Looking Back: Motivation and History of HCI

- Various interfaces between humans and various machines
  - Human Computer Interaction (HCI) is slightly more specialised
- There are difference between good / nice design and usability
- Utility, Usability, Likability
- Important for many different jobs / projects
- HCI is a multidisciplinary area
  (Computer Science, Psychology, Design, Sociology, Anthropology)
- One main content of the lecture: integration into development processes
- History
  - fast changing environment / technology / applications / ...
  - many metaphors already around for years (e.g. windows on PC desktop)
  - increasing importance and impact of usability
  - university research often at the root of novel advances and progress

Looking Back: User Study Design

- Purpose of user studies
- Placement within the development process
- Types of user studies
  - Observational, experimental
  - Within subjects, between groups
- Independent vs. dependent variables
- Setup process
  - Form hypotheses → design the study → run a pilot study → recruit participants → run the study → analyze the data
  - Results must be valid, reliable, generalisable, important

User Study Design

2.1. The Purpose of User Studies

2.2. Research Aims: Reliability, Validity and Generalizability

2.3. Research Methods and Experimental Designs

2.4. Ethical Considerations

2.5. HCI-related and practical information for your own studies

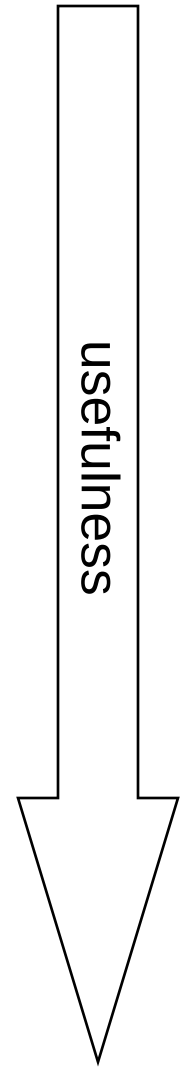
2.6 Interpretation of Data and Presentation of Results

Interpretation and Presentation of Results – Overview

- Types of Data
- Distributions
- Metrics to describe data
  - Averages
  - Standard deviation / variance
  - Quantiles
- Statistics
  - T-test
  - ANOVA
- Reporting results

Types of Data

- Nominal (categorical) data
  - No relationship between the size of the number
  - Operations: A=B, A!=B
  - E.g. numbers in a football team
- Ordinal Data
  - Order / ranking
  - Operations: A>B, A<B, A=B
  - E.g. marks in school: 1, 2, 3, 4, 5, 6
- Interval scale data
  - Equal intervals = equal differences in the measured property
  - Zero point is arbitrary
  - E.g. temperature (°C/°F)
- Ratio scale data
  - Fixed zero point
  - E.g. wpm, error rates

