ARISTOTLE UNIVERSITY
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FACULTY OF HEALTH SCIENCES - SCHOOL OF MEDICINE

MSc Health Statistics and Data Analytics

Repeated measures analysis

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Statistical tests

Testing for...	Parametric	Non-Parametric Equivalent
Differences between the means of two independent groups	Independent t-test	Mann-Whitney test
Differences between paired (matched) samples e.g. weight before and after a diet for each subject	Paired t-test	Wilcoxon signed rank test
Differences in the means of 3+ independent groups for one variable	One-way ANOVA	Kruskal-Wallis test
Differences between 3+ measurements on the same subject	Repeated Measures ANOVA	Friedman test

Objectives

- Choose appropriate statistical procedure to compare a continuous outcome between more than two dependent groups
- Know the assumptions of repeated measures ANOVA
- Recognize when a Friedman test should be used instead
- Conclude on your hypothesis based on the test results

Repeated measures ANOVA

- One categorical variable with more than 2 categories (often time 1, time 2, time 3…)

- One continuous variable measured for each participant at all “times”

Null Hypothesis: No change in mean score across the groups (ie, no change over “time”)

Ho: $\mu_1=\mu_2=\mu_3=\ldots$

Alternative Hypothesis: There are mean differences among the groups

Ha: At least one group mean (μ) is different from another

Assumptions of Repeated measures ANOVA

- Continuous variable is normally distributed in each group.
- No outliers
- Sphericity: all possible differences between times have the same variances.

  e.g. Variance(time2 – time1) = Variance(time3 - time1) = Variance(time3 – time2)

  - Check for sphericity (Mauchly's Test)
    - If P>0.05 then repeated measures ANOVA
    - If P<0.05 then repeated measures ANOVA with corrected df (Greenhouse-Geisser Correction)

Sphericity-Example

Time 1	Time 2	Time 3	1-2	1-3	2-3
10	12	8	-2	2	4
15	15	12	0	3	3
25	30	20	-5	5	10
35	30	28	5	7	2
30	27	20	3	10	7
		Variance	**15.7**	**10.3**	**10.7**

Sphericity is met when these variances are roughly equal. In these data there is some deviation from sphericity because the variance of the differences between times 1 and 3 (15.7) is greater than the variance if the differences between 1 and 3 (10.3) and between 2 and 3 (10.7).

If Mauchly's test statistic is significant: the condition of sphericity has not been met

If Mauchly's test statistic is not significant then it is reasonable to conclude that the variances of differences are not significantly different

Repeated measures ANOVA-Example

Subject	Time 1 (0 mins)	Time 2 (30 mins)	Time 3 (60 mins)	Time 4 (120 mins)
1	96	92	86	92
2	110	106	108	114
3	89	86	85	83
4	95	78	78	83
5	128	124	118	118
6	100	98	100	94
7	72	68	67	71
8	79	75	74	74
9	100	106	104	102
Mean	**96.56**	**92.56**	**91.11**	**92.33**
SD	16.4	17.8	17.2	16.5

Short-term effect of enalaprilat on heart rate, beats per minute

Repeated measures ANOVA-Example

- 1st Normality assumption-We assume that the assumption of normality is not violated

- 2nd Sphericity assumption

  H_0: sphericity
  H_α: no-sphericity

Machly's test->p-value=0.412-The assumption of sphericity is not violated. As a result, there is no need to use Greenhouse-Geisser correction

- The null hypothesis is that the mean heart rates are equal at different time points

$$H_0: 96.56=92.56=91.11=92.33$$

- The alternative is that at least one of them is different

$$H_\alpha: \mu_i \neq \mu_j \ , \ i,j=1, 2, 3,4$$

- Rejection of the H_0 will not tell us which means are different from each other : this is an overall test that we do!

Repeated measures ANOVA-Example

- The p-value from the repeated measures ANOVA test is 0.018

- Post hoc analysis is needed to determine which means are different

  Post hoc analysis:

  - Perform multiple related samples t-Tests with the Bonferroni/Tukey correction method

Retuning to our example:

```
# A tibble: 6 x 10
  .y.        group1 group2    n1    n2 statistic    df     p p.adj p.adj.signif
* <chr>      <chr>  <chr>  <int> <int>     <dbl> <dbl> <dbl> <dbl> <chr>
1 heart_rate t0     t120       9     9      2.43      8 0.041 0.248 ns
2 heart_rate t0     t30        9     9      2.05      8 0.074 0.447 ns
3 heart_rate t0     t60        9     9      2.63      8 0.03  0.181 ns
4 heart_rate t120   t30        9     9     -0.142     8 0.89  1     ns
5 heart_rate t120   t60        9     9      0.866     8 0.412 1     ns
6 heart_rate t30    t60        9     9      1.48      8 0.176 1     ns
```

Friedman test

- The Friedman test is a non-parametric statistical procedure for comparing more than two samples that are related or dependent

- The parametric equivalent to this test is the repeated measures analysis of variance(ANOVA)

- It is used to test differences between groups when the dependent variable being measured is ordinal. It can also be used for continuous data when normality assumption is being violated