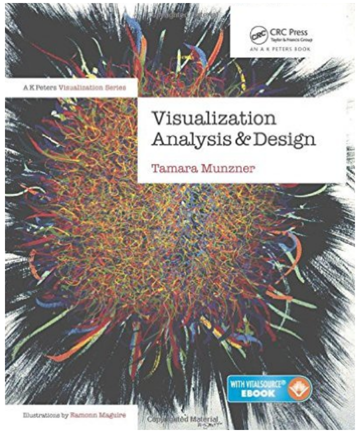
Guidelines from Munzner (and Weber; Stevens; Mackinlay; Cleveland & McGill)

Dr. Gaurav Bansal

Reference: *Visualization Analysis & Design* by Munzner



Any visualization has two basic components:

Marks: used to represent items. Examples: points and lines.

Channels: visual variables that change appearance based on attribute values. Examples: color of the point, length of the line, color of the line, etc.

Marks and Channels

Marks – Examples:

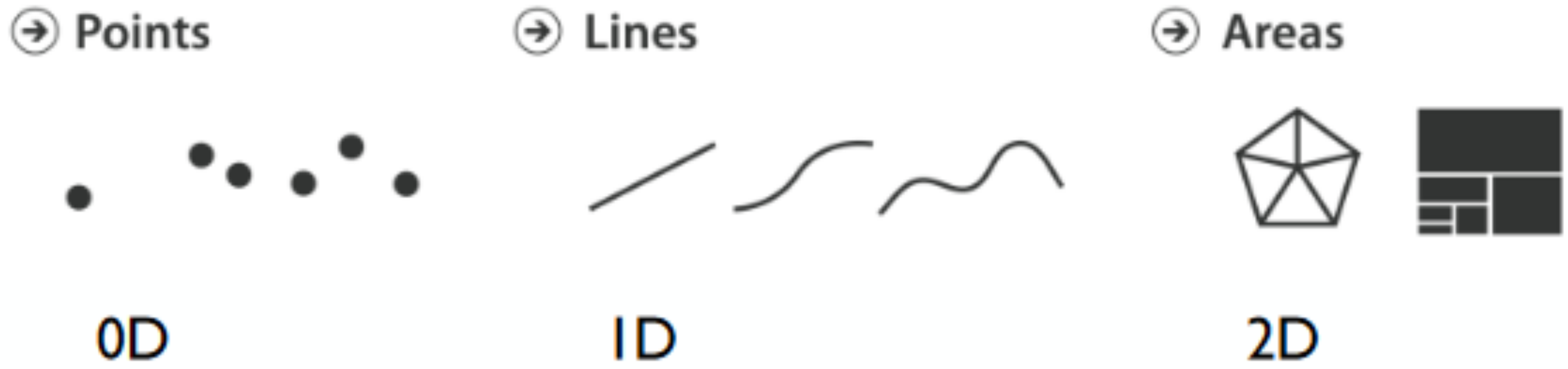
- Points (0D)
- Lines (1D)
- Areas (2D)

Channels – Examples:

- Position,
- Shape,
- Tilt (angle),
- Color,
- Size (Length, area, volume)

Marks for Items

Basic geometric elements

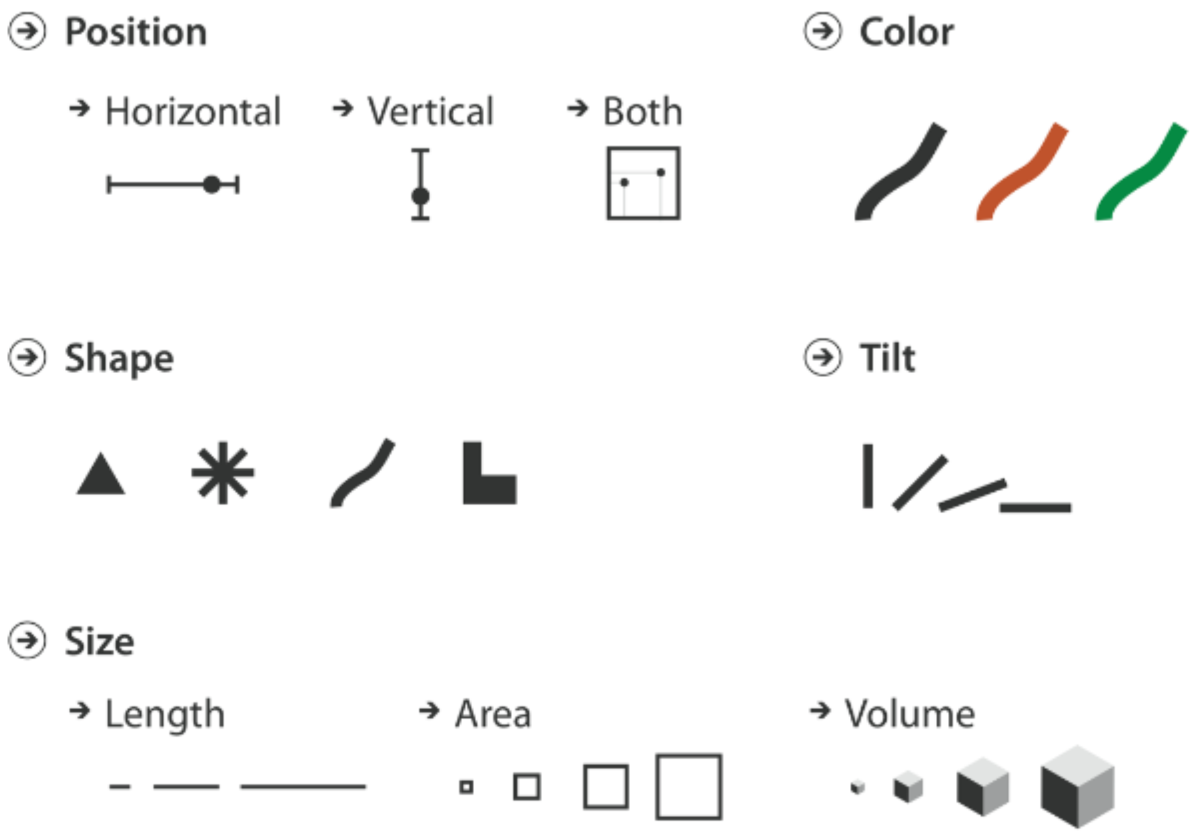


3D mark: Volume, but rarely used

http://www.cs171.org/2015/assets/slides/05-marks_channels.pdf

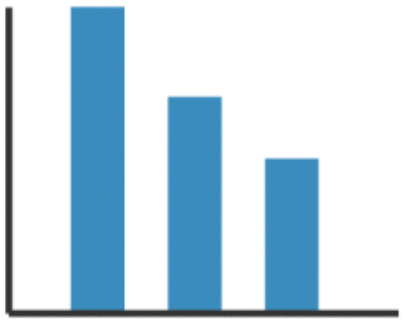
Channels (aka Visual Variables)

