Hypothesis testing

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Why do we need to know about hypothesis testing?

- Hypothesis testing is used to compare populations
- Hypothesis testing is everywhere!
  - Can a change in price lead to increased revenue?
  - Will changing a website address result in increased traffic?
  - Is a medication effective in the treatment of a health condition?

[1] Image credit: https://unsplash.com/@towfiqu999999

The history of hypothesis testing

- Hypothesis testing dates back to the 1700s!

- Human sex ratio
  - More male births than female births

[1] Image credit: https://unsplash.com/@kellysikkema

Assume nothing!

- Start by assuming no difference exists
- This is called the ***null hypothesis***

Male versus female birth ratio

- **Null hypothesis:**
  - No difference in gender birth ratio between women who do and do not take vitamin C consumption
- **Alternative hypothesis:**
  - A **difference** exists in gender birth ratio between the two populations
  - **More** female births occur among women taking vitamin C supplements

Hypothesis testing workflow

- Define the target populations
  - Adult women taking or not taking vitamin C supplements
- Develop null and alternative hypotheses
  - Births are equally like to be male or female in both populations
  - More births are female among women taking vitamin C supplements
- Collect or access sample data
- Perform statistical tests on the sample data
- Draw conclusions about the population

How much data do we need?

- Central limit theorem
  - Mean male and female births gets closer to the population means as sample size increases
  - Time and resource intensive

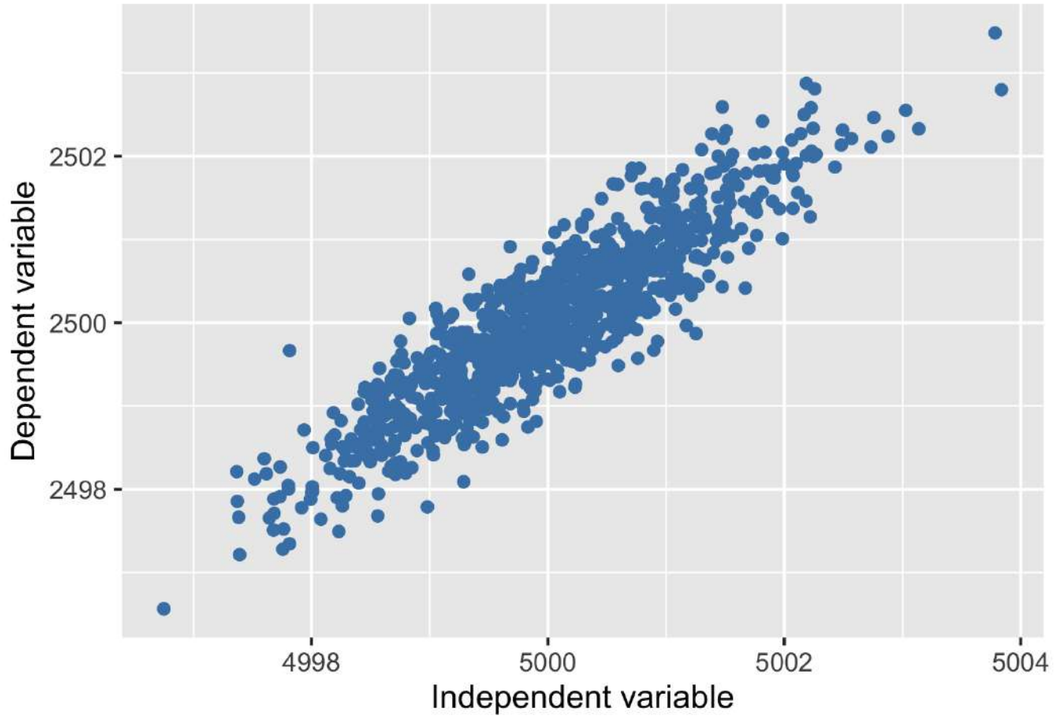
- Look at peer-reviewed research on similar hypothesis tests to decide on the sample size

[1] Image credit: https://unsplash.com/@jxnsartstudio

Independent and dependent variables

- **Independent variable:**
  - Unaffected by other data
  - Vitamin C supplementation
- **Dependent variable:**
  - Affected by other data
  - Birth gender ratio

- Commonly used to describe hypothesis test results



Let's practice!

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Experiments

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Experiments, treatment, and control

- Experiments are a subset of hypothesis testing
  - Experiments are not just conducted in academia

Experiments aim to answer: *What is the effect of the treatment on the response?*

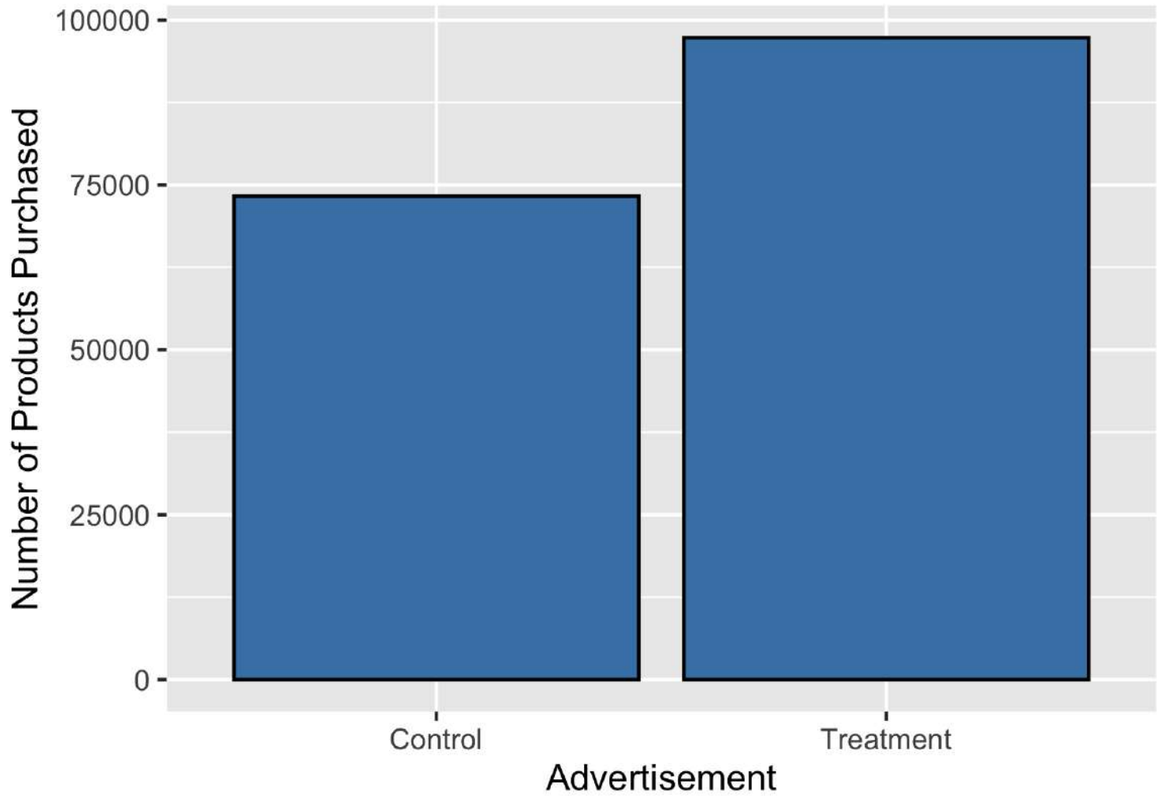
- Treatment: independent variable
- Response: dependent variable

[1] Image credit: https://unsplash.com/@nci

Advertising as a treatment

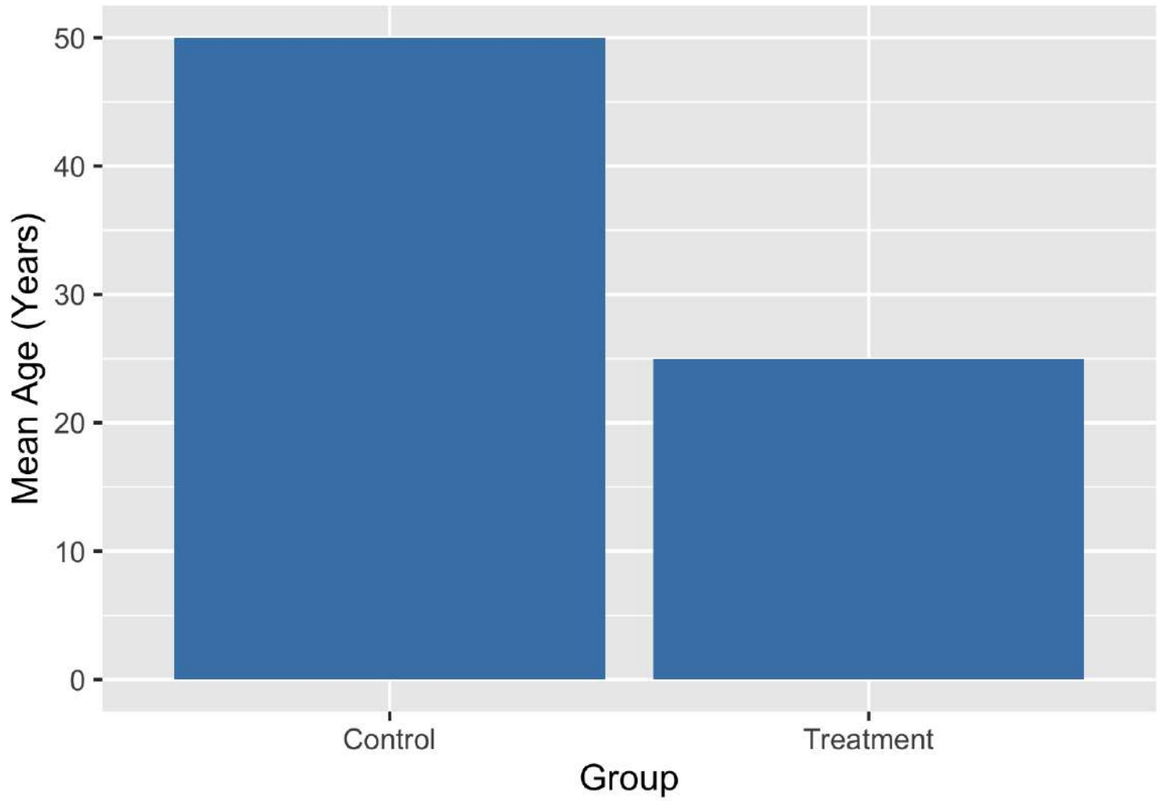
What is the effect of an advertisement on the number of products purchased?