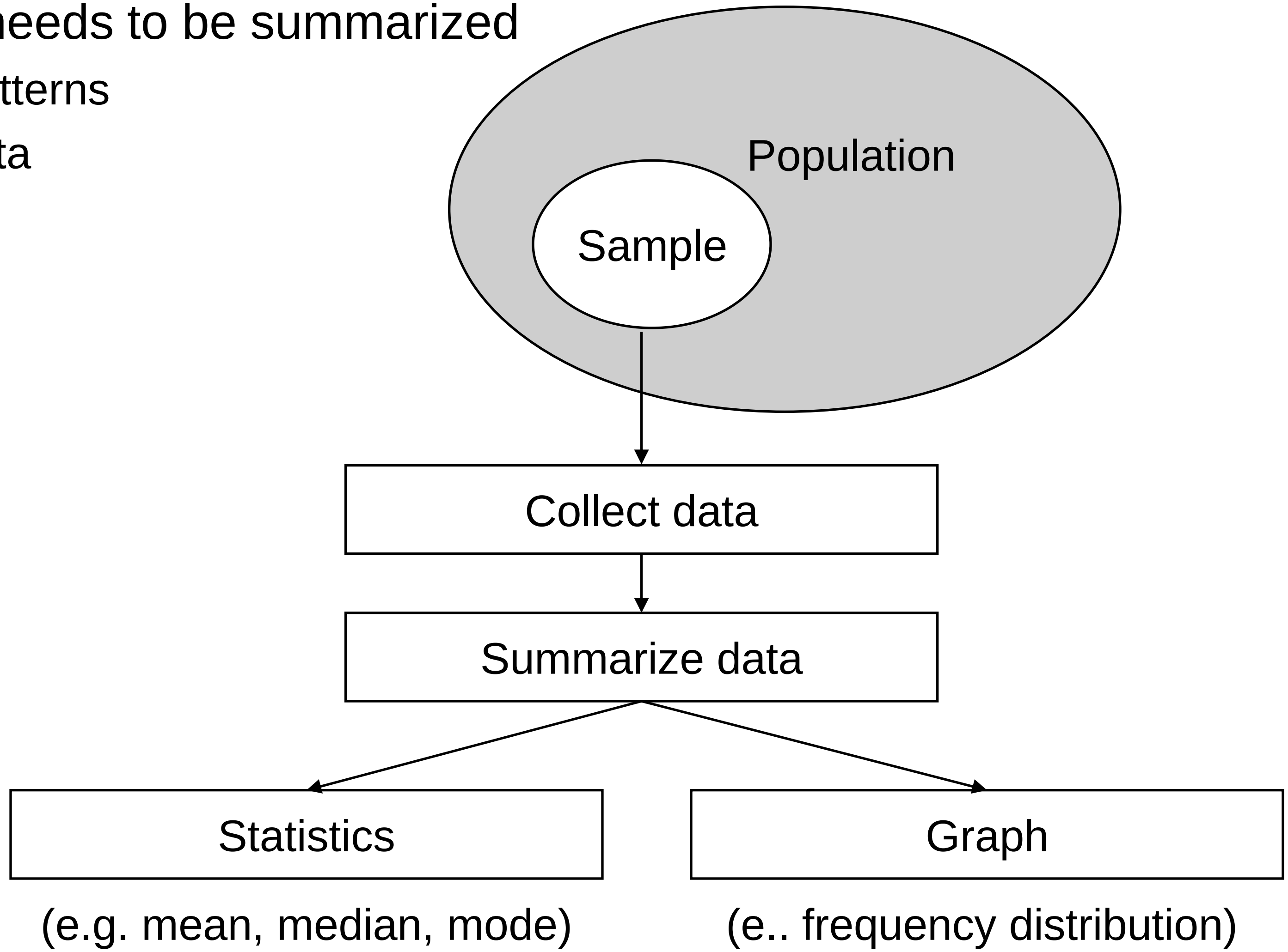


Types of Variables

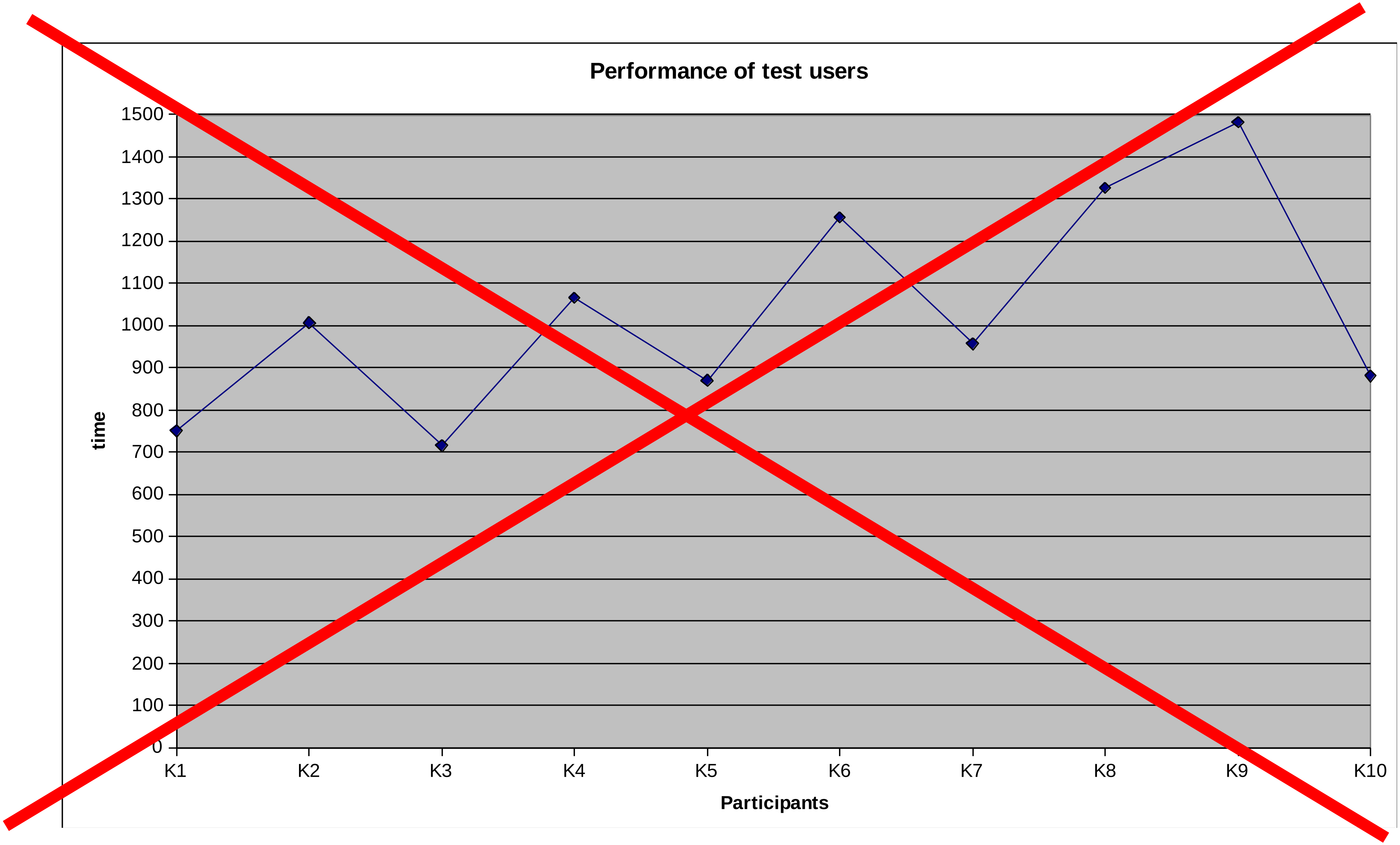
- Discrete Data
  - Distinct and separate
  - Can be counted
  - E.g. Likert scales, preferences from a list, ...
- Continuous Data
  - Any value within a finite or infinite interval
  - Always have a order
  - E.g. weight, length, task completion time, ...

Summarizing Data

- Collected data needs to be summarized
  - Recognize patterns
  - Aggregate data
- Two ways:
  - Statistics
  - Graph



Don't Do This



Performance of test users
time
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
Participants

Frequency Distributions (Histrograms)