Control appearance proportional to or based on attributes



http://www.cs171.org/2015/assets/slides/05-marks_channels.pdf

Using Marks and Channels



Mark: Line

Mark: Point

Adding Hue

Adding Size

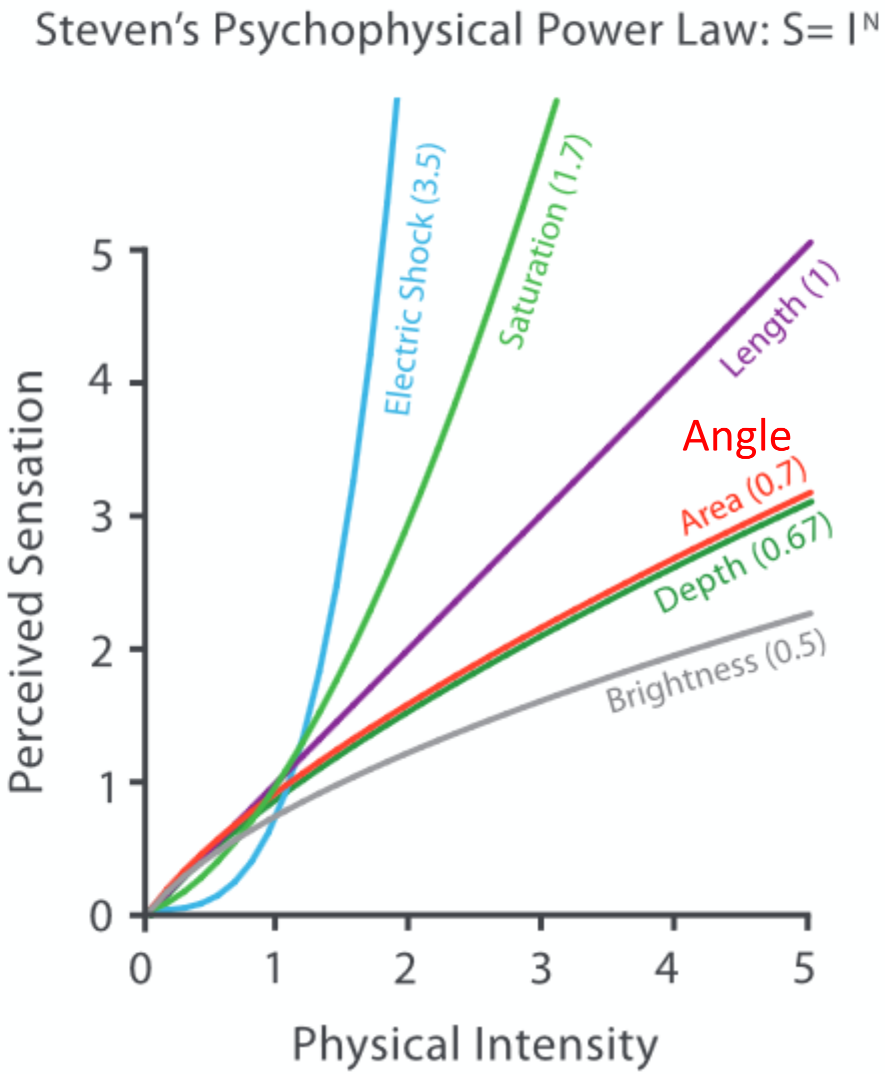
Figure 1: line is used as a mark, and the length of the line along with the position of the top of the line are the two channels. X axis can be used to show categorical variables, and y axis can be used to show a quantitative variable

Figure 2: Point is used as Mark, and the position is used as Channel. Here we can show two different quantitative variables – one on x and one on y axes respectively.

Figure 3: Point is used as Mark, and the position along with color are used as two different channels. Here we can show two different quantitative variables – one on x and one on y axes respectively, we can also show one additional categorical variable using the color channel.

Figure 4: Point is used as Mark, and the position along with color and size are used as three different channels. Here we can show two different quantitative variables – one on x and one on y axes respectively, we can also show one additional categorical variable using the color channel. We can show additional quantitative variable using size of the points.

All Channels are not Created Equal



Steven's law suggests that we accurately perceive one unit change in length.

For other channels either we overestimate (e.g., N>1; electric shock) or we underestimate (e.g., N<1; brightness).

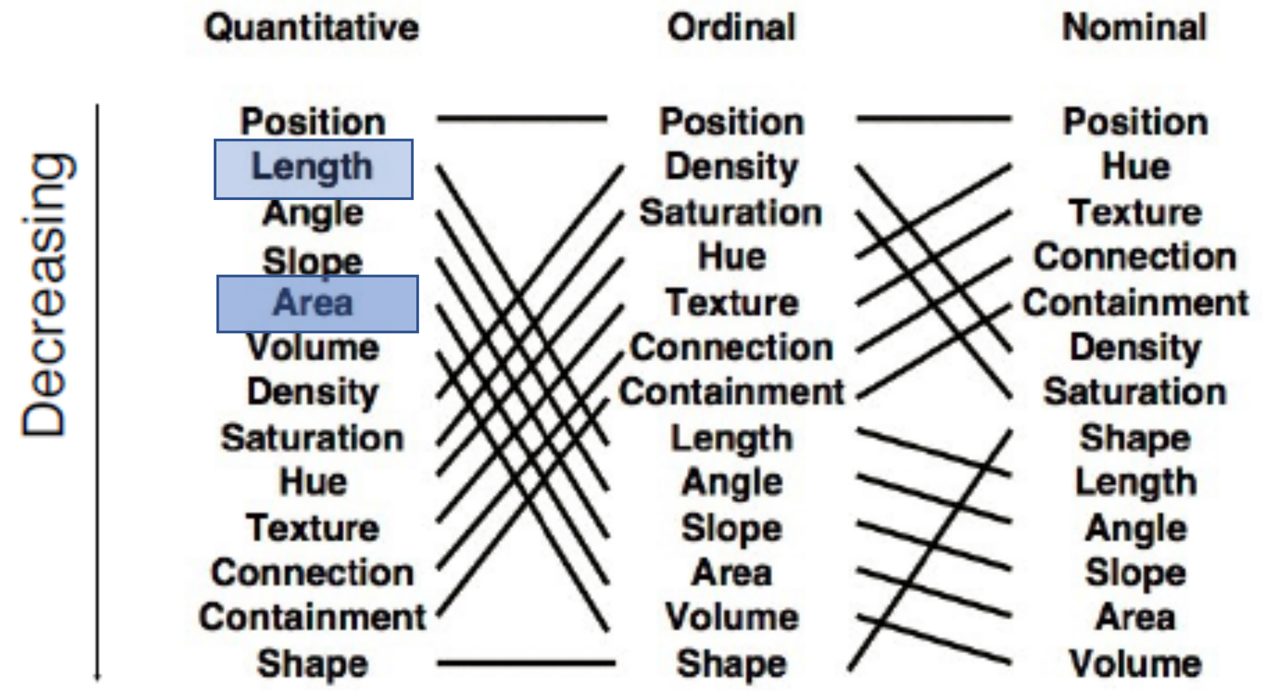
If area is doubled, we perceive the change to be little less than double. Similarly, when brightness is doubled, we perceive the change to be little less than double as well. (Our senses are better at judging changes in *area* than they are at judging changes in *brightness.*)

However, we perceive one unit change in electric shock as more than one unit change .(this is not at all surprising to me!!)

