

# Multiple Comparison Procedures To A Control

## For AN(C)OVA Models

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## Basic Information

Automatic statistics for the file:

File
recovery.csv

Your selection for the encoding: UTF-8

Your selection for the decimal character: .

Observations (rows with at least one non-missing value): 41

Variables (columns with at least one non-missing value): 2

Variables considered continuous: 1

Variables considered continuous
minutes

Variables considered categorical: 1

Variables considered categorical
blanket

## Model Information

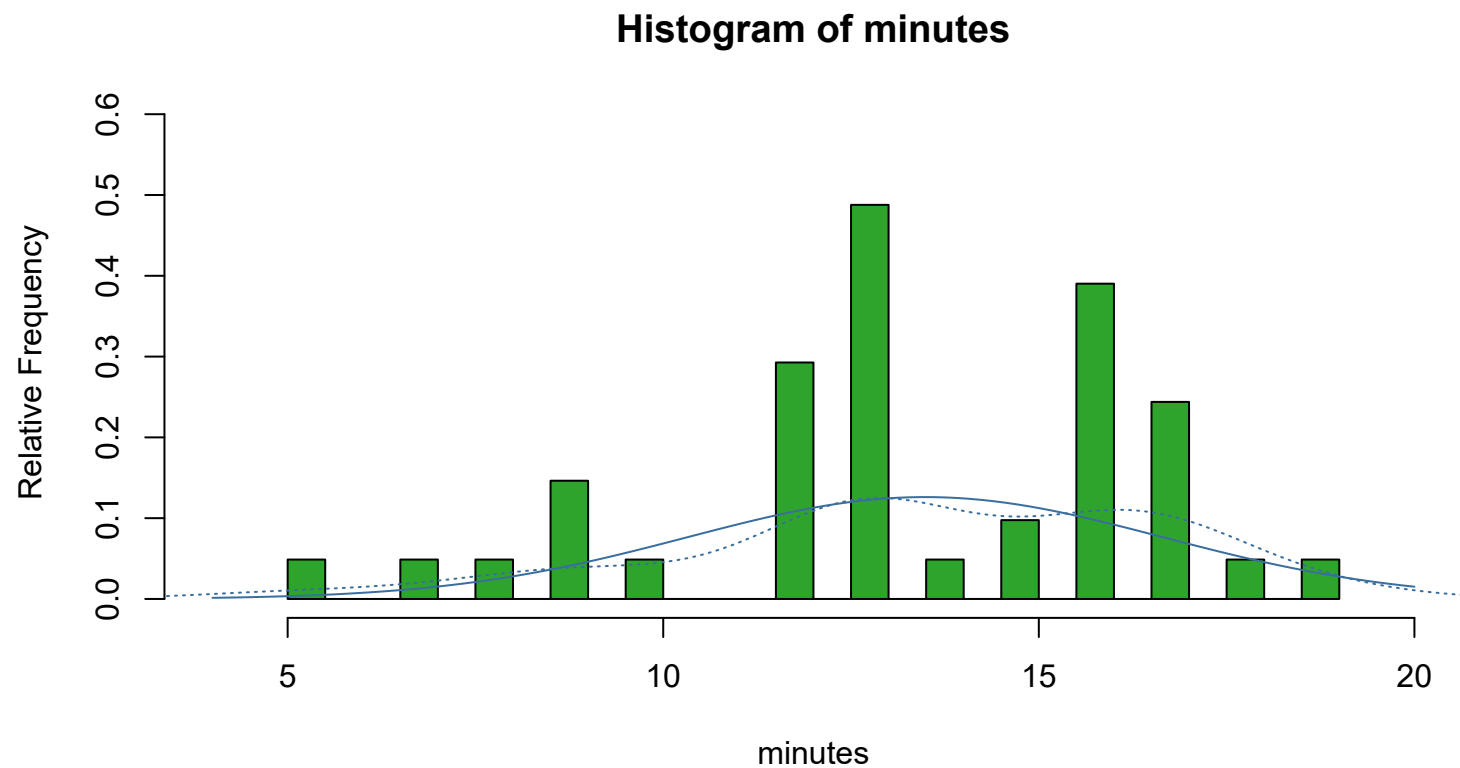
You defined the following linear model: minutes~blanket

