Data Visualisation

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Chapter 7 – Designing The Visualisation

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The Visualisation Design Process

Getting Started

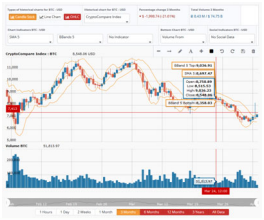
- Data visualisation has both **aesthetic** and **scientific** design elements.
- The aesthetic elements are more **subjective** and can be strongly biased by the designer's **artistic preferences**.
- However, the **scientific** aspects of presenting numbers and measurements has a more **logical sequence of steps** that we can follow[1],[2], which are essentially:

[1] S.M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)
[2] Michael Schermann - A Reader on Data Visualization, Patterns - https://mschermann.github.io/data_viz_reader/patterns.html

Know The Purpose

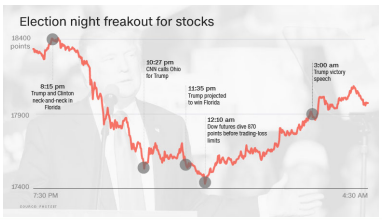
What Is It For?

- First, find out if the **purpose**[3] of the visualisation is **exploratory** or **explanatory**[1].
- **Exploratory** visualisation is designed help us explore and analyse the data to **derive insights** and **test hypotheses**.
- When we want to share our specific findings to an audience, **explanatory** visualisation is used to **communicate** the **specific story** embedded in the data.
- These two purposes are seldom effectively served by the same visualisation design.



Exploratory chart of Bitcoin prices from CryptoCompare.

Taken from [4]



Explanatory chart of the stock market performance during 2016 US Presidential election night.

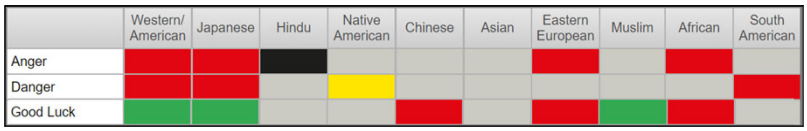
Taken from [4]

[3] R. Kosara, Reflecting on the Design Criteria for Explanatory Visualizations (2016) - https://research.tableau.com/sites/default/files/Kosara-C4PGV-2016.pdf
[4] DataViz Tip #21: Explanatory vs. Exploratory Charts - https://www.amcharts.com/dataviz-tip-21-explanatory-vs-exploratory-charts/

Know Your Audience

Who Is It For?

- It is important to know the audience the visualisation is targeted for as factors like their **cultural** background, **expertise** level, etc can influence the design of an effective and meaningful visualisation[5].
- For example, for a Chinese audience, the colour red represents a positive event (e.g. increasing profits), while western audiences tend to view green as representing a positive trends.
- **Discipline variations** too can be significant. Visualisation charts the financial community is familiar with are usually different from that of scientific communities, and these differences can even vary between the various scientific & engineering disciplines.



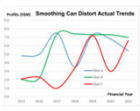
[6] Image extracted from R. Allison, Colors represent different things, in different cultures (2017) - https://blogs.sas.com/content/sastraining/2017/06/29/colors-in-different-cultures/

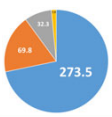
[5] Mustapha Mekhatria, 5 Steps to Create an Effective Data Visualization (2017) - https://www.highcharts.com/blog/post/5-steps-to-create-an-effective-data-visualization/

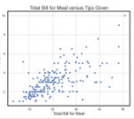
Know The Right Chart Type

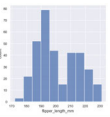
Which Should I Use?

- While it is possible to visualise the data using several different chart types, it is important to choose the type that can best communicate the story **clearly** and **accurate** by separating the background noise from the **intended message**[7].
- There are four basic chart types:
  - **Comparison chart** - e.g. a line chart displaying the profits of 3 departments over 7 years.
  - **Composition chart** - e.g. a pie chart displaying the market share of telcos in Singapore.
  - **Relationship chart** - e.g. a scatter plot of the relationship between tips given and cost of meal.
  - **Distribution chart** - e.g. a column histogram displaying the distribution of exam grades.







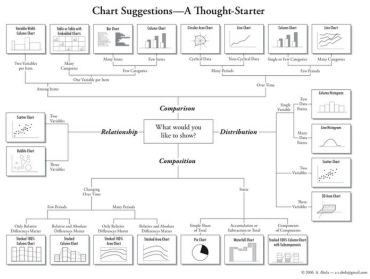


[7] Jānis Gulbis, Data Visualization – How to Pick the Right Chart Type? (2016) - https://eazybi.com/blog/data_visualization_and_chart_types/

Selecting The Chart

Which Should I Use?

