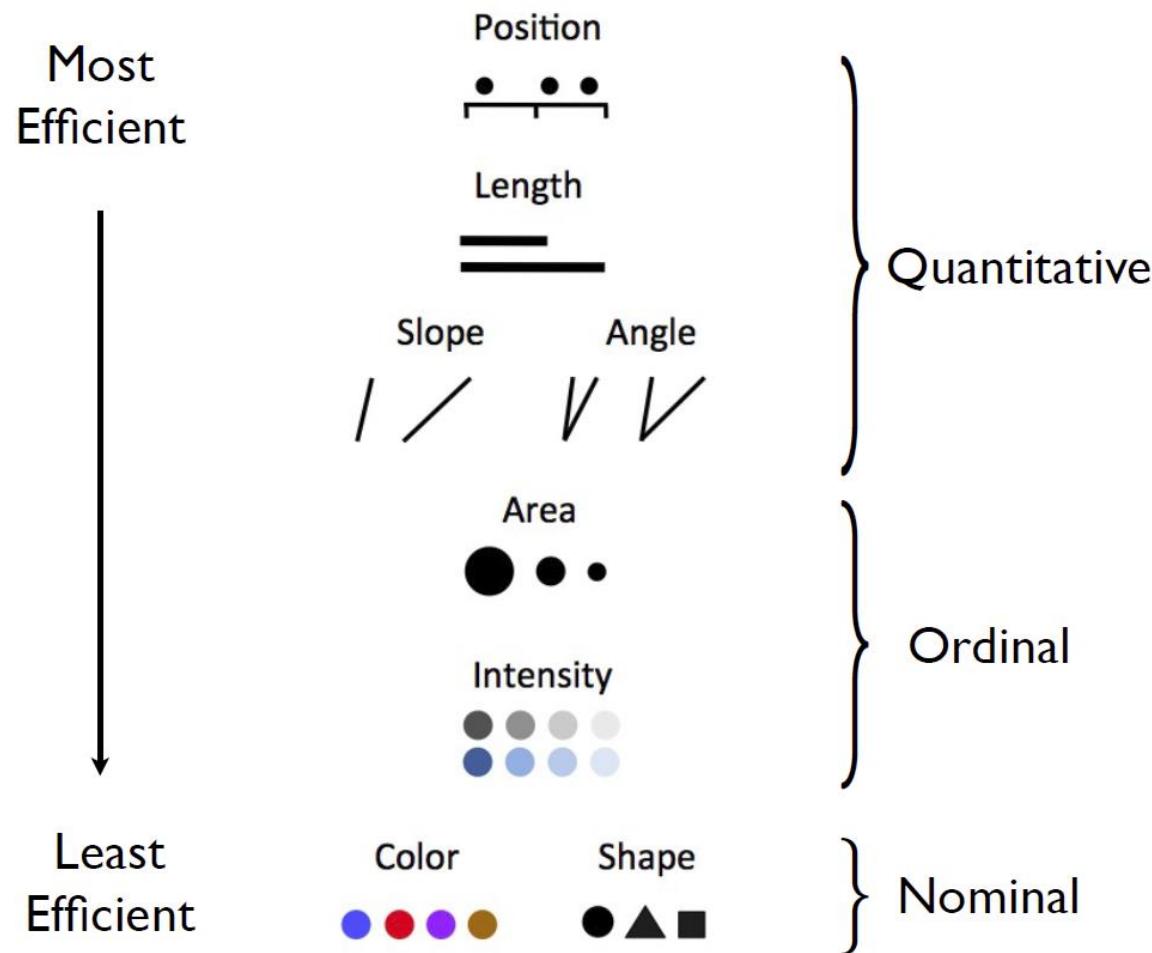


Closure

Perceptual Task (Mackinlay, 1986)



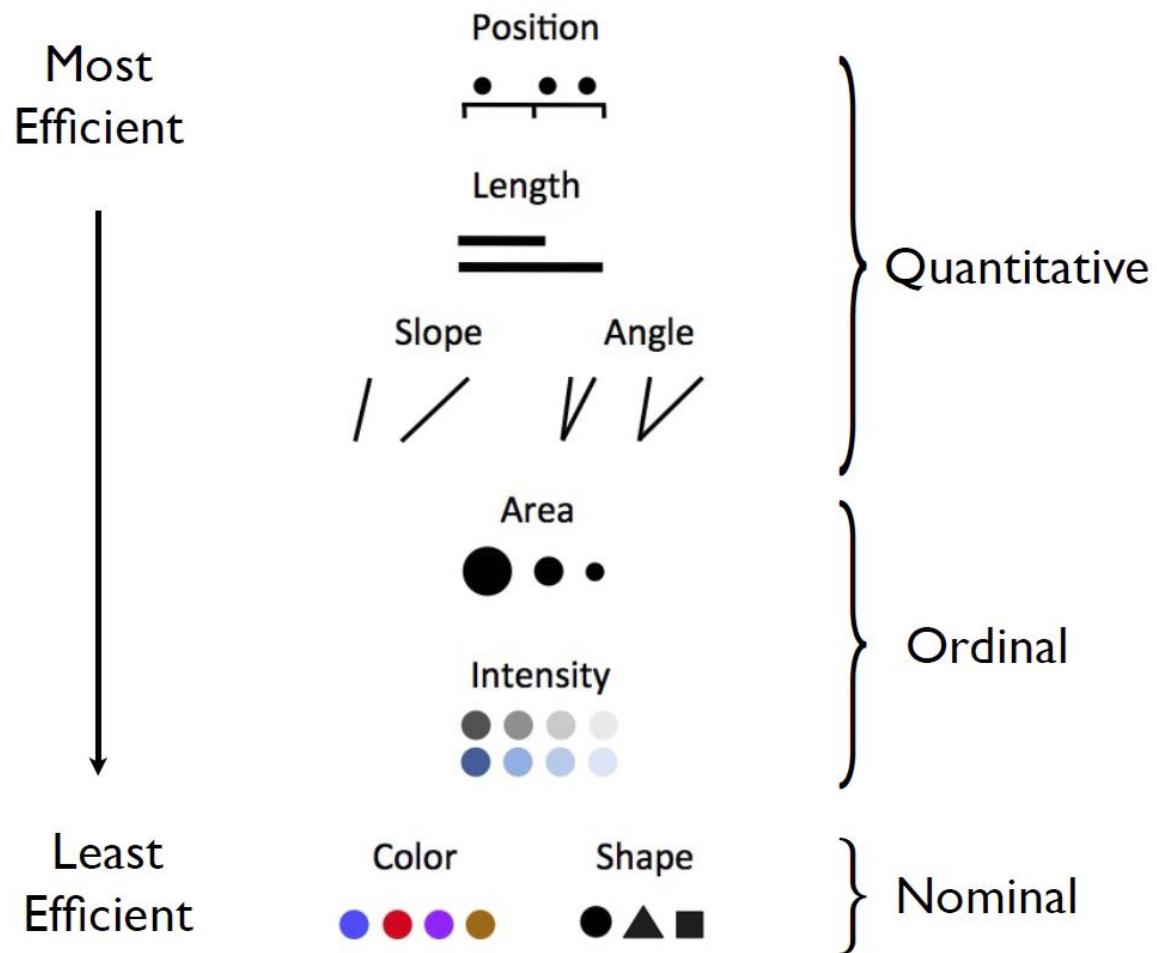
Perceptual Task (Mackinlay, 1986)



Effective Visual Encoding

- **Challenge:** Pick the best encoding (or mapping) from many possibilities. Consider:
 - **Importance Ordering:** Encode the most important information in the most perceptually accurate way.
 - **Expressiveness:** Depict all the data, and only the data
 - **Consistency:** The properties of the image (visual attributes) should match the properties of the data

Importance Ordering



Expressiveness

- A length is interpreted as a quantitative value
- Length of bar says something untrue about data

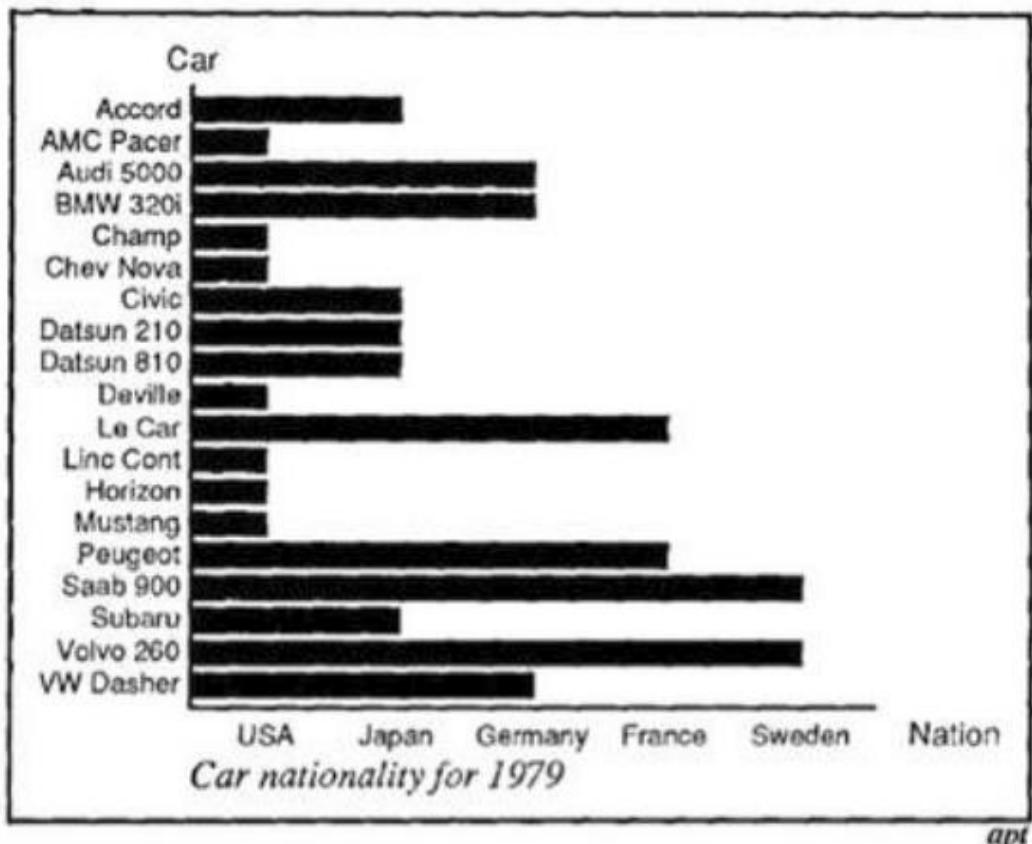
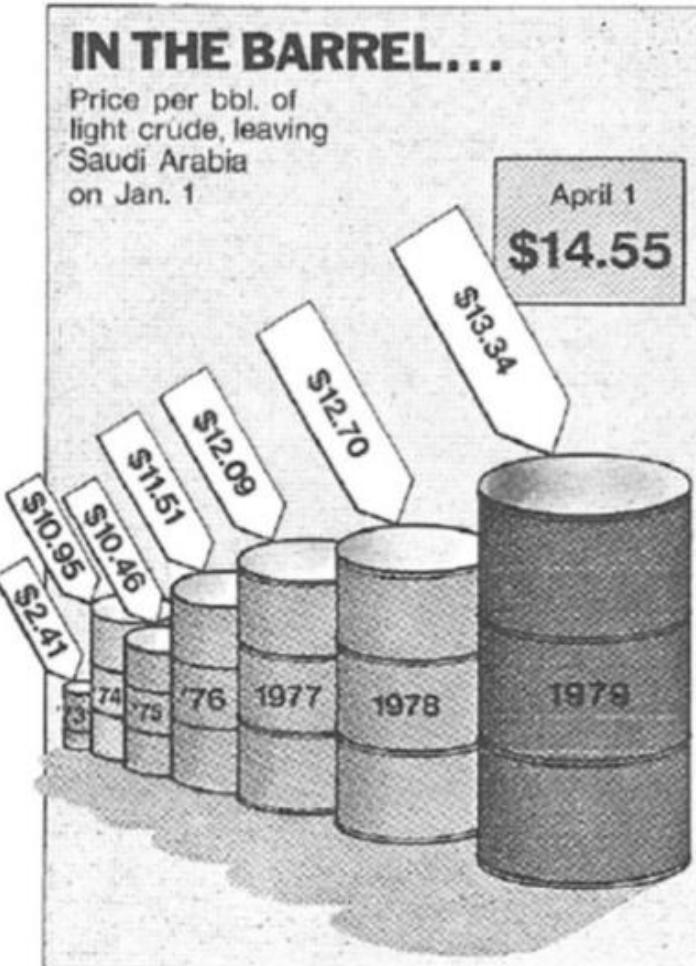


Fig. 11. Incorrect use of a bar chart for the *Nation* relation. The lengths of the bars suggest an ordering on the vertical axis, as if the USA cars were longer or better than the other cars, which is not true for the *Nation* relation.

Consistency

- The properties of the image (visual attributes) should match the properties of the data
- E.g. don't map one-dimensional data to two-or three- dimensional representations!

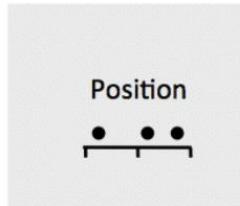


[Tufte, Edward R (1983), *The Visual Display of Quantitative Information*, Graphics Press, from *Time Magazine*, April 9, 1979, p. 57.]

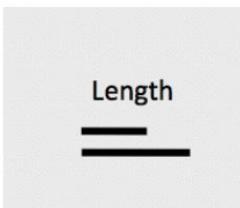
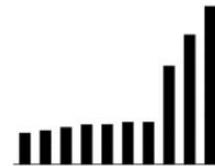
Effectiveness of Attributes

Most Effective

For Quantitative/Ordinal Data



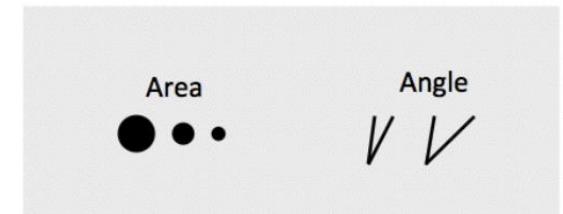
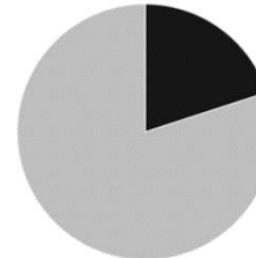
Position
• • •



Length
— —

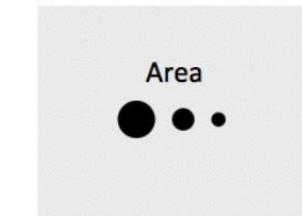
Less Effective

For Quantitative/Ordinal Data



Area
● ● ●

Angle
V V



Area
● ● ●

Least Effective: Color For Quantitative/Ordinal Data

SANFORD AND SELNICK

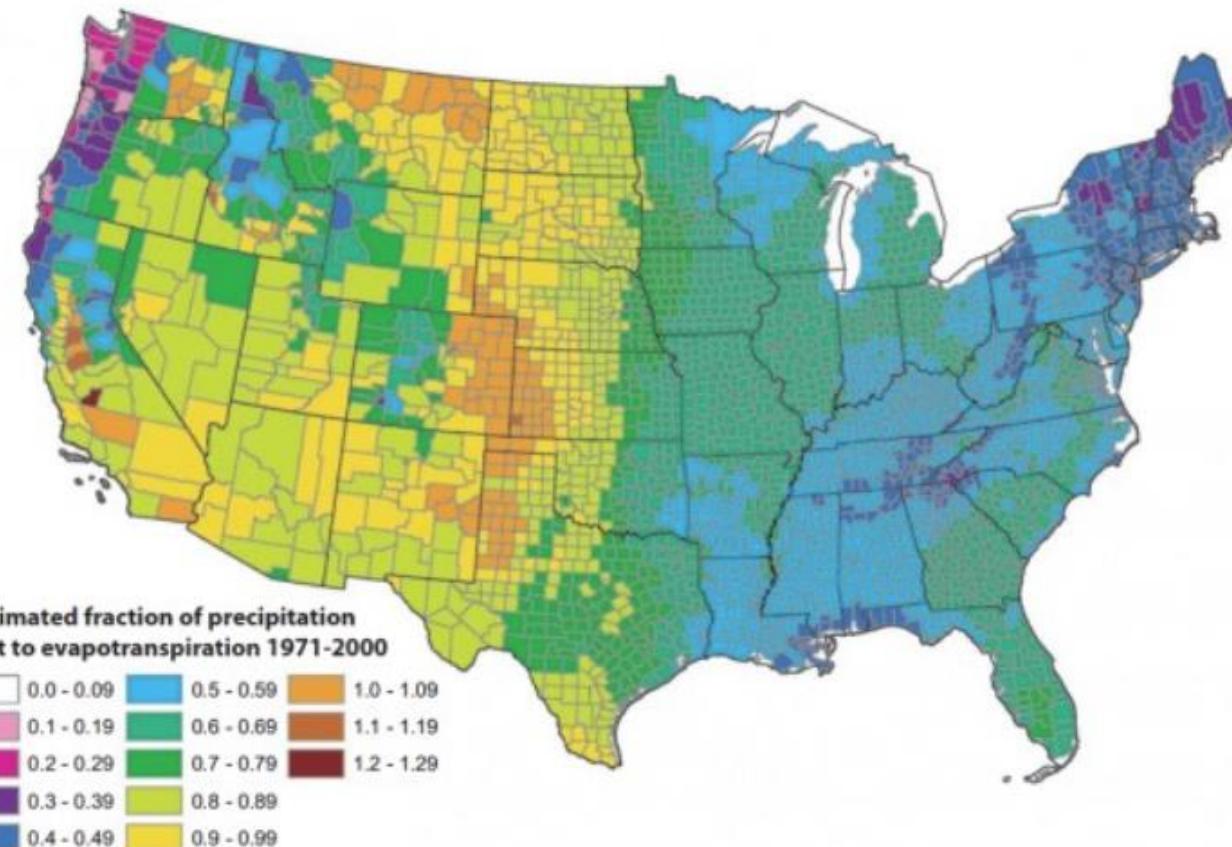


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM 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.

