Human Centred Systems Design

Quantitative Research Methods

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Evaluation in HCI

- ✓ Measuring Usability — Week 8 → Assignment hand-out (Tuesday 14th November (week 8))
- ✓ Qualitative Research Methods — Week 9
- ✓ Experimental Design — Week 10
- ⇨ Quantitative Research Methods — Week 11 → Assignment hand-in via MOLE (Monday 11th December (week 12))

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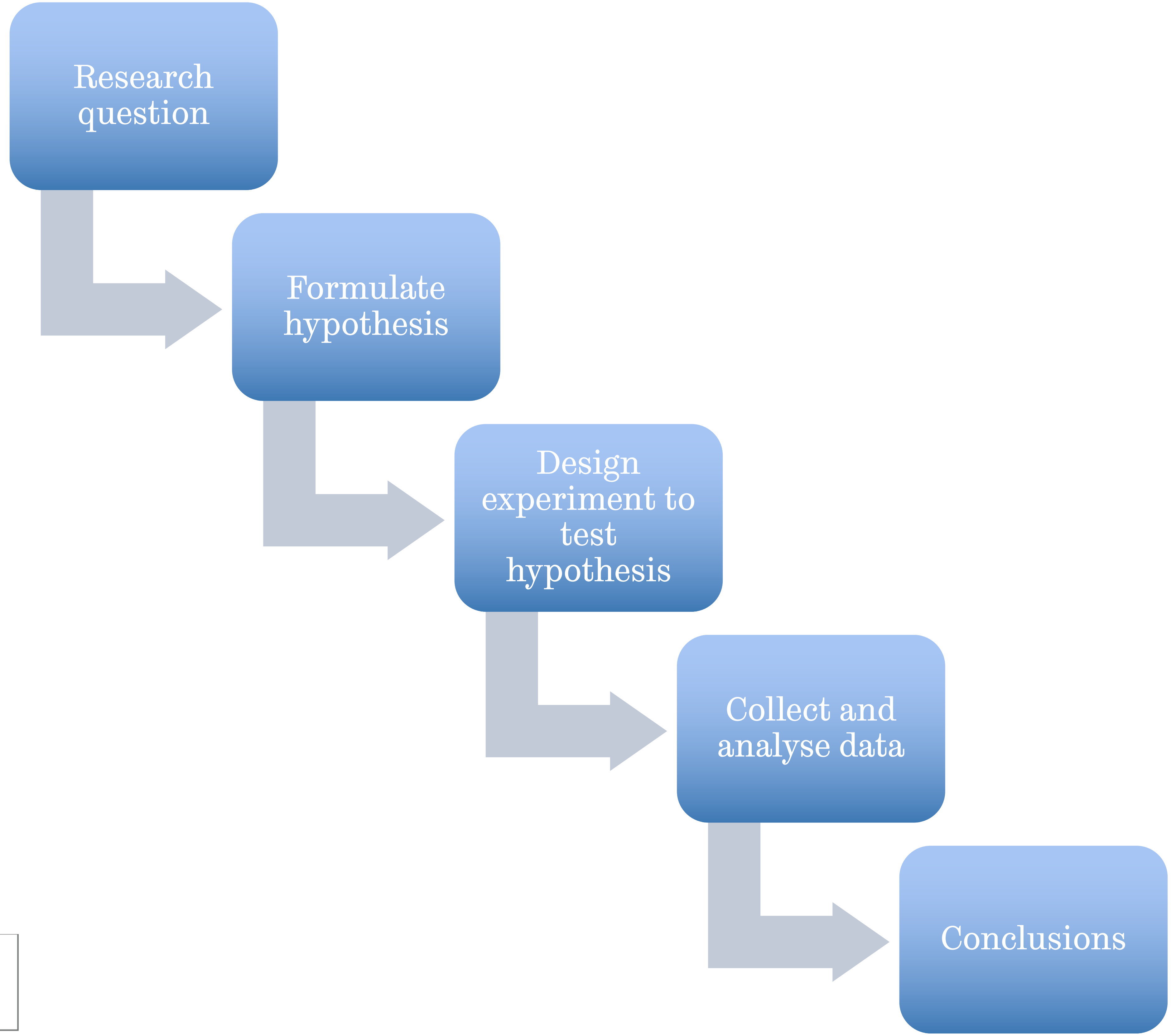
Experimental Research Methods



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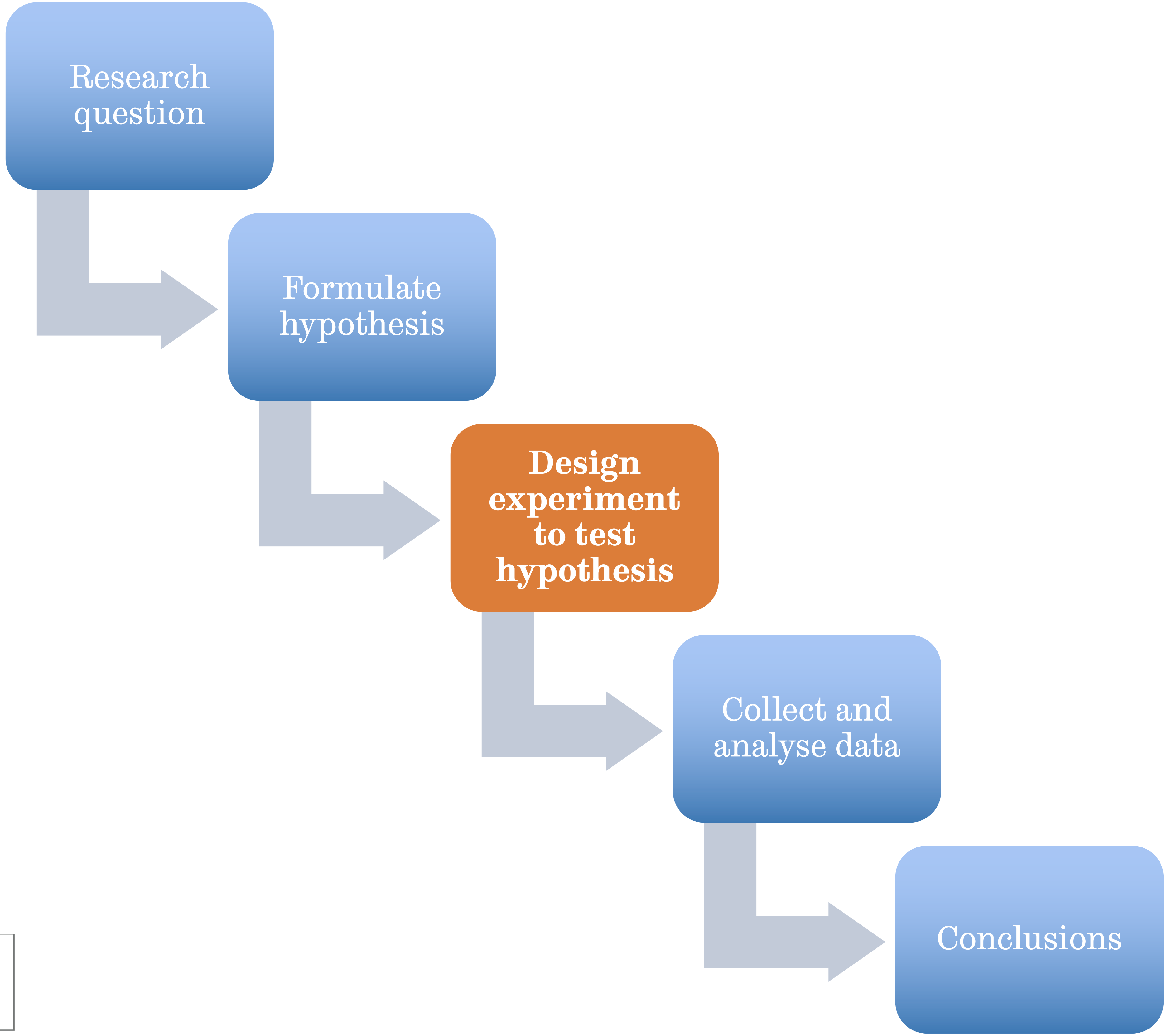
Experimental Research Methods



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Qualitative research	vs.	Quantitative research
Discover ideas and gain insight and understanding	**Aim**	Test hypotheses and specific research questions
Observe, survey and interpret	**Approach**	Measure and test
Mixed	**Data collection**	Structured
Researcher involved and results subjective	**Researcher independence**	Researcher uninvolved observer, objective results
Small samples, naturalistic setting	**Sample size**	Larger samples for generalisable results

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Qualitative Research Methods

- Qualitative vs Quantitative Data
- Qualitative Research Methods
- Traditionally, in Human-Computer Interaction:
  1. Surveys
  2. Interviews
  3. Focus groups
  4. Diaries
  5. Ethnographic research

Mostly descriptive!

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Quantitative Research Methods

❶

- **Descriptive statistics**
  - organising data
  - summarising data
  - simplifying data
  - describing and presenting data

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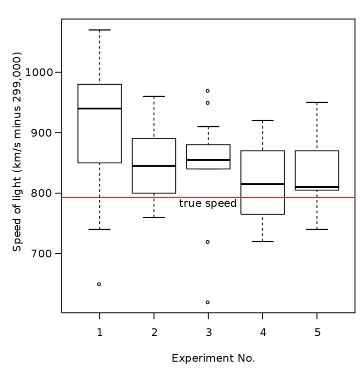
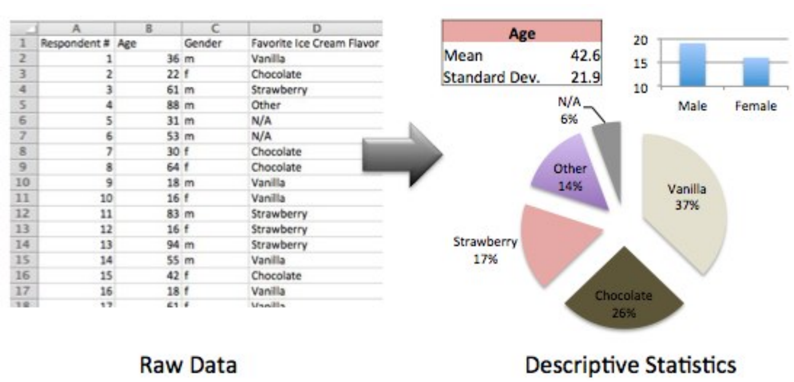
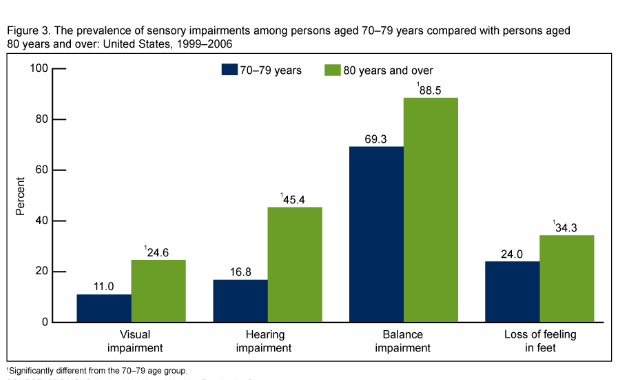
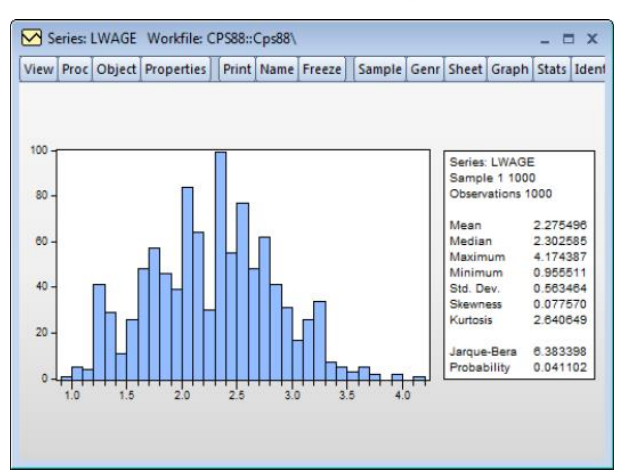
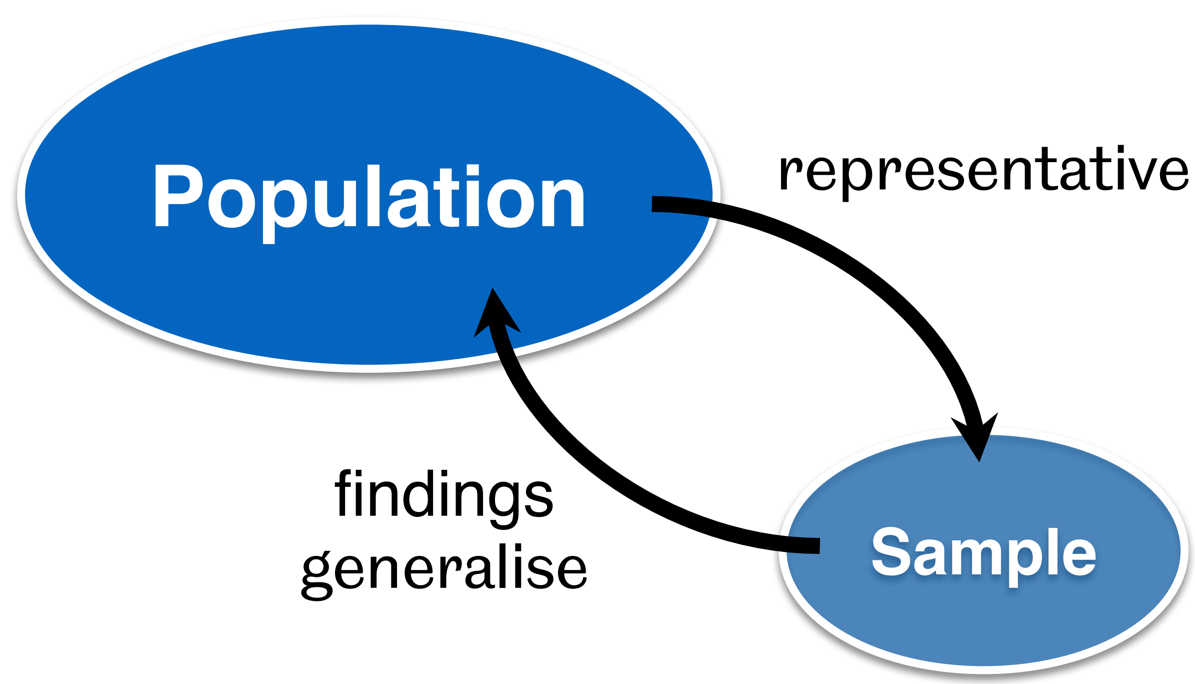
- **Inferential statistics**
  - generalising from samples to populations
  - making predictions
  - hypothesis testing











Example: Tossing a coin

- Toss a coin 10 times and record the order of heads (H) and tails (T)
- Which is more likely?
  - HHHHHHHHHH?
  - TTTTTTTTTT?
  - HTTHHTTHHT?

- <u>Research question</u>:
  Is this coin fair or in favour of heads?