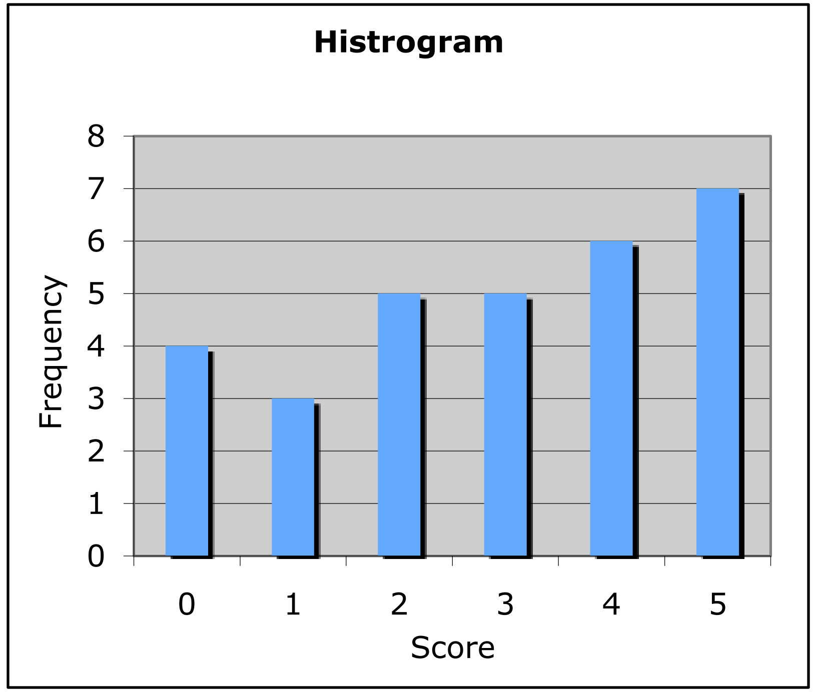
- Example: days needed to answer my email

  Data: `5 2 2 3 4 4 3 2 0 3 0 3 2 1 5 1 3 1 5 5 2 4 0 0 4 5 4 4 5 5`

- Count the number of times each score occurs

  ⇨ Frequency table:

Days	*Frequency*	*Frequency (%)*
0	4	13%
1	3	10%
2	5	17%
3	5	17%
4	6	20%
5	7	23%



Averages: Mode, Median, Mean

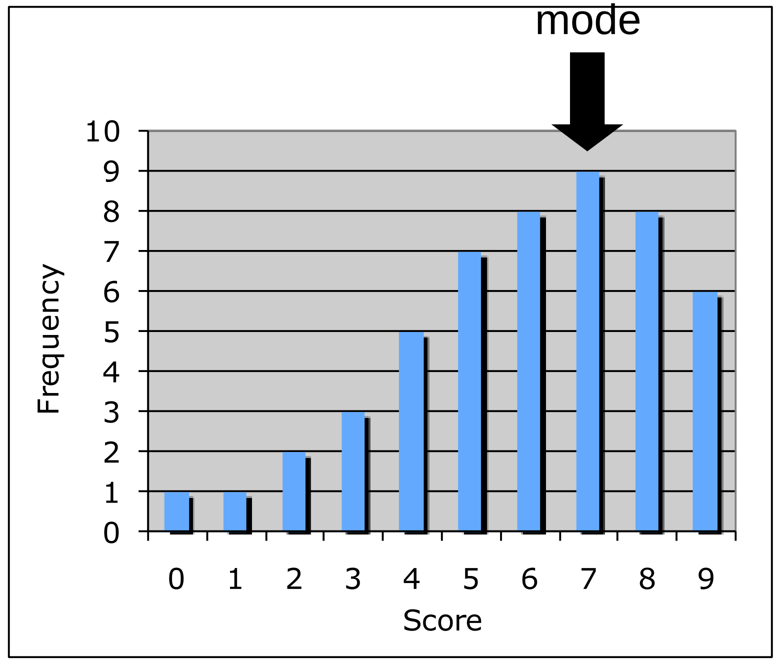
- How can the data be summed up in a single value?
- Idea: get the centric point

- Three ways:
  - Mode
    - » The most frequent score
  - Median
    - » Middle score
  - Mean
    - » Average

Mode

- The most frequent score
- Describes how most people behave

- Pros:
  - Easy to calculate and understand
  - Can be used with nominal data
- Cons:
  - There can be more than one modes
  - Mode can change dramatically by adding only one dataset
  - Independent of all other data in the set



Median (Mdn)

- Middle score of the distribution

  Example data: 1 7 3 9 6 9 2

- Sorted by magnitude: 9 9 7 6 3 2 1 ⇨ median = 6
- If #scores even ⇨ average two middle scores

  Example data: 1 7 3 9 4 6 9 2

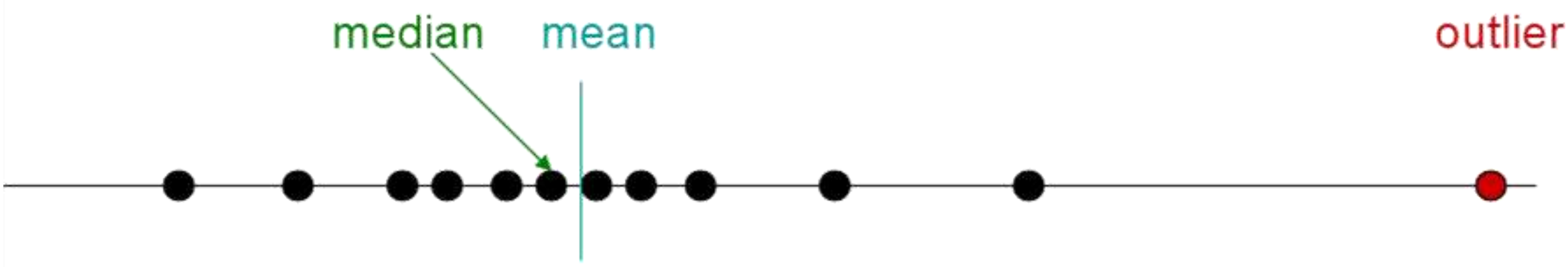
- Sorted by magnitude: 9 9 7 6 4 3 2 1 ⇨ median = 5
- Pros:
  - Relatively unaffected by outliers (very low or high scores) and skewed distributions
  - Can be used with ordinal, interval and ratio data
- Cons:
  - Does not consider all scores of the data set
  - Not very stable

if n is odd: $x_{(n+1)/2}$

if n is even: $(x_{n/2} + x_{n/2+1}) / 2$

Mean (M)

