Lesson 2: Designing Graphs to Enlighten: Principles and Best Practices

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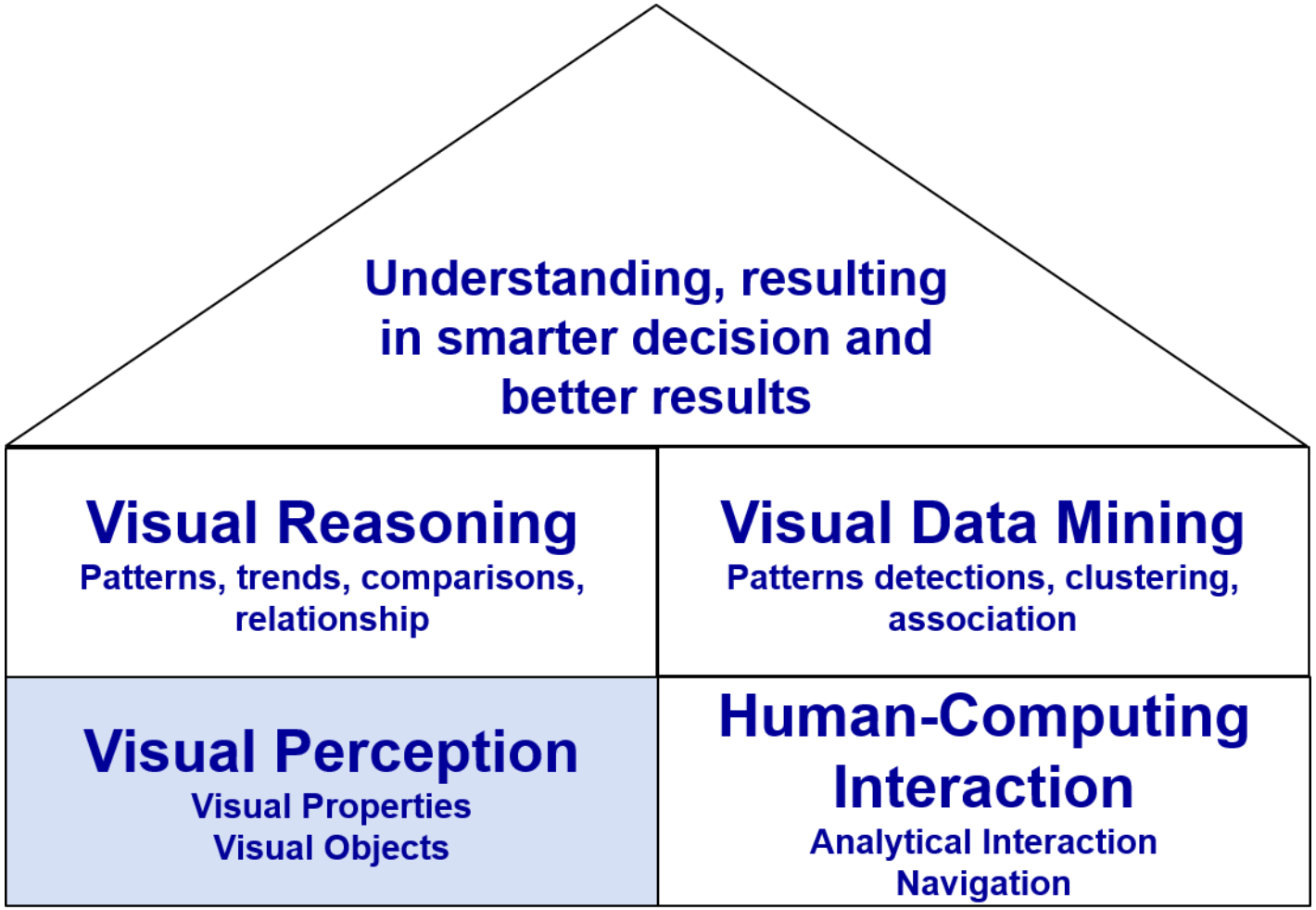
What will you learn from this lesson?

- Human perception and information processing
- Perceptual and design principles for effective visual analytics
- Principles of Graphic Design
  - Rules for Encoding Values in Graph
  - JunkCharts
  - Practical Guides for Using Colour in Charts
  - Data-ink
- Storytelling with Charts

Building Block of Visual Analytics



Data visualisation design process

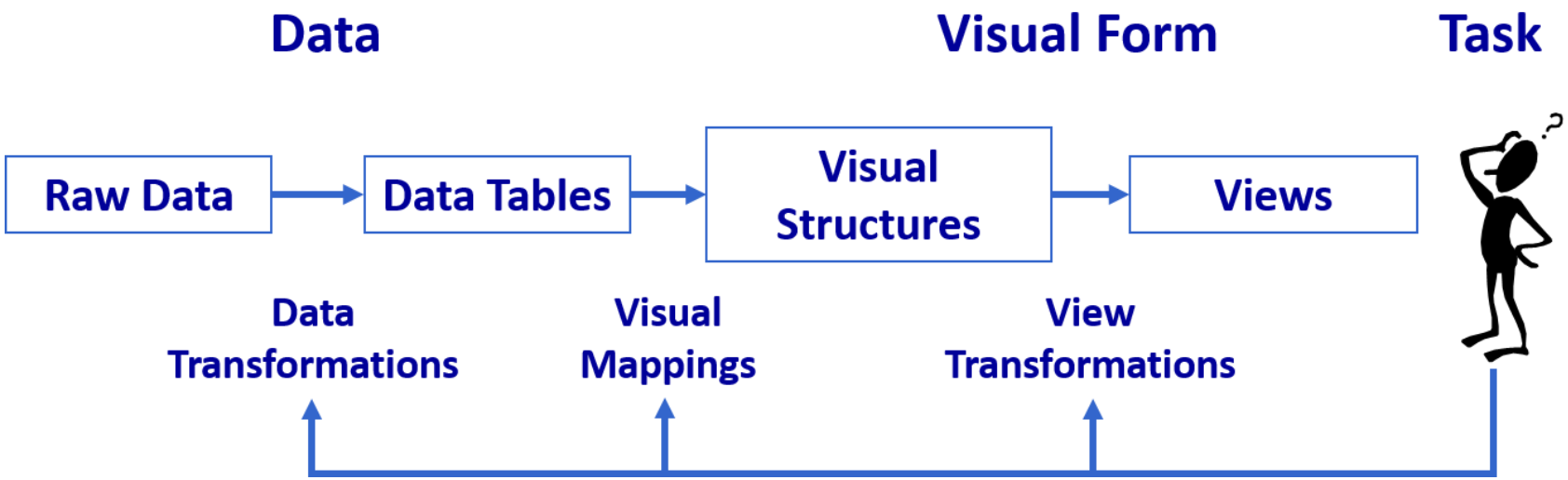
- Start with a clear message
- Search for appropriate data
- Prepare the data
- Use the right graph type
- Express and explain
- Review and seek feedback from experts and casual readers

DataViz design process

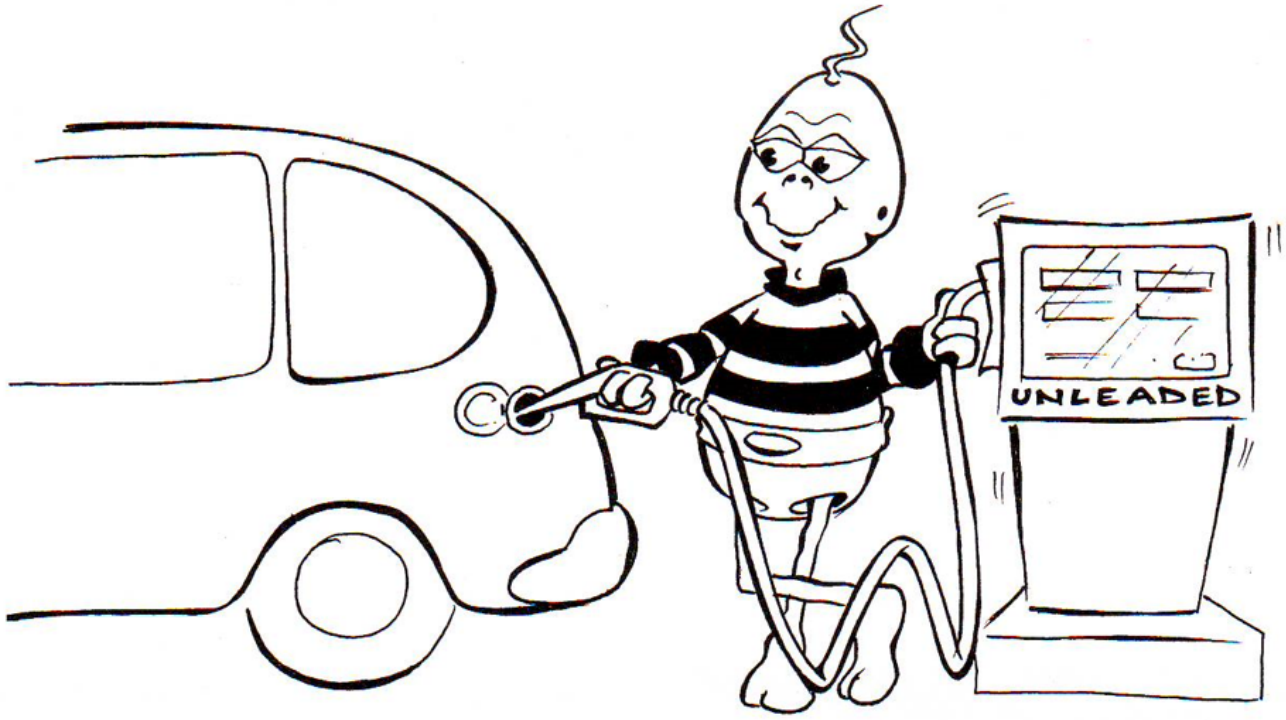
Data Management
- Select data source
- Clean data
- Categorise data
- Moderate data

Visualisation
- Information design
- Visual encoding
- Interface design

Visual Analytics
- Observations
- Hypothesis
- Evidence (+/-)
- Summarise
- Communicate



The Devil is in the Data

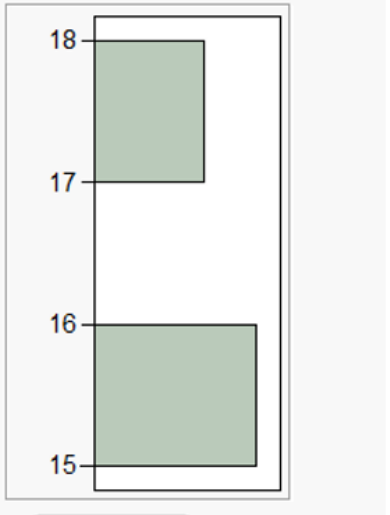


Numbers Worth Knowing

- Categorical data: numbers that summarise (i.e. sex, property type, planning region)
  - nominal, ordinal, interval, hierarchical
  - time series
- Continuous data: numbers that measure (i.e. unit price, age, monthly salary)
  - ranking, ratio

Data Understanding

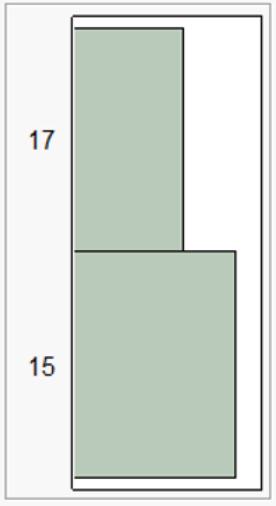
- Avoid garbage in, garbage out problem. For example, display size should be classified as categorical instead of continuous.



Quantiles

Moments

Mean	15.813329
Std Dev	0.9824242
Std Err Mean	0.001801
Upper 95% Mean	15.816859
Lower 95% Mean	15.809799
N	297572

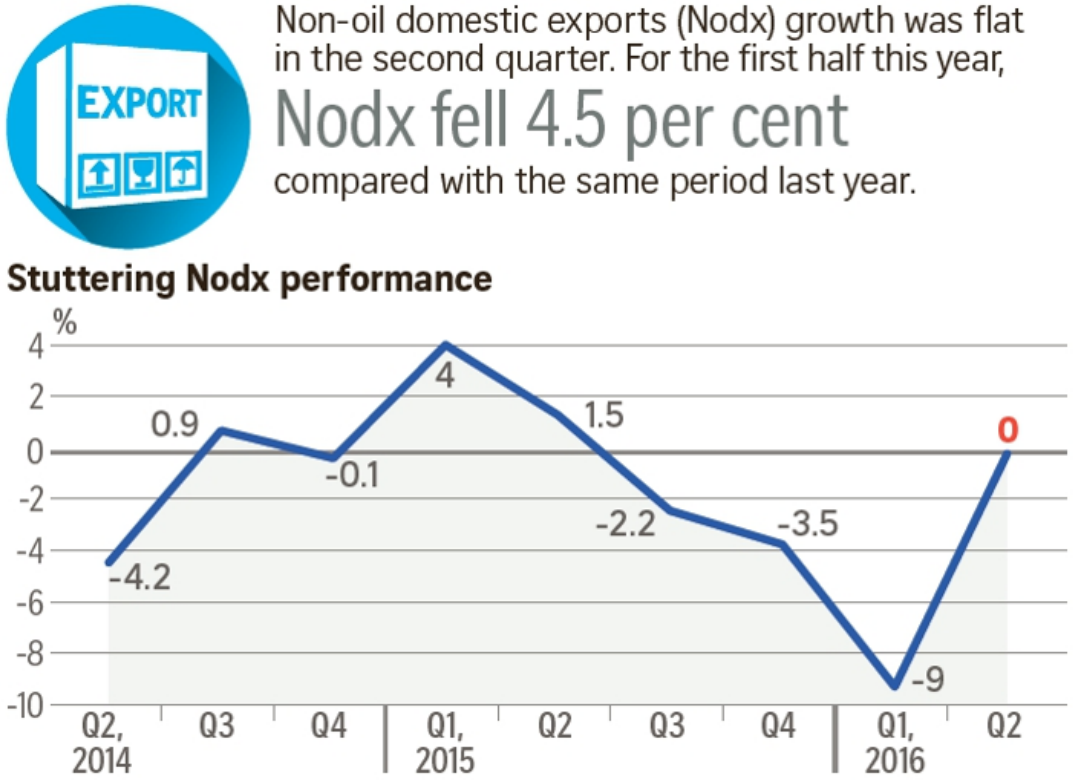


Frequencies

Level	Count	Prob
15	176560	0.59334
17	121012	0.40666
Total	297572	1.00000
N Missing	0	
2 Levels		

Graphical Integrity: Show Me the Truth

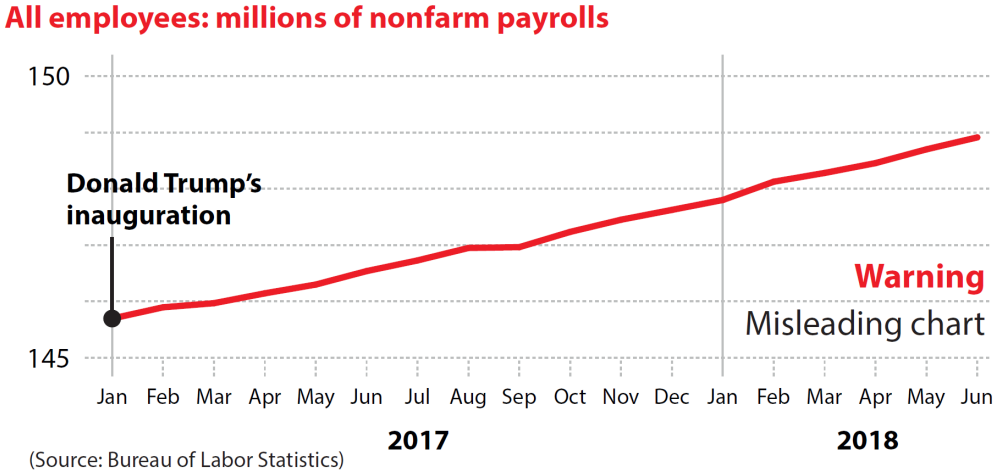
- Don't lie to yourself (or to others) with charts



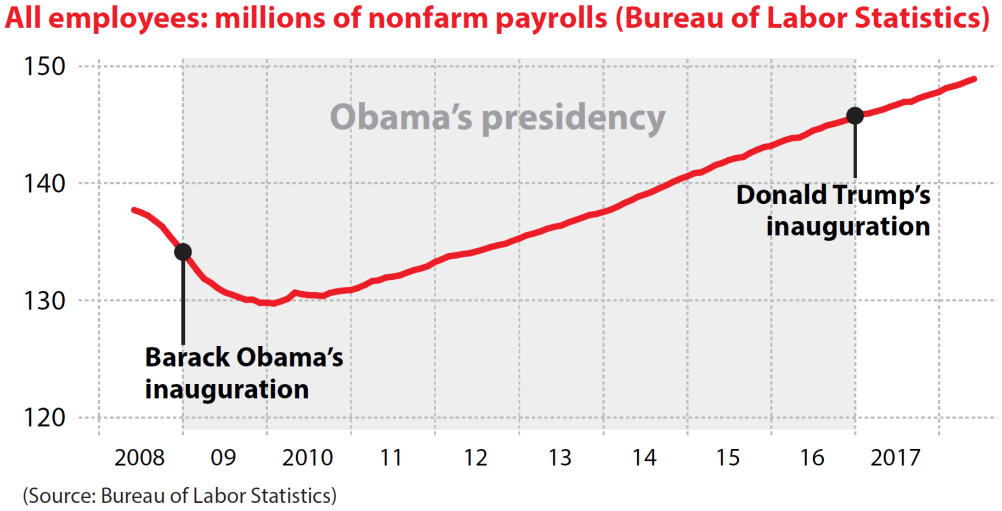
Graphical Integrity: Show Me the Truth

- Snapshot can be misleading!

Donald Trump liked to claim that the job market was a "disaster" before he was sworn in but recovered right after, and he used charts that cropped the horizontal axis in a convenient place.



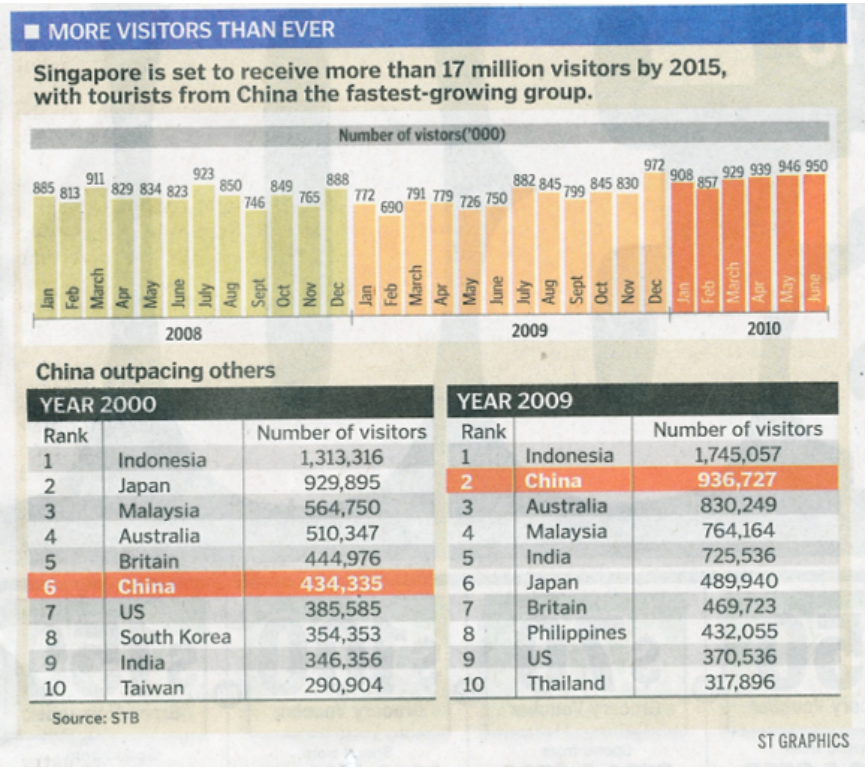
But if we go back in time and mark the point when Trump became president, we'll see that there's no remarkable change in the trajectory and slope of the line. Jobs began recovering in 2010.



Source: Cairo, Alberto (2019) **How Charts Lie**, W.W. Norton & Company, USA. pg 168.

Graphical Integrity: Show Me the Truth

- Do not miss-out what had happened in between.



MORE VISITORS THAN EVER

Singapore is set to receive more than 17 million visitors by 2015, with tourists from China the fastest-growing group.

