Imperial College London

Introduction to Statistics

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Overview

Session 1

- Describe your data
  - Descriptive statistics - summarising the data
  - Visualisation (plots and figures)
- Inferential analysis:
  - Inference about population from sample
- Given two groups of data
  - Test the differences between groups (**hypothesis testing**)
  - Test the relationship between two variables (correlation)

Session 2

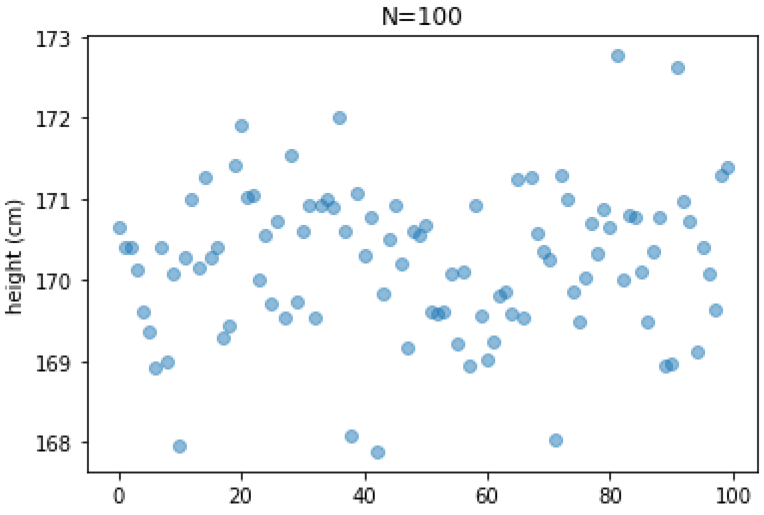
- Lab Practice using SPSS

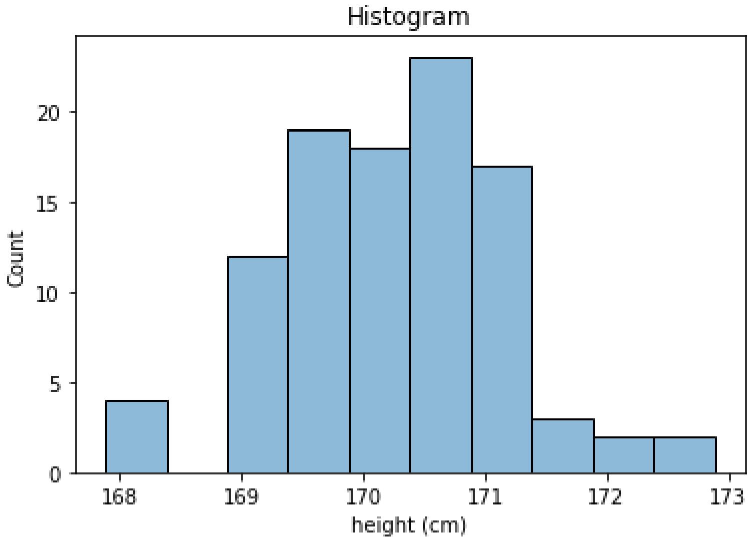
Describe your data

How would you describe it?

N=9

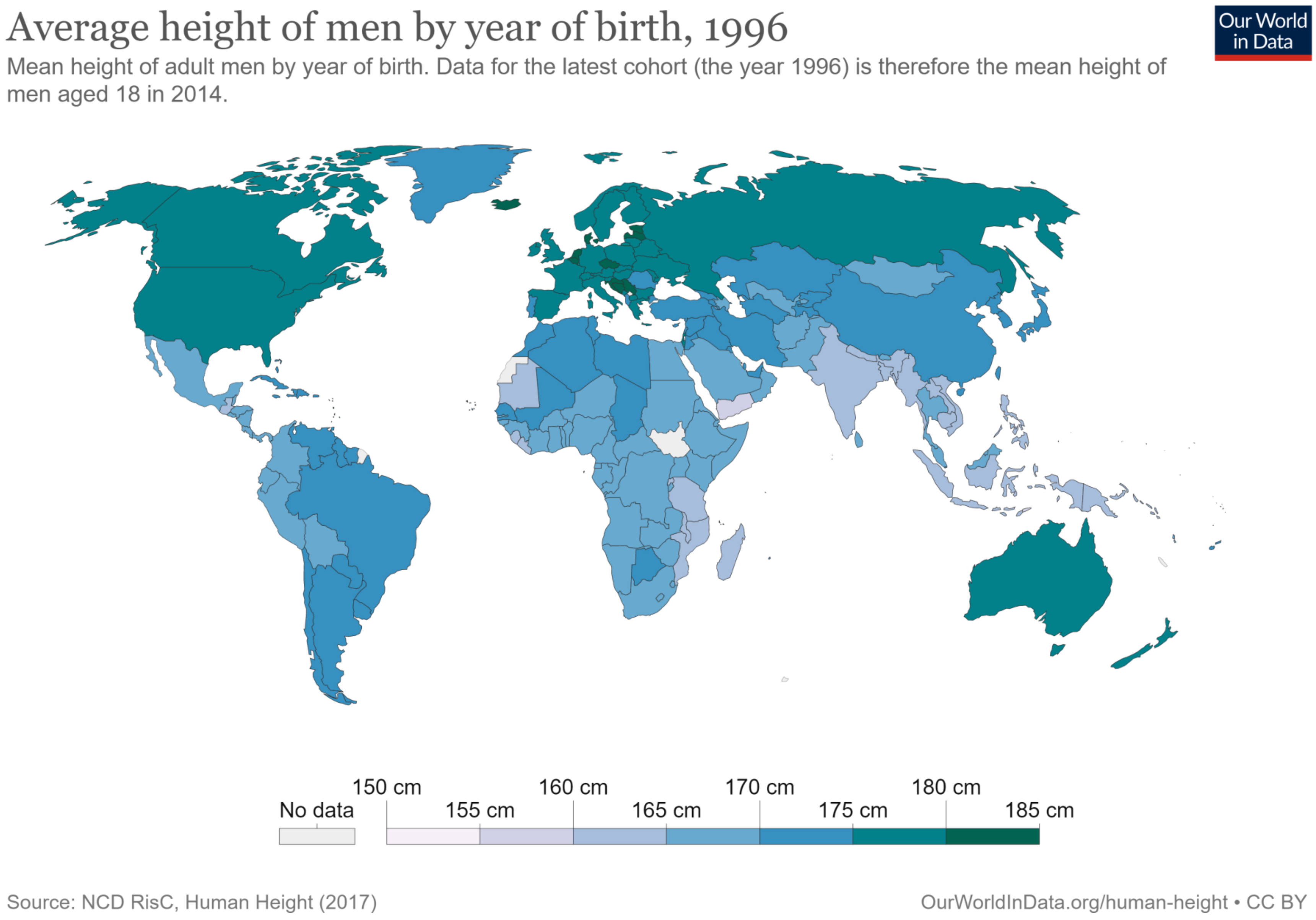
Height (cm)
167
168
160
170
171
160
162
165
167





Average – centre tendency of data
Variability – spread of data
Nice plots!

Example


Average height of men by year of birth, 1996
Mean height of adult men by year of birth. Data for the latest cohort (the year 1996) is therefore the mean height of men aged 18 in 2014.
Our World in Data
No data
150 cm
155 cm
160 cm
165 cm
170 cm
175 cm
180 cm
185 cm
Source: NCD RisC, Human Height (2017)
OurWorldInData.org/human-height • CC BY

Types of Variable

Numerical

- Quantitative: blood pressure, sugar level, no of cells, height, BMI

  Continues, Discrete

Categorical

- Qualitative: ethnicity, disease or not? , sex?

  binary (2 categories), nominal (>2 cat.)

- Ordinal: satisfaction-rating, age-group

Operators (where?)

- +. -, x
- >, <
- =, ≠

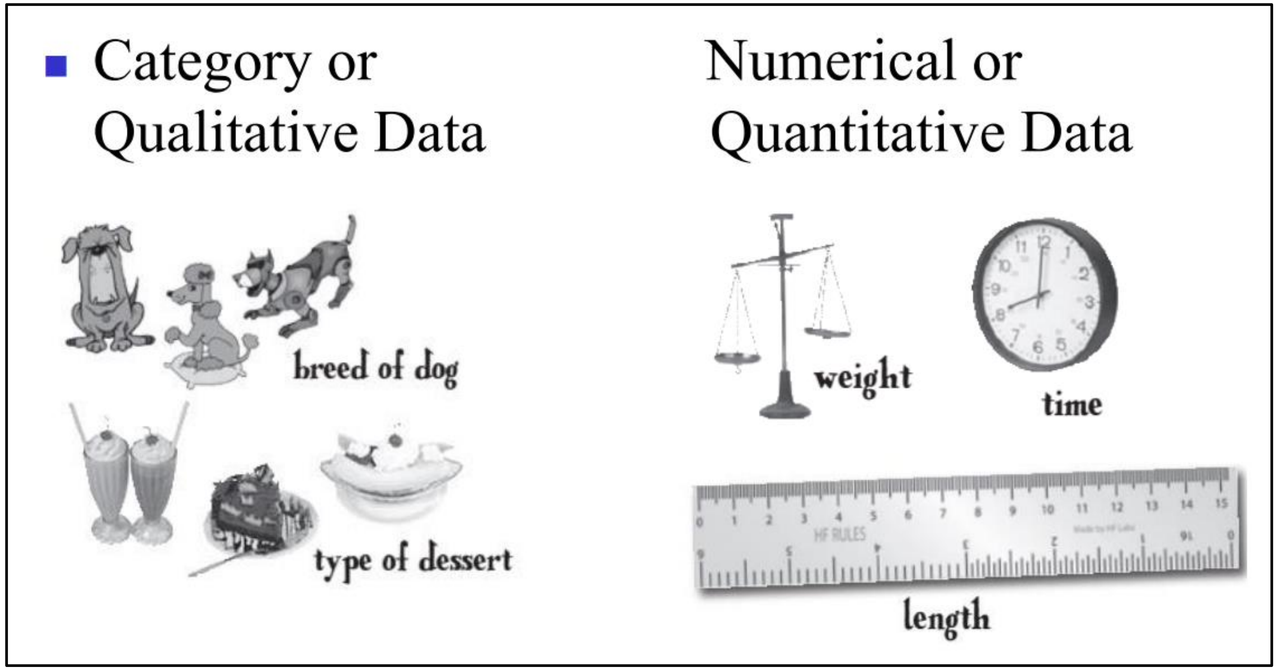
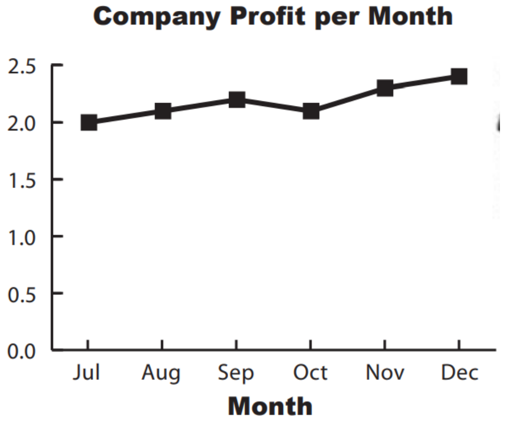


Image Ref: Book: First Head “Statistics” O’Relley

Visualisation – just plotting the data

Impression of visualization: Profit of company

Month	Jul	Aug	Sep	Oct	Nov	Dec
Profit (millions)	2.0	2.1	2.2	2.1	2.3	2.4



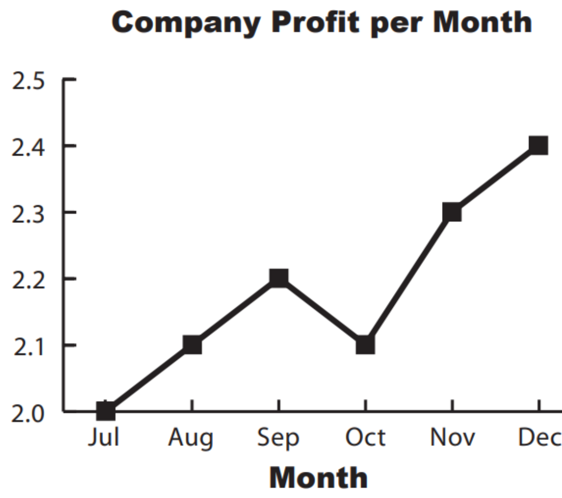


Image Ref: Book: First Head "Statistics" O'Relley

Plot & type of variable

Numerical

- Quantitative: (height)

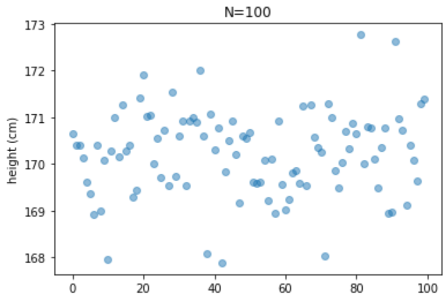
Categorical

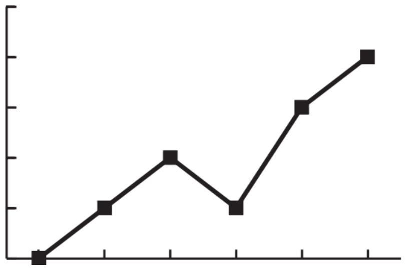
- Qualitative:

