# The theory of data visualisation

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# Data Visualisation

- A scientific discipline involving the creation and study of the visual representation of data whose goal is to communicate information clearly and efficiently to users.

- Data Visualisation is both an art and a science.

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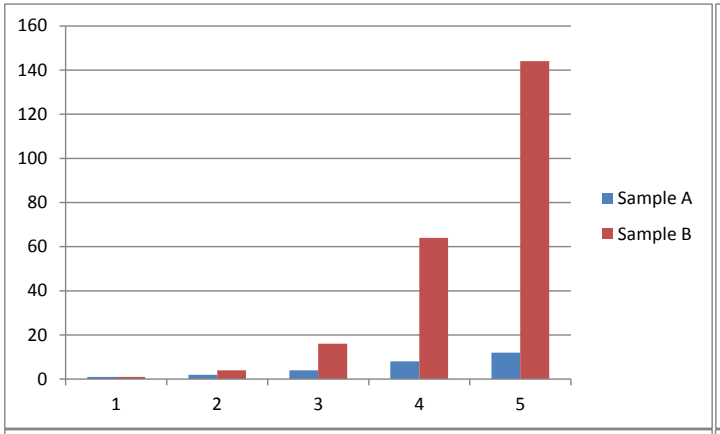
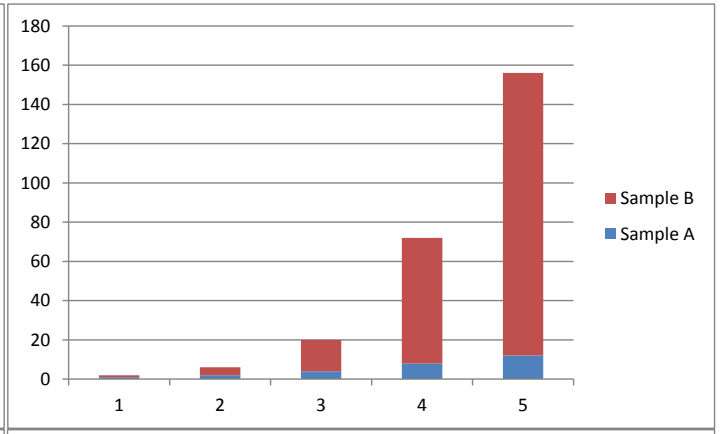
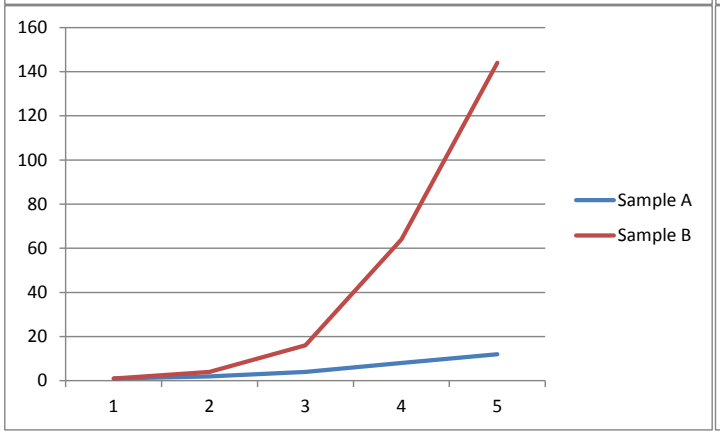
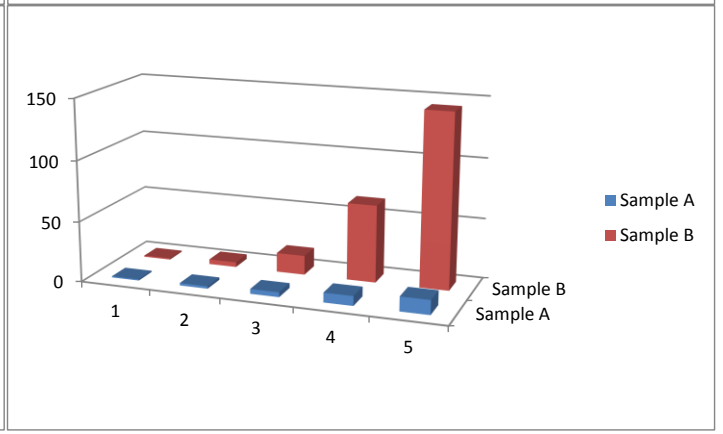
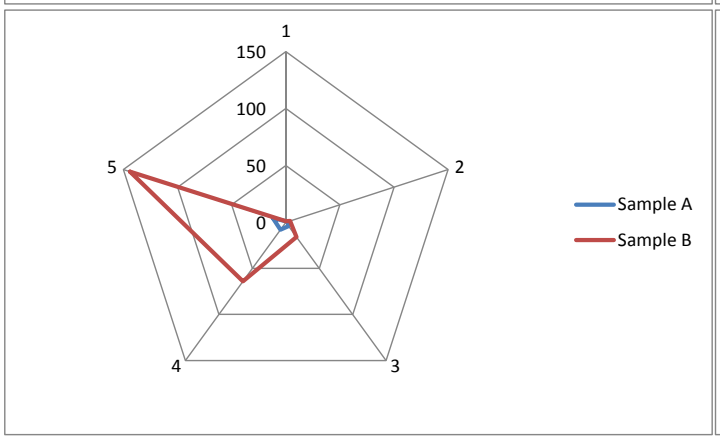
| Sample A | Sample B |
|---|---|
| 1 | 1 |
| 2 | 4 |
| 4 | 16 |
| 8 | 64 |
| 12 | 144 |

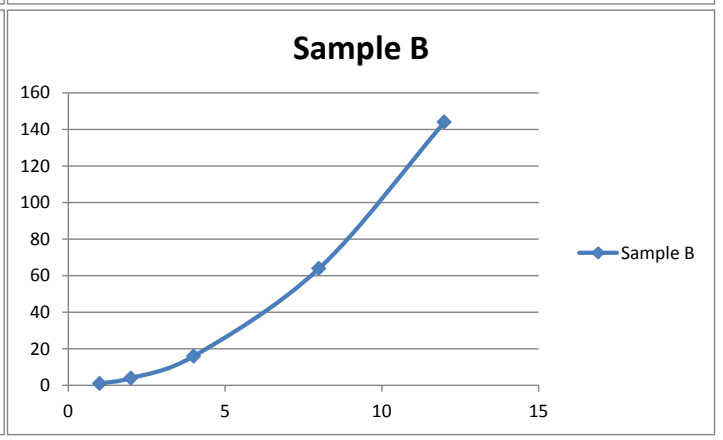
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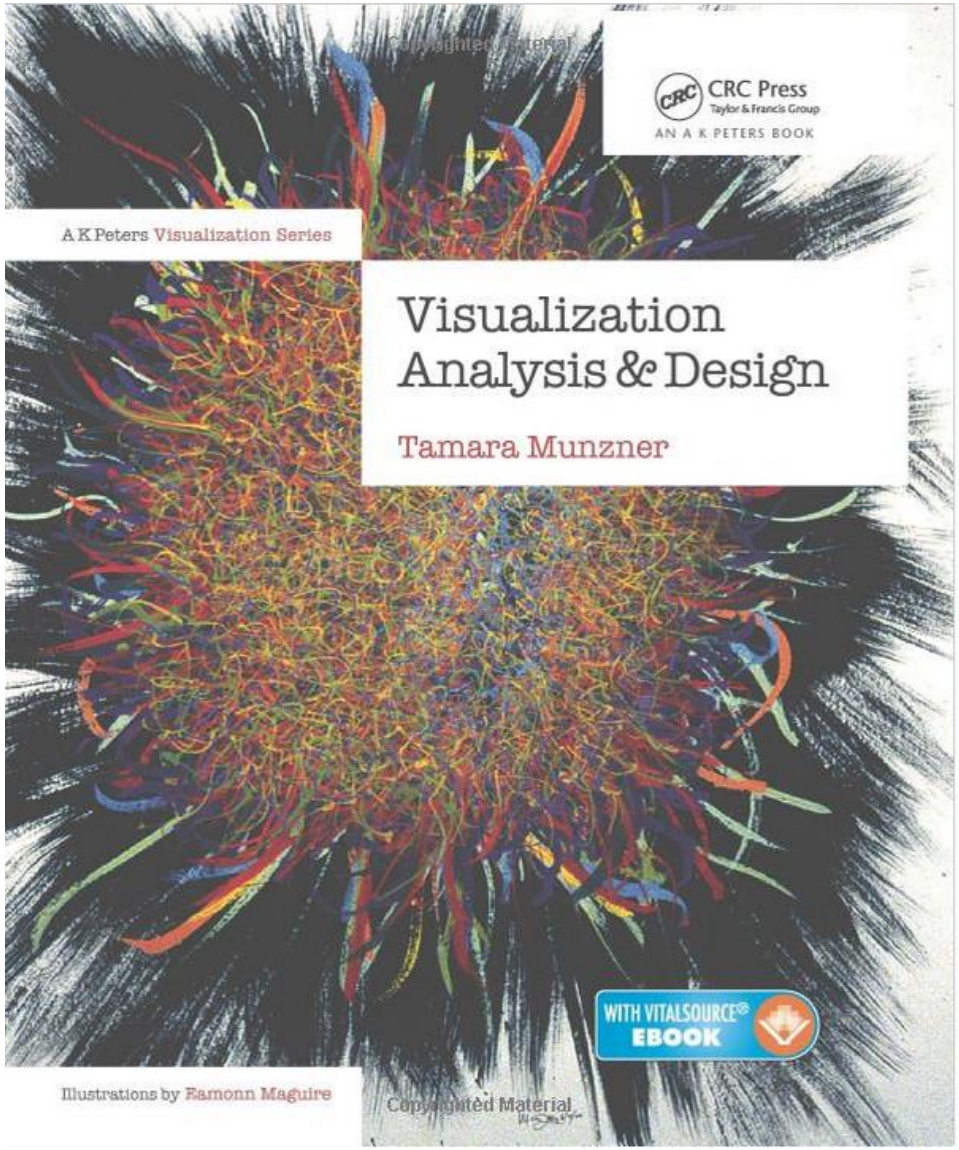