- Treatment: advertisement
- Response: number of products purchased



Controlled experiments

- Participants are assigned to *either* the treatment group or the control group
  - ***Treatment group*** sees the advertisement
  - ***Control group*** does not see the advertisement
- Groups should be comparable to avoid introducing *bias*
- If groups are not comparable, this could lead to drawing incorrect conclusions



The gold standard of experiments

- **Randomization**
  - Participants are assigned to treatment/control *randomly*, not based on any other characteristics
  - Choosing randomly helps ensure that groups are comparable
  - Known as a **randomized controlled trial**

- **Blinding**
  - Participants will not know which group they're in
  - Participants receive a placebo, which resembles the treatment but has no effect
  - In clinical trials it is common to use a sugar pill

The gold standard of experiments

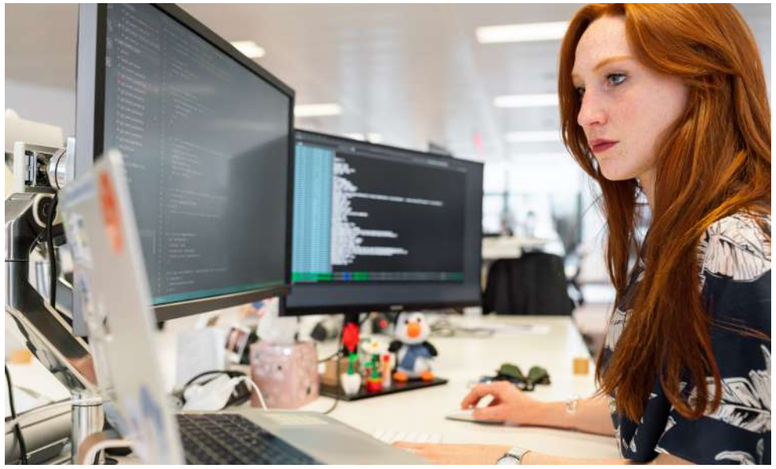
- **Double-blind randomized controlled trial**
  - Person administering the treatment/running the study doesn't know whether the treatment is real or a placebo
  - Prevents bias in the response and/or analysis of results

Fewer opportunities for bias = more reliable conclusion about causation

Randomized Controlled Trials vs. A/B testing

- **Randomized controlled trial**
  - Can be multiple treatment groups
  - Popular in science, clinical research

- **A/B testing**
  - Popular in marketing, engineering
  - Only split evenly into two groups



[1] Image credits: https://unsplash.com/@towfiqu999999; https://unsplash.com/@thisisengineering

Let's practice!

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Correlation

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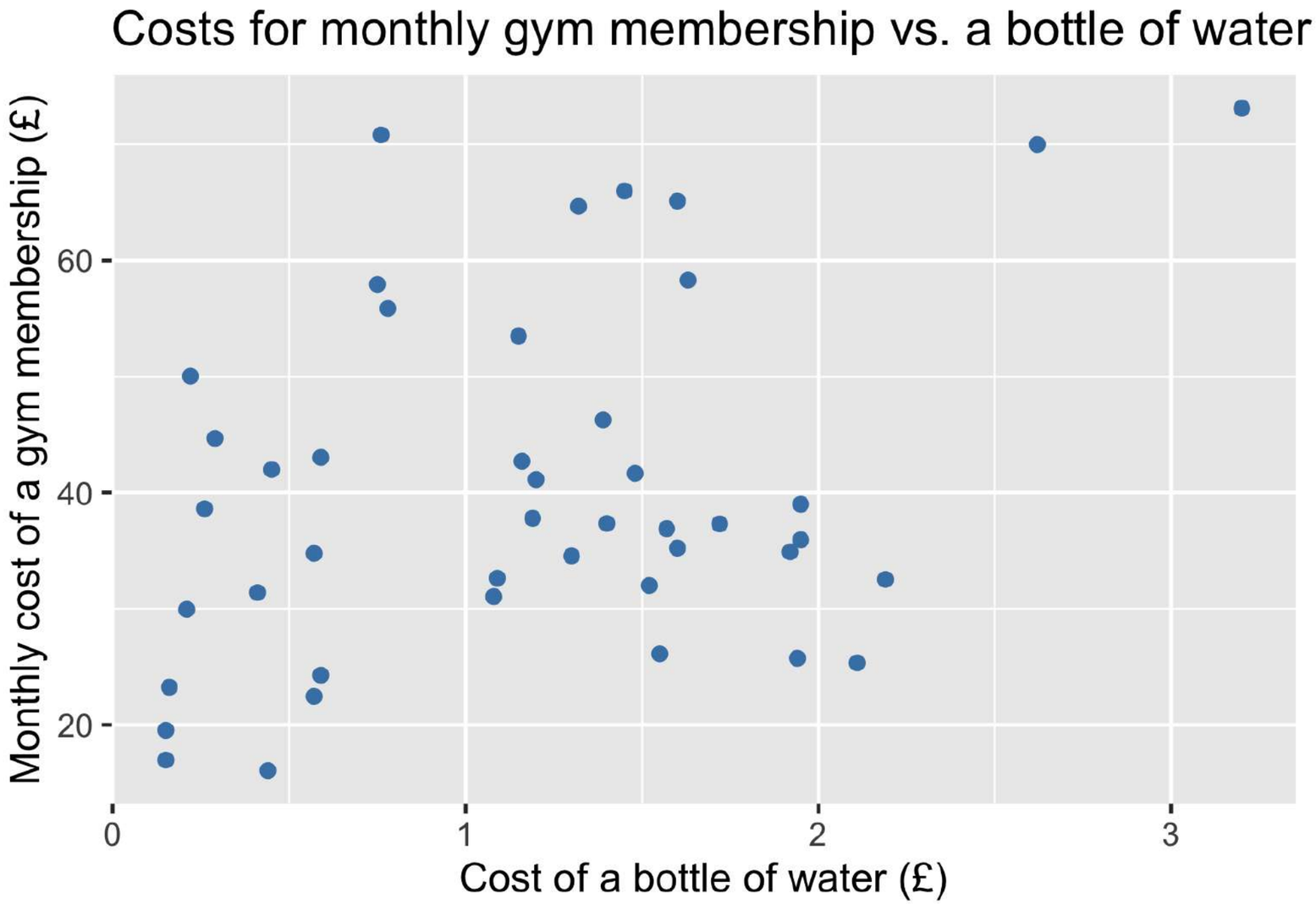
Relationships between two variables



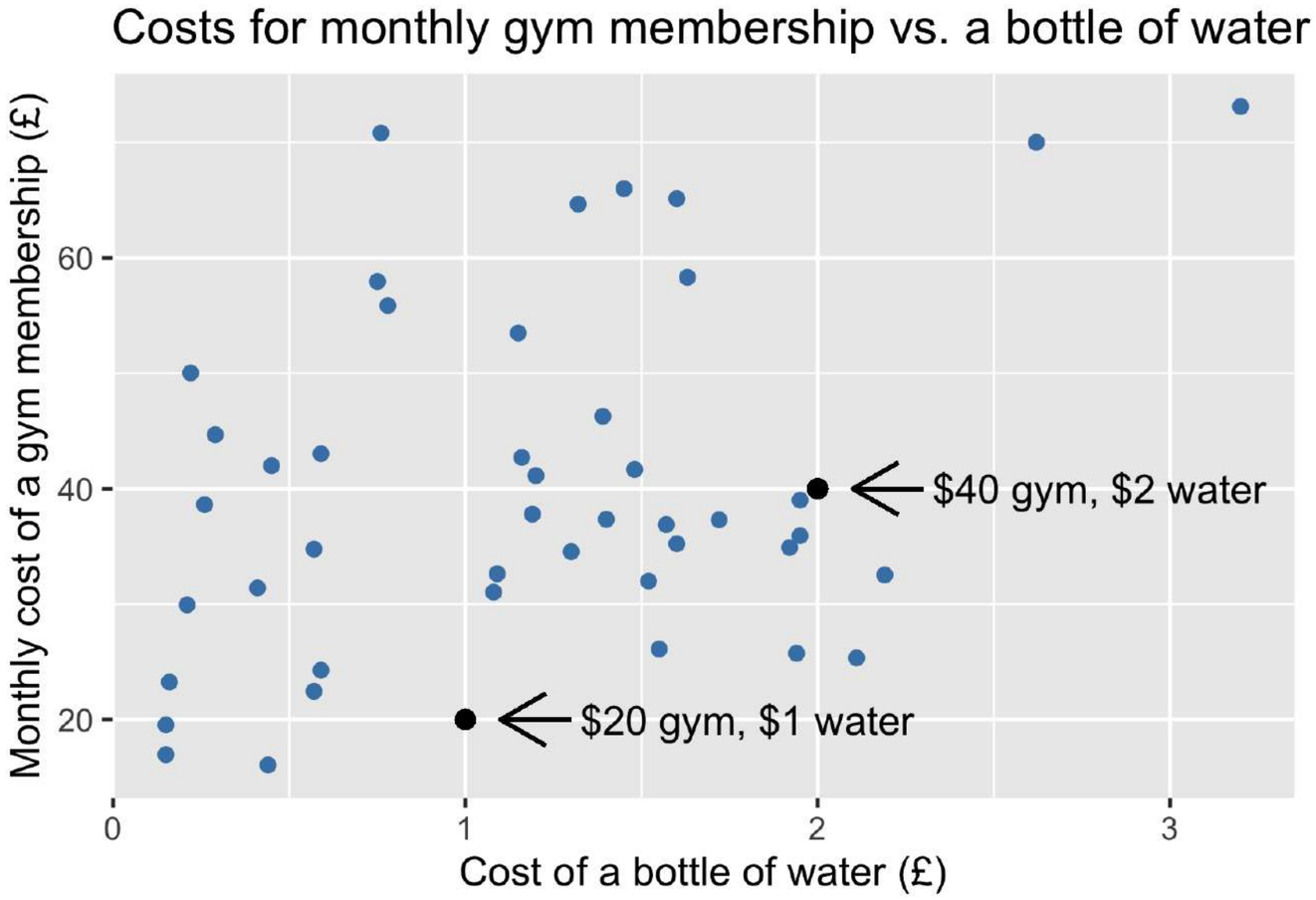
Pearson correlation coefficient

- Published by Karl Pearson in 1896!
- Quantifies the strength of a relationship between two variables
- Number between **minus one** and **one**
- Magnitude corresponds to strength of relationship
- Sign (+ or -) corresponds to direction of relationship

