Statistical Inference - Course Project - Part 2

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The Effect of Vitamin C on Tooth Growth in Guinea Pigs

Summary

We will analyze a dataset containing the length of odontoblasts (teeth) in each of 10 guinea pigs at each of three dose levels of Vitamin C (0.5, 1, and 2 mg) with each of two delivery methods (orange juice or ascorbic acid).

This source of this dataset is the paper called The Growth of the Odontoblasts of the Incisor Tooth as a Criterion of the Vitamin C Intake of the Guinea Pig by E. W. Crampton, published in 1946, and cited in the Statistics of Bioassay by C. I. Bliss publised by the Academic Press Inc in 1953.

The dataset contains 60 observations of 3 variables:

1. `len` - tooth length; numeric
2. `supp` - supplement type, *VC* - ascorbic acid, or *OJ* - orange juice; factor.
3. `dose` - dose in milligrams; numeric, discrete: 0.5, 1, or 2 mg

Here is a sample of the dataset:

```
kable(ToothGrowth[c(10:13,50:52),], caption = 'T1. Sample Data')
```

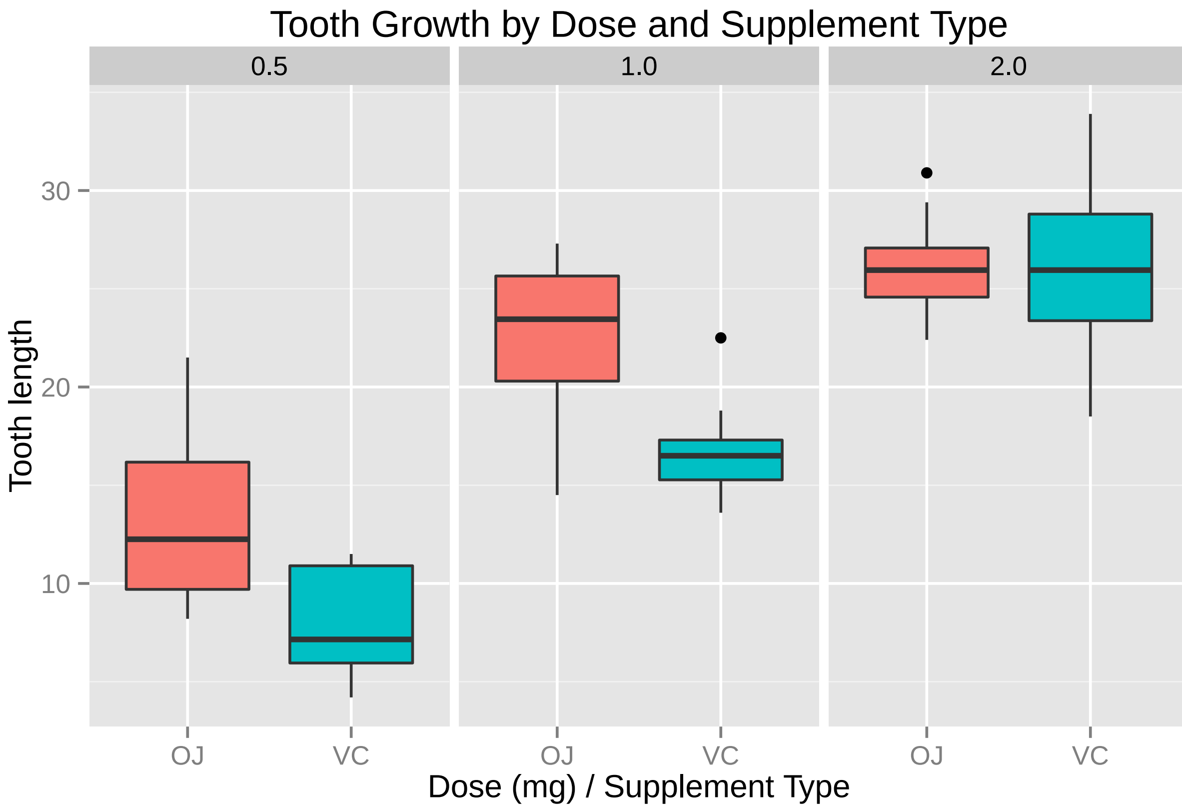
Table 1: T1. Sample Data

	len	supp	dose
10	7.0	VC	0.5
11	16.5	VC	1.0
12	16.5	VC	1.0
13	15.2	VC	1.0
50	27.3	OJ	1.0
51	25.5	OJ	2.0
52	26.4	OJ	2.0

Comparison of Tooth Growth

First let's examine the data through a box plot.

```
ggplot(data=ToothGrowth, aes(y=len, x=supp, fill=supp)) +
    geom_boxplot() +
    facet_wrap(~dose) +
    labs(title="Tooth Growth by Dose and Supplement Type", x='Dose (mg) / Supplement Type', y='Tooth len
    guides(fill=guide_legend('Supplement Type')) + theme(legend.position = "none")
```



We immediately notice that there seems to be a positive correlation between the dose type and the growth.

There is some obvious variance in the data. Let's examine a few questions we might have.

How much variance in the growth can be attributed to the supplement type?

