Mensch-Maschine-Interaktion 2
Übung 10

Ludwig-Maximilians-Universität München

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Today

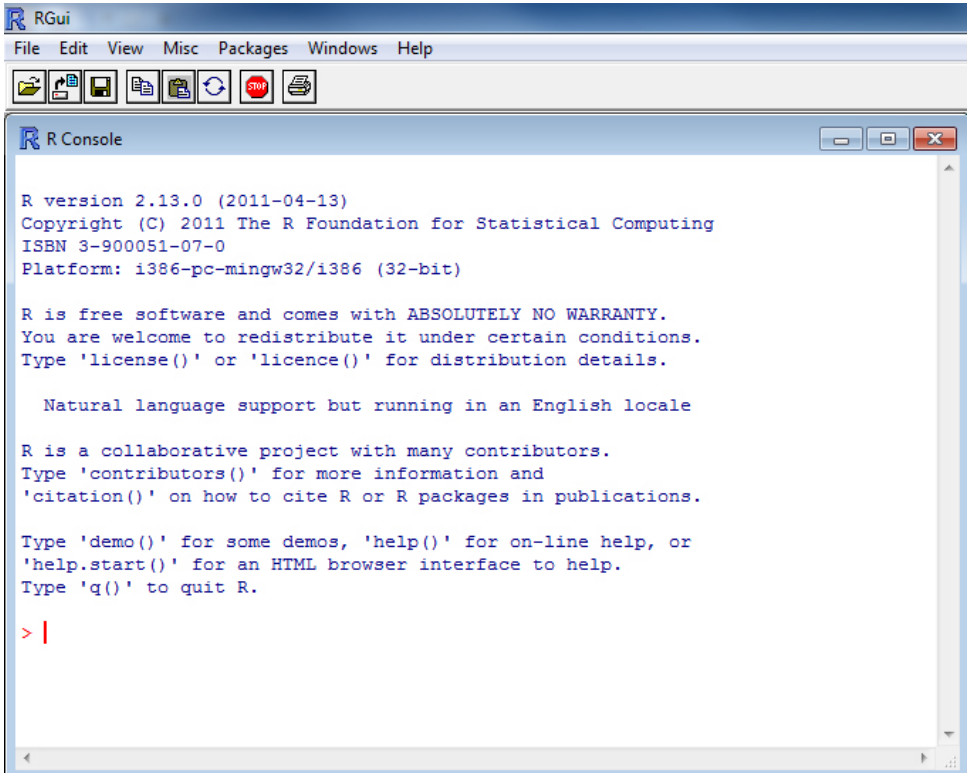
Analyzing Experimental Data - Tutorials

Statistical Analysis –Software

- Excel
  - \+ Fast and easy
  - \- Limited functionality
- SPSS (not covered in this lecture)
  - \+ Flexible
  - \+ Powerful
  - \- Complex
  - \- Very expensive
- R
  - \+ Flexible
  - \+ Powerful
  - \+ Free
  - \- No graphical user interface

Short Introduction to R

- Mathematical/statistical computing software
- Free alternative to SPSS
- Also offers a comprehensive programming language



R Project website http://www.r-project.org/

R - Assign values

```
> a = 1  # a stores the value 1
```

or

```
> a <- 1 # a stores the value 1
```

```
> a <- c(1,3,4,5)   # c is a method and stands for combine
> a[2] # access an element in the list
[1] 3
```

R – Read a CSV file

```
> a <- read.csv(file="file.csv", head=TRUE,sep=",")
    # file: location of the file, head: does it have a header or not, sep
    = seperator
```

web	mobile
50.7	52.6
46.8	50.8
52.3	49.9
49.6	51.9
56.2	56.2
47.6	52.7
52.1	54.8
49.3	56.3
47.5	49.8
51.4	51.6

```
> attach(a) # make the columns of file.csv available to R
> web
[1] 50.7 46.8 52.3 49.6 56.2 47.6 52.1 49.3 47.5 51.4
```

Analysis

Evaluate Results - Exemplary Study

Task and Results are fictional!!

Task: Compare the input speed of a web based system and a mobile app

Results in seconds:

web	mobile
50.7	52.6
46.8	50.8
52.3	49.9
49.6	51.9
56.2	56.2
47.6	52.7
52.1	54.8
49.3	56.3
47.5	49.8
51.4	51.6
Average 50.4	52.7

-> Average values of both do not provide enough insights!

