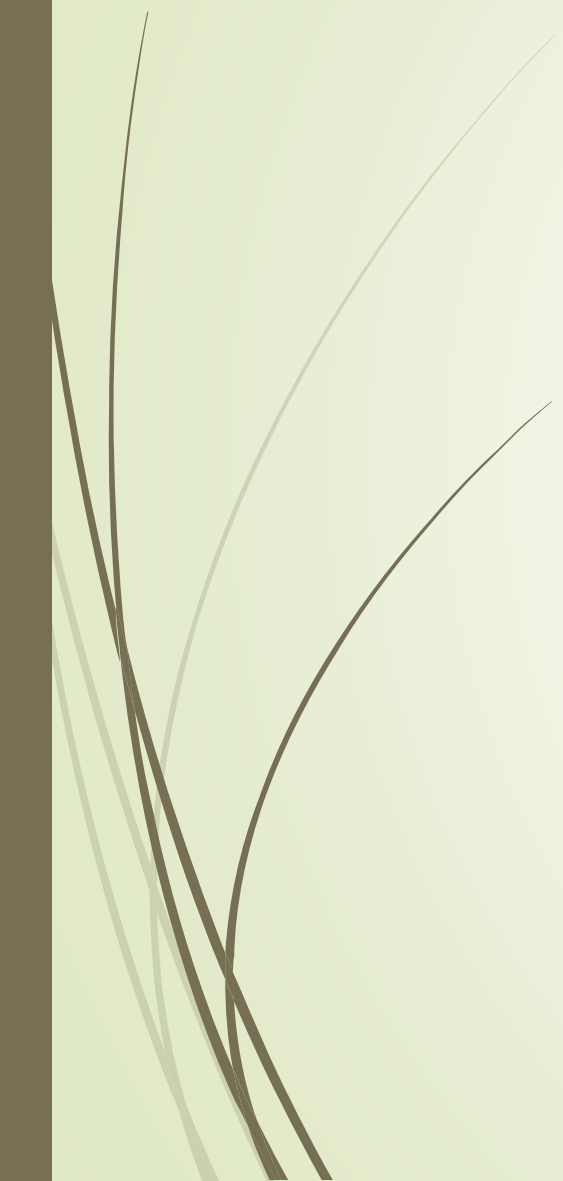
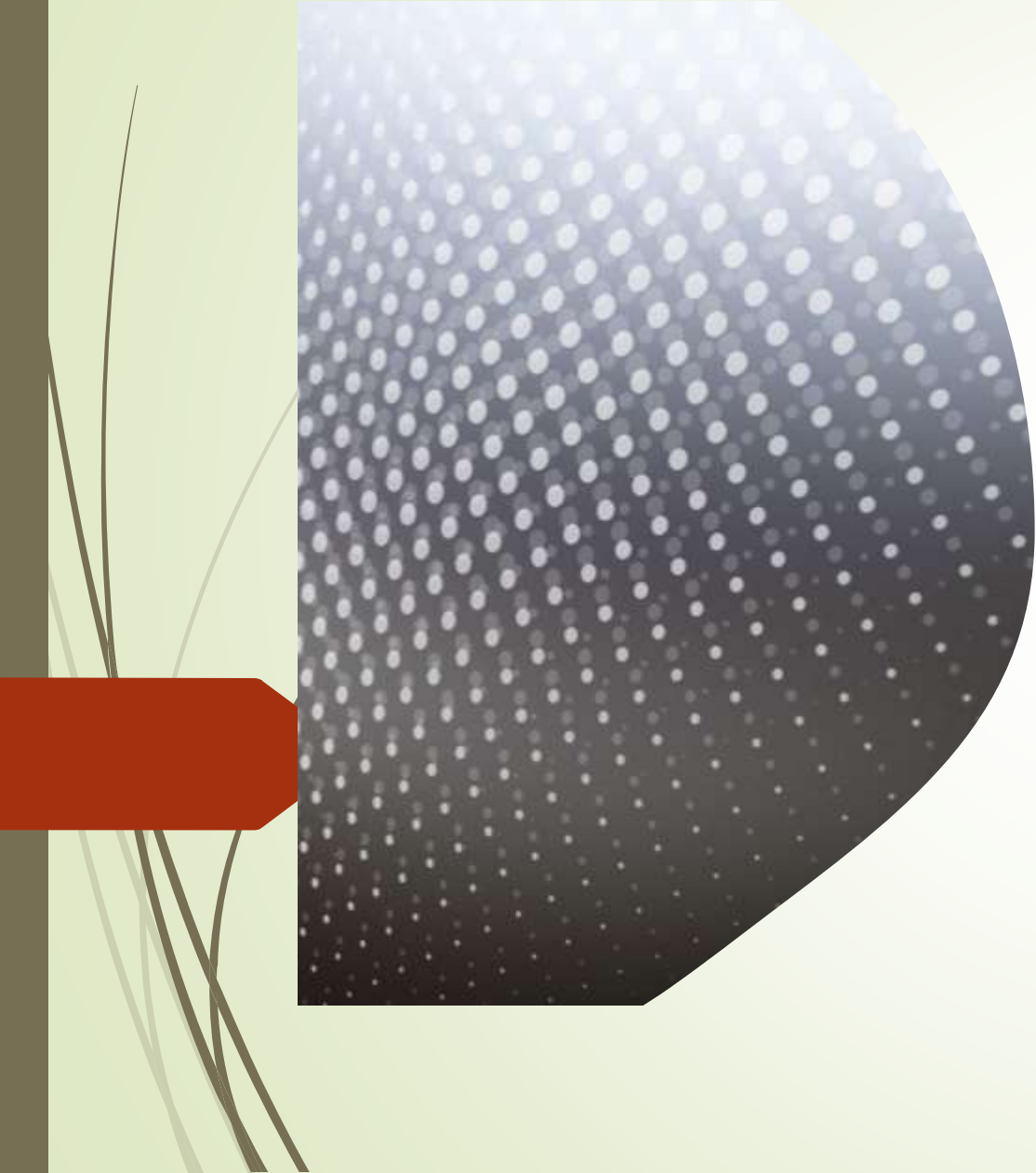




