A Few Things You May Need to Create an Effective Visualization

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Visualization is important

29, 31, 37, 41, 23, 43, 47, 19, 53, 17, 59, 61, 67, 71, 73, 13, 79, 83, 89, 11, 97, 101, 103, 107, 109, 113, 127, 131, 137, 139, 7, 149, 151, 157, 163, 167, 173,
49, 179, 181, 121, 191, 193, 197, 199, 5, 211, 25, 169, 223, 227, 229, 233, 239, 241, 990, 251, 143, 257, 91, 77, 263, 119, 133, 269, 271, 125, 187, 277, 161,
281, 283, 960, 209, 966, 85, 95, 65, 221, 930, 293, 115, 924, 55, 203, 145, 307, 247, 155, 311, 217, 289, 313, 900, 840, 253, 317, 870, 185, 35, 984, 996, 331,
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888, 301, 265, 367, 894, 876, 373, 361, 175, 341, 379, 864, 846, 852, 69, 87, 93, 295, 816, 828, 57, 329, 383, 111, 750, 51, 792, 123, 343, 129, 305, 834, 389,
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944, 976, 493, 530, 532, 848, 975, 405, 520, 608, 510, 516, 578, 752, 489, 656, 688, 904, 345, 497, 518, 544, 776, 808, 824, 856, 872, 285, 483, 504, 525,
592, 632, 664, 712, 844, 892, 908, 916, 932, 956, 964, 255, 435, 499, 506, 536, 568, 584, 585, 596, 604, 628, 652, 668, 674, 692, 694, 698, 706, 716, 718,
724, 734, 746, 758, 764, 766, 772, 778, 788, 794, 796, 802, 818, 838, 842, 862, 866, 878, 886, 898, 914, 922, 926, 934, 958, 974, 982, 998, 2, 4, 8, 16, 32, 64,
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142, 146, 195, 212, 486, 615, 118, 122, 296, 368, 416, 519, 106, 188, 442, 448, 470, 511, 561, 645, 693, 164, 172, 248, 509, 94, 232, 474, 515, 531, 567, 705,
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174, 617, 649, 619, 144, 198, 873, 240, 725, 679, 879, 631, 909, 108, 138, 156, 671, 70, 96, 927, 921, 875, 641, 667, 114, 168, 643, 933, 72, 707, 745, 939,
132, 647, 102, 951, 963, 999, 54, 180, 755, 48, 775, 653, 689, 721, 981, 36, 210, 659, 24, 126, 661, 935, 18, 78, 993, 12, 150, 697, 845, 6, 785, 66, 703, 673,
749, 677, 84, 120, 713, 683, 763, 737, 815, 691, 90, 731, 847, 42, 835, 701, 791, 833, 60, 709, 865, 767, 719, 30, 781, 727, 733, 895, 779, 925, 739, 793, 803,
905, 743, 751, 799, 757, 761, 769, 931, 817, 955, 889, 773, 965, 787, 985, 917, 869, 995, 797, 851, 871, 809, 811, 841, 821, 959, 823, 827, 829, 913, 973, 893,
839, 901, 899, 923, 853, 857, 859, 863, 949, 877, 881, 979, 883, 943, 887, 907, 911, 919, 989, 929, 961, 937, 941, 947, 953, 967, 971, 977, 983, 991, 997, ,

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

can you tell me the trend of these numbers from left to right?

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45

What Does This Example Tell Us?

Cognitive study has shown that human visual system is the most effective channel to transport information to the brain.

Stimulus → Eye → Brain

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45

Leading to the introduction of **visualization**

Which gender and income group of people has different trend of triglyceride (the percentage of fat) level over years from the others?

	Male		Female	
Income\Age	<65	65 and above	<65	65 and above
0-$24,999	250	200	375	550
$25,000+	430	300	700	500

Triglyceride Level
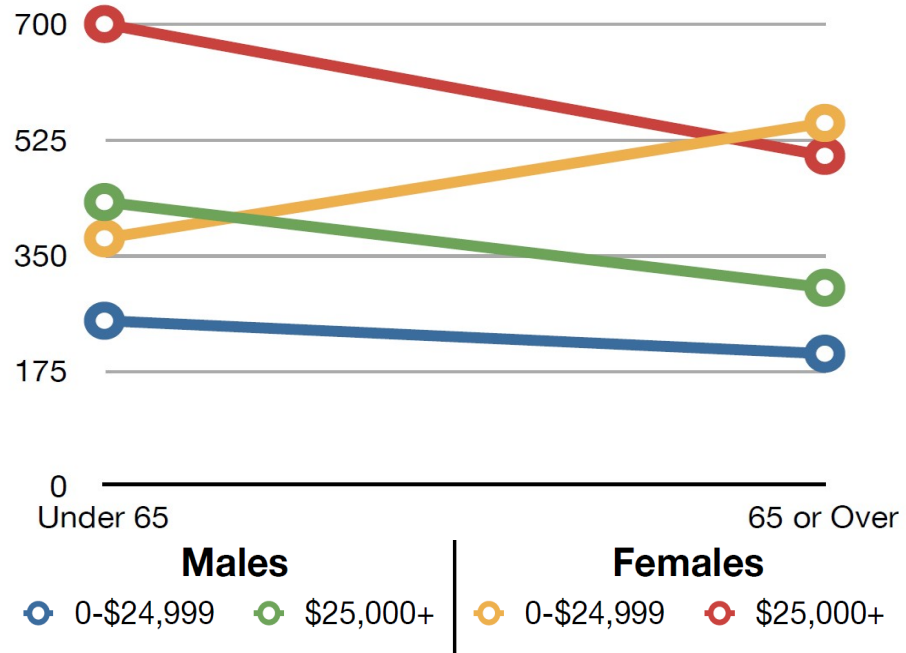
	Under 65	65 or Over
Males 0-$24,999	~250	~205
Males $25,000+	~425	~305
Females 0-$24,999	~375	~560
Females $25,000+	700	~500

Males · 0-$24,999 · $25,000+ | **Females** · 0-$24,999 · $25,000+

"Visualization is really about **external cognition**, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind."

Tool/Means to enable a User **insights into Data** via **Visual Representation**

(or an understanding of the story behind the data)

Data Mining or Visualization?

A Few Things about Perception and Cognition

"Visualization is really about external cognition, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind."

Stuart Card

Long term memory
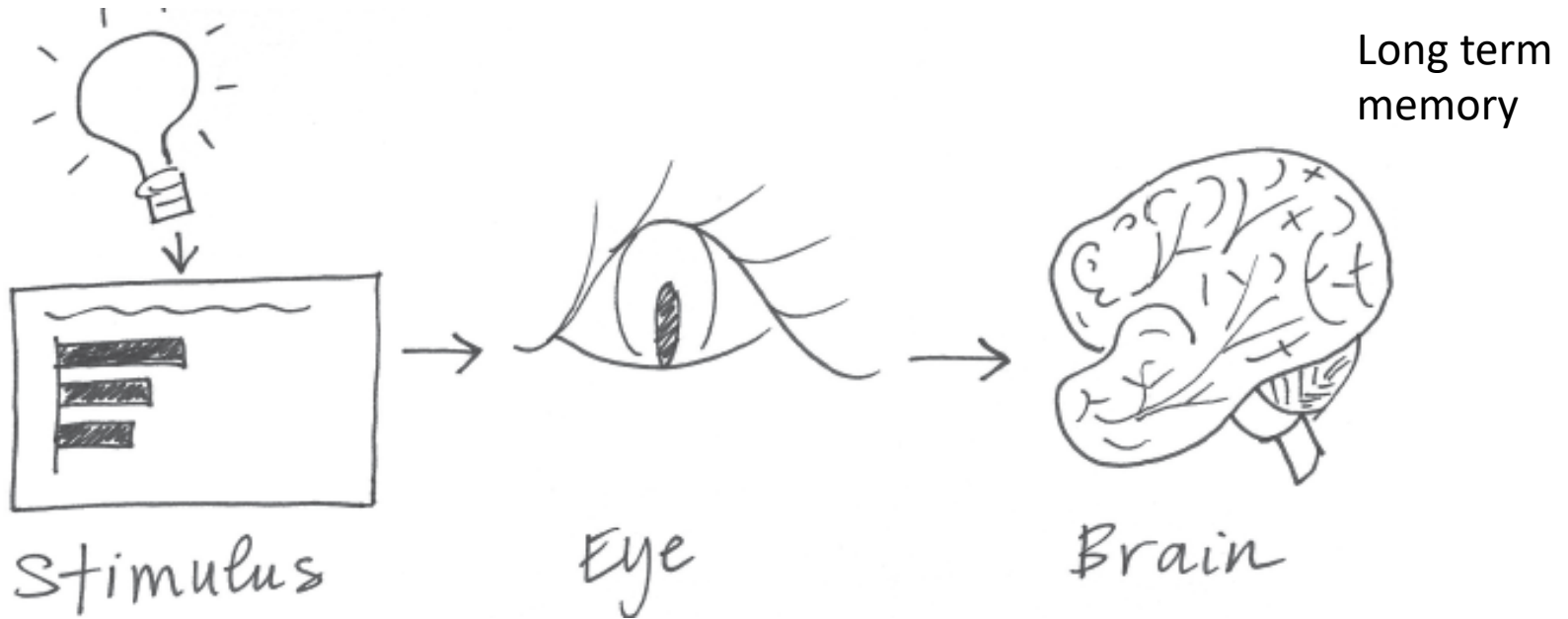
Visual stimulus

Visual perception

→ We see things: Shapes, colors, sizes, texture, orientation, transparency, etc.

