ToothGrowth

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Introduction

In this report we will examine the effect of Vitamin C on Tooth Growth in Guinea Pigs. Each animal received one of three dose levels of vitamin C (0.5, 1, and 2 mg/day) by one of two delivery methods, orange juice or ascorbic acid.

Basic data exploration

60 Guinea pigs were followed in the study. These 60 pigs were randomly assigned to one of the six combinations of dose and delivery method.

```
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 ...
```

```
table(ToothGrowth$supp,ToothGrowth$dose)
```

```
##
##      0.5  1  2
##   OJ  10 10 10
##   VC  10 10 10
```

There are no missing values for the toothlength recordings. The tooth length varied from 4.20 to 33.90 with an average of 18.81.

```
sum(is.na(ToothGrowth$len))
```

```
## [1] 0
```

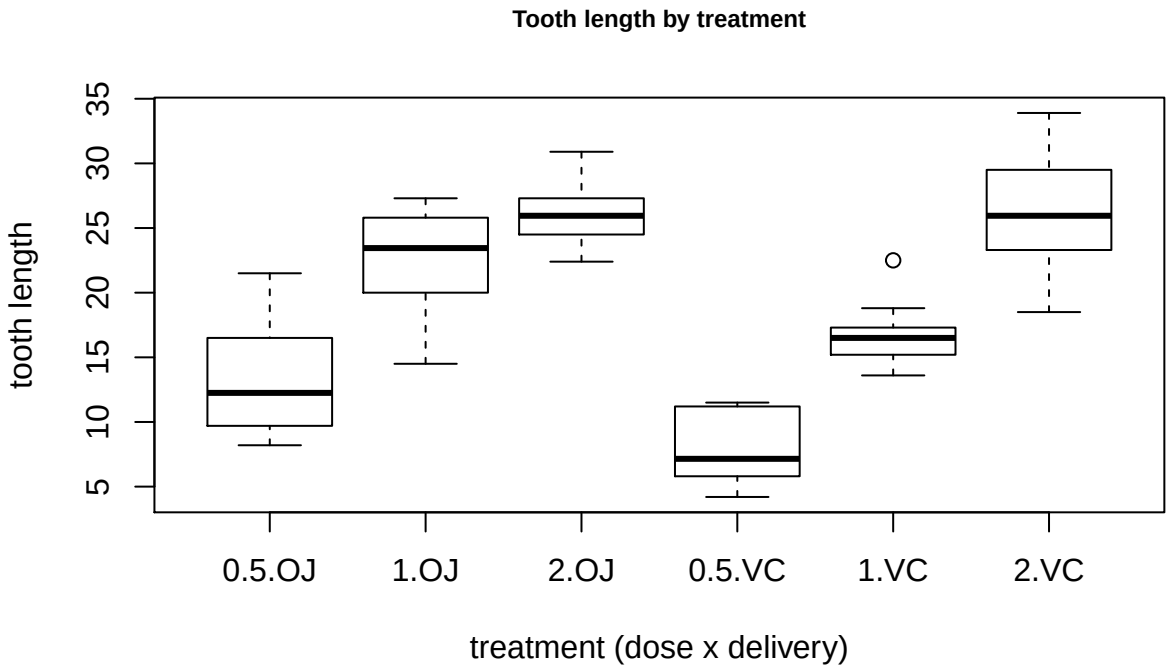
```
summary(ToothGrowth$len)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    4.20   13.08   19.25   18.81   25.28   33.90
```

Data summary

Regardless of the deliverly method, higher doses of Vitamin C seem to lead to higher tooth lengths. With the exception of the highest dose, vitamin C intake by orange juice seems to lead to longer teeth than vitamin C intake by asorbic acid. At the highest dose the median tooth length seems similar between both delivery methods, although that the outcome of asorbic acid seems far more uncertain than the outcome of orange juice. Therefore it seems that the best results on teeth growth are obtained by vitamin C delivery via orange juice at the highest dose.

```
par(mfrow=c(1,1),cex.main=0.75)
boxplot(len~dose+supp,data=ToothGrowth, xlab="treatment (dose x delivery)", ylab="tooth length", main="
```



Is tooth growth dependent on supp and dose ?