- A suitable chart can be determined by answering several questions[7].
  - How many variables do you want to show in a single chart? (1, 2, 3 or many?)
  - How many items (data points) will you display for each variable? (only a few or many?)
  - Will you display values over a period of time, or among items or groups?
- The chart selection diagram by Andrew Abela can then be used to pick the right chart for the data type being visualise.

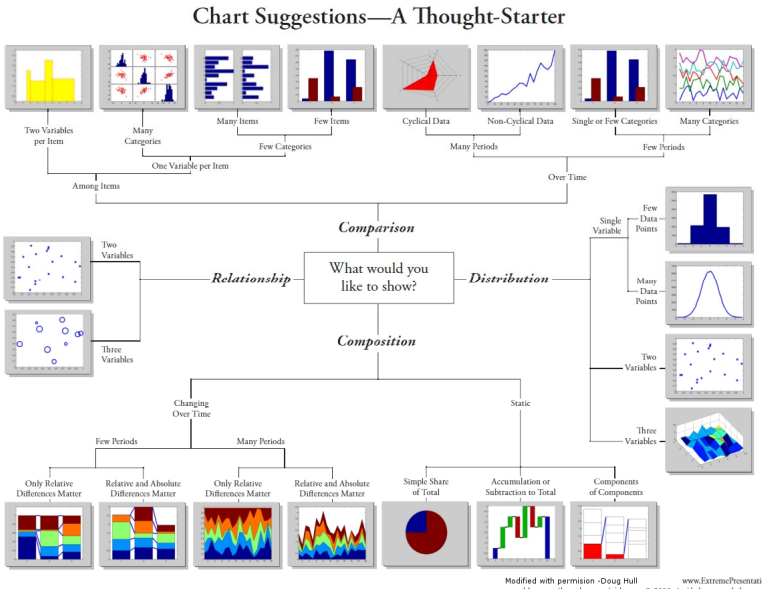


[7] Jānis Gulbis, Data Visualization – How to Pick the Right Chart Type? (2016) - https://eazybi.com/blog/data_visualization_and_chart_types/

Selecting The Chart

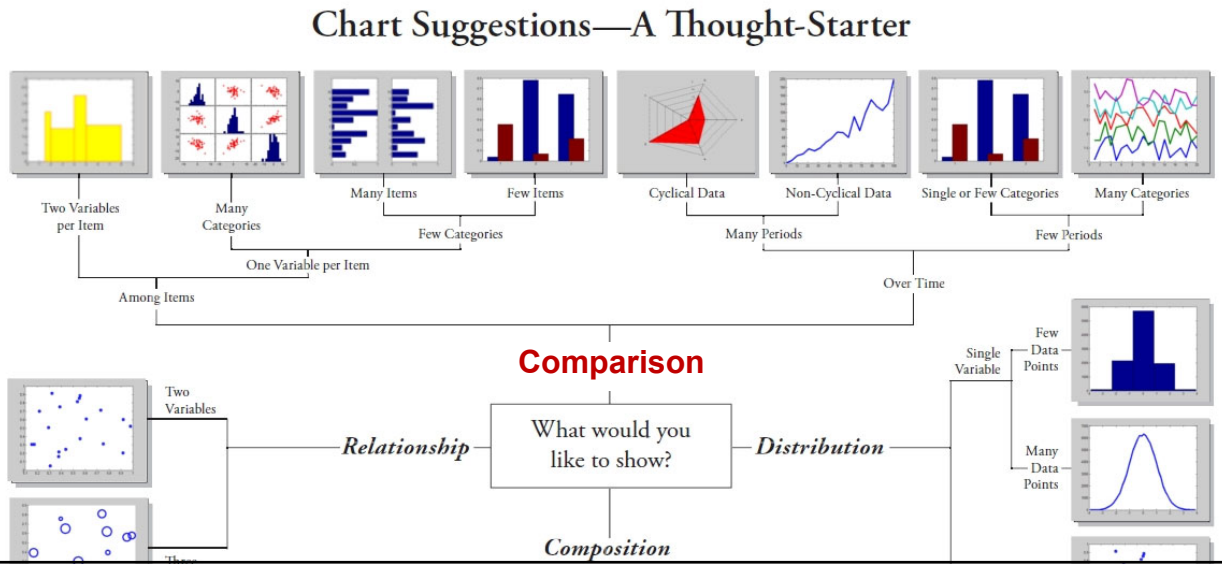
Which Should I Use?

- Andrew Abela's Chart Chooser in Colour[8].



