Tooth Growth Analysis

April 25, 2015

Objective

The goal of this report is to analyze the ToothGrowth dataset and understand how tooth growth in guinea pigs varies by supplement and/or dosage.

Data

The dataset contains information about six sets of ten guinea pigs. Each row denotes a single, unique guinea pig and the three columns denote the length of the tooth (len), the supplement (supp) and dose (dose) the pig was fed.

```
library(datasets)
str(ToothGrowth)
```

```
## 'data.frame':    60 obs. of  3 variables:
##  $ len : num  4.2 11.5 7.3 5.8 6.4 10 11.2 11.2 5.2 7 ...
##  $ supp: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
##  $ dose: num  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...
```

```
summary(ToothGrowth)
```

```
##       len        supp         dose      
##  Min.   : 4.20   OJ:30   Min.   :0.500  
##  1st Qu.:13.07   VC:30   1st Qu.:0.500  
##  Median :19.25           Median :1.000  
##  Mean   :18.81           Mean   :1.167  
##  3rd Qu.:25.27           3rd Qu.:2.000  
##  Max.   :33.90           Max.   :2.000  
```

Exploratory data analysis

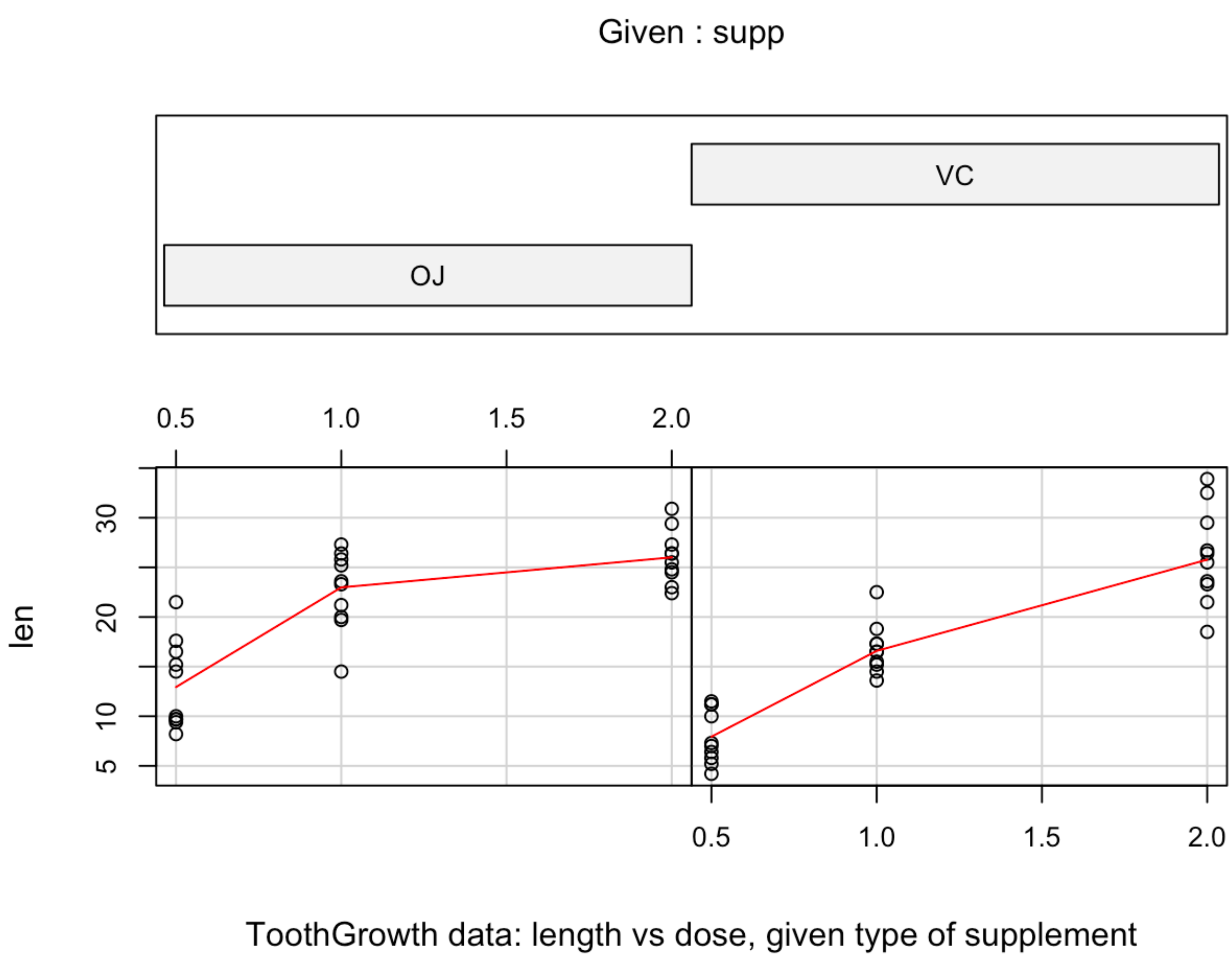
We notice that the mean tooth length is more for OJ than for VC and that the length is proportional to the dosage.

```
aggregate(len ~ supp + dose, ToothGrowth, mean)
```

```
##   supp dose   len
## 1   OJ  0.5 13.23
## 2   VC  0.5  7.98
## 3   OJ  1.0 22.70
## 4   VC  1.0 16.77
## 5   OJ  2.0 26.06
## 6   VC  2.0 26.14
```