Cognition

→ Mental process of acquiring knowledge from perception, experiences and others: How to interpret/ understand what we see

Our Eyes

Rods
- ~115,000,000
- Concentrated on the periphery of the retina
- Sensitive to intensity
- <u>Most sensitive at 500 nm (~green)</u>

Source: starizona.com

Cones
- ~7,000,000
- Concentrated near the center of the retina
- Sensitive to color
- Three of cones: long(~red), medium (~green), and short (~blue) wavelengths
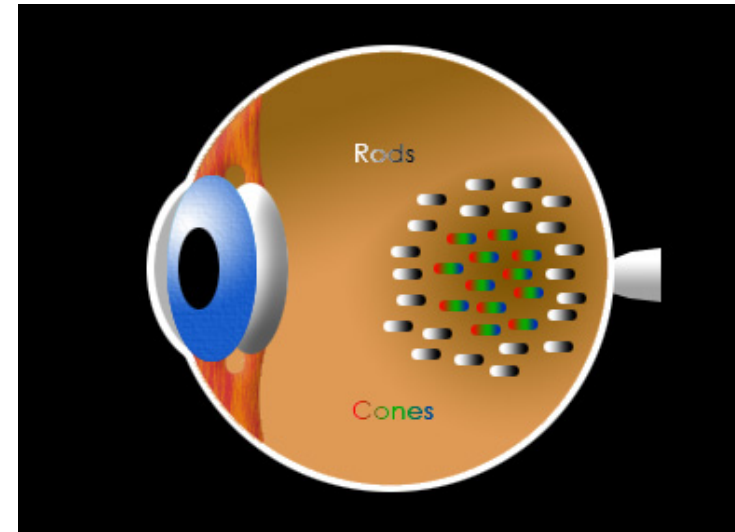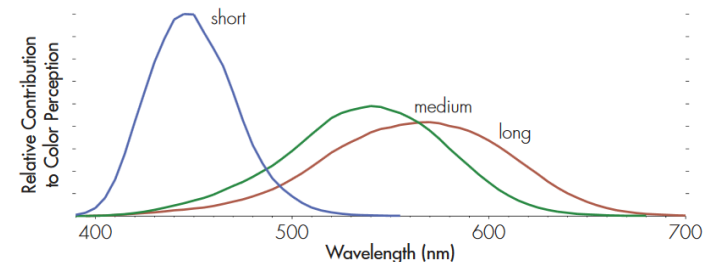
A few properties of our visual perception

Selective Attention Test

from Simons & Chabris (1999)

Let us look at another example

This is what is called change-blindness.

These examples tell us that people need to pay a lot of attention in order to capture the changes.

Therefore, **visualization should emphasize /highlight changes to help relieve the cognition load.**
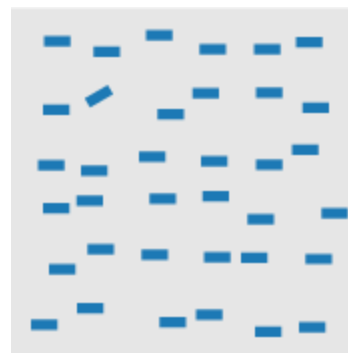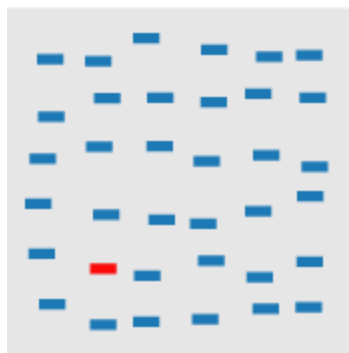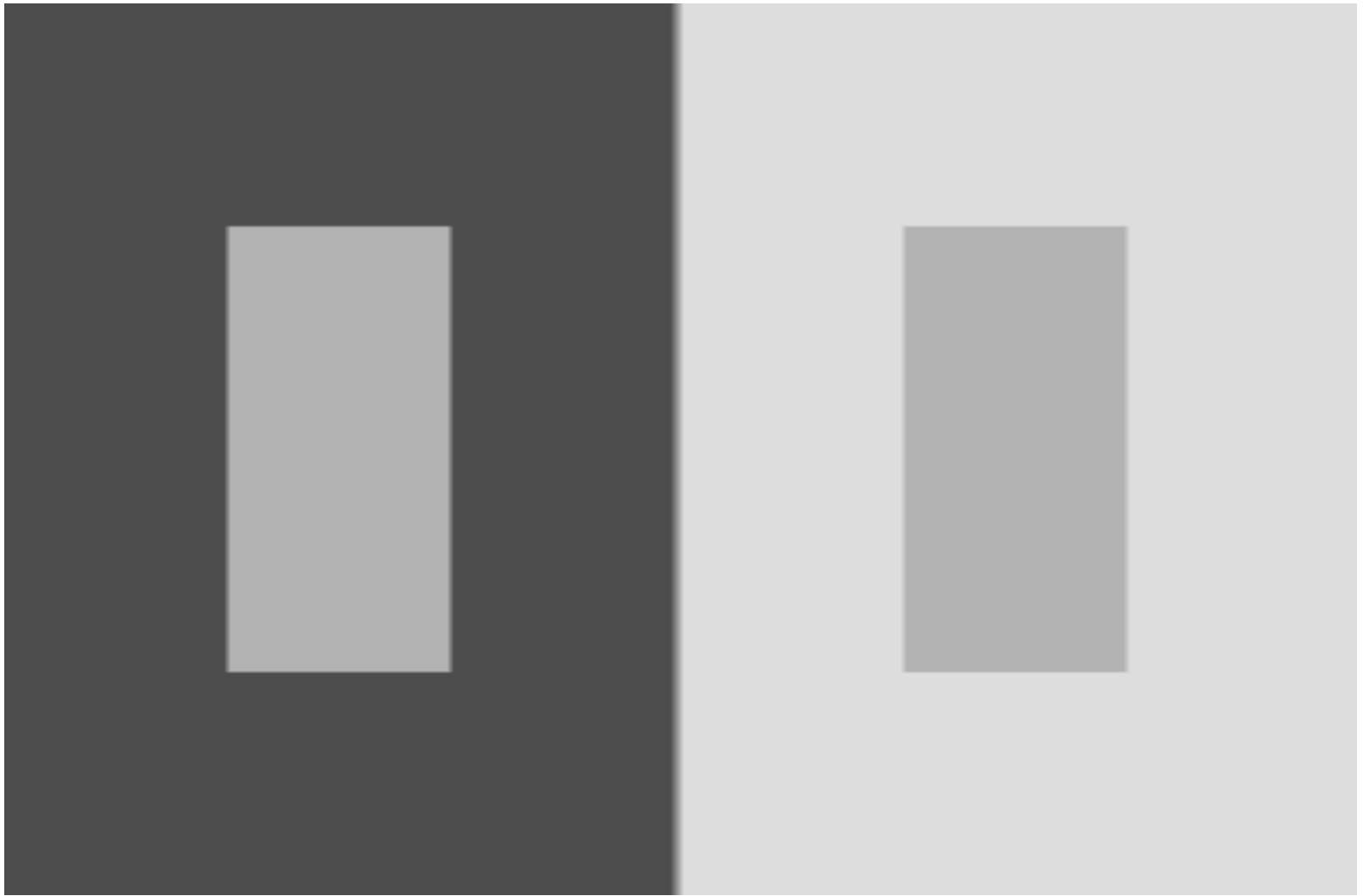
Our visual perception system is good at observing **relative difference** and is easy to be drawn to the **boundaries** of different regions / objects.

