Title: Paper-Airplane-Flight-Analysis

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date: “2026-01-15”

output: pdf_document

2026-01-18

```
> DS_Aufgabe5 <-
+   readXL("5_Technischer Vergleich mit Konkurrenz.xlsx",
+    rownames=FALSE, header=TRUE, na="", sheet="Daten", stringsAsFactors=TRUE)
```

```
Error:
! `path` does not exist: '5_Technischer Vergleich mit Konkurrenz.xlsx'
```

```
> library(abind, pos=17)
```

```
> library(e1071, pos=18)
```

Zusammenfassungen für numerische Variablen: DS_Aufgabe5

```
> numSummary(DS_Aufgabe5[,c("Konkurrent.A", "Konkurrent.B", "Konkurrent.C",
+   "Konkurrent.D", "Unser.Modell"), drop=FALSE], statistics=c("mean", "sd",
+   "IQR", "quantiles"), quantiles=c(0,.25,.5,.75,1))
```

```
                mean        sd    IQR   0%    25%   50%    75% 100%  n
Konkurrent.A 7.210333 0.3757703 0.4550 6.42 7.0450 7.290 7.5000 7.84 30
Konkurrent.B 2.977333 0.2476780 0.2950 2.41 2.7875 3.000 3.0825 3.49 30
```

```
Konkurrent.C 5.182667 0.3550613 0.4650 4.60 4.9125 5.205 5.3775 6.16 30
Konkurrent.D 6.037333 0.3217188 0.4475 5.40 5.8175 6.020 6.2650 6.67 30
Unser.Modell 3.081000 0.2832003 0.4900 2.59 2.8550 3.060 3.3450 3.62 30
```

```
> Aufgabe5_StackedData <- stack(DS_Aufgabe5[, c("Konkurrent.A","Konkurrent.B",
+   "Konkurrent.C","Konkurrent.D","Unser.Modell")])
> names(Aufgabe5_StackedData) <- c("variable", "factor")
```

Levenes Test: variable ~ factor

```
> Tapply(variable ~ factor, var, na.action=na.omit,
+   data=Aufgabe5_StackedData) # variances by group
```

