

## Introduction to Inferential Statistics

### Can Dolphins Communicate? (Source: Tintle et al.; 2012, John Wiley and Sons)

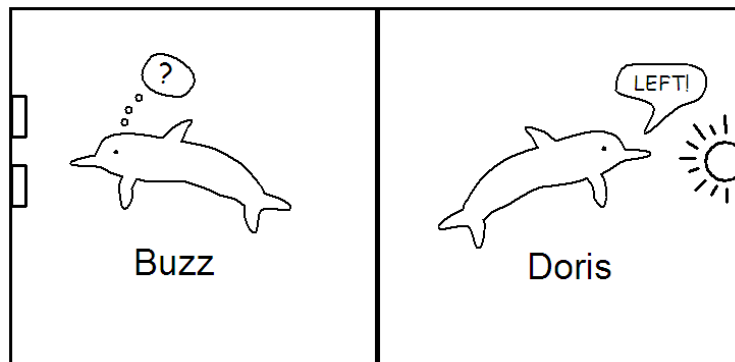
A famous study from the 1960's explored whether two dolphins (Doris and Buzz) could communicate abstract ideas. Researchers believed dolphins could communicate simple feelings like "Watch out!" or "I'm happy," but Dr. Jarvis Bastian wanted to explore whether they could also communicate in a more abstract way, much like humans do. To investigate this, Dr. Bastian spent many years training Doris and Buzz and exploring the limits of their communicative ability.

During a training period lasting many months, Dr. Bastian placed buttons underwater on each end of a large pool—two buttons for Doris and two buttons for Buzz. He then used an old automobile headlight as his signal. When he turned on the headlight and let it shine steadily, he intended for this signal to mean "push the button on the right." When he let the headlight blink on and off, this was meant as a signal to "push the button on the left." Every time the dolphins pushed the correct button, Dr. Bastian gave the dolphins a reward of some fish. Over time Doris and Buzz caught on and could earn their fish reward every time.

Then Dr. Bastian made things a bit harder. Now, Buzz had to push his button before Doris. If they didn't push the buttons in the correct order—no fish. After a bit more training, the dolphins caught on again and could get earn their fish reward every time. The dolphins were now ready to participate in the real study to examine whether they could communicate *with each other*.

Dr. Bastian placed a large canvas curtain in the middle of the pool. (See Figure 1.1.) Doris was on one side of the curtain and could see the headlight, whereas Buzz was on the other side of the curtain and could not see the headlight. Dr. Bastian turned on the headlight and let it shine steadily. He then watched to see what Doris would do. After looking at the light, Doris swam near the curtain and began to whistle loudly. Shortly after that, Buzz whistled back and then pressed the button on the right—he got it correct and so both dolphins got a fish. But this single attempt was not enough to convince Dr. Bastian that Doris had communicated with Buzz through her whistling. Dr. Bastian repeated the process several times, sometimes having the light blink (so Doris needed to let Buzz know to push the left button) and other times having it glow steadily (so Doris needed to let Buzz know to push the right button). He kept track of how often Buzz pushed the correct button.

**Figure 1.1:** Depending whether or not the light was blinking or shown steadily, Doris had to communicate to Buzz as to which button to push.



In one phase of the study, Dr. Bastian had Buzz attempt to push the correct button a total of 16 different times. In this phase of the study, Buzz pushed the correct button 15 out of 16 times.

This means that the **proportion** of the time that Buzz was correct was \_\_\_\_\_

**Think about it:** Based on these data, do you think Buzz somehow knew which button to push? Is 15 out of 16 correct pushes enough to convince you? Or do you think that Buzz could have just been guessing? How might you justify your answer?

What are the two possible explanations for Buzz pushing the correct button most of the time?

(1) \_\_\_\_\_

(2) \_\_\_\_\_

These are the two possible explanations to be evaluated. It's certainly *possible* that Buzz was just guessing and got lucky! But does this seem like a reasonable explanation to you? How would you argue against someone who thought this was the case?

So how are we going to decide between these two possible explanations? One approach is to **model** the random process (repeated attempts to push the correct button) and then see whether the observed data is consistent with guessing. That is, is it the kind of result that we might expect to see just by chance if Buzz was just guessing?

Suppose "Buzz was simply guessing". What proportion of the time out of 16 tries would we expect him to be correct? To investigate, we can model guessing behavior using a coin flip to represent (or **simulate**) Buzz's choice of which button to push *assuming he is just guessing*.

To generate this artificial data, we can let "heads" represent \_\_\_\_\_

and let "tails" represent that \_\_\_\_\_.

This gives Buzz a 50% chance of pushing the correct button. This can be used to represent the "Buzz was just guessing" or the "random chance alone" explanation.

How do we **simulate** coin flipping with 16 flips of a coin?