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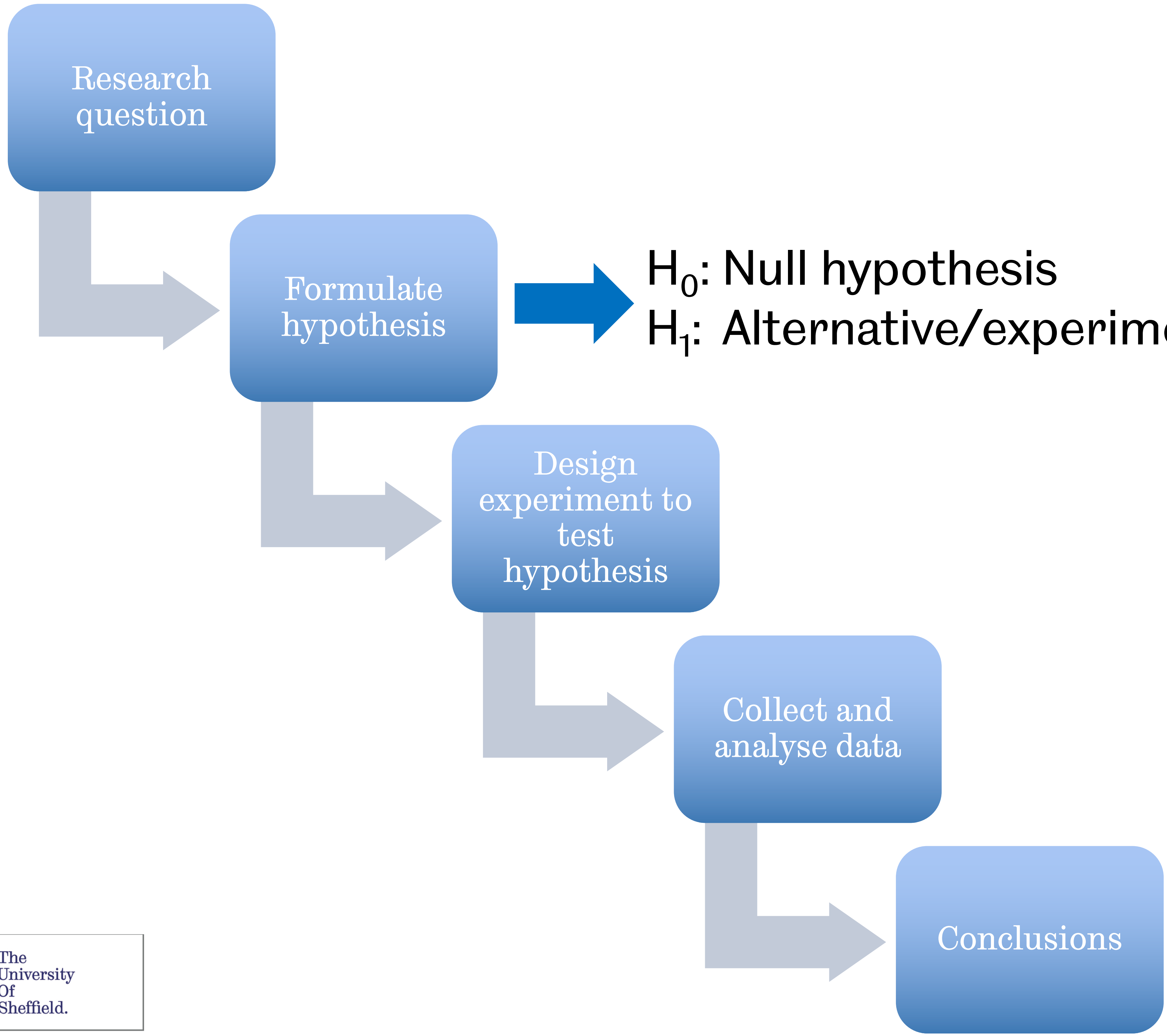
Experimental Research Methods



H_0: Null hypothesis
H_1: Alternative/experimental hypothesis

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Null hypothesis

- H_0 – The hypothesis that nothing has changed
  - E.g. That our actions have not had a corresponding effect
  - E.g. There is no difference between experimental treatments

We can never prove the null hypothesis
We may just find evidence to reject it

Experimental (alternative) hypothesis

- H_1 – The hypothesis we are interested in, what we are testing for
  - E.g. That something has changed in the world because of our actions

It is mutually exclusive with the null hypothesis, i.e. they can not happen simultaneously

Null hypothesis: Example

- Research question: do dogs eat bananas?
- H_1 – Experimental/alternative hypothesis: dogs eat bananas
- H_0 – Null hypothesis: dogs do not eat bananas

- Null hypothesis is tested –
  It can be rejected if a dog is seen eating a banana

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Null hypothesis: Example

- We believe that people will be able to remember more words from a list when
(a) they are organised into meaningful groups than when (b) they are presented randomly.

- H_0 – Null Hypothesis:
  - There is no difference in the number of words people can remember under condition (a) and condition (b)
- H_1 – Experimental/Alternative Hypothesis:
  - People will remember more words in condition (a) than in condition (b)

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Example: Tossing a coin

- Research question:
  Is this coin fair or biased in favour of heads?
- H_0 - null hypothesis: the coin is fair (i.e., the probability of a head is 0.5)
- H_1: alternative/experimental hypothesis: the coin is biased in favour of a head (i.e. the probability of a head is greater than 0.5, e.g. it is 0.7)
- Experiment: Toss a coin 10 times and record the order of heads (H) or tails (T)
- Testing: On the basis of the outcomes, make your decision.

Example: Tossing a coin

- Research question:

But…

How many times should we toss the coin to be sure?

Is 10 times sufficient?

order of heads (H) or tails (T)

- Testing: On the basis of the outcomes, make your decision.

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Example (and a Task)

a) Mike's height is 6'2". Mary's height is 5'8".

So Mike is taller than Mary.

b) The average height of three males (Mike, John, and Ted) is 5'5". The average height of three females (Mary, Rose, and Jessica) is 5'10".

So females are taller than males.

<u>Some questions</u>:

- *Which of the above statements are correct?*
- *Why?*

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Example (possible answers)

> b) The average height of three males (Mike, John, and Ted) is 5’5”. The average height of three females (Mary, Rose, and Jessica) is 5’10”.
>
> *So females are taller than males.*

- It’s common sense, males are generally taller than females
- I can easily find 3 other males and 3 other females, in which the average height of the males is higher than that of the females
- There are only 3 individuals in each group! The sizes of the comparison groups are too small
- The individuals in both the male and female groups are not representative of the general population

Clear example of inappropriate sampling!

Why would I want to do this in HCI?

- Because we want to demonstrate something
- e.g.
  - Improvement in processing
  - Better user interface design
  - More acceptable robot
- We want robust findings that allow us to draw reliable conclusions

Significance Tests

- Purpose:
  Indicate whether observed differences between assessment results occur because of sampling error or chance.
- When are they necessary?
  - When all values of the members of the comparison groups are known, direct comparison of values is possible and we can draw a conclusion.
    Not needed, there is no uncertainty involved
  - When the population is large, we can only sample a sub-group of people from the entire population
    Needed, as they allow us to determine how confident we are that the results observed from the sampling population can be generalized to the entire population

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Example (and a Task)

a) Mike's height is 6'2". Mary's height is 5'8".
b) The average height of three males (Mike, John, and Ted) is 5'5".
The average height of three females (Mary, Rose, and Jessica) is 5'10".

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  Not needed, there is no uncertainty involved

a) or b)????

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a) or b)????

Example (and a Task)

a) Mike's height is 6'2". Mary's height is 5'8".
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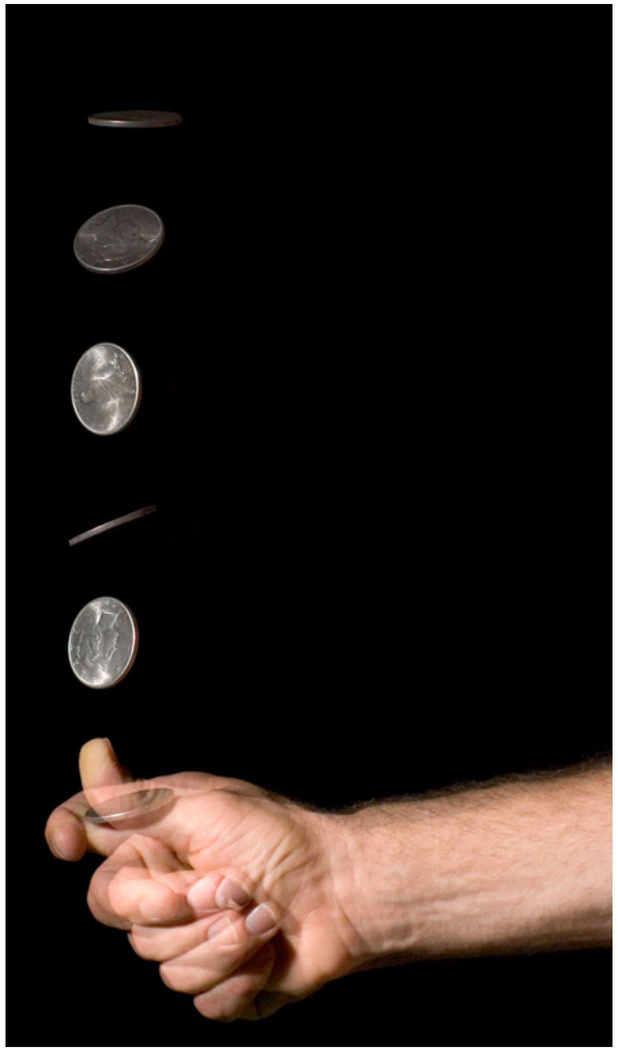
b) The average height of three males (Mike, John, and Ted) is 5'5".
The average height of three females (Mary, Rose, and Jessica) is 5'10".

Example: Tossing a coin

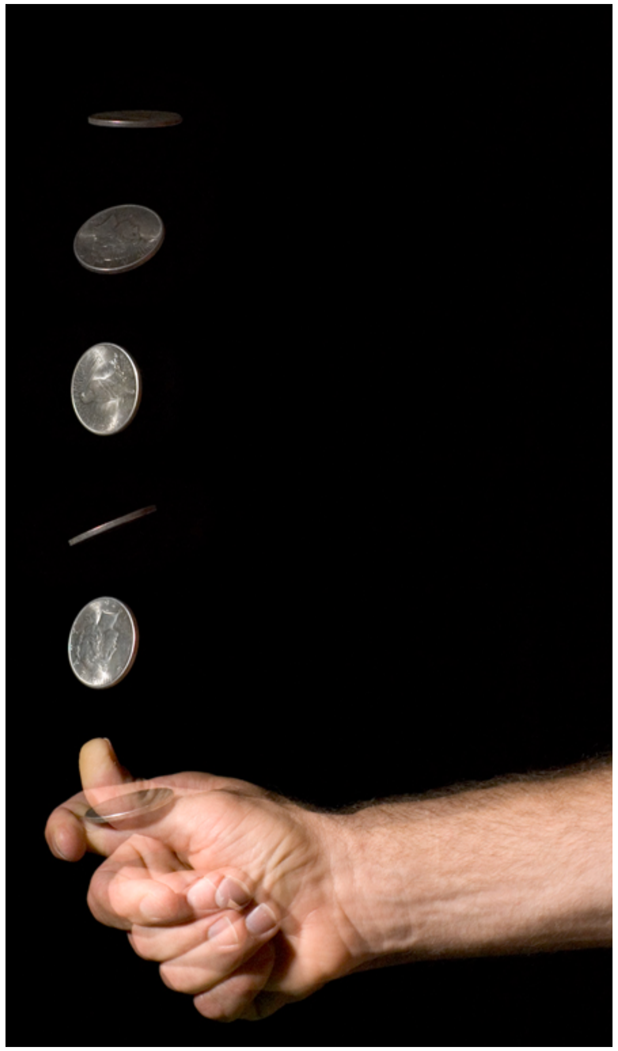
- Research question:
  Is this coin fair or biased in favour of heads?
- Experiment: Toss a coin 10 times and record the order of heads (H) or tails (T)



Tossing a coin: Possible outcomes

- Coin is not biased
  - Our data indicates that it is not biased
    - Correct decision
  - Our data indicates that it is biased
    - Incorrect decision

- The incorrect case is an example of Type I error (false positive)



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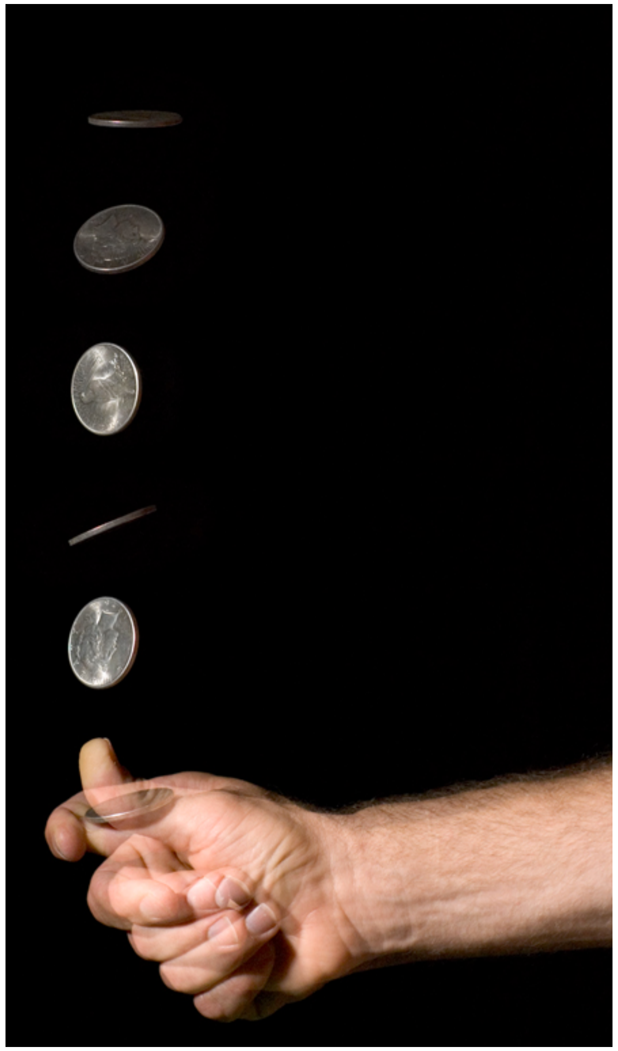
Tossing a coin: Possible outcomes

- Coin is biased
  - Our data indicates that it is biased
    - Correct Decision
  - Our data indicates that it is not biased
    - Incorrect Decision

- The incorrect case is an example of <u>Type II Error (false negative)</u>



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Type I and Type II errors

- All significance tests are subject to the risk of Type I and Type II errors
  - <u>Type I error (*α error or “false positive”*)</u>*:*
    The mistake of rejecting the null hypothesis when it is true and should have not been rejected
  - <u>Type II error (*β error or a “false negative”*)</u>*:*
    The mistake of not rejecting the null hypothesis when it is false and should have been rejected

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Type I and Type II errors: example

- H_0: The defendant is innocent
- H_1: The defendant is guilty

A judicial case (innocence is presumed)		**Jury decision ("prediction")**	
		Not guilty	Guilty
Reality (truth)	Not guilty	✓	Type I error
	Guilty	Type II error	✓

Type I and Type II errors: example

- H_0: No difference between ease of use of ATMS with touch screens vs ATMs with buttons
- H_1: ATMs with touch screens are easier to use than ATMs with buttons

HCI experiment		**Study conclusion ("prediction")**	
		???	???
Reality (truth)	???	✓	Type I error
	???	Type II error	✓

Type I and Type II errors: example

- H_0: No difference between ease of use of ATMS with touch screens vs ATMs with buttons
- H_1: ATMs with touch screens are easier to use than ATMs with buttons

HCI experiment		**Study conclusion ("prediction")**	
		No difference	Touchscreen ATM easier
Reality (truth)	No difference	✓	Type I error
	Touchscreen ATM easier	Type II error	✓

Type I and Type II errors: example

- H_0: Patient does not suffer from disease A
- H_1: Patient does suffer from disease A

Diagnosis test		Outcome of diagnosis test ("prediction")	
		Negative	Positive
Reality (truth)	Negative	???	???
	Positive	???	???

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Type I and Type II errors: example

- H_0: Patient does not suffer from disease A
- H_1: Patient does suffer from disease A

Diagnosis test		Outcome of diagnosis test ("prediction")	
		Negative	Positive
Reality (truth)	Negative	✓	Type I error
	Positive	Type II error	✓

Type I and Type II errors

- Typical considerations:
  - It is generally believed that Type I errors are worse than Type II errors
  - Statisticians call Type I errors a mistake that involves "gullibility"
    - A Type I error may result in a condition worse than the current state
  - Type II errors are mistakes that involve "blindness"
    - A Type II error can cost the opportunity to improve the current state

Controlling risks of errors

- In statistics,
  - the probability of making a Type I error is called alpha (α) or significance level (p-value)
  - the probability of making a Type II error is called beta (β)
  - the statistical power of a test, defined as $1-\beta$, refers to the probability of successfully rejecting *a* null hypothesis when it is false and should be rejected

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Controlling risks of errors

- Alpha (α) and beta (β) are interrelated and under the same conditions:
  - a decrease in α reduces the chance of making Type I errors,
  - but increases the chance of making Type II errors
- In experimental research, it is generally believed that
  - Type I errors are worse than Type II errors

So a very low *p*-value (0.05) is widely adopted to control the occurrence of Type I errors

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Controlling risks of errors

Research question

Formulate hypothesis

Design experiment to test hypothesis

Collect and analyse data

Conclusions

Careful experiment design

- Check again the formulation of your research question an hypotheses
- Ensure sample sizes are high enough
- Be rational about approach
- Repeat experiments

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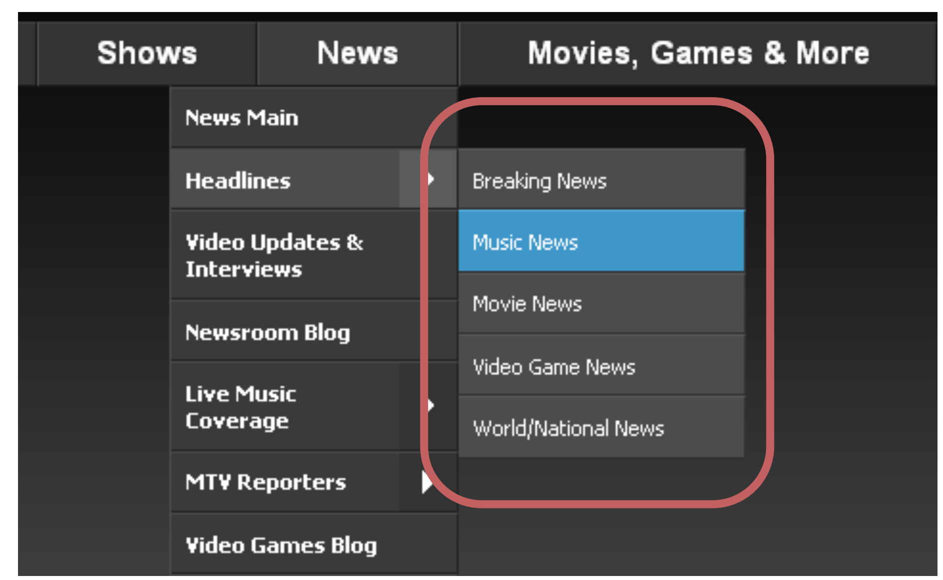
Example: Research Question

The developers of a website want to know
if a pull-down menu or a pop-up menu is better

- Research question:
  - Which menu type is best for navigating the site?

vs.



