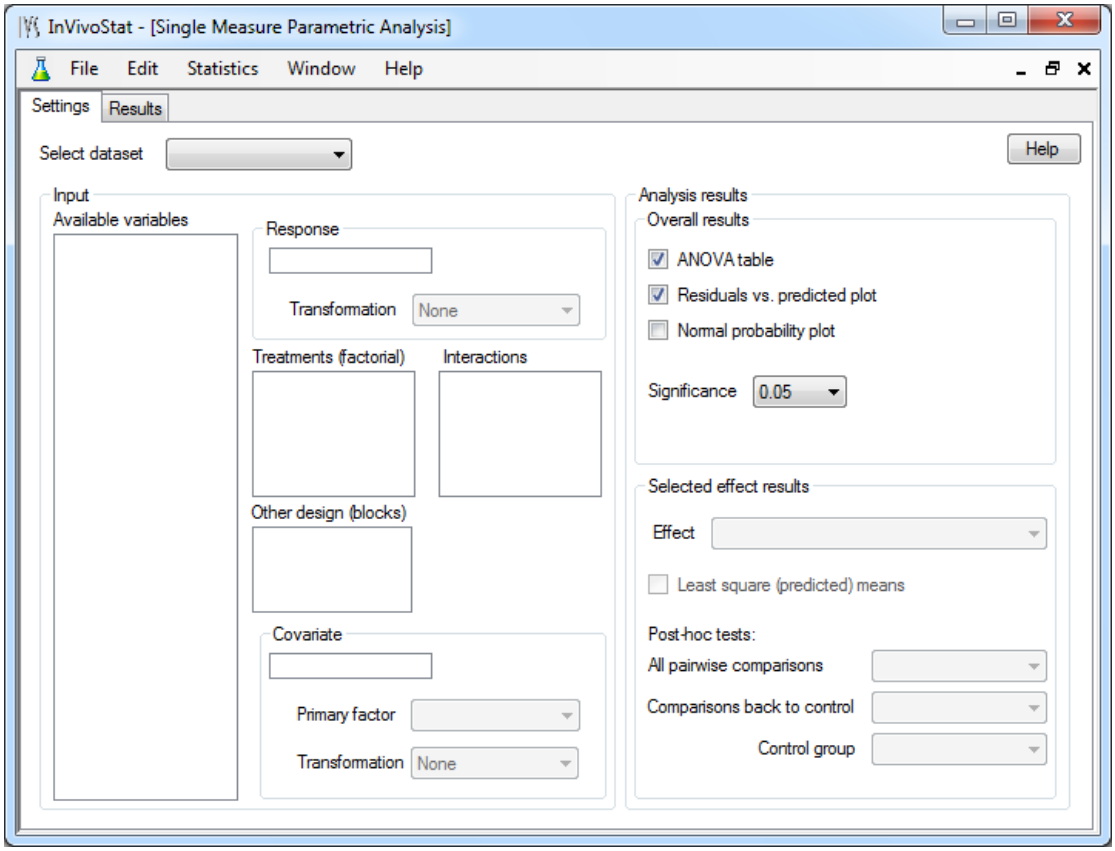
InVivoStat

Single Measures Parametric Analysis Module

Tipsheet

The Single Measures Parametric Analysis module in InVivoStat is available from the Statistics drop-down menu entitled 'Single Measures Parametric Analysis'. The user interface is:

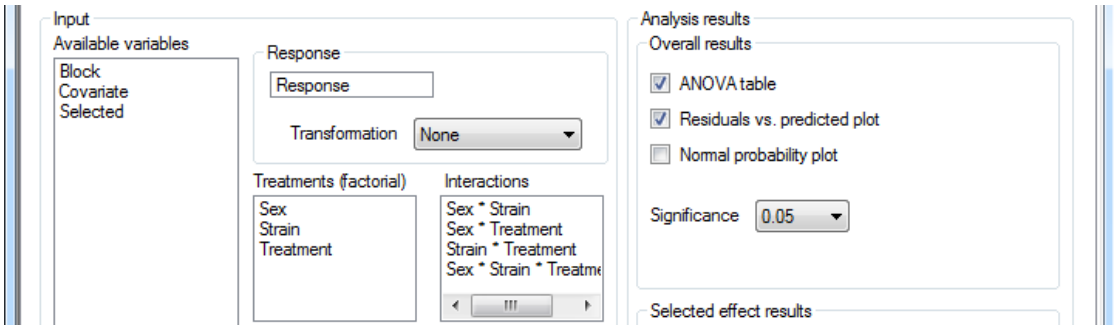


The Single Measures Parametric Analysis module performs a general linear model analysis. This allows the user to fit multiple treatment (factorial) factors, other design (blocks) factors and a single covariate. All interactions involving the treatment factors are included in the statistical model but none of the interactions involving the blocking factors are included. The user can also check the interactions involving the covariate by choosing the 'Assess covariate interactions' option in the Output Options window.

Note that if your experiment involves more than one treatment factor (and are analysing your data using a multi-way ANOVA/ANCOVA) then all combinations of the levels of the treatment factors must be present in the experimental design. If some combinations of the levels of the treatment factors are missing then you need to use the Incomplete Factorial Parametric Analysis module instead.

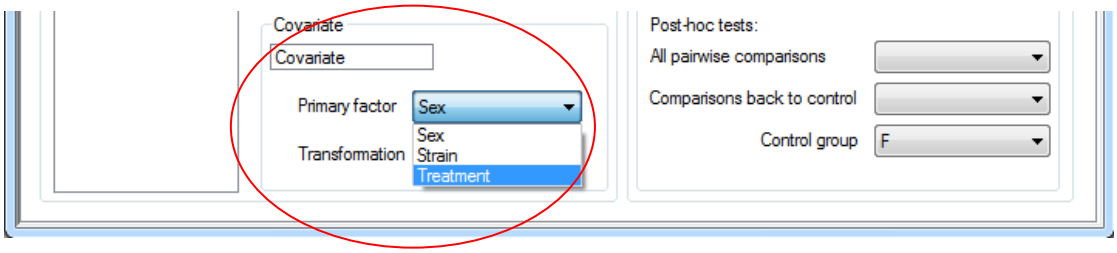
1 Setting up the model

Once the dataset has been opened, the user can select the variables for the analysis by dragging and dropping them from the 'Available variables' list into the 'Response', 'Treatments (factorial)', 'Other design (blocks)' and 'Covariate' boxes.



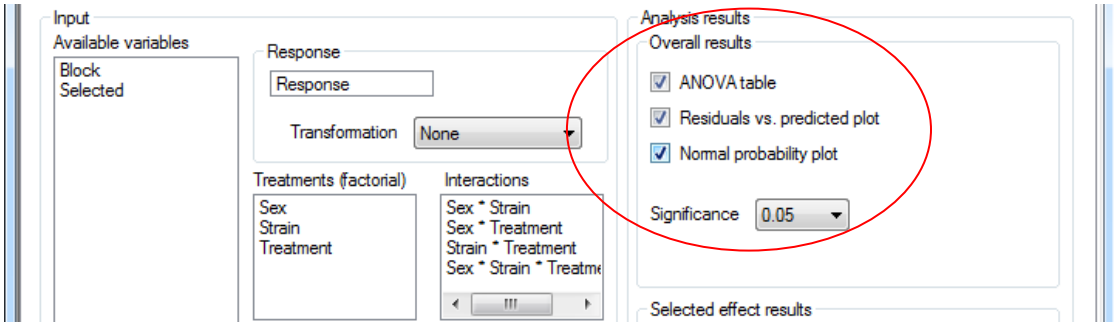
Once selected, the user has the option of applying a transformation to the response variable, either $\log_{10}$, $\log_e$, square root, arcsine or rank. If selected the covariate will be transformed using the same transformation, unless otherwise specified by the user.

