ToothGrowth: Examining the Effect of Vitamin C Supplementation on Odontoblast Length

Executive Summary

Here, we examine the effect of vitamin supplementation on a proxy measure of tooth growth in guinea pigs. Both sources of vitamin C tested, orange juice and ascorbic acid, dose-dependently increased odontoblast length. Although at lower vitamin C-equivalent doses orange juice was more effective than ascorbic acid at increasing odontoblast length, both supplements were equally effective at the highest dose.

Explanatory Data Analysis and Basic Dataset Summary

After loading the ToothGrowth dataset and ggplot2 for visualization, let's examine the data using the str function.

```
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 ...
```

We see a simple data frame with 3 variables. According to the annotation of this dataset, 'len' is the length of odontoblast cells of 60 guinea pigs at 3 dose levels (dose) and 2 delivery methods (supp), n = 10 each. We can further see the distribution of the variables using the summary function.

```
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
```

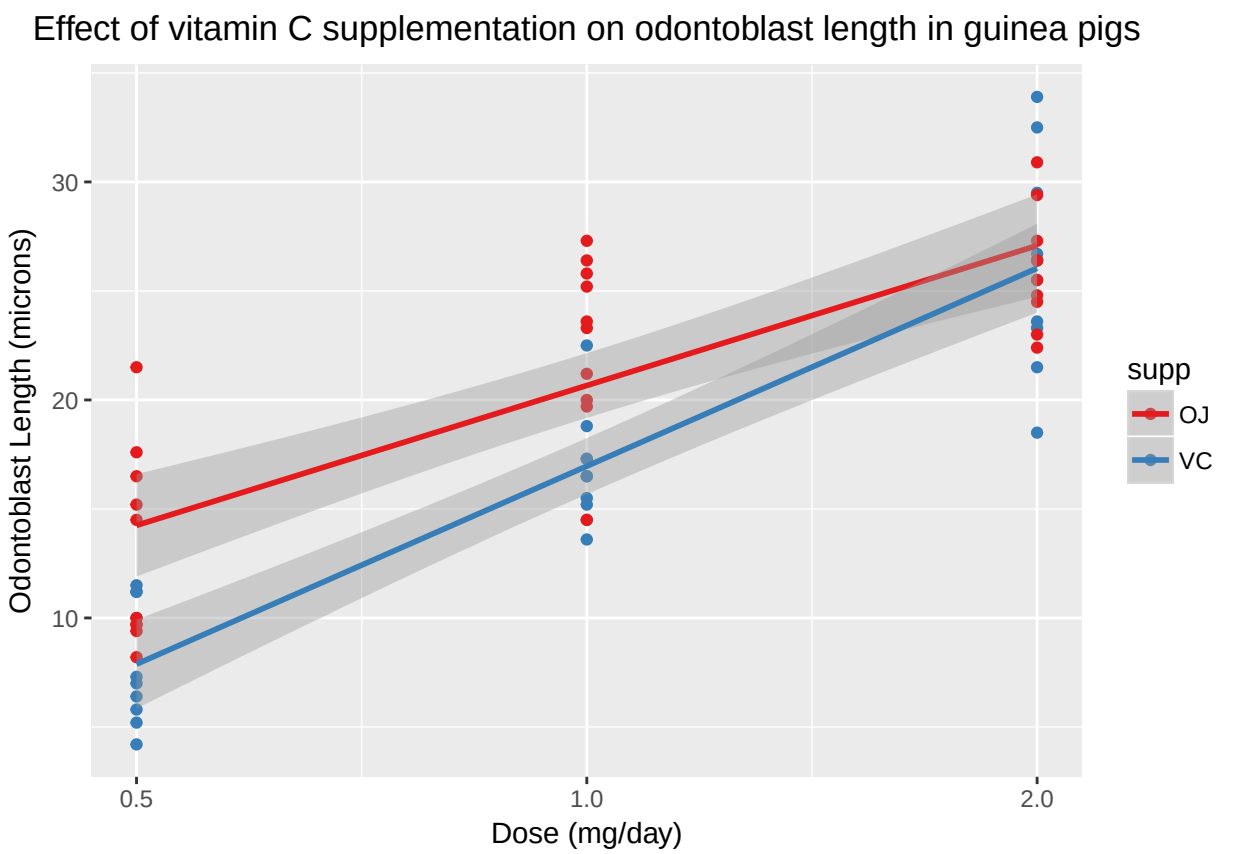
```
unique(ToothGrowth$dose)
```

```
## [1] 0.5 1.0 2.0
```