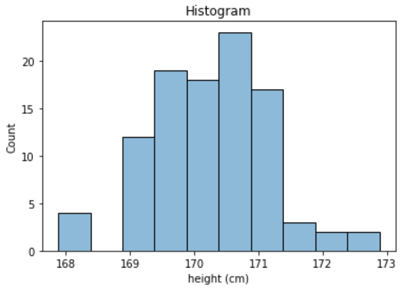
Genre	Units sold
Sports	27,500
Strategy	11,500
Action	6,000
Shooter	3,500
Other	1,500

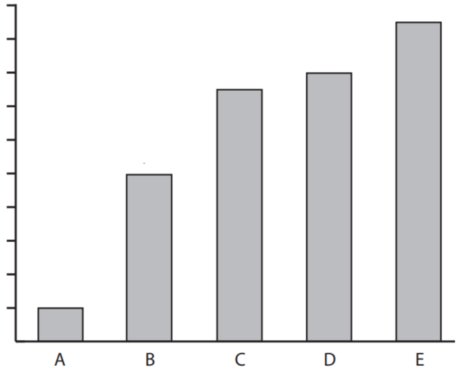
- Ordinal:

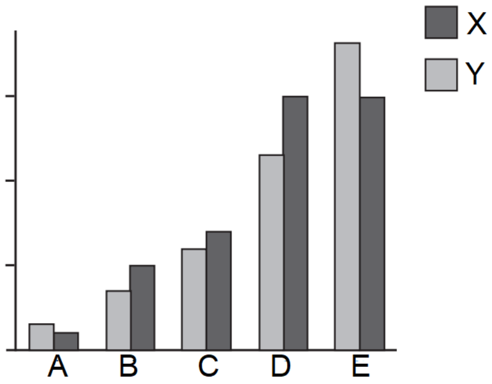
Hours	Frequency
0–1	4,300
1–3	6,900
3–5	4,900
5–10	2,000
10–24	2,100

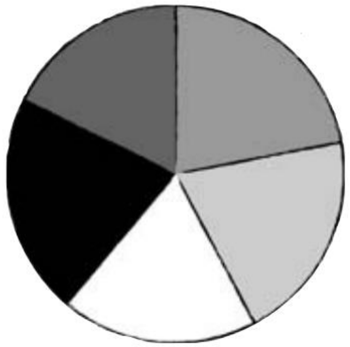












Descriptive Statistics

Summarizing the data

- Average: Mean, Mode, Median
- Frequency distribution
- Spread/variability: Range, Percentile, Standard deviation
- Skewness, Outliers

- What?, When?, Which?

Average: mean, mode, median

Most representative value of data

- Height in class

  [4, 4, 5, 4, 4, 4, 5, 4, 3, 5.5, 6, 4.5, 4.2, 5.2, 5,5, 6,1]

- Preference of drink

  [tea, tea, coffee, coffee, tea, tea, milk, tea, coffee, coffee]

- Age-group

  [10-15, 10-15, 10-15, 15-20, 20-25, 20-25, 20-25]

Mean: sum of all values/ number of values

Median: middle value of sorted sequence

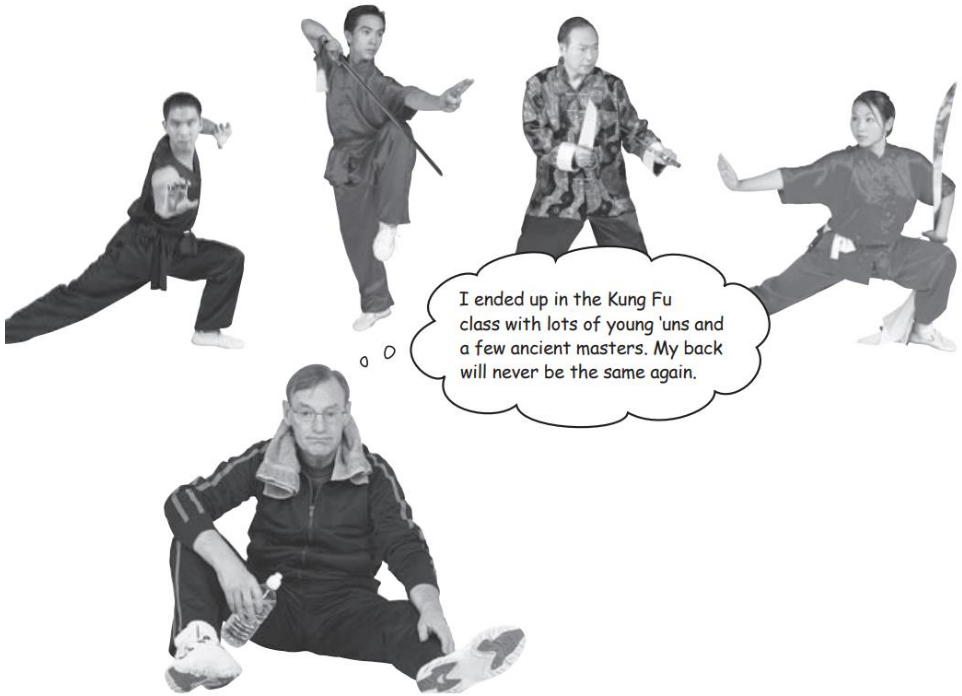
Mode : most frequent value

The Health Club
Statsville's Premier Spa

Let’s see a case: health club

Health club pride to have class for everybody

New customer in 50s



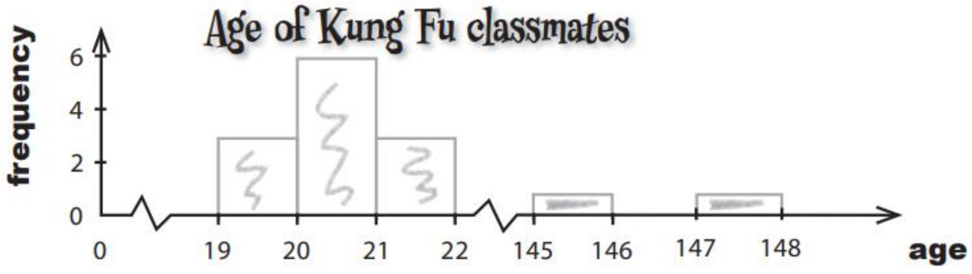
- Tuesday Evening

Class	Mean age
Class 1 :	17
Class 2 :	25
Class 3 :	38

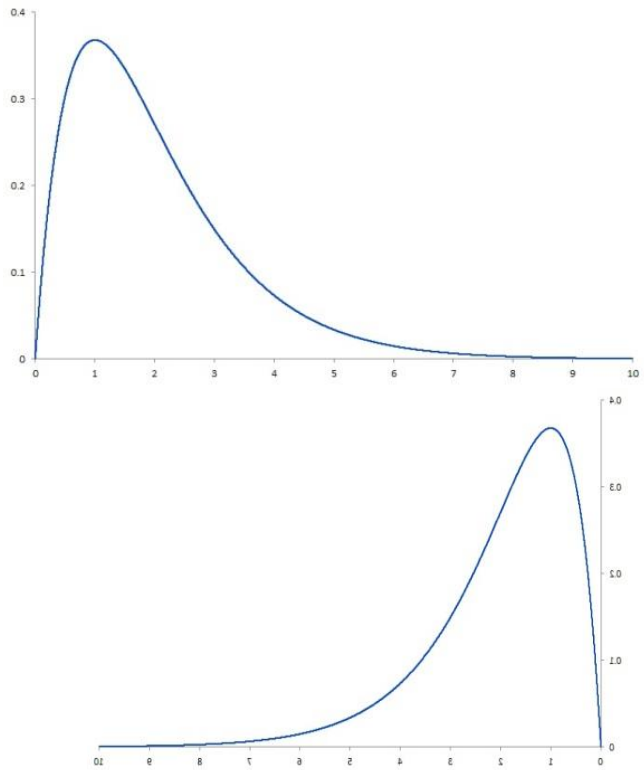
Which class new customer should attend??

Health club

Age	19	20	21	145	147
Frequency	3	6	3	1	1



Skewed distribution



Median: 19 19 20 20 20 21 21 100 102

Here's the number in the middle. This is the median, 20.

Median saved the day

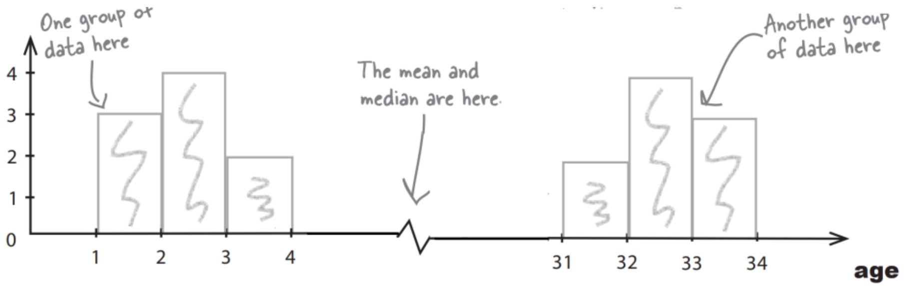
Health club

Mean = 17

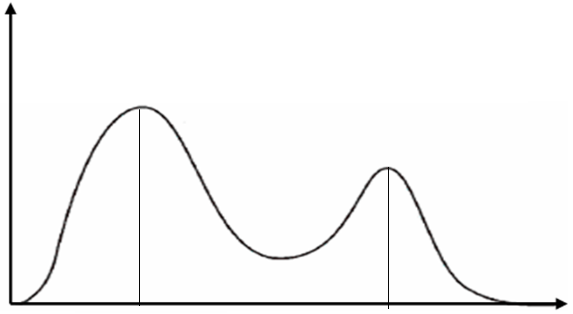
Median = 17

Can anything go wrong?

teenager

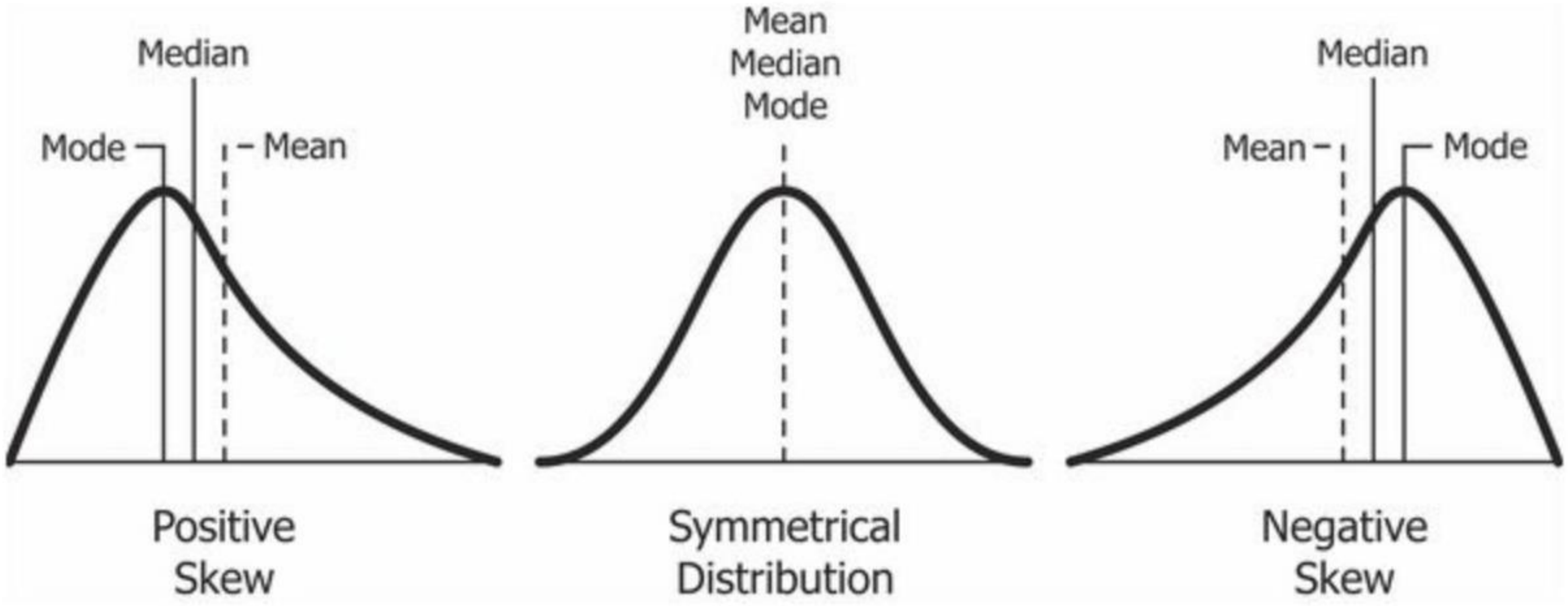


Class was for parents who bring their children to teach swimming?