Statistical tests





Chi Square Corrections



When we
apply Chi
square?

- Two groups
- A qualitative variable of interest
- The association between two qualitative variables
- Comparing the observed distribution with theoretical distribution

Cochran rule

	G1	G2	...	Total
E1	a	b	...	a + c + ...
E2	c	d	...	c + d + ...
...	...	...	...	...
Total	a + c + ...	b + d + ...	...	a + b + c + d + ...

$$Chi^2 = \sum \frac{(O - T)^2}{T}$$

- Chi square test result is valid only when 80% of theoretical frequencies are more than 5 and all theoretical frequencies are more than 1

Theoretical contingency table – COCHRANE rule

	Group 1	Group 2	Total
Var 1	a^t	b^t	a^t+b^t
Var 2	c^t	d^t	c^t+d^t
Total	a^t+c^t	b^t+d^t	$a^t+b^t+c^t+d^t$

Theoretical table

All Values >5 – Chi
square test

One value between 2 and 5–
Yates Corrected Chi Square

More values between 0 and
5– Fisher Exact test

Yates corrected chi-square

- Yates correction, involves reducing by 0.5 units the difference between the observed and the probable frequency within the Chi square before squaring.

$$\text{Chi square} = \sum \frac{(O - T - 0,5)^2}{T}$$

Example 1

- ▶ We are studying the hypothetical association between alcohol consumption and the occurrence of hepatic cirrhosis. For that, in a sample of 32 persons we have the following distribution. What statistical test should we use?

	Cirrhosis yes	Cirrhosis no	Total
Alcohol Yes	8	4	12
Alcohol No	6	14	20
Total	14	18	32

	Cirrhosis yes	Cirrhosis no	Total
Alcohol Yes	5,25	6,75	12
Alcohol No	8,75	11,25	20
Total	14	18	32

All theoretical frequencies > 5
Chi Square test

P=0,04

Example 2

- ▶ We are studying the hypothetical association between alcohol consumption and the occurrence of hemochromatosis. For that, in a sample of 25 persons we have the following distribution. What statistical test should we use?