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http://www.cs.ubc.ca/~tmm/talks.html

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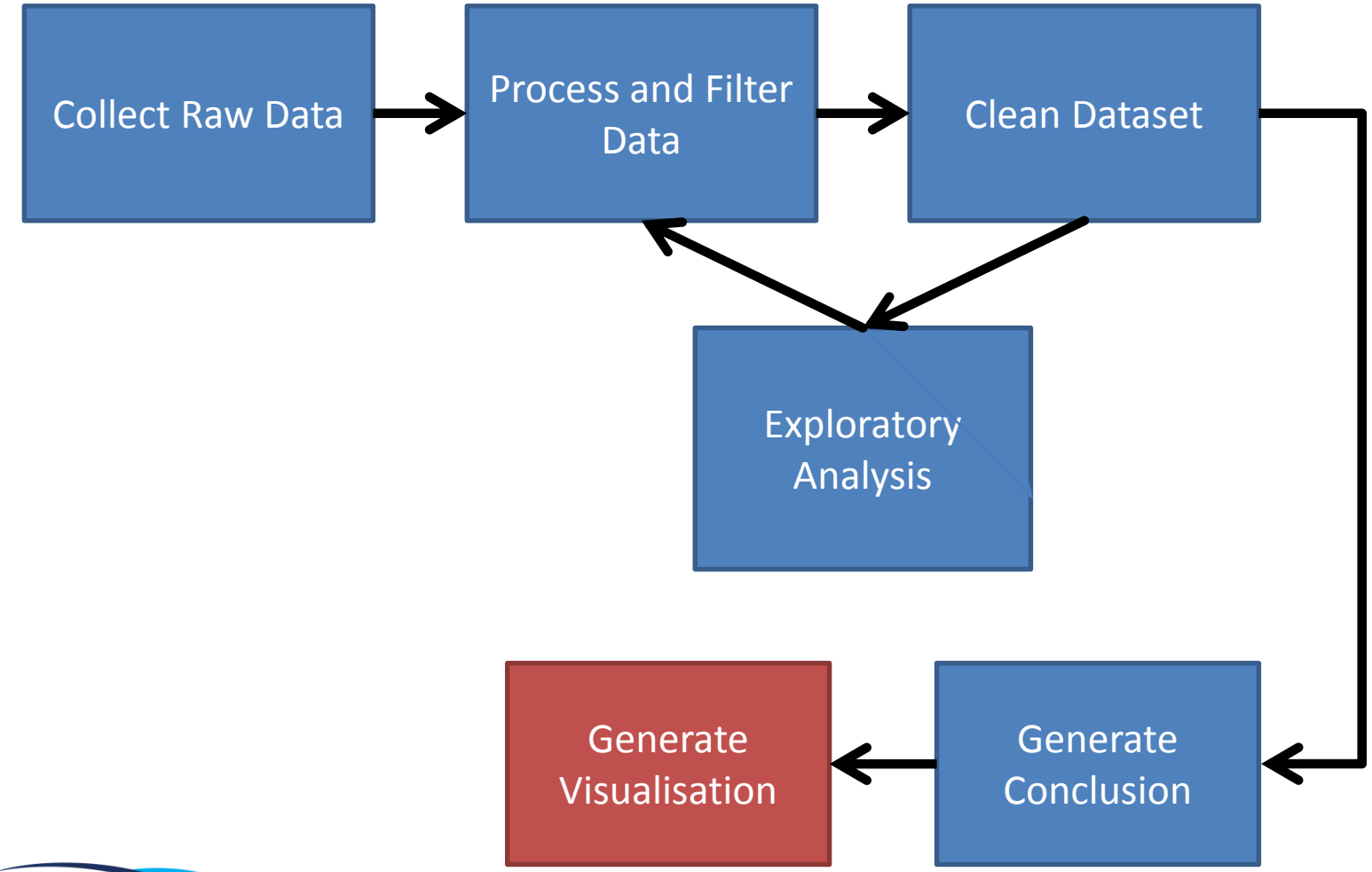
# Data Viz Process

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# A data visualisation should…

- Show the data
- Not distort the data
- Summarise to make things clearer
- Serve a clear purpose
- Link to the accompanying text and statistics

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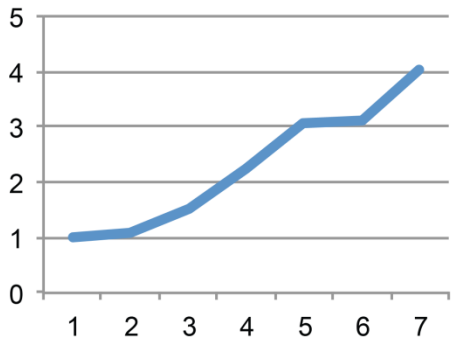
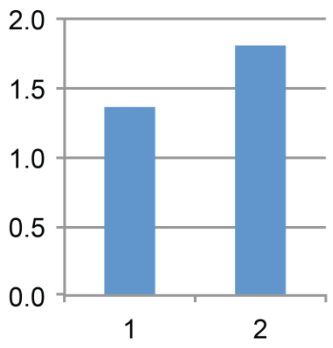
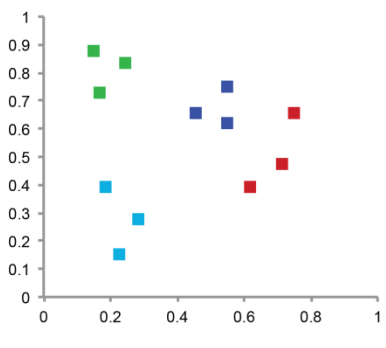
# Different representations have common elements



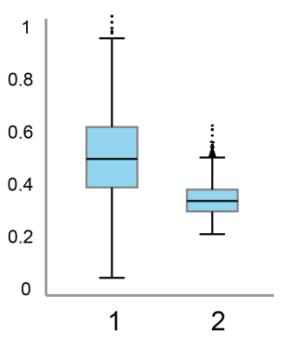

Relationship




Comparison




Composition




Distribution

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# Graphical Representations

- Basic questions
  - How are you going to turn the data into a graphical form (weight becomes length etc.)
  - How are you going to arrange things in space
  - How are you going to use colours, shapes etc. to clarify the point you want to make

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# Marks and Channels

- Marks
  - Geometric primitives
    - Lines
    - Points
    - Areas
  - Used to represent data sets
- Channels
  - Graphical appearance of a mark
    - Colour
    - Length
    - Position
    - Angle
  - Used to encode data

