Independent Samples t-Test: Chips Ahoy® vs. Supermarket Brand

Dex Whittinghill, Rowan University, adapted from a one-sample activity introduced to me by my colleague Ron Czochor.

Detailed Instructor's Notes

At this point in the course the students should have seen the one sample hypothesis test for the population mean. For each point below the instructor can spend as little or as much time as he or she wants. I present the instructions for carrying out the activity, along with Teaching Notes and Warnings.

1. **Making a Conjecture.** Begin by asking the students if they are familiar with Chips Ahoy® cookies. (They should be.) Then ask them if they remember how many chips Chips Ahoy® claimed to have in a bag. It used to be "1000 chips in every bag," which translated into about 20.8 chips per cookie (there used to be 48 cookies in a bag). Finally, ask them how they think the number of chips per Chips Ahoy® cookie compares to the number of chips per cookie for your supermarket brand (Acme, Shop Rite, etc.). With a vote, find out whether the students think that Chips Ahoy® cookies have more, less, the same, or a different amount of chips per cookie than a supermarket brand.

2. **Formulating the Hypotheses.** Ask the students how they could gather data to evaluate their hypotheses. Students should suggest "take a sample of each kind of cookie and count the number of chips in each kind of cookie." Ask the students "what parameters would we be comparing?" and "how can we write null and alternative hypotheses?" At this point develop the null and alternative hypotheses for comparing two parameters, and point out the different ways to write them down (i.e., $mu1 = mu2$ vs. $mu1 \neq mu2$, and $mu1 - mu2 = 0$ vs. $mu1 - mu2 \neq 0$). In the process of defining the parameters, you will have to address/define what are the populations from which the samples came?

   Teaching Notes. When defining the parameters the populations from which the samples are drawn are important. The samples may not be representative of the whole country. (Girl Scout cookies with the same name are made by different companies for different regions. These samples could be representative of only a few states, and the parameters must be defined accordingly.

3. **Randomness and Independence.** Now you can present the independent samples t-test statistic as you usually would. However, when you get to the point of addressing assumptions, be sure to discuss the concepts of random samples (are the samples of cookies random?) and the independence of samples (were the two samples independent of each other?) in this context. [Note for the students that the sample-size/population-shape assumptions cannot be fully addressed without the data.].

Teaching Notes. The concept of comparing the mean number of chips gives numerous points for discussion. If some assumptions fail, be prepared to "continue for the sake of illustration" and write the caveat on the board.

Random samples. The samples are not random samples, but actually "convenience cluster samples of size 1." You have collected one bag (a single cluster) from a local store (the "convenience").

Independent random samples. The samples might be considered independent because they come from different companies. On the other hand they might not because they come from the same store?

4. **Uniform Guidelines (and Learning Curve?).** Before the students take one cookie from each brand and count the number of chips in each, the practical aspects of counting chips must be considered. How can we count the number of chips? How can we break up the cookies to count the chips? What constitutes a "chip"? A class consensus must be reached, though students can always confer with their neighbors about "is this a chip?"

   Teaching Notes. The concept of a learning curve may come up when you discuss the guidelines for how to count the chips. If so, then randomize the order in which students get the two brands of cookie.

5. **Gathering the Data.** The students count the number of chips in a one cookie from each brand, and report their observations to the instructor. Be sure to address the sample-size/population-shape assumptions when you have the data. The data is in your software or calculator, so you can address the assumptions with class input. (If students are in groups, nothing really changes, except that when they check with group-mates on "is this a chip" it should contribute to uniformity.)

   Teaching Notes.

   Sample size conditions. If the populations of the number of chips are normal, we can use the independent samples t-test. Histograms and normal probability plots can be used to verify or eliminate normality. Of course if the sample sizes are large enough, the sample means are normal, but these conditions differ from text to text! For instance in some books the conditions are more robust, and depend on the sum of the sample sizes (Moore and McCabe), whereas in others the sample sizes must individually be at least 30 (say). Hence the size of the class needed to make the activity work well may depend on the text you use.

   Population variances equal? If you use the pooled t-test my experience is that samples should satisfy the conditions. Consider switching to the approximate t-test if you have not already!

6. **The t-Test.** The students carry out, individually or as a class, the hypothesis test using the pooled data. This includes defining the parameters (in 2 above), writing down the null and

alternative hypotheses (in 2 above), the value of the test statistic, the P-value, and the statistical and real-world conclusions.

Warnings.

a) If you teach in a computer lab, you can have the students move outside to break up the cookies. Crumbs in the keyboard may disqualify you from using the lab/classroom again.
b) Be sure to point out that although the sample sizes may be the same for the two samples, this is not a paired t-test.

Adaptations.

a) The counting can be done in a take-home fashion. Give the students one of each cookie to take home in little plastic bags; adequately marking the cookies so that the data is not mixed up (wrap one in a piece of paper or little envelope, use markers, or see below).
b) Because this is not a paired t-test, you can have some students do two of one kind of cookie, so that you get different sample sizes. If you have a very large class you can have each student do one kind of cookie and get unequal sample sizes.
c) Having extra cookies (and milk) for consumption is optional, because the counting is a destructive process.
d) If you are independently wealthy or your school has a large budget, you can compare Chips Ahoy® to a regional bakery's "gourmet" brand. (In at least New Jersey, we could choose Entenmann's!)