**Learn By Doing** – One-Way ANOVA

The purpose of this activity is to give you guided practice in carrying out the ANOVA F-test.

**Background:** Critical Flicker Frequency (CFF) and Eye Color

There is various flickering light in our environment; for instance, light from computer screens and fluorescent bulbs. If the frequency of the flicker is below a certain threshold, the flicker can be detected by the eye. Different people have slightly different flicker "threshold" frequencies (known as the *critical flicker frequency*, or CFF).

Knowing the critical threshold frequency below which flicker is detected can be important for product manufacturing as well as tests for ocular disease. Do people with different eye color have different threshold flicker sensitivity? A 1973 study ("The Effect of Iris Color on Critical Flicker Frequency," *Journal of General Psychology* [1973], 91–95) obtained the following data from a random sample of 19 subjects.

| Eye Color | Threshold Frequency (CFF) |
|---|---|
| Brown | 26.8 |
| Brown | 27.9 |
| Brown | 23.7 |
| Brown | 25 |
| Brown | 26.3 |
| Brown | 24.8 |
| Brown | 25.7 |
| Brown | 24.5 |
| Green | 26.4 |
| Green | 24.2 |
| Green | 28 |
| Green | 26.9 |
| Green | 29.1 |
| Blue | 25.7 |
| Blue | 27.2 |
| Blue | 29.9 |
| Blue | 28.5 |
| Blue | 29.4 |
| Blue | 28.3 |

Do these data suggest that people with different eye color have different threshold sensitivity to flickering light?

In other words, do the data suggest that threshold sensitivity to flickering light is related to eye color?

**Comment:** We recommend that before starting, you create for yourself a figure that summarizes this problem, similar to the figures that we presented for the examples that we used in this part.

**Question 1:**

**What is the explanatory variable (X) and how many values does it take? What are those values? What is the response variable (Y)?**

**Your answer**

**OUR ANSWER**

We want to check whether CFF is related to eye color, therefore, the explanatory variable is eye color, which takes three values: Brown, Green and Blue, and the response variable is CFF.

**Question 2:**

**What are the hypotheses that are being tested here? Be sure that you define clearly the parameters that you are using.**

**Your answer**

**OUR ANSWER**

The hypotheses that being tested here are:

Ho: $\mu 1 = \mu 2 = \mu 3$

Ha: not all the $\mu$'s are equal

Where:

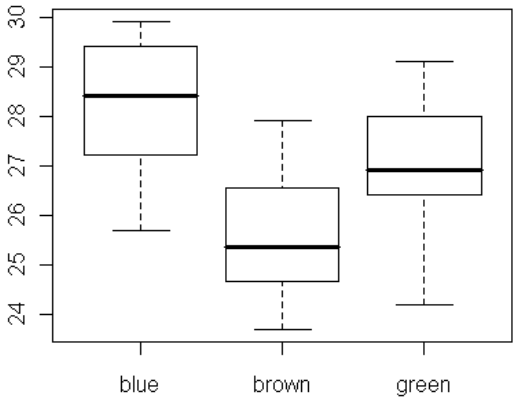
$\mu 1$ = mean CFF of people that have brown eyes.

$\mu 2$ = mean CFF of people that have green eyes.

$\mu 3$ = mean CFF of people that have blue eyes.

**Question 3:**

**Are the conditions that allow us to safely use the ANOVA F-test met?**




**Summary statistics:**

| Column | n | Mean | Std. Err. | Std. Dev. | Min | Q1 | Median | Q3 | Max |
|---|---|---|---|---|---|---|---|---|---|
| Blue | 6 | 28.166666 | 0.6237877 | **1.5279616** | 25.7 | 27.2 | 28.4 | 29.4 | 29.9 |
| Brown | 8 | 25.5875 | 0.4827146 | **1.3653231** | 23.7 | 24.65 | 25.35 | 26.55 | 27.9 |
| Green | 5 | 26.92 | 0.82425725 | **1.8430952** | 24.2 | 26.4 | 26.9 | 28 | 29.1 |

**Your answer**

**OUR ANSWER**

Let's check the conditions:

(i) We are told that the sample was chosen at random, so the three eye-color samples are independent.

(ii) The sample sizes are quite low, but the boxplots do not display any extreme violation of the normality assumption in the form of extreme skewness or outliers.

(iii) We can assume that the equal population standard deviation condition is met, since the rule of thumb is satisfied (1.843 / 1.365 is less than 2).

In summary, we can safely proceed with the ANOVA F-test.

**Question 4:**

**Based on the graph that produced for answering the previous question, summarize what the data suggest about how CFF is related to eye color. Do you think that the data provide enough evidence against the null hypothesis? (There is no right or wrong answer here, just your feelings from looking at the data.)**

**Your answer**

**OUR ANSWER**

The data suggest that the CFF of the people with brown eyes is the lowest (on average), followed by green-eyed people, and people with blue eyes have the highest CFF (on average). It seems like that there is a reasonable amount of evidence in the data against Ho. The three boxplots do not overlap much, and it really doesn't seem very likely that the three populations from which these three samples were chosen all share the same mean.

**Question 5:**

**Carry out the ANOVA F-test and state the test statistic and p-value. Interpret the p-value and draw your conclusion in context.**

**ANOVA table**

| Source | df | SS | MS | F-Stat | P-value |
|---|---|---|---|---|---|
| Treatments | 2 | 22.997286 | 11.498643 | **4.802346** | **0.0232** |
| Error | 16 | 38.31008 | 2.39438 | | |
| Total | 18 | 61.30737 | | | |

**Your answer**

**OUR ANSWER**

The test statistic is 4.8 (which is quite large), and the p-value is 0.023, indicating that it is unlikely (probability of 0.023) to get data like those observed assuming that CFF is not related to eye color (as the null hypothesis claims). Since the p-value is small (in particular, smaller than .05), we have enough evidence in the data to reject Ho.

**Conclusion:** There is enough evidence that the mean CFFs in the three eye-color populations are not all the same. In other words, there is enough evidence that CFF is related to eye color.