Example p. 35 / Beispiel S. 35

FK

automatic

Working directory

```
> setwd("D:/kronthafranz/Documents/01Lehre/06Quantitative Forschungsmethoden
dt en")
```

Load data

```
> load("D:/kronthafranz/Documents/01Lehre/06Quantitative Forschungsmethoden
dt en/05ANOVA/production.RData")
```

Define factos

```
> production <- within(production, {
+   f_group <- as.factor(group)
+ })

> production <- within(production, {
+   f_method <- as.factor(method)
+ })
```

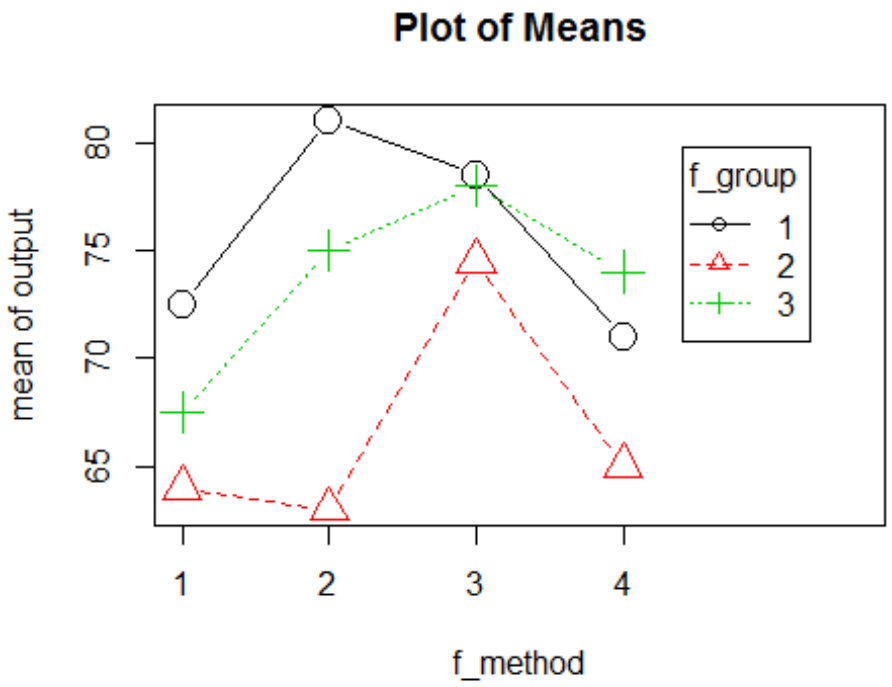
Descriptive statistics

```
> with(production, (tapply(output, list(f_group, f_method), mean,
na.rm=TRUE)))

     1  2    3  4
1 72.5 81 78.5 71
2 64.0 63 74.5 65
3 67.5 75 78.0 74

> with(production, (tapply(output, list(f_group, f_method), sd, na.rm=TRUE)))

         1        2         3        4
1 6.363961 2.828427 0.7071068 5.656854
2 4.242641 1.414214 2.1213203 4.242641
3 3.535534 4.242641 4.2426407 2.828427

> with(production, (tapply(output, list(f_group, f_method), function(x)
+   sum(!is.na(x)))))

  1 2 3 4
1 2 2 2 2
```

```
2 2 2 2 2
3 2 2 2 2
```

Plot means

```
> with(production, plotMeans(output, f_method, f_group, error.bars="none",
+   connect=TRUE))
```



Check assumptions

Independence of observations

Matter of design of the experiment

Equality of variance

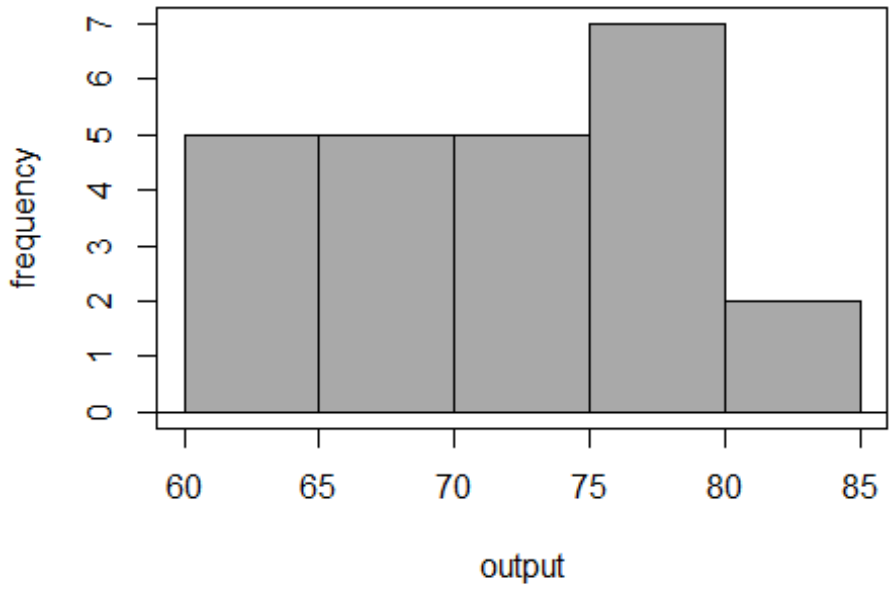
```
> with(production, tapply(output, list(f_group, f_method), var, na.rm=TRUE))

     1  2    3  4
1 40.5  8  0.5 32
2 18.0  2  4.5 18
3 12.5 18 18.0  8

> with(production, tapply(output, list(f_group, f_method), var, na.rm=TRUE))

     1  2    3  4
1 40.5  8  0.5 32
```

```
2 18.0  2  4.5 18
3 12.5 18 18.0  8
```