	Hemochromatosis yes	Hemochromatosis no	Total
Alcohol Yes	4	3	7
Alcohol No	3	15	18
Total	7	18	25

P (uncorrected) = 0,04

	Hemochromatosis yes	Hemochromatosis no	Total
Alcohol Yes	1,96	5,04	7
Alcohol No	5,04	12,96	18
Total	7	18	25

P (Yates Corrected) = 0,05

One theoretical frequency <5
Yates corrected Chi Square test

Example 3

- ▶ We are studying the hypothetical association between alcohol consumption and the occurrence of Wilson disease. For that, in a sample of 11 persons we have the following distribution. What statistical test should we use?

P (Fisher Exact test) = 0,55

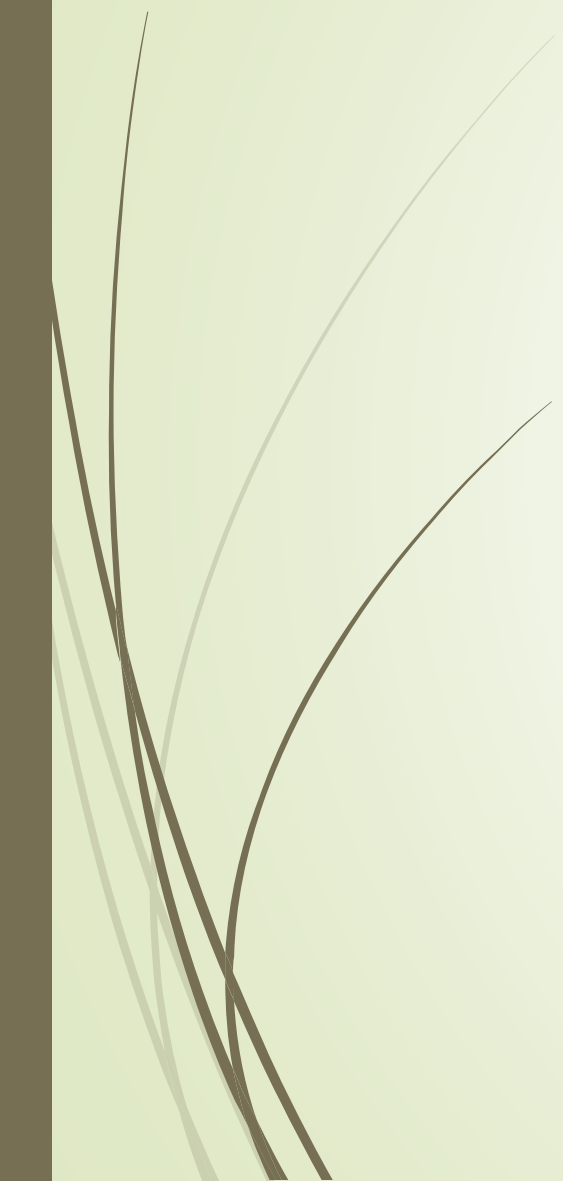
	Wilson Disease Yes	Wilson Disease No	Total
Alcohol Yes	2	3	5
Alcohol No	1	5	6
Total	3	8	11