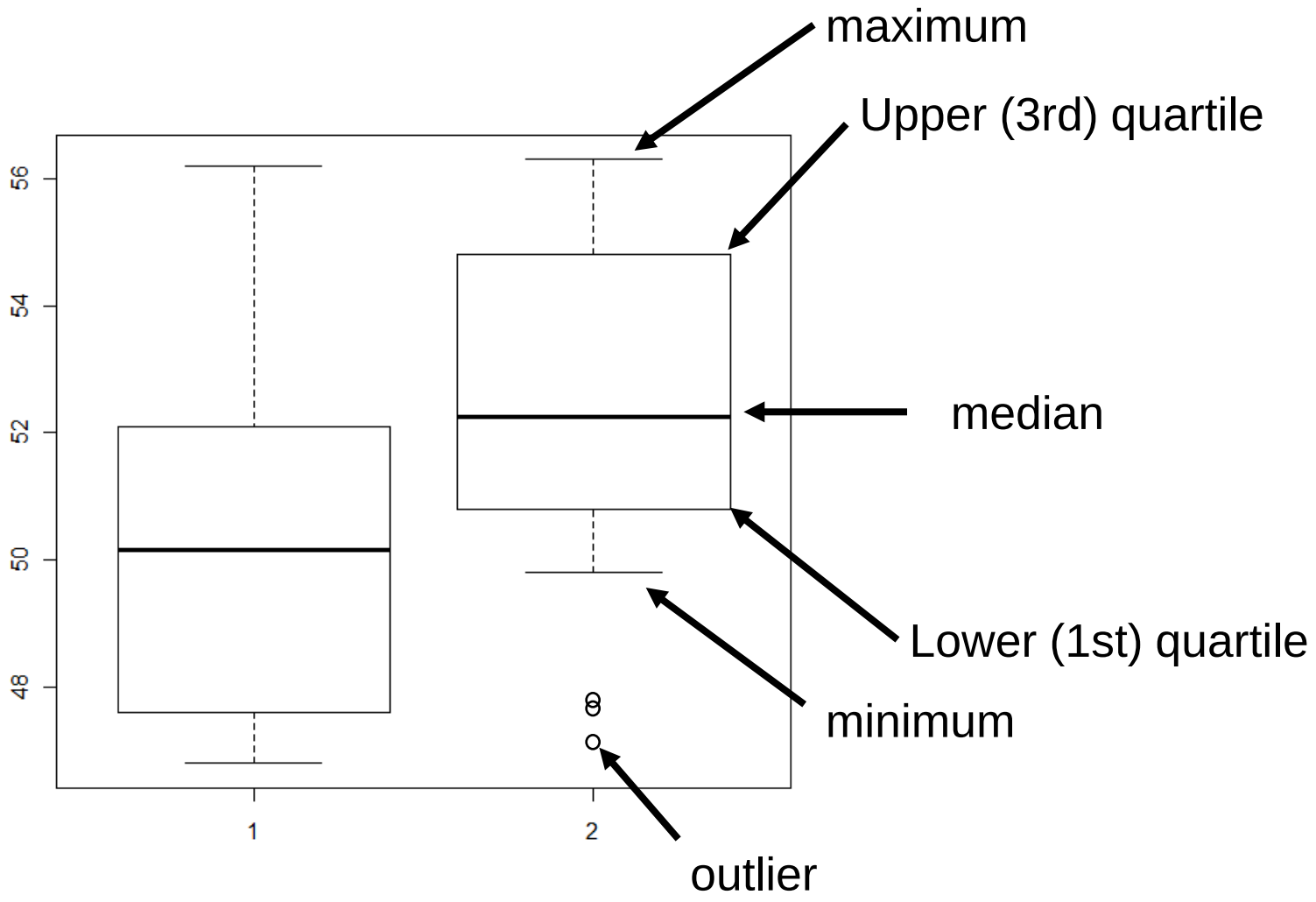
Analysis

Boxplots

Boxplot

- Also known as
  - box-and-whisker diagram
  - candlestick chart
- Quick overview of the most important values
- Most appropriate for quantitative data

Boxplot


maximum
Upper (3rd) quartile
median
Lower (1st) quartile
minimum
outlier
56
54
52
50
48
1
2

Boxplot - 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

Boxplot in Excel

Visualize distribution of results
-> Create a Box-and-Whiskers Diagram:

Calculate min/max, median, 1st/3rd quartile (e.g. values in B2:B10):

=MAX(B2:B10)
=PERCENTILE(B2:B10,0.75)
(German: =QUANTIL(B2:B10;0,75))
=MEDIAN(B2:B10)
=PERCENTILE(B2:B10,0.25)
(German: =QUANTIL(B2:B10;0,25))
=MIN(B2:B10)

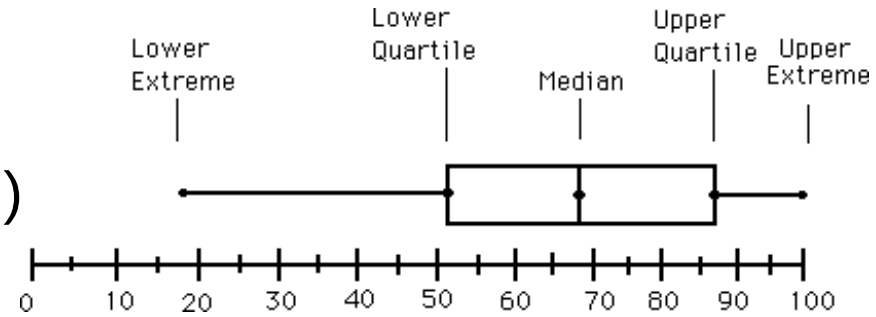


Image from http://ellerbruch.nmu.edu/cs255/jnord/boxplot.html
Tutorials: http://blog.immeria.net/2007/01/box-plot-and-whisker-plots-in-excel.html
http://www.bloggpro.com/box-plot-for-excel-2007/