[1] https://royalsocietypublishing.org/doi/10.1098/rsta.1896.0007

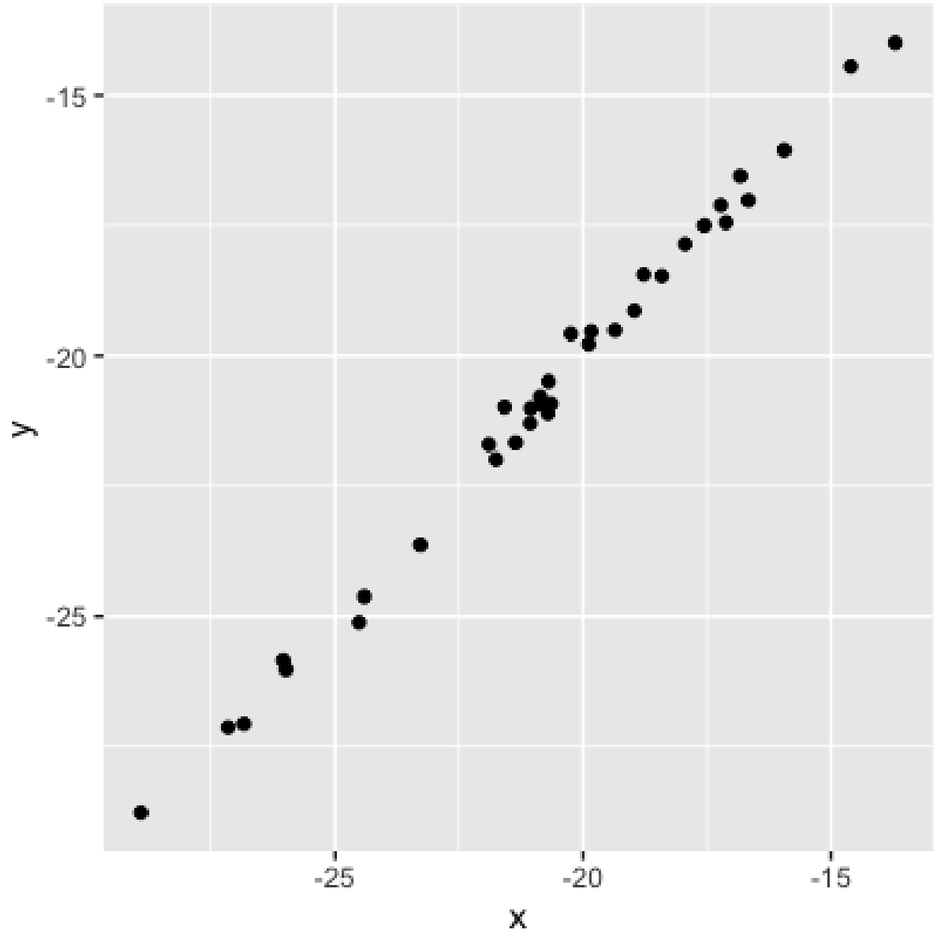
Linear relationships

- Linear = proportionate changes between dependent and independent variables



Values = strength of the relationship

0.99 (very strong relationship)



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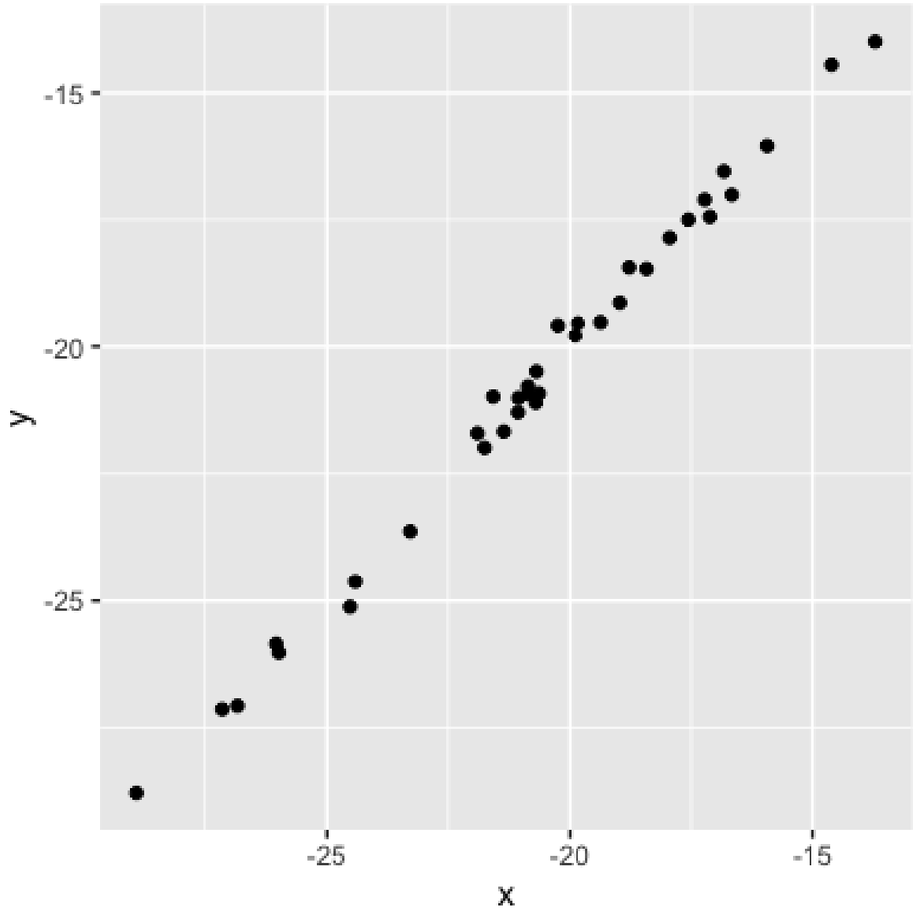
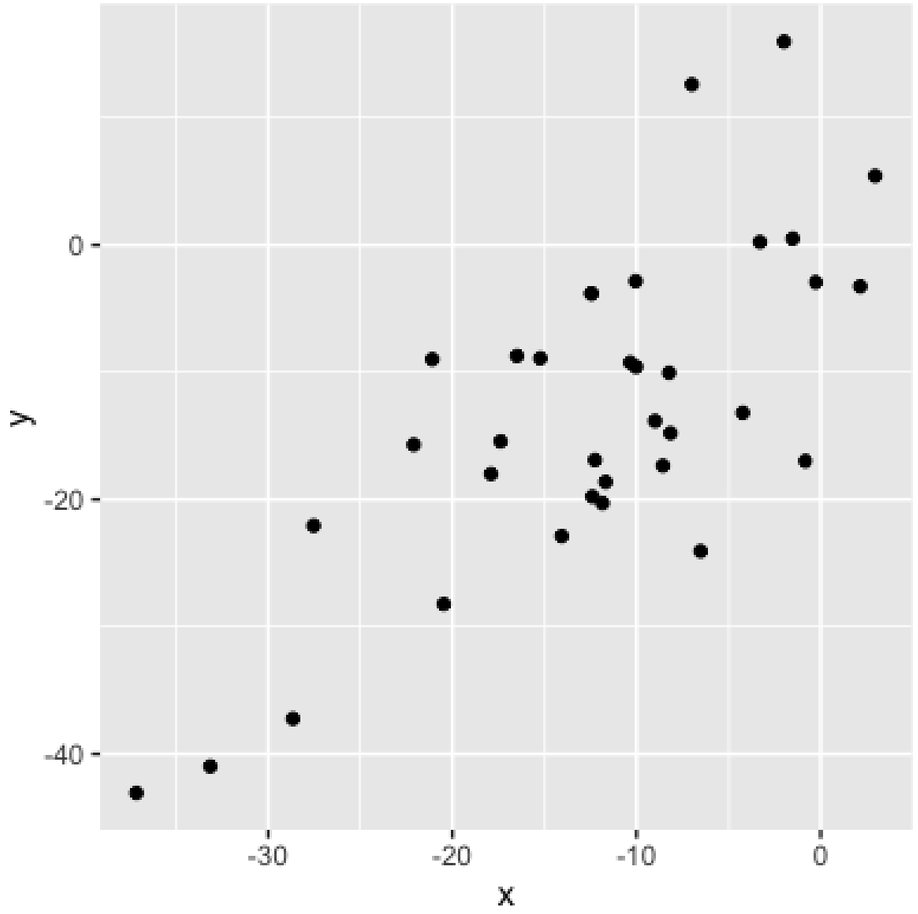
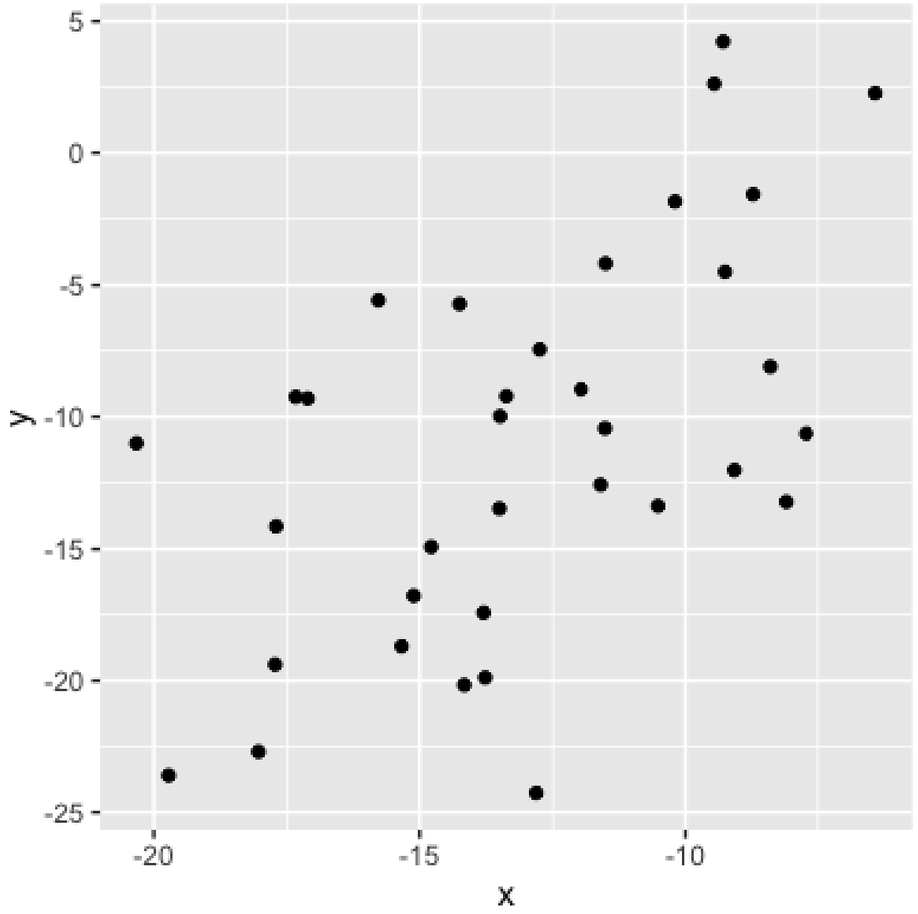


