Lesson 2: Designing Graphs to Enlighten

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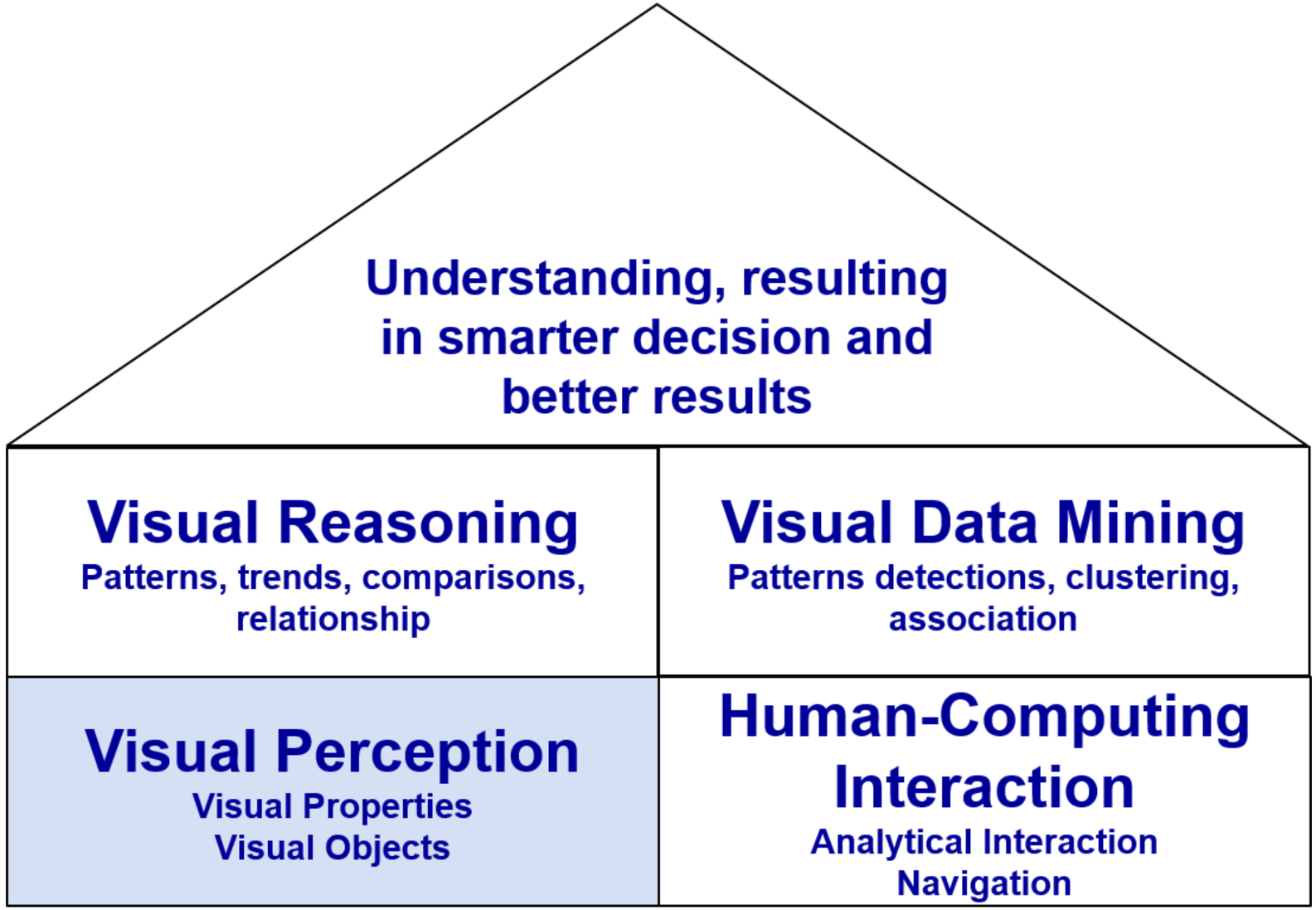
What will you learn from this lesson?

- Data visualisation design process
- The Devil is in the data
- Human perception and information processing
- Components of a graph
- Principles and practical guides for data visualisation design
- Data visualisation critics framework

Building Block of Visual Analytics



DataVis design process

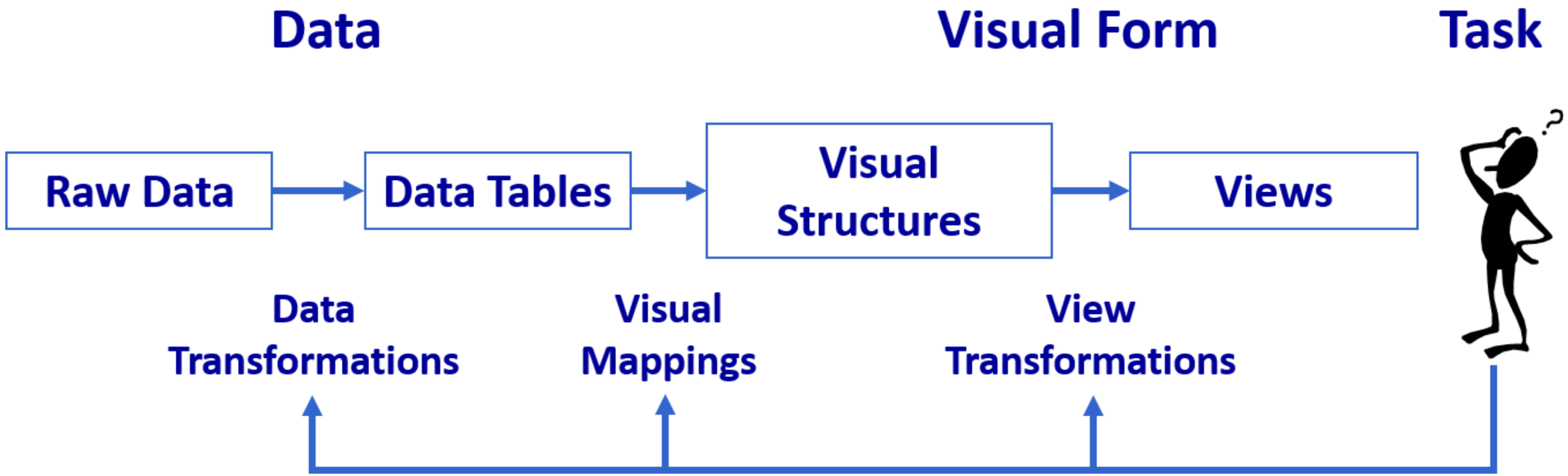
- Start with a clear message
- Select the right data
- Use the right visualisations
- Express and explain
- Review and seek feedback from experts and casual readers

DataViz design process: Start with a clear message

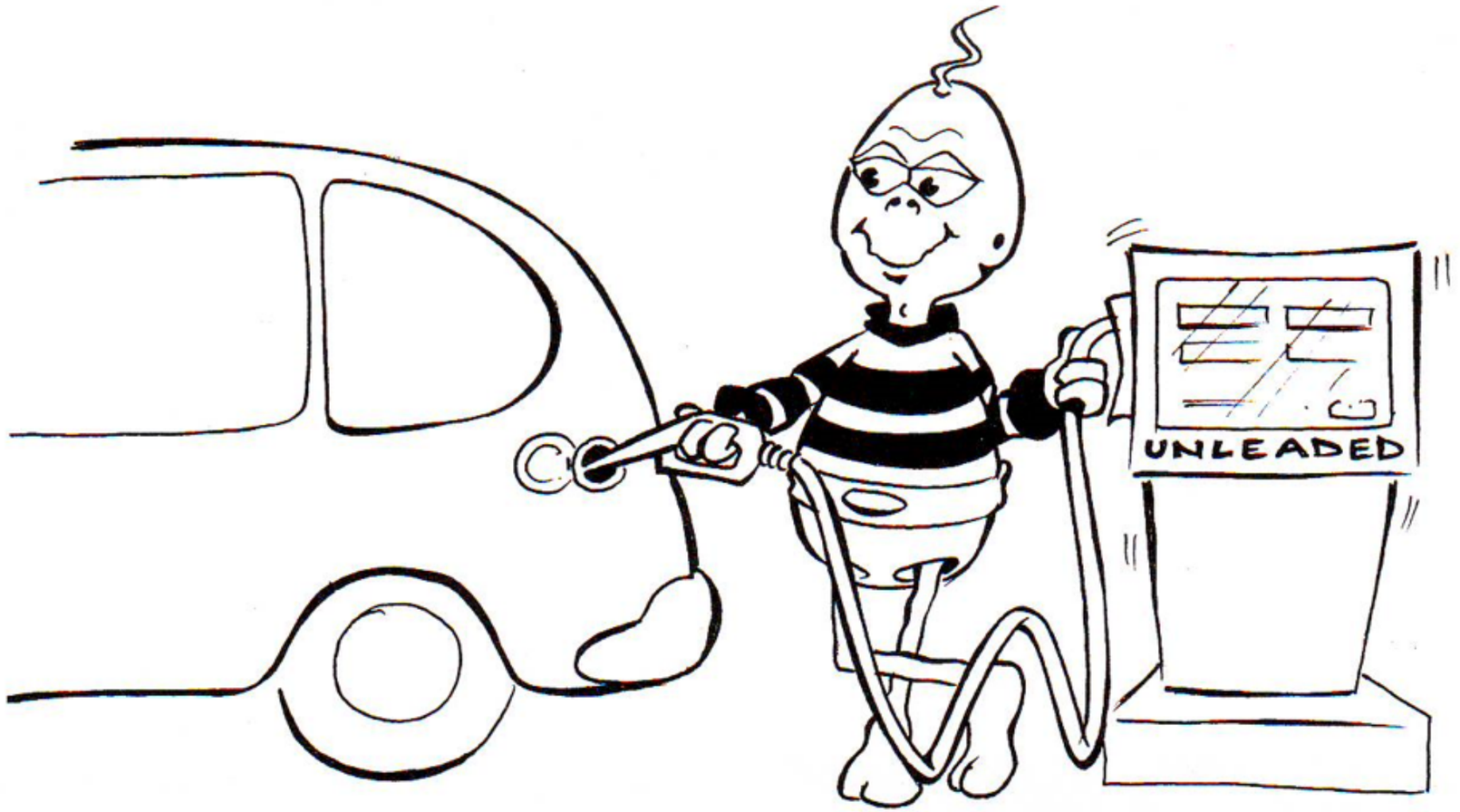
Data Management
- Select data source
- Clean data
- Categorise data
- Moderate data

Visualisation
- Information design
- Visual encoding
- Interface design

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

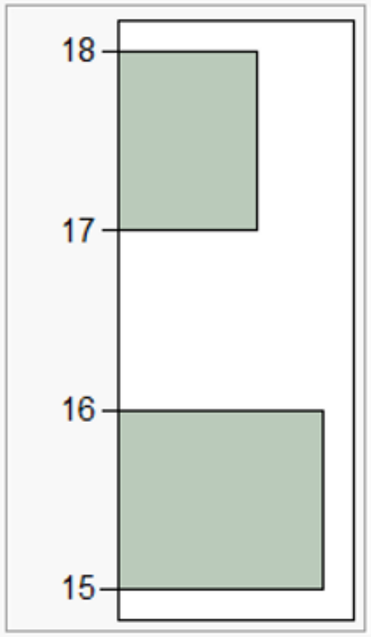


The Devil is in the Data



Numbers Worth Knowing

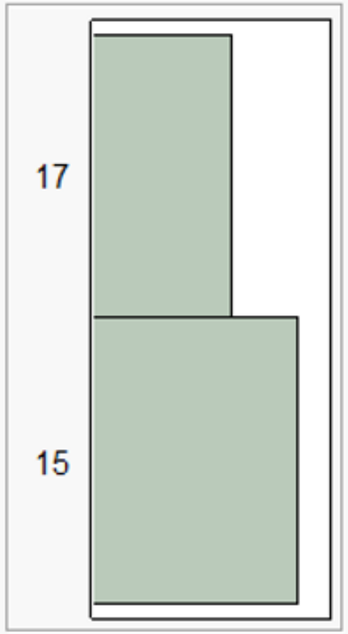
Not all numerical data are continuous!



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

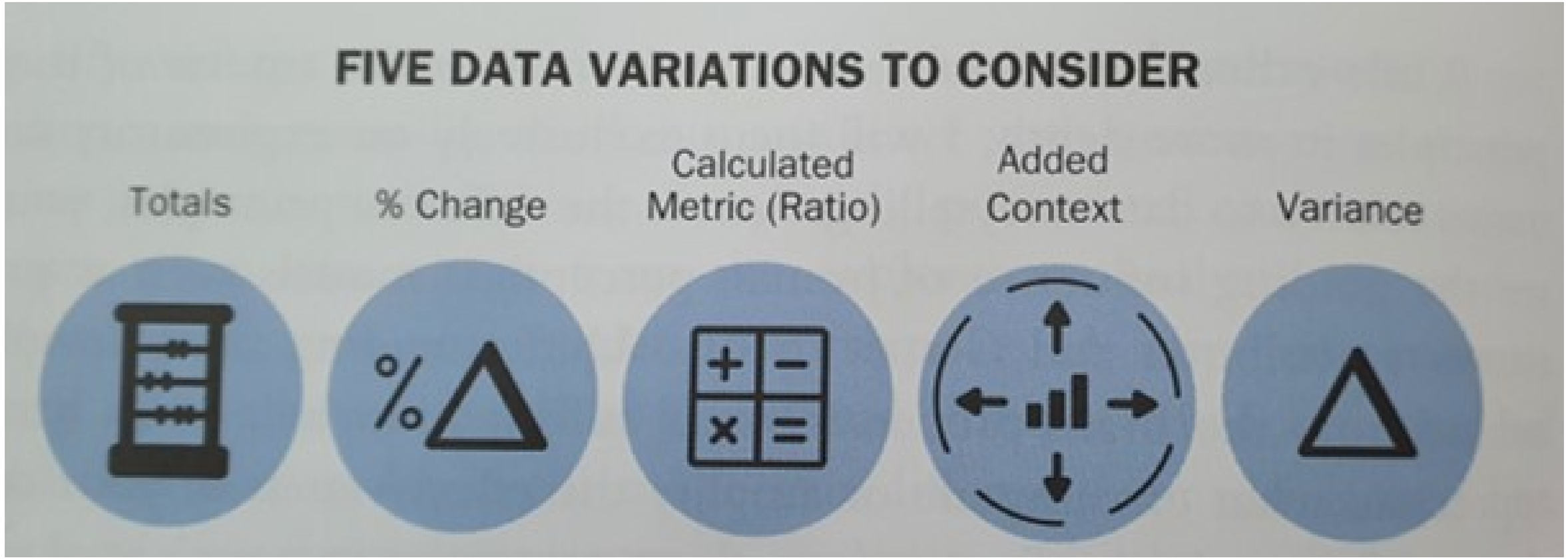
Level	Count	Prob
15	176560	0.59334
17	121012	0.40666
Total	297572	1.00000

N Missing 0

2 Levels

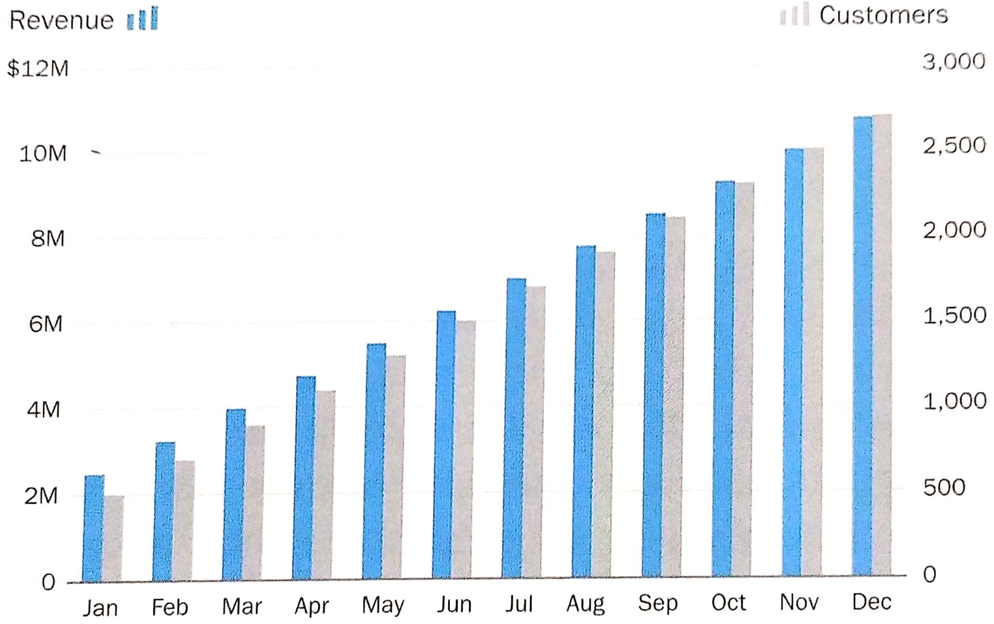
Visualising the Right Data

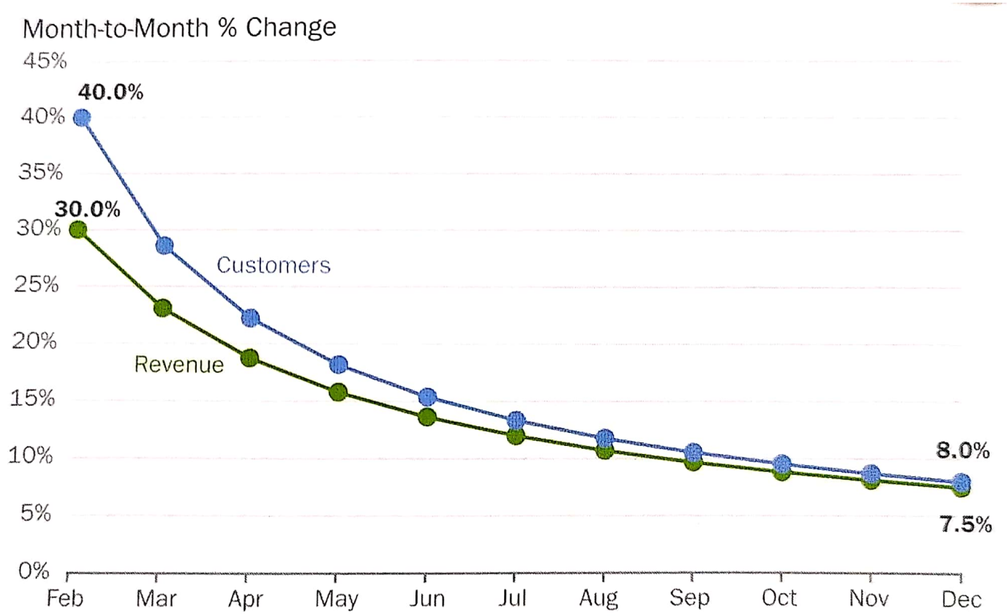
- There are more than one way to present the data.



Visualising the Right Data

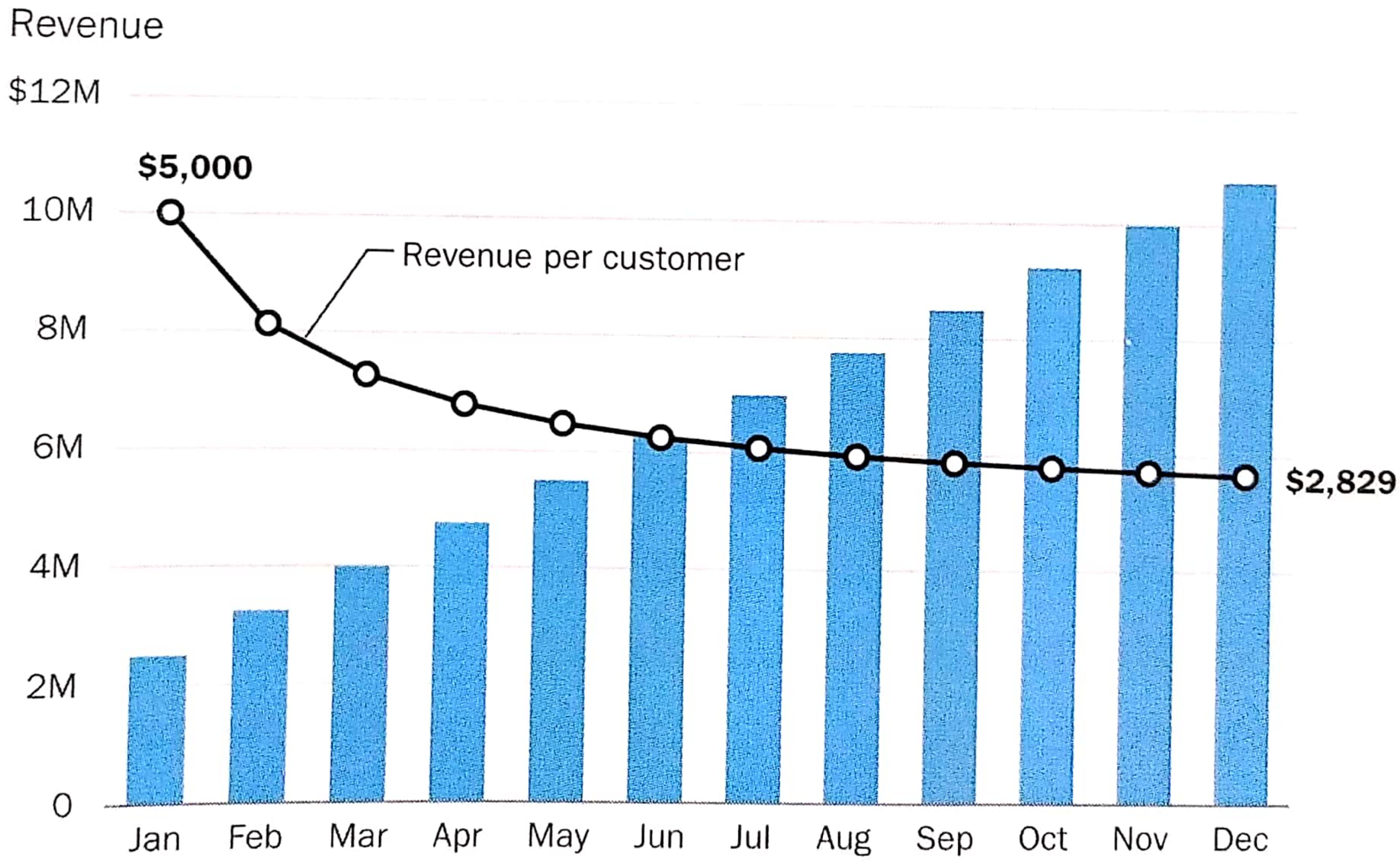
- Derived values reveal more interesting patterns than absolute values.



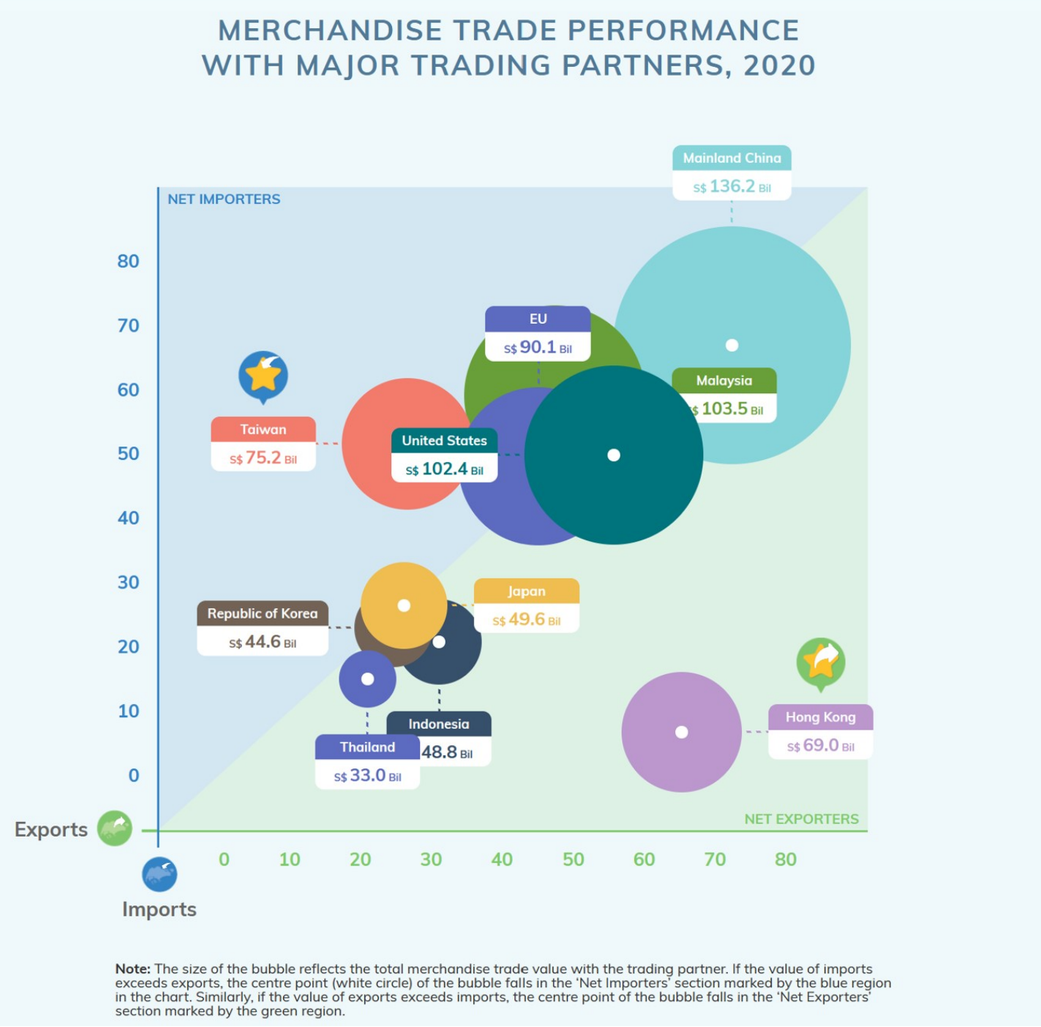


Visualising the Right Data

- Derived values reveal more interesting patterns than absolute values.