If a covariate is selected, then the user has the option of selecting the 'Primary factor'. This factor is used to categorise the scatterplot (produced in the output). The Primary factor should be one of the factors of interest to the experimenter.



2 Selecting the analysis options

There are several results from the General Linear Model analysis that are available to the user. These are selected before running the analysis.



The output options include:

1) ANOVA table
Produces overall tests of the effect of the terms in the statistical model.

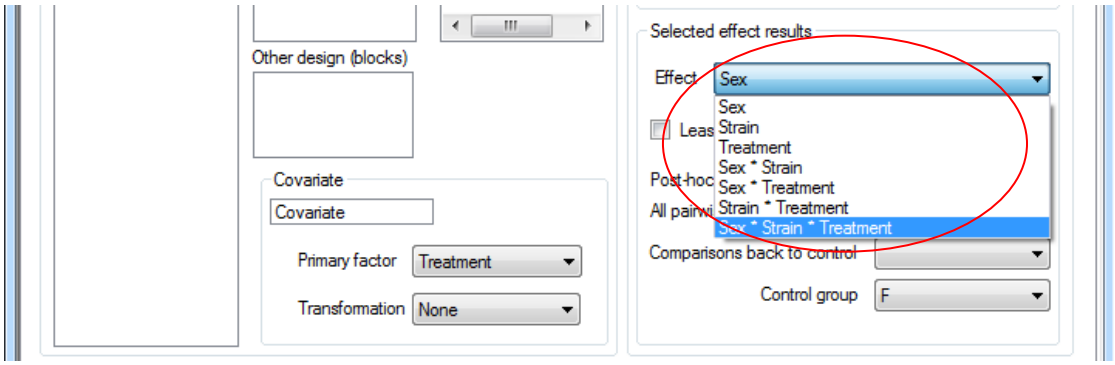
2) Residuals vs. predicted plot
Allows the user to check the homogeneity of variance assumption of the parametric analysis.

3) Normal probability plot
Allows the user to check the normality assumption of the parametric analysis.

4) Significance level
The default is 0.05, or 5%, although this can be changed.

The user then has various other options available:

5) Selected effect
This is the effect that the user is interested in comparing the levels of.

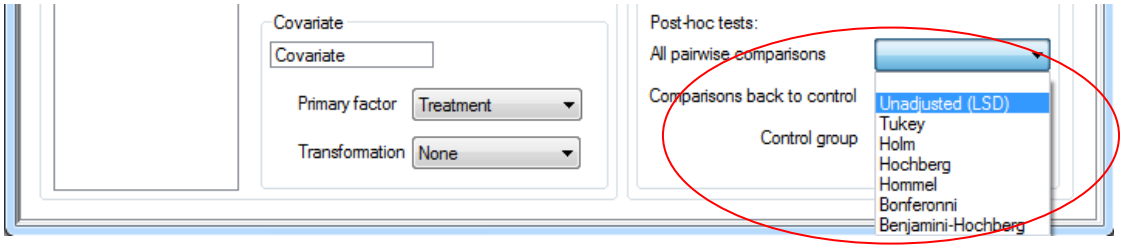


6) Least square means

These are the predicted means from the statistical analysis and take into account all effects in the statistical model, such as the covariate.

7) All pairwise tests

Produces all pairwise comparisons between the levels of the Selected effect. The user has the option of adjusting the p-values for multiple comparisons. Options include Holm, Hochberg, Hommel, Benjamini-Hochberg, Tukey or Bonferonni.



8) Comparisons back to control

Produces all to one comparisons between the levels of the Selected effect. The user should select the control group from the drop down list. This option is only available if the user selects a main effect as the Selected effect. The user has the option of adjusting the p-values for multiple comparisons. Options include Holm, Hochberg, Hommel, Benjamini-Hochberg, Dunnett or Bonferonni.

3 Output Results

Response and covariate

InVivoStat identifies the response being analysed and also the covariate (if one is selected). This section also describes any transformations that have been applied.

Scatterplot of the raw data

InVivoStat produces a scatterplot of the raw data. This should be used to identify possible outliers. On the plot the X-axis corresponds to the levels of the highest order interaction between the treatment factors and the Y-axis corresponds to the response.

Categorised scatterplot of the raw data (ANCOVA only)

When fitting a covariate in a statistical analysis, certain assumptions are made. This plot allows the user to test these assumptions. Underneath the plot is a list of the assumptions and also advice on how the plot can be used to assess them.

ANOVA/ANCOVA table

The ANOVA/ANCOVA table gives tests of the overall effect of the model terms. InVivoStat presents the Type III model fit as this was felt to be a reasonably robust approach. Below the table any statistically significant effects are listed.

Diagnostic plots

If requested InVivoStat produces the residuals vs. predicted plot and the normal probability plot. The residuals plotted on the residuals vs. predicted plot are the standardized residuals as these can provide a test for outliers. Any observation with a residual greater (or less than) 3 could be considered an outlier.

Plot of the predicted means

InVivoStat produces a plot and table of the least square means from the model, with confidence intervals.

All pairwise tests

InVivoStat produces a table of all pairwise comparisons between the levels of the Selected effect (either a main effect or an interaction). As well as the size of the difference between the means, InVivoStat also provides p-values to test these comparisons either unadjusted for multiplicity or with a multiple comparison adjustment. A list of statistically significant comparisons is given below the table.

All to one comparisons

InVivoStat produces a table of all to one pairwise comparisons between the levels of the Selected effect. As well as the size of the difference between the means, along with confidence intervals, InVivoStat provides p-values either unadjusted for multiplicity or with a multiple comparison adjustment.

References

Finally a list of references for the methods applied in the analysis is given.

4 Controlling the output

The user has the ability to control various aspects of the output. These are available from the

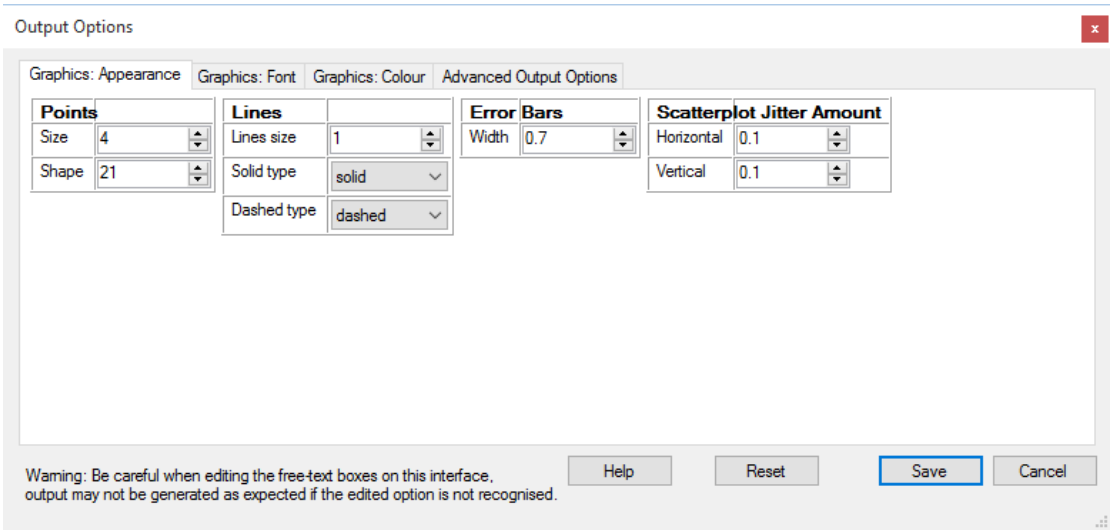
Statistics → Options → Output Options

menu and should be selected before performing the analysis.

