Prof. Dr. Hendrik Godbersen

Crash Course

Foundations of Quantitative Research

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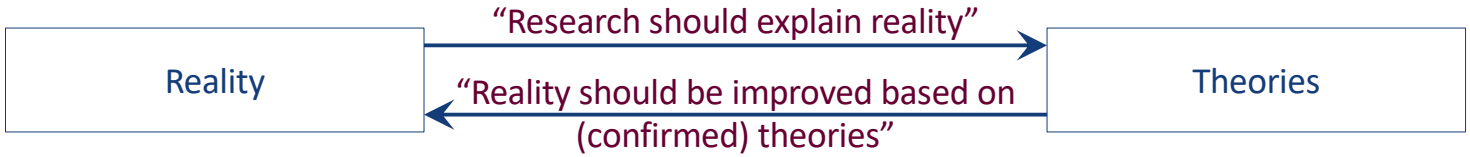
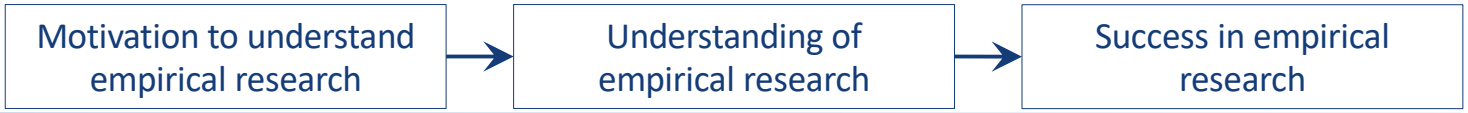
- Reality ("normal" life)
  - Complex / not entirely overt / dynamic (constant change)
- Research & its relationship with reality
  - Reality should be explained through theories, developed through research
  - Theories (abstract explanations of reality) should form the basis on which reality can be improved



- Elements of theories
  - Constructs/concepts: simplified & generalised abstractions of elements of reality
  - Hypotheses: relationships between constructs
- Model
  - Simplified image of reality
  - Research context:

    models = theories

Example of a theory/model



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Social Constructivism

- Understanding of reality
  - Reality = constructed ("created") by humans (& no objective reality)
  - Reality = individual – because of its construction by individual people
  - Reality = social – because of its construction in social interactions
- Examples of constructed reality
  - Individually constructed reality: individual preferences for movies (e.g., thrillers, romantic comedies etc)
  - Socially constructed reality: laws that are passed in parliaments
- Consequences for qualitative research
  - First-order constructs: phenomena that are experienced by "normal" people
  - Second-order constructs: constructed conclusions of researchers to explain the first-order constructs of "normal" people

Phenomenology

- Phenomenon
  - Subjective experience of environment or parts thereof
  - Please note: phenomenon = experience of environment & phenomenon ≠ environment itself
- Example of phenomenon
  - "Objective" event: kiss with the love of one's life
  - Phenomenon: experience of emotions such as romance, passion, fulfilment etc.
- Consequences for qualitative research
  - Stronger focus on comprehensive understanding of how people subjectively experience their reality
  - Lesser focus on scientific explanation of an "objective" reality

Epistemological approach, research procedure & objective of qualitative research

- Epistemological approach
  - Induction (general definition) = generalising from specific instances
  - Developing theories/models from specific situations/contexts
- Principle research process
  - Data collection by capturing the phenomena experienced by people (e.g., qualitative interviews or group discussions)
  - Data analysis through interpretative & discovering methods (e.g., Grounded Theory Methodology, Qualitative Content Analysis)
  - Development of a theory/model based on the analysed phenomena
- Epistemological objective
  - Understanding & explaining a constructivist-phenomenological reality by…
  - …developing theories/models from the subjective experiences of people

Example of an inductive knowledge gain

- Specific observation of a child
  - Whenever a driver turns the steering wheel to the right, the car drives to the right
  - Whenever a driver turns the steering wheel to the left, the car drives to the left
- Inductive development of a generalised "law", which is used later as a driver
  - A car drives into the direction into which the steering wheel is turned

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Simplified example of a quantitative research project

1) Theory: Work satisfaction affects organisational commitment

2) Empirical test of the theory: Standardised survey of several 100 or 1,000 participants

Completely dissatisfied ☐ ☐ ☐ ☐ ☐ ☐ Completely satisfied

Not committed at all ☐ ☐ ☐ ☐ ☐ ☐ Fully committed

3) Conclusion: Confirmation or rejection of theory – work satisfaction affects organisational commitment or it does not

Critical Rationalism & Scientific Realism (Karl Popper, 1934/1989)

- Understanding of reality
  - Objectively existing world
  - Characteristics of reality: complex, not entirely overt & dynamic
- Consequences for understanding of theories/knowledge
  - All knowledge (theories) = conjectural knowledge (& not absolute truth)
  - Theories ≈ generalised rules/laws
  - Falsification: one cannot prove/verify that a theory is true – one can only prove that a theory is not true (falsified)
- Consequences for quantitative research
  - Generalised theories are tested in specific situations
  - Reality is explained through (manifold) theories…
    - …which could be confirmed (= not falsified)
    - …which could be falsified

Example of an inductive knowledge gain (& its flaw)

- Observation (lake 1): white swans
- Observation (lake 2): white swans
- Observation (lake …): white swans
- Observation (lake n): white swans

→ "absolute" conclusion that all swans are white ≠ correct because…

- Observation lake (n+1): black swan

→ Proof that not all swans are white

Epistemological approach, research procedure & objective of quantitative research

- Epistemological approach
  - Deduction (general definition) = from generalised rules to specific instances
  - Applying generalised theories/models to specific situation/contexts
- Principle research process
  1) Development of a theory/model from existing literature
  2) Data collection through standardised questionnaires
  3) Data analysis with statistical methods (testing theories/models)
  4) Accepting or rejecting theories/models based on statistical analysis
- Epistemological objective
  - "Drawing" a simplified image of reality through…
  - …testing of theories/models (confirming or falsifying theories)

Example for a deductive-nomological reasoning

- General rule/law
  - If someone is a Royal Marine, he has the fitness level of an international athlete.
- Specific condition
  - Jonathan is a Royal Marine.
- Deductive consequence
  - Jonathan has the fitness level of an international athlete.

Explanans

Explanandum

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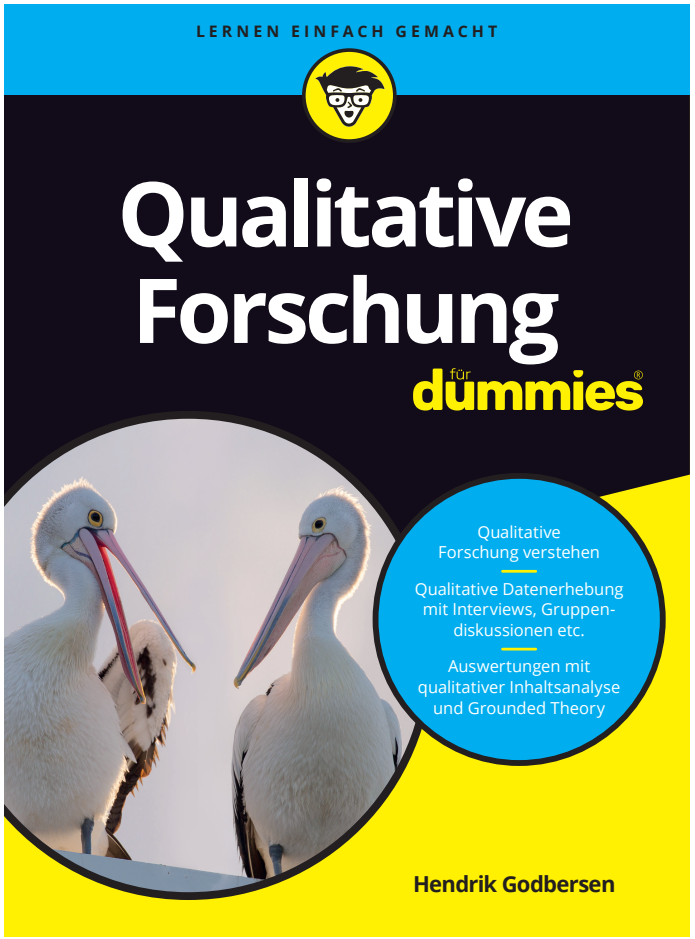

Godbersen, H. (2024). Qualitative Forschung für Dummies. Weinheim: Wiley-VCH.

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Eepistemic Goal of Qualitative Research

The objective of Qualitative Research is

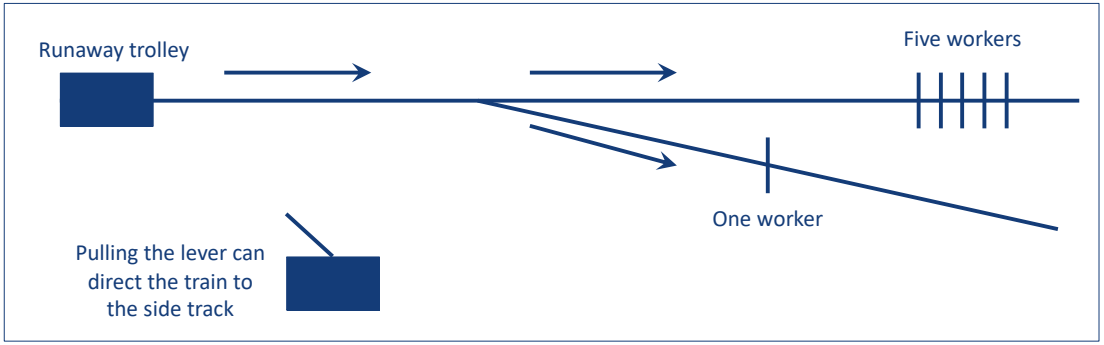
- to comprehensively examine the experiences of people with regard to specific situations and/or objects,
- to discover and explain their thoughts, emotions and behaviours in these contexts, and
- to develop generalisable theories (models) on this basis.