Number of vistors('000)

2008												2009												2010				
Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June
885	813	911	829	834	823	923	850	746	849	765	888	772	690	791	779	726	750	882	845	799	845	830	972	908	857	929	939	946	950

China outpacing others

YEAR 2000

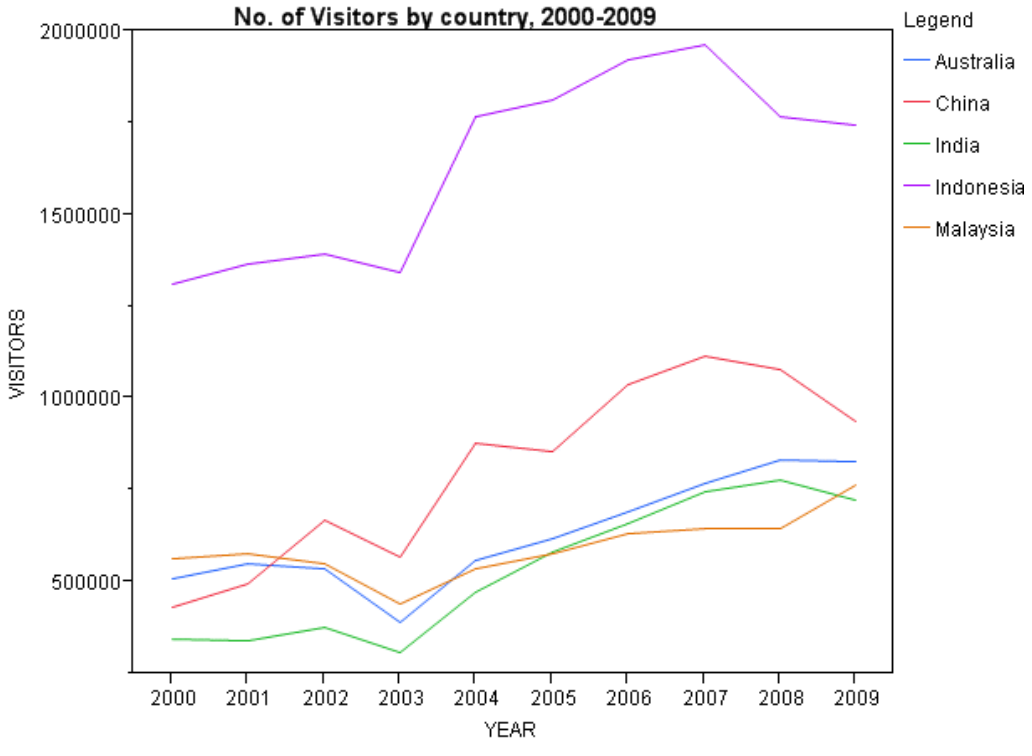
Rank		Number of visitors
1	Indonesia	1,313,316
2	Japan	929,895
3	Malaysia	564,750
4	Australia	510,347
5	Britain	444,976
6	China	434,335
7	US	385,585
8	South Korea	354,353
9	India	346,356
10	Taiwan	290,904

YEAR 2009

Rank		Number of visitors
1	Indonesia	1,745,057
2	China	936,727
3	Australia	830,249
4	Malaysia	764,164
5	India	725,536
6	Japan	489,940
7	Britain	469,723
8	Philippines	432,055
9	US	370,536
10	Thailand	317,896

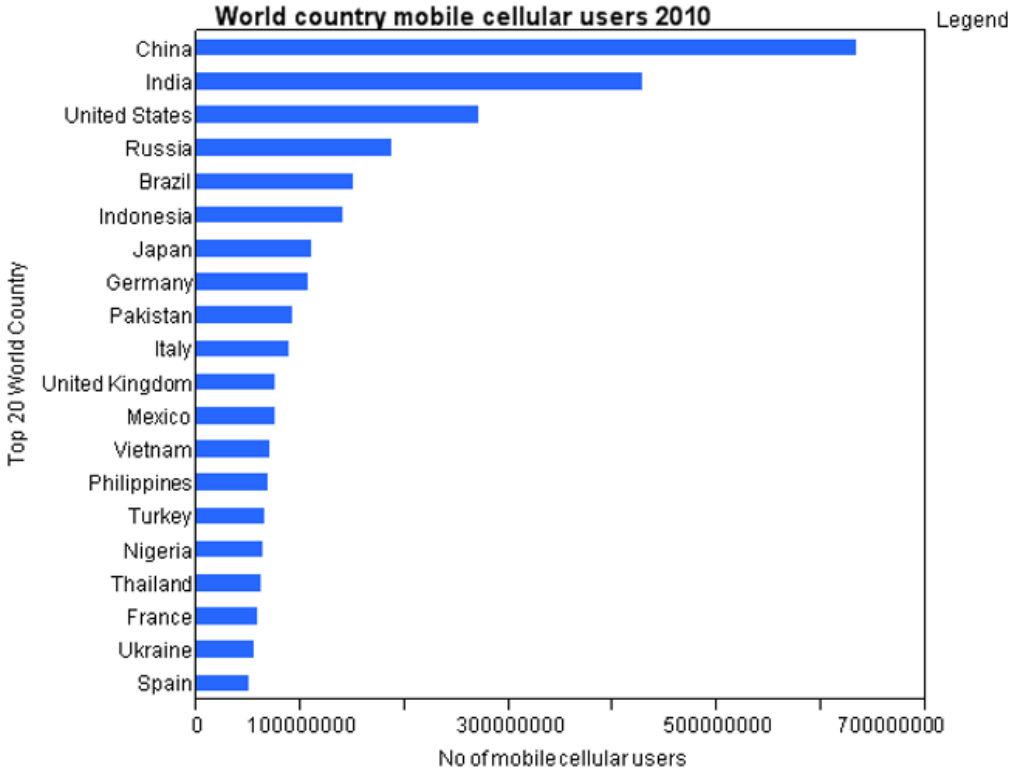
Source: STB

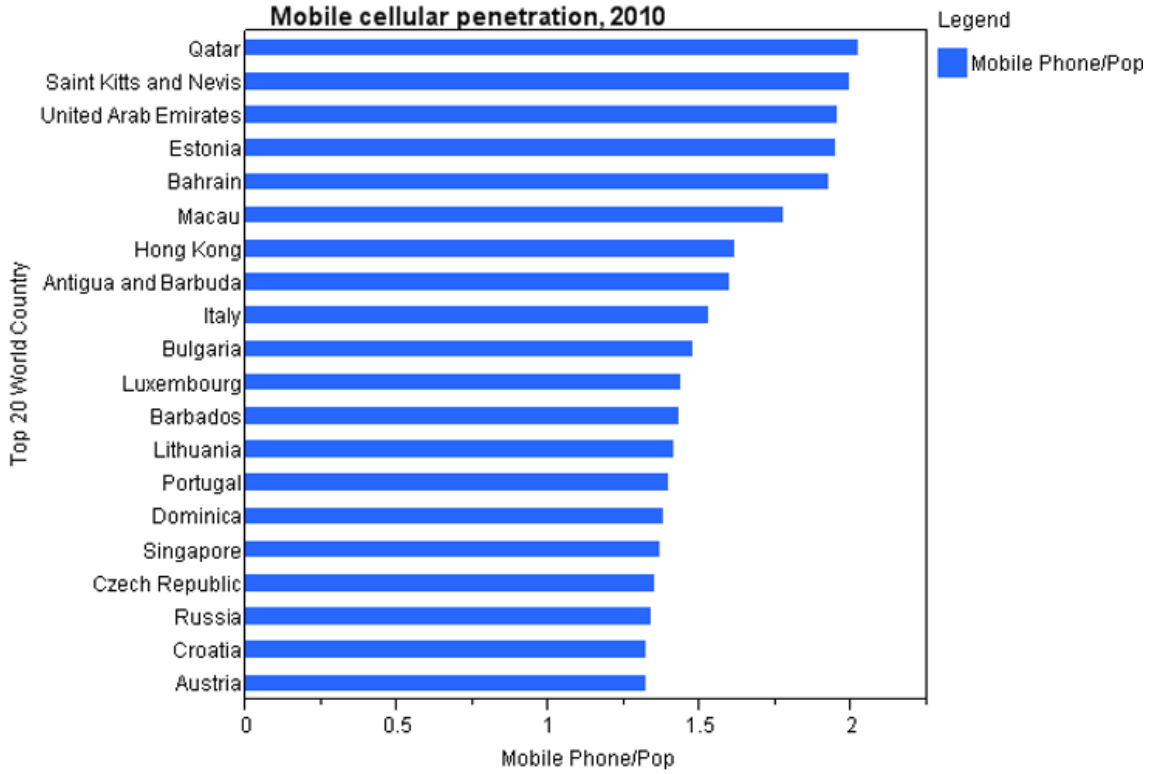
ST GRAPHICS



Graphical Integrity: Show Me the Truth

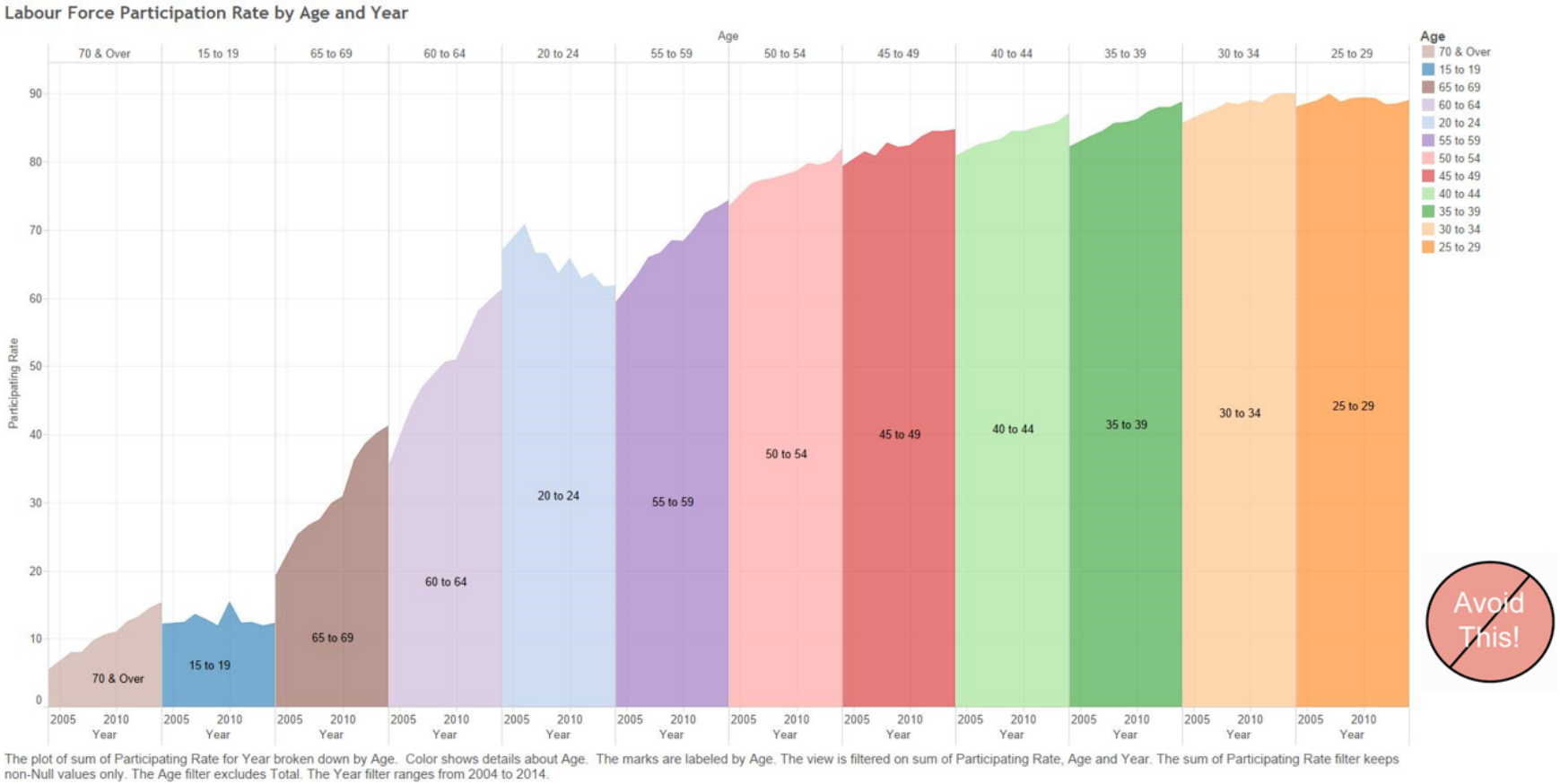
- Sometimes, data need to be transformed.



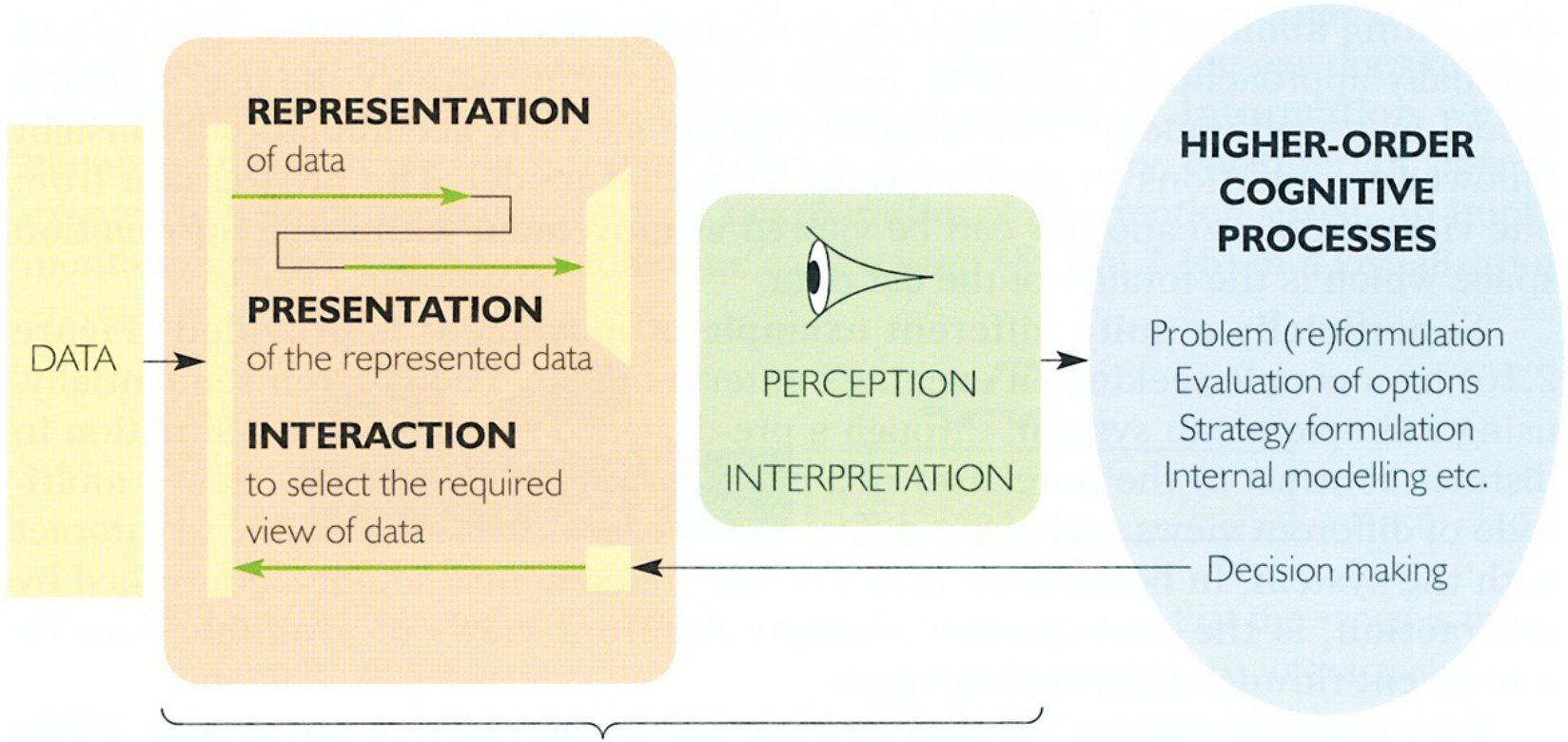


Graphical Integrity: Show me the truth

Designing graph to enlighten people – not to entertain them



Human Perception and Information Processing



Pre-attentive Processing

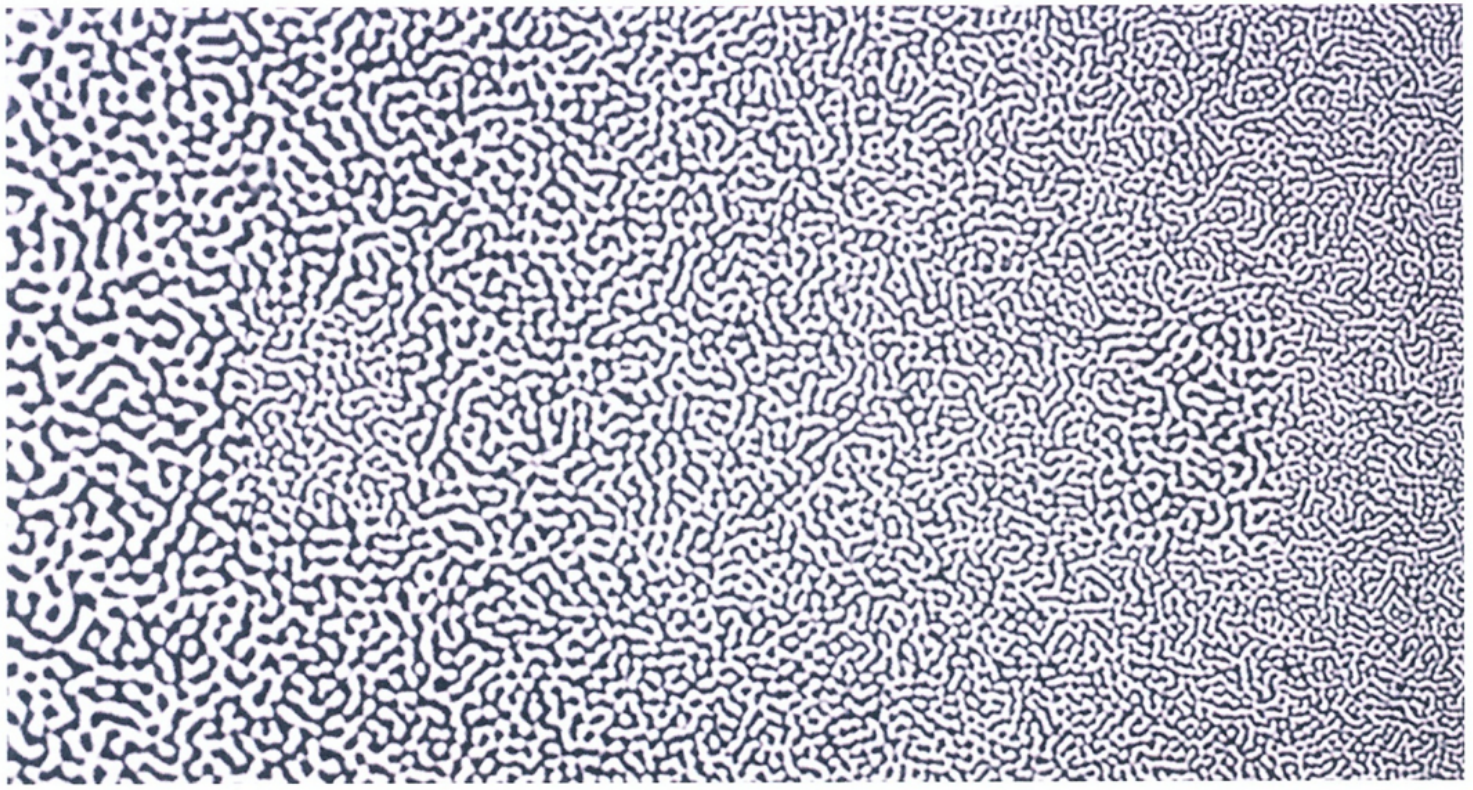
- A limited set of visual properties are processed preattentively (without need for focusing attention).
- This is important for design of visualizations
  - What can be perceived immediately?
  - Which properties are good discriminators?
  - What can mislead viewers?

How Visual Sensing Works?

Fact 1: We see what we know and expect.

How Visual Sensing Works?

Fact 2: We do not attend to everything we see.



How Visual Sensing Works?

Fact 3: We don’t remember everything we see

How Visual Sensing Works?

Fact 3: We don’t remember everything we see

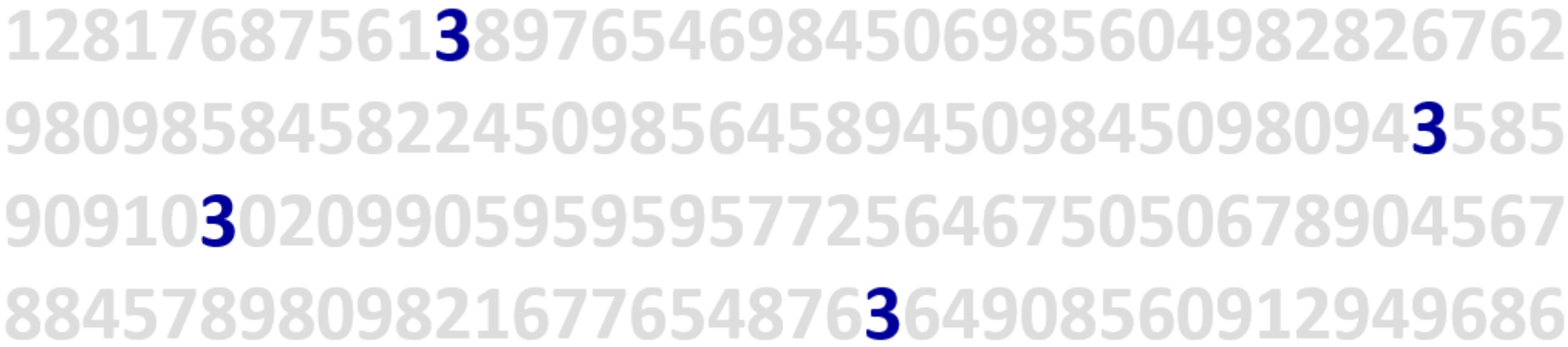
QW

How Many 3’s?

