Research Methodology
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Lecture - 41
Issues in Hypothesis Testing Part 01

We have earlier learnt that proposing and testing hypotheses are sometimes called 'the method of science'. The reason is that, whenever we are faced with a question of 'how did it happen?', 'when does it happen?' ─ these kind of questions, we make scientific guesses, which are the hypotheses. In order to qualify as hypothesis, they have to satisfy certain criteria, which I talked about earlier. Once they satisfy these criteria, we say that these are scientifically formulated hypotheses.

Then we go about testing the hypotheses. We have said that the way to approach any problem is to formulate as many hypotheses as possible that are consistent with the clues, the initial clues, and then eliminate the wrong hypotheses. Let us try to understand the reason once again.

How do we test a hypothesis? We can test, because one of the conditions of a guess being a hypothesis was that it has to have experimentally or observationally testable predictions. So, there has to be predictions. So, if the hypothesis is true, then what are the consequences? Then it has to be stated.

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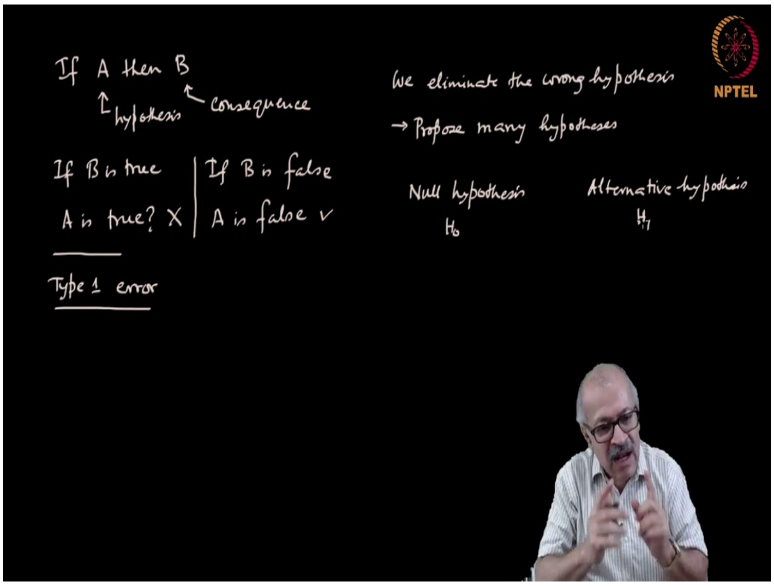

It will be stated in the form: if A then B. A is the hypothesis and B is the consequence. While doing the logic part we have seen that, if B is true, then can we say A is true? No, we cannot say that, because yes, if A happens then B would happen, but that does not mean that there cannot be any other factor that can also cause the event B.

So, if B is true, there is no logical way to conclude that A must be true. We have seen that a hypothesis will lead to a consequence and we actually test the consequence because the hypothesis, by itself, in most cases cannot be tested. We test the consequence. But if the consequence is found to be true, we cannot say that the hypothesis is true. That would be a logical error known as ‘affirming the consequent’.

So, that is definitely not a method of science, which means that proposing and testing hypothesis does not mean that, if the hypothesis is tested and the consequences are tested to be true, we cannot pronounce that the hypothesis is true. This is not the method.

But if B is false, not true, then definitely it is true that A is false. We had learnt that as the modus tollens. So, if the consequence is tested to be false, then the hypothesis is definitely false. So, we can falsify a hypothesis, but we cannot prove a hypothesis to be true, based on the testing of the consequence.

This is a correct logic. So, we always test and negate, falsify, eliminate the wrong hypotheses. Now, in order for this plan to work in science, it is necessary to be able to propose as many hypotheses as possible that are consistent with the initial clues. ‘As many’ means logically we should exhaust all possible mechanisms by which a particular event could have happened.

And then we have to eliminate the wrong ones. Then only you can converge onto the one that is correct. But you can never be sure that you have actually formulated all possible hypotheses. So, whenever a hypothesis is not to proved to be wrong, then it is provisionally accepted as a working hypothesis. We go ahead with that.

So, we have to propose many hypotheses. Now, hypotheses is the plural word. We have to propose as many hypotheses as possible, and then we have to eliminate the wrong ones. Therefore, you would notice that, many of us will spend our lifetime, or a very significant portion of our time, in proposing hypotheses, which will ultimately be proved wrong.

In doing so, are we failure as scientists? No. Being able to propose hypotheses that are scientifically valid hypotheses—I said that there are certain criteria that have to be satisfied in order for a hypothesis to be a scientific hypothesis—if we propose the hypothesis satisfying those criteria, then we are doing good science.

Because, even if the hypothesis is proved to be wrong, that is a progress for science because other scientists would not spend their time trying to propose and test that particular possibility. So, proposing a hypothesis that is ultimately proved to be false is also good science.

It is sometimes taken as a common sense idea that, a successful scientist is one who proposes the right hypothesis, ultimately that comes to be true. No. Good science is done by people who propose some hypothesis which was a possibility. But that possibility turned out to be wrong. It is perfectly valid science: we have to understand that.

Most important is that, we have to propose as many hypotheses as possible. So, a scientist has to think: how many different kinds of sequence of events could lead to the event that we are trying to explore? How many possible events and then we have to test those. Maximizing the number of possible course of events or possible hypotheses is the right way of doing science. That is first point.