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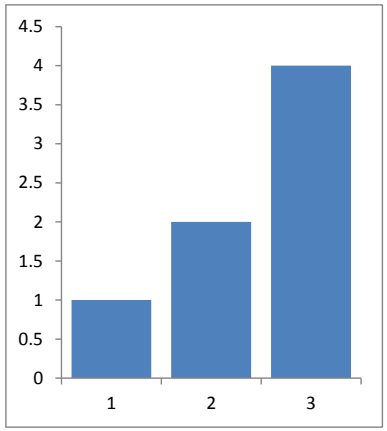
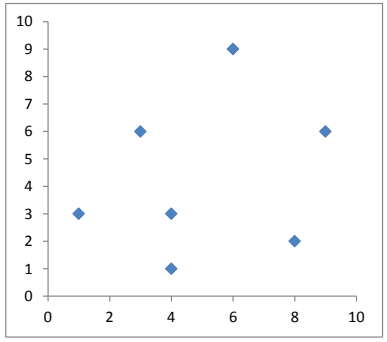
# Figures are a combination of marks and channels

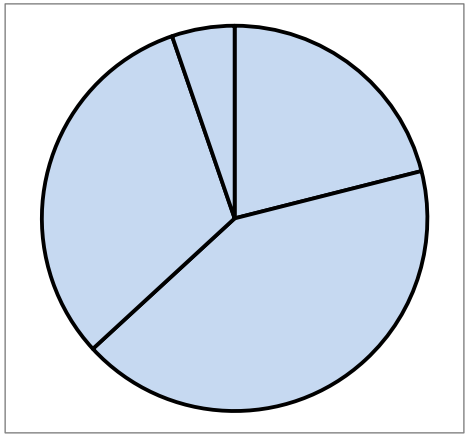



1 Mark = Rectangle
1 Channel = Length of longest side



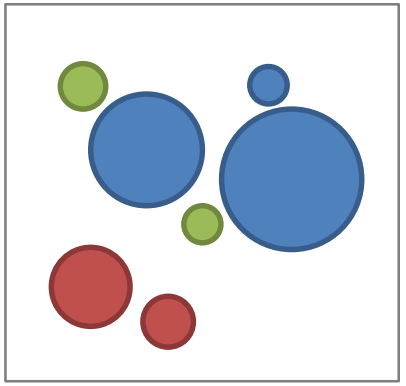

1 Mark = Diamond shape
2 Channels = X position, Y position

1 Mark = Circle segment
1 Channel = Angle



1 Mark = Circle
4 Channels:

X position
Y position
Area
Colour



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# Golden Rules

- Effectiveness
  - Encode the most important information with the most effective channel
- Expressiveness
  - Match the properties of the data and channel

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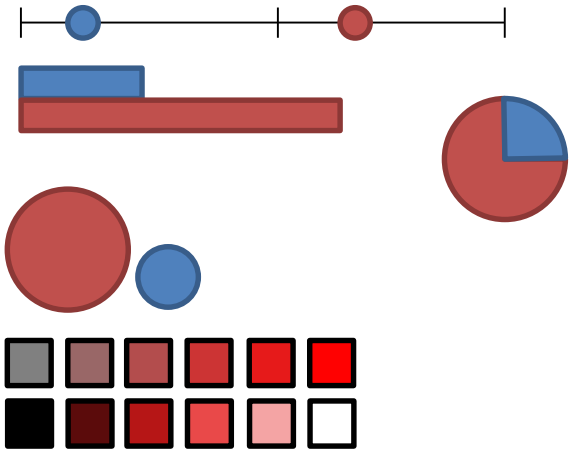
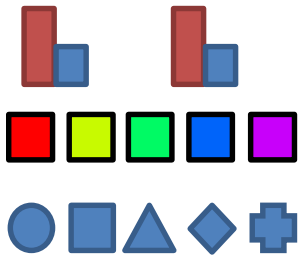
# Types of channel

- Quantitative
  - Position on scale
  - Length
  - Angle
  - Area
  - Colour (saturation)
  - Colour (lightness)



- Qualitative
  - Spatial Grouping
  - Colour (hue)
  - Shape



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# Colour

- Technical representations of colour
  - Red + Green + Blue (RGB)
  - Cyan + Magenta + Yellow + Black (CMYK)
- Perceptual representation of colour
  - Hue + Saturation + Lightness (HSL)

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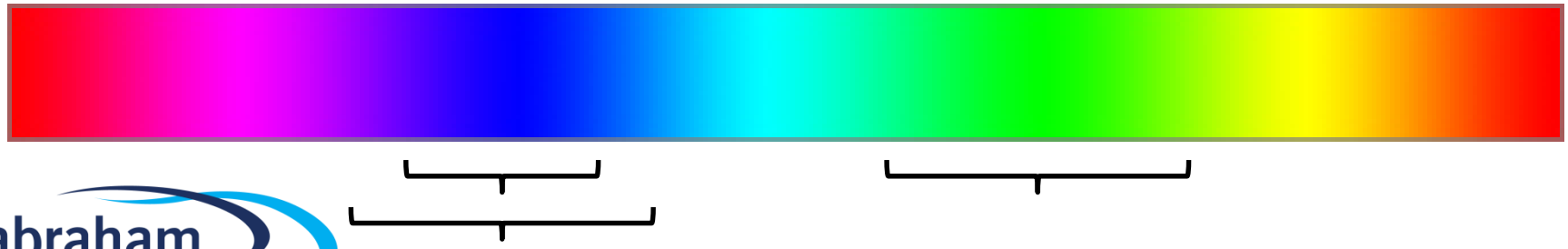
# HSL Representation

- Hue = Shade of colour = Qualitative
- Saturation = Amount of colour = Quantitative
- Lightness = Amount of white = Quantitative

- Humans have no innate quantitative perception of hue but we have learned some (cold – hot, rainbow etc.)

- Our perception of hue is not linear



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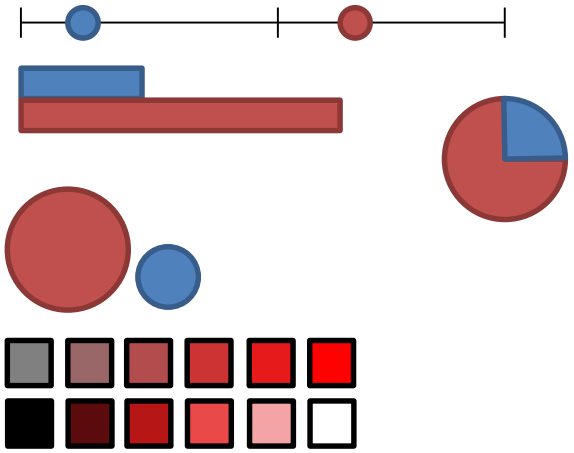

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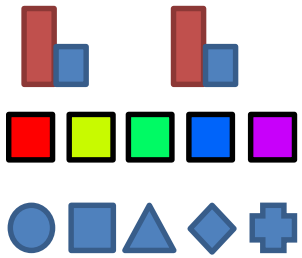

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# Data Types

- Quantitative
  - Height, Length, Weight, Expression etc.
- Ordered
  - Small, Medium, Large
  - January, February, March
- Categorical
  - WT, Mutant1, Mutant2
  - GeneA, GeneB, GeneC

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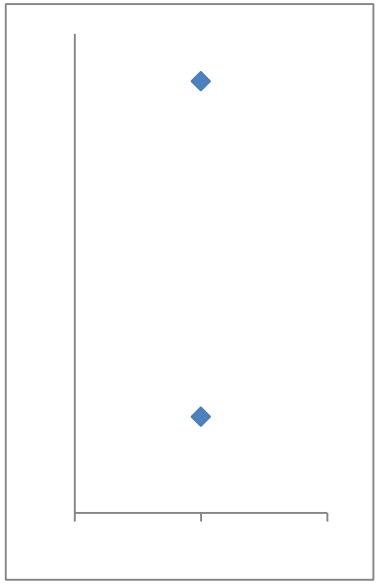
# Effectiveness of quantitation



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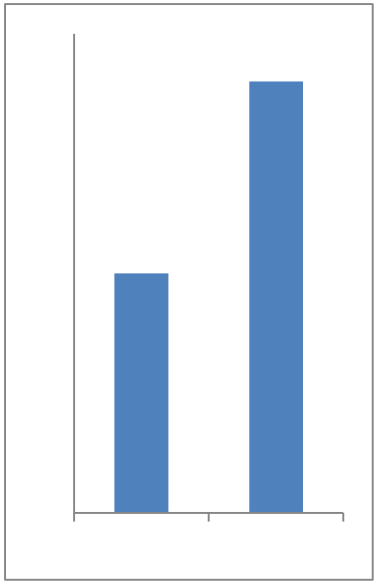