Note: Angle (slope) is also underestimated!

Channel Rankings

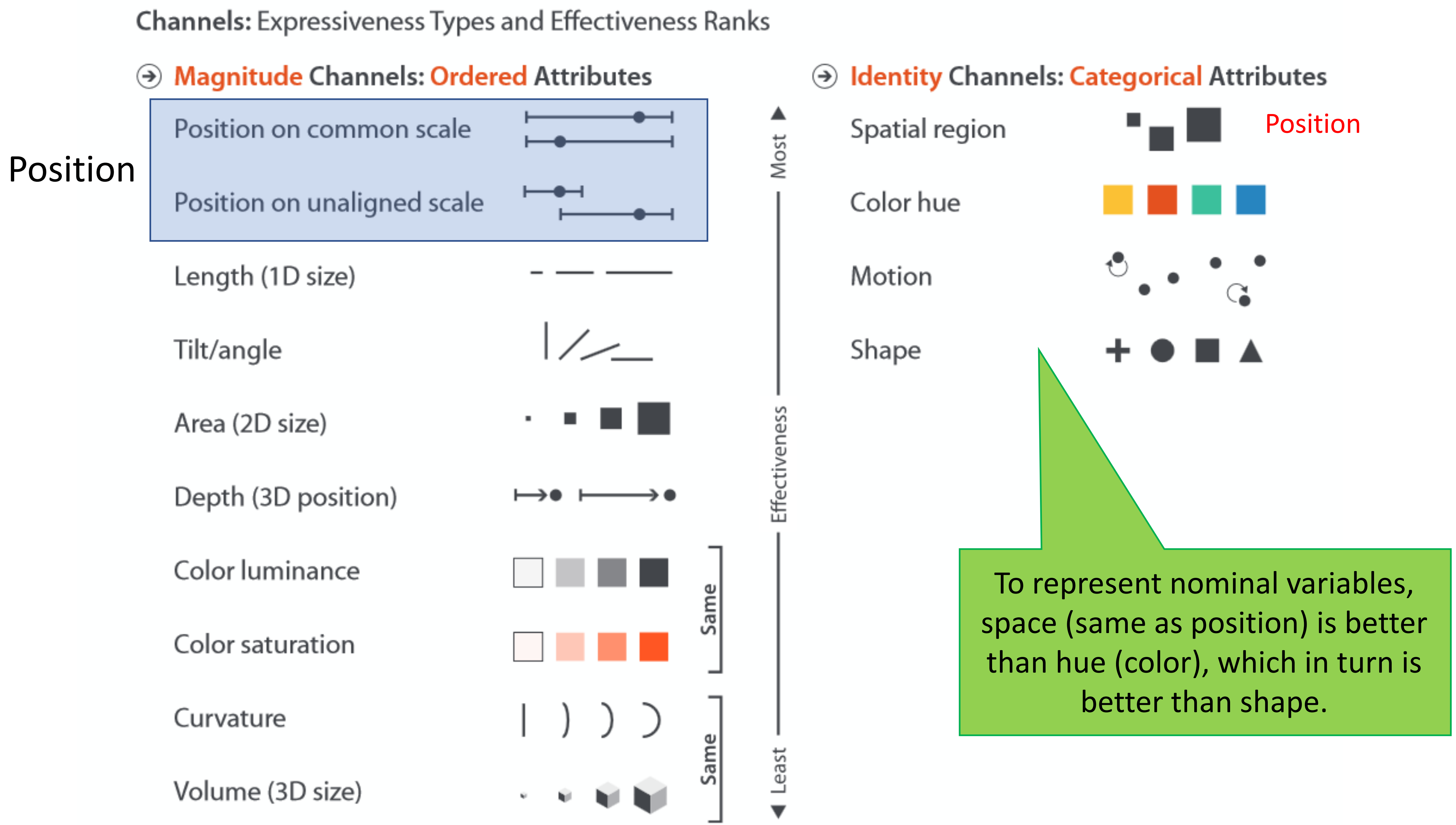
Jock Mackinlay, 1986



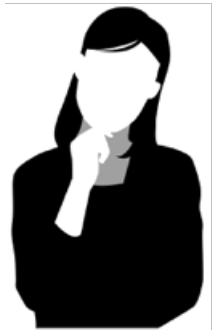
Not all channels are equally effective all the time!

For instance, for quantitative variables length (of a bar in a bar chart) is better than area of the pie chart!

[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, 1986]


Channels: Expressiveness Types and Effectiveness Ranks
Magnitude Channels: Ordered Attributes
Position
Position on common scale
Position on unaligned scale
Length (1D size)
Tilt/angle
Area (2D size)
Depth (3D position)
Color luminance
Color saturation
Curvature
Volume (3D size)
Same
Same
Most
Effectiveness
Least
Identity Channels: Categorical Attributes
Spatial region
Position
Color hue
Motion
Shape
To represent nominal variables, space (same as position) is better than hue (color), which in turn is better than shape.

How much darker?



Make a guess. The answer is on the next slide…

How much darker?

