

A2- Exercise1 and 2

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Exercise 1

a. Randomized design

A randomized design with two categorical factors, with

1. the first factor having three categorical levels and
2. the second factor having two levels and
3. having three samples for each unique categorie

can be produced with the following R code:

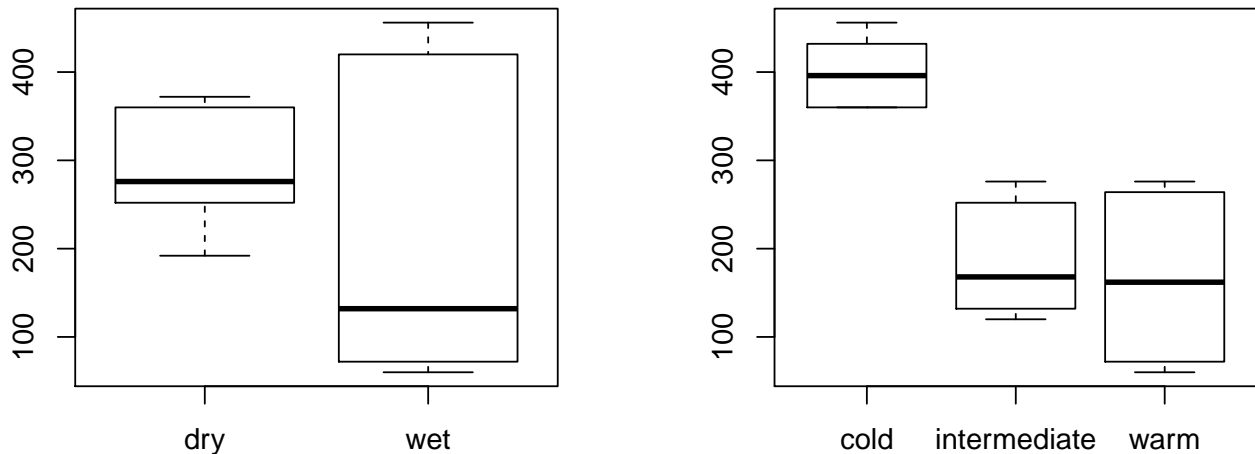
```
I=3; J=2; N=3  
rbind(rep(1:I,each=N*J),rep(1:J,N*I),sample(1:(N*I*J)))
```

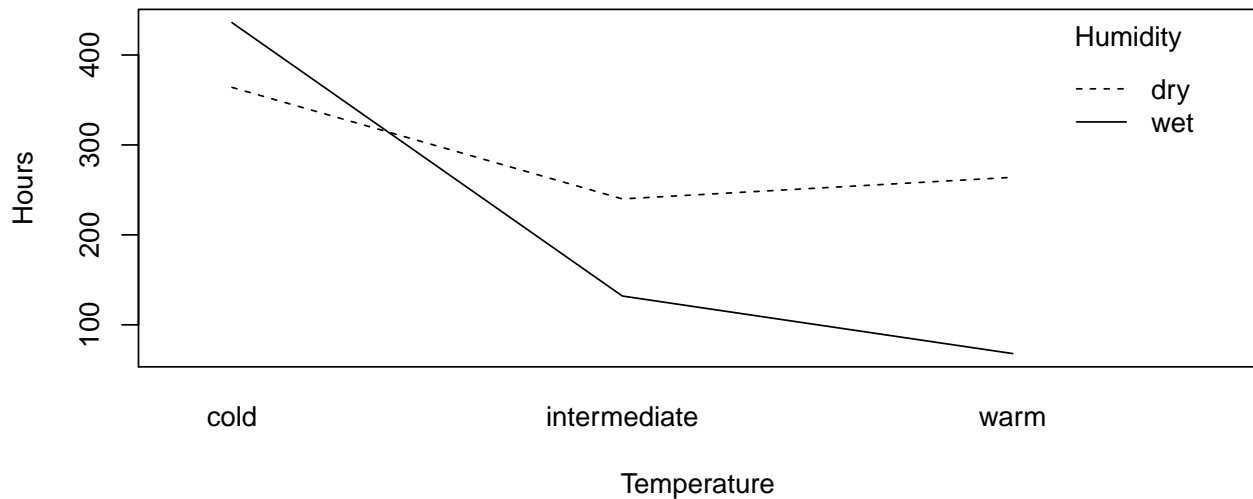
b. Plotting

The boxplot and interaction plot below confirms our intuition:

1. A cold environment causes a much slower decay
2. Wet bread has a much wider distribution (variance)
3. On average dry bread decays slower than wet bread
4. However, wet and cold (frozen) bread has the slowest decay

From the non-parallel lines in the interaction plot and the wide distribution of the wet sample we conclude that the (wet) humidity amplifies the effect of the temperature and thus it can be explained by the strong interaction between the two factors (opposed to the errors in the measurement).





c. Two way ANOVA

From the two-way anova result below, we can conclude that both factors have a main effect on the decay time of bread. It can also be concluded that the factors have an interaction effect.

```
## Analysis of Variance Table
##
## Response: hours
##
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
humidity	1	26912	26912	62.296	4.316e-06 ***
environment	2	201904	100952	233.685	2.461e-10 ***
humidity:environment	2	55984	27992	64.796	3.705e-07 ***
Residuals	12	5184	432		

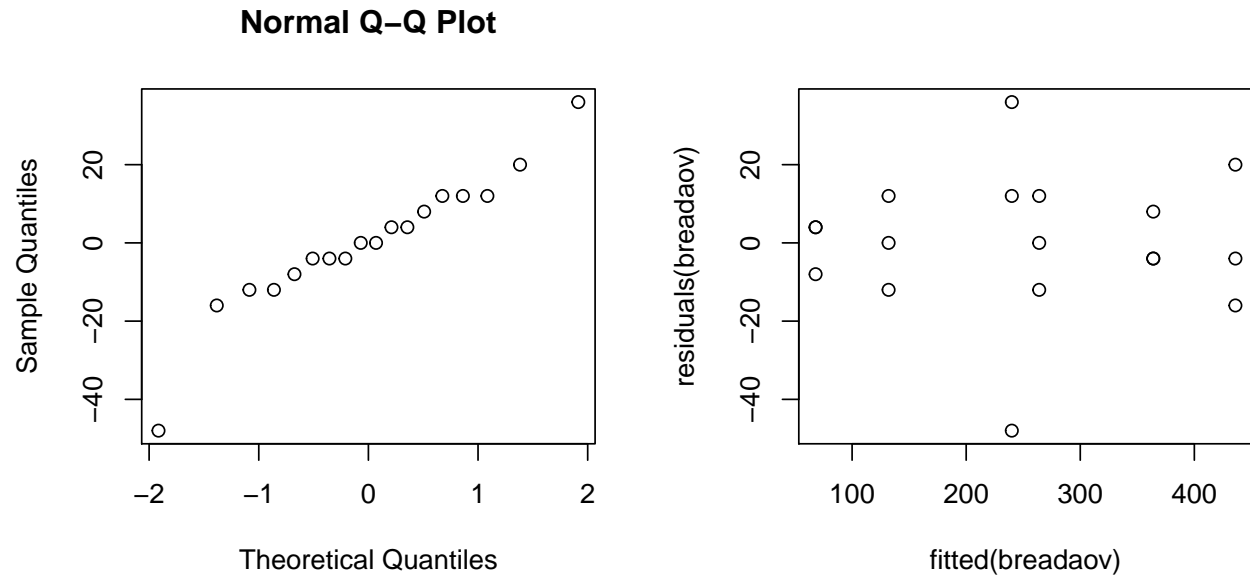
```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

d. Coefficients – need review —

According to the means of squares, on average the environment has the biggest effect on the decay. However this can not be concluded so easily, because it is being compared to one base (the first category), instead of a more comprehensive analysis.

e. Diagnostics

The first requirement is that for each unique category, there should be at least 2 samples, which is the case. Then the most important requirement is that the data among the factors should approximately have equal variances. This has been tested in b. and the conclusion was that they approximately were the same. A different test we can do after the ANOVA test, is check whether the error is normally distributed, which is to be expected of a random variable. In the following QQplot it can be seen that the residuals are approximately normally distributed. And in the fitted residuals plot it can be seen that the spread is approximately the same among the fitted values, however there are 2 outliers in the middle.