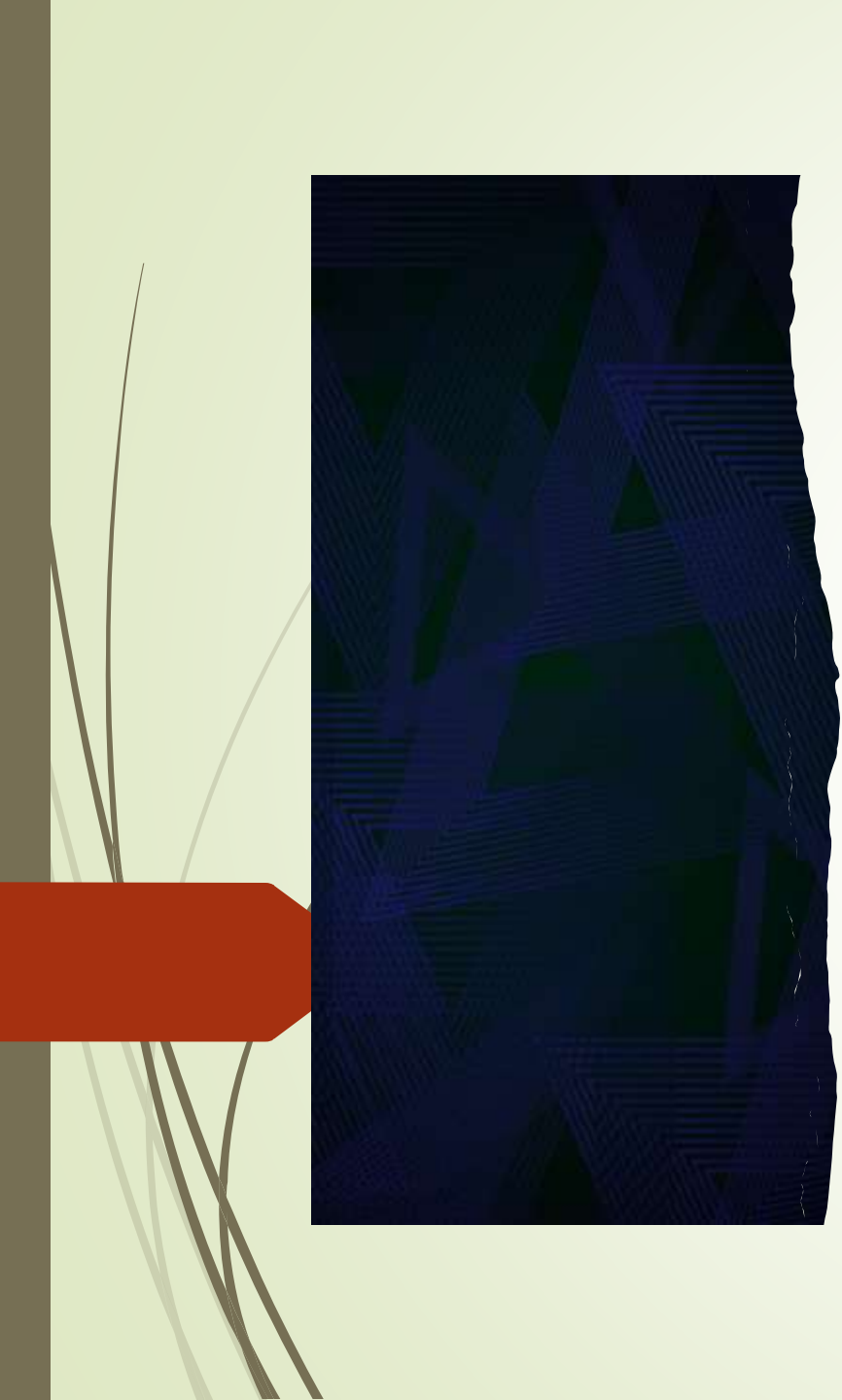
	Wilson Disease Yes	Wilson Disease No	Total
Alcohol Yes	1,36	3,64	5
Alcohol No	1,64	4,36	6
Total	3	8	11

More than one theoretical frequency <5 – Fisher exact test



Choosing the test – more than 2 samples

- Data following the normal distribution : **ANOVA test**
 - Data not following the normal distribution: **Kruskal-Wallis test**
- 



Quantitative analysis ANOVA TEST.

Choosing the appropriate test



If you have more than two groups

- ▶ Performing multiple separate t-tests increases the probability of obtaining a statistically significant result purely by chance (**Type I error**)
- ▶ **ANOVA tests one overall hypothesis:** all group means are equal. It controls the Type I error rate for this overall test.



One Way ANOVA

- More than two samples
- The main assumptions for a **one-way ANOVA** are:
 - **Continuous dependent variable:** the outcome is quantitative, such as blood pressure or weight.
 - **One categorical independent variable:** participants belong to separate groups defined by one factor, such as treatment type.
 - **Independent observations:** each participant contributes one observation and belongs to only one group.
 - **Approximately normal residuals:** the outcome is approximately normally distributed within each group, particularly when samples are small.
 - **Equal variances:** the outcome has approximately equal variances across groups.
 - **No extreme outliers:** substantial outliers within groups may distort the results.
- **Levene's test** is commonly used to assess equality of variances before ANOVA.