Excel – Calculate absolute/relative values

Create a Box-and-Whiskers Diagram:

	web	mobile
	50.7	52.6
	46.8	50.8
	52.3	49.9
	49.6	51.9
	56.2	56.2
	47.6	52.7
	52.1	54.8
	49.3	56.3
	47.5	49.8
	51.4	51.6
Max	56.2	56.3
3rd Quartile	51.9	54.3
Median	50.2	52.3
1st Quartile	48.0	51.0
Min	46.8	49.8

absolute

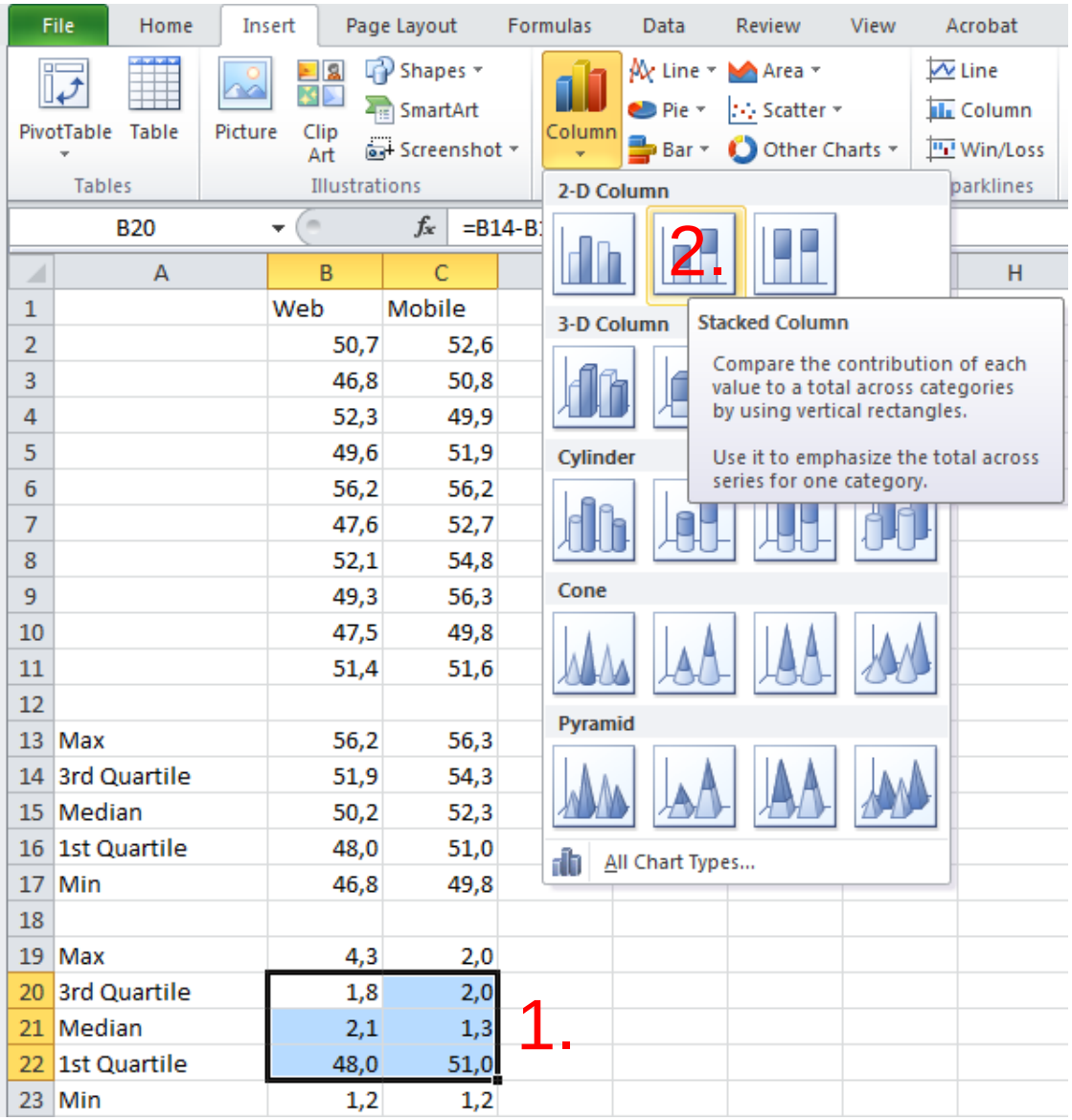
In order to create a boxplot with Excel, we do not need absolute values (left), but relative values (right)

(relative to lowest drawn box -> 1st Quartile)

Max-3rd Quartile	Max	4.3	2.0
3rd Quartile-Median	3rd Quartile	1.8	2.0
Median-1st quartile	Median	2.1	1.3
	1st Quartile	48.0	51.0
1st Quartile-Min	Min	1.2	1.2