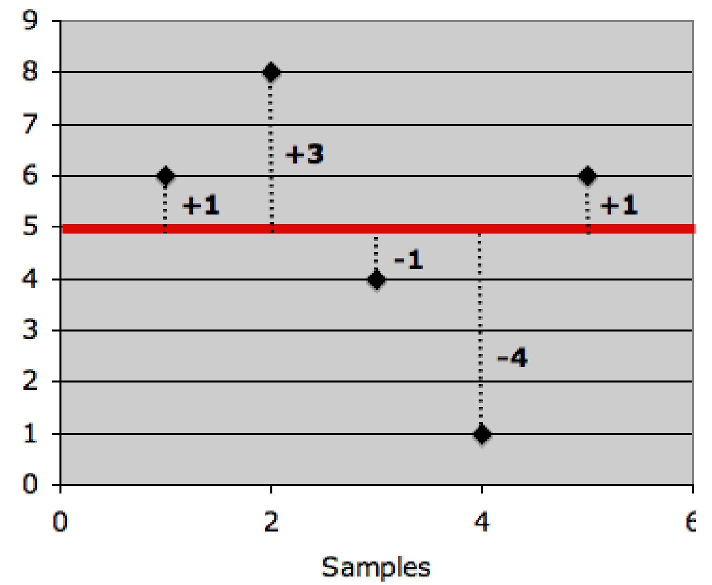
- Sum of all scores divided by #scores:
- Most often used if ‘average’ is mentioned
- Pros:
  - Considers every score
    ⇨ most accurate summary of the data
  - Resistant to sampling variation: removing one sample changes the mean far less than mode or median
- Cons:
  - Heavily affected by extreme scores and skewed distributions
  - Can only be used with interval and ratio data

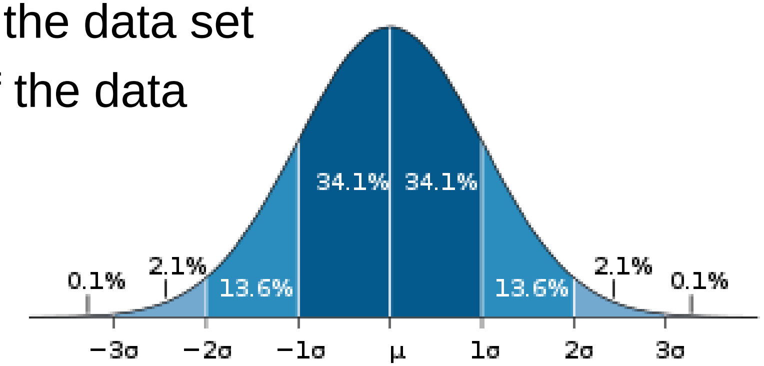


Standard Deviation and Variance

- How do you measure the accuracy of the mean?
- Example data set 1: 5 5 5 5 5 ⇨ mean = 5
- Example data set 2: 6 8 4 1 6 ⇨ mean = 5
- Which of the data sets is better reflected by the mean?

- If $x_1, x_2, \ldots x_n$ are the data in a sample with mean m
  - **Deviation** = difference between mean and scores $= \sum (x_i - m)$
  - **Variance** $s^2 = \frac{\sum(x_i - m)^2)}{n}$ $(= E(X^2) - m^2)$
  - **Standard deviation** (**SD**) $s = \sqrt{Var(X)}$
- Both variance and standard deviations measure the
  - Accuracy of the data set
  - Variability of the data

