TECHNISCHE HOCHSCHULE
OSTWESTFALEN-LIPPE
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS

Study Design & Data Analysis

Prof. Dr. Dr. Dr. Carsten Röcker & Hitesh Dhiman, M.Sc.

Overview

- Variables and Constructs
- Scales of Measure
- Questionnaire
- Data Analysis
- Research Topic

Overview

- **Variables and Constructs**
- Scales of Measure
- Questionnaire
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Variables

- **Independent Variable (IV)**
  - characteristic changed to produce different conditions
  - e.g., age, affinity towards technology

- **Dependent Variable (DV)**
  - characteristics measured in the experiment
  - e.g., general attitude towards assistance systems

Constructs

- hypothetical construct = explanatory variable that is not directly observable
  - e.g., intelligence, aggression, life satisfaction
- have to be operationalized in order to be measures
- requires to specify a measurement procedure

Constructs

Example: Intelligence

- definition: *“capacity for abstract thought, understanding, communication, reasoning, learning, planning and problem solving“*
- measurement = e.g., the score obtained in Raven’s Progressive Matrices Test
  - developed by John C. Raven (1936)
  - multiple choice test
  - 60 questions
  - scored automatically after 40 minutes

Constructs

Example: Affinity towards Technology

- TA-EG Questionnaire
  (Fragebogen zur Technikaffinität: Einstellung zu und Umgang mit elektronischen Geräten)
- 19 items addressing affinity towards technology

	Trifft voll zu	Trifft eher zu	Teils /teils	Trifft eher nicht zu	Trifft gar nicht zu
1. Ich liebe es, neue elektronische Geräte zu besitzen.	❑	❑	❑	❑	❑
2. Elektronische Geräte machen krank.	❑	❑	❑	❑	❑
3. Ich gehe gern in den Fachhandel für elektronische Geräte.	❑	❑	❑	❑	❑
4. Ich habe bzw. hätte Verständnisprobleme beim Lesen von Elektronik- und Computerzeitschriften.	❑	❑	❑	❑	❑
5. Elektronische Geräte ermöglichen einen hohen Lebensstandard.	❑	❑	❑	❑	❑
6. Elektronische Geräte führen zu geistiger Verarmung.	❑	❑	❑	❑	❑
7. Elektronische Geräte machen vieles umständlicher.	❑	❑	❑	❑	❑
8. Ich informiere mich über elektronische Geräte, auch wenn ich keine Kaufabsicht habe.	❑	❑	❑	❑	❑
9. Elektronische Geräte machen unabhängig.	❑	❑	❑	❑	❑
10. Es macht mir Spaß, ein elektronisches Gerät auszuprobieren.	❑	❑	❑	❑	❑
11. Elektronische Geräte erleichtern mir den Alltag.	❑	❑	❑	❑	❑
12. Elektronische Geräte erhöhen die Sicherheit.	❑	❑	❑	❑	❑
13. Elektronische Geräte verringern den persönlichen Kontakt zwischen den Menschen.	❑	❑	❑	❑	❑
14. Ich kenne die meisten Funktionen der elektronischen Geräte, die ich besitze.	❑	❑	❑	❑	❑
15. Ich bin begeistert, wenn ein neues elektronisches Gerät auf den Markt kommt.	❑	❑	❑	❑	❑
16. Elektronische Geräte verursachen Stress.	❑	❑	❑	❑	❑
17. Ich kenne mich im Bereich elektronischer Geräte aus.	❑	❑	❑	❑	❑
18. Es fällt mir leicht, die Bedienung eines elektronischen Geräts zu lernen.	❑	❑	❑	❑	❑
19. Elektronische Geräte helfen, an Informationen zu gelangen.	❑	❑	❑	❑	❑

Constructs

Potential Problems

- operational definitions might
  - not accurately capture the intended construct
    - i.e. lack validity
  - be subjective
    - i.e. depends on how the construct is defined and measured

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Scales of Measure

- used to classify variables
- four types
  - nominal
  - ordinal
  - interval
  - ratio
- qualitative: nominal
- quantitative: ordinal, interval, ratio

Nominal Scale

- possible to distinguish between items
- grouping according to names
- but: no order
- examples
  - gender (male, female)
  - place of birth (Lemgo, Detmold, etc.)

