Experimental Design and Data Analysis: Assignment 4

This assignment consists of 4 exercises. Throughout this assignment tests should be performed using a level of 0.05.

You will need the `R` packages `multcomp` and `lme4`, which aren't included in the standard distribution of `R`. To install a package choose `Packages -> install packages..` from the menu (visible when the `R` console window is selected) and follow the instructions. (You need to be connected to the internet.) `R` will write the package to the hard disk of your computer. To use the package either type

```
> library(multcomp)
> library(lme4)
```

or choose `Packages -> Load package..` from the menu. Installing is a one-time task, loading the package is necessary at every `R` session.

EXERCISE 1
(Data by Stephan Hagens and Katinka Slingerland, Course DOEANOVA 2009.) If left alone bread will become moldy, rot or decay otherwise. To investigate the influence of temperature and humidity on this process, the time to decay was measured for 18 slices of white bread, which were placed in 3 different environments and humidified or not. The data are given in the file `bread.txt`, with the first column time to decay in hours, the second column the environment (cold, warm or intermediate temperature) and the third column the humidity.

1. The 18 slices came from a single loaf, but were randomized to the 6 combinations of conditions. Which R code can be used to help this randomization process, and how would you carry this out if given a single loaf of bread?

2. Make two boxplots of `hours` versus the two factors.

3. Make two interaction plots, keeping the two factors fixed in turn.

4. Perform an analysis of variance to test the null hypotheses that:

   - there is an interaction effect of the two factors.
   - there is a main effect of the factor `temperature`.
   - there is a main effect of the factor `humidity`.

5. Describe the interaction effect in words.

6. Which of the two factors has the greatest (numerical) influence on the decay? Is this a good question?

7. Make a qq plot of the `residuals`. Is there reason to distrust the assumption that the populations are normal? Which data-point seems to fit the model less well?

8. Make a plot of fitted values versus residuals. Is there an indication of heteroscedasticity?

EXERCISE 2

A researcher is interested in the time it takes a student to find a certain product on the internet using a search engine. There are three different types of interfaces with the search engine and especially the effect of these interfaces is of importance. There are five different types of students, indicating their level of computer handling (the lower the value of this indicator, the better the computer handling of the corresponding student).

Fifteen students are selected; three from each group with a certain level of computer handling.

1. Number the selected students 1 to 15 and show how the students could be randomized to the interfaces in a randomized block design, with the help of the R random generator.

The experiment was run according to a randomized block design, as described. The data is given in the file `search.txt`.

2. Make some graphical summaries of the data. Are any interactions between interface and skill apparent?

3. Test the null hypothesis that the search time is the same for all interfaces. (Beware that the levels of the factors are coded by numbers!)

4. Estimate the time it takes a typical user of skill level 4 to find the product on the website if the website uses interface 3.

5. Make diagnostic plots to test the assumptions for the analysis. Comments?

6. Perform the non-parametric Friedman test to test whether there is an effect of interface.

7. Test the null hypothesis that the search time is the same for all interfaces by a one-way analysis of variance test, ignoring the variable `skill`. Is it right/wrong or useful/not useful to perform this test on this dataset? What assumption on the way the data were obtained is necessary for this test to be valid, and was this assumption met?

EXERCISE 3

The file `cream.txt` contains data on an experiment to produce sour cream. Yogurt was placed in sweet cream, and yogurt bacteria were allowed to develop. Interest was in their number. Bacteria produce lactic acid, and as a surrogate for their number, the acidity of the cream was measured. Interest was in the effect of the type of yogurt used as a `starter`. The mixtures of yogurt and sweet cream were kept at constant temperature in a yogurt maker, in which

five different `positions` could be used. The experiment was carried out with five `batches` of sweet cream, which were meant to have the same composition. With each batch each of five types of `starter` was used, with the yogurt placed in one of the five positions. The combinations of levels of three factors formed a three-dimensional latin square.

The data are obtained in the file `cream.txt`.

1. Analyse the data in a three-way experiment without interactions: use the model formula `acidity~starter+batch+position`. (Beware to include the explanatory variables as *factors* in the analysis.) Show the Anova table and formulate the conclusions.

2. Also show the output of the `summary` command. (Use the default "treatment" contrasts.)

3. Produce a table of p-values for testing all hypotheses $H_0 : \alpha_i = \alpha_{i'}$ on equality of differences of the main effects for `starter` simultaneously ($i, i' \in \{1, 2, \ldots, 5\}$). Which starters lead to significantly different acidity? Interpret.

4. A p-value for the test $H_0 : \alpha_2 = \alpha_1$ is also in the output of `summary` in 2). What is it? Is it coincidence that it is smaller than the simultaneous p-value?

5. Produce a table of confidence intervals for testing all differences $\alpha_j - \alpha_{j'}$ of the main effects for `starter` with simultaneous confidence level 95 % ($i, i' \in \{1, 2, \ldots, 5\}$). Which intervals do not contain the number 0? Comment.

EXERCISE 4

In a study on the effect of feedingstuffs on lactation a sample of nine cows were fed with two types of food, and their milk production was measured. All cows were fed both types of food, during two periods, with a neutral period in-between to try and wash out carry-over effects. The order of the types of food was randomized over the cows.

The observed data can be found in the file `cow.txt`, where `A` and `B` refer to the types of feedingstuffs.

1. Test whether the type of feedingstuffs influences milk production using an ordinary "fixed effects" model, fitted with `lm`.

2. Estimate the difference in milk production.

3. Repeat 1. and 2. by performing a mixed effects analysis, modelling the cow effect as a random effect (use the function `lmer`). Compare your results to the results found using a fixed effects model.

4. Study the commands:

```
> attach(cow)
> t.test(milk[treatment=="A"],milk[treatment=="B"],paired=TRUE)
```

Does this produce a valid test for a difference in milk production? Is its conclusion compatible with the one obtained in a)? Why?