Graphical Integrity: Show Me the Truth

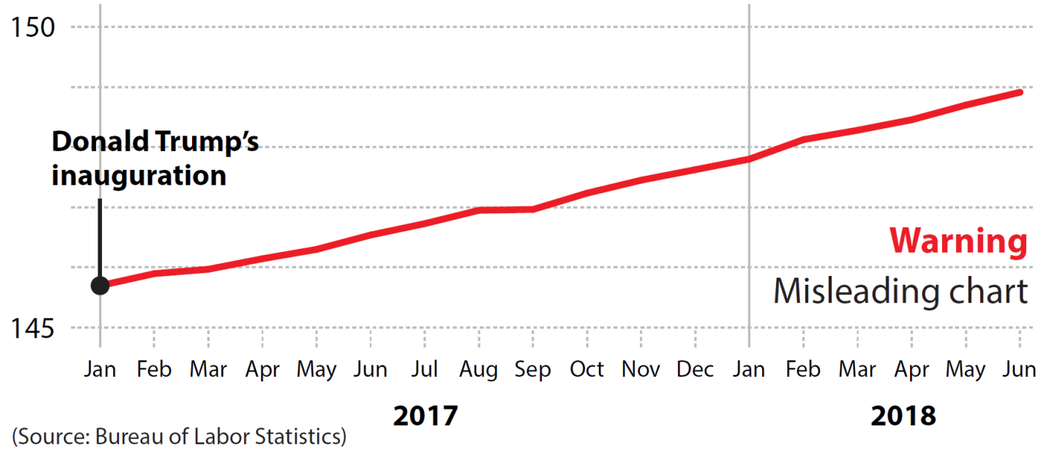


Source: Department of Statistics

Graphical Integrity: Show Me the Truth

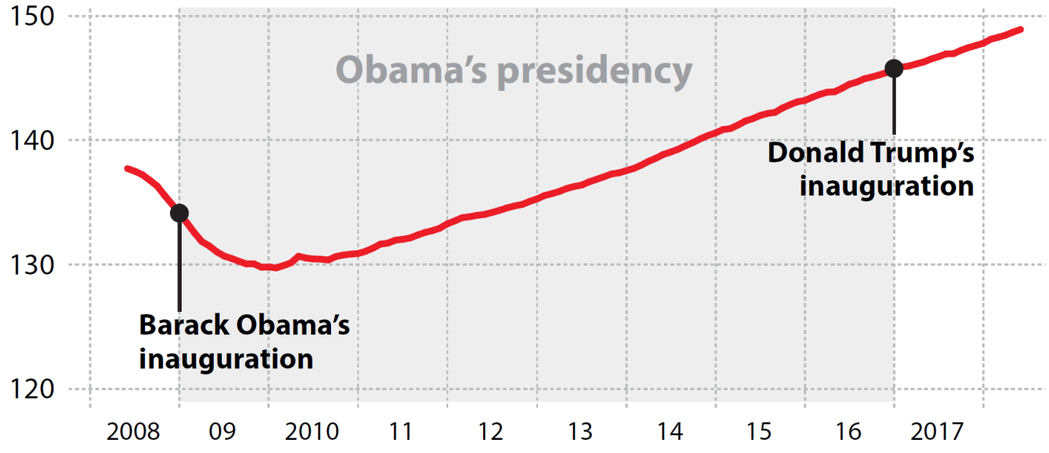
Snapshot can be misleading!

All employees: millions of nonfarm payrolls



(Source: Bureau of Labor Statistics)

All employees: millions of nonfarm payrolls (Bureau of Labor Statistics)

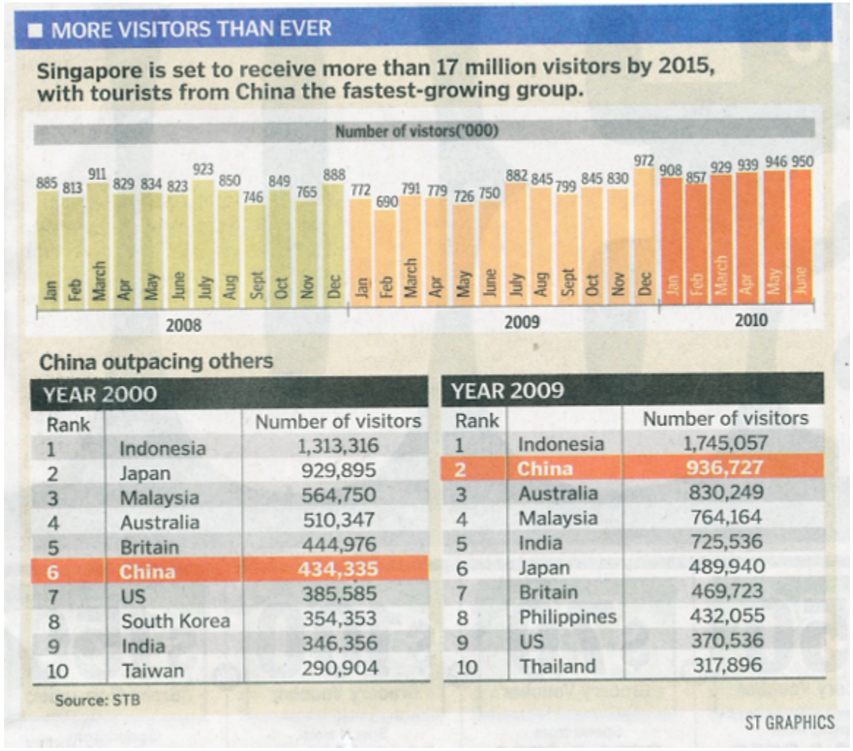


(Source: Bureau of Labor Statistics)

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)

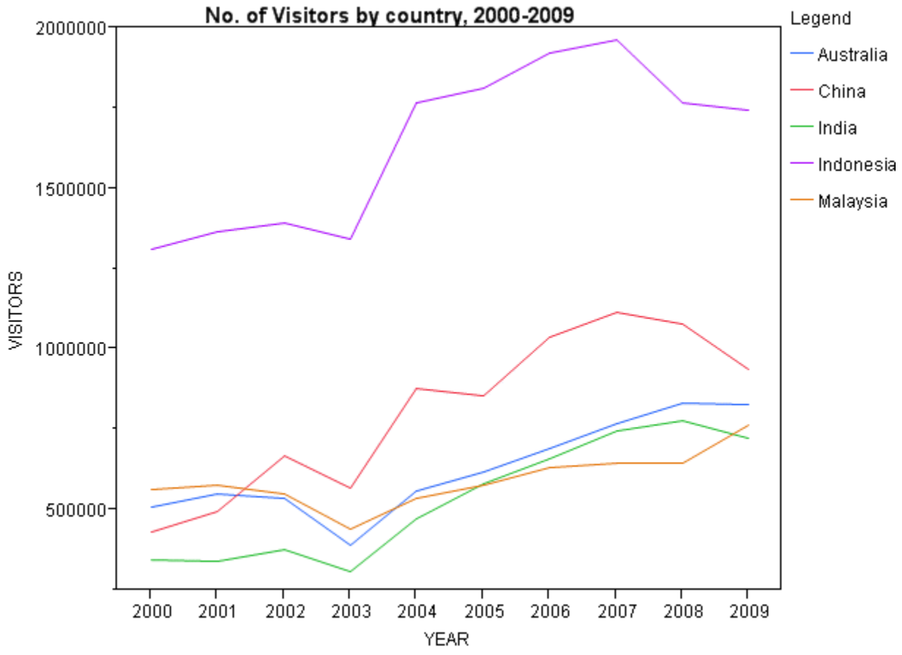
China outpacing others

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

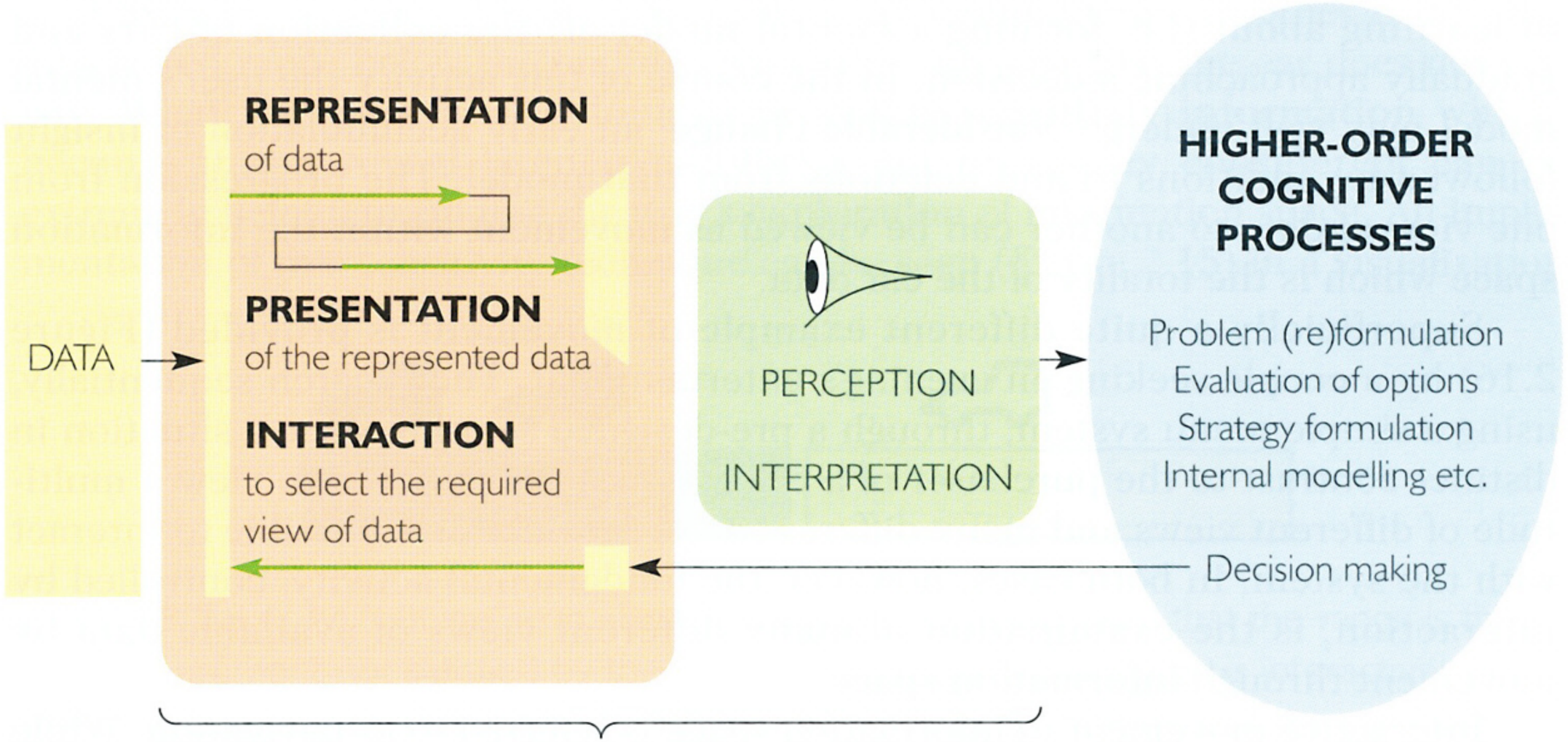
YEAR 2009		
Rank		Number of visitors
1	Indonesia	1,745,057
2	China	936,727
3	Australia	830,249
4	Malaysia	764,164
5	India	725,536
6	Japan	489,940
7	Britain	469,723
8	Philippines	432,055
9	US	370,536
10	Thailand	317,896

Source: STB

ST GRAPHICS



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?

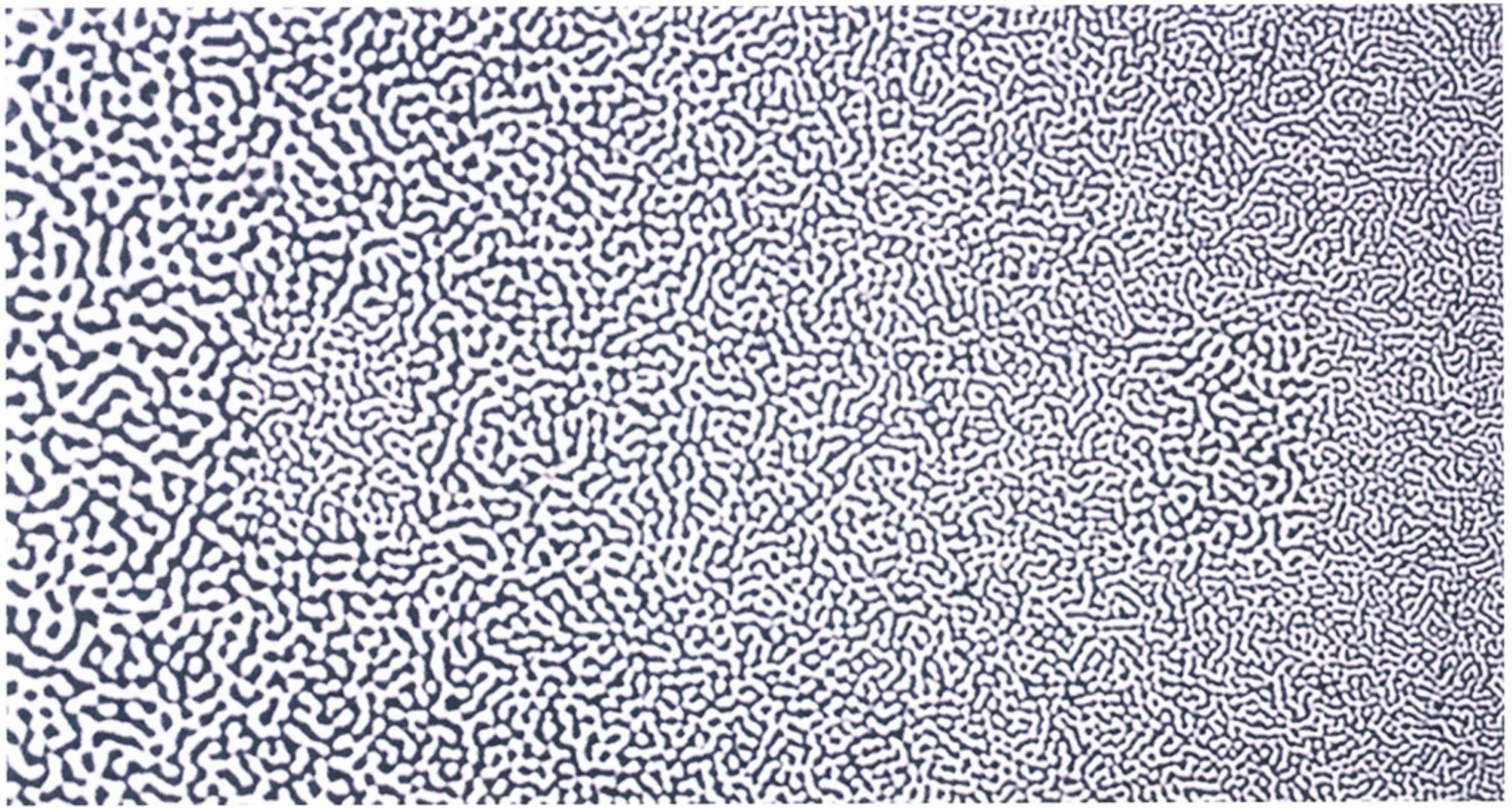
Fact 1:

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.

How Visual Sensing Works?

How Many 3’s?

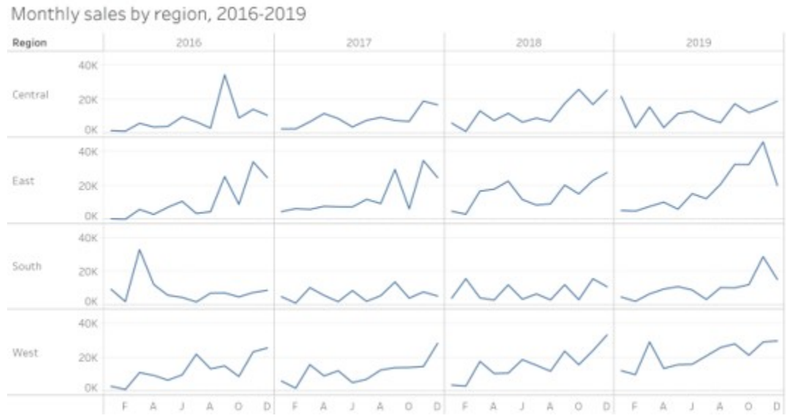
12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496863

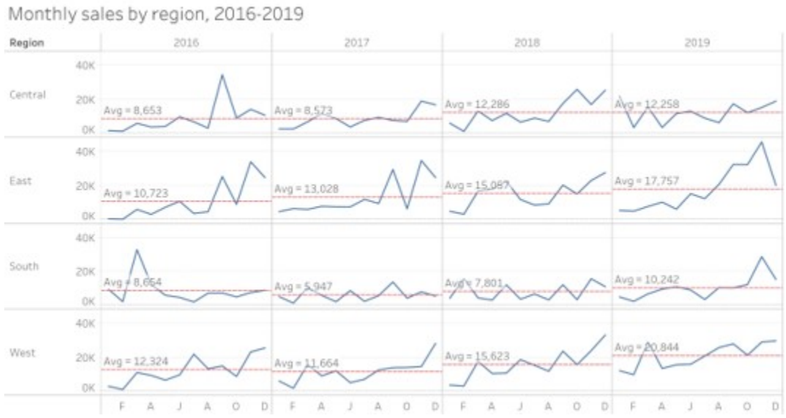
How Visual Sensing Works?

Now you see them!

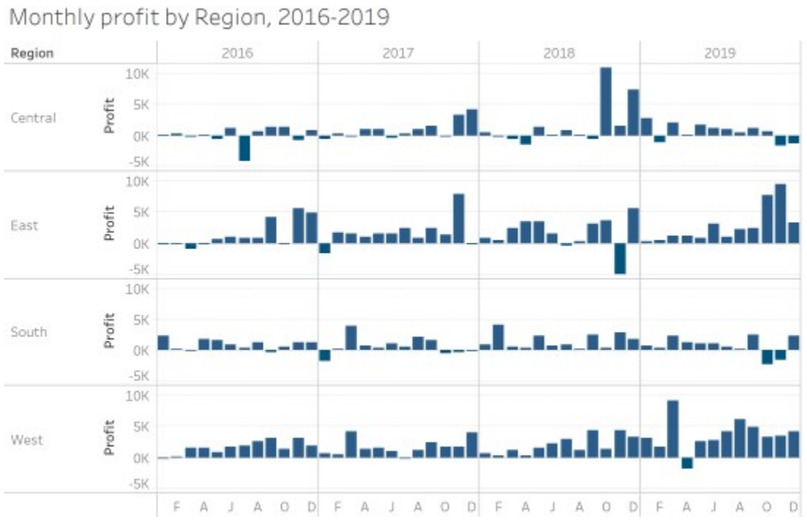
1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

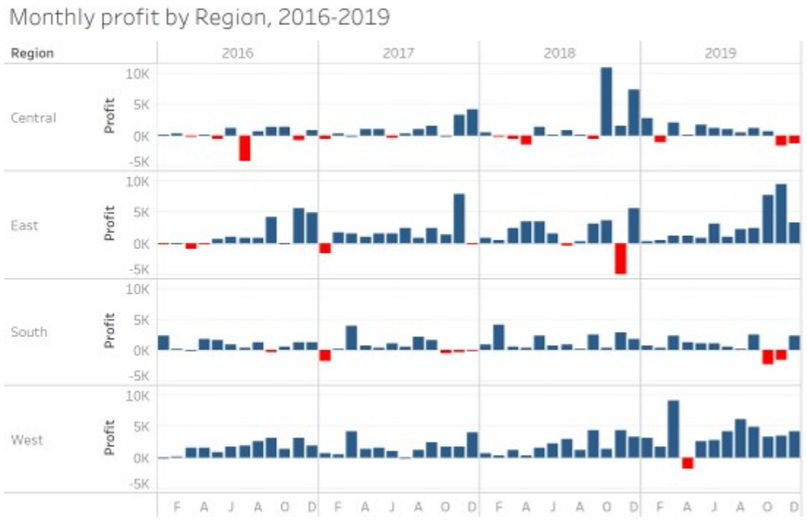
Application of pre-attentive principle in data visualisation design



