Exploration 1.1: Can dogs rapidly learn names of objects?

Introduction to Chance Models

LEARNING GOALS

- Recognize the difference between parameters and statistics.
- Describe how to use coin tossing to simulate outcomes from a chance model of the random choice between two events.
- Use the **One Proportion** applet to carry out the coin tossing simulation.
- Identify whether or not study results are statistically significant and whether or not the chance model is a plausible explanation for the data.
- Implement the 3S strategy: find a statistic, simulate results from a chance model, and comment on strength of evidence against observed study results happening by chance alone.
- Differentiate between saying the chance model is plausible and the chance model is the correct explanation for the observed data.

Making conclusions from data can be done in carefully planned studies using sound principles of science and statistics. The principles can be summarized as the six steps of a statistical investigation (outlined below), which is in line with the scientific method.

Six steps of a Statistical Investigation

STEP 1: Ask a research question that can be addressed by collecting data. These questions often involve comparing groups, asking whether something affects something else, or assessing people's opinions.
STEP 2: Design a study and collect data. This step involves selecting the people or objects to be studied and deciding how to gather relevant data on them, and carrying out this data collection in a careful, systematic manner.
STEP 3: Explore the data, looking for patterns related to your research question as well as unexpected outcomes that might point to additional questions to pursue.
STEP 4: Draw inferences beyond the data by determining whether any findings in your data reflect a genuine tendency and estimating the size of that tendency.
STEP 5: Formulate conclusions that consider the scope of the inference made in Step 4. To what underlying process or larger group can these conclusions be generalized? Is a cause-and-effect conclusion warranted?
STEP 6: Look back and ahead to point out limitations of the study and suggest new studies that could be performed to build on the findings of the study.

You will see these six steps in headers throughout this exploration as we explore a study to see if dogs can rapidly learn names of objects. Typically, animals learn through operant conditioning. For example, dogs are taught to sit by rewarding them with a treat or some other positive reinforcement. After reinforcing this behavior many times, dogs learn to sit when requested to do so. The same thing happens in nature. If bears find salmon abundant in a river, they are likely to return again and again if they are continually rewarded with a meal.

We are looking at something a little different here. Researchers want to see if dogs can rapidly learn names of objects by just being told what they are and not conditioned with some sort of reward. Learning new words after a single encounter or very few encounters is known as fast mapping. This is what allows preschool children to quickly add to their vocabularies. It was long thought that this was an ability that only humans possessed. However previous research challenged this idea and indicated that some dogs also have this ability. Researchers in Hungary (Fugazza et al. 2021) decided to test this with a couple of well-trained dogs. That is dogs that already had learned words of objects (mostly dog toys) and could retrieve the appropriate one when asked.

One of the dogs in the study was a 9-year-old Yorkshire terrier named Vicky Nina. She already learned the names of a number of her toys and could retrieve them when asked by her owner or the experimenter. In the study the dog was shown two new toys, like a small stuffed lion and dolphin. The owner would play with the new toys (one at a time) with the dog using just four repetitions of the toy's name. Two minutes after the exposure to the toy, the dog was tested. Using two rooms in a house, the two new objects were placed in one room and the researcher, owner, and the dog were in another room out of sight of the two objects. The researcher would show the owner the name of the object she wanted the dog to retrieve, and the owner would ask the dog to retrieve it. Two different rooms were used so there would be no way the dog would get any clues from the owner or researcher as to which object to retrieve other than the initial request. Vicky Nina (who would always bring back one of the two objects) was tested with different new objects in 20 different trials. (In this video, you can see the other dog in the study, named Whisky, using the method described above and another method described later to learn the names of the objects. Whisky is also shown being tested when only given two objects to choose from. Whisky is from Norway, so the owner is speaking Norwegian to the dog.)

STEP 1: State the research question.

1. Based on the description of the study, state the research question. That is, what question do the researchers what to answer.

Before we go any further let's introduce a few basic terms that we will use.