Mode is our solution

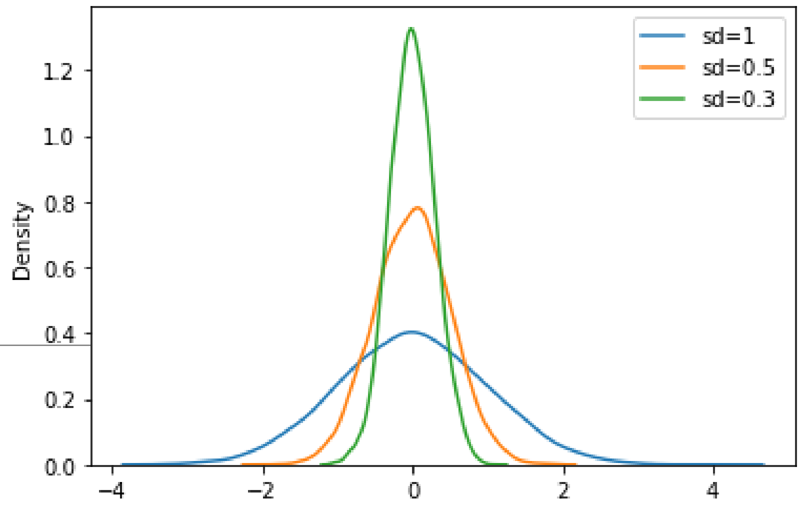
Skewness

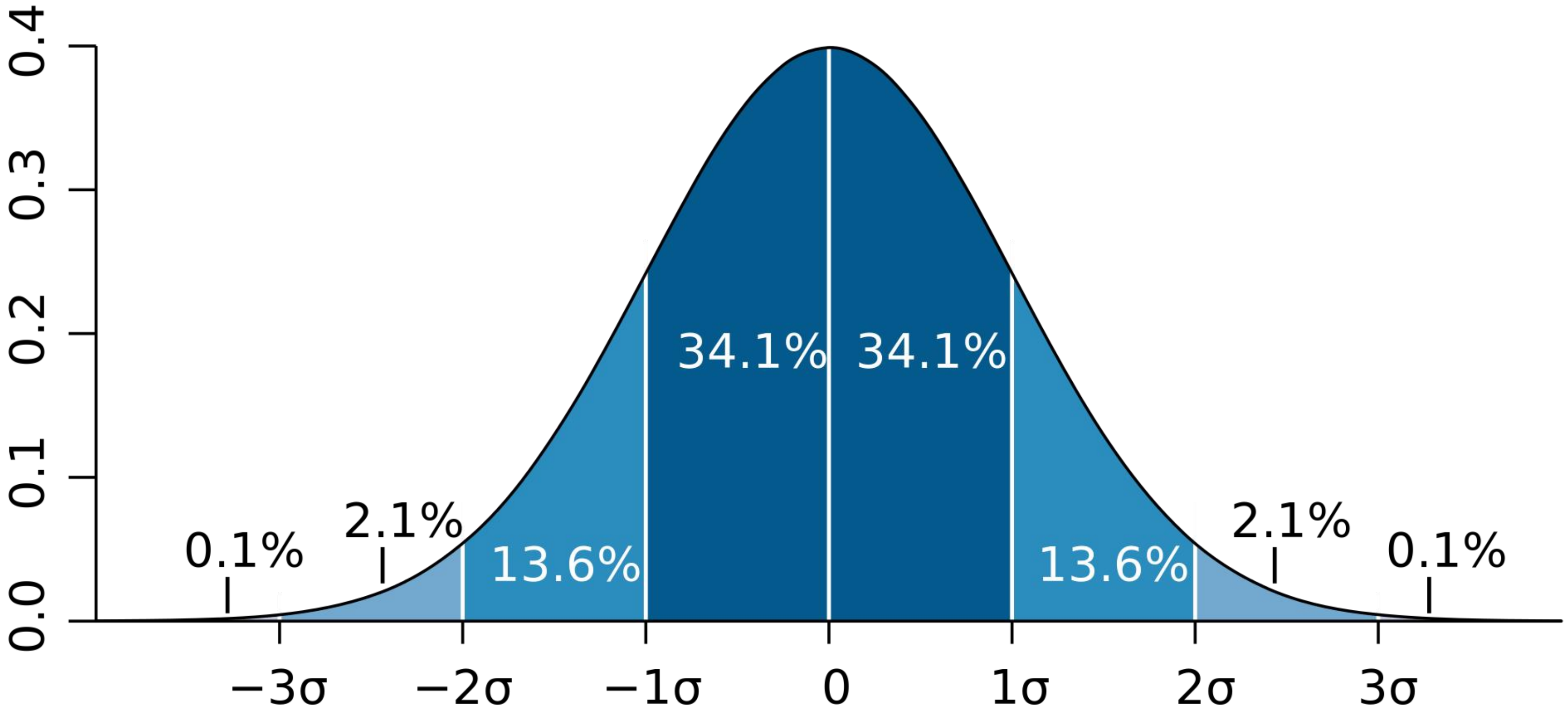


https://en.wikipedia.org/wiki/Skewness

Spread/Variability

Normal distribution





Standard deviation σ

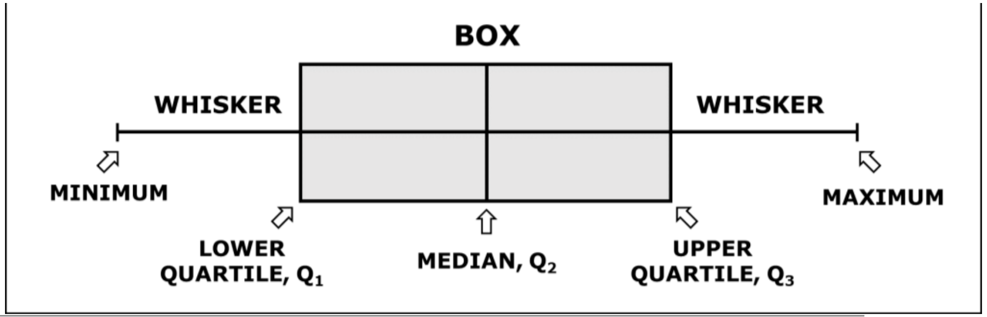
sd

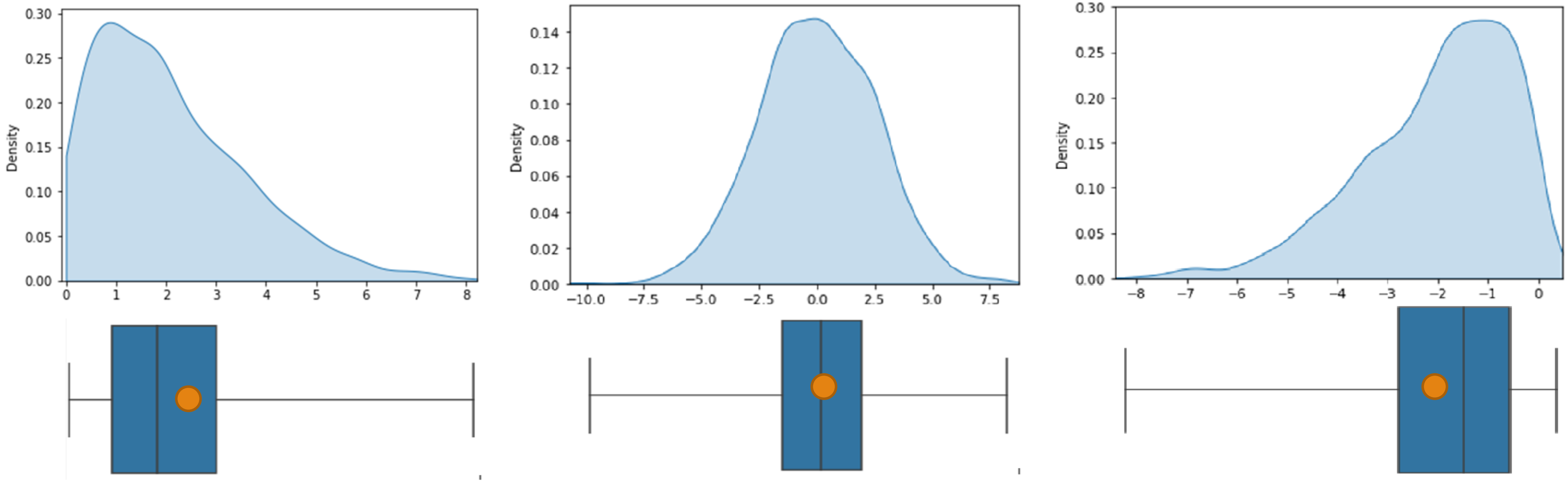
Variance σ^2

var

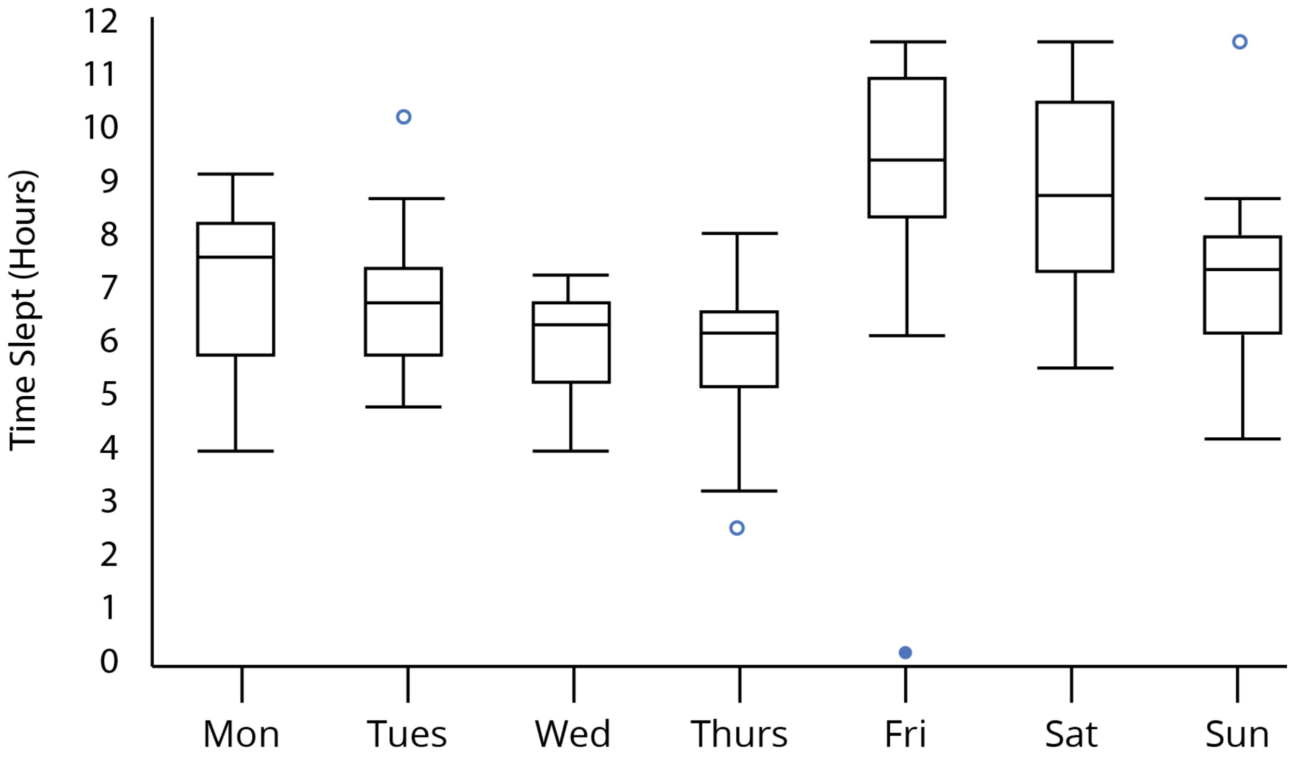
https://en.wikipedia.org/wiki/Normal_distribution

Box-whisker plot





Visual comparison with boxplot



Can we categorise cont. data?

- To improve the interpretation

- Example : BMI into 2 or 3 categories - high or low BMI

- Implications?
  - Loss of information – loss of statistical power to detect the differences
  - Impact of choosing –where to cut
  - Splitting at median (dichotomising) - reduces statistical power