Nominal Scale: Analysis

- no mathematical operations possible
- but: descriptive statistics, e.g.,
  - comparisons (e.g., absolute and relative frequencies)
  - histograms, charts
  - mode (most common item)

Ordinal Scale

- rank order exist
- but: no relative degree of difference
- examples
  - school grade
    - very good, good, satisfactory, ...
  - satisfaction with a product
    - very satisfied, satisfied, unsatisfied, very unsatisfied
  - level of agreement with a statement
    - completely agree, mostly agree, mostly disagree, completely disagree

Ordinal Scale: Analysis

- all operations for nominal scale
- ranking (1st, 2nd, 3rd, …)
- median (middle-ranked)

Interval Scale

- similar to ordinal scale
- but: relative degree of difference
- example: measurement of temperature on Celsius scale
  - zero point arbitrarily defined
  - ratios are not allowed
    - e.g., 20 °C not “twice as hot“ as 10 °C

Interval Scale: Analysis

- all operations for ordinal scale
- mean
- standard deviation

Ratio Scale

- similar to interval scale
- but: non-arbitrary zero point
- examples
  - temperature measured in Kelvin
  - time measured in seconds
- mostly applies for measurements in natural sciences and engineering
  - e.g., distance A is “twice as long“ as distance B
- interval and ratio scale subsumed as metric scales

Ratio Scale: Analysis

- all statistical measures are allowed

Overview

- Variables and Constructs
- Scales of Measure
- **Questionnaire**
  - Types
  - Question Formats
  - Wording
  - Measuring Feedback: Likert Scale
- Data Analysis
- Research Topic

Questionnaire

- questionnaire = research instrument consisting of a series of questions
- designed for statistical analysis
- advantages
  - cheap
  - low effort (compared to verbal questioning in interviews)
  - standardized answers support data analysis
- disadvantages
  - standardized answers may frustrate users
  - respondents must be able to read

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Questionnaire: Test vs. Survey

Test

- assessment of an individual aspect
  - e.g., IQ test
- questions usually have one correct answer
  - *Who was the first man on the moon?*
- items are often aggregated into a scale or index

Questionnaire: Test vs. Survey

Survey

- aims at gathering opinions and information
  - often no correct or incorrect answer
  - e.g., *What is your favorite food?*
- feedback usually anonymous
- often measures separate variables
- presented as response statistics

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Question Formats

Five Basic Question Formats[1]

1. Open-ended
   "The job tasks I enjoy most are _____."
2. Modified open-ended
   "I was ____ years old when I began my current job."

[1]Source: Survey Questionnaire Design. Fairfax County Department of Neighborhood and Community Services. Economic, Demographic and Statistical Research. Fairfax, VA, 2012.

Question Formats

3. Closed-ended with ordered response choices

“How would you rate your preferences for the following job tasks?”

Writing	☐ Enjoy ☐ Neutral ☐ Dislike
Editing	☐ Enjoy ☐ Neutral ☐ Dislike
Organizing	☐ Enjoy ☐ Neutral ☐ Dislike

Question Formats

4. Closed-ended with unordered response choices

   “Which of the following job tasks do you like the most?”

   - ☐ Writing
   - ☐ Editing
   - ☐ Organizing

Question Formats

5. Partially close-ended

   “Which job task do you most enjoy doing?”

   - ☐ Writing
   - ☐ Editing
   - ☐ Organizing
   - ☐ Other (please specify) _____

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Wording

General Rules for Stating Questions[1]

- be concise and unambiguous
- avoid double questions
- avoid questions involving negatives
- ask for precise answers
- avoid leading questions

[1]Source: Survey Questionnaire Design. Fairfax County Department of Neighborhood and Community Services. Economic, Demographic and Statistical Research. Fairfax, VA, 2012.

Wording

Be Concise and Unambiguous

- make questions brief and clear
- avoid jargon and technical terms
  - avoid: *„do you believe that the UK should have a bicameral parliament?“*
  - instead: *„do you believe that the UK should have upper and lower houses of parliament?“*
- check for ambiguity
  - avoid: „have you been to the cinema recently“
  - instead: „have you been to the cinema in the last two weeks?“

Wording

Avoid Double Questions

- sometimes questions hide a dual question
- example: *„Do you think the British should eat less and exercise more?“*
- instead ask:

Do you think the British should eat less?	☐ yes	☐ no
Do you think the British should exercise more?	☐ yes	☐ no

Wording

Avoid Questions Involving Negatives

- don't confuse the respondent by language like this:

Are you against a ban on smoking?	☐ yes ☐ no

Wording

Ask for Precise Answers

- ask for precise answers if you think
  - the information is available and
  - there are no other constraints (e.g., too intrusive on privacy)
- example: „Give your age on 1st January 2020: ☐☐ years“
- instead of:

Are you …	☐ under 18 ☐ 18 - 65 ☐ over 65

Wording

Ask for Precise Answers: Advantages

- less room for error
  - e.g., by ticking the wrong box
- exact answer may be re-coded
  - e.g., different age groups
- possible to compute statistical parameters
  - e.g., mean and standard deviation

Wording

Avoid Leading Questions

- avoid phrasing questions like:
  “Do you agree with the majority of people that the health service is failing?“

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Measuring Feedback: Likert Scale

- developed by psychologist Rensis Likert
- most widely used measuring scales for surveys
- respondents specify their level of agreement with a given statement