Color

Color names if
you're a girl...

Maraschino	Red
Cayenne	Purple
Maroon	
Plum	
Eggplant	
Grape	
Orchid	
Lavender	
Carnation	Pink
Strawberry	
Bubblegum	
Magenta	
Salmon	
Tangerine	Orange
Cantaloupe	
Banana	Yellow
Lemon	
Honeydew	Green
Lime	
Spring	
Clover	
Fern	
Moss	
Flora	
Sea Foam	Blue
Spindrift	
Teal	
Sky	
Turquoise	

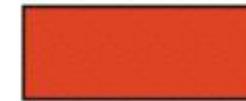
Color names if
you're a guy...

*Actual color names
if you're a girl ...*

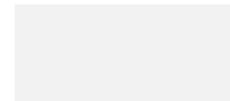


*Actual color names
if you're a guy ...*

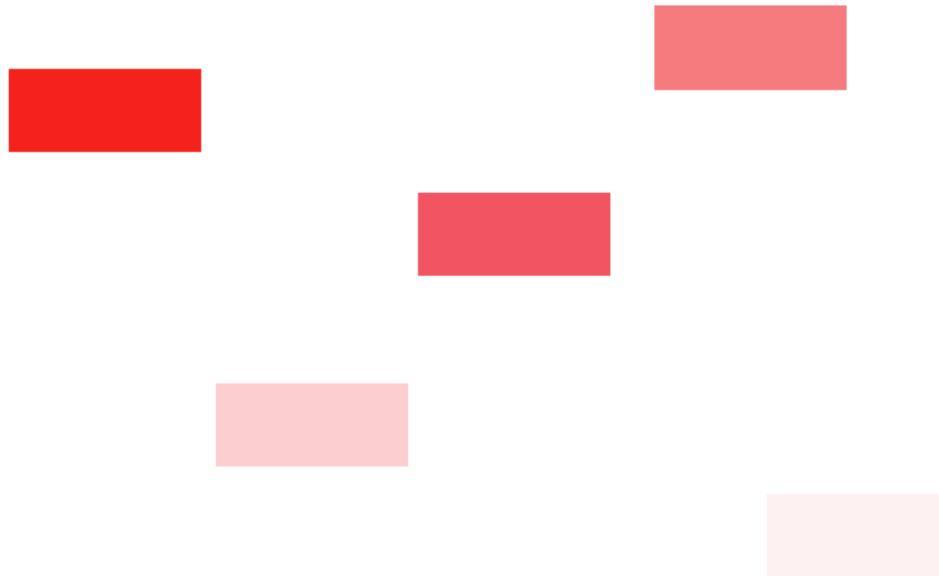
Order These Colors



Order These Colors



Order These Colors



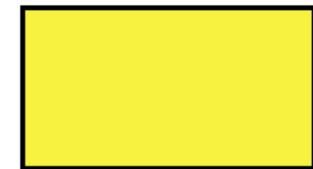
Brightness



Saturation



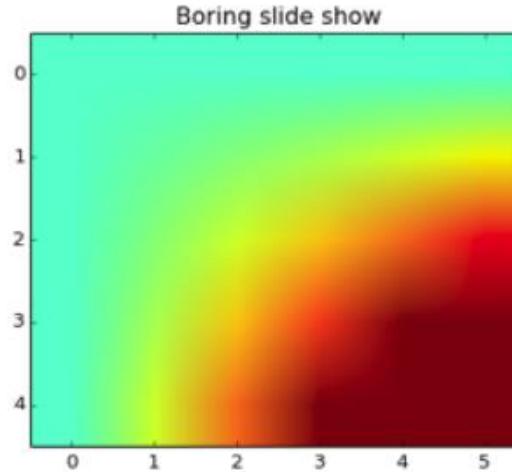
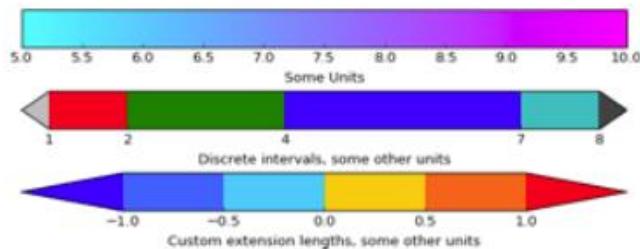
Hue



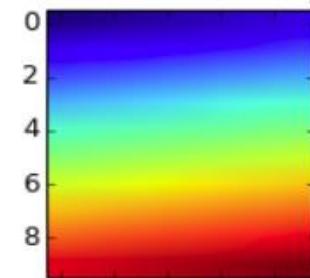
Perceived as Ordered

Not as much

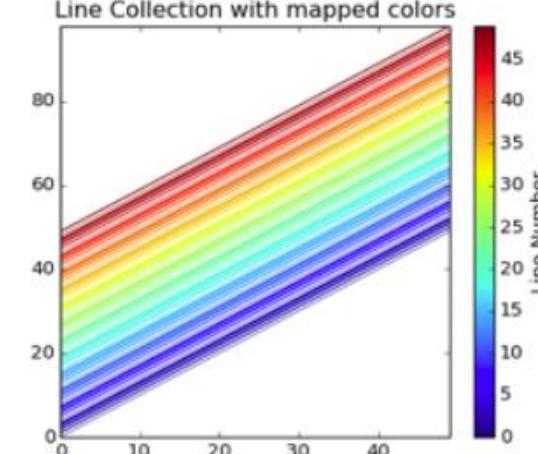
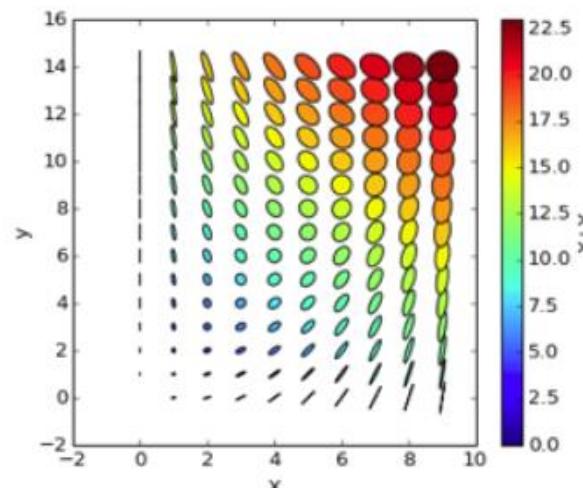
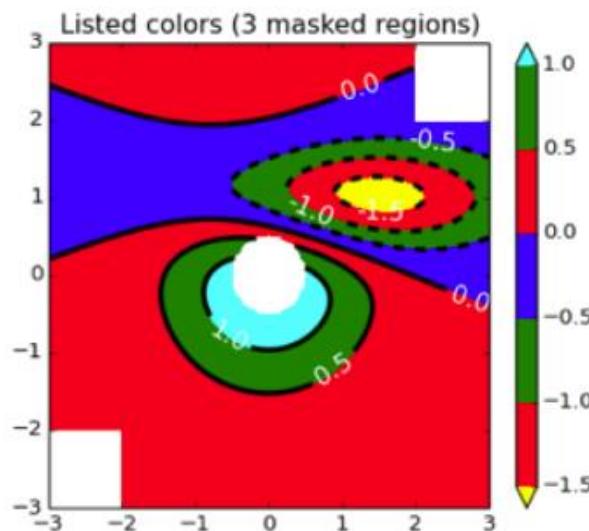
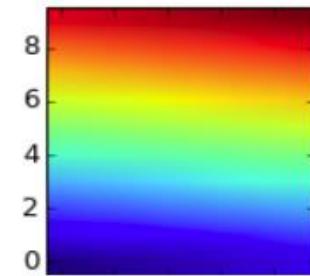
Rainbow Colors



blue should be up



blue should be down



Rainbow Colormap



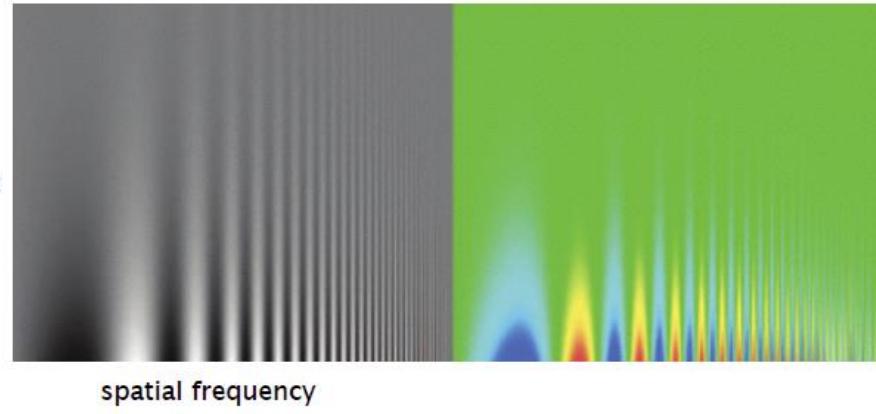
hard to order



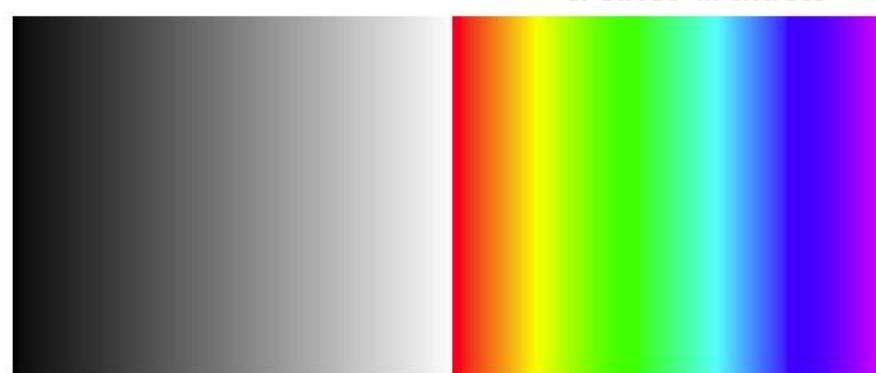
easy to order



contrast

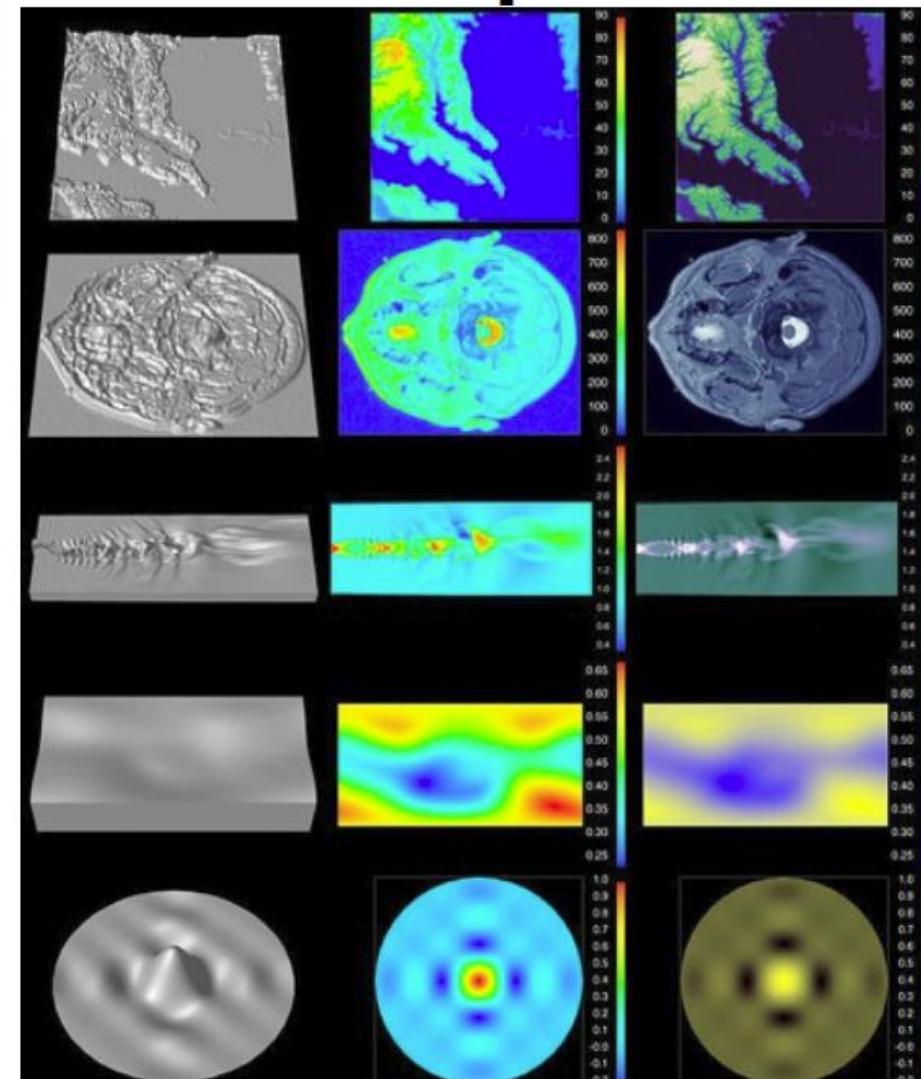
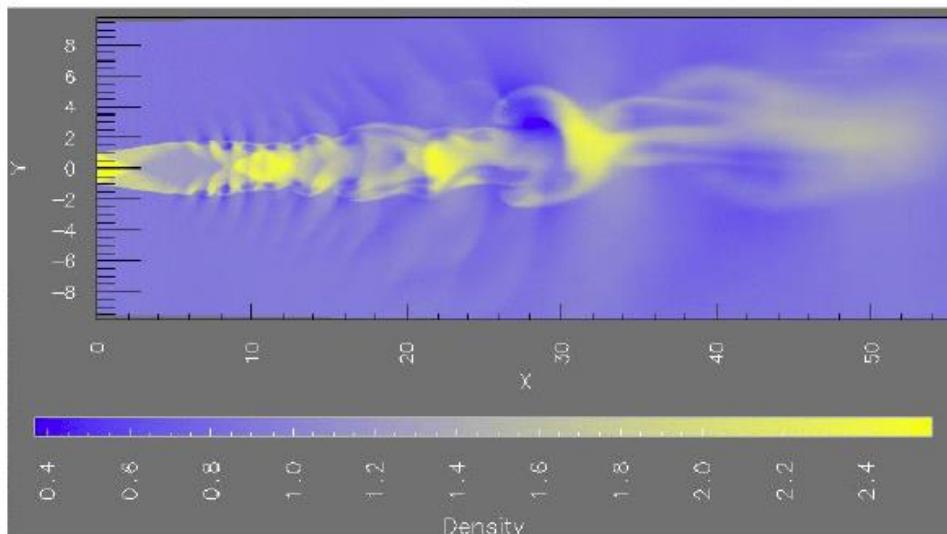
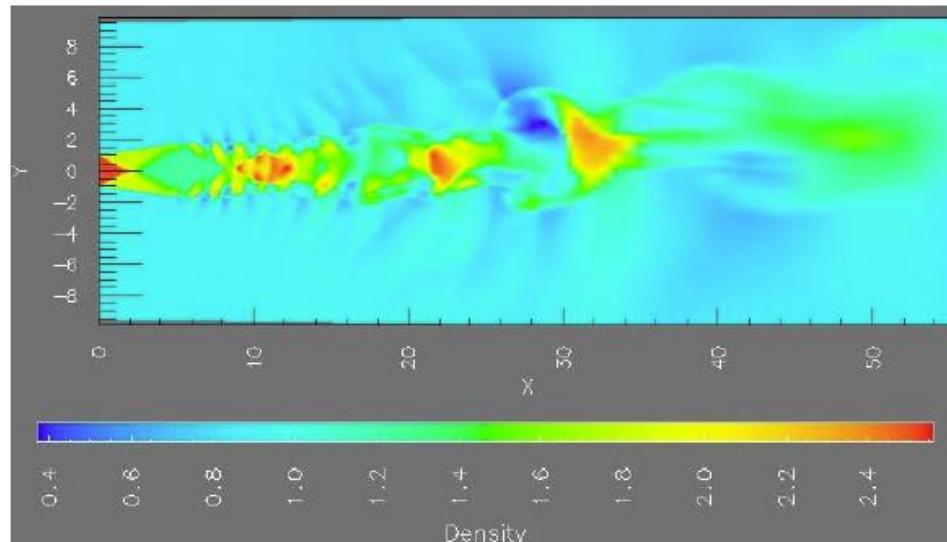