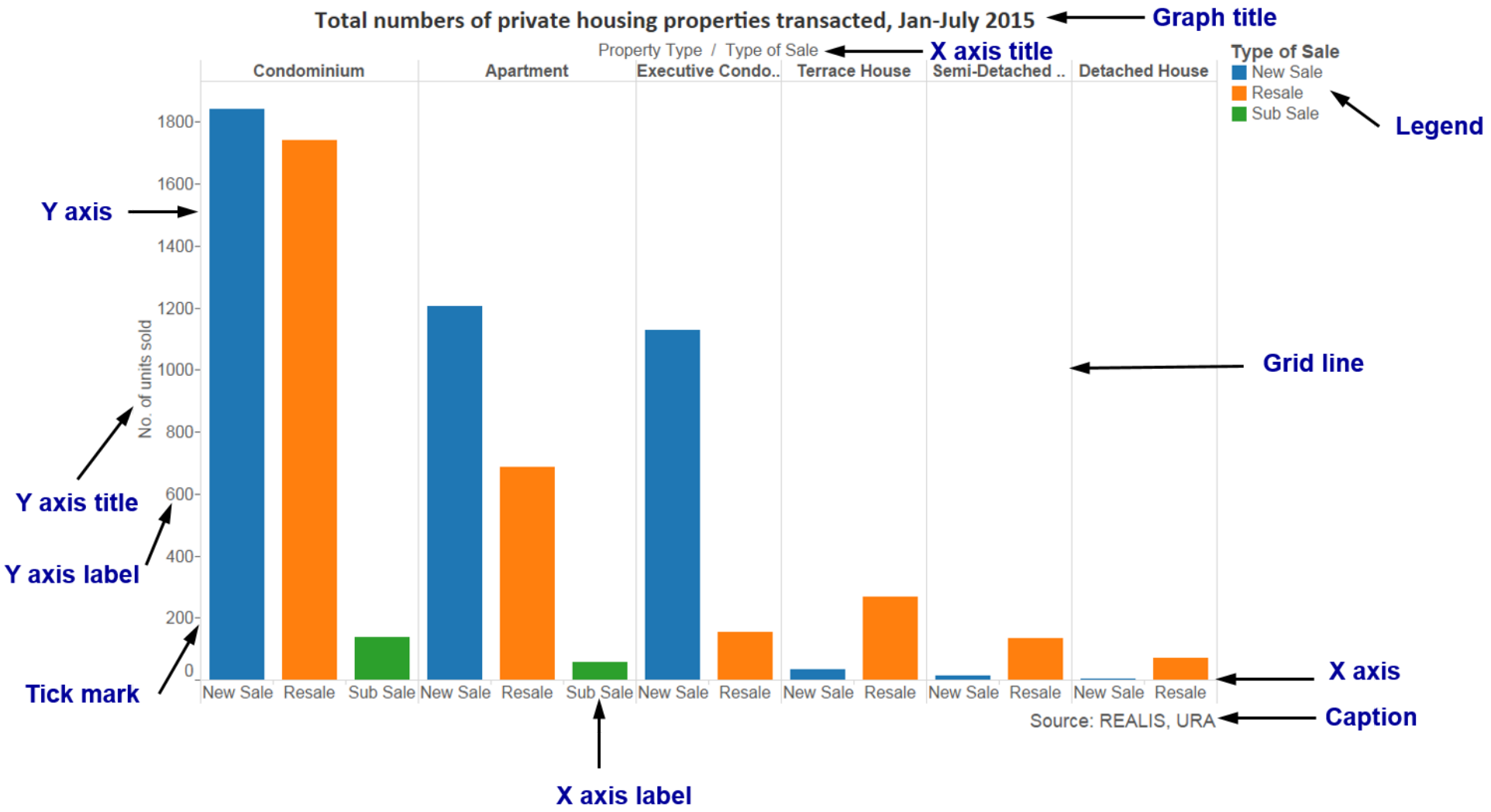
12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496868

QW

How Many 3’s?



Components of a graph



Bertin's Semiology of graphics

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'	

Jacques Bertin

Grammar of a language

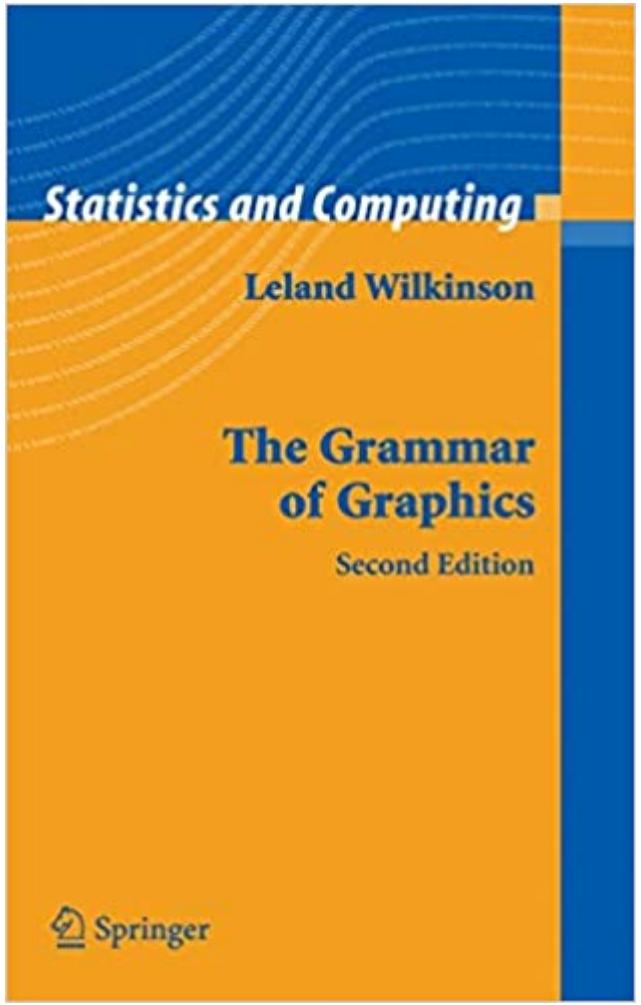
- Grammar of a language defines the rules of structuring words and phrases into meaningful expressions.

The quick brown fox jumps over the lazy dog

Article	*The*
Adjective	*quick brown*
Noun	*fox*
Verb	*jumps*
Preposition	*over*
Article	*the*
Adjective	*lazy*
Noun	*dog.*

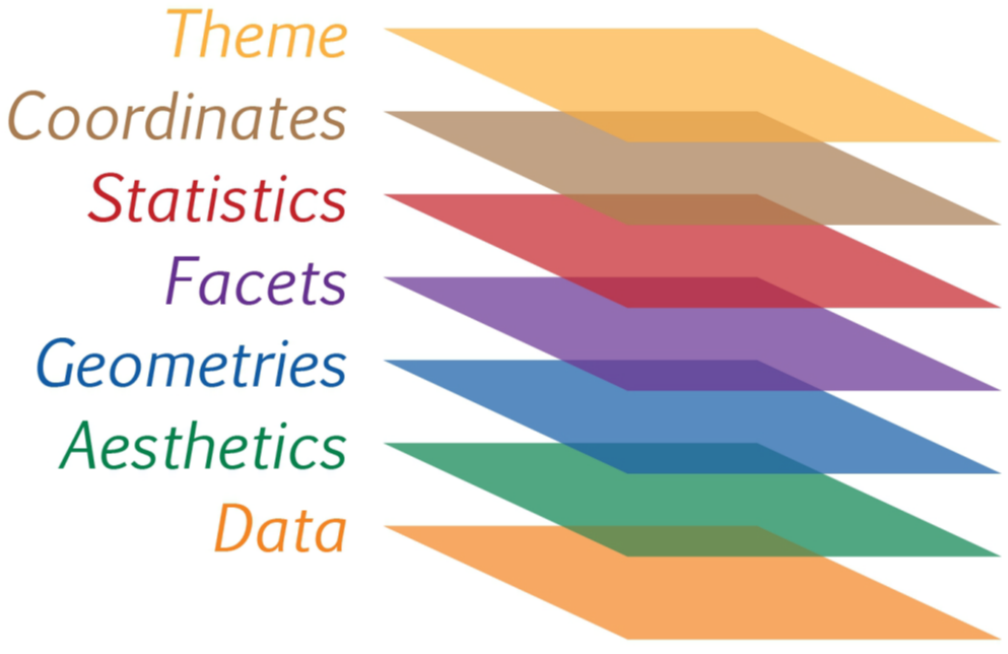
The Grammar of Graphics

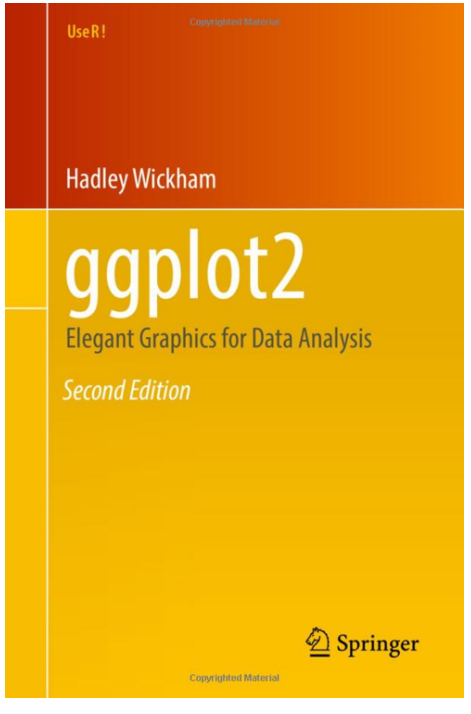
- The grammar of graphics is an answer to a question: What is a statistical graphic?
- Grammar of graphics defines the rules of structuring mathematic and aesthetic elements into a meaningful graph.
- Two principles:
  - Graphics = distinct layers of grammatical elements
  - Meaningful plots through aesthetic mapping



A Layered Grammar of Graphics

Design principles of ggplot2 r package





Design principles for effective visual presentation

- Rules for Encoding Values in Graph
- JunkCharts
- Practical Guides for Using Colour in Charts
- Data-ink

Design principles for effective visual presentation

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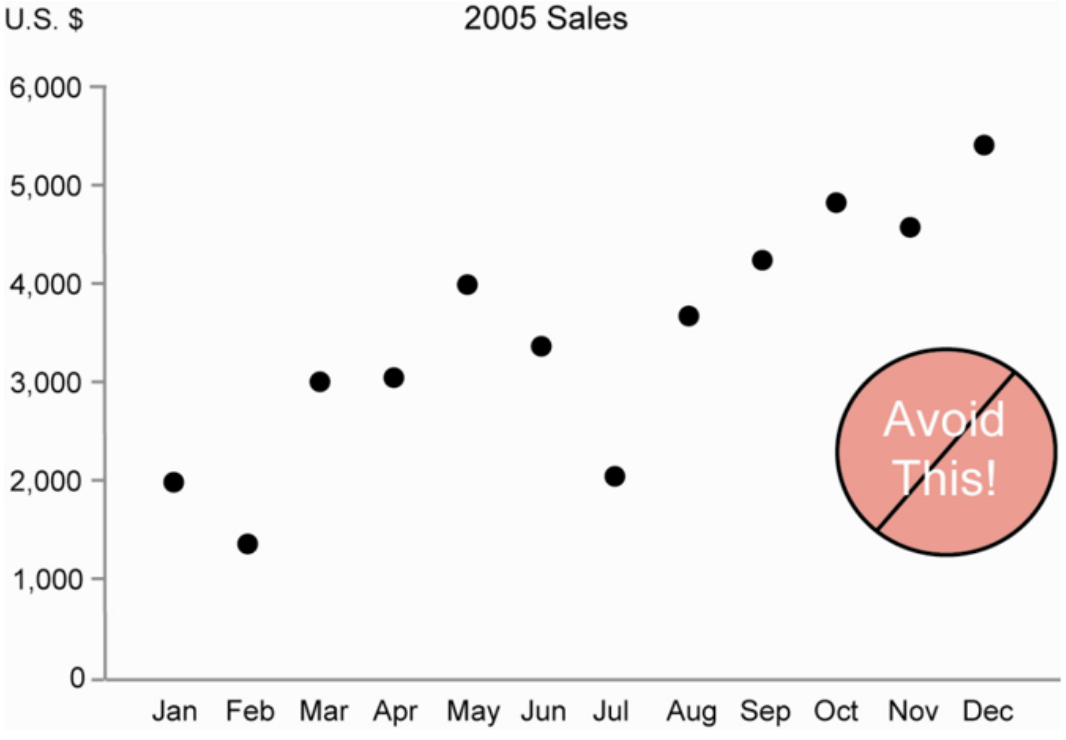
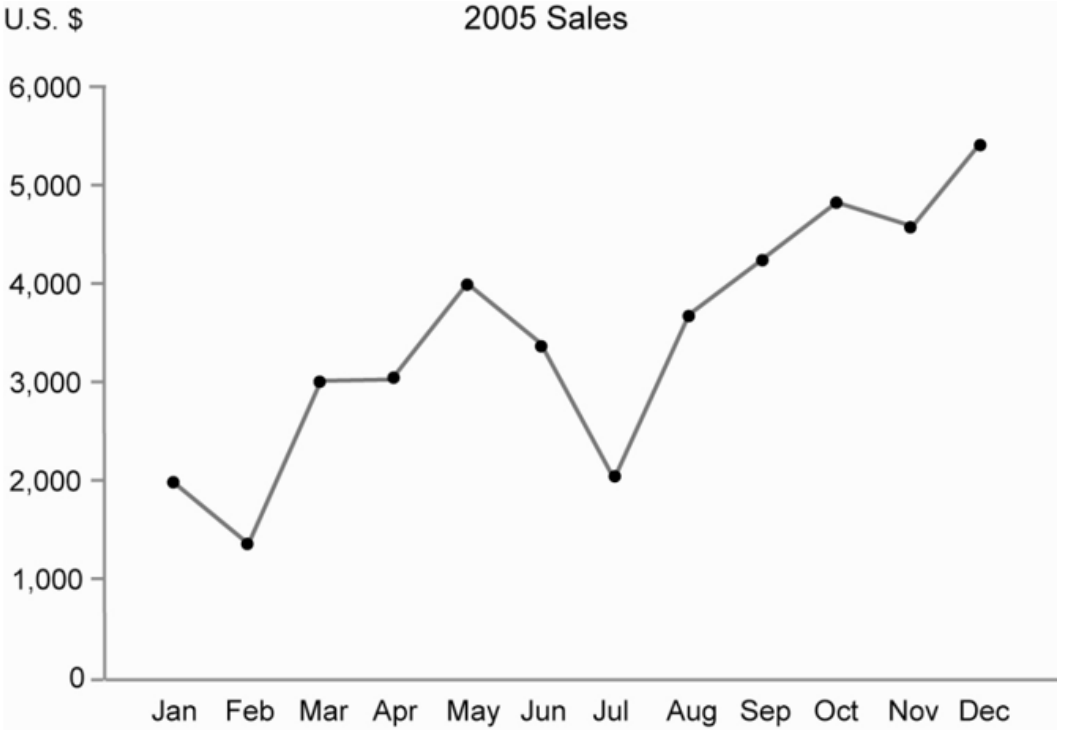
Rules for Encoding Values in Graph

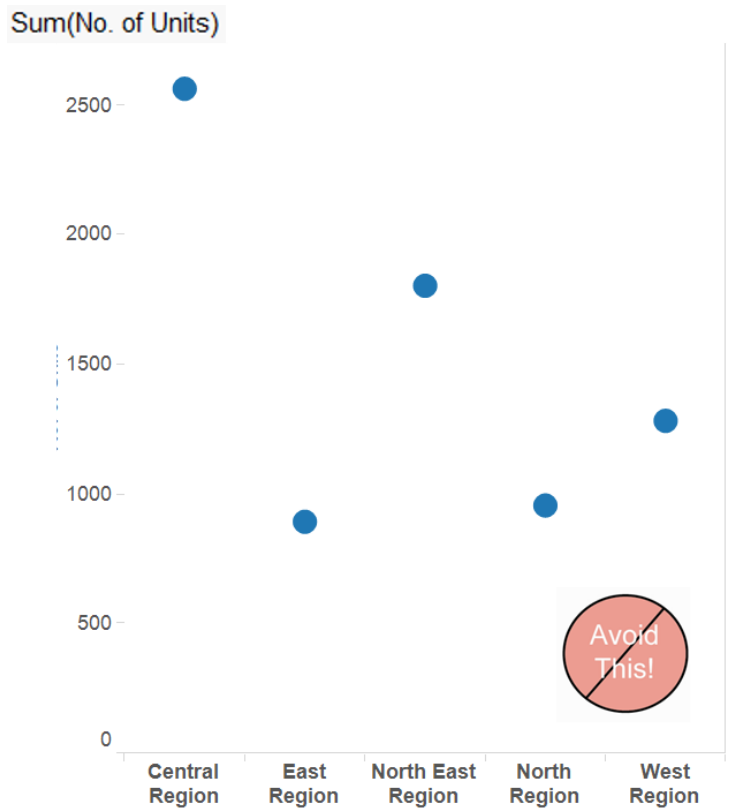
Rule 1: Avoid using point alone to display time-series data

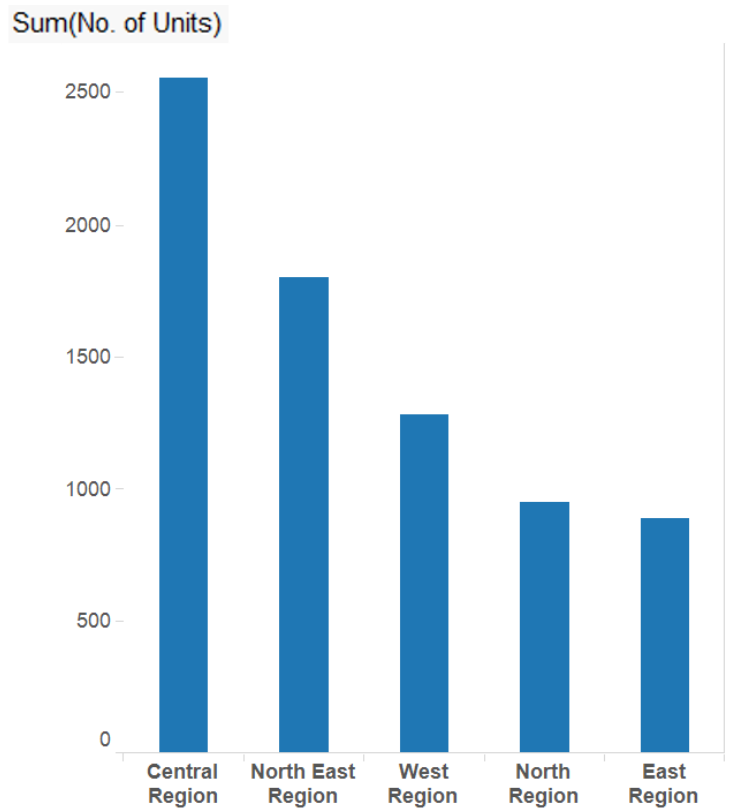




Rules for Encoding Values in Graph

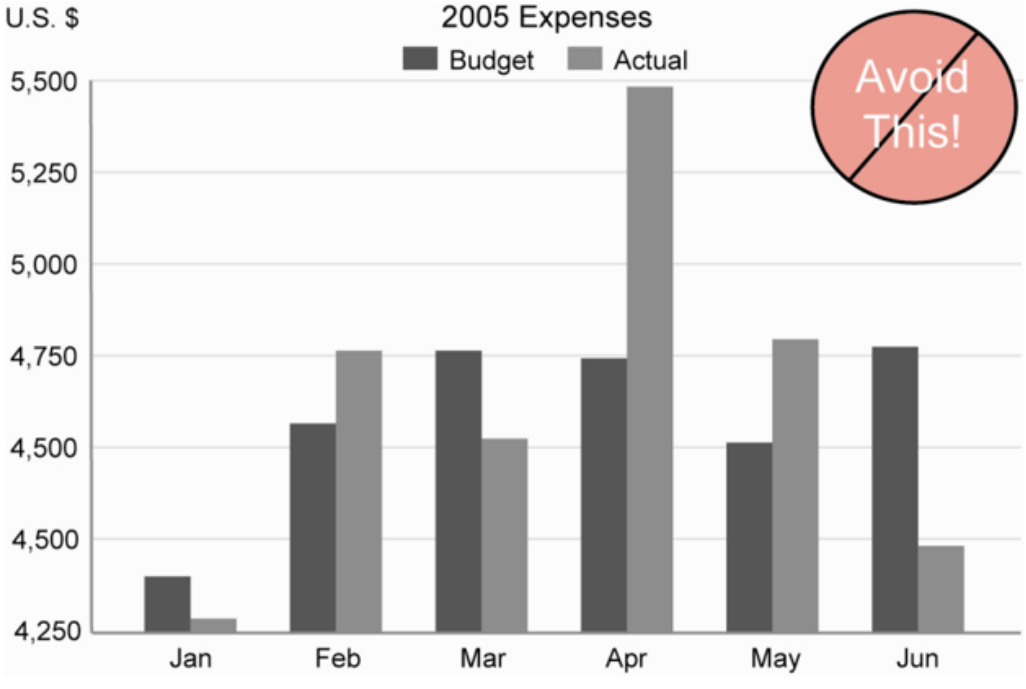
Rule 2: Avoid using points to represent discrete values