A

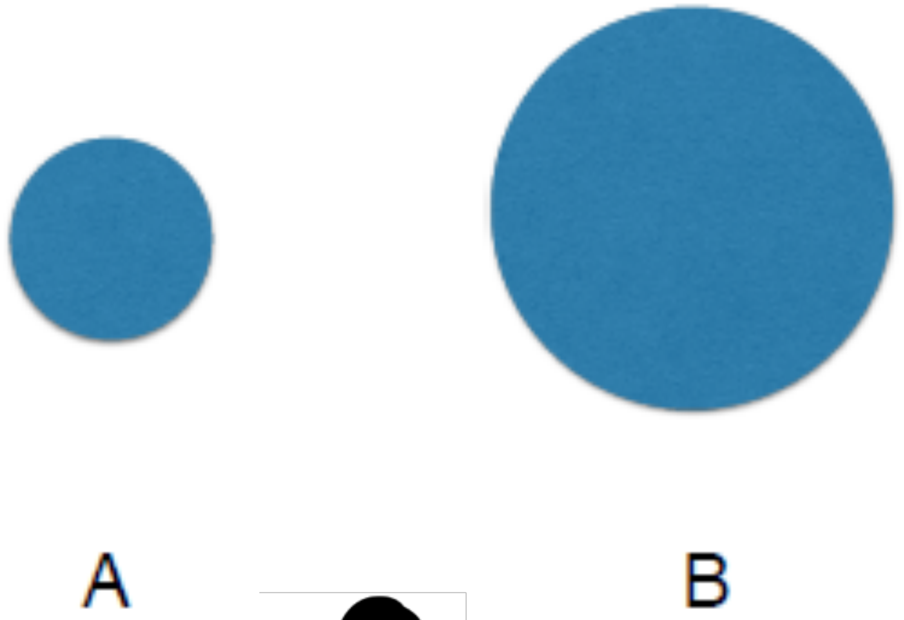
B

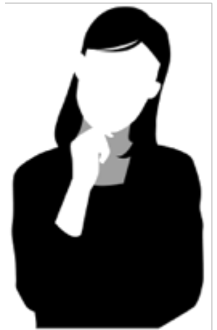
Correct Answer:
2X

(I am not sure if everyone got this right!)

Note: Per Steven's Law if brightness is increased, the corresponding stimulus is perceived to be less than the actual increase.

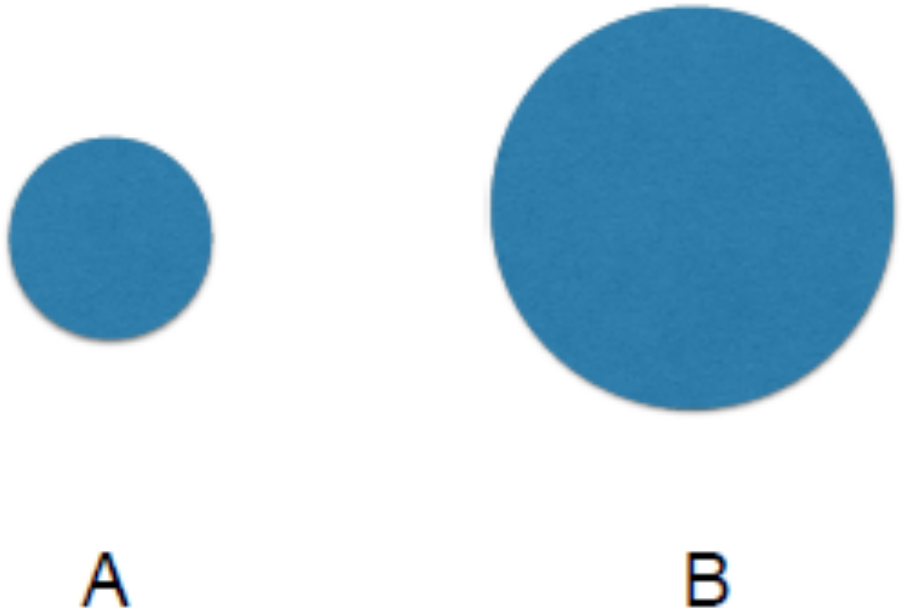
How much larger (diameter)?





Make a guess. The answer is on the next slide…

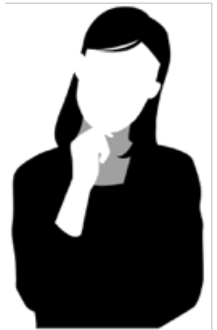
How much larger (diameter)?



Correct Answer:
2X

This is relatively easy, as we are comparing lengths here.

How much larger (area)?



Make a guess. The answer is on the next slide…

How much larger (area)?

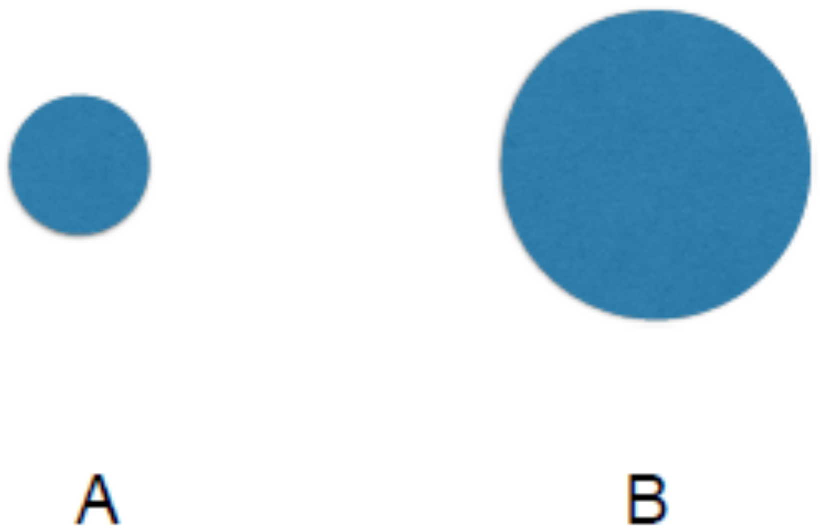
Correct Answer:
3X

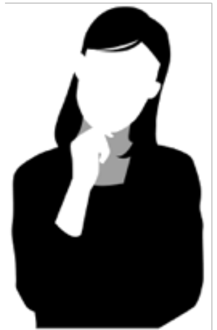
(I am not sure if everyone got this right!)

This is tricky because we are comparing areas (and not lengths).

Note: Per Steven’s Law. if area is increased, the corresponding stimulus is perceived to be less than the actual increase. Also note that the perceived stimulus for change in area is more accurate than that for brightness! (Refer to Steven's Law.)

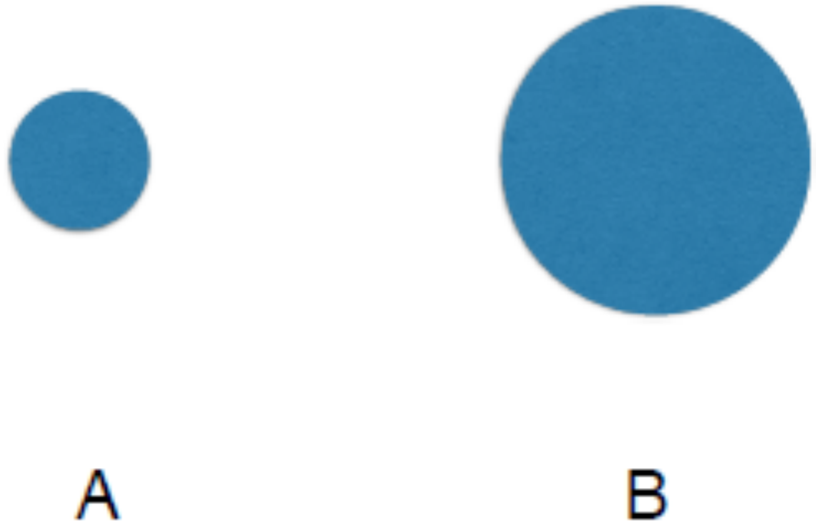
How much larger (area)?