Measuring Feedback: Likert Scale

- example format of a typical five-level Likert item
  - strongly disagree
  - disagree
  - neither agree nor disagree
  - agree
  - strongly agree
- alternative: „forced choice" method
  - usage of an even-point scale
  - elimination of the middle/neutral option

Measuring Feedback: Likert Scale

Potential Problems

- respondents may…
  - avoid using extreme response categories *(central tendency bias)*
  - agree with presented statements *(acquiescence bias)*
  - provide socially accepted responses *(social desirability bias)*

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Main Statistical Methodologies

- **Descriptive Statistics**
  - aims at summarizing a sample
  - goal: organization and presentation of empirical data

- **Inferential Statistics**
  - applies statistical procedures to test hypotheses

Overview

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  - **Descriptive Statistics**
  - Inferential Statistics
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Descriptive Statistics

Two Sets of Properties

- Central Tendency
  - seeks to characterize the distribution's central or typical value
- Dispersion (or Variability)
  - characterizes the extent to which members of the sample depart from its center and each other

General Methods

- Tables
- Diagrams
- Indexes

Descriptive Statistics

Analyzing Empirical Data

- Counting Frequencies
- Drawing Diagrams
- Calculation of Mean Values
- Identification of Minimum and Maximum
- Calculation of Standard Deviation

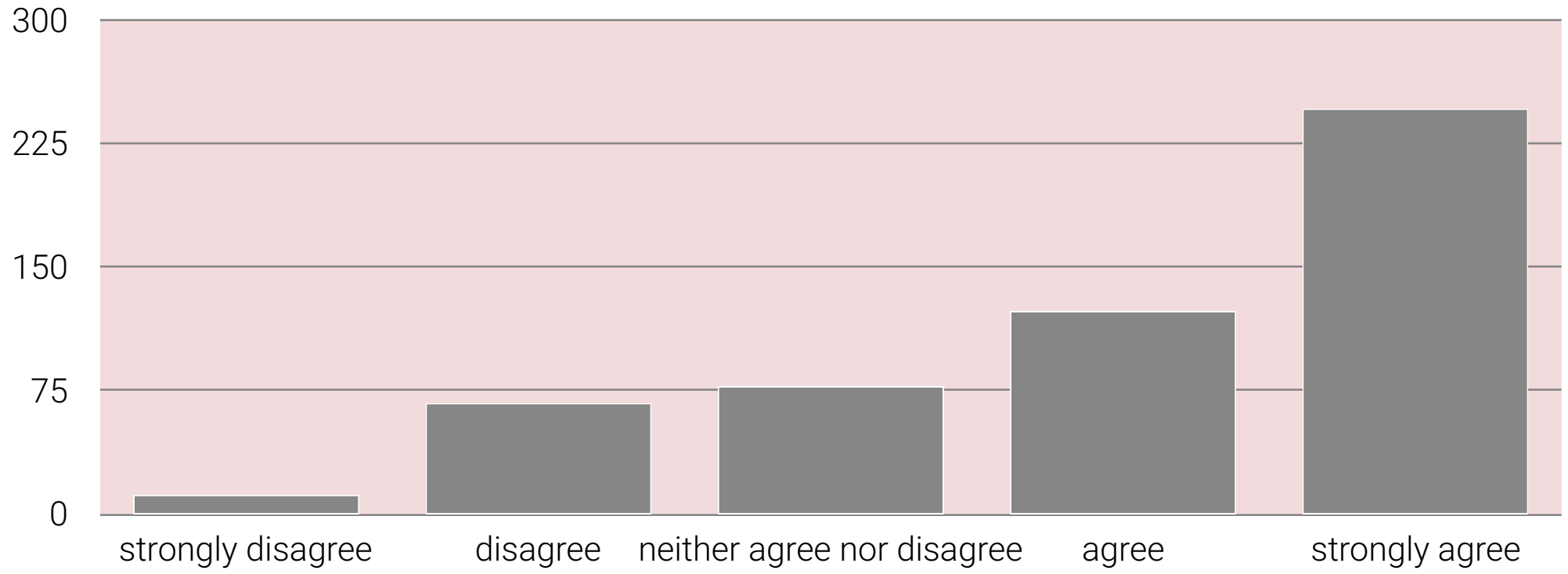
Frequencies: Table

- counting of responses
- absolute frequency
- relative frequency

	Absolute Frequency	Relative Frequency
strongly disagree	12	2.3 %
disagree	67	12.7 %
neither agree nor disagree	78	14.8 %
agree	123	23.4 %
strongly agree	246	46.8 %