Relative to 1st Quartile

Excel – Create a stacked column chart I

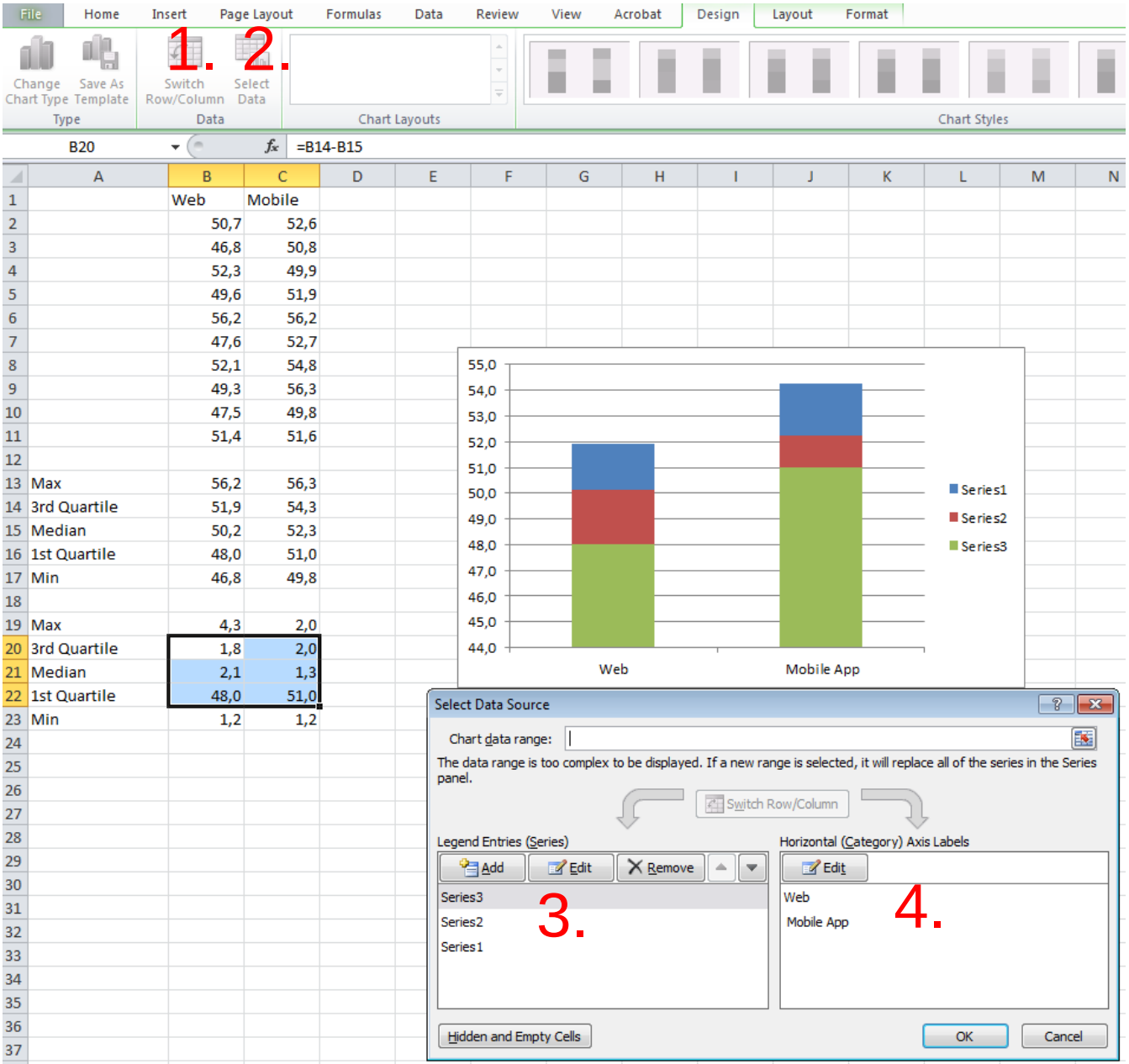


	A	B	C
1		Web	Mobile
2		50,7	52,6
3		46,8	50,8
4		52,3	49,9
5		49,6	51,9
6		56,2	56,2
7		47,6	52,7
8		52,1	54,8
9		49,3	56,3
10		47,5	49,8
11		51,4	51,6
12			
13	Max	56,2	56,3
14	3rd Quartile	51,9	54,3
15	Median	50,2	52,3
16	1st Quartile	48,0	51,0
17	Min	46,8	49,8
18			
19	Max	4,3	2,0
20	3rd Quartile	1,8	2,0
21	Median	2,1	1,3
22	1st Quartile	48,0	51,0
23	Min	1,2	1,2

1. select 3rd Quartile, Median and 1st Quartile values
2. create a stacked column chart

