Five Minute Science Lesson: Ten Types of Probability Events

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The purpose of science is to understand the universe. A simple way to do this would be to obtain all possible data for all possible questions of inquiry, and then observe the evidence directly – with deterministic perfection, immune to both random variation and human behavior. A practical problem is that the universe is enormous, and it is not likely that we, as humans, will ever be able to observe all evidence from every locale – at least not during our relatively short lifespans. Another problem is that reality can sometimes be complex, and many of our questions involve interactions, including correlation and causality, between various phenomena of interest. And while may aspects of reality may be subject to cause-and-effect laws described by Newtonian physics, some real phenomena appear to conform only to random probability distributions. Indeed, many complex aspects of reality can be more easily characterized by random probability distributions than by deterministic or causal models. Human behavior, at both the individual and group level, is an example of this. Throughout history there has been interesting discussion about the degree to which human behavior is volitional or deterministic. Regardless of the answer to this enduring question, many aspects of human behavior are most effectively described and quantified using statistics and probability models[1].

Because much of our scientific knowledge – about the universe and human be-

1 A probability model is a mathematical and statistical representation of what we expect, such as when observing the physical universe or when observing human behavior at the individual or group level.

havior – is subject to inherent uncertainty, statistics is sometimes referred to as the mathematical language of science. And much of our scientific activities intended to quantify our knowledge about reality are actually developed to quantifying the level of uncertainty associated with our conclusions. The fact that we can characterize many aspects of reality, including human behavior, as conforming to known probability distributions[2] means that we can achieve objective and reproducible scientific conclusions about phenomena for which deterministic conclusions are not possible. Whereas basic science is concerned directly with understanding the universe and reality, applied science is concerned with a more practical question: "what can we do with it?"

Practitioners who wish to develop expertise in any scientific endeavor will be obligated to become familiar with the conceptual language of statistical and probability theory. This applies also to scientific research and also to scientific tests – such as those in medicine, psychology, risk assessment/risk management, and forensics. A scientific test, of any type, can be thought of as a form of scientific experiment with a single subject. Table 1 briefly summarizes ten different types of

Table 1. Different types of probability events

Type of probability event	Description
1. Certainty	Our knowledge or conclusion about reality, some tiny aspect of the universe, is correct without any possibility of error or variation (the information is immune to human behavior or interference). To express certainty about a physical or material object is to assert that it exists in a manner that conforms exactly to our knowledge and description – without any possibility for error or variation. To express certainty about an event is to assert that our our knowledge or conclusion about an event is without any potential for error or variation – that it is impossible that an event has not occurred in the manner which we have concluded.
2. Impossibility	A variant of certainty. Our knowledge about the non-existence of some thing or non-occurrence of some event is without any variation or error. As with certainty, impossibility is immune to influence from human behavior and random variation.
3. Simple probability (frequentist probability)	The number of times in which an event occurs compared to the number or times the event could possibly occur. Simple probability is the proportion of occurrences to possibilities. This definition of frequentist probability is somewhat constrained; it requires observable and repeatable phenomena – it cannot apply to single events, or to unobservable events in the past or future. Other definitions of probability have potentially broader application.
4. Compound probability	The compound (combined) probability for two or more probability events is equal to the probability of the first event multiplied by the probability of the second event, and so on. This applies only to independent probability events.

[2] Probability distributions and probability models can be calculated in a variety of ways. These can include empirical methods in which data is obtained from the real universe and then studied to learn the type of probability distribution that can characterize the data (e.g., the number of deaths by horse kick in the Prussian army was shown to conform to a a Poisson distribution). Theoretical distributions such as the Gaussian, Beta, Binomial/Multinomial, Chi, Hypergeometric, or Poisson distribution can be calculated theoretically, using facts and information subject to mathematical and logical proof. Powerful computers have led to the widespread use of Monte-Carlo methods, simulation techniques, and machine learning (AI) methods that can study problems for which the complexity and scale would render exact calculations prohibitive.

Type of probability event	Description
5. Independent probability events	Independent probability events are those for which each different outcome can have no possible effect on other outcomes. Independence means there is no possibility for any shared source of variation. Coin tosses are an example of independent probability events. Each toss of a coin is independent because there is no possibility that any coin toss could influence the outcomes of subsequent coin tosses.
6. Non-independent (dependent)	Non-independent probability events are those for which there is some possibility that the outcome of one event may be influenced by the outcome of another event. In other words, non-independent probability events may have a common or shared source of variance. The term dependent is sometimes used interchangeably with the term non-independent, though the notion of dependent can also be used to convey an explicit assumption that the outcome of one event is expected to influence other outcomes. The term non-independent does not convey assertions or expectations about the degree to which this actually occurs, but merely acknowledges that a set of probability events cannot satisfy the requirements for independence.
7. Mutually exclusive (disjoint) probability	Mutually exclusive probability events, also referred to as disjoint, cannot occur together in the same universe (at the same time). The occurrence of one event or outcomes precludes the occurrence of the other. In other words, the probability of both events at the same time is 0 (zero). A single coin toss is a classic example of this – the outcome is either heads or tails, but not both. Probability events that are not mutually exclusive are mutually inclusive or non-mutually exclusive (they can occur at the same time).
8. Complimentary probability events	Complimentary probability events are those for which the sum of the set of probabilities is equal to 1 (one), based on the Compliment Rule of mathematics. The Complement Rule states that the sum of the probabilities of an event and its complement must be equal 1 (one). Complementary events are non-independent because the strength of one probability influences the value of the other.
9. Exhaustive probability events	A set of probability events is exhaustive if at least one of the events must occur. A six-sided die is an example exhaustive set of probability events. The probability that none of them occur is equal to 0 (zero).
10. Non-exhaustive	A set or array of events is non-exhaustive if it is possible for none of them to occur.

probability events,Probabilistic information is fundamental to all scientific activities and all scientific knowledge. A Familiarity with and understanding of different types of probability events is a requisite aspect of expertise for all professionals involved in the production or use of scientific information, notwithstanding that powerful microcomputers have relieved most professionals from the burden of doing their own calculations. When thinking of probability as related to events – the number of observed occurrences compared to the number of possible occurrences – it is useful to think of the notion of probability as relating to outcome of an event or trial. For a single event, the term probability can be broadly defined as the *strength of occurence of some possible outcome*, compared to the strength of some other possibility. Applied to events, the notion of time becomes implicit; a probability of occurrence can increase over longer periods of time, but that is a rabbit-hole for a different paper. This project is intended only to provide a brief introduction to the array of different types of probability events.