CHAPTER 9. ANALYSIS OF VARIANCE (TWO-WAY)

9.1. Recap: One-way Analysis of variance

9.2. What is “Two-Way Analysis of Variance”?

9.3. How can I interpret the results of a “Two-way ANOVA”?

1. Example Magazines (Dataset 1)
2. Example Magazines (Dataset 2)
3. Example Magazines (Dataset 3)
4. Example Magazines (Dataset 4)

Chapter 9: Assignments

1. **The director of a university department wishes to see whether there is a difference in the knowledge of students of a course, depending on the teaching method used (1 or 2), and professor that teaches the course (A or B). Four students from each professor and teaching method are randomly selected and they are asked to attend to a single exam. Is there a significant effect of the professor and the teaching method on the student´s results? Which professor and/or method provided the best results?**

	Professor A	Professor B
Method 1	20, 25, 22, 29	30, 32, 35, 29
Method 2	15, 18, 22, 21	21, 27, 18, 15

- When you don't have any confidence level, then it is 95%=0,05. In this case we have written the following code to find the significant difference.

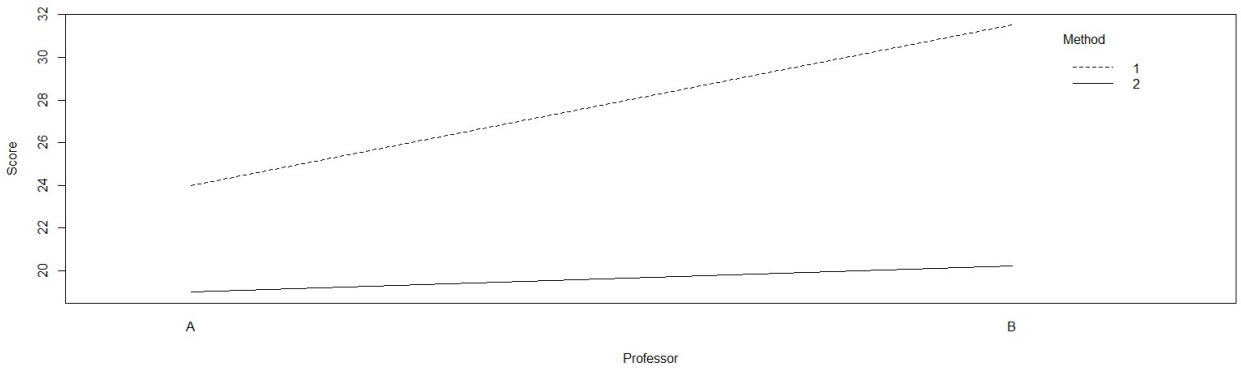
```
1  Two_way_anova_UniversityDepartment = aov(Score ~ Method + Professor + Method*Professor, data=UniversityDepartment)
2  summary(Two_way_anova_UniversityDepartment)
```

- Afterwards, we can see that out of this code we have got the following results of the summary.

```
> summary(Two_way_anova_UniversityDepartment)
                Df Sum Sq Mean Sq F value  Pr(>F)
Method           1 264.06  264.06  18.030 0.00114 **
Professor        1  76.56   76.56   5.228 0.04120 *
Method:Professor 1  39.06   39.06   2.667 0.12838
Residuals       12 175.75   14.65
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- In this case, we can interpret the following p-value (Pr(>F)) as followed:
    - Method: Because the p-value is significantly lower than the confidence level then there is a significant effect of Method on the score.
    - Professor: Whereas if we look closer, then the p-value is lower than the confidencelevel of 0,05, and therefore we can say that there is a significant effect of Professor on the score.
    - Method:Professor: In this case, we can see that the p-value is greater than 0,05, which tells us that there isnt any significance.
- Now, we will try and write our interactionplot.

```
interaction.plot(UniversityDepartment$Professor, UniversityDepartment$Method, UniversityDepartment$Score, xlab = "Professor", ylab ="Score", trace.label="Method")
```



- According to the graph, we can see that the Method 1 is greater at the right end compared to method 2. Whereas if you look at the Professor B, he is also at the right end, under Method 1. This results in a higher score.

2. **A gardening company is testing new ways to improve plant growth. Plants are randomly selected and exposed to a combination of two factors, a "Light" in two different strengths and a plant food supplement with two different mineral supplements. After a number of weeks, the plants are measured for growth and the results (in cm) are the following. Which combination of light and supplement provides the best results?**

	Supp. 1	Supp. 2
Light 1	26.7 25.2	28.6 29.3
Light 2	32.3 32.8	26.1 24.2

- We will go to Excel and try to create a new file where write all the dataset.
- Afterwards, we will import the file into R. (REMEMBER THAT THE FACTORS "HAVE" TO BE CHARACTERS, OTHERWISE PROBLEMS CAN HAPPEN).

