From the subjective to the objective: Can we measure an apple’s bitterness?

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Preliminary on balanced incomplete block designs (BIBDs)

■ **TABLE 4.22**
Balanced Incomplete Block Design for Catalyst Experiment

Treatment (Catalyst)	Block (Batch of Raw Material)				
	1	2	3	4	$y_{i.}$
1	73	74	—	71	218
2	—	75	67	72	214
3	73	75	68	—	216
4	75	—	72	75	222
$y_{.j}$	221	224	207	218	$870 = y_{..}$

```{r}
one.way <- aov(time~factor(block)+factor(treatment), data=df)
summary(one.way)
```

```
                 Df Sum Sq Mean Sq F value  Pr(>F)
factor(block)     3  55.00  18.333   28.20 0.00147 **
factor(treatment) 3  22.75   7.583   11.67 0.01074 *
Residuals         5   3.25   0.650
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Background

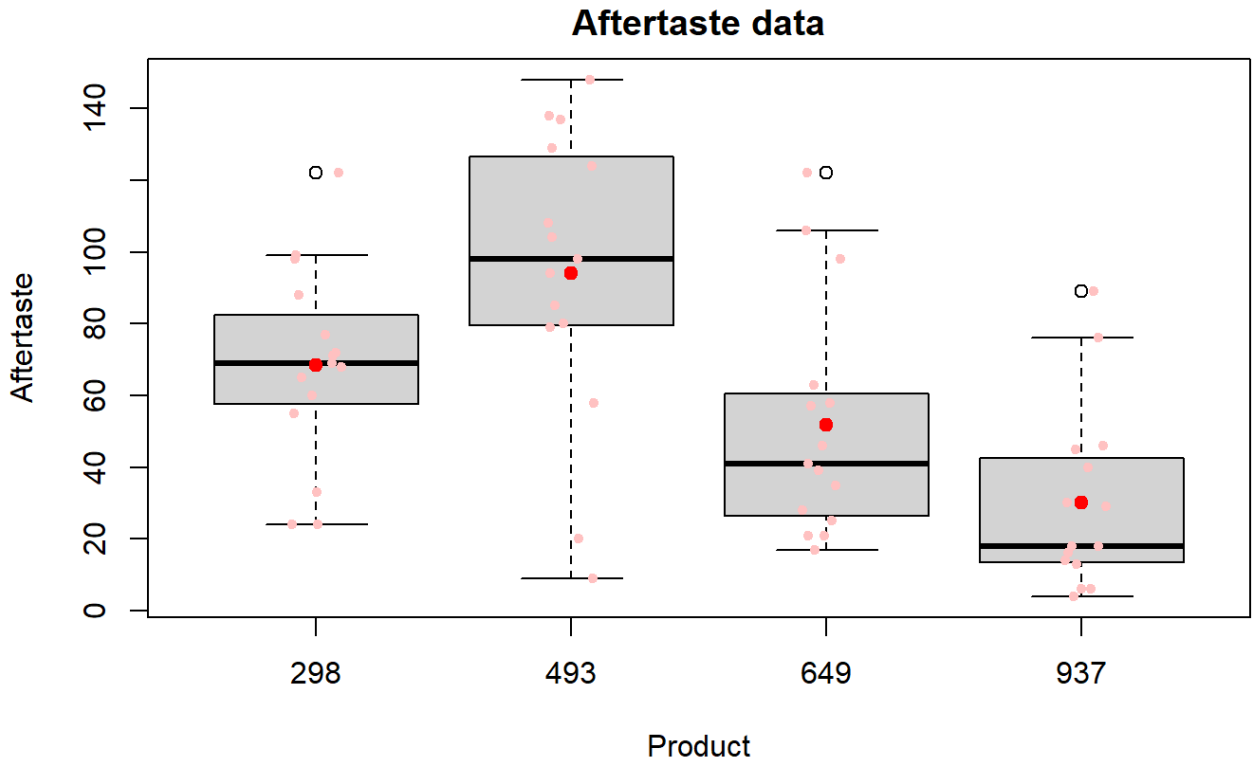
1. 20 tasters (blocks) assessed 3 out of 4 different varieties of apples (treatments)