To answer this question, we will examine the *t-statistic* and the *p-value* for each length by supplement, for each individual dose. The observations are obviously not paired, and from the chart above we can tell the variance between the sets of observations are not equal.

```
mkci <- function(ttestval) {
    paste('[ ', round(ttestval$conf.int[1], 4), ', ', round(ttestval$conf.int[2], 4), ' ]', sep='')
}
dose.test <- function(dose) {
    dose.set <- ToothGrowth[which(ToothGrowth$dose == dose), c('len', 'supp')]
    t.test(len ~ supp, data=dose.set, paired = F, var.equal = F)
}
d05 <- dose.test(0.5)
d1 <- dose.test(1)
d2 <- dose.test(2)

df <- data.frame(
    dose=c(0.5, 1, 2),
    t.statistic=c(d05$statistic, d1$statistic, d2$statistic),
    p.value=c(d05$p.value, d1$p.value, d2$p.value),
    conf.int=c(mkci(d05), mkci(d1), mkci(d2))
```

```
)
colnames(df) <- c('Dose', 't-statistic', 'p-value', '95% Confidence Interval')
kable(df, caption = 'T2. Supplement Effect on Growth')
```

Table 2: T2. Supplement Effect on Growth

Dose	t-statistic	p-value	95% Confidence Interval
0.5	3.1697328	0.0063586	[1.7191, 8.7809]
1.0	4.0327696	0.0010384	[2.8021, 9.0579]
2.0	-0.0461361	0.9638516	[-3.7981, 3.6381]

How much variance can be attributed to the dose?

We will now perform the same investigation as above, except this time we will investigate the effect of the various doses by supplement type.

```
supp.test <- function(supp, dose) {
    supp.set <- ToothGrowth[which(ToothGrowth$supp == supp & ToothGrowth$dose %in% dose), c('len', 'dos
    t.test(len ~ dose, data=supp.set, paired = F, var.equal = F)
}
d.oj.5vs1 <- supp.test('OJ', c(0.5, 1))
d.oj.1vs2 <- supp.test('OJ', c(1, 2))
d.vc.5vs1 <- supp.test('VC', c(0.5, 1))
d.vc.1vs2 <- supp.test('VC', c(1, 2))

df <- data.frame(
    supp.dose=c('OJ 0.5 vs 1mg', 'OJ 1 vs 2mg', 'VC 0.5 vs 1mg', 'VC 1 vs 2mg'),
    t.statistic=c(d.oj.5vs1$statistic, d.oj.1vs2$statistic, d.vc.5vs1$statistic, d.vc.1vs2$statistic),
    p.value=c(d.oj.5vs1$p.value, d.oj.1vs2$p.value, d.vc.5vs1$p.value, d.vc.1vs2$p.value),
    conf.int=c(mkci(d.oj.5vs1), mkci(d.oj.1vs2), mkci(d.vc.5vs1), mkci(d.vc.1vs2))
)
colnames(df) <- c('Supplement Type/Dose', 't-statistic', 'p-value', '95% Confidence Interval')
kable(df, caption='T3. Supplement Effect on Growth')
```

Table 3: T3. Supplement Effect on Growth

Supplement Type/Dose	t-statistic	p-value	95% Confidence Interval
OJ 0.5 vs 1mg	-5.048635	0.0000878	[-13.4156, -5.5244]
OJ 1 vs 2mg	-2.247761	0.0391951	[-6.5314, -0.1886]
VC 0.5 vs 1mg	-7.463430	0.0000007	[-11.2657, -6.3143]
VC 1 vs 2mg	-5.469814	0.0000916	[-13.0543, -5.6857]

Conclusions

From the study we propose two null-hypotheses:

1. Supplement type has no effect on growth
2. Dosage has no effect on growth

Using the calculations we performed above, let's examine each.

H_0: Supplement Type Has No Effect on Growth From examining the second table (T2), we can conclude:

- At **0.5mg dose level** we can reject the null hypothesis as there is statistically significant difference between the means of **OJ** and **VC**; we notice that the *95% confidence interval* does not include 0, and the *p-value* is very small at $alpha = 0.05$;
- The same can be said for the **1mg dose level**, thus we reject the null hypothesis for this dose too: the *VC* has significant improvement on tooth growth;
- At the **2mg dose level**, the story reverses as it seems that the supplement type does not produce a statistically significant difference between *OJ* and *VC*; we thus fail to reject the null hypothesis at the *95% confidence level.*

H_0: Dosage Has No Effect on Growth Unlike the supplement type, the dose has a statistically significant impact on all supplement delivery types (Table 3).

- For **OJ**, the *p-value* as very small when testing between **0.5mg and 1mg doses**, as well as between **1mg and 2mg**; furthermore, for either test 0 is not in the *95% confidence interval; as such, we can confidently reject the null hypothesis for the* OJ* supplement at all doses.
- Similarly, we can also reject the null hypothesis for **VC** at **all dose levels**: the dose has a statistically significant impact on the growth of teeth.

Worth noting that the sample size being small for each one of the supplement-dosage combination, the test power is quite reduce. We would need a bigger sample in order to detect more significant differences between the various combinations.