[8] Andrew Abela's Chart Chooser - https://apandre.files.wordpress.com/2011/02/chartchooserincolor.jpg

Selecting The Chart



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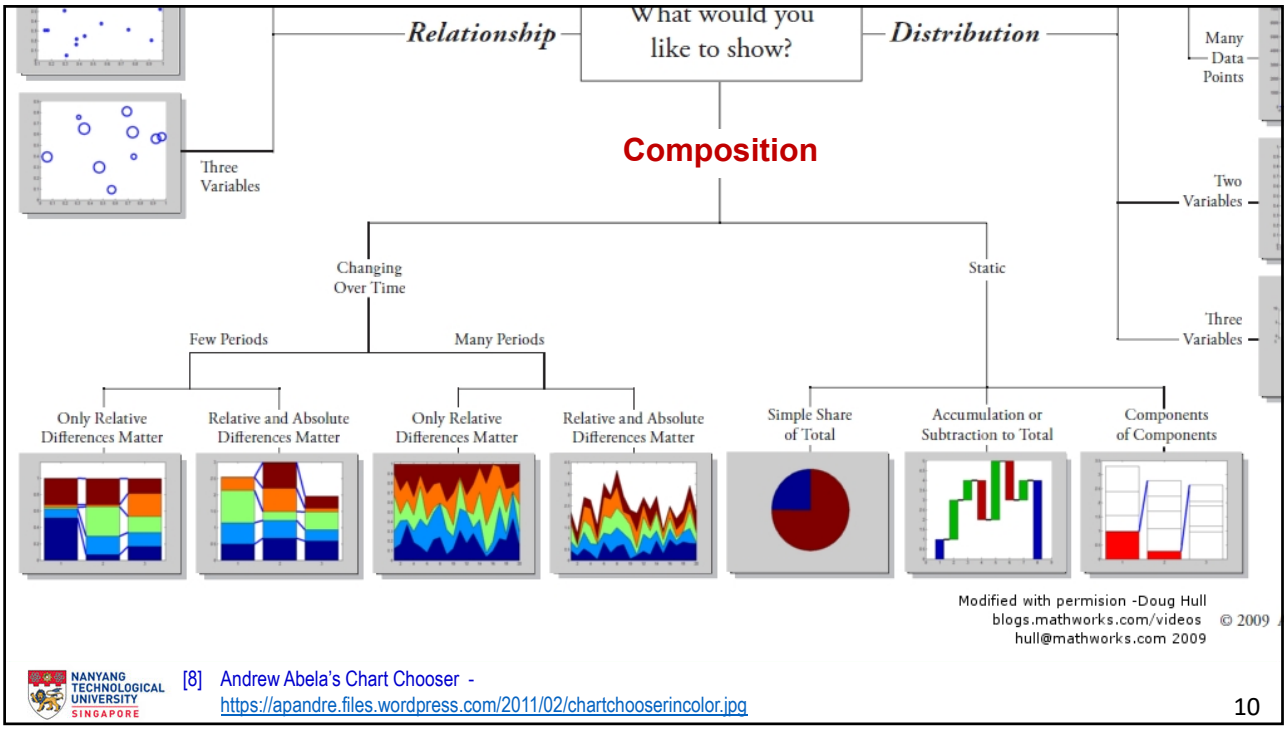

[8] Andrew Abela's Chart Chooser - https://apandre.files.wordpress.com/2011/02/chartchooserincolor.jpg

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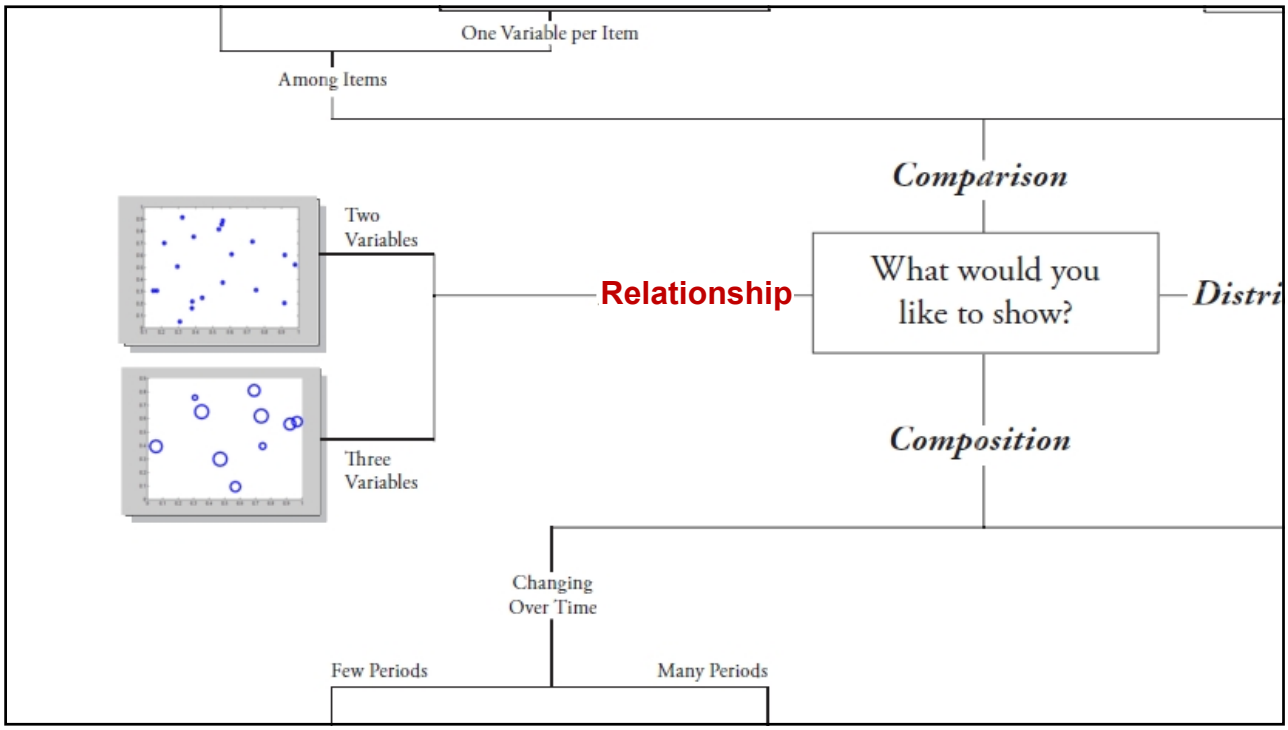
One Variable per Item
Among Items
Comparison
Two Variables
Relationship
What would you like to show?
Distri
Three Variables
Composition
Changing Over Time
Few Periods
Many Periods