lower resolution



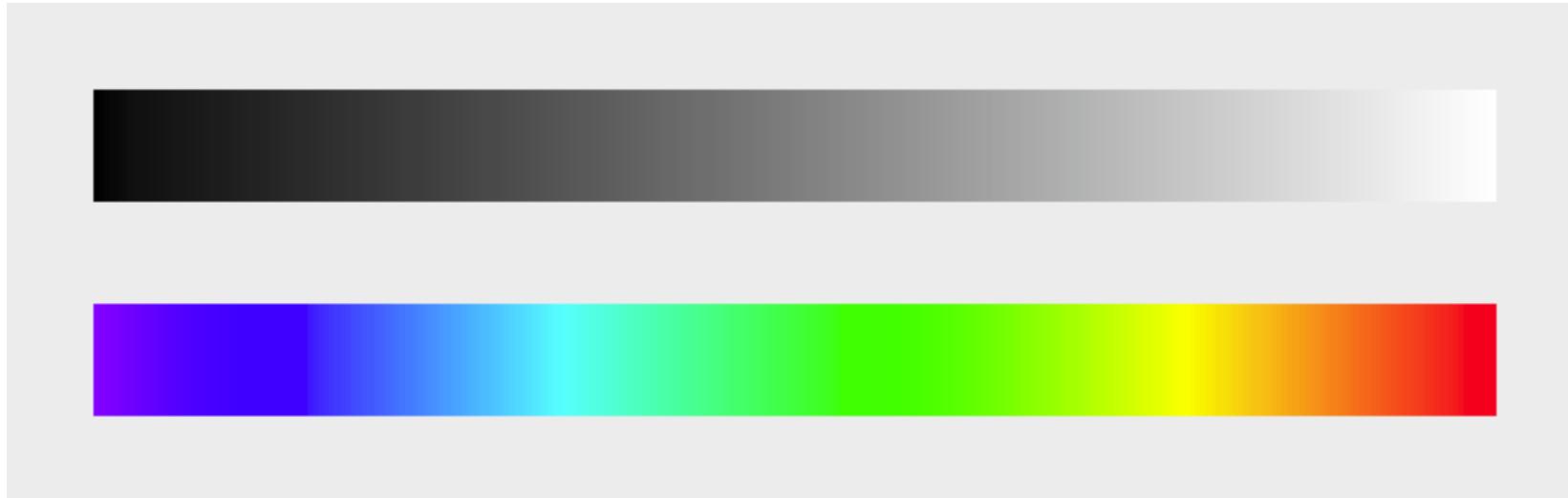
creates artifacts

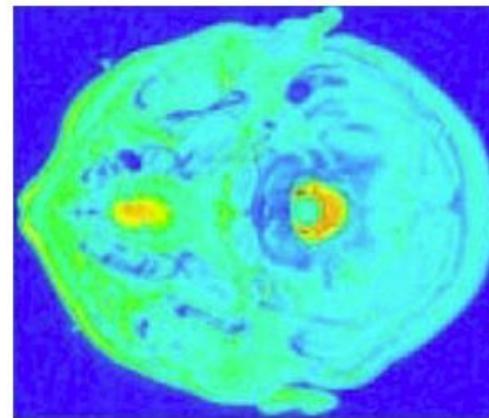
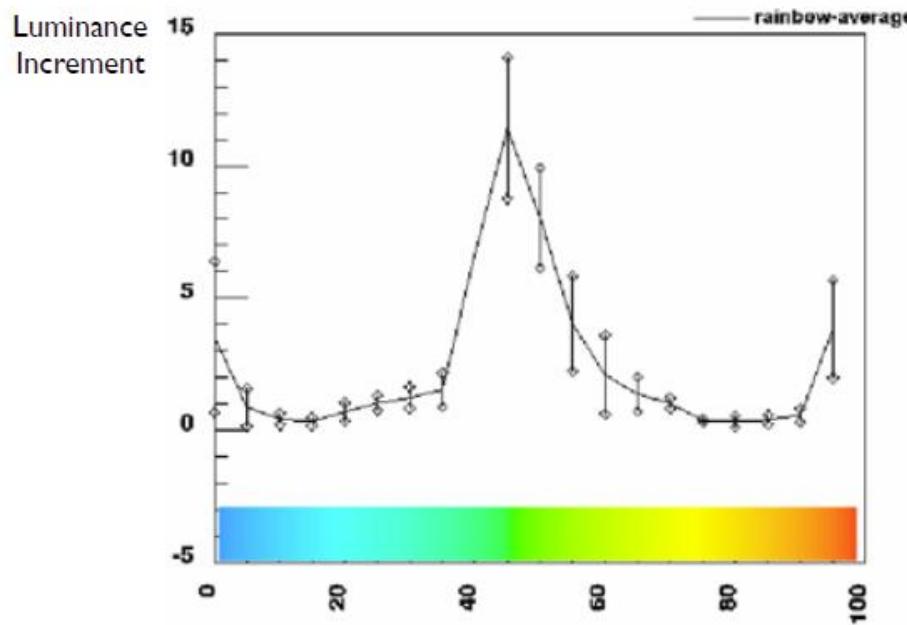
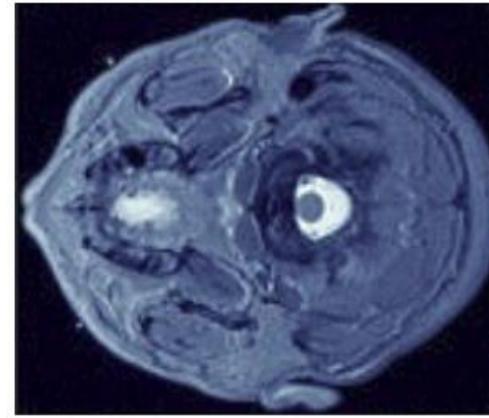
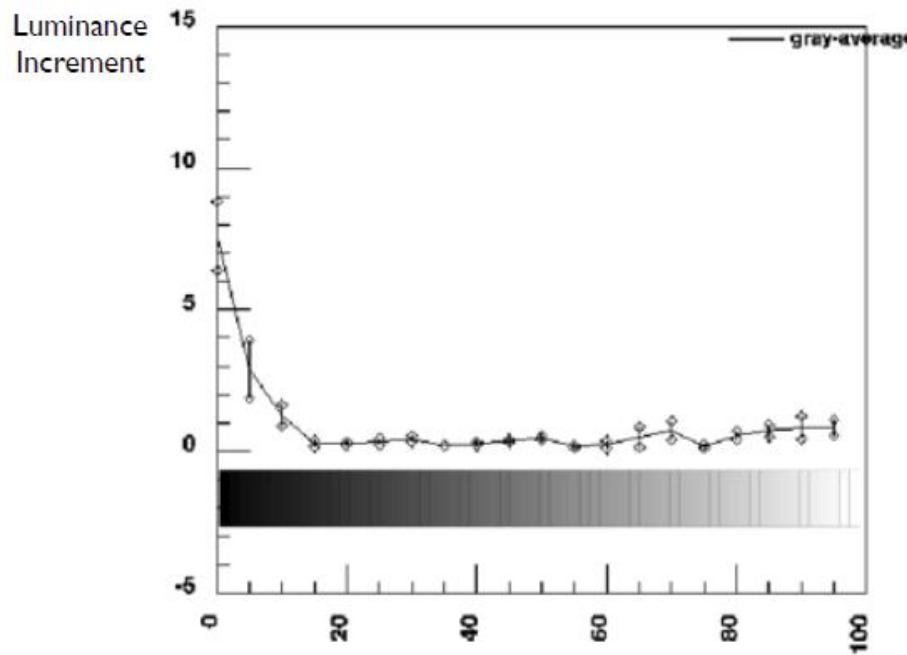
Rainbow Colormap



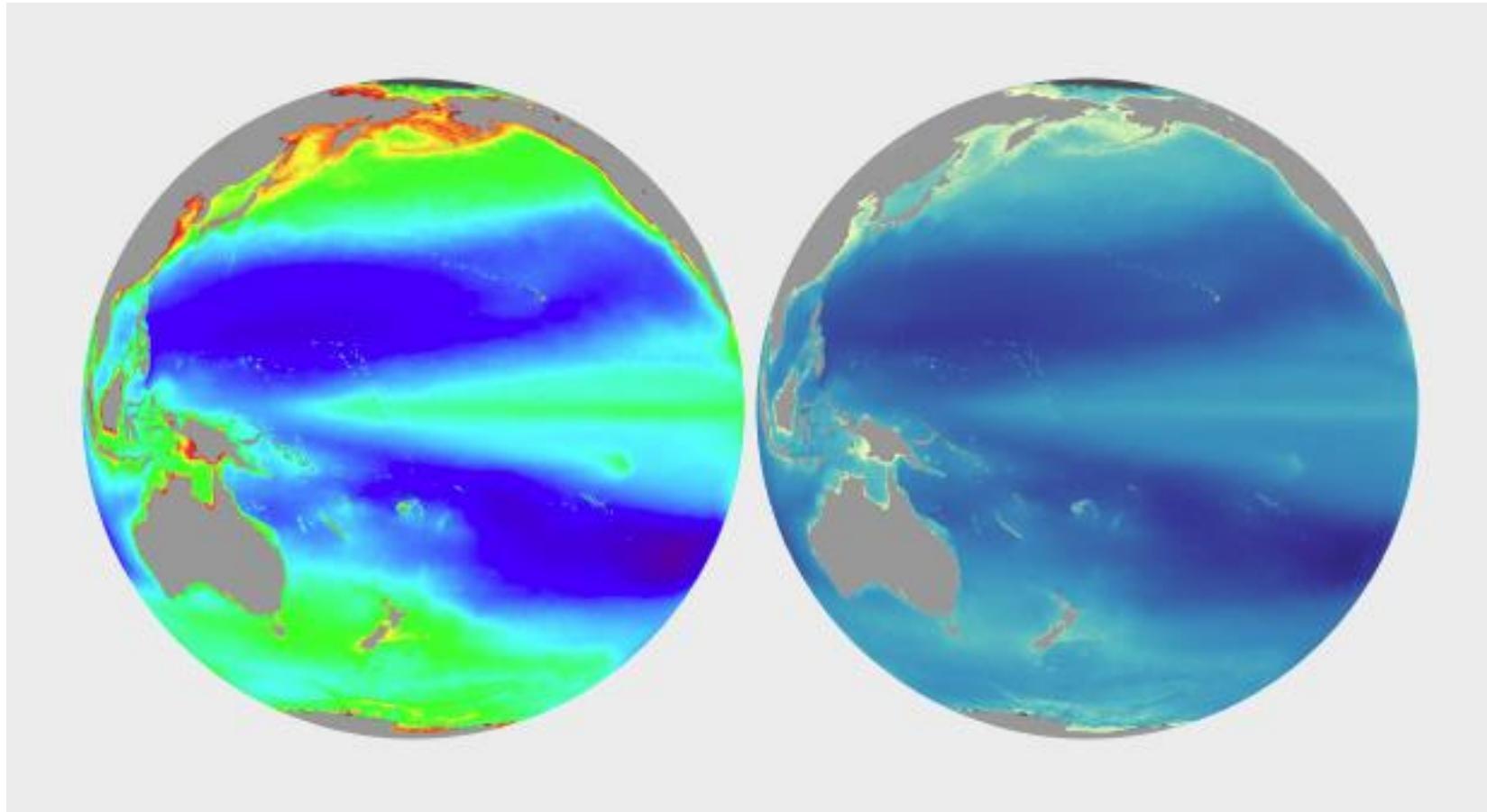
Rainbow Colormap

Rainbow map is perceptually nonlinear





Rainbow Colormap



Map Example Revisited

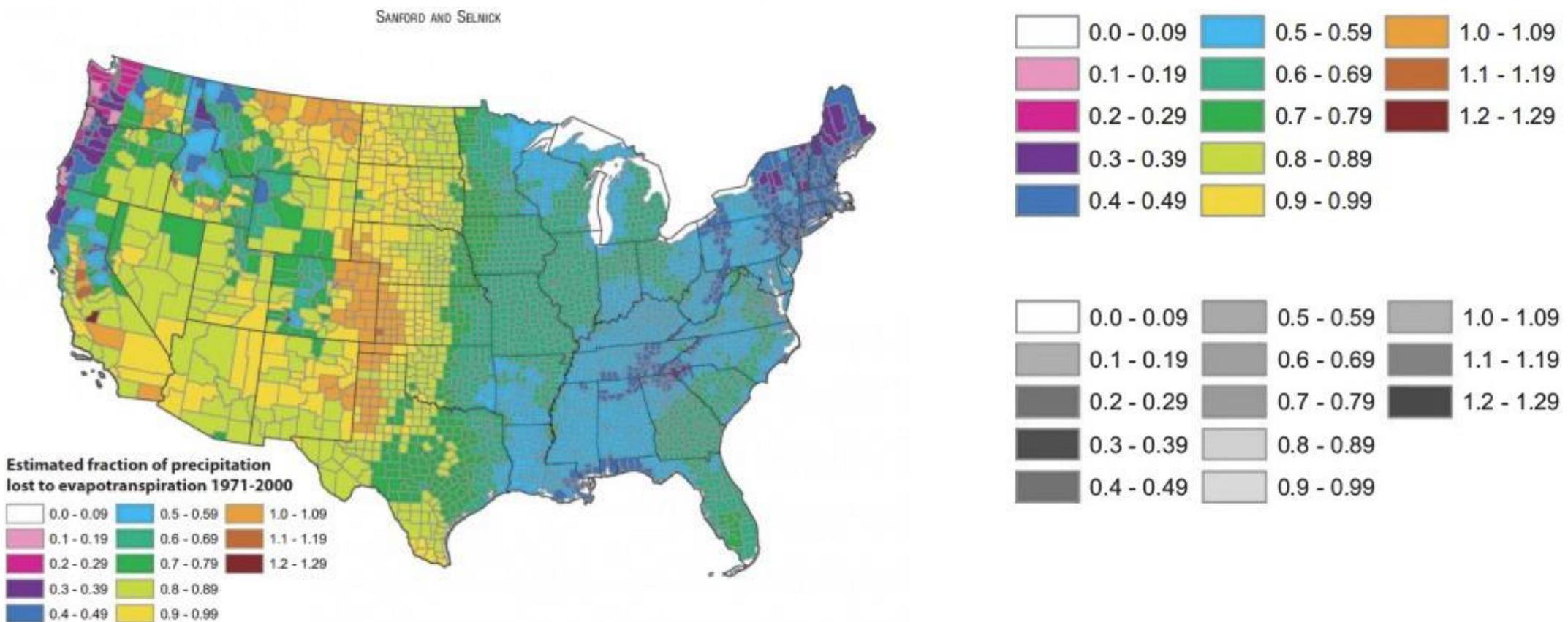
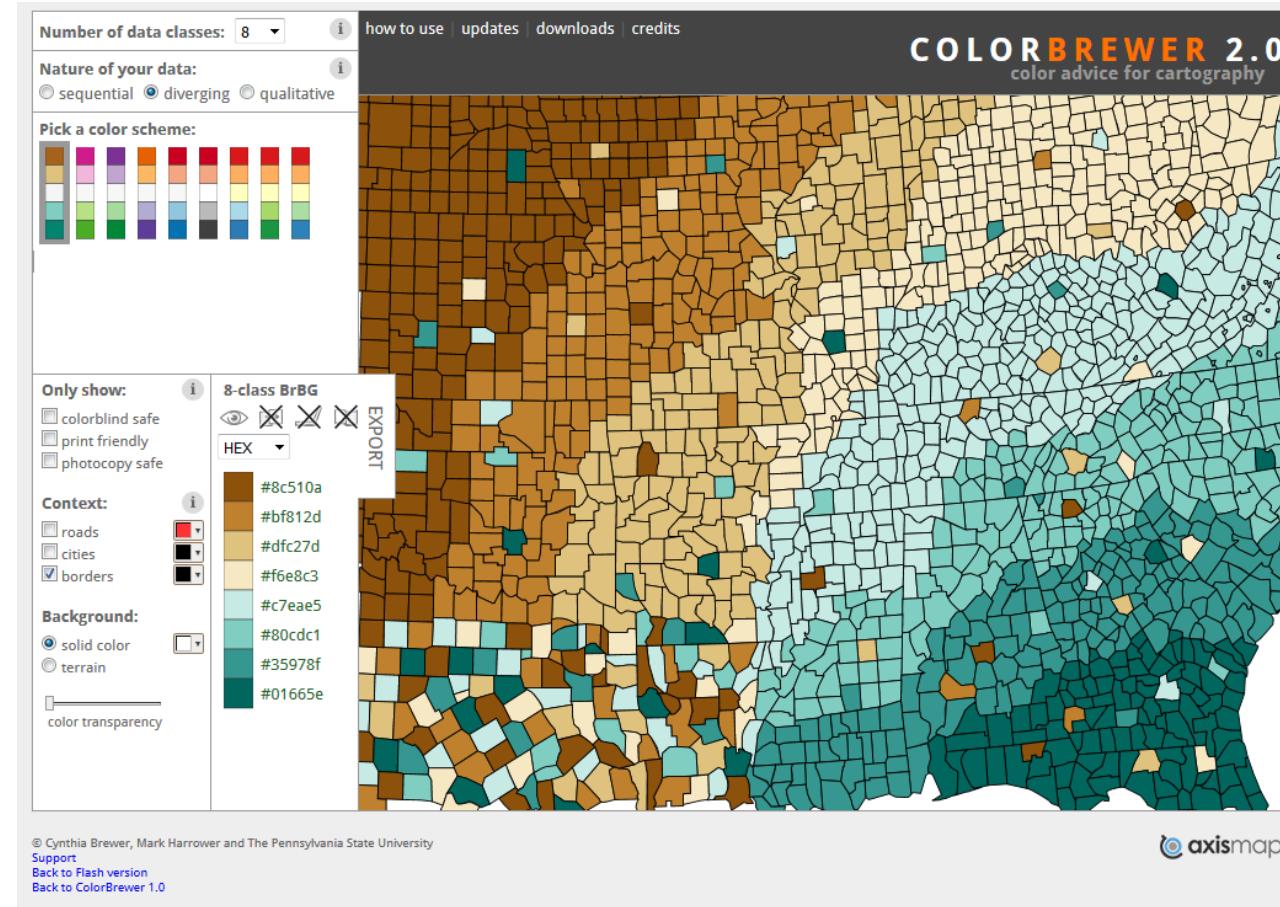