Users can manipulate various global characteristics of the plots produced. Plots can be generated in pdf format and also in black and white.

If a covariate is included in the statistical model, then the user can formally test the covariate interactions by selecting 'Assess covariate interactions'. The user can also view the covariate regression coefficients (by selecting the 'Covariate regression coefficients' option).

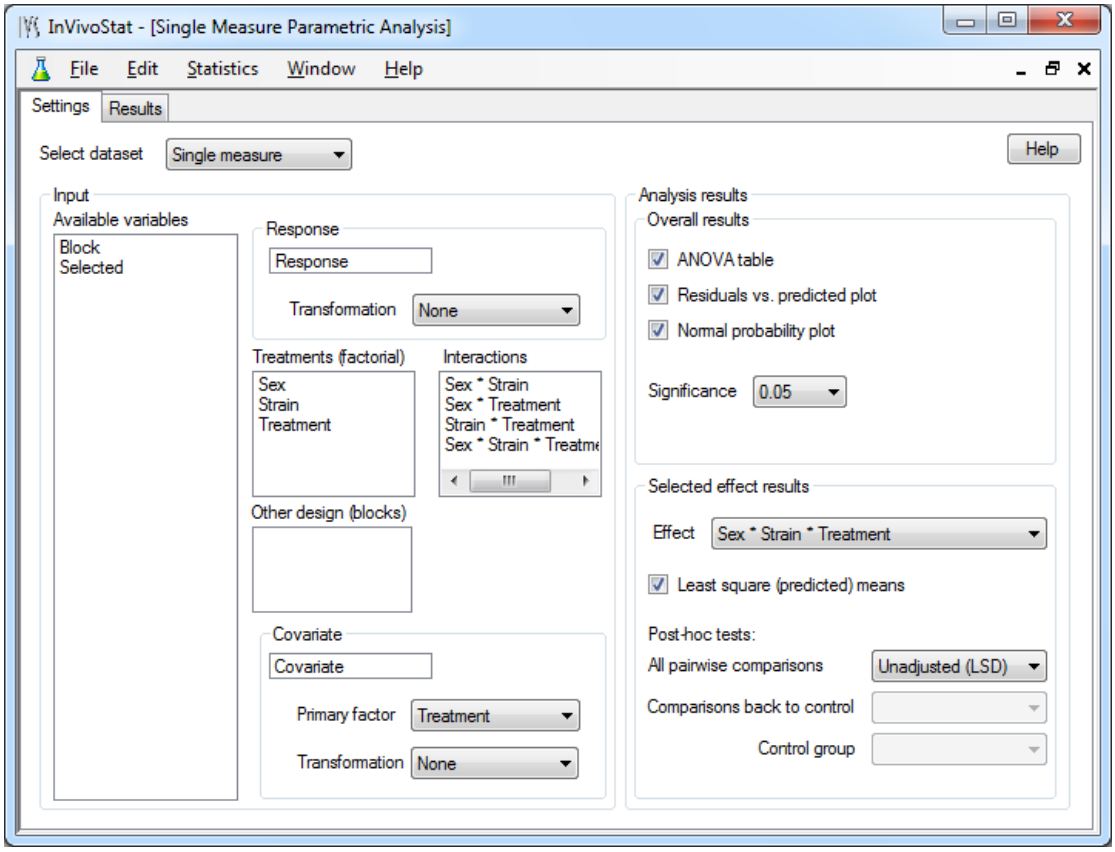
If the response has been log transformed, by selecting 'Display geometric means' the back transformed means are given (and plotted).



More information on the options can be found in the Getting Started tipsheet.

5 Sample output

Options:

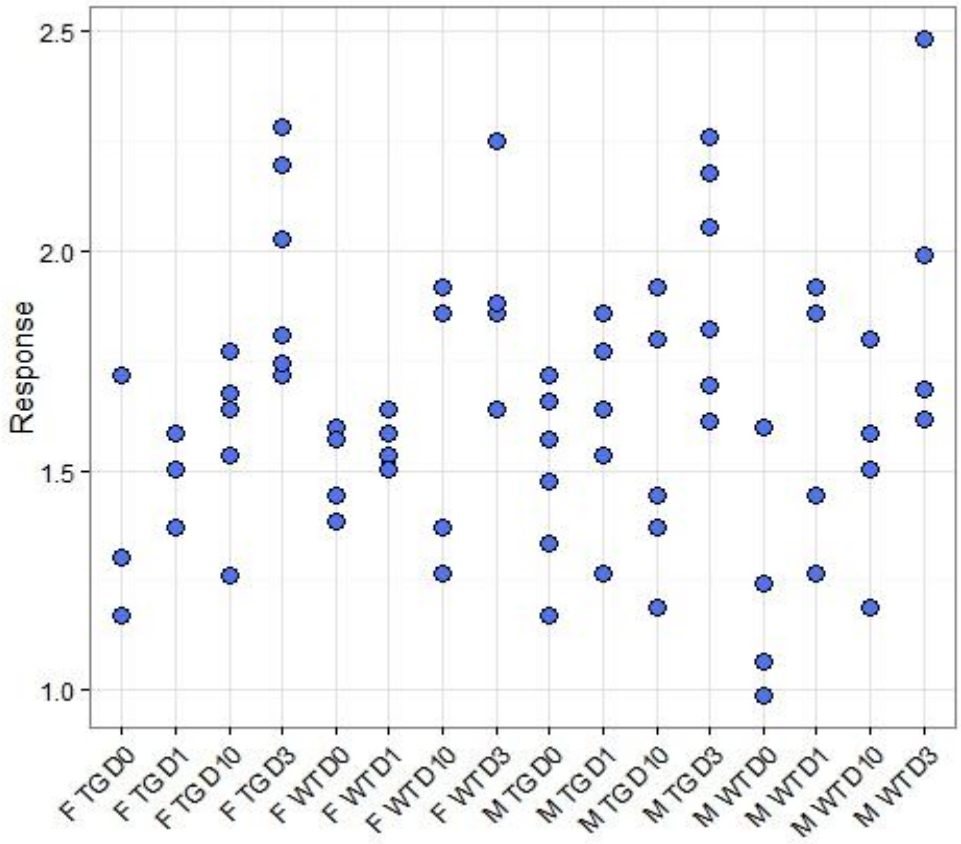


InVivoStat Single Measure Parametric Analysis

Response and covariate

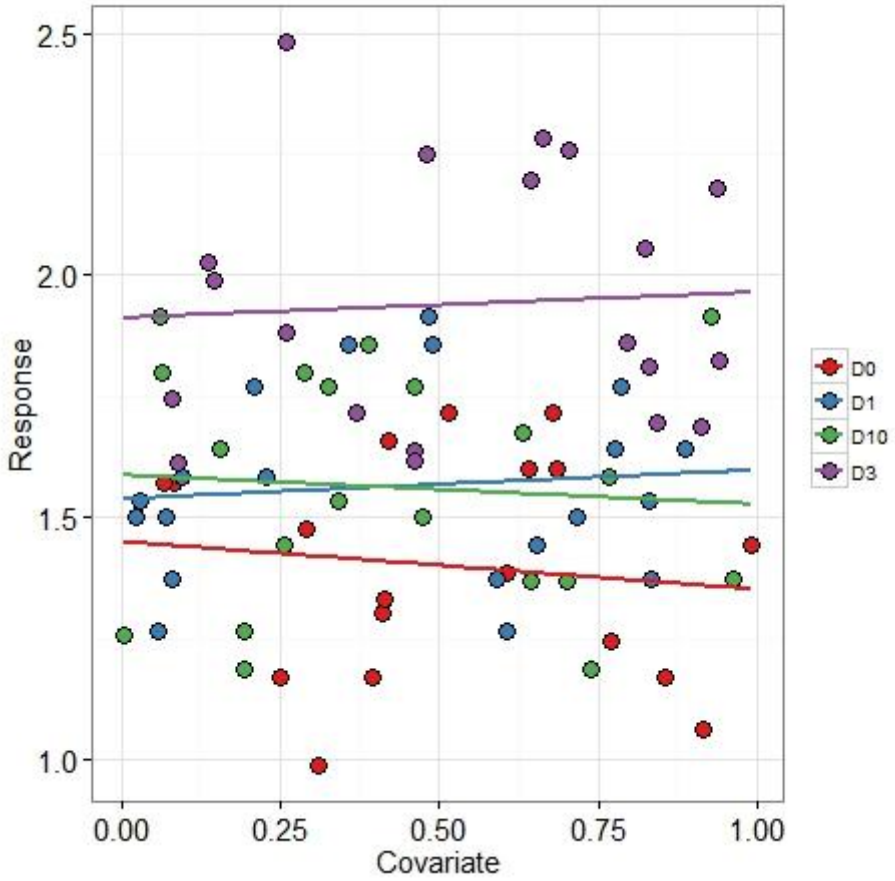
The Response response is currently being analysed by the Single Measures Parametric Analysis module, with Covariate fitted as a covariate.

Scatterplot of the raw data



Tip: Use this plot to identify possible outliers.

Covariate plot of the raw data



Tip: Is it worth fitting the covariate? You should consider the following:

a) Is there a relationship between the response and the covariate?... It is only worth fitting the covariate if there is a strong positive (or negative) relationship between them. The lines on the plot should not be horizontal.

b) Is the relationship similar for all treatments?... The lines on the plot should be approximately parallel.

c) Is the covariate influenced by the treatment?... We assume the covariate is not influenced by the treatment so there should be no separation of the treatment groups along the x-axis on the plot.

These issues are discussed in more detail in Morris (1999).

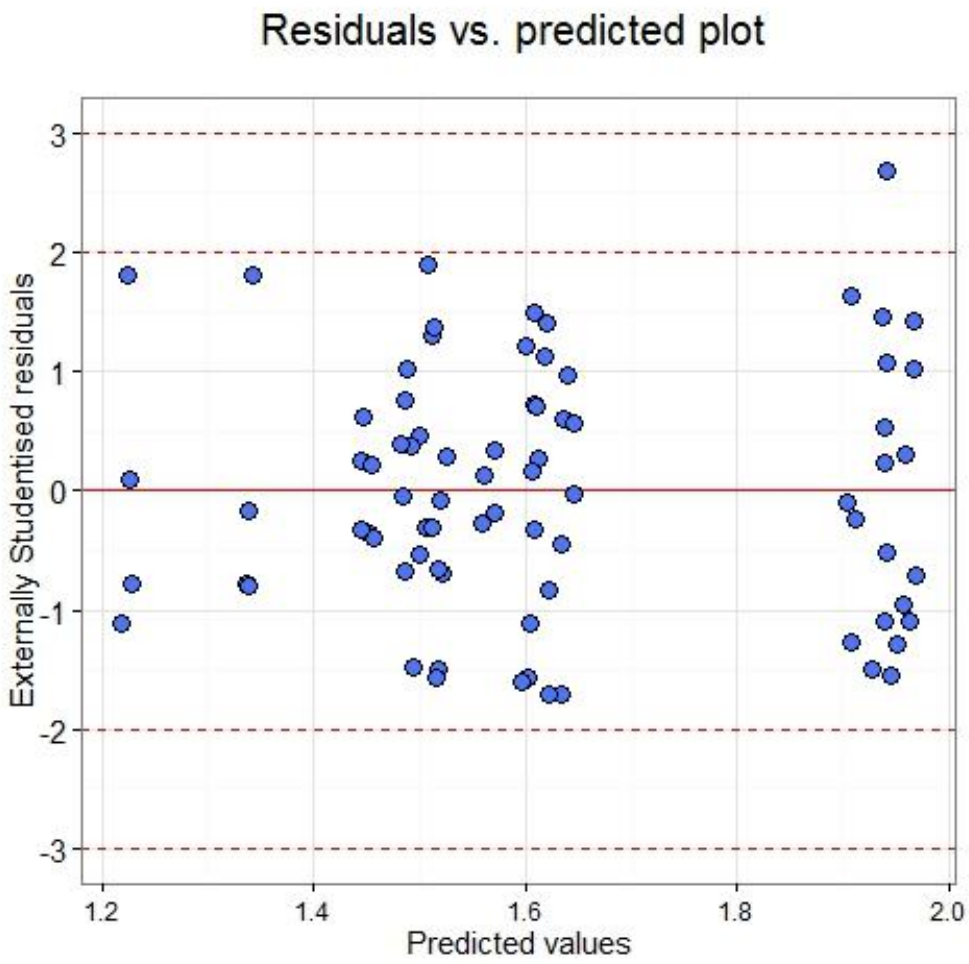
Analysis of Covariance (ANCOVA) table

	Sums of squares	Degrees of freedom	Mean square	F-value	p-value
Covariate	0.00	1	0.00	0.02	0.8834
Sex	0.00	1	0.00	0.00	0.9803
Strain	0.00	1	0.00	0.04	0.8519
Treatment	3.07	3	1.02	16.99	< 0.0001
Sex * Strain	0.06	1	0.06	1.03	0.3149
Sex * Treatment	0.14	3	0.05	0.76	0.5193
Strain * Treatment	0.03	3	0.01	0.17	0.9157
Sex * Strain * Treatment	0.16	3	0.05	0.89	0.4522
Residuals	3.67	61	0.06		

Comment: ANCOVA table calculated using a Type III model fit, see Armitage et al. (2001).
Conclusion: There is a statistically significant overall difference between the levels of Treatment.