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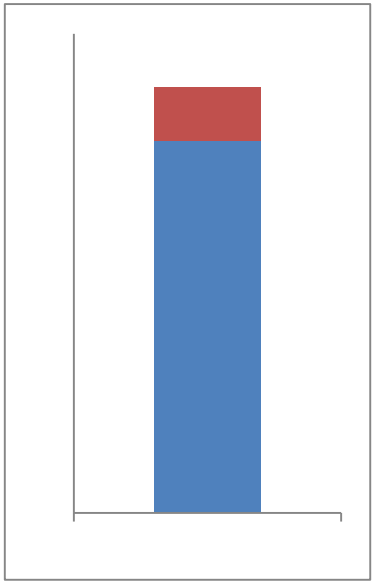
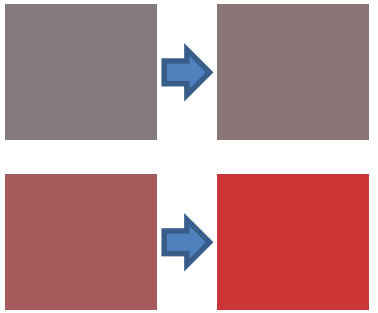
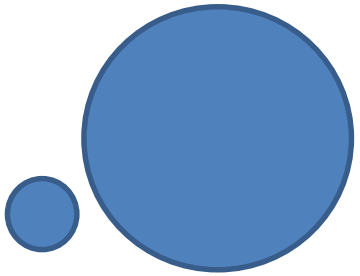


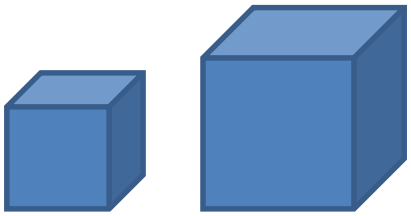
7X



2X



16X



3.4X

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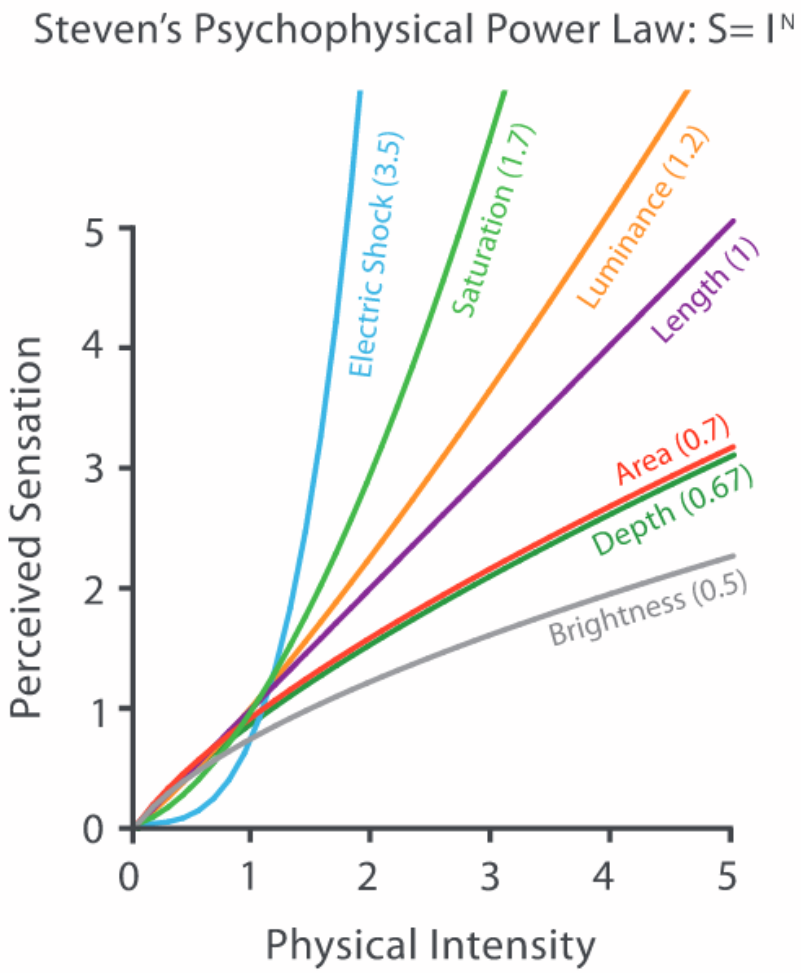
# Quantitation Perception

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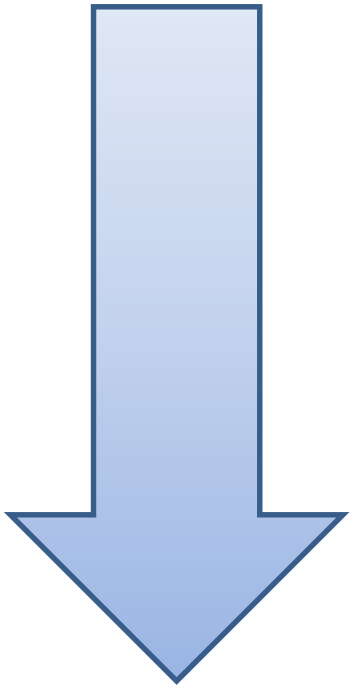
# Most Quantitative Representations

Good quantitation



Poor quantitation

- Bar chart
- Stacked bar chart with common start
- Stacked bar chart with different starts
- Pie charts
- Bubble plots (circular area)
- Rectangular area
- Colour (luminance)
- Colour (saturation)

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# Discriminability

- If you encode categorical data are the differences between categories easy for the user to perceive correctly?

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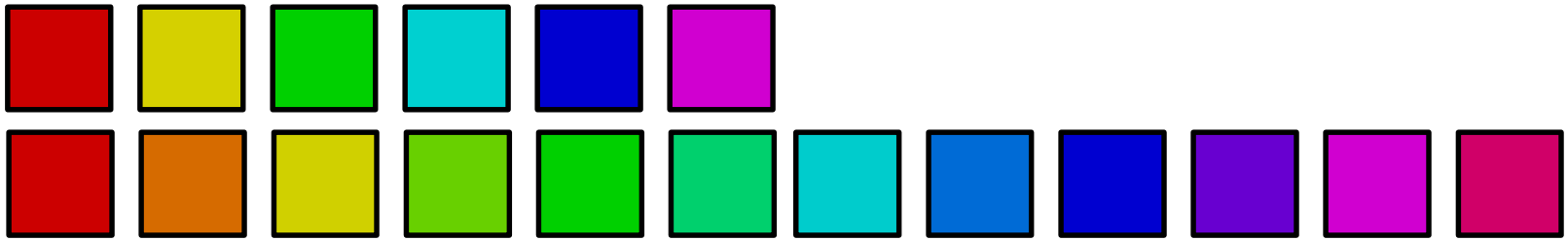
# Qualitative Discrimination

- How many colours can you discriminate?



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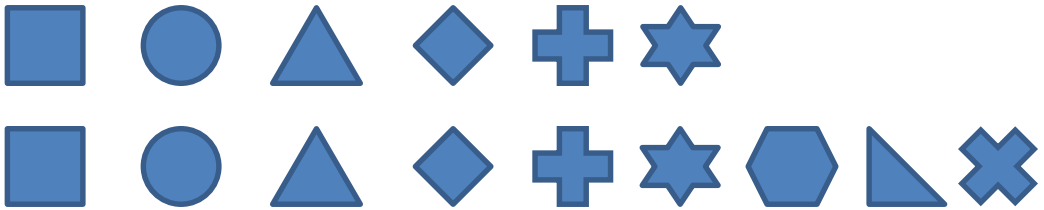
# Qualitative Discrimination

- How many (fillable) shapes can you discriminate?