0.75 (strong relationship)



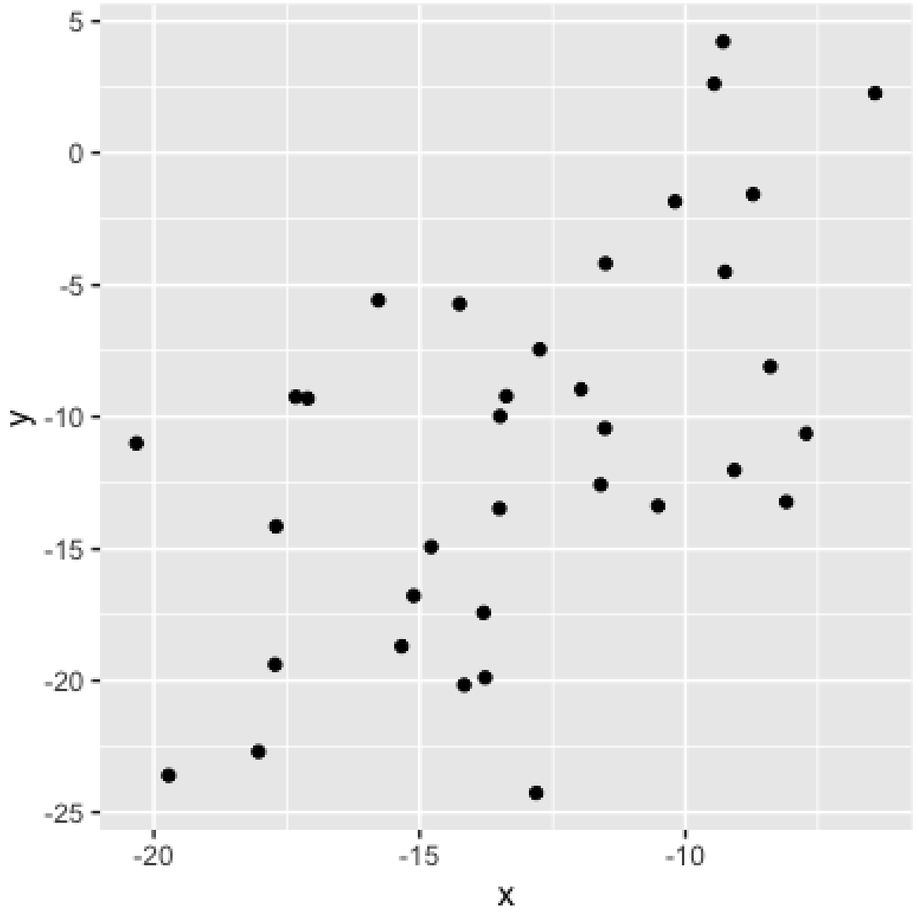
Values = strength of the relationship

0.56 (moderate relationship)

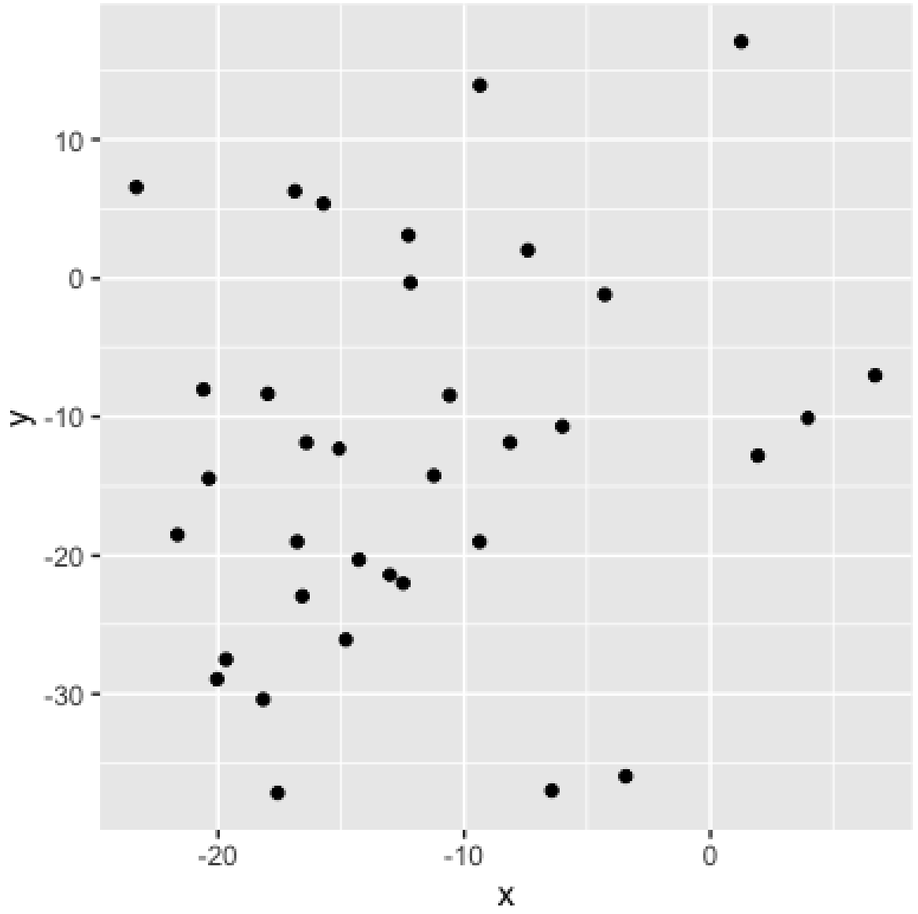


Values = strength of the relationship

0.56 (moderate relationship)

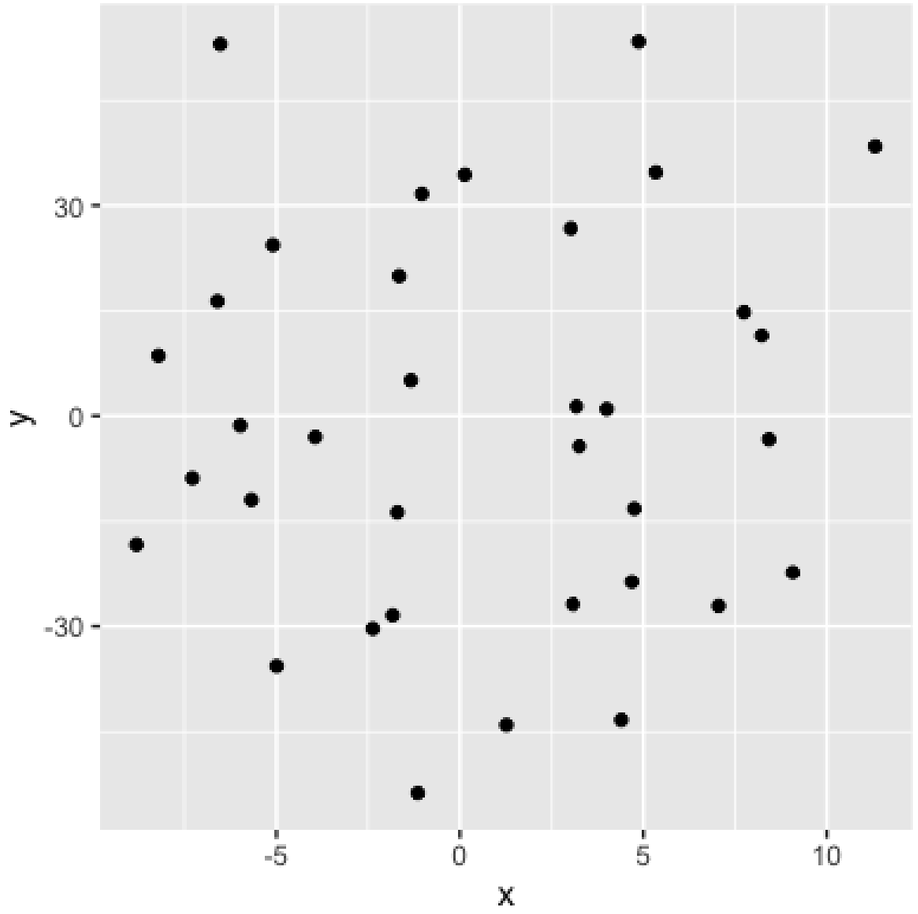


0.21 (weak relationship)



Values = strength of the relationship

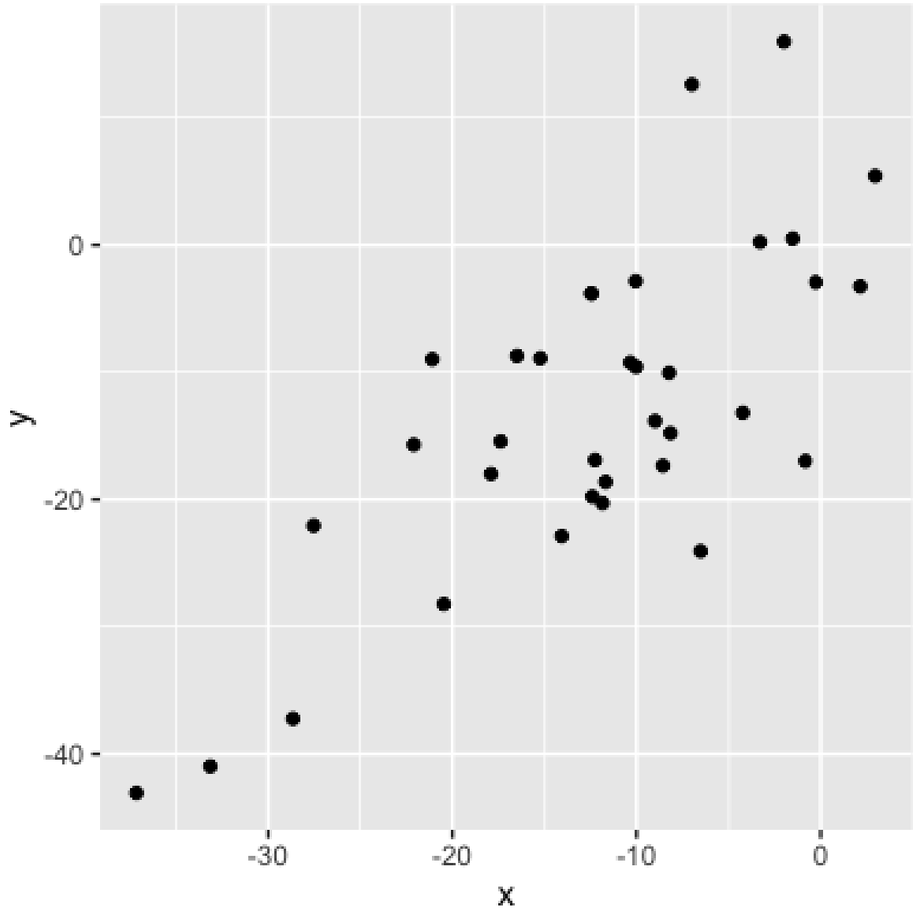
0.04 (no relationship)