Mach Banding

Perceived Intensity

Actual Intensity
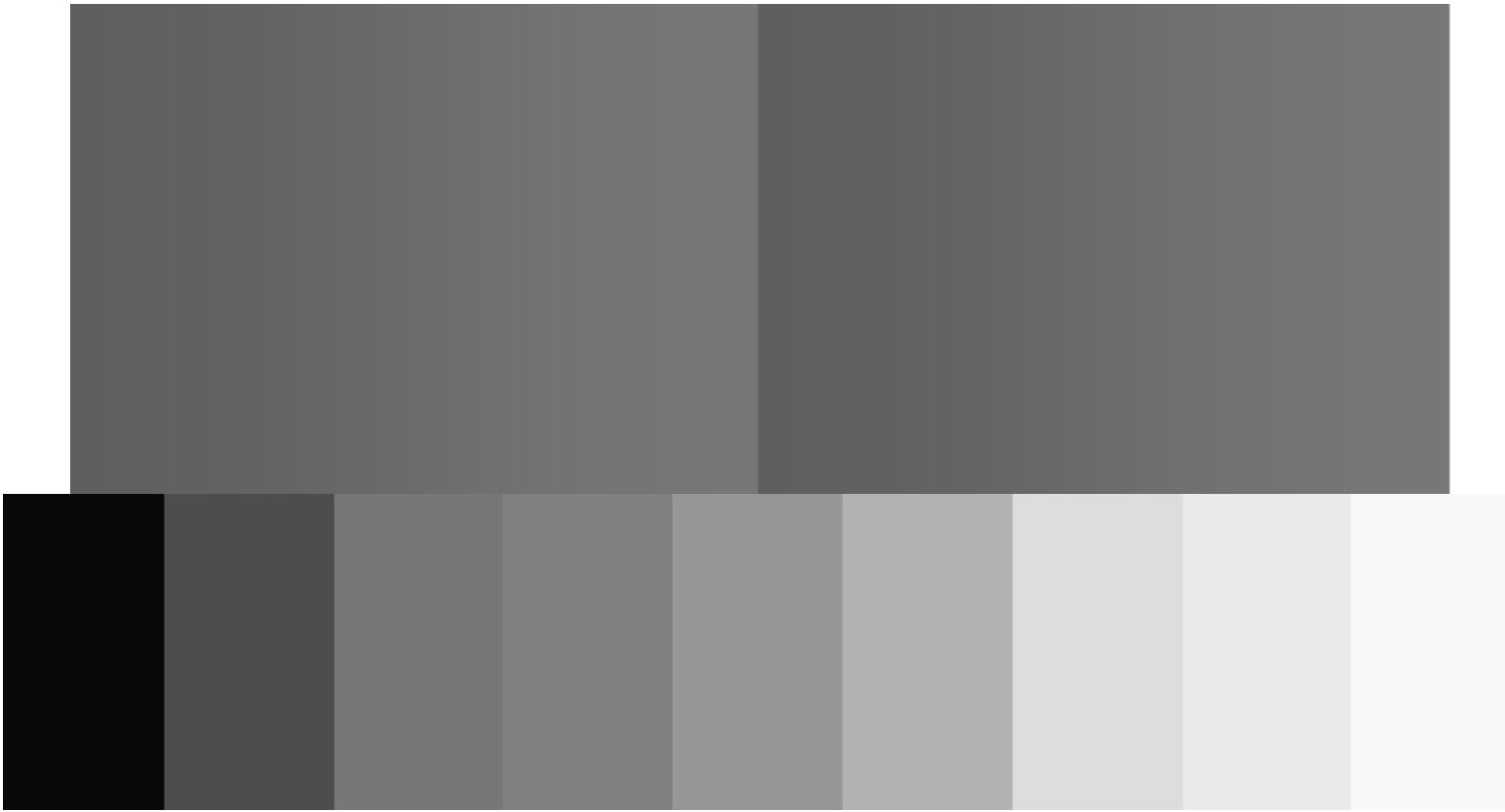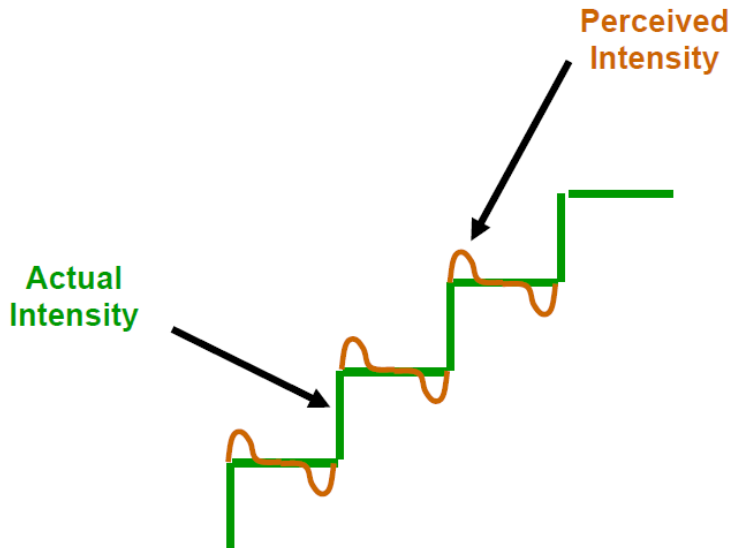
Relative vs. Absolute
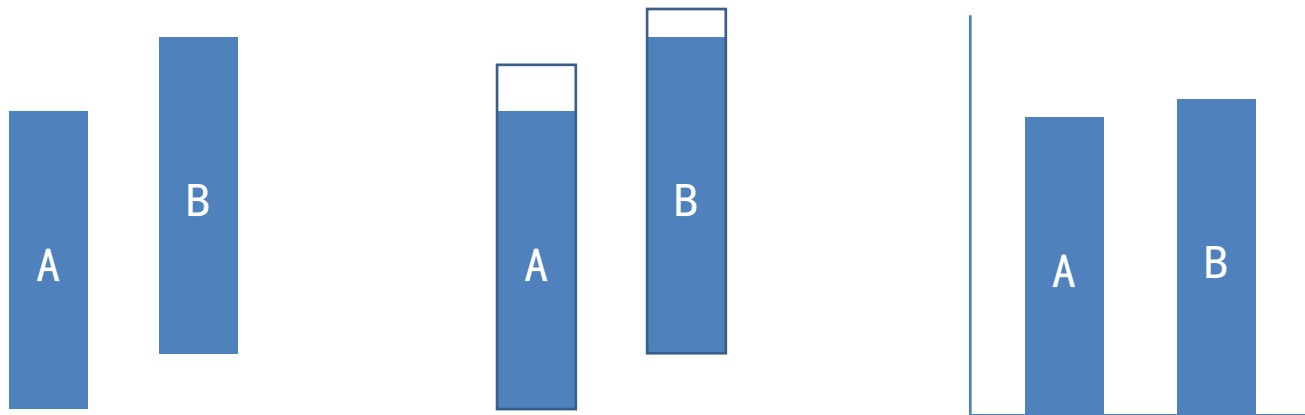
Weber's Law

We judge based on the relative difference rather than the individual absolute values.

"*What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.*"

Polyshyn

Long term memory

Brain

Back to the effectiveness of information conveying via visual channel
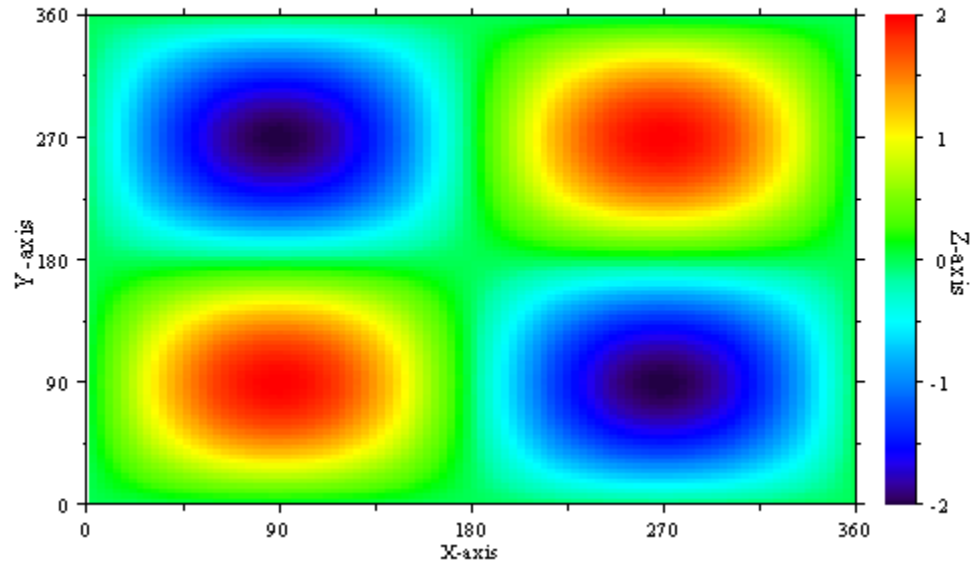
pre-attentive property of visual channel

Pre-attentive processing

"An understanding of what is processed pre-attentively is probably the most important contribution that visual science can make to data visualization" **(Ware, 2004, p. 19)**

Pre-attentive vs. attentive

Pre-attentive	Task	Attentive
< 500ms < 10ms	Individual object	> 500ms > 10ms
Parallel processing		Sequential processing

Brain

Long term memory

Pre-attentive features
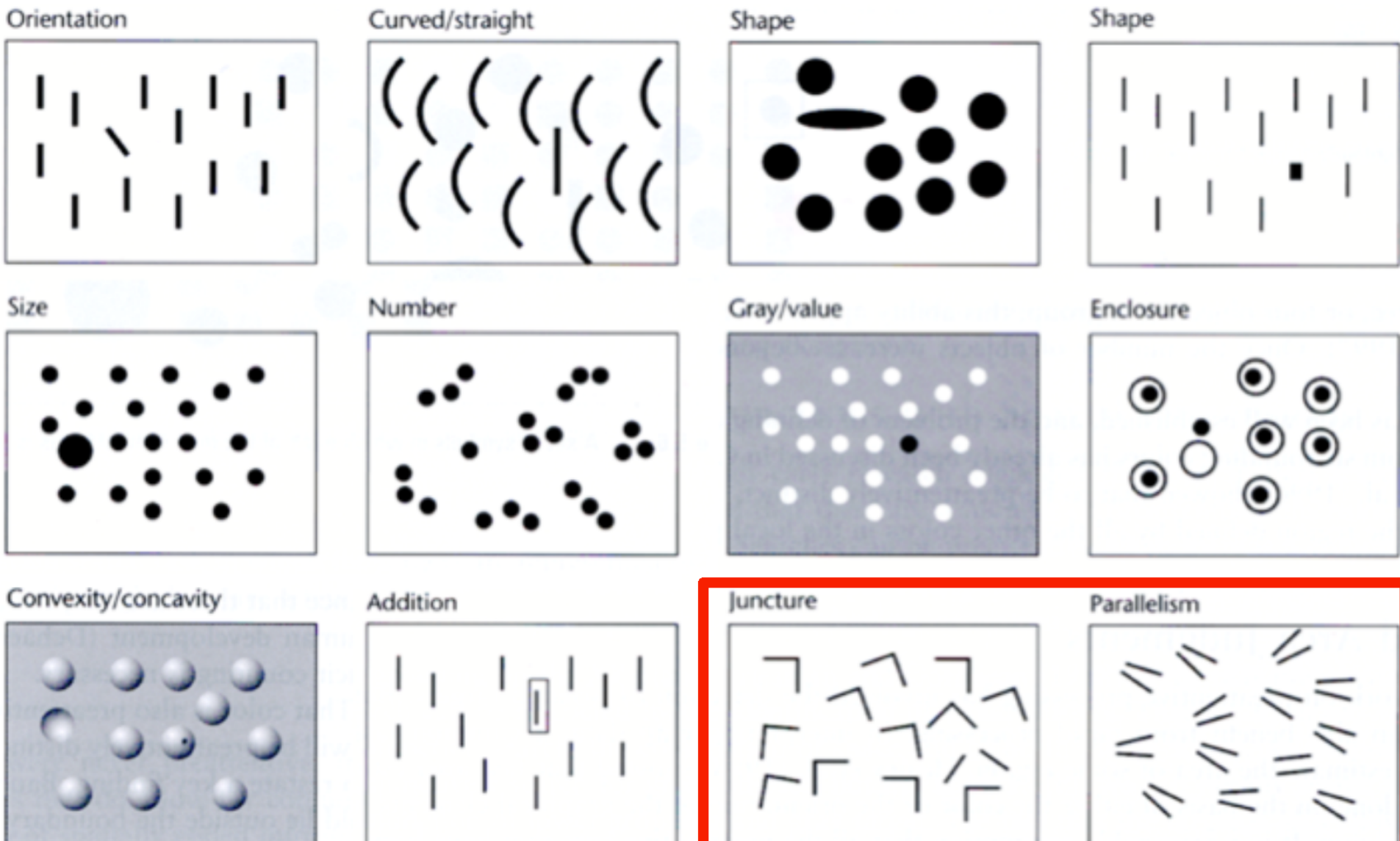
Orientation

Curved/straight

Shape

Shape

Size

Number

Gray/value

Enclosure

Convexity/concavity

Addition

Juncture

Parallelism

128176875613897654698450698560498282676298098584582245098564589450984509809435859091030209905959577256467505067890456788457898098216776548763649085609129498686

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959577256467505067890456
88457898098216776548763649085609129686

Gestalt Principles

Why we like to consider /separate background and fore ground when seeing things?