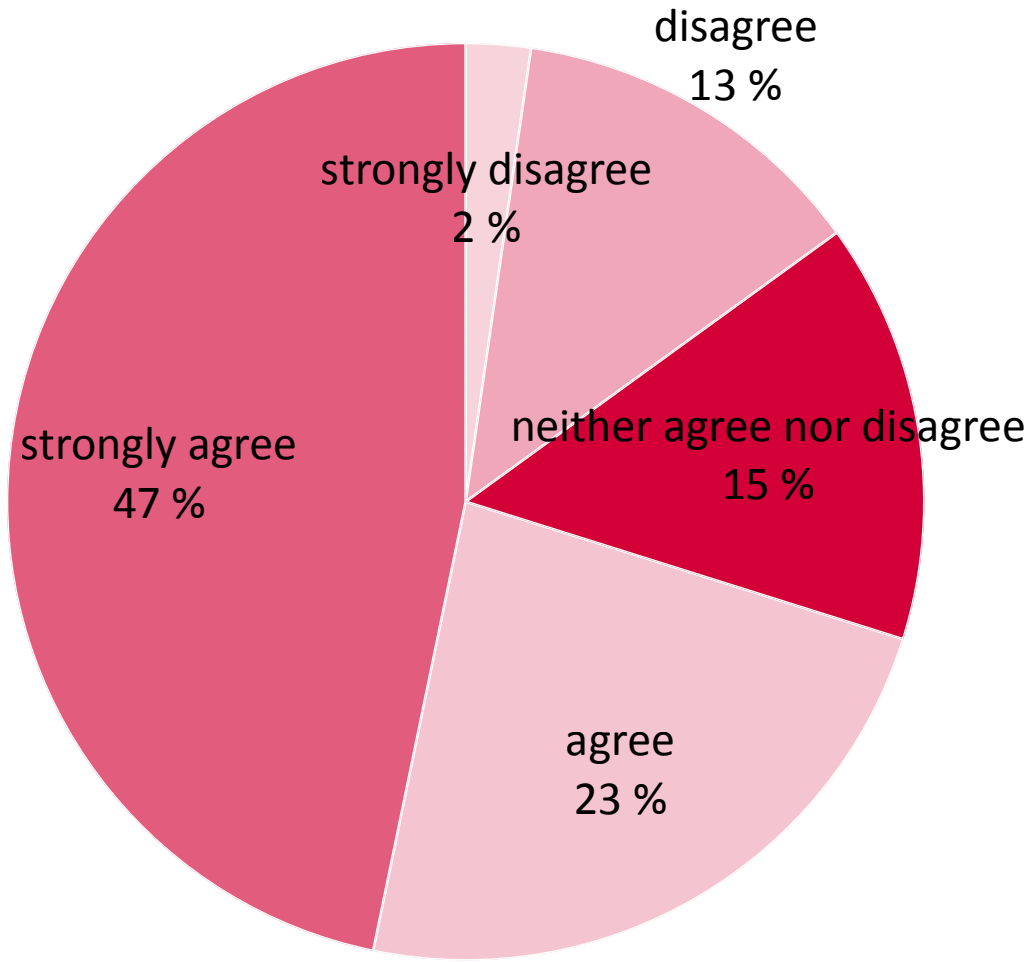
Frequencies: Histogramm

- Histogramm = graphical representation of the frequency distribution



Frequencies: Charts

- pie charts
- bar chart



Measures of Central Tendency

- describe the center of a distribution using a numerical value
- different measures
  - arithmetic mean
  - median
  - mode
- type of measure that should be used depends on the research question, the nature of data, and the scales of measurement

Measures of Central Tendency

Arithmetic Mean

- the sum of all of the numbers in a sample divided by the number of items in that sample
- requires metric scale

Measures of Central Tendency

Median

- numerical value separating the higher half of a data sample from the lower half
  - i.e. 50% of the data are above and the other 50% are below the median
- in case there is no middle value, the median is calculated as the arithmetic mean of the two middle values
- advantage: no influence of extreme values (outliers)

