Topic #6: Hypothesis

A hypothesis is a suggested explanation of a phenomenon or reasoned proposal suggesting a possible correlation between multiple phenomena. The term derives from the ancient Greek, hypotithenai meaning "to put under" or "to suppose". The scientific method requires that one can test a scientific hypothesis. Scientists generally base such hypotheses on previous observations or on extensions of scientific theories.

Usage

In early usage, scholars often referred to a clever idea or to a convenient mathematical approach that simplified cumbersome calculations as a hypothesis; when used this way, the word did not necessarily have any specific meaning. Cardinal Bellarmine gave a famous example of the older sense of the word in the warning issued to Galileo in the early 17th century: that he must not treat the motion of the Earth as a reality, but merely as a hypothesis.

In common usage in the 21st century, a hypothesis refers to a provisional idea whose merit needs evaluation. For proper evaluation, the framer of a hypothesis needs to define specifics in operational terms. A hypothesis requires more work by the researcher in order to either confirm or disprove it. In due course, a confirmed hypothesis may become part of a theory or occasionally may grow to become a theory itself. Normally, scientific hypotheses have the form of a mathematical model. Sometimes, but not always, one can also formulate them as existential statements, stating that some particular instance of the phenomenon being studied has some characteristic and causal explanations, which have the general form of universal statements, stating that every instance of the phenomenon has a particular characteristic.

Any useful hypothesis will enable predictions, by reasoning (including deductive reasoning). It might predict the outcome of an experiment in a laboratory setting or the observation of a phenomenon in nature. The prediction may also invoke statistics and only talk about probabilities. Karl Popper, following others, has argued that a hypothesis must be falsifiable, and that a proposition or theory cannot be called scientific if it does not admit the possibility of being shown false. By this additional criterion, it must at least in principle be possible to make an observation that would disprove the proposition as false, even if one has not actually (yet) made that observation. A falsifiable hypothesis can greatly simplify the process of testing to determine whether the hypothesis has instances in which it is false.

It is essential that the outcome be currently unknown or reasonably under continuing investigation. Only in this case does the experiment, test or study potentially increase the probability of showing the truth of an hypothesis. If the researcher already knows the outcome, it is called a consequence - and the researcher should have already considered this while formulating the hypothesis. If the predictions are not assessable by observation or by experience, the hypothesis is not yet useful, and must wait for others who might come afterward to make possible the needed observations. For example, a new technology or theory might make the necessary experiments feasible.

Types of hypothesis

A proposition may take the form of asserting a causal relationship (such as "A causes B"). An example of a proposition often but not necessarily involves an assertion of causation is: If a particular independent variable is changed there also a change in a certain dependent variable. This is also known as an "If and Then" statement, whether or not it asserts a direct cause-and-effect relationship.

A hypothesis about possible correlation does not stipulate the cause and effect per se, only stating that 'A is related to B'. Causal relationships can be more difficult to verify than correlations, because quite commonly intervening variables are also involved which may give rise to the appearance of a possibly direct cause-and-effect relationship, but which upon further investigation turn out to be more directly caused by some other factor not mentioned in the proposition. Also, a mere observation of a change in one variable, when correlated with a change in another variable, can actually mistake the effect for the cause, and vice-versa (i.e., potentially get the hypothesized cause and effect backwards).Empirical hypotheses that experimenters have repeatedly verified may become sufficiently dependable that, at some point in time, they become considered as "proven".

While some people are tempted to term such hypotheses "laws", this would be a mistake since the nature of a hypothesis is explanatory and the nature of a law is descriptive (e.g. Matter can neither be created or destroyed, only changed in form). A more accurate way to refer to such repeatedly verified hypotheses would to simply refer to them as "adequately verified", or "dependable".

Null hypothesis

In statistics, a null hypothesis is a hypothesis set up to be nullified or refuted in order to support an alternative hypothesis. When used, the null hypothesis is presumed true until statistical evidence in the form of a hypothesis test indicates otherwise. The use of the null hypothesis is controversial.

The null hypothesis is generally that which is presumed to be true initially. Hence, we reject only when we are quite sure that it is false, often 90, 95, or 99% confident that the data do not support it.

For example, if we want to compare the test scores of two random samples of men and women, a null hypothesis would be that the mean score of the male population was the same as the mean score of the female population:

H0 : ?1 = ?2
where:
H0 = the null hypothesis
m1 = the mean of population 1, and
m2 = the mean of population 2.

Alternatively, the null hypothesis can postulate that the two samples are drawn from the same population, so that the variance and shape of the distributions are equal, as well as the means.

Formulation of the null hypothesis is a vital step in testing statistical significance. Having formulated such a hypothesis, one can establish the probability of observing the obtained data or data more different from the prediction of the null hypothesis, if the null hypothesis is true. That probability is what is commonly called the "significance level" of the results.

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Limitations

A null hypothesis is only useful if it is possible to calculate the probability of observing a data set with particular parameters from it. In general it is much harder to be precise about how probable the data would be if the alternative hypothesis is true.If experimental observations contradict the prediction of the null hypothesis, it means that either the null hypothesis is false, or we have observed an event with very low probability. This gives us high confidence in the falsehood of the null hypothesis, which can be improved by increasing the number of trials. However, accepting the alternative hypothesis only commits us to a difference in observed parameters; it does not prove that the theory or principles that predicted such a difference is true, since it is always possible that the difference could be due to additional factors not recognised by the theory.

For example, rejection of a null hypothesis (that, say, rates of symptom relief in a sample of patients who received a placebo and a sample who received a medicinal drug will be equal) allows us to make a non-null statement (that the rates differed); it does not prove that the drug relieved the symptoms, though it gives us more confidence in that hypothesis.

The formulation, testing, and rejection of null hypotheses is methodologically consistent with the falsificationist model of scientific discovery formulated by Karl Popper and widely believed to apply to most kinds of empirical research. However, concerns regarding the high power of statistical tests to detect differences in large samples have led to suggestions for re-defining the null hypothesis, for example as a hypothesis that an effect falls within a range considered negligible. This is an attempt to address the confusion among non-statisticians between significant and substantial, since large enough samples are likely to be able to indicate differences however minor.

The theory underlying the idea of a null hypothesis is closely associated with the frequentist theory of probability, in which probabilistic statements can only be made about the relative frequencies of events in arbitrarily large samples. A failure to reject the null hypothesis is meaningful only in relation to an arbitrarily large population from which the observed sample is supposed to be drawn.