Why can we separate object with different shapes and/or other attributes?

What is a good shape?

 ......

People started thinking these questions in the beginning of 1900

The overall layout is more important than the individual elements, as the visual representation is perceived and understood as a whole in the beginning.

proximity   We tend to think of objects that are physically close together as belonging to part of a group.

Example 1

Example 2

Similarity

Objects that are of similar color, shape, size, or orientation are perceived as related or belonging to part of a group.
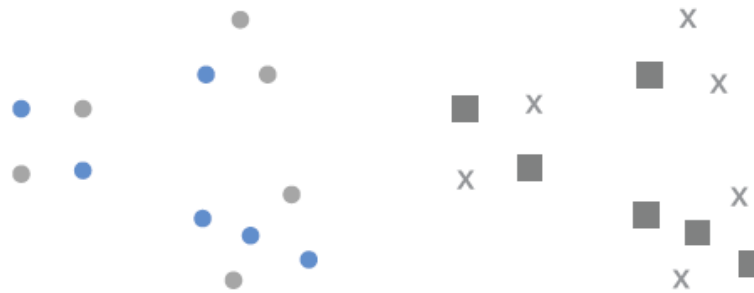
Example 1

Example 2

This can be leveraged in tables to help draw our audience's eyes in the direction we want them to focus.

From Storytelling with Data

Enclosure

We think of objects that are physically enclosed together as belonging to part of a group.
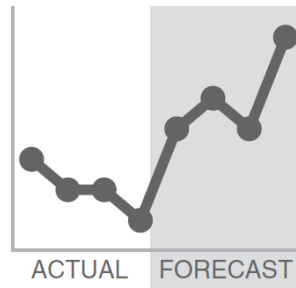
Example 1

Example 2

One way we can leverage the enclosure principle is to draw a visual distinction within our data.

From Storytelling with Data

Closure

People like things to be simple and to fit in the constructs that are already in our heads.

Example 1
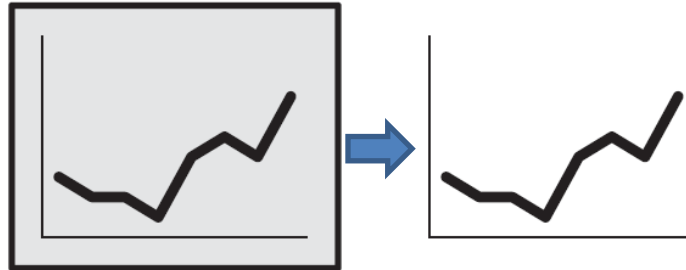
Example 2

We can remove chart borders and background shading and our graph still appears as a cohesive entity.

Continuity

When looking at objects, our eyes seek the smoothest path and naturally create continuity in what we see even where it may not explicitly exist.
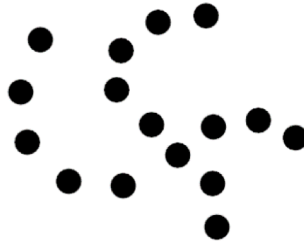
Example 1
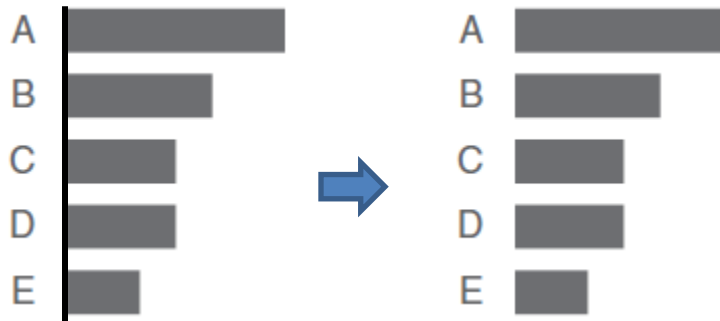
Example 2

Remove unnecessary axis if things are aligned.

Connection

We tend to think of objects that are physically connected as part of a group.
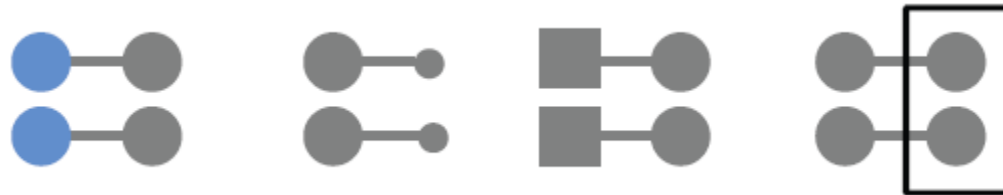
Example 1
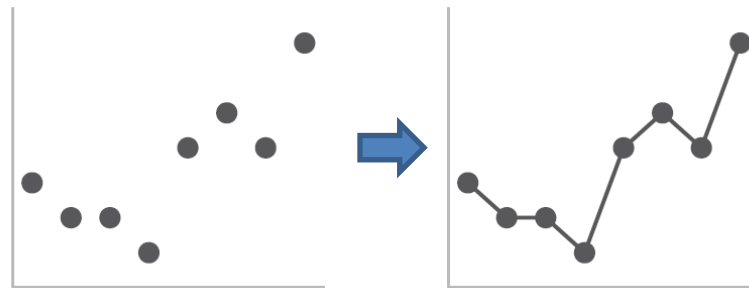
Example 2

One way that we frequently leverage the connection principle is in line graphs, to help our eyes see order in the data.

From Storytelling with Data

Other useful principles

Simplicity
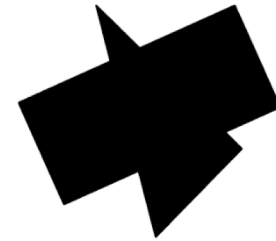
Common fate
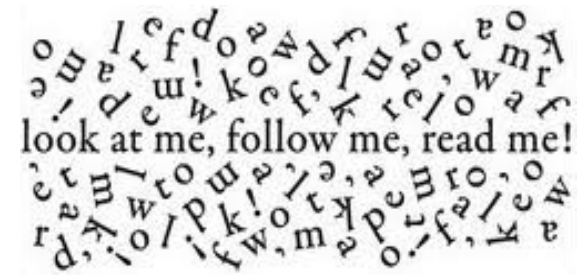
Symmetry
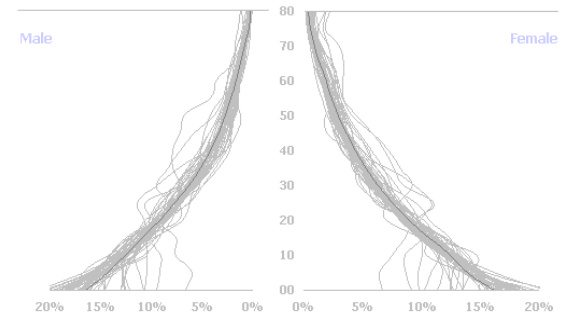
Past experience
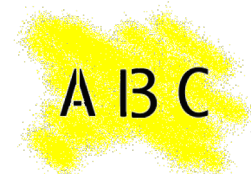
Visual attributes / cues that can be used for encoding

Space

Location

Annotation

Size

Color

Brightness

Saturation

Hue

Color scheme

Transparency

Orientation

Shapes

Texture

Animation

How much bigger is the lower bar?

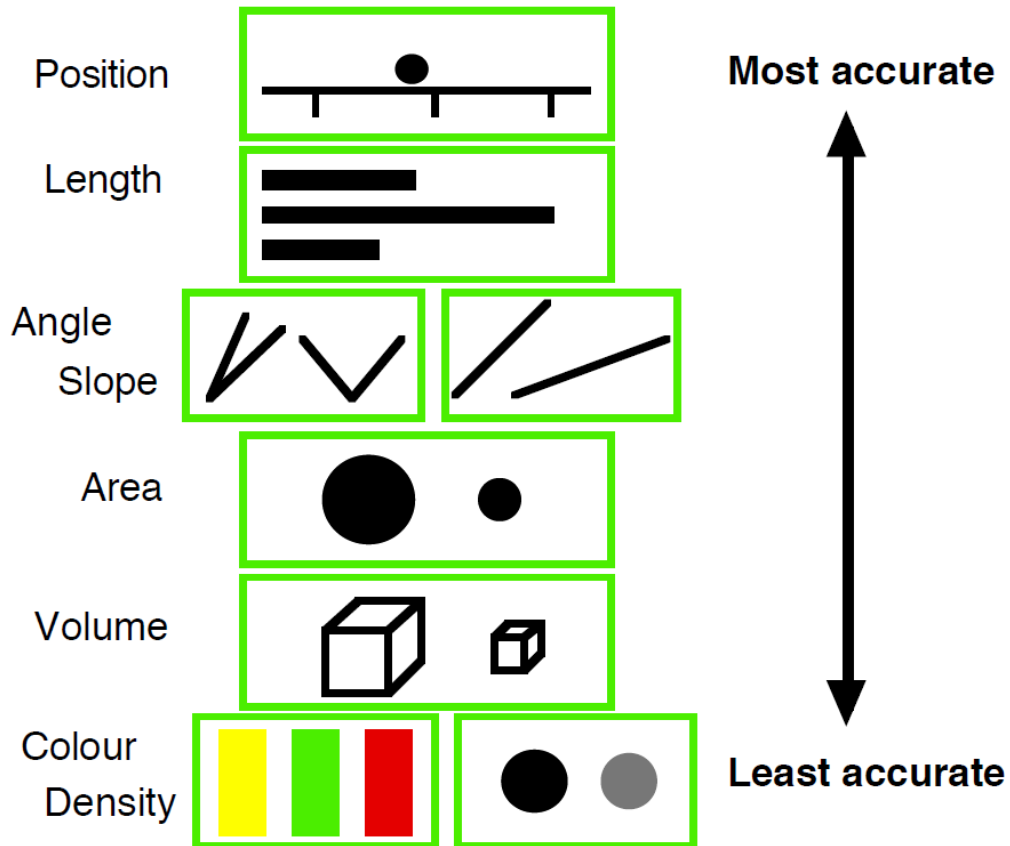How much bigger is the lower bar?