2. Tasters are labeled a-t and apples are labeled 298, 493, 649 and 937
3. The tasters then had to then rank the taste of these apples based on their aftertaste from 0 (strong dislike) to 150 (strong like)
4. The experiment was conducted as a balanced incomplete block design

Hypothesis

H0: Equality of treatment means for the aftertaste of the apples

Ha: Inequality between at least two of the means of the aftertaste

Boxplots

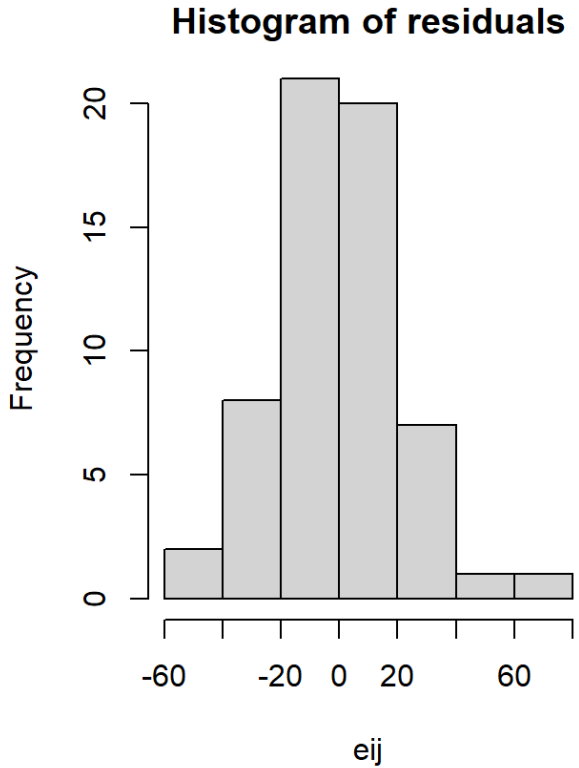

Aftertaste data
Aftertaste
0
20
40
60
80
100
140
298
493
649
937
Product

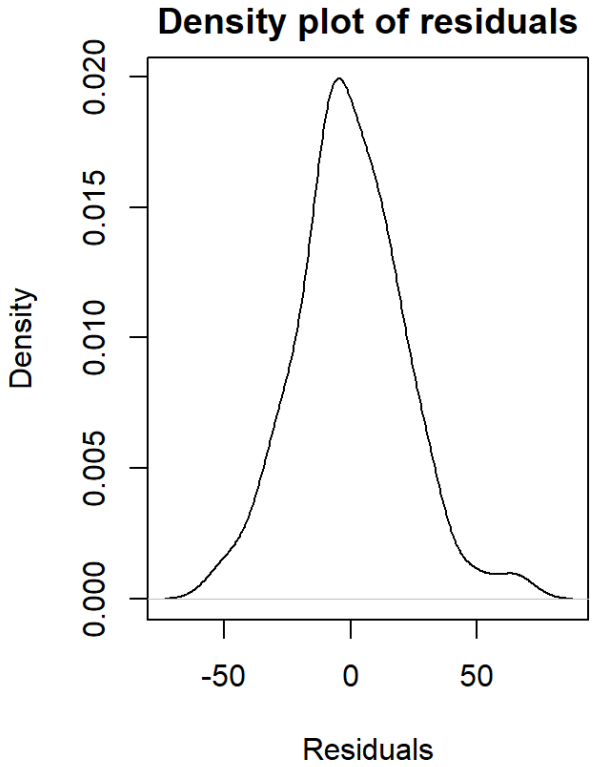
ANOVA Assumptions

1. Data are **i.i.d normally distributed**
2. **Homogenity of variance** among treatments (in our case, aftertaste values of apple products), which is called homoscedasticity, which is not to be pronounced...
3. Balanced design

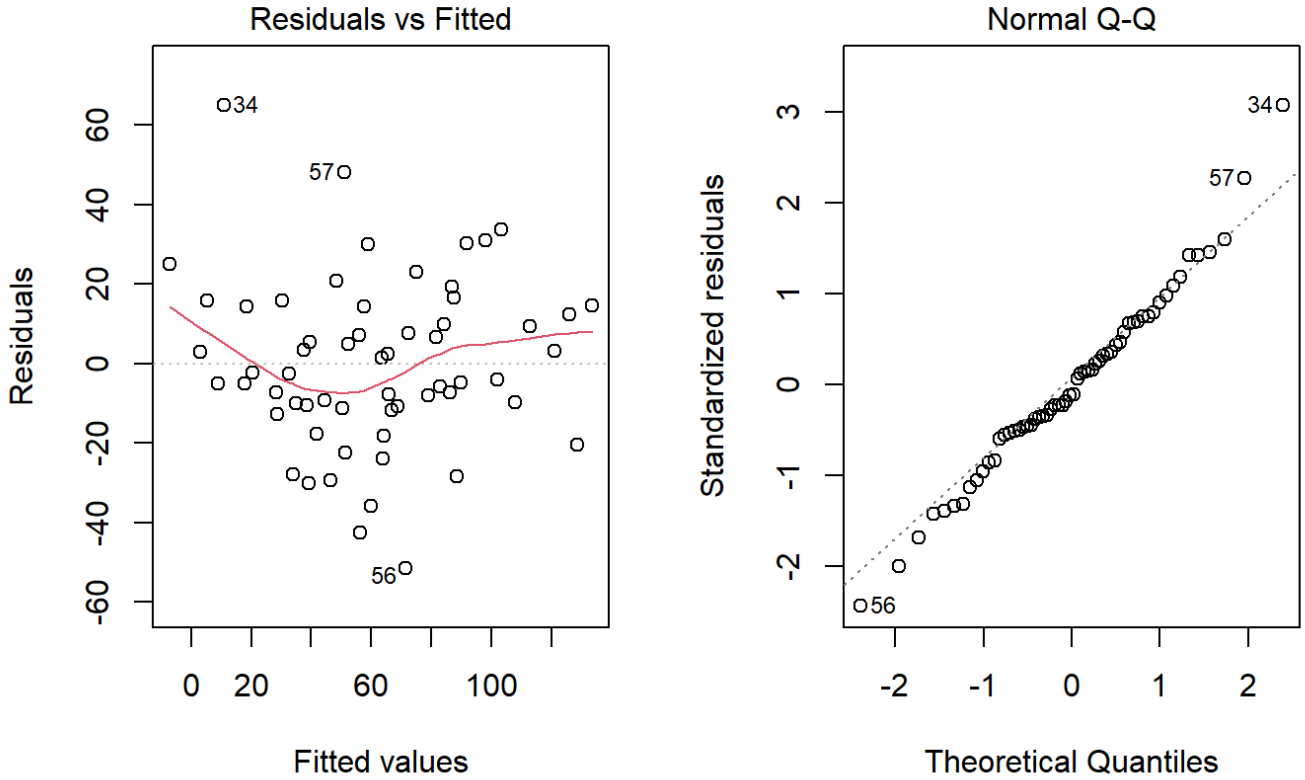
Ethan begins here

Plots of Residuals





Diagnostic Plots



Shapiro-Wilk Test