Principles of Qualitative Research

Principles	Application in qualitative research project
Comprehensive understanding of subjective phenomena	• Primary focus on research subjects (participants) & less on research objects • Research objective is to describe, explain & understand the subjective reality of research subjects • Considering all details to gain a comprehensive understanding of research subjects & their subjective reality
Openness when developing theories	• Open research questions • Data collection through open questions & low degree of standardisation
Flexibility & circularity of qualitative research	• Flexibility (openness to adjustments) in data collection & analysis • Circular process & no linear execution of research steps (esp. during analysis)
Gaining knowledge through an interaction of researcher & participants	• Relationship of research & participant = co-operation to gain knowledge • Interaction between research & participant – prerogative of interpretation of subjective reality lies with participant • "Only" task of researcher: gaining information & understanding subjective reality of participants

Research Example: Moral Dilemma Decisions

- "Primal academic dilemma": Trolley Dilemma
  - Runaway trolley rolls down the main track & would kill five workers
  - Pulling a lever directs the trolley to a side track which leads to the death of one worker



- Possible decisions
  - Utilitarian decision (pulling the lever): maximising the utility for a maximum number of people
  - Deontological decision (not pulling the lever): focusing on rules & individual rights & duties
- Research objectives: development of a model/theory about
  - Subjective reasons for & against moral dilemma decisions
  - Dealing with inner conflicts when making moral dilemma decisions
  - Application of utilitarian & deontological decision-making in "real" life

Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

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Collection of Qualitative Data

Quantitative understanding of sample	**Qualitative understanding of sample**
Objective	
Statistical Representativeness (often, but not always)**:** The distribution of attributes in the sample matches the distribution of attributes in the population at a high confidence level and with a low margin of error – example: ("What candidate (or party) would you vote for if we had a general election today?")	**Content representativeness:** Comprehensive explanation & understanding of a phenomenon in its width & depth (to develop theories on this basis)
Sample size	
Large sample sizes	**Small sample sizes**
Sampling approach	
Amongst others, **probability sampling/random sampling** (each element of the population has the same probability to be drawn into the sample)	**Conscious sampling / purposive sampling** – selecting participants who can be expected to substantially contribute to gaining knowledge & understanding

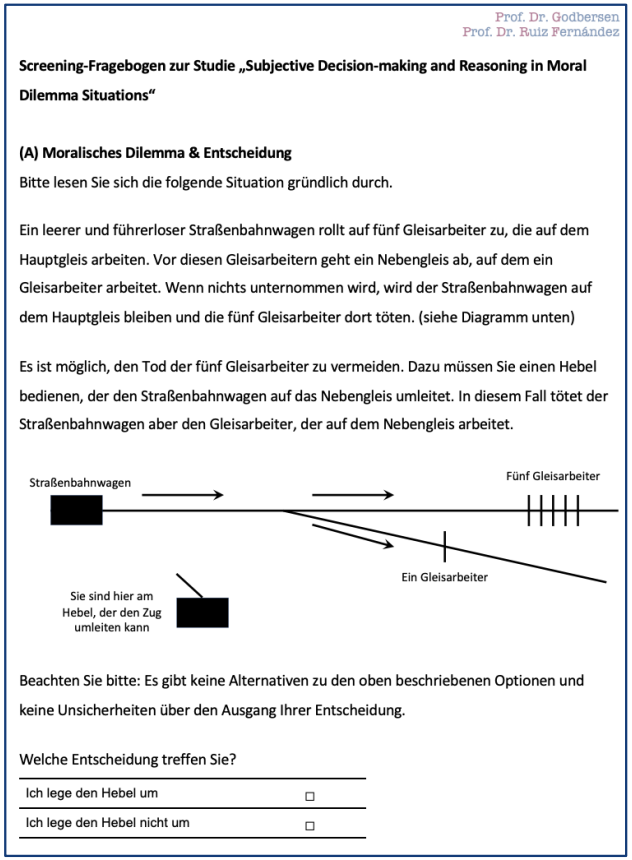
Research example: Moral Dilemma Decisions

Sampling plan (n = 18)

Dilemma	Utilitarian decision			Deontological decision		
	male	female	total	male	female	total
Switch	2	1	3	1	2	3
Loop	2	1	3	1	2	3
Footbridge	1	2	3	2	1	3
Sum	**5**	**4**	**9**	**4**	**5**	**9**

Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

Screener



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Screening-Fragebogen zur Studie „Subjective Decision-making and Reasoning in Moral Dilemma Situations"

(A) Moralisches Dilemma & Entscheidung

Bitte lesen Sie sich die folgende Situation gründlich durch.

Ein leerer und führerloser Straßenbahnwagen rollt auf fünf Gleisarbeiter zu, die auf dem Hauptgleis arbeiten. Vor diesen Gleisarbeitern geht ein Nebengleis ab, auf dem ein Gleisarbeiter arbeitet. Wenn nichts unternommen wird, wird der Straßenbahnwagen auf dem Hauptgleis bleiben und die fünf Gleisarbeiter dort töten. (siehe Diagramm unten)

Es ist möglich, den Tod der fünf Gleisarbeiter zu vermeiden. Dazu müssen Sie einen Hebel bedienen, der den Straßenbahnwagen auf das Nebengleis umleitet. In diesem Fall tötet der Straßenbahnwagen aber den Gleisarbeiter, der auf dem Nebengleis arbeitet.

Beachten Sie bitte: Es gibt keine Alternativen zu den oben beschriebenen Optionen und keine Unsicherheiten über den Ausgang Ihrer Entscheidung.

Welche Entscheidung treffen Sie?

Ich lege den Hebel um	☐
Ich lege den Hebel nicht um	☐

Methods of data collection

- Qualitative Interviews
  - Semi-structured interview
  - Narrative interview
  - …
- Group discussions
- Written questionnaires
- Observations
- Secondary data
- …

Please note:

- Qualitative data must normally be documented through audio or video recordings
- The audio or video recordings must normally be literally transcribed

Semi-structured Interviews

- Definition
  - In a semi-structured interview, a researcher interviews a participant based on an interview guideline with mainly open questions. The order of questions and their formulation are to be used flexibly during the interview itself to accommodate the individual participant & his/her subjective view on the world.
- Research object as starting point
  - Starting point (& content) of semi-structured interviews = to be examined phenomenon
  - Precondition: Research object can be clearly defined but is not examined in-depth
- Role of participants & epistemic goal of semi-structured interviews
  - Role of participants: Participants & their subjective views of the world = core of qualitative interviews
  - Epistemic goal: Explaining & understanding motives, attitudes, psychological processes, behaviour etc. of people with regard to a research object
- Preconditions on the side of the participants
  - Participants are capable of verbalising their thoughts & feelings
  - Participants are willing to share their thoughts & feelings

Example of an interview guideline: Moral Dilemma Decisions

Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

(1) Welcome & warm-up

- Stimulus: dilemma
- Which decision do you make?
- How do you feel when dealing with the dilemma & making a decision?

(2) Reasons for & against the decision

- Why did you decide to intervene so that the five workers survive & the one worker dies?
- Why did you not decide for the alternative, in which the one worker survives & the five workers die?
- Making such a decision, you face a dilemma with reasons for one or the other decision. How do you deal with this dilemma?

(3) Public explanation of the decision

- How would you explain your decision in a public interview?
- How would you explain your decision to the bereaved of the worker who died?

(4) Generalised decision-making

- You made a utilitarian decision. In which situation in "normal" life is this type of decision-making the right one & why?
- You did not make a deontological decision. In which situation in "normal" life is type form of decision-making the right one & why?
- These two types of decision-making – utilitarian & deontological – can cause inner conflicts. How do you deal with such conflicts in general?

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1 Preparatory Steps

- 1.1 Defining the analytic frame on the basis of theory, research questions & interview guideline
- 1.2 Transcription of interview recordings

2 Coding & Category System

- 2.1 Comprehensive familiarisation with transcripts
- 2.2 Deriving the deductive categories from theory, research questions & interview guideline
- 2.3 Deductive & inductive coding of the transcripts & development of a (hierarchical) category system

3 Model Development

- 3.1 Analysing the contexts of categories
- 3.2 Deriving a theoretical model from the category system & contexts of categories

4 Result Reporting in Research Paper

- 4.1 Reporting of categories
- 4.2 Reporting of developed model

Coding, Categories & Category Systems as Core of Qualitative Analysis

- Coding / developing Categories
  1) Identifying words, statements, sentences etc. that should be coded
  2) Assigning codes/categories to words, statements, sentences etc.

- Defining categories (codes) in qualitative research papers

Dimensions of defining categories	**Research example: Moral Dilemma Decisions**
Designation of category	Hoping for understanding and forgiveness
Definition of category	Participant states that, against the backdrop of his or her perceived guilt, he or she hopes that others and/or the bereaved can understand or even forgive his or her decision.
Example (quote from a transcribed interview)	"…naturally, the forgiveness and understanding of the bereaved is important to me".
Optional: Rule for applying category	

Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

Coding, Categories & Category Systems as Core of Qualitative Analysis

Example of a hierarchical category system – Moral Dilemma Decisions

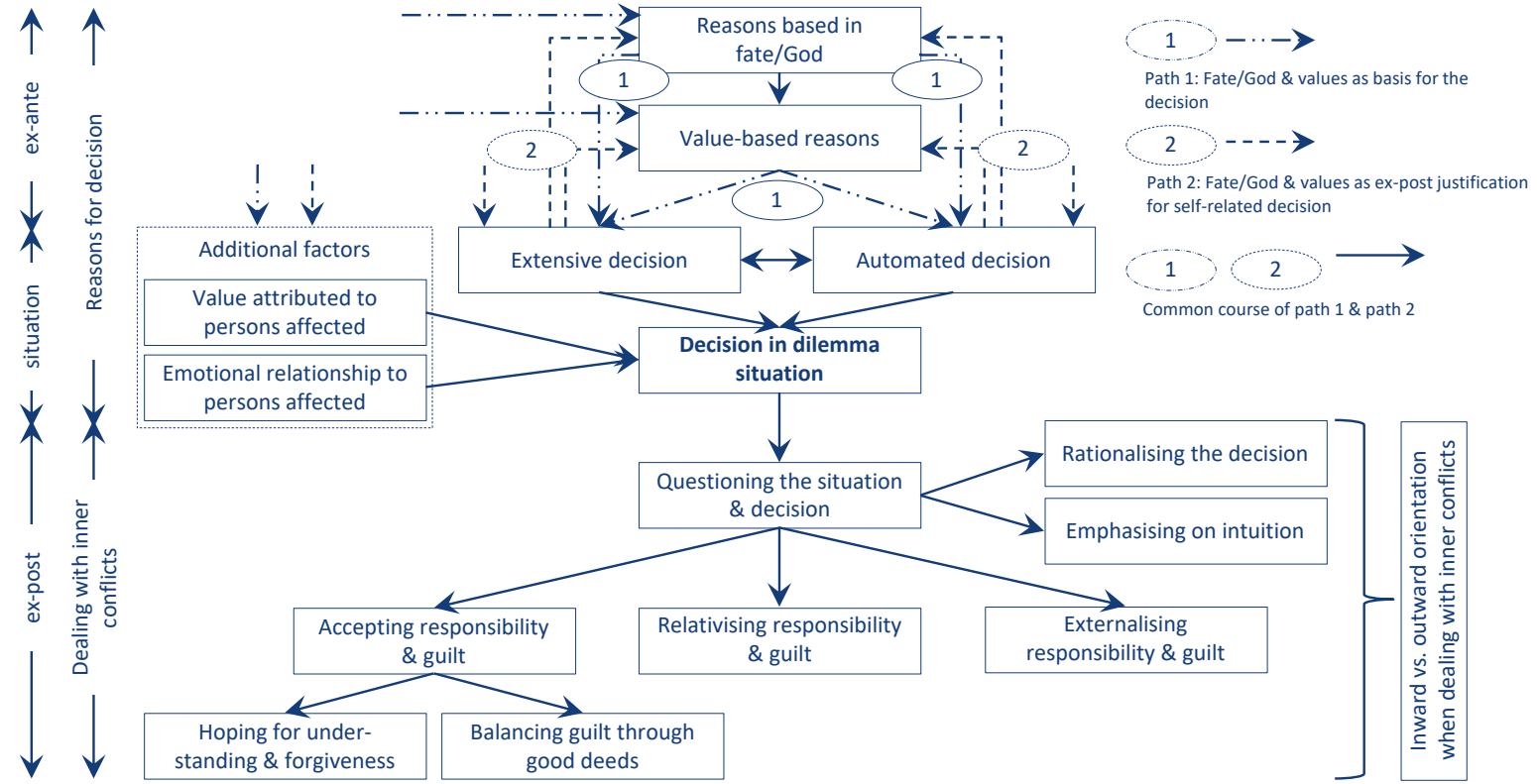
- 1.1 Reasons for utilitarian decisions → Deductive category
  - 1.1.1 Situation & decision-related reasons
  - 1.1.2 Value-based reasons
  - 1.1.3 Determination of own actions by fate/God

  → Inductive category
- 1.2 Reasons for deontological decisions → Deductive category
  - 1.2.1 Situation & decision-related reasons
  - 1.2.2 Value-based reasons
  - 1.2.3 Non-interference with course of events determined by God/fate
  - 1.2.4 De-Involvement because of indifference toward people

  → Inductive category
- …

Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

Overall model of decision-making & dealing with inner conflicts in moral dilemma situations



Source: Godbersen, H. & Ruiz Fernández, S. (in preparation). Subjective Decision-making and Reasoning in Moral Dilemma Situations.

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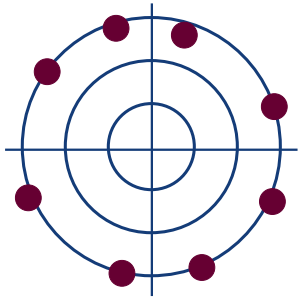
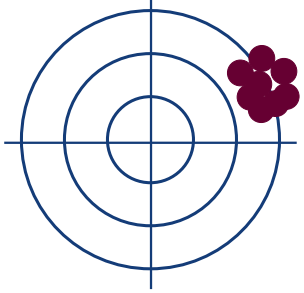
Overview of Quality Criteria

Quality Criterion	Definition
Objectivity	A measurement is objective when it is independent from the researcher (every researcher comes to the same results)
Reliability	A measurement is reliable when it is precise / consistent (repeated measurements would produce the same results)
Validity	A measurement is valid when it is accurate & measures what it intends to measure

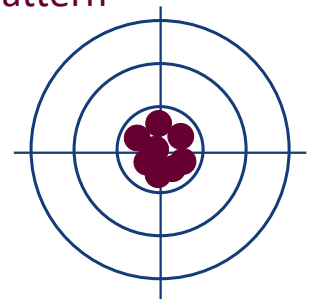
Not reliable (& and therefore not valid)
“shot pattern”



Reliable but not valid
“shot pattern”



Reliable & valid
”shot pattern”



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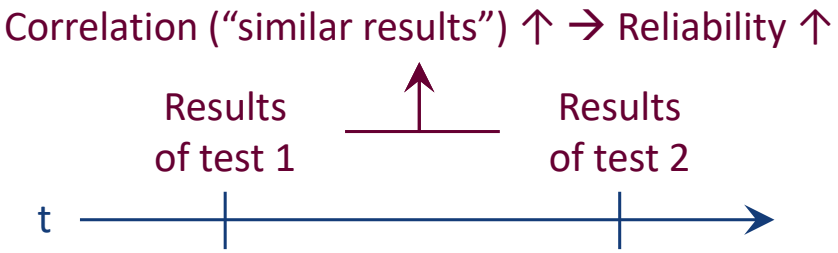
Reliability

- Concept of reliability & methodological consequence
  - Definition: Precision / consistency of a measurement
  - Methodological consequence: Repeated or parallel measurements must come to similar results
- Methods to test reliability
  - Test-retest reliability
    - Test-retest reliability is high when a repeated measurement with the same instrument comes to similar results
  - Split-half-test reliability
    - See next slide
  - Cronbach's alpha
    - See next slide



Reliability

- Usage of split-half tests & Cronbach's alpha
  - Reflective measurements: multiple items measure one construct & the construct is reflected in these items (construct causes its items)
- Split-half test
  - Corelation ("similar results") of the halves of items, which reflectively measure one construct

- Cronbach's alpha
  - Average inter-item corelation ("similar results") of all items of one construct
  - Values between 0 & 1
  - The closer Cronbach's alpha to 1 → the higher the reliability

Construct: Normative organisational commitment		Cronbach's alpha = .82
	It would not be fair to terminate the relationship with my employer because my employer steadily supported me.	
	Because of the long relationship with my employer I feel obliged to a certain considerateness.	
	In the relationship with my employer, I feel obliged to fairness.	
	Moral obligations toward my employer play a role for me.	

Source: Godbersen, H., Dudek, B. & Ruiz Fernández, S. (2024): The Relationship Between Organizational Commitment, Commitment to Supervisor and Servant Leadership. Frontiers in Organizational Psychology.

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Concept & Types of Validity

- Concept of validity
  - Accuracy of a measurement with regard to its theoretical constructs
  - Measurement measures what it intends to measure

- Types of validity
  - Construct validity
    - Content validity
    - Criterion validity
  - Internal validity
  - External validity
  - Statistical validity

Please note:

- You can find further types of validity in the literature (e.g., convergence validity & discriminant validity).
- Some scholars categorise the types of validity differently (e.g., construct, content & criterion validity on one level).

Construct Validity with Content & Criterion Validity

Construct validity

- Definition: Representation of a theoretical construct by a measurement instrument

Content validity

- Definition: (logical) adequacy of a measurement instrument to comprehensively & precisely represent a theoretical construct
- Test: Content-wise comparison of the measurement instrument & the theoretical construct, based on logic & expertise

Criterion validity

- Definition: Adequacy of a measurement instrument to represent a theoretically (& empirically) established relationship with an external criterion (another construct)
- Test:
  1) Measuring the construct (to be validated) & an external criterion (another construct)
  2) Statistical analysis of the relationship between construct & criterion
  3) Comparison of the empirical relationship between construct & criterion with the respective relationship, established through theory (& previous empirical research)

Content Validity

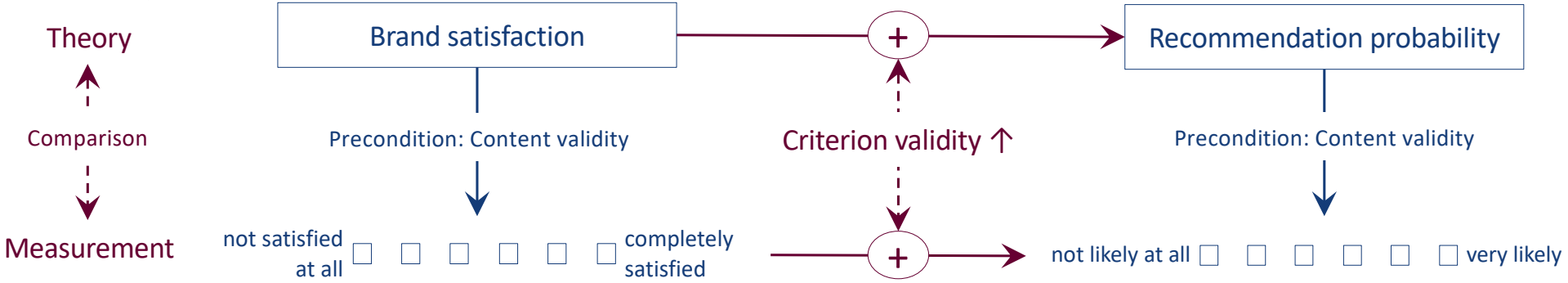
- Definition
  - (logical) adequacy of a measurement instrument to comprehensively & precisely represent a theoretical construct
- Test
  - Content-wise comparison of the measurement instrument & the theoretical construct, based on logic & expertise
- Example

Construct to be measured: **Brand satisfaction**

How likely is it that you recommend brand X to others?	How satisfied are you with brand X?
not likely at all ☐ ☐ ☐ ☐ ☐ ☐ very likely	not satisfied at all ☐ ☐ ☐ ☐ ☐ ☐ completely satisfied
→ **Not valid** because probability of recommendation is measured	→ **valid** because brand satisfaction is actually measured