- Worst for binary than 4 or more categories

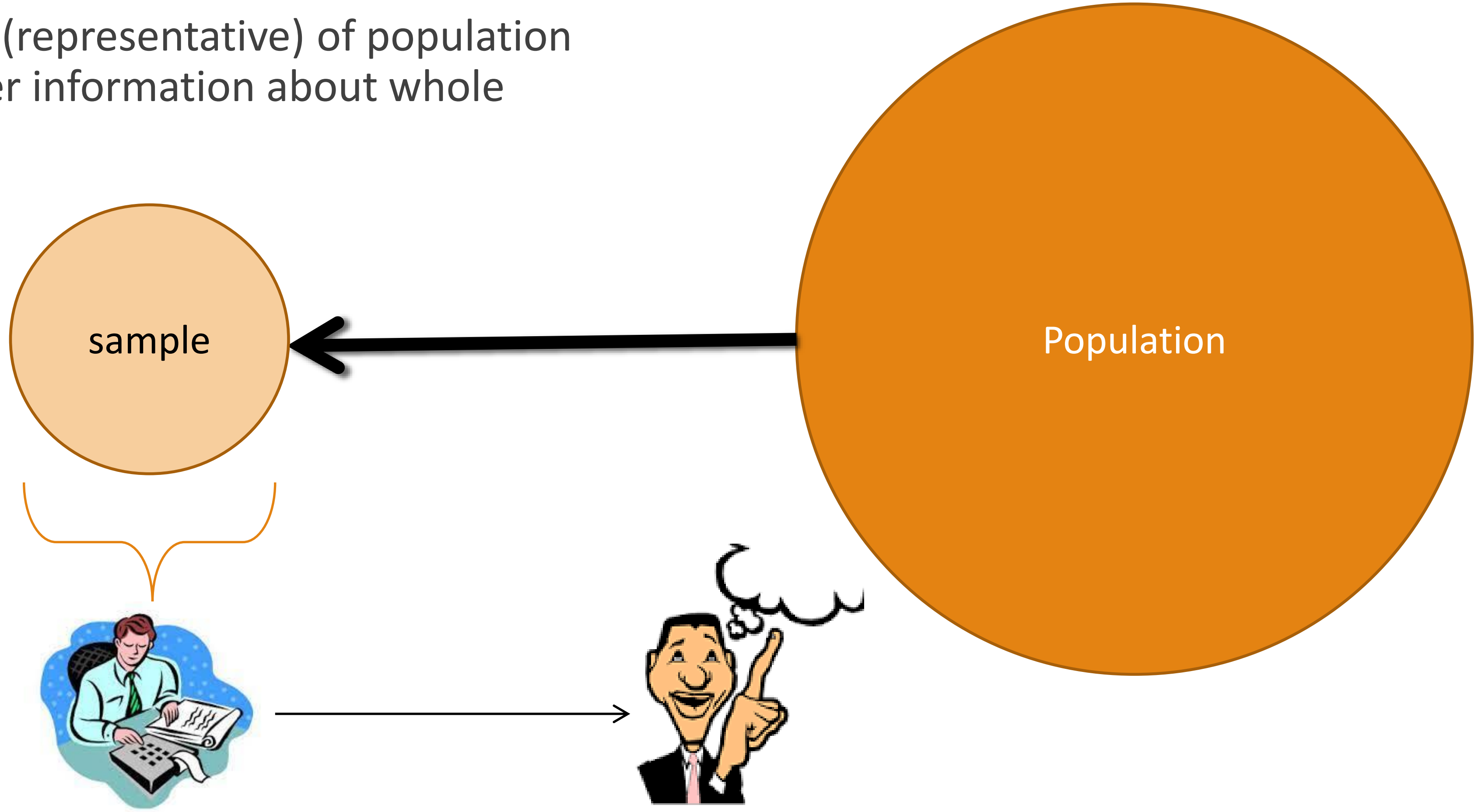
Inferential Statistics

Inferential Statistics

- Sample and Population
- Estimate population parameters from sample, and its accuracy (standard error)
- Standard error and standard deviation
- Confidence interval
- Size of data

Population & Sample

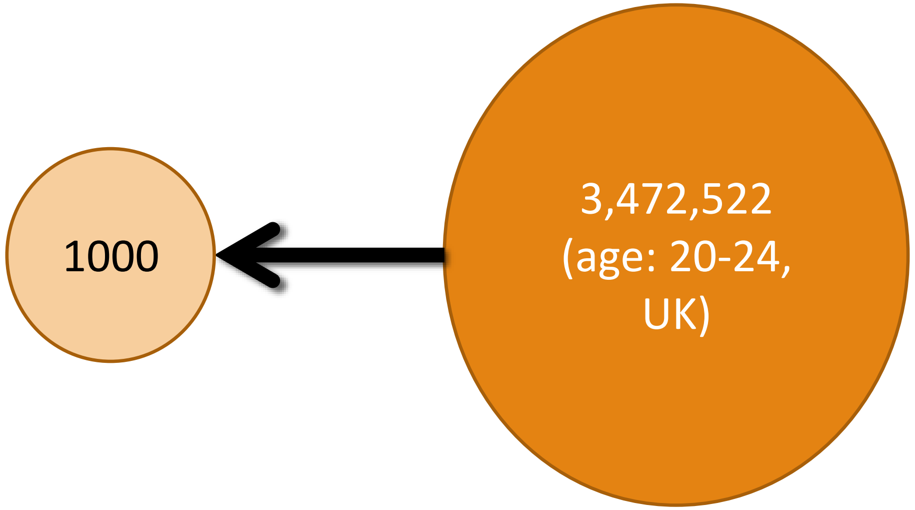
Sample is a subset (representative) of population from which we infer information about whole ***population***



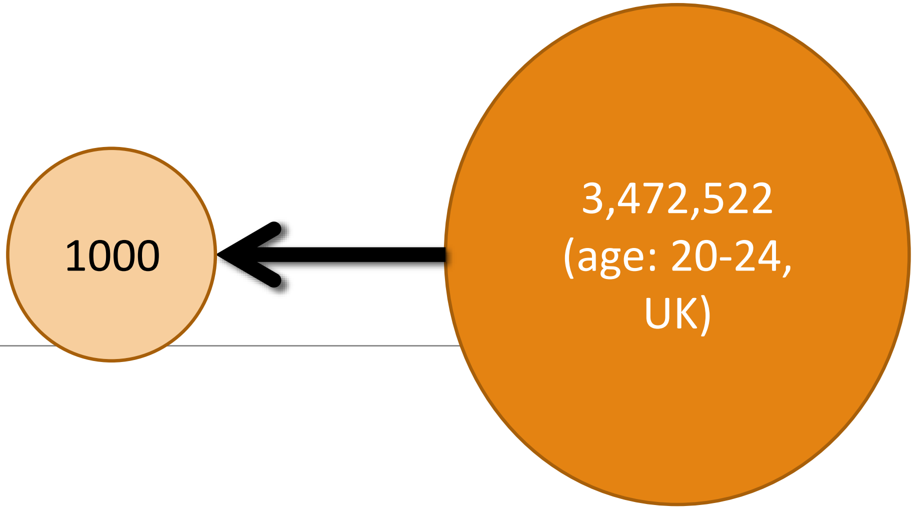
When it can be misleading?

- Sample is not representative of population (validity)

- Not large enough data (accuracy)



Estimation of parameter



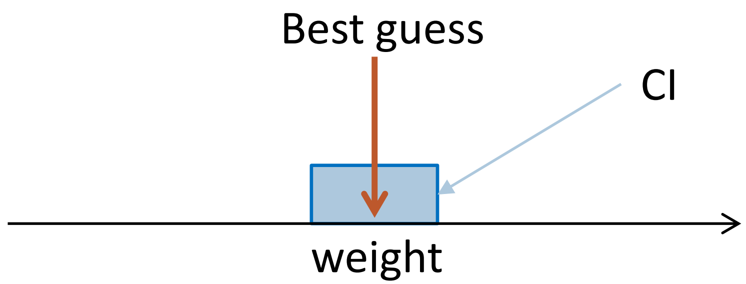
Mean weight of population

Best guess:

- Sample mean weight of is estimation of population mean weight
- uncertainty of this estimation (not exact value)

Accuracy of best guess

-Standard Error (SE)



Plausible values for true unknown

- Confidence Interval (CI)

CI for mean weight			
Mean	90%CI	95%CI	99%CI
169.5	165.5 - 173.4	163.7 - 174.2	163.0 - 175.9

Standard Deviation Vs Standard Error

SD:

- measure of spread/variability of data
- descriptive statistics
- for normally distributed data, 2SD includes 95% of observed values

SE:

- accuracy of estimation of population
- inferential statistics
- for 95% CI, hypothesis testing etc
- range of values likely to include true population parameter

Standard Error and CI

Standard Error:

$$SE = \frac{SD\ of\ population}{\sqrt{sample\ size}} \approx \frac{SD\ of\ sample}{\sqrt{sample\ size}}$$

95% Confidence Interval

$$95\%\ CI = sample\ mean \pm 1.96 \times SE$$

Means of all (hypothetical) samples follow normal distribution and 95% of them lie within mean ± 1.96xSE

Let’s compute – Lab session

Data

Sample mean

Standard deviation

Standard error

Confidence interval

Example 1

Effect of sample size!

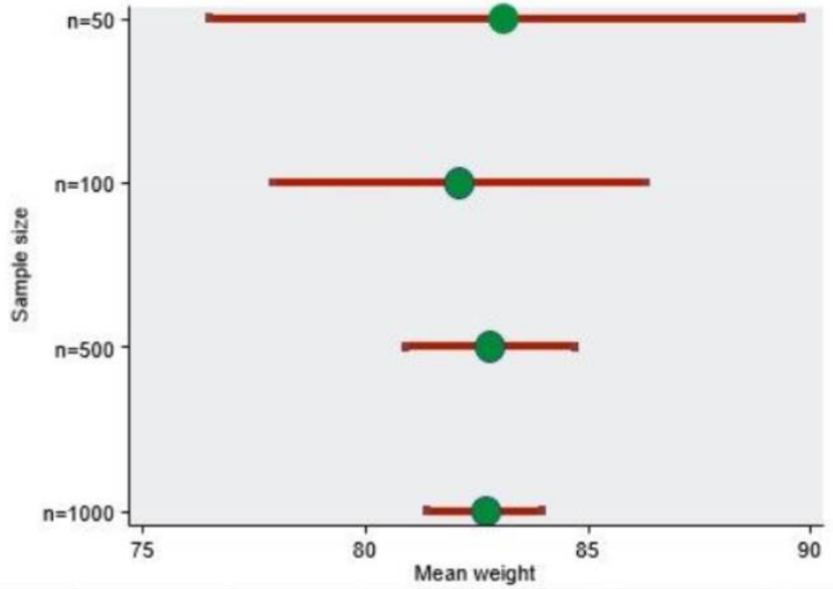
Sample mean = 81.4 kg, Standard Deviation = 21.4kg, n=1000

SE = ?

:

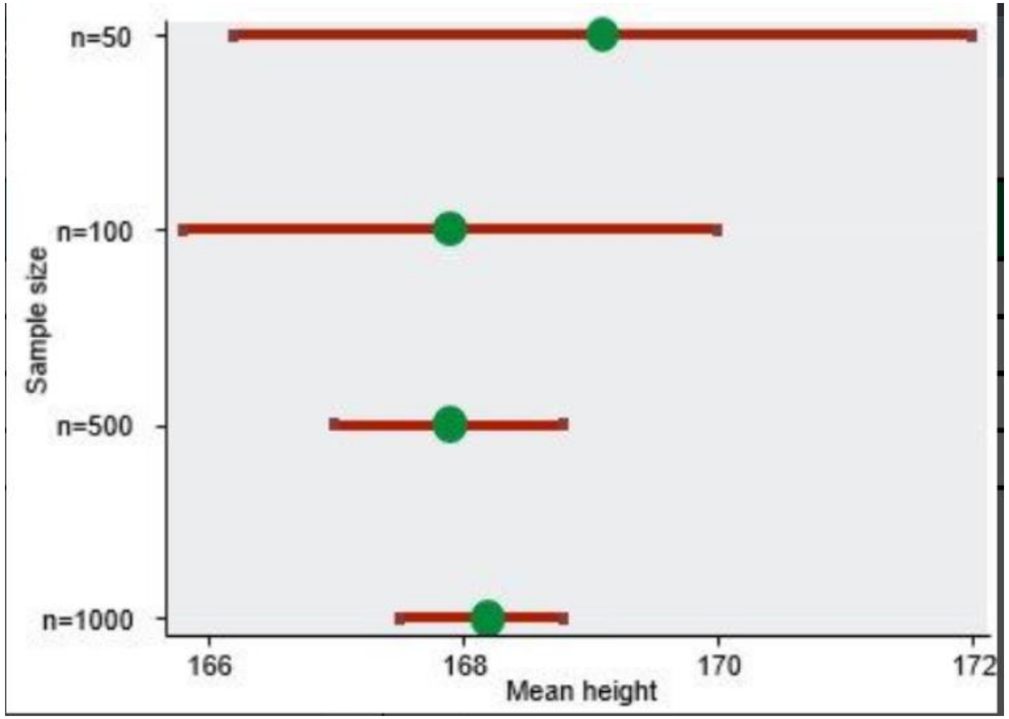
CI= ?

n of sample	Weight (mean)	Weight (SE)	95% CI
50	83.1	3.3	76.5-89.8
100	82.1	2.1	77.9-86.3
500	82.8	0.96	80.9-84.7
1000	82.7	0.68	81.4-84.0



Example 2

n of sample	Height		95% CI
	mean	SE	
50	169.1	1.5	166.2 - 172.0
100	167.9	1.1	165.8 - 170.0
500	167.9	0.5	167.0 - 168.8
1000	168.2	0.3	167.5 - 168.8



Simulation

https://nikeshbajaj.github.io/P/Stats/Stats_Sampling_demo.html

Or

https://c4fa.github.io/nikJS/Stats/

Others

https://onlinestatbook.com/stat_sim/sampling_dist/index.html

https://onlinestatbook.com/2/index.html

Proportion and CI

Estimating proportion of population that have particulate condition A.

Find the proportion in sample p = #A/total

$$SE\ of\ the\ proportion\ p\ = \sqrt{\frac{p(1-p)}{n}}$$

$$95\%CI\ of\ the\ proportion\ p\ = p \pm 1.96 \times SE$$

**np>5 & n(1-p)>5*

Example:
Find proportion of obese people (BMI>30), given sample of 1000 people, among which 391 are obese.

p = 391/1000 = 0.391
SE = 0.0154
95%CI = 0.362 to 0.422

Question:
151 have asthma in 1000, compute..?