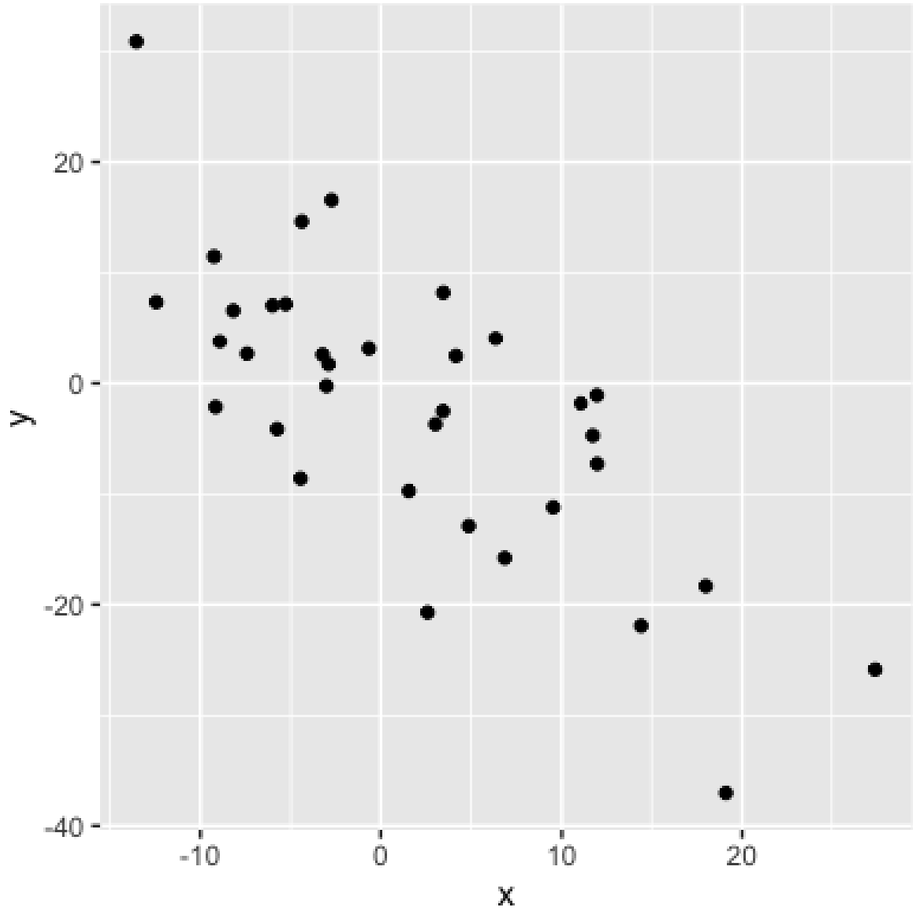
- Knowing the value of **x** doesn't tell us anything about **y**