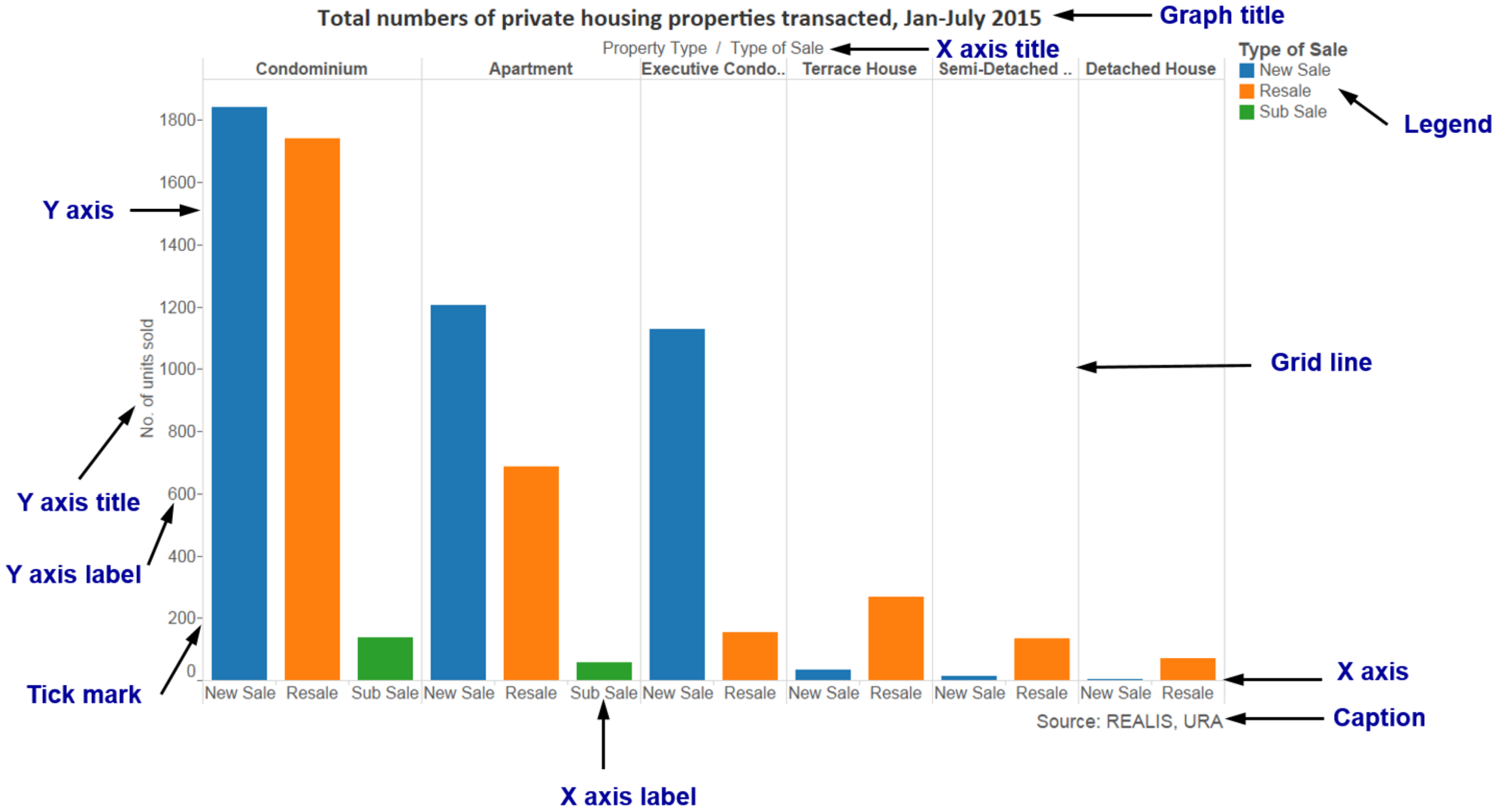


Application of pre-attentive principle in data visualisation design

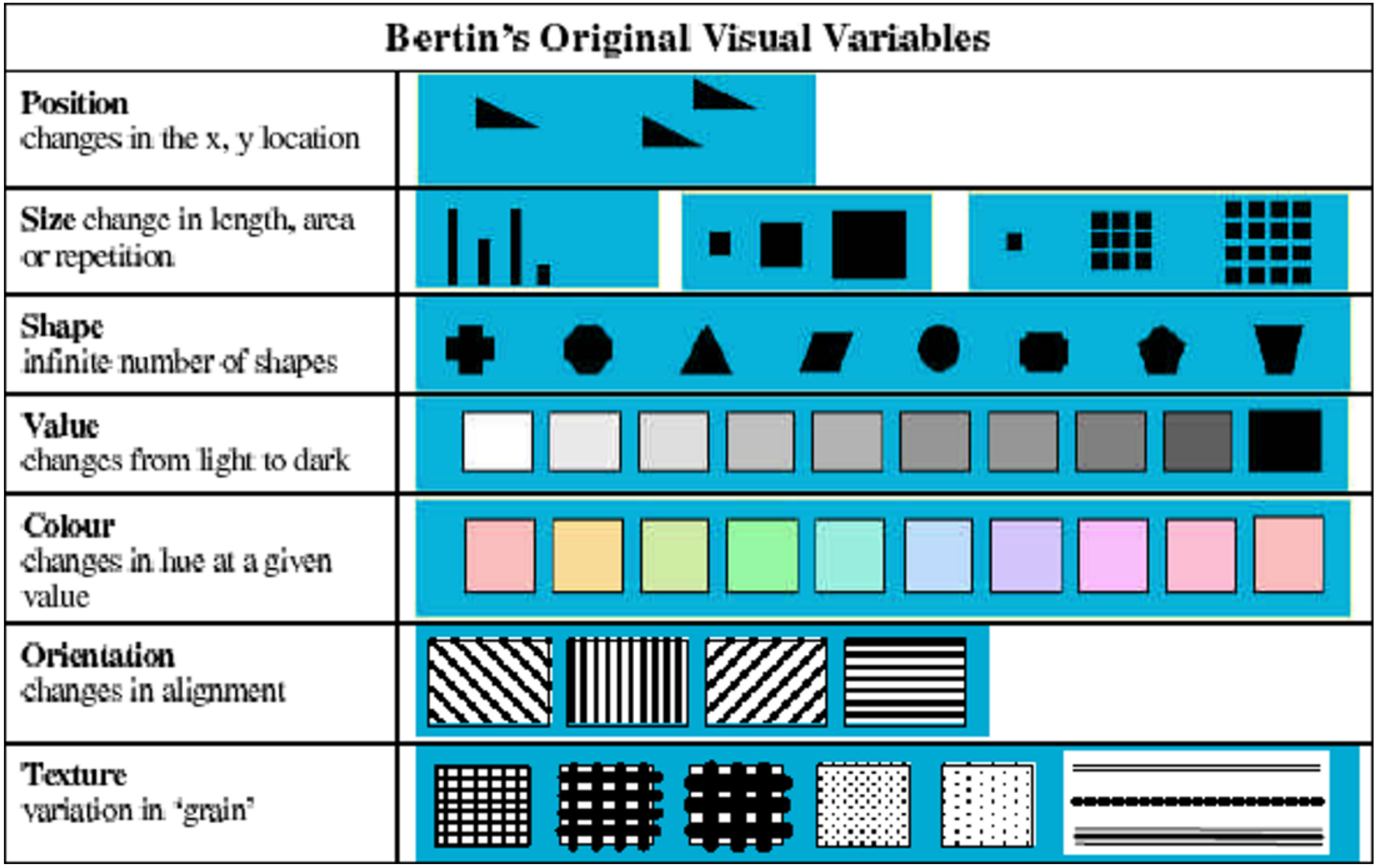




Components of a graph

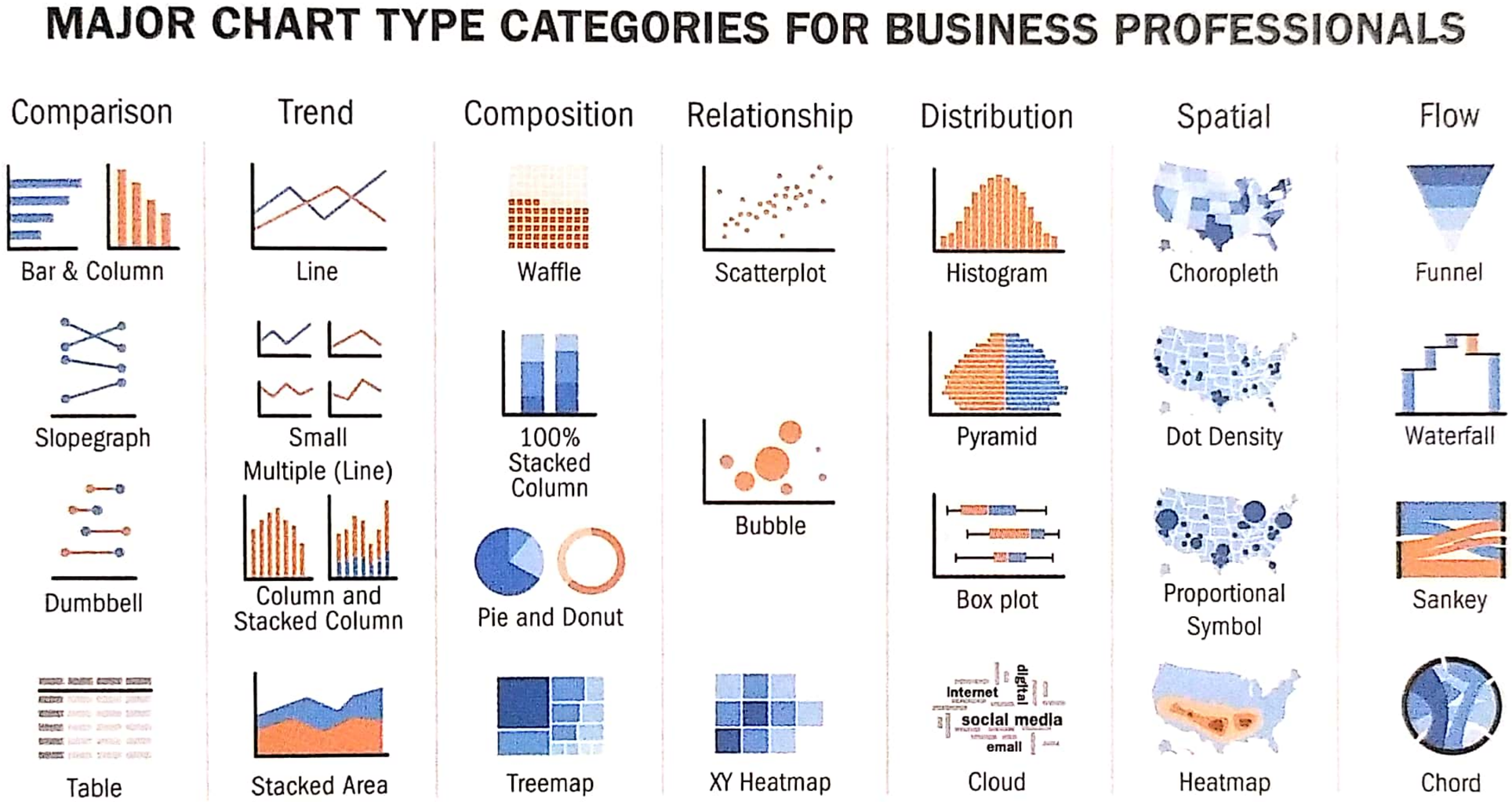


Bertin’s Semiology of graphics



Jacques Bertin

Choosing the Right Visualisation



Design principles for effective visual presentation

- Guides 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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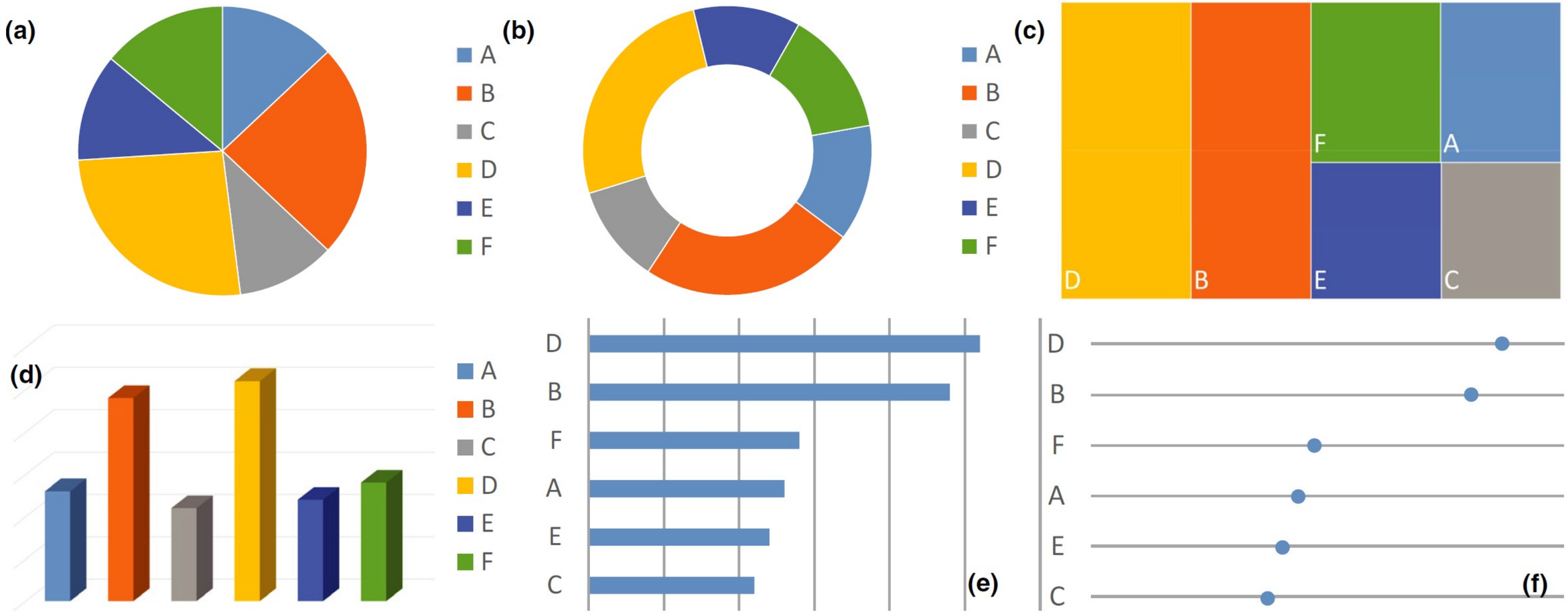
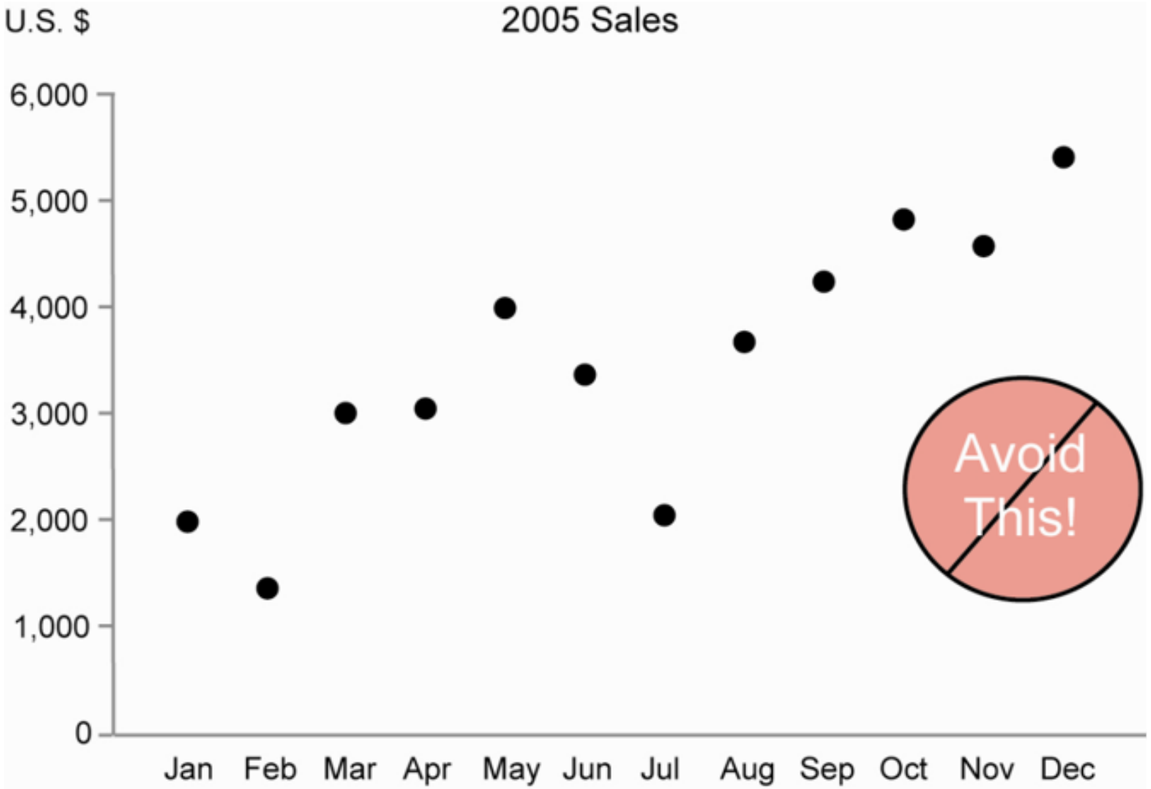
General Guide: Show the Data Clearly



Guides for Encoding Values in Graph

Guide 1:

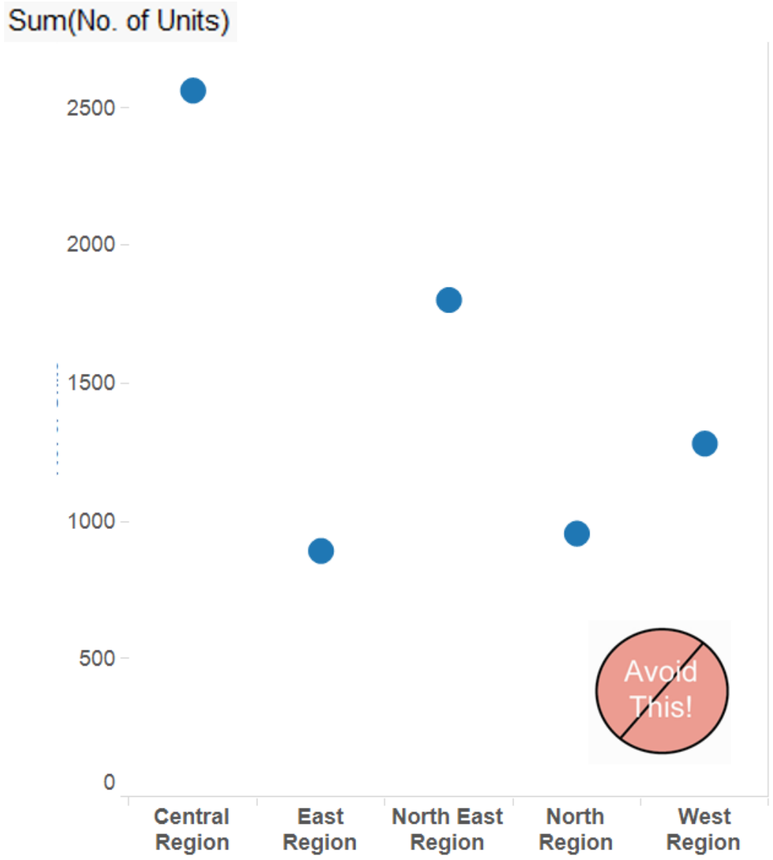
Avoid using point alone to display time-series data.

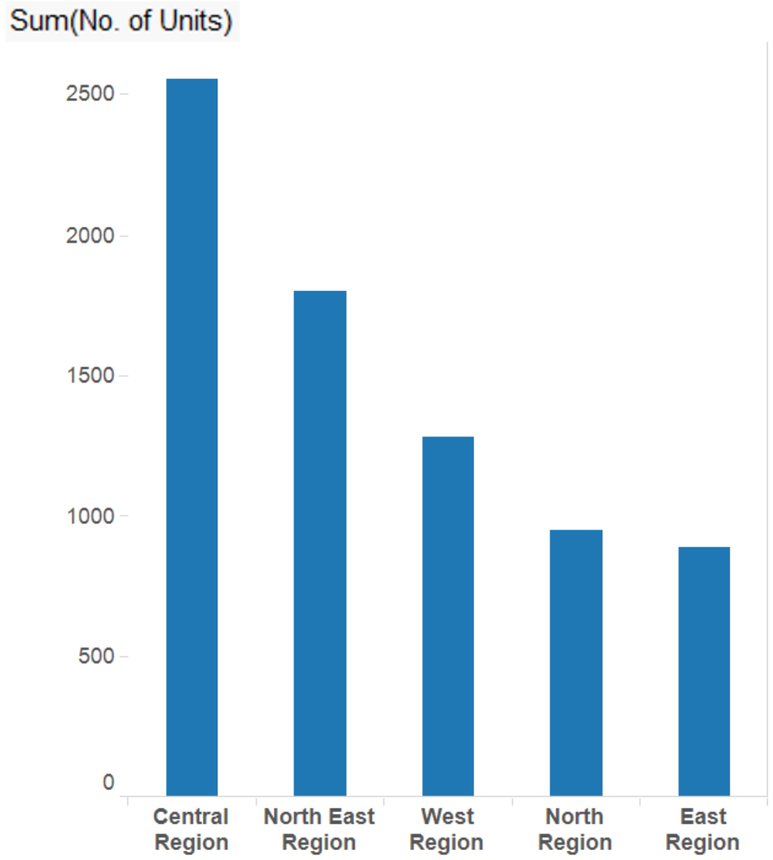


Guides for Encoding Values in Graph

Guide 2:

Avoid using points to represent discrete values

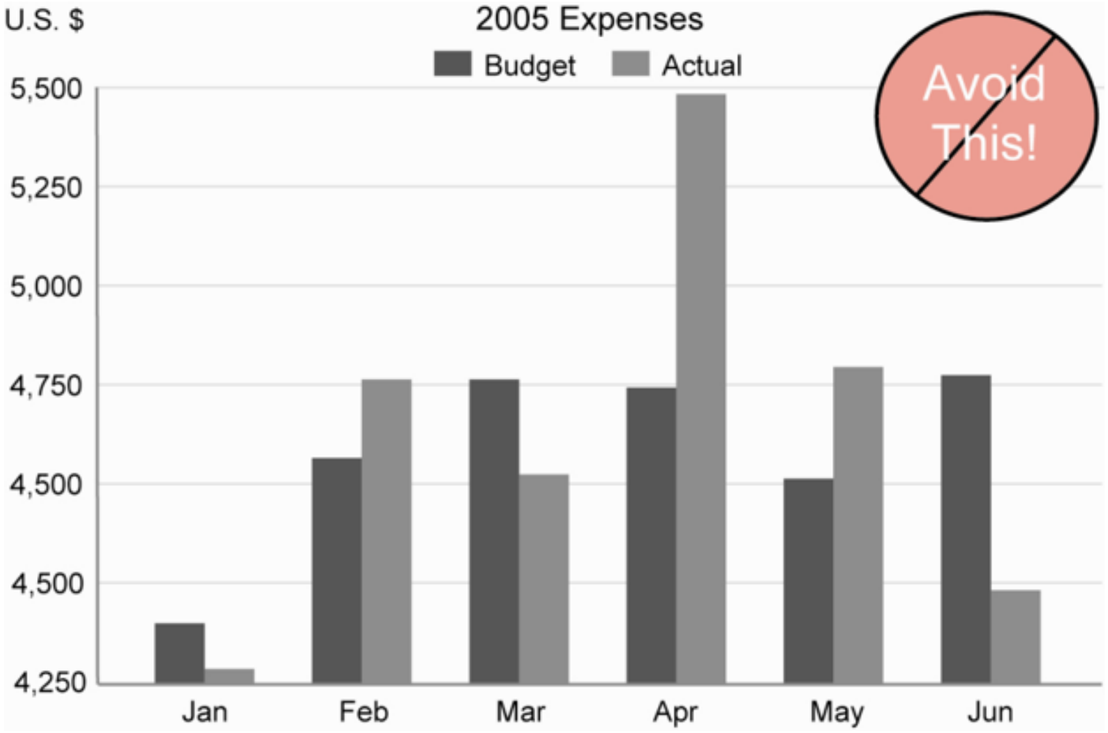


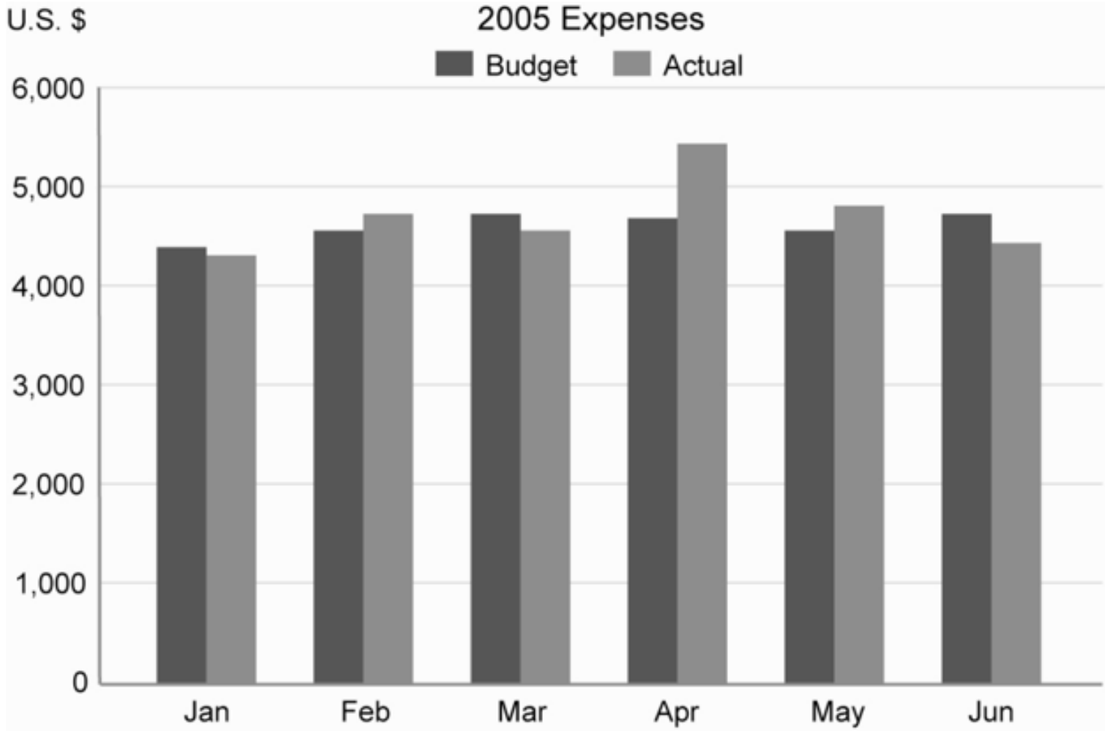


Guides for Encoding Values in Graph

Guide 3:

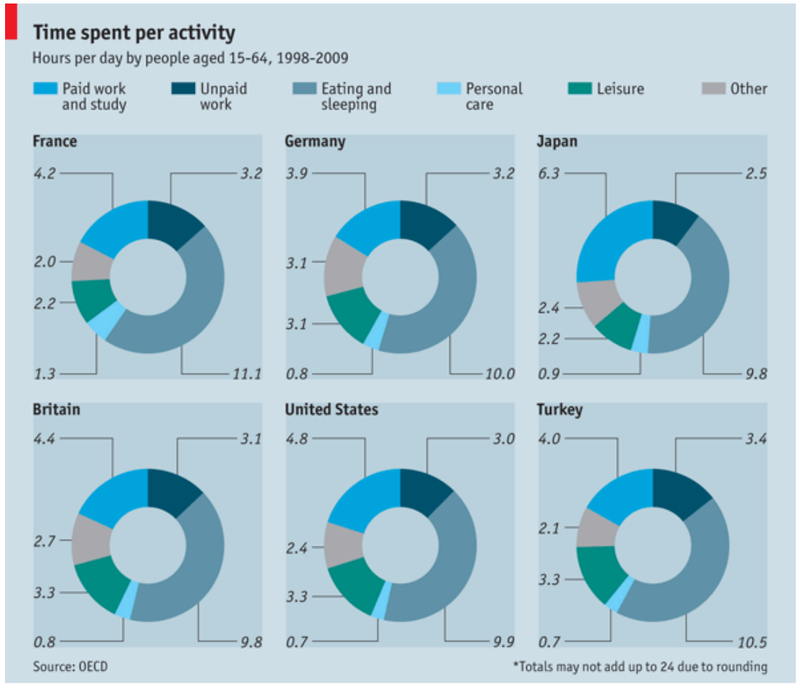
Bars don’t work unless the quantative scale begins at zero