-> resulting chart has wrong rows/columns

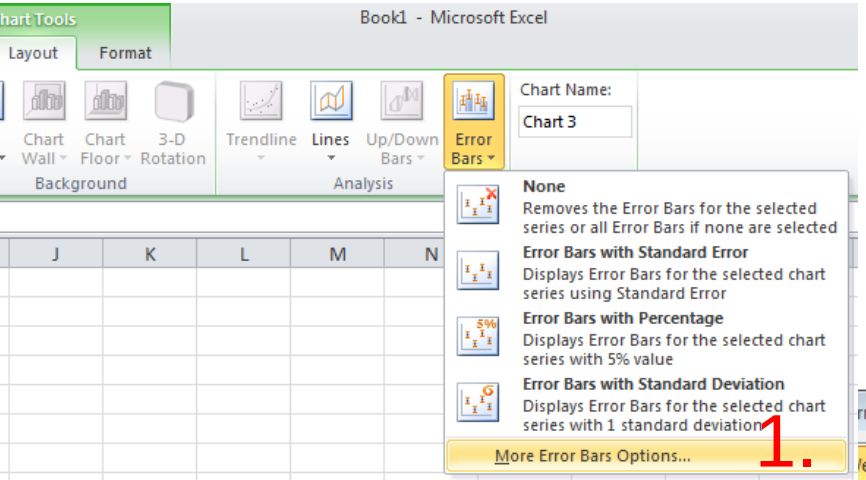
Excel – Create a stacked column chart II

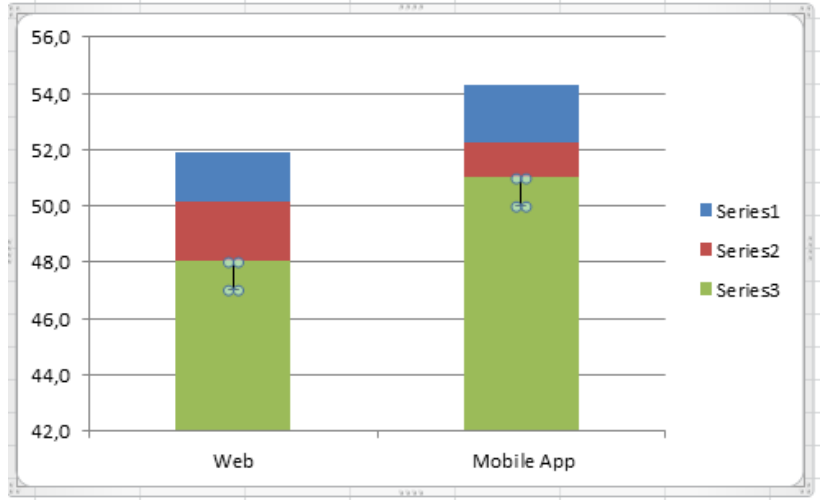


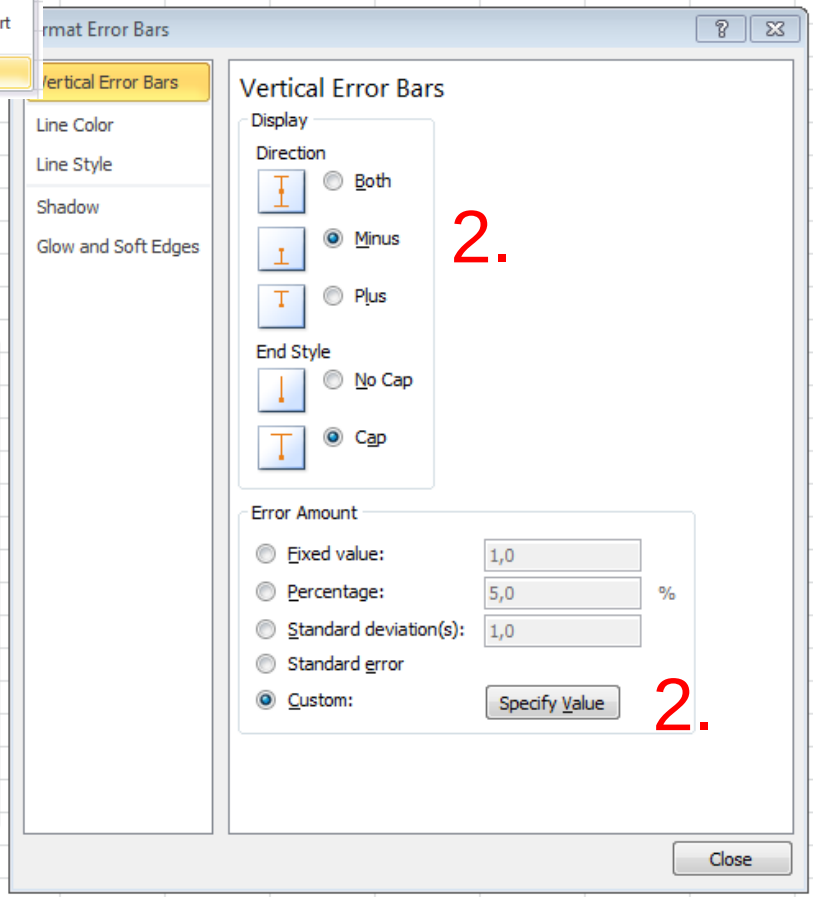
1. Switch rows and columns
2. Select data
3. Swap legend entries (1st quartile is at bottom)
4. Name labels for x-axis