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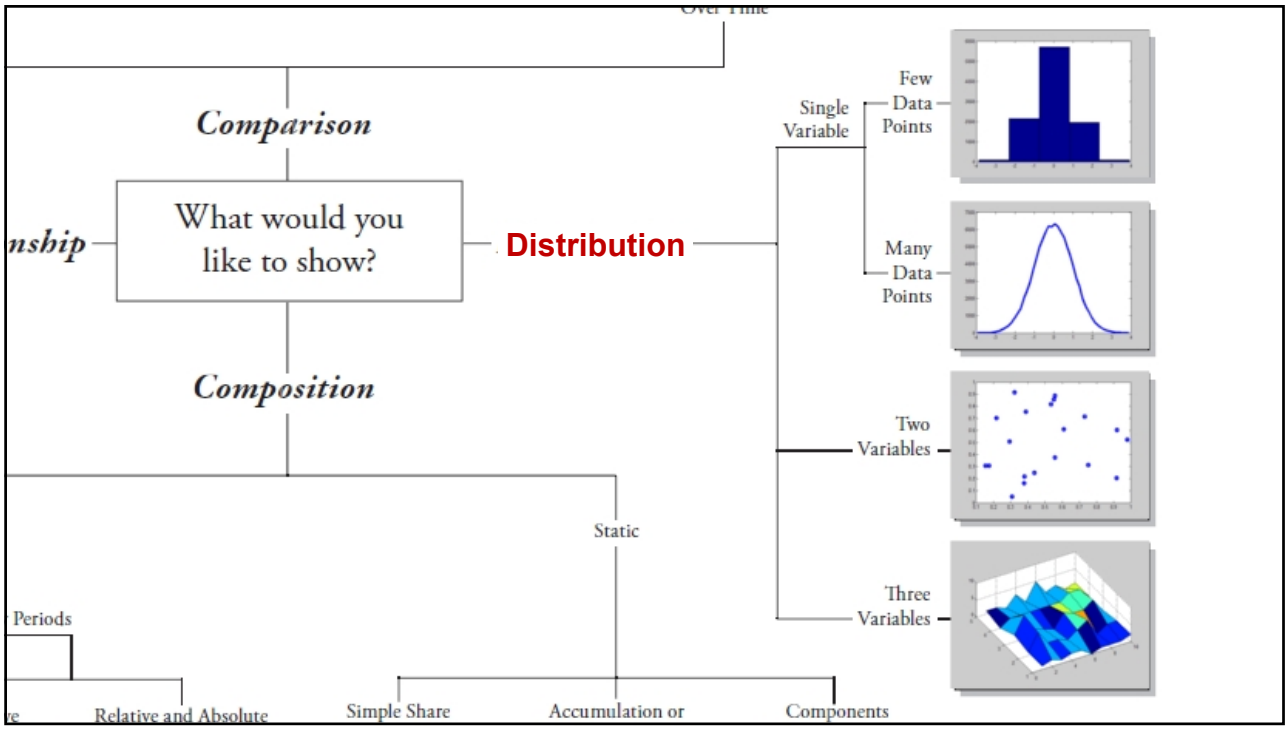
Comparison
nship
What would you like to show?
Distribution
Composition
Single Variable
Few Data Points
Many Data Points
Two Variables
Three Variables
Static
Periods
Relative and Absolute
Simple Share
Accumulation or
Components