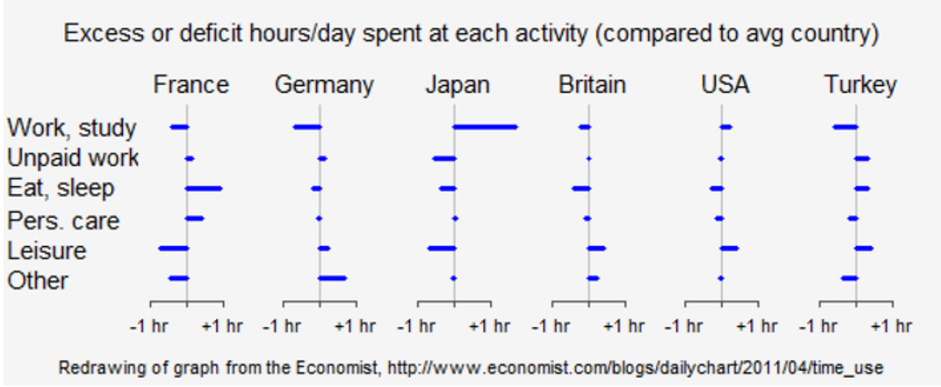


Guide for Encoding Values in Graph

> **Guide 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

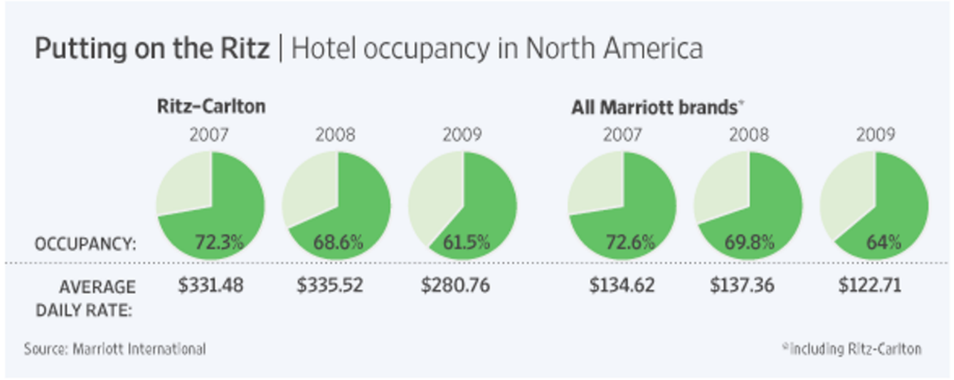


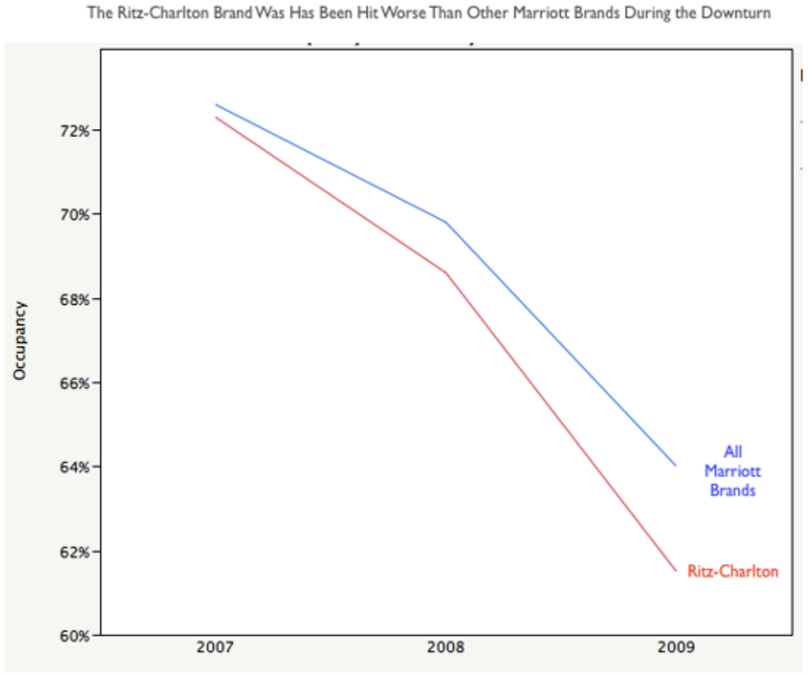
Reference: JunkCharts

Guide for Encoding Values in Graph

Guide 5:

Avoid pie chart if you are comparing changes over time





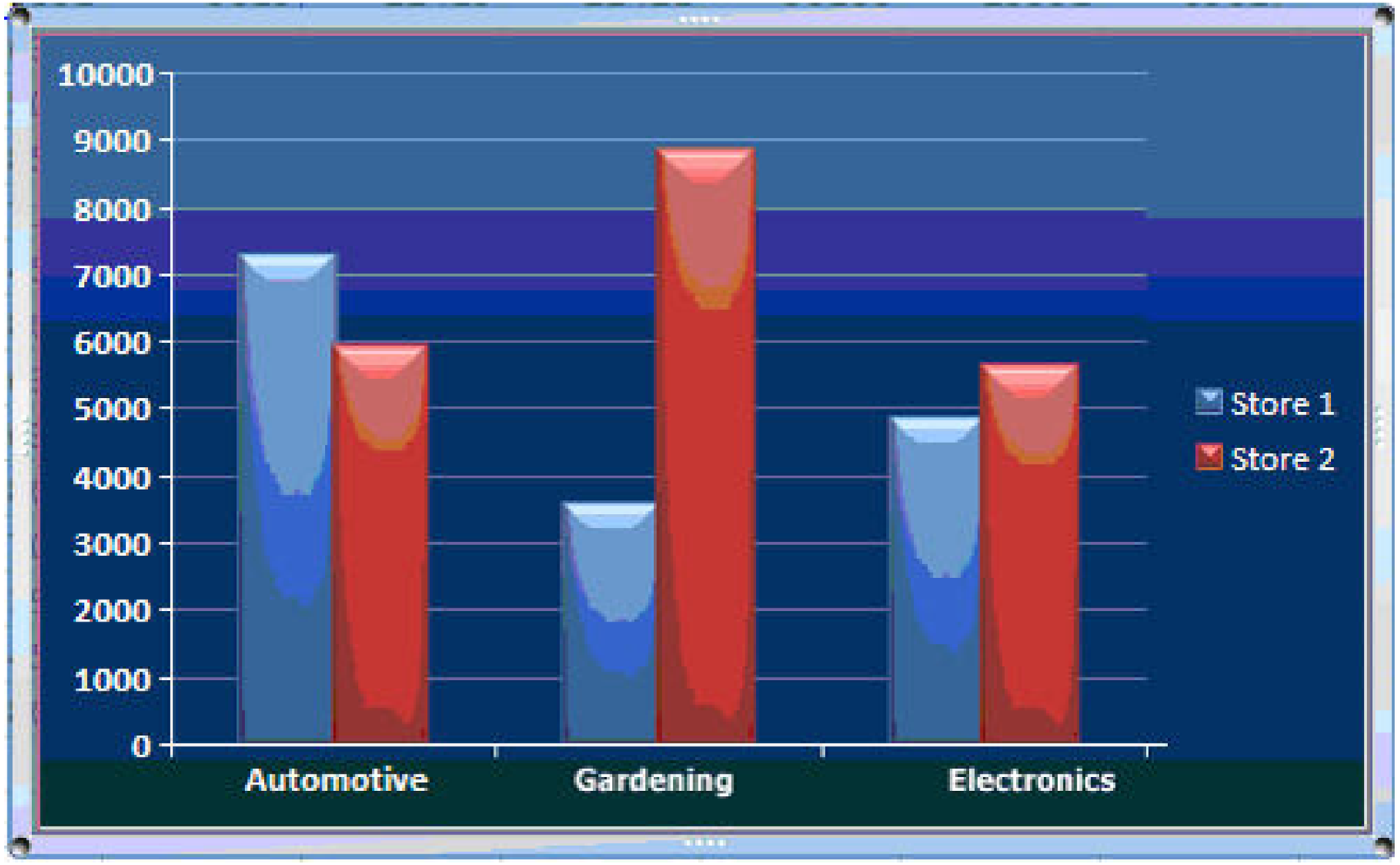
:scale 80%

Design principles for effective visual presentation

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

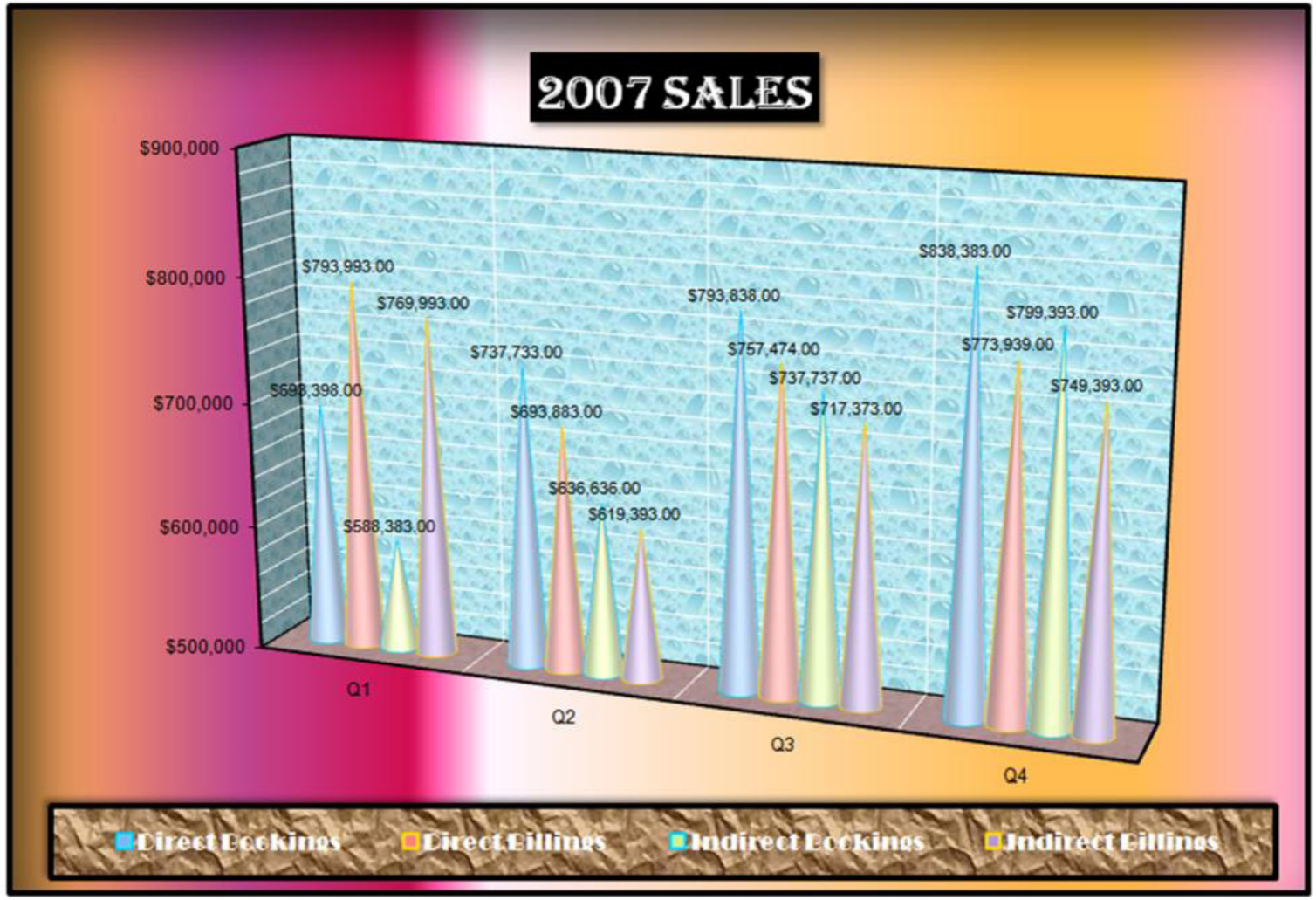
ChartJunk I

Avoid using unnecessary colour shading for the bar.



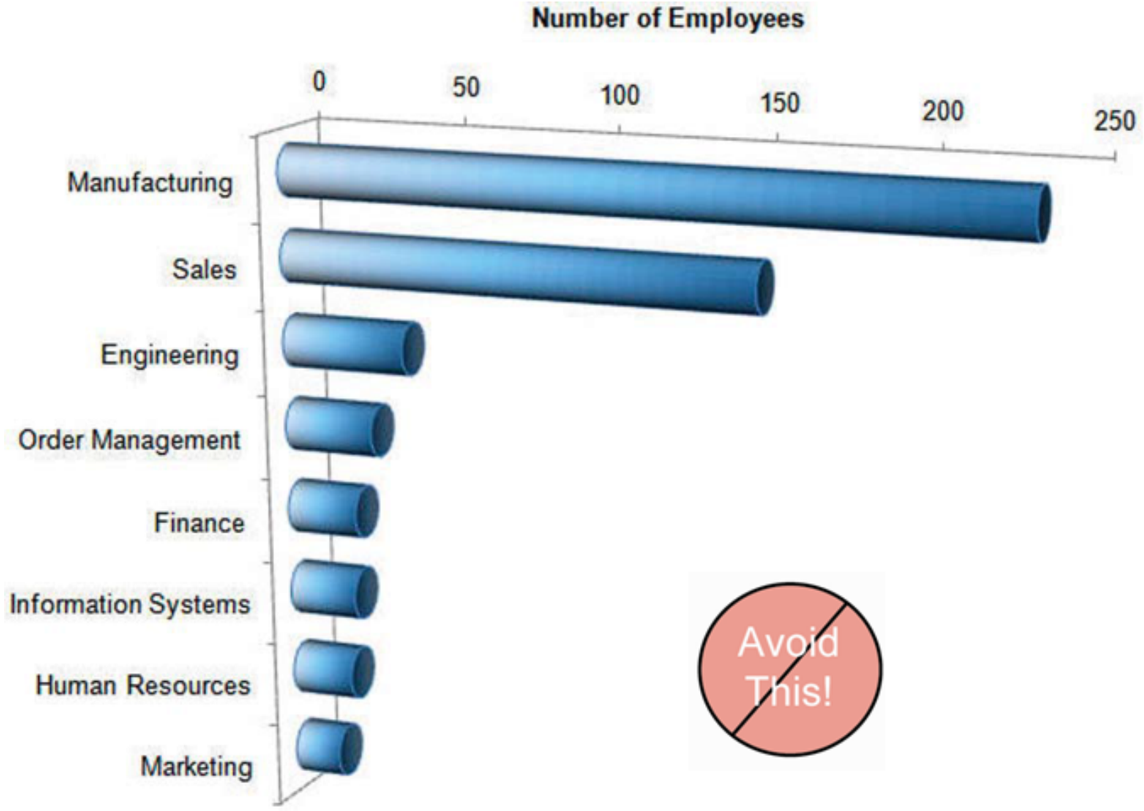
ChartJunk II

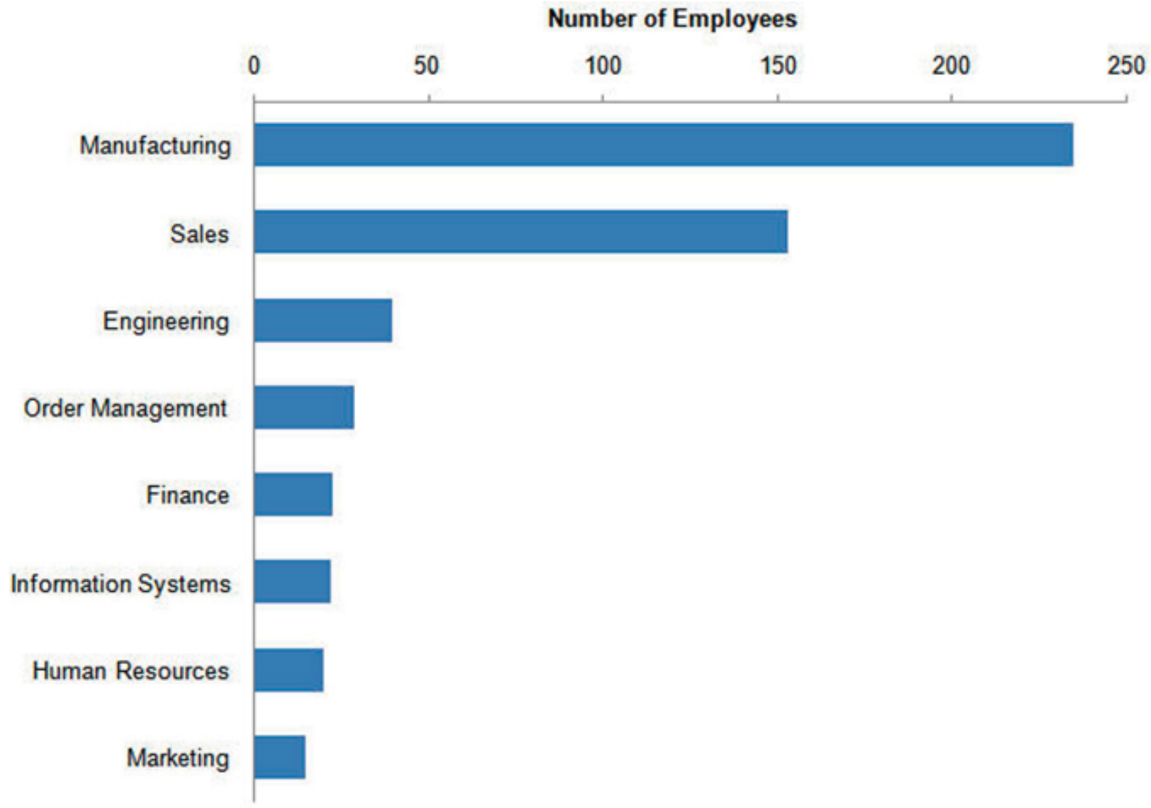
Avoid colourful or wallpaper background.



ChartJunk III

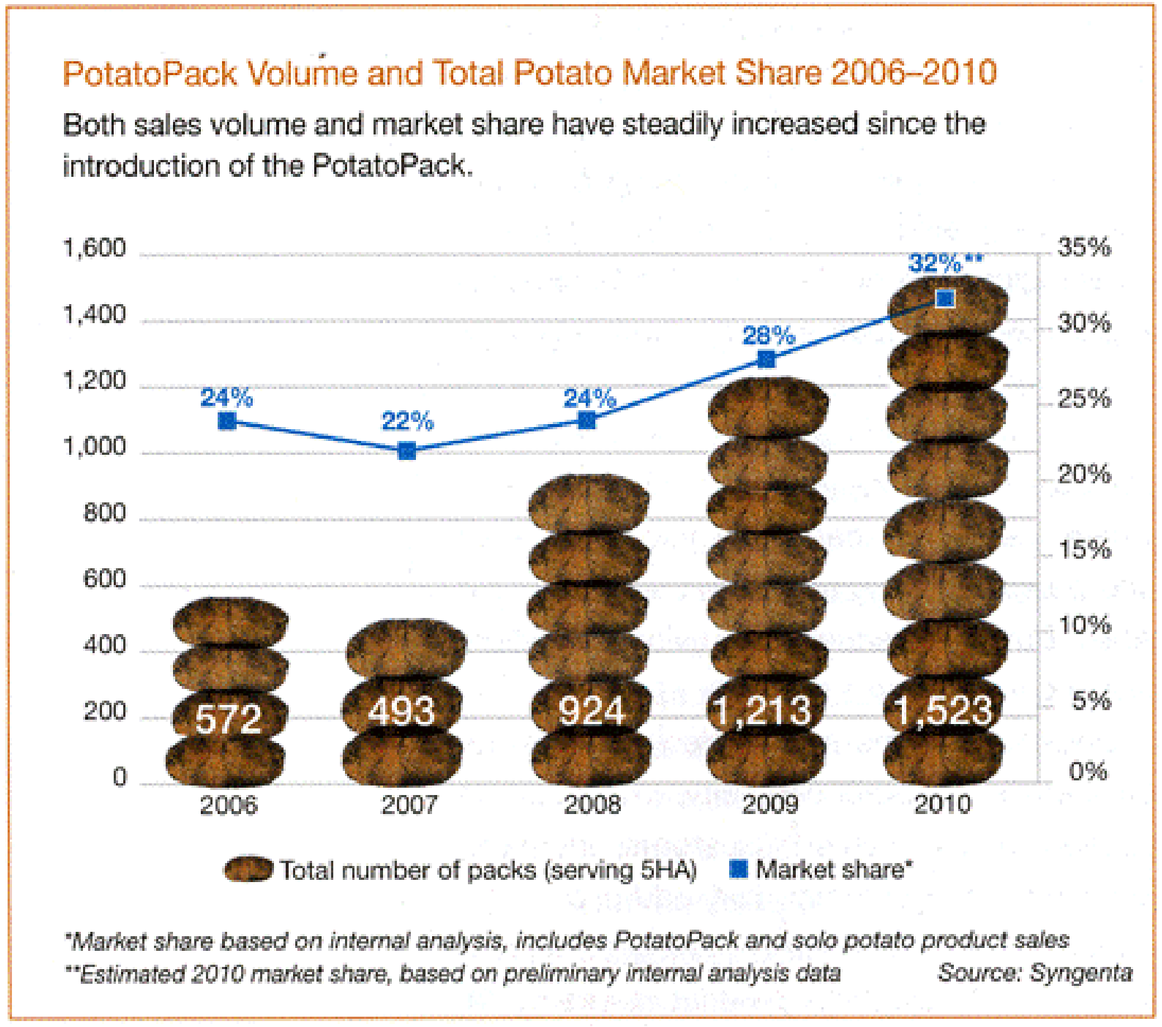
Avoid using 3D effects in graphics.





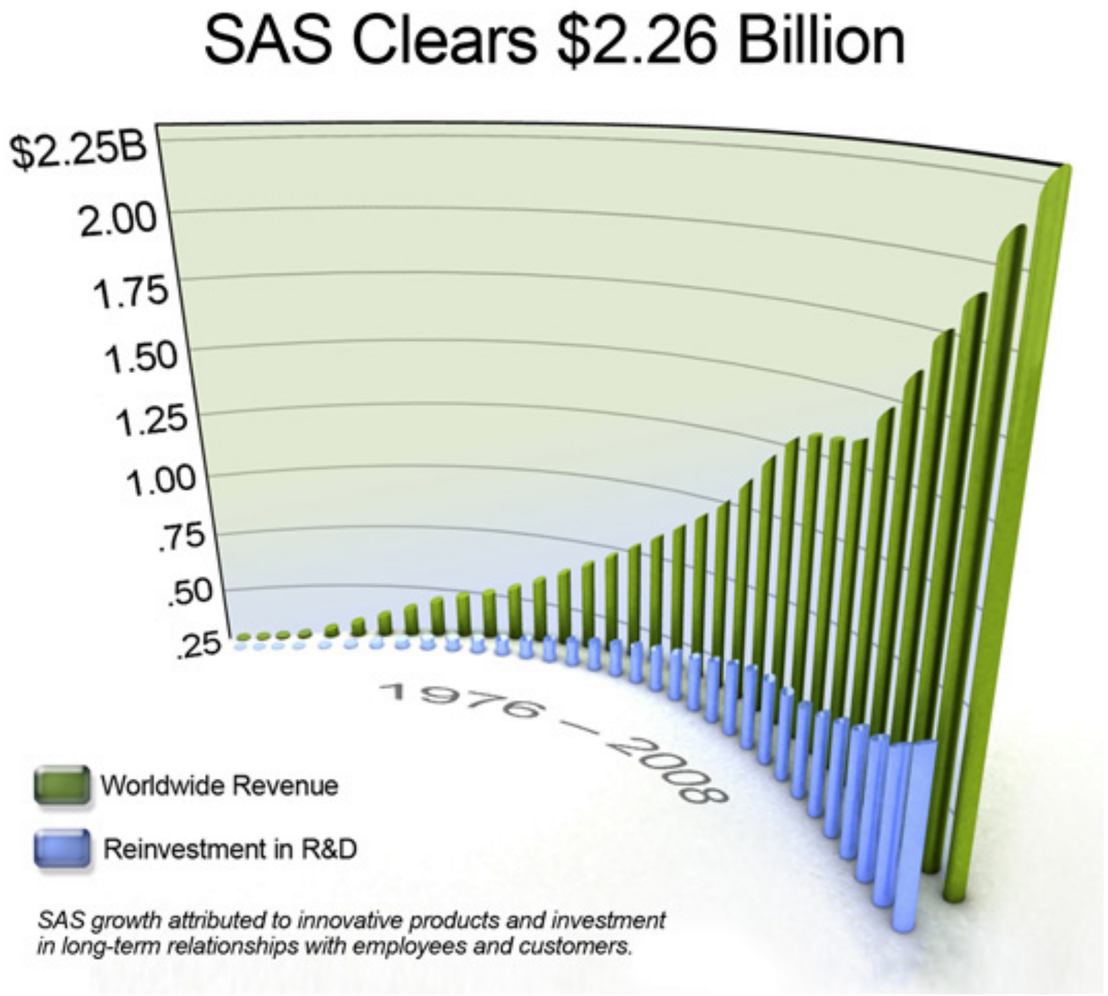
ChartJunk IV

Avoid using misleading graphical representation.



