

12.3 Exercises

Basic Concepts

1. If you found that MST is much larger than MSE, would you tend to think that the population means were similar or different? Explain how this ratio brings you to this conclusion.
2. What kind of distribution does the ratio $\frac{MST}{MSE}$ have?
3. What are the degrees of freedom associated with $\frac{MST}{MSE}$?
4. If the variability among the sample means is very similar to the variability among the sample observations, what value will F be close to? Explain why.
5. Is the null hypothesis generally rejected for large or small values of the F -statistic? Explain why this is the case.
6. What are the null and alternative hypotheses for the F -test?
7. What are the assumptions of the F -test?
8. What is the rejection region for the F -test?
9. Can P -values be used to make a decision for the F -test? What is the decision rule?

Exercises

10. The results of a comparison of four popular minivans are reported in the following table. One of the features the researchers compared was the distance (in feet) required for the minivan to come to a complete stop when traveling at a speed of 60 miles per hour (braking distance). Suppose the braking distances were measured for five minivans of each type with the following results.

Braking Distances (Feet)			
Minivan A	Minivan B	Minivan C	Minivan D
150	153	155	167
152	150	150	164
151	156	157	169
149	151	158	162
153	155	155	173

- a. Can the researchers conclude at $\alpha = 0.10$ that there is a difference among average braking distances for the four minivan models?
 - b. What assumptions did the researchers make in performing the test procedure in part a.? Do the data appear to satisfy these assumptions? Explain.
11. A steel company is considering the relocation of one of its manufacturing plants. The company's executives have selected four areas that they believe are suitable locations. However, they want to determine if the average wages are significantly different in any of the locations, since this could have a major impact on the cost of production. A survey of hourly wages of similar workers in each of the four areas is performed with the following results.

Hourly Wages (\$)			
Area 1	Area 2	Area 3	Area 4
10	15	13	20
12	16	14	16
11	18	15	18
13	17	15	17
10	14	12	16

- a. Do the data indicate a significant difference among the average hourly wages in the four areas at $\alpha = 0.05$?
- b. What assumptions were made in performing the test in part a.? Do the data appear to satisfy these assumptions? Explain.
12. A director of training at a large temporary services company has learned of three different methods for teaching a person to type. He is interested in determining if there is a difference in the average typing speeds for employees who are taught to type using each of the three methods. He randomly selects 15 new employees and then randomly assigns five employees to learn to type by each of the training methods. At the end of the course, he measures the number of correct words per minute for each employee. The results are as follows.

Typing Speeds (Correct Words per Minute)		
Method 1	Method 2	Method 3
45	50	60
50	55	63
40	49	55
43	52	52
47	53	58

- a. Can the director of training conclude that there is a difference among the average typing speeds of the employees for the three methods at $\alpha = 0.10$?
- b. What assumptions did the director of training make in performing the test in part a.? Do the data appear to satisfy these assumptions? Explain.
13. A physical trainer has four workouts that he recommends for his clients. The workouts have been designed so that the average maximum heart rate achieved is the same for each workout. To test this design he randomly selects 12 people and randomly assigns three of them to use each of the workouts. During each workout, he measures the maximum heart rate in beats per minute with the following results.

Maximum Heart Rates (Beats per Minute)			
Workout #1	Workout #2	Workout #3	Workout #4
180	160	175	185
185	170	180	190
170	175	170	180

- a. Can the physical trainer conclude at $\alpha = 0.05$ that there is a difference among the average maximum heart rates which are achieved during the four workouts?
- b. What assumptions did the physical trainer make in performing the test procedure in part a.? Do the data appear to satisfy these assumptions? Explain.

14. The results of a survey comparing the costs of staying one night in a full-service hotel (including food, beverages, and telephone calls, but not taxes or gratuities) for several major cities are given in the following table.

Hotel Costs per Night (\$)				
New York	Los Angeles	Atlanta	Houston	Phoenix
300	240	190	195	238
320	250	198	190	240
325	230	185	200	236
350	245	195	192	248
275	235	182	198	228

- Do the data suggest that there is a significant difference among the average costs of one night in a full-service hotel for the five major cities at $\alpha = 0.05$?
 - What assumptions were made in performing the test procedure in part a.? Do the data appear to satisfy these assumptions? Explain.
 - Based on the analysis you performed in part b., which cities, if any, do you think have significantly different average costs for a one-night stay in a full-service hotel? Explain.
15. Consider the following information regarding the dividends paid per share by companies in the banking, transportation, and energy industries.

Dividends per Share (\$)		
Banking	Transportation	Energy
1.52	1.00	2.08
3.12	1.20	2.68
1.32	0.20	0.70
0.60	0.40	2.00
1.20	1.09	1.91
1.00	0.61	1.60
1.19	0.35	1.28

- Do the data provide sufficient evidence to conclude that there is a significant difference among the average dividends paid per share for the three different industries? Use $\alpha = 0.10$.
- What assumptions were made in performing the test procedure in part a.? Do the data appear to satisfy these assumptions? Explain.
- Based on the analysis you performed in part b., which industries, if any, do you think pay significantly different average dividends per share? Explain.

12.4 Multiple Comparison Procedures

In the previous sections, we used one-way ANOVA to test whether differences existed between population means. In the earlier examples, when we rejected the null hypothesis that all of the population means were equal, we were *only* testing if differences existed. However, the results of the one-way ANOVA test do not indicate which population means are different. To determine which population means are different, we need to perform more tests to determine if there are statistically significant differences between two population means such as $\mu_1 - \mu_2$, for example. Multiple comparison procedures present several options to the analyst when comparing means after finding significance when performing a one-way ANOVA. The ones