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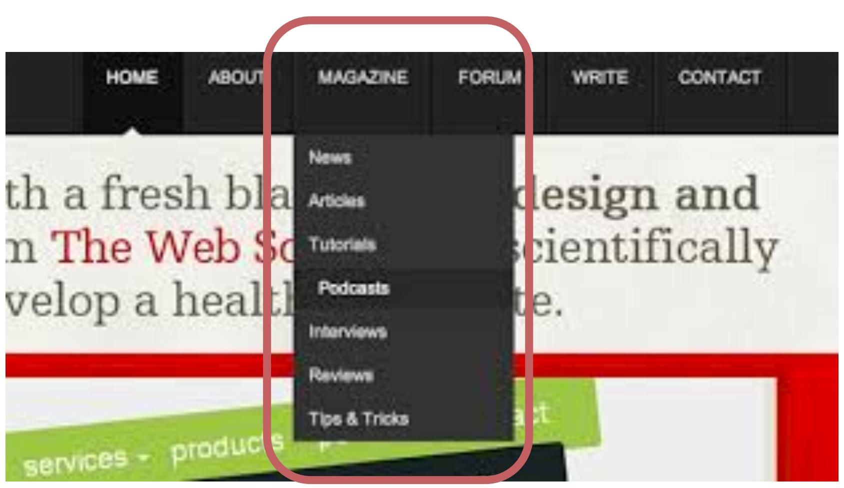
Formulating a hypothesis: Example

The developers of a website want to know
if a pull-down menu or a pop-up menu is better

- <u>Research question</u>:
  - Which menu type is best for navigating the site?
- <u>What we evaluate (*independent variable*)</u>:
  - the type of menu (pull-down or pop-up)
- <u>On the basis of what measure (*dependent variable*)</u>:
  - time spent locating web pages



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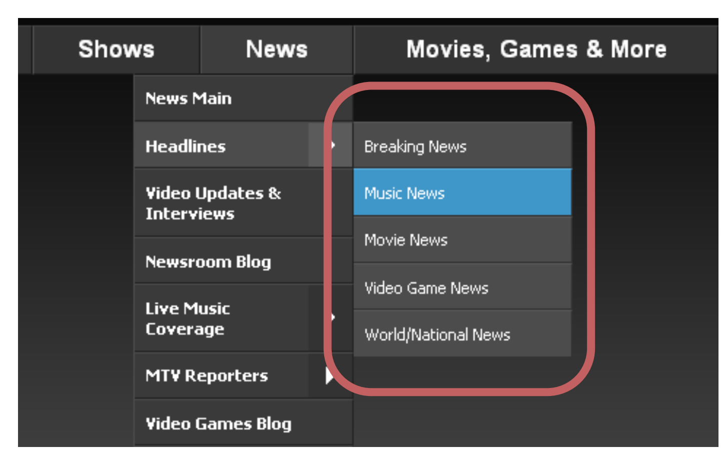

In HCI, we typically evaluate

- Technology
  - e.g. types of technology or device, types of design…
- Users:
  - e.g. age, gender, computer experience, professional domain, education, culture, motivation, mood, and disabilities
- Context of use:
  - e.g. physical status, user status, social status…

Independent variables

In HCI, measures typically used

- Efficiency:
  - e.g., task completion time, speed
- Accuracy:
  - e.g., error rate
- Subjective satisfaction:
  - e.g., Likert scale ratings
- Ease of learning and retention rate
- Physical or cognitive demand
  - e.g., NASA task load index

Dependent variables

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Formulating a hypothesis: Example

The developers of a website want to know
if a pull-down menu or a pop-up menu is better

- Research question:
    - Which menu type is best for navigating the site?
- What we evaluate (*independent variable*):
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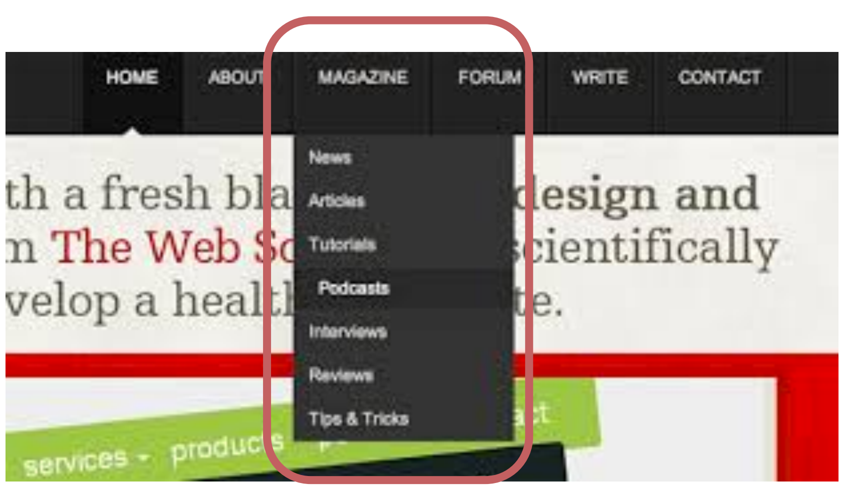

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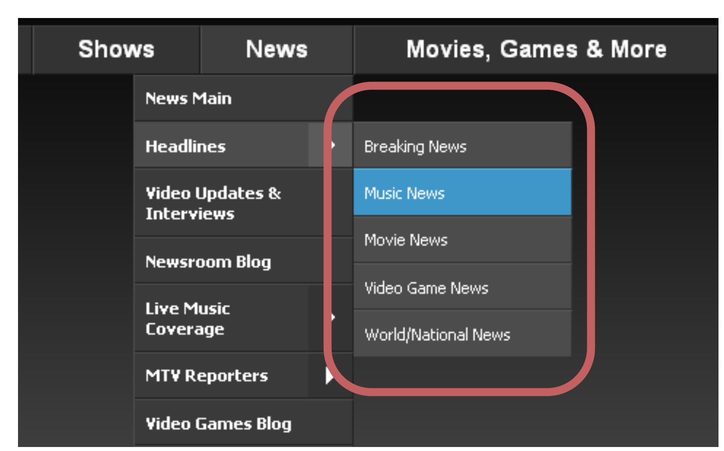

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Example: H_0 and H_1 hypotheses

The developers of a website want to know
if a pull-down menu or a pop-up menu is better

- Research question:
  - Which menu type is best for navigating the site?
- H_0 (null hypothesis):
  - There is no difference between both menu types in the time spent locating pages
- H_1 (alternative hypothesis):
  - There is a difference between both menu types in the time spent locating pages

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Example: H_0 and H_1 hypotheses

The developers of a website want to know if a pull-down menu or a pop-up menu is better

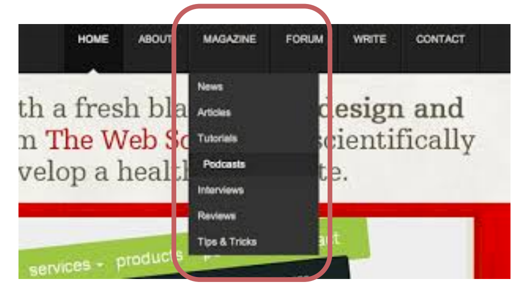
independent variable

- <u>Research question</u>:
  - Which menu type is best for navigating the
- <u>H_0 (null hypothesis)</u>:
  - There is no difference between both menu types in the time spent locating pages

dependent variable

- <u>H_1 (alternative hypothesis)</u>:
  - There is a difference between both menu types in the time spent locating pages

Task



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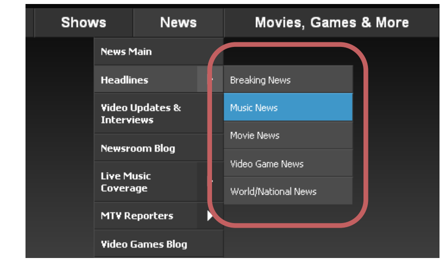

The developers of a website want to know if a pull-down menu or a pop-up menu is better

- <u>Research question</u>:
  - Which menu type is best for navigating the site?
- <u>What we evaluate (*independent variable*)</u>:
  - the type of menu (pull-down or pop-up)

Please, work in pairs for 5 min and propose other metrics (dependent variables) and build the corresponding null (H_0) and experimental/alternative hypotheses (H_1).

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Example: H_0 and H_1 hypotheses

The developers of a website want to know if a pull-down menu or a pop-up menu is better

- Research question:
  - Which menu type is best for navigating the site?
- H_0 (null hypothesis):
  - There is no difference in user satisfaction rating between the pull-down menu and the pop-up menu
- H_1 (alternative hypothesis):
  - There is a difference in user satisfaction between the pull-down menu and the pop-up menu

Example: H_0 and H_1 hypotheses

The developers of a website want to know if a pull-down menu or a pop-up menu is better

independent variable

- Research question:
  - Which menu type is best for navigating the site?

dependent variable

- H_0 (null hypothesis):
  - There is no difference in user satisfaction rating between the pull-down menu and the pop-up menu
- H_1 (alternative hypothesis):
  - There is a difference in user satisfaction between the pull-down menu and the pop-up menu

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Example: Experiment Design

- Two alternatives are possible:

Between subjects design

1. Recruit <u>two</u> groups of people:
    - Group 1 will see the version of the website with pop up menus,
    - Group 2 will see a version of the website with pull down menus

Within subjects design

2. Recruit <u>only one</u> group of people:
    - All participants will experience both websites

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Randomisation

- Randomisation refers to the random assignment of treatments to the experimental units or participants (Oehlert 2000)
- In a totally randomized experiment, no one, including the investigators themselves, is able to predict the condition to which a participant is going to be assigned
- Available strategies include:
  - *traditional*: tossing a coin, throwing dice, drawing capsules out of an urn...
  - *software-based*: based on the generation of random numbers
- In HCI, randomisation is typically applied in:
  - selecting participants
  - designing the tasks
  - altering the order of exposure to experiments
  - ...

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Oehlert, Gary W. (2000) A first course in design and analysis of experiments.

Randomisation: example

- Randomized control trial
  - participants randomly allocated to various conditions in the study

    - Counter example: testing a drug vs placebo.
      Giving drug to those whose faces you liked, and placebo to those with faces you did not like wouldn't be a good method

Significance Tests: Interpretation

- Inferential statistical tests
  - All calculate the probability of an outcome occurring.
    - Zero probability –
    - Probability of 1 –
    - Probability of .50 –

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Significance Tests: Interpretation

- Inferential statistical tests
  - All calculate the probability of an outcome occurring.
    - Zero probability – something will not happen
    - Probability of 1 – something will happen
    - Probability of .50 – happens half the time.
      - E.g. Unbiased coin, .50 probability of Heads occurring

Significance Tests

- Statistical test will tell you the probability of seeing these scores if the null hypothesis is correct.
- E.g. $p=0.16$
    - 16% chance of seeing this difference between conditions if the null hypothesis is true

or

    - 16% chance that we will be wrong if we conclude that the experimental hypothesis is true

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Example

Do men and women differ in their driving ability?

- Experiment:
  - Test in driving simulator:
    - 30 men make 6 errors each on average,
    - 30 women make 4 errors each on average
- Statistical test:
  - Run statistical test to compare the scores
    - $p = 0.16$

Please, discuss in pairs for 10 min, what the null hypothesis could be, and provide a plausible intepretation of the p-value

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Example

Do men and women differ in their driving ability?

- Experiment:
  - Test in driving simulator:
    - 30 men make 6 errors each on average,
    - 30 women make 4 errors each on average
- Statistical test:
  - Run statistical test to compare the scores
    - $p = 0.16$
      - 16% probability that we will be wrong if we conclude that men and women drive differently

or

      - 16% chance of obtaining these scores if the null hypothesis (no difference) is true

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Acceptable risk levels

- Level of risk you will accept (or cutoff for significance):
  - alpha α
- In human research, standard level of alpha α :
  - e.g. $\alpha = 0.05$
  - Interpretation:
    - 5% chance of conclusions being wrong
    - also expressed as a 95% confidence interval
- In medicine, level of risk accepted tends to be lower:
  - e.g. $\alpha = 0.01$

Levels of certainty

- Generically expressed as a p-value
  - e.g. $p < 0.05$
- Read as:
  - The probability that, given the null hypothesis, the results seen would have arisen
- Do not read as:
  - The probability that there is an effect
- Subtle but significant distinction

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Statistical significance and p-values

- A small **p-value** (typically $\leq \alpha$) **indicates** strong evidence against the null hypothesis, so you reject the null hypothesis (i.e. experiment indicates that a significant difference exists)
- A **large p-value** ($> \alpha$) **indicates** weak evidence against the null hypothesis, so you fail to reject the null hypothesis

- We typically seek:
  - p value lower than α
- In HCI usually $p<0.05$
  - E.g. (possibly) there is a significant difference in the number of words people can remember from a random list, and the number they can remember from an organised list.

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Computation of p-values

- Generally depends on statistical test undertaken
- Can be computed from first principles

- Used to be reflected in statistical tables
  - Compute value
  - Look up p value
- Now Excel, SPSS, etc.

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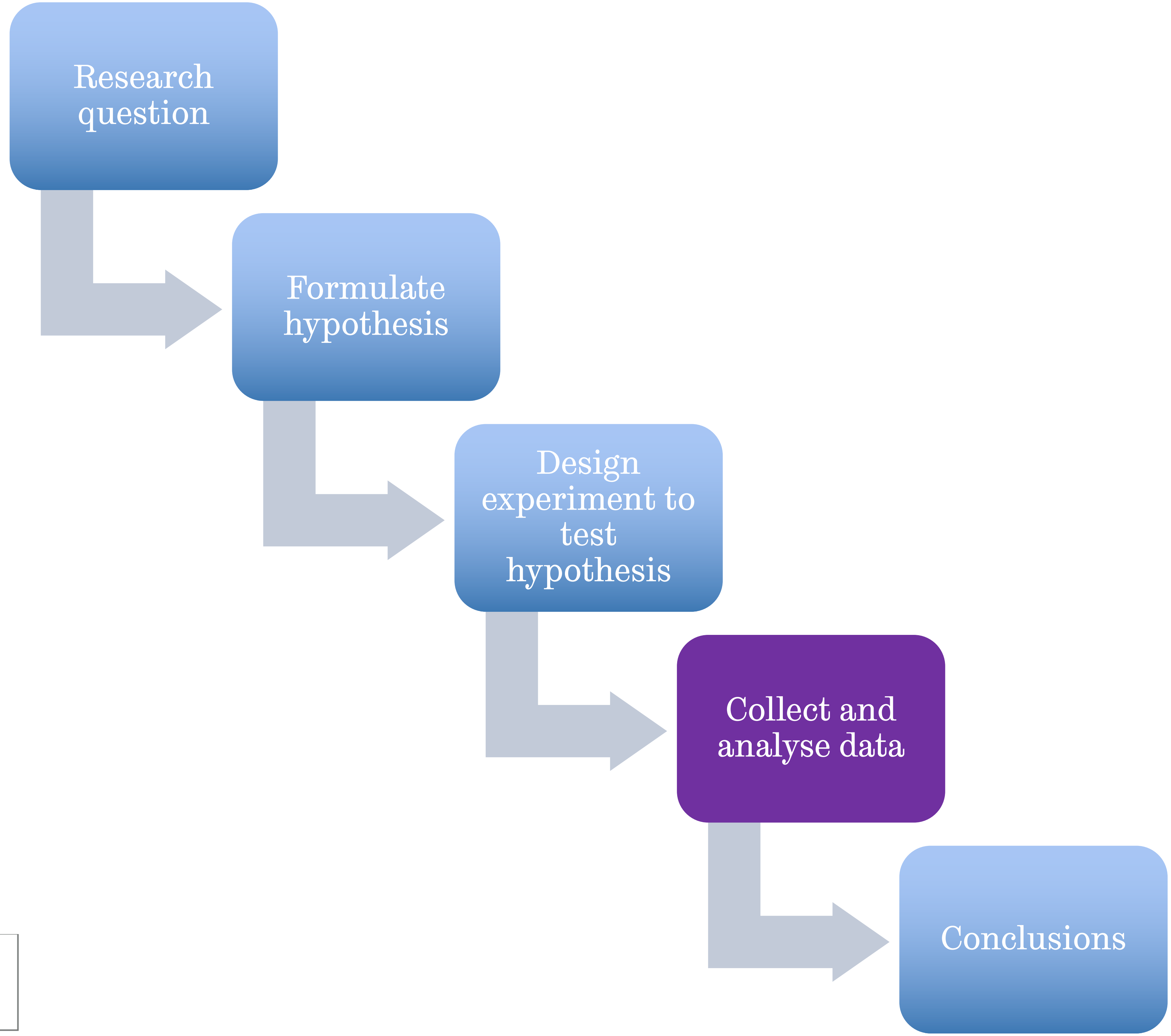
An experiment DOES NOT *PROVE* THE HYPOTHESIS, it just provides evidence (statistically significant?) to support the hypothesis.

