Case Study 3

Alexis, Kamryn, Addison, Minh

Using a cell phone while driving is known to affect reaction time. In one study, 54 male adults aged 22-24 were asked to drive in a simulator under various conditions and their reaction time would be measured. During each simulation, the driver begins talking on the cell phone and after a certain time on the phone has elapsed the car ahead of the driver hits its brake. The time between when the leading car hits its breaks and when the driver in the simulator hits his breaks is then recorded. The researchers randomly assigned each driver to one of 6 conditions which are the factor level combinations of condition (day or night) and duration of the cell phone call (30, 60, or 90 seconds) and recorded the reaction time for each driver.

```
#load dataset
drive <- read_csv("distracted_driving.csv")
#convert variable type as needed
drive$Condition <- as.factor(drive$Condition)
drive$Duration <- as.factor(drive$Duration)
```

1. [3pts] Before we get too far into our analysis, let's first check whether the assumptions for this analysis are reasonably satisfied. Using the appropriate tools, explain if each of the three assumptions are reasonably satisfied. Note: to check the assumptions you will need to run the interaction model.

```
#run model of interest
drive_lm <- lm(Time~Condition*Duration, data=drive)
summary(drive_lm)
```

```
##
## Call:
## lm(formula = Time ~ Condition * Duration, data = drive)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -213.33 -125.00  -19.44   50.83  566.67
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  164.44      60.37   2.724  0.00897 **
## ConditionNight               151.11      85.37   1.770  0.08307 .
## Duration60                   168.89      85.37   1.978  0.05365 .
## Duration90                   -51.11      85.37  -0.599  0.55219
## ConditionNight:Duration60   -318.89     120.73  -2.641  0.01111 *
## ConditionNight:Duration90     17.78     120.73   0.147  0.88355
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 181.1 on 48 degrees of freedom
## Multiple R-squared:  0.1965, Adjusted R-squared:  0.1128
## F-statistic: 2.348 on 5 and 48 DF,  p-value: 0.05505
```

Answer: Independence. Can be reasonably satisfied as data is not collected from clusters as well as eu=ou=driver, as well as the response is not collected over time.

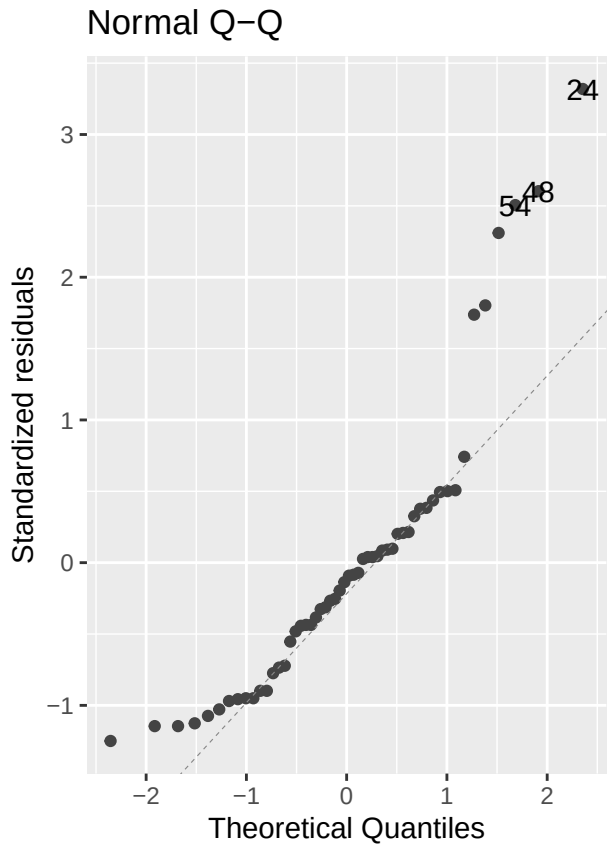
Answer: Equal Variance. Assumption is violated as s_{max} / s_{min} > 2 (272.3/44.2 = 6.16)

```
favstats(Time~Condition+Duration, data=drive)
```

```
##   Condition.Duration min  Q1 median  Q3 max     mean        sd n missing
## 1             Day.30  70  90    180 220 250 164.4444  67.47427 9       0
## 2           Night.30 120 140    190 350 760 315.5556 251.25242 9       0
## 3             Day.60 120 170    180 460 900 333.3333 272.30498 9       0
## 4           Night.60  90 110    170 230 250 165.5556  63.46478 9       0
## 5             Day.90  60  80    120 130 200 113.3333  44.15880 9       0
## 6           Night.90  90 120    200 290 710 282.2222 221.29041 9       0
```