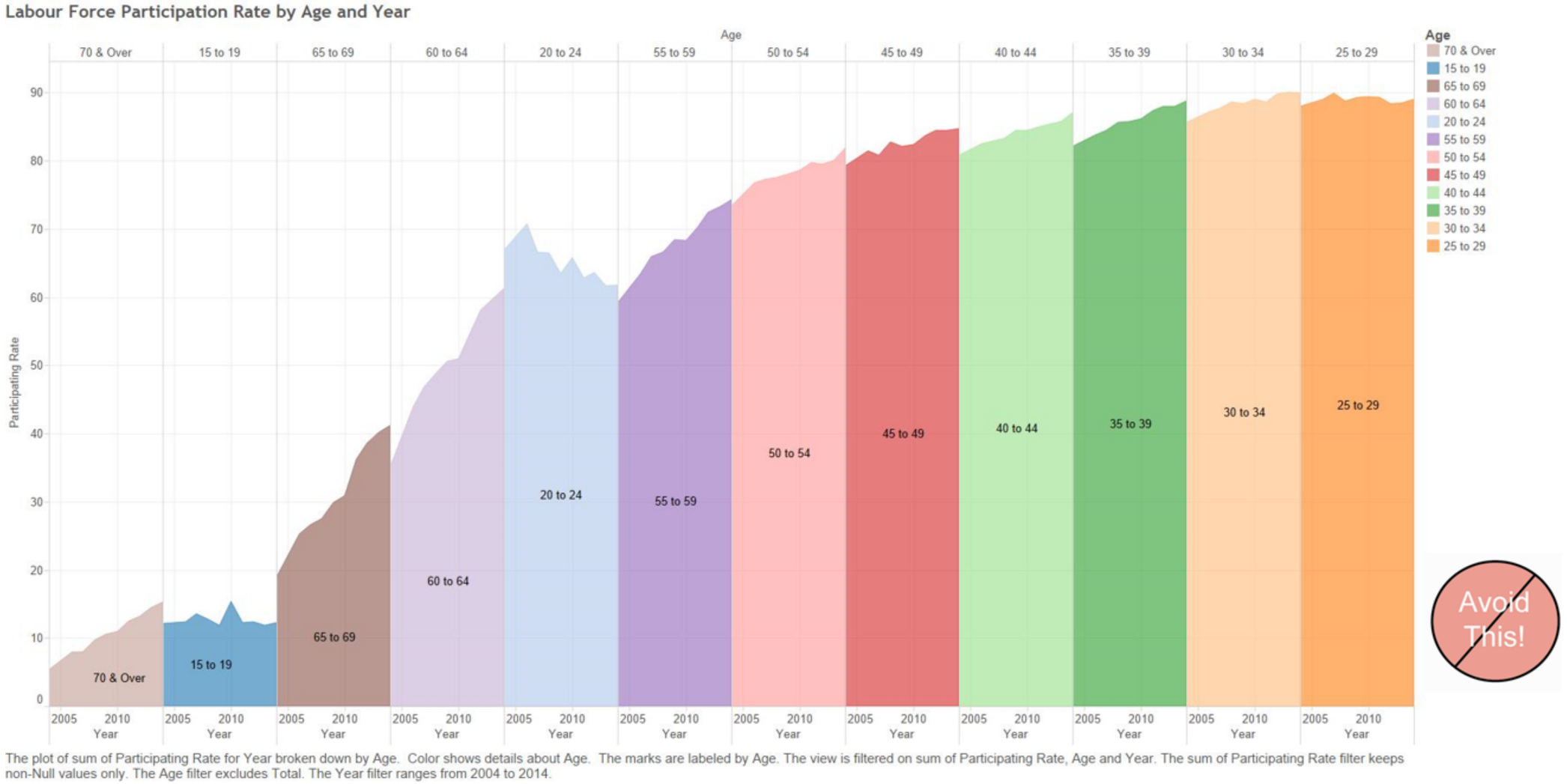
ChartJunk V

Avoid using artistic design which is difficult to visualise.



ChartJunk VI

Designing graph to enlighten people – not to entertain them.



The plot of sum of Participating Rate for Year broken down by Age. Color shows details about Age. The marks are labeled by Age. The view is filtered on sum of Participating Rate, Age and Year. The sum of Participating Rate filter keeps non-Null values only. The Age filter excludes Total. The Year filter ranges from 2004 to 2014.

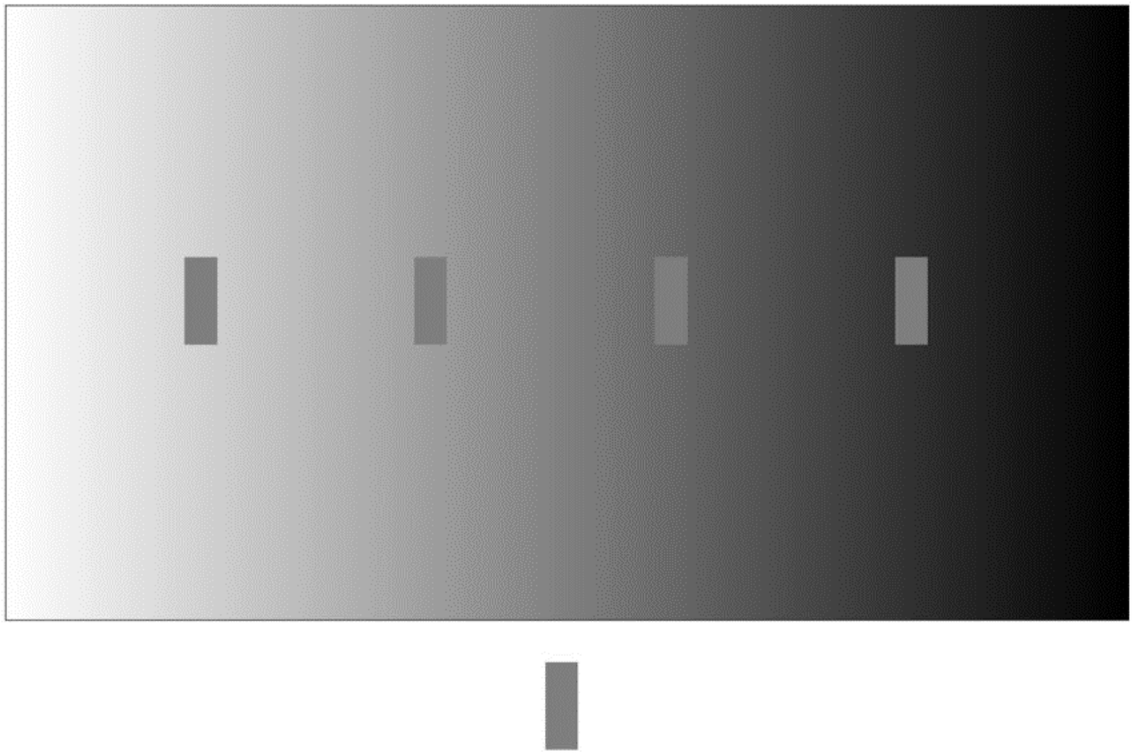
Design principles for effective visual presentation

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

Practical Guides for Using Colour in Charts

Guide 1:

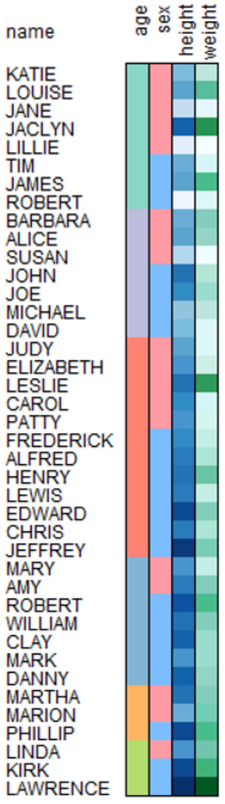
If you want different objects of the same colour in a graph to look the same, make sure that the background- the colour that surrounds them – is consistent.



Practical Guides for Using Colour in Charts

Guide 2:

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

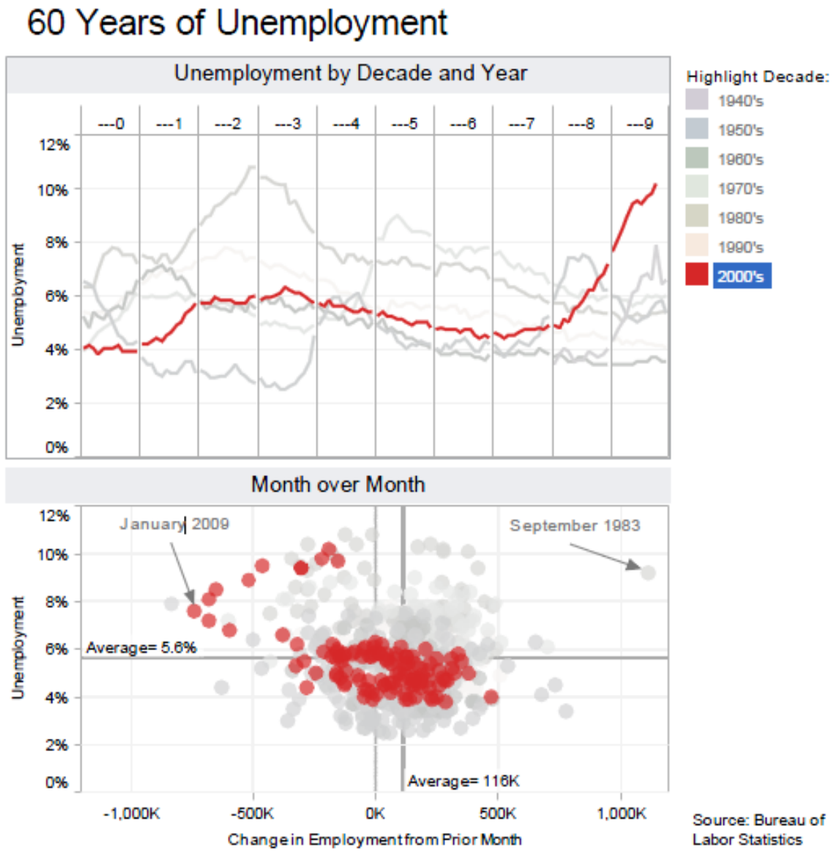


	name	age	sex	height	weight	mean weight by age
1	KATIE	12	F	59	95	99.000
2	LOUISE	12	F	61	123	99.000
3	JANE	12	F	55	74	99.000
4	JACLYN	12	F	66	145	99.000
5	LILLIE	12	F	52	64	99.000
6	TIM	12	M	60	84	99.000
7	JAMES	12	M	61	128	99.000
8	ROBERT	12	M	51	79	99.000
9	BARBARA	13	F	60	112	94.714
10	ALICE	13	F	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

Guide 3:

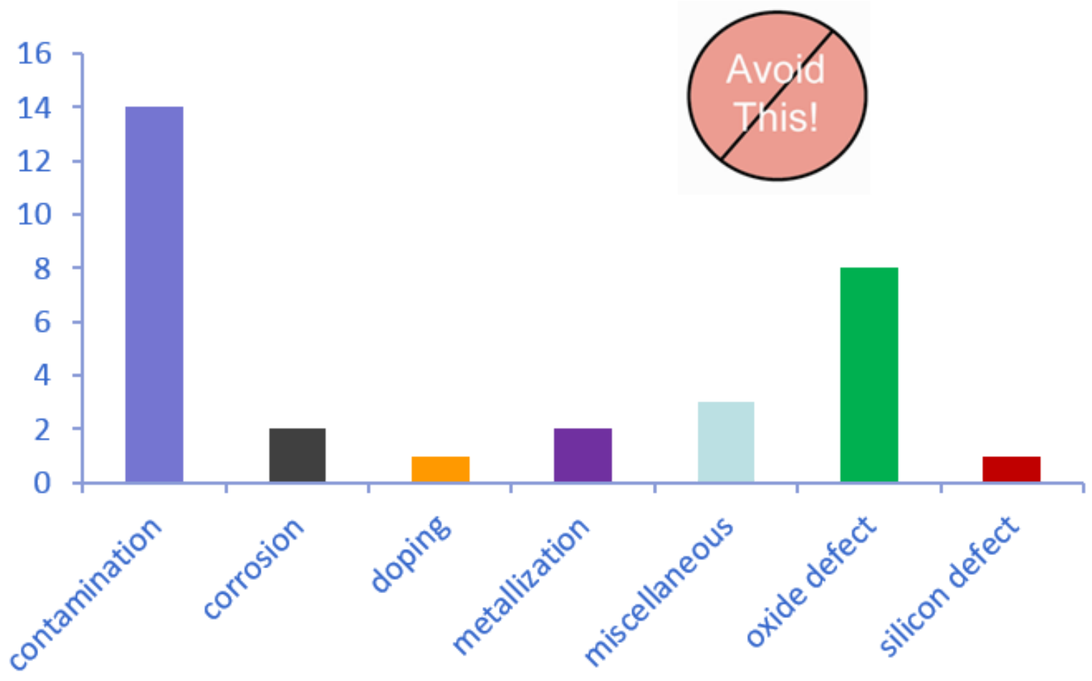
Use color only when needed to serve a particular communication goal.

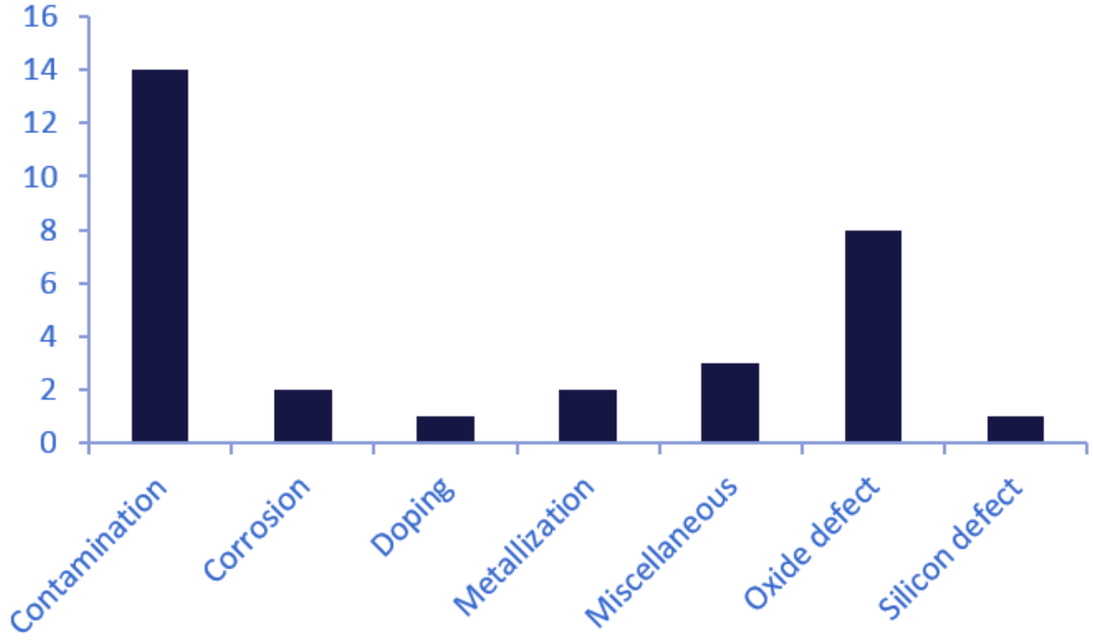


Practical Guides for Using Colour in Charts

Guide 4:

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





Practical Guides for Using Colour in Charts

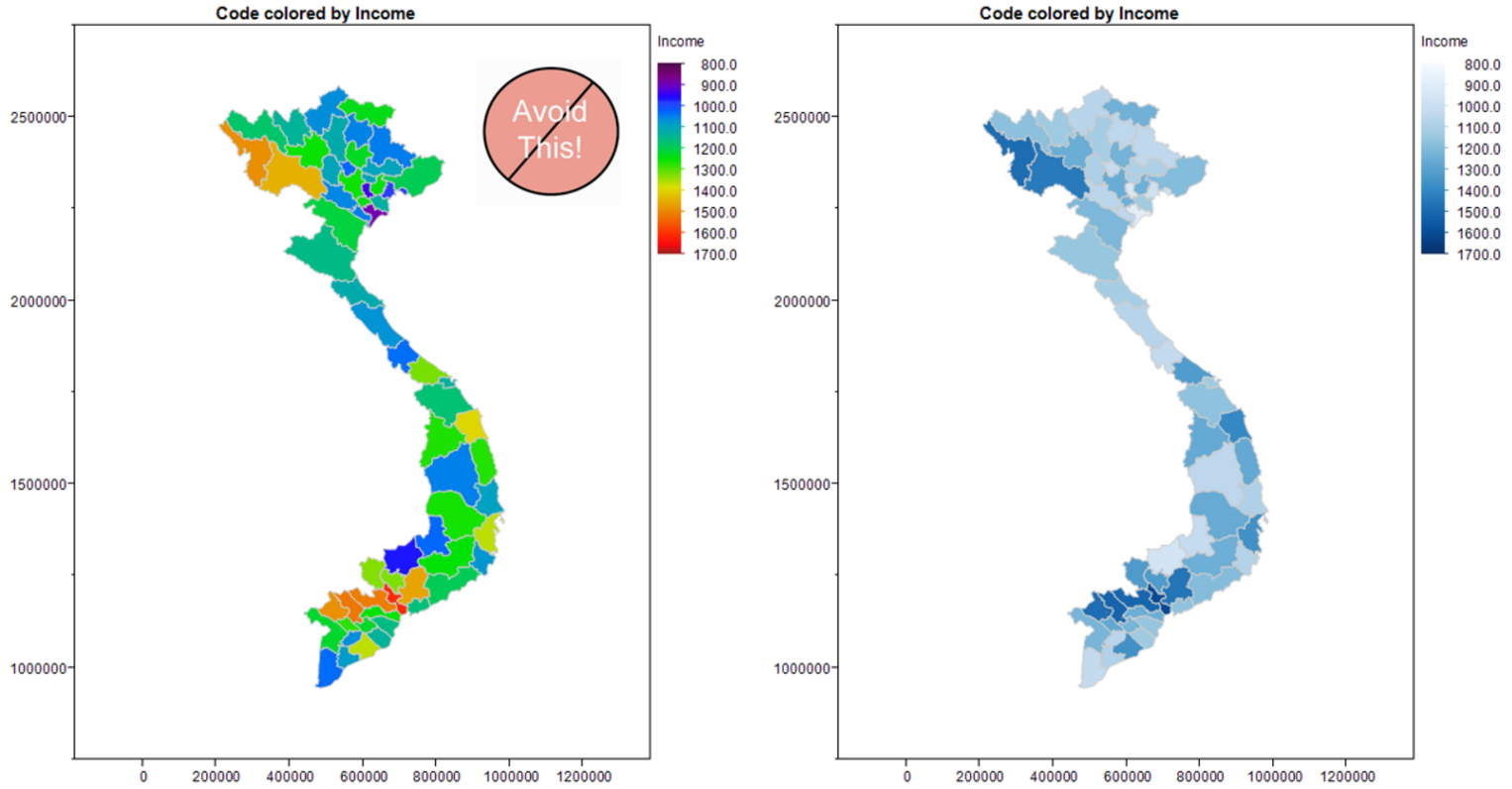
Guide 5:

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

Practical Guides for Using Colour in Charts

Guide 6:

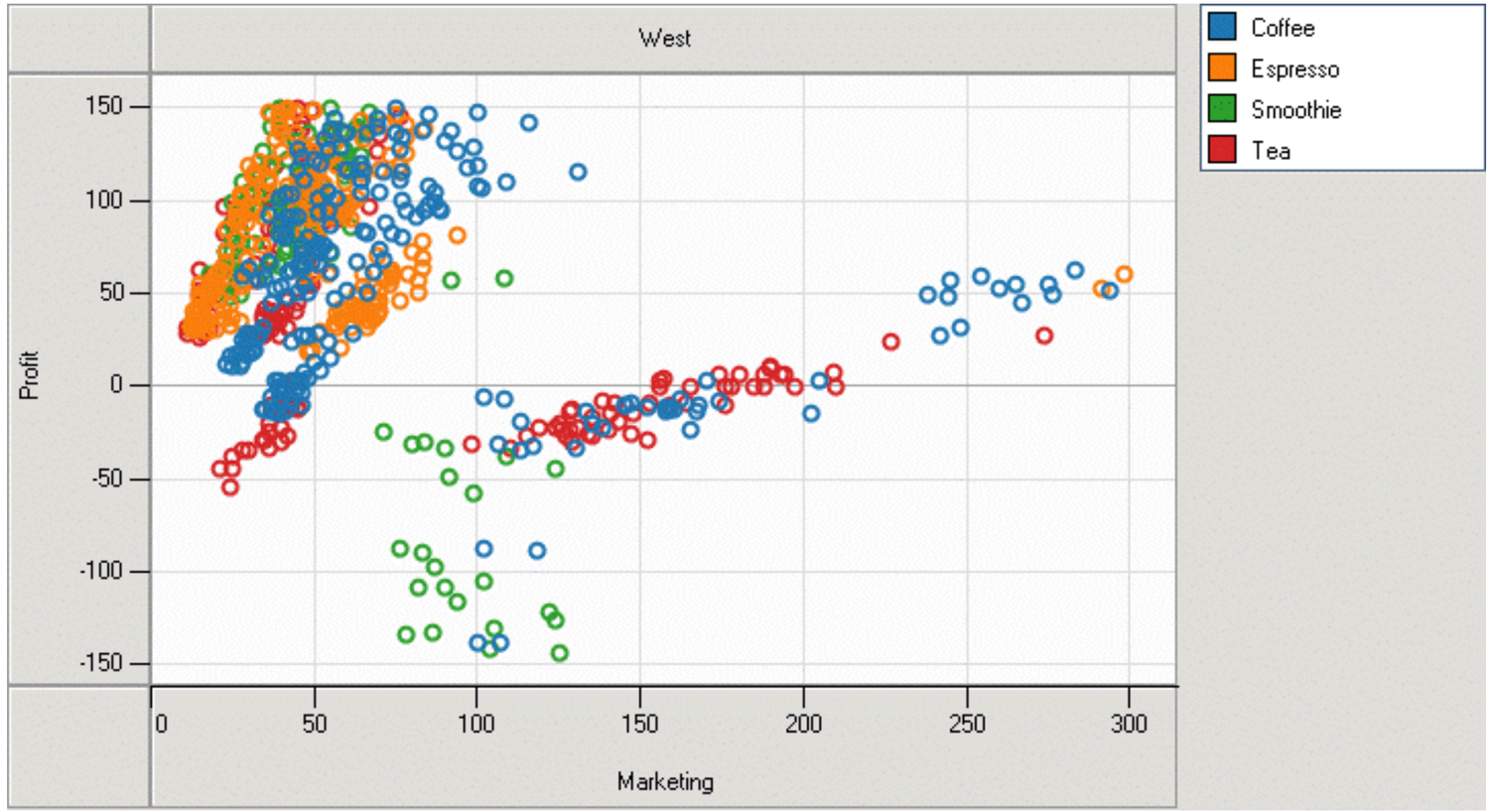
When using colour to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colours for low values to increasingly darker and brighter colours for high values.



Practical Guides for Using Colour in Charts

Guide 7:

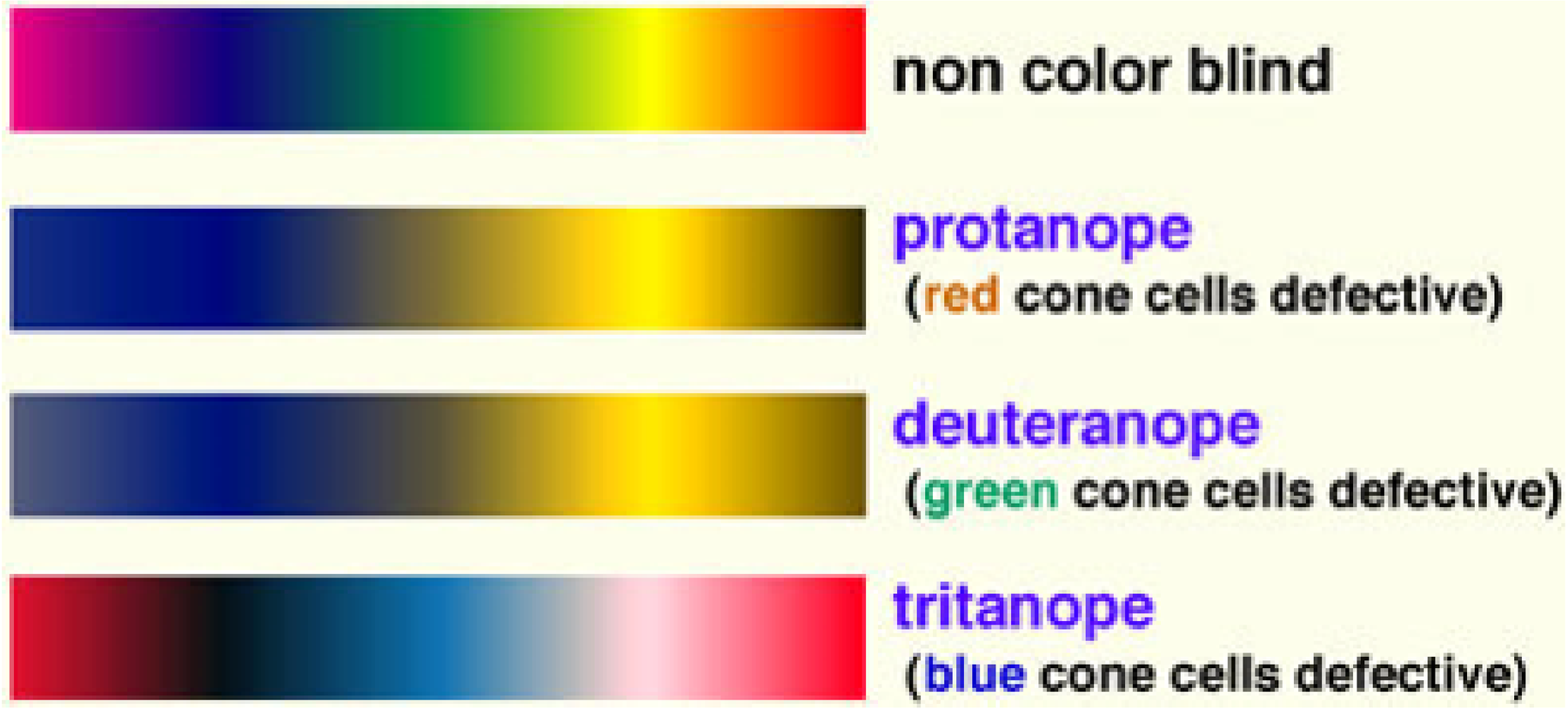
Non-data components of a graph should be displayed just visibly enough to perform their role, but not more so, for excessive salience could cause them to distract attention from the data.