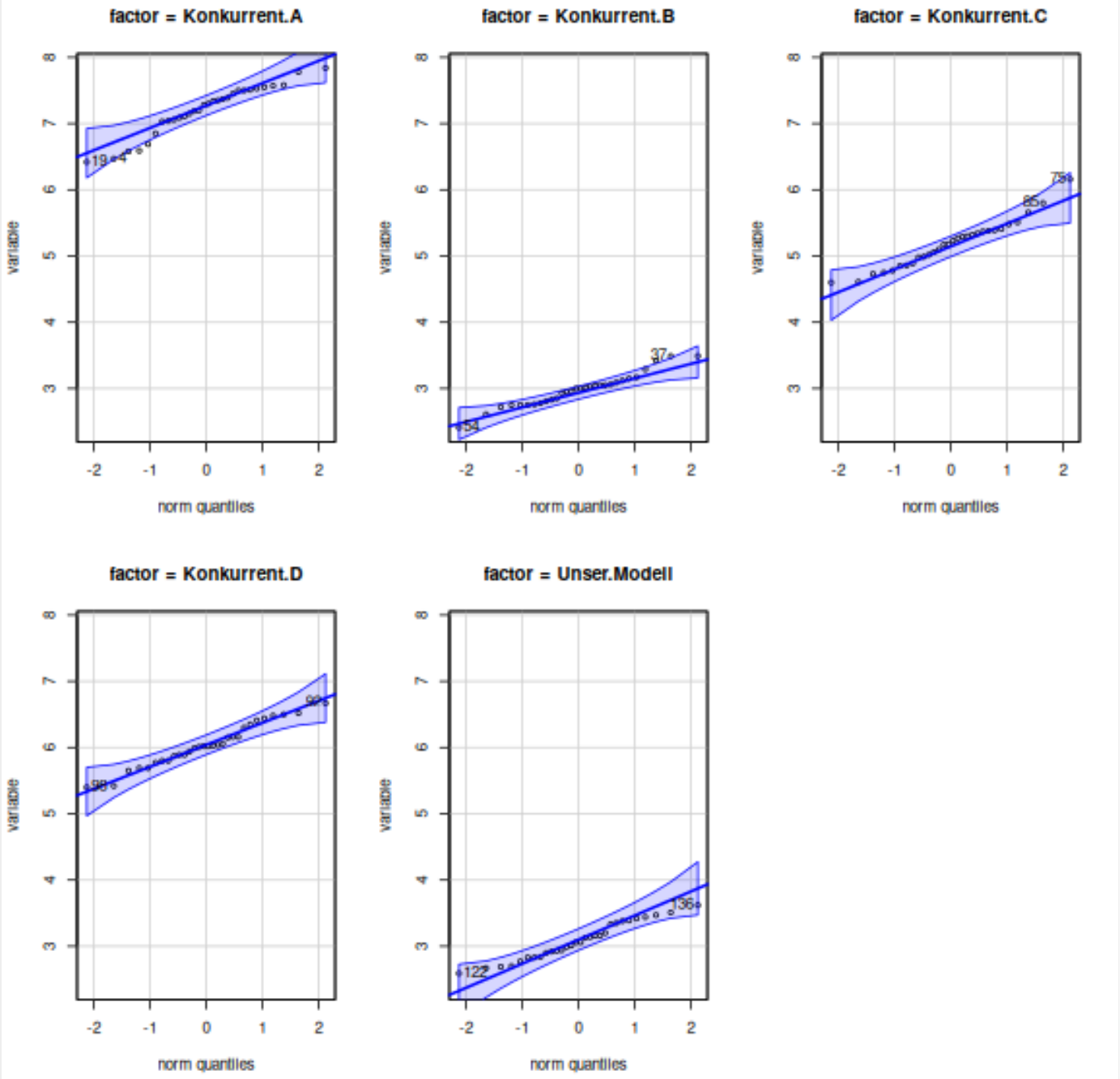
```
Konkurrent.A Konkurrent.B Konkurrent.C Konkurrent.D Unser.Modell
  0.14120333   0.06134437   0.12606851   0.10350299   0.08020241
```

```
> leveneTest(variable ~ factor, data=Aufgabe5_StackedData, center="median")
```

```
Levene's Test for Homogeneity of Variance (center = "median")
       Df F value Pr(>F)
group   4  1.3319 0.2609
      145
```

Quantile-Comparison Plot: variable

```
> with(Aufgabe5_StackedData, qqPlot(variable, dist="norm", id=list(method="y",
+    n=2, labels=rownames(Aufgabe5_StackedData)), groups=factor))
```



plot of chunk unnamed-chunk-8

Test auf Normalverteilung: variable ~ factor

```
> normalityTest(variable ~ factor, test="shapiro.test",
+   data=Aufgabe5_StackedData)
```

```
 --------
 factor = Konkurrent.A

        Shapiro-Wilk normality test

data:  variable
```

```
W = 0.94325, p-value = 0.1113

 --------
 factor = Konkurrent.B

        Shapiro-Wilk normality test

data:  variable
W = 0.96553, p-value = 0.4251

 --------
 factor = Konkurrent.C

        Shapiro-Wilk normality test

data:  variable
W = 0.967, p-value = 0.4607

 --------
 factor = Konkurrent.D

        Shapiro-Wilk normality test

data:  variable
W = 0.97552, p-value = 0.6982

 --------
 factor = Unser.Modell

        Shapiro-Wilk normality test

data:  variable
W = 0.96597, p-value = 0.4354

 --------

 p-values adjusted by the Holm method:
             unadjusted adjusted
Konkurrent.A 0.11129    0.55644
Konkurrent.B 0.42506    1.00000
Konkurrent.C 0.46068    1.00000
Konkurrent.D 0.69817    1.00000
Unser.Modell 0.43543    1.00000
```

```
> library(mvtnorm, pos=19)
```

```
> library(survival, pos=19)
```

```
> library(MASS, pos=19)
```

```
> library(TH.data, pos=19)
```

```
> library(multcomp, pos=19)
```