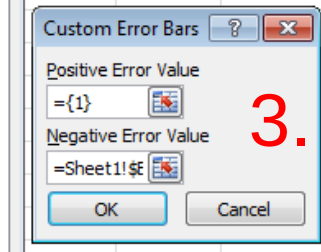
Excel – Create error bars

1. Select Chart -> Layout -> Insert error bar with more options
2. Select „Minus“ and „custom“ error amount
3. Set as negative value „Min“ values
4. Repeat for „Max“ error bar



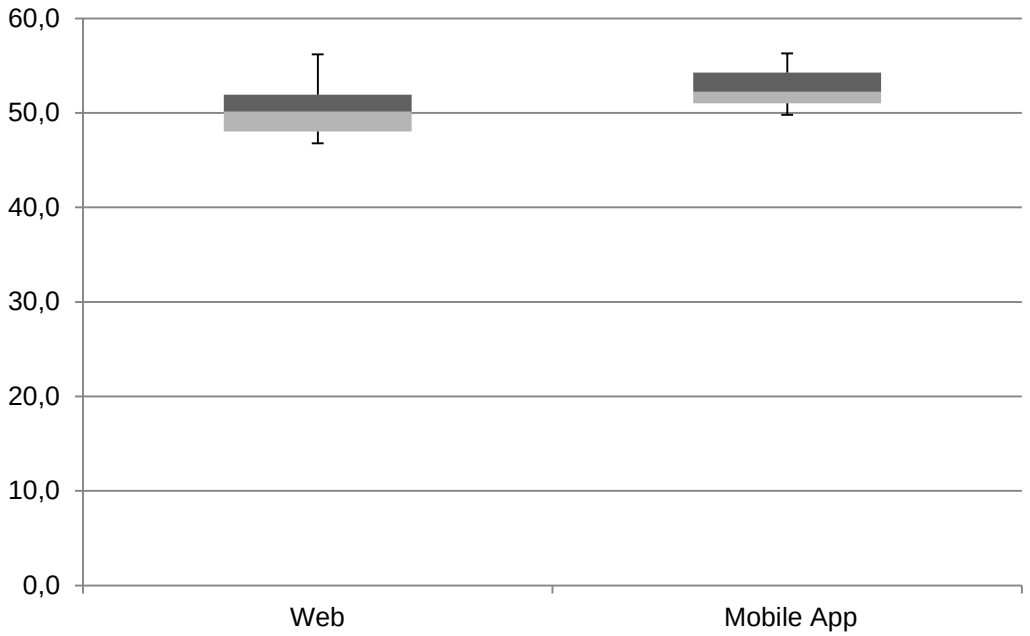






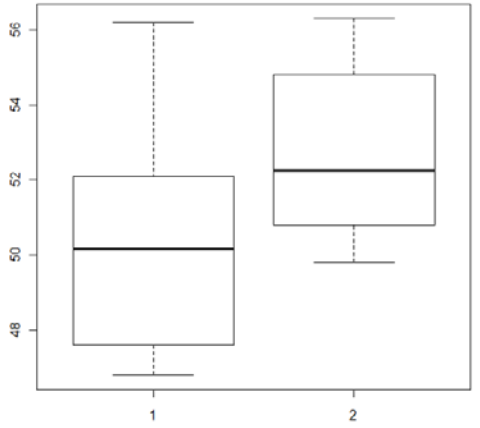
Excel – Tweak visualization

1. Select boxes of first quartile and format (no fill, no border)
2. Optional: Choose different colors
3. Admire result

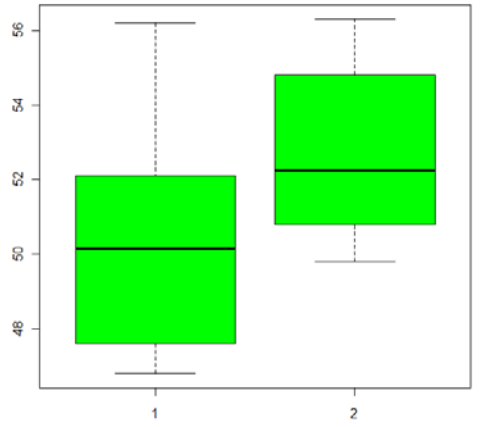


R - Boxplot

> boxplot(web,mobile)



> boxplot(web,mobile,col="green")