You are interested in the factor: blanket

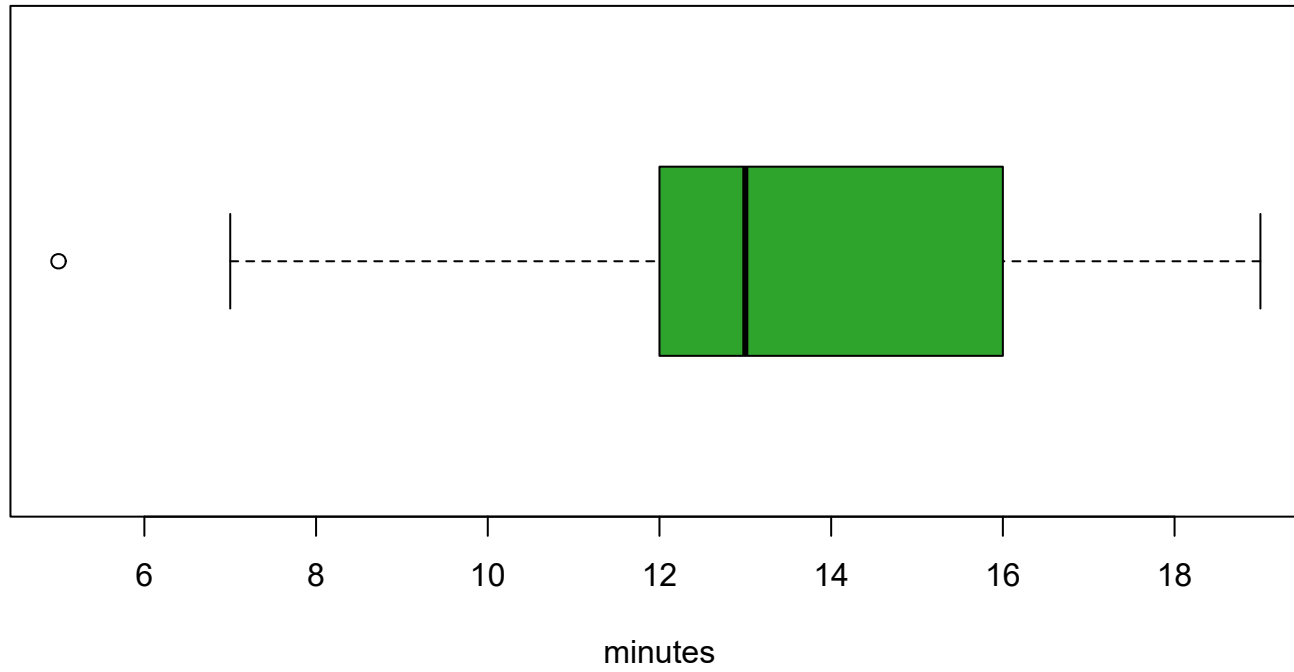
You are interested in pairwise comparisons to the reference level: b0