Definition

Data can be thought of as the values measured or categories recorded on individual entities of interest. These individual entities on which data are recorded will be called ***observational units***.

The recorded characteristics of the observational units are the ***variables*** of interest. Some variables are ***quantitative***, that are numerical values on which ordinary arithmetic operations make sense. For example, height, number of siblings, and age are quantitative variables. Other variables are ***categorical***, that are category designations. For example, eye color, marital status, and whether or not you voted in the last election are categorical variables.

STEP 2: Design a study and collect data.

In the 20 trials Vicky Nina was tested, she brought back the correct object 15 times.

2. What are the observational units and how many are there?

3. Identify the variable in the study. What are the possible outcomes of this variable? Is this variable quantitative or categorical?

Definition

The set of observational units on which we collect data is called the ***sample***. The number of observational units in the sample is the ***sample size***. A ***statistic*** is a number summarizing the results in the sample.

STEP 3: Explore the data.

With categorical data, we typically identify one of the outcomes as "success" then report the number of successes or the proportion of successes as the statistic.

4. Determine the observed statistic and produce a simple bar graph of the data (have one bar whose height is the proportion of times Vicky Nina picked the correct object and another whose height is the proportion of times she picked the wrong object).
5. If the conjecture is that Vicky Nina can quickly learn the names of the objects and can retrieve the correct one, is the statistic in the *direction* suggested by this conjecture?

6. Could Vicky Nina have gotten 15 out of 20 correct even if she really didn't learn the correct names and was randomly guessing between the two objects each time?

7. Do you think it is likely Vicky Nina would have gotten 15 out of 20 correct if she was just guessing randomly each time?

STEP 4: Draw inferences beyond the data. There are two possibilities for why Vicky Nina chose the object 15 out of 20 times:

- She is merely picking an object at random and in these 20 trials and happened to guess correctly in 15 of them. That is, she got more than half correct just by random chance alone.
- She is doing something other than merely guessing and perhaps has quickly learned (fast mapped) the names of some of the objects.

While we know that Vicky Nina got 15 correct out of these 20 attempts, are we convinced she would be correct more than half the time in the long run? We can think of these 20 attempts as a small part of a *random process*, an endless series of potential attempts that are identical apart from "random chance." It is this random process that we want to make inferences (or conclusions) about. In particular, we want to make conclusions about the long-run proportion (i.e., probability) that Vicky Nina will choose the correct object in this situation. This unknown long-run proportion is called a ***parameter***.

Definition

For a random process, a ***parameter*** is a long-run numerical property of the process, such as the probability of success

We don't know the value of the parameter, but the two possibilities listed above suggest two different possibilities.

8. What is the value of the parameter if Vicky Nina is picking an object at random? Give a specific value.

9. What is the possible range of values (greater than or less than some value) for the parameter if Vicky Nina is not just guessing and perhaps can learn the object names quickly?

The Chance Model

Statisticians often use *chance models* to generate data from random processes to help them investigate the process and/or make comparisons to other processes. In particular, they can see whether the observed statistic from an unknown process is consistent with the values of the statistic simulated by the chance model. More specifically, we need to develop a chance model that will generate statistics (number of correct picks) that would occur if Vicky Nina was always just picking an object at random. We can then determine whether Vicky Nina's results are consistent with the results from the chance model or if her results are very unlikely to occur in the chance model. In the latter case, we could say her results provide evidence that Vicky Nina's random process is different from the chance model.

How can we develop this chance model? To model randomly (equally) guessing between two objects can easily be done with a toss of a coin. So let's start there.

10. Explain how you could use a coin toss to represent Vicky Nina's choices if she is guessing between the objects each time. How many times do you have to toss the coin to represent Vicky Nina's attempts? What does heads represent?

11. If Vicky Nina was guessing randomly each time how many out of the 20 times would you expect her to choose the correct object?