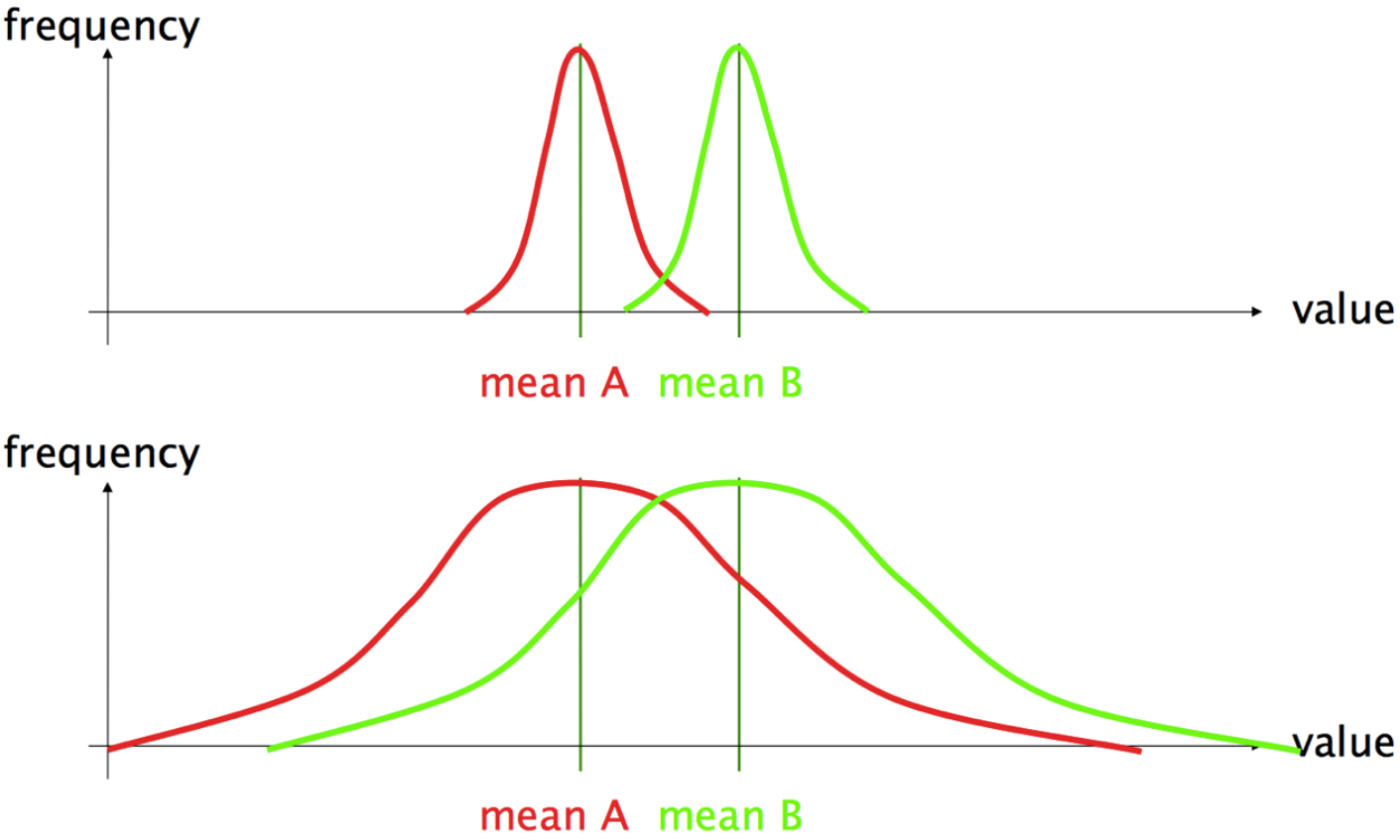


Analysis

Comparing Values

Comparing Values

- Significant differences between measurements?



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 necessarily 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

Excel – t-test

Excel-Funktion: TTEST oder T.Test (2010)

TTEST(array1,array2,tails,type)

Array1 is the first data set.
Array2 is the second data set.
Tails specifies the number of distribution tails.

- 1 one-tailed distribution (testing for a directed hypothesis, e.g. higher, larger, faster)
- 2 two-tailed distribution (difference between array1 and array2)

Type is the kind of t-Test to perform.

- 1 Paired (within subjects)
- 2 Two-sample equal variance (between subjects)
- 3 Two-sample unequal variance (between subjects)

e.g. =TTEST(B2:B11;C2:C11;2;1)

If result of t-test < 0.05 differences are significant (for 5% significance level)

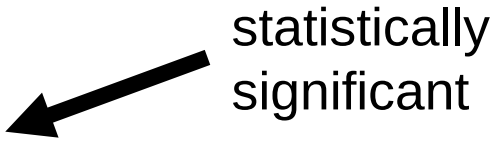
Definition from http://office.microsoft.com/de-de/excel-help/ttest-HP005209325.aspx?CTT=1

R - paired samples t-test

```
> t.test(web,mobile,paired=T)
# paired data t-test
```

```
Paired t-test

data:  mobile and web
t = -2.7197, df = 9, p-value = 0.02362
alternative hypothesis: true difference in
means is not equal to 0
95 percent confidence interval:
 -4.2314137 -0.3885863
sample estimates:
mean of the differences
                 -2.31
```