As seen above, 'supp' is a factor variable taking one of 2 forms, OJ (orange juice) or VC (ascorbic acid, also known as vitamin C). Although 'dose' is a continuous numeric variable, only 3 doses were actually administered - 0.5, 1, and 2 mg/day. 'len' ranges from 4.2 microns up to 33.9 microns, with a mean of 18.8 and median of 19.25. Now, let's plot the data and see how the different experimental conditions affected length.

Importantly - this is dose-response data and on a linear scale, it is described not by a straight line but a rectangular hyperbola as the reponse reaches a ceiling at high doses; however, when the x-axis is log transformed, it appears as a sigmoidal, or s-shaped, curve and the region from about 15%-85% of maximal response is approximately linear. Therefore, we will tell ggplot2 to log10 transform our data and plot a linear regression line to the data. Note that with only 3 doses, it is not possible to know what the maximal response is, and we could be outside of the linear range. Still, this is much better than trying to fit a linear model to the original data which we KNOW is not linear.

```
ggplot(data = ToothGrowth, mapping = aes(x = dose, y = len, color = supp)) +
    scale_x_log10(breaks = c(0.5, 1, 2)) +
    scale_colour_brewer(palette = "Set1") +
    geom_point() +
    geom_smooth(method = "lm") +
    labs(title = "Effect of vitamin C supplementation on odontoblast length in guinea pigs", x = "Dose
    theme(plot.title = element_text(hjust = 0.5))
```



Importantly, we see that at the lowest equivalent dose, the 95% confidence intervals for orange juice (OJ) and ascorbic acid (VC) are non-overlapping, suggesting that orange juice is a superior supplement at this dose; however, at the highest dose the confidence intervals overlap - suggesting that there is no difference between supplement type when dose is high enough.

Statistical Inference

These days dose-response data is generally fit using using nonlinear regression; however, based on the instructions for this assignment, we will use a linear model on the log-transformed data. Assuming we are between 15% and 85% of maximal response, this is a fair representation as the sigmoidal curve is roughly linear in this range; with only 3 doses tested, however, we can't be certain that this assumption is correct. In fact, since the highest dose has plateaued for Orange Juice supplementation, it is likely that we've already reached a saturation point in response.

Assumptions aside, here are the details of the model:

```
tooth_fit <- lm(len ~ log(dose)*supp, data = ToothGrowth)
tooth_fit
```

```
##
```

```
## Call:
## lm(formula = len ~ log(dose) * supp, data = ToothGrowth)
##
## Coefficients:
##      (Intercept)         log(dose)             suppVC  log(dose):suppVC
##           20.663            9.255           -3.700             3.845
```

And the ANOVA table for the fit is as follows:

```
anova(tooth_fit)
```

```
## Analysis of Variance Table
##
## Response: len
##                Df  Sum Sq Mean Sq  F value    Pr(>F)
## log(dose)       1 2400.95 2400.95 173.5134 < 2.2e-16 ***
## supp            1  205.35  205.35  14.8404 0.0003033 ***
## log(dose):supp  1   71.02   71.02   5.1327 0.0273658 *
## Residuals      56  774.89   13.84
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Breaking down the output, we see significant main effects for both log(dose) as well as the type of supplement; that is, the effect of vitamin C supplementation is dose-dependent and there is a significant difference between vitamin C powder and orange juice (which likely contains other pro-tooth-growth nutrients). However, there is also a significant interaction effect between log(dose) and supplement type, and looking at the graph we can say that the increased potency of orange juice over pure vitamin C is overcome when doses are high enough to saturate response. In conclusion, orange juice is a more potent supplement with regard to tooth growth - but if the dose is high enough, pure vitamin C is just as good.