Sign = direction

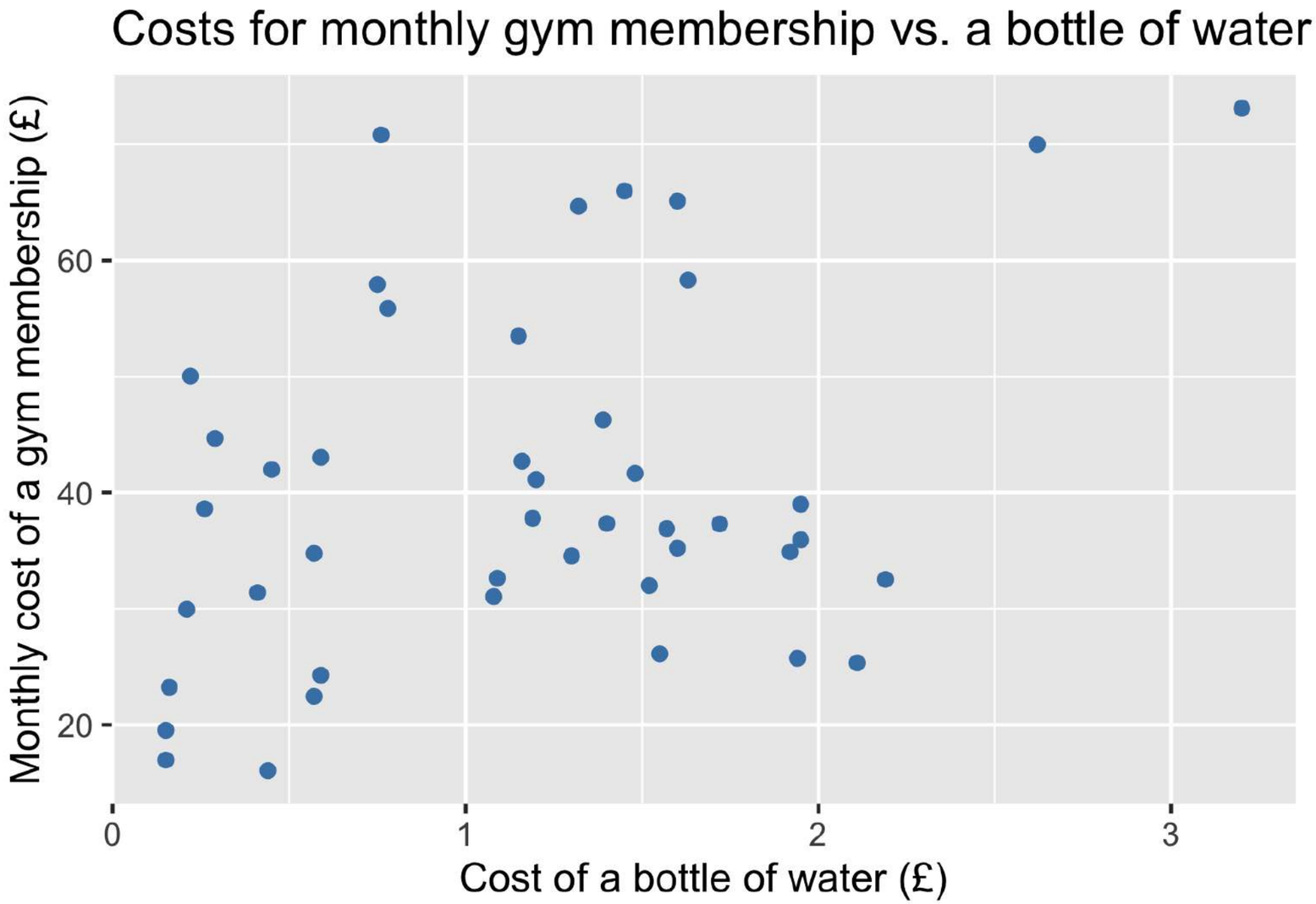
0.75: as x increases, y increases



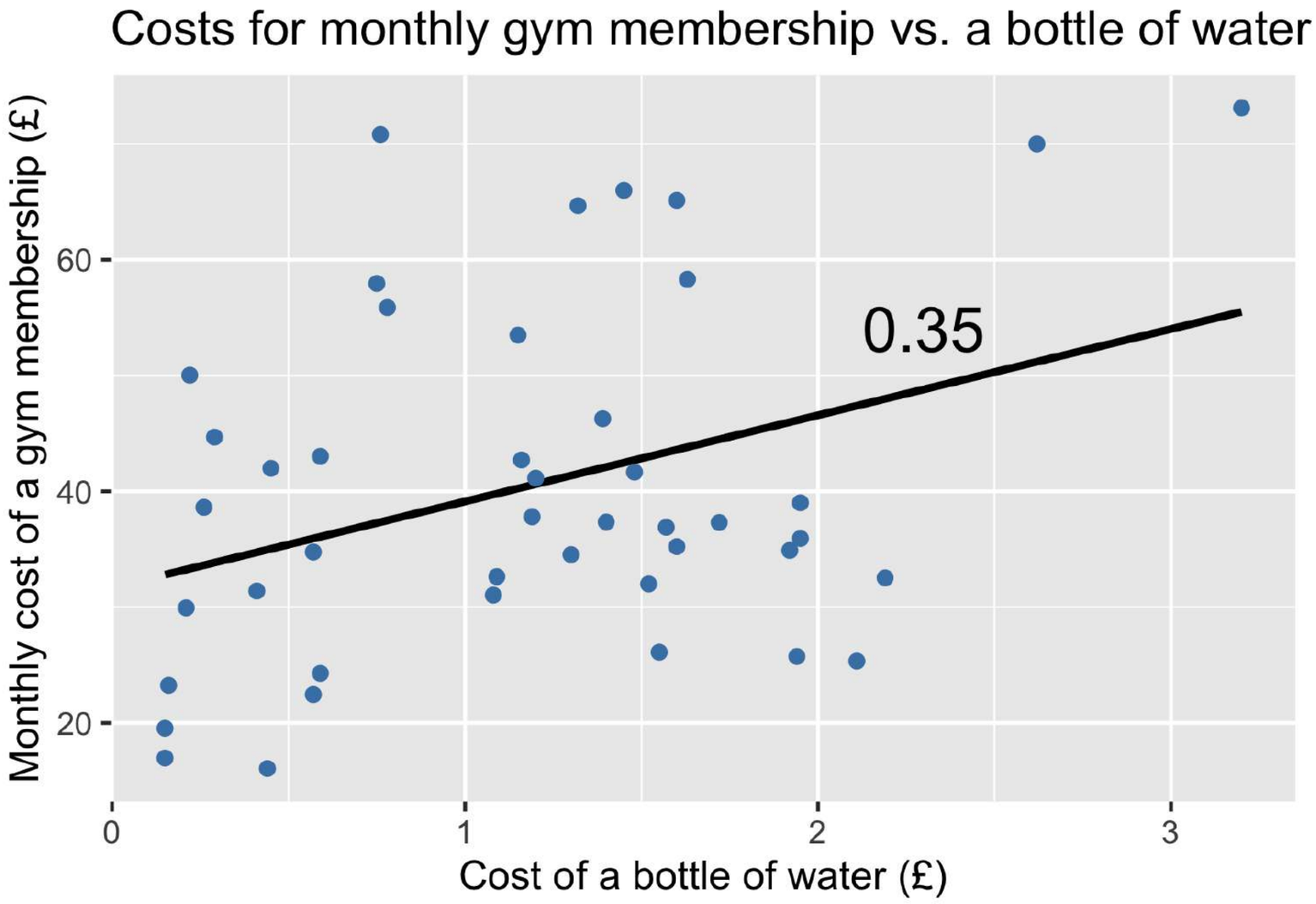
-0.75: as x increases, y decreases



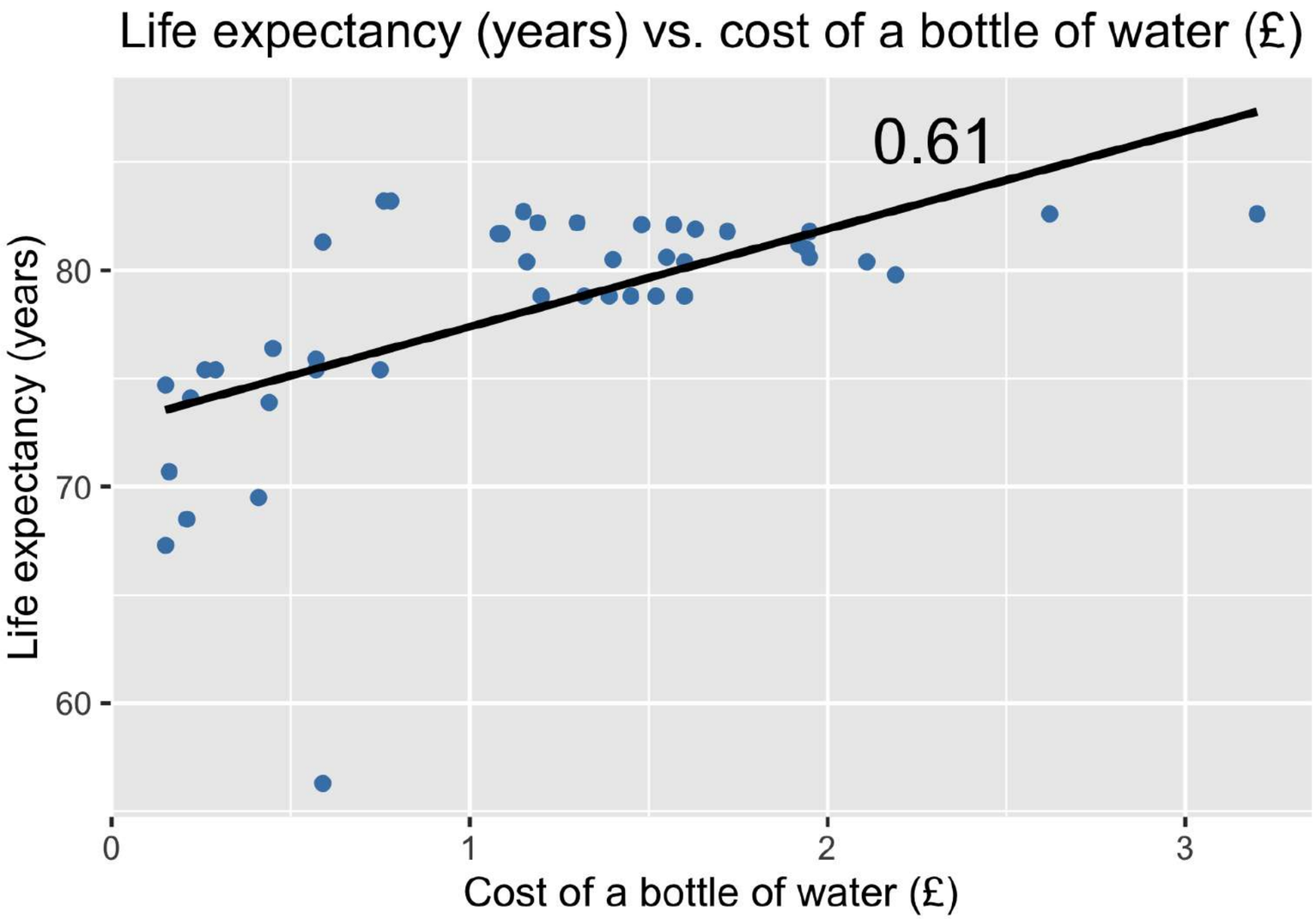
Gym costs vs. water costs



Adding a trendline



Life expectancy vs. cost of a bottle of water



Correlation does not equal causation

- Will increasing the cost of water result in an increase in life expectancy?

- Correlation does not equal **causation**

[1] Image credit: https://unsplash.com/@micheile; https://unsplash.com/@jon_chng

Confounding variables

- What else might be affecting life expectancy?
  - A bottle of water costs more in countries with strong economies
  - These countries generally offer access to high-quality healthcare
- The strength of the *economy* could be a **confounding variable**
  - A confounding variable is not measured, but may affect the relationship between our variables

Let's practice!

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Interpreting hypothesis test results

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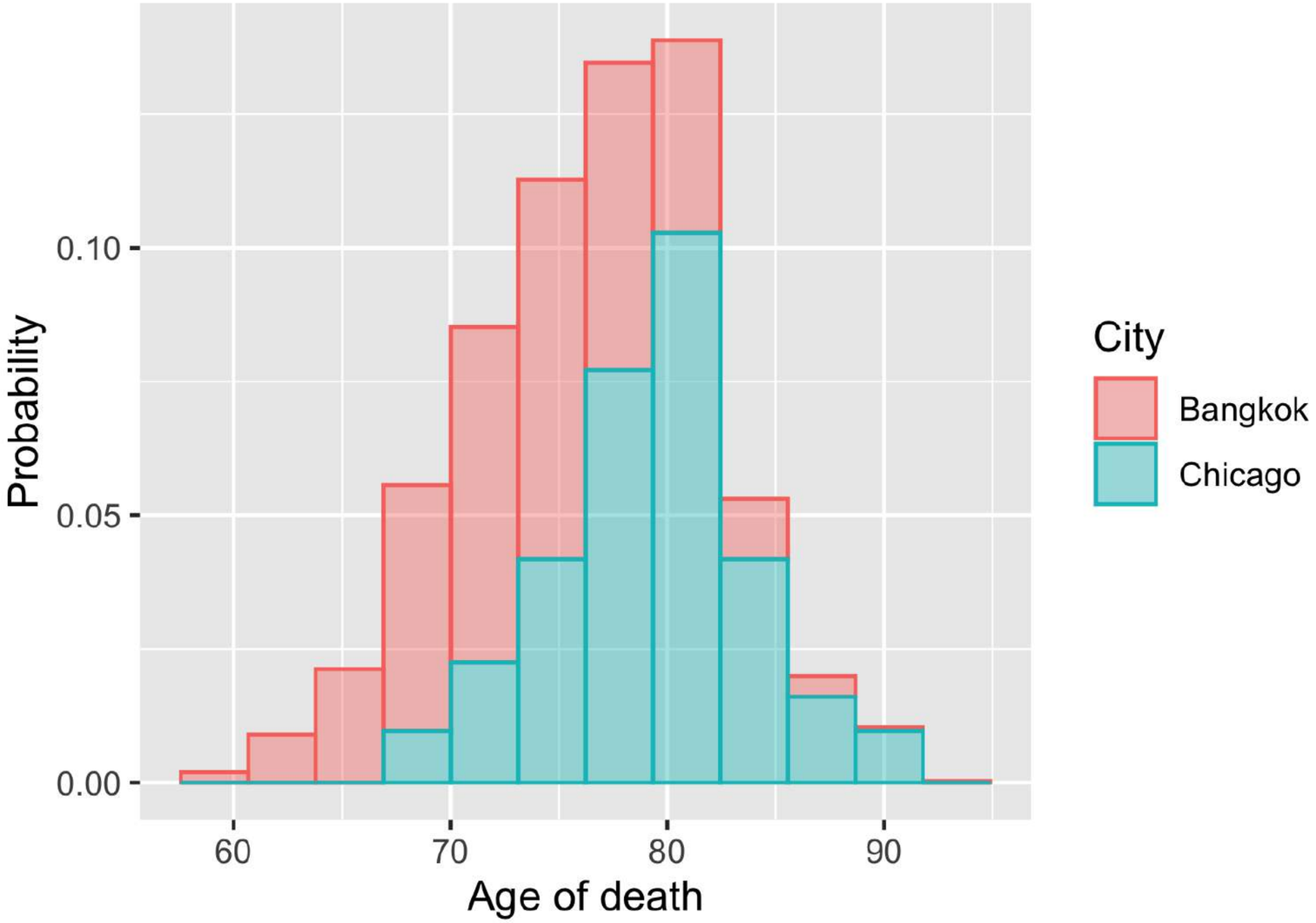
Life expectancy in Chicago vs. Bangkok

- **Null hypothesis:**
  - There is no difference in life expectancy between Chicago residents and Bangkok residents
- **Alternative hypothesis:**
  - Chicago residents have a longer life expectancy than Bangkok residents