Ein-Weg-Varianzanalyse: variable ~ factor

```
> AnovaModel.1 <- aov(variable ~ factor, data=Aufgabe5_StackedData)
> summary(AnovaModel.1)
```

```
             Df Sum Sq Mean Sq F value Pr(>F)
factor        4  411.5   102.9    1004 <2e-16 ***
Residuals   145   14.9     0.1
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

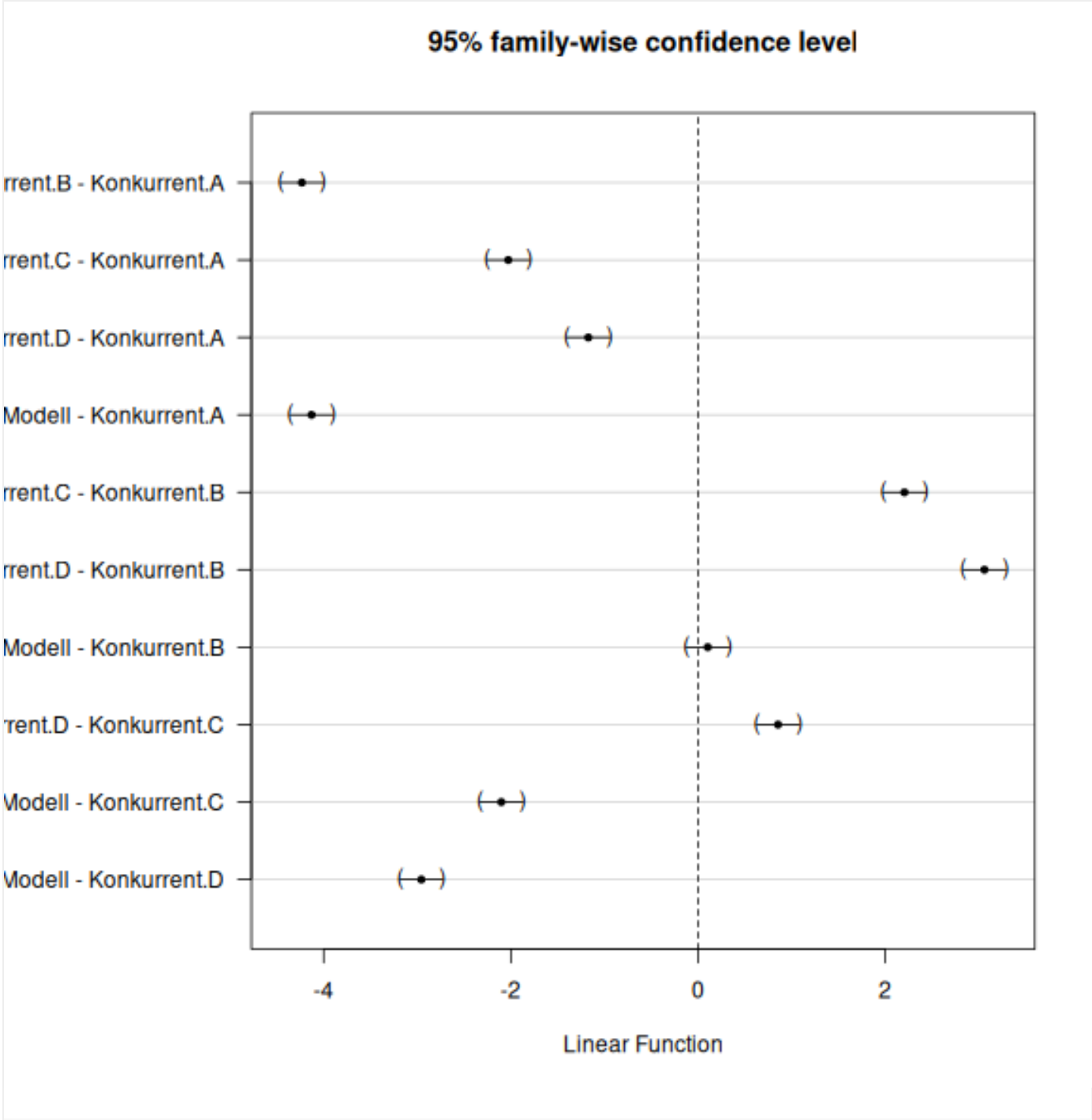
```
> with(Aufgabe5_StackedData, numSummary(variable, groups=factor,
+   statistics=c("mean", "sd")))
```