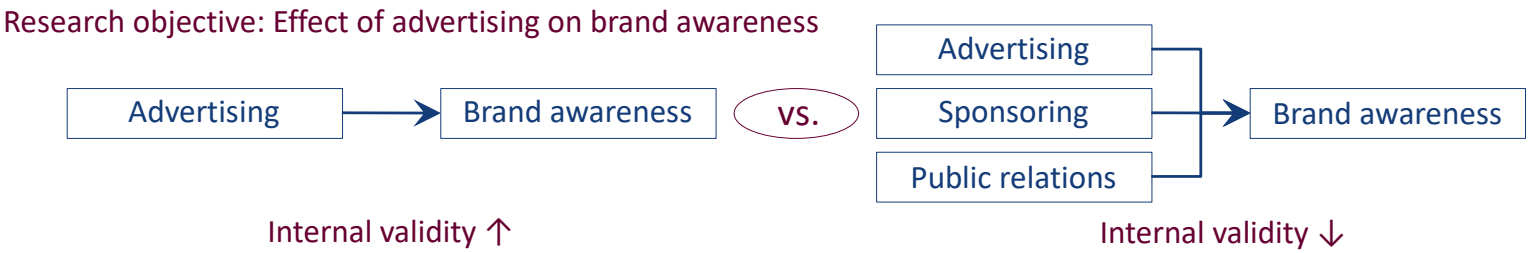
Criterion Validity

- Definition
  - Adequacy of a measurement instrument to represent a theoretically (& empirically) established relationship with an external criterion (another construct)
- Test:
  1) Measuring the construct (to be validated) & an external criterion (another construct)
  2) Statistical analysis of the relationship between construct & criterion
  3) Comparison of the empirical relationship between construct & criterion with the respective relationship, established through theory (& previous empirical research)
- Example



Internal, External & Statistical Validity

- Internal validity
  - Extent to which the variation (change) of a dependent variable is only caused by the variation (change) of one or more independent variables (and not by external/other factors)
  - Example



- External validity
  - Generalisation of results with regard to other persons, areas, times, contexts etc.
  - Example

- Statistical validity
  - Adequacy of the statistical analyses & correctness in their application

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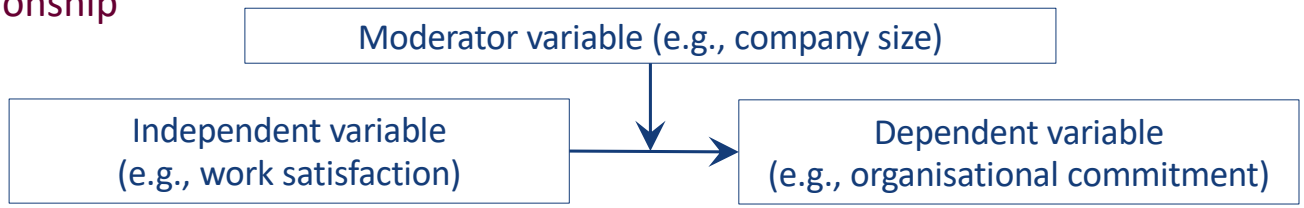
Relationships Between Variables/Constructs

- Bidirectional relationship

- Unidirectional relationship

- Mediated relationship

- Moderated relationship



- Nonsense correlation

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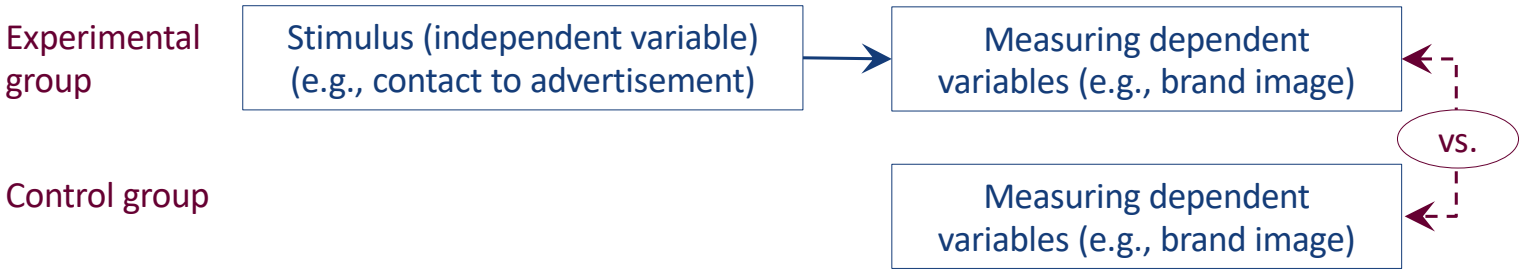
Epistemological Goal & Setting of Experiments

- Epistemological goal & research question of experiments
  - Epistemological goal: Testing the causal relationship of one or more independent variables and one or more dependent variables
  - Research question: Does one or more independent variables have an (causal) effect on one or more dependent variables?
- Setting of a simple experiment (two groups)

1) Forming two groups
   - Experimental group
   - Control group
2) Experimental manipulation (independent variable)
   - Experimental group → Exposure to stimulus
   - Control group → No exposure to stimulus
3) Measuring dependent variable & comparison of experimental & control group

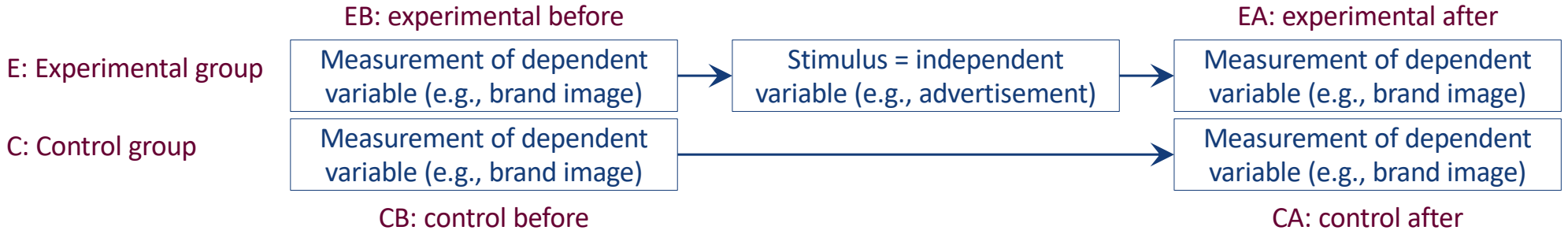


Experiments, Validity & Quasi-experiments

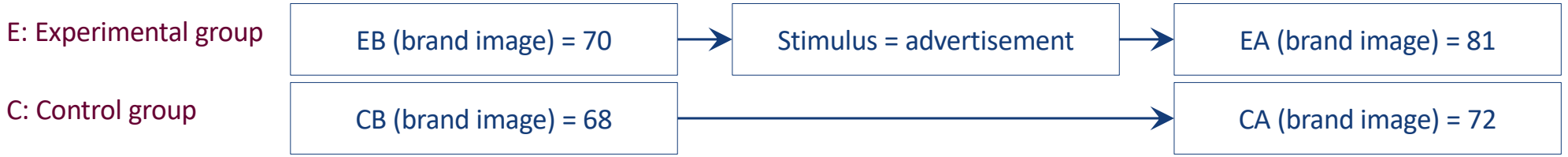
- Characteristics of ("real") experiments
  - Minimising the influence of environmental factors
    - → Laboratory conditions (constant environmental conditions)
  - Minimising the influence of personal factors
    - → Homogeneous samples for experimental & control group
    - → Randomised allocation of participants to experimental & control group
- Implications for internal & external validity
  - Internal validity (explanation of the variation of the dependent variable only through the variation of the independent variable) ↑
  - External validity (generalisation of results with regard to other persons, areas, times, contexts etc.) ↓
- Quasi-experiments
  - Example: Field experiment
  - Validity in comparison to "real" experiments: internal validity ↓ & external validity ↑

EBA-CBA Experiment

- Setting of an EBA-CBA experiment



- Example: Effect of an advertisement on brand image (measurement: “0 not good” to “100 very good”)



1) EBA = EA – EB = 81 – 70 = 11
2) CBA = CA – CB = 72 – 68 = 4
3) EBA – CBA = 11 – 4 = 7

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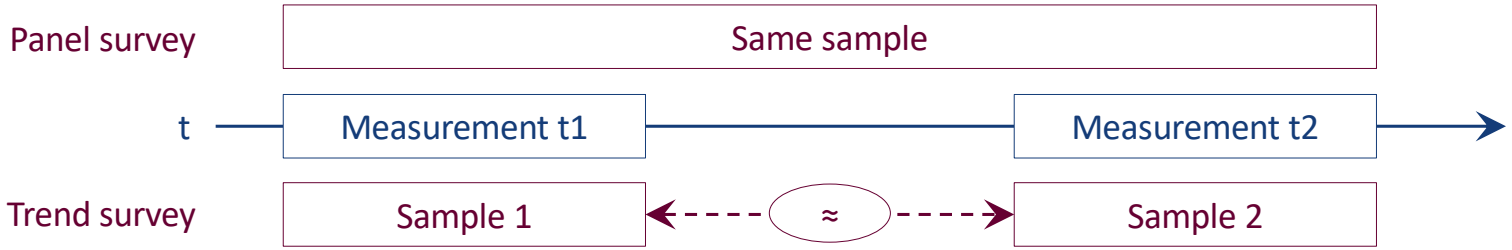
- Epistemological goal
  - Measuring the development of variables and/or effects over time
- Panel vs trend studies
  - Panel survey → the same sample
  - Trend survey → similar but not the same samples (representing a population)



- Advantages & disadvantages of panel & trend surveys

Longitudinal studies	Advantage	Disadvantage
Panel surveys	Measurement of "real" changes "within" the participants	Possible panel effect (influence of measurement by previous measurement)
Trend surveys	No influence by previous/first measurement (no panel effect)	Possible effects because of different samples (different structure)

Example

- Study: Customer Expectations and Their Fulfilment in the German Food Retail Market Before and During the Covid-19 Pandemic – A Longitudinal Study with the Means-End Theory of Complex Cognitive Structures.
- Research objective: Measuring the changes in customer expectations & their fulfilment in the food retail market during the COVID-19 pandemic
- Data collection: March/April 2019 & March/April 2022

Study 1							
Age	Mikrozensus		Sample				
	Abs.	%	Male	Female	Diverse	Total (abs.)	Total (%)
18 to 29	11,392,991	19.12%	136	154	0	290	24.13%
30 to 39	9,494,804	15.93%	98	105	0	203	16.89%
40 to 49	13,350,868	22.40%	116	123	0	239	19.88%
50 to 64	16,328,559	27.40%	149	158	0	307	25.54%
65 to 74	9,034,590	15.16%	76	87	0	163	13.56%
Sum	59,601,812	100.00%	575	627	0	1,202	100.00%
Study 2							
Age	Mikrozensus		Sample				
	Abs.	%	Male	Female	Diverse	Total (abs.)	Total (%)
18 to 29	11,392,991	19.12%	105	115	0	220	19.86%
30 to 39	9,494,804	15.93%	104	105	0	209	18.86%
40 to 49	13,350,868	22.40%	95	105	0	200	18.05%
50 to 64	16,328,559	27.40%	141	158	1	300	27.08%
65 to 74	9,034,590	15.16%	89	90	0	179	16.16%
Sum	59,601,812	100.00%	534	573	1	1,108	100.00%

Fig. 9.2 Distribution of Age and Gender (n for Study 1 = 1202; n for Study 2 = 1108) and Age Distribution in the German Population According to Mikrozensus 2011 *Source:* Statistisches Bundesamt n. d.