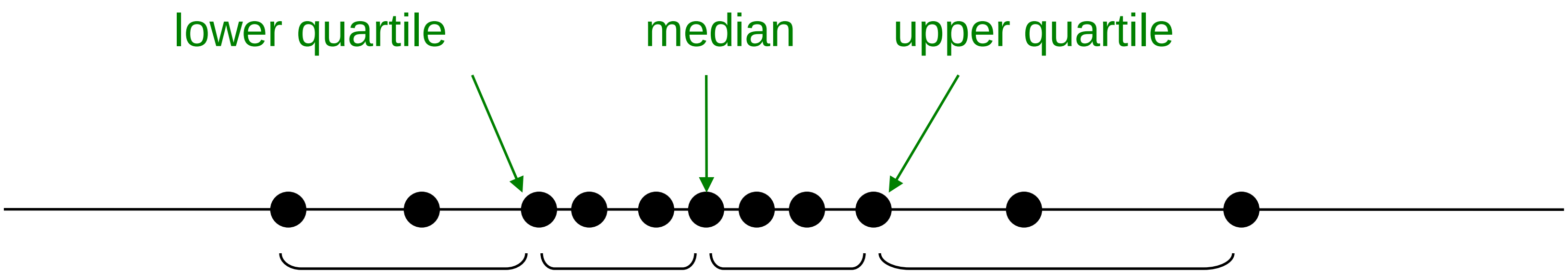




http://en.wikipedia.org/wiki/Normal_distribution

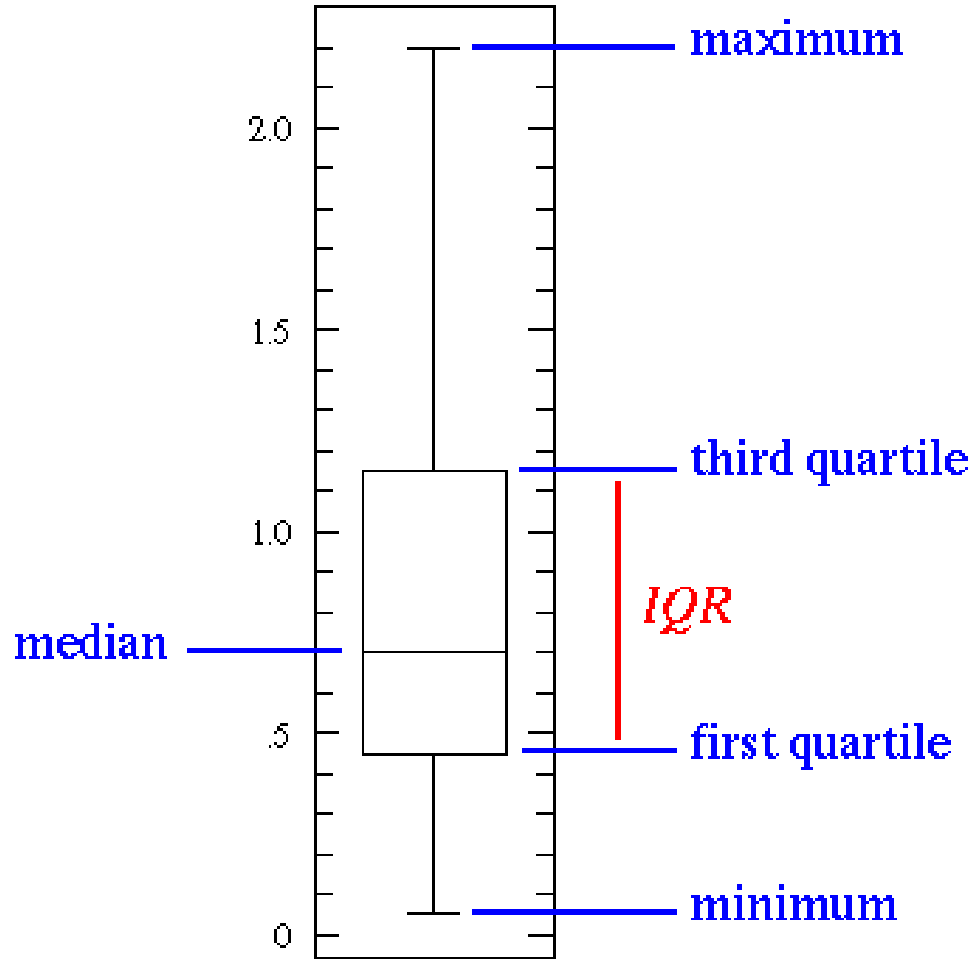
Quantile, Quartile and Percentile

- Quantile
  - ‘Cut points' that divide a sample of data into groups containing (as far as possible) equal numbers of observations.
- Quartile (Quantile of 4)
  - Values that divide a sample of data into 4 groups containing (as far as possible) equal numbers of observations
- Percentile (Quantile of 100)
  - Values that divide a sample of data into 100 groups containing (as far as possible) equal numbers of observations



Boxplots

- Also known as
  - box-and-whisker diagram
  - candlestick chart
- Quick overview of the most important values

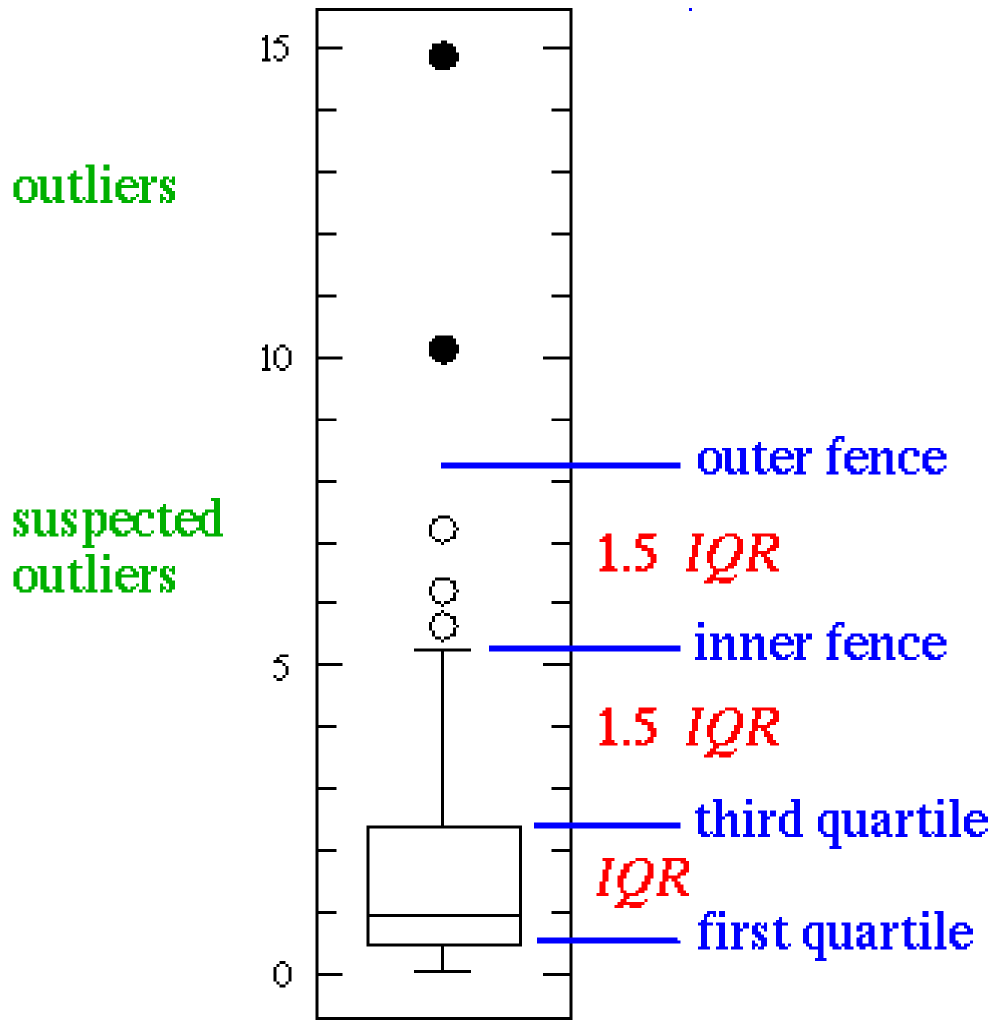


Source: http://www.physics.csbsju.edu/stats/box2.html

Outliers

- Try to avoid outliers!
  - Improve your test equipment
  - Eliminate sources of disturbances
  - Repeat parts of your experiment in case of disturbance