Given two groups of data

TEST FOR DIFFERENCES

TEST FOR ASSOCIATIONS

Hypothesis Testing (p-value)

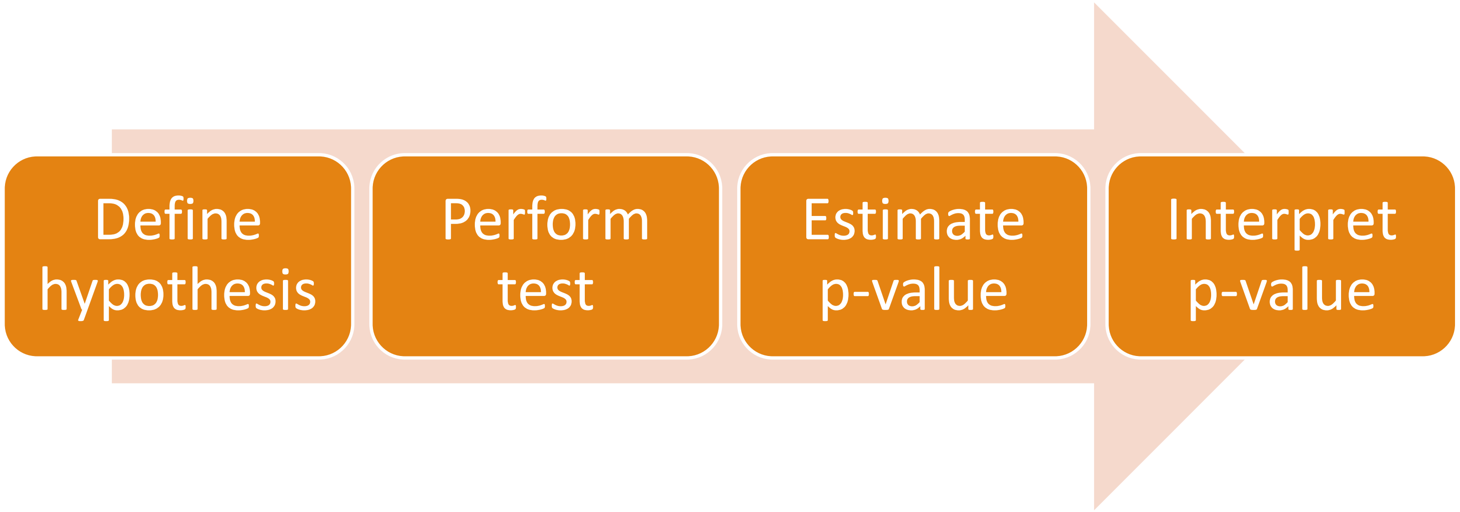
- Hypothesis? testing? P-value?

- Type I and type II error,

- Multiple testing and statistical power

Hypothesis and Testing

- Hypothesis: A statement about a true value of parameters and their relationship in a defined **population**
- Testing: The procedure, based on **sample,** to determine if the hypothesis is a ***reasonable statement****



Define Hypothesis

You have a question/statement? → **Define hypothesis**

In science to verify if a hypothesis is a reasonable statement, you need to test it against its contrary which is assumed to be true.

Null Hypothesis H0

Assumed to be true → No true difference or relationship between observed values in the sampled population

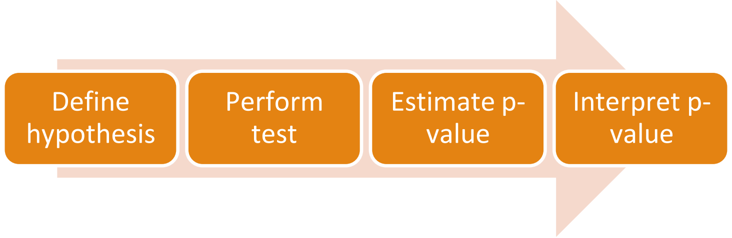
Alternative Hypothesis H1

To be proven → There **IS** true difference or relationship between ..

Example: Let's make some hypothesis

- Your friend says, you are always late.

Question:



Examples 1

Is lung function different between genders?

H0: lung function in men = lung function in women

H1: lung function in men ≠ lung function in women

Alternative Hypothesis – sides

- H1: lung function in men ≠ lung function in women - two sided
- H1: lung function in men < lung function in women - one sided
- H1: lung function in men > lung function in women - one sided

Define hypothesis → Perform test → Estimate p-value → Interpret p-value

Example 2

Is height in a class A and class B different?

H0: ?

H1: ?

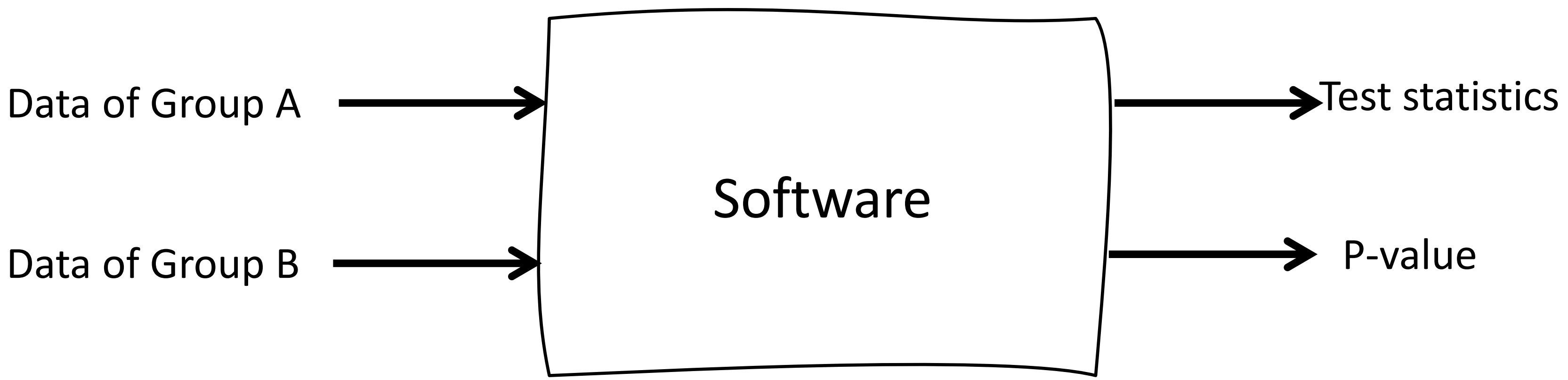
Question:

Can an alternative hypothesis be:

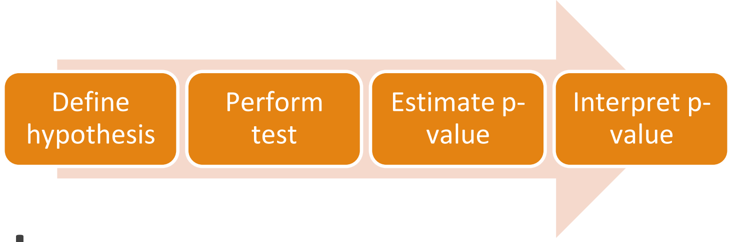
- **There is no difference between two samples?**
- **Two sample groups are same?**

Performing a test

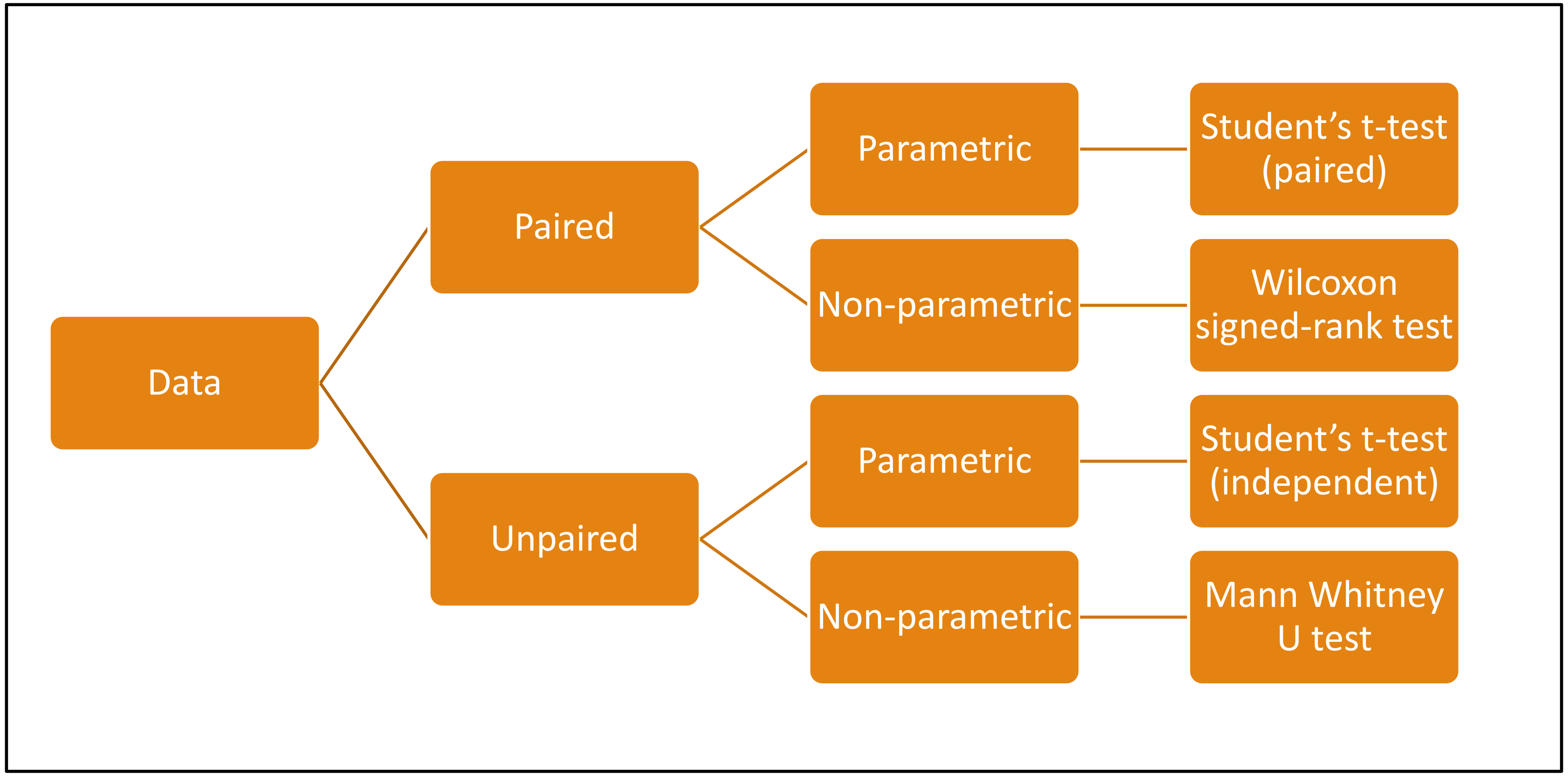
Performing a test on a two groups for establishing differences or association, we use software.

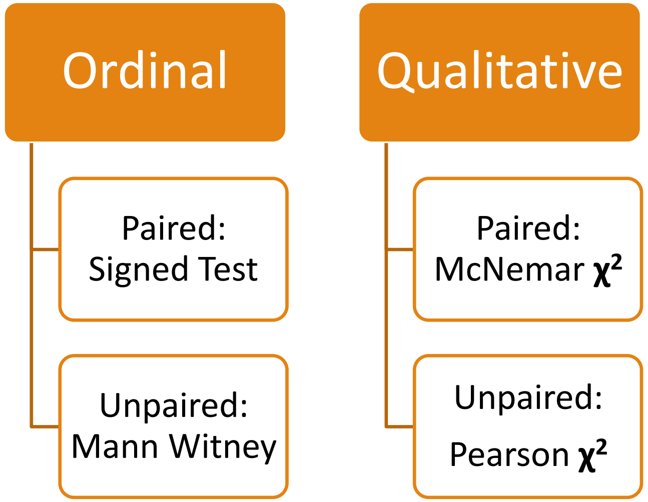


Good news! You don't need to remember the formulas
But you need to know, which test to perform and how to the read results



Perform test – right statistical test





Perform test

Estimate p-value

Test & P-value

With a right test, compute test statistics, that summarise the different/relationship in your sample.

- Use test statistics to compute p-value, that tells you either to ***accept or reject null hypothesis***

P-value: Probability of obtaining the difference/effect observed in given sample by pure effect of **chance**, when null hypothesis is true.

- If two samples comes from same population, how likely we see a difference between them

- Ranges from 0 to 1.
- To conclude a statistical significance , we need a cut-off value α (i.e. 0.05)
- NOT the probability of making a mistake!