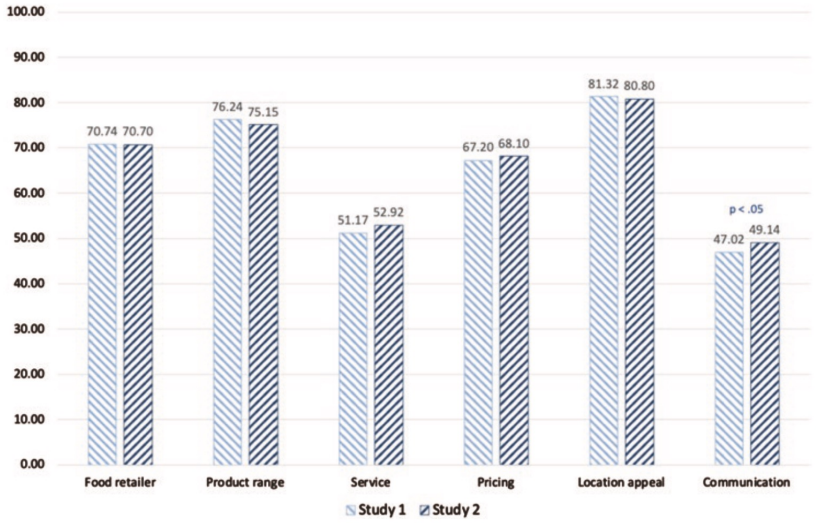


Fig. 9.5 Calculated Quality for the Food Retailers as a Whole and their Performance Categories on a Scale from 0 "Not Good" to 100 "Very Good" (n for Study 1 = 1202; n for Study 2 = 1108)

Source: Godbersen, H., Szabo, T. & Ruiz Fernández, S. (2023). Customer Expectations and Their Fulfilment in the German Food Retail Market Before and During the Covid-19 Pandemic – A Longitudinal Study with the Means-End Theory of Complex Cognitive Structures. In: L. Rothe, J. Naskrent & M. Stumpf & J. Westphal (eds.), Marketing & Innovation 2023: Future Shopping - Der Handel in der (Nach-)Coronazeit (pp. 173-198).

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- Epistemological goal
  - Measuring attributes and/or effects at a point in time
- Example
  - Study: The Relationship Between Organizational Commitment, Commitment to Supervisor and Servant Leadership
  - Research question (amongst others): Which effect do the facets of servant leadership have on the facets of commitment to supervisor?
  - Data collection: September & October 2023

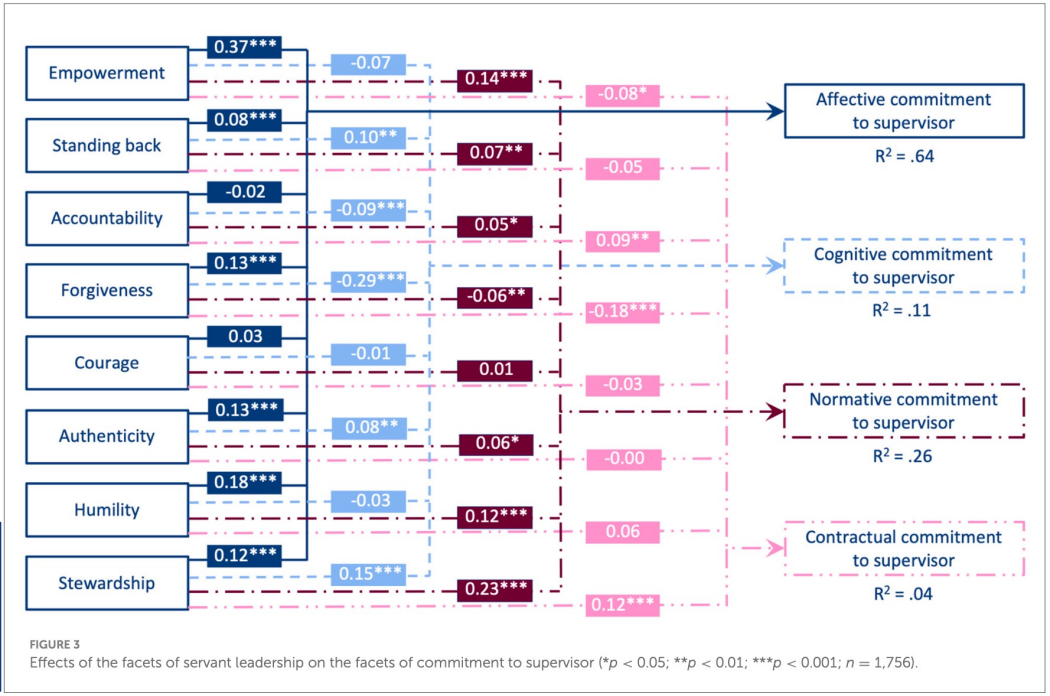

FIGURE 3
Effects of the facets of servant leadership on the facets of commitment to supervisor (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; $n = 1{,}756$).

Source: Godbersen, H., Dudek, B. & Ruiz Fernández, S. (2024). The Relationship Between Organizational Commitment, Commitment to Supervisor and Servant Leadership. Frontiers in Organizational Psychology, doi: 10.3389/forgp.2024.1353959.

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"Logic" of Inductive Statistics

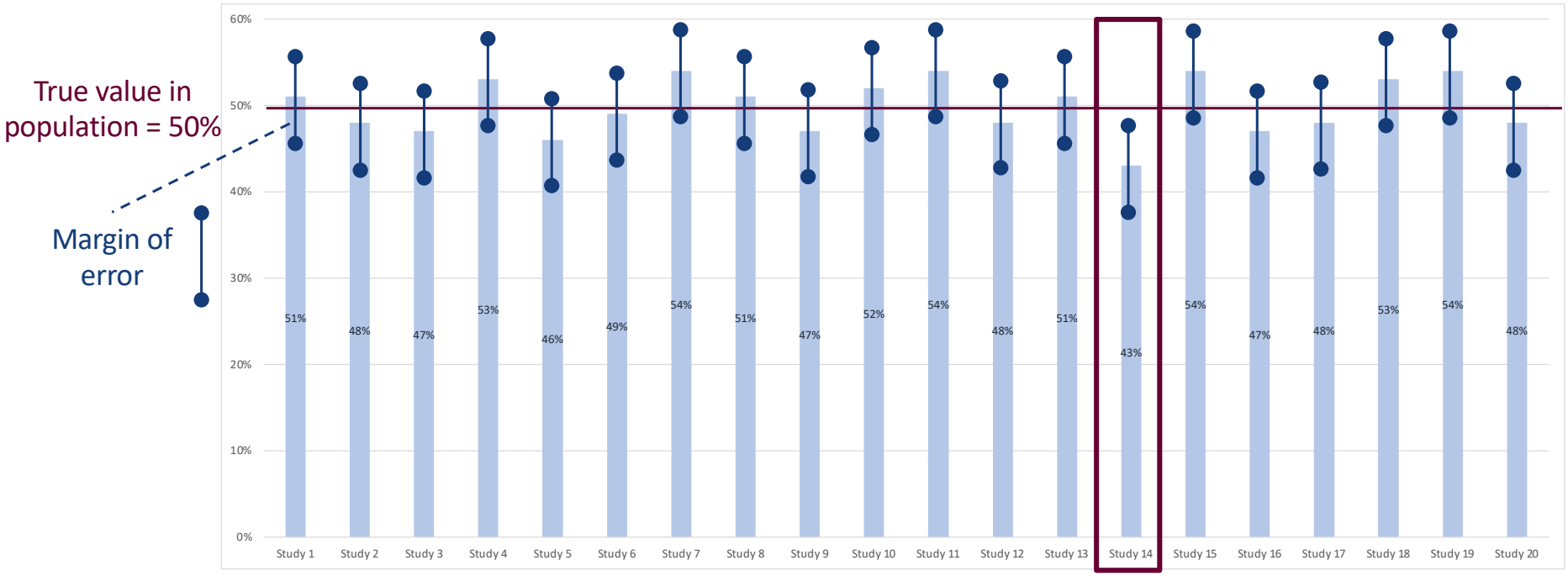
- Central question of inductive statistics

With what probability (confidence level) and margin of error ("range") do the results of the sample reflect the true values in the population?

- Utilisation of inductive statistics
  - Ex ante (before data collection): Determining the sample size (number of participants) at an assumed confidence level (probability with which the values in the sample represent the true value in the population) & an assumed margin of error (deviation of the measured values from the true value in the population)
  - Ex post (after data collection): Determining the confidence level (probability with which the values in the sample represent the true value in the population) & margin of error (deviation of the measured values from the true value in the population) of a measurement at a given (realised) sample size (number of participants)

"Logic" of Inductive Statistics

- Confidence level: probability with which the values in the sample represent the true value in the population) & an assumed, e.g., 95%
- Margin of error: deviation of the measured values from the true value in the population ("range"), e.g., 5%



"Logic" of Inductive Statistics

- Necessity of inductive statistics
  - Inductive statistics ≠ necessary: rather exploratory/explanatory research designs, e.g., examination if A generally has an effect on B
  - Inductive statistics = necessary: rather descriptive-representative designs, e.g. election polling ("What candidate (or party) would you vote for if we had a general election today?")
- Please note
  - Representativity: A sample is representative when the distribution of attributes of the sample resembles the distribution of attributes in the population.
  - → Inductive statistics does not determine the extent of representativity – but the confidence level & margin of error
  - → Options for drawing a representative sample
    - Quota sampling: recruiting participants based on a quota that represents the distribution of attributes in the population
    - Random sampling / probability sampling: each person or entity of of the population has the same chance to be selected into the sample

Excursus: Example of a quota sample

TABLE 1 Employed population in Germany by gender and age groups (Statistisches Bundesamt, 2023) and sample by gender and age groups ($n = 1{,}756$).