Measures of Central Tendency

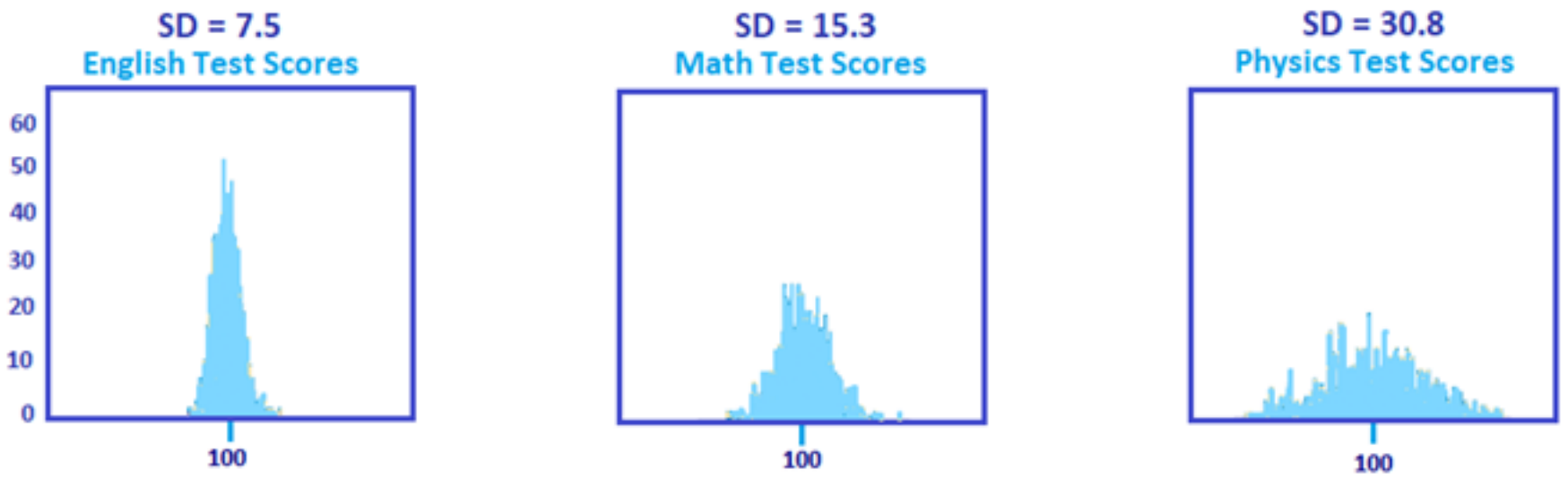
Mode

- value that appears most often in a set of data
- used for categorial variables

Standard Deviation

- measures the amount of variation from the average
  - low standard deviation: data points tend to be very close to the mean
  - high standard deviation: data points are spread out over a large range of values
- only usable for metric values

Standard Deviation: Example



Source: www.calculators.org

Presentation of Results

- questionnaire uses mostly ordinal scales
- numerical coding „transforms“ data to interval scale
- numerical operations become possible
  - e.g., mean, standard deviation

Presentation of Results in Written Form

- *„… the importance was rated on a 5-point scale (not important at all = 1, very important = 5) …“*
- *„… x was regarded as important (M=3.84, SD=1.23) …“*

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  - **Inferential Statistics**
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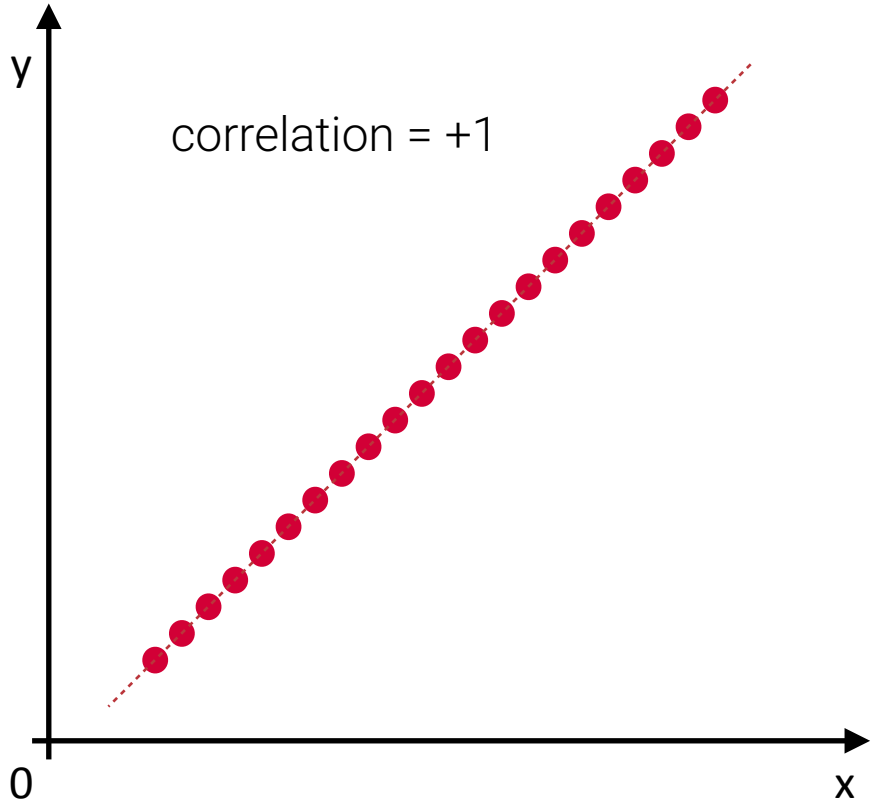
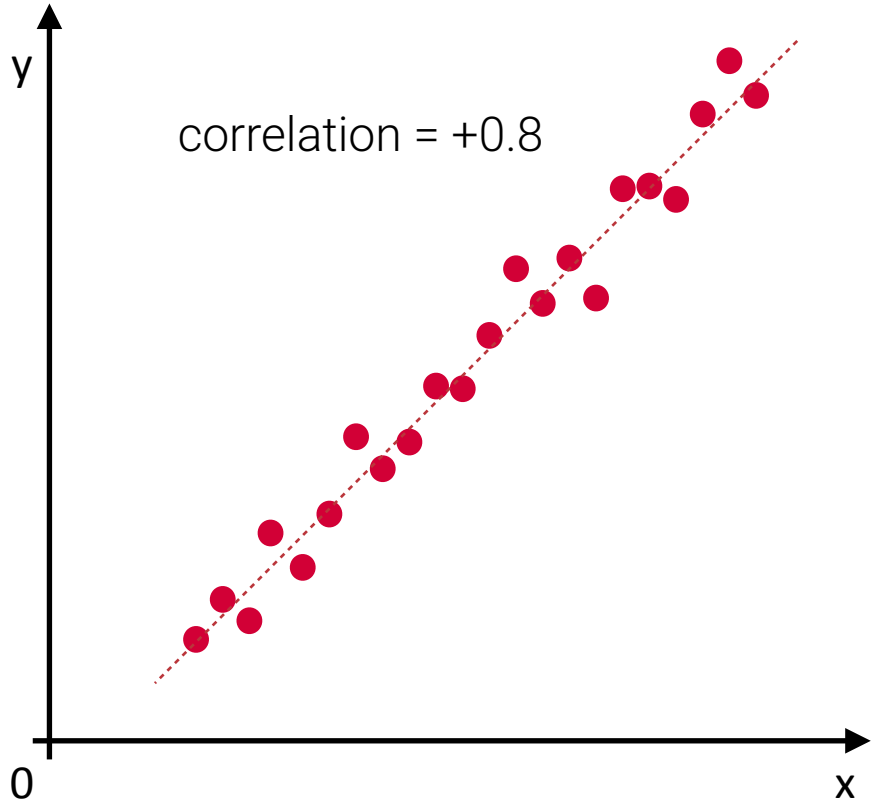
Correlation