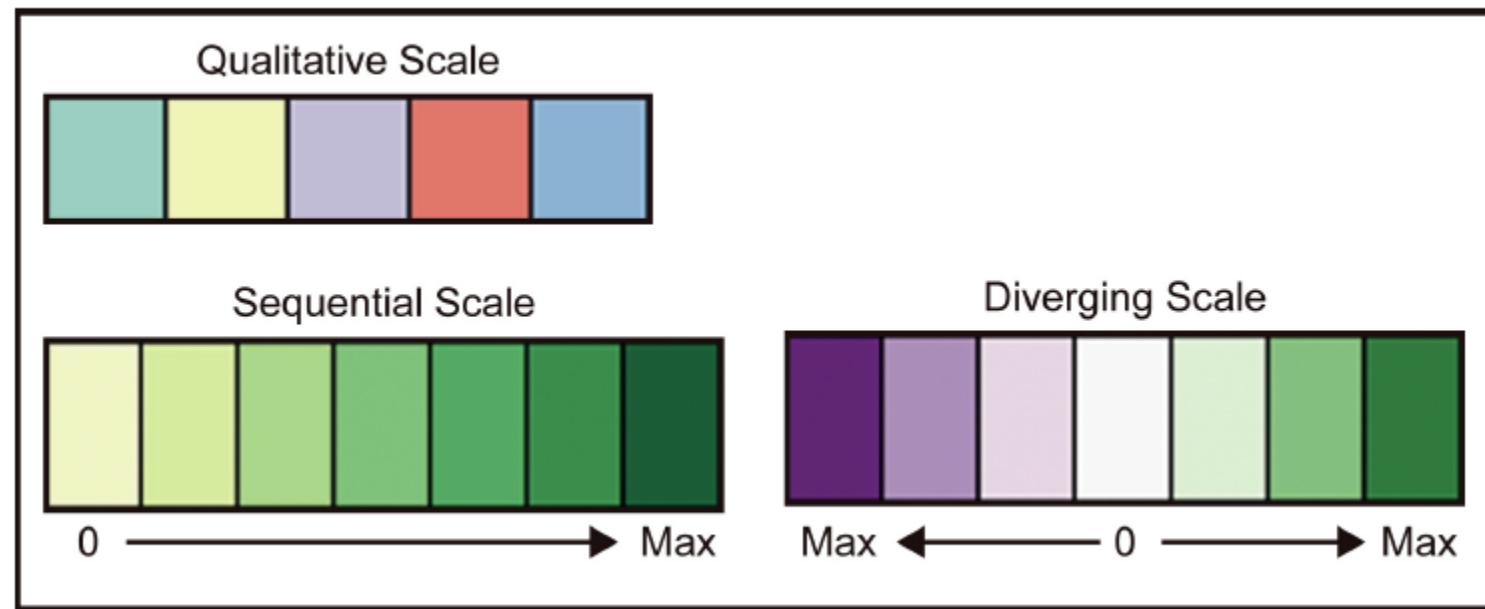
FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM 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.

Use ColorBrewer! - <http://colorbrewer2.org/>

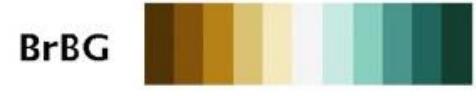
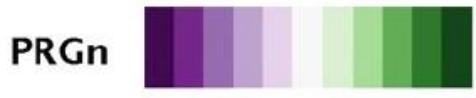
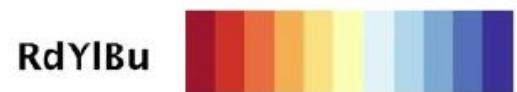
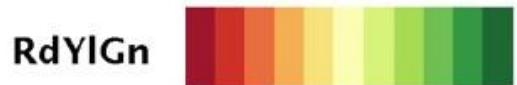


Brewer Scales (Cynthia Brewer)

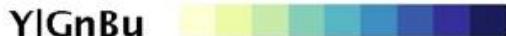
Nominal
Ordinal



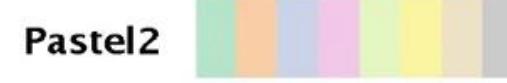
Diverging



Sequential

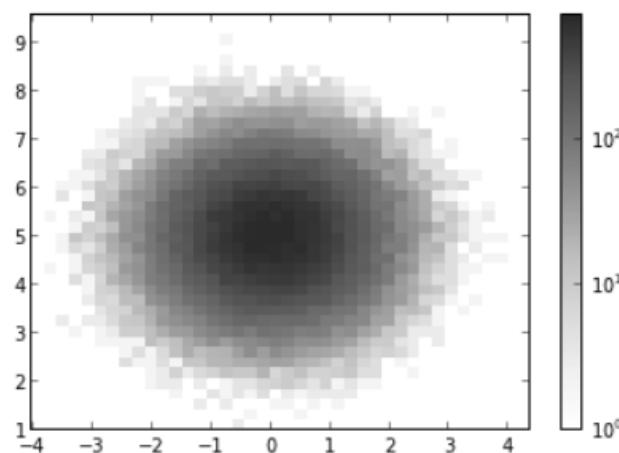
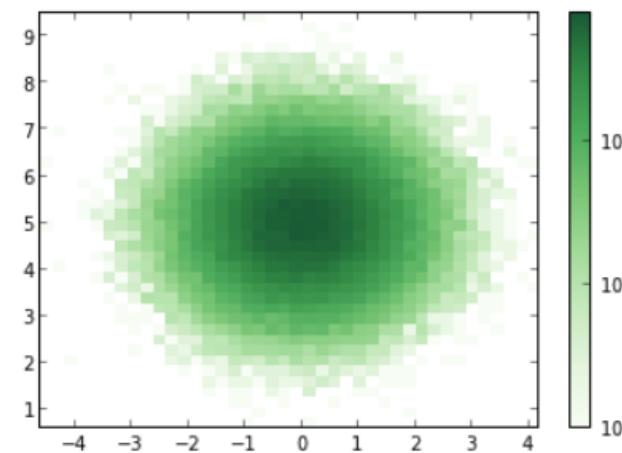
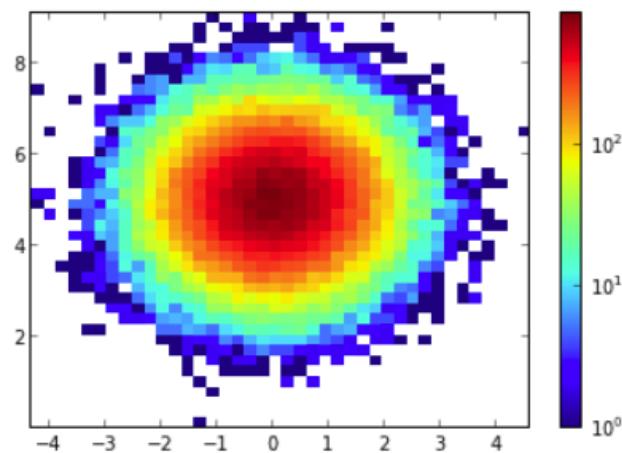


Qualitative



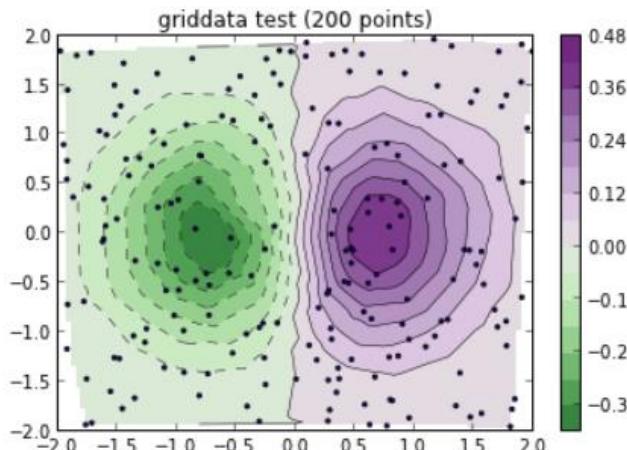
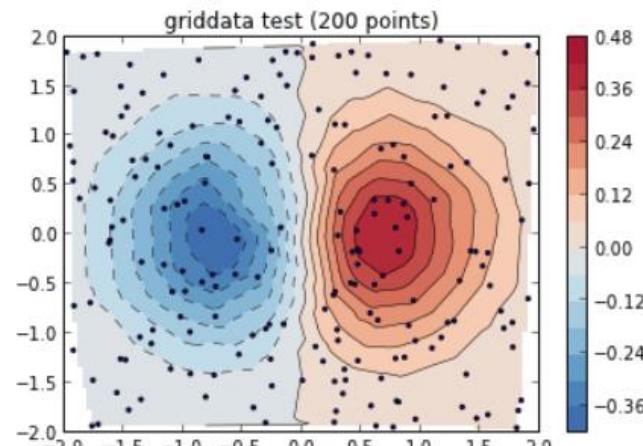
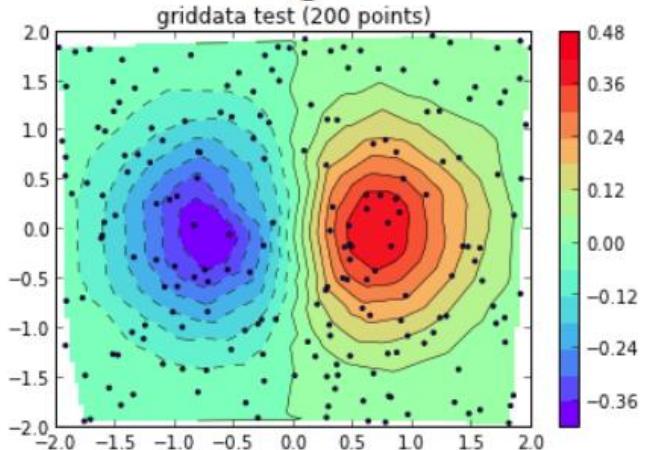
Sequential Brewer Scales

No!

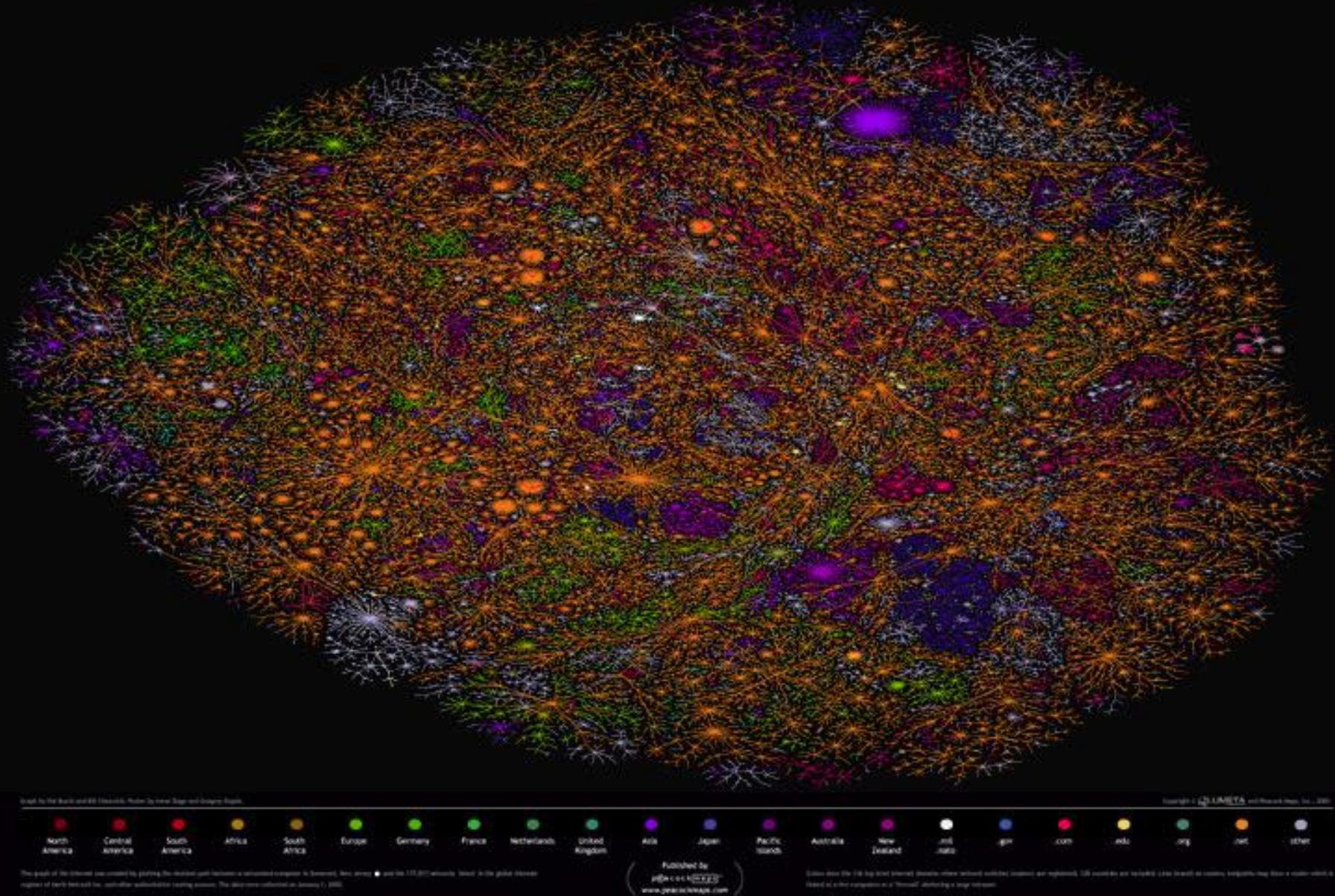


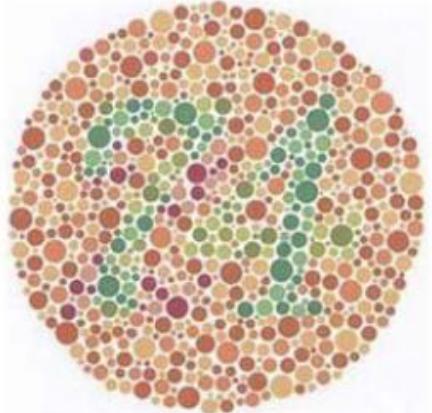
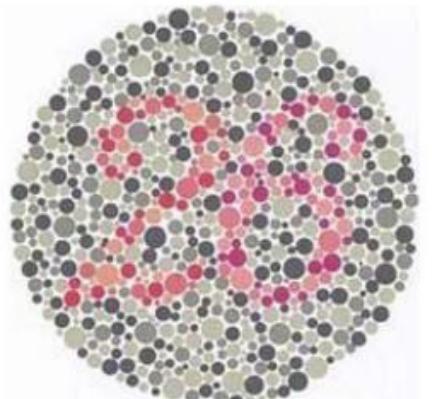
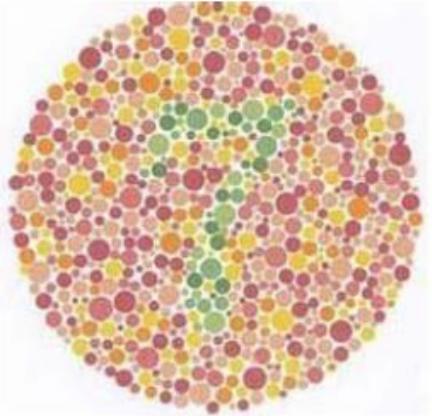
Divergent Brewer Scales

Not great



The Internet: 2002





Color Blindness

8% of males, 1% of females

Most common is red-green weakness / blindness

Color	Color name	RGB (1–255)	CMYK (%)	P	D
	Black	0, 0, 0	0, 0, 0, 100		
	Orange	230, 159, 0	0, 50, 100, 0		
	Sky blue	86, 180, 233	80, 0, 0, 0		
	Bluish green	0, 158, 115	97, 0, 75, 0		
	Yellow	240, 228, 66	10, 5, 90, 0		
	Blue	0, 114, 178	100, 50, 0, 0		
	Vermillion	213, 94, 0	0, 80, 100, 0		
	Reddish purple	204, 121, 167	10, 70, 0, 0		

Fonts

A helpful guide

Title 28 bold monospace:
Consolas, Lucida Console, Courier New

Title 28 bold serif:
Palatino Linotype, Times New Roman, Georgia,
Baskerville, Garamond, Cambria

Title 28 bold san-serif:
Century Gothic, Verdana, Tahoma, Arial, Arial
Narrow, Franklin Gothic Medium, Lucida Sans, Luci-
da Sans Unicode, GillSans, Calibri, Trebuchet

Body Copy 11 monospace:
Consolas 1234567890, Lucida Console 1234567890,
Courier New 1234567890

Body Copy 11 serif:
Palatino Linotype 1234567890, Times New Roman 1234567890,
Baskerville 1234567890, Georgia 1234567890, Cambria
1234567890

Body Copy 11 san-serif:
Century Gothic 1234567890, Lucida Sans 1234567890, Lu-
cida Sans Unicode 1234567890, Verdana 1234567890,
GillSans 1234567890, Calibri 1234567890, Arial 1234567890, Arial
Narrow 1234567890, Verdana 1234567890, Tahoma 1234567890..