Age groups	Employed population in 1,000				Sample				
	Female	Male	Total	Total in %	Female	Male	Diverse	Total	Total in %
25 to <35 years	3,987	4,746	8,733	23.68%	239	228	0	467	26.59%
35 to <45 year	4,272	4,868	9,140	24.78%	209	214	2	425	24.20%
45 to <55 year	4,601	4,942	9,543	25.88%	209	216	1	426	24.26%
55 to <65 year	4,515	4,947	9,462	25.66%	221	217	0	438	24.94%
Gesamt	17,375	19,503	36,878	100.00%	878	875	3	1,756	100.00%

Source: Godbersen, H., Dudek, B. & Ruiz Fernández, S. (2024). The Relationship Between Organizational Commitment, Commitment to Supervisor and Servant Leadership. Frontiers in Organizational Psychology, doi: 10.3389/forgp.2024.1353959.

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- Equations
  - Equation for infinite population:

$$n = \frac{z^2 \times p \times (1-p)}{\Delta p^2}$$

  - Equation for finite population:

$$n = \frac{z^2 \times p \times (1-p)}{\Delta p^2 + \frac{z^2 \times p \times (1-p)}{N}}$$

  - Rule of thumb: If n/N < 0.05 → you can use the equation for sampling an infinite population
- Variables
  - n = Sample size
  - N = Size of population
  - z = z-value, depends on confidence level (probability with which the values of the sample reflect the true values of the population)
  - Δp = Margin of error (how many percentage points the results from the sample may differ from the true value of the population; standard: 3%)
  - p = Distribution in the sample (if no other indication, 50%)

Sample size (infinite population)

$$n = \frac{z^2 \times p \times (1-p)}{\Delta p^2}$$

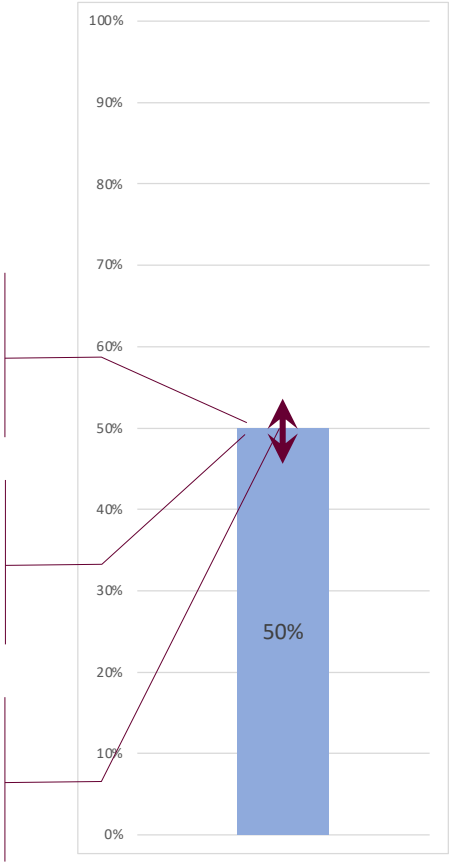
(4) (2) (1) (3)

p (assumed distribution)	50%	(1)
(1-p)	50%	
z (confidence level = 95%)	1.96	(2)
Δp (margin of error)	3%	(3)
n (sample size)	1,067	(4)

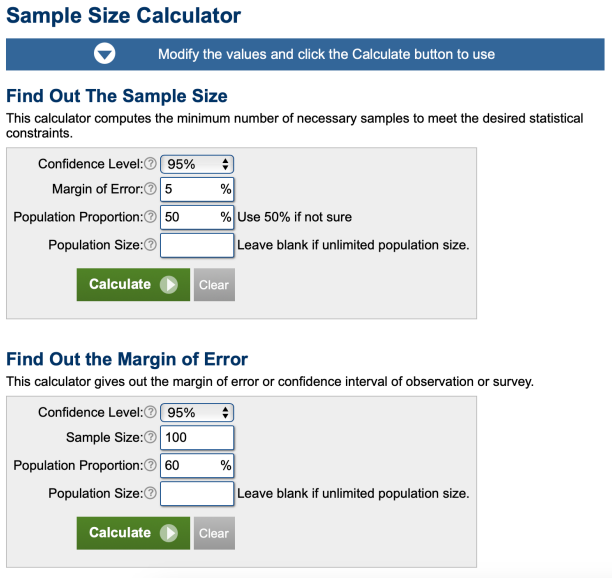
(1) Assumption of a distribution of 50%

(2) The measured values of the sample reflect the true values of the population at a probability of 95%

(3) With a probability of 95% (2), the true values of the population are in a range of +/- 3% from the measured values (47% to 53%)



- Es ante: Sample sizes can be calculated through online tools



Source: https://www.calculator.net/sample-size-calculator.html. Accessed: 2023-08-24

- Ex post: After data collection, the equation can be solved for z (or Δp) so that the level of confidence (or the margin of error) can be determined

$$n = \frac{z^2 \times p \times (1-p)}{\Delta p^2} \qquad n = \frac{z^2 \times p \times (1-p)}{\Delta p^2 + \frac{z^2 \times p \times (1-p)}{N}}$$

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„Purpose“ of Descriptive Statistics

- Objective of descriptive statistics
  - Descriptive statistics aims to describe a sample or population by summarising a dataset through coefficients
- Examples for descriptive statistics

TABLE 1 Employed population in Germany by gender and age groups (Statistisches Bundesamt, 2023) and sample by gender and age groups ($n = 1,756$).

Age groups	Employed population in 1,000				Sample				
	Female	Male	Total	Total in %	Female	Male	Diverse	Total	Total in %
25 to <35 years	3,987	4,746	8,733	23.68%	239	228	0	467	26.59%
35 to <45 year	4,272	4,868	9,140	24.78%	209	214	2	425	24.20%
45 to <55 year	4,601	4,942	9,543	25.88%	209	216	1	426	24.26%
55 to <65 year	4,515	4,947	9,462	25.66%	221	217	0	438	24.94%
Gesamt	17,375	19,503	36,878	100.00%	878	875	3	1,756	100.00%

TABLE 5 Descriptive statistics of the facets of organizational commitment, commitment to supervisor and servant leadership ($n = 1,756$).

Construct	Minimum	Maximum	Mean	Standard deviation	VIF
Organizational commitment					
Affective organizational commitment	1.20	6.00	4.55	1.03	
Cognitive organizational commitment	1.00	6.00	2.91	1.24	
Normative organizational commitment	1.00	6.00	3.71	1.19	
Contractual organizational commitment	1.00	6.00	4.08	1.79	
Commitment to supervisor					
Affective commitment to supervisor	1.00	6.00	4.23	1.28	1.59
Cognitive commitment to supervisor	1.00	6.00	2.93	1.20	1.21
Normative commitment to supervisor	1.00	6.00	3.81	1.16	1.79
Contractual commitment to supervisor	1.00	6.00	3.87	1.70	1.13
Servant leadership					
Empowerment	1.00	6.00	4.53	1.05	2.55
Standing back	1.00	6.00	3.91	1.17	1.70
Accountability	1.00	6.00	5.01	0.88	1.41
Forgiveness	1.00	6.00	4.33	1.26	1.35
Courage	1.00	6.00	3.86	1.26	1.30
Authenticity	1.00	6.00	3.39	1.15	1.63
Humility	1.00	6.00	4.03	1.18	2.70
Stewardship	1.00	6.00	4.09	1.17	1.69

Source: Godbersen, H., Dudek, B. & Ruiz Fernández, S. (2024). The Relationship Between Organizational Commitment, Commitment to Supervisor and Servant Leadership. Frontiers in Organizational Psychology, doi: 10.3389/forgp.2024.1353959.

- Please note: In academic research, descriptives statistics chiefly serve to describe a sample through sociodemographic & context variables. Work that solely utilises descriptive statistics does not normally meet academic standards.

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Scale of Measurement

Scale of measurement		Mathematical characteristics	Characteristics of values	Example	Measure of central tendency
Categorical (dichotomous)	Nominal	=/≠	Values are equal or not.	Gender	• Mode
	Ordinal	=/≠ ; </>	Values are larger, smaller or equal.	Olympic ranks	• Mode • Median
Metric (continuous)	Interval	=/≠ ; </> ; −; +	The distance between values can be determined.	Temperature	• Mode • Median • Arithmetic mean
	Ratio	=/≠ ; </> ; +/− ; */÷	The distance and ratio between values can be determined.	Height	

Scale of Measurement

- Nominal scale of measurement

  What gender describes you best?

  Female ☐
  Male ☐
  Non-binary ☐

- Ordinal scale of measurement

  Please evaluate the following products by bringing them into an order from 1 (best product) to 3 (worst product).