$P < 0,05$

- If $p < 0.05$ in a one-way ANOVA, there is evidence that **at least one group mean differs**. To identify which groups are different, perform **post hoc comparisons (Tukey's Honestly Significant Difference)**

Example

- A researcher compares **mean systolic blood pressure after treatment** in three independent groups receiving different medications. The results are summarized below.

Group	Participants	Mean Blood pressure
Treatment A	30	140 mmHg
Treatment B	35	132 mmHg
Treatment C	28	130 mmHg

- The observations are independent, distributions are approximately normal, and variances are similar.
- **One-way ANOVA**
 - $H_0: \mu_A = \mu_B = \mu_C$.
 - H_1 : At least one group mean differs.
 - Suppose the ANOVA gives **$p < 0.001$** . We reject H_0 , but this result does not identify which groups differ

Example

Group	Participants	Mean Blood pressure
Treatment A	30	140 mmHg
Treatment B	35	132 mmHg
Treatment C	28	130 mmHg

- ▶ Tukey's HSD analysis
- ▶ The post hoc results are:

Comparasion	Mean difference	Adjusted p	Significant at 0.05?
A-B	8 mmHg	0.002	yes
A-C	10 mmHg	<0.001	yes
B-C	2 mmHg	0.65	no

- ▶ Interpretation: Mean blood pressure is significantly higher with Treatment A than with either B or C. There is insufficient evidence of a difference between B and C



Two-way ANOVA

- ▶ Examines two factors and their interaction
- ▶ Examining how treatment and gender affect blood pressure
- ▶ **Two-way ANOVA tests three questions:**
 - ▶ **Main effect of medication:** Does mean blood pressure differ among medications, averaging across sex?
 - ▶ **Main effect of sex:** Does mean blood pressure differ between females and males, averaging across medications?
 - ▶ **Interaction between medication and sex:** Does the effect of medication differ depending on sex?



Two-ways ANOVA prerequisites

- **One continuous dependent variable**, such as blood pressure.
- **Two categorical independent variables (factors)**, such as medication type and sex, each with at least two levels.
- **Independent observations**: each participant contributes one measurement and belongs to only one combination of factor levels.
- **Approximately normally distributed residuals**: outcomes within each combination of factor levels should be approximately normal, particularly with small samples.
- **Equal variances across cells**: for example, similar blood pressure variances in all six medication-by-sex groups.
- **No extreme outliers** that could substantially distort the results.
- **Multiple observations per cell** to estimate within-group variability and test the interaction between the factors.
- **Levene's test** is commonly used to assess equality of variances before ANOVA.

Example

- A researcher studies how **medication type** and **gender** affect systolic blood pressure after treatment.
- **Factor 1:** Medication—A, B, or C.
- **Factor 2:** Gender—female or male.
- **Dependent variable:** Systolic blood pressure (mmHg)

Gender	Medication A	Medication B	Medication C
Female	140 mmHg	130 mmHg	120 mmHg
Male	142 mmHg	132 mmHg	122 mmHg

Two-Way Anova result

Effect	p	Interpretation
Medication	<0.001	There is evidence that mean blood pressure differs among medications. Follow with Tukey's comparisons to identify which medication pairs differ.
Gender	0.12	There is insufficient evidence of a difference in mean blood pressure between females and males, averaging across medications.
Medication x Gender	1	There is insufficient evidence that the effect of medication differs by sex. Here, the medication differences are identical in both sexes



Repeated-measures ANOVA

- Compares measurements taken from the same participants across times or conditions
- Comparing blood pressure before, during, and after treatment

Example

A researcher measures **systolic blood pressure in the same eight patients** before treatment, after four weeks, and after eight weeks.

Mean before	Mean after 4 weeks	Mean after 8 weeks
155.5 mmHg	149.38 mmHg	145 mmHg

- Use a **one-way repeated-measures ANOVA** because the same patients are measured at three time points.
- H_0 : Mean blood pressure is equal at all three time points.
- H_1 : At least one time point has a different mean.
- If the ANOVA gives $p < 0.05$, conclude that mean blood pressure differs across time. Follow with **paired comparisons adjusted for multiple testing**, such as paired t-tests with a Holm correction, to identify which time points differ.