Let's now perform some formal testing whether there is a statistically significant difference in tooth length between any of the 6 treatments of (delivery method x dose) combinations.We will therefore perform a series of pairwise t-tests. As we have 6 treatments there are 15 different pairwise comparisons we can make. In order to control for the false discovery rate we will correct the p-values of these tests by the method of Benjamini, Hochberg, and Yekutieli.

```
ToothGrowth$treatment <- as.factor(paste(ToothGrowth$dose,"_",ToothGrowth$supp))
iter <- 1
pvalues <- matrix(rep(0,45),nrow=15,ncol=3)
for (i in 1:5) {
    group1 <- subset(ToothGrowth,treatment==levels(treatment)[i])
    j <- i+1
    while (j <= 6) {
```

```
        group2 <- subset(ToothGrowth,treatment==levels(treatment)[j])
        to_test <- rbind(group1,group2)
        pvalues[iter,1] <- levels(ToothGrowth$treatment)[i]
        pvalues[iter,2] <- levels(ToothGrowth$treatment)[j]
        pvalues[iter,3] <- t.test(len ~treatment, data=to_test,var.equal=FALSE)$p.value
        j <- j+1
        iter <- iter+1
    }
}
names(pvalues) <- c("group1", "group2", "pvalues")
pvaluesadj <- p.adjust(pvalues[,3],method='BH', n=15)
cbind(pvalues,pvaluesadj)
```

```
##                                                  pvaluesadj
##  [1,] "0.5 _ OJ" "0.5 _ VC" "0.00635860676409681"  "0.00867082740558656"
##  [2,] "0.5 _ OJ" "1 _ OJ"   "8.7849190551615e-05"  "0.000152593384277311"
##  [3,] "0.5 _ OJ" "1 _ VC"   "0.0460103325763758"   "0.0530888452804336"
##  [4,] "0.5 _ OJ" "2 _ OJ"   "1.32378387769724e-06" "3.3094596942431e-06"
##  [5,] "0.5 _ OJ" "2 _ VC"   "7.19625352400603e-06" "1.54205432657272e-05"
##  [6,] "0.5 _ VC" "1 _ OJ"   "3.65520673032589e-08" "2.34078870724605e-07"
##  [7,] "0.5 _ VC" "1 _ VC"   "6.81101770286506e-07" "2.04330531085952e-06"
##  [8,] "0.5 _ VC" "2 _ OJ"   "1.36213964789889e-11" "2.04320947184834e-10"
##  [9,] "0.5 _ VC" "2 _ VC"   "4.6815774144921e-08"  "2.34078870724605e-07"
## [10,] "1 _ OJ"   "1 _ VC"   "0.00103837587229988"  "0.00155756380844982"
## [11,] "1 _ OJ"   "2 _ OJ"   "0.0391951420462442"   "0.0489939275578052"
## [12,] "1 _ OJ"   "2 _ VC"   "0.0965261233826698"   "0.103420846481432"
## [13,] "1 _ VC"   "2 _ OJ"   "2.36107420204684e-07" "8.85402825767565e-07"
## [14,] "1 _ VC"   "2 _ VC"   "9.15560305663864e-05" "0.000152593384277311"
## [15,] "2 _ OJ"   "2 _ VC"   "0.963851588723373"    "0.963851588723373"
```

For any pairwise comparision, we will reject the null hypothesis that both treatments are equal when the adjusted p-value is smaller than 0.05.

First focussing on the pairwise comparisons of different doses with the same application method, we can conclude with 95% confidence that higher doses of Vitamin C lead to higher tooth length.

Next we focus whether vitamin C supplied by orange juice versus asorbic acid leads to different tooth length. Here the conclusions are mixed, although ath the lowest level there clearly is a larger tooth length for oranje juice suppliances than for ascorbic acid, this no longer holds for higher doses due to increased uncertainty in the outcome of either delivery method.

Overall, when ranking the treatment methods 0.5 VC has the shortest tooth length, followed by 0.5 OJ and 1 VC. The next best tooth length is obtained by 1 OJ. There seems to be weak evidence that 2 OJ leads to larger tooth length than 1 OJ. However, there is no evidence that 2 OJ and 2 VC lead to different tooth length.

Conclusions

We examined the effect of 3 different doses and 2 different supply methods of Vitamin C on tooth length of Guinea Pigs. We concluded that 2 mg vitamin C/day supplied by orange juice or ascorbic acid lead to the best tooth growth.