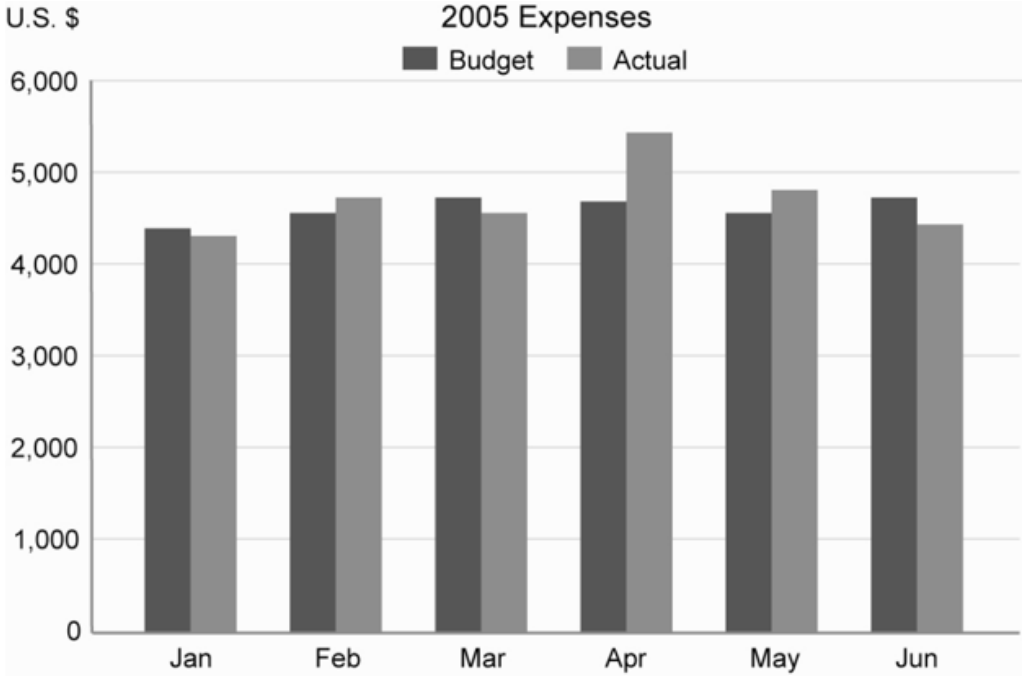




Rules for Encoding Values in Graph

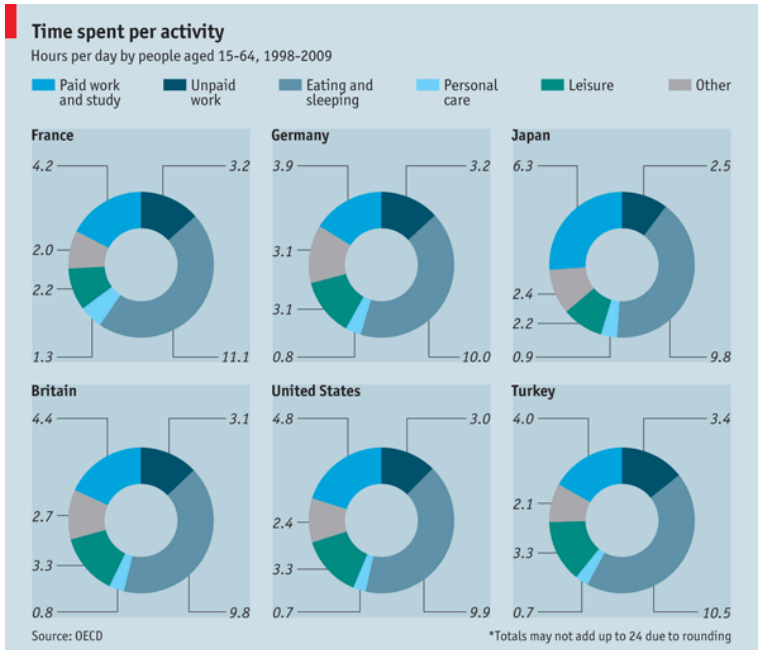
Rule 3: Bars don’t work unless the quantative scale begins at zero



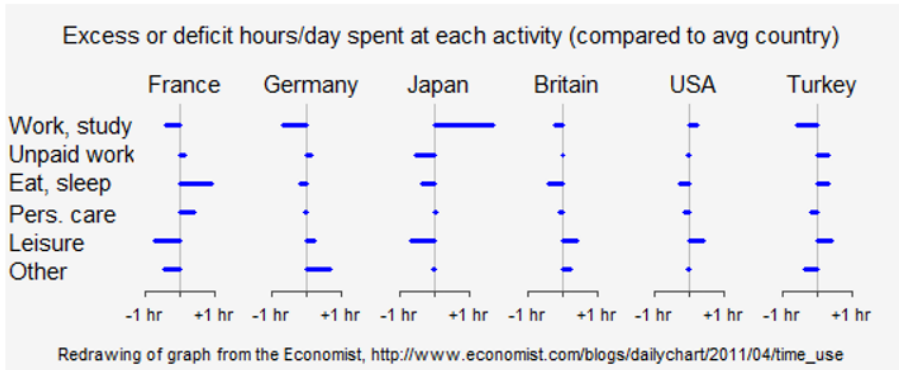


Rule for Encoding Values in Graph

Rule 4: Avoid pie chart if possible because our eyes are not good in reading areas



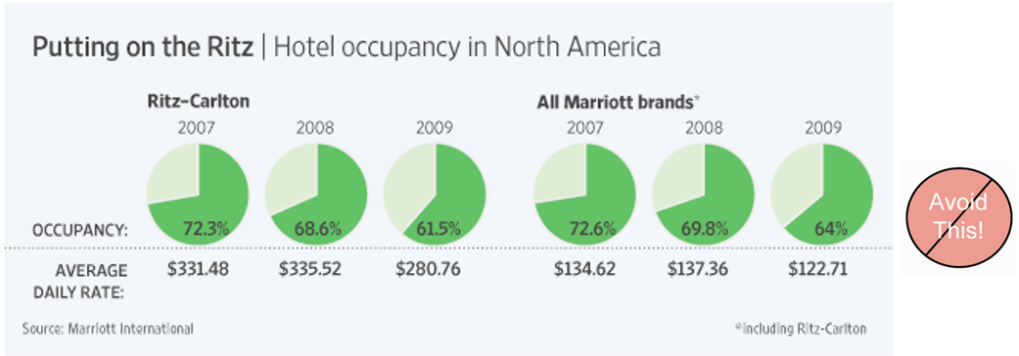
Source: Time use: A day in the life,
Apr 19th 2011, 15:00 by The Economist online

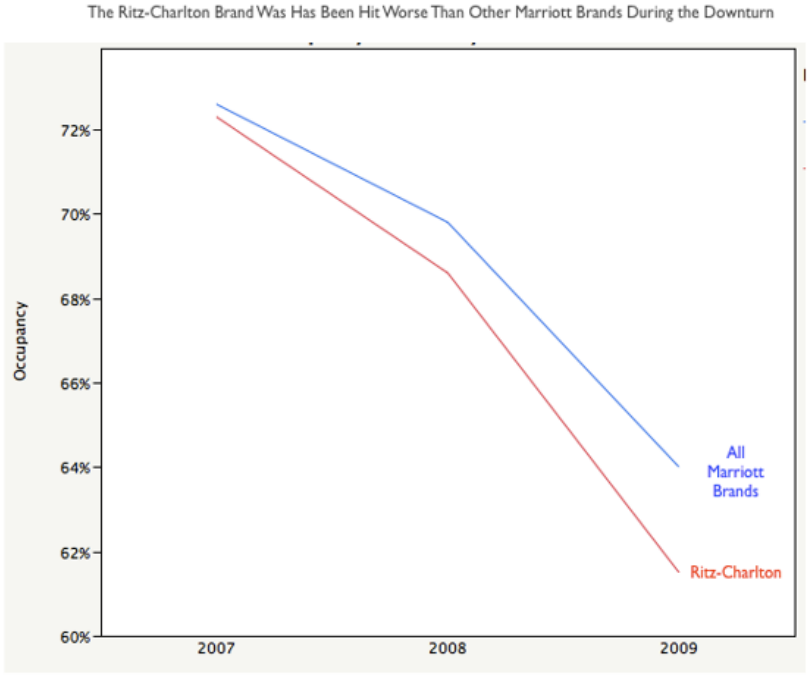


Reference: http://junkcharts.typepad.com/junk_charts/2015/09/a-not-so-satisfying-rose.html

Rule for Encoding Values in Graph

Rule 5: Avoid pie chart if you are comparing changes over time





Design principles for effective visual presentation

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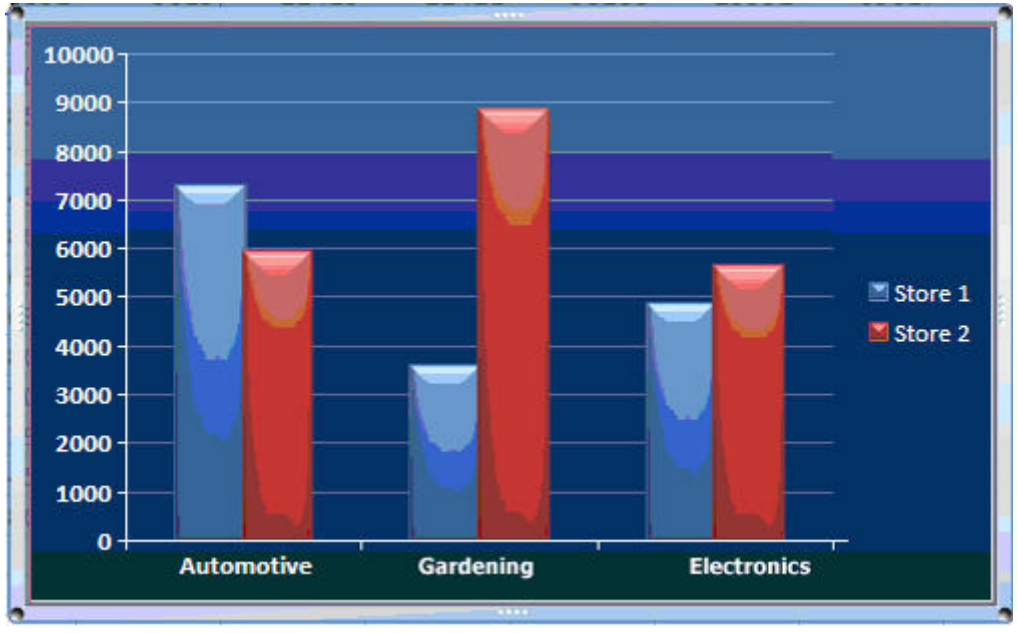
What is ChartJunk?

- Chartjunk refers to all visual elements in charts and graphs that are not necessary to comprehend the information represented on the graph, or that distract the viewer from this information.
- It was first introduced by Edward Tufte in his 1983 book *The Visual Display of Quantitative Information*.
- There is an interesting blog called Junk Charts by Kaiser Fung.