- Can combine with colour, but need to maintain similar fillable areas

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# Separability

- The effectiveness of a channel does not always survive being combined with a second channel.
- There are large variations in how much two different channels interfere with each other
- Trying to put too much information on a figure can erode the impact of the main point you're trying to make

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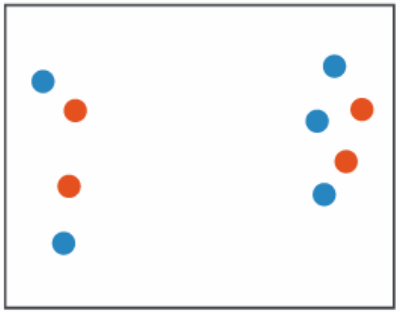
# Separability

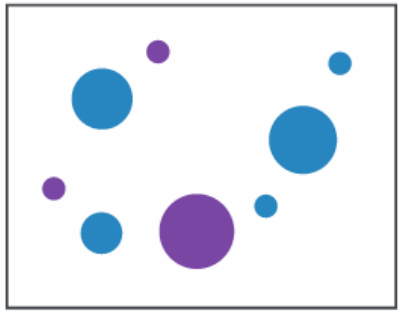
Position
+ Hue (Color)



Fully separable

There is no confusion between the two channels

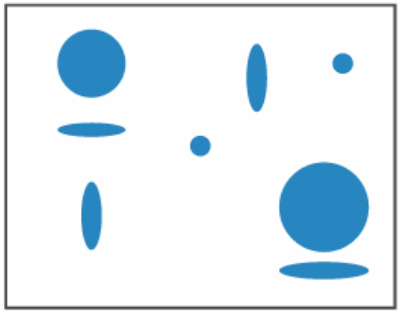
Size
+ Hue (Color)



Some interference

Larger points are easier to discriminate than smaller ones

Width
+ Height



Some/significant interference

We tend to focus on the area of the shape rather than the height/width separately

Red
+ Green

Major interference

Humans are very bad at separating combined colours

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# Popout

- A distinct item immediately stands out from the others
- Triggered by our low level visual system
- You don’t need to actively look at every point (slow!) to see it

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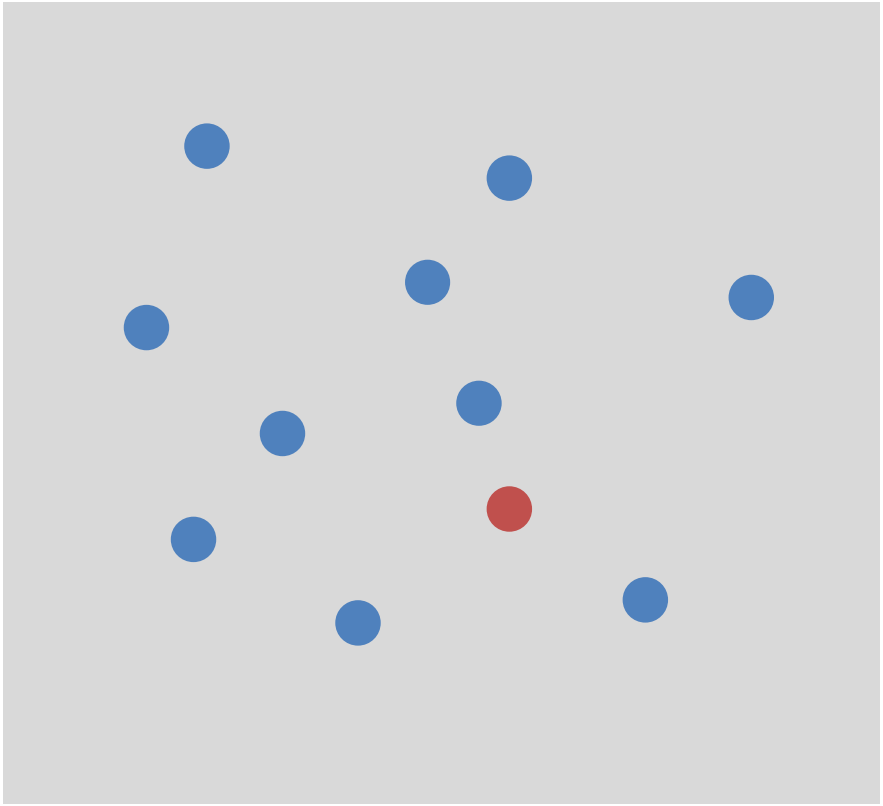
# Popout

(find the red circle)



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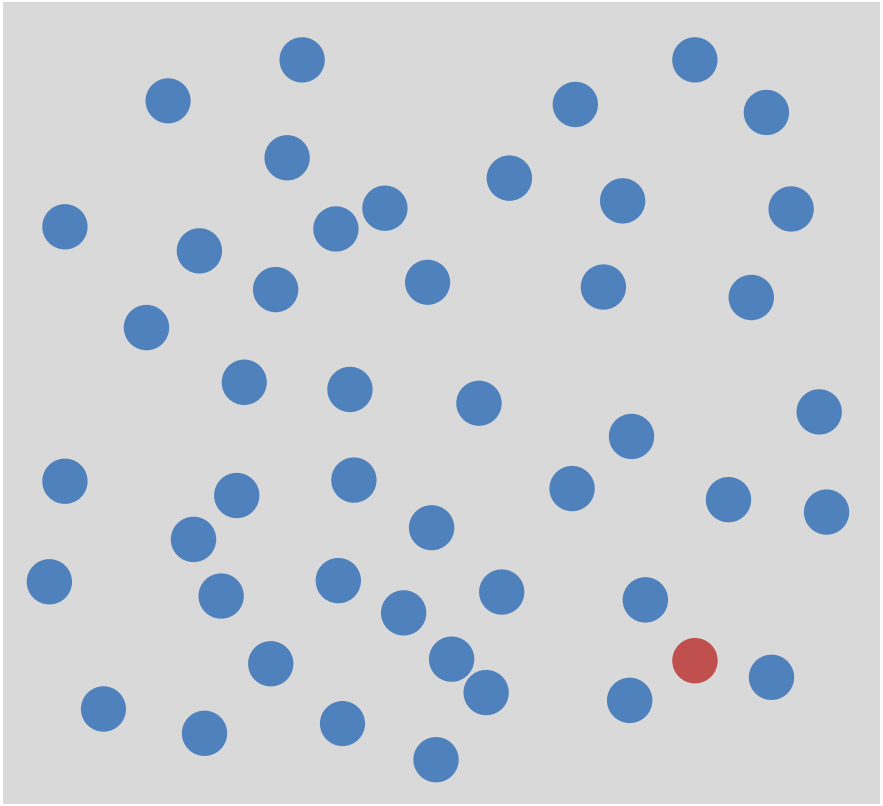
# Popout

Speed of identification is independent of the number of distracting points



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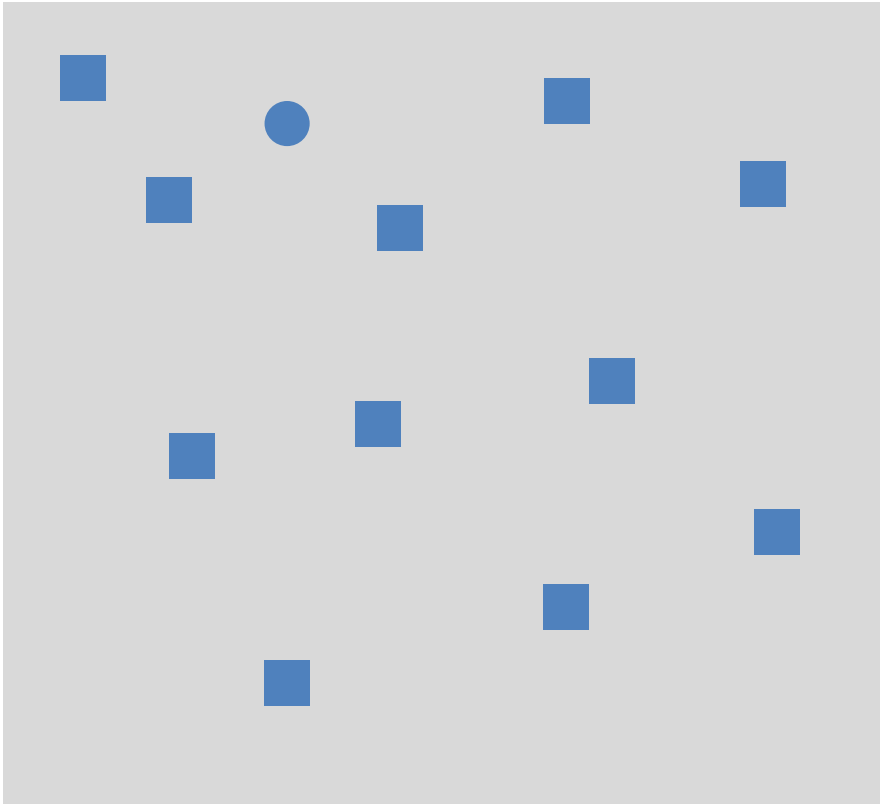
# Popout

(Find the circle)