- Outliers are not generally bad – they give valuable information
- With large data sets outliers can often not be avoided



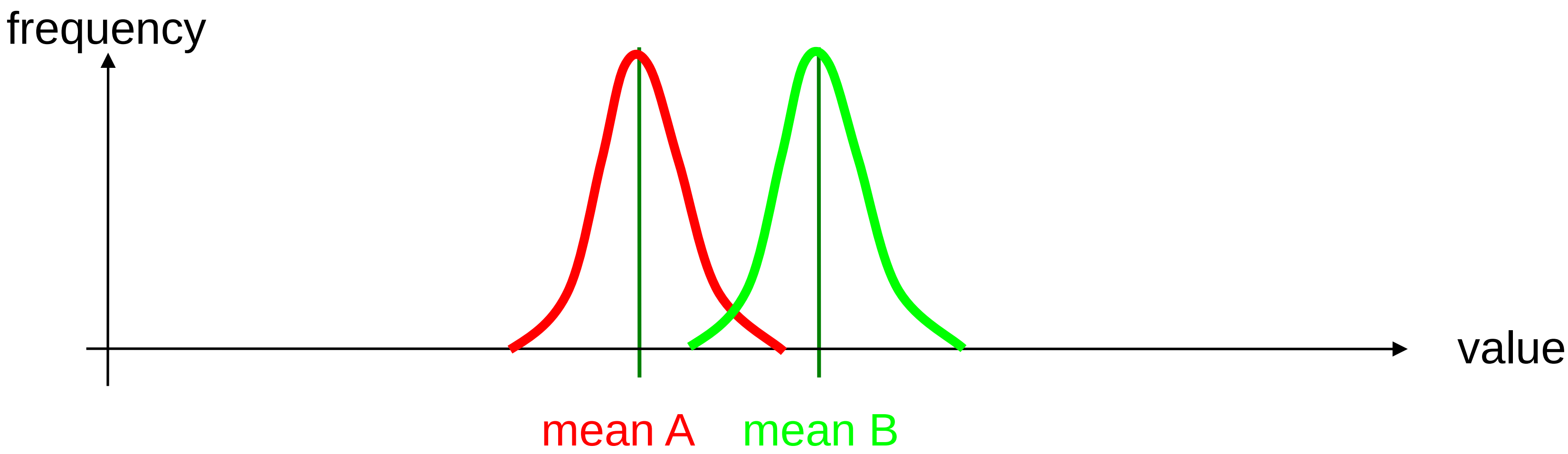
Creating Boxplots with Excel

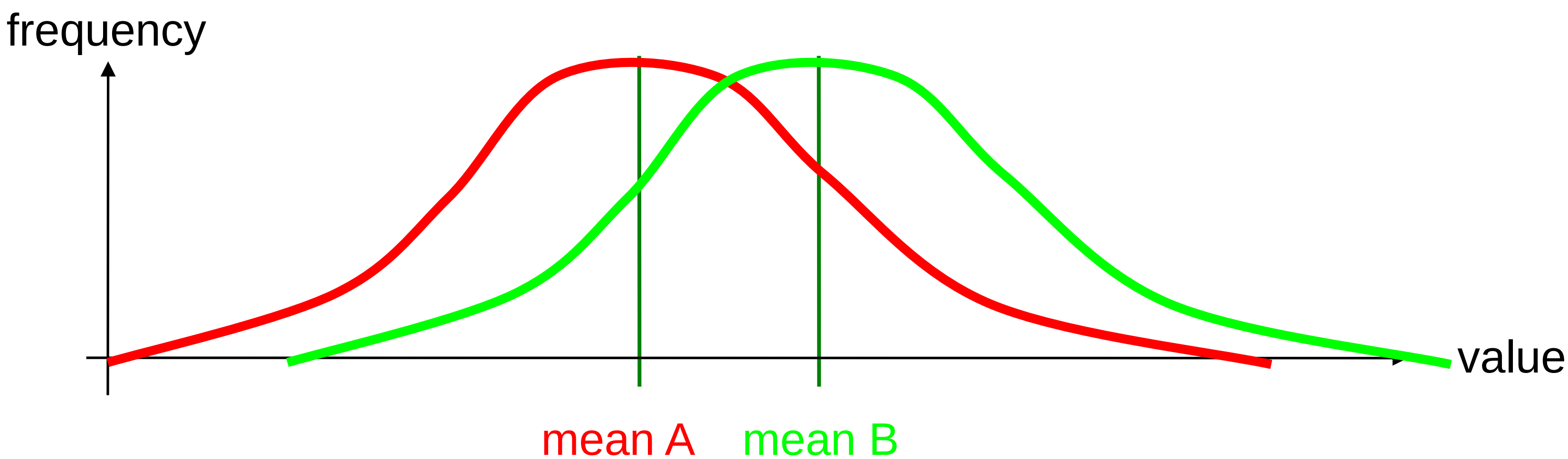
- Useful functions in Excel (and many other applications)
  - MIN, MAX
  - MEDIAN
  - AVERAGE
  - QUARTILE
  - PERCENTILE

- Box Plots with Excel 2007
  - http://blog.immeria.net/2007/01/box-plot-and-whisker-plots-in-excel.html
  - http://www.bloggpro.com/box-plot-for-excel-2007/

Comparing Values

- Significant differences between measurements?