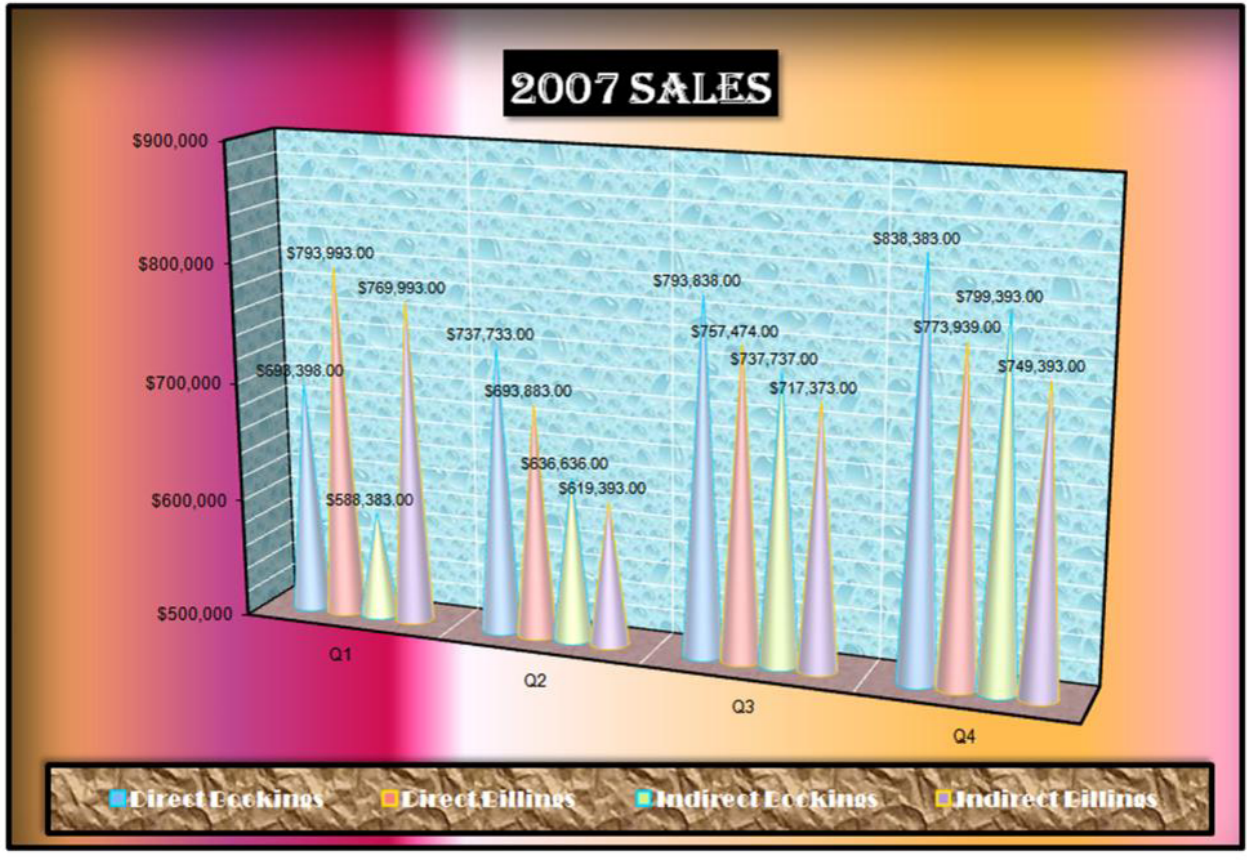
ChartJunk I

- Avoid using unnecessary colour shading for the bar



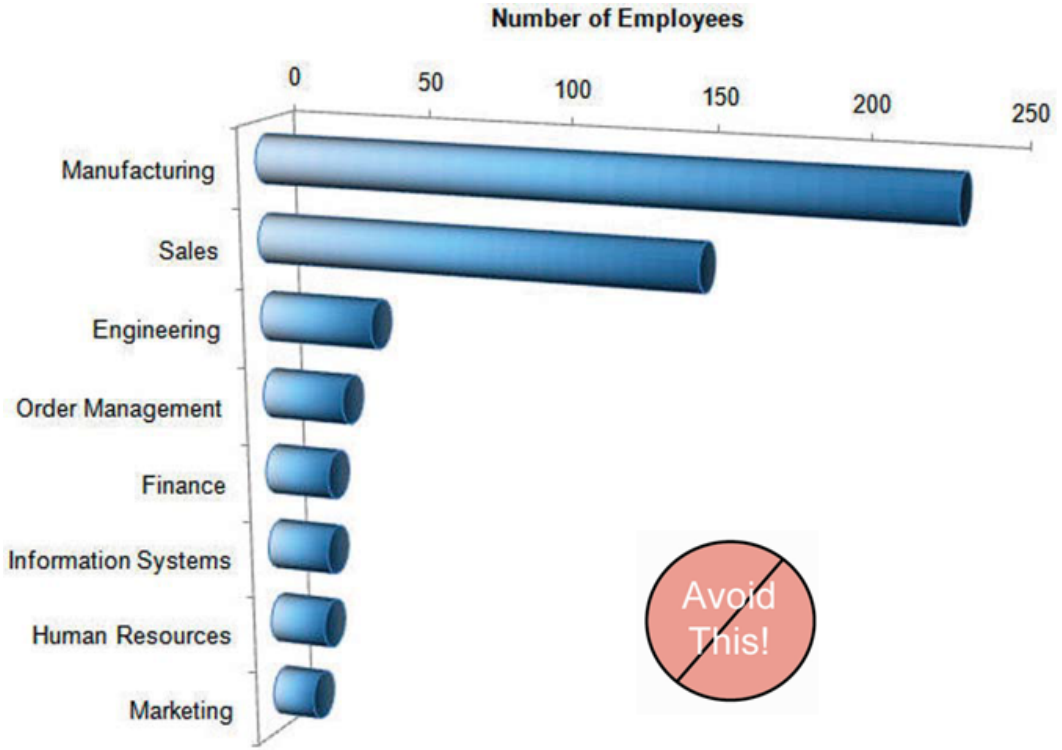
ChartJunk II

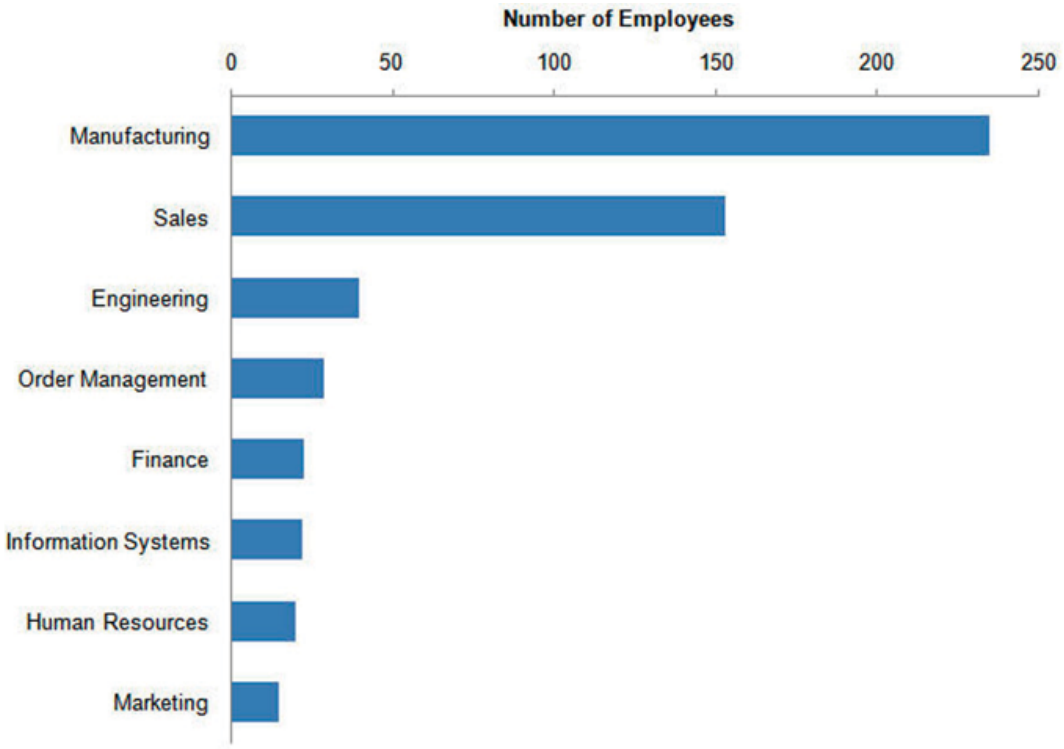
Avoid colourful or wallpaper background



ChartJunk III

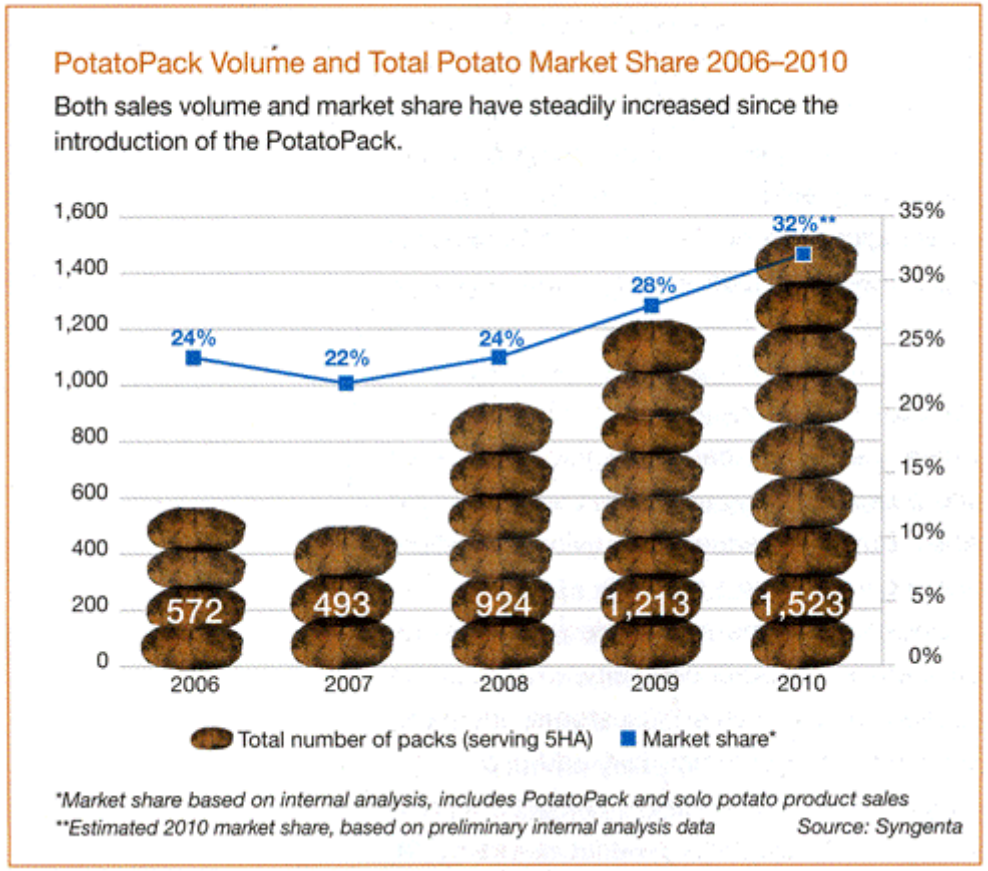
Avoid using 3D effects in graphics





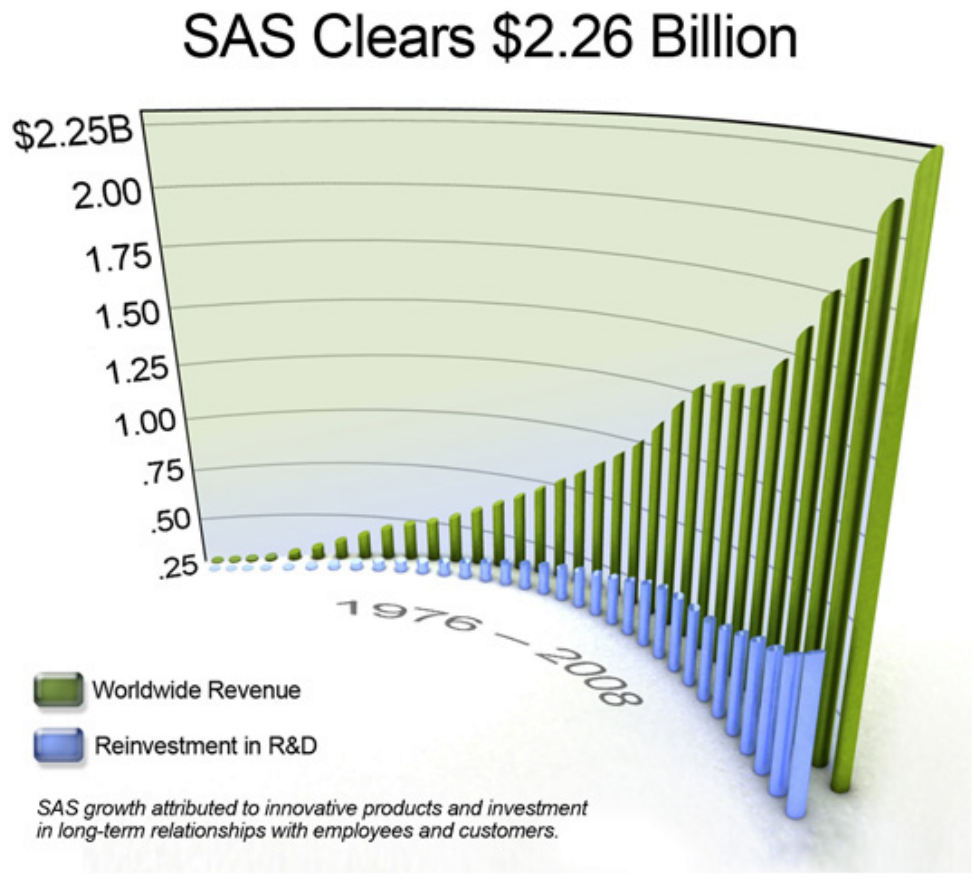
ChartJunk IV

Avoid using misleading graphical representation



ChartJunk V

Avoid using artistic design which is difficult to visualise



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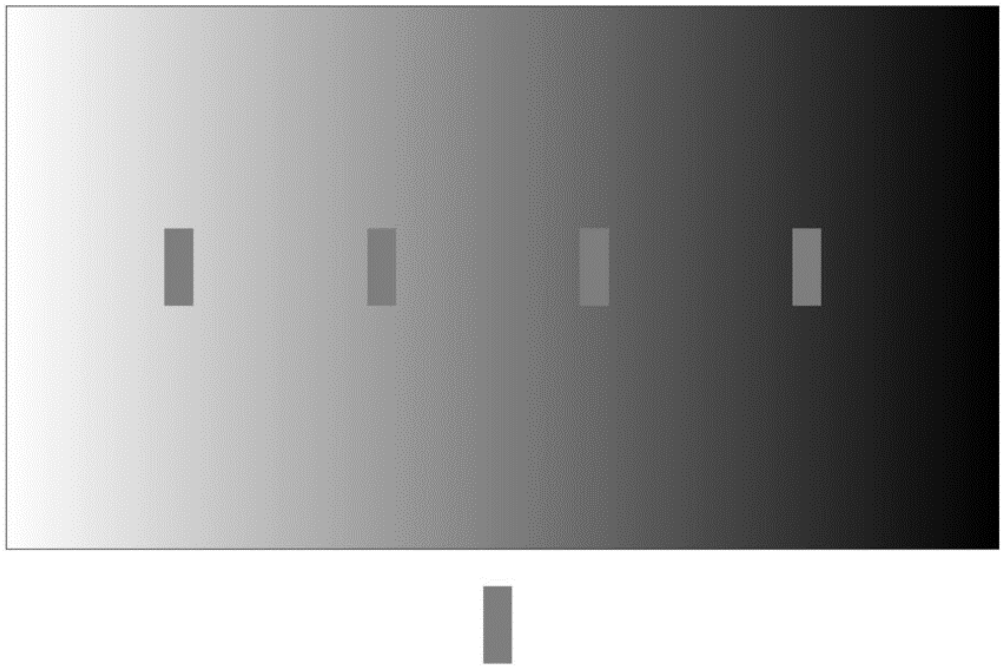
- **Practical Guides for Using Colour in Charts**
- Data-ink

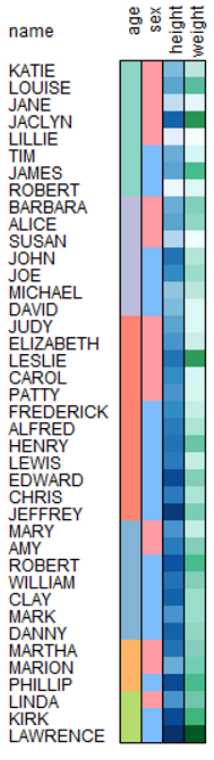
Practical Guides for Using Colour in Charts

Rule 1: If you want different objects of the same colour in a graph to look the same, make sure that the background- the colour that surrounds them – is consistent.



Practical Guides for Using Colour in Charts

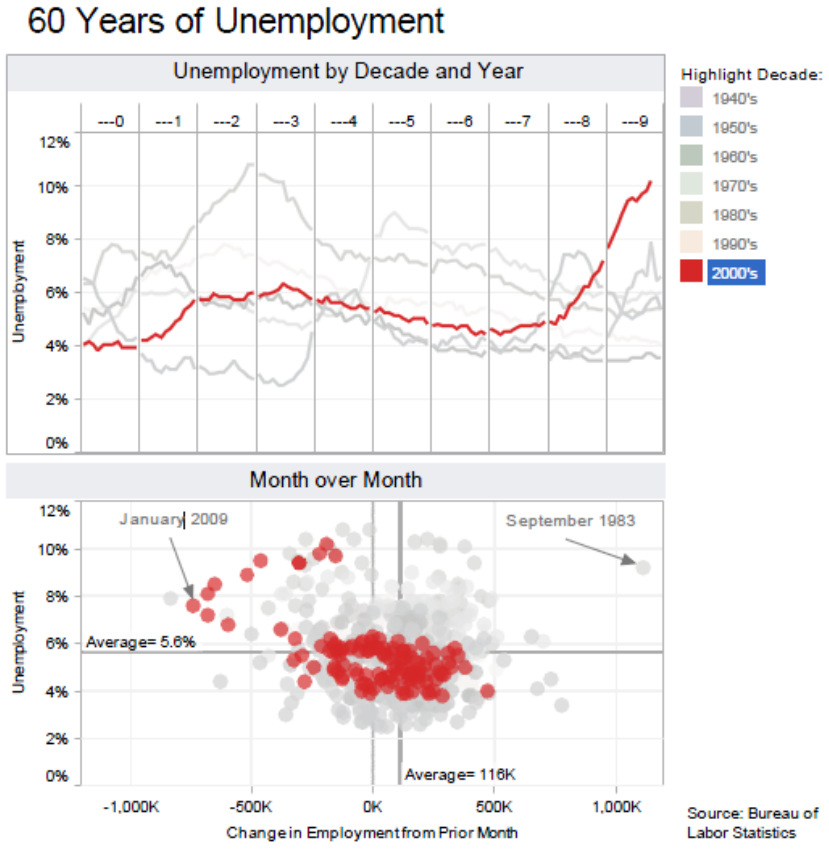
Rule 2: If you want objects in a graph to be easily seen, use a background colour that constracts sufficiently with the object.



	name	age	sex	height	weight	mean weight by age
1	KATIE	12	F	59	95	99.000
2	LOUISE	12	F	61	123	99.000
3	JANE	12	F	55	74	99.000
4	JACLYN	12	F	66	145	99.000
5	LILLIE	12	F	52	64	99.000
6	TIM	12	M	60	84	99.000
7	JAMES	12	M	61	128	99.000
8	ROBERT	12	M	51	79	99.000
9	BARBARA	13	F	60	112	94.714
10	ALICE	13	F	61	107	94.714
11	SUSAN	13	F	56	67	94.714
12	JOHN	13	M	65	98	94.714
13	JOE	13	M	63	105	94.714
14	MICHAEL	13	M	58	95	94.714
15	DAVID	13	M	59	79	94.714
16	JUDY	14	F	61	81	100.833
17	ELIZABETH	14	F	62	91	100.833
18	LESLIE	14	F	65	142	100.833
19	CAROL	14	F	63	84	100.833
20	PATTY	14	F	62	85	100.833
21	FREDERICK	14	M	63	93	100.833
22	ALFRED	14	M	64	99	100.833
23	HENRY	14	M	65	119	100.833
24	LEWIS	14	M	64	92	100.833
25	EDWARD	14	M	68	112	100.833
26	CHRIS	14	M	64	99	100.833
27	JEFFREY	14	M	69	113	100.833
28	MARY	15	F	62	92	108.286
29	AMY	15	F	64	112	108.286
30	ROBERT	15	M	67	128	108.286
31	WILLIAM	15	M	65	111	108.286

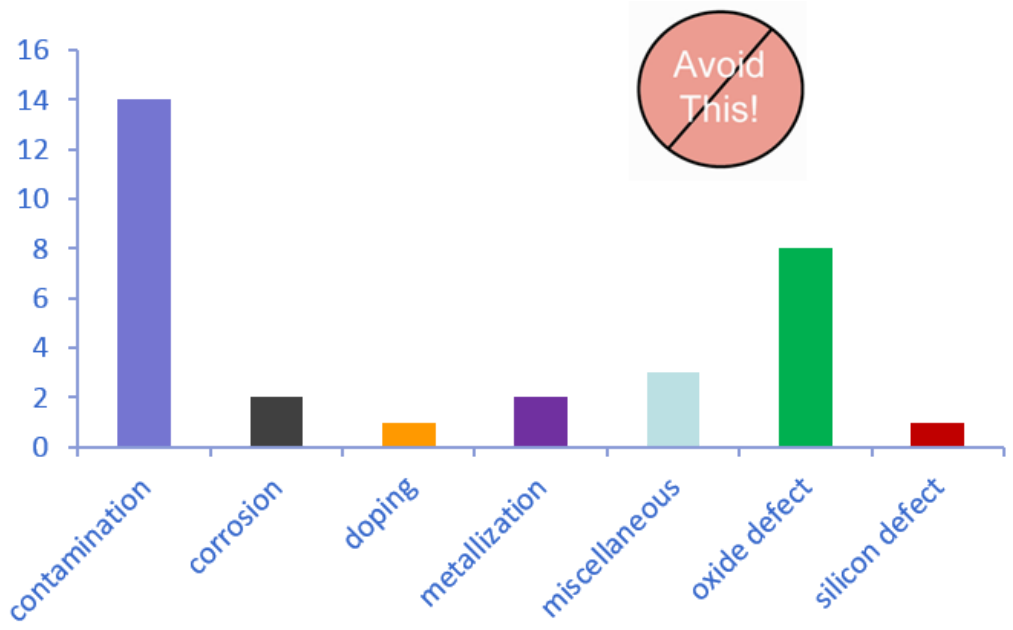
Practical Guides for Using Colour in Charts

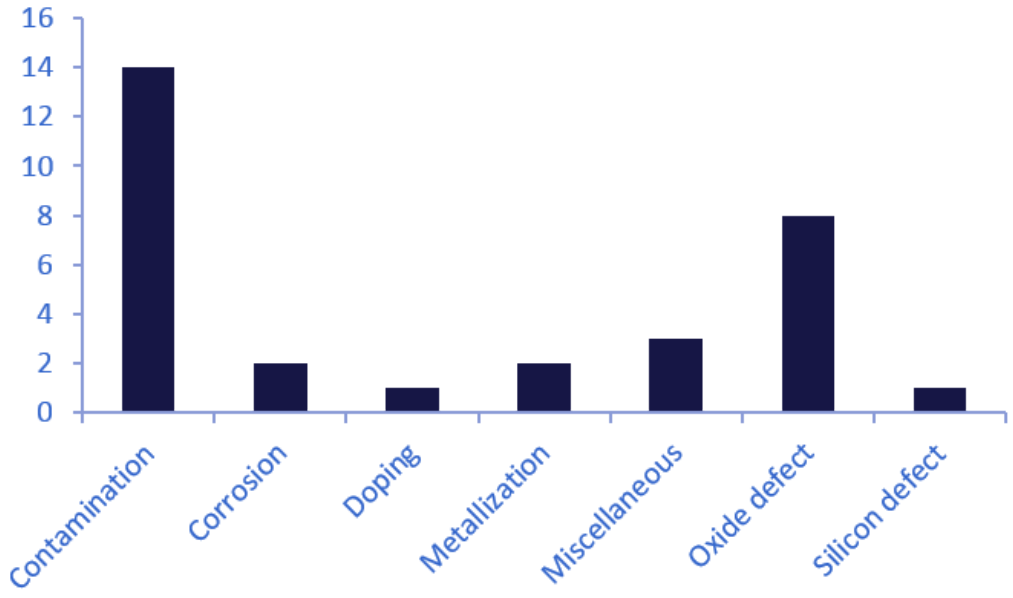
Rule 3: Use color only when needed to serve a particular communication goal.



Practical Guides for Using Colour in Charts

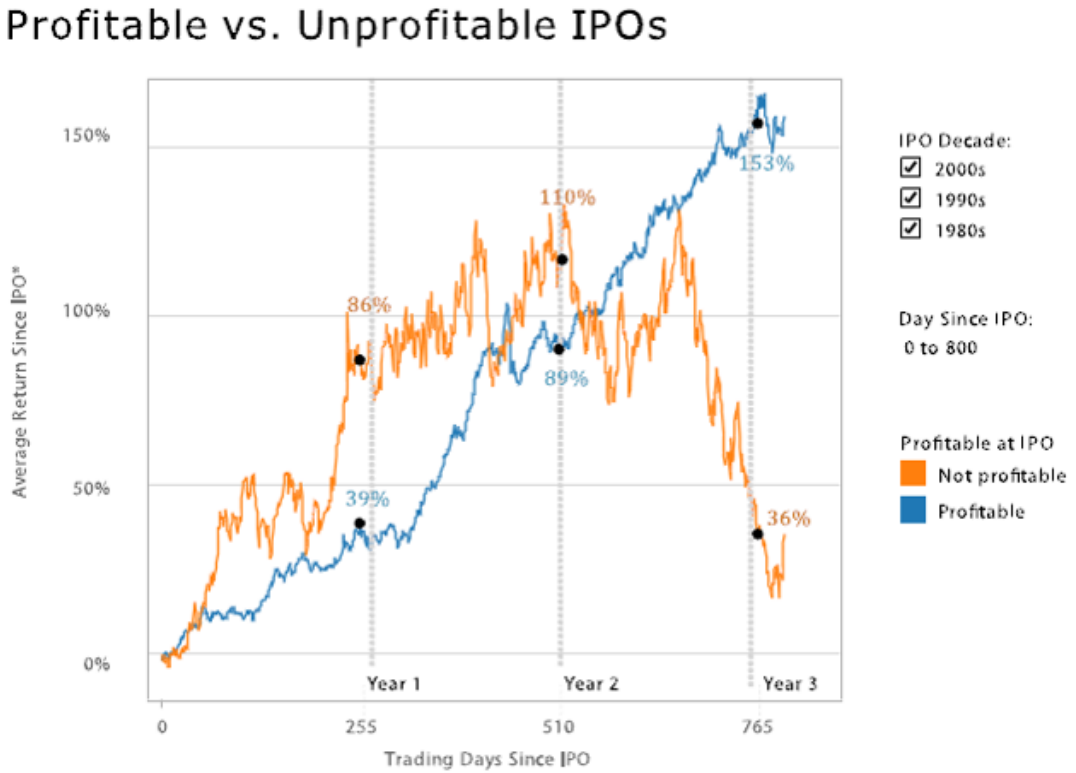
Rule 4: Use different colours when they correspond to differences of meaning in the data.





Practical Guides for Using Colour in Charts

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



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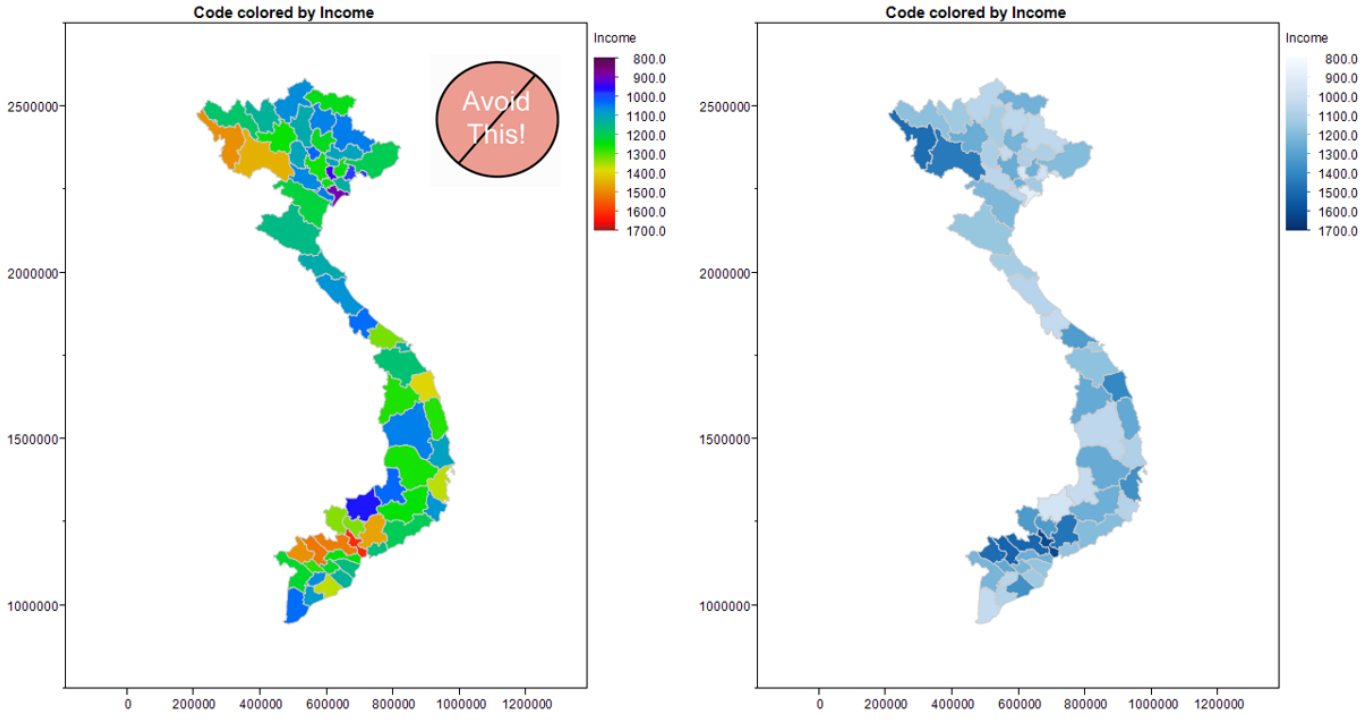
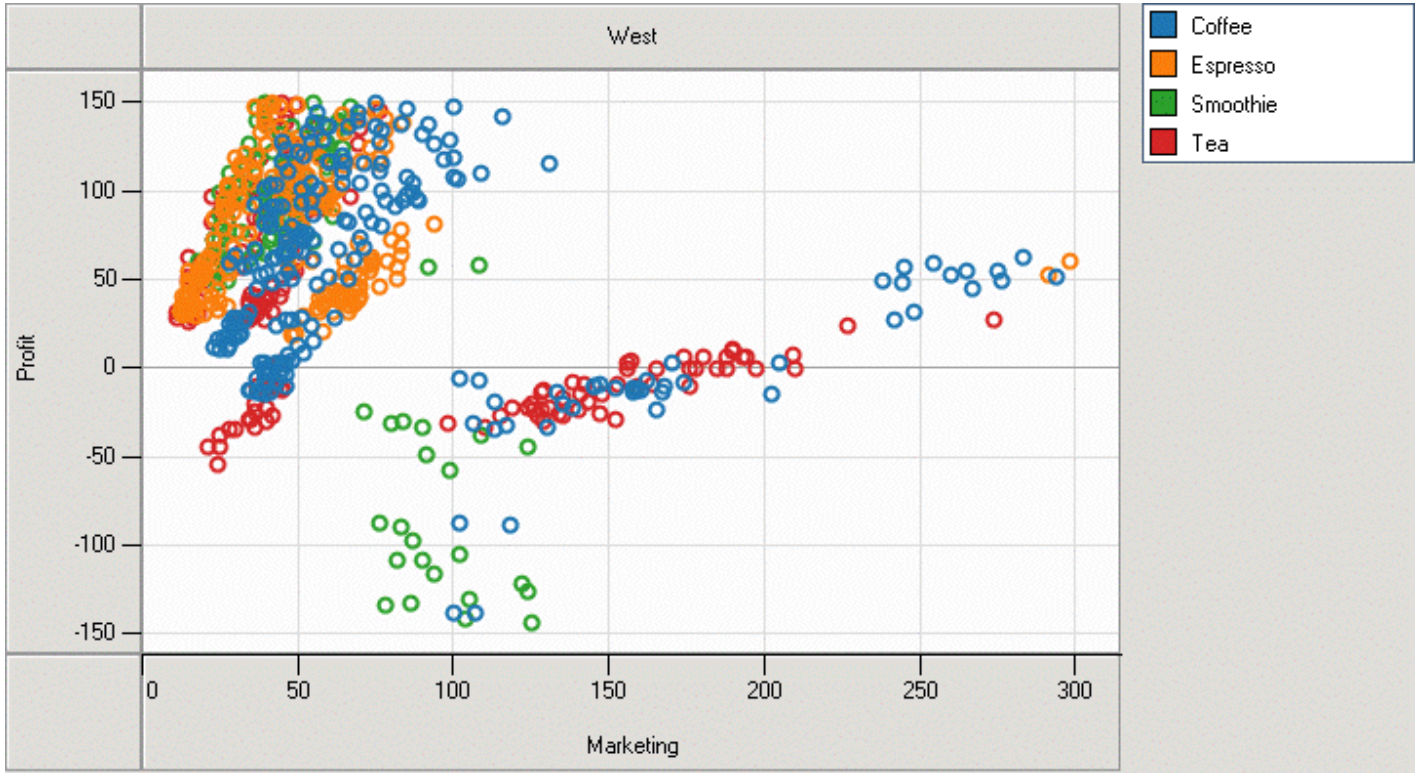
Rule 6: When using colour to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colours for low values to increasingly darker and brighter colours for high values.



