An Example of ANOVA using R
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In class we handed out "An Example of ANOVA". Below we redo the example using R. There are three groups with seven observations per group. We denote group i values by yi:

> y1 = c(18.2, 20.1, 17.6, 16.8, 18.8, 19.7, 19.1)
> y2 = c(17.4, 18.7, 19.1, 16.4, 15.9, 18.4, 17.7)
> y3 = c(15.2, 18.8, 17.7, 16.5, 15.9, 17.1, 16.7)

Now we combine them into one long vector, with a second vector, group, identifying group membership:

> y = c(y1, y2, y3)
> n = rep(7, 3)
> n
[1] 7 7 7
> group = rep(1:3, n)
> group
[1] 1 1 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 3

Descriptive Summaries

Here are summaries by group and for the combined data. First we show stem-leaf diagrams.

> tmp = tapply(y, group, stem)

The decimal point is at the |

16 | 8
17 | 6
18 | 28
19 | 17
20 | 1

The decimal point is at the |

15 | 9
16 | 4
17 | 47
Now we show summary statistics by group and overall. We locally define a temporary function, `tmpfn`, to make this easier.

```r
> tmpfn = function(x) c(sum = sum(x), mean = mean(x), var = var(x),
+   n = length(x))
> tapply(y, group, tmpfn)

\[
\begin{array}{lllll}
\text{sum} & \text{mean} & \text{var} & \text{n} \\
130.300000 & 18.614286 & 1.358095 & 7.000000 \\
123.600000 & 17.657143 & 1.409524 & 7.000000 \\
117.900000 & 16.842857 & 1.392857 & 7.000000 \\
371.800000 & 17.704762 & 1.798476 & 21.000000 \\
\end{array}
\]
```
ANOVA Table

While we could show you how to use R to mimic the computation of SS by hand, it is more natural to go directly to the ANOVA table. See Appendix 11 for other examples of the use of R commands for ANOVA.

```r
> data = data.frame(y = y, group = factor(group))
> fit = lm(y ~ group, data)
> anova(fit)
```

Analysis of Variance Table

Response: y

<table>
<thead>
<tr>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>11.0067</td>
<td>5.5033</td>
<td>3.9683</td>
<td>0.03735*</td>
</tr>
<tr>
<td>18</td>
<td>24.9629</td>
<td>1.3868</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The `anova(fit)` object can be used for other computations on the handout and in class. For instance, the tabled F values can be found by the following. First we extract the treatment and error degrees of freedom. Then we use `qt` to get the tabled F values.

```r
> df = anova(fit)
> names(df) = c("trt", "err")
> df

trt err
2 18

> alpha = c(0.05, 0.01)
> qf(alpha, df["trt"], df["err"], lower.tail = FALSE)

[1] 3.554557 6.012905
```

Confidence Interval for Variance

A confidence interval on the pooled variance can be computed as well using the `anova(fit)` object. First we get the residual sum of squares, SSTrt, then we divide by the appropriate chi-square tabled values.

```r
> anova(fit)["Residuals", "Sum Sq"]

24.96286

> anova(fit)["Residuals", "Sum Sq"]/qchisq(c(0.025, 0.975), 18, + lower.tail = FALSE)

[1] 0.7918086 3.0328790
```
Comparison of Means

Chapter 12 concerns comparing means after conducting an analysis of variance overall F-test. Here is a way to conduct pairwise t-tests.

```r
> pairwise.t.test(y, group)

$method
[1] "t tests with pooled SD"

$data.name
[1] "y and group"

$p.value
     1     2
2 0.29149  NA
3 0.03445 0.29149

$p.adjust.method
[1] "holm"

attr("class")
[1] "pairwise.htest"
```