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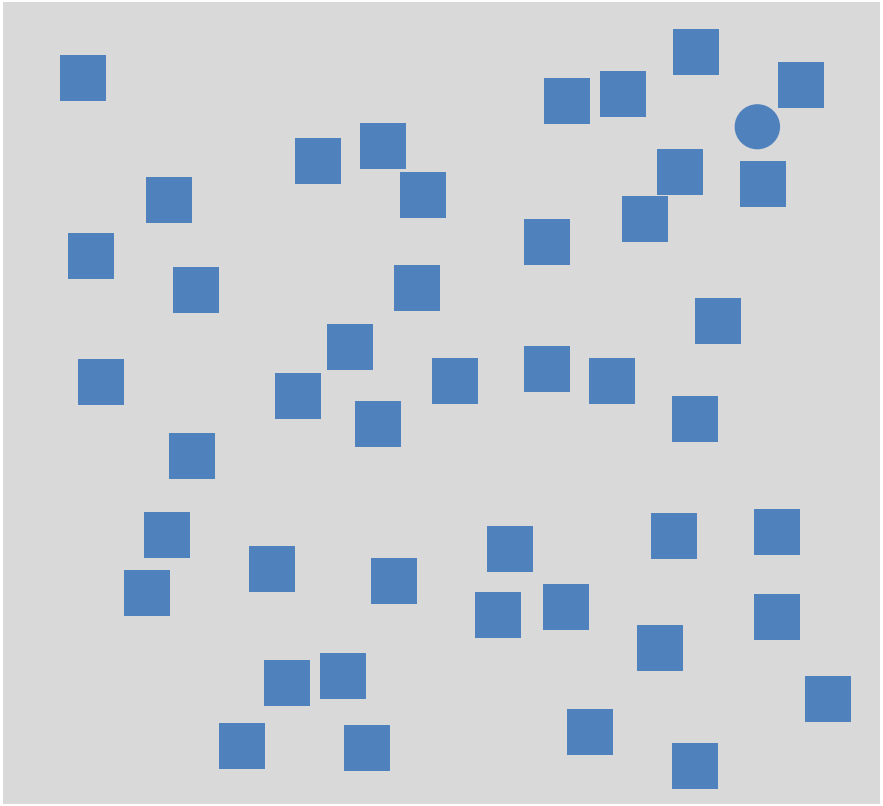
# Popout

Colour pops out more than shape



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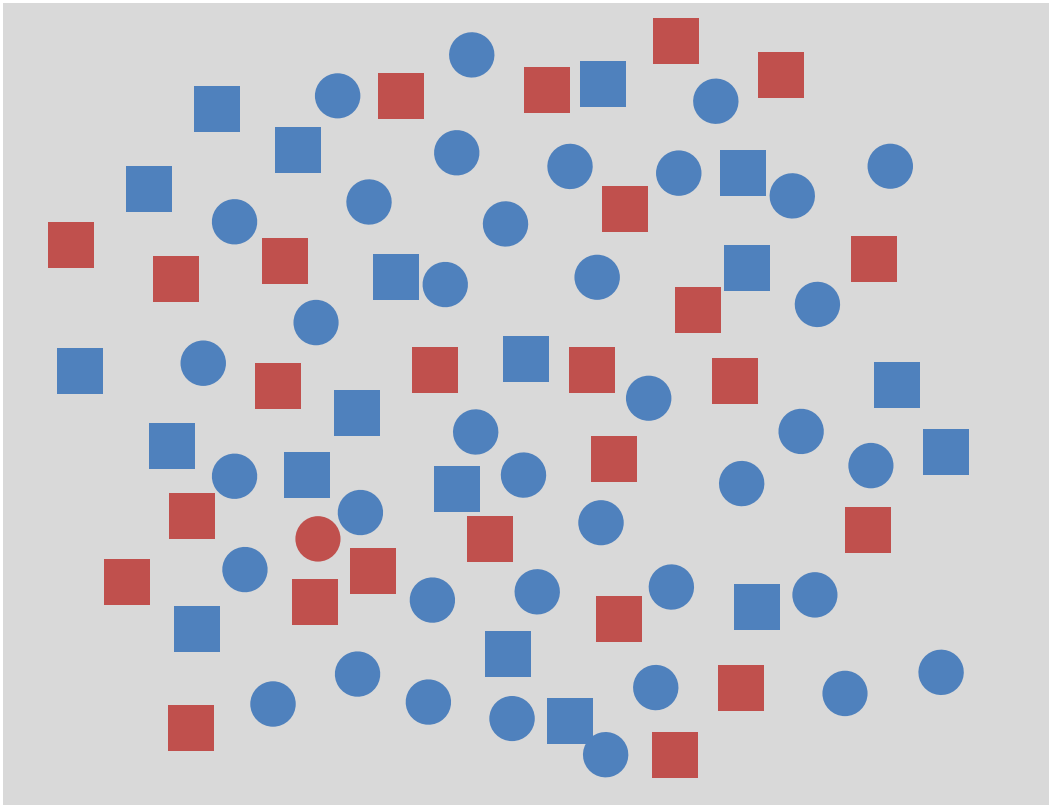
# Popout

Mixing channels removes the effect
(Find the red circle)



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# Use of space

- Where you want a viewer to focus on specific subsets of data you can help their perception by using the layout or highlighting of data to draw their attention to the point you're making

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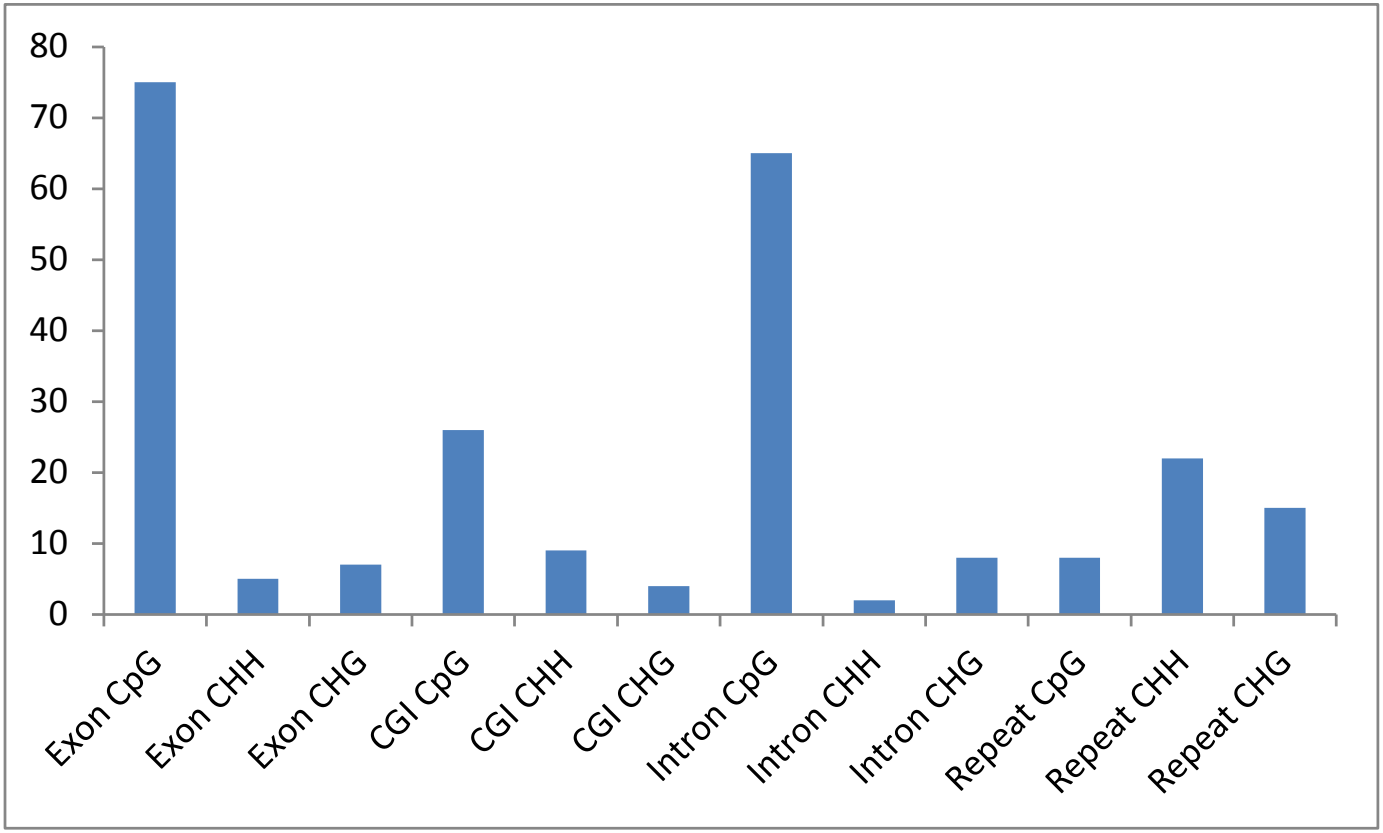
# Grouping