Example: Pepsi Challenge

- The Pepsi Challenge
  - Let participants „blindly“ taste glasses of Pepsi/Coca Cola and identify it
  - Half the glasses are filled with Pepsi, half with Coca Cola
  - 2 glasses ⇨ chance of guessing correct = (1:2)
  - 4 glasses ⇨ chance of guessing correct = (1:6)
  - 6 glasses ⇨ chance of guessing correct = (1:20)
  - 8 glasses ⇨ chance of guessing correct = (1:70)

  ⇨ More choices means less probable that the result occurred by chance
- Differences can be due to
  - The manipulation caused a real difference
  - The difference occurred by chance
- Appropriate level of confidence: 95%
- **Significance**: A difference is „significant“ if the probability of the result occurring by chance ≤ 5%

Significance

- In statistics, a result is called significant if it is unlikely (probability $p \leq 5\%$) to have occurred by chance.
- **Never use the word significant if you don‘t mean statistically significant!**
- It does not mean that the result is of practical significance!

- T-Test can be used to calculate the probability p
  - The t-test gives the probability that both populations have the same mean (and thus their differences are due to random noise)
- A result of 0.05 from a t-test is a 5% chance for the same mean

T-Test in Excel

- Mean and T-Test can be calculated using MS Excel
  - AVERAGE
  - TTEST
- TTEST(…) Parameters:
  1. Data row 1
  2. Data row 2
  3. Ends / Tails (e.g. A higher B => 1-tailed; A different from B => 2-tailed)
  4. Type (use 'paired' for within-subjects tests)

	A	B
K1	751	1097
K2	1007	971,5
K3	716	1121
K4	1066,5	1096,5
K5	871	932
K6	1256,5	926,5
K7	957	1111
K8	1327	1211,5
K9	1482	1062
K10	881	976
Mean	**1031,5**	**1050,5**

T-test	**0,8236863**

	A	B
K1	826,5	1382
K2	806	1066
K3	791	1276,5
K4	896,5	1352
K5	696	1191
K6	1121	1066
K7	891	1217
K8	1327	1412
K9	1277	1266,5
K10	656	1101
Mean	**928,8**	**1233**

T-test	**0,0020363**

Analysis of Variance (ANOVA)

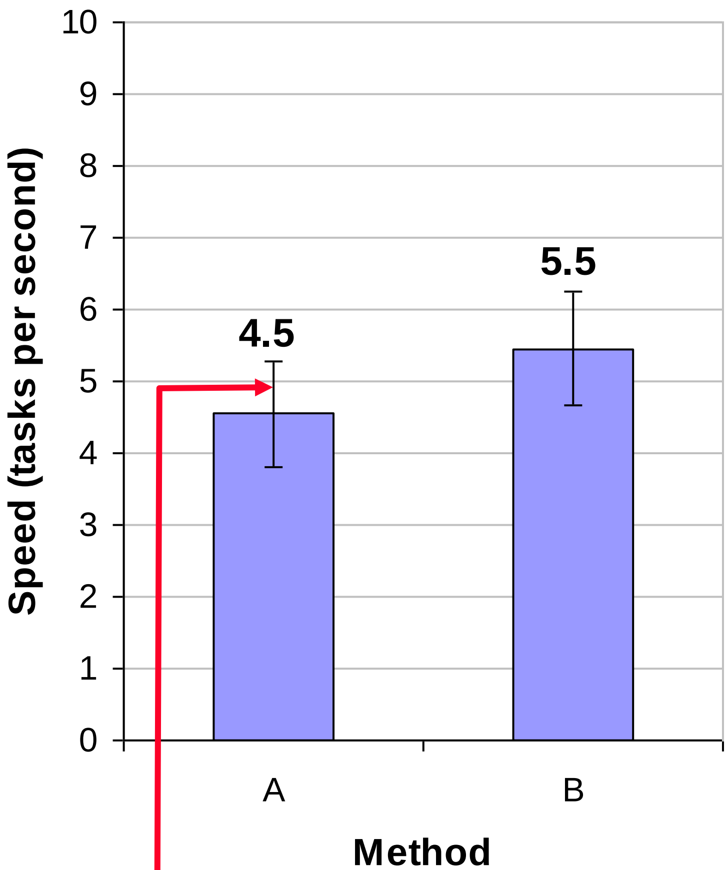
- Generalisation of the t-test
- Can cope with more than 2 data sets
- For 2 sets, basically the same as t-test => use t-test
- Can cope with more independent variables with multiple levels
- Multivariate ANOVA for more than one dependent variable
- Excel: http://office.microsoft.com/en-au/excel/HP100908421033.aspx

"The experiment used a repeated measures within-participant factorial design 3 x 2 x 3 (interaction technique x transfer type x task type)."

"The independent variable interaction technique consisted of three levels: standard Bluetooth, touch & connect and touch & select."

Khooviraj, Rukzio, Hardy, Holleis. To appear in MobileHCI'09

Significant Example



Error bars show
1 standard deviation

Example #1		
Participant	Method	
	A	B
1	5,3	5,7
2	3,6	4,6
3	5,2	5,1
4	3,3	4,5
5	4,6	6,0
6	4,1	7,0
7	4,0	6,0
8	5,0	4,6
9	5,2	5,5
10	5,1	5,6
Mean	4,5	5,5
SD	0,73	0,78

Source: MacKenzie, Empirical Research in HCI:What? Why? How?

