Professor Notes on 1-Way ANOVA Homework 3

- For the independence assumption, be clear that you have thought through what it means to be independent within or among groups. It is not adequate to just say "the groups are independent." Also note that there is nothing in the data that speaks to independence. Assessing independence is purely a thought process.
- On the first question of the second part, you must use the p-value from the ANOVA table. That is the p-value that assesses whether all group means are equal or not. The Tukey's multiple comparisons are only used to assess difference in paired means AFTER it has been determined that there is a difference in means. The linear models coefficients table is not appropriate for answering that question (you should get out of the habit of using `summary()` on your `lm()` results).
- The second question should include a plot of means with appropriate significance letters. Note that when using Tukey's method that there should be letters on each point. With Dunnett's method it may be appropriate to leave one point without a letter, but this should be explained in the figure label.
- In the second to last questions, make sure to clearly indicate which group is greater (or lesser). Don't just say that you are 95% confident that the difference is between such-and-such.
- Make sure to note how concise the answer key is. Work to get your answers this concise.

Temperature and Turtle Hatchings I

1. The individuals appear to be independent both within and among groups as each egg was put into its own container and randomly given a temperature such that the results for any one egg would not impact the results of any other egg given the same (within) or different (among) temperature.

2. The Levene's test suggests that the variances are equal among the temperature groups ($p = 0.398$). The boxplots of residuals are very roughly equal in height and thus support the conclusion of equal variances (Figure 1-Right).

3. The Anderson-Darling normality test suggests that the residuals are normally distributed ($p = 0.694$). The histogram of the residuals is slightly (but not strongly) left-skewed (Figure 1-Left). The Anderson-Darling tests though is definitive and, thus, the residuals appear to be normal.

4. There are no significant outliers ($p = 0.773$), though the residual plot suggests possible outliers in the 25C group (Figure 1).

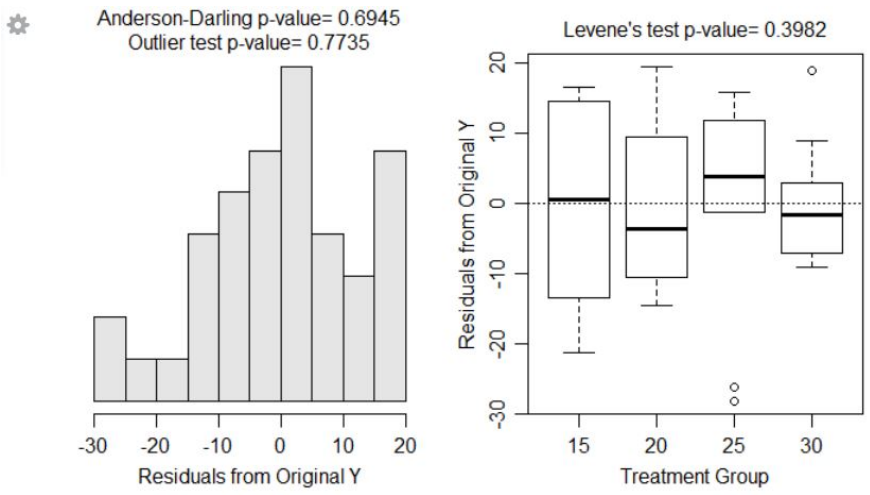

Figure 1. Histogram of residuals (left) and boxplot of residuals by treatment group (right) for the turtle study.

Temperature and Turtle Hatchings II

1. The mean days to hatch is significantly different among the four temperature groups ($p < 0.0005$; Table 1).

Table 1. Analysis of variance table for the days to hatch by temperature group.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Temperature	3	8025.5	2675.16	15.978	9.082e-07
Residuals	36	6027.3	167.43		

2. It appears that the mean days to hatch for the 30C group is significantly lower than the mean days to hatch for 15C ($p < 0.0005$), 20C ($p = 0.001$), and 25C ($p < 0.0005$) groups (Table 2). The mean days to hatch for all other pairs of temperature groups are not significantly different (Table 2). These results are shown visually in Figure 2.

Table 2. Tukey's multiple comparison results for the days to hatch by sea turles at various temperature groups.

	Estimate	Std. Error	t value	p value
20 - 15 = 0	-13.8	5.786623	-2.3848108	9.802479e-02
25 - 15 = 0	-9.2	5.786623	-1.5898739	3.970558e-01
30 - 15 = 0	-38.3	5.786623	-6.6187141	3.274652e-07
25 - 20 = 0	4.6	5.786623	0.7949369	8.562600e-01
30 - 20 = 0	-24.5	5.786623	-4.2339033	7.627224e-04
30 - 25 = 0	-29.1	5.786623	-5.0288402	8.538479e-05

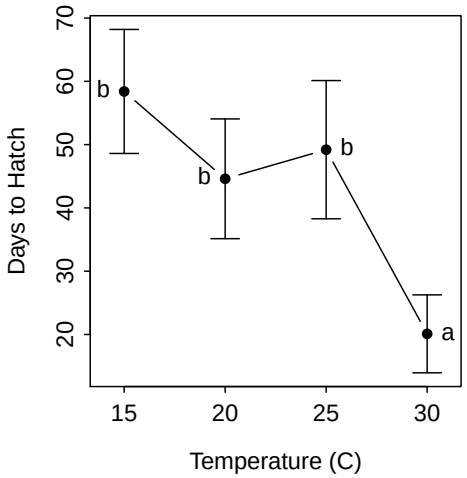

Figure 2. Plot of mean (with 95% CI) days to hatch by sea turtles at various temperature groups. Different letters indicate means that are significantly different.

3. The mean days to hatch for sea turtles at 30C is between 22.7 and 53.9 days lower than that at 15C, between 8.9 and 40.1 days lower than that at 20C, and between 13.5 and 44.7 days lower than that at 25C (Table 3).

Table 3. Tukey's confidence interval results for the difference in mean days to hatch by sea turtles for each pair of temperature groups.

	Estimate	lwr	upr
20 - 15	-13.8	-29.38226	1.782258
25 - 15	-9.2	-24.78226	6.382258
30 - 15	-38.3	-53.88226	-22.717742

```
25 - 20      4.6 -10.98226  20.182258
30 - 20    -24.5 -40.08226  -8.917742
30 - 25    -29.1 -44.68226 -13.517742
```

R Appendix

```r
library(NCStats)
setwd("c:/biometry/")
d <- read.csv("turtles.csv")
d$Temperature <- factor(d$Temperature)

# First question
lm1 <- lm(Days~Temperature,data=d)
transChooser(lm1)

# Second question
anova(lm1)
mc1 <- glht(lm1,mcp(Temperature="Tukey"))
summary(mc1)
confint(mc1)
fitPlot(lm1,xlab="Temperature (C)",ylab="Days to Hatch")
addSigLetters(lm1,c("b","b","b","a"),pos=c(2,2,4,4))
```