Exercise 2

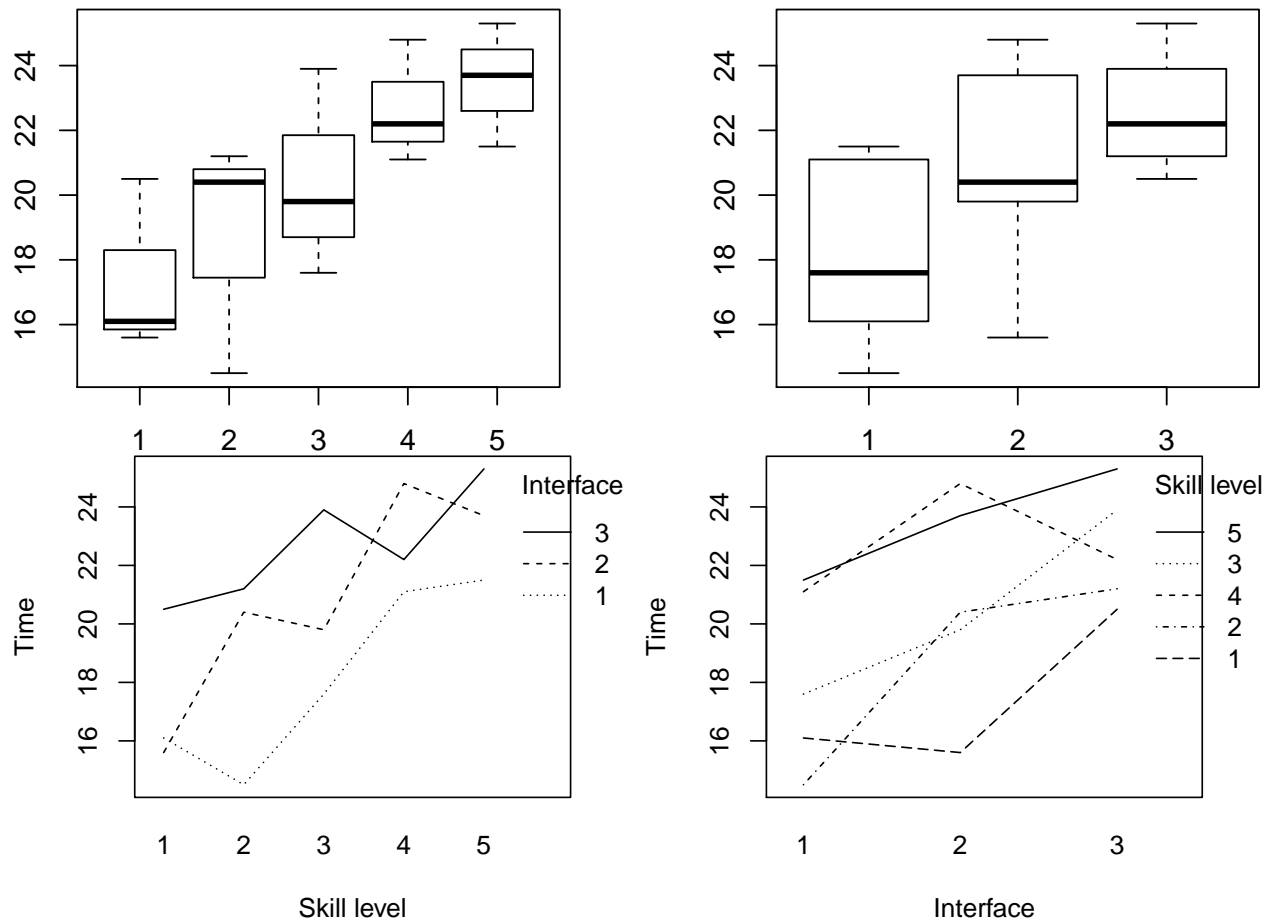
a. Randomized block design

The following code generates a random block design with five blocks, a factor with three levels, and one sample per unique categorie.

```
B=5;
if1 = sample(1:5)
if2 = sample(6:10)
if3 = sample(11:15)
for (i in 1:B) print(c(if1[i], if2[i], if3[i]))
```

b. Graphical pre-analysis

The boxplots below suggest that indeed the skill level and the interfaces matter for the search time. Where skill level 1 is indeed the fastest, and interface 1 is the fastest from the three interfaces. And from the interaction plots below it can be observed that overall the factors have the same pattern; all lines start in the lower left corner and end towards the upper right corner. However, they are not perfectly parallel, this can be explained by the small sample sizes which causes local irregularities. Thus we conclude that there is no interaction between the two factors.



c. Anova with 1 block factor

From the ANOVA results below it can be concluded that the search time is not the same for all interfaces. Furthermore, we can estimate the time it takes for a user with skill level 3 to find a product using interface 2 by looking at the summary table and adding the coefficients of these two categories to the intercept. Thus that would be $15.015 + 3.033 + 2.7 = 20.748$.