Experimental Research Methods



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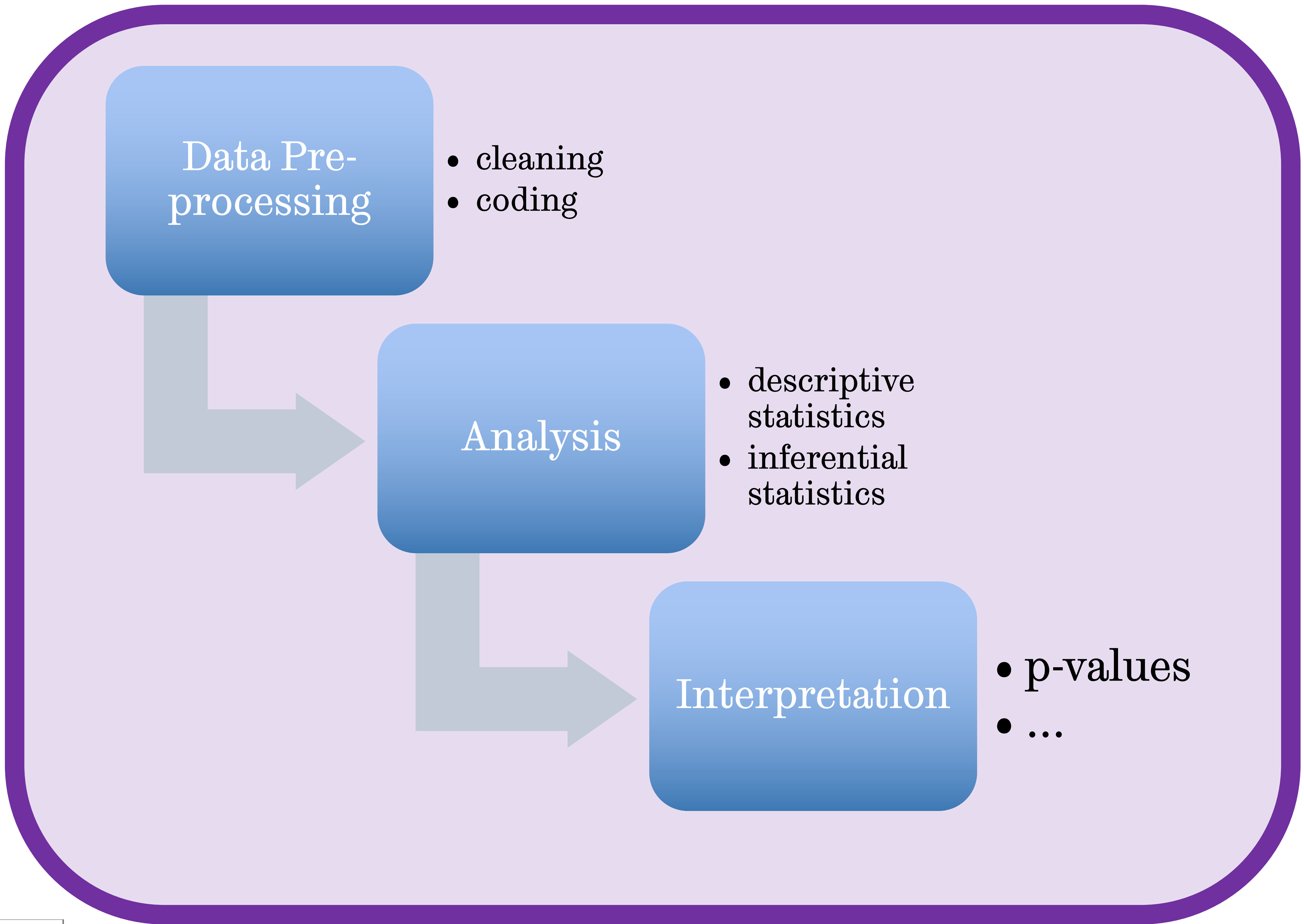
Data Collection and Analysis



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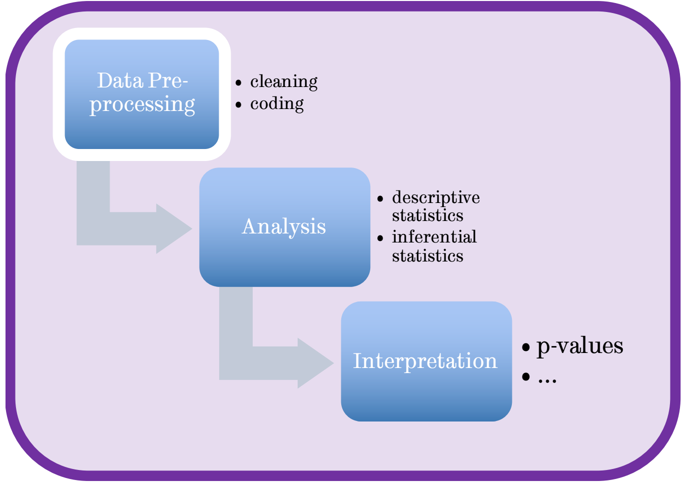
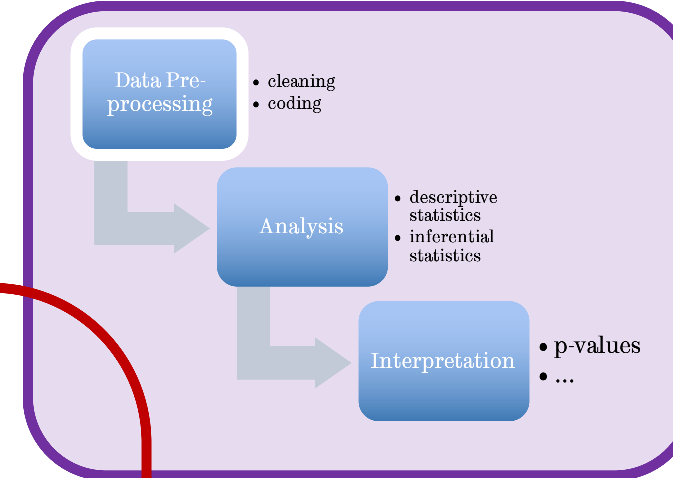
Data pre-processing



- Cleaning up data
  - Detect errors
  - Formatting
- Coding
  - Types of data that need to be coded
  - Be consistent
- Organizing the data
  - Accommodate to the requirements of statistical software

Example



Variable	Coding scheme
Demographic characteristics	
Gender: Female	Dichotomous: 0 = no, 1 = yes
Race	
African American	All dichotomous: 0 = no, 1 = yes
Asian American	
Latino	
White	
Age	Range from 16 to 73

- What happens to missing data?
- What happens with cases where a wrong value is provided? (e.g. age = 270…)

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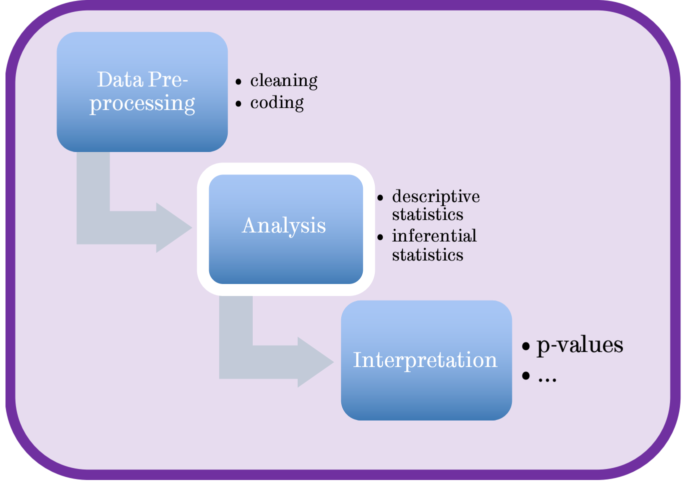
Descriptive statistics



- Purpose:
  - understanding the nature of the data set
    - Typically used:
      - Measures of spread:
        - variances, standard deviations, ranges…
      - Measures of central tendency:
        - means, medians, modes…

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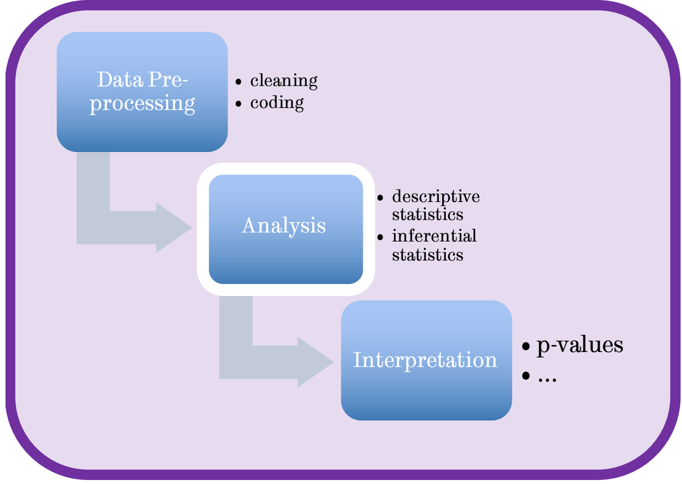
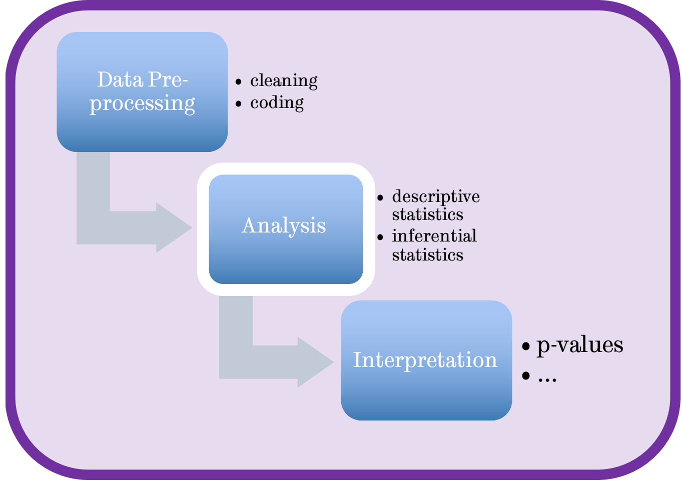
Example



Variable	Coding scheme	Mean	Standard deviation
Demographic characteristics			
Gender: Female	Dichotomous: 0 = no, 1 = yes	.54	.49
Race			
African American	All dichotomous: 0 = no, 1 = yes	.03	.17
Asian American		.38	.49
Latino		.14	.35
White		.35	.48
Age	Range from 16 to 73	20.29	2.96

Descriptive statistics



- Measures of spread indicate:
  - How much the data points deviate from the centre of the data set
  - How spread out the data is
  - E.g.:
    - Range, variance and standard deviation
      - Range measures the distance between the highest and lowest scores in the data set

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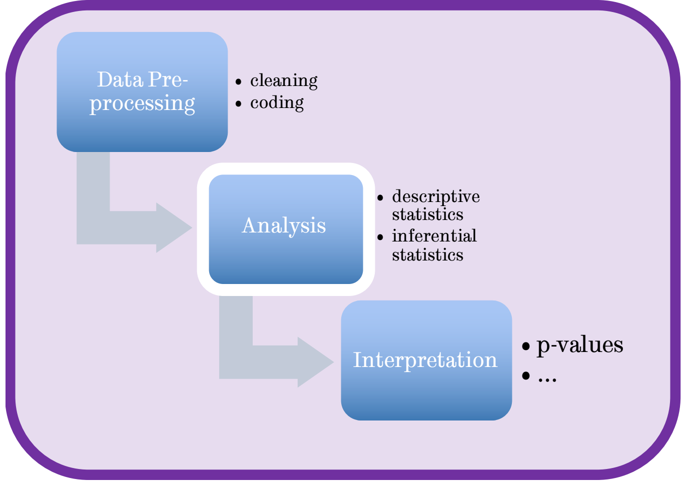
Descriptive statistics



- Measures of central tendency indicate:
  - Where the bulk of the data is located
  - E.g.:
    - Mean of a data set or arithmetic average
  - Can be useful to compare the means of multiple groups
    - If the means are different, could conduct a significance test to see if that difference is statistically significant - see later

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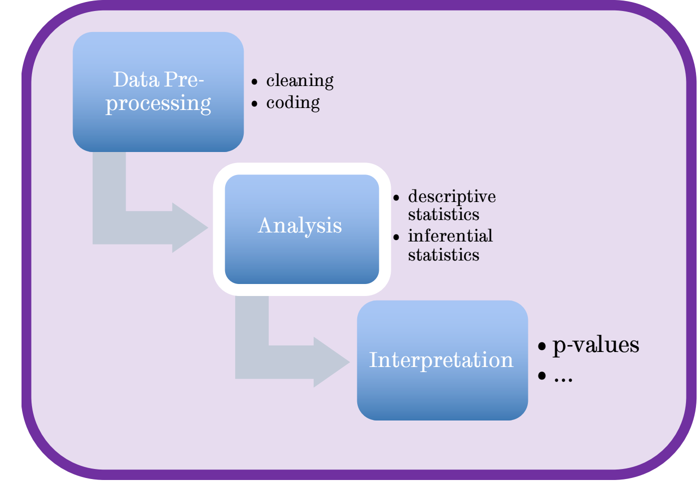
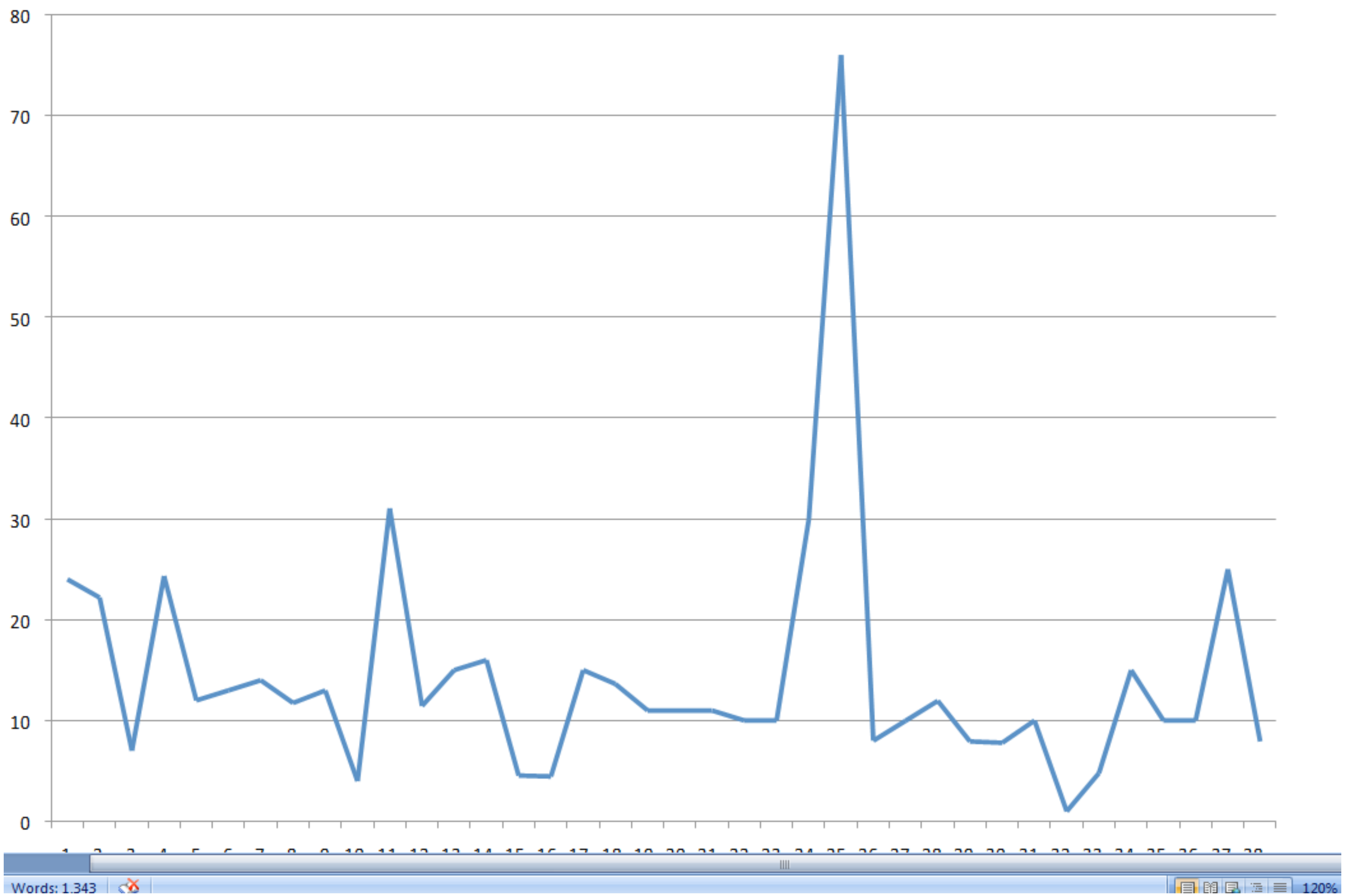
Descriptive statistics