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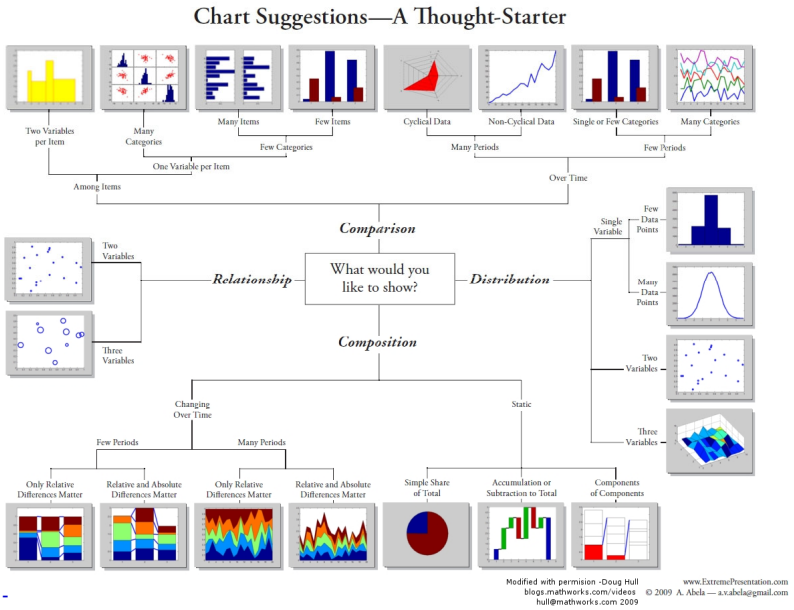
Selecting The Chart

Which Should I Use?

- Andrew Abela's Chart Chooser in Colour[8].

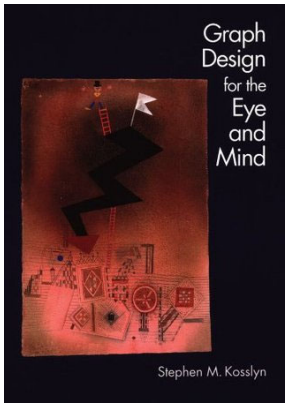


[8] Andrew Abela's Chart Chooser - https://apandre.files.wordpress.com/2011/02/chartchooserincolor.jpg

Psychological Principles of Effective Graphics

The Eight-Fold Way

- Stephen Kosslyn proposed eight very useful principles to guide the design of **effective data visualisation**[1].
- This principles are rooted in his findings about how humans **perceive** and **comprehend visual information**.
- The eight principles are organised into three groups, with each group addressing different goals of:
  - **Connect** with your audience.
  - **Direct** the audience attention through the visual.
  - **Promote** understanding and memory retention.



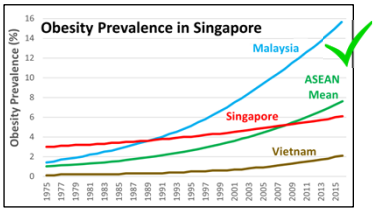
[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

1. Connect with audience

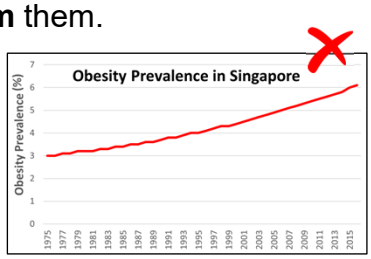
Principle of Relevance

The Goldilocks Principle

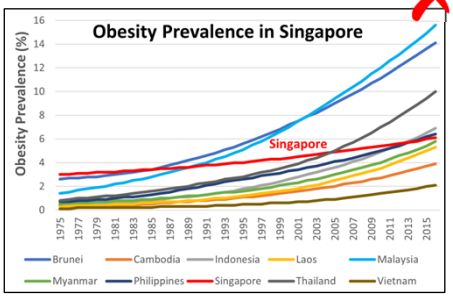
- **Communication is most effective when neither too much nor too little information is presented**[1].
- Decide on **exactly what message** you want to convey. Then use only the **relevant data** that will help you communicate this message.
- Presenting too little may **puzzle** the audience, while presenting too much will distract and **overwhelm** them.



Just right – comparison gives meaning



Too little info – no context to give meaning



Too much info – cluttered & confusing!

[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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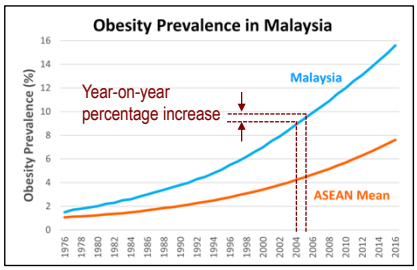
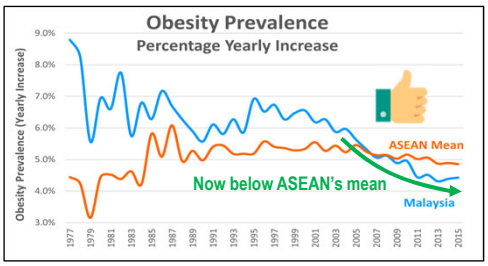
Ethical Visualisation

Don't Hide Behind Percentages

- The Director of Weight Loss is concern about the effectiveness of his obesity prevention programmes and has to give an update to the cabinet next week. He decided to use year-on-year % increases in his chart...