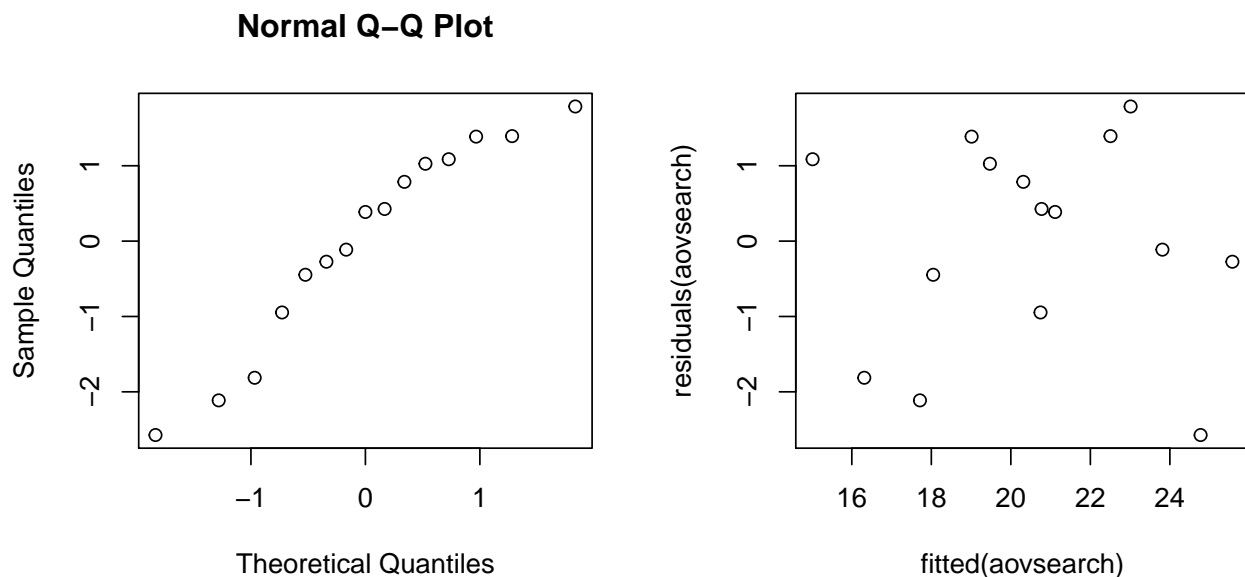
```
## Analysis of Variance Table
##
## Response: time
##           Df Sum Sq Mean Sq F value    Pr(>F)
## interface  2  50.465  25.2327   7.8237 0.01310 *
## skill      4  80.051  20.0127   6.2052 0.01421 *
## Residuals  8  25.801   3.2252
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

##
## Call:
## lm(formula = time ~ interface + skill, data = search)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.5733 -0.6967  0.3867  1.0567  1.7867
```

```
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)  15.013      1.227  12.238 1.85e-06 ***
## interface2    2.700      1.136   2.377 0.04474 *
## interface3    4.460      1.136   3.927 0.00438 **
## skill12       1.300      1.466   0.887 0.40118
## skill13       3.033      1.466   2.069 0.07238 .
## skill14       5.300      1.466   3.614 0.00684 **
## skill15       6.100      1.466   4.160 0.00316 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.796 on 8 degrees of freedom
## Multiple R-squared:  0.8349, Adjusted R-squared:  0.7111
## F-statistic: 6.745 on 6 and 8 DF,  p-value: 0.008395
```

d. Diagnostics

The QQ-plot of the residuals below looks normally distributed, which is good. The fitted residuals do not depict any outliers.



e. Friedmann test

The result of the Friedman test is the same as the ANOVA: we reject the H_0 , thus there is a difference in sesarch times.

```
##
## Friedman rank sum test
##
## data:  search$time, search$interface and search$skill
## Friedman chi-squared = 6.4, df = 2, p-value = 0.04076
```

f. One-way ANOVA

The one-way ANOVA returns no significant difference in the search time between the interfaces. This result is not very usefull, because 1) we removed a lot of information from the model and 2) the model now assumes that the block is a random selection of all available blocks, which is not the case because the blocks were fixed/predetermined.

```
## Analysis of Variance Table
##
## Response: time
##           Df  Sum Sq Mean Sq F value  Pr(>F)
## interface  2   50.465   25.233   2.8605 0.09642 .
## Residuals 12  105.852    8.821
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```