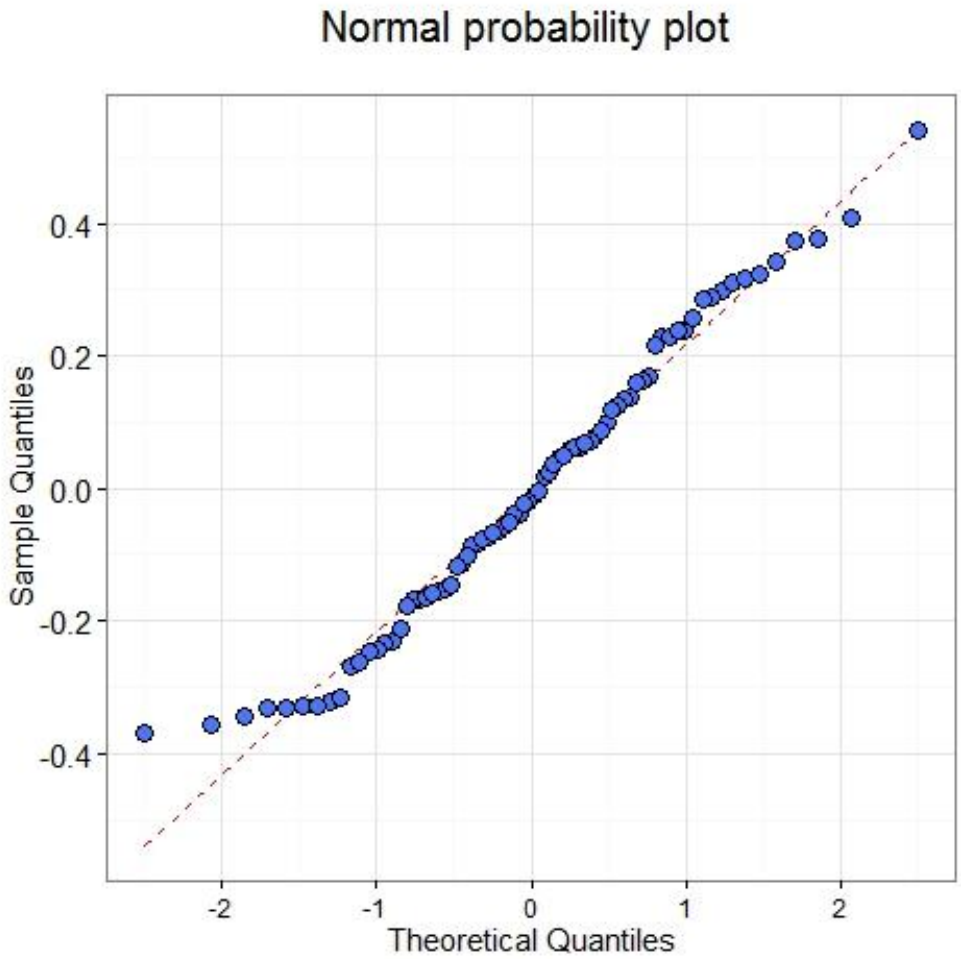
Tip: While it is a good idea to consider the overall tests in the ANCOVA table, we should not rely on them when deciding whether or not to make pairwise comparisons.

Diagnostic plots



Tip: On this plot look to see if the spread of the points increases as the predicted values increase. If so the response may need transforming.

Tip: Any observation with a residual less than -3 or greater than 3 (SD) should be investigated as a possible outlier.



Tip: Check that the points lie along the dotted line. If not then the data may be non-normally distributed.

Plot of the least square (predicted) means with 95% confidence intervals

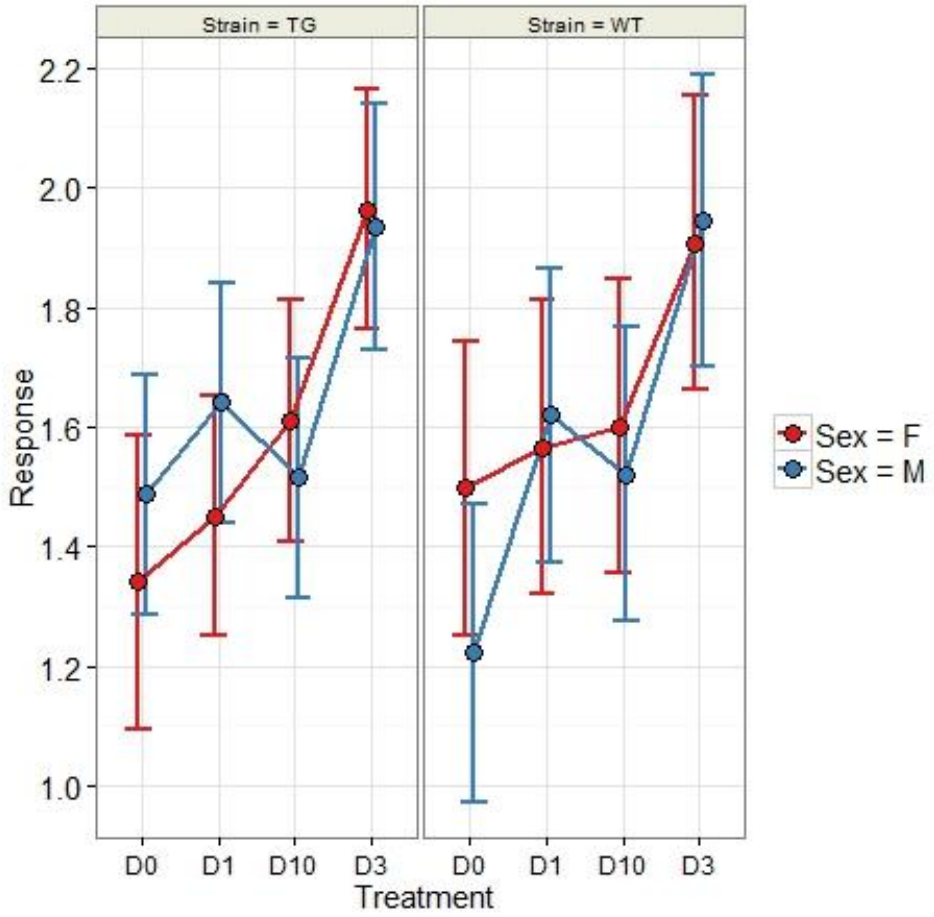


Table of the least square (predicted) means with 95% confidence intervals

	Sex	Strain	Treatment	Mean	Lower 95% CI	Upper 95% CI
ID						
1	F	TG	D0	1.341	1.095	1.586
2	M	TG	D0	1.488	1.287	1.688
3	F	WT	D0	1.498	1.251	1.744
4	M	WT	D0	1.221	0.973	1.469
5	F	TG	D1	1.451	1.250	1.652
6	M	TG	D1	1.640	1.439	1.841
7	F	WT	D1	1.566	1.320	1.811
8	M	WT	D1	1.620	1.374	1.865
9	F	TG	D10	1.610	1.407	1.813
10	M	TG	D10	1.515	1.314	1.715
11	F	WT	D10	1.601	1.355	1.847
12	M	WT	D10	1.520	1.274	1.767
13	F	TG	D3	1.963	1.763	2.164
14	M	TG	D3	1.934	1.727	2.140
15	F	WT	D3	1.908	1.662	2.153
16	M	WT	D3	1.944	1.699	2.190