Malaysia's alarming increase in obesity prevalence



Percentage increase from one year to the next (smoothing on moving average data, 3 samples)

Has ethical visualisation been violated here?

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Note: Obesity dataset available at: https://ourworldindata.org/grapher/share-of-adults-defined-as-obese

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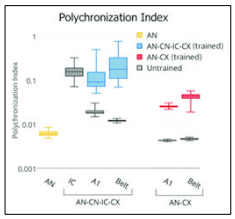
2. Connect with audience

Principle of Appropriate Knowledge

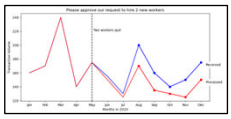
Know Your Audience

- **Communication requires prior knowledge of relevant concepts, jargon and symbols**[1].
- **Know** you audience and their familiarity with the content and charts being shared. Good visuals present new information but it should not be so new that it is unrelated to the knowledge the audience possess.

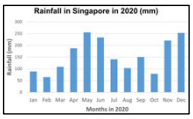
Candlestick chart
(used in financial visualisation)



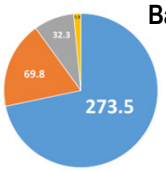
Box & whisker chart
(scientific visualisation)



Line chart



Bar chart



Pie chart

The common & familiar type of charts

[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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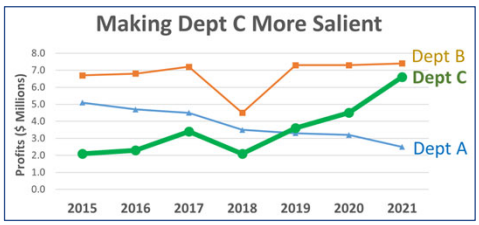
3. Direct and hold attention

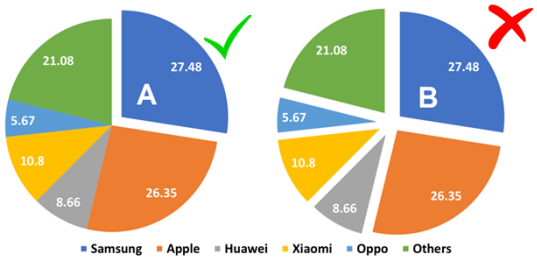
Principle of Salience

Attention to the Important

- **Attention is drawn to large perceptible differences**[1].
- The most visually prominent aspects of a visual will **draw attention** to them, for this reason they should embed the **most important** information being conveyed.
- All visual properties are relative, so what counts as "visually striking" depends on the properties of the display as a whole.



Vary the saliency of the line to indicate its importance



The contrast of the intact segment pieces makes the exploding pie segment (A) more salient[1]

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[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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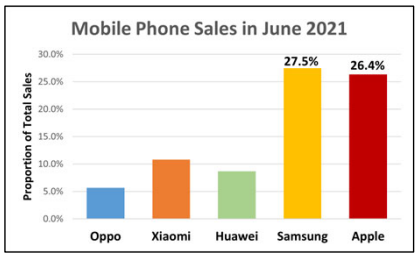
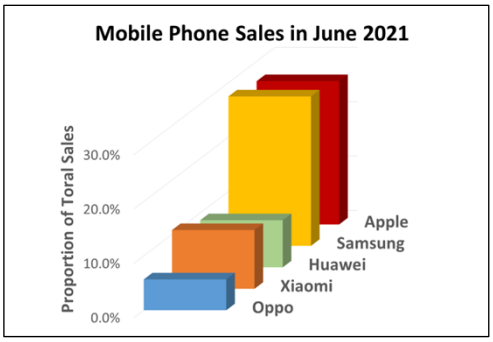
Ethical Visualisation

Don't Hide Behind Another 3D Bar

- Apple mobile sales has fallen behind slightly in June 2021. An Apple sales executive was wondering how to present these figures to her boss and was thinking of using a colourful 3D bar chart…



Proportion of worldwide mobile phone sales in June 2021



The 3D occluding bar chart

Has ethical visualisation been violated here?

Note: We see partially covered objects as further away. Our **size constancy** mechanism makes the rearmost object larger than they actually are[1].