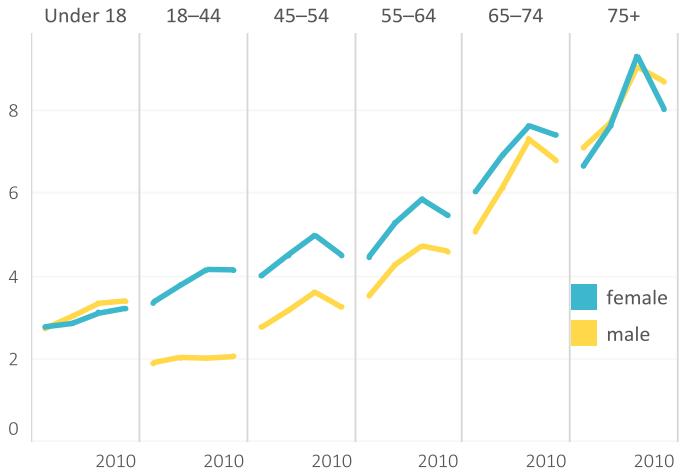
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gia1234567890, Cambria1234567890

Numbers 8 san-serif:
Century Gothic,1234567890, Lucida Sans1234567890, Lucida Sans Uni-
code1234567890, Verdana1234567890, GillSans1234567890, Calibri1234567890, Cal-
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Tahoma1234567890, Trebuchet1234567890

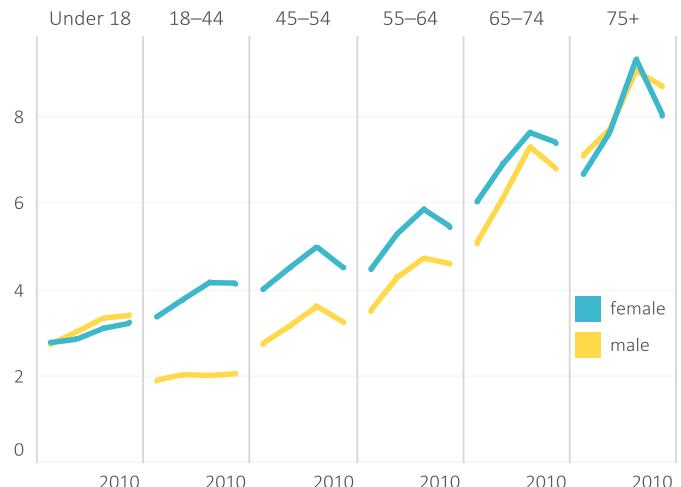
Health Care Visits

Average visits per person for males and females in different age categories for the years 1995-2010



Health Care Visits

Average visits per person for males and females in different age categories for the years 1995-2010



Title: Consolas 28
bold

Body text: Consolas 11

Headers: Calibri 9

Legends: Calibri 8

Numbers: Calibri 8

Title: GillSans MT
28 bold

Body text: GillSans MT 11

Headers: Calibri Light 9

Legends: Calibri Light 8

Numbers: Calibri Light 8

Title: Century Gothic 28 bold

Body text: Palatino Linotype 11

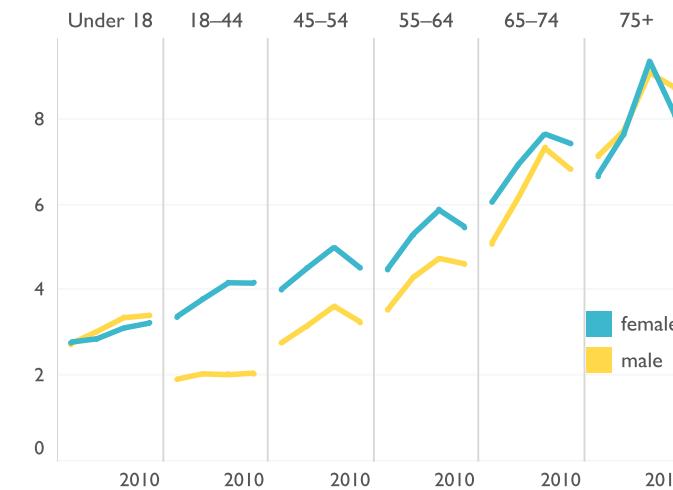
Headers: GillSans MT 9

Legends: GillSans MT 8

Numbers: GillSans MT 8

Health Care Visits

Average visits per person for males and females in different age categories for the years 1995-2010



Title: Georgia 28 bold

Body text: Franklin Gothic Medium 11

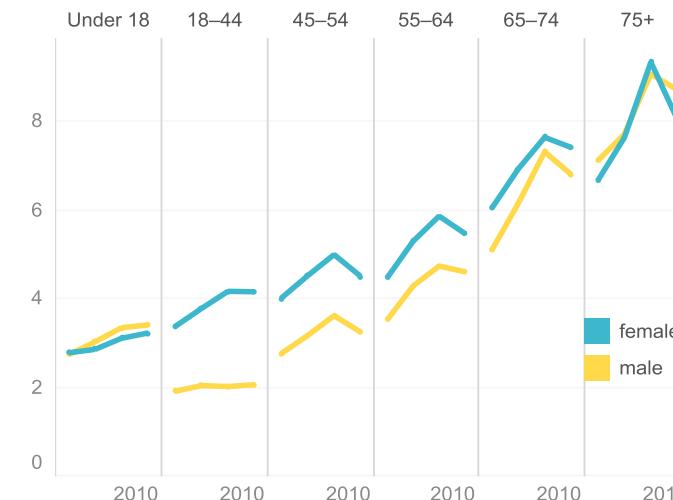
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Legends: Arial 8

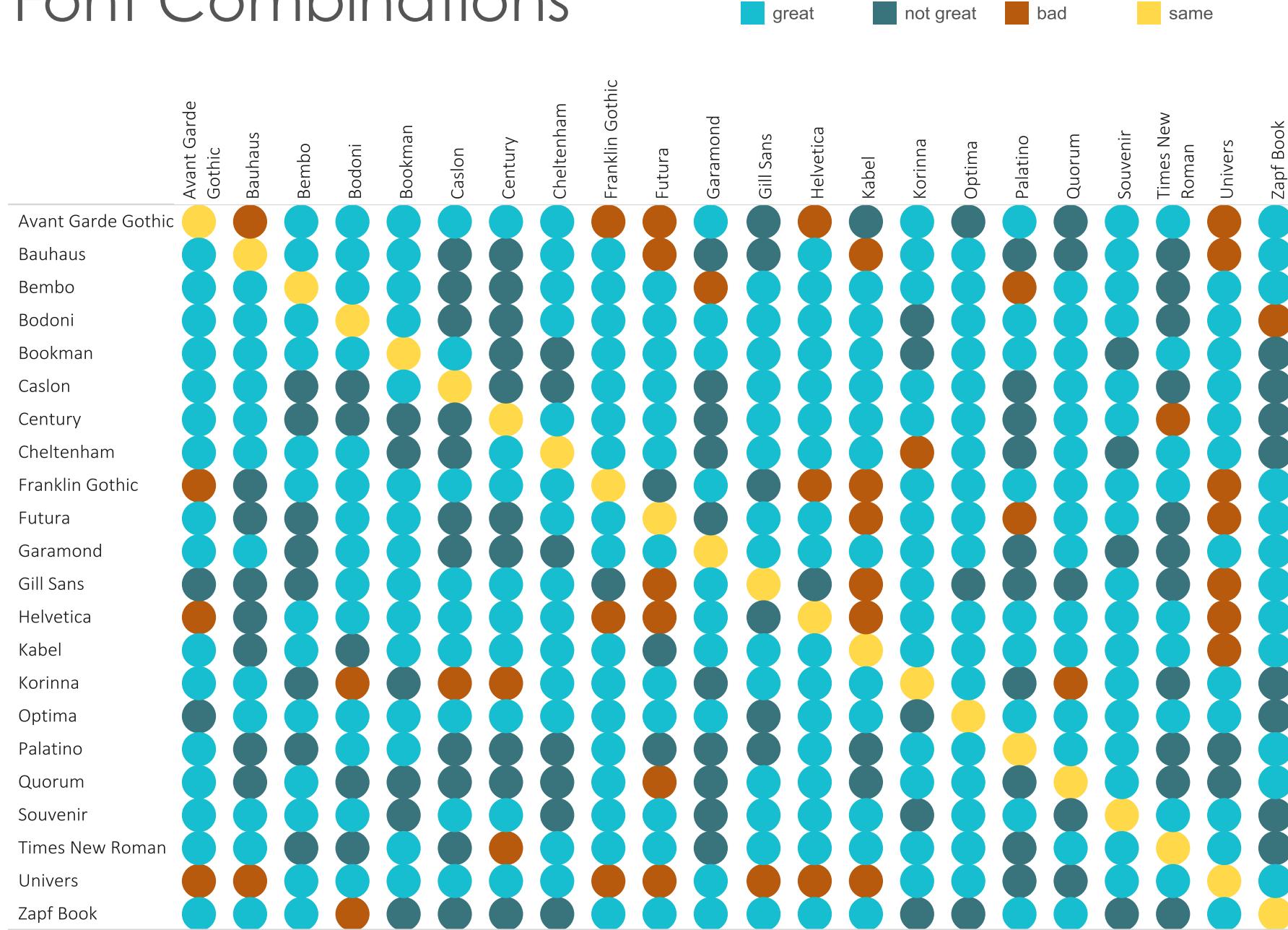
Numbers: Arial 8

Health Care Visits

Average visits per person for males and females in different age categories for the years 1995-2010



Font Combinations



Graphical Excellence & Honesty in Data Visualization

Edward Tufte

Graphical Excellence (Tufte)

Well-designed presentation of interesting data – a matter of
substance
statistics
design

That which gives the viewer the greatest number of ideas in the shortest time with
the least ink in the smallest space

Nearly always multivariate

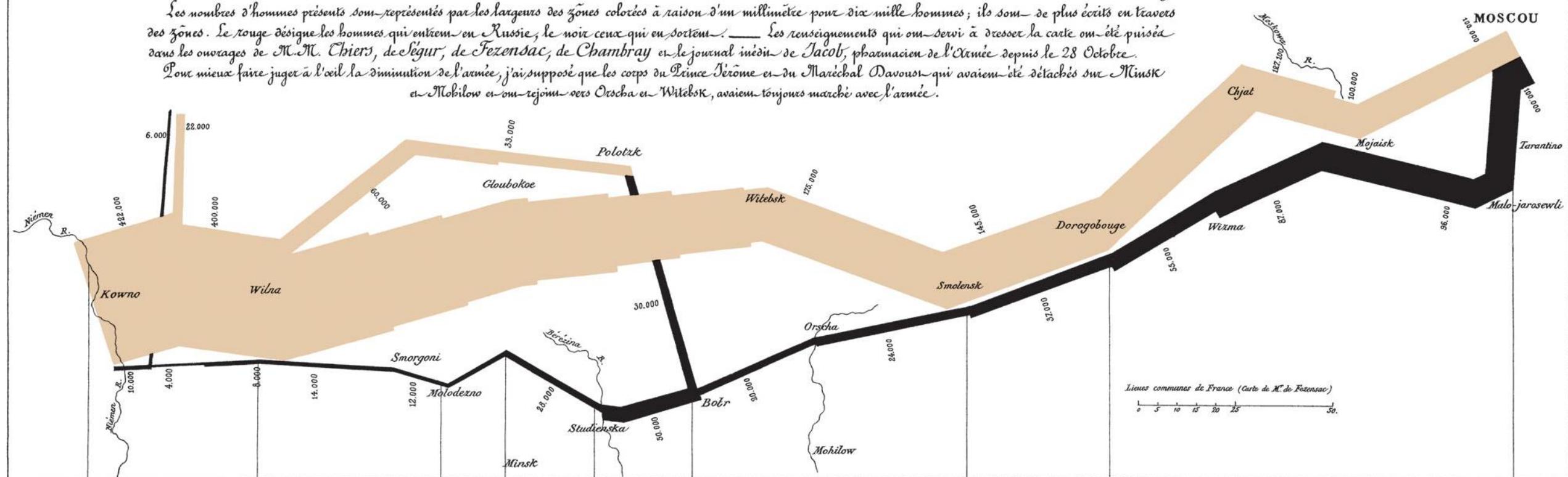
...and requires telling the truth about the data

Carte Figurative des pertes successives en hommes de l'Armée Française dans la Campagne de Russie 1812-1813.

Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite. Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Séguir, de Fezensac, de Chambray et le journal médical de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avaient été détachés sur Minsk et Mohilow se sont rejoints vers Orscha en Witebsk, avaient toujours marché avec l'armée.



Lieux communs de France (Carte de M^e de Fezensac)

TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop
le Niemen gelé.

- 26° le 7 X.^{bre}

- 30° le 6 X.^{bre}

- 24° le 1^{er} X.^{bre}

- 20° le 28 9.^{bre}

- 11°

- 21° le 14 9.^{bre}

- 9° le 9 9.^{bre}

Pluie 24 8.^{bre}

Zéro le 18 8.^{bre}

30 degrés

Imp. Lith. Regnier et Dourdet.

Timing cycle for ignition of engines
to make orbit corrections: "Zone of
corrective engines."

Happy New Year!

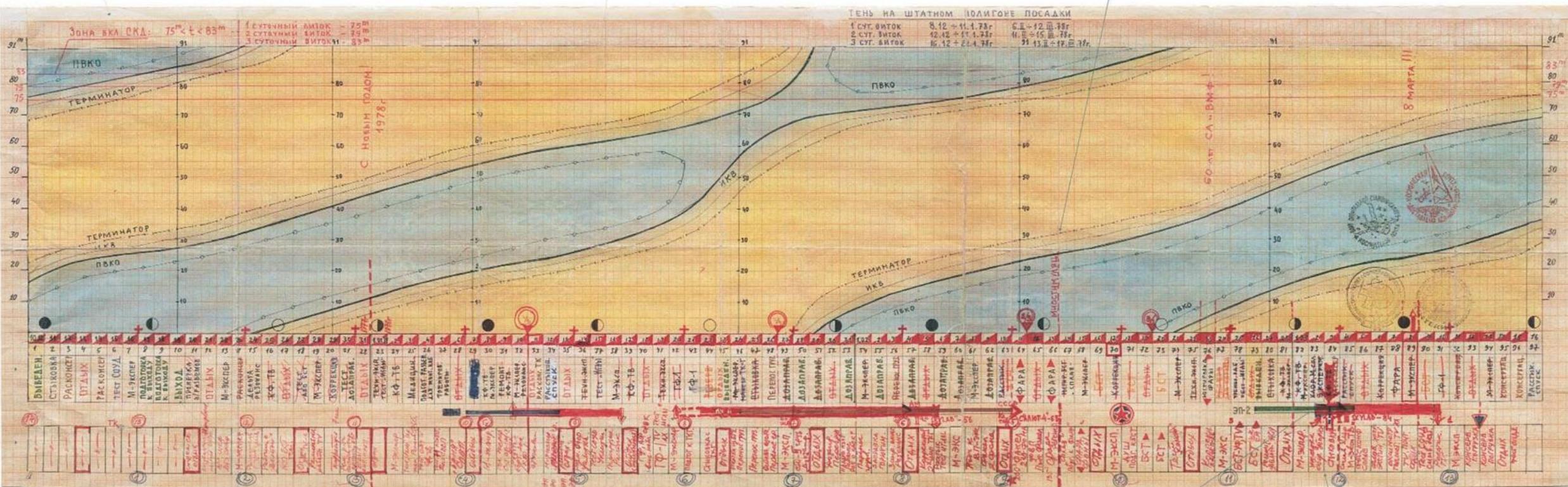
С Новым Годом!
1978г

Visit by Soyuz 27, January 10-16. Grechko
caught a cold, probably from one of the
guests. Visits are marked by solid red lines
between the planned and actual schedules.