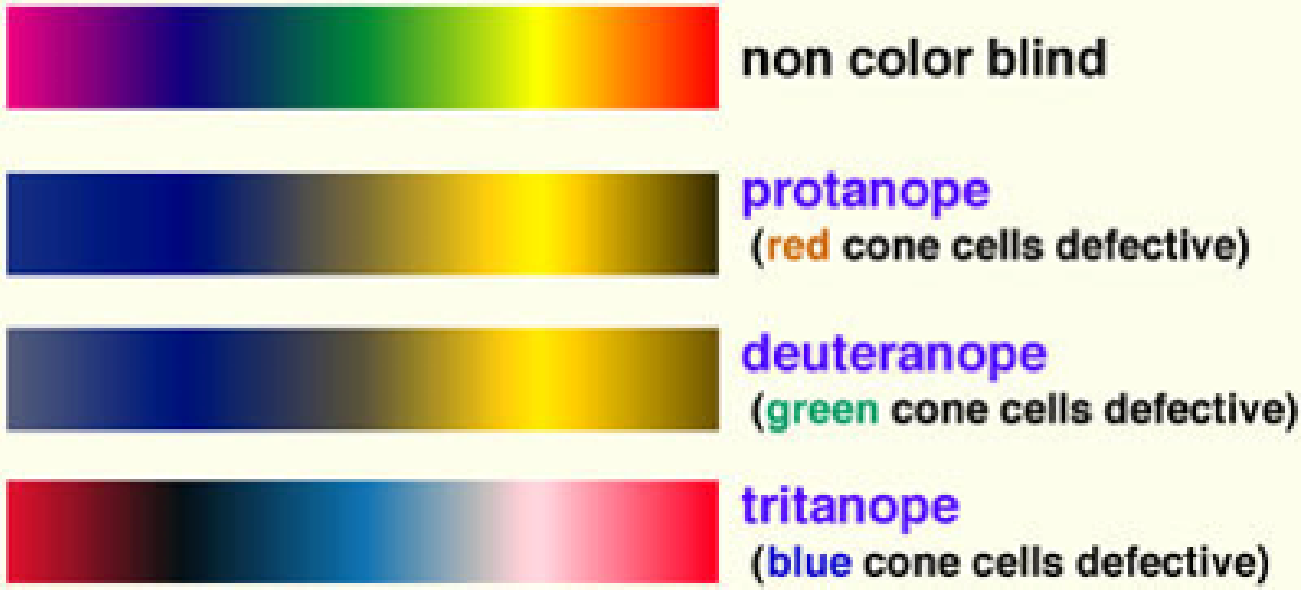
Practical Guides for Using Colour in Charts

Rule 7: Non-data components of a graph should be displayed just visibly enough to perform their role, but not more so, for excessive salience could cause them to distract attention from the data.



Practical Guides for Using Colour in Charts

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



Design principles for effective visual presentation

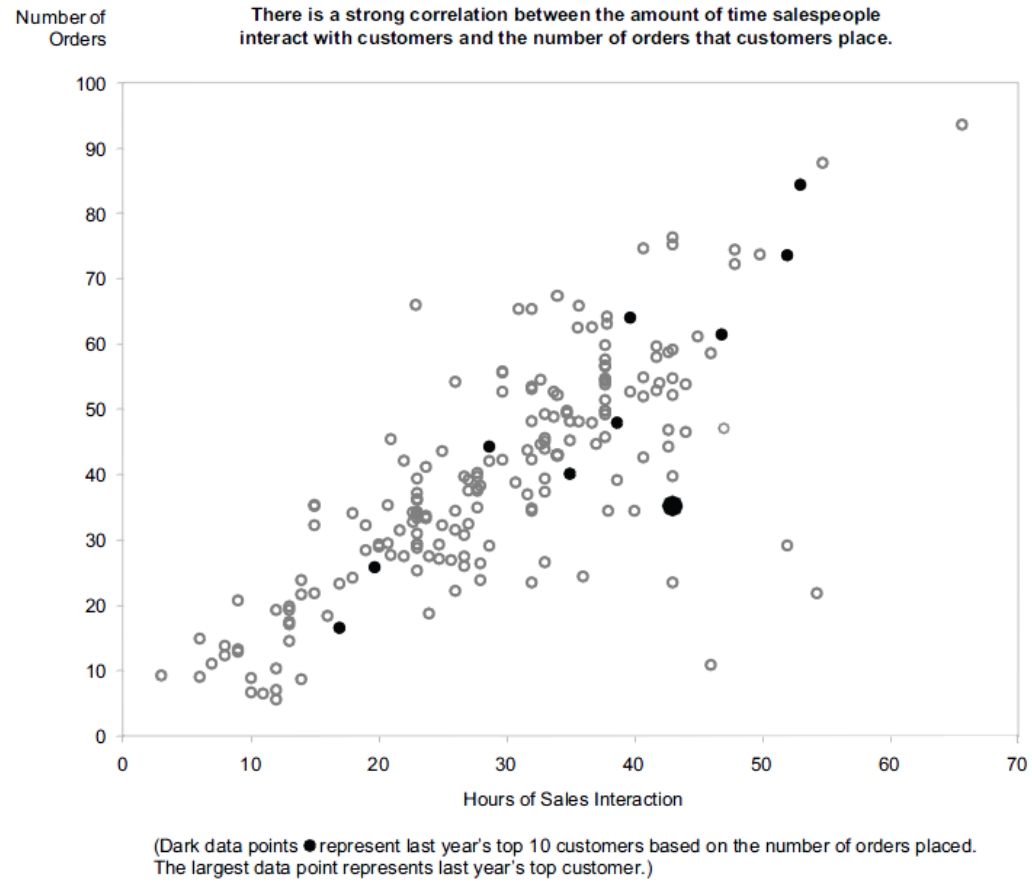
- Rules for Encoding Values in Graph
- JunkCharts
- Practical Guides for Using Colour in Charts
- **Data-ink**

Data-ink

- Reduce the non data-ink
  - Removed unnecessary non data-ink
  - De-emphasise or regularise the remaining non data-ink
- Enhance the data-ink
  - Remove unnecessary data-ink
  - Emphasise the remaining data-ink

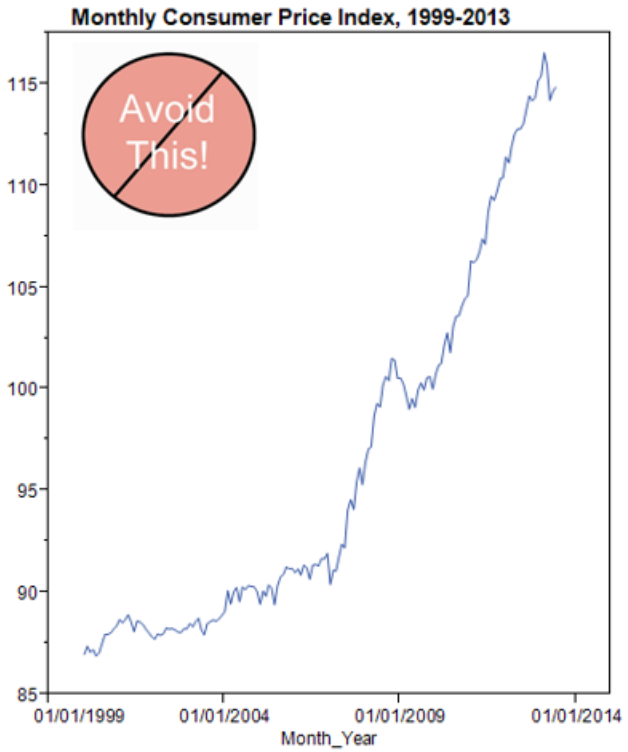
Practical used of data-ink

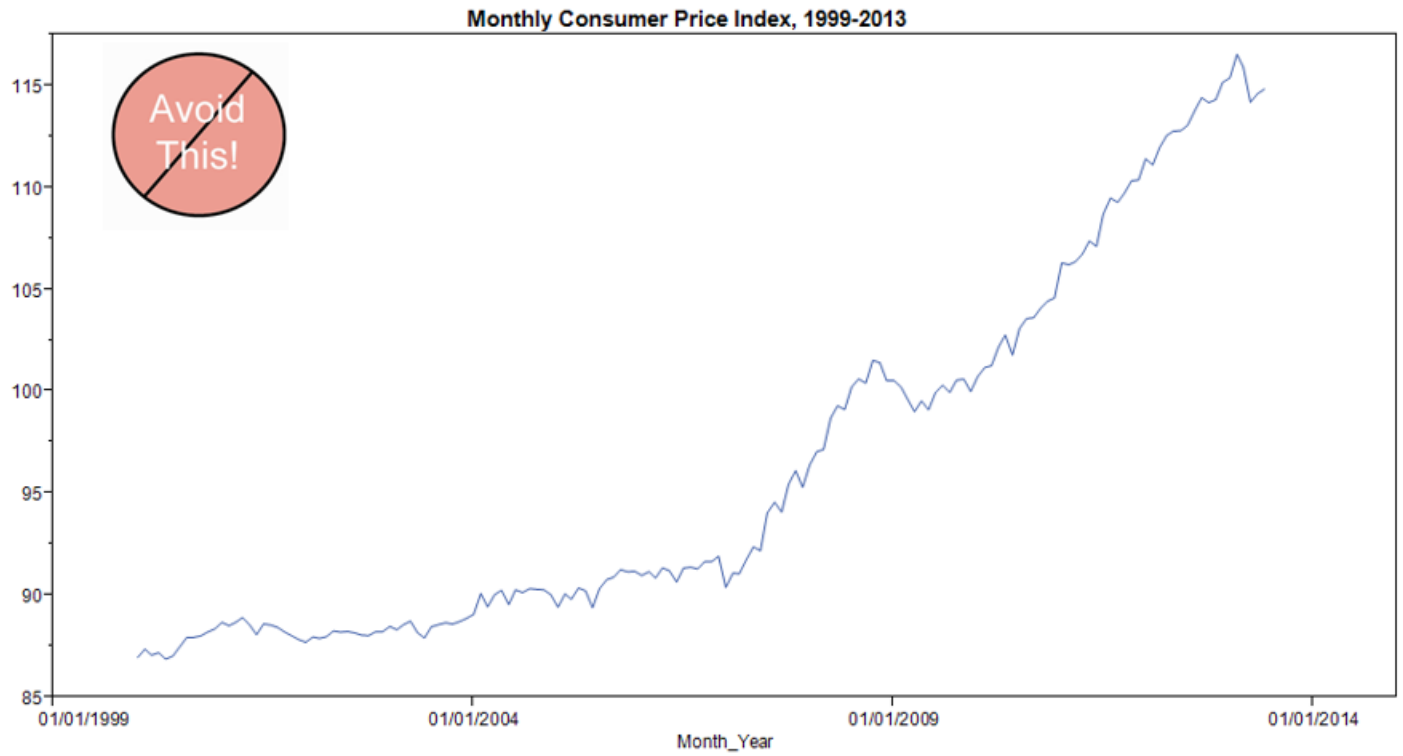
Shouting to emphasize what's interesting



What should the relative lengths of the axis be?

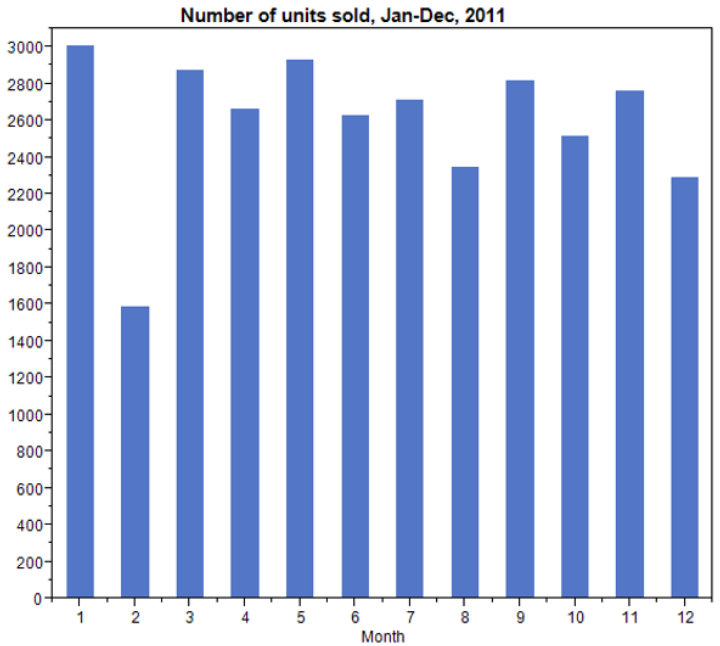
- Should not manipulate the aspect ratio to intentionally exaggerate or downplay the rate of change.
- Stick to the convention of making your graphs wider than being tall.

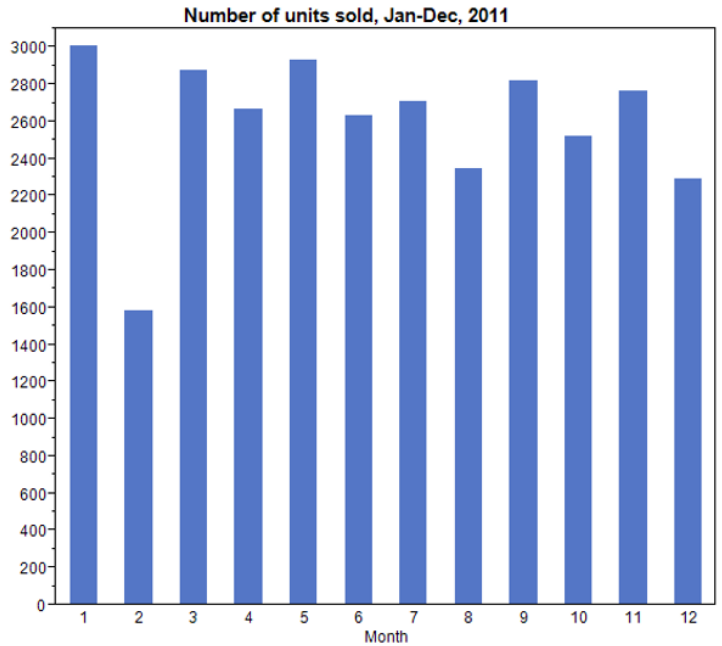




When can you eliminate tick mark?

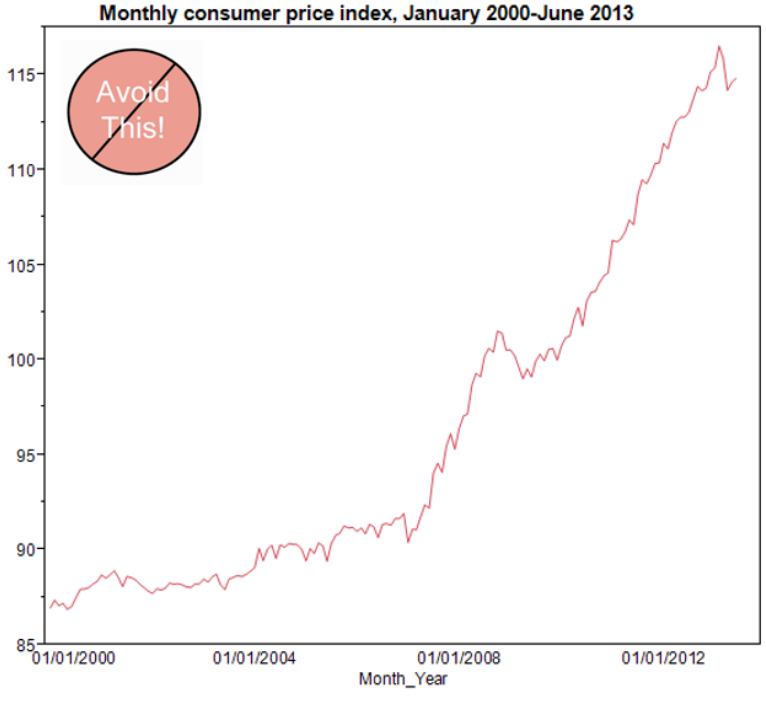
Tick marks are superfluous on categorical scale.

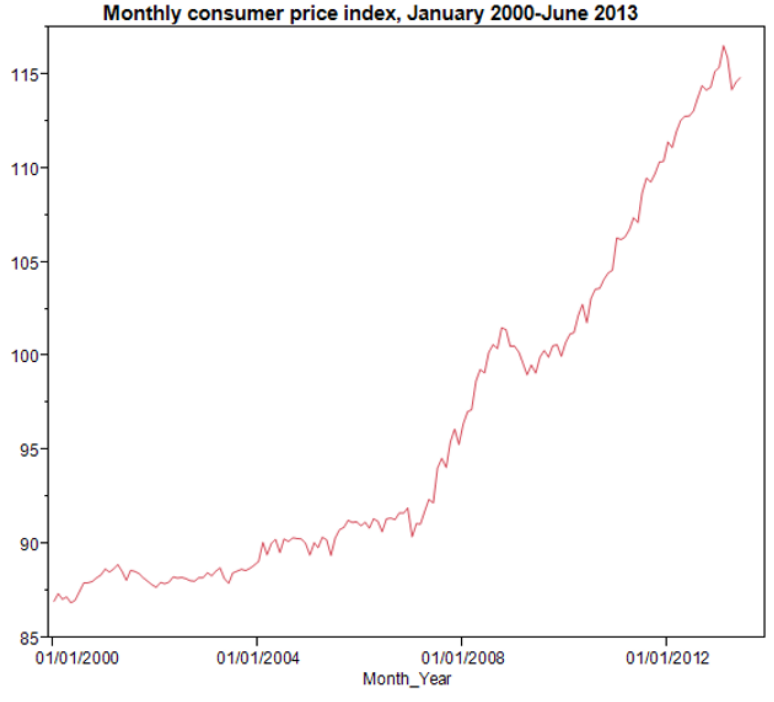




When you shouldn't eliminate tick mark?

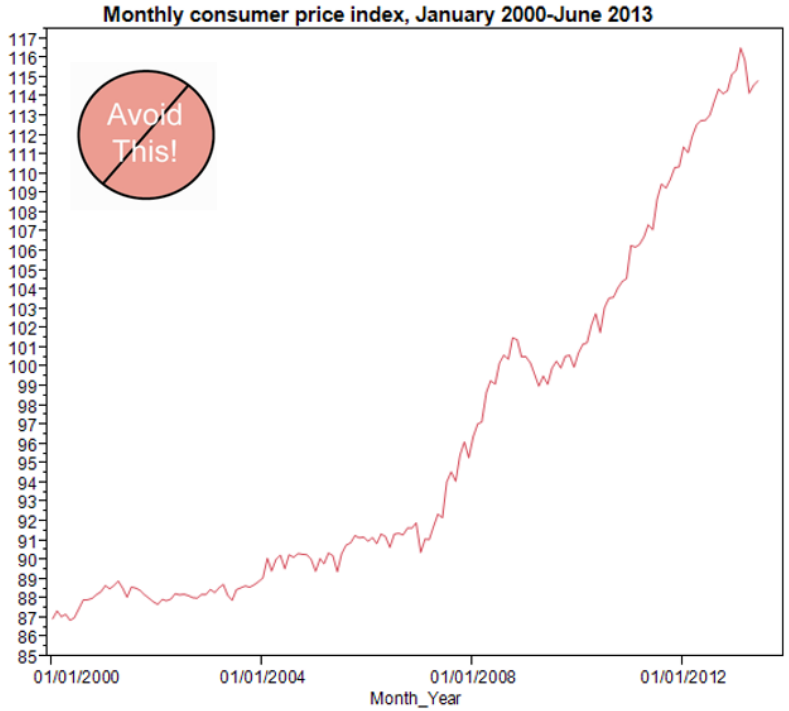
Tick marks are necessary on continuous scale.

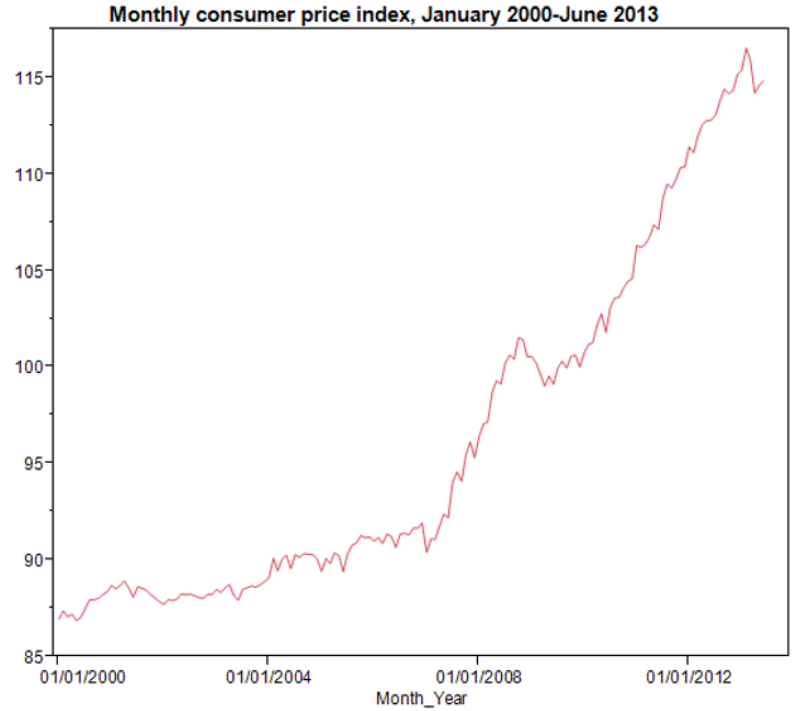




How many tick marks should you use?