Answer: Normality. Not reasonably satisfied as both tails deviate severly away from the reference line and sample size is not sufficiently large enough to override these effects.

```
autoplot(drive_lm, which = 2)
```



2. [3pts] Hopefully you noticed some issues with the assumptions. Recall that one common remedy is to transform the response with a preference for using the natural log. Transform the response and reevaluate whether the assumptions are now reasonably satisfied.

```r
drive_lm2 <- lm(log(Time)~Condition*Duration, data=drive)
summary(drive_lm2)
```

```
##
## Call:
## lm(formula = log(Time) ~ Condition * Duration, data = drive)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.89991 -0.47867 -0.05111  0.37514  1.24170
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                  5.0115     0.1966  25.485   <2e-16 ***
## ConditionNight               0.4924     0.2781   1.771   0.0830 .
## Duration60                   0.5492     0.2781   1.975   0.0540 .
## Duration90                  -0.3474     0.2781  -1.249   0.2176
## ConditionNight:Duration60   -1.0129     0.3933  -2.575   0.0131 *
## ConditionNight:Duration90    0.2433     0.3933   0.619   0.5390
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.5899 on 48 degrees of freedom
## Multiple R-squared:  0.2475, Adjusted R-squared:  0.1692
## F-statistic: 3.158 on 5 and 48 DF,  p-value: 0.01521
```

Answer: Independence. Independence is still reasonably satisfied as data is not collected from clusters and eu=ou=driver, as well as data is not collected over time.

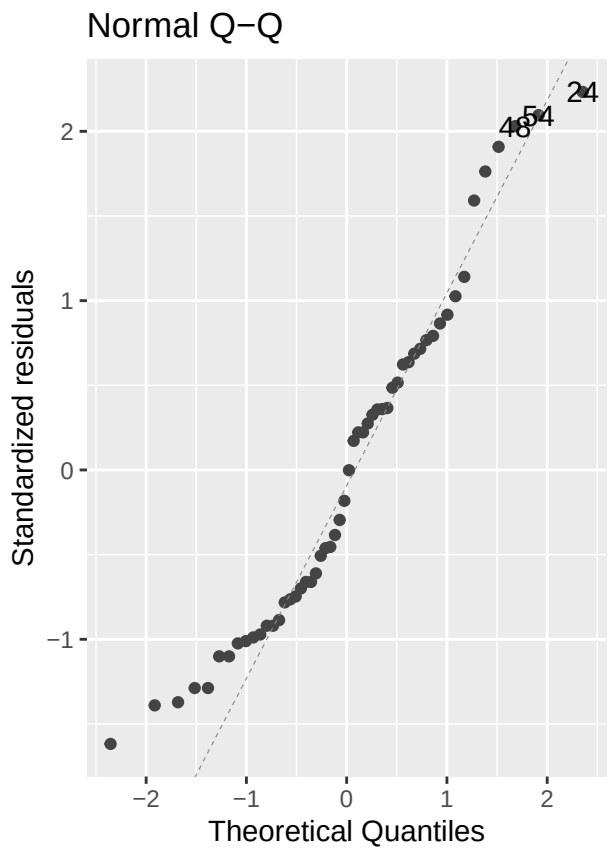
Answer: Equal Variance.Assumption is met as s_{max} / s_{min} < 2 (.73/.39 = 1.87)

```r
favstats(log(Time)~Condition+Duration, data=drive)
```

```
##   Condition.Duration      min       Q1   median       Q3      max     mean
## 1             Day.30 4.248495 4.499810 5.192957 5.393628 5.521461 5.011466
## 2           Night.30 4.787492 4.941642 5.247024 5.857933 6.633318 5.503843
## 3             Day.60 4.787492 5.135798 5.192957 6.131226 6.802395 5.560699
## 4           Night.60 4.499810 4.700480 5.135798 5.438079 5.521461 5.040210
## 5             Day.90 4.094345 4.382027 4.787492 4.867534 5.298317 4.664016
## 6           Night.90 4.499810 4.787492 5.298317 5.669881 6.565265 5.399715
##          sd n missing
## 1 0.4755357 9       0
## 2 0.7262304 9       0
## 3 0.7113035 9       0
## 4 0.3995190 9       0
## 5 0.3869852 9       0
## 6 0.7205301 9       0
```

