Exploration 7.3: Effects of Badminton on Executive Function

Theory-based approach to analyzing data from paired samples

LEARNING GOALS

- Identify when a theory-based approach would be valid to find the p-value or a confidence interval for paired data.
- Use the **Theory-Based Inference** applet to find theory-based p-values and confidence interval for paired data.

STEP 1: State a research question. Many studies have shown an association between various types of exercise and an increase in various types of cognitive abilities including *executive function*. Executive function is a wide-ranging set of cognitive processes that help someone successfully get things done. One of these processes is called inhibitory control. A person displaying inhibitory control will control their impulses in order to use a more appropriate behavior that will get them to their goal. Research done in Japan (Takahashi and Grove, 2019) investigated whether a single session of a complex exercise, in this case playing badminton, *increases* inhibitory control.

STEP 2: Design a study and collect data. Twenty healthy undergraduate students volunteered to participate in this study. They were asked to refrain from using alcohol and strenuous activity for 24 hours prior to testing and to refrain from smoking, eating, and caffeine consumption for 2 hours prior. The undergraduates visited the laboratory on two different days. One day they played badminton for 10 minutes against a researcher and on the other day (as a control) they rested in a chair and were instructed to spend time operating their smartphones. The order of these interventions was randomly determined. To measure inhibitory control, they used a Stroop test. In this kind of test, names of colors (like red) are written in a different color (like blue). The participant has to identify the color of the word and not the name of the word. Because their impulse would be to identify the name over the color, the researcher thought this was a good test to measure inhibitory control. The undergraduates were tested on how many of these identifications they could get correct in 60 seconds. The higher the score would indicate a higher level of inhibitory control. They did this both before the intervention and then again after the intervention. How much they improved (post-Stroop test – pre-Stroop test) was used to show the effect the activity had on improving inhibitory control. They compared these differences for each participant between playing badminton and just sitting at rest (the control).

1. Before we look at the data and start the analysis, let's make sure you understand the study design.

    a. What is the explanatory variable? Is it categorical or quantitative?

    b. There are a couple of different pairings going on here. One is the pre- and post-Stroop test scores that were used to get an improvement score. The other is the difference in the improvement scores between the intervention (badminton) and the control (sitting) treatments. The response variable involves both of these. What is the response variable? Is it categorical or quantitative?

2. State the relevant hypotheses in words.

3. Define the parameter of interest and give the symbol that should be assigned to it.

4. State the relevant hypotheses in symbols.

STEP 3: Explore the data.

5. Paste the data, **Badminton**, into the **Matched Pairs** applet and answer the following questions.

    a. What is the sample mean improvement score for the badminton intervention?

    b. What is the sample mean improvement score for the control?

    c. What are the mean and standard deviation for the differences in the two (badminton – control)?

STEP 4: Draw inferences.

6. Use simulation to determine a p-value using the applet. Explain how you did so.

Notice that your simulated null distribution should be bell-shaped. This is no coincidence. A theory-based method exists that predicts this to occur when certain validity conditions are met.

> ***Validity conditions for theory-based analysis of paired data***
> Theory-based methods of inference will work well for paired data if the distribution of differences has a symmetric distribution, or you have at least 20 pairs (i.e., at least 20 differences) and the distribution of the sample differences is not strongly skewed. This test is known as a ***paired t-test***.

7. Are the validity conditions met for these data? Explain.

8. Because the sample is large enough without strong skewness in the distribution of differences, we can use a theory-based approach. We will do this using the **Matched Pairs** applet again.

    a. In the applet, change the statistic from **Avg Difference** to ***t*-statistic**. What is the value of the observed standardized statistic? What does that number tell you?

    b. In light of the value of the standardized statistic, do you expect the p-value to be small or not small? How are you deciding?

    c. Find a simulation-based p-value using the *t*-statistic. What is the value of this p-value? Is it similar to the p-value found using the Avg Difference as the statistic?

    d. Click on the **Overlay *t*-distribution** box to display a theory-based p-value. What is the value of this p-value? Is it similar to the simulation-based p-value you found in part (c)?

9. In the applet, click on the **95% CI for average difference** button to find a 95% confidence interval for the average difference.

a. Report this 95% confidence interval

b. Do the conclusions you would draw from the 95% confidence interval agree with those using the standardized statistic and the theory-based p-value? How are you deciding?

STEP 5: Formulate Conclusions.

10. Based on the above analysis, state your conclusion in the context of the study. Be sure to comment on:
    - *Statistical significance:* Does a complex exercise seem to improve mean inhibitory control in the long run? How are you deciding?
    - *Estimation:* Interpret the 95% confidence interval you found.
    - *Causation:* Can you conclude causation? If yes, what causes what? If not, how are you deciding?
    - *Generalization:* Can you extend the results of this study? Other kinds of complex exercises? Other kinds of people? How are you deciding?

STEP 6: Look back and ahead. Besides comparing the complex exercise the control, the researchers also compared a simple exercise (running on a treadmill) to the control and did not find a significant difference. They showed that both exercises were done at similar intensity levels, leading them to believe that the cognitive aspects of playing badminton made the difference.

11. A limitation that they brought up was that the badminton intervention differed from a real badminton match because they did not keep score, so no victory or defeat was determined. They also pointed out that the participants were not experienced badminton players. Why do you think these two things are considered limitations?

Exploring Further

A theory-based matched pairs test is basically a single mean *t*-test. To see this, open the **Theory-Based Inference** applet and do the following:

- Choose **One mean** from the pull-down menu.
- Enter the sample size, sample mean, and sample standard deviation for the *differences*. Some of these you found in #5(c).
- Check the box for **Test of Significance**.
- Enter the appropriate information for the hypotheses.
    - Make sure the appropriate sign for the alternative hypotheses is chosen.
- Press **Calculate**.

12. How do the *t*-statistic and p-value compare to the theory-based results you found earlier?

Reference

Takahashi S, Grove PM (2019) Comparison of the effects of running and badminton on executive function: A within-subjects design. PLoS ONE 14(9): e0216842. https://doi.org/10.1371/journal.pone.0216842