Shadow on site of landing.

A cargo ship brought up an electric
muscle-stimulator (**МЧОСТИМУЛЯЦИЯ**) to
supplement the daily exercise regime,
which the cosmonauts were neglecting.

Markings for space-mail delivery.



Grechko and Romanenko arrive at
space station *Salyut 6*, via *Soyuz 26*.

Actual activity for each day, recorded in
red pen, while in orbit. As the flight goes
on, the pen tip squashes and broadens.

Planned activity for each day, schedule
prepared prior to flight, with variously
colored pens. Note the many deletions
and changes (e.g., ~~отдых~~).

Red boxes (OTDЫХ) indicate every 6th day of rest (revised
schedule).

Spacewalk (**выход** ВЫХОД) by Grechko on December 20. When Grechko returned, Romanenko decided on the spur of the moment to look around outside. While pushing himself through the tight airlock, he lost his grip and began to drift away from the spacecraft! Romanenko's line was not secure; at the last second, Grechko caught hold of the line and pulled his floating colleague to safety. The cosmonauts waited until months after their return to Earth before saying anything to authorities about their near disaster. Romanenko went on to spend 430 days in space on this and later flights.

Visit by Progress 1, January 20 to February 6. This automated cargo ship, without a crew, brought equipment, fresh fruit, mustard, horseradish, bread, music tapes and a cassette recorder, clothes, linen, air filters, an atlas, newspapers, and mail.

БАНЯ СПАТ (БАНЯ) "Steamroom," a traditional Russian bath. Surrounded by quotation marks, the word is used here sarcastically, mocking the engineering jargon (the acronym **СПАТ**) that calls a space-bath "A System of Taking Water Procedures."

On a television broadcast of February 10, Grechko noted a birthday: "Hello everyone. Today marks the one hundred and fiftieth birthday of Jules Verne, the remarkable French writer. There's hardly a person who hasn't read his books, at any rate not among the cosmonauts, because Jules Verne was a dreamer, a visionary who saw flights in space. I'd say this flight too was predicted by Jules Verne."

A visiting cosmonaut quietly mentioned to Romanenko that Grechko's father had just died. Romanenko decided to tell Grechko only after they were safely back to earth.

This red arrow celebrates the 84th day in orbit when *Salyut 6* equaled the space endurance record set five years earlier by America's *Skylab 4*. A thick red line extends from the 84th to the 91st day, when Grechko and Romanenko exceeded the previous endurance record by the officially necessary ten percent.

February 23, the 60th anniversary of the Soviet Army and Navy. The cosmonauts observed notable dates to mark the progress on their very long stay in space.

8 МАРТА!!! March 8, International Women's Day. Grechko and Romanenko made a television broadcast and prepared mail to send back on *Soyuz 28*.

Visit by *Soyuz 28*, March 2-10. In addition to a Czech cosmonaut (who became the first non-Soviet, non-American in space), the visitors brought a package with fresh onions, garlic, Bulgarian peppers, lemons, apples, milk, gingerbread, and honey.



Principles of Graphical Integrity

The representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented.

Lie Factor = (size of effect shown in graphic) / (size of effect in data)

Clear, detailed, and thorough labeling should be used.

Show data variation, not design variation.

Graphics must not quote data out of context.

The number of information-carrying (variable) dimensions depicted should not exceed the number of dimensions in the data

The Lie Factor =

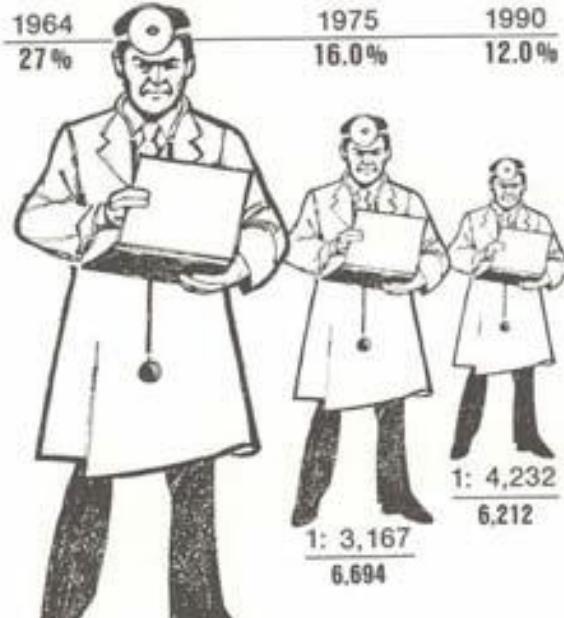
(size of effect shown in graphic)

(size of effect in data)

THE SHRINKING FAMILY DOCTOR In California

Percentage of Doctors Devoted Solely to Family Practice

1964	1975	1990
27%	16.0%	12.0%



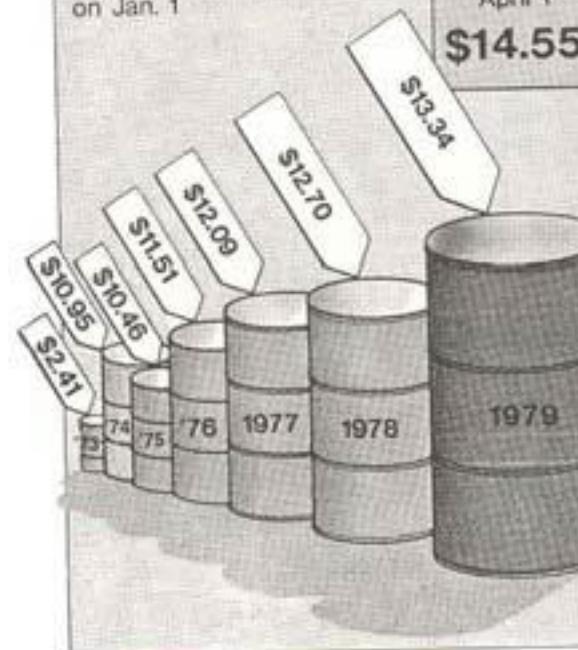
1: 2,247 RATIO TO POPULATION

8,023 Doctors

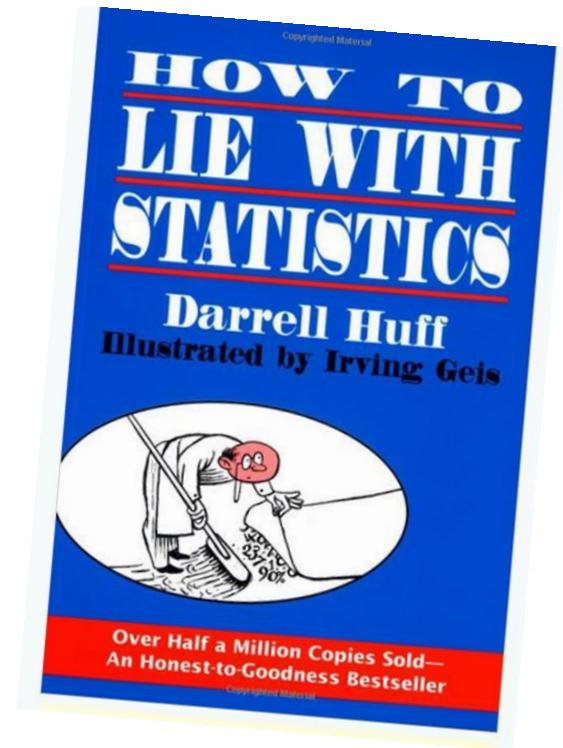
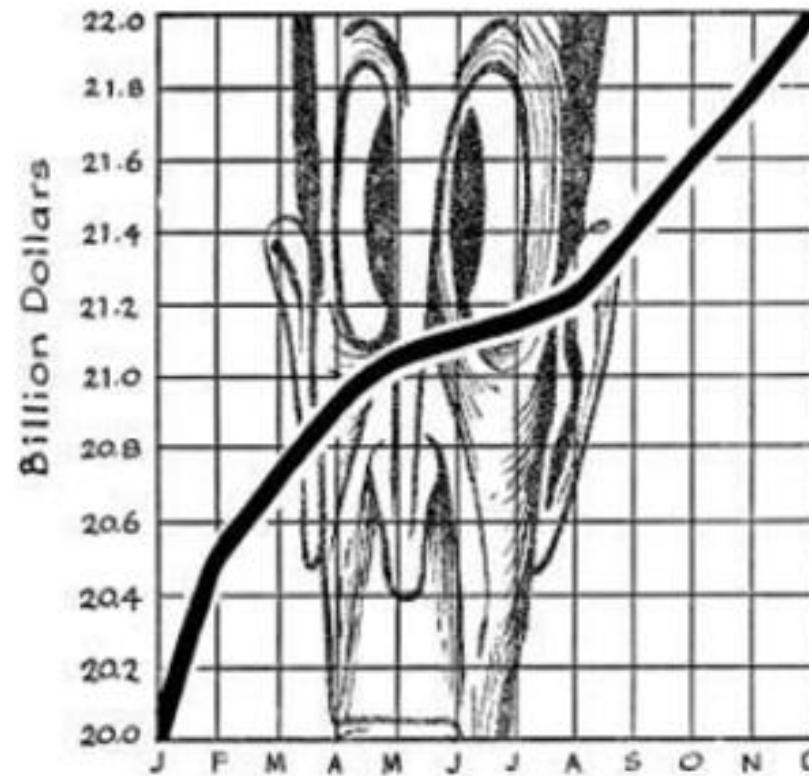
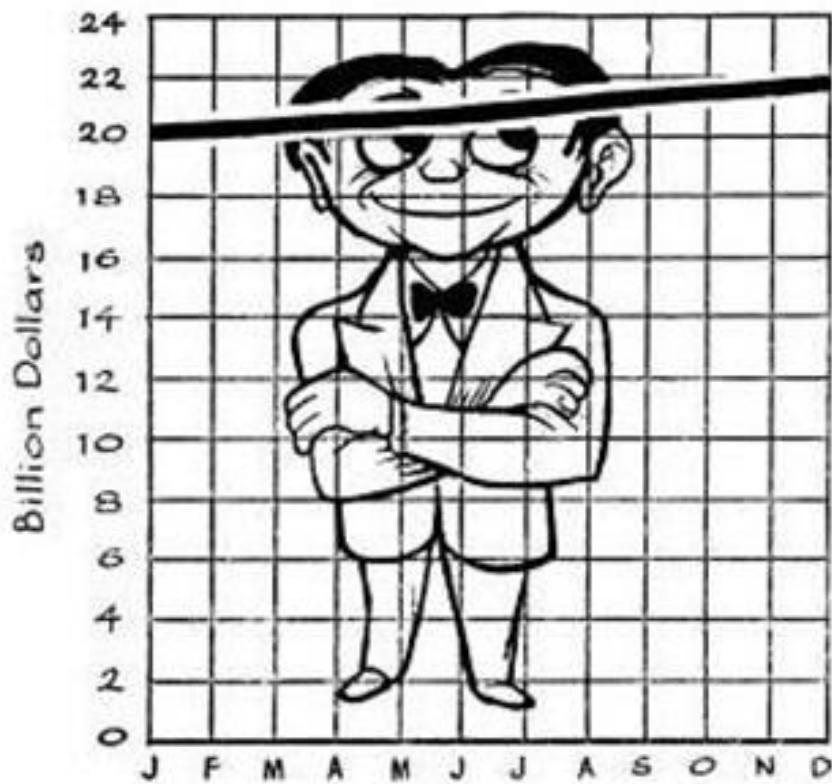
IN THE BARREL...

Price per bbl. of
light crude, leaving
Saudi Arabia
on Jan. 1

April 1
\$14.55

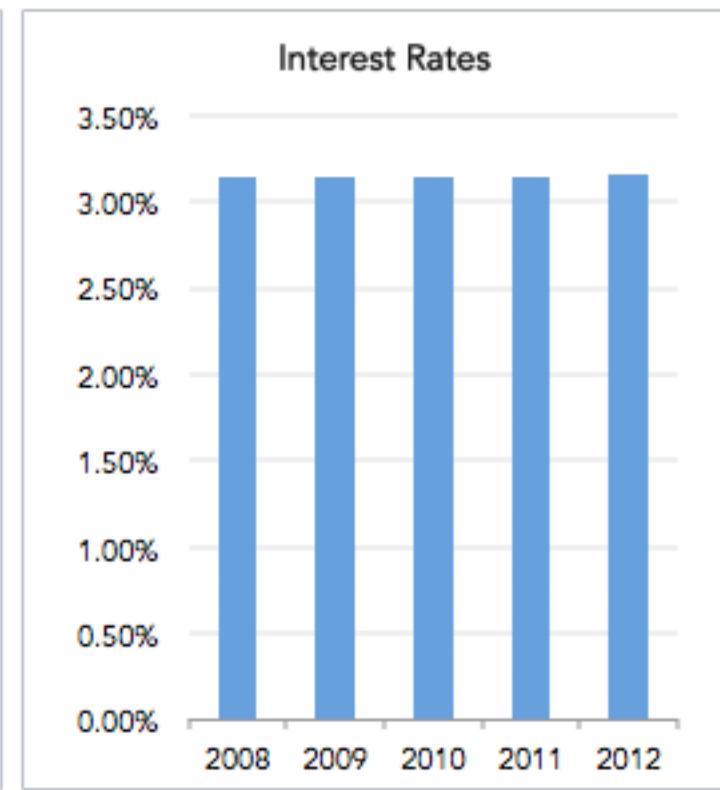
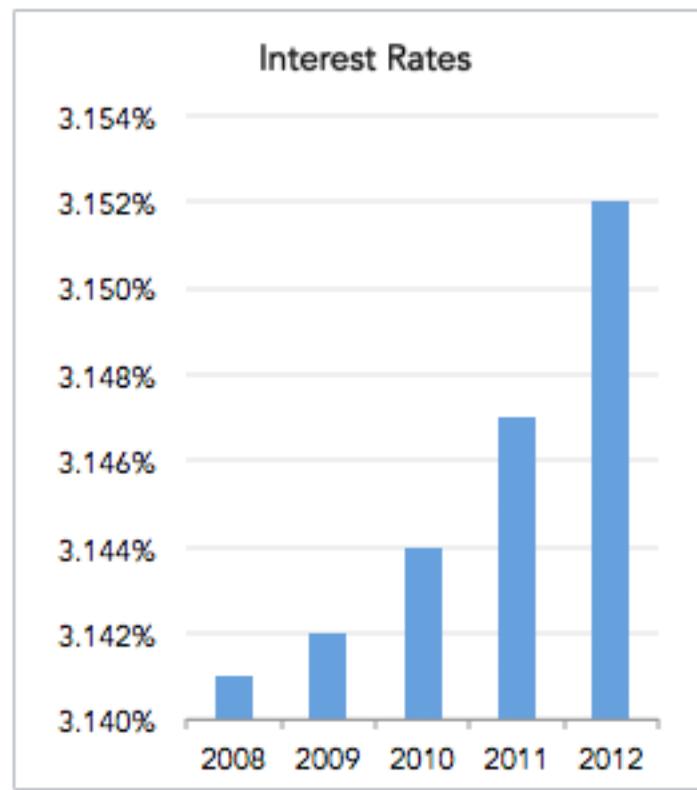