P-value

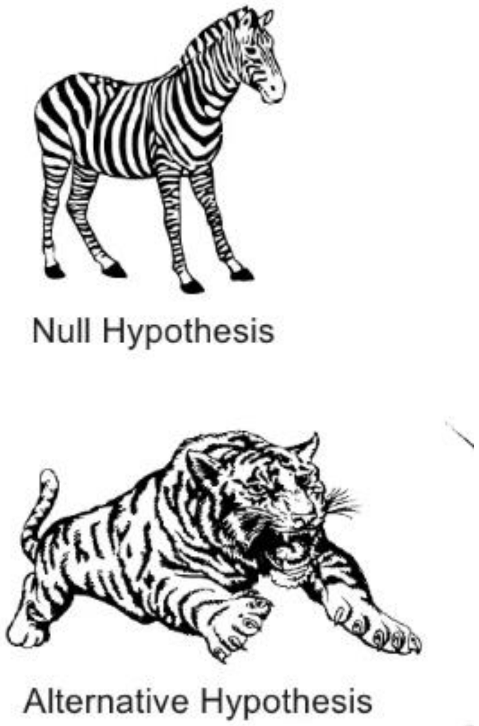
Example:

- If p-value is <0.05, we are confident enough to reject the null hypothesis.
- α = 0.05 → 5% chance of rejecting null hypothesis, even if it is true.
- α = 0.05 → probability of committing a type I error

	Null hypothesis H0	
	True	Not True
Accept H0 (fail to reject H0, $p>\alpha$)	Right	Type 2 Error (False negative with probability β)
Reject H0 ($p<\alpha$)	Type 1 Error (False positive with probability α)	Right

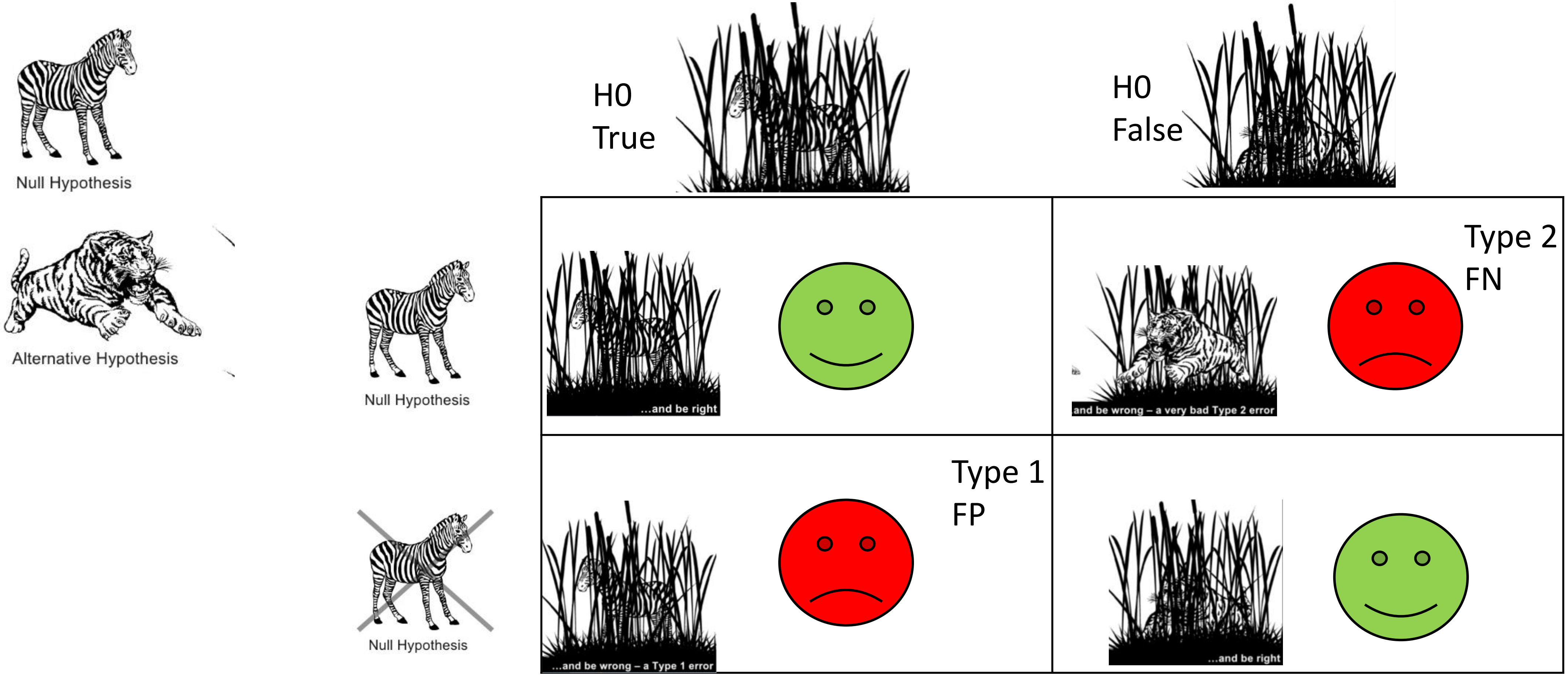
https://www.slideshare.net/smulford/type-1-and-type-2-errors

Type 1 and Type 2 Error



https://www.slideshare.net/smulford/type-1-and-type-2-errors

Type 1 and Type 2 Error



Type 1 and Type 2 Error

Type 1 Error (α):

- Rejecting TRUE null hypothesis
- False Positive
- α=0.05, 5% probability of false positive

Type 2 Error (β)

- Failing to reject FALSE null hypothesis
- False Negative
- Power is probability that we correctly rejects the Null Hypothesis
- Power = 0.8, β =0.20 (1-power), power 80%

P-value: summary

Smaller the p-value, stronger the evidence against null hypothesis

If p-value is <0.05:

- It is unlikely that any difference found in samples are due to chance
- Reject the null hypothesis in favour of alternative hypothesis
- **Statistical significance**

If p-value is <0.001:

- Strong evidence of significant results

What is p=0.049 or p=0.051?

- p-value is a guideline to decide if results deserves second look
- Ref: Scientific method: Statistical errors

Multiple testing

Each test has a 5% chance of 1 false positive

So running multiple tests increases the probability of false positive

On same dataset, testing for multiple outcomes, single outcomes in multiple sub-groups, or multiple effects.

- Before testing, limit your objectives and outcomes to be tested.
- If you have to apply for multiple testing, apply α correction methods (e.g. Bonferroni, α/n)

Significance and Meaningful

Statistically significant results does not always have meaningful relevance and vice-versa

Example:

- Two class groups A and B, have statistical significant ($p<0.001$) difference of 2 marks in a subject.
- Men and women have a statistically significant difference of 0.5mL in lung function

Power and Sample size (N)

- Low power (due small sample size) increase the probability of False Negative

- You might find no difference between groups, and that might be False Negative, due to high β or low power (small sample size)

Example

Group	N	Mean	sd
Male	421	3555.20	909.75
Female	407	2500.77	625.99

Difference in mean = 1054.43
p-value <0.0001
T-statistics = 0.81

Group	N	Mean	sd
Male	12	3548.08	917.3
Female	8	2993.00	571.3

Difference in mean = 555.08
p-value = 0.4319
T-statistics = 0.81

Sample Size calculation

For two groups with mean m1 and m2, and standard deviation of sd, we need N samples in each group to be able to reject a null hypothesis with probability of False positive as 5% and probability of False negative of 80%

$$N\ in\ each\ group = f(\alpha,\beta) \times \frac{2(sd^2)}{(m_2 - m_1)^2}$$

$$f(\alpha,\beta) = f(0.05,0.20) = 7.85$$

Don’t worry about the formula, it is available in all the software.

Important thing to notice → smaller the difference you like to detect, more samples you need, smaller the sd is less sample you need

Choosing the correct Test

Numerical

- **Quantitative:** blood pressure, sugar level, no of cells, height, BMI | cont., discrete

Categorical

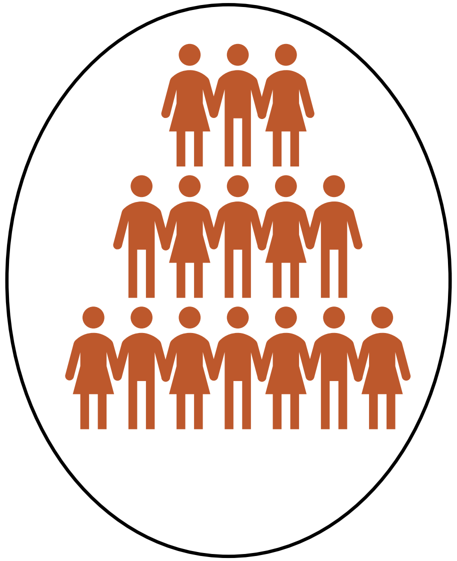
- Qualitative: ethnicity, disease or not? , sex? | binary (2), nominal (>2)
- Ordinal: satisfaction-rating, age-group

Unpaired (independent)	**Paired (dependent)**
- Data collected from each sample is independents of time (usually collected once)	- Data collected from same subjects at different time (before and after treatment)
- Different subjects in different groups	- Same subjects in different groups
- BMI, age, height of subject	- BMI, before and after a treatment

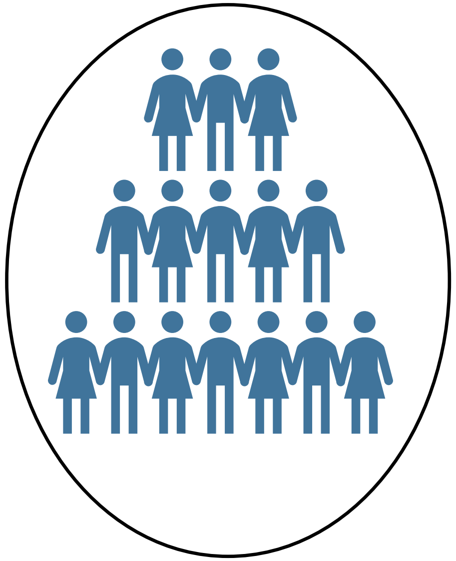
Examples?

