The Effect of Vitamin C on Tooth Growth in Guinea Pigs

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Synopsis

Based on the `ToothGrowth` data from the R `datasets` package, we analyze the effect of vitamin C on the length of odontoblasts in guinea pigs. We want to study whether the amount of vitamin C or the method it is delivered to guinea pigs affect the length of the odontoblasts. We conjecture that they do.

Data

The dataset contains the length of odontoblasts (cells responsible for tooth growth) in 60 guinea pigs that received different doses of vitamin C by different methods. 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 (a form of vitamin C and coded as VC).

```
set.seed(0);
data("ToothGrowth");
```

Packages

The following packages will be used to perform the analysis.

```
library(dplyr);
library(ggplot2);
```

Exploratory analysis

We start by having a look at the size of our data set: dim = 60 x 3. Hence we have, as expected, 3 observations for 60 subjects. Let us have a look at the head, the tail and the structure of our data

```
##    len supp dose
## 1  4.2   VC  0.5
## 2 11.5   VC  0.5
## 3  7.3   VC  0.5
```

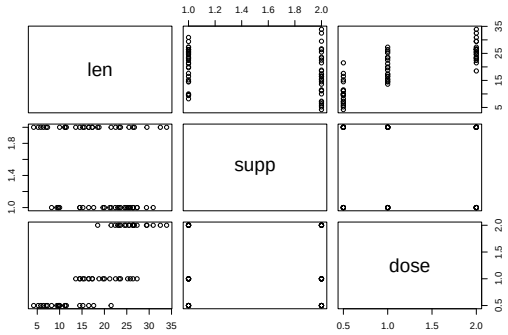
```
##     len supp dose
## 58 27.3   OJ    2
## 59 29.4   OJ    2
## 60 23.0   OJ    2
```

```
## '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 ...
```

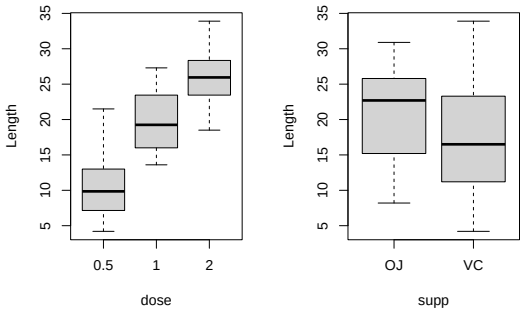
respectively. The dataset is already clean and we may provide a basic summary of the data:

```
##       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
```

By keeping in mind our working questions, we can also have a quick look at potential correlations:



Apparently, the dose level has a clear effect, while we cannot draw conclusions about the delivery method, yet. Two boxplots, one by dose level and one by delivery method, confirm the effect of dose level and suggest a possible effect of delivery method:



Hypothesis tests

In view of the relative small size of samples and under the reasonable hypothesis that the underlying data are iid Gaussian, we are going to perform two group T tests for equality of means.

Compare tooth growth by dose level

Our first hypothesis is that a higher dose level of vitamin C leads to a higher length of odontoblasts. To support this hypothesis we compare level 1 with level 0.5 and level 2 with level 1, the null hypothesis always being that there is no significant difference in the means and the alternative being that a higher level of vitamin C entails a longer length of odontoblasts.

First we split the three groups according to the rule

- group 1: dose level = 0.5 mg/day,
- group 2: dose level = 1 mg/day,

- group 3: dose level = 2 mg/day

and we compute their sample means:

```
## grp1.len grp2.len grp3.len
##   10.605   19.735   26.100
```

Then we perform a T test to check whether there is a significant difference between the means at level $\alpha = 0.05$. If we compare group 2 (dose level = 1 mg/day) with group 1 (dose level = 0.5 mg/day):

```
t.test(grp2, grp1, alternative = "greater")$p.value
```

```
## [1] 6.341504e-08
```

We can reject the null hypothesis that the two means coincide, since the p-value is much smaller than 0.05. Similarly, if we compare group 3 (dose level = 2 mg/day) with group 2 (dose level = 1 mg/day):

```
t.test(grp3, grp2, alternative = "greater")$p.value
```

```
## [1] 9.532148e-06
```

then we can reject the null hypothesis of equal means, since the p-value is much smaller than 0.05. There is no need, in this case, to test group 3 versus group 1.

Therefore, we conclude that a higher level of vitamin C is correlated with a longer length of the odontoblasts at level 0.05.

For the sake of clarity, we can also compute two-sided 95% T confidence intervals for the means using the `conf.int` component of `t.test`:

```
##              min      max
## grp1mn  8.499046 12.71095
## grp2mn 17.668512 21.80149
## grp3mn 24.333643 27.86636
```

Comparing the computed means (ref:splitDose) with the confidence intervals we computed, we can confirm that we may safely reject the null hypotheses at level 0.05.

Compare tooth growth by delivery method

Our second hypothesis is that also the delivery method is correlated with tooth growth. Namely, that subjects that received vitamin C with orange juice has longer odontoblasts.

Let us begin by separating the two groups, OJ versus VC, and by computing the respective sample means:

```
##   OJ.len   VC.len
## 20.66333 16.96333
```

Then we perform a T test to check whether there is a significant difference between the means at level $\alpha = 0.05$. If we compare the OJ group with the VC group:

```
t.test(suppOJ,suppVC,alternative = "greater")$p.value
```

```
## [1] 0.03031725
```

then we can reject the null hypothesis of equal means at level 0.05, because the p-value is slightly smaller.

We conclude that there can be a relationship between the delivery method and the length of the odontoblasts. Namely, subjects which received vitamin C via orange juice have, on average, longer odontoblasts than those who received it via ascorbic acid.