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Note: Mobile sales dataset available at: https://gs.statcounter.com/vendor-market-share/mobile

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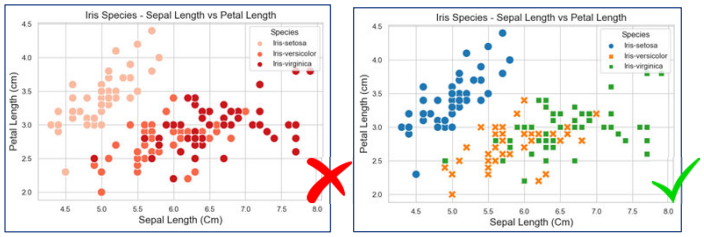
4. Direct and hold attention

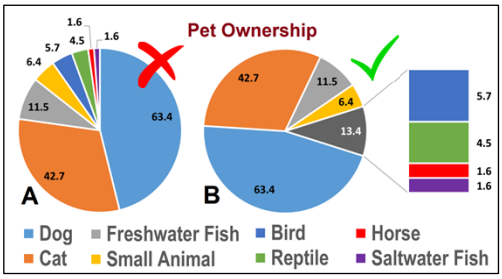
Principle of Discriminability

Maintain Good Contrast

- **Two properties must differ by a large enough proportion or they will not be distinguished**[1].
- This principle relates to Weber's law on just noticeable difference. Be mindful your design and colour choices allow viewers to discriminate between variables and between the variable and its background.



Combine strong distinctive colours & shapes to improve discriminability



Small pie segments in A cannot be discriminated. Design B allows them to be visualise.

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[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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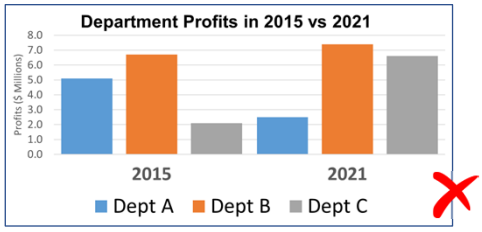
5. Direct and hold attention

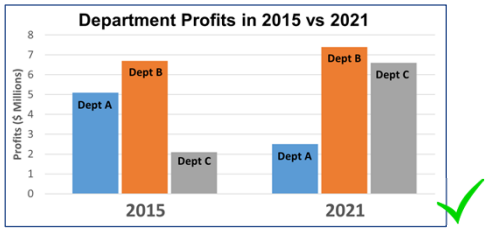
Principle of Perceptual Organisation

Making Visual Sense

- **People automatically group elements into units, which they then attend to and remember**[1].
- We should exploit the various Gestalt laws that govern how we group visual object at a sub-conscious level to improve the effectiveness of our visual communication.



This visual does a poor job in showing the comparative change in department profits



The Dept bar proximity and direct labelling create distinct groups & association to aid visual comparison

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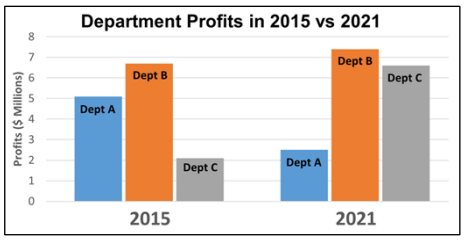
[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

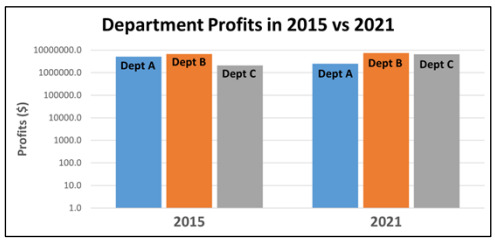
Ethical Visualisation

Scales That Mislead

- The profits of **Dept A** has been steadily declining over the years and is currently the lowest. There is a critical profit review with the board to decide its fate going forward. The head of Dept A is working on the presentation charts….



Profits of Dept A is currently the lowest of the three departments



The $\log_{10}$ scale applied to the $M profits hides the big profit differentials

Has ethical visualisation been violated here?

Note: The logarithmic scale has a tendency to compress the distances between large numbers making even large differences insignificant[1].

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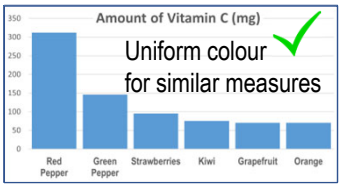
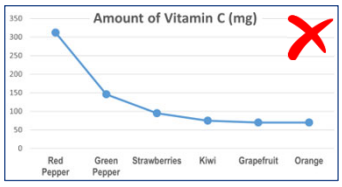
6. Promote understanding and memory

Principle of Compatibility

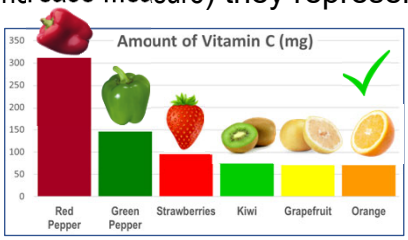
Saying The Same Thing

- **A message is easier to understand if its form is compatible with its meaning**[1].
- Compatibility dictates that we choose the right type of chart for the intended purposes (e.g. trends and continuous changes are best depicted with line charts, whilst discrete entities are better served with bar charts).
- Visual attributes (e.g. colours, height, etc) should match the meaning (e.g. red for "stop" & green for "go") and the variations (increase height maps to increase measure) they represent.