To be honest – this example was boring

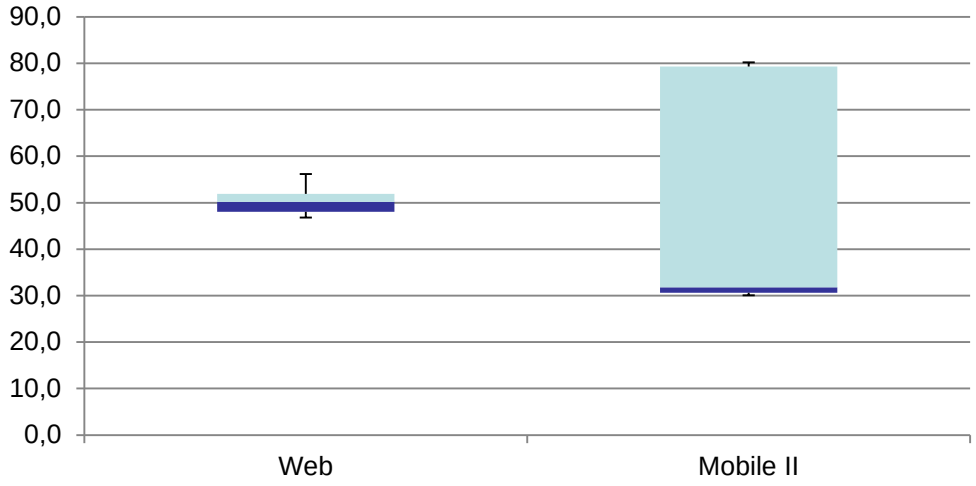
But what if results had been like this:

	Web	Mobile II
	50,7	80,2
	46,8	30,1
	52,3	30,5
	49,6	80,2
	56,2	32,4
	47,6	31,2
	52,1	78,1
	49,3	79,7
	47,5	30,2
	51,4	31,1
Average	50,4	50,4

“On average web and mobile app have the same task completion time” (!!!)

Boxplot and t-test reveal more insights

	Web	Mobile II
	50,7	80,2
	46,8	30,1
	52,3	30,5
	49,6	80,2
	56,2	32,4
	47,6	31,2
	52,1	78,1
	49,3	79,7
	47,5	30,2
	51,4	31,1
Average	50,4	50,4



p= 0,99805

- Median of mobile app is much lower (-18.4 seconds)
- but: also very high task completion times were measured (max = 80,2 seconds)

=> Look into qualitative data for explanation

ANOVA

Comparing Values with more than 2 means

Analysis of Variance (ANOVA)

- Generalization 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

Two-way repeated measures ANOVA

- **Two-way** = two or more independent variables
- **Repeated measures** = all participants contribute to all data sets

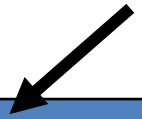
Two-way repeated measures ANOVA in R

1. Preparing the data set
2. idata frame
3. Linear model
4. Anova() function
5. Interpreting results

1. Preparing the data (e.g.: data.csv)

- One row per user!!
- One column for each possible combination of the independent variables
- Example:
  - Independent variables: Size (3 levels), Color (2 levels)
  - Dependent variable: Speed (in ms)

Needs to be exactly in this order!!



	userid	size1color1	size1color2	size2color1	size2color2	...
1	u1	2132	2881	2232	2776	...
2	u2	2205	2914	2172	2957	...
3	u3	2201	2854	2388	2601	...
...	...	...	...	...	...	...

2. idata Frame (e.g.: idata.csv)

- Used by Anova() to define the structure of the analysis
- For previous example:
  - Independent variables: Size (5 cm,8 cm,10 cm), Color (red, blue)

	Size	Color	
1	5	red	← size1color1
2	5	blue	← size1color2
3	8	red	← size2color1
4	8	blue	← size2color2
5	10	red	← size3color1
6	10	blue	← size3color2

Read the files

```
> data <- read.csv(file="data.csv")
> idata <- read.csv(file="idata.csv")
```

3. Formulate the linear model

```
> dataBind <-
    cbind(data$size1color1,data$size1color2,data$size2color1
    ,data$size2color2,data$size3color1,data$size3color2)
    # get the required columns from the original dataset

> model <- lm(dataBind ~ 1)
    # define the linear model
```

4. Anova() function

- Requires the car package (> library(car))
  - Install if necessary (> install.packages(”car"))
- Anova(mod, idata, idesign)
  - mod: the linear model
  - idata: the idata frame
  - idesign: multiplication of the independent variable

```
> analysis <- Anova(model, idata = idata, idesign = ~size * color)
```

5. Interpreting the Results

- Get the results:

```
> analysis
> summary(analysis, multivariate=FALSE)
```

```
                    SS num Df Error SS den Df          F   Pr(>F)
(Intercept) 152384401      1    16978      3 26926.5410 4.99e-07 ***
size             2712      2     2998      6     2.7133  0.14478
color         2517480      1    75815      3    99.6165  0.00214 **
size:color      25331      2    46488      6     1.6347  0.27120
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Significant main effect for color

Attention

- There are specific rules on how to report this but it is not required to do it correctly for this exercise.
- If you are interested in knowing how to correctly report the data, read:
  - A. Field, G. Hole, How to Design and Report Experiments, SAGE Publications, London, 2003.