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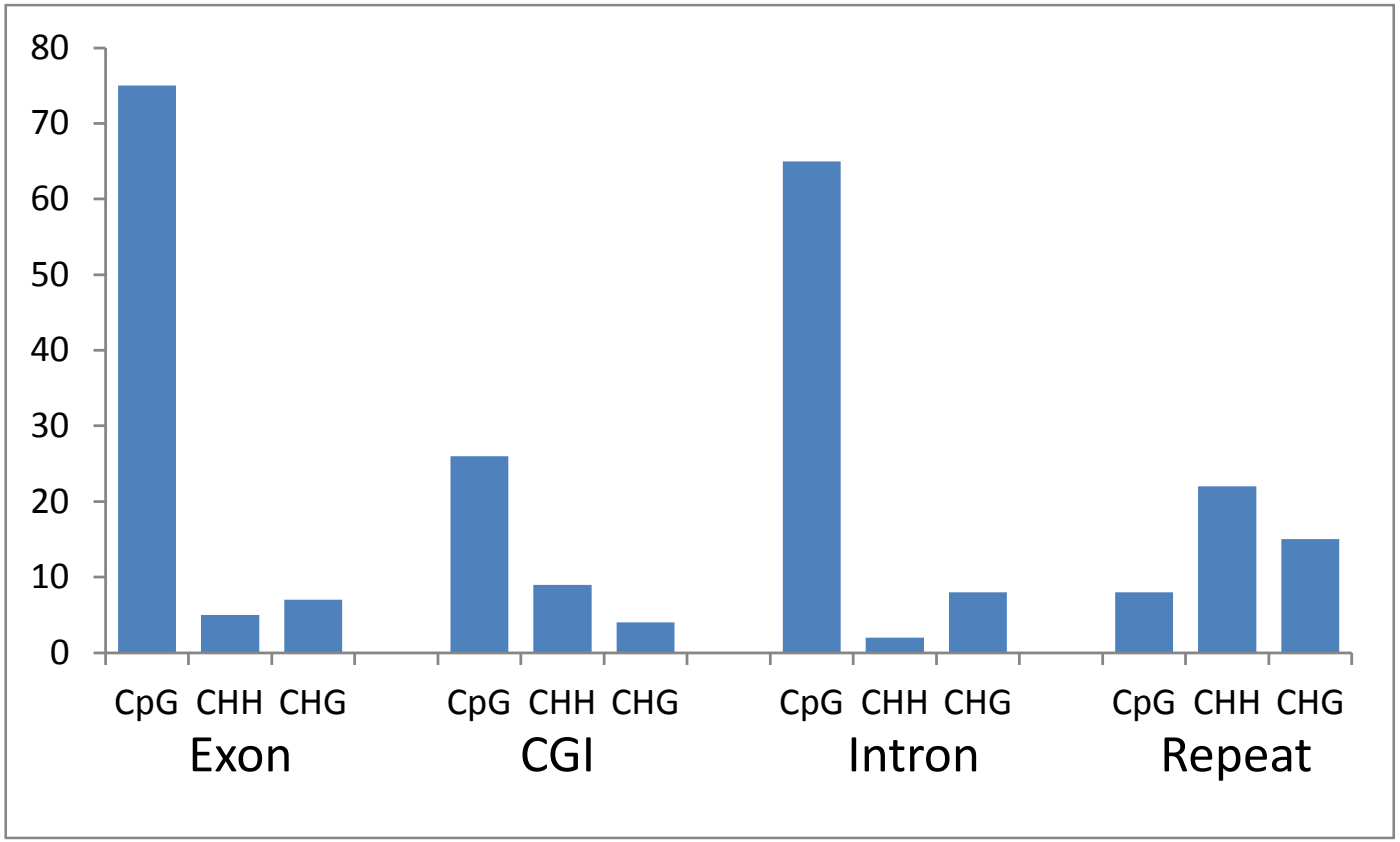


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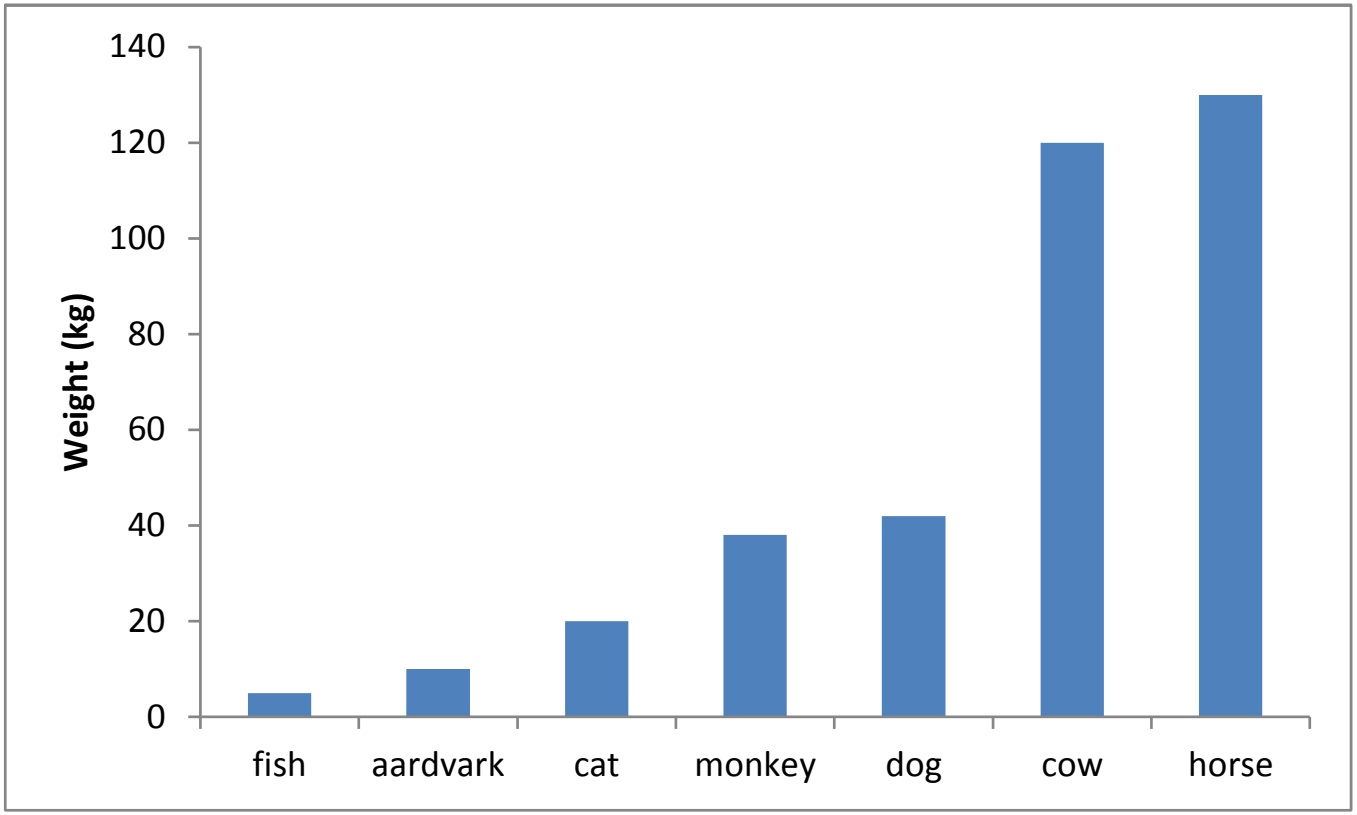
# Ordering

- Is a monkey heavier than a dog?