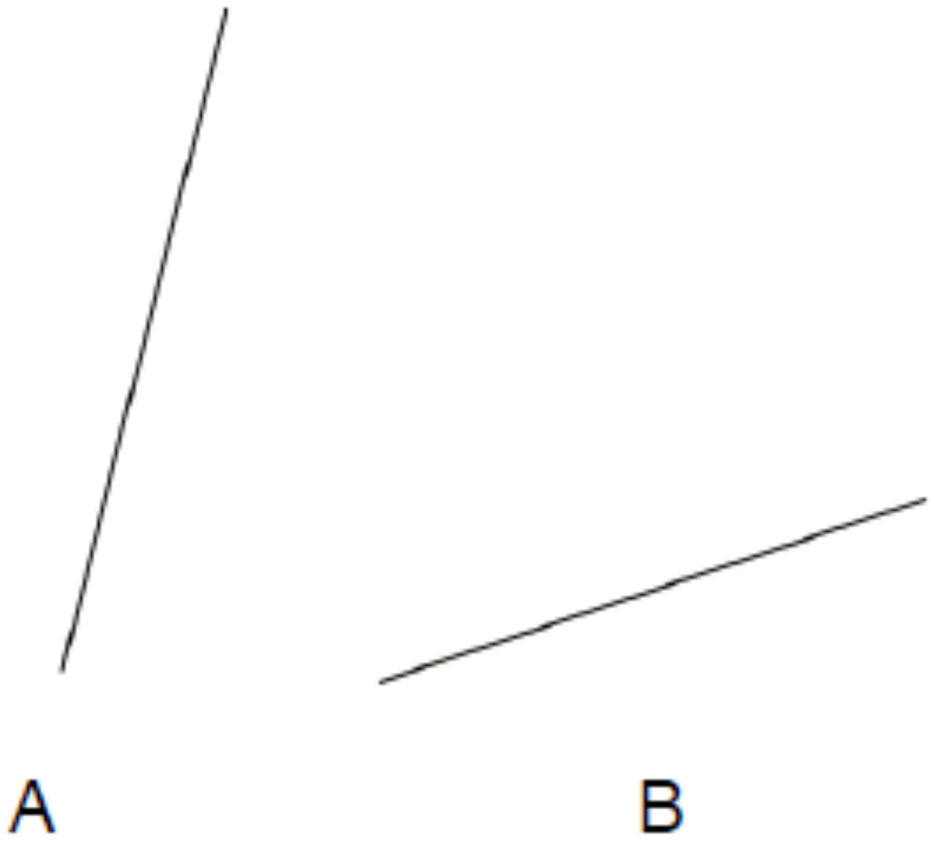
Make a guess. The answer is on the next slide…

How much larger (area)?



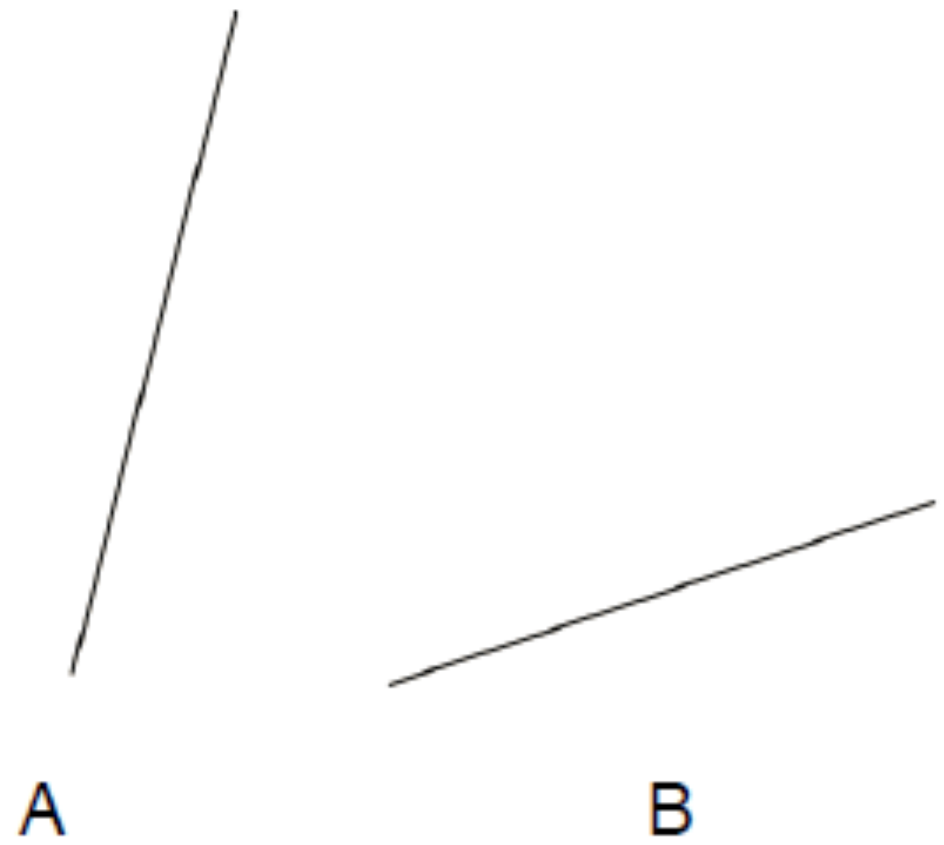
Correct Answer:
5X

How much steeper?



Make a guess. The answer is on the next slide…

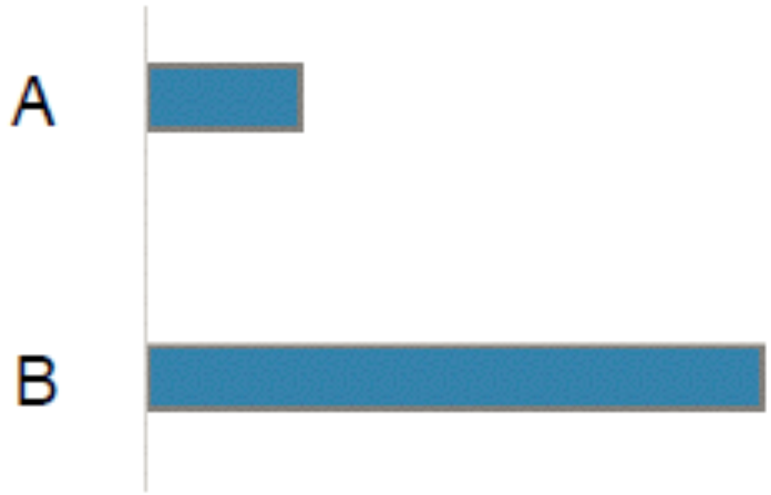
How much steeper?