X 4

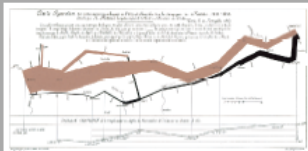How much bigger is the right circle?

How much bigger is the right circle?

X 5
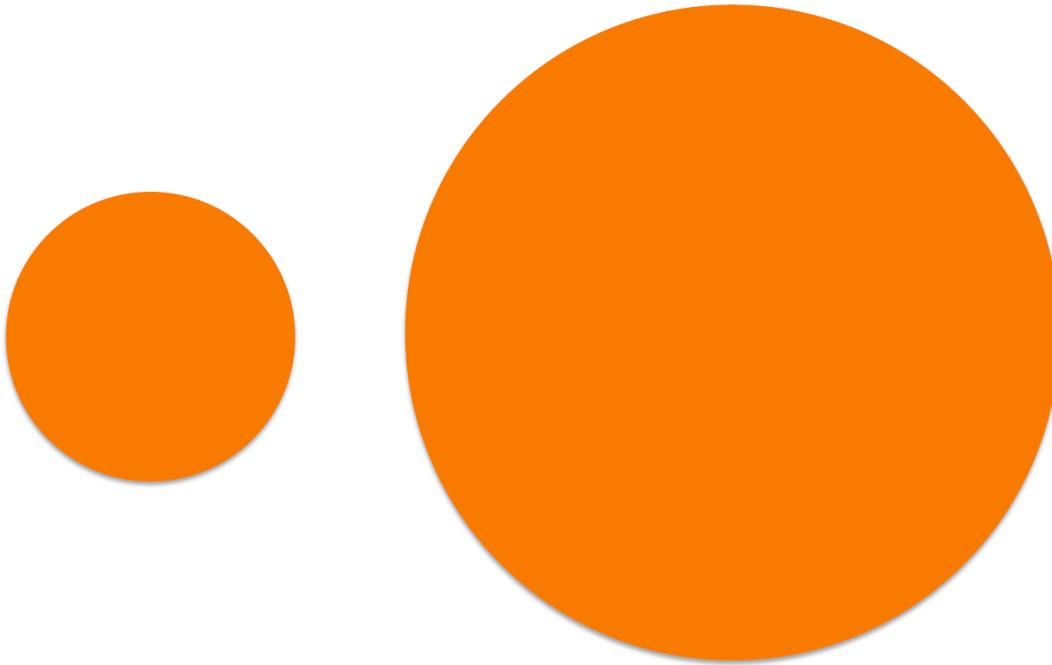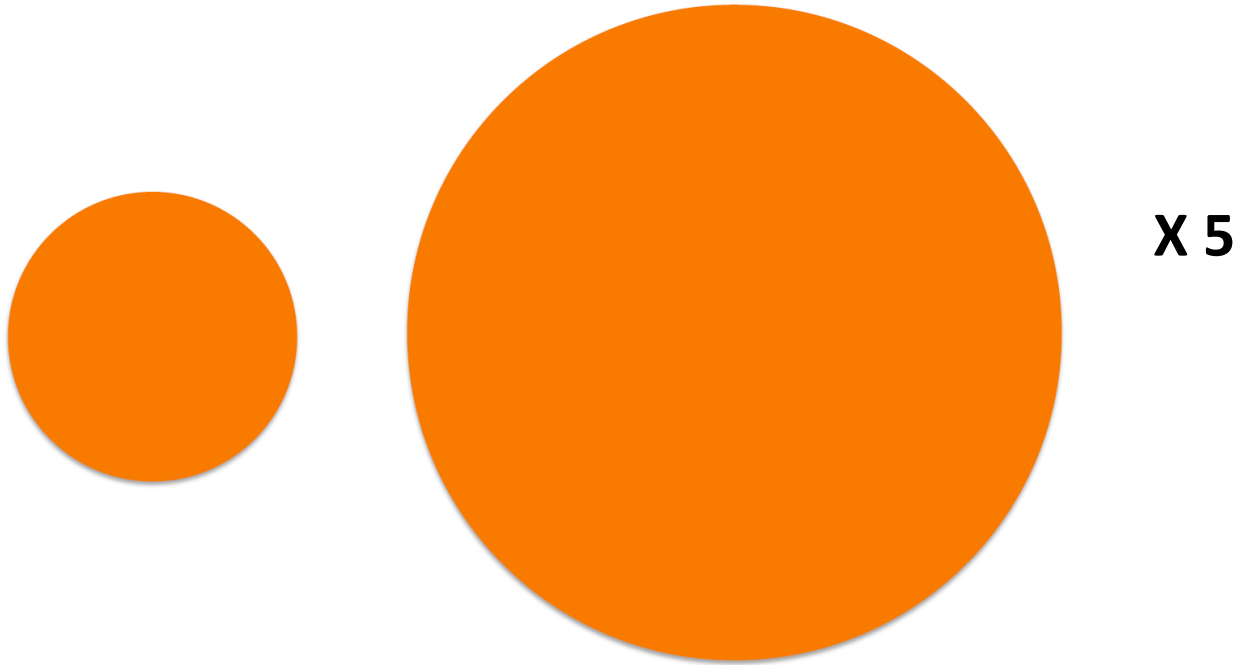
Accuracy of the judgement of the encoded quantity data

Quantitative, ordinal and categorical data
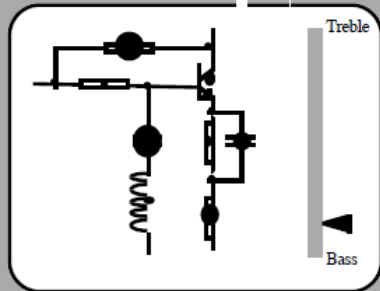
Quantitative	Ordinal	Categorical
Position	Position	Position
Length	Density	Colour hue
Angle	Colour saturation	Texture
Slope	Colour hue	Connection
Area	Texture	Containment
Volume	Connection	Density
Density	Containment	Colour saturation
Shape	Length	Shape
	Angle	Length
	Slope	Angle
	Area	Slope
	Volume	Area
		Volume
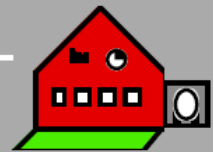
Guidance for the encoding of quantitative, ordinal and categorical Data (Mackinlay 1986)

Expressiveness and Effectiveness

- **Expressiveness (Tell the truth)**   graphical integrity

    It requires the visual representations accurately encode the information of the data that needs to be conveyed, i.e., fidelity or authentic to the data.

- **Effectiveness (Do it effectively)** with clarity, precision, emphasis, …

    The use of the visual attributes/cues should reflect the importance of the information (or the characteristics) of the data.


Tufte's principles

Principles of Plots

- Improve **vision**
  1. **Reduced clutter**, make data stand out
  2. Use **visually prominent** graphical eleme
  3. Use proper scale lines and a data rectan
  4. Reference lines, labels, notes, and keys
  5. Superposed data set

- Improve **understanding**
  1. **Provide explanations** and draw conclusions
  2. Use all available space
  3. **Align** juxtaposed plots
  4. Use log scales when appropriate
  5. Bank to 45°
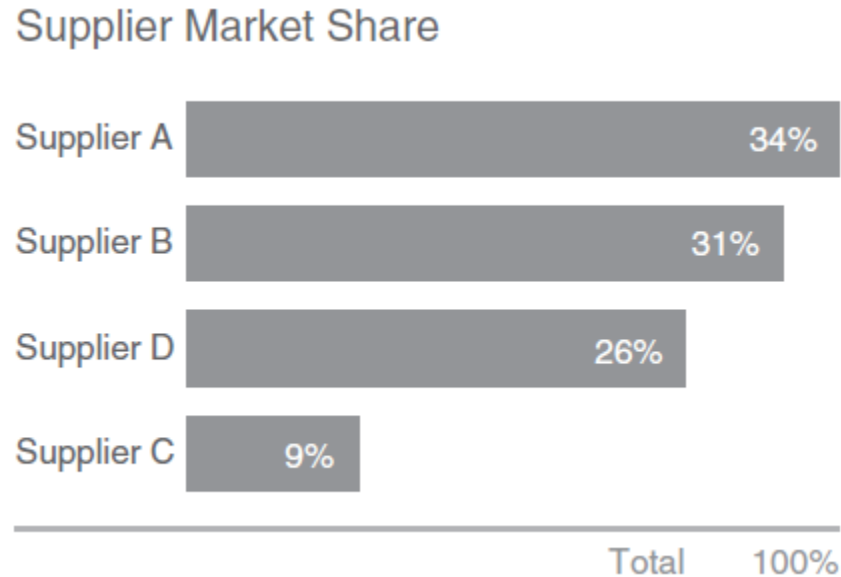
To avoid