```
                 mean        sd data:n
Konkurrent.A 7.210333 0.3757703     30
Konkurrent.B 2.977333 0.2476780     30
Konkurrent.C 5.182667 0.3550613     30
Konkurrent.D 6.037333 0.3217188     30
Unser.Modell 3.081000 0.2832003     30
```

```
> local({
+   .Pairs <- glht(AnovaModel.1, linfct = mcp(factor = "Tukey"))
+   print(summary(.Pairs)) # pairwise tests
+   print(confint(.Pairs, level=0.95)) # confidence intervals
+   print(cld(.Pairs, level=0.05)) # compact letter display
+   old.oma <- par(oma=c(0, 5, 0, 0))
+   plot(confint(.Pairs))
+   par(old.oma)
+ })
```

```

         Simultaneous Tests for General Linear Hypotheses

Multiple Comparisons of Means: Tukey Contrasts


Fit: aov(formula = variable ~ factor, data = Aufgabe5_StackedData)

Linear Hypotheses:
                                Estimate Std. Error t value Pr(>|t|)
Konkurrent.B - Konkurrent.A == 0 -4.23300    0.08265 -51.216  <0.0001 ***
```

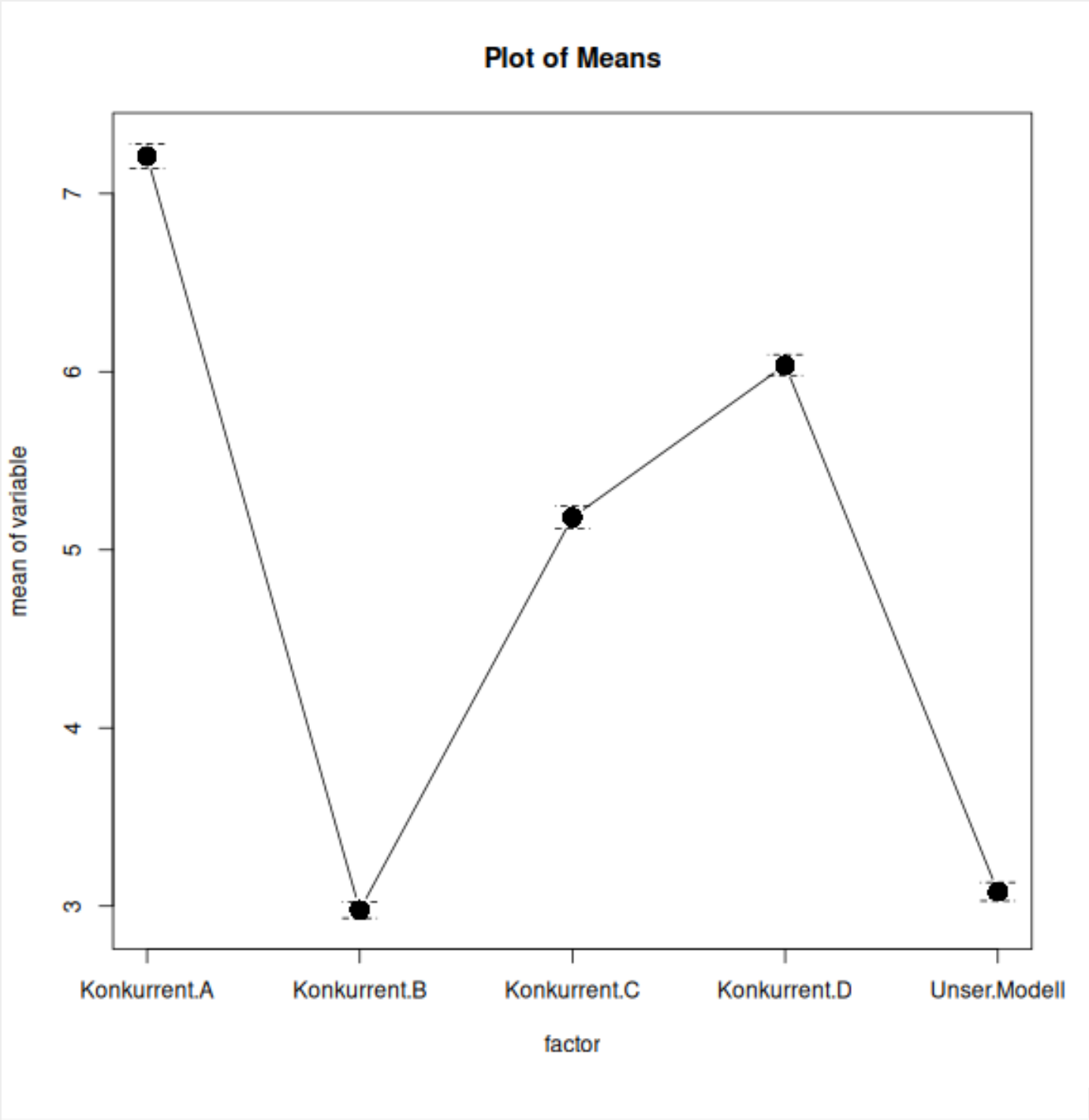
```
Konkurrent.C - Konkurrent.A == 0 -2.02767    0.08265 -24.533  <0.0001 ***
Konkurrent.D - Konkurrent.A == 0 -1.17300    0.08265 -14.192  <0.0001 ***
Unser.Modell - Konkurrent.A == 0 -4.12933    0.08265 -49.962  <0.0001 ***
Konkurrent.C - Konkurrent.B == 0  2.20533    0.08265  26.683  <0.0001 ***
Konkurrent.D - Konkurrent.B == 0  3.06000    0.08265  37.024  <0.0001 ***
Unser.Modell - Konkurrent.B == 0  0.10367    0.08265   1.254    0.719
Konkurrent.D - Konkurrent.C == 0  0.85467    0.08265  10.341  <0.0001 ***
Unser.Modell - Konkurrent.C == 0 -2.10167    0.08265 -25.429  <0.0001 ***
Unser.Modell - Konkurrent.D == 0 -2.95633    0.08265 -35.769  <0.0001 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
(Adjusted p values reported -- single-step method)