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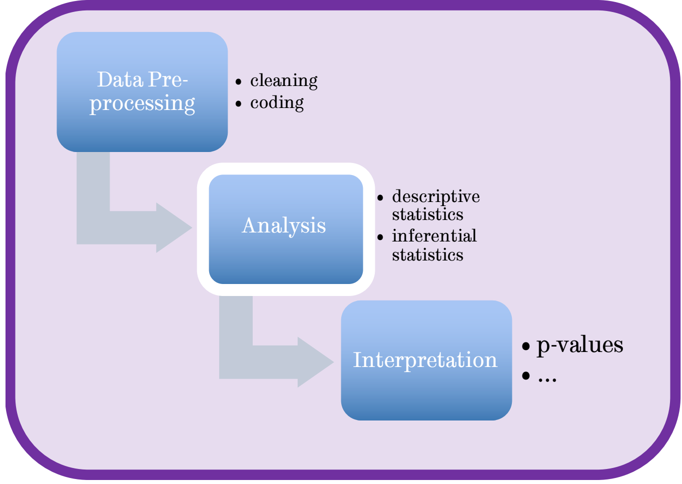
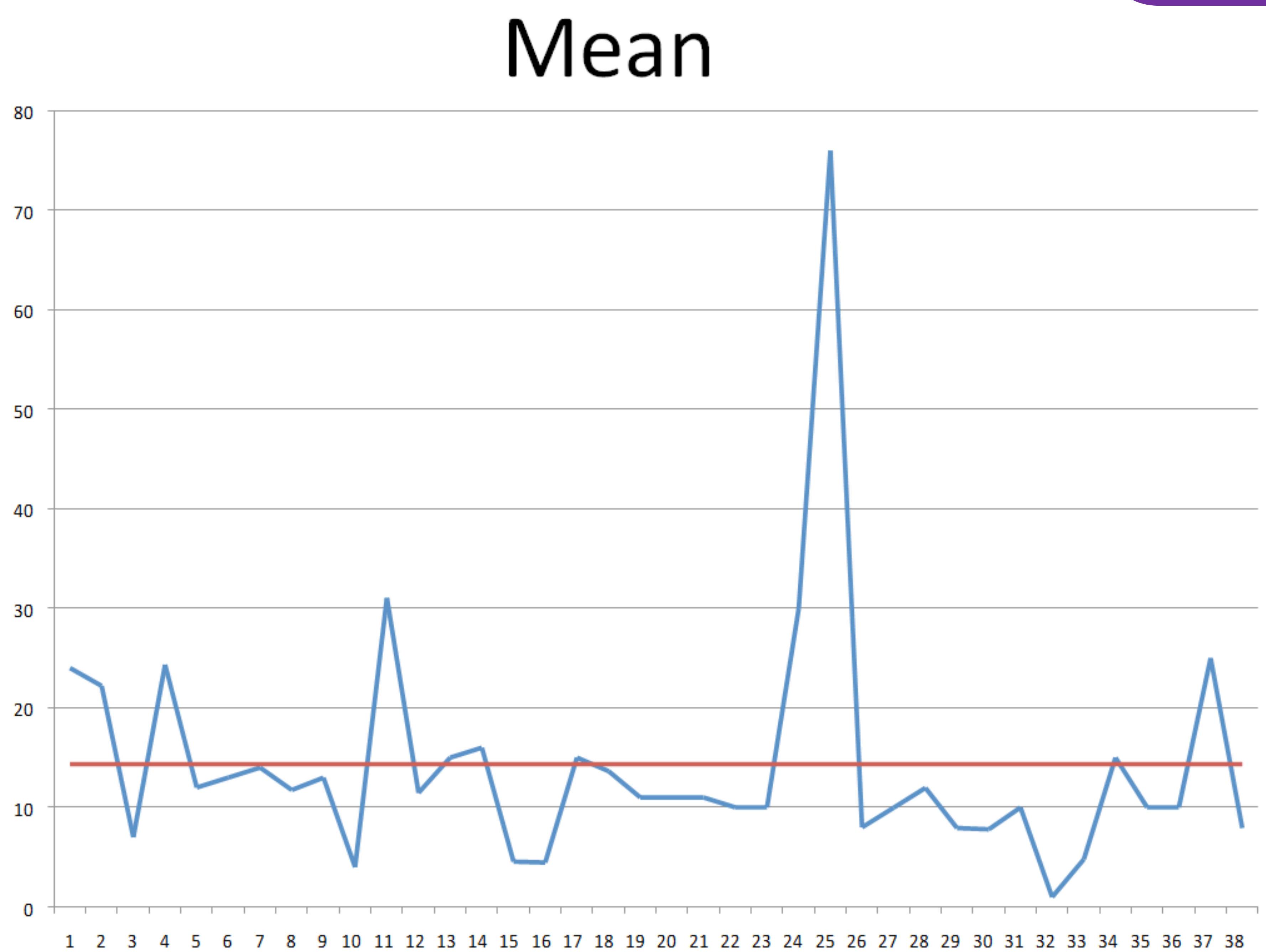
Descriptive statistics





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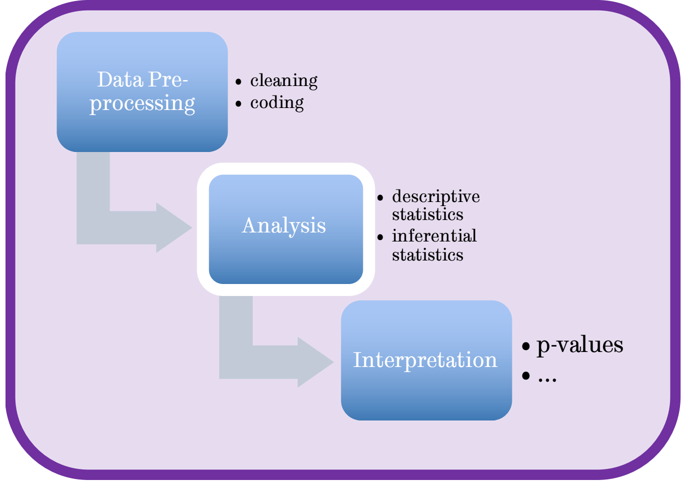
Descriptive statistics



- Other measures of central tendency
- Median
  - Order values, median is central value (or mean of two central values)
  - If data is skewed then mean and median will differ significantly
- Mode
  - The most commonly occurring value
    - Rarely used

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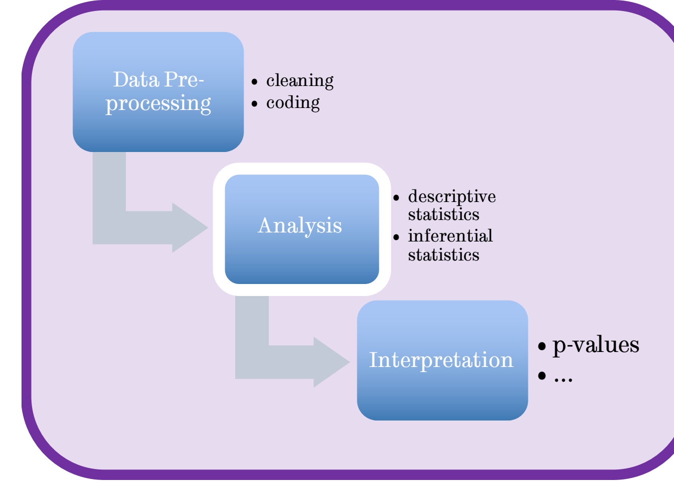
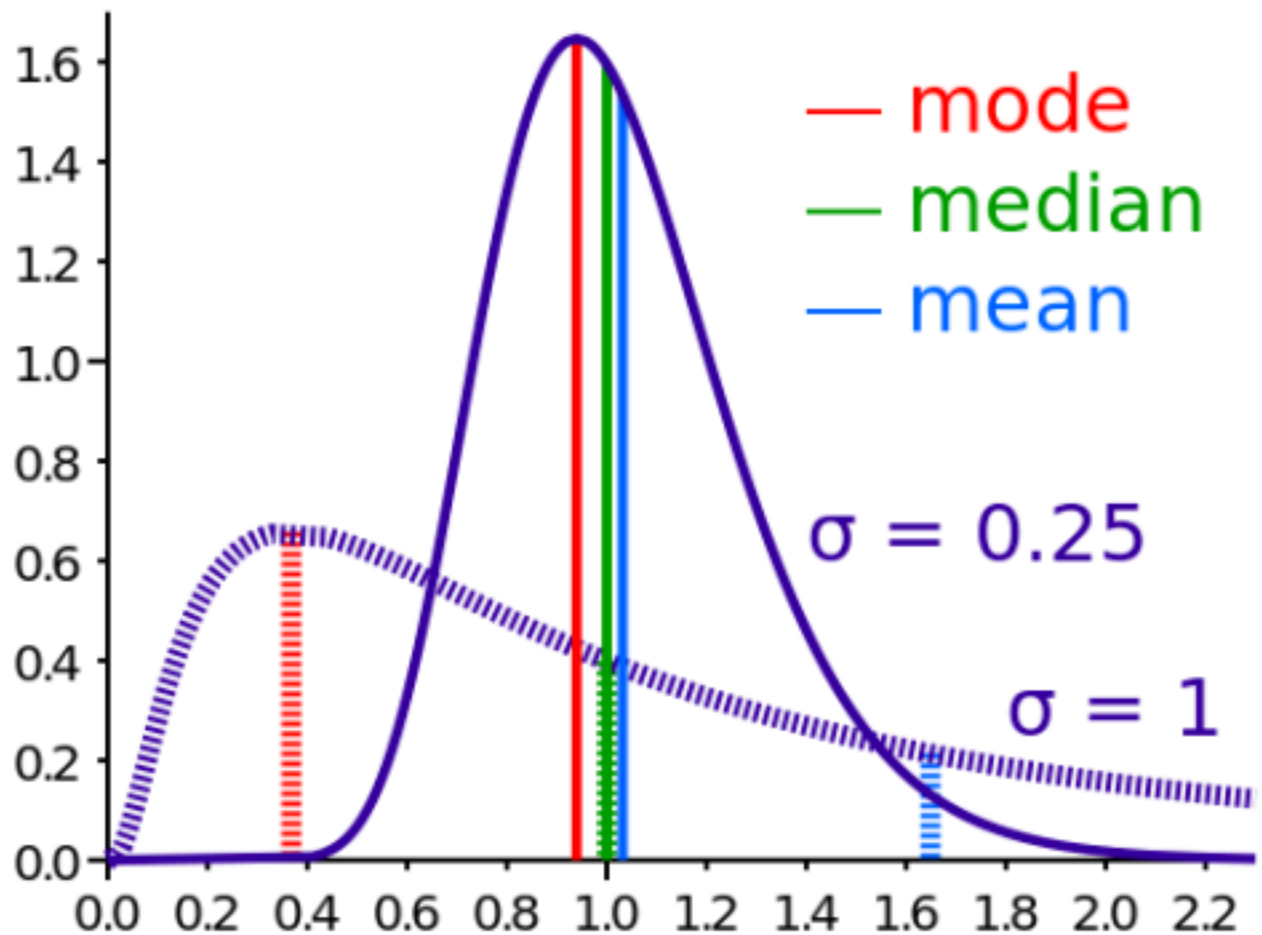


Descriptive statistics



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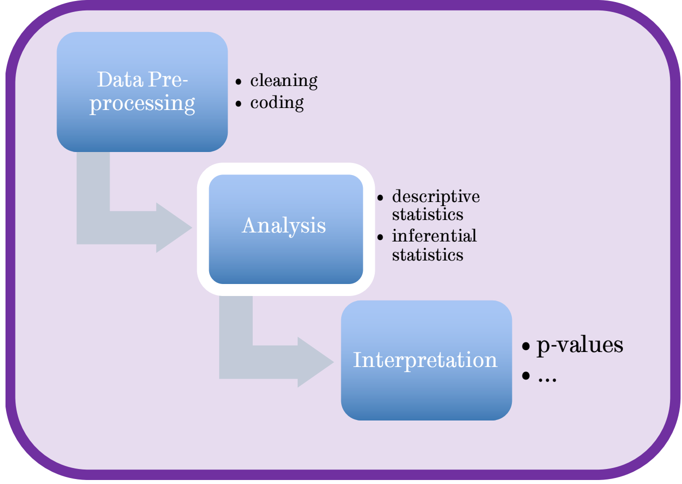
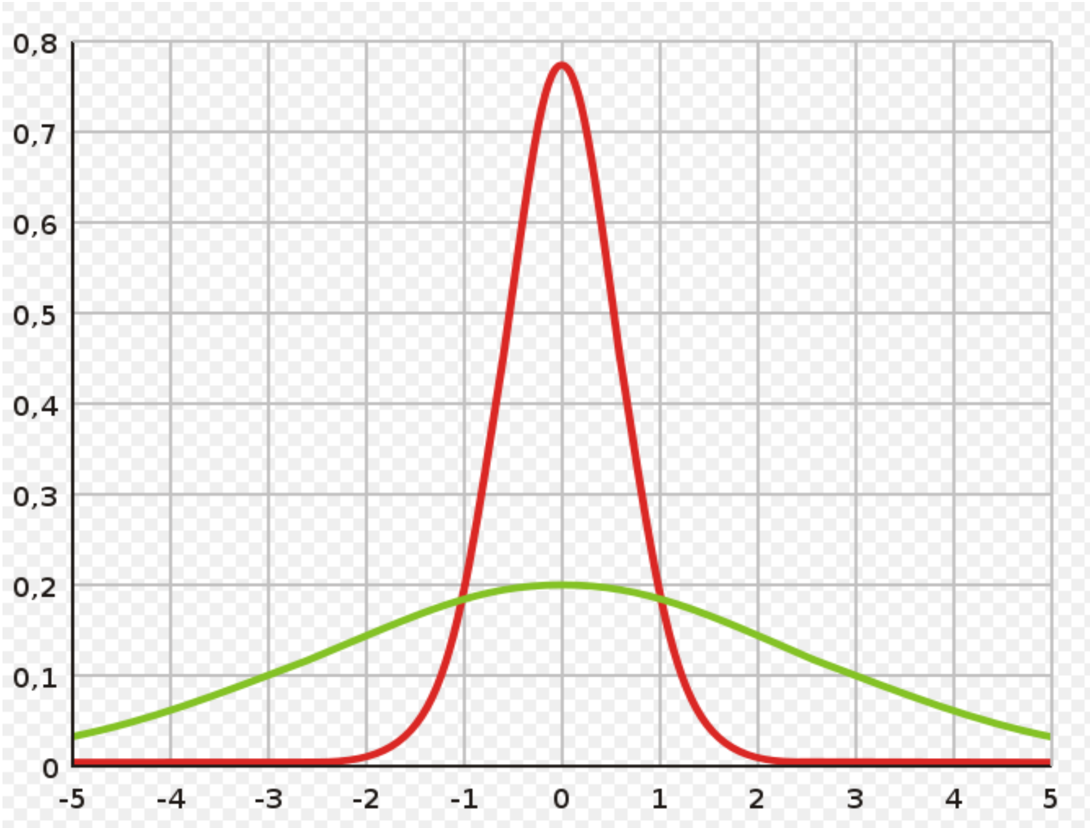
Descriptive statistics



- The variance of a data set is the mean of the squared distances of all the scores from the mean of the data set
- The square root of the variance is called the standard deviation