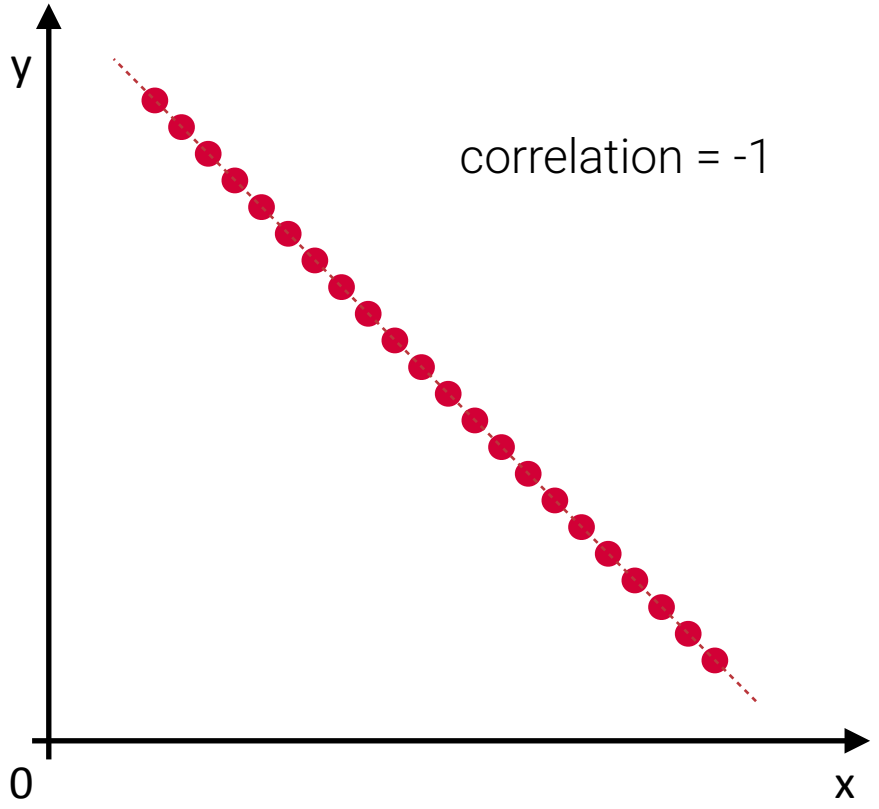
- correlation = linear association between two variables
- defines the nature and the strength of the relation between the variables