All pairwise comparisons without adjustment for multiplicity (LSD test)

Comparison	Difference	Lower 95% CI	Upper 95% CI	Std error	p-value
F,TG,D0 vs. M,TG,D0	-0.147	-0.464	0.170	0.158	0.3566
F,TG,D0 vs. F,WT,D0	-0.157	-0.506	0.191	0.174	0.3702
F,TG,D0 vs. M,WT,D0	0.119	-0.231	0.469	0.175	0.4979
F,TG,D0 vs. F,TG,D1	-0.111	-0.427	0.206	0.158	0.4878
F,TG,D0 vs. M,TG,D1	-0.300	-0.616	0.017	0.158	0.0633
F,TG,D0 vs. F,WT,D1	-0.225	-0.572	0.122	0.173	0.1989
F,TG,D0 vs. M,WT,D1	-0.279	-0.627	0.068	0.174	0.1133
F,TG,D0 vs. F,TG,D10	-0.270	-0.587	0.048	0.159	0.0945
F,TG,D0 vs. M,TG,D10	-0.174	-0.491	0.143	0.158	0.2760
F,TG,D0 vs. F,WT,D10	-0.260	-0.608	0.087	0.174	0.1396
F,TG,D0 vs. M,WT,D10	-0.180	-0.527	0.167	0.174	0.3043
F,TG,D0 vs. F,TG,D3	-0.623	-0.939	-0.306	0.158	0.0002
F,TG,D0 vs. M,TG,D3	-0.593	-0.915	-0.271	0.161	0.0005
F,TG,D0 vs. F,WT,D3	-0.567	-0.914	-0.220	0.174	0.0018
F,TG,D0 vs. M,WT,D3	-0.604	-0.951	-0.257	0.173	0.0009
M,TG,D0 vs. F,WT,D0	-0.010	-0.329	0.308	0.159	0.9493
M,TG,D0 vs. M,WT,D0	0.266	-0.054	0.587	0.160	0.1012
M,TG,D0 vs. F,TG,D1	0.037	-0.247	0.320	0.142	0.7973
M,TG,D0 vs. M,TG,D1	-0.153	-0.436	0.131	0.142	0.2859
M,TG,D0 vs. F,WT,D1	-0.078	-0.395	0.239	0.158	0.6233
M,TG,D0 vs. M,WT,D1	-0.132	-0.449	0.185	0.159	0.4086
M,TG,D0 vs. F,TG,D10	-0.123	-0.407	0.161	0.142	0.3916
M,TG,D0 vs. M,TG,D10	-0.027	-0.311	0.256	0.142	0.8491
M,TG,D0 vs. F,WT,D10	-0.113	-0.431	0.205	0.159	0.4789
M,TG,D0 vs. M,WT,D10	-0.033	-0.350	0.284	0.158	0.8370
M,TG,D0 vs. F,TG,D3	-0.476	-0.759	-0.192	0.142	0.0014
M,TG,D0 vs. M,TG,D3	-0.446	-0.736	-0.156	0.145	0.0031
M,TG,D0 vs. F,WT,D3	-0.420	-0.737	-0.103	0.159	0.0103

M,TG,D0 vs. M,WT,D3	-0.457	-0.773	-0.140	0.158	0.0054
F,WT,D0 vs. M,WT,D0	0.277	-0.071	0.624	0.174	0.1163
F,WT,D0 vs. F,TG,D1	0.047	-0.272	0.365	0.159	0.7705
F,WT,D0 vs. M,TG,D1	-0.142	-0.461	0.176	0.159	0.3755
F,WT,D0 vs. F,WT,D1	-0.068	-0.416	0.280	0.174	0.6974
F,WT,D0 vs. M,WT,D1	-0.122	-0.469	0.225	0.174	0.4853
F,WT,D0 vs. F,TG,D10	-0.112	-0.434	0.209	0.161	0.4869
F,WT,D0 vs. M,TG,D10	-0.017	-0.334	0.300	0.159	0.9154
F,WT,D0 vs. F,WT,D10	-0.103	-0.450	0.244	0.174	0.5548
F,WT,D0 vs. M,WT,D10	-0.023	-0.372	0.327	0.175	0.8977
F,WT,D0 vs. F,TG,D3	-0.465	-0.783	-0.148	0.159	0.0048
F,WT,D0 vs. M,TG,D3	-0.436	-0.754	-0.118	0.159	0.0080
F,WT,D0 vs. F,WT,D3	-0.410	-0.757	-0.062	0.174	0.0216
F,WT,D0 vs. M,WT,D3	-0.447	-0.795	-0.098	0.174	0.0128
M,WT,D0 vs. F,TG,D1	-0.230	-0.551	0.091	0.160	0.1568
M,WT,D0 vs. M,TG,D1	-0.419	-0.740	-0.098	0.160	0.0113
M,WT,D0 vs. F,WT,D1	-0.345	-0.694	0.005	0.175	0.0533
M,WT,D0 vs. M,WT,D1	-0.398	-0.746	-0.051	0.174	0.0255
M,WT,D0 vs. F,TG,D10	-0.389	-0.713	-0.065	0.162	0.0194
M,WT,D0 vs. M,TG,D10	-0.294	-0.612	0.025	0.159	0.0702
M,WT,D0 vs. F,WT,D10	-0.380	-0.727	-0.032	0.174	0.0328
M,WT,D0 vs. M,WT,D10	-0.299	-0.651	0.053	0.176	0.0940
M,WT,D0 vs. F,TG,D3	-0.742	-1.062	-0.423	0.160	< 0.0001
M,WT,D0 vs. M,TG,D3	-0.712	-1.029	-0.395	0.159	< 0.0001
M,WT,D0 vs. F,WT,D3	-0.686	-1.035	-0.338	0.174	0.0002
M,WT,D0 vs. M,WT,D3	-0.723	-1.073	-0.373	0.175	0.0001
F,TG,D1 vs. M,TG,D1	-0.189	-0.472	0.094	0.142	0.1870
F,TG,D1 vs. F,WT,D1	-0.115	-0.432	0.202	0.158	0.4716
F,TG,D1 vs. M,WT,D1	-0.169	-0.486	0.149	0.159	0.2926
F,TG,D1 vs. F,TG,D10	-0.159	-0.443	0.125	0.142	0.2667
F,TG,D1 vs. M,TG,D10	-0.064	-0.347	0.220	0.142	0.6554
F,TG,D1 vs. F,WT,D10	-0.150	-0.468	0.168	0.159	0.3500
F,TG,D1 vs. M,WT,D10	-0.069	-0.386	0.248	0.158	0.6634