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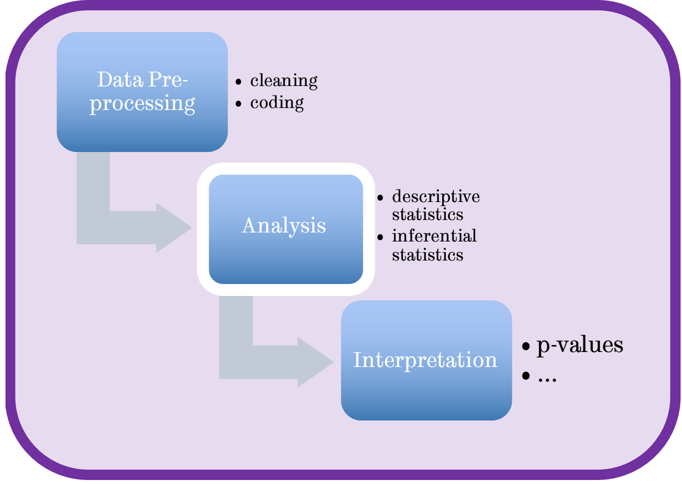
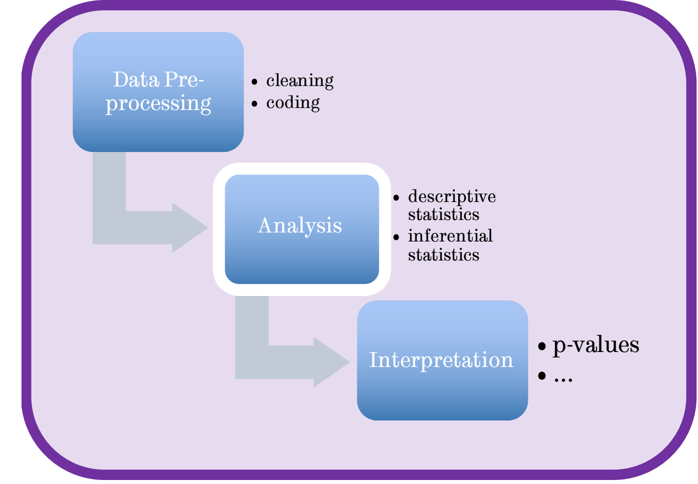
Descriptive statistics

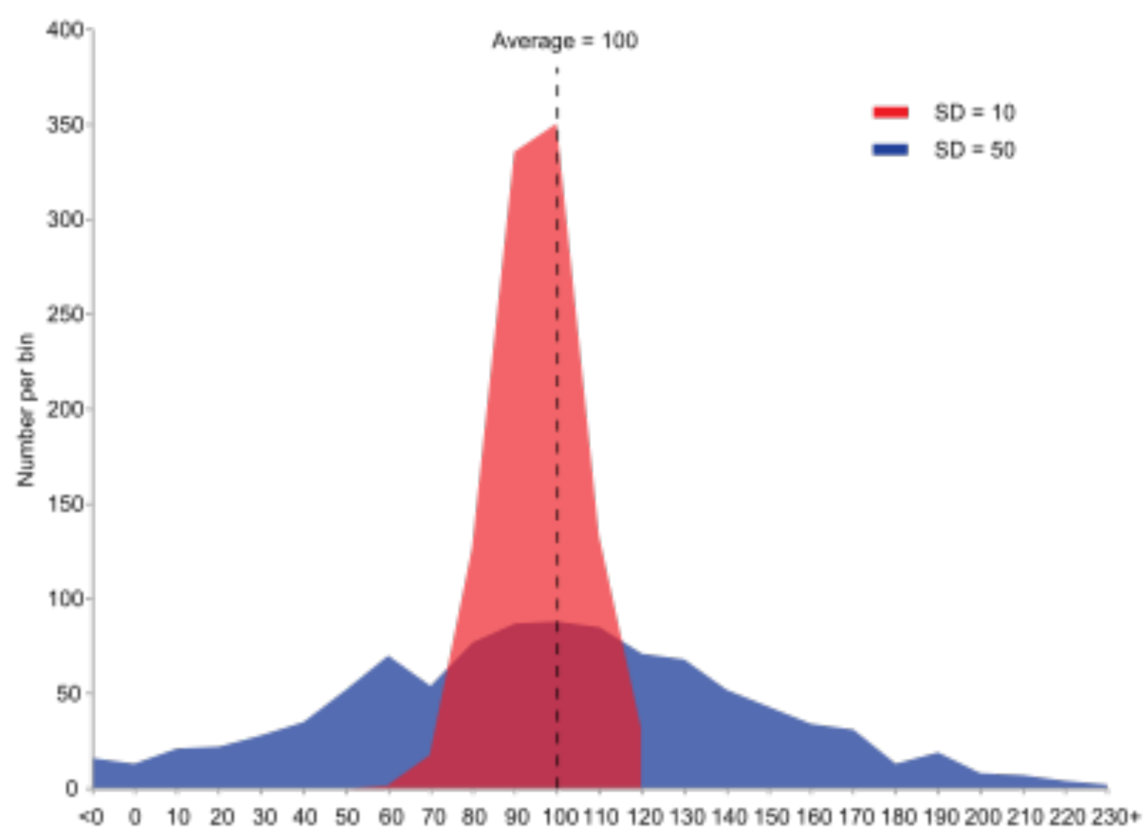


- Variance:
  - measure of how far a set of numbers is spread out
    - zero-variance indicates that all the values are identical.
    - non-zero variance is always positive:
      - a small variance indicates that the data points tend to be very close to the mean (expected value) and hence to each other,
      - while a high variance (or standard deviation) indicates that the data points are very spread out from the mean and from each other.

Descriptive statistics



- Two sample populations with the same mean and different standard deviations



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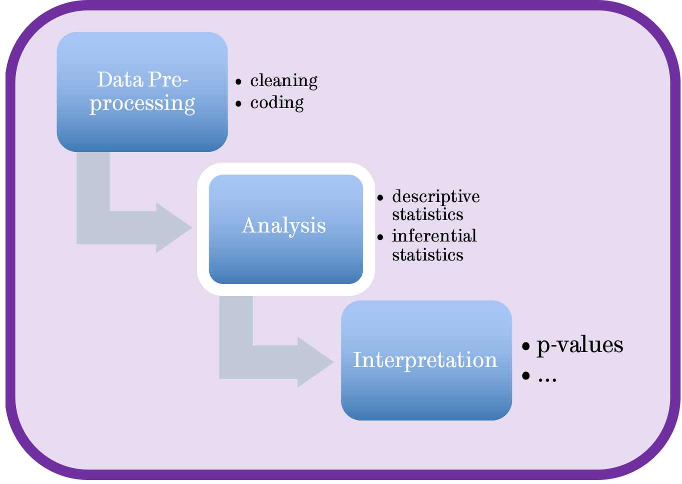
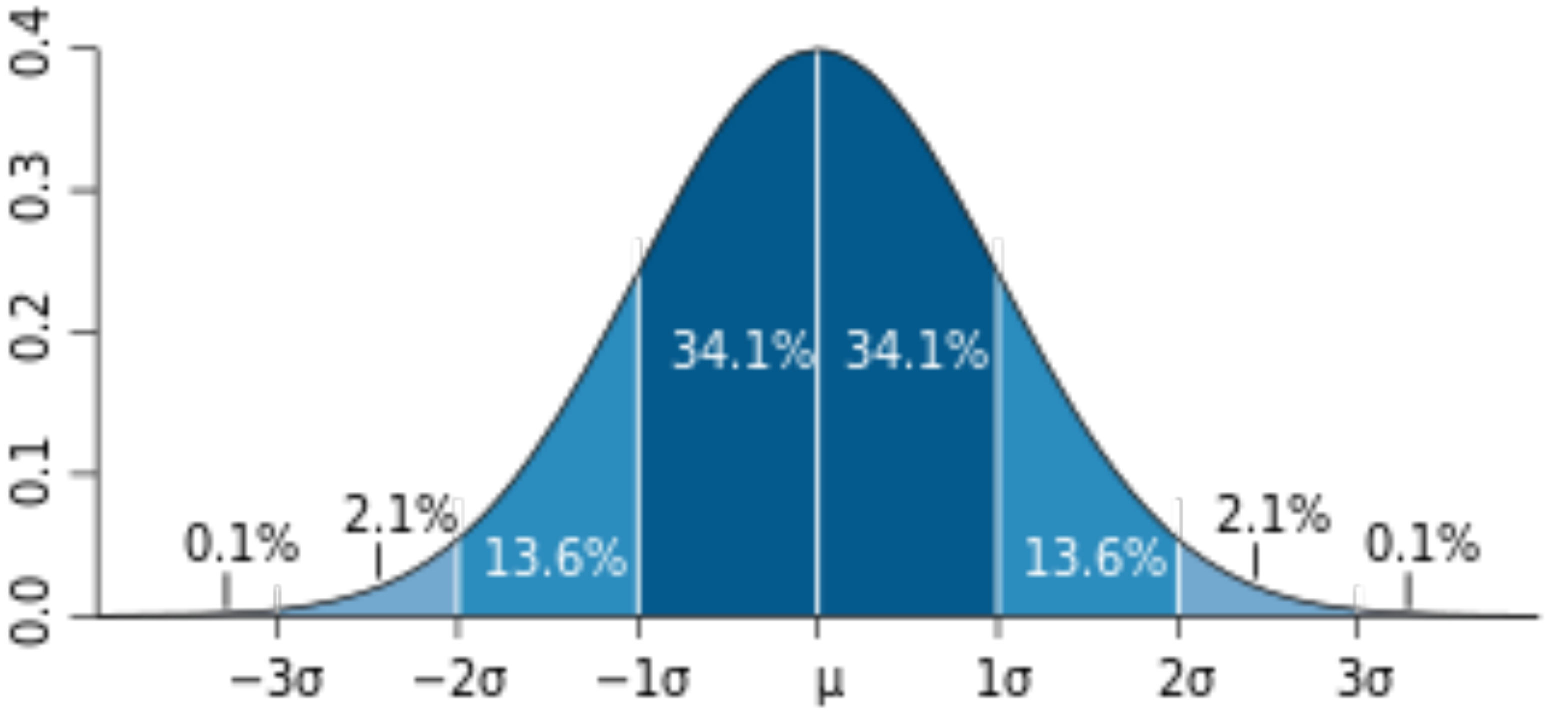


Descriptive statistics

- Plot of a normal distribution (or bell-shaped curve) where each band has a width of 1 standard deviation
  - many attributes from different fields are normally distributed
    - e.g. heights of a population, student grades, IQ
  - Parametric tests assume that the data is normally distributed



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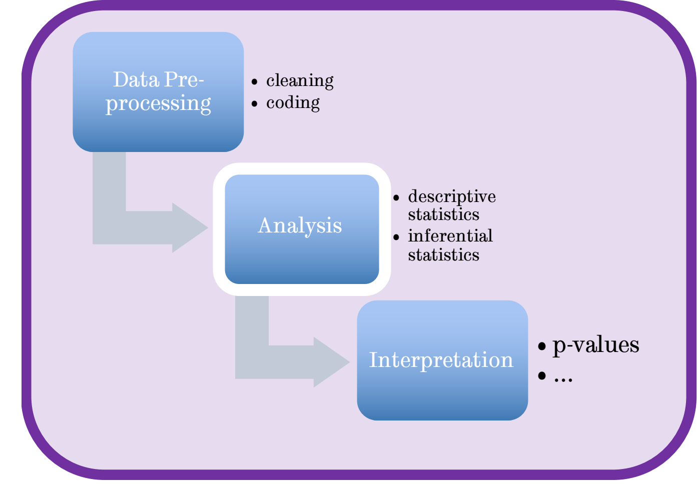
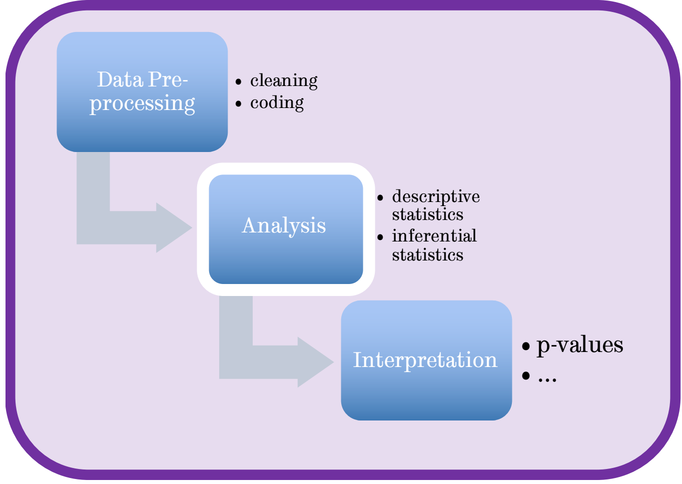
Descriptive statistics

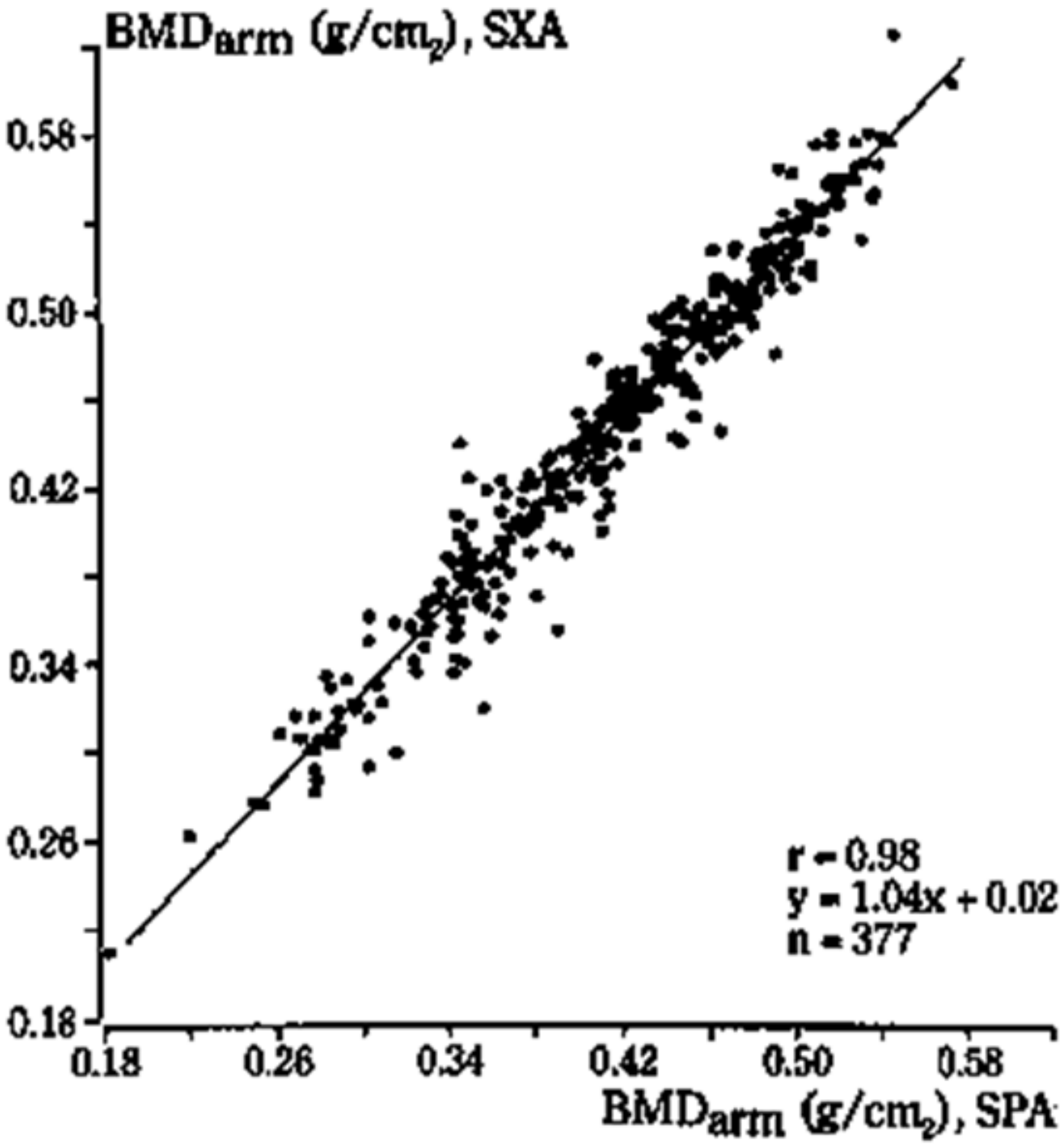


- Correlation
  - Measure of how changes in variable X match changes in variable Y
  - E.g.
    - Distance to work correlates with time taken to reach work
    - Level of education correlates with salary

Task

- Correlated or uncorrelated?