## Descriptive Plots

### Dependent Variable

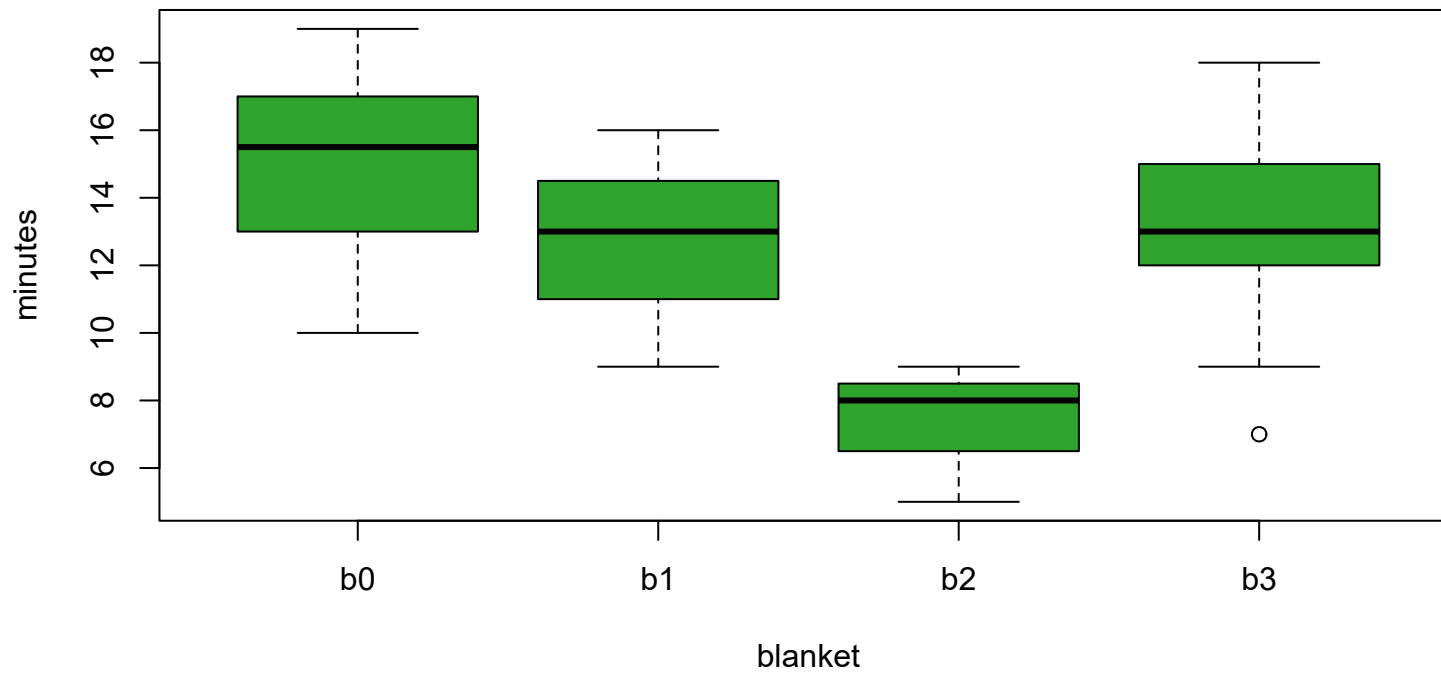


**Boxplot of minutes**



## Dependent Against Categorical Factors

**Boxplot of minutes ~ blanket**



## Analysis of variance

### Effect of the separate expressions of the given variables (Parameter Estimates)

Variable	Value	Std.Error	T.value	P.value	sign. level <sup>1</sup>	Significance at 5 percent error
(Intercept)	11.98	0.57	20.91	<0.001	***	Intercept Significant.
blanket1	2.82	0.70	4.00	<0.001	***	Significant. A Difference between the effect of blanket1 and its reference.
blanket2	0.68	1.20	0.57	0.573		Not Significant. No difference between the effect of blanket2 and its reference.
blanket3	-4.65	1.20	-3.87	<0.001	***	Significant. A Difference between the effect of blanket3 and its reference.

<sup>1</sup> '\*\*\*': sign. to 0.1% error. '\*\*': sign. to 1% error. '\*': sign. to 5% error. '.' : sign. to 10% error. ' ' : not sign. ' - ' : no statement.