Unpaired & Paired

Unpaired

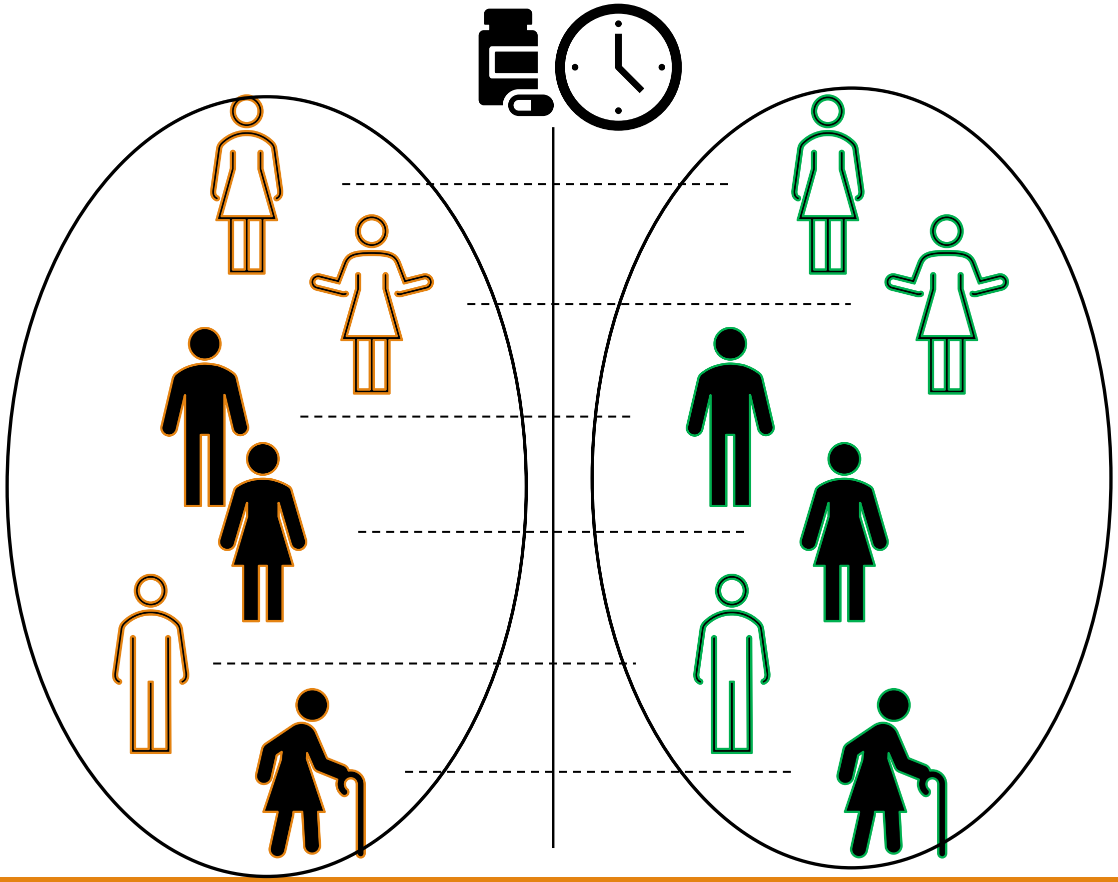


A



B

Paired



Parametric & Non-parametric

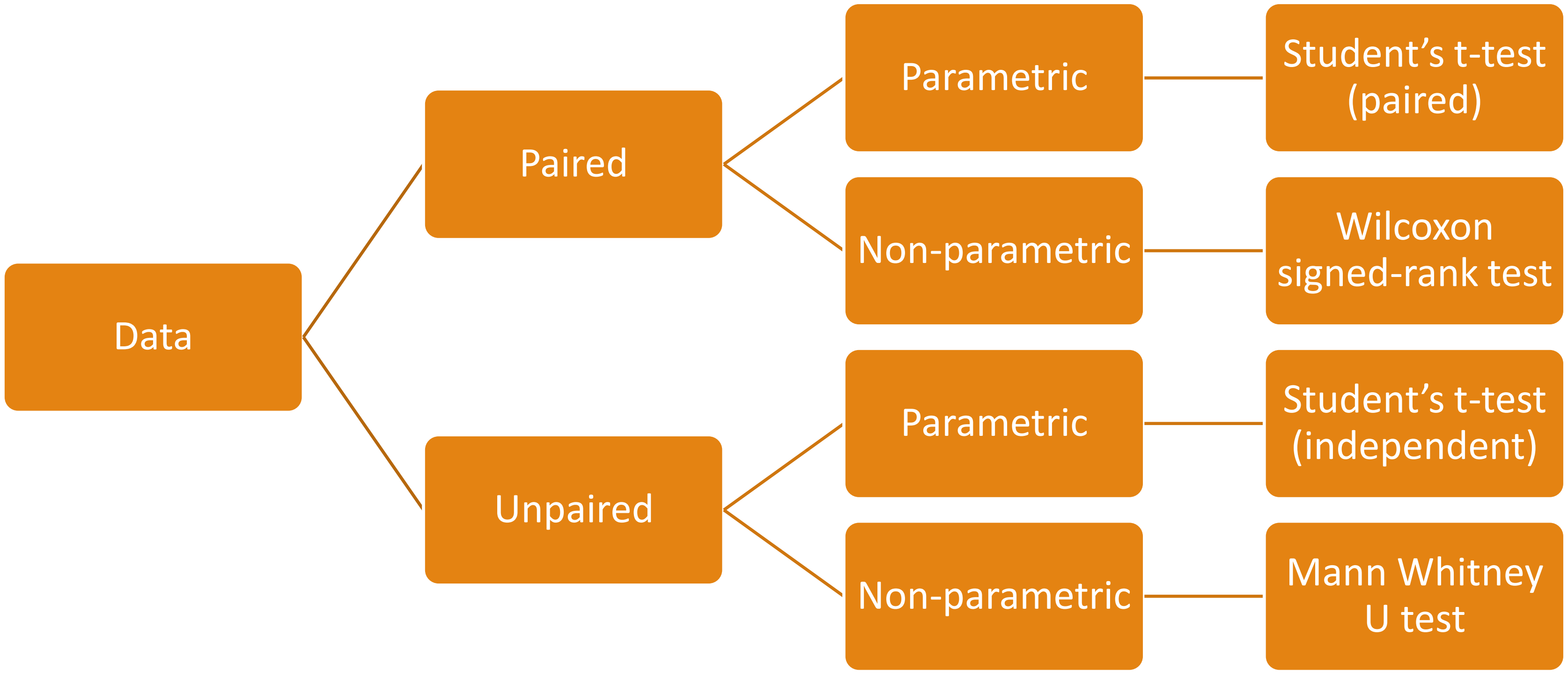
Parametric Tests

- Relies on the underlaying statistical distribution
- Normally distributed data (normality test)

Non-parametric Tests

- Do not depend on any distribution

Tests


Data
Paired
Unpaired
Parametric
Non-parametric
Parametric
Non-parametric
Student’s t-test (paired)
Wilcoxon signed-rank test
Student’s t-test (independent)
Mann Whitney U test

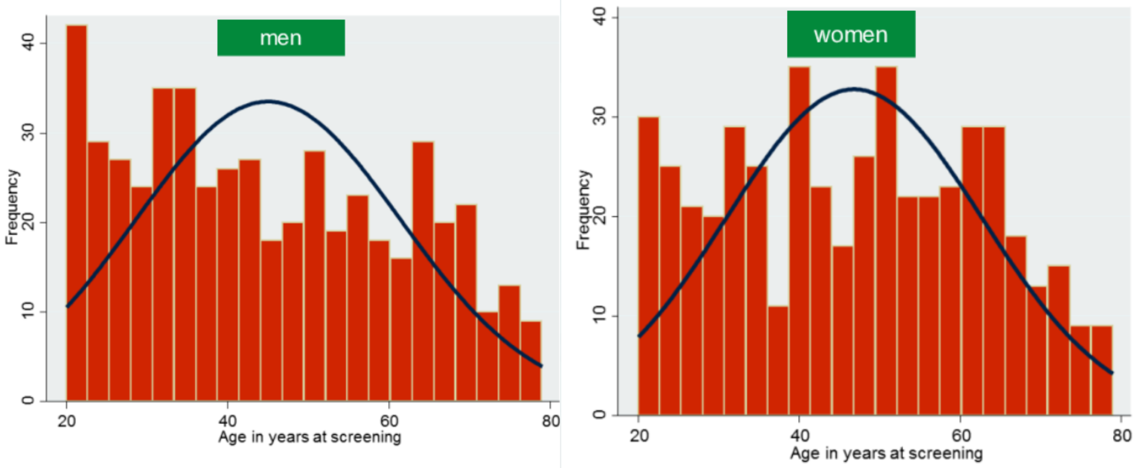
Example 1

Is average age of men and women different in given sample (dataset)?*

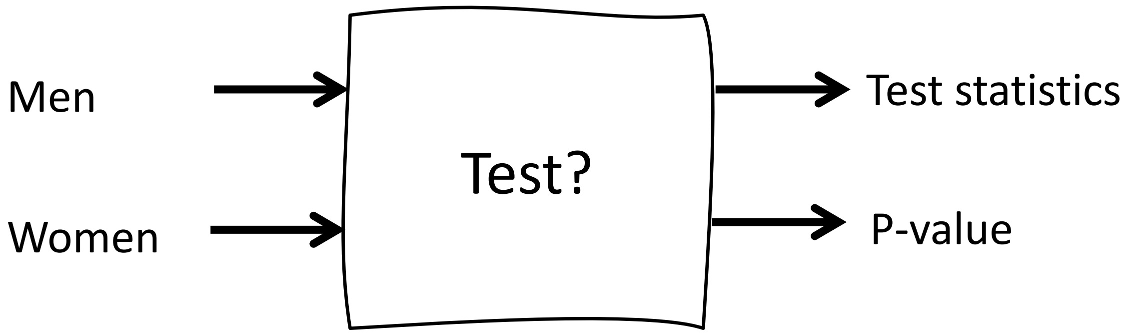
H0: $\mu_{men} = \mu_{women}$

H1: $\mu_{men} \neq \mu_{women}$

Paired? Normality? Equal variance?



Group	N	mean age	sd	sd^2
Men	514	45	16.41	269.38
Women	486	46.83	15.87	251.81



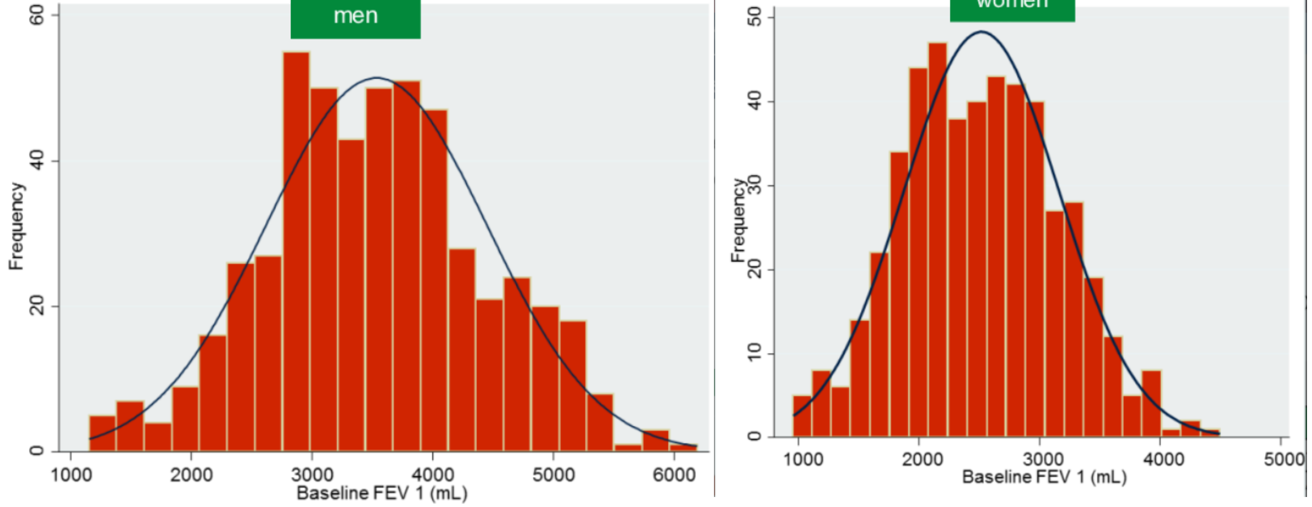
Test statistics: 1.79

P-value: 0.0741

Age difference?

Example 2

Is the average lung function in men different to one in women in general population

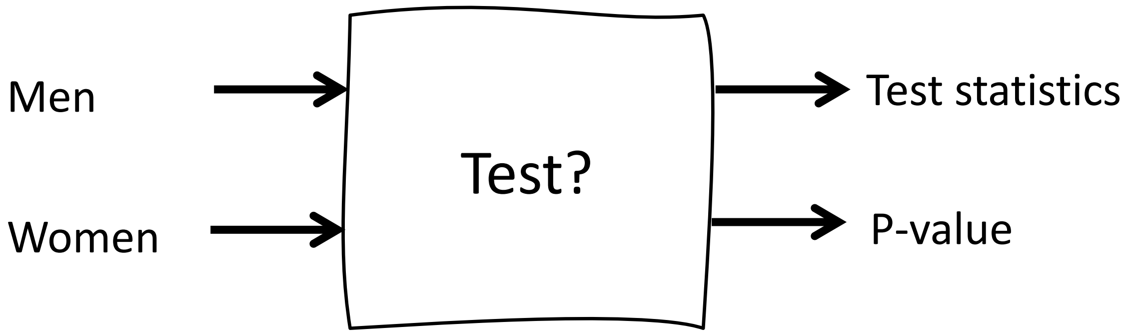


H0: $\mu_{men} = \mu_{women}$

H1: $\mu_{men} \neq \mu_{women}$

Group	N	mean fev1(mL)	s d
Men	514	3535.08	915.08
Women	486	2515.17	646.08

Paired? Normality? Equal variance?

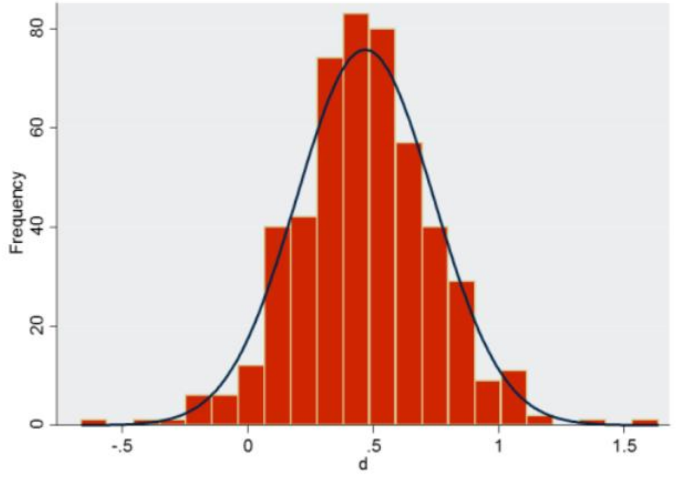


Test statistics: 20.26

P-value: 0.001

difference?

Example 3



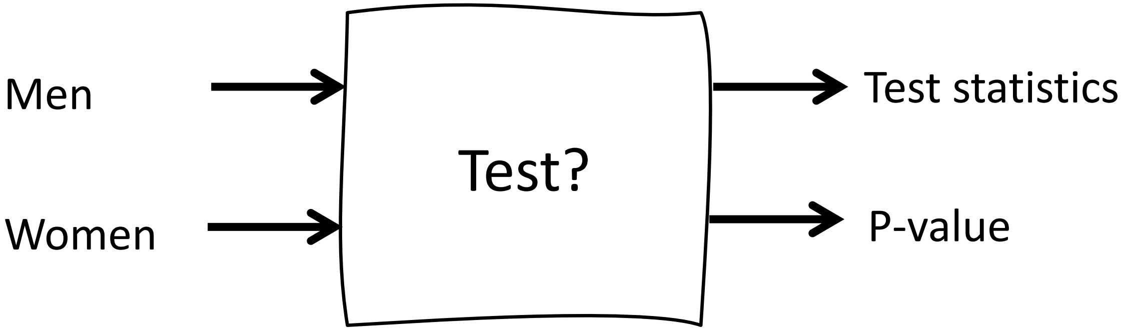
Has the lung function changed after intense exercise in the study

H0: $\mu_{before} = \mu_{after}$: $\boldsymbol{\mu_d = 0}$

H1: $\mu_{before} \neq \mu_{after}$: $\boldsymbol{\mu_d \neq 0}$

	N	mean	median	sd	sd
d	496	0.47	0.47	0.27	0.01

Paired? Normality? Equal variance?

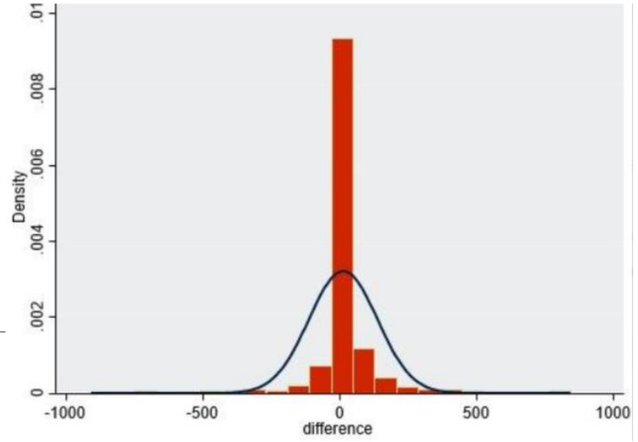


Test statistics: 38.13

P-value<0.001

difference?