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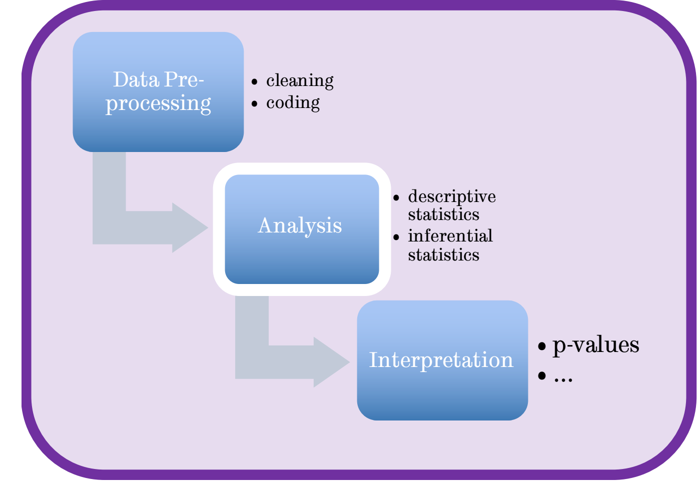
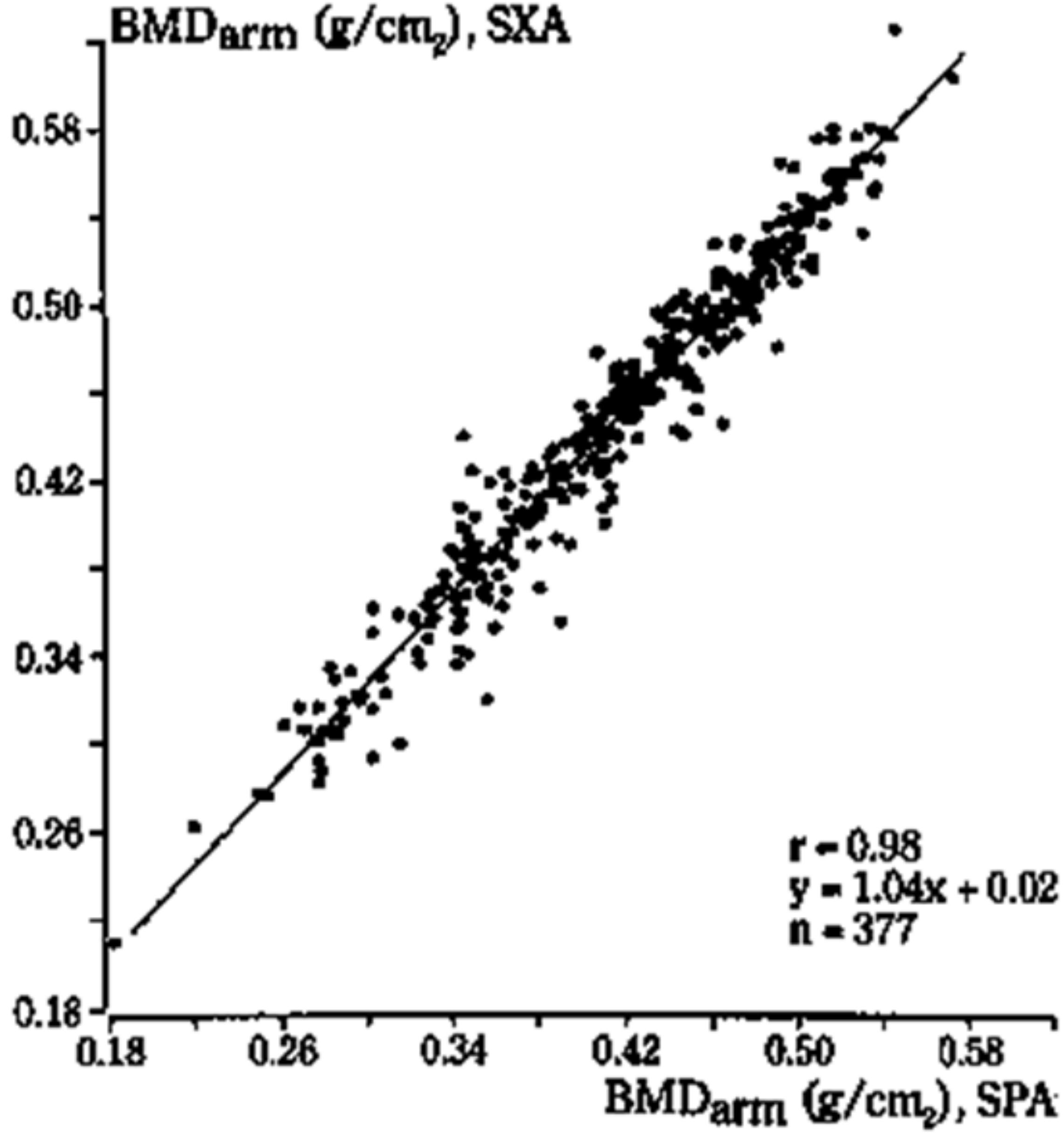


Example

- Highly correlated



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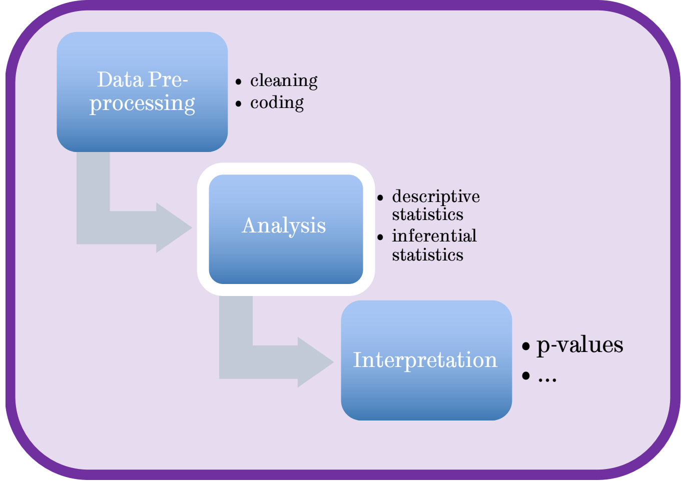
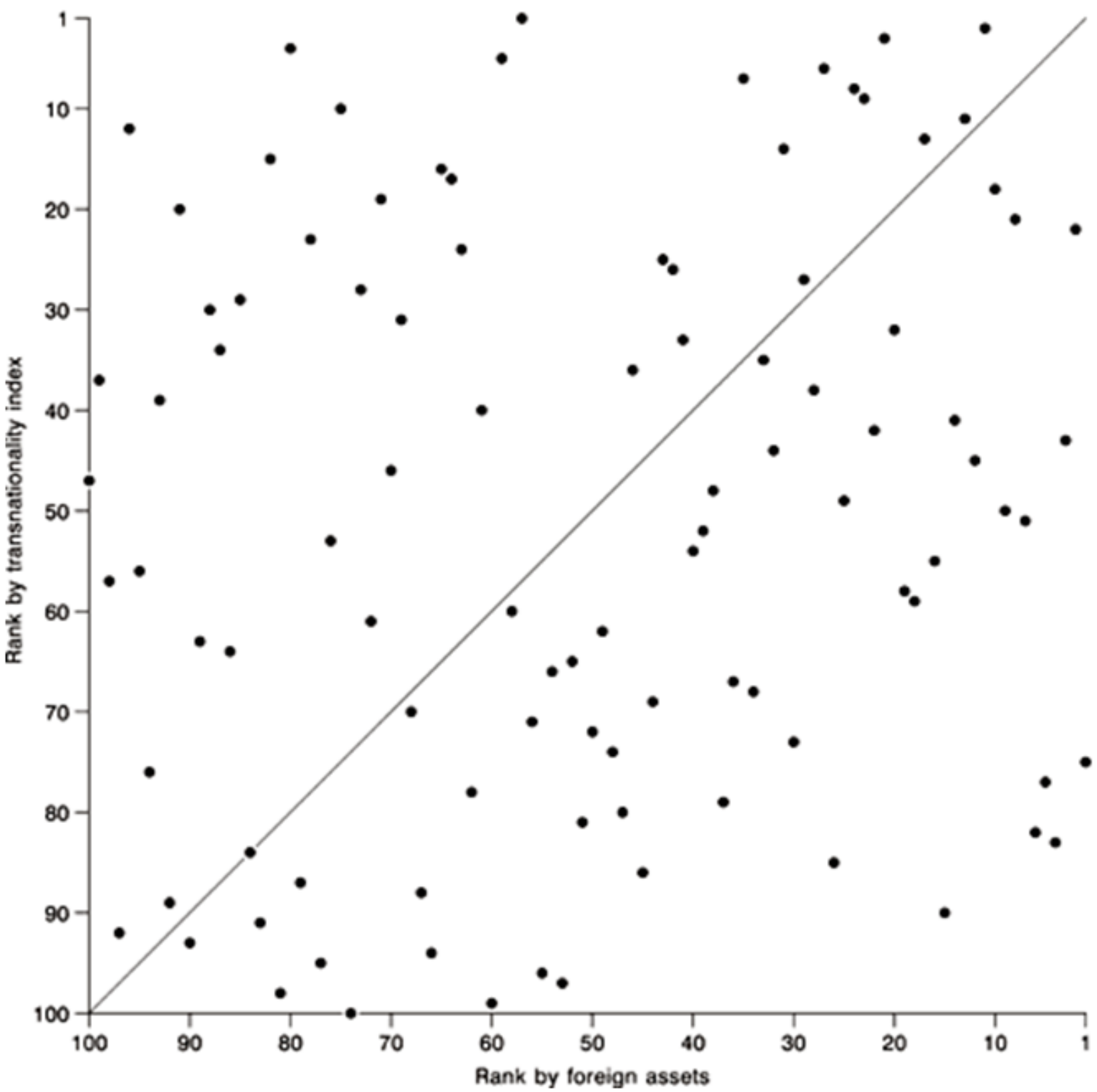
Task

- Correlated or uncorrelated?





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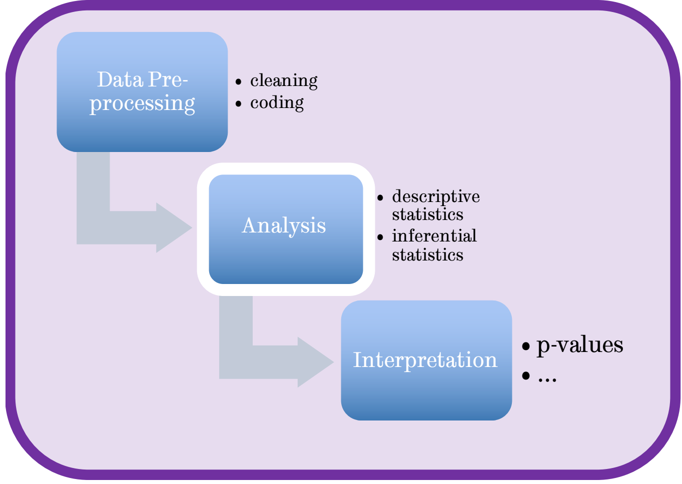
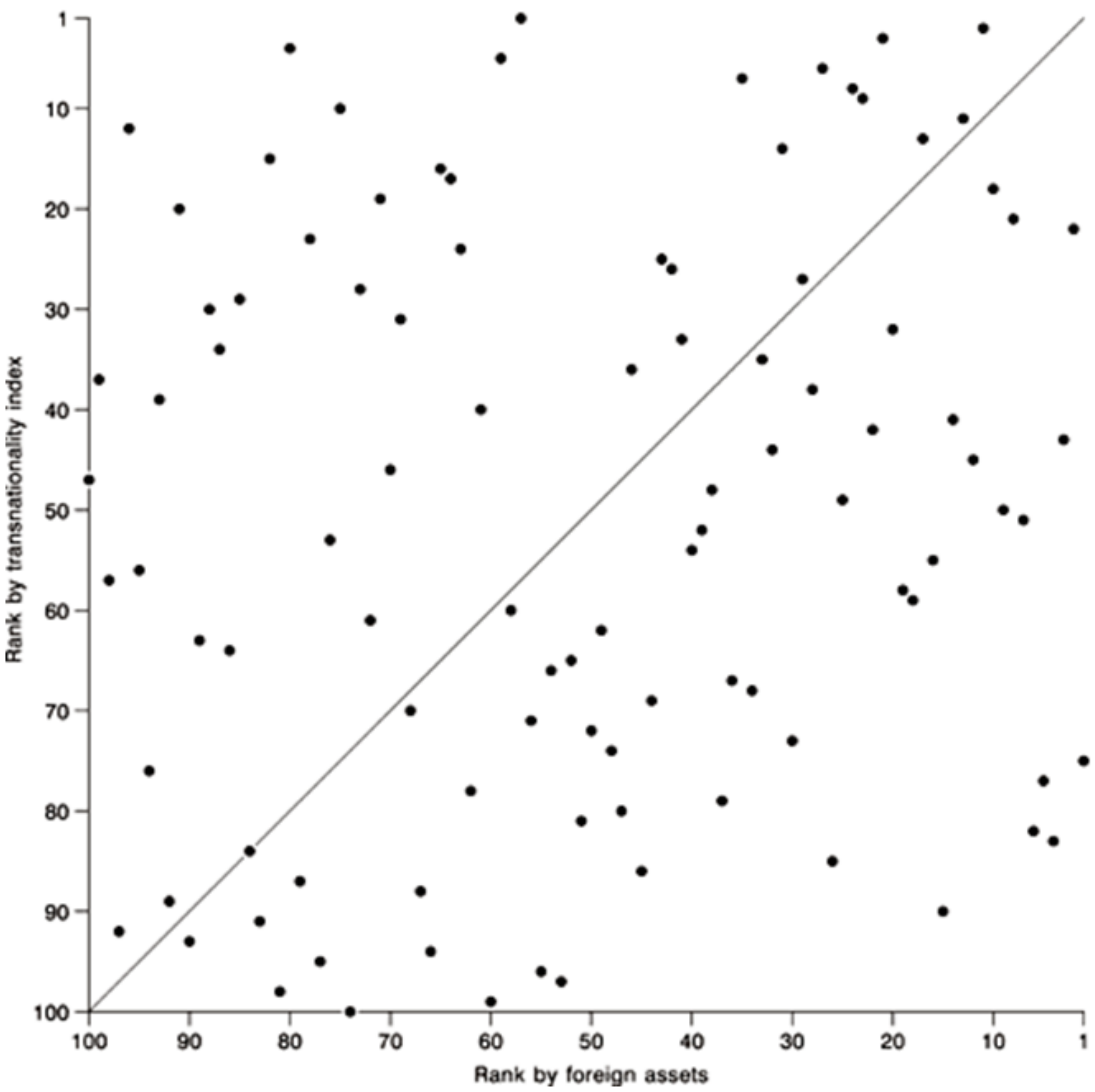
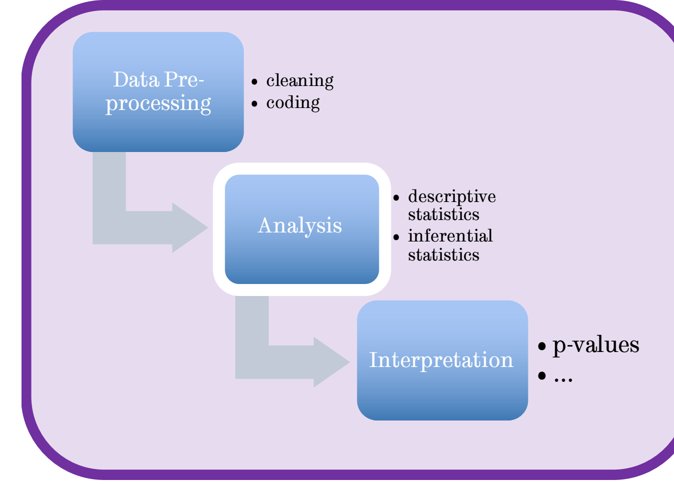
Example

- Uncorrelated

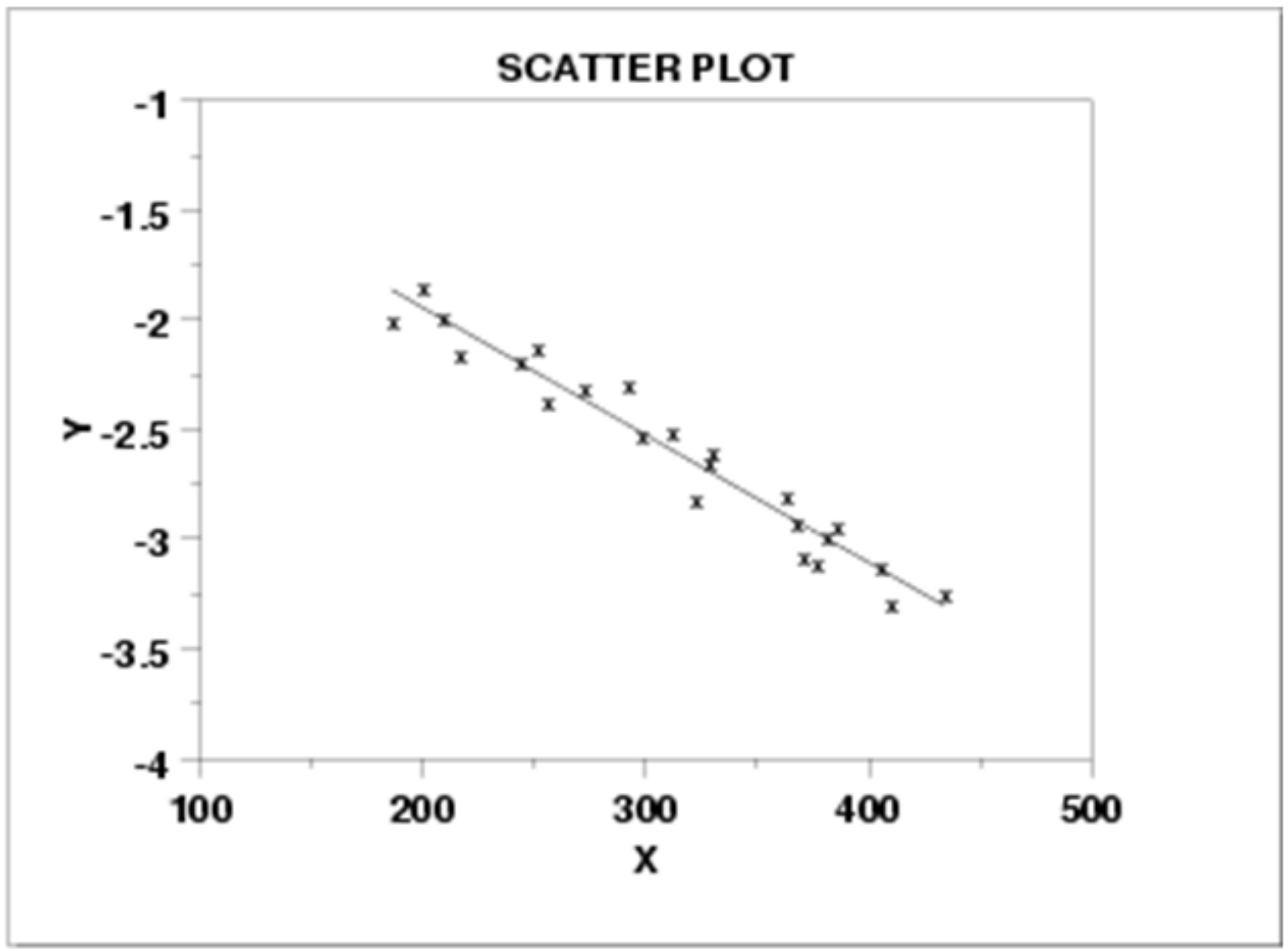




Task



- Correlated or uncorrelated?