Answer: Normality. Not reasonably satisfied as dots follow reference line with some deviation, but sample size is large enough and we can disregard this assumption.

```
autoplot(drive_lm2, which = 2)
```



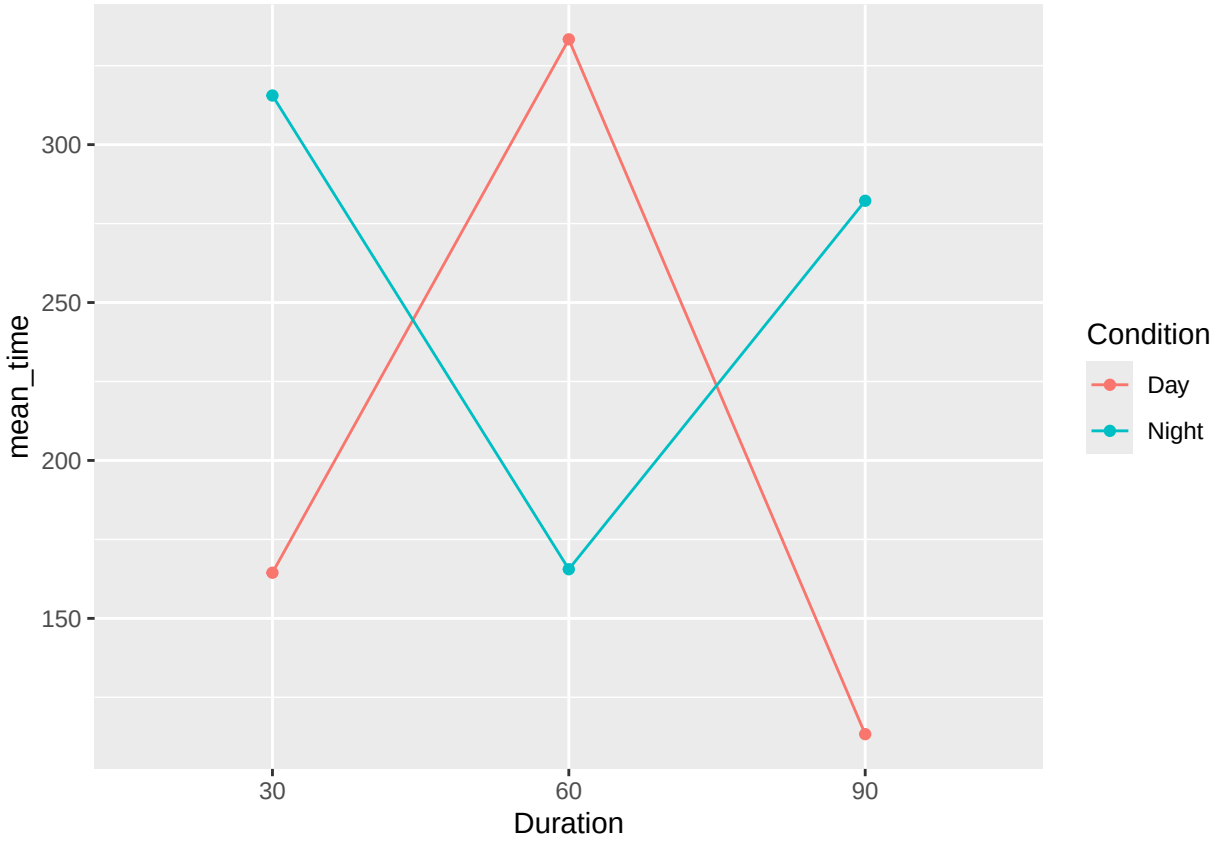
For the remainder of this Case Study use log(Time) as the response

3. [3pts] Obtain the interaction plot. Explain what this plot indicates about how condition and duration affect the log of reaction time. Be specific–it is not sufficient to say if there is or is not interaction.

```
drive_sum <- drive %>%
  group_by(Condition,Duration) %>%
  summarise(mean_time = mean(Time))
```

```
## `summarise()` has grouped output by 'Condition'. You can override using the
## `.groups` argument.
```

```
ggplot(data=drive_sum,aes(x=Duration, mean_time)) +
  geom_line(aes(group=Condition, color=Condition)) +
  geom_point(aes(color=Condition))
```



Answer: The interaction plot indicates that the effect of duration of a phone call on reaction time depends on whether it is day or night. There does not necessarily appear to be an effect of duration of a phone call and reaction time themselves, but further anaylsis would be advised.