Honesty in Data Visualization

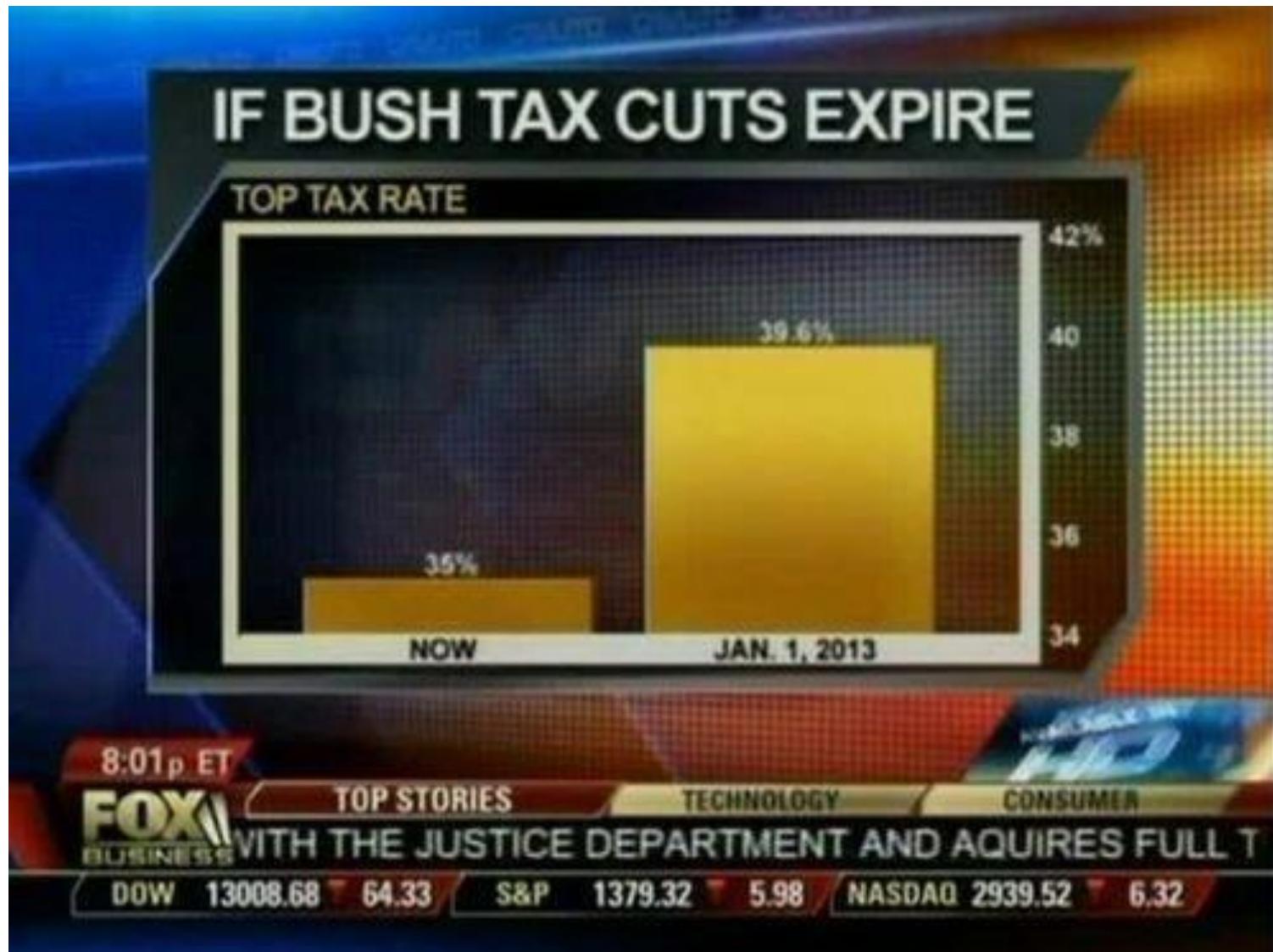


Lies - Truncated Y-Axis

Same Data, Different Y-Axis



Lies - Truncated Y-Axis

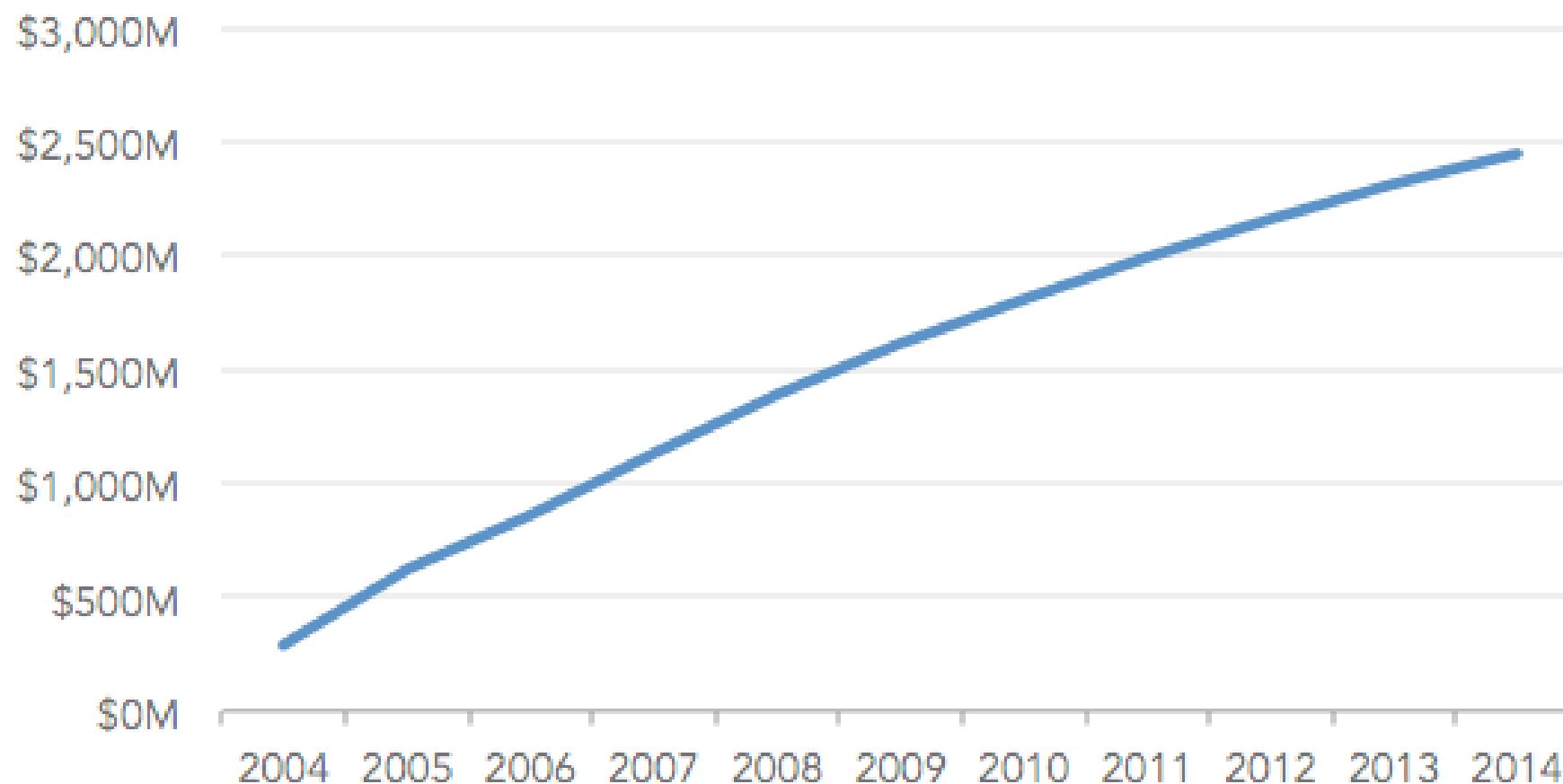


Lies - Truncated Y-Axis



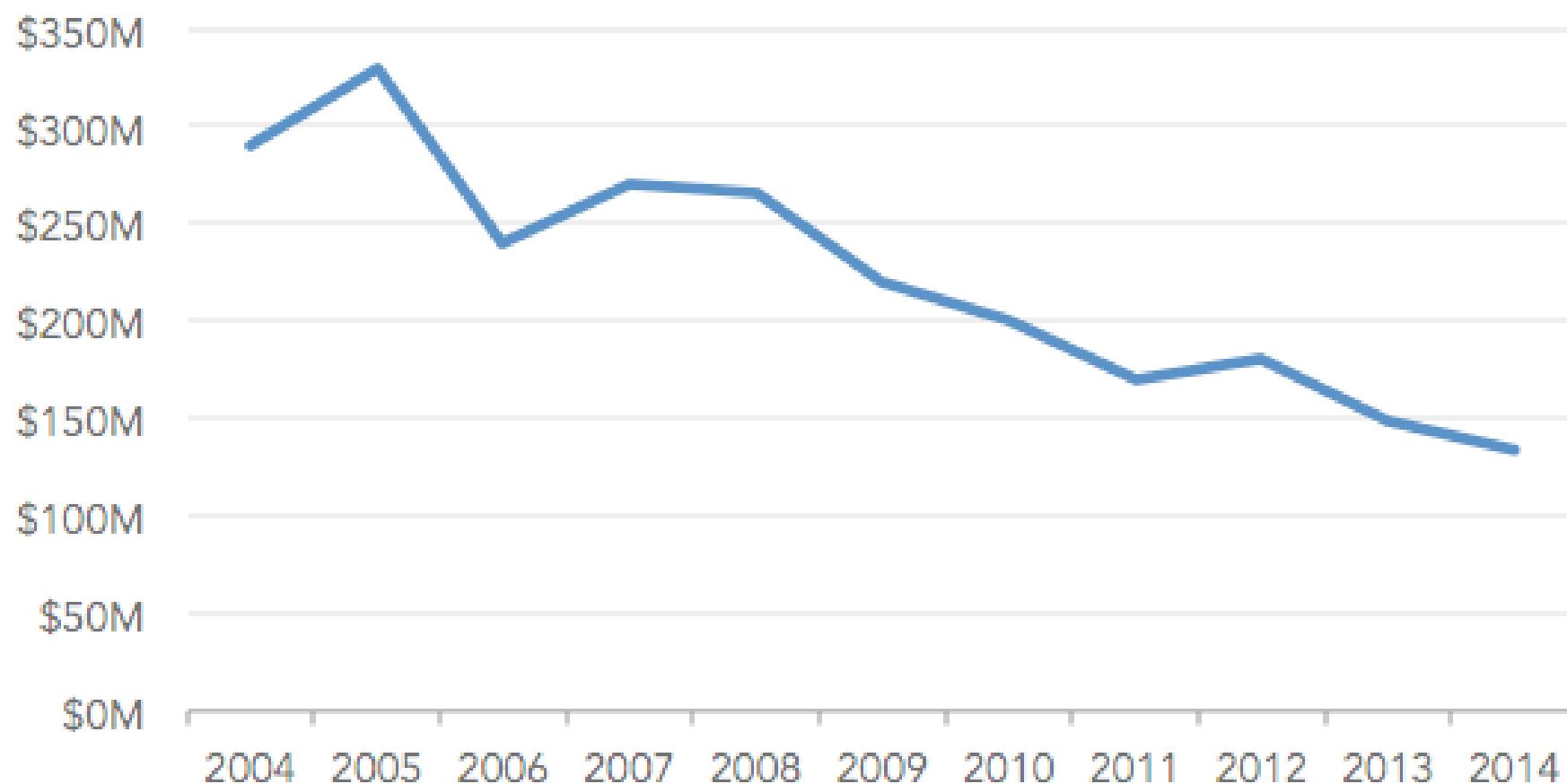
Lies - Cumulative Graphs

Cumulative Annual Revenue

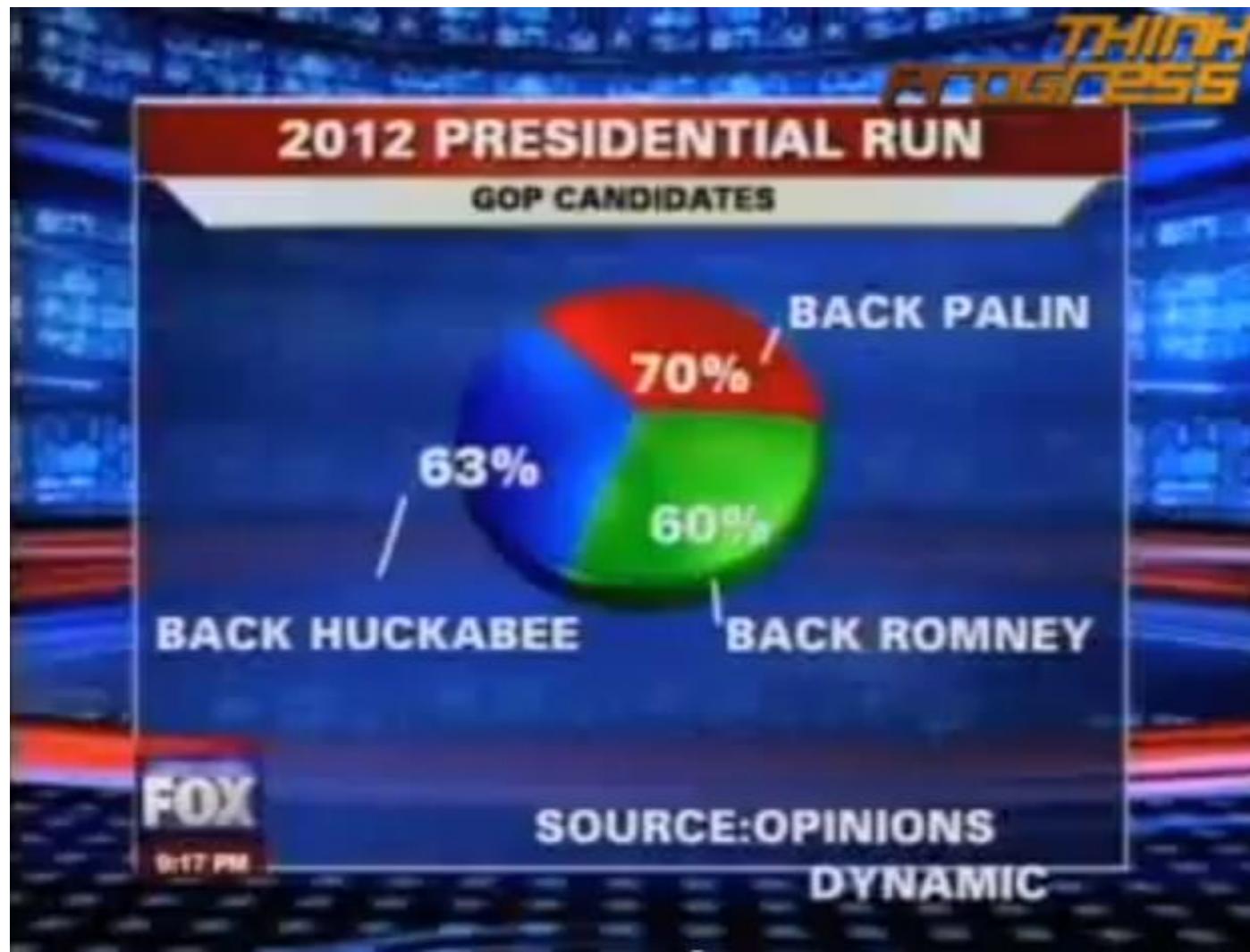


Lies - Cumulative Graphs

Annual Revenue



Lies - Ignoring Conventions

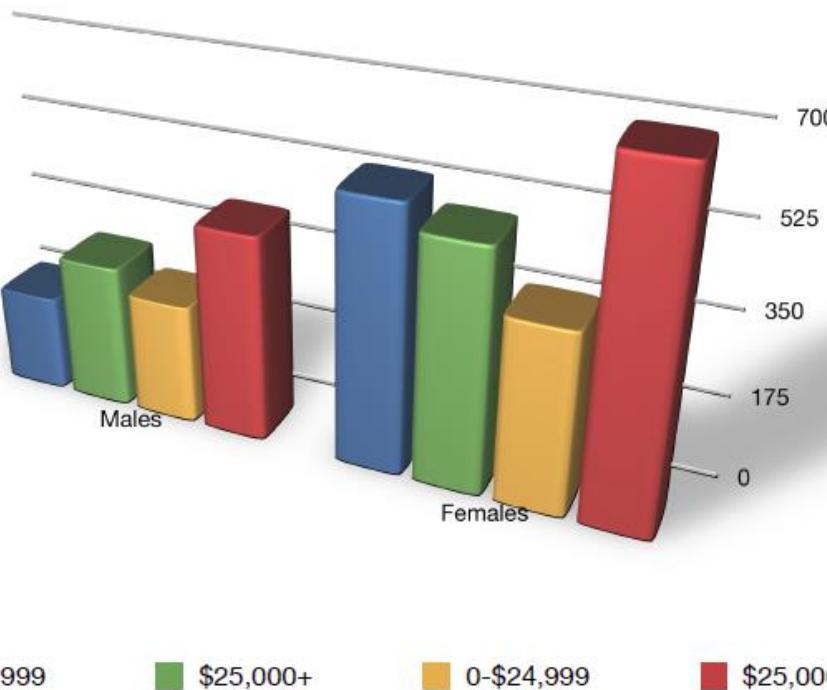


Why Do People Lie?