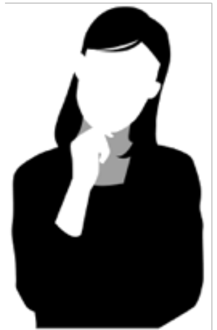


Correct Answer:
~4X

Angles are difficult to compare. The pecking order for quantitative variables is: Position, and then length, and then angles, followed by area…

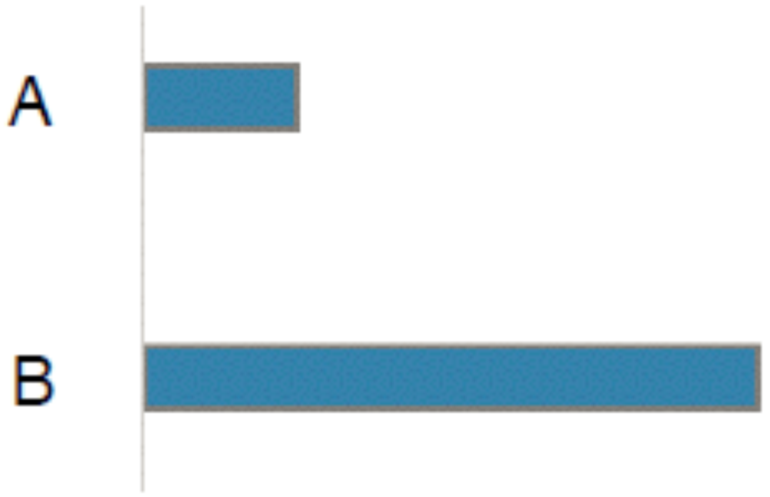
How much longer?





Make a guess. The answer is on the next slide…

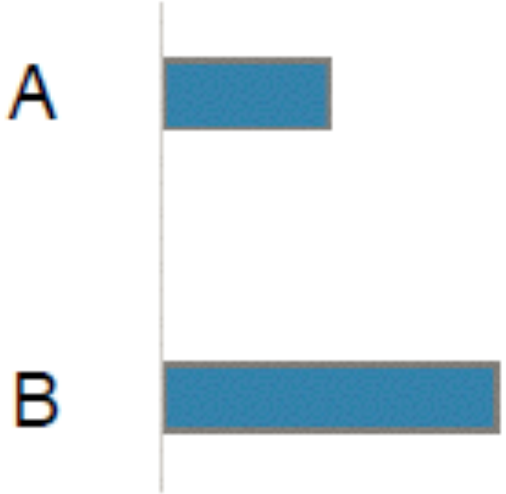
How much longer?

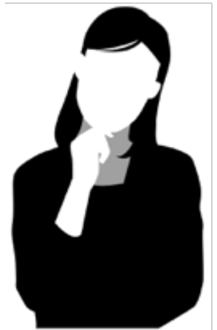


Correct Answer:
4X

This should be relatively easier. The channel here is length. Length is the second best channel after position.

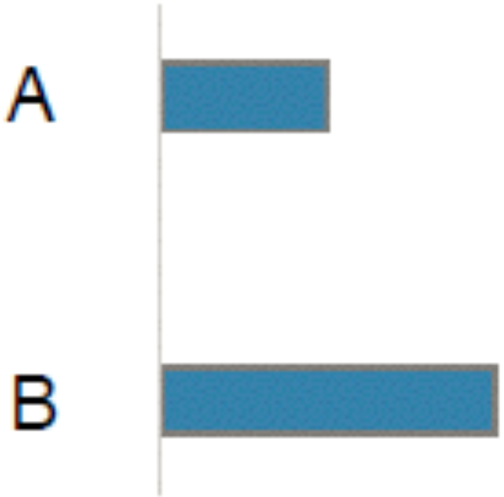
How much longer?





Make a guess. The answer is on the next slide…

How much longer?



Correct Answer:
2X

Trivia

If we use “salt” or “sucrose (sugar)” as a channel:

- We perceive things to be more salty (or sucrosated) than they are.
- If the salt (or sucrose) content is actually doubled, we perceive the corresponding difference to be more than double .
- Phenomenon can be plotted somewhere in between length and electric shock in the Steven’s power law (order would be: length, sugar, salt and then electric shock).

If we use “saccharine” as a channel:

- We perceive things to be less saccharinated than they are.
- If the saccharine content is actually doubled, we perceive the corresponding difference to be less than double.
- Phenomenon can be plotted somewhere in between length and brightness in the Steven’s power law.

Reference: http://www.cis.rit.edu/people/faculty/montag/vandplite/pages/chap_6/ch6p10.html

Weber Law 1

The **Difference Threshold** (or **J**ust **N**oticeable **D**ifference) is the minimum amount by which stimulus intensity must be changed in order for the subject to notice.

$$\frac{\Delta I}{I} = k$$

where ΔI (delta I) represents the difference threshold, I represents the initial stimulus intensity and k signifies that the proportion on the left side of the equation remains constant despite variations in the I term

http://viscog.psych.northwestern.edu/publications/HarrisonYangFranconeriChang2014.pdf

Weber Law 2

Say, my JND for perceiving differences in two lengths is 5% (i.e. k=.05).

Then I will be able to visually spot the difference between two lengths of 100 units and 105 units (both are 5 units apart, i.e. 5% difference).

I will not be able to visually spot differences between two lengths of 1000 units and 1005 units, even though both are exactly 5 units apart.

- Since my JND is 5%, that would mean that I can spot difference between 1000 and 1050, but not between 1000 and anything less than 1050.

Weber Law 3

You start by lifting 4 lbs of weight.
You lift additional 1 lb of weight before noticing any difference.

Your JND is 1 lb

You start by lifting 10 lbs of weight.
You lift additional 2.5 lbs of weight before you notice any difference.

Your JND is 2.5 lbs

For weight of 4 lbs, your incremental threshold for detecting a difference was 1 lb.
For weight of 10 lbs, your incremental threshold for detecting a difference was 2.5 lbs.

In either case your Weber fraction for Just Noticeable Difference (JND) is: **¼ = 2.5/10 = .25** This is Weber Law.