(1) Make up a sequence of 16 flips of a coin (pretend you're flipping a coin and write down H or T for each flip). Write your made-up sequence here:

How many heads did you get in your made-up, "random" sequence?

Is this result truly random? Explain.

- (2) Use the Random Number Table in the textbook appendix (use Row #21) to get a sequence of 16 random numbers. Write those numbers down below. Then make the even numbers heads and the odd numbers tails and write that sequence underneath the number sequence.

Is this sequence truly random?

How many heads did you get in this sequence?

What is the proportion of heads?

- (3) Now flip a coin 16 times and write down the result.

How many heads did you get in this sequence? Is this result random?

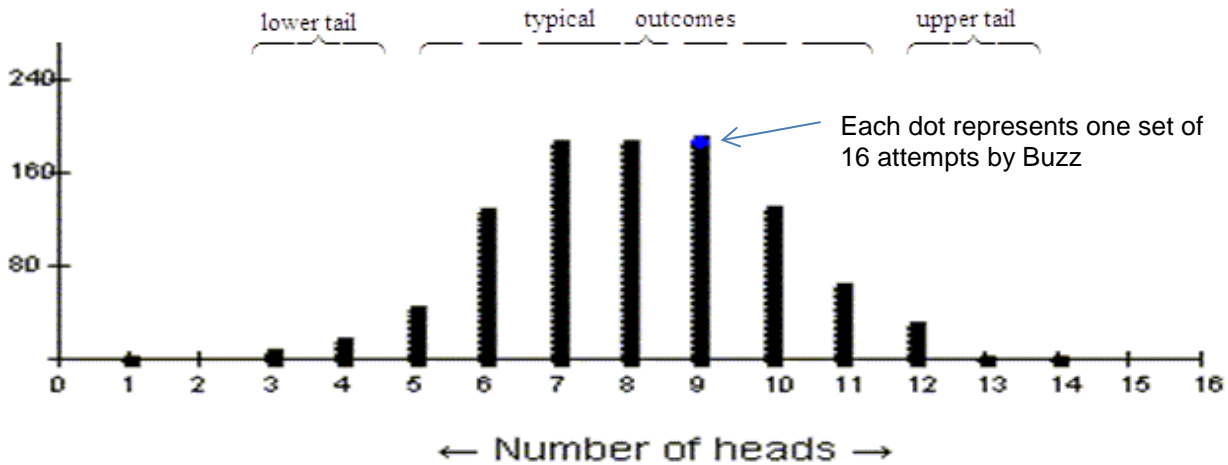
Find the proportion of heads in 16 flips.

- (4) Now simulate the 16 flips using the Rossman/Chance applet (see result below)  
**Using and evaluating the coin flip guessing model**

Because coin flipping is a random process, we know that we won't obtain the same number of heads with every set of 16 flips. But are some numbers of heads more likely than others? Does the distribution of the number of heads that result in 16 flips have a predictable long-run pattern? In particular, how much variability is there in our simulated statistics between repetitions (sets of 16 flips) just by random chance?

In order to investigate these questions, we need to continue to flip our coin to get many, many sets of 16 flips (or many repetitions of the 16 choices where we are modeling Buzz is simply guessing each time). We did this, and Figure 1.4 shows what we found when we graphed the number of heads from each set of 16 coin flips. Here, the appears to be large enough to give us a fairly accurate sense of the long-run behavior for the number of heads in 16 tosses.

**Figure 1.4:** A dotplot showing 1000 repetitions of flipping a coin 16 times and counting the number of heads



Let's think carefully about what the graph in Figure 1.4 shows. For this graph, one dot represents one set of 16 coin tosses and the *variable*, what we measure about each set of 16 coin tosses, is the number of heads.

What outcomes (number of heads in 16 flips) are pretty common? \_\_\_\_\_

What outcomes are more unusual? \_\_\_\_\_

What outcomes are exceedingly rare? \_\_\_\_\_

So what does this have to do with the dolphin communication study? Well, we said that we would flip a coin to simulate what could happen if Buzz was really just guessing each time he pushed the button in 16 attempts. We saw that getting results like 15 heads out of 16 never happened in our 1000 repetitions—showing that 15 is an exceedingly rare outcome, far in the tail of the distribution of the simulated statistics, if Buzz is simply guessing.

In short, even though we expect some variability in the results for different sets of 16 tosses, the pattern shown in this distribution indicates that an outcome of 15 heads is outside the typical chance variability we would expect to see when Buzz is simply guessing.

In the actual study, Buzz really did push the correct button 15 times out of 16, an outcome that would rarely occur if Buzz was just guessing. So, our coin flip guessing model tells us that we have very strong evidence that Buzz was not just guessing to make his choices. Therefore, we don't believe the "by chance alone" explanation is a good one for Buzz. We instead believe the study result provides strong enough evidence to be statistically significant, not a result that happened by chance alone.