- **Try not to use pie charts**

Supplier Market Share
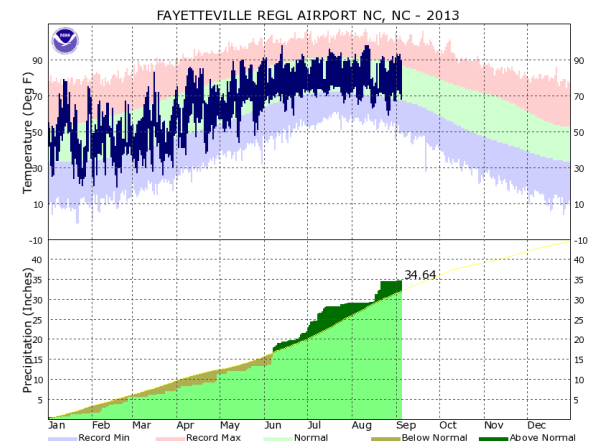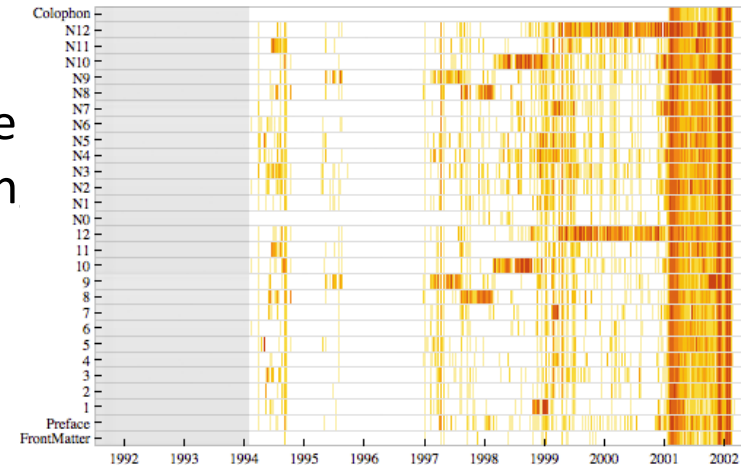
- Supplier A
- Supplier B
- Supplier C
- Supplier D
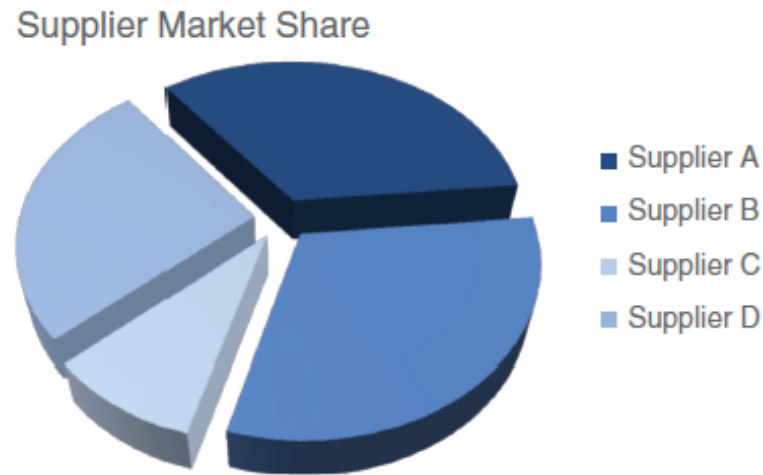
Which supplier is the largest based on this visual?

From "Storytelling with data"

To avoid

- **Try not to use pie charts**

Most pie charts can be replaced by the following form of histogram

Supplier Market Share

Supplier A	34%
Supplier B	31%
Supplier D	26%
Supplier C	9%

Total   100%

From "Storytelling with data"

To avoid

- **Never use 3D in your plots**

Number of issues

From "Storytelling with data"
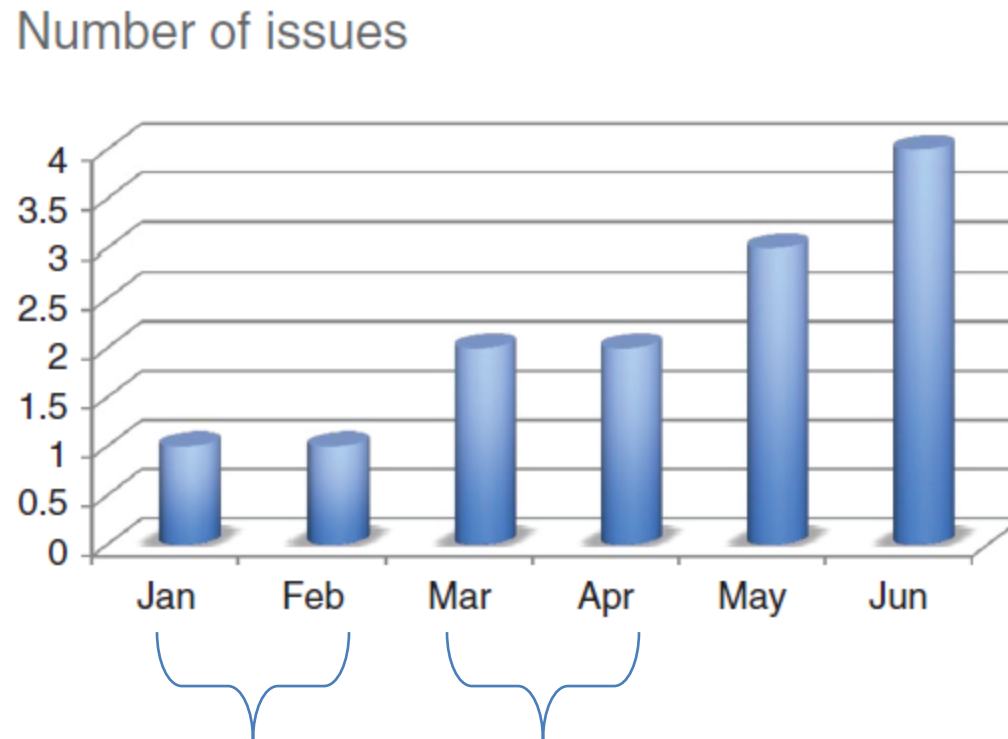
To avoid

- **Secondary *y*-axis: generally not a good idea**
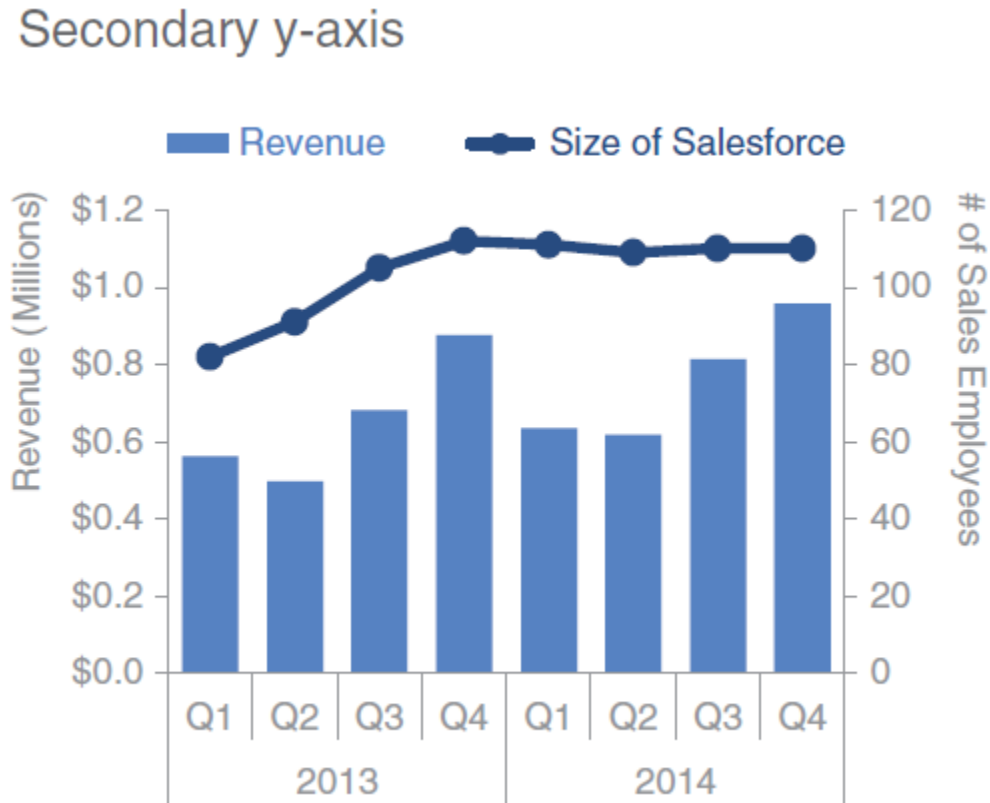
To avoid

- **Secondary *y*-axis: possible alternatives**
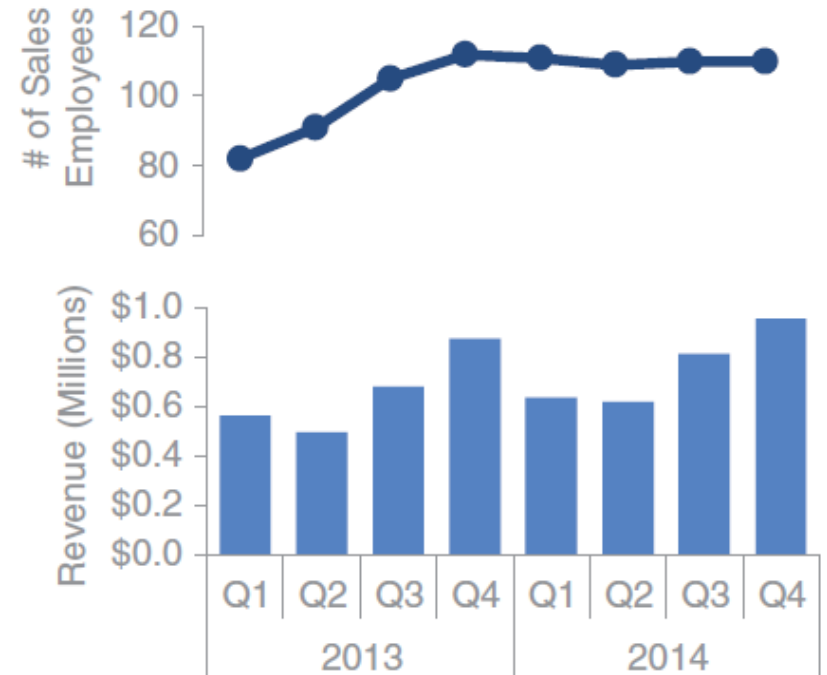
From "Storytelling with data"
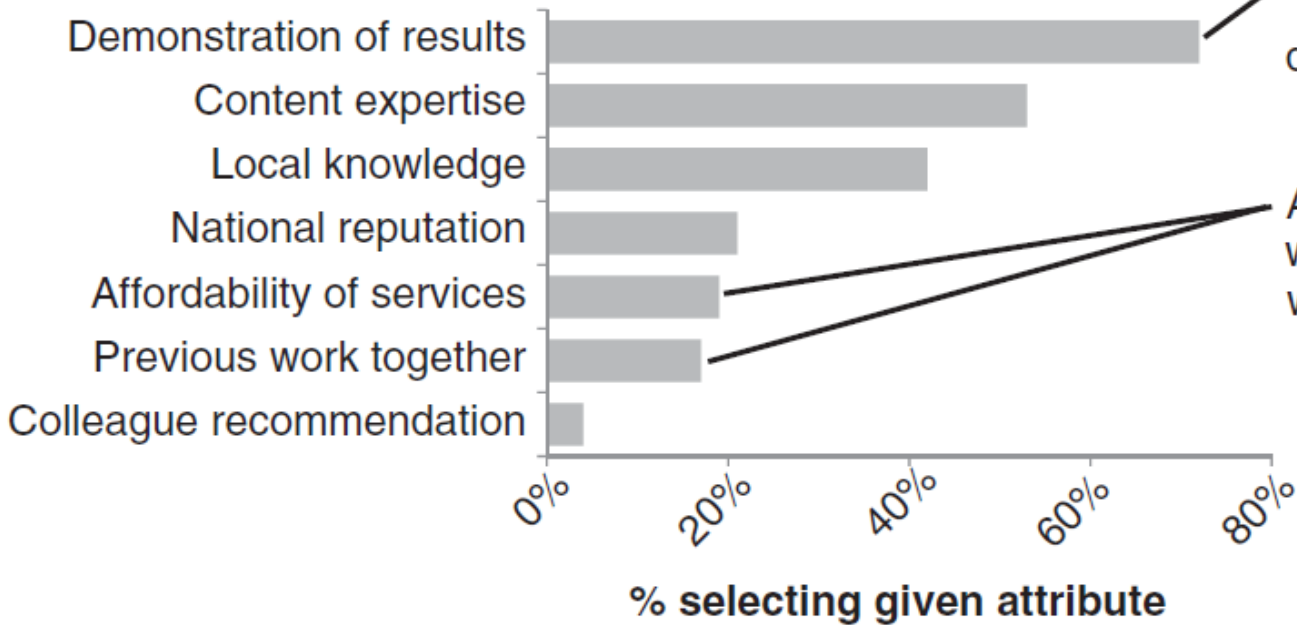
Demonstrating effectiveness is most important consideration when selecting a provider