Practical Guides for Using Colour in Charts

Guide 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.

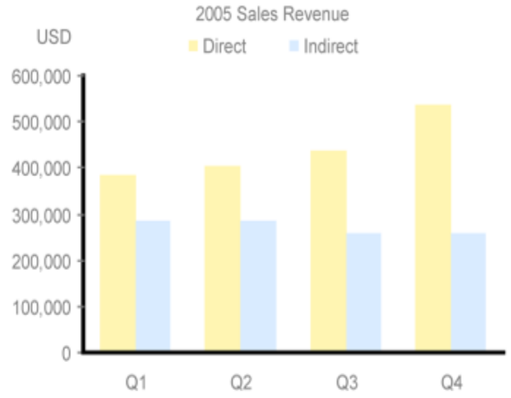


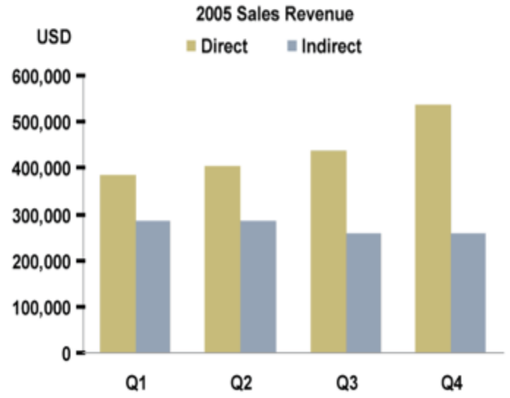
Design principles for effective visual presentation

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

Data-ink

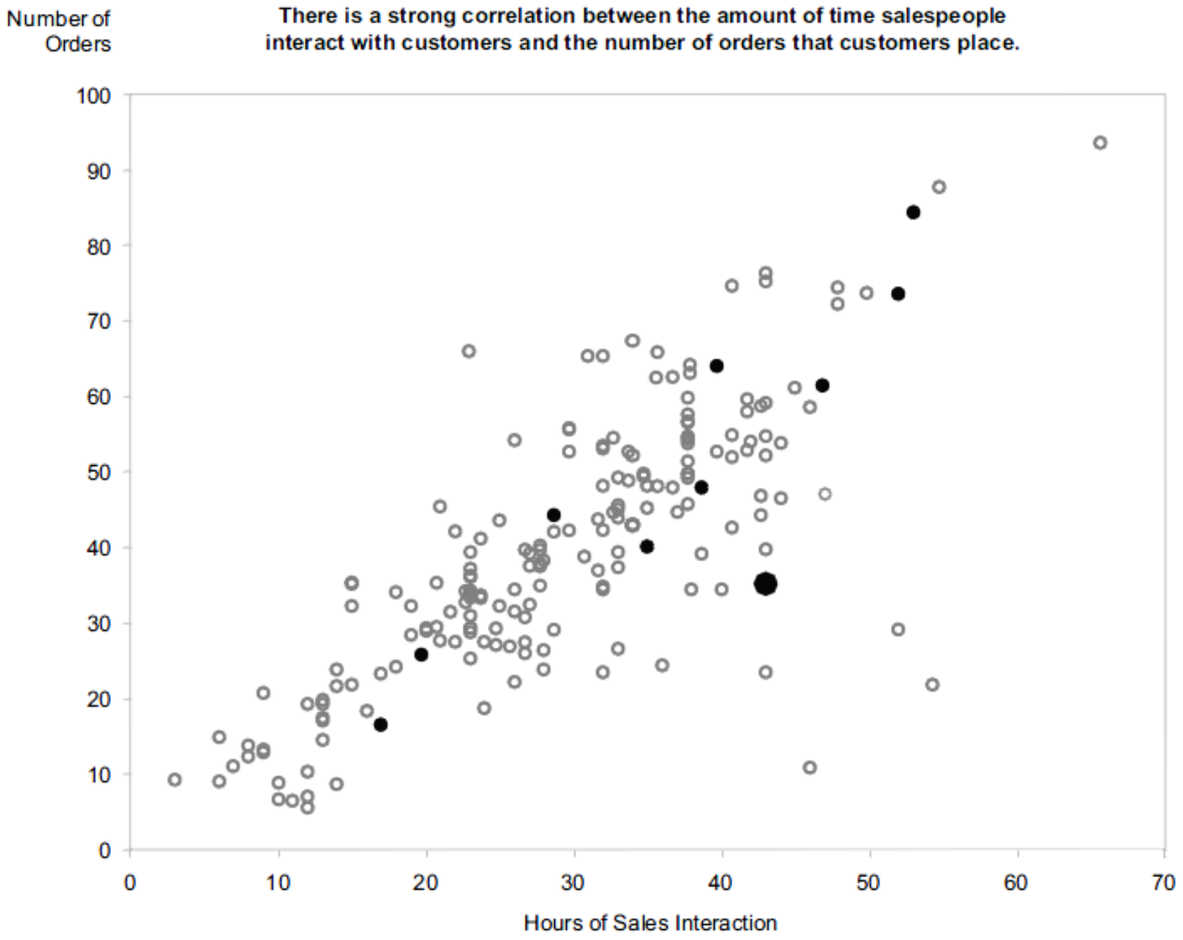
- Reduce the non data-ink
  - Removed unnecessary non data-ink
  - De-emphasise or regularise the remaining non data-ink
- Enhance the data-ink
  - Remove unnecessary data-ink
  - Emphasise the remaining data-ink





Practical used of data-ink

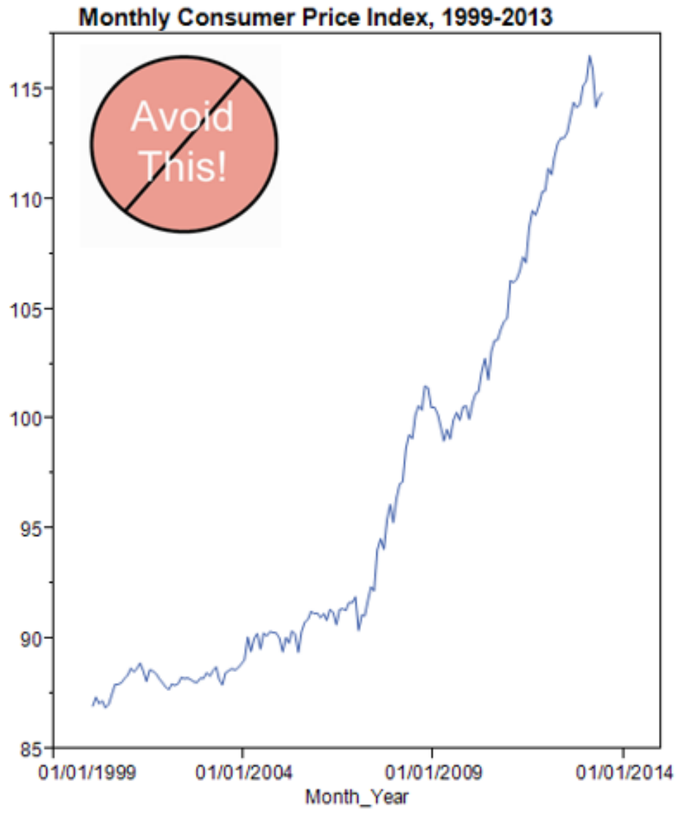
Shouting to emphasize what's interesting

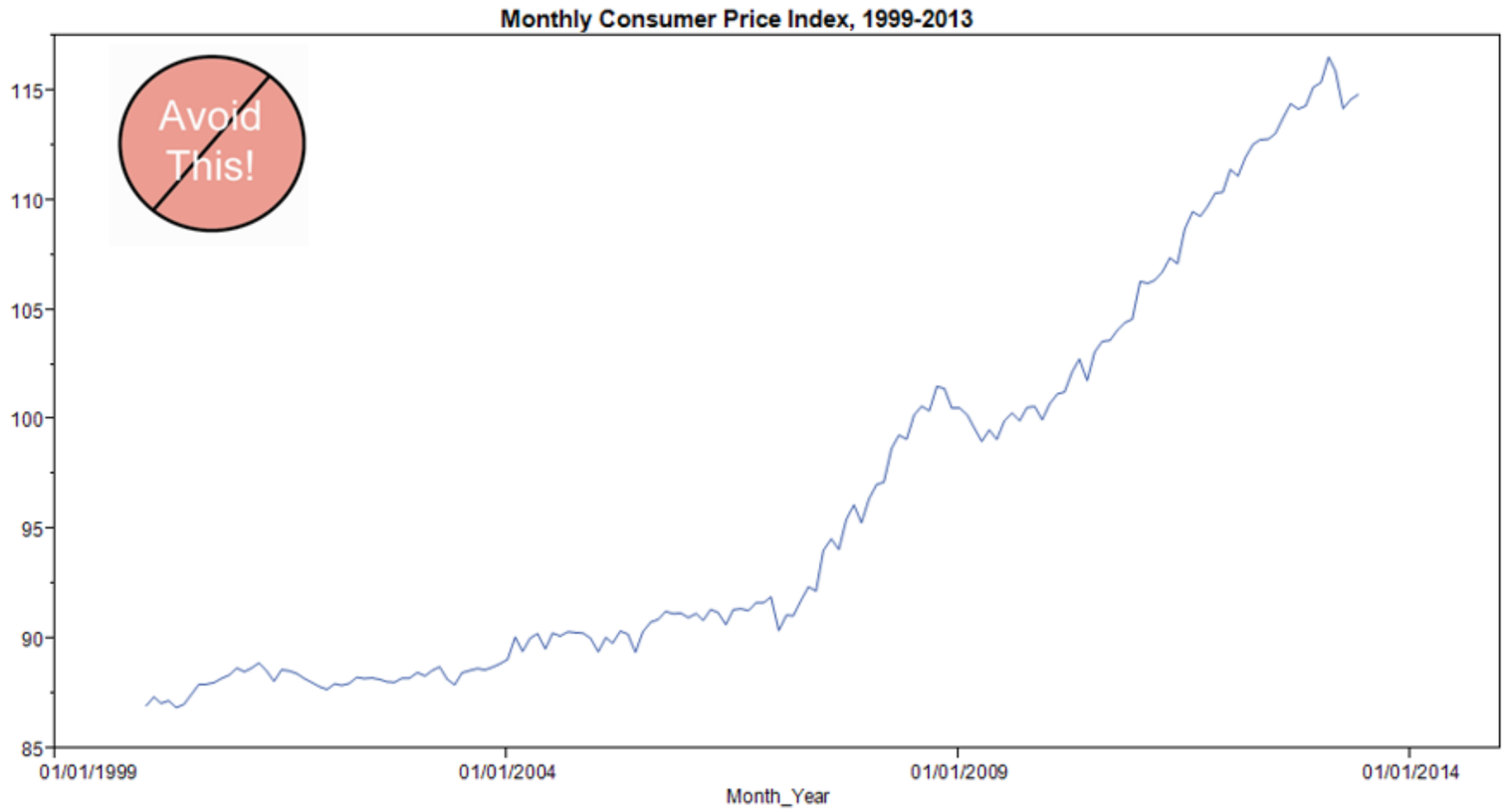


(Dark data points ● represent last year's top 10 customers based on the number of orders placed. The largest data point represents last year's top customer.)

What should the relative lengths of the axis be?

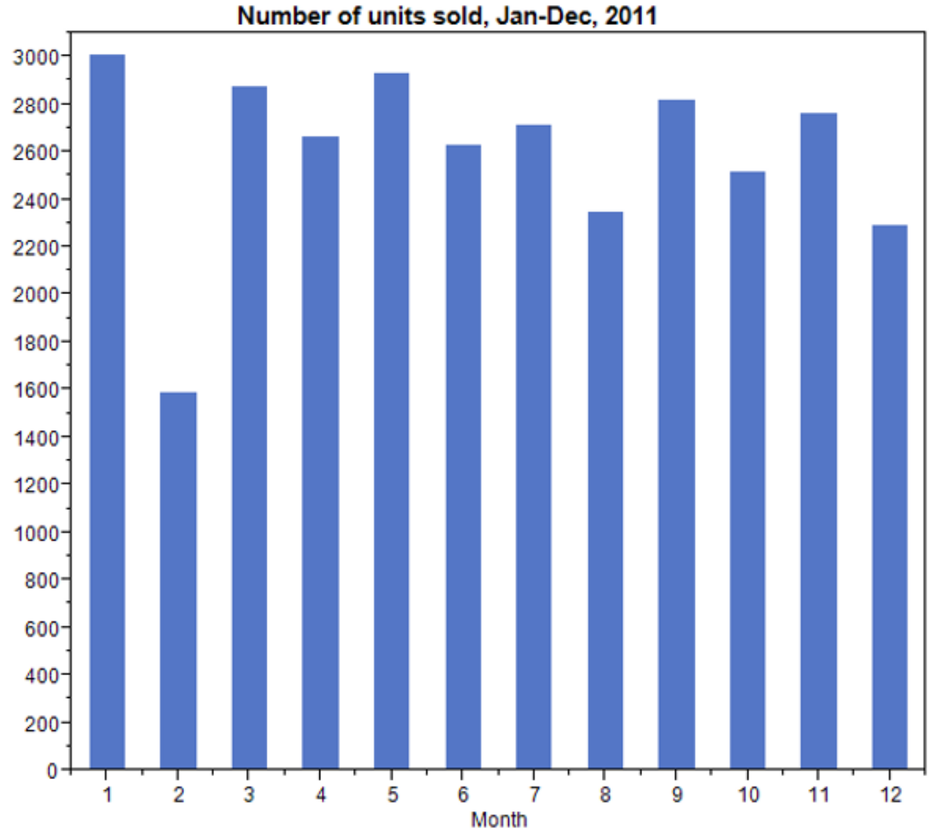
- Should not manipulate the aspect ratio to intentionally exaggerate or downplay the rate of change.
- Stick to the convention of making your graphs wider than being tall.

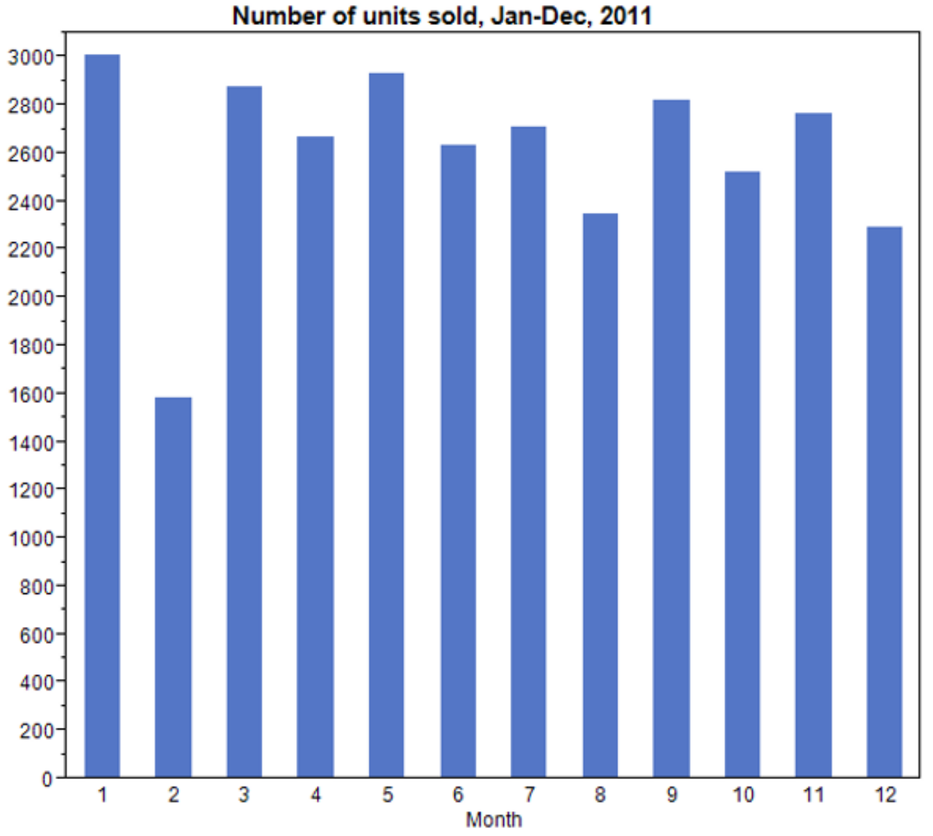




When can you eliminate tick mark?

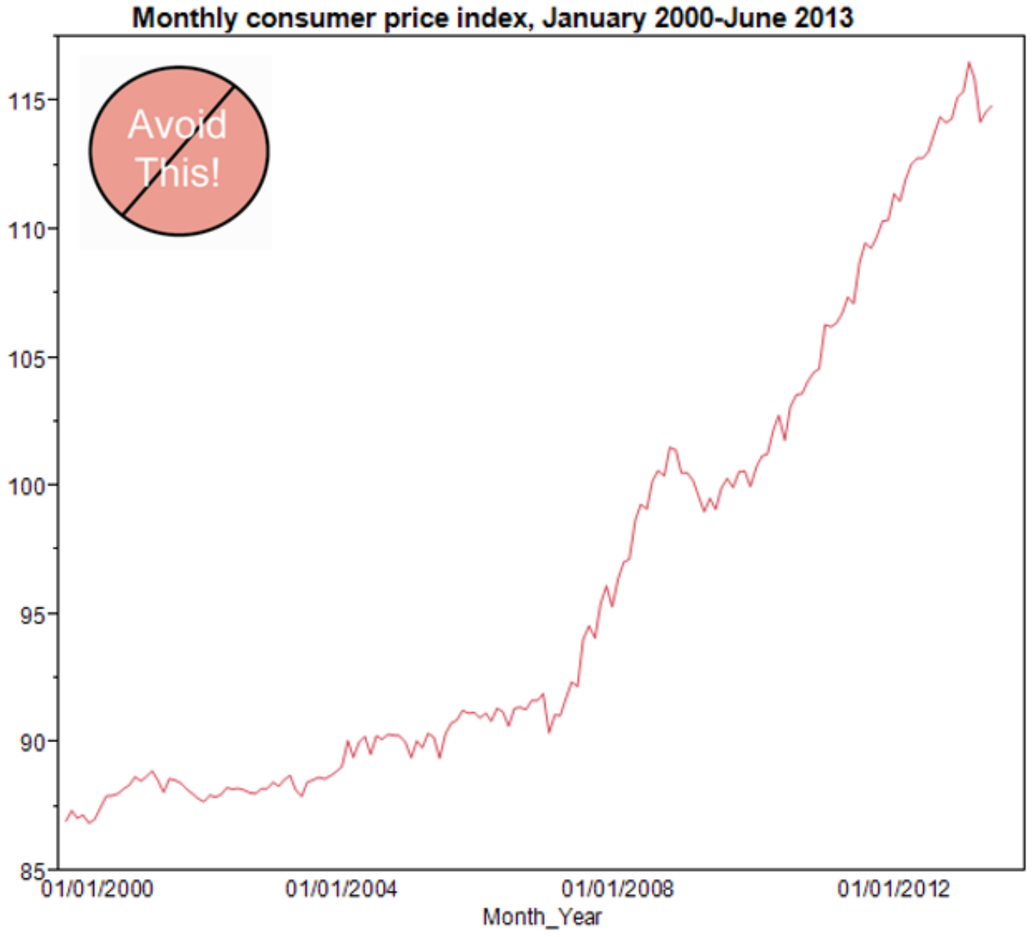
Tick marks are superfluous on categorical scale.

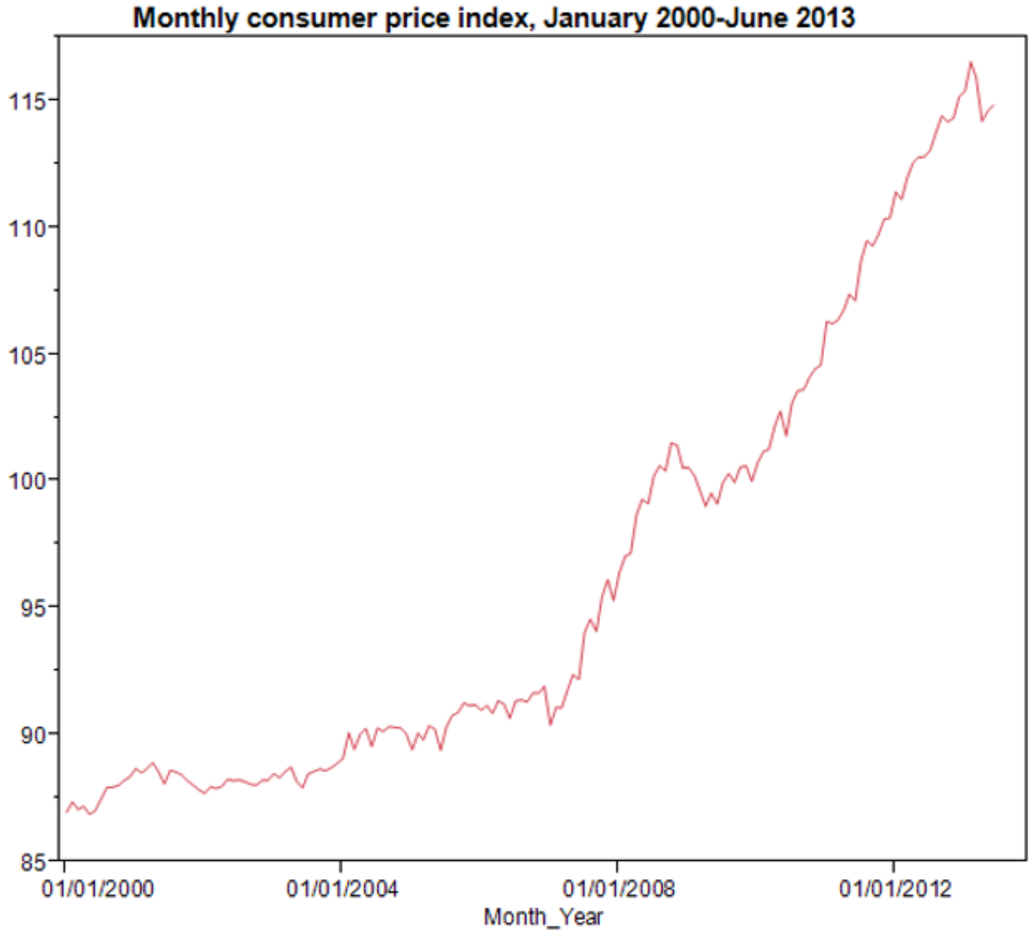




When you shouldn’t eliminate tick mark?