12. Simulate one repetition of Vicky Nina guessing randomly by tossing a coin 20 times and letting heads represent selecting the correct object ("success") and tails represent selecting the incorrect object ("failure"). Count the number of heads in your 20 tosses. Combine your results with the rest of the class to create a *dotplot* of the distribution for the number of heads out of 20 flips of a coin.

    a. Was there variation in the number of heads in 20 tosses across the students in your class?

    b. Where does 15 heads fall in the distribution? Would you consider it an unusual outcome or a fairly typical outcome for the number of heads in 20 coin tosses?

    c. Based on your answer to the previous question, do you think it is plausible (believable) that Vicky Nina was just guessing which object to choose? Explain your reasoning.

Using an Applet to Simulate Tossing a Coin Many Times

To really visualize the behavior of the number of heads in 20 coin tosses (which we are using to model the number of correct picks by Vicky Nina assuming she is guessing at random), we need to *simulate* many more outcomes of the chance model. Open the **One Proportion** applet to have the computer repeat the coin tossing process many, many times.

Notice that the probability of heads has been set to be 0.50, representing guessing between two objects. Set the number of tosses to 20 and press the **Draw Samples** button.

13. What was the resulting number of heads?

Notice that the number of heads in this set of 20 tosses is then displayed by a dot on the graph. Uncheck the **Show animation** box and press the **Draw Samples** button 9 more times. This will demonstrate how the number of heads varies randomly across each set of 20 tosses. Nine more dots have been added to your dotplot. Now change the **Number of repetitions** from 1 to 90 and press **Draw Samples** so you have 100 dots in your dotplot.

14. Is a pattern starting to emerge in your dotplot?

15. Complete the following sentence to describe what the dots in your dotplot represent.

Each dot represents the number of times Vicky Nina chooses the _______object out of ______ attempts assuming she is __________.

Now change the **Number of repetitions** from 90 to 900 and press **Draw Samples**. The applet will now show the results for the number of heads in 1,000 different sets of 10 coin tosses.

Remember that we conducted this simulation to assess whether Vicky Nina's result (15 correct in 20 attempts) would be unlikely to occur by chance alone if she were just guessing between the pair of objects for each attempt.

16. Locate the result of getting 15 heads in the dotplot created by the applet. Now that we have an even better understanding on the long-run behavior of the distribution of the number of heads in 20 coin tosses, would you consider 15 heads an unlikely result in the tail of the distribution of the number of heads?

17. Let's translate your answer to #16 to Vicky Nina. Would you say there is strong evidence that Vicky Nina would be very unlikely to have picked the correct object 15 times in 20 attempts if she was randomly guessing between the two objects each time?

Definition
A result is ***statistically significant*** if it is unlikely to occur just by random chance. If our observed result appears to be consistent with the chance model, we say that the chance model is ***plausible*** or believable.

18. Do the results of this study appear to be statistically significant?

19. Do the results of this study suggest that Vicky Nina just guessing is a plausible explanation for her picking the correct cup 15 out of 20 times?

Summarizing Your Understanding

20. In #16 you were asked about the results of the simulated coin tosses. Then in #17 you used the coin tossing results to answer a question about Vicky Nina. Let's dig into this transition a little be more to understand the connection between the simulated model (coin tossing) to the real study with Vicky Nina. To do this, answer the following.

    a. What does one coin toss represent in terms of Vicky Nina and the toys?

    b. What does getting a result of a head represent in terms of Vicky Nina and the toys?

c. What does getting a result of a tail represent in terms of Vicky Nina and the toys?

d. The chance of a result of a head in a coin toss is ½. What does this probability mean in terms of Vicky Nina and her toys?

e. One dot in the dotplot made in the applet represented the number of heads out of 20 tosses. What does this dot represent in terms of Vicky Nina and her toys?

The 3S Strategy

We call the process of simulating could-have-been statistics under a specific chance model the ***3S strategy***. After forming our research conjecture and collecting the sample data, we will use the 3S strategy to weigh the evidence against the chance model. This 3S strategy will serve as the foundation for addressing the question of statistical significance in Step 4 of the statistical investigation method.