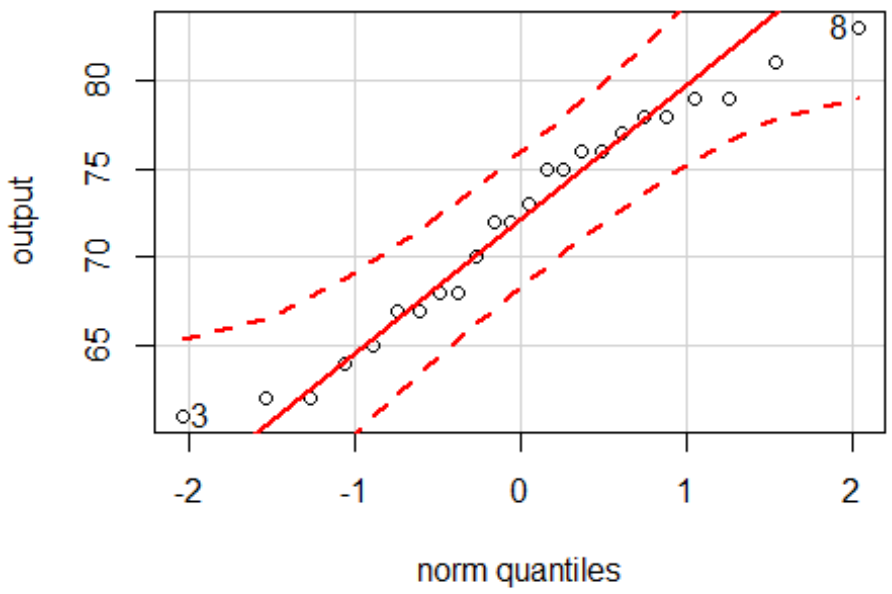
```
> leveneTest(output ~ f_group*f_method, data=production, center="mean")

Levene's Test for Homogeneity of Variance (center = "mean")
      Df    F value    Pr(>F)
group 11 4.9877e+29 < 2.2e-16 ***
      12
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Normal distribution

```
> with(production, Hist(output, scale="frequency", breaks="Sturges",
col="darkgray"))
```




```
> with(production, qqPlot(output, dist="norm", id.method="y", id.n=2,
+   labels=rownames(production)))
```




```
 3  8
 1 24
```

```
> normalityTest(~output, test="shapiro.test", data=production)


    Shapiro-Wilk normality test

data:  output
W = 0.95365, p-value = 0.3245
```

ANOVA

```
> AnovaTwoWay.1 <-aov(output ~ f_method*f_group, data=production)

> summary(AnovaTwoWay.1)

                Df Sum Sq Mean Sq F value  Pr(>F)
f_method         3  276.0   92.00   6.133 0.00902 **
f_group          2  364.8  182.38  12.158 0.00130 **
f_method:f_group  6  147.2   24.54   1.636 0.22020
Residuals        12  180.0   15.00
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

> TukeyHSD(AnovaTwoWay.1)

  Tukey multiple comparisons of means
    95% family-wise confidence level
```

```
Fit: aov(formula = output ~ f_method * f_group, data = production)

$f_method
    diff        lwr        upr     p adj
2-1    5  -1.638665 11.6386647 0.1686744
3-1    9   2.361335 15.6386647 0.0079118
4-1    2  -4.638665  8.6386647 0.8079080
3-2    4  -2.638665 10.6386647 0.3247013
4-2   -3  -9.638665  3.6386647 0.5559655
4-3   -7 -13.638665 -0.3613353 0.0377806

$f_group
      diff        lwr       upr     p adj
2-1 -9.125 -14.291296 -3.958704 0.0013508
3-1 -2.125  -7.291296  3.041296 0.5336071
3-2  7.000   1.833704 12.166296 0.0091964