```
        Shapiro-Wilk normality test

data:  eData$aftertaste
W = 0.94845, p-value = 0.01318
```

Levene's Test

```
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group 19   0.555 0.9156
      40
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group  3  0.9128 0.4407
      56
```

ANOVA

```r
appletaste.aov=aov(aftertaste~panelist+product, data=eData)
summary(appletaste.aov)
```

```
            Df Sum Sq Mean Sq F value   Pr(>F)
panelist    19  30461    1603   2.206   0.0194 *
product      3  34014   11338  15.599 1.02e-06 ***
Residuals   37  26892     727
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Fisher LSD Test for difference of Means

```
$product
             diff    lwr.ci    upr.ci     pval
493-298  18.28889  -1.65748  38.23526  0.0712 .
649-298 -11.88889 -31.83526   8.05748  0.2348
937-298 -43.37778 -63.32415 -23.43141 8.7e-05 ***
649-493 -30.17778 -50.12415 -10.23141  0.0040 **
937-493 -61.66667 -81.61304 -41.72030 2.8e-07 ***
937-649 -31.48889 -51.43526 -11.54252  0.0028 **
```

Tukey's Test for difference of means

```
$product
             diff     lwr.ci     upr.ci    pval
493-298  18.28889  -8.189782  44.767560 0.26354
649-298 -11.88889 -38.367560  14.589782 0.62596
937-298 -43.37778 -69.856449 -16.899107 0.00048 ***
649-493 -30.17778 -56.656449  -3.699107 0.02020 *
937-493 -61.66667 -88.145337 -35.187996 1.6e-06 ***
937-649 -31.48889 -57.967560  -5.010218 0.01438 *
```

Conclusion

1. Accept Ha in favour of H0
2. Conclude that there is a significant difference in the taste of at least 2 of the varieties of apples