- Lack of quantitative skills
- Desire to “jazz up” the data
- Desire to simplify the data

Maximize Data-Ink Ratio

$$\text{Data-Ink Ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$



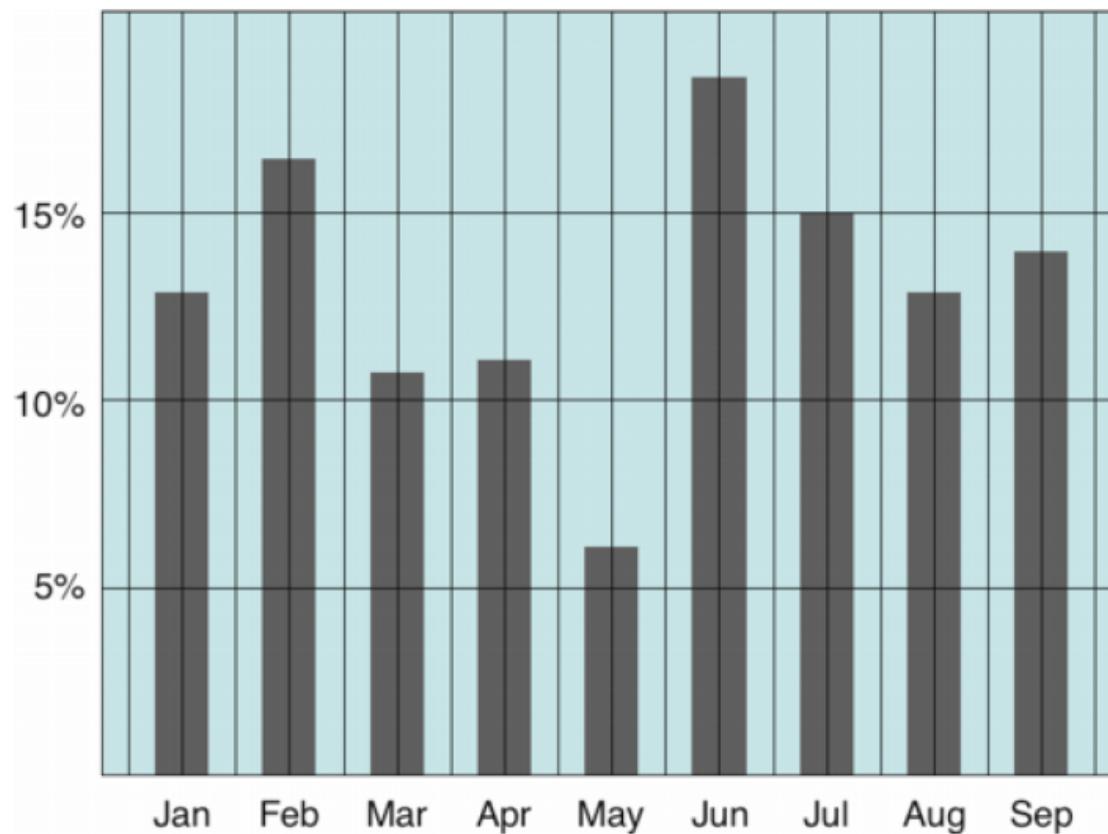
Maximize Data-Ink Ratio

$$\text{Data-Ink Ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$



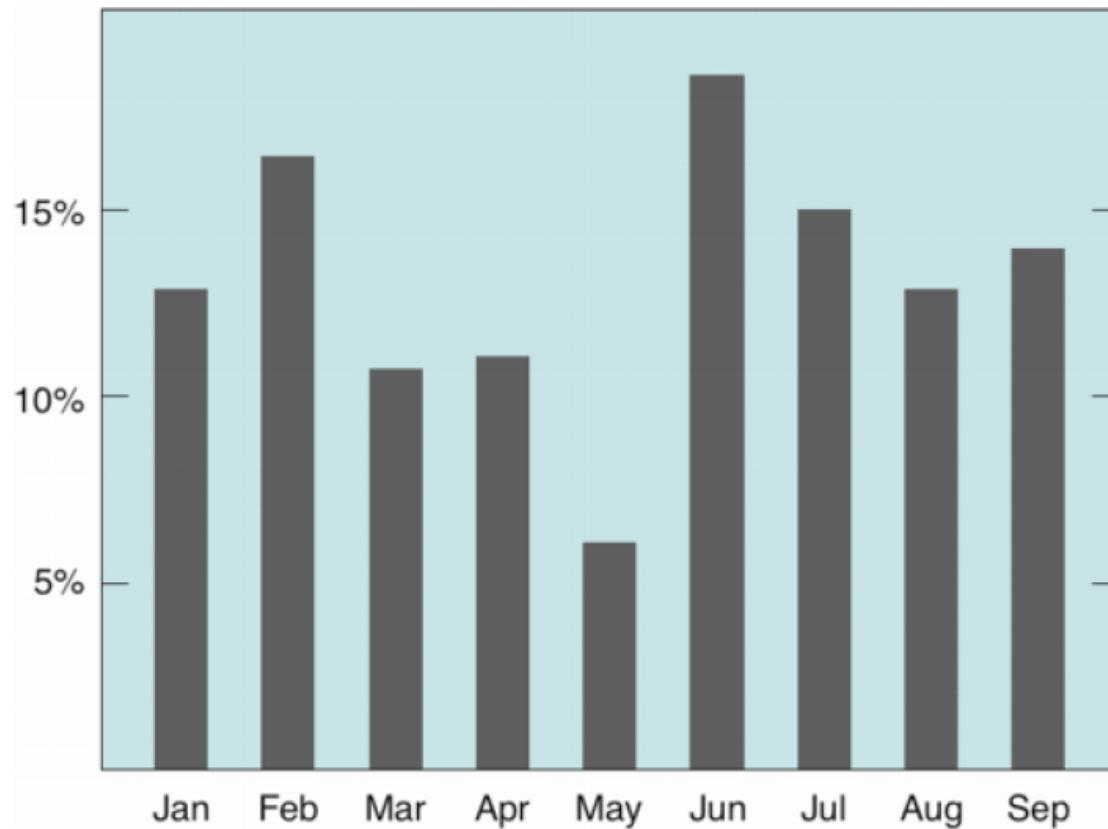
Avoid Chart Junk

Extraneous visual elements that distract from the message



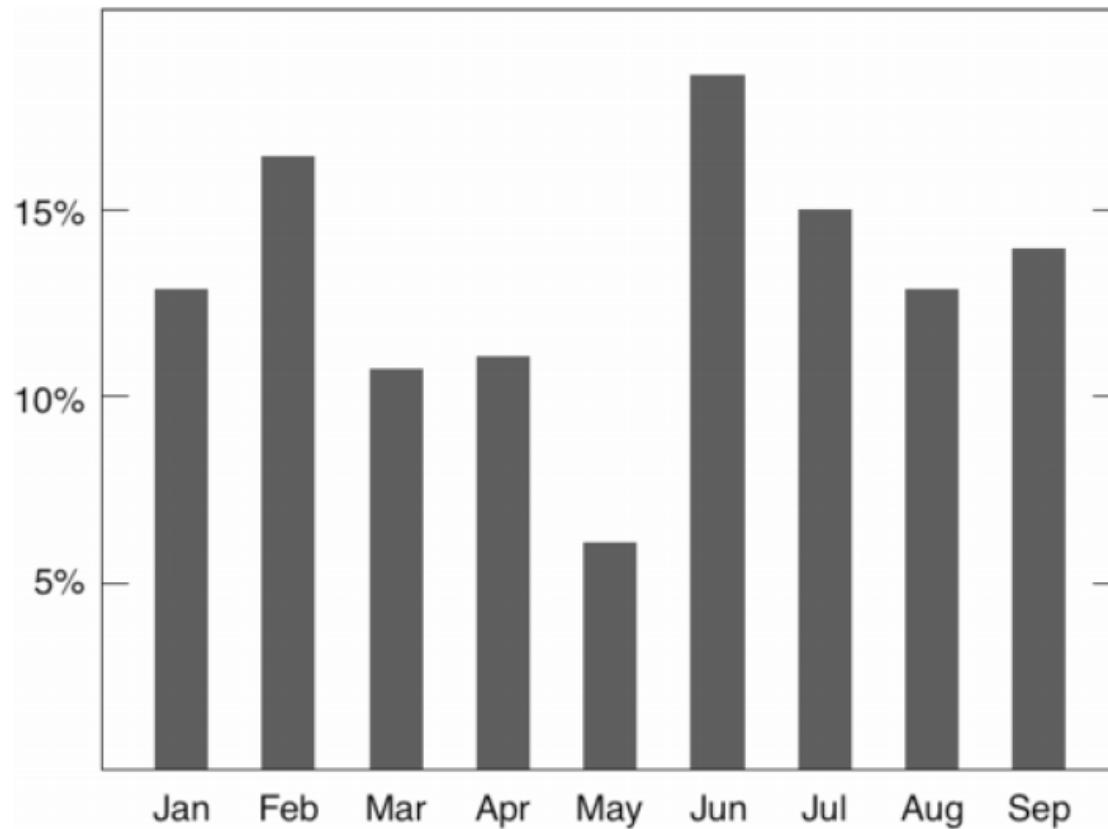
Avoid Chart Junk

Extraneous visual elements that distract from the message



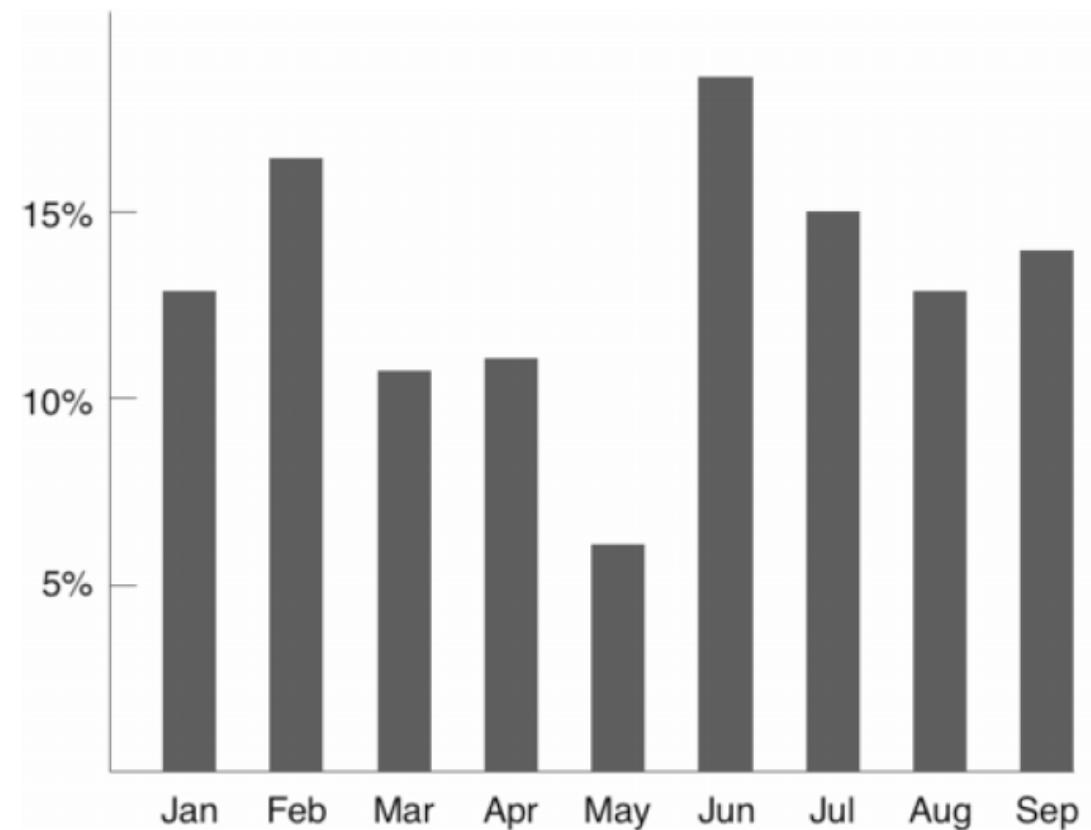
Avoid Chart Junk

Extraneous visual elements that distract from the message



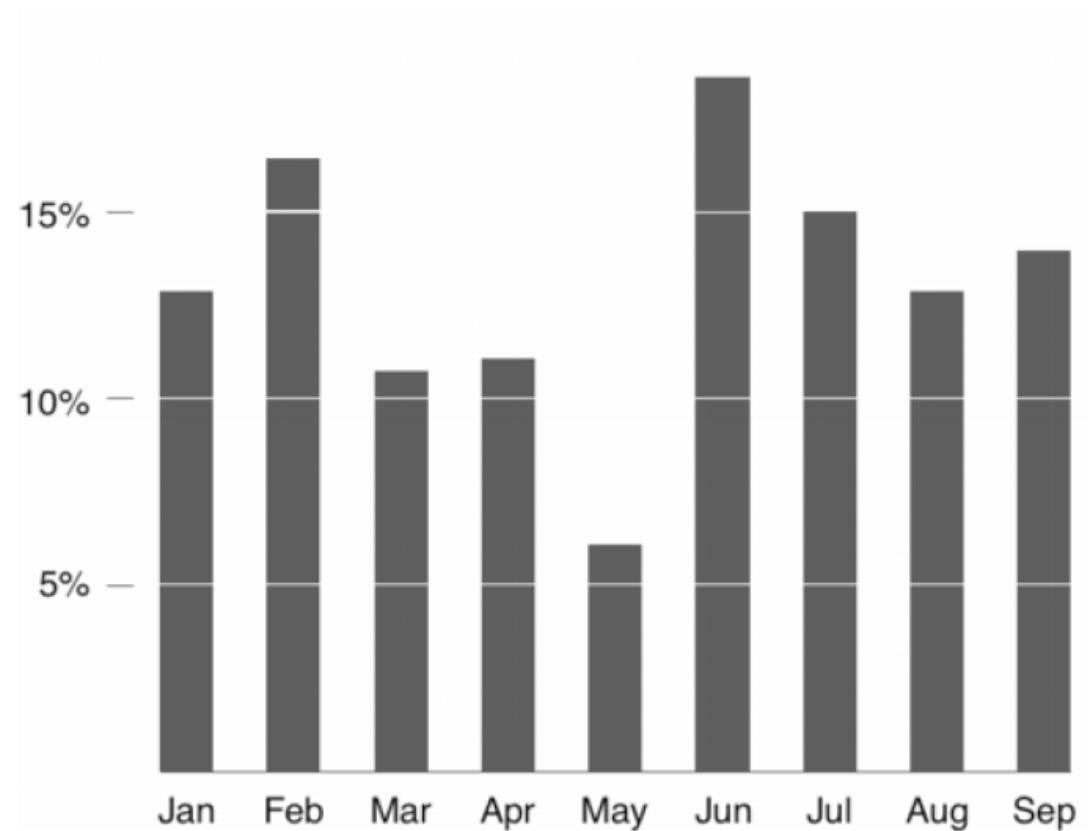
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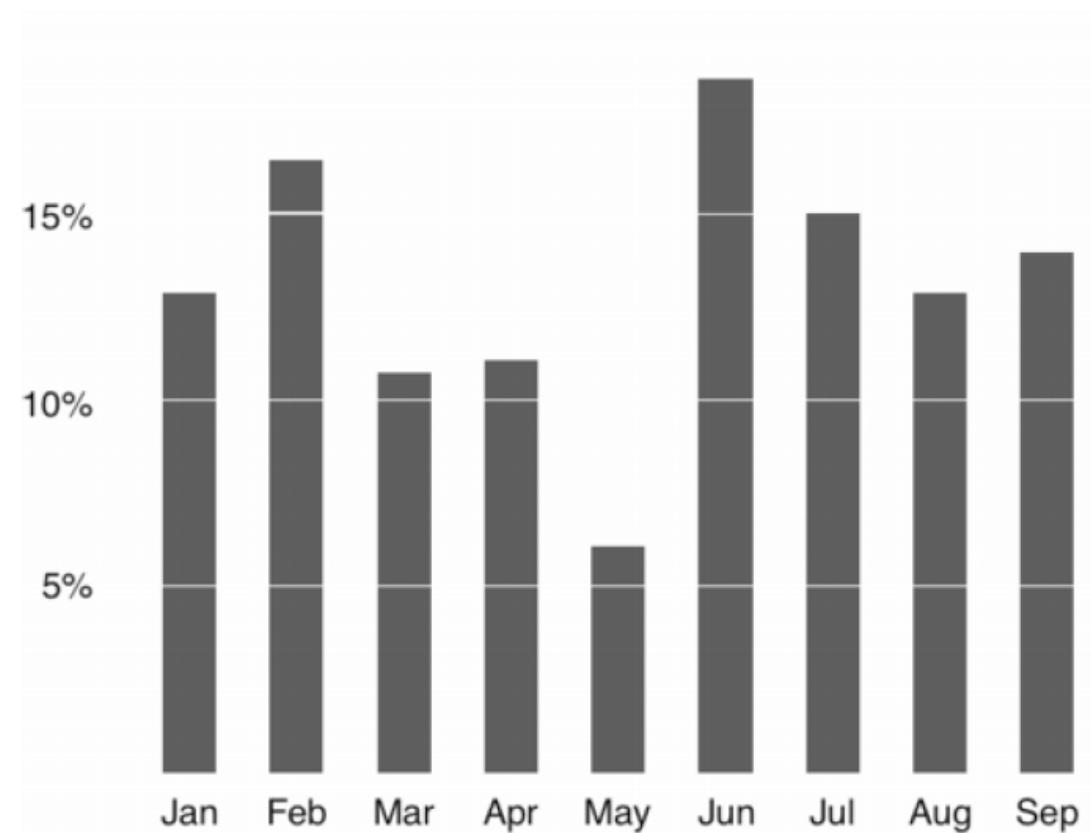
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Critiquing a Visualization

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- First, consider the purpose of the visualization and who the intended audience is.
- Then, ascertain your initial reaction.
- Then, examine the visualization in detail.
- Then, answer questions like...

Critiquing a Visualization

1. Is the design visually appealing / aesthetically pleasing?
2. Is it immediately understandable? If not, is it understandable after a short period of study?
3. Does it provide insight or understanding that was not obtainable with the original representation (text, table, etc.)?
4. Does it provide insight or understanding better than some alternative visualization would? Or does it require excessive cognitive effort? What kind of visualization might have been better?

Critiquing a Visualization

5. Does the visualization reveal trends, patterns, gaps, and/or outliers?
Can the viewer make effective comparisons?
6. Does the visualization successfully highlight important information,
while providing context for that information?
7. Does it distort the information? If it transforms it in some way, is
this misleading or helpfully simplifying?
8. Does it omit important information?
9. Is it memorable?

Critiquing a Visualization

I 0. Does it use visual components properly?

- Does it properly represent the data using lines, color, position, etc?
- Does it transform nominal, ordinal, and quantitative information properly?

I I. Does it use labels and legends appropriately?