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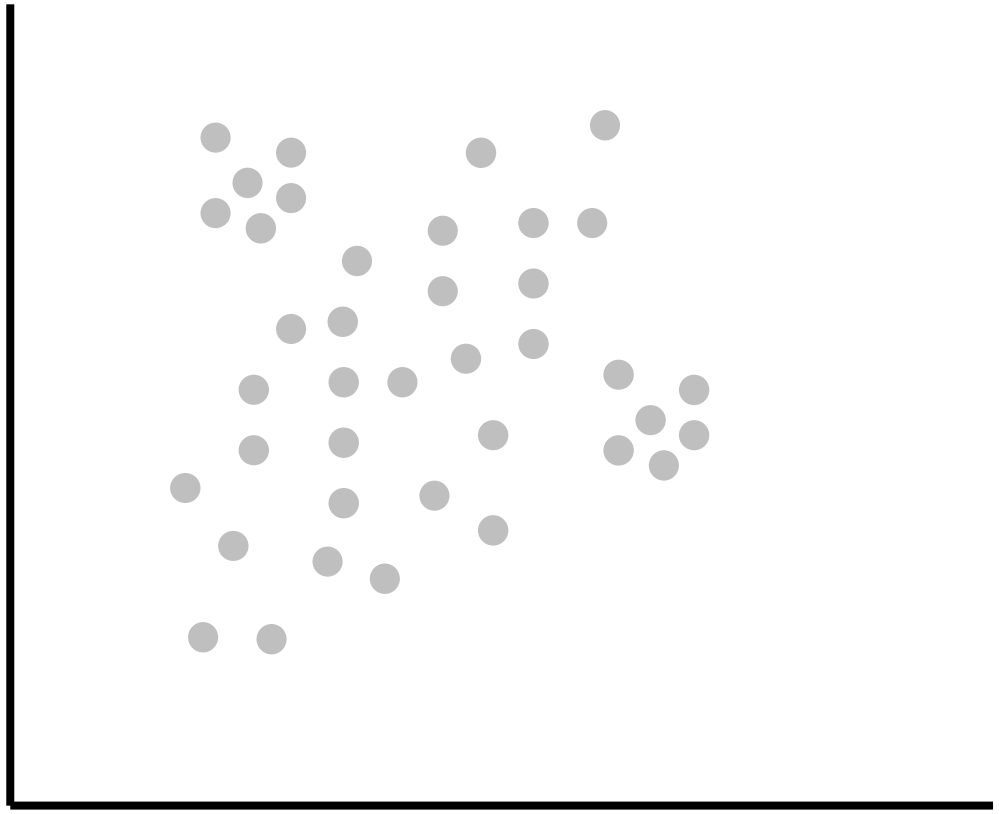
# Containment



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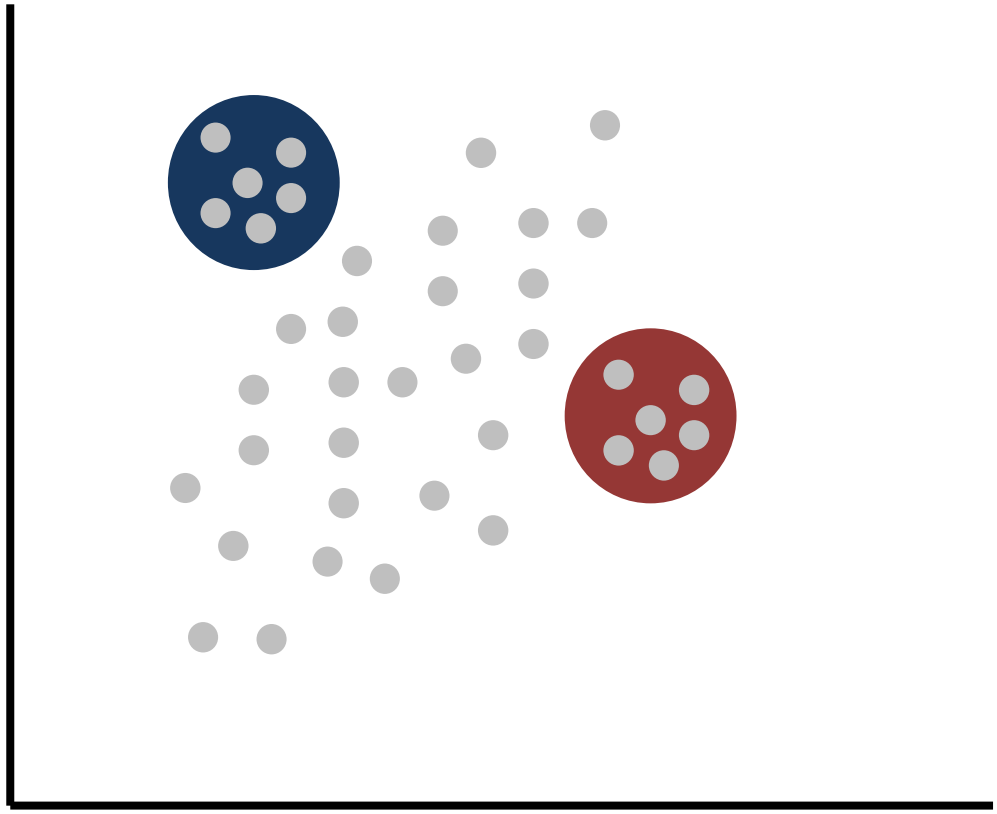

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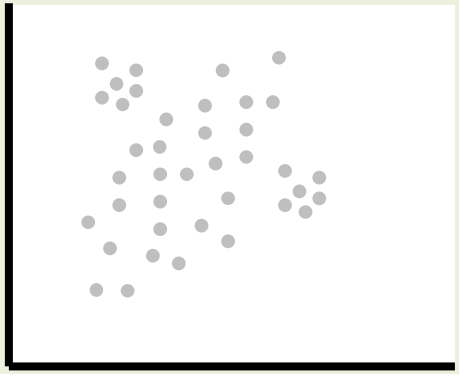
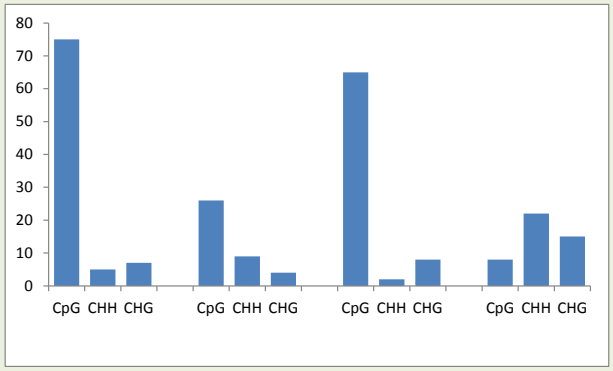
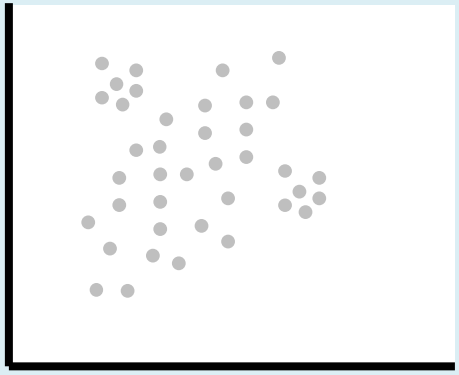
# Containment / Linking

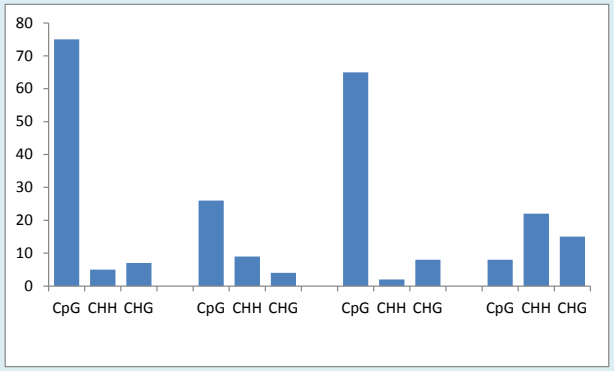
Wild Type






Mutant



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# Validation

- Always try to validate plots you create
- You have seen your data too often to get an unbiased view
- Show the plot to someone not familiar with the data
  - What does this plot tell you?
  - Is this the message you wanted to convey?
  - If they pick multiple points, do they choose the most important one first?

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# General Rules

- No unnecessary figures
  - Does a graphical representation make things clearer?
  - Would a table be better?
- One point per figure
  - Design each figure to illustrate a single point
  - Adding complexity compromises the effectiveness of the main point
- No absolute reliance on colour
  - Figures should ideally still work in black and white
  - Colour should help perception
- No 3D
  - 3D is hardly ever justified and makes things less clear
- Figures should be self-contained
  - Must be understandable without additional information

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