In general, what attributes are the most important to you in selecting a service provider? *(Choose up to 3)*

Survey shows that demonstration of results is the single most important dimension when choosing a service provider.

- Demonstration of results
- Content expertise
- Local knowledge
- National reputation
- Affordability of services
- Previous work together
- Colleague recommendation

(x-axis: 0%, 20%, 40%, 60%, 80%)

% selecting given attribute

Affordability and experience working together previously, which were hypothesized to be very important in the decision making process, were both cited less frequently as important attributes.

Data source: xyz; includes N number of survey respondents. Note that respondents were able to choose up to 3 options.

What are the issues?

From "Storytelling with data"

Demonstrating effectiveness is most important consideration when selecting a provider

In general, **what attributes are the most important** to you in selecting a service provider?

(Choose up to 3)

% selecting given attribute

Survey shows that **demonstration of results** is the single most important dimension when choosing a service provider.

Affordability and **experience working together previously**, which were hypothesized to be very important in the decision making process, were both cited less frequently as important attributes.

Data source: xyz; includes N number of survey respondents.
Note that respondents were able to choose up to 3 options.

Alignment
Use left-justified alignment rather than central alignment

Eliminate diagonal elements as much as possible.
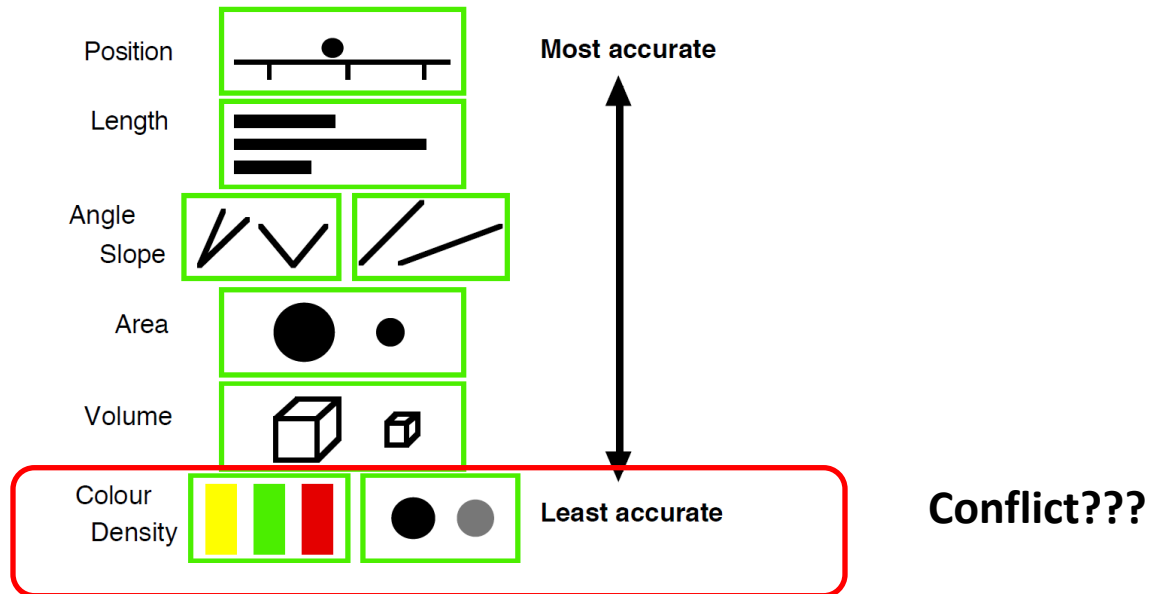
Importance of White Space!!

Effective use of colors is important in visualization

Color is a crucial tool to convey **quantitative** information.

Color is a crucial tool to convey **quantitative** information.
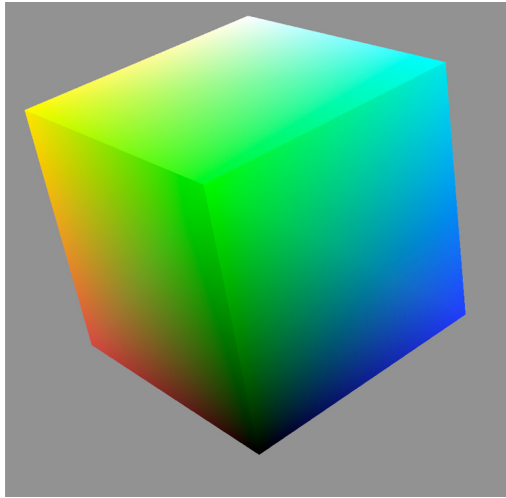

Conflict???
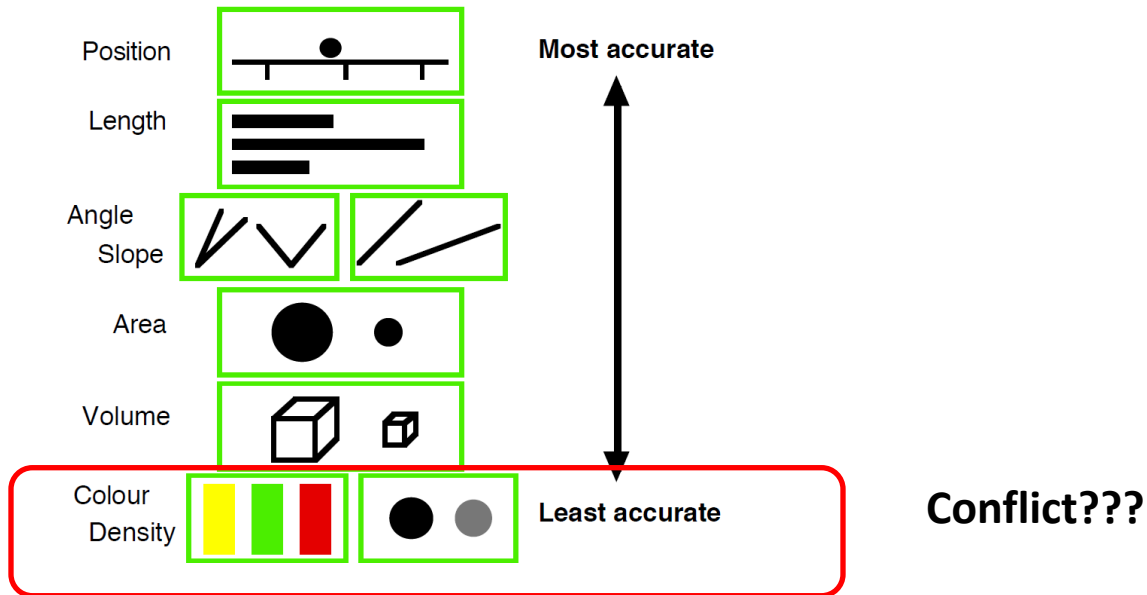
Color is one of the most effective ways to **encode data defined in two-dimensional space**.
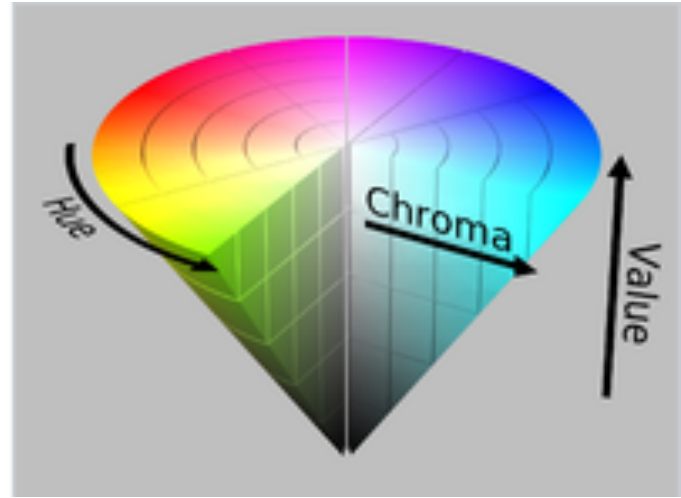
Differences in color can distinguish different categories (for example cropland, forest, or urban areas in a land cover map) or indicate quantity (percent forest cover or population).
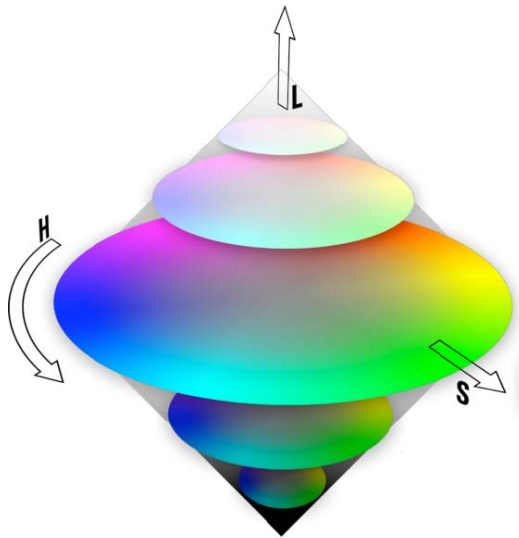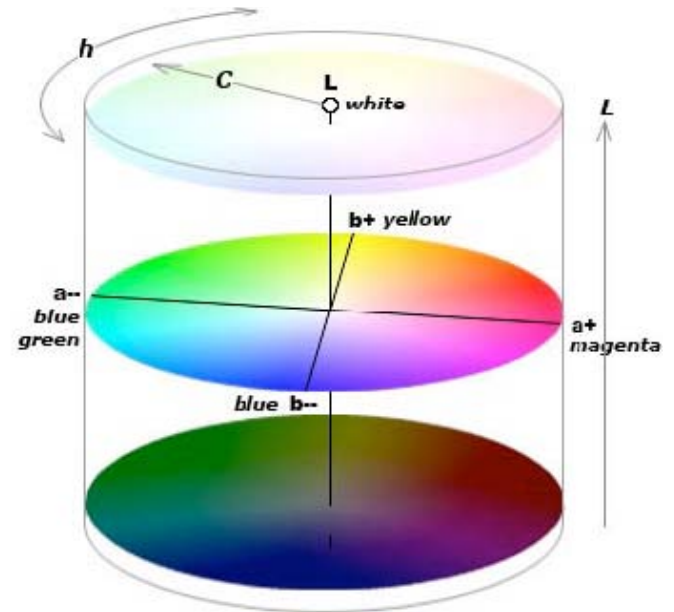
Widely used color spaces