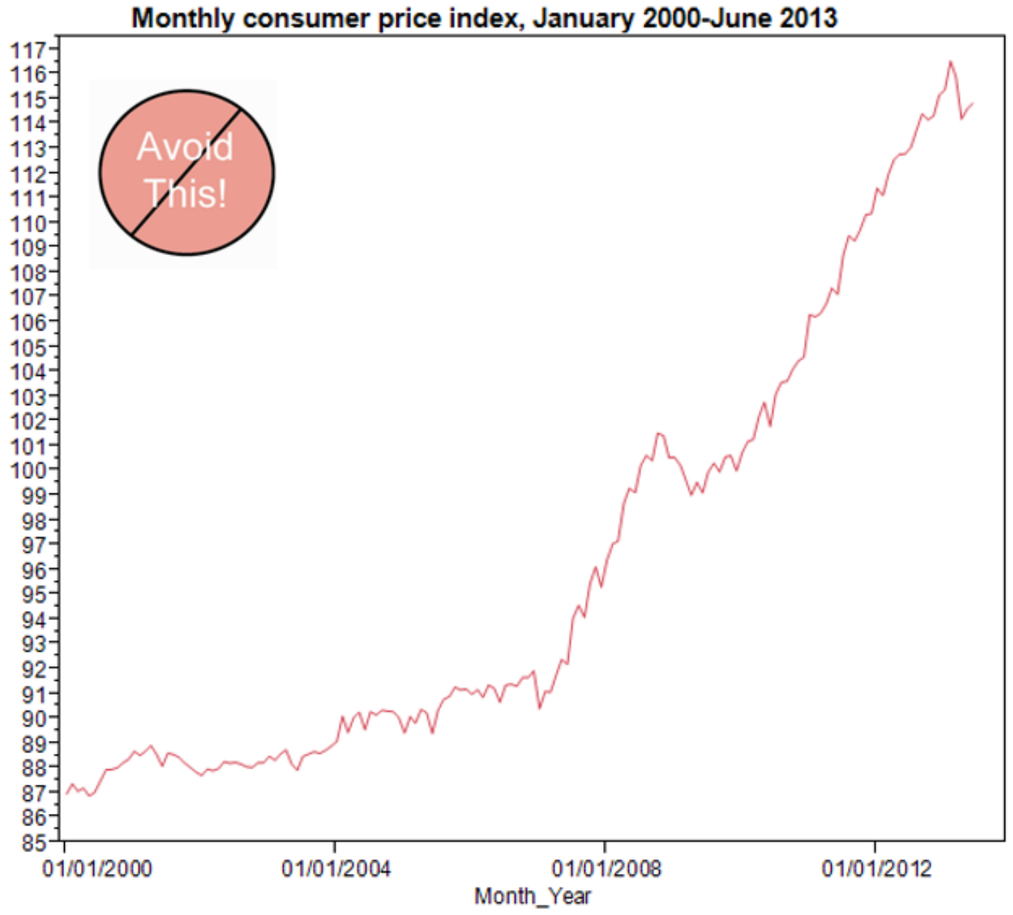
Tick marks are necessary on continuous scale.

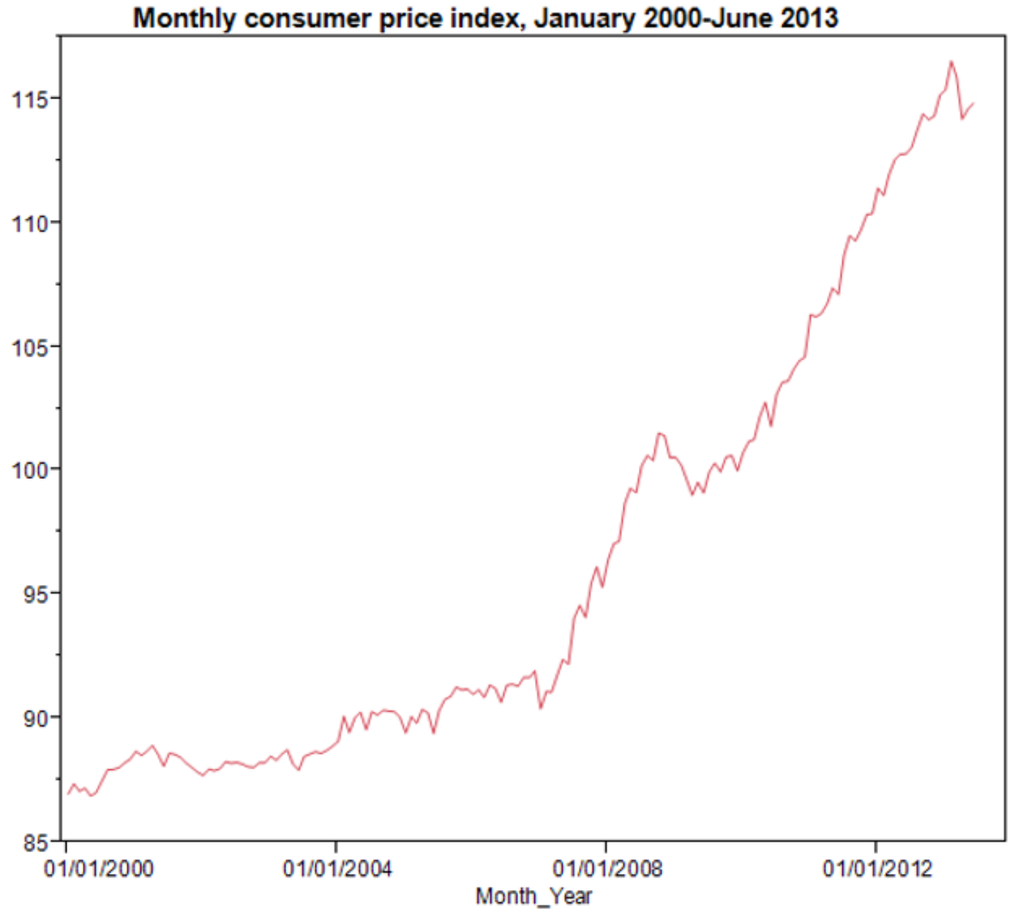




How many tick marks should you use?

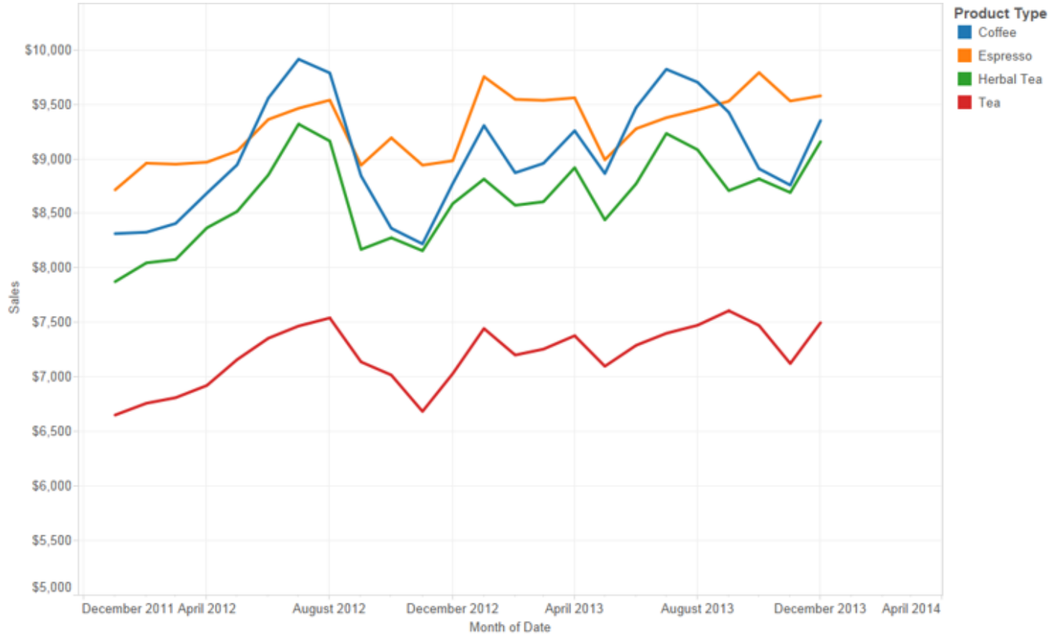
- There is no exact number that works best in all circumstances, and the size of the graph is a factor that must considered: the longer the scale line, the more tick marks it should contain.



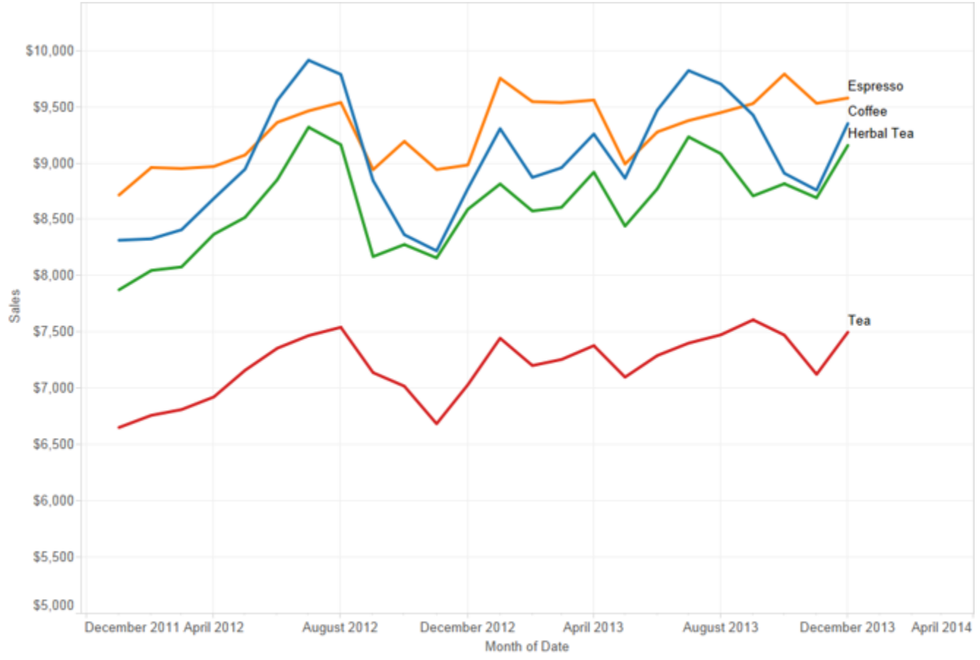


When can you eliminate legends?

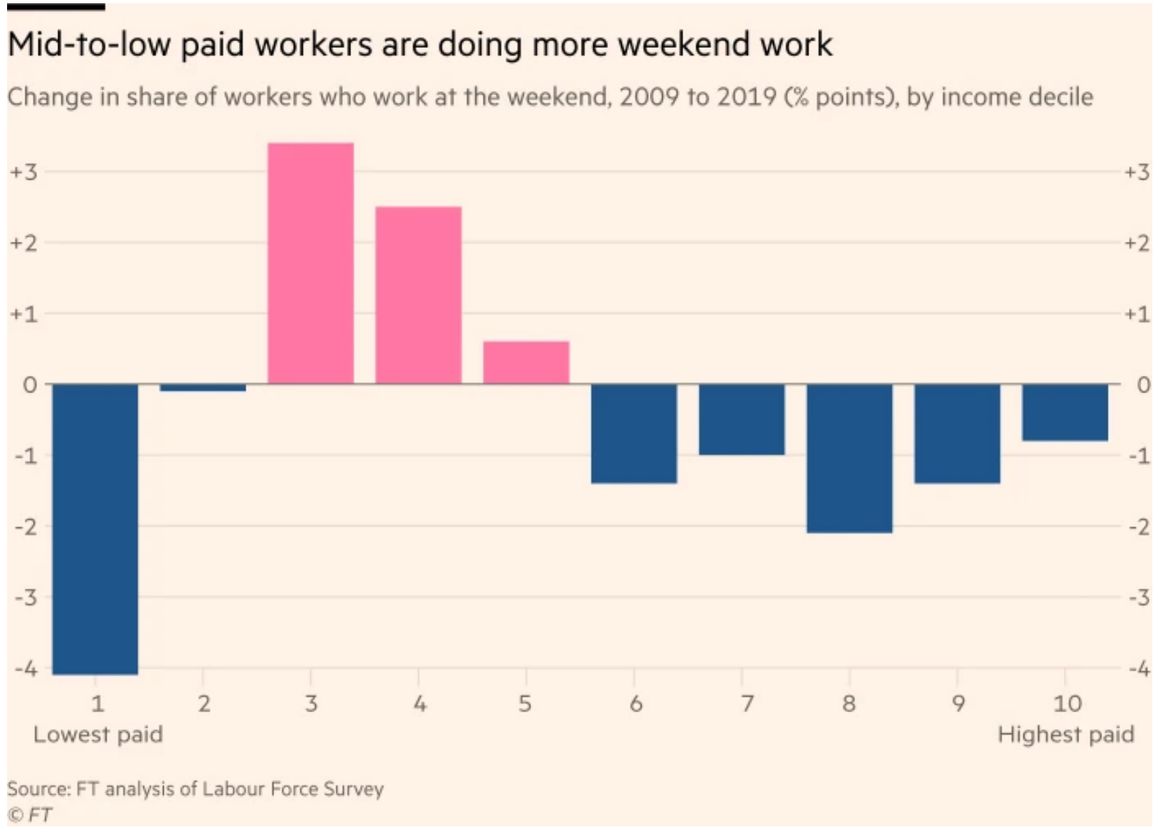
- In this graph, a legend is used to indicate product types.



In this graph, product types are labeled directly.



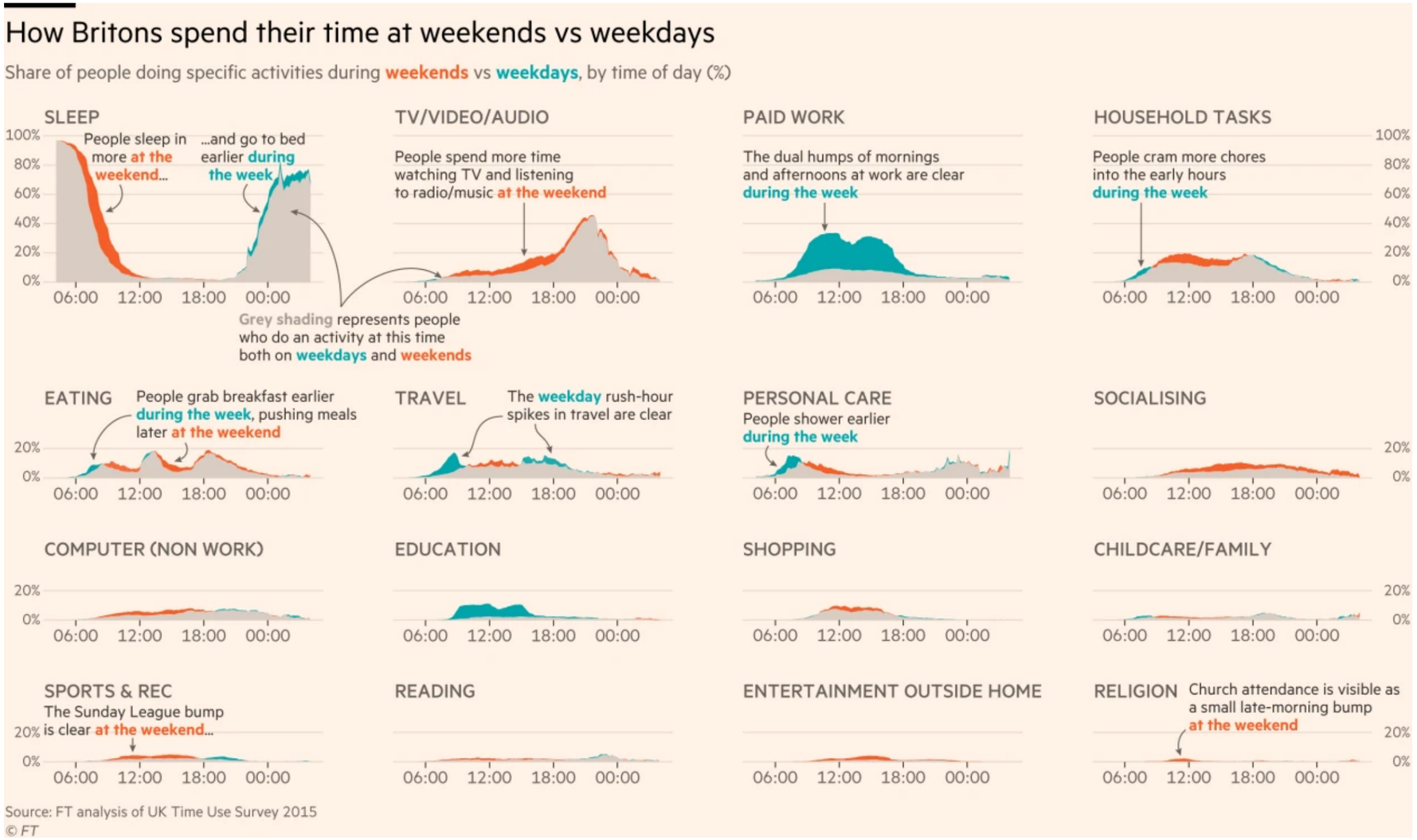
An enligthening data visualisation will be incomplete without a well worded title