Example 4

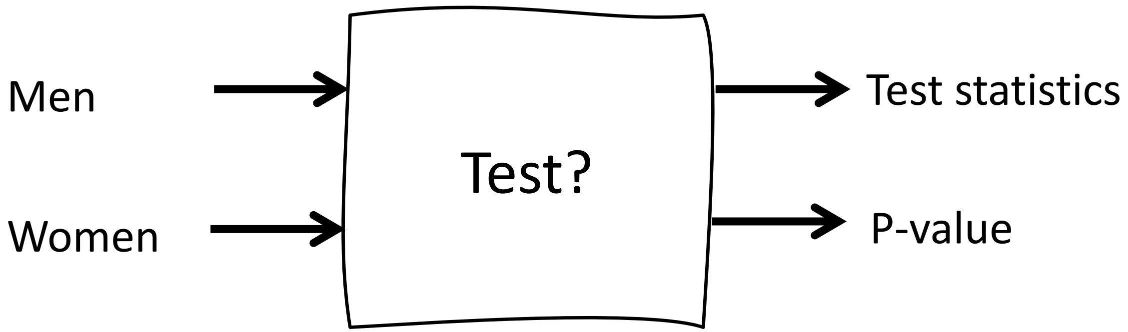


Has total immunoglobulin E (IgE) changed over time (over 10 years)

H0: $\mu_{before} = \mu_{after}$: $\boldsymbol{\mu_d} = \mathbf{0}$

H1: $\mu_{before} \neq \mu_{after}$: $\boldsymbol{\mu_d} \neq \mathbf{0}$

Paired? Normality? Equal variance?



Test statistics: 10

P-value>0.05

Let’s give it a try

From the statement from list, let’s define a hypothesis, testing approach:

1. Effectiveness of a teaching method for a subject
2. Effectiveness of a drug on elderly >50 for lung function
3. Lung function of smokers and non-smokers

Association between two

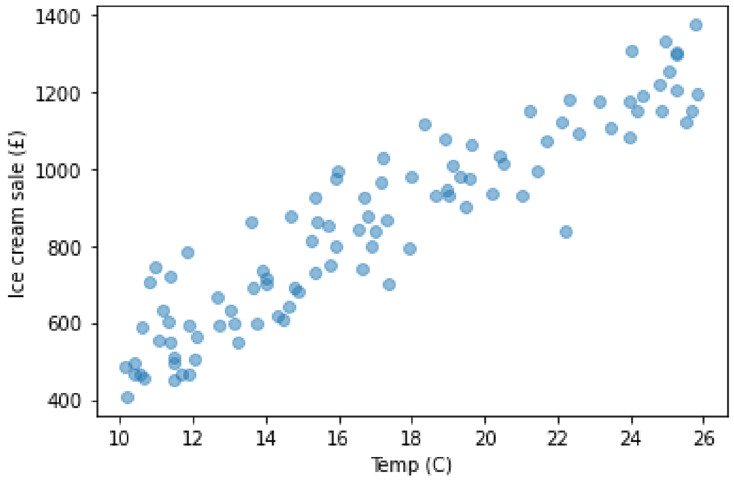
Correlation

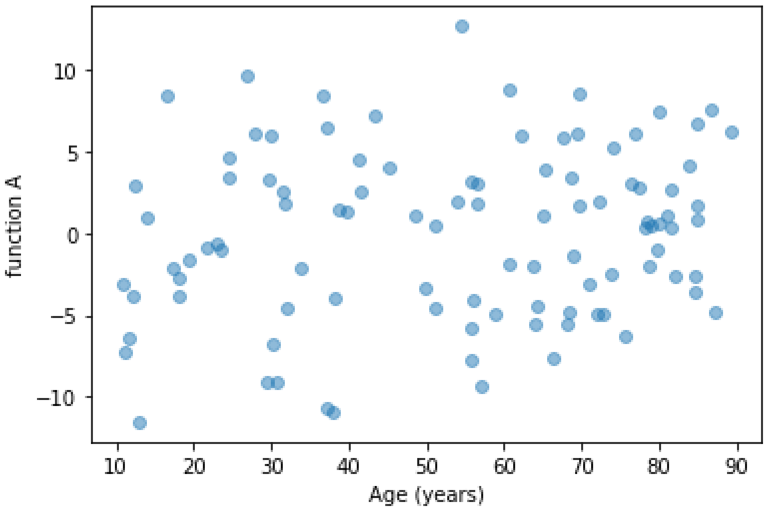
- Investigate a relationship between two independent variables (i.e. x and y)

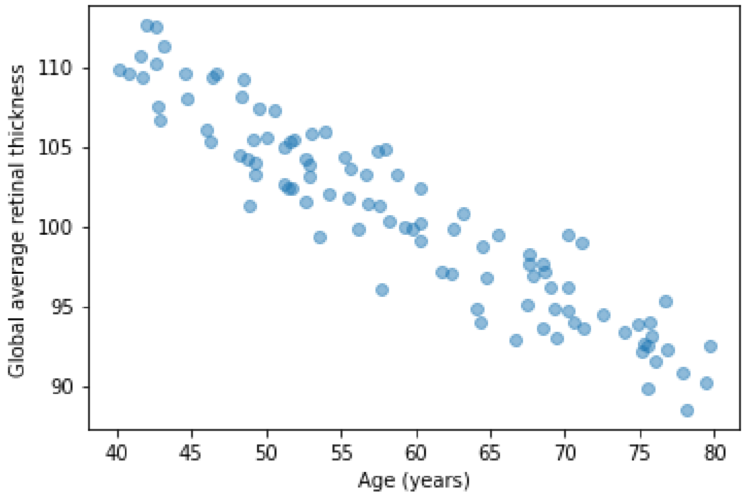
- Does x increases as y or vice-versa?

- Is relation linear?

One simple way is to plot scatter graph and see

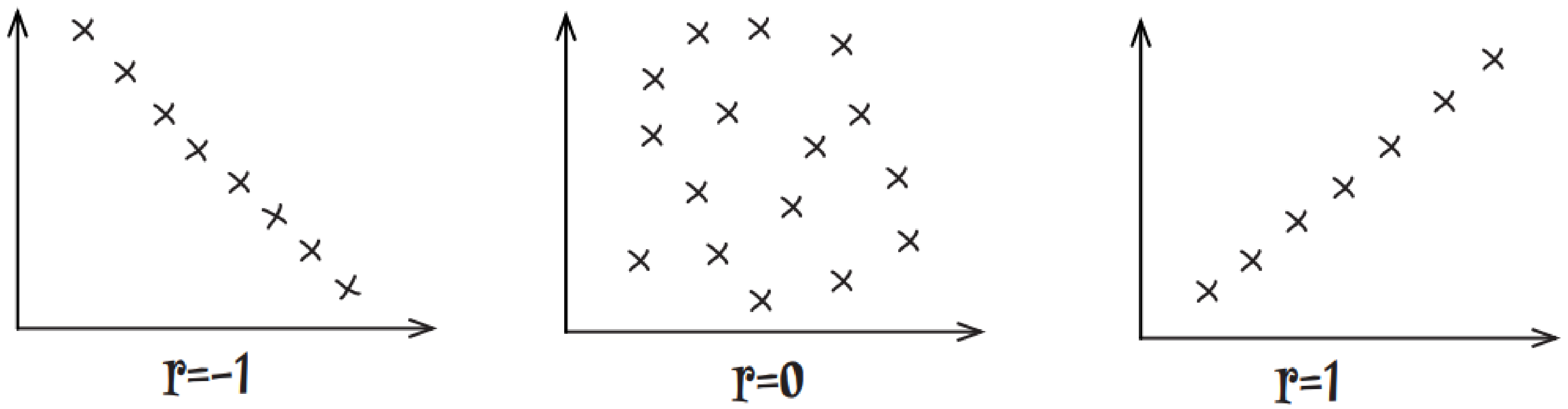




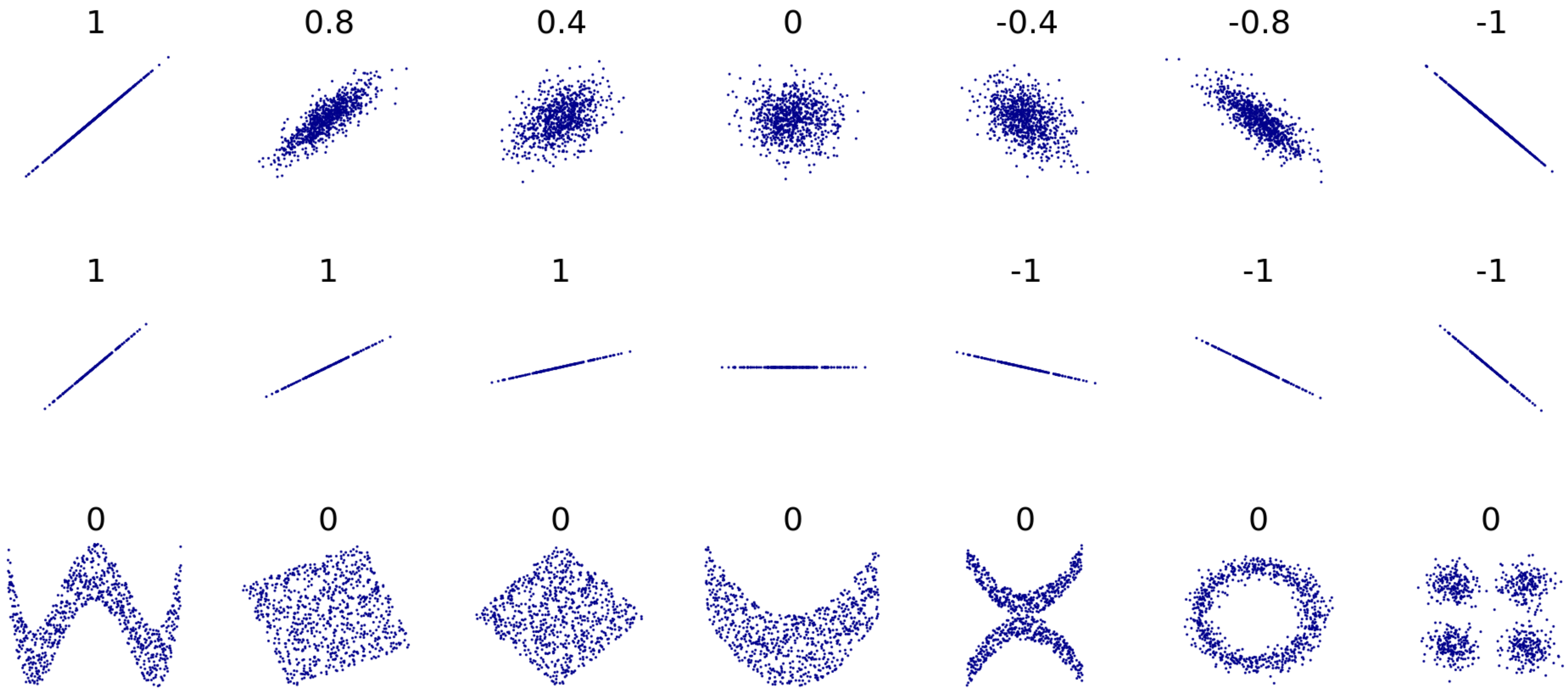


Quantifying Correlation

Pearson Correlation Coefficient r or ρ (rho)



Pearson Correlation Coefficient



https://en.wikipedia.org/wiki/Correlation

Correlation

Pearson Correlation Coefficient

Parametric test

- x, y: normally distributed
- linear relationship

Generally:

- $|r| < 0.4$ → weak
- $0.4 < |r| < 0.7$ → moderate
- $0.7 < |r|$ → strong

$r = 0$, no ***linear*** relationship

Spearman Rank correlation

Non-parametric test

Based on ranks rather than exact values

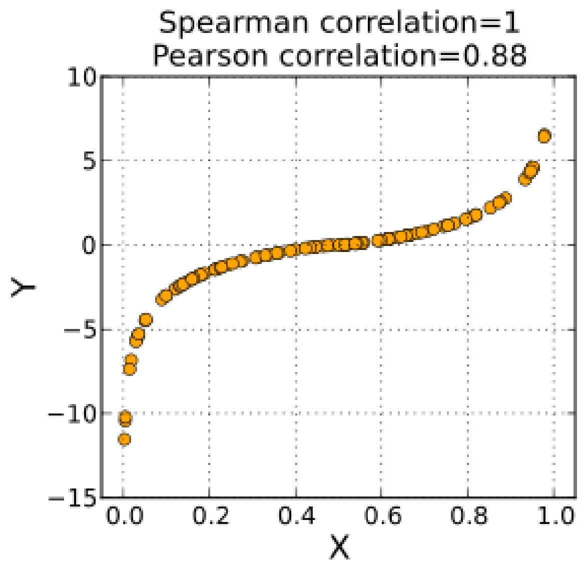


Image: https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient

Correlation and P-value

P-value can be obtained from correlation with

Null Hypothesis $H0 : r = 0$

Alternative Hypothesis $H1 : r \neq 0$

P-value tells us the probability of getting high correlation between x and y by pure chance

Examples

1. BMI vs Age, r= 0.13, p-value =0.08

2. BMI vs Age, r= 0.13, p-value =0.04

3. lung function before vs after exercise, r= 0.93, p-value = 0.001

Correlation

A strong correlation between x and y does **Not mean**

- x causes y : X → Y
- y causes x : Y → X
- x and y are caused by one or more other variables z: Z→X, Z → Y

Correlation is not causation

Stats Demo links:
https://nikeshbajaj.github.io/P/Stats/Stats_Sampling_demo.html
https://c4fa.github.io/nikJS/Stats/

If you have any question or doubt, please contact me via email

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