  Product A ____
  Product B ____
  Product C ____

- Metric scale of measurement

  How old are you in years? ____

- Rating scale (strictly speaking an ordinal scale; can however be treated as a metric scale)

  How satisfied are you with product XY in a scale from 1 „completely dissatisfied“ to 6 „completely satisfied“?

  completely dissatisfied ☐ ☐ ☐ ☐ ☐ ☐ completely satisfied

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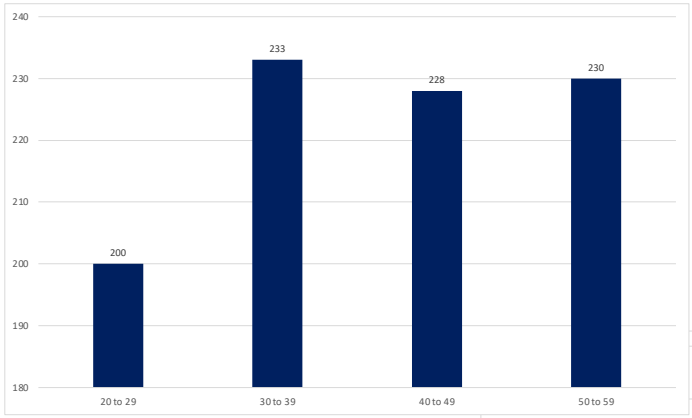
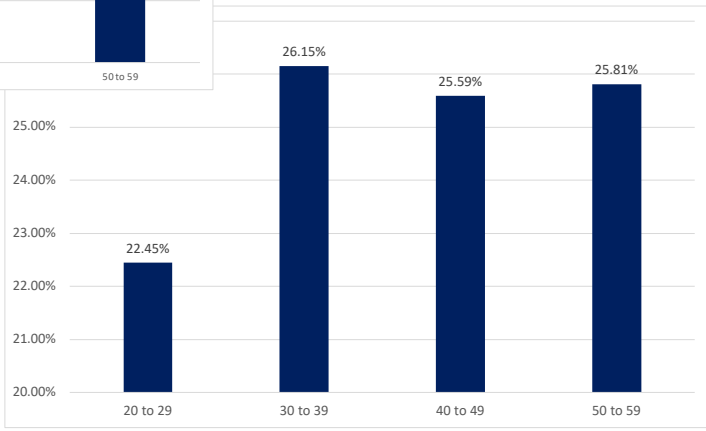
Frequencies

- Absolute frequency
  - Number of times a value of a variable occurred



- Relative frequency
  - Ratio of an absolute frequency of a value to the total number of values for a variable



Age group	female	male	total
20 to 29	22.08%	22.84%	22.45%
30 to 39	28.35%	23.78%	26.15%
40 to 49	23.16%	28.21%	25.59%
50 to 59	26.41%	25.17%	25.81%
SUM	100.00%	100.00%	100.00%

- Cross tabulation (contingency table)
  - Combination of the distribution of two variables

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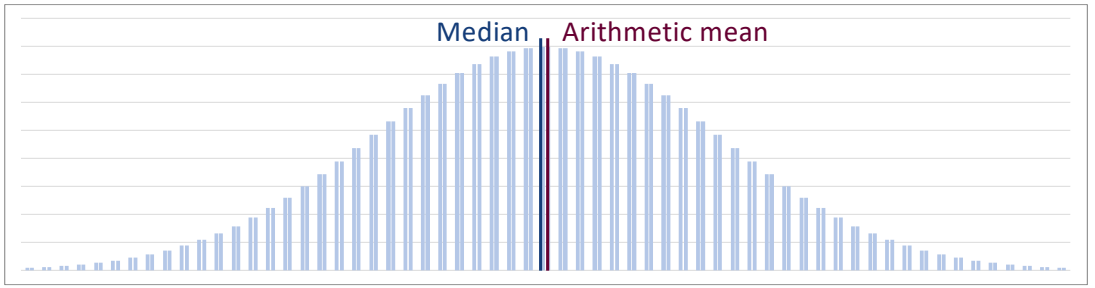
Measures of Central Tendency

- Arithmetic mean
  - Sum of all values divided by the number of all values; metric measurement level required
- Median
  - Value that separates the higher and lower half of a distribution; ordinal measurement level required
- Mode
  - Most frequent value of frequency distribution; nominal measurement level required

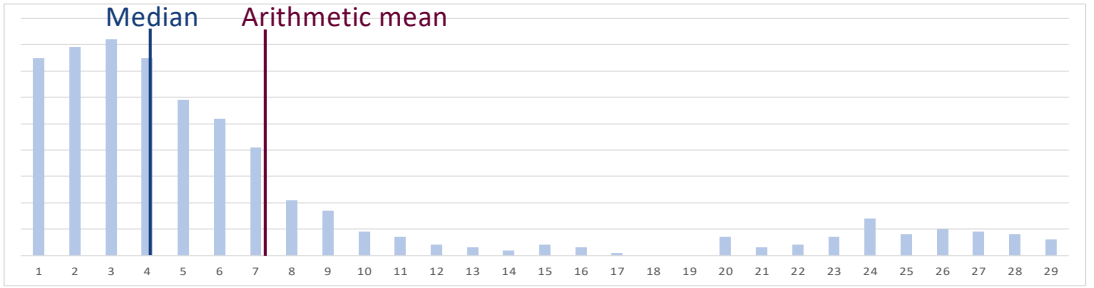
Participant	Variable A	
1	23	
2	27	
3	30	
4	35	
5	40	Median
6	55	
7	60	Mode
8	60	
9	75	
Sum	405	
Arithmetic mean	45	

Distributions

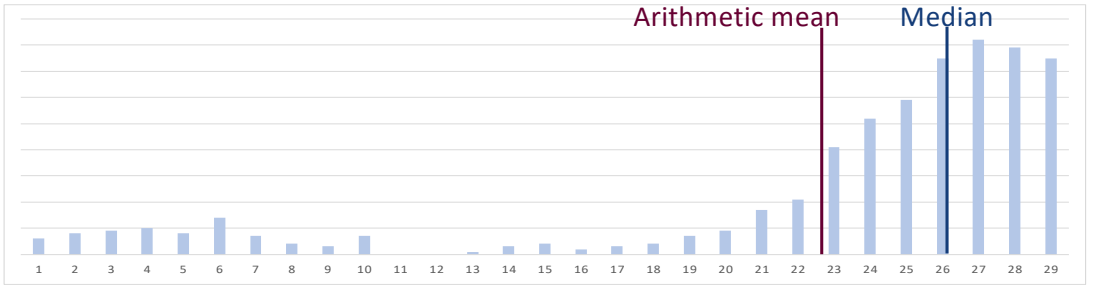
- Normal distribution
  - Arithmetic mean ≈ median



- Right-skewed distribution (right tailed)
  - Arithmetic mean > median



- Left-skewed distribution (left-tailed)
  - Arithmetic mean < median



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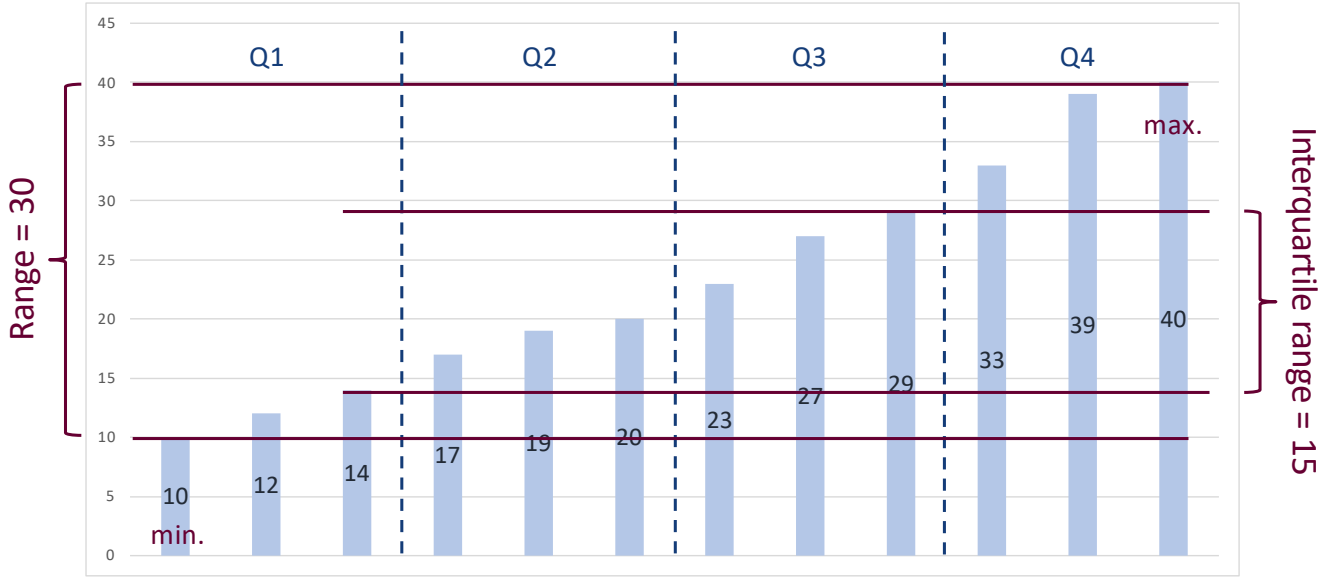
Range & Interquartile Range

- Minimum, Maximum & Quartiles
  - Minimum = lowest value of a dataset
  - Maximum = highest value of a dataset
  - Quartile 1 (Q1) = value that marks the lowest 25% of a data set
  - Quartile 3 (Q3) = value above which the highest 25% of a dataset lie

- Range = maximum – minimum

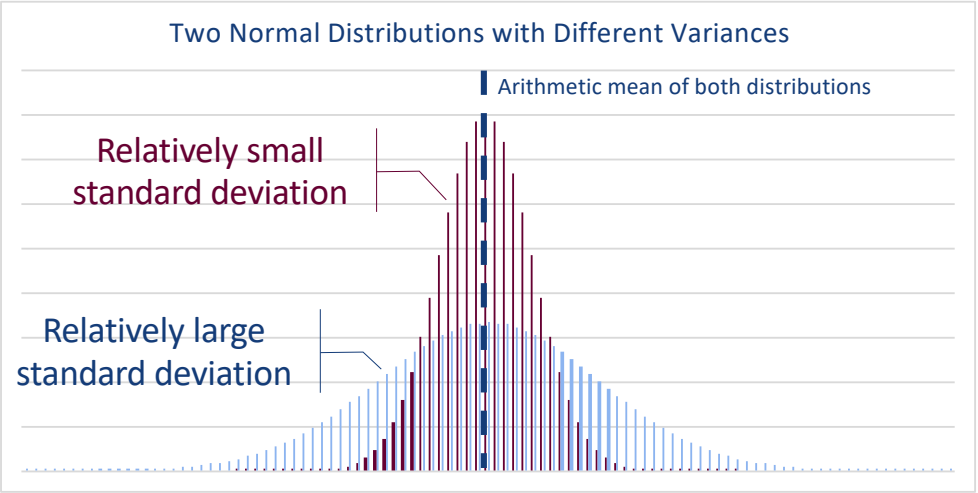
- Interquartile range = Q3 – Q1



Variance & Standard Deviation

- Variance
  - Average squared difference of values from their arithmetic mean (please note: empirical variance→ /n; sample variance → /n-1)