3S Strategy for Measuring Strength of Evidence

1. Statistic: Compute the statistic from the observed sample data.
2. Simulate: Identify a "by-chance-alone" explanation for the data. Repeatedly simulate values of the statistic that could have happened when the chance model is true.
3. Strength of evidence: Consider whether the value of the observed statistic from the research study is unlikely to occur if the chance model is true. If we decide the observed statistic is unlikely to occur by chance alone, then we can conclude that the observed data provide strong evidence against the plausibility of the chance model. If not, then we consider the chance model to be a plausible (believable) explanation for the observed data; in other words what we observed could plausibly have happened just by random chance.

Let's review how we have already applied the 3S strategy to this study.

21. **Statistic.** What is the statistic in this study?

22. **Simulate.** Fill in the blanks to describe the simulation.

    We tossed a coin ____ times and kept track of how many times it came up heads. We then repeated this process _____ more times, each time keeping track of how many heads were obtained in each of the ______ tosses.

23. **Strength of evidence.** Fill in the blanks to summarize how we are assessing the strength of evidence for this study.

    Because we rarely obtained a value of ________ heads when flipping the coin _______ times, this means that it is ____________ (believable/unlikely) that Vicky Nina is just guessing, because if Vicky Nina was just guessing she ____________ (rarely/often) would get a value like _________ correct out of ______ attempts.

STEP 5: Formulate conclusions.

24. Based on this analysis, are you convinced that Vicky Nina can quickly learn the names of objects? Why or why not?

STEP 6: Look back and ahead.

25. A single study will not provide all of the information needed to fully understand a broad, complex research question. Thinking back to the original research question, what additional studies would you suggest conducting next?

Exploring Further

One important step in a statistical investigation is to consider other models and whether the results can be confirmed in other settings. In this case, the researchers wanted to see whether a different method of teaching the dogs the names of the new objects would have similar results.

The way the Vicky Nina was taught the names of the new objects that was described earlier is called a *social condition*. The researchers also tried to teach Vicky Nina the names of new objects through an *exclusion condition*. They did this by placing a new object on the floor with seven of Vicky Nina's toys in which she had already learned the names. A new object was given to the owner and the owner decided what name (not similar to any names already known to Vicky Nina) would go with the new object. The researchers then asked Vicky Nina to get the new object by saying, "Bring <name of new object>." Because Vicky Nina knew the names of the other objects, it was thought that she could exclude them from what was being asked of her and bring back the correct new object. For each new object, she went through four training sessions using this exclusion condition. The question is, does this training method also work for teaching a dog new words. To answer this, the researchers then tested Vicky Nina in the same manner as previously described.

26. In 20 trials, Vicky Nina chose the correct object 12 times.

    a. Using the dotplot you obtained when you simulated 1,000 sets of 20 coin flips assuming Vicky Nina was just guessing, locate the result of getting 12 heads. Would you consider 12 heads an unlikely result in the tail of the distribution?

    b. Based on the results of 1,000 simulated sets of 20 coin flips each, would you conclude that Vicky Nina would be very unlikely to have picked the correct object 12 times in 20 attempts if she was randomly guessing between the two objects each time? Explain how your answer relates to the applet's dotplot.

    c. Is this study's result statistically significant?

    d. Do the results of this study suggest that Vicky Nina just guessing is a plausible explanation for her picking the correct cup 12 out of 20 times?

    e. Does this study prove that Vicky Nina cannot learn the names of objects using this exclusion condition?

27. Compare the analyses between the two studies. How does the unusualness of the observed statistic compare between the two studies? Does this make sense based on the value of the observed statistic in the two studies? Does this make sense based on the different training methods? Explain. (*Hint*: Why might the results differ for social and exclusion conditions? Why would this matter?)

Reference

Fugazza, C., Andics, A., Magyari, L. *et al.* Rapid learning of object names in dogs. *Sci Rep* **11,** 2222 (2021). https://doi.org/10.1038/s41598-021-81699-2