### Total influence of factors (ANOVA Type III)

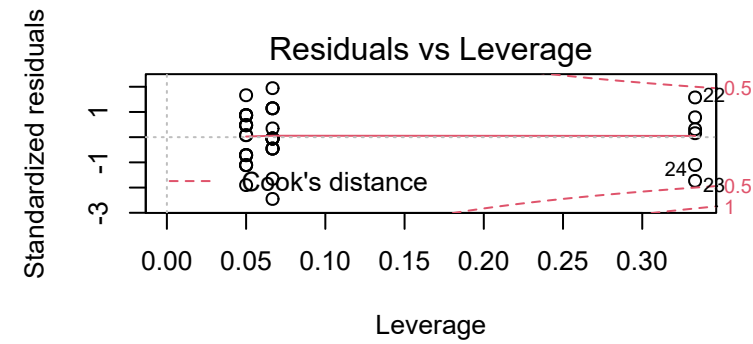
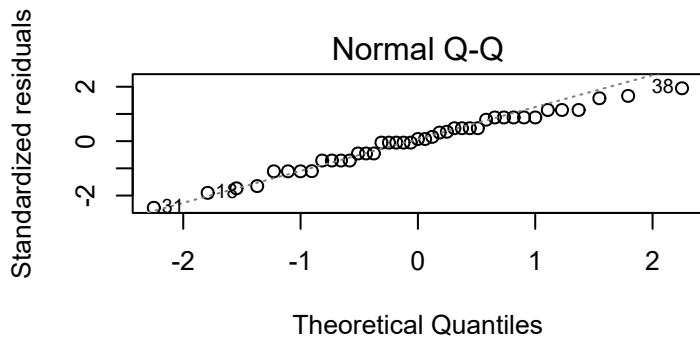
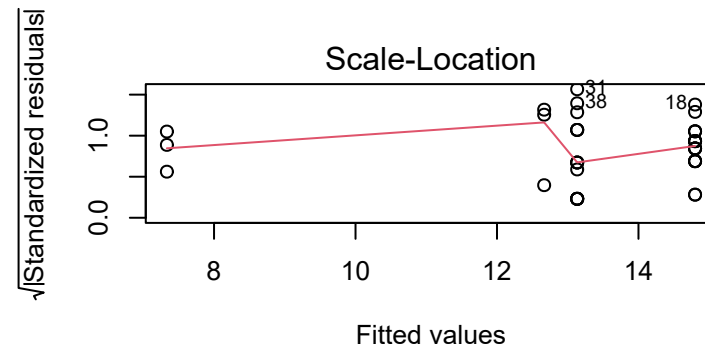
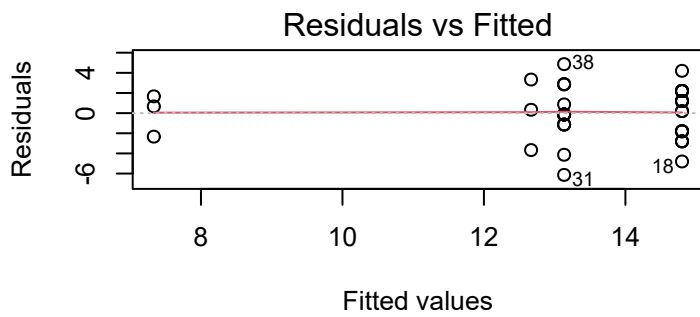
Variable	Sum.Sq	Df	F.value	P.value	Interpretation (5% error)
(Intercept)	2933.11	1	437.13	<0.001	Intercept significantly different from zero.
blanket	151.98	3	7.55	<0.001	There exist significant differences between the levels of factor 2.
Residuals	248.27	37			

Error in eval(expr, envir, enclos): object '.' not found

### Goodness Of Fit Measures

To evaluate the model, some parameters are listed below.

	Values	Explanation	Interpretation
Multiple R-Squared	0.38	Fraction of variance explained by the model.	0: No fitting of data by the model. , 1: Perfect fit.
Adjusted R-Squared	0.33	Adjusted R-Squared by penalizing higher p.	A higher value means a better fit by the model.
F-statistic	7.55	Overall significance of the model.	Note the P-value to assess significance.
P-value	<0.001	P-value of the F-statistic.	Significance to the 5% error. The model is better than the only-intercept model.



## Multiple Comparisons of Means to a Control

Theoretical background: Testing multiple hypotheses simultaneously and each at the same pre-specified significance level, increases the probability of false positive effects. The probability to commit at least one false positive decision increases with the number of hypotheses. A solution to overcome this problem is given by multiple comparisons procedures. Here, we do not control the per-hypothesis Type I error but the probability of committing at least one Type I error over all hypotheses. Using p-values adjusted for multiplicity, individual hypotheses can be finally compared with the pre-specified significance level.

### Dunnet

#### Multiple Comparison: Dunnet Contrasts

Test whether the factor level b0 of the factor blanket is different from the other levels. The Null Hypothesis is for example  $b1 - b0 = 0$ .