F,TG,D1 vs. F,TG,D3	-0.512	-0.796	-0.229	0.142	0.0006
F,TG,D1 vs. M,TG,D3	-0.483	-0.773	-0.192	0.145	0.0015
F,TG,D1 vs. F,WT,D3	-0.456	-0.774	-0.139	0.159	0.0055
F,TG,D1 vs. M,WT,D3	-0.493	-0.810	-0.176	0.158	0.0028
M,TG,D1 vs. F,WT,D1	0.074	-0.242	0.391	0.158	0.6407
M,TG,D1 vs. M,WT,D1	0.020	-0.297	0.338	0.159	0.8979
M,TG,D1 vs. F,TG,D10	0.030	-0.254	0.314	0.142	0.8338
M,TG,D1 vs. M,TG,D10	0.125	-0.158	0.409	0.142	0.3802
M,TG,D1 vs. F,WT,D10	0.039	-0.279	0.357	0.159	0.8056
M,TG,D1 vs. M,WT,D10	0.120	-0.197	0.437	0.158	0.4525
M,TG,D1 vs. F,TG,D3	-0.323	-0.607	-0.040	0.142	0.0261
M,TG,D1 vs. M,TG,D3	-0.293	-0.584	-0.003	0.145	0.0477
M,TG,D1 vs. F,WT,D3	-0.267	-0.585	0.050	0.159	0.0971
M,TG,D1 vs. M,WT,D3	-0.304	-0.621	0.013	0.158	0.0595
F,WT,D1 vs. M,WT,D1	-0.054	-0.401	0.293	0.174	0.7576
F,WT,D1 vs. F,TG,D10	-0.044	-0.362	0.273	0.159	0.7809
F,WT,D1 vs. M,TG,D10	0.051	-0.266	0.368	0.158	0.7481
F,WT,D1 vs. F,WT,D10	-0.035	-0.383	0.313	0.174	0.8411
F,WT,D1 vs. M,WT,D10	0.045	-0.302	0.393	0.174	0.7943
F,WT,D1 vs. F,TG,D3	-0.397	-0.714	-0.081	0.158	0.0148
F,WT,D1 vs. M,TG,D3	-0.368	-0.690	-0.046	0.161	0.0258
F,WT,D1 vs. F,WT,D3	-0.342	-0.689	0.005	0.174	0.0536
F,WT,D1 vs. M,WT,D3	-0.378	-0.725	-0.032	0.173	0.0330
M,WT,D1 vs. F,TG,D10	0.009	-0.310	0.329	0.160	0.9530
M,WT,D1 vs. M,TG,D10	0.105	-0.212	0.422	0.158	0.5101
M,WT,D1 vs. F,WT,D10	0.019	-0.328	0.366	0.174	0.9139
M,WT,D1 vs. M,WT,D10	0.099	-0.249	0.448	0.174	0.5706
M,WT,D1 vs. F,TG,D3	-0.344	-0.661	-0.027	0.159	0.0341
M,WT,D1 vs. M,TG,D3	-0.314	-0.633	0.005	0.160	0.0538
M,WT,D1 vs. F,WT,D3	-0.288	-0.635	0.059	0.174	0.1023
M,WT,D1 vs. M,WT,D3	-0.325	-0.672	0.023	0.174	0.0664
F,TG,D10 vs. M,TG,D10	0.096	-0.190	0.381	0.143	0.5059
F,TG,D10 vs. F,WT,D10	0.009	-0.311	0.330	0.160	0.9535

F,TG,D10 vs. M,WT,D10	0.090	-0.227	0.407	0.158	0.5728
F,TG,D10 vs. F,TG,D3	-0.353	-0.638	-0.068	0.142	0.0159
F,TG,D10 vs. M,TG,D3	-0.323	-0.618	-0.029	0.147	0.0321
F,TG,D10 vs. F,WT,D3	-0.297	-0.616	0.022	0.159	0.0670
F,TG,D10 vs. M,WT,D3	-0.334	-0.652	-0.016	0.159	0.0396
M,TG,D10 vs. F,WT,D10	-0.086	-0.403	0.231	0.159	0.5889
M,TG,D10 vs. M,WT,D10	-0.006	-0.323	0.312	0.159	0.9717
M,TG,D10 vs. F,TG,D3	-0.449	-0.732	-0.165	0.142	0.0024
M,TG,D10 vs. M,TG,D3	-0.419	-0.706	-0.132	0.144	0.0049
M,TG,D10 vs. F,WT,D3	-0.393	-0.709	-0.076	0.158	0.0159
M,TG,D10 vs. M,WT,D3	-0.430	-0.746	-0.113	0.158	0.0087
F,WT,D10 vs. M,WT,D10	0.080	-0.268	0.429	0.174	0.6462
F,WT,D10 vs. F,TG,D3	-0.362	-0.680	-0.045	0.159	0.0259
F,WT,D10 vs. M,TG,D3	-0.333	-0.651	-0.014	0.159	0.0409
F,WT,D10 vs. F,WT,D3	-0.307	-0.654	0.040	0.174	0.0823
F,WT,D10 vs. M,WT,D3	-0.343	-0.691	0.004	0.174	0.0527
M,WT,D10 vs. F,TG,D3	-0.443	-0.760	-0.126	0.159	0.0070
M,WT,D10 vs. M,TG,D3	-0.413	-0.738	-0.089	0.162	0.0134
M,WT,D10 vs. F,WT,D3	-0.387	-0.735	-0.039	0.174	0.0298
M,WT,D10 vs. M,WT,D3	-0.424	-0.771	-0.077	0.174	0.0175
F,TG,D3 vs. M,TG,D3	0.030	-0.259	0.318	0.144	0.8377
F,TG,D3 vs. F,WT,D3	0.056	-0.261	0.373	0.158	0.7259
F,TG,D3 vs. M,WT,D3	0.019	-0.298	0.336	0.158	0.9051
M,TG,D3 vs. F,WT,D3	0.026	-0.294	0.346	0.160	0.8708
M,TG,D3 vs. M,WT,D3	-0.011	-0.332	0.311	0.161	0.9471
F,WT,D3 vs. M,WT,D3	-0.037	-0.384	0.310	0.174	0.8327

Conclusion: The following pairwise tests are statistically significantly different at the 5% level: F,TG,D0 vs. F,TG,D3, F,TG,D0 vs. M,TG,D3, F,TG,D0 vs. F,WT,D3, F,TG,D0 vs. M,WT,D3, M,TG,D0 vs. F,TG,D3, M,TG,D0 vs. M,TG,D3, M,TG,D0 vs. F,WT,D3, M,TG,D0 vs. M,WT,D3, F,WT,D0 vs. F,TG,D3, F,WT,D0 vs. M,TG,D3, F,WT,D0 vs. F,WT,D3, F,WT,D0 vs. M,WT,D3, M,WT,D0 vs. M,TG,D1, M,WT,D0 vs. M,WT,D1, M,WT,D0 vs. F,TG,D10, M,WT,D0 vs. F,WT,D10, M,WT,D0 vs. F,TG,D3, M,WT,D0 vs. M,TG,D3, M,WT,D0 vs. F,WT,D3, M,WT,D0 vs. M,WT,D3, F,TG,D1 vs. F,TG,D3, F,TG,D1 vs. M,TG,D3, F,TG,D1 vs. F,WT,D3, F,TG,D1 vs. M,WT,D3, M,TG,D1 vs. F,TG,D3, M,TG,D1 vs. M,TG,D3, F,WT,D1

vs. F,TG,D3, F,WT,D1 vs. M,TG,D3, F,WT,D1 vs. M,WT,D3, M,WT,D1 vs. F,TG,D3, F,TG,D10 vs. F,TG,D3, F,TG,D10 vs. M,TG,D3, F,TG,D10 vs. M,WT,D3, M,TG,D10 vs. F,TG,D3, M,TG,D10 vs. M,TG,D3, M,TG,D10 vs. F,WT,D3, M,TG,D10 vs. M,WT,D3, F,WT,D10 vs. F,TG,D3, F,WT,D10 vs. M,TG,D3, M,WT,D10 vs. F,TG,D3, M,WT,D10 vs. M,TG,D3, M,WT,D10 vs. F,WT,D3, M,WT,D10 vs. M,WT,D3.