```
Two_way_anova_GrowthPlants = aov(Growth ~ Light + Supp + Light*Supp, data=GrowthPlants)
summary(Two_way_anova_GrowthPlants)
```

- The following results have come up:

```
            Df Sum Sq Mean Sq F value  Pr(>F)
Light        1   3.92    3.92   4.752 0.09477 .
Supp         1   9.68    9.68  11.733 0.02665 *
Light:Supp   1  54.08   54.08  65.552 0.00126 **
Residuals    4   3.30    0.82
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

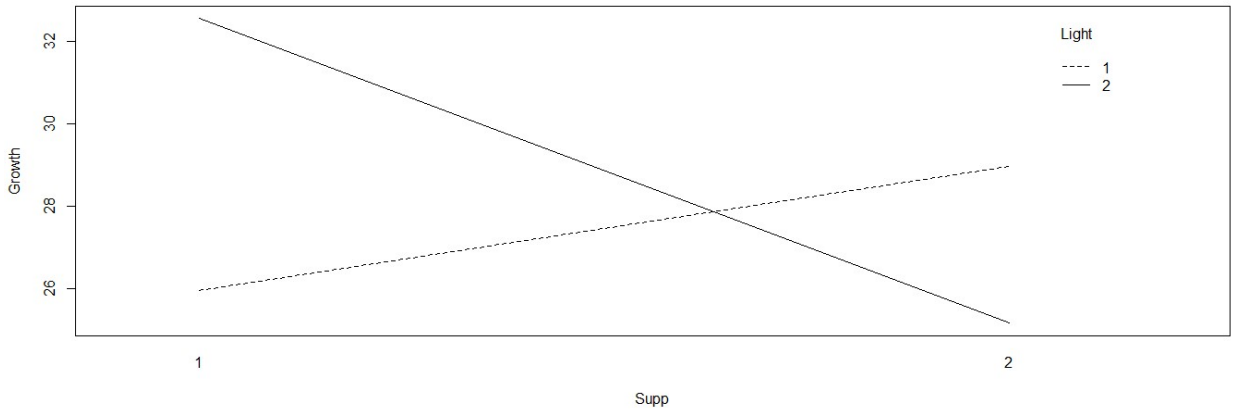
- We can see, that because we have got a signifance level, then we will consider it to be 95% =0,05. In this case we can interpret the following values:
    - Light: The p-value is 0,94, which is higher than 0,05. No significance

- Supp: The p-value is 0,02, which is lower than 0,05. Yes significance
- Light:Supp: The p-value is 0,001, which is lower than 0,05. Yes significance

- Now we will write the interactionsplot.

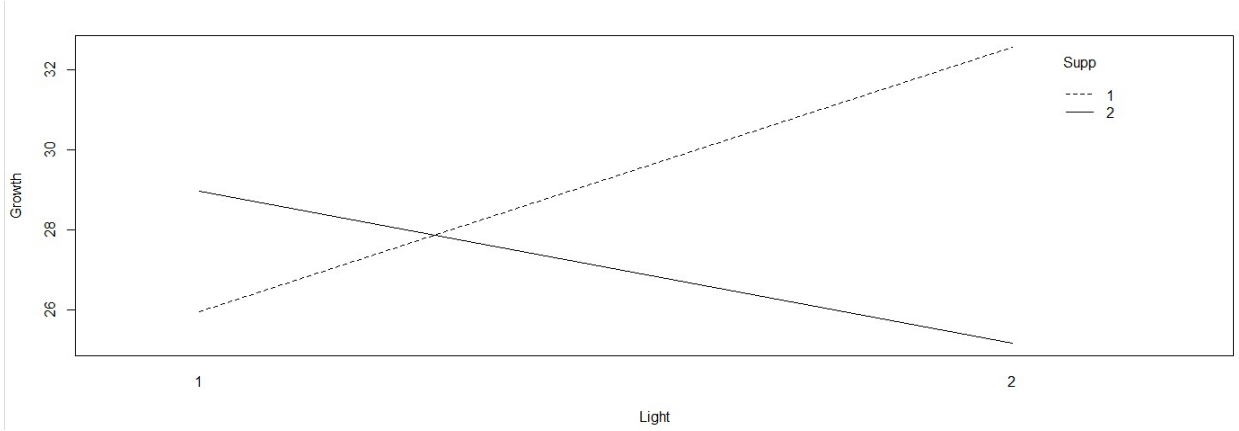
```
interaction.plot(GrowthPlants$Supp, GrowthPlants$Light, GrowthPlants$Growth, xlab = "Supp", ylab ="Growth", trace.label="Light")
```