This is also apparent from the following plot produced using code from the ToothGrowth R dataset help page for additional clarity.

```
require(graphics)
coplot(len ~ dose | supp, data = ToothGrowth, panel = panel.smooth,
       xlab = "ToothGrowth data: length vs dose, given type of supplement")
```

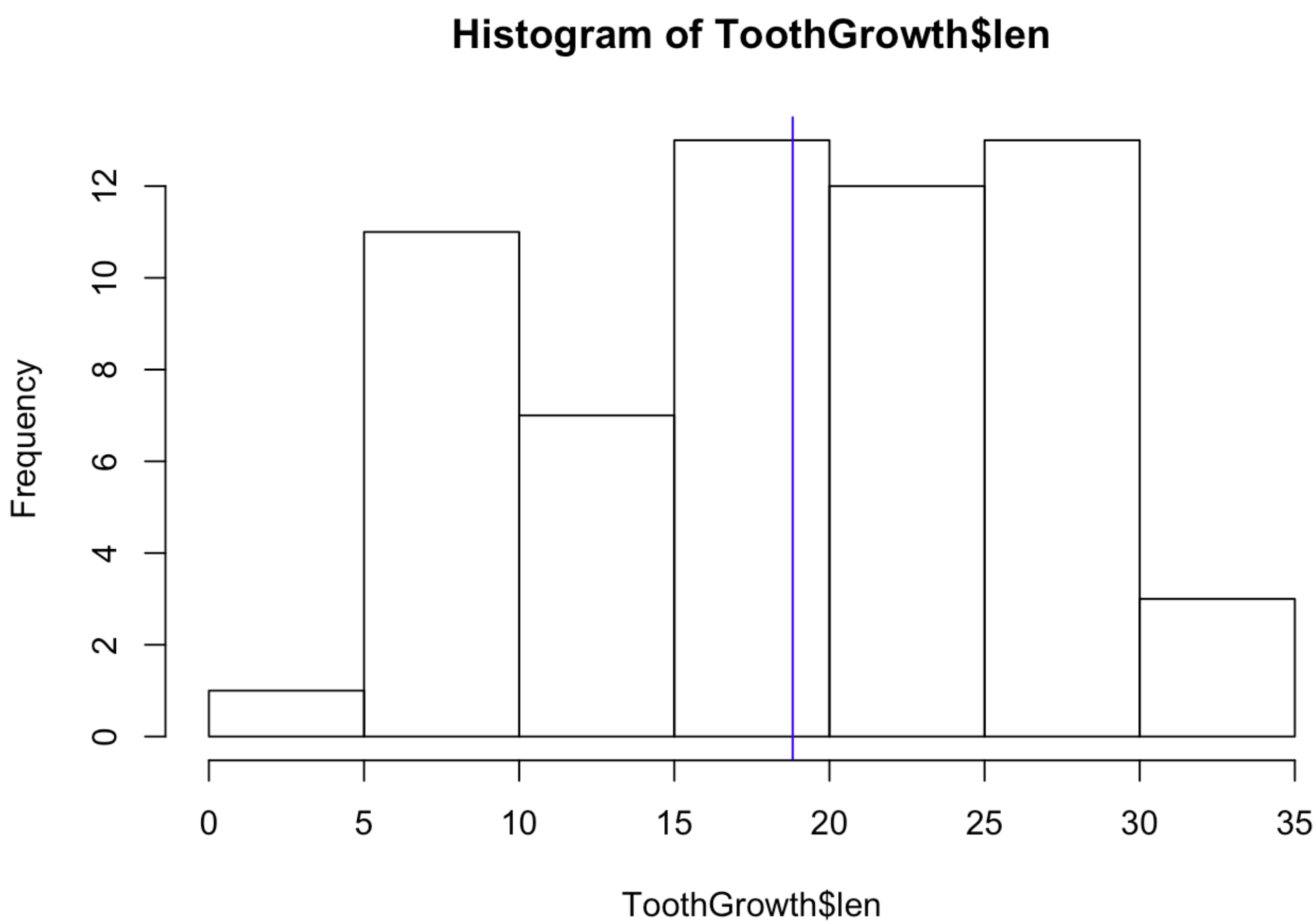


We want to test if the differences are indeed significant. This can be done using t-tests.