Then we have to test the hypothesis. In doing so, many times we find that scientists err, they make errors in testing hypotheses. Why does it happen? It happens due to various reasons: improper application of statistical techniques, improper measurement, improper planning of the experiment, etc. But all that happens, in the main, because of subjective judgement of the scientist.

Many times, scientists have some prior idea which he or she believes to be true without testing, before testing. If somebody has proposed a hypothesis, he or she often develops sort of a kinship with that hypothesis and often unconsciously tries to find that hypothesis to be true.

And these are very dangerous situations, because that is what are the pitfalls in science. That is what sometimes leads a scientist astray. What kind of errors can one commit? There are, in the main, two types of errors that are identified. The first one is called the type 1 error.

I have already said that every hypothesis has the opposite, the null hypothesis. There will always be a null hypothesis and an alternative hypothesis. Null hypothesis is often denoted as H0 and alternative as H1. For example, if you are proposing that particular kind of drug is cure to say COVID-19, then the null hypothesis would say that that particular drug has no effect on COVID-19. So, the opposite of the alternative hypothesis, the hypothesis you are making is the alternative, its opposite is the null.

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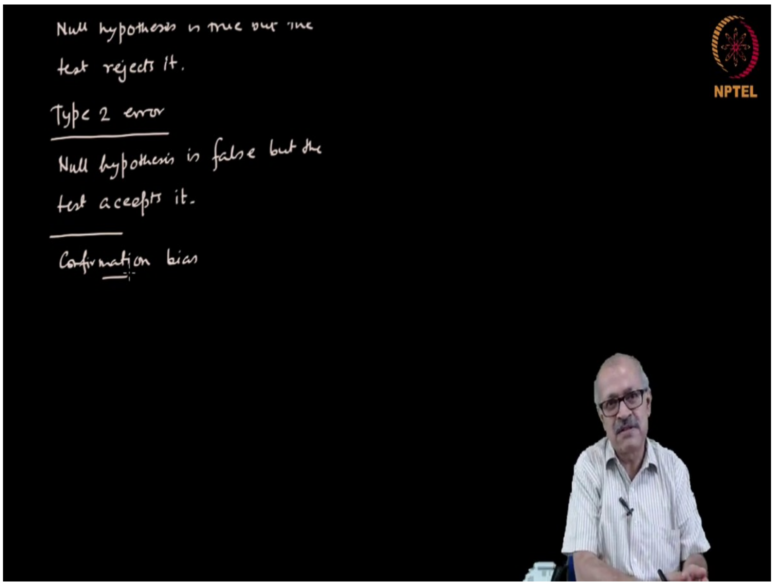

The type 1 error is where the null hypothesis is true, but the test rejects it and accepts the alternative hypothesis. So, this is type 1 error. This is a common form of error because, as I said, often the scientist believes in the hypothesis that he or she has proposed, and tries to obtain evidence in favour of it. Sometimes deliberately, sometimes unknowingly, this happens.

If somebody has a deliberate inclination of trying to prove something right, then the errors are very common. This is a very common error that happens. If somebody believes, for example, that cow urine is a cure to a certain kind of disease, and he or she tries to obtain evidence in favour of that hypothesis, this type 1 error is certain to happen. These are the things that we are seeing these days, and it is a very typical situation.

The type 2 error is where the null hypothesis is actually false, but the test accepts it. When we go into the actual test procedures, we have to be very careful about the possibility of committing these two types of errors; type 1 error and type 2 error. And let me tell you that the occurrence of these errors are very common.

So, type 2 error is where you infer the absence of something which is actually present. Then it you commit a type 2 error. So, these kind of situations are actually very common. The main culprit in most of these cases is what is known as 'confirmation bias'. Confirmation bias is: you have a belief and you are setting up the test in such a way that confirms the belief.

You have a bias towards a belief and you are trying to set up a test by which your objective is to confirm it, rather than test it. Your objective should be an impersonal judgement as to what truth is. But if you already have a pet hypothesis, or if you already have a belief, you will err.

That is why, science always tries to avoid all belief systems. Science says 'do not believe unless you have evidence'. Science actually tries to obtain evidence. That is why I have said at the initial part of the course, that there was the subjective way of thinking and the objective way of thinking, and still the subjective way of thinking is ingrained in our psychology. Because that is there in the society, in the act of becoming a scientist, you have to practice eliminating the subjective ways of thinking, and to practice objective ways. But that does not happen overnight. Often scientists have the subjective beliefs and that is what often leads to confirmation bias.

If you have a confirmation bias, often one performs one sided experiments, one chooses the samples in a wrong way, in a biased way, and sometimes the data collection is also biased because the scientist is trying to prove something. And after the data are collected, often the data that do not satisfy the belief of the scientist are ignored and the scientist sometimes cherry picks the data that satisfy.

All these are kinds of events that happen. These are typical cases of scientific misconduct. I will come to that part later. But let me tell you that, in testing hypothesis, one has to be very very careful about avoiding confirmation bias, because confirmation bias is so very common. If there is any evidence of there being any confirmation bias in the data or in the way you report in a paper, the paper is guaranteed to be rejected.

So, this is one of the major situations where papers are rejected, or maybe after the paper is accepted it has to be retracted. All these things happen because of confirmation bias. Now let us try to understand how one has to plan an experiment to avoid any subjective judgement on part of the experimenter, any possibility of confirmation bias on the part of the experimenter.

I am trying to mean that a scientist has to be aware of the possibility that he or she himself or herself is having a confirmation bias. So, we set up the experiment in such a way so that even my own beliefs cannot interfere with my results. That is necessary.