- The following is giving us a interactionplot.



- In this case we can see that the plot is overlapping eachother, therefore we will change the names of the code in the interaction plot.

```
interaction.plot(GrowthPlants$Light, GrowthPlants$Supp, GrowthPlants$Growth, xlab = "Light", ylab ="Growth", trace.label="Supp")
```



- We can in this case see, that the combination of Supplyment 1 and Light 2 is the best for the growing of Plants.

3. **Two types of paint (A and B), were tested to see how many months they lasted before it began to peel. They were tested in two climatic conditions to study the effects of climate on the paint. Each group contained five test panels. At α=0.01, analyze the data shown. Which paint lasts longer and in which climate?**

- We will start by writing the code again.

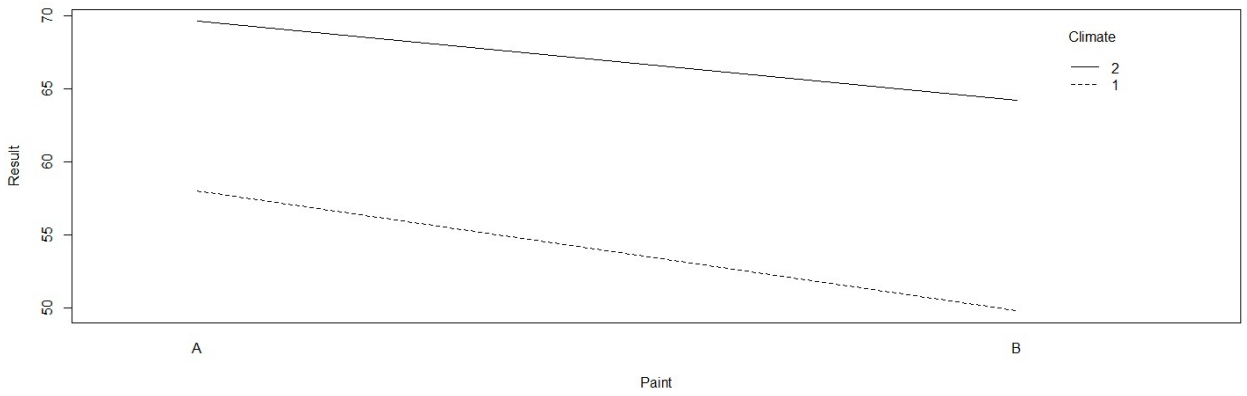
```
Two_way_anova_Paint = aov(Result ~ Paint + Climate + Paint*Climate, data=Paint)
summary(Two_way_anova_Paint)
```

- Now we will look at the results:

```
             Df Sum Sq Mean Sq F value  Pr(>F)
Paint         1  231.2   231.2   3.035 0.10067
Climate       1  845.0   845.0  11.093 0.00424 **
Paint:Climate 1    9.8     9.8   0.129 0.72452
Residuals    16 1218.8    76.2
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

- We can say the following about the results, with the confidence level of 95%=0,05.
    - Paint: The p-value is greater than 0,05, which is not significantly different.
    - Climate: The p-value is lower than 0,05, which is significantly different.
    - Paint:Climate: The p-value is greater than 0,05, which is not significantly different.
- Now we will plot the interactiongraph, with the following code:

```
interaction.plot(Paint$Paint, Paint$Climate, Paint$Result, xlab = "Paint", ylab ="Result", trace.label="Climate")
```



- The graph shows us that the Climate 2 is better than Climate 1.

	Climate 1	Climate 2
Paint A	60, 53, 58, 62, 57	58, 66, 68, 76, 80

Paint B	36, 41, 54, 65, 53	58, 63, 79, 55, 66