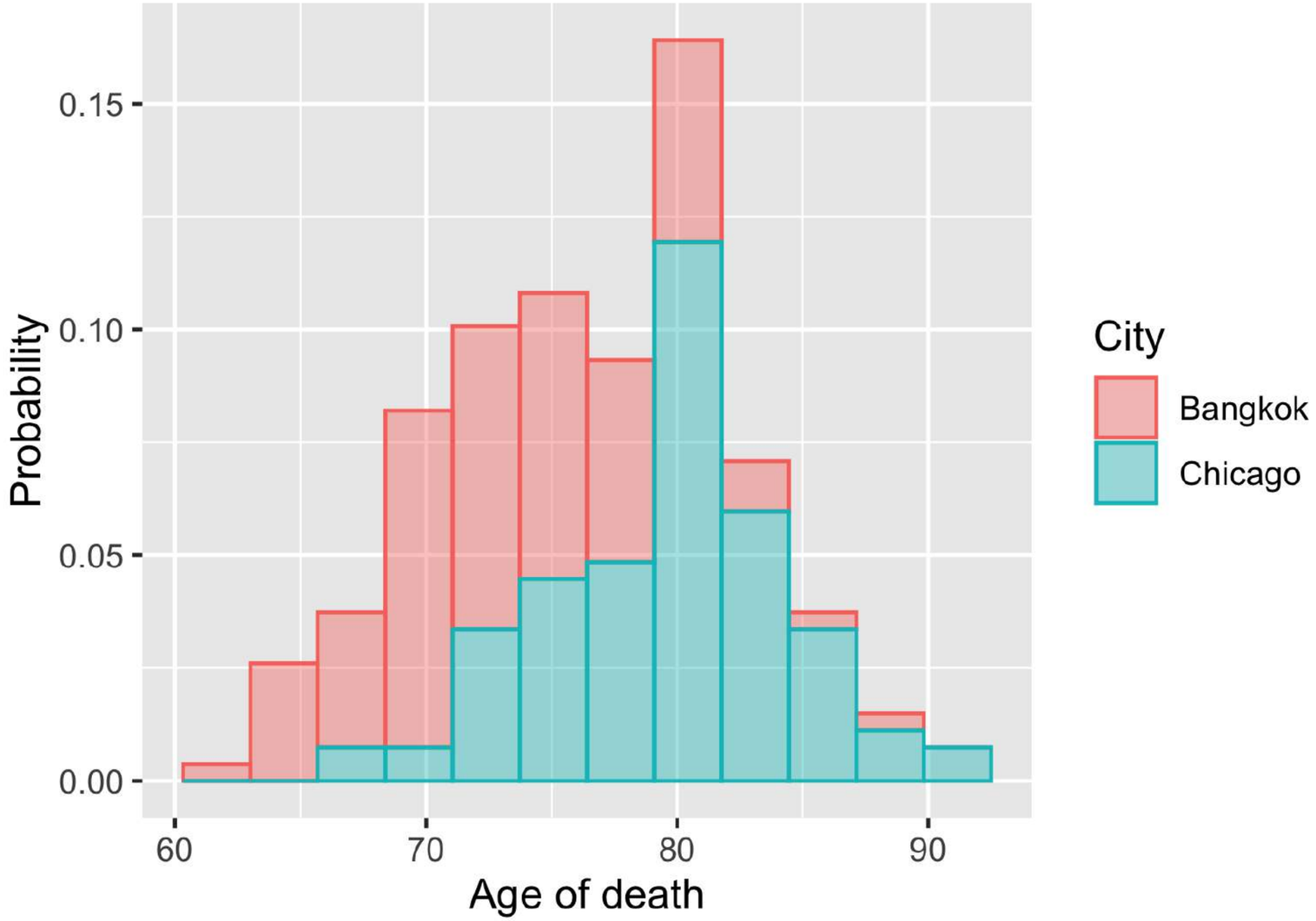
Chicago

Bangkok

Sampling distribution



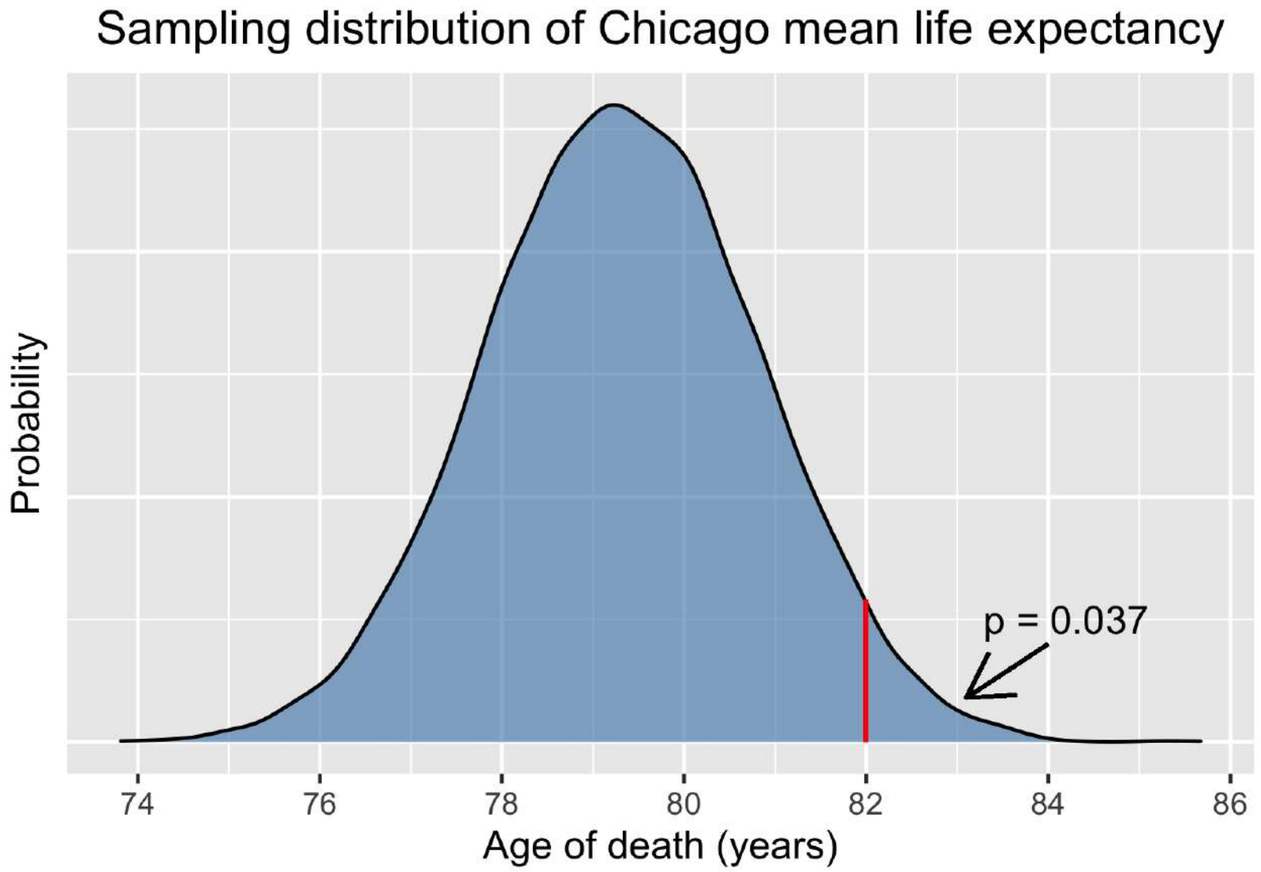
Different samples



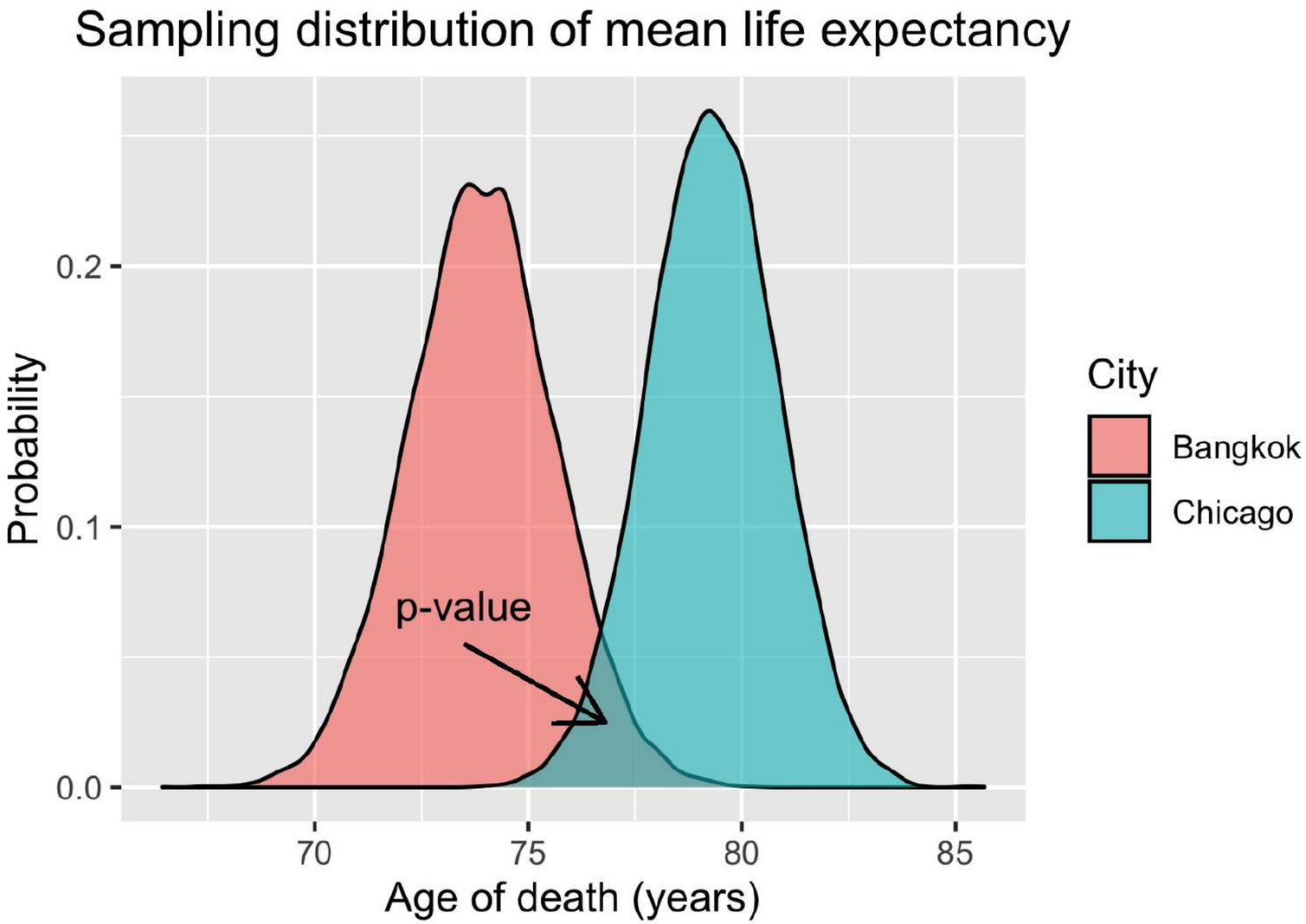
Sampling distribution of mean life expectancy

p-value

- p
  - Probability of achieving this result, assuming the null hypothesis is true



p-value


Sampling distribution of mean life expectancy
Probability
0.2
0.1
0.0
p-value
70
75
80
85
Age of death (years)
City
Bangkok
Chicago

Significance level (α)

- To reduce the risk of drawing a false conclusion:
  - Set a probability threshold for rejecting the null hypothesis
- Known as α or *significance level*
- Decided before data collection to minimize bias:
  - Otherwise they could choose a different α to serve their interests
- A typical threshold is 0.05
  - 5% chance of wrongly concluding that Chicago residents live longer than Bangkok residents
- If $p \leq \alpha$, reject the null hypothesis
- These results are said to be *statistically significant*

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypotheis		

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypotheis		Type II Error

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	
Accept null hypotheis	Correct conclusion	Type II Error

Type I/II error

	Null hypothesis is TRUE	Null hypothesis is FALSE
Reject null hypothesis	Type I Error	Correct conclusion
Accept null hypotheis	Correct conclusion	Type II Error

Drawing a conclusion

Let's practice!

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Congratulations!