$$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{\bar{x}})^2}{n}$$



- Standard deviation
  - Average difference of values from their arithmetic mean

$$\sigma = \sqrt{\sigma^2}$$

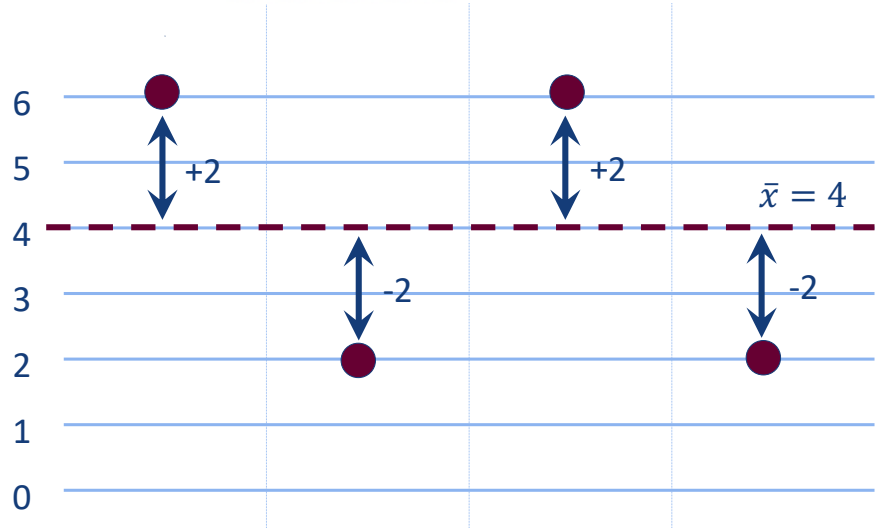
Variance & Standard Deviation

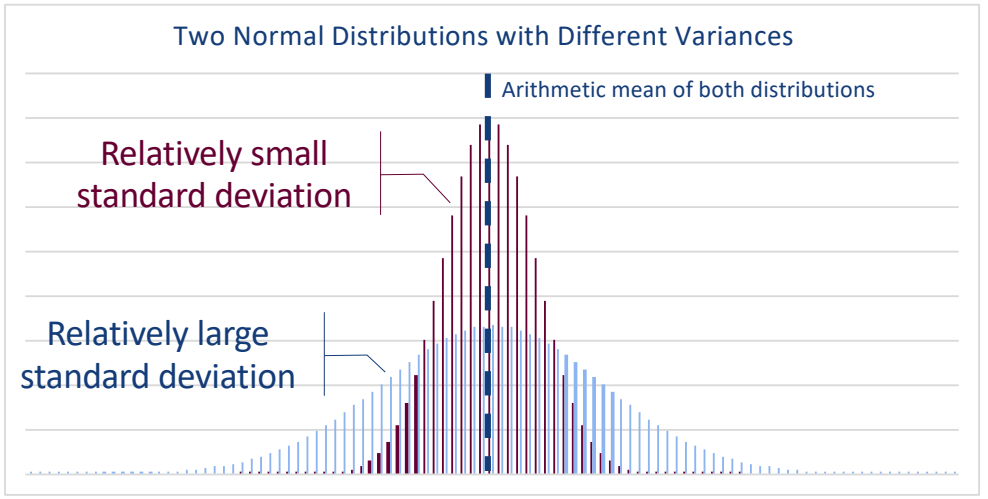
- Variance

$$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{\bar{x}})^2}{n}$$

- Standard deviation

$$\sigma = \sqrt{\sigma^2}$$





$\sum_{i=1}^{n}(x_i - \bar{\bar{x}})$ → (+2) + (-2) + (+2) + (-2) = 0

$\sum_{i=1}^{n}(x_i - \bar{\bar{x}})^2$ → $(+2)^2 + (-2)^2 + (+2)^2 + (-2)^2 =$ 4 + 4 + 4 + 4 = 16

$\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{\bar{x}})^2}{n}$ → 16 / 4 = 4

$\sigma = \sqrt{\sigma^2}$ → $\sqrt{4} = 2$

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Hypotheses, Alpha Error & Beta Error

- "Logic" of inferential statistics
  - Test if a significant ("real or actual") effect is confirmed of falsified
  - Testing hypotheses
- Hypotheses
  - Research hypothesis (alternative hypothesis) H_1
    - Effect (difference, influence etc.) exists
    - Example: Men & women prefer different colours
  - Null hypothesis H_0
    - Effect (difference, influence etc.) does not exist
    - Example: Men & women do not prefer different colours
- Quantitative research as a "black & white world"
  - Either the research hypothesis H_1 is "true" or the null hypothesis H_0 is "true"

Please note:

- In a quantitative research paper, only the research hypothesis H_1 is presented. The inferential statistical methods, however, test against the null hypothesis H_0 (see "quantitative black & white world").
- In a quantitative research paper, formulating hypotheses is not necessarily required. Research questions are also possible. These, however, must be clearly answerable ("yes no principle").

Hypotheses, Alpha Error & Beta Error

- Quantitative “black & with world”: H_1 vs H_0
- Alpha error
  - Rejecting H_0 – although H_0 is true (≈ H_1 is confirmed – although H_1 is not true)
- Beta error
  - Confirming H_0 – although H_0 is not true (≈ H_1 is rejected – although H_1 is true)

Alpha & Beta Error Example of a Medical Diagnosis		Measured effect	
		H_1: Patient = ill	H_0: Patient = healthy
True effect	H_1: Patient = ill	✓	Beta error
	H_0: Patient = healthy	Alpha error	✓

- Alpha level ≈ p-value with a range between 0.00 & 1.00

Directional & Non-directional Hypotheses & Testing

Hypothesis	Test
Non-directional hypothesis Example: Group A & group B have different incomes.	Bidirectional (two-tailed) test A > B & B > A
Directional hypothesis Example: Group A has a higher income than group B.	Directional (one-tailed) test A > B

- Please note
  - α level within the same dataset
    - α(one-tailed test) = ½ α(two-tailed test)
    - α(two-tailed test) = 2 α(one-tailed test)
  - Directional hypotheses can only be formulated if the direction of the respective effect can be “solidly” deduced from existing literature

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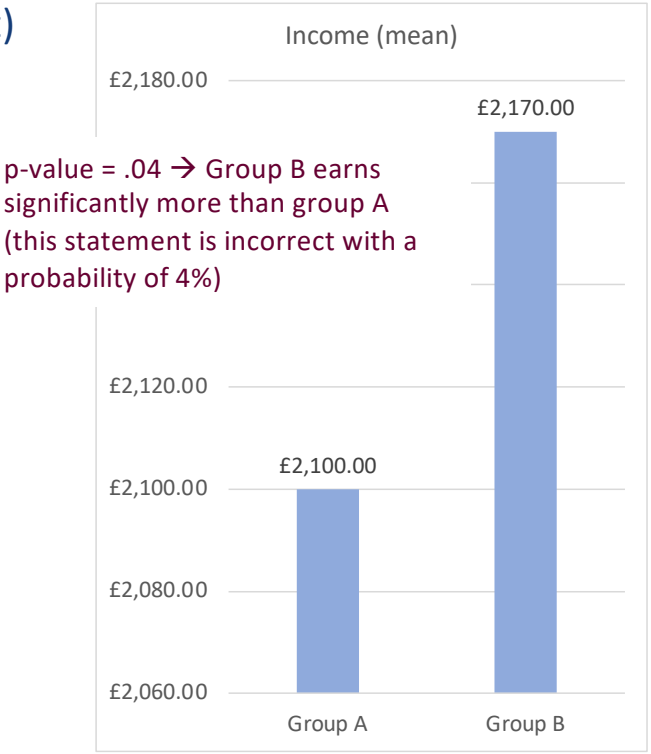
"Logic" of Inferential Statistics

- Inferential statistics determines if effects are significant
  - Significant = not coincidental (common language: an effect "really" exists)
  - Non-significant = coincidental (common language: there is no effect)
- The quantitative "black and white world":
  - H1: Effect XY exists.
  - H0: Effect XY does not exist.
- „Logic" of inferential statistical procedures
  - The inferential statistical methods try to reject H0.
  - Results: p-value with values between 0 and 1.
  - p-value = probability that H0 holds true if H0 was rejected.
- Steps of the analysis
  - (1) p-value → Significance: $p < .05$ = significant (higher degrees of significance at $p < .01$ and $p < .001$
  - (2) If p-value < .05: interpreting the measured values (arith. mean, frequencies etc.) → direction & strength of the effect



Example: Chi²-test

- H_1: Men & women prefer different colours.
- H_0: Men & women do not prefer different colours.

- **Statistical Analysis („in the background")**:
  1) Calculation of the expected frequencies (e) which would indicate no difference between the variables (column sum * row sum / number of observations)
  2) Test if the observed values (h) significantly deviate from the expected values

V1	Female	Male	Sum
Blue	h = 15 e = 25	h = 35 e = 25	50
Red	h = 35 e = 25	h = 15 e = 25	50
Sum	50	50	100

p-value = 0.0001447

V2	Female	Male	Sum
Blue	h = 24 e = 25	h = 26 e = 25	50
Red	h = 26 e = 25	h = 24 e = 25	50
Sum	50	50	100

p-value = 0.8415

Scale of Measurement

Scale of measurement		Mathematical characteristics	Characteristics of values	Example	Measure of central tendency
Categorical (dichotomous)	Nominal	=/≠	Values are equal or not.	Gender	• Mode
	Ordinal	=/≠ ; </>	Values are larger, smaller or equal.	Olympic ranks	• Mode • Median
Metric (continuous)	Interval	=/≠ ; </> ; −; +	The distance between values can be determined.	Temperature	• Mode • Median • Arithmetic mean
	Ratio	=/≠ ; </> ; +/− ; */÷	The distance and ratio between values can be determined.	Height	

Overview & Systematic of Inferential Statistical Methods

Inferential Statistical Methods		Independent variable	
		categorical (dichotomous)	metric (continuous)
Dependent variable	categorical	Chi^2 test	Discriminant analysis
	metric	t-test*** (2 groups) & Analysis of variances (≥ 3 groups)	Regression (dependence) & correlation (interdependence)

*** „Additional" tests:

- Shapiro-Wilk test
  (tests if a variable is normally distributed; precondition for t-tests at small sample sizes, n ≤ 50)
- Mann-Whitney test/Wilcoxon test
  (tests if 2 groups differ on an at least ordinally scaled variable, without requiring a normal distribution)

Exploratory Data Analysis	Principal component analysis / cluster analysis (≠ inferential statistics)

Prof. Dr. Hendrik Godbersen

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