Statistics Package Exercise: Carrying Out the ANOVA F-test

Learning Objective: In a given context, carry out the inferential method for comparing groups and draw the appropriate conclusions.

The purpose of this activity is to give you guided practice in carrying out the ANOVA F-test and to teach you how to obtain the ANOVA F-test's output using statistical software.

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.

- R
- StatCrunch
- TI Calculator
- Minitab
- Excel

R Instructions

To open R with the data set preloaded, right-click here and choose "Save Target As" to download the file to your computer. Then find the downloaded file and double-click it to open it in R.

The data have been loaded into the data frame

```
flicker
```

. Enter the command

```
flicker
```

to see the data. The two variables in the data frame are

```
color
```

and

```
cff
```

.

Now use R to create side-by-side boxplots of CFF by eye color, and supplement them with the descriptive statistics of CFF by eye color. Use the output to check whether the conditions that allow us to safely use the ANOVA F-test are met.

To do this in R, enter the commands:

- ```
  boxplot(flicker$cff~flicker$color,xlab="Eye
  Color",ylab="CFF")
  ```
- ```
  tapply(flicker$cff, flicker$color, mean)
  ```
- ```
  tapply(flicker$cff, flicker$color, sd)
  ```
  ```

Learn By Doing (1/1 point)

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

Your Answer:

a.) yes, randomly sampled, and independent
b.) distributions seem okay -- means are kinda in the middle of each. No outliers, too.
c.) standard deviations also look similar

Our Answer:

RStatCrunch TI CalculatorMinitabExcel R Here is the graph: Here are the standard deviations: 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. StatCrunch The following is the descriptive statistics and graph: 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. TI Calculator Here is the graph . The following are the descriptive statistics: 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. Minitab Here is the graph: The following are the descriptive statistics: 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. Excel Here are the descriptive statistics and the graph:. Note that these might look a little different than the ones you generated depending on the version of Excel you are using, but the values should be the same. 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.

Resubmit Reset

- R
- StatCrunch
- TI Calculator
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- Excel

R Instructions

For the next question, we need to carry out the ANOVA F-test using R. To do this, we use the

```
aov()
```

command. Similar to the

```
lm()
```

command, the

```
aov()
```

command produces more output than we need, so we will save the output to a variable name and then use other commands to extract the information of interest. We choose here a generic name,

```
cff.aov
```

, but any name would work within the code as long as it is used throughout.

- ```
  cff.aov=aov(cff~color,flicker)
  ```

Now we can extract the ANOVA table from

```
cff.aov
```

using either

```
summary()
```

or

```
anova()
```

, which both return the same result.

- ```
  summary(cff.aov)
  ```

- ```
  anova(cff.aov)
  ```

Note: For more advanced analysis of assumptions for ANOVA, we can use functions such as

```
plot(cff.aov,1)
```

for residual plots,

```
plot(cff.aov,2)
```

for normal QQ plots, and

```
residuals(cff.aov)
```

to extract the residuals.

Learn By Doing (1/1 point)

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

Your Answer:

p-value is 0.0232

that means that there's enough evidence to reject Ho, so eye color really does have an effect on the CFF.

Our Answer:
RStatCrunch TI CalculatorMinitabExcel R Here is the R output: The test statistic F is 4.8 (which is quite large), and the p-value is .023, indicating that it is unlikely (probability of .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 and conclude that the mean CFFs in the three eye-color populations are not all the same. In other words, we can conclude that CFF is related to eye color. StatCrunch Here is the StatCrunch output: The test statistic F is 4.8 (which is quite large), and the p-value is .023, indicating that it is unlikely (probability of .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 and conclude that the mean CFFs in the three eye-color populations are not all the same. In other words, we can conclude that CFF is related to eye color. TI Calculator Here
```

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