$`f_method:f_group`
         diff         lwr        upr     p adj
2:1-1:1   8.5  -6.8763439 23.8763439 0.5789463
3:1-1:1   6.0  -9.3763439 21.3763439 0.8984712
4:1-1:1  -1.5 -16.8763439 13.8763439 0.9999993
1:2-1:1  -8.5 -23.8763439  6.8763439 0.5789463
2:2-1:1  -9.5 -24.8763439  5.8763439 0.4406069
3:2-1:1   2.0 -13.3763439 17.3763439 0.9999863
4:2-1:1  -7.5 -22.8763439  7.8763439 0.7221590
1:3-1:1  -5.0 -20.3763439 10.3763439 0.9651948
2:3-1:1   2.5 -12.8763439 17.8763439 0.9998793
3:3-1:1   5.5  -9.8763439 20.8763439 0.9374342
4:3-1:1   1.5 -13.8763439 16.8763439 0.9999993
3:1-2:1  -2.5 -17.8763439 12.8763439 0.9998793
4:1-2:1 -10.0 -25.3763439  5.3763439 0.3781198
1:2-2:1 -17.0 -32.3763439 -1.6236561 0.0257664
2:2-2:1 -18.0 -33.3763439 -2.6236561 0.0171407
3:2-2:1  -6.5 -21.8763439  8.8763439 0.8484691
4:2-2:1 -16.0 -31.3763439 -0.6236561 0.0387722
1:3-2:1 -13.5 -28.8763439  1.8763439 0.1062819
2:3-2:1  -6.0 -21.3763439  9.3763439 0.8984712
3:3-2:1  -3.0 -18.3763439 12.3763439 0.9993521
4:3-2:1  -7.0 -22.3763439  8.3763439 0.7888899
4:1-3:1  -7.5 -22.8763439  7.8763439 0.7221590
1:2-3:1 -14.5 -29.8763439  0.8763439 0.0713138
2:2-3:1 -15.5 -30.8763439 -0.1236561 0.0475448
3:2-3:1  -4.0 -19.3763439 11.3763439 0.9928524
4:2-3:1 -13.5 -28.8763439  1.8763439 0.1062819
1:3-3:1 -11.0 -26.3763439  4.3763439 0.2711633
2:3-3:1  -3.5 -18.8763439 11.8763439 0.9975493
3:3-3:1  -0.5 -15.8763439 14.8763439 1.0000000
4:3-3:1  -4.5 -19.8763439 10.8763439 0.9829342
1:2-4:1  -7.0 -22.3763439  8.3763439 0.7888899
```

```
2:2-4:1  -8.0 -23.3763439  7.3763439 0.6511940
3:2-4:1   3.5 -11.8763439 18.8763439 0.9975493
4:2-4:1  -6.0 -21.3763439  9.3763439 0.8984712
1:3-4:1  -3.5 -18.8763439 11.8763439 0.9975493
2:3-4:1   4.0 -11.3763439 19.3763439 0.9928524
3:3-4:1   7.0  -8.3763439 22.3763439 0.7888899
4:3-4:1   3.0 -12.3763439 18.3763439 0.9993521
2:2-1:2  -1.0 -16.3763439 14.3763439 1.0000000
3:2-1:2  10.5  -4.8763439 25.8763439 0.3215016
4:2-1:2   1.0 -14.3763439 16.3763439 1.0000000
1:3-1:2   3.5 -11.8763439 18.8763439 0.9975493
2:3-1:2  11.0  -4.3763439 26.3763439 0.2711633
3:3-1:2  14.0  -1.3763439 29.3763439 0.0871519
4:3-1:2  10.0  -5.3763439 25.3763439 0.3781198
3:2-2:2  11.5  -3.8763439 26.8763439 0.2271207
4:2-2:2   2.0 -13.3763439 17.3763439 0.9999863
1:3-2:2   4.5 -10.8763439 19.8763439 0.9829342
2:3-2:2  12.0  -3.3763439 27.3763439 0.1891065
3:3-2:2  15.0  -0.3763439 30.3763439 0.0582614
4:3-2:2  11.0  -4.3763439 26.3763439 0.2711633
4:2-3:2  -9.5 -24.8763439  5.8763439 0.4406069
1:3-3:2  -7.0 -22.3763439  8.3763439 0.7888899
2:3-3:2   0.5 -14.8763439 15.8763439 1.0000000
3:3-3:2   3.5 -11.8763439 18.8763439 0.9975493
4:3-3:2  -0.5 -15.8763439 14.8763439 1.0000000
1:3-4:2   2.5 -12.8763439 17.8763439 0.9998793
2:3-4:2  10.0  -5.3763439 25.3763439 0.3781198
3:3-4:2  13.0  -2.3763439 28.3763439 0.1292588
4:3-4:2   9.0  -6.3763439 24.3763439 0.5080489
2:3-1:3   7.5  -7.8763439 22.8763439 0.7221590
3:3-1:3  10.5  -4.8763439 25.8763439 0.3215016
4:3-1:3   6.5  -8.8763439 21.8763439 0.8484691
3:3-2:3   3.0 -12.3763439 18.3763439 0.9993521
4:3-2:3  -1.0 -16.3763439 14.3763439 1.0000000
4:3-3:3  -4.0 -19.3763439 11.3763439 0.9928524
```

Interpretation:

Reject H0 for factor method, meaning the method used influences the productivity

Reject H0 for factor group, meaning the groups have an influence on productivity

Do not reject H0 for the interaction, meaning there is no interaction between productivity and method

There is a difference between method 3 and 1 at the 5% level, method 3 is more productive than 1

There is a difference between method 4 and 3 at the 5% level, method 3 is more productive than 4

There is a difference between group 2 and 1 at the 5% level, group 1 is more productive than 2

There is a difference between method 3 and 2 at the 5% level, group 3 is more productive than 2