Practices of Science: False Positives and False Negatives

NGSS Science and Engineering Practices | Using Mathematics and Computational Thinking

Scientists can sometimes make mistakes or misinterpret data. One mistake that scientists can make is concluding that something is true when it is actually false or concluding that something is false when it is actually true. A false positive is when a scientist determines something is true when it is actually false (also called a type I error). A false positive is a "false alarm." A false negative is saying something is false when it is actually true (also called a type II error). A false negative means something that is there was not detected; something was missed.

SF Fig. 1.4. Jar of candy
Image by Jordan Wang

For example, a teacher puts out a jar full of candy and asks each student to hypothesize how many candy pieces are in the jar. John hypothesizes that there are 42 candies. John counts the number candies in the jar. There are 42 candies—John is correct! However, John did not realize that he accidentally missed a few candy pieces that fell on the floor while he was counting. There are actually 46 pieces of candy. In this example, John has made the mistake of a false positive. He said something was true (that his hypothesis of 42 candies in the jar is correct) when it was actually false (there are really 46 candies in the jar). In other words, he accepted his hypothesis when his hypothesis was actually false.

Sarah also makes a hypothesis about the number of candies in the jar. Sarah hypothesizes that the jar contains 46 candies. Sarah also counts the number of candies in the jar. Like John, Sarah accidentally misses a few candy pieces and counts 42 pieces. Sarah rejects her hypothesis. Sarah has made the mistake of a false negative. She said her hypothesis of 46 was false when it was actually true (there really were 46 candies in the jar). This means that Sarah rejected her hypothesis when it was actually correct.

SF Table 1.3 shows how the decision about accepting or rejecting a hypothesis creates true or false conditions based on the relationship between the hypothesis and reality.

SF Table 1.3. Relationship between reality and hypothesis decisions

Decision	Reality/Nature	
	Hypothesis True	Hypothesis False
Hypothesis Accepted	True Positive (correct outcome)	False Positive
Hypothesis Rejected	False Negative	True Negative (correct outcome)

All tests have a chance of resulting in false positive and false negative errors. They are an unavoidable problem in scientific testing. This creates problems in data analysis in many scientific fields. For example, a blood test can be used to screen for a number of diseases, including diabetes. To test for diabetes, doctors look at the sugar level in blood when a person has not eaten recently. High blood sugar while fasting is an indicator of diabetes. If a patient did not fast before their blood test, the test may show high levels of blood sugar. The patient may be diagnosed with diabetes when they actually do not have the disease. This is a false positive. This can lead to unnecessary medical treatment. On the other hand a false negative is when the test shows that a patient does not have diabetes when they actually do. In this case the patient may not get treatment and get worse because their disease was undetected.

These examples demonstrate that scientists have to be careful when they make decisions. They try to minimize errors and collect additional information or perform a test multiple times. This is difficult because reducing one type of error often increases the other type of error. Based on the consequences of their decision, one type of error may be more preferable than the other.

In criminal courts, it is generally considered preferable to make a false negative, where the criminal is found innocent when they are really guilty than to convict someone who is innocent (a false positive). On the other hand, with security metal detectors, security would prefer the metal detector indicate it found metal even if it is not present (a false positive) than fail to detect metal when it actually is present (false negative). A false negative could potentially be a security risk.

Because scientists know they might have made an error, they are clear about their procedure and how confident they are in their decision when they share their results.