Warning: As these tests are not adjusted for multiplicity there is a risk of generating false positive results. Only use the pairwise tests you planned to make a-priori, these are the so called planned comparisons, see Snedecor and Cochran (1989).

Analysis description

The data were analysed using a 3-way ANCOVA approach, with Sex, Strain and Treatment as treatment factors and Covariate as the covariate. This was followed by planned comparisons of the predicted means to compare the levels of the Sex * Strain * Treatment interaction.

For more information on the theoretical approaches that are implemented within this module, see Bate and Clark (2014).

Statistical references

Bate ST and Clark RA. (2014). The Design and Statistical Analysis of Animal Experiments. Cambridge University Press.

Armitage P, Matthews JNS and Berry G. (2001). Statistical Methods in Medical Research. 4th edition; John Wiley & Sons. New York.

Morris TR. (1999). Experimental Design and Analysis in Animal Sciences. CABI publishing. Wallingford, Oxon (UK).

Snedecor GW and Cochran WG. (1989). Statistical Methods. 8th edition; Iowa State University Press, Iowa, USA.

R references

R Development Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Barret Schloerke, Jason Crowley, Di Cook, Heike Hofmann, Hadley Wickham, Francois Briatte, Moritz Marbach and Edwin Thoen (2014). GGally: Extension to ggplot2. R package version 0.4.5. http://CRAN.R-project.org/package=GGally

Erich Neuwirth (2011). RColorBrewer: ColorBrewer palettes. R package version 1.0-5. http://CRAN.R-project.org/package=RColorBrewer

H. Wickham. ggplot2: elegant graphics for data analysis. Springer New York, 2009.

H. Wickham. Reshaping data with the reshape package. Journal of Statistical Software, 21(12), 2007.

Hadley Wickham (2011). The Split-Apply-Combine Strategy for Data Analysis. Journal of Statistical Software, 40(1), 1-29. URL http://www.jstatsoft.org/v40/i01/.

Hadley Wickham (2012). scales: Scale functions for graphics. R package version 0.2.3. http://CRAN.R-project.org/package=scales

John Fox and Sanford Weisberg (2011). An {R} Companion to Applied Regression, Second Edition. Thousand Oaks CA: Sage. URL: http://socserv.socsci.mcmaster.ca/jfox/Books/Companion

Lecoutre, Eric (2003). The R2HTML Package. R News, Vol 3. N. 3, Vienna, Austria.

Louis Kates and Thomas Petzoldt (2012). proto: Prototype object-based programming. R package version 0.3-10. http://CRAN.R-project.org/package=proto

Max Kuhn, contributions from Steve Weston, Jed Wing, James Forester and Thorn Thaler (2013). contrast: A collection of contrast methods. R package version 0.19. http://CRAN.R-project.org/package=contrast

Russell V. Lenth (2014). lsmeans: Least-Squares Means. R package version 2.00-1. http://CRAN.R-project.org/package=lsmeans

Torsten Hothorn, Frank Bretz and Peter Westfall (2008). Simultaneous Inference in General Parametric Models. Biometrical Journal 50(3), 346--363.

Analysis dataset

	Response	Covariate	Treatment	Sex	Strain
1	1.17	0.2514	D0	F	TG
2	1.30	0.4100	D0	F	TG
3	1.72	0.6793	D0	F	TG
4	1.17	0.3962	D0	F	TG
5	1.39	0.6052	D0	F	WT
6	1.44	0.9922	D0	F	WT
7	1.60	0.6852	D0	F	WT
8	1.57	0.0823	D0	F	WT
9	1.33	0.4141	D0	M	TG
10	1.57	0.0676	D0	M	TG
11	1.66	0.4219	D0	M	TG
12	1.47	0.2903	D0	M	TG

13	1.72	0.5147	D0	M	TG
14	1.17	0.8544	D0	M	TG
15	1.06	0.9139	D0	M	WT
16	1.24	0.7695	D0	M	WT
17	1.60	0.6424	D0	M	WT
18	0.99	0.3100	D0	M	WT
19	1.37	0.5913	D1	F	TG
20	1.50	0.0230	D1	F	TG
21	1.59	0.2288	D1	F	TG
22	1.37	0.8339	D1	F	TG
23	1.50	0.7166	D1	F	TG
24	1.37	0.0801	D1	F	TG
25	1.64	0.7762	D1	F	WT
26	1.53	0.8309	D1	F	WT
27	1.50	0.0713	D1	F	WT
28	1.59	0.0970	D1	F	WT
29	1.77	0.2096	D1	M	TG
30	1.86	0.4884	D1	M	TG
31	1.26	0.0570	D1	M	TG
32	1.64	0.8866	D1	M	TG
33	1.53	0.0309	D1	M	TG
34	1.77	0.7858	D1	M	TG
35	1.44	0.6545	D1	M	WT
36	1.92	0.4820	D1	M	WT
37	1.86	0.3587	D1	M	WT
38	1.26	0.6071	D1	M	WT
39	1.26	0.0035	D10	F	TG
40	1.77	0.3257	D10	F	TG
41	1.67	0.6326	D10	F	TG
42	1.64	0.1571	D10	F	TG
43	1.53	0.3426	D10	F	TG
44	1.77	0.4610	D10	F	TG
45	1.92	0.9277	D10	F	WT

46	1.37	0.7024	D10	F	WT
47	1.86	0.3880	D10	F	WT
48	1.26	0.1935	D10	F	WT
49	1.80	0.2869	D10	M	TG
50	1.19	0.7394	D10	M	TG
51	1.37	0.9639	D10	M	TG
52	1.44	0.2581	D10	M	TG
53	1.92	0.0598	D10	M	TG
54	1.37	0.6430	D10	M	TG
55	1.50	0.4731	D10	M	WT
56	1.59	0.7687	D10	M	WT
57	1.80	0.0630	D10	M	WT
58	1.19	0.1942	D10	M	WT
59	2.03	0.1377	D3	F	TG
60	2.20	0.6435	D3	F	TG
61	2.28	0.6616	D3	F	TG
62	1.72	0.3688	D3	F	TG
63	1.75	0.0808	D3	F	TG
64	1.81	0.8304	D3	F	TG
65	1.86	0.7942	D3	F	WT
66	1.64	0.4610	D3	F	WT
67	2.25	0.4802	D3	F	WT
68	1.88	0.2598	D3	F	WT
69	1.69	0.8419	D3	M	TG
70	1.82	0.9396	D3	M	TG
71	2.26	0.7052	D3	M	TG
72	1.61	0.0902	D3	M	TG
73	2.06	0.8240	D3	M	TG
74	2.18	0.9376	D3	M	TG
75	1.99	0.1465	D3	M	WT
76	1.69	0.9109	D3	M	WT
77	1.62	0.4604	D3	M	WT
78	2.48	0.2597	D3	M	WT