One Factor Experiment

Deming

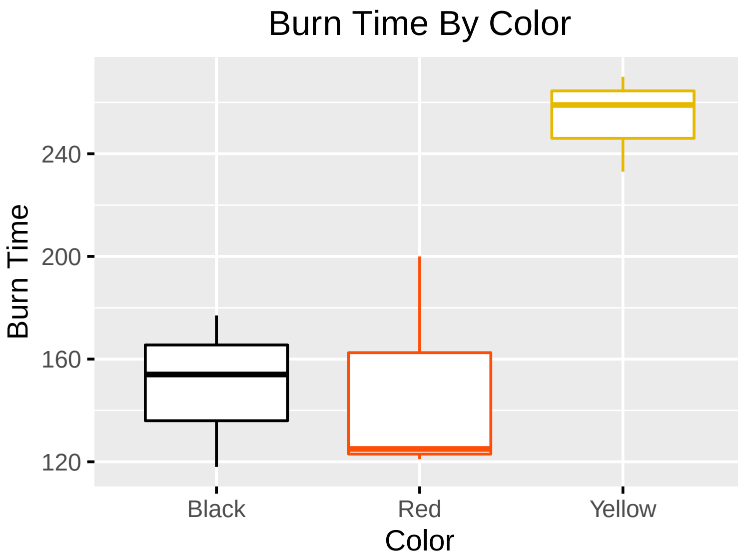
Introduction and Data

In 2013, a video claiming that you can burn crayons in an emergency (for light) became popular on YouTube–even though burning crayons is probably not a great idea at all. Regardless, we are interested in discovering whethe one pack of a single color of crayons burns longer than a normal pack of crayons with multiple colors in each pack. We will measure the time in seconds that each crayon burns. The explanatory variable in this experiment was the color of crayon, with `color` having three levels: Yellow, Black, and Red. Each crayon was set, safely, on a holder and started on fire with a torch. Timing began at the point of a sustained flame and was stopped when the flame went out or became too dim to be effective. Three boxes of crayons were purchased, and 9 total crayons measured (three for each level of `color`). The data table is below.

experiment	Color	Time
1	Yellow	270
2	Black	177
3	Red	121
4	Red	200
5	Yellow	259
6	Red	125
7	Black	118
8	Yellow	233
9	Black	154

Exploratory Data Analysis

Below we have plotted the distributions of burn time for each of the three colors. We can see that for the black and yellow crayons, the shape of the burn time distribution is relatively symmetric, and likely can be considered approximately normal. The distribution of times for the red crayon appears to have a slight right-skewness, but we will analyze later whether the red crayons' burn times deviate significantly from a normal. We can see that the red crayons' times appear to be a bit more spread out than the times of the other two colors, indicating a potential difference in variance. The red and yellow crayons have comparable spread, with the black crayons perhaps being spread out a bit more from the yellow–although this difference



is likely not significant. Below is a table displaying the means and standard deviations of the burn times for each color. We can clearly see that the standard deviation for the red crayons is much larger than the standard deviation for the other two, and the mean burn time for the yellow crayon is much larger than the mean burn time for the other two crayons.

Color	Mean	SD
Black	149.67	29.74
Red	148.67	44.50
Yellow	254.00	19.00

Analysis

We want to find out if there is a statistically significant difference between the burn time for each color. To do this, we will test the following hypotheses:

$$H_o: \ \mu_{black} = \mu_{red} \ = \mu_{yellow}$$
$$H_a: \ At\ least\ one\ \mu_i\ is\ different\ from\ the\ rest$$

Before conducting this ANOVA test, we want to make sure that the distributions of burn times for each color are approximately normal, and that the variances do not differ significantly. To test whether the normality assumption is met, we conducted a Shapiro-Wilk test null hypothesis that the sample comes from a normal distribution, and alternative hypothesis that the sample does not come from a normal distribution. This test returned a p-value of 0.39, so we fail to reject the null hypothesis and conclude that the distributions can be considered approximately normal.

To determine whether the variances are significantly different from each other, we conducted a Levene test, which has null hypothesis that the variances of each group are homogeneous and alternative that they differ from each other. That test returned a p-value of 0.829, so we can conclude that the variances are not significantly different between crayon colors.

The following table shows the results of the ANOVA test stated above.

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Color        2  21982   10991   10.22 0.0117 *
## Residuals    6   6451    1075
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We can see from the table that the p-value for the test that color is significant with respect to burn time is 0.0117. At a 0.05 significance level, we reject the null hypothesis that all means are signficant and conclude that at least one color's average burn time is different from the rest. From the table of means and standard deviations seen above, we can infer that the yellow crayon is the cause of that difference, but we want to compute pair-wise confidence intervals to analyze where the difference is coming from. The table below displays the confidence intervals along with the corresponding color pair. We can see clearly that the confidence interval for the difference in mean burn times for the Red-Black crayon color combination contains zero, meaning that the difference in mean burn time for the black crayon is not significantly different from the red crayon. A plot of the confidence intervals is also shown below the table.

	diff	lwr	upr
Red-Black	-1.0000	-83.14813	81.14813
Yellow-Black	104.3333	22.18520	186.48146
Yellow-Red	105.3333	23.18520	187.48146

We also plotted the confidence intervals on the plot below, and we can see that the differences in mean burn time between Yellow-Black and Yellow-Red are greater than zero for both groups, which means that the mean burn time for yellow crayons is greater than the mean burn time for both red and black crayons. Based on these results, we can conclude that color matters if one wants to burn crayons for light, and Yellow (lighter colors) burn longer than Red and Black (darker colors). However, it might be best to just purchase a flashlight.