

Scientists observed 31 adult rhesus monkeys, aged 5 to 27 years old, to see if aging affected motor functions and incidence of parkinsonian signs with the purpose of establishing that rhesus monkeys are a suitable model for analyzing the biological processes leading to motor slowing in humans (Zhang *et al.*, *Journal of Gerontology* 2000). The animals were divided into three groups: young adults, 5 to 8 years old ($n = 10$), middle-aged adults, 12 to 17 years old ($n = 10$), and aged adults, 21 to 27 years old ($n = 11$).

The researchers measured several variables. One of these was daily home-cage activity, measured over a 30 day observation period by the average number of times per hour the animal moved in its cage across an infrared beam. Summary statistics of this variable (mean \pm SD) by group were: young (132 ± 16), middle-aged (56 ± 10), and aged (50 ± 13).

Another variable was movement impairment measured using the Nonhuman Primate Motor Dysfunction Assessment Scale with possible scores ranging from 0 to 7, where a score of 0 indicates no impairment while a score of 7 indicates heavy impairment. Scores for each monkey are an average of the scores from the same trained observers making evaluations of the same video taped observation period. Young monkeys showed no impairment. Means and standard deviations for the middle-aged and aged adults were 2.61 ± 1.11 and 4.86 ± 1.16 respectively.

- (a) Select a method from the course that would be appropriate to address the question, “Do adult rhesus monkeys of different age classes exhibit different mean levels of physical activity?”

Solution: ANOVA would be an appropriate method. We are comparing means from more than one population.

- (b) For the method you selected in part (a), state null and alternative hypotheses, both in the context of the problem and using statistical notation. Define any statistical notation you introduce.

Solution: *In the context of the problem:* The null hypothesis is that population mean activity is the same for all the adult monkey age groups. The alternative hypothesis is that they are not all the same.

In symbols: Let μ_1 , μ_2 , and μ_3 be the three population means for the young adult, middle-aged adult, and aged adult populations.

$$H_0: \mu_1 = \mu_2 = \mu_3$$

H_A : the μ_i are not all equal.

- (c) For the method you selected in part (a), find the value of the test statistic. Show your work. You may use these facts. The average activity of all 31 animals is 78.39 counts per hour.

$$10 \times (132 - 78.39)^2 + 10 \times (56 - 78.39)^2 + 11 \times (50 - 78.39)^2 = 42619.36 \quad \text{and} \quad 9 \times 16^2 + 9 \times 10^2 + 10 \times 13^2 = 4894$$

Solution:

Source	df	SS	MS	F
between	2	42619.36	21309.68	121.92
within	28	4894	174.79	
total	30	47513.36		

The F statistic is 121.92.

- (d) For the method you selected in part (a), describe how the p -value would be calculated. (For example, you might answer something similar to “the p -value would be the area to the right of the test statistic under a t distribution with 17 degrees of freedom”.)

Solution: The p -value is the area to the right of 121.92 under an F distribution with 2 and 28 degrees of freedom.

- (e) Suppose that the 0.9999 quantile of the reference distribution you used in the previous part is 13.03. Write a summary of your conclusions in the context of the problem. (Assume that your audience has limited statistical knowledge but understands the scientific content very well.)

Solution: There is very strong evidence that adult rhesus monkeys of different ages have different levels of physical activities as measured under the experimental conditions ($p < 0.0001$, F test, one-way ANOVA).

- (f) Side-by-side dot plots of the impairment scores show no outliers and very little skewness. Find a 95% confidence interval for the difference in impairment between middle-aged and aged rhesus monkeys. Interpret this confidence interval in the context of the problem. (You may assume 19 degrees of freedom.)

Solution: This setting has two independent samples. A 95% confidence interval for the difference in population mean

impairment between the two groups is -2.25 ± 1.04 , or from -3.3 to -1.2, as measured on the Nonhuman Primate Motor Dysfunction Assessment Scale. We are 95% confident that the mean impairment of aged monkeys is from 1.2 to 3.3 points higher than that of middle-aged Rhesus monkeys.

- (g) The monkeys were obtained from a commercial supplier. Nineteen of the monkeys had been bred in captivity by the supplier, nine of the monkeys had been captive bred by a different supplier, while the remaining three monkeys had been caught in the wild. Discuss how the method of procuring monkeys for the study could potentially affect the validity of any inferences you have made.

Solution: The monkeys were not a random sample from the populations of interest, which could bias the results. If, for example wild-born monkeys tend to be more impaired than those born in captivity and if all of the wild-born monkeys were in one age group, the effects of birthplace could be confounded with the effects of age.