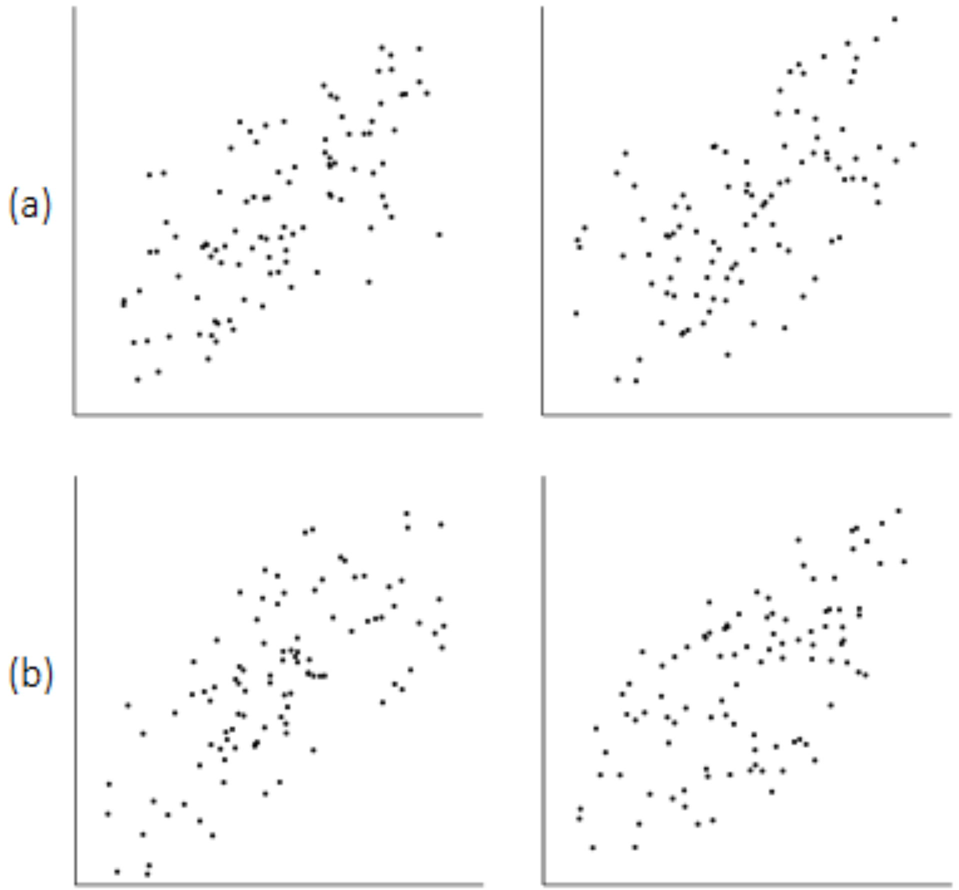


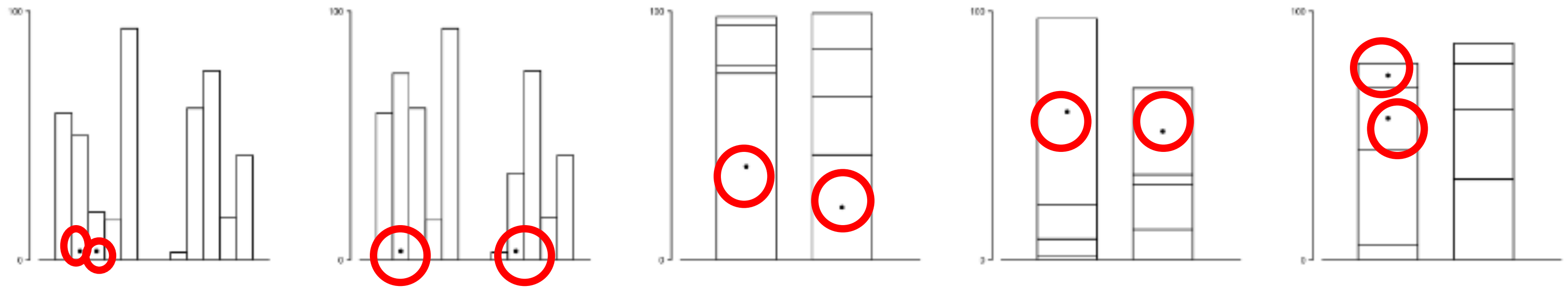
Fig. 1: a) A sample starting comparison from the experiment: $r = 0.7$ on the left and $r = 0.6$ on the right. Participants were asked to choose which of the two appeared to be more highly correlated. b) The staircase procedure hones in on the just-noticeable difference by gradually making comparisons more difficult: $r = 0.7$ on the left and $r = 0.65$ on the right.

Research also shows that JND is applicable to not only changes in **lengths** (100 vs. 105) but also to changes in **correlation strengths**.

IEEE Trans Vis Comput Graph. 2014 Dec;20(12):1943-52. doi: 10.1109/TVCG.2014.2346979.

Ranking Visualizations of Correlation Using Weber's Law.

Harrison L, Yang F, Franconeri S, Chang R.



(a) Adjacent Bars (Type 1) | (b) Separated Bars (Type 3) | (c) Aligned Stacked Bars (Type 2) | (d) Unaligned Stacked Bars (Type 4) | (e) Divided Bar (Type 5)

Fig. 1: The five bar chart tasks studied in Cleveland & McGill [1]. Study participants were asked to estimate the height of the shorter marked bar as a percent of the taller marked bar. Cleveland & McGill's ranked these tasks from lowest error (Type 1) to highest error (Type 5).

In their seminal paper, Cleveland and McGill (1984) showed that comparisons made using two adjacent bars are more accurate than those made using separated bars; refer to the dots that are being compared in figure **(a)** to the dots that are being compared in figure **(b)**.

Figures **(a)** through **(e)** have been ranked in the descending order of accuracy. When comparing the areas associated with the "two dots" (as shown in each figure respectively), **(a)** is preferred to figure **(b)**, and so on.

Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods

William S. Cleveland; Robert McGill

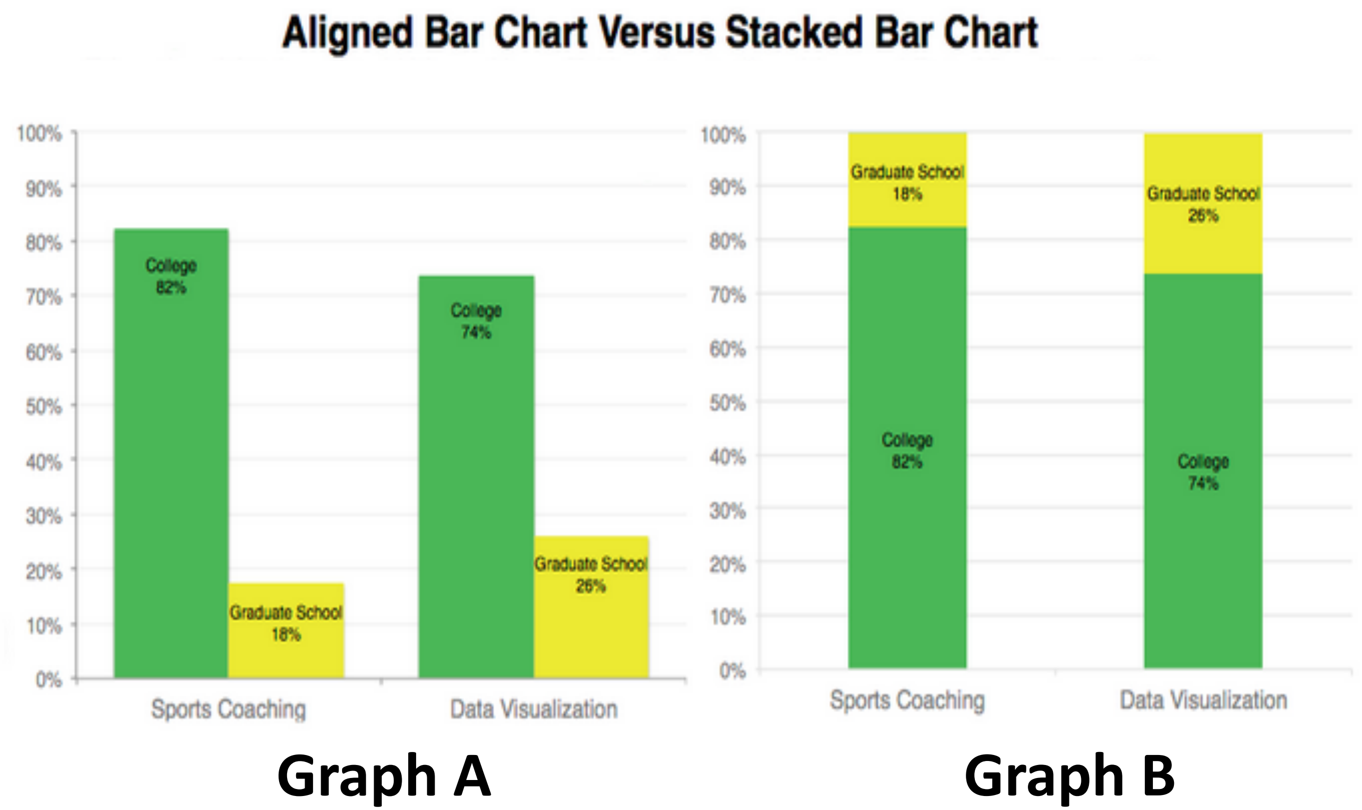
Journal of the American Statistical Association, Vol. 79, No. 387 (Sep., 1984), 531-554.

Stable URL:
http://links.jstor.org/sici?sici=0162-1459%28198409%2979%3A387%3C531%3AGPTEAA%3E2.0.CO%3B2-Y

Journal of the American Statistical Association is currently published by American Statistical Association.

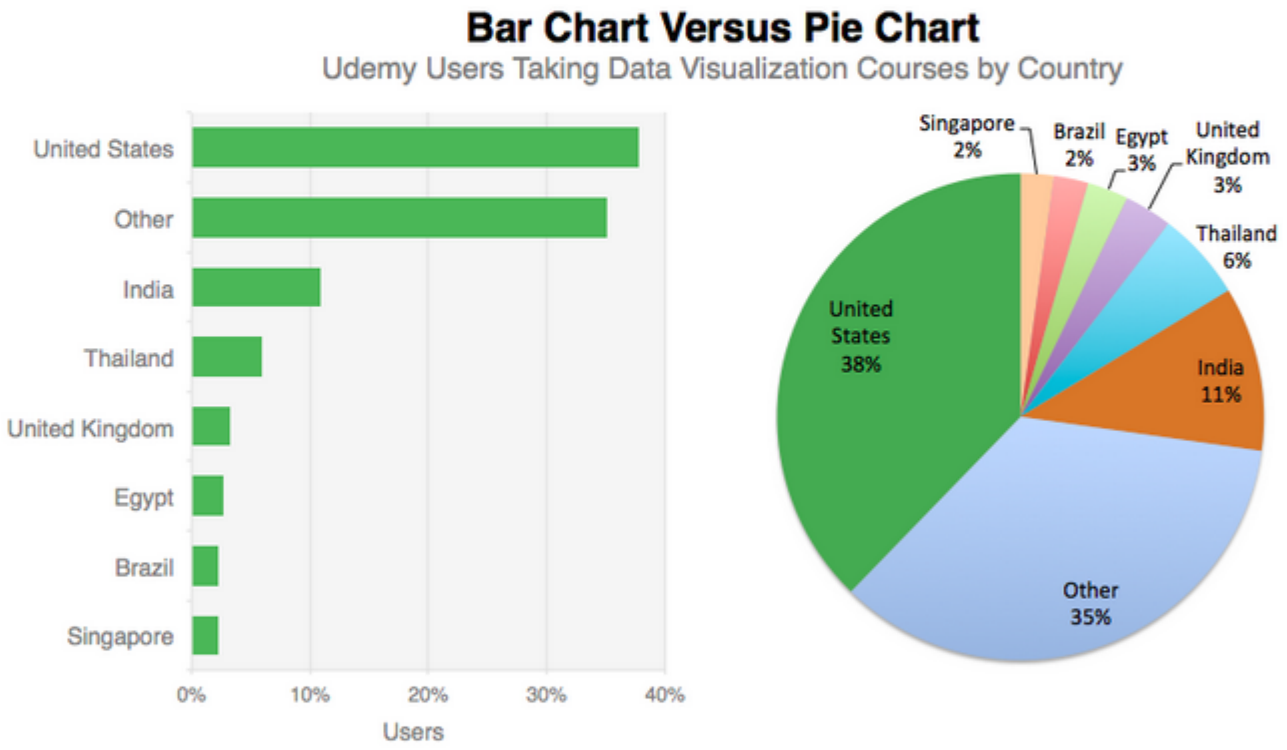
I encourage you to read the Cleveland and McGill paper. It is the same paper reference by Edward Tufte and Stephen Few.

This paper is available as an optional reading in the online course.



Based on Cleveland and McGill's (1984) findings, it can be argued comparing the green and the yellow areas would have higher response (or perception) accuracy in Graph A than in Graph B.

https://priceonomics.com/how-william-cleveland-turned-data-visualization/



Comparing lengths in a bar chart is more accurately perceived than comparing areas in a pie chart.

Based on:

- Cleveland and McGill, 1984
- Mackinlay, 1986
- suggestions from Munzner

https://priceonomics.com/how-william-cleveland-turned-data-visualization/

Questions? Thoughts? Visit the course's online discussion forum.