

## 4.1: Finding Probabilities

There are two basic ways to find **simple probabilities**. One way to find a probability is *a priori* or using logic without any real-world evidence or experience. If we know a die is not loaded, we know the probability of rolling a two is 1 out of 6 or .167. Probabilities are easy to find if every possible outcome has the same probability of occurring. If that is the case, the probability is the number of ways your outcome can be achieved over all possible outcomes.

The second method to determine a probability is called *posterior*, which uses the experience and evidence that has accumulated over time to determine the likelihood of an event. If we do not know that the probability of getting ahead is the same as the probability of getting a tail when we flip a coin (and, therefore, we cannot use an *a priori* methodology), we can flip the coin repeatedly. After flipping the coin, say, 6000 times, if we get 3000 heads you can conclude the probability of getting ahead is .5, i.e., 3000 divided by 6000.

Sometimes we want to look at probabilities in a more complex way. Suppose we want to know how Martinez fares against right-handed pitchers. That kind of probability is referred to as a **conditional probability**. The formal way that we might word that interest is: what is Martinez's probability of getting a hit given that the pitcher is right-handed? We are establishing a condition (right-handed pitcher) and are only interested in the cases that satisfy the condition. The calculation is the same as a simple probability, but it eliminates his at-bats against lefties and only considers those at-bats against right-handed pitchers. In this case, he has 23 hits in 56 at-bats (against right-handed pitchers) so his probability of getting a hit against a right-handed pitcher is  $23/56$  or .411. (This example uses the posterior method to find the probability, by the way.) A conditional probability is symbolized as  $P(A|B)$  where A is getting a hit and B is the pitcher is right-handed. It is read as the probability of A given B or the probability that Martinez will get a hit given that the pitcher is right-handed.

Another type of probability that we often want is a joint probability. A **joint probability** tells the likelihood of two (or more) events both occurring. Suppose you want to know the probability that you will like this course and that you will get an A in it, simultaneously – the best of all possible worlds. The formula for finding a joint probability is:

$$P(A \cap B) = P(A) * P(B|A) \text{ or } P(B) * P(A|B) \quad (4.1) \quad P(A \cap B) = P(A) * P(B|A) \text{ or } (B) * P(A|B)$$

The probability of two events occurring at the same time is the probability that the first one will occur times the probability the second one will occur given that the first one has occurred.

If events are independent the calculation is even easier. Events are independent if the occurrence or non-occurrence of one does not affect whether the other occurs. Suppose you want to know the probability of liking this course and not needing to get gas on the way home (your definition of a perfect day). Those events are presumably independent so the  $P(B|A) = P(B)$  and the joint formula for independent events become:

$$P(A \cap B) = P(A) * P(B) \quad (4.2) \quad P(A \cap B) = P(A) * P(B)$$

The final type of probability is the union of two probabilities. The **union of two probabilities** is the probability that either one event will occur or the other will occur – either, or, it does not matter which one. You might go into a statistics class with some dread and you might say a little prayer to yourself: Please let me either like this class or get an A. I do not care which one, but please give me at least one of them." The formula and symbols for that kind of probability are:

$$P(A \cup B) = P(A) + P(B) - P(A \cap B) \quad (4.3) \quad P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

It is easy to understand why we just add the  $P(A)$  and the  $P(B)$  but it may be less clear why we subtract the joint probability. The answer is simple - because we counted where they overlap twice (those instances in both A and in B) so we have to subtract out one instance.

If, though, the events are mutually exclusive, we do not need to subtract the overlap. Mutually exclusive events are events that cannot occur at the same time, so there is no overlap. Suppose you are from Chicago and will be happy if either the Cubs or the White Sox win the World Series. Those events are mutually exclusive since only one team can win the World Series so to find the union of those probabilities we simply have to add the probability of the Cubs winning to the probability of the White Sox winning.

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