Discrete bars are more compatible to nominal data then continuous lines



If multi-coloured bars used, matching bar colour to fruit colour improves compatibility

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[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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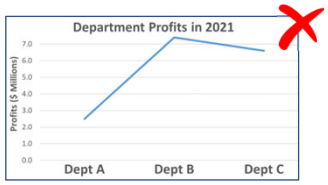
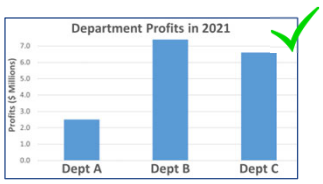
7. Promote understanding and memory

Principle of Information Changes

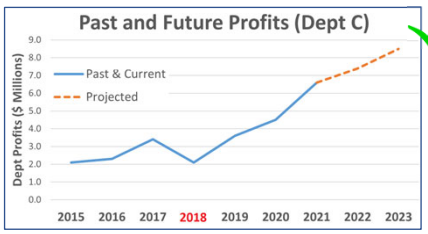
Meaningful Changes

- **People expect changes in properties to carry information**[1].
- Changes in the visual (e.g. changing colour, texture, line height & width, etc) will be interpreted by viewer as conveying information .
- Similarly, viewers expect any information that should be conveyed in the visual will be indicated by some visible change (e.g. transition from current to projected profits in line chart should be indicated by a different colour or pattern).





If entities don't vary continuously, use bar instead of line



Projected profits & recession year clearly indicated

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[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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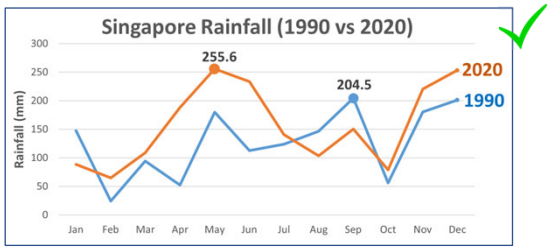
8. Promote understanding and memory

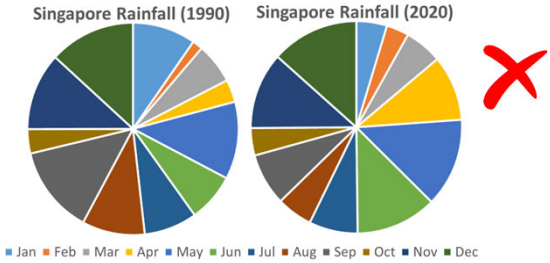
Principle of Capacity Limitation

Too Much Means Only A Little

- **People have a limited capacity to retain and process information. A message will not be understood if too much information must be retained or processed**[1].
- We can only maintain a limited amount of information in mind at any one time. Visuals should not require the viewer to hold more than about **four perceptual groups** in mind at once.



Visualising peak months with minimal cognitive load



Too many colours to compare!

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[1] Stephen M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

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Summary

Designing The Visualisation

- Effective visualisation design requires you to know the **purpose** and the **audience** you are designing for before you begin selecting what **suitable chart** to use.
- During the data visualisation design process, you need to be mindful of how humans **perceive** and **comprehend visual information**.
- Employ the eight psychological principles proposed by Kosslyn to help **connect** with the audience, **direct** their attention to your main points and facilitate their **understanding** and **retention** of your intended message.

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References for Designing the Visualisation

[1] S.M. Kosslyn, Graph Design for the Eye and Mind, Oxford University Press (2006)

[2] Michael Schermann - A Reader on Data Visualization, Patterns - https://mschermann.github.io/data_viz_reader/patterns.html

[3] R. Kosara, Reflecting on the Design Criteria for Explanatory Visualizations (2016) - https://research.tableau.com/sites/default/files/Kosara-C4PGV-2016.pdf

[4] DataViz Tip #21: Explanatory vs. Exploratory Charts - https://www.amcharts.com/dataviz-tip-21-explanatory-vs-exploratory-charts/

[5] Mustapha Mekhatria, 5 Steps to Create an Effective Data Visualization (2017) - https://www.highcharts.com/blog/post/5-steps-to-create-an-effective-data-visualization/

[6] Image extracted from R. Allison, Colors represent different things, in different cultures (2017) - https://blogs.sas.com/content/sastraining/2017/06/29/colors-in-different-cultures/

[7] Jānis Gulbis, Data Visualization – How to Pick the Right Chart Type? (2016) - https://eazybi.com/blog/data_visualization_and_chart_types/

[8] Andrew Abela's Chart Chooser - https://apandre.files.wordpress.com/2011/02/chartchooserincolor.jpg

Note: All online articles were accessed between June to July 2025