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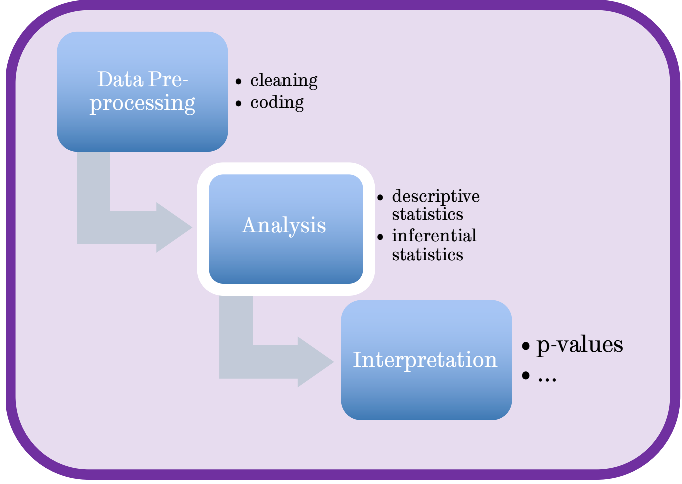
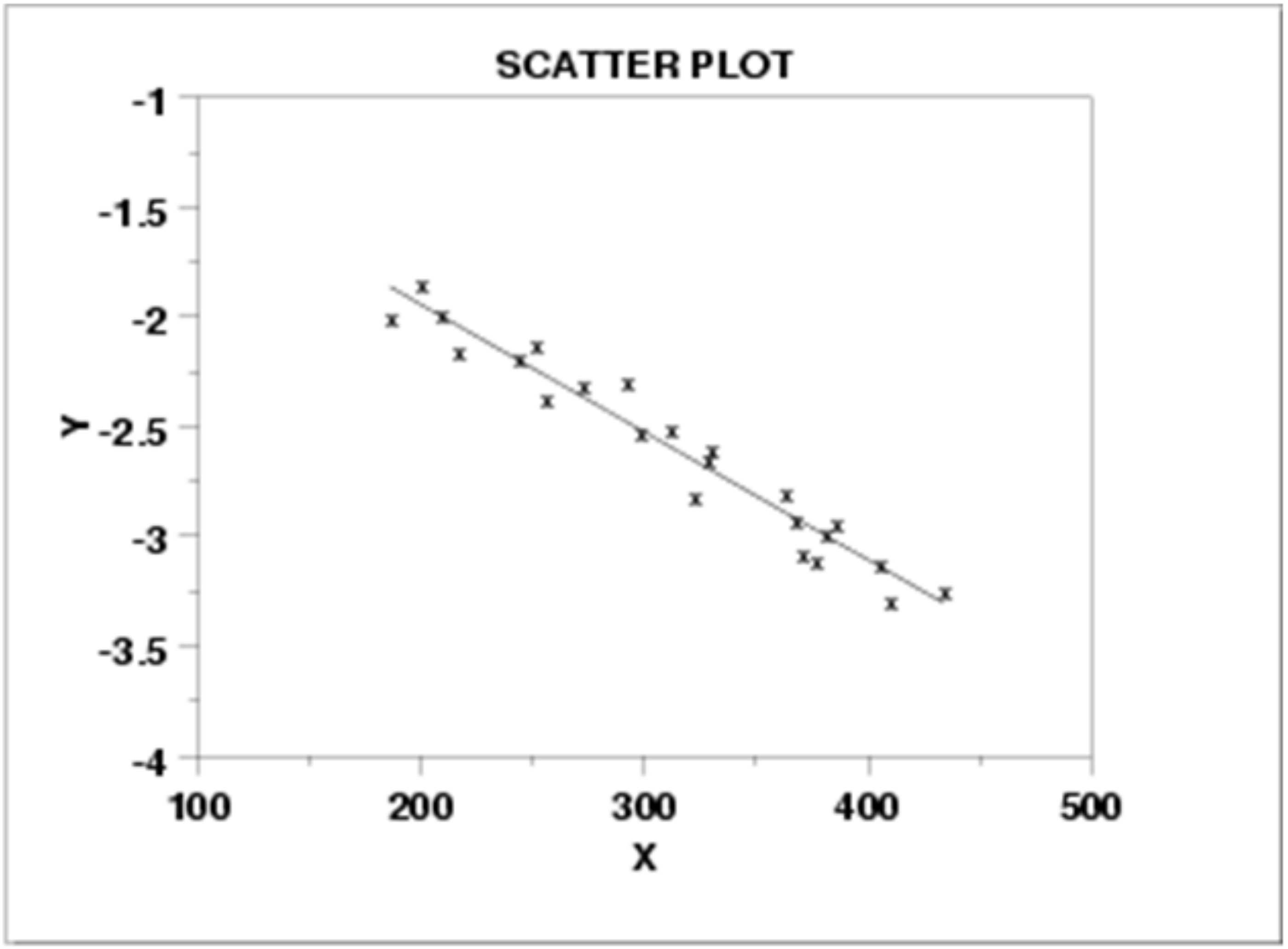


Example

- Negatively correlated



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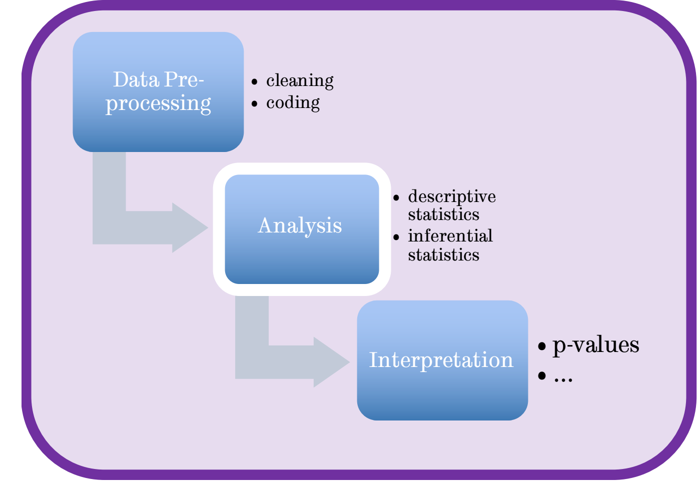
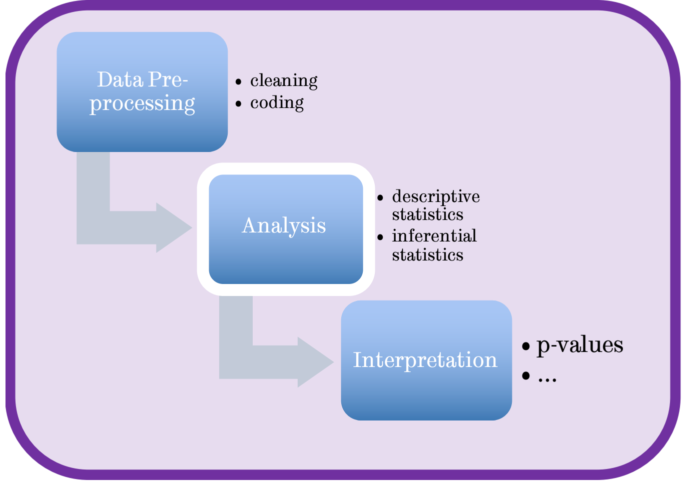
Descriptive statistics



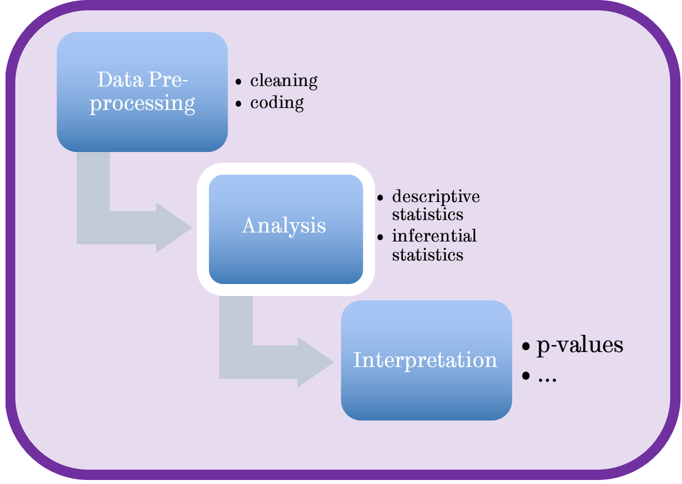
- Correlation:
  - tells us very little
  - suggests a relationship between two variables
  - relationship which might not necessarily be linear
  - does not suggest that there is a direct connection
- Correlation is NOT causation
  - Classic scientific fallacy
  - Because two variables move in the same direction does not mean they are linked
    - Secondary factor
    - Weird correlation effects



Task

- Correlation between women taking Hormone Replacement Therapy (HRT) and decreased Coronary Heart Disease.
- But Controlled Trials demonstrated that HRT significantly increases chances of Coronary Heart Disease
- Why?

Task



- Correlation between women taking Hormone Replacement Therapy (HRT) and decreased Coronary Heart Disease.
- But Controlled Trials demonstrated that HRT significantly increases chances of Coronary Heart Disease
- Why?

confounding factor

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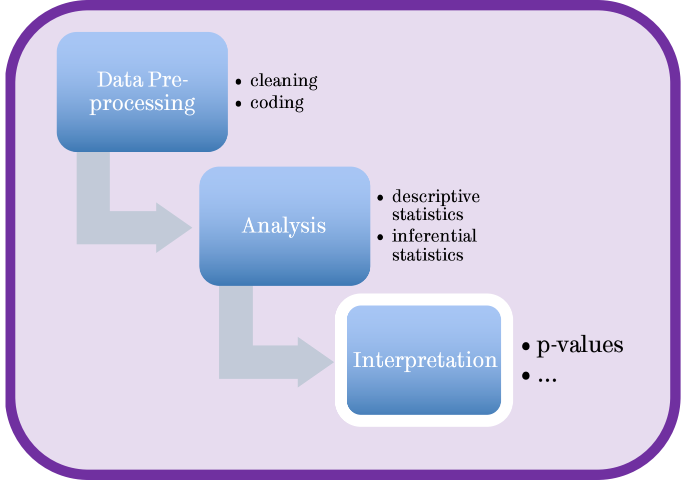

Descriptive statistics

- Examining the data
  - Can reveal nature of relationship
  - Can indicate if significant correlation is really significant
- Consider the nature of effects
  - Why is there correlation
  - Is there a confounding factor?
  - Common sense

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Experimental research

- We measure:
  - Dependent Variables
- In the presence of
  - Independent Variables

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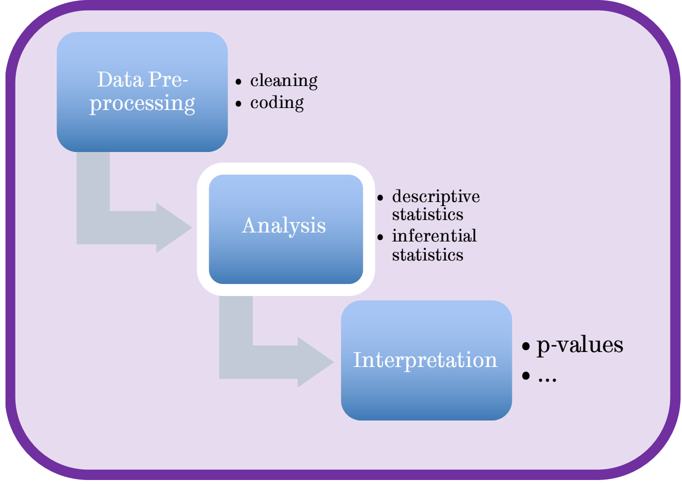
Inferential Statistics

- Tests of significance



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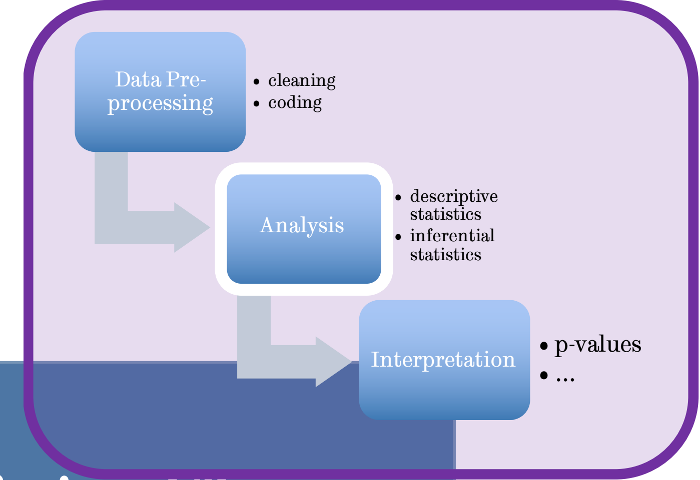
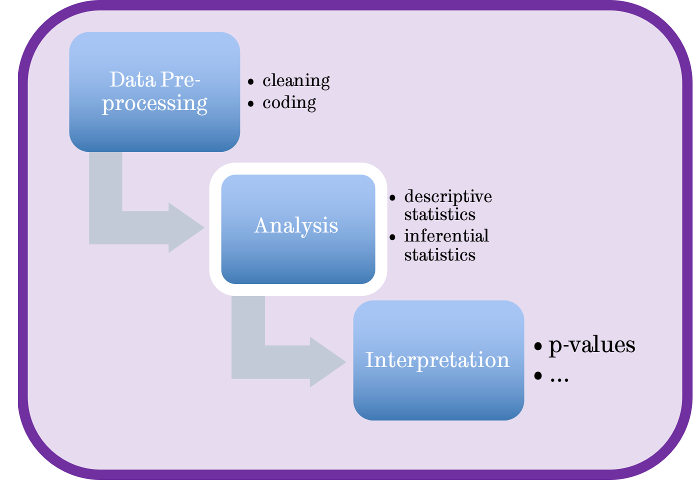
Statistics books

- Usually the thinner the better
-
- Bigger Books
  - Go through everything from first principles
- Thinner Books
  - Stick to the things you’ll use professionally

Comparison of means



Experiment design	Number of Independent variables	Number of conditions for each independent variable	Types of significance tests
Between group	1	2	Independent samples t test
	1	3 or more	One way ANOVA
	2 or more	2 or more	Factorial ANOVA
Within group	1	2	Paired samples t test
	1	3 or more	Repeated measures ANOVA
	2 or more	2 or more	Repeated measures ANOVA



Significance tests

- Choosing the right statistical test
  for the experiment is not straightforward:
  - there are more tests available depending on the nature of the samples (e.g. non parametric tests such as Mann-Whitney U test for differences between independent samples, and Sign Test for differences between related samples)
- Experiment design is far more important than statistical accuracy
  - T-tests for comparing means in two conditions
  - ANOVAs for more than two conditions
  - Correlation for comparing two populations
  - CHI Squared when conditions are right

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Summary

- Quantitative research methods
  - Null hypothesis and alternative (or experimental) hypothesis
  - Significance, p-values, confidence interval…
  - Descriptive statistics vs inferential statistics
    - Measures of central tendency
    - Measures of spread
    - Correlation
  - Tests of significance and their suitability

Evaluation in HCI

✓	Measuring Usability	Week 8 →	Tuesday 14th November (week 8): Assignment hand-out
✓	Qualitative Research Methods	Week 9	
✓	Experimental Design	Week 10	
✓	Quantitative Research Methods	Week 11 →	Monday 11th December (week 12): Assignment hand-in via MOLE

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