RGB

HSV

HSL

CIELab

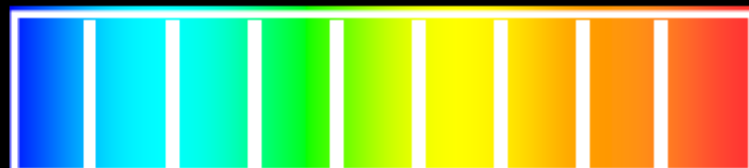# A Gallery of Color Scales

Sequential schemes

Qualitative scheme

Divergent scheme

Sequential schemes

Qualitative scheme

Transitions between some colors, green and red, for example, occur very rapidly, leading to false contrast. Other transitions, especially green, are gradual, and there is a loss of detail. Rainbow palettes have another deficiency: because the overall brightness of the colors increases and decreases over the range of hues there is no natural progression of values.

Grayscale palette

An alternative is to only use brightness, not color, to encode value, but surrounding tones can significantly alter the perceived values of pixels. Grayscale palettes are best limited to black and white reproductions.

Perceptual palette

A better approach is to use a color scheme that spirals through a perceptual color space, with each step equally different in hue, saturation, and brightness.
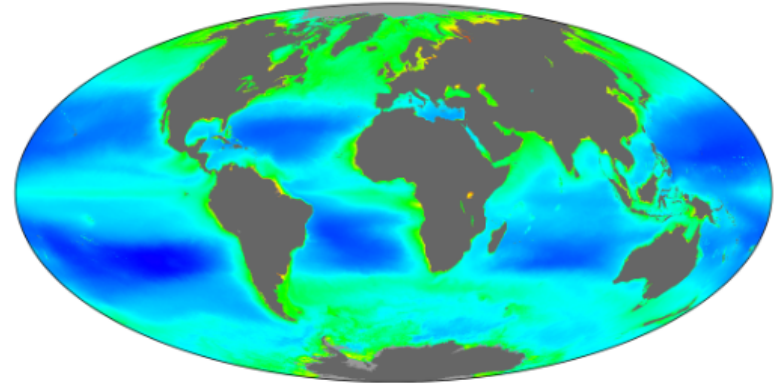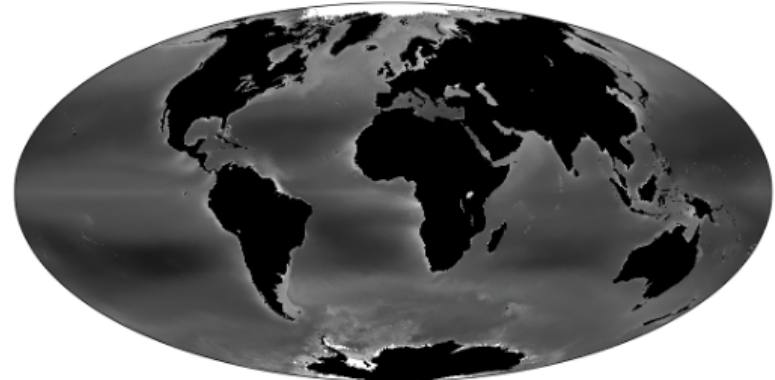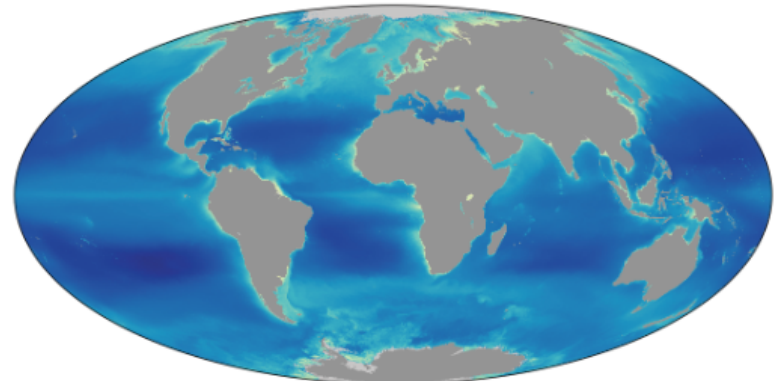
Color Alone Doesn't Cut It

I sure hope that my life does not depend on being able to read this quickly and accurately!

Properly choose color pairs to provide sufficient contrast

Black	White	Red	Yellow	Orange	Green	Cyan	Blue	Magenta
	Black	Black	Black	Black	Black	Black	Black	Black
White		White	White	White	White	White	White	White
Red	Red		Red	Red	Red	Red	Red	Red
Yellow	Yellow	Yellow		Yellow	Yellow	Yellow	Yellow	Yellow
Green	Green	Green	Green	Green		Green	Green	Green
Blue	Blue	Blue	Blue	Blue	Blue	Blue		Blue

Do Not Attempt to Fight Pre-Established Color Meanings

Red	**Green**	**Blue**
Stop	On	Cool
Off	Plants	Safe
Dangerous	Carbon	Deep
Hot	Moving	Nitrogen
High stress	Money	
Oxygen		
Shallow		
Money loss		

Do different colors affect your mood?

by David Johnson

Like death and taxes, there is no escaping color. It is ubiquitous. Yet what does it all mean? Why are people more relaxed in green rooms? Why do weightlifters do their best in blue gyms?

Colors often have different meanings in various cultures. And even in Western societies, the meanings of various colors have changed over the years. But today in the U.S., researchers have generally found the following to be accurate.

Black

Black is the color of authority and power. It is popular in fashion because it makes people appear thinner. It is also stylish and timeless. Black also implies submission. Priests wear black to signify submission to God. Some fashion experts say a woman wearing black implies submission to men. Black outfits can also be overpowering, or make the wearer seem aloof or evil. Villains, such as Dracula, often wear black.

White

Brides wear white to symbolize innocence and purity. White reflects light and is considered a summer color. White is popular in decorating and in fashion because it is light, neutral, and goes with everything. However, white shows dirt and is therefore more difficult to keep clean than other colors. Doctors and nurses wear white to imply sterility.

Red

The most emotionally intense color, red stimulates a faster heartbeat and breathing. It is also the color of love. Red clothing gets noticed and makes the wearer appear heavier. Since it is an extreme color, red clothing might not help people in negotiations or confrontations. Red cars are popular targets for thieves. In decorating, red is usually used as an accent.

Related Links

Color Psychology Quiz

Color: Psychology, Symbolism, and Interesting Facts

What Is Color?

The History of Color

Seasonal Color Analysis

What Colors Mean - from FactMonster.com

Color Blindness

Academic Colors

Color Printing

Astronomical Color

Be Aware of Color Vision Deficiencies (CVD)

- There is actually no such thing as "color blindness"
- CVD affects ~10% of Caucasian men
- CVD affects ~4% of non-Caucasian men
- CVD affects ~0.5% of women
- The most common type of CVD is red-green
- Blue-yellow also exists

Nikolas lubel
@nikolasiubel

Snow White was color blind, otherwise she would've been able to tell the apple was poisioned, says my DataViz prof.
#DataVizQMSS

Reply   Retweet   Favorite   More

Other Color Facts

In visualization applications, we must be aware that _our perception of color changes_ with:

- The surrounding color
- How close two objects are
- How long you have been staring at the color
- Sudden changes in the color intensity

Beware of Color Pollution

Just because you have millions of colors to choose from

doesn't mean you must use them all •••

Siggraph tutorial on colors

https://media.siggraph.org//education/cgsource/color/TM_Rhyne_Color_Theory_Class_SIGGRAPH_Education_Committee2.pdf

Presentation

https://www.youtube.com/watch?v=KJv1N8akoUs