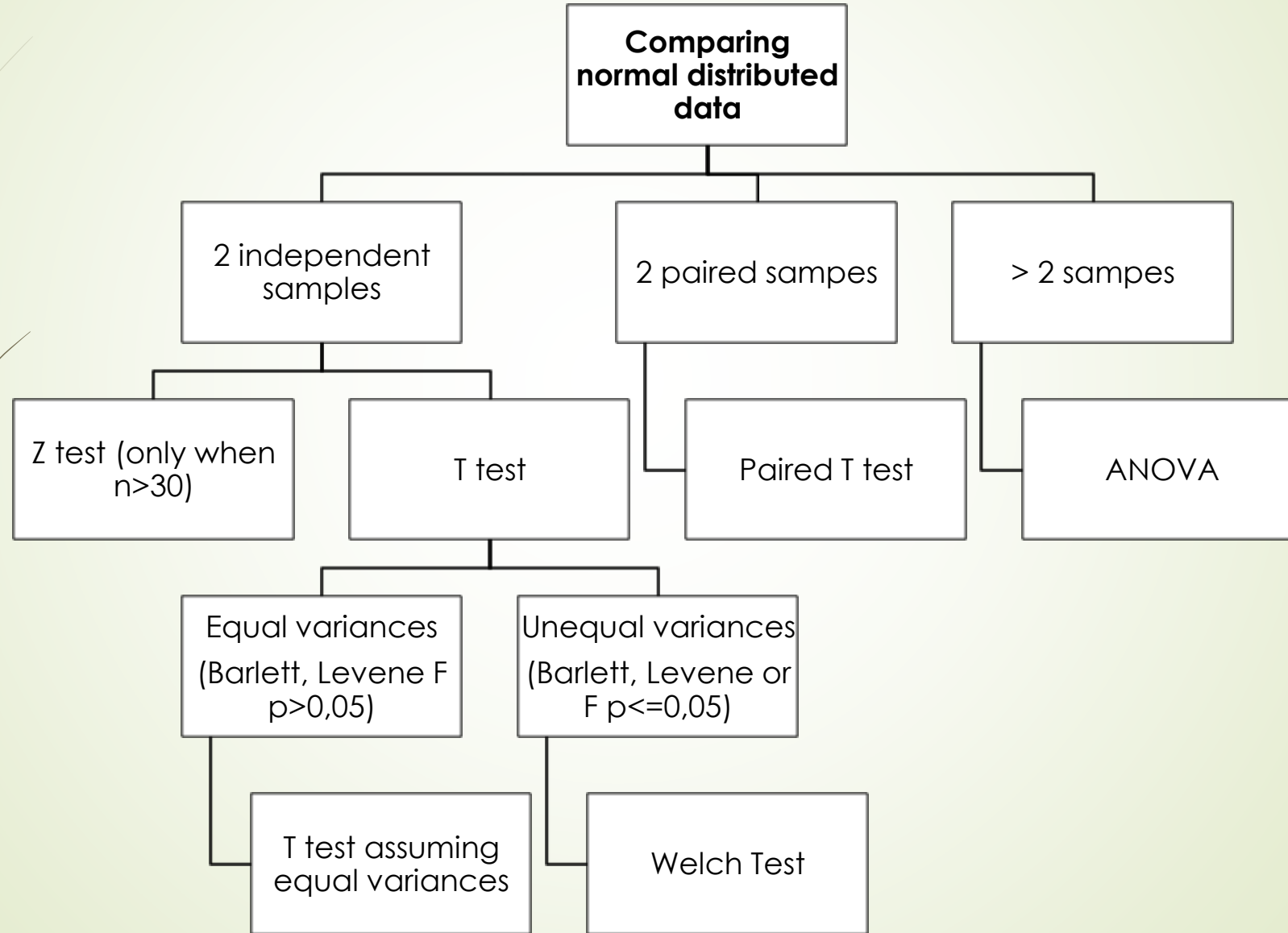
Welch's ANOVA

- ▶ Compares independent group means when variances are unequal
- ▶ Comparing three treatment groups with different variances

AND SO ON...