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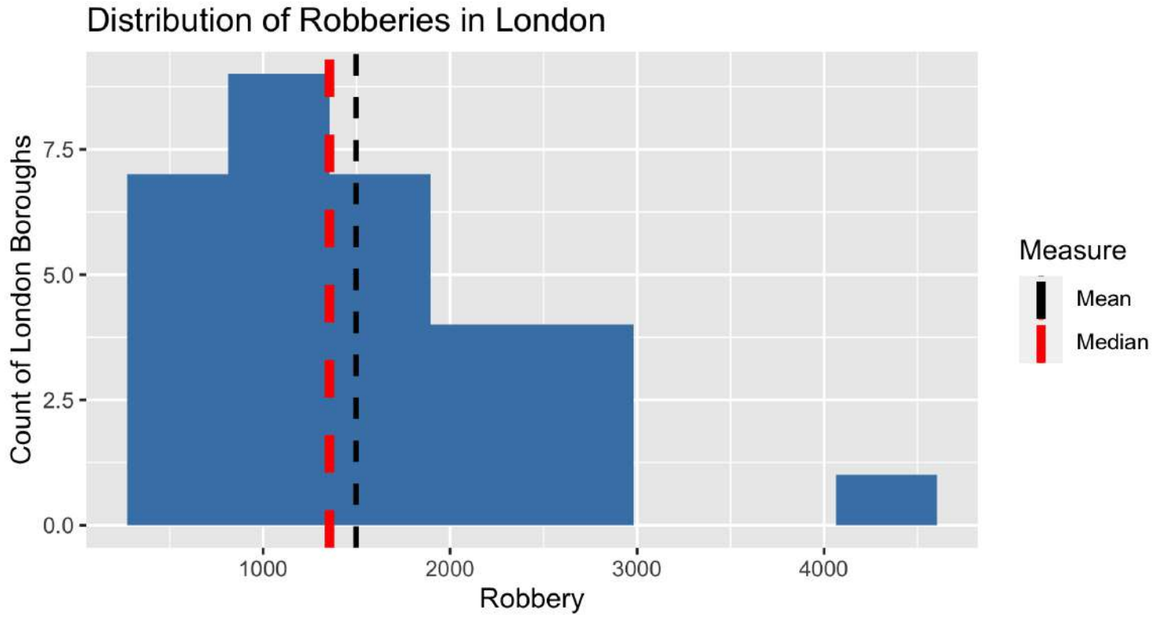
What you've covered

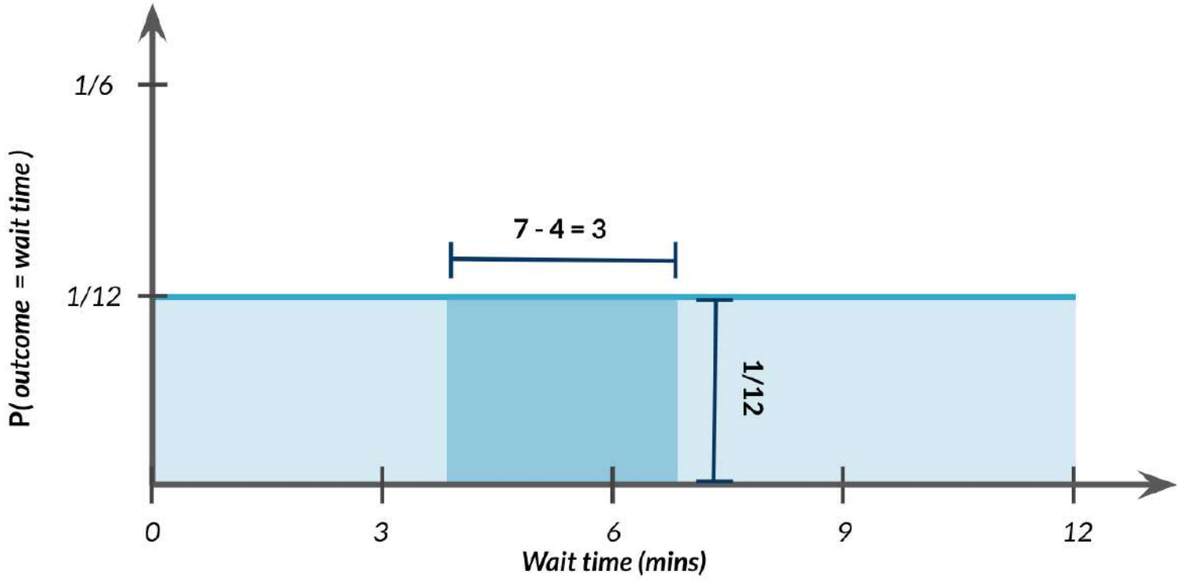
- Types of data
  - Ordinal, nominal, continuous, interval
- Descriptive and inferential statistics
- Measures of center
  - Mean, median, mode
- Measures of spread
  - Variance, standard deviation



What you've covered

- Probability

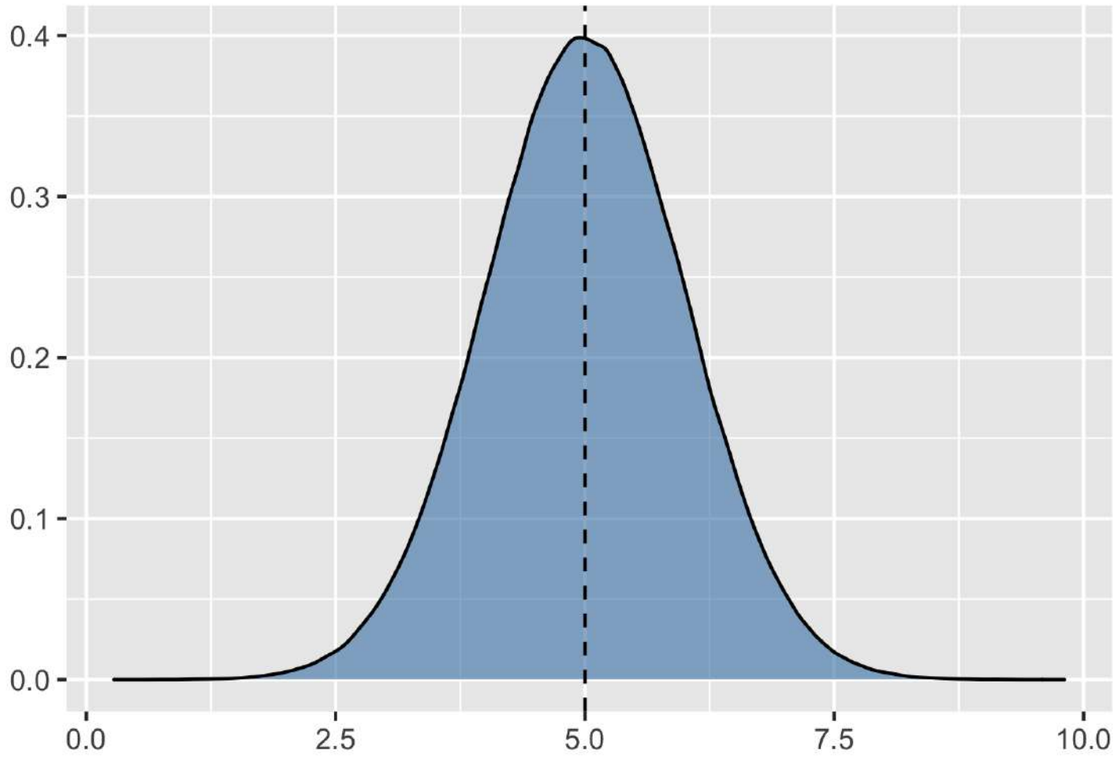
$$P(4 \leq \text{wait time} \leq 7) = 3 \times 1/12 = 3/12$$



- Conditional probability
- Discrete distributions
- Continuous distributions

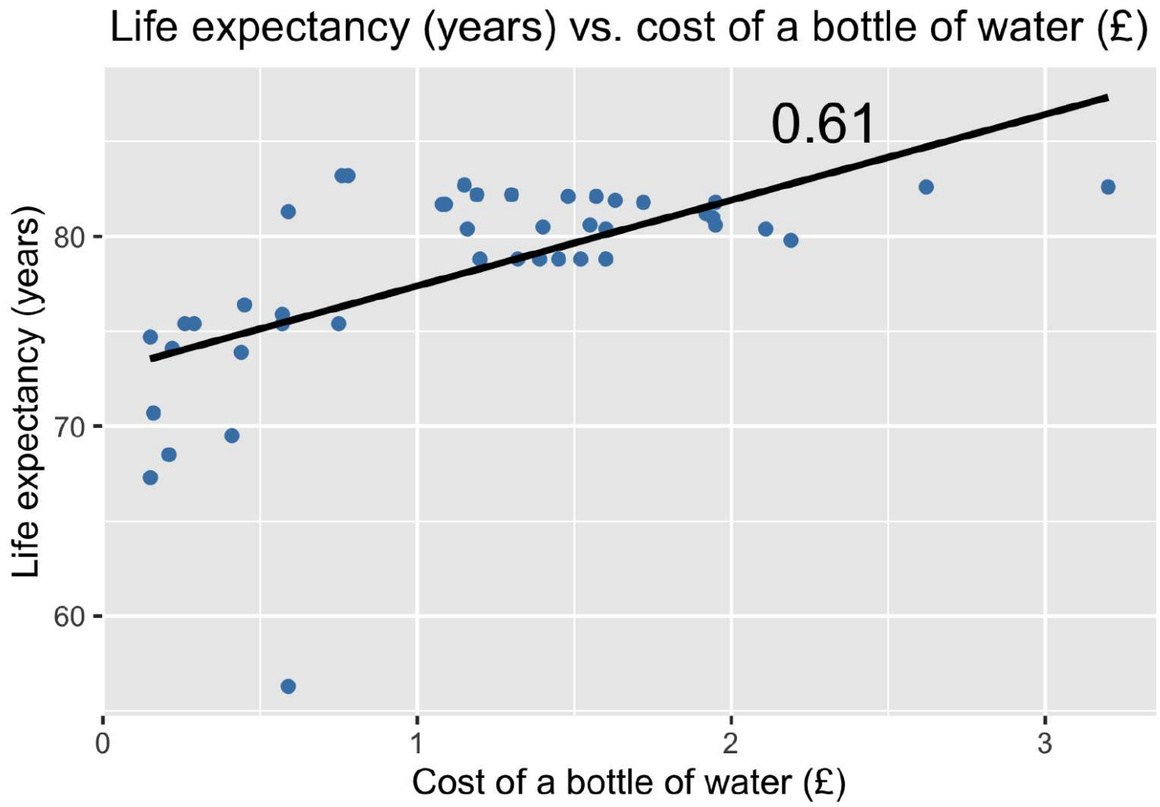
What you've covered

- The binomial distribution
- The normal distribution
- The Poisson distribution
- The central limit theorem



What you've covered

- Hypothesis testing
- Randomization, treatment, and control
- Correlation
- Interpreting hypothesis test results



Where to from here?

- Understanding Data Science
- Data Science for Business
- Understanding Machine Learning

Thank you!

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