Null Hypothesis	Value	Std.Error	T.value	adjusted P.value	Sign. level <sup>1</sup>	Significance at 5 percent Type I error
$b1 - b0 = 0$	-2.13	1.60	-1.33	0.456	***	Not Significant. Level b0 of factor blanket is not different than b1 <sup>2</sup>
$b2 - b0 = 0$	-7.47	1.60	-4.66	<0.001		Significant. Level b2 of factor blanket is significantly different than b0 <sup>3</sup>
$b3 - b0 = 0$	-1.67	0.88	-1.88	0.182		Not Significant. Level b0 of factor blanket is not different than b3 <sup>2</sup>

<sup>1</sup> '\*\*\*': sign. to 0.1% error. '\*\*': sign. to 1% error. '\*': sign. to 5% error. ' . ': sign. to 10% error. ' ': not sign. ' - ': no statement.

<sup>2</sup> H1 does not hold significantly.

<sup>3</sup> H1 holds significantly.

#### Simoultaneous Confidence Intervals: Dunnet Contrasts

Simultaneous Confidence Intervals which includes the true value of the difference between the reference level b0 and the other levels of blanket

Null Hypothesis	Value	Lower bound	Upper bound	Interpretation
$b1 - b0 = 0$	-2.13	-6.12	1.86	The interval (-6.12, 1.86) traps the true difference b1-b0 with probability 95 percent. <sup>2</sup>
$b2 - b0 = 0$	-7.47	-11.46	-3.48	The interval (-11.46, -3.48) traps the true difference b2-b0 with probability 95 percent. <sup>1</sup>
$b3 - b0 = 0$	-1.67	-3.87	0.53	The interval (-3.87, 0.53) traps the true difference b3-b0 with probability 95 percent. <sup>2</sup>

<sup>1</sup> Remark: Zero is not in the confidence interval.

<sup>2</sup> Remark: Zero is in the confidence interval.



## Dunnet Sandwich

The sandwich function provides a heteroskedasticity-consistent estimate of the covariance matrix. Thus, the sandwich estimate is resistant to the violation of the variance homogeneity assumption.

### Multiple Comparison: Dunnett Contrasts Sandwich

Test whether the factor level b0 of the factor blanket is different from the other levels. The Null Hypothesis is for example  $b1 - b0 = 0$ .

Null Hypothesis	Value	Std.Error	T.value	adjusted P.value	Sign. level <sup>2</sup>	Significance at 5 percent Type I error
$b1 - b0 = 0$	-2.13	1.73	-1.23	0.521	***	Not Significant. Level b0 of factor blanket is two.sided than b1 <sup>3</sup>
$b2 - b0 = 0$	-7.47	1.11	-6.73	<0.001		Significant. Level b2 of factor blanket is significantly two.sided than b0 <sup>4</sup>
$b3 - b0 = 0$	-1.67	0.86	-1.93	0.167		Not Significant. Level b0 of factor blanket is two.sided than b3 <sup>3</sup>

<sup>1</sup> Note: Due to the applied sandwich estimator, the standard errors of the effects may be unequal.

<sup>2</sup> '\*\*\*': sign. to 0.1% error. '\*\*': sign. to 1% error. '\*': sign. to 5% error. ' . ': sign. to 10% error. ' ': not sign. ' - ': no statement.

<sup>3</sup> H1 does not hold significantly.

<sup>4</sup> H1 holds significantly.

### Simultaneous Confidence Intervals: Dunnett Contrasts Sandwich

Simultaneous Confidence Intervals which includes the true value of the difference between the reference level b0 and the other levels of blanket.

Null Hypothesis	Value	Lower bound	Upper bound	Interpretation
$b1 - b0 = 0$	-2.13	-6.45	2.19	The interval (-6.45, 2.19) traps the true difference b1-b0 with probability 95 percent. <sup>2</sup>
$b2 - b0 = 0$	-7.47	-10.23	-4.70	The interval (-10.23, -4.7) traps the true difference b2-b0 with probability 95 percent. <sup>1</sup>
$b3 - b0 = 0$	-1.67	-3.82	0.49	The interval (-3.82, 0.49) traps the true difference b3-b0 with probability 95 percent. <sup>2</sup>

<sup>1</sup> Remark: Zero is not in the confidence interval.

<sup>2</sup> Remark: Zero is in the confidence interval.

## References

- Bretz, Frank, and Peter Westfall Torsten Hothorn. 2010. *Multiple Comparisons Using R*. 1st Edition. Chapman; Hall/CRC. <https://doi.org/10.1201/9781420010909>.
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