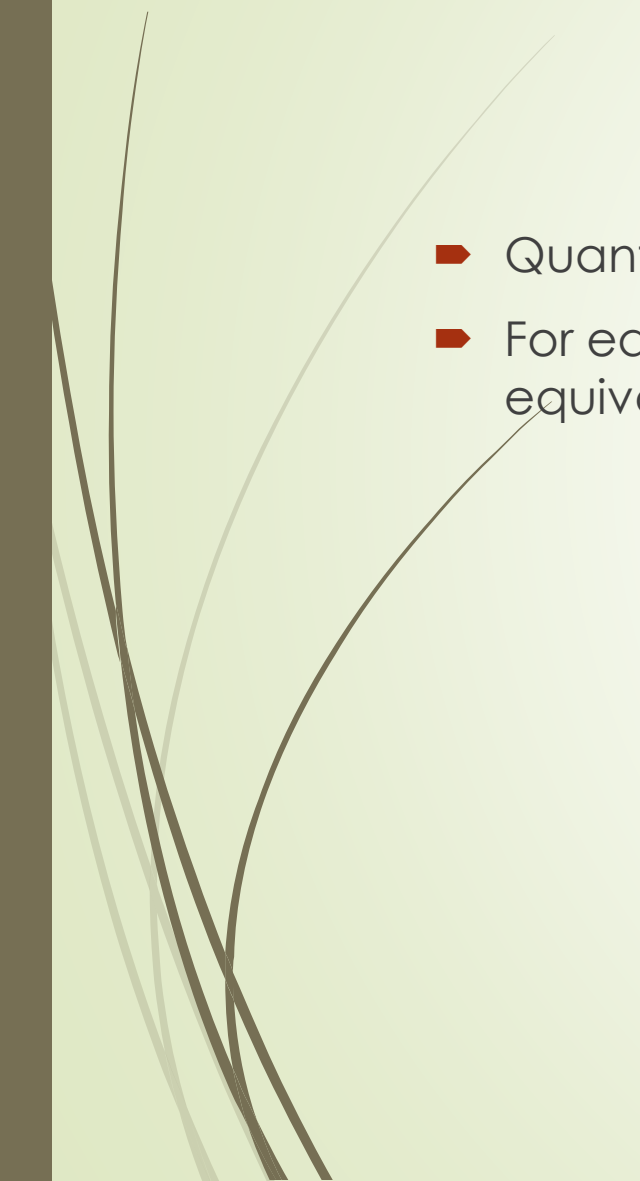
Type	Independent Variables	Dependent Variables	Assumptions	Unique Feature
One-way ANOVA	1 Categorical	1 continuous	Independent observations, normality, homogeneity of variances, no significant outliers	compares 3 or more groups
Two-way (n-way) ANOVA	2 (n) Categorical	1 continuous	Independent observations, normality, homogeneity of variances, no significant outliers	Tests interactions
Repeated Measures ANOVA	1 within-subjects IV	1 continuous	Sphericity, normality	Same participants in all conditions hence fewer participants
One-way MANOVA	1 Categorical	2 continuous	multivariate normality, homogeneity of variance-covariance matrices, no multicollinearity	Analyzes multiple DVs simultaneously
ANCOVA	1 categorical + 1 continuous covariate	1 continuous	Independent observations, linearity, homogeneity of regression slopes	Adjusts for confounding

Choosing the test– quantitative normal distributed data





Non-parametrical tests

- Quantitative variables, data are not normal distributed
 - For each parametrical test we have the non-parametrical equivalent
- 

Parametrical and non-parametrical tests

Parametrical test	Non-parametrical equivalent test
Z, ANOVA	Kruskal-Wallis
Student (independent samples) First apply test for variances F, Levine, Barlet, etc.	Mann-Whitney U Mann-Whitney-Wilcoxon Wilcoxon-Mann-Whitney Wilcoxon rank-sum
Student (paired samples)	Wilcoxon signed-rank

Choosing the test – quantitative variables