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

- More example can be found here

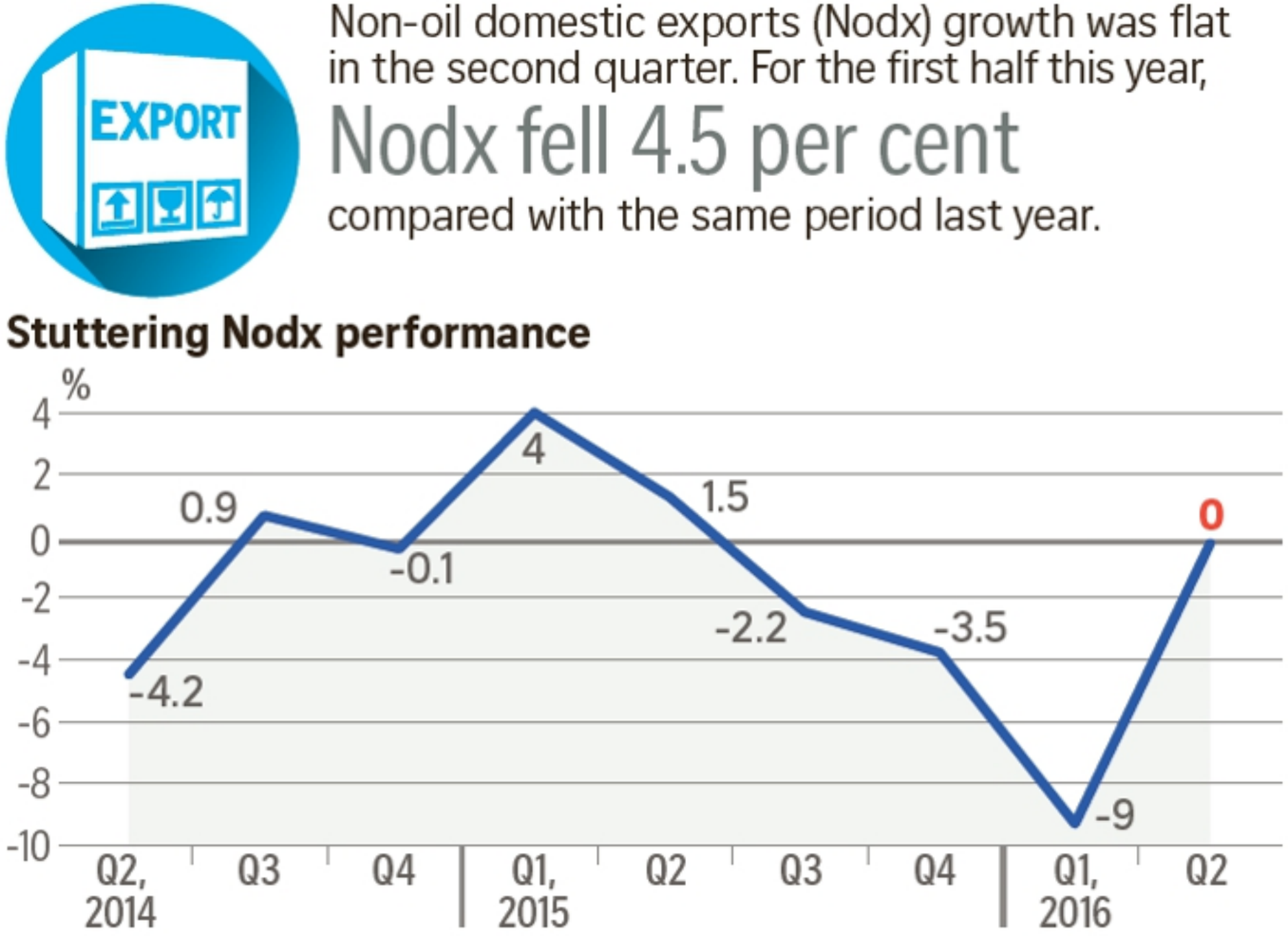
Using Annotation to tell data story



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

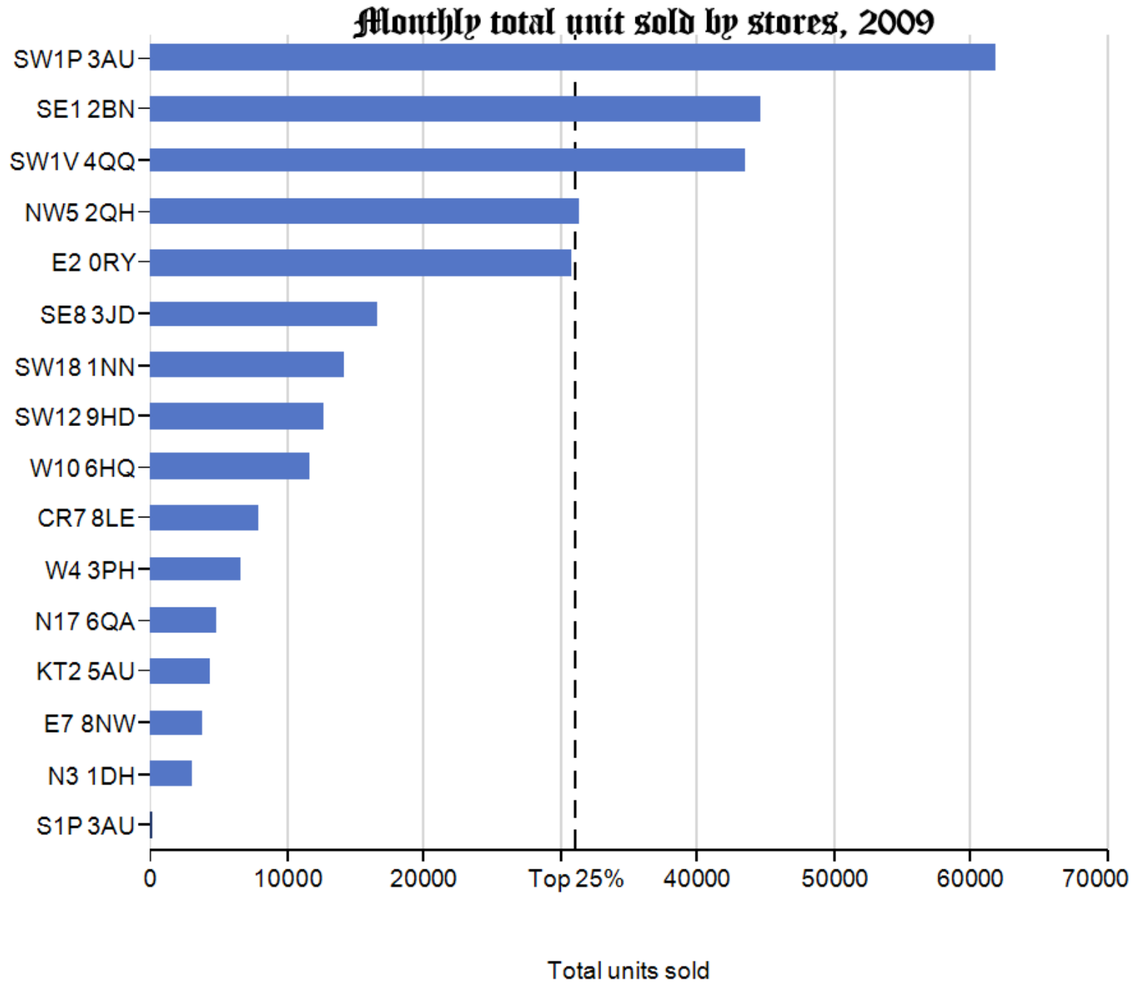
Graphical Integrity: Show Me the Truth

Don’t lie to yourself (or to others) with charts



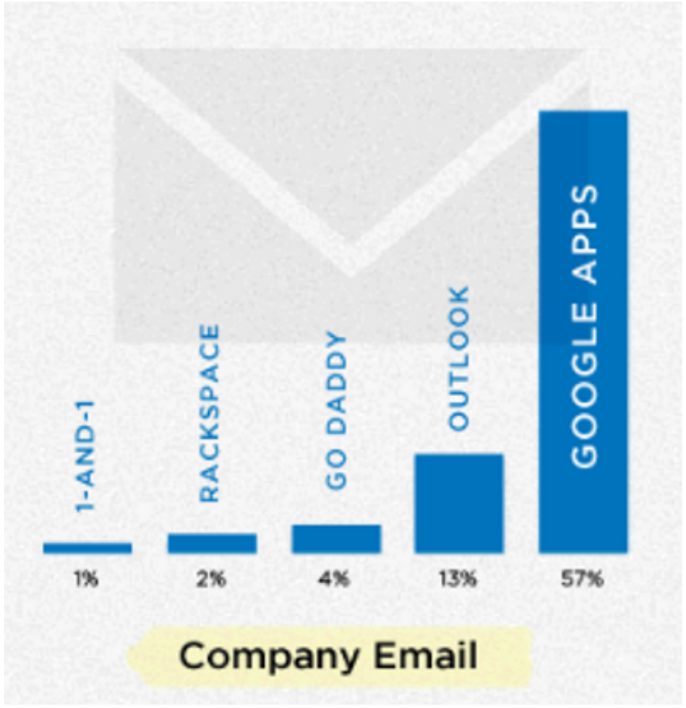
Graph typography

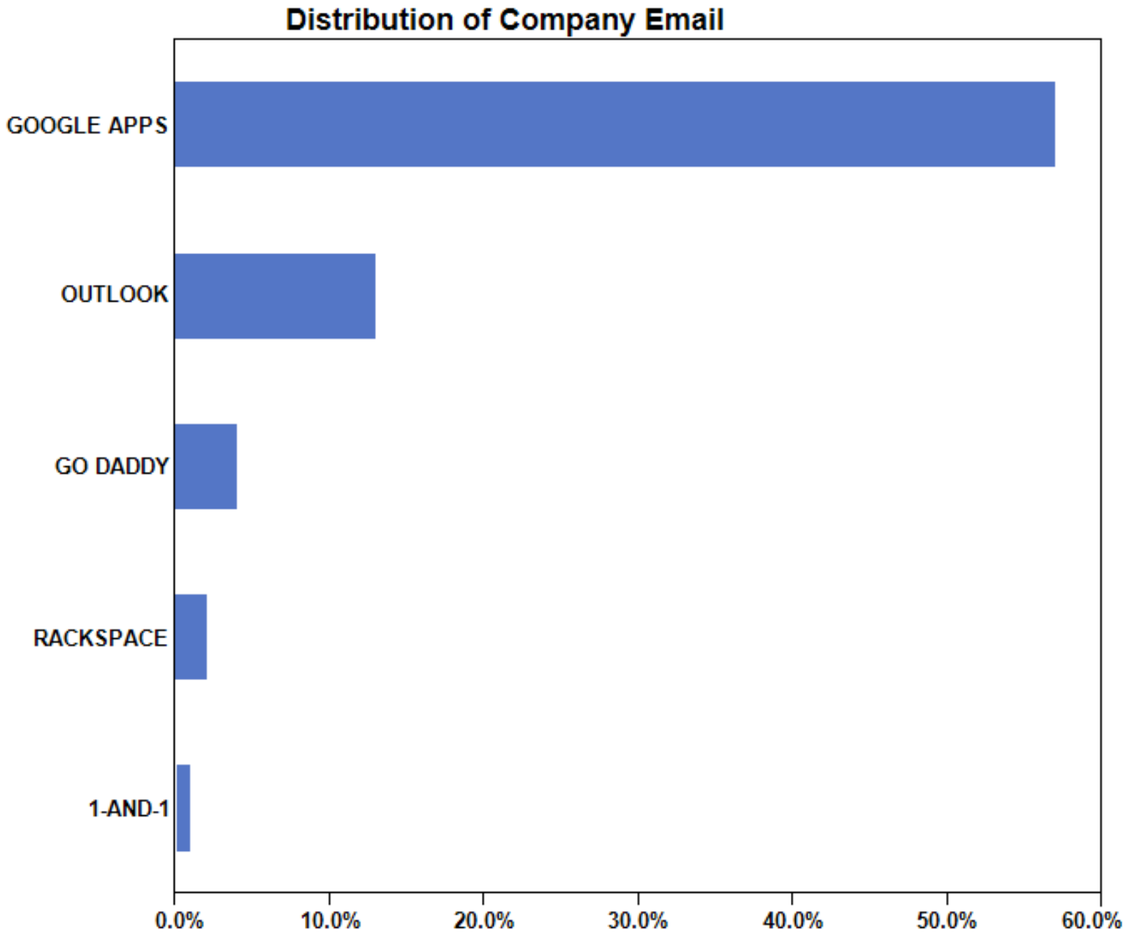
Avoid using artistic fonts



Graph Labeling

Orientation of label should be reader friendly

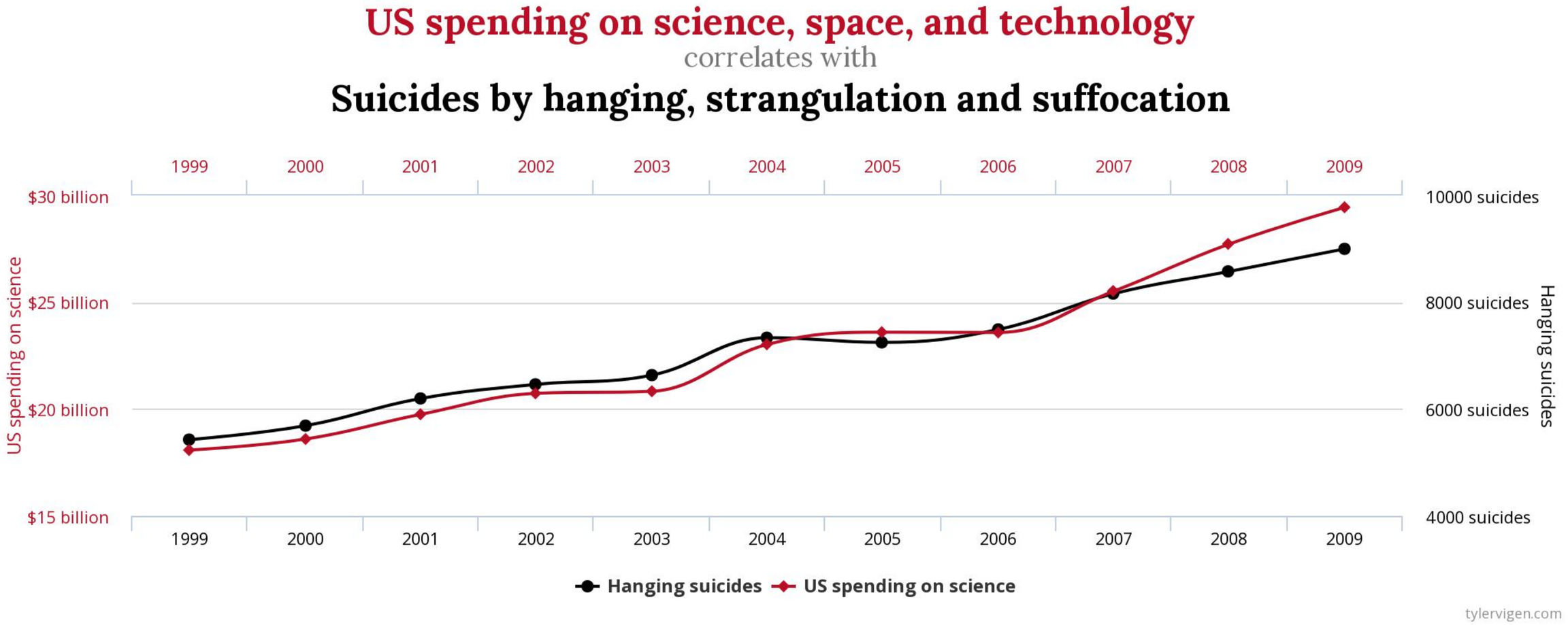




Three Bugs of Charts Interpretation

- 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

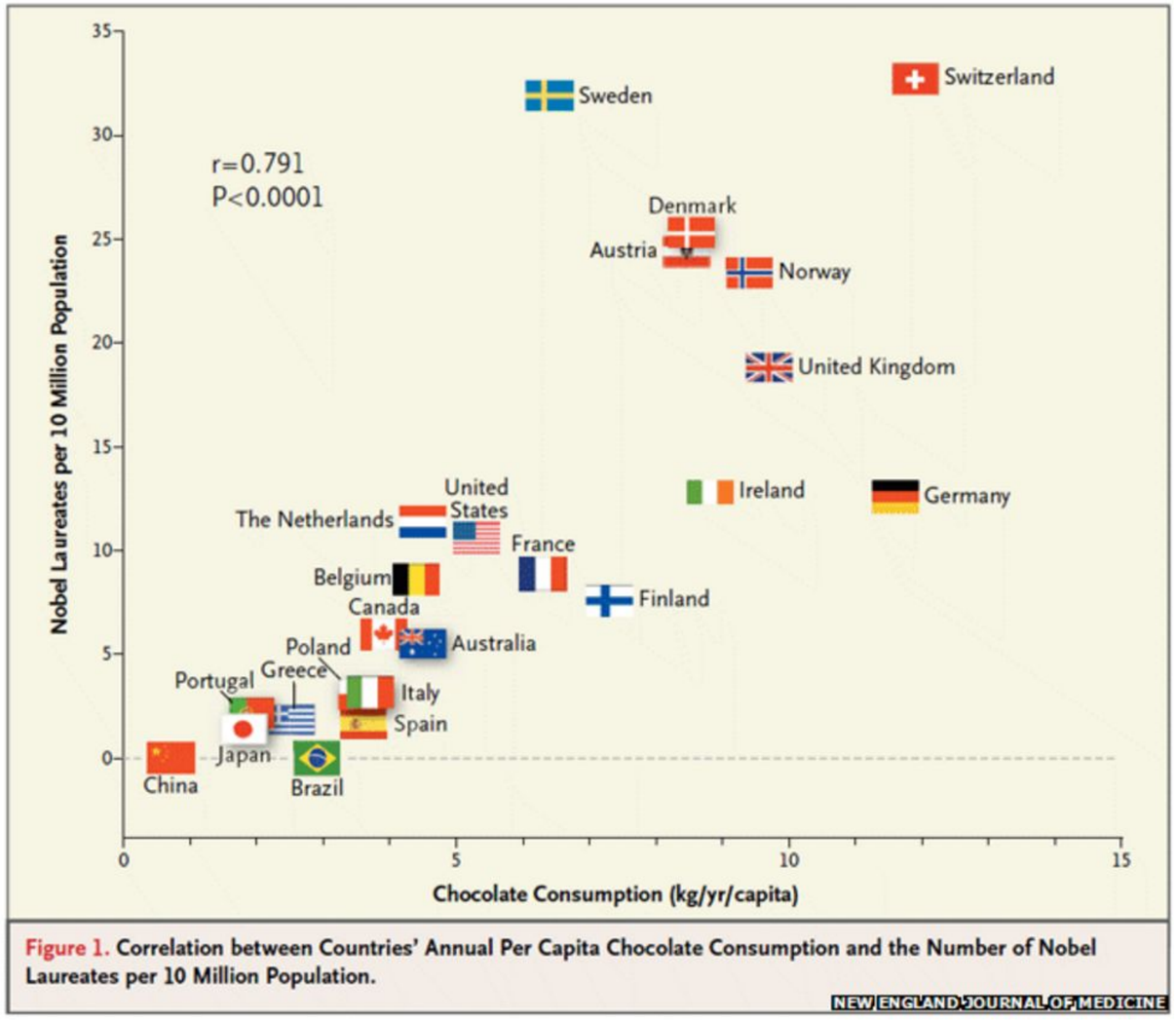


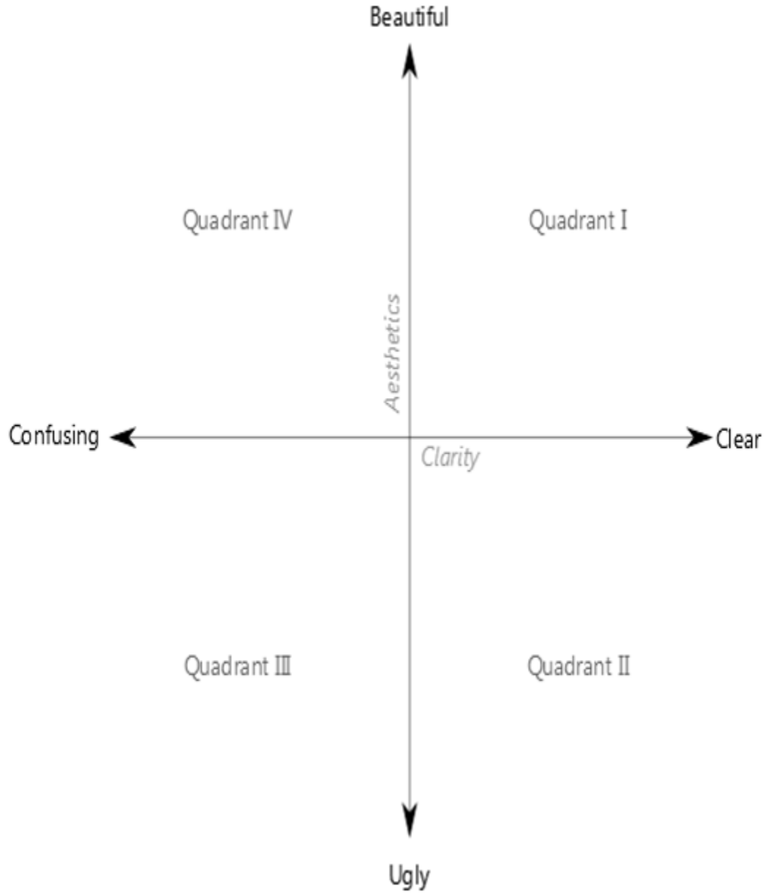
Figure 1. Correlation between Countries' Annual Per Capita Chocolate Consumption and the Number of Nobel Laureates per 10 Million Population.

NEW ENGLAND JOURNAL OF MEDICINE

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

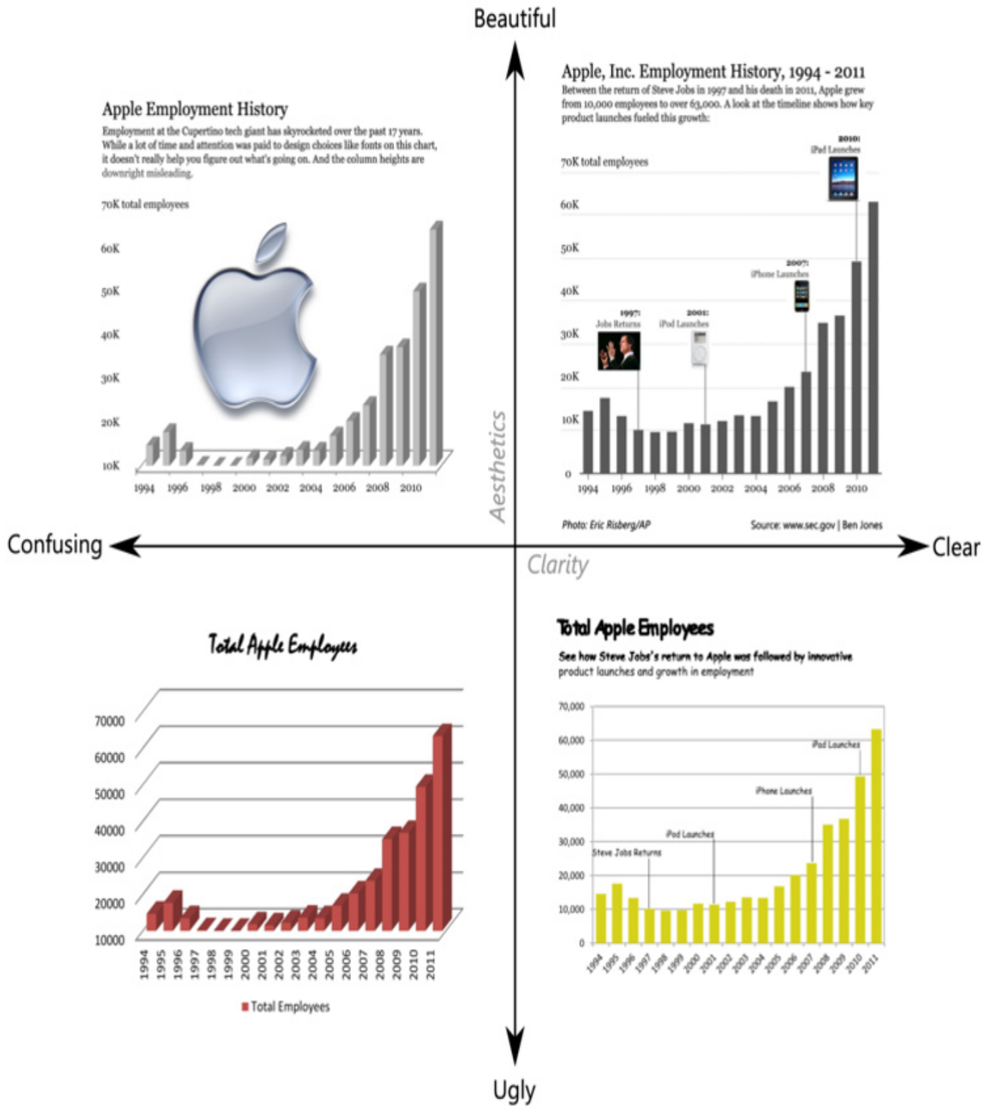
Data Visualization: Clarity or Aesthetics?

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:



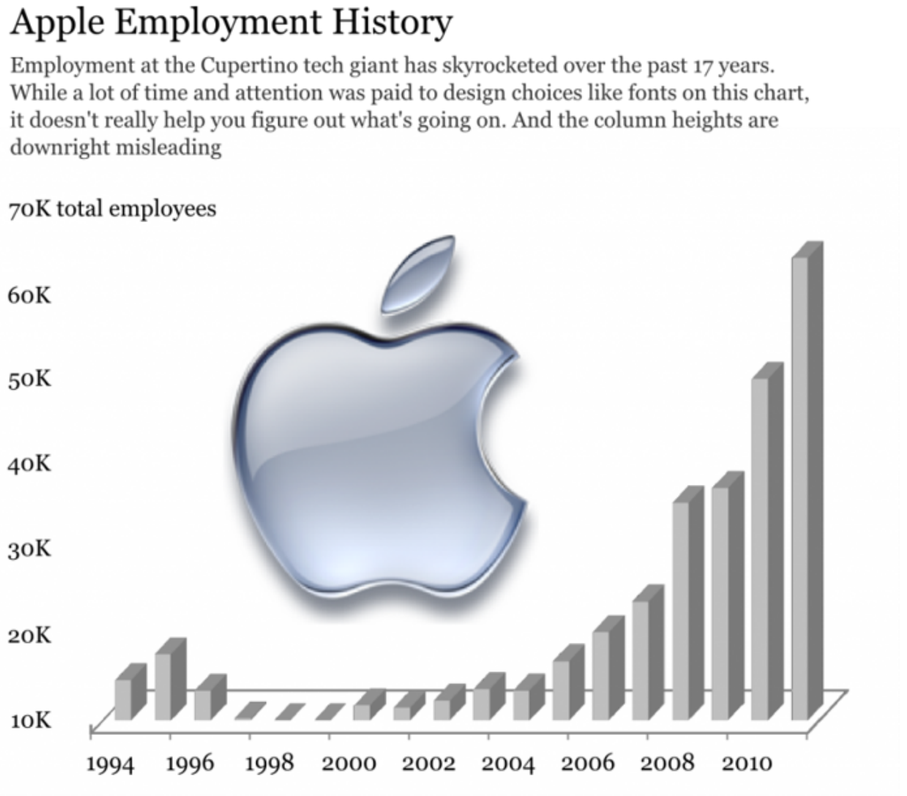
Source: Data Visualisation: Clarity or Aesthetics

A Tale of Four Quadrants



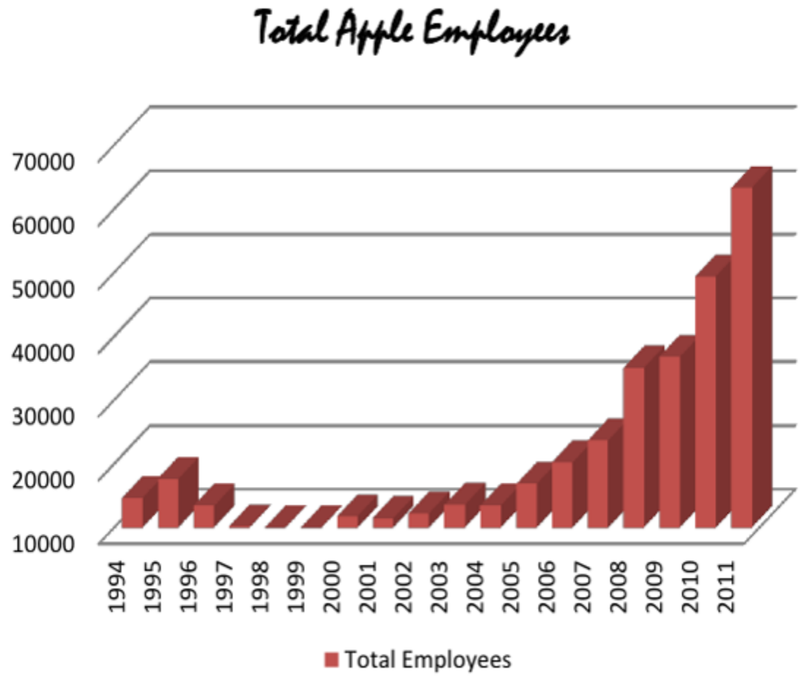
Quadrant IV – Confusing yet Beautiful

- 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.



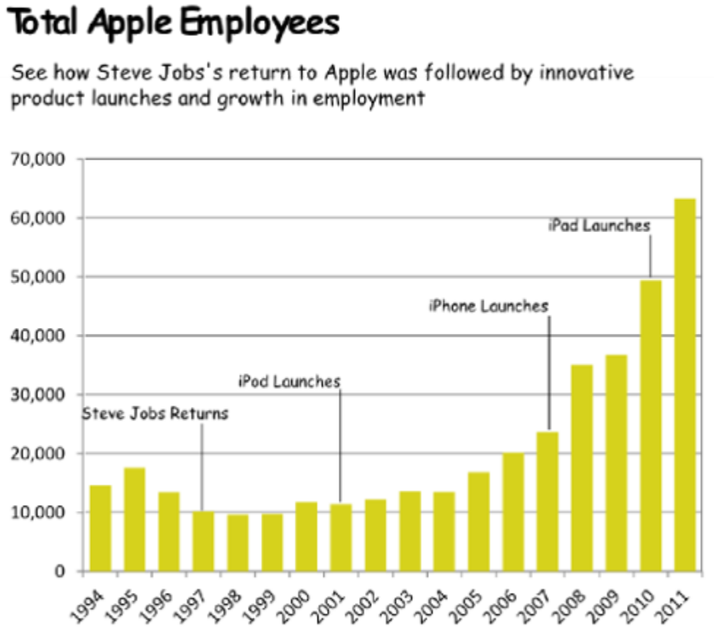
Quadrant III – Confusing and Ugly

- 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.



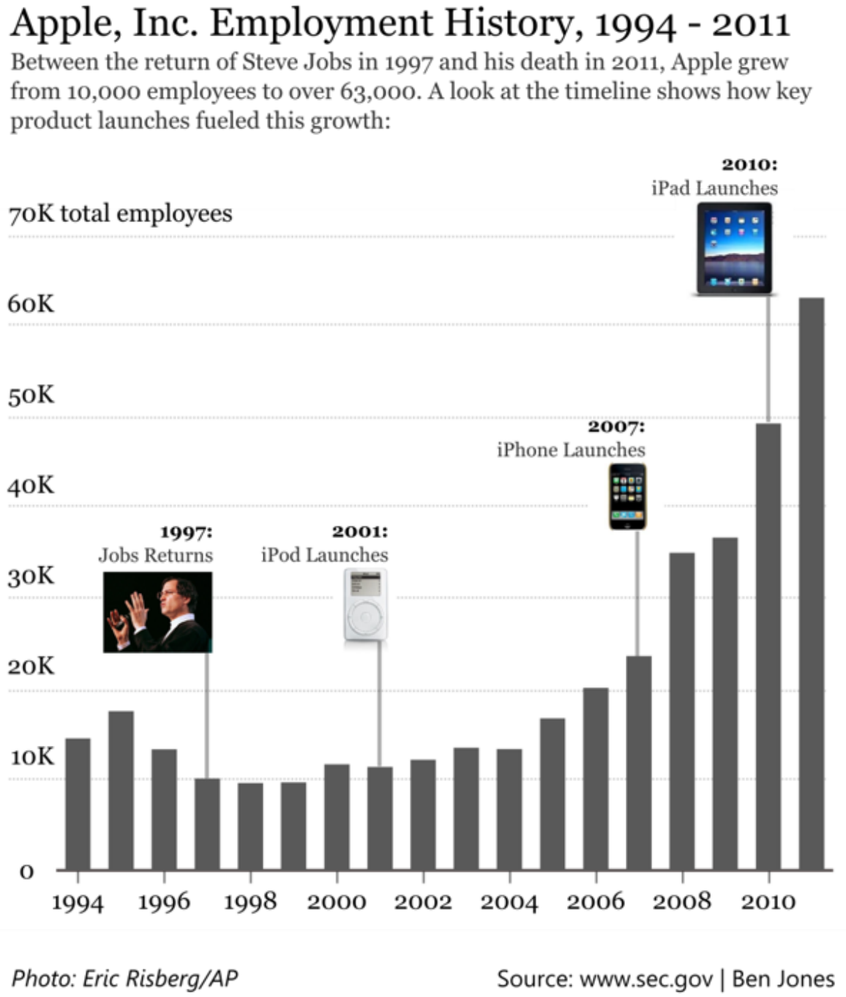
Quadrant II – Clear but Ugly

- 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.



References

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Robbins, Naomi B. (2005) **Creating More Effective Graphs**, John Wiley & Sons, New Jersey, USA

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