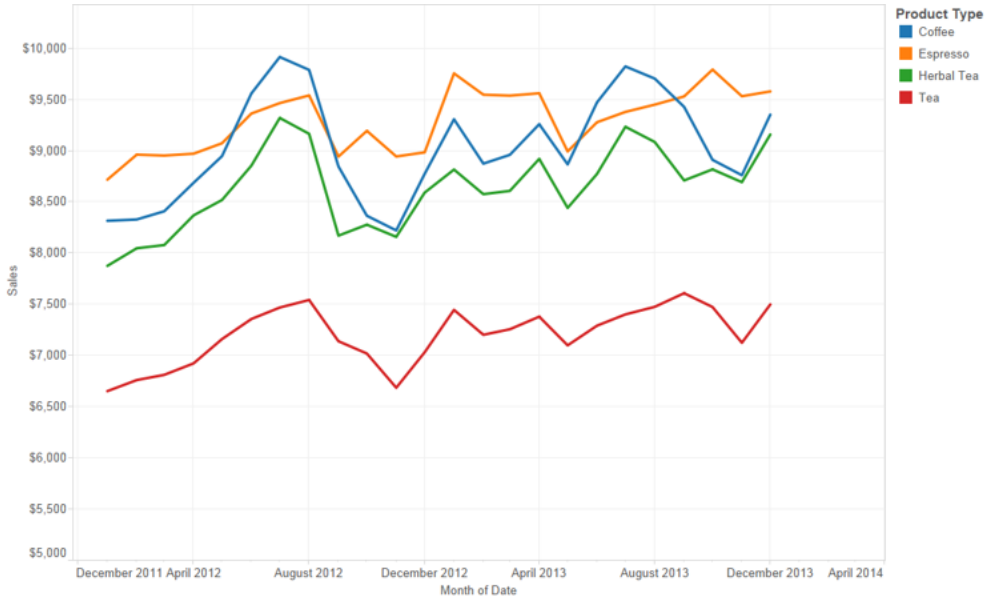
- There is no exact number that works best in all circumstances, and the size of the graph is a factor that must considered: the longer the scale line, the more tick marks it should contain.



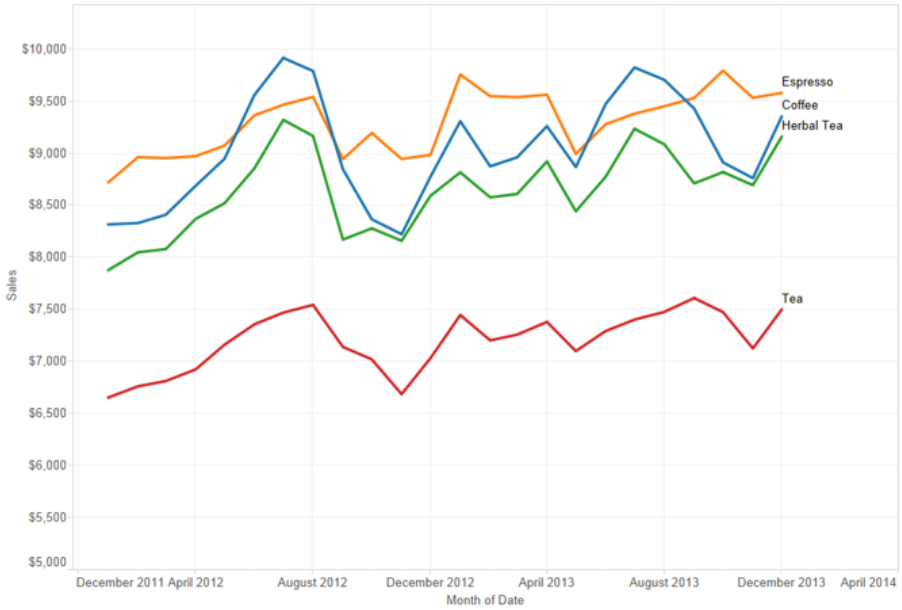


When can you eliminate legends?

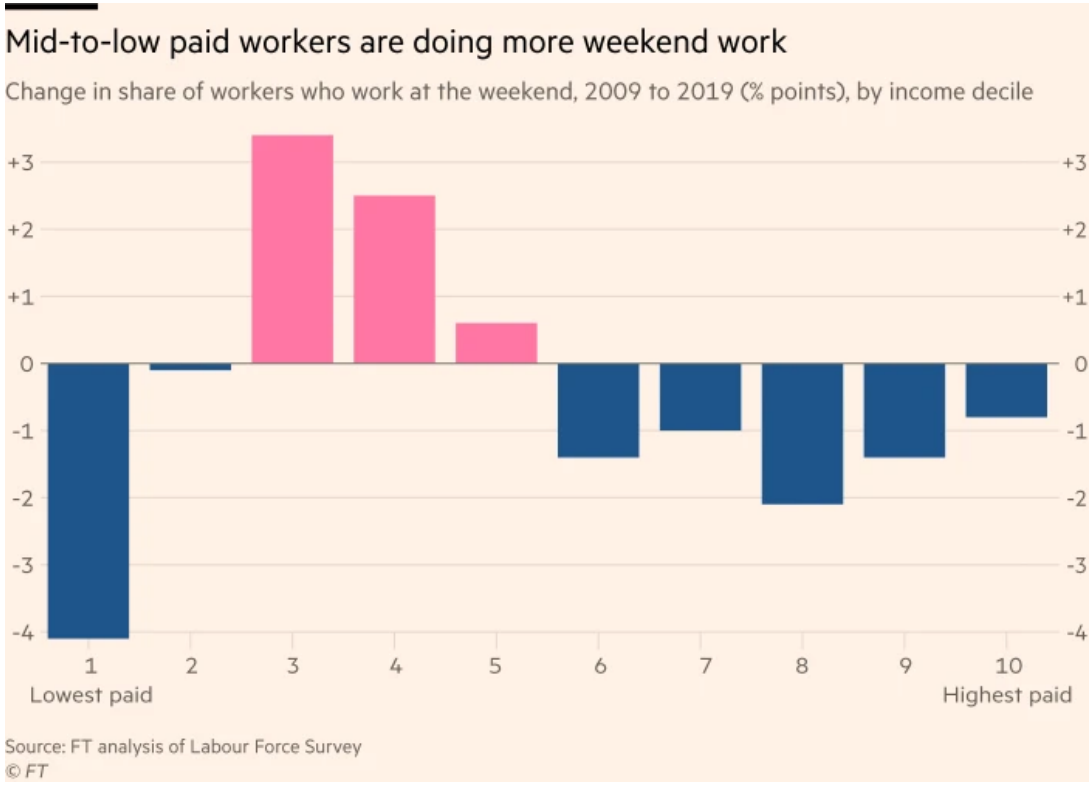
- In this graph, a legend is used to indicate product types.



- In this graph, product types are labeled directly.



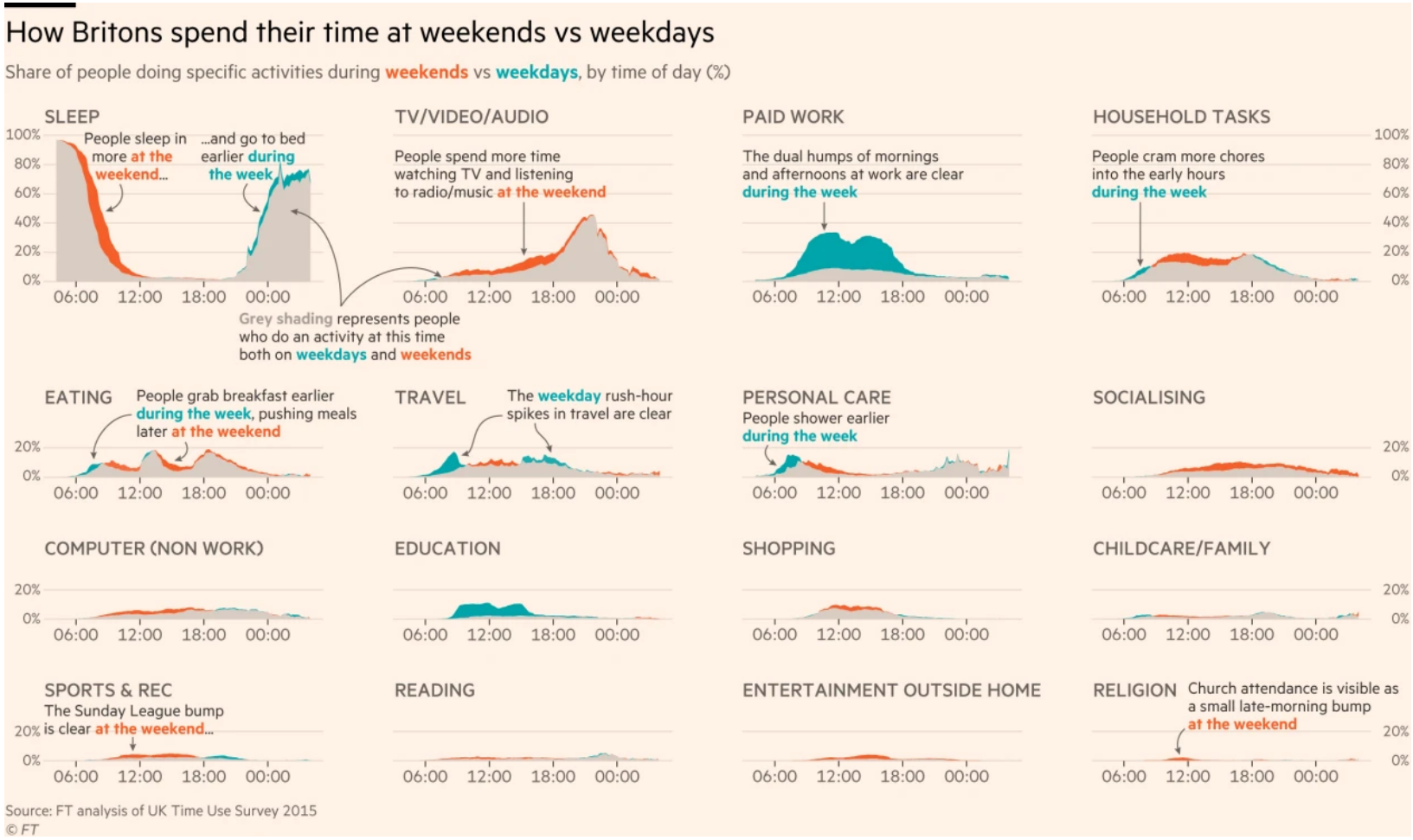
An enligthening data visualisation will be incomplete without a well worded title



Source: The truth about weekend working, Financail Times, January 23 2020.

- More example can be found here

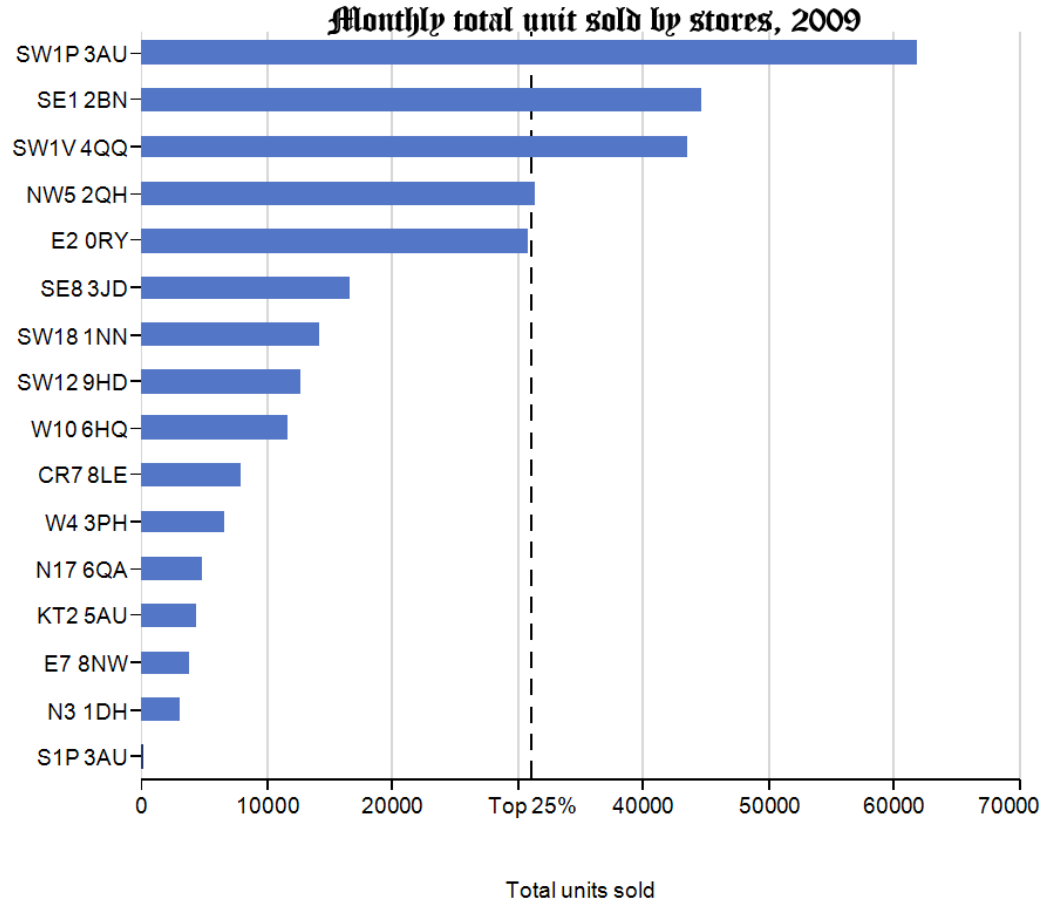
Using Annotation to tell data story



Source: The truth about weekend working, Financail Times, January 23 2020.

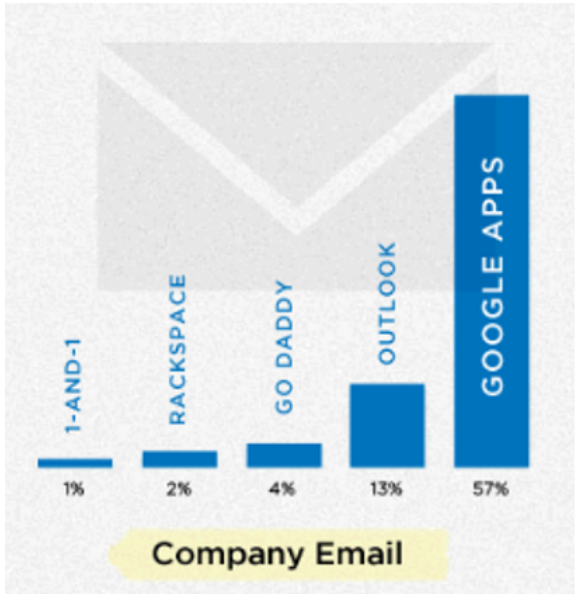
Graph typography

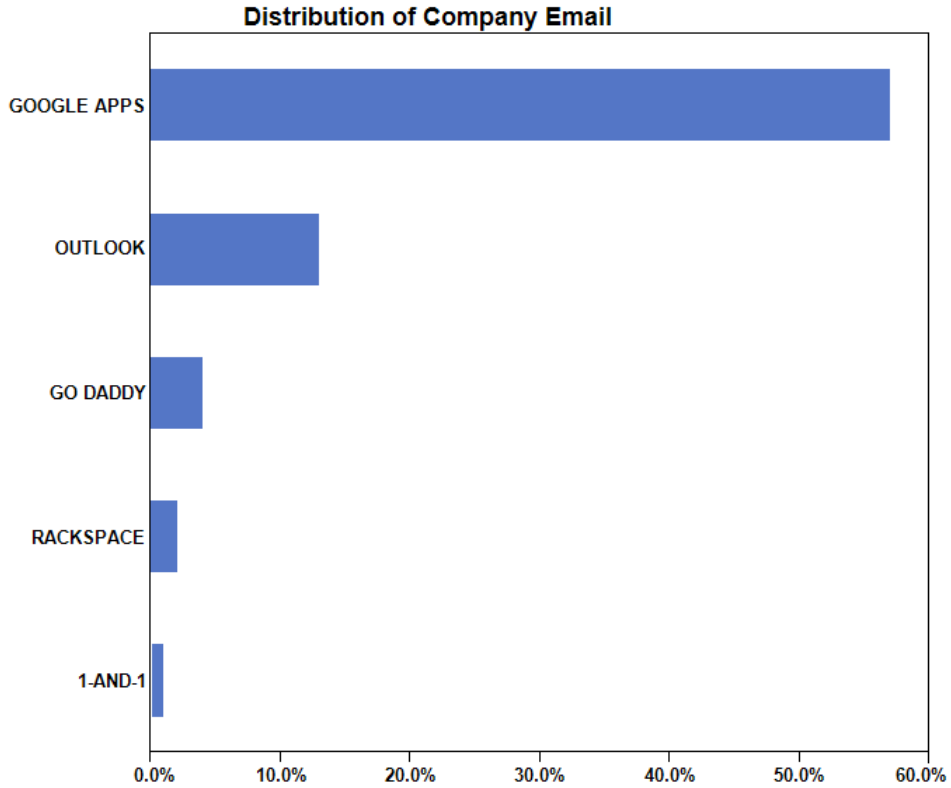
Avoid using artistic fonts



Graph Labeling

Orientation of label should be reader friendly





When should you use other text?

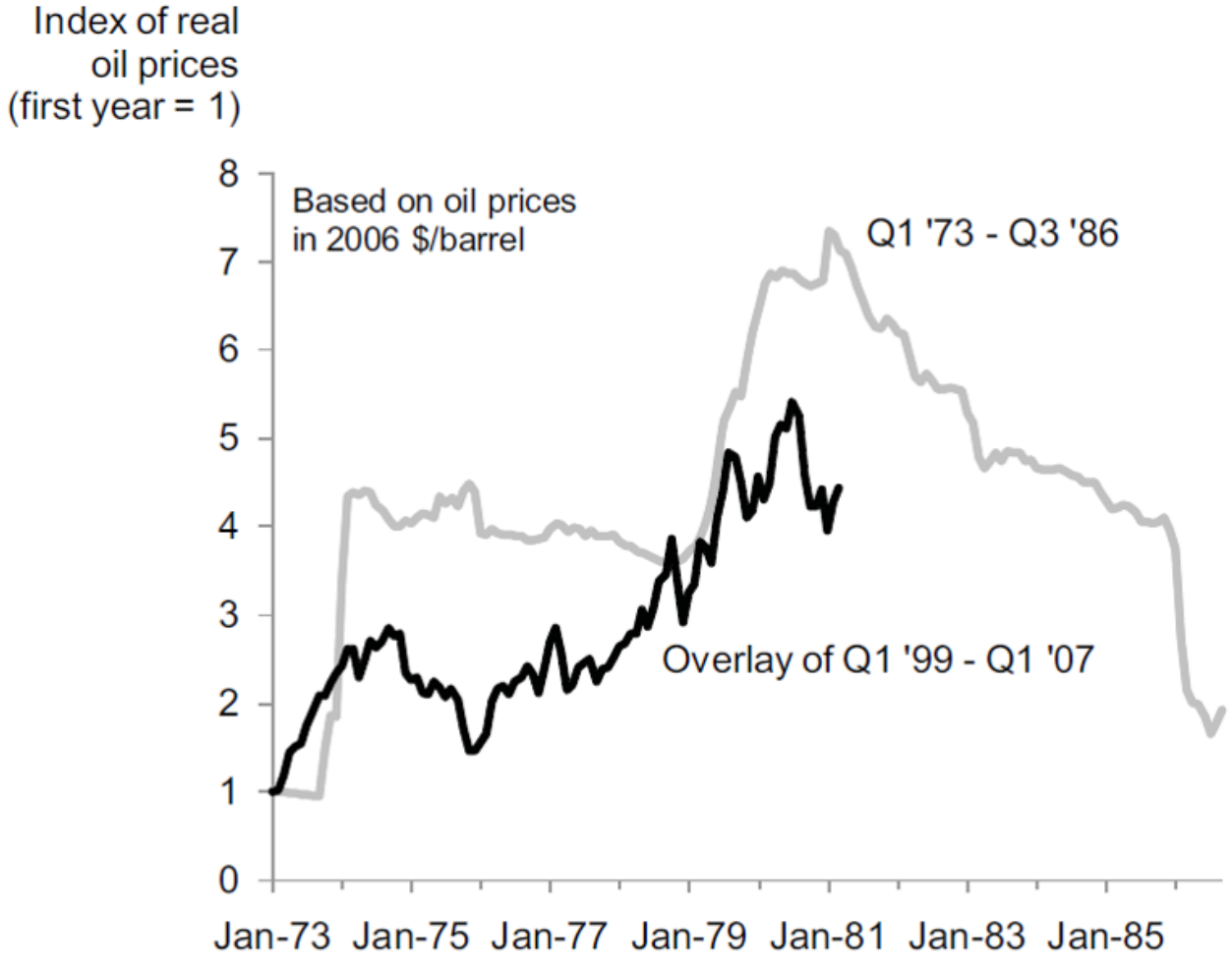
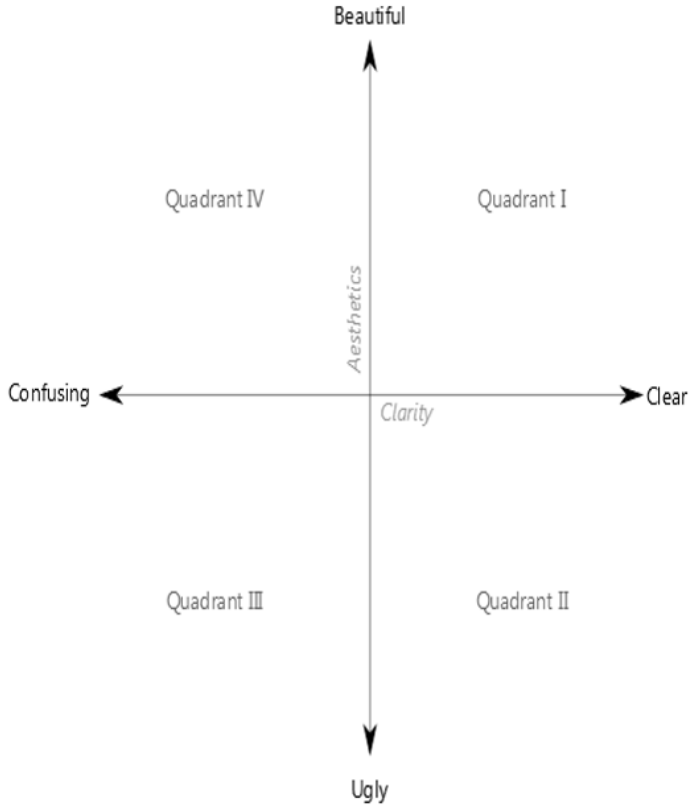