Assumptions

The t interval works well when the distribution of the data is roughly symmetric and mound shaped. This turns out to be true for the distribution of tooth length.

```
hist(ToothGrowth$len)
abline(v=mean(ToothGrowth$len), col="blue")
```



We know from the data that the variance of length is not the same across groups and since each observation is a different guinea pig, we choose to test using independent t-tests with unequal variance.

t - tests

There are two sets of tests that we need to run.

1. Test whether the mean length differs by supplement for the same dosage. This would mean three tests for each level of dosage. For example, for a dosage of 0.5, is the mean tooth length different for pigs that were given OJ than the mean length of the pigs that were given VC?

The test is designed as follows: Null hypothesis is that the true difference in means of the two groups being compared is equal to 0. That is, there is no benefit in using one supplement over the other.

```
tg05<- subset(ToothGrowth, dose==0.5)
t.test(len ~ supp, paired = FALSE, var.equal=FALSE, tg05)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## t = 3.1697, df = 14.969, p-value = 0.006359
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  1.719057 8.780943
## sample estimates:
## mean in group OJ mean in group VC
##            13.23             7.98
```

The t-statistic is pretty large and the p-value is small (much smaller than 0.05). The p-value denotes the probability that the t-statistic would be this large when the null hypothesis is true. Further, the 95% confidence interval does not include 0. Hence, we reject the null hypothesis.

The test for dose 1.0 yields similar results and we reject the null hypothesis.

```
tg10<- subset(ToothGrowth, dose==1.0)
t.test(len ~ supp, paired = FALSE, var.equal=FALSE, tg10)
```

However, the test for dose 2.0 yields a very high p-value and the confidence interval at the 95% level includes 0. Hence, we fail to reject the null hypothesis.

```
tg20<- subset(ToothGrowth, dose==2.0)
t.test(len ~ supp, paired = FALSE, var.equal=FALSE, tg20)
```

2. The second set of tests is to check whether the tooth length varies by dosage for each supplement. This amounts to three tests per supplement (0.5 vs 1.0, 1.0 vs 2.0 and 0.5 vs 2.0), that is, a total of six tests.

The test for 0.5 vs 1.0 dosage levels for the OJ supplement is designed as follows:

```
tgOJ0510<- subset(ToothGrowth, dose %in% c(0.5, 1.0) & supp=="OJ")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgOJ0510)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by dose
## t = -5.0486, df = 17.698, p-value = 8.785e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -13.415634  -5.524366
## sample estimates:
## mean in group 0.5   mean in group 1
##             13.23             22.70
```

Here, the (absolute value of the) t-statistic is large and the p-value is very small. The confidence interval does not include 0, so we reject the null hypothesis that the true difference in means between the 0.5 and 1.0 dosage groups is equal to 0.

The other tests for doses of OJ (0.5 vs 2.0 and 1.0 vs 2.0) yield similar results and we reject the null hypothesis in each case.

```
tgOJ0520<- subset(ToothGrowth, dose %in% c(0.5, 2.0) & supp=="OJ")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgOJ0520)

tgOJ1020<- subset(ToothGrowth, dose %in% c(1.0, 2.0) & supp=="OJ")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgOJ1020)
```

The three tests above are repeated for the VC supplement and in each case, we reject the null hypothesis.

```
tgVC0510<- subset(ToothGrowth, dose %in% c(0.5, 1.0) & supp=="VC")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgVC0510)

tgVC0520<- subset(ToothGrowth, dose %in% c(0.5, 2.0) & supp=="VC")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgVC0520)

tgVC1020<- subset(ToothGrowth, dose %in% c(1.0, 2.0) & supp=="VC")
t.test(len ~ dose, paired=FALSE, var.equal=FALSE, tgVC1020)
```

A summary of the results is shown below:

Test	t-statistic	p-value	95 percent confidence interval	Result
0.5 (OJ vs VC)	3.1697	0.006359	1.719057 8.780943	Reject null
1.0 (OJ vs VC)	4.0328	0.001038	2.802148 9.057852	Reject null
2.0 (OJ vs VC)	-0.0461	0.9639	-3.79807 3.63807	Fail to reject null
OJ (0.5 vs 1.0)	-5.0486	8.785e-05	-13.415634 -5.524366	Reject null
OJ (0.5 vs 2.0)	-7.817	1.324e-06	-16.335241 -9.324759	Reject null
OJ (1.0 vs 2.0)	-2.2478	0.0392	-6.5314425 -0.1885575	Reject null
VC (0.5 vs 1.0)	-7.4634	6.811e-07	-11.265712 -6.314288	Reject null
VC (0.5 vs 2.0)	-10.3878	4.682e-08	-21.90151 -14.41849	Reject null
VC (1.0 vs 2.0)	-5.4698	9.156e-05	-13.054267 -5.685733	Reject null

Conclusion

From the t-tests above, it appears that OJ is a better supplement compared to VC at lower doses. However, at a dosage level of 2.0, the difference between the two is not statistically significant.

Further, as dosage level of each supplement is increased, the mean tooth length seems to be different between groups, indicating that it is likely beneficial to use higher dosage level to achieve greater tooth growth.