4. [5pts] Conduction the appropriate hypothesis test to test whehter it is necessary to include the interaction term in this model.

a. Set up the hypotheses of interest.

Answer: H_0**:** $(ab)_{ij} = 0$ **for all ij** H_A**: at least one** $(ab)_{ij} \neq 0$ **i = 30,60,90 j = Day, Night**

b. Report the appropriate test statistic, df, and p-value.

```
anova(drive_lm2)
```

```
## Analysis of Variance Table
##
## Response: log(Time)
##                    Df  Sum Sq Mean Sq F value   Pr(>F)
## Condition           1  0.7510 0.75102  2.1581 0.148347
## Duration            2  0.7497 0.37486  1.0772 0.348651
## Condition:Duration  2  3.9947 1.99733  5.7394 0.005822 **
## Residuals          48 16.7043 0.34801
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Answer: f = 5.7394, df = 5 and 48, p = 0.0058

c. Provide a conclusion for this hypothesis test making sure to clearly indicate whether it is necessary to include the interaction.

Answer: With a p-value of 0.0058 (f = 5.7394, df = 5 and 48) there is very strong evidence that there exist an interaction between condition and duration that affects log reaction time to respond or the effect of duration depends on condtion. Therefore we reject the null hypothesis.

5. [3pts] You present your work so far to your collaborators. They notice that the p-values associated with the F-tests for the main effects of condition and duration are relatively large. Based on what they remember from their one statistics course, they believe that the main effects should be removed from the model because they are not statistically significant. Do you agree or disagree with your collaborators? Explain.

Answer: Because we have determined that an interaction is present, due to the principle of marginality, we would need to include the lower order terms being both the Condition and Duration factors when including higher order terms like an interaction, even if they seem statistically insignificant.

6. [6pts] There are several follow-up questions your collaborators are interested in. For each question or request, if it is not reasonable to answer explain why not and if it is reasonable to answer, use the appropriate tools to answer it.

a. How does average log reaction time differ among the different phone call durations for drivers driving under day conditions?

```
#calculate cell means by condition
drive_means <- emmeans(drive_lm2, ~Duration|Condition)

#obtain CIs
confint(pairs(drive_means))
```

```
## Condition = Day:
##  contrast                estimate    SE df lower.CL upper.CL
##  Duration30 - Duration60   -0.549 0.278 48   -1.222    0.123
##  Duration30 - Duration90    0.347 0.278 48   -0.325    1.020
##  Duration60 - Duration90    0.897 0.278 48    0.224    1.569
##
## Condition = Night:
##  contrast                estimate    SE df lower.CL upper.CL
##  Duration30 - Duration60    0.464 0.278 48   -0.209    1.136
##  Duration30 - Duration90    0.104 0.278 48   -0.568    0.777
##  Duration60 - Duration90   -0.360 0.278 48   -1.032    0.313
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 3 estimates
```

Answer: This is reasonable to answer because it is a question regarding simple effects. We are analyzing the difference between levels of one factor (Duration) for a given factor (Condition).

There is not a significant difference in log reaction times for drivers driving during the day after a phone call of 30 seconds vs 60 seconds, nor after a phone call of 30 seconds vs 90 seconds. However, the reaction time for drivers on the phone for 60 seconds is longer than drivers on the phone for 90 seconds.

b. What is the average difference in log reaction time for drivers under day and night conditions?

Answer: We would not compare marginal means as there is an interaction present.

c. How much larger is the difference in average log reaction time between night and day conditions for drivers with phone calls of 90 seconds compared to drivers with phone calls of 30 seconds?

```
drive_means2 <- emmeans(drive_lm2,~Duration*Condition)
confint(contrast(drive_means2, list(nvd30v90=c(1,0,-1,-1,0,1))))
```

```
##  contrast estimate    SE df lower.CL upper.CL
##  nvd30v90    0.243 0.393 48   -0.547     1.03
##
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
```

Answer: There is not a significant difference in averagelog reaction time between night and day conditions for drivers with phone calls of 90 seconds compared with phone calls of 30 seconds. We are 95% confident that the difference in average log reaction time between night and day conditions for drivers with phonecalls of 90 seconds vs 30 seconds is -0.547 and 1.03 seconds.