Figure 4: Real refinery acquisition cost for imported crude oil to the U.S.
(First year of time series = 1.0)

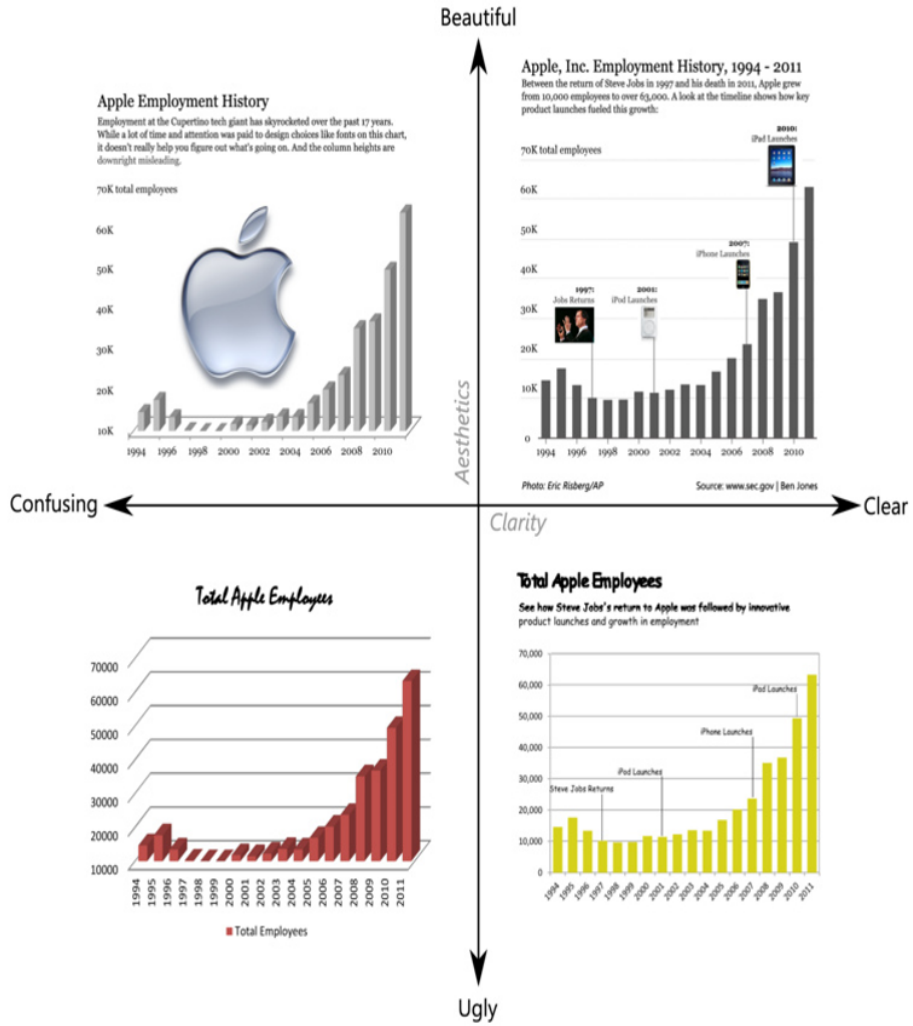
Data Visualization: Clarity or Aesthetics?

Mapping data visualizations on a Cartesian coordinate system where "clarity" is placed along the horizontal (x) axis and "aesthetics" is placed along the vertical (y) axis provides a framework to gage the objective and subjective merits of a graphic:



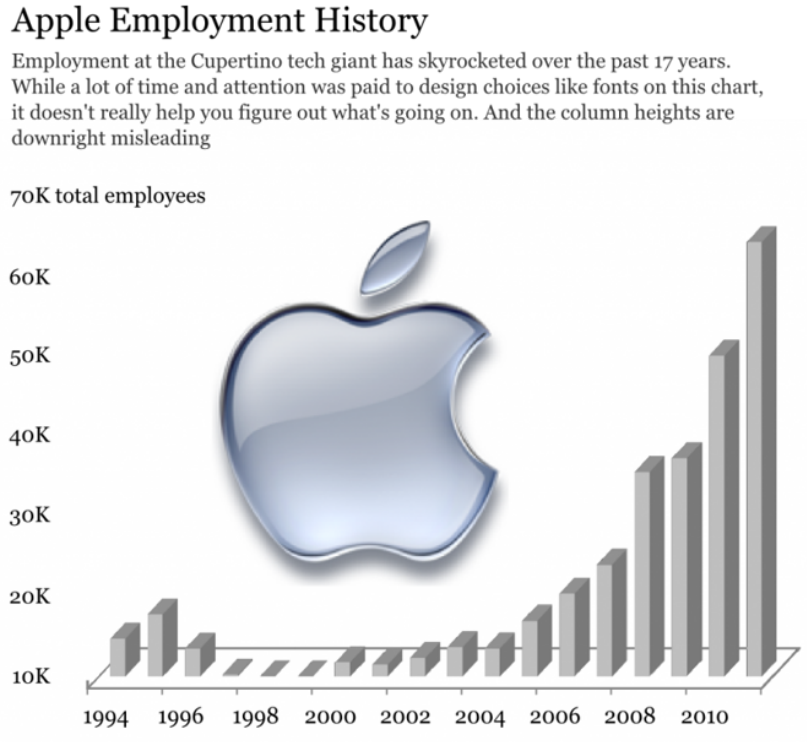
Source: http://dataremixed.com/2012/05/data-visualization-clarity-or-aesthetics/

A Tale of Four Quadrants



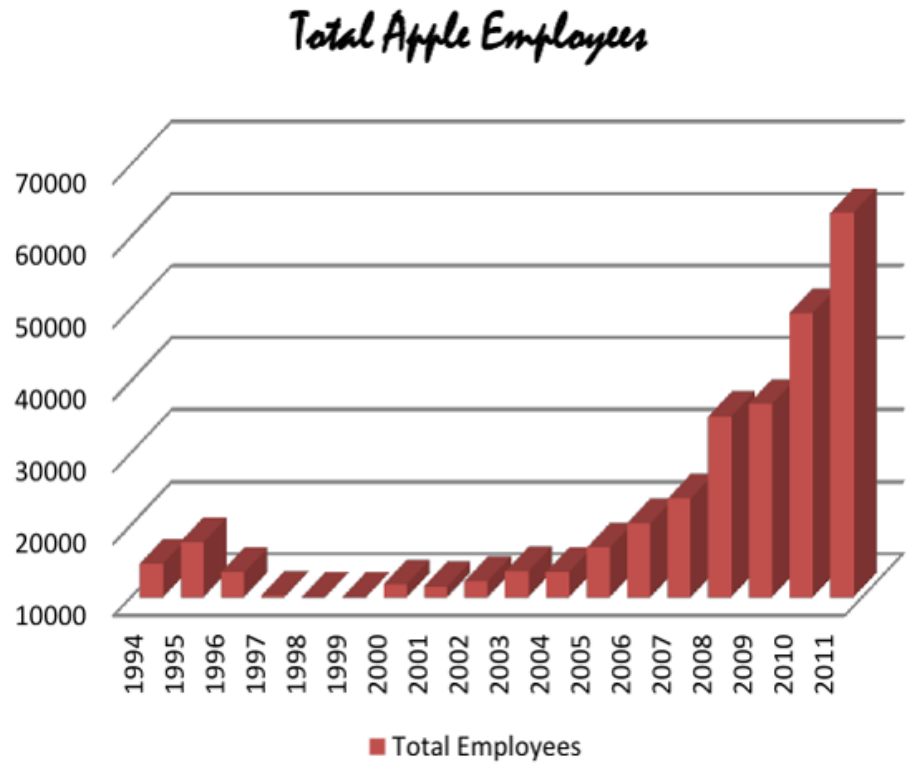
Quadrant IV – Confusing yet Beautiful

- Why is it “beautiful”?
  - Well placed & aligned title & lead-in.
  - Attention to detail with font selection.
  - Inclusion of image.
- Why is it “confusing”?
  - Y-axis starts at 10K (column height misleading).
  - 3D effect makes it difficult to gage heights.
  - Title & lead-in aren’t helpful.



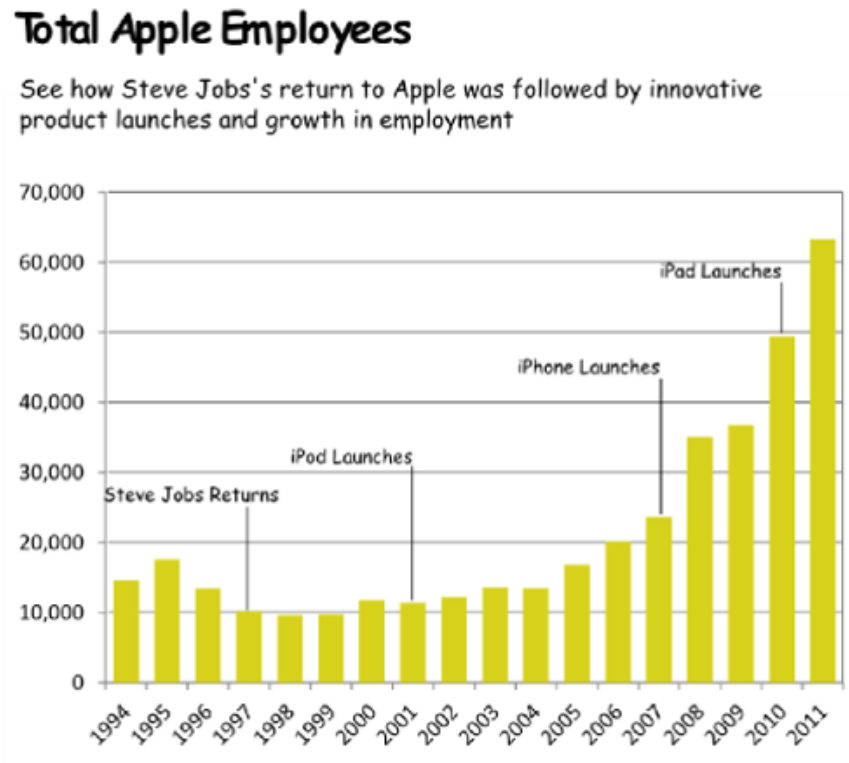
Quadrant III – Confusing and Ugly

- Why is it “ugly”?
  - Horrible font & color choice.
  - Grid lines are too dark & distracting.
  - Format of axes (vertical x-axis labels, number format of y-axis).
- Why is it “confusing”?
  - Y-axis starts at 10K (column height misleading).
  - 3D effect makes it difficult to gage heights.
  - No lead-in or call-outs to provide context.



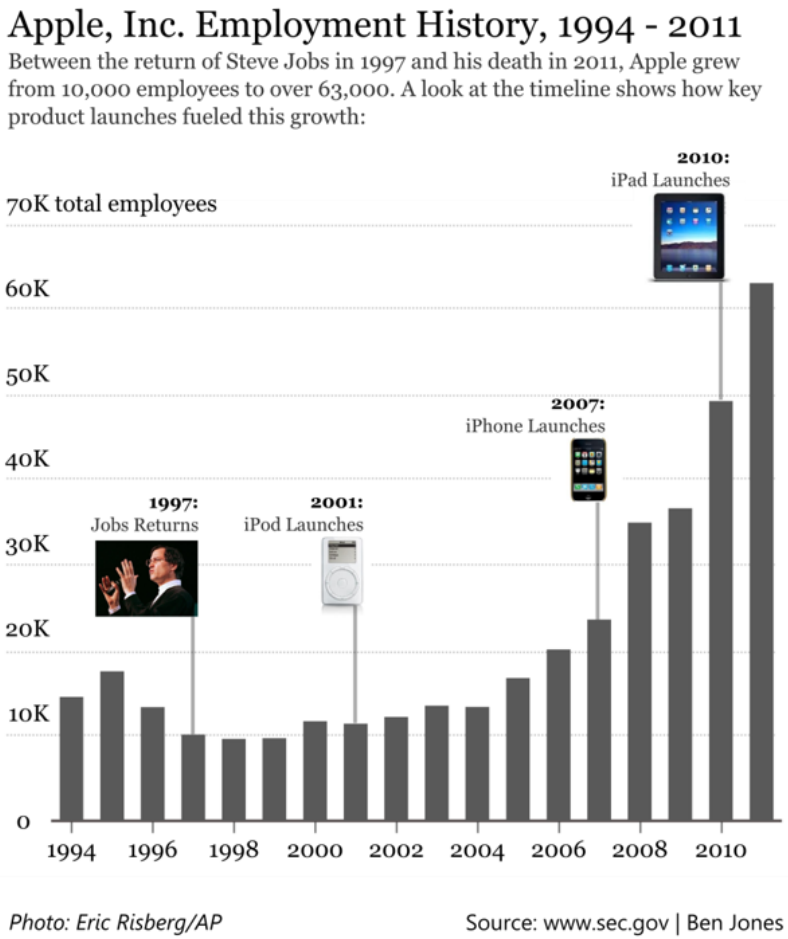
Quadrant II – Clear but Ugly

- Why is it “ugly”?
  - Poor color (puke yellow?) and font (Comic Sans?) choices.
  - Slightly pixelated – poor attention to image quality detail.
  - Chart details – axis orientation, grid lines, outline.
- Why is it “clear”?
  - The y-axis starts at 0 and the 2D columns are easy to gage.
  - For the first time, we see call-outs of relevant events on the timeline.
  - This time the lead-in paragraph is actually informative.



Quadrant I – Clear and Beautiful

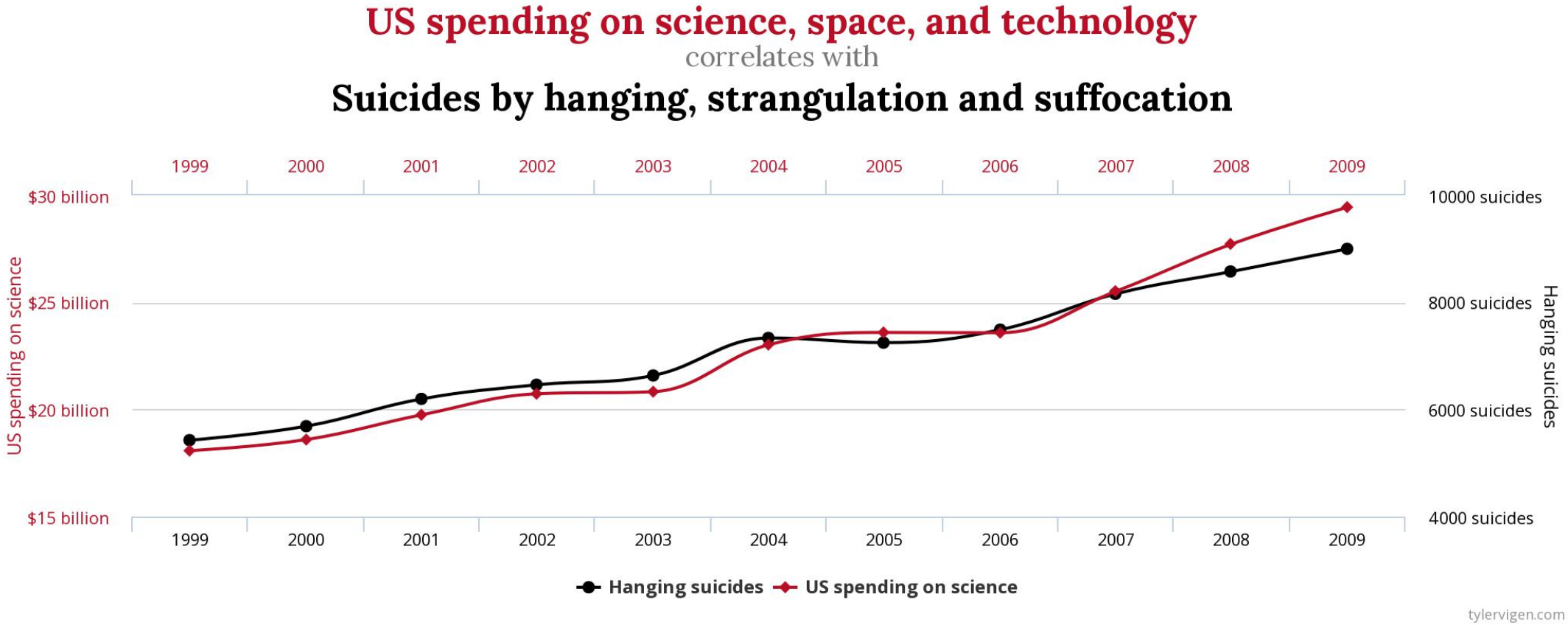
- Why is it “beautiful”?
  - Good font & color choices throughout.
  - Soft gridlines don’t distract.
  - All elements well aligned and spaced.
  - High res images are “useful” chartjunk.
- Why is it “clear”?
  - The y-axis starts at 0 and the 2D columns are easy to gage.
  - Call-outs with images aid cognition.
  - Improved title & lead-in verbiage provide further elucidation.
  - For the first time, a photo credit and data source are included.



Three Bugs of Charts Interpretation

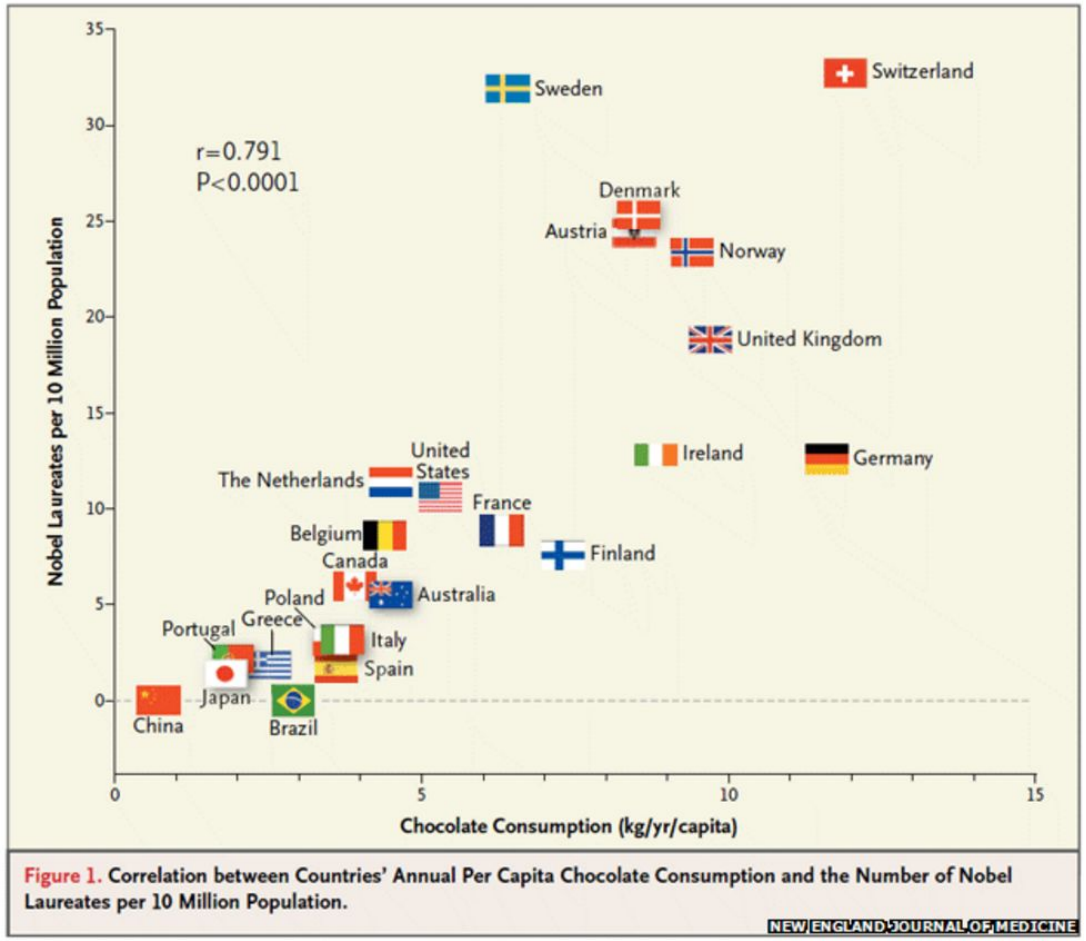
- The **Patternicity** bug: We detect interating patterns, regardless of whether or not they are real.
- The **Storytelling** bug: We immediately come up with a coherent explanation for those patterns.
- The **Confirmation** bug: We start seeing all further information we receive, even the one that conflicts with our explanation, in a way that confirmed it. We refuse to give our explanation up, no matter what.

Three Bugs example



Source: Spurious Correlation

Stop the Fallacy of Visual Storytelling



Source: Franz H. Messerli (2012)Chocolate Consumption, Cognitive Function, and Nobel Laureates, *The New England Journal of Medicine*.

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Few, Stephen (2012) (2nd edition) **Show Me the Numbers: Designing Tables and Graphs to Enlighten**, Analytics Press, Oakland, USA

Cairo, Alberto (2019) **How Charts Lie**, W.W. Norton & Company, USA.

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Wong, Dona M. (2010) **The Wall Street Journal Guide to Information Graphics**, W. W. Norton & Company, Inc. New York.

Tufte, Edward (2nd Edition) **The Visual Display of Quantitative Information**, Graphics Press LLC, Connecticut, USA.

Highly recommended blog

- The Functional Art
- Junk Charts
- Perceptual Edge
- EagerEyes
- Statistical Graphics and more
- Visualizing data
- Visualizing Economics