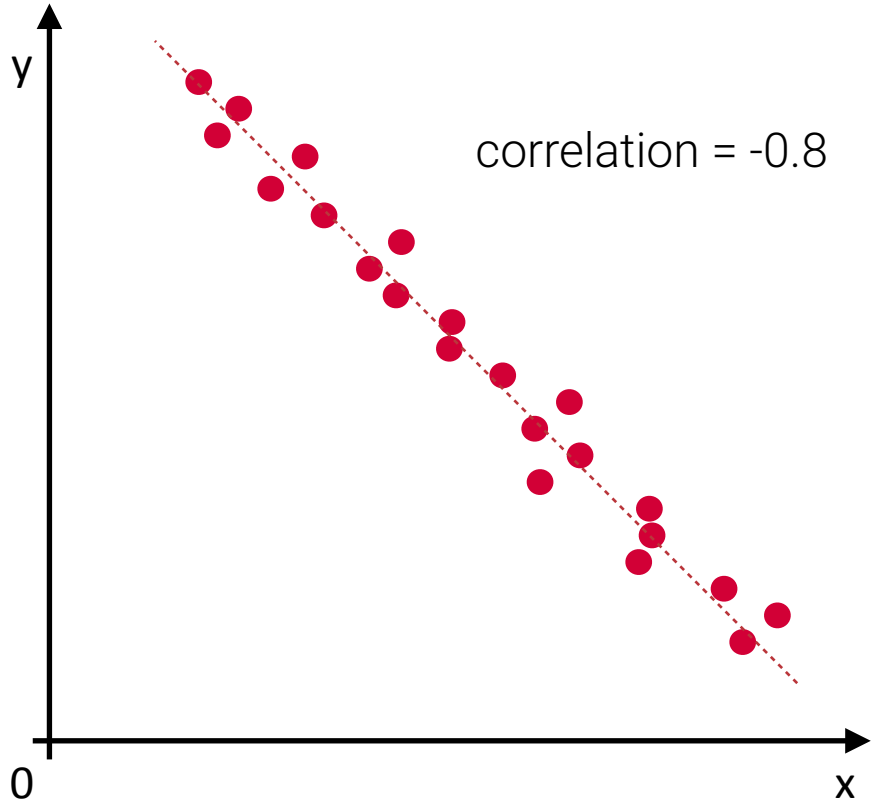
Correlation





Correlation





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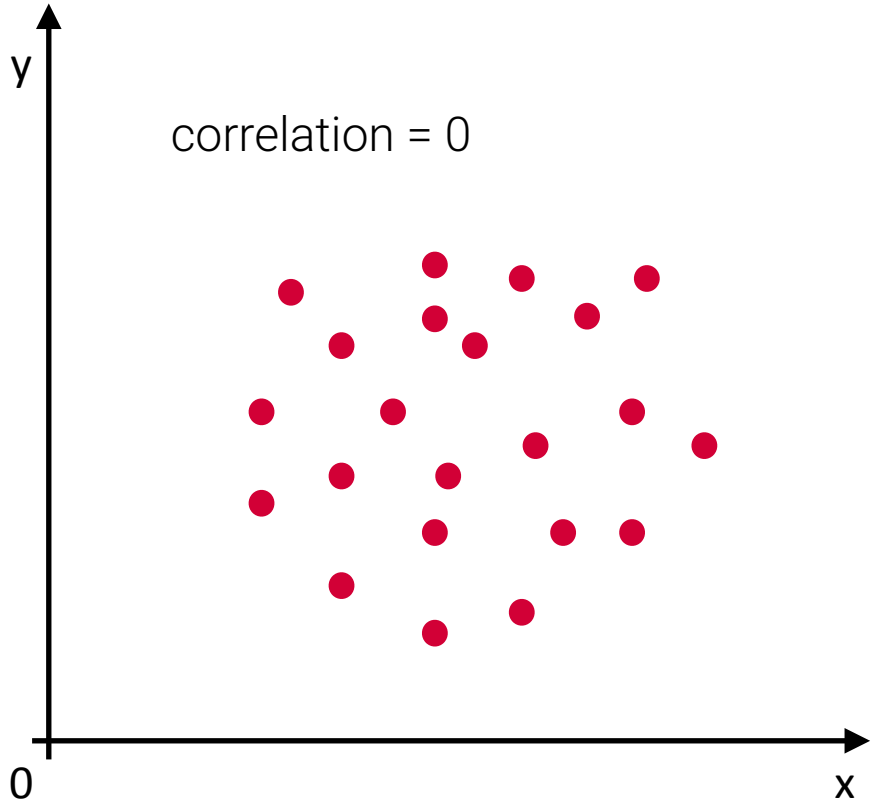