Significant Example - Anova

ANOVA Table for Speed

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Subject	9	5.839	.649				
Method	1	4.161	4.161	8.443	.0174	8.443	.741
Method * Subject	9	4.435	.493				

Probability that the difference in the means is due to chance

Reported as…

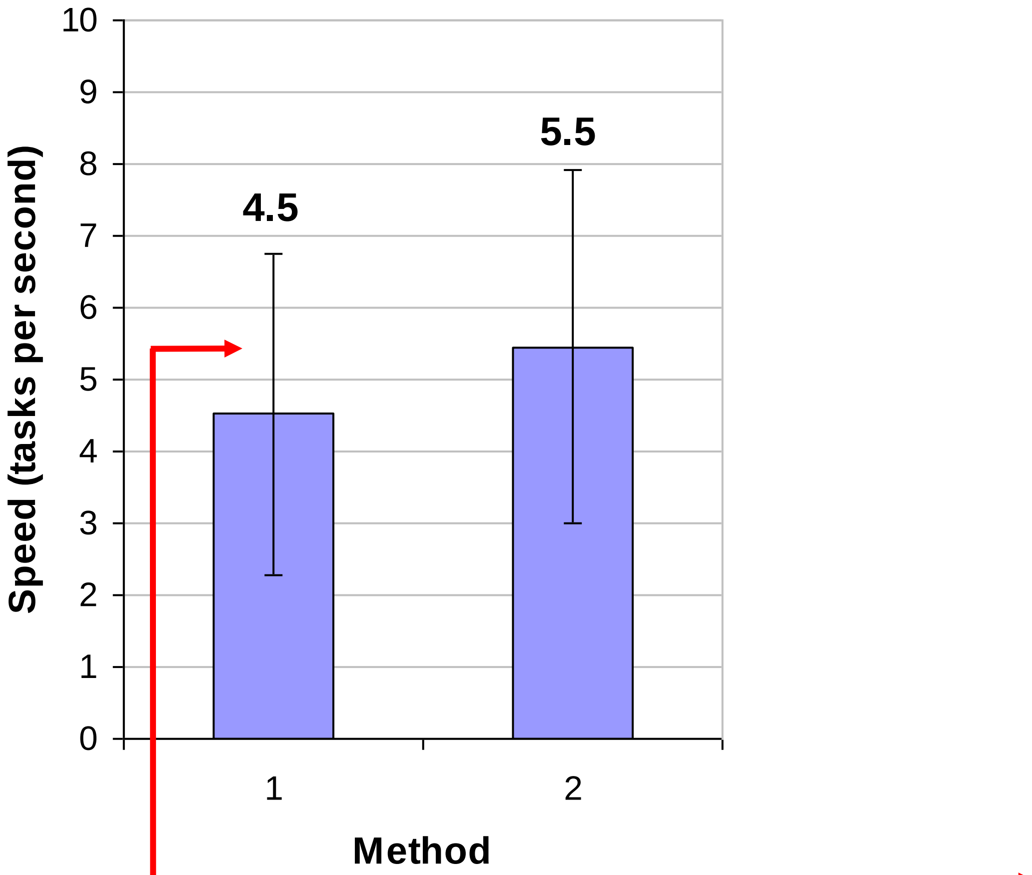
$F_{1,9} = 8.443, p < .05$

Thresholds for "p"

- **.05**
- .01
- .005
- .001
- .0005
- .0001

Source: MacKenzie, Empirical Research in HCI:What? Why? How?

Not Significant Example



Error bars show
1 standard deviation

Source: MacKenzie, Empirical Research in HCI:What? Why? How?

Not Significant Example - Anova

ANOVA Table for Speed

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Subject	9	37.017	4.113				
Method	1	4.376	4.376	.634	.4462	.634	.107
Method * Subject	9	62.079	6.898				

Probability that the difference in the means is due to chance

Reported as…

$F_{1,9}$ = 0.634, ns

Note: For non- significant effects, use “ns” if

- $F < 1.0$, or
- $p > .05$ (if $F > 1.0$)

Source: MacKenzie, Empirical Research in HCI:What? Why? How?

ANOVA in Excel

http://office.microsoft.com/en-au/excel/HP100908421033.aspx: One-Way ANOVA

Anova: Single Factor

Which Bowler is Best?

SUMMARY

Groups	*Count*	*Sum*	***Average***	***Variance***
Pat	6	922	153.6667	92.26667
Mark	6	1070	178.3333	116.6667
Sheri	6	937	156.1667	54.96667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***
Between Groups	2212.111	2	1106.056	**12.57358**	0.000621	**3.682317**
Within Groups	1319.5	15	87.96667			
Total	3531.611	17				

ANOVA test online: http://www.physics.csbsju.edu/stats/anova.html

Overview Parametric and Non-Parametric Tests

Experiment Design	Parametric Test	Non-Parametric Test
2 groups with different participants (one indep. variable)	Independent T-Test	Mann-Whitney Test
2 groups with same participants (one indep. variable)	Dependent T-Test	Wilcoxon Signed-Rank Test
≥ 3 levels groups with different participants and one indep. variable	One-way independent ANOVA	Kruskal-Wallis Test
≥ 3 levels groups with same participants and one indep. variable	One-way repeated measures ANOVA	Friedman‘s ANOVA
...	...	...

Reporting Study Results

Sections of a report

1. Title
2. Abstract (brief summary of about 150 words)
3. Introduction (motivation)
   - Description of previous research
   - Rationale of your work
4. **Method**
   - **Overview of the study**
   - **Variables, levels, participants, procedure, ...**
5. **Results**
   - **What was scored?**
   - **Descriptive and inferential statistics**
6. **Discussion**
7. References
8. (Appendices)

4 Answers

Why?

How?

What?

So what?

This Lecture is not Enough!

- We strongly recommend to teach yourself.
  There is plenty of material on the WWW.

- Further Literature:
  - Andy Field & Graham Hole: How to design and report experiments, Sage
  - Jürgen Bortz: Statistik für Sozialwissenschaftler, Springer
  - Christel Weiß: Basiswissen Medizinische Statistik, Springer
  - Lothar Sachs, Jürgen Hedderich: Angewandte Statistik, Springer
  - Various books by Edward R. Tufte
  - ... and many more ...

References

- Carmines, E. and Zeller, R. (1979). Reliability and Validity Assessment. Newbury Park: Sage Publications
- Colosi, L (1997) The Layman's Guide to Social Research Methods http://www.socialresearchmethods.net/tutorial/Colosi/lcolosi1.htm
- Field, A. and Hole, G. (2003). How to Design and Report Experiments. Sage Publications