         Simultaneous Confidence Intervals

Multiple Comparisons of Means: Tukey Contrasts


Fit: aov(formula = variable ~ factor, data = Aufgabe5_StackedData)

Quantile = 2.7627
95% family-wise confidence level


Linear Hypotheses:
                               Estimate lwr     upr
Konkurrent.B - Konkurrent.A == 0 -4.2330  -4.4613 -4.0047
Konkurrent.C - Konkurrent.A == 0 -2.0277  -2.2560 -1.7993
Konkurrent.D - Konkurrent.A == 0 -1.1730  -1.4013 -0.9447
Unser.Modell - Konkurrent.A == 0 -4.1293  -4.3577 -3.9010
Konkurrent.C - Konkurrent.B == 0  2.2053   1.9770  2.4337
Konkurrent.D - Konkurrent.B == 0  3.0600   2.8317  3.2883
Unser.Modell - Konkurrent.B == 0  0.1037  -0.1247  0.3320
Konkurrent.D - Konkurrent.C == 0  0.8547   0.6263  1.0830
Unser.Modell - Konkurrent.C == 0 -2.1017  -2.3300 -1.8733
Unser.Modell - Konkurrent.D == 0 -2.9563  -3.1847 -2.7280

Konkurrent.A Konkurrent.B Konkurrent.C Konkurrent.D Unser.Modell
         "a"          "b"          "c"          "d"          "b"
```



plot of chunk unnamed-chunk-15

Plot of Means: variable by factor

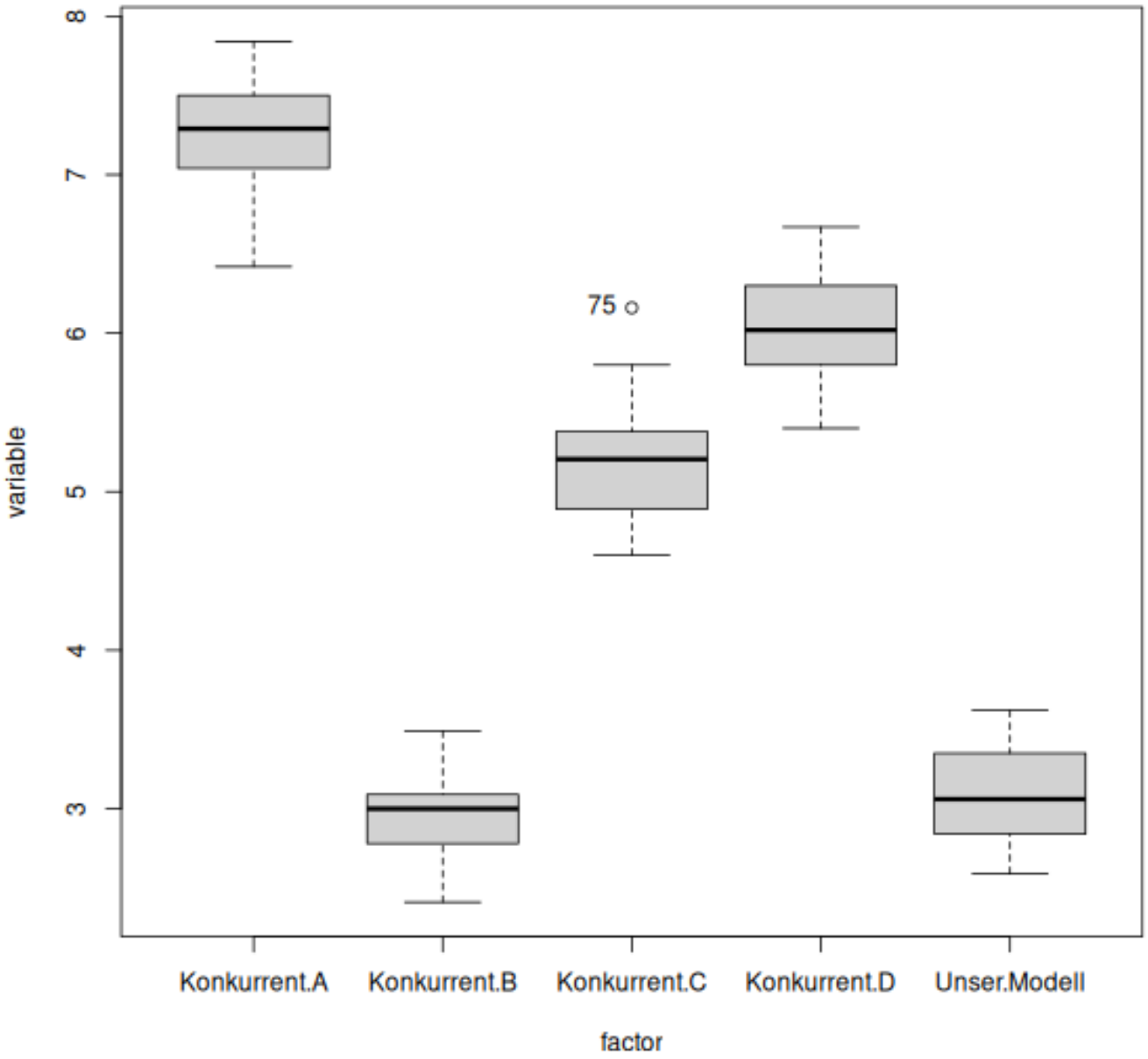
```
> with(Aufgabe5_StackedData, plotMeans(variable, factor, error.bars="se",
+   connect=TRUE))
```



plot of chunk unnamed-chunk-16

Boxplot: variable ~ factor

```
> Boxplot(variable ~ factor, data=Aufgabe5_StackedData, id=list(method="y"))
```



plot of chunk unnamed-chunk-17

```
[1] "75"
```