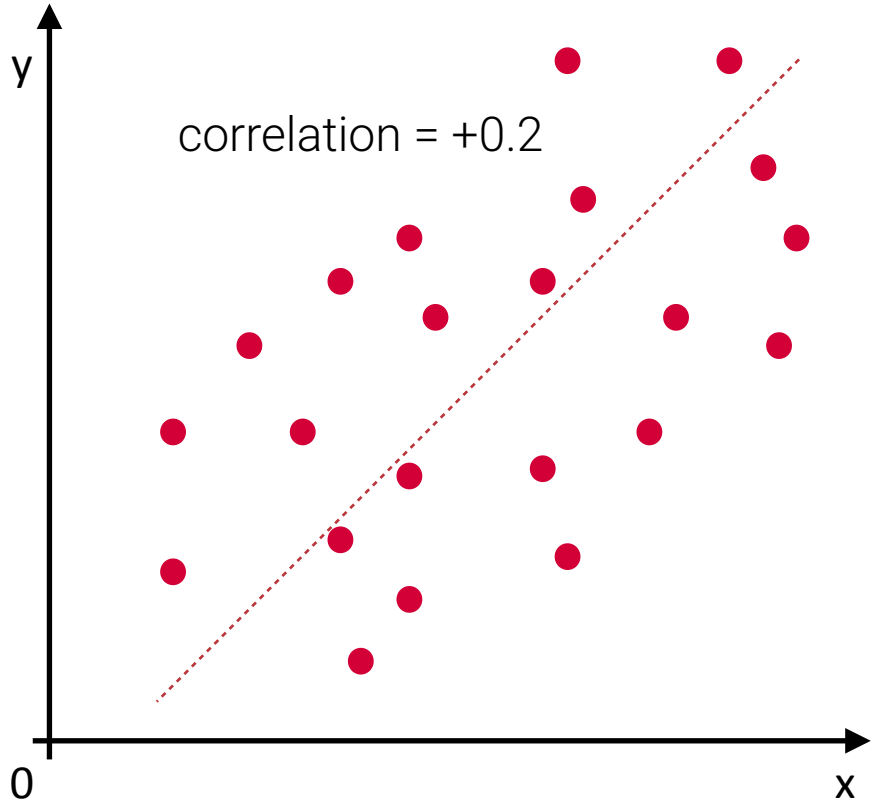

Correlation

- correlation lies between -1 and +1
  - -1 = perfect negative correlation
  - 0 = no relation between variables
  - 1 = perfect positive correlation

Correlation

- correlation coefficient = numerical measure of the correlation
- different measures for correlation exist

Pearson Correlation Coefficient

- describes strength and direction of the relationship between two variables

$$\rho_{X,Y} = \frac{\operatorname{cov}(X, Y)}{\sigma_X \ \sigma_Y}$$

cov = covariance
σ_X = standard deviation of X
σ_Y = standard deviation of Y

Correlation

Degree of Correlation

Correlation Coefficient	Strength of Correlation
$0 < r \leq 0.19$	Very Low Correlation
$0.2 \leq r \leq 0.39$	Low Correlation
$0.4 \leq r \leq 0.59$	Moderate Correlation
$0.6 \leq r \leq 0.79$	High Correlation
$0.8 \leq r \leq 1.0$	Very High Correlation

t-Test

- comparison of means
- restricted to 2 samples
  - for 3 or more samples use e.g. ANOVA
- two different types
  - independent samples t-test
    - for two independent groups
  - dependent t-test
    - if same people are in both groups

t-Test

Example: Comparison of Mean Weight

- random sample of 10 female and 10 male participants
- weight measured in kg

Female	Male
62	81
68	76
55	94
84	55
63	61
62	72
53	73
72	71
77	82
48	64
Mean = 64.4	**Mean = 72.9**

Question

- *„Is the mean weight significantly different between female and male participants?“*

t-Test

P-Value

- provides probability that observed difference is statistically significant, i.e. is not observed by chance
- smaller p-values provide stronger evidence
- established conventions for interpretation of p-value
  - $p > 0.10$ => no significant difference
  - $0.05 < p \leq 0.10$ => marginally significant difference
  - $0.01 < p \leq 0.05$ => significant difference
  - $p \leq 0.01$ => highly significant difference

t-Test

Question

- *„Is the mean weight significantly different between female and male participants?“*

- independent sample t-test delivers p-value of $p = 0.1073$
- *„The mean weight of female and male participants is not significantly different.“*

Female	Male
62	81
68	76
55	94
84	55
63	61
62	72
53	73
72	71
77	82
48	64
Mean = 64.4	**Mean = 72.9**

Chi-Squared Test

- data in form of frequency distributions
- comparison of two or more groups

Chi-Squared Test

Example: Social Media Usage

- comparison of different age groups

	no usage	<5 hours /week	5 -10 hours /week	10 - 15 hours /week	>15 hours /week	Total
< 20 years	0	3	23	56	78	160
20 - 40 years	2	5	34	42	27	110
40 - 60 years	5	17	36	24	4	86
< 60 years	20	32	25	6	1	84
Total	27	57	118	128	110	440

Question

- *„Is the distribution significantly different among the age groups?“*

Tools for Statistical Analysis

- IBM SPSS
  - 30-day free trial period
- PSPP
  - free license
- JASP
  - free license
- Microsoft Excel

Additional Resources

- books
- lecture notes
- online courses
- video tutorials

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Research Topic

- please see separate slide set

Summary

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