

Popper's Philosophy of Science

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Anyone who has attended a summer Seminar Laboratory Workshop at the Institute of General Semantics in recent years has heard Stuart Mayper speak of Sir Karl R. Popper's philosophy of science as best illustrating the methodological view espoused by General Semantics as a discipline. Stuart reviews some of the key features of Popper's philosophy and shows how major paradigm shifts in scientific beliefs over the millennia conform to the system described by Popper. For those of you who have never been to an Institute seminar, or are otherwise not familiar with the recent philosophy of science, I will review the salient features of Popper's philosophy of science.

Almost everyone is familiar with the classical method of reasoning known as modus ponens. The well known example goes as follows:

If Socrates is a man then Socrates is mortal.
Socrates is a man.
Therefore, Socrates is mortal.

Few know that the progress of science no longer depends primarily upon this method, but on the less familiar form known as modus tollens, which goes like this:

If Socrates is a god, then Socrates is immortal.
Socrates is not immortal.
Therefore, Socrates is not a god.

Karl Popper's philosophy of science uses modus tollens as the central method of disconfirming, or falsifying, scientific hypotheses. Scientists start with a current scientific theory and use the usual methods of deductive reasoning to derive specific conclusions, of which some are "predictions". Strictly deductive reasoning is "truth preserving", that is, it is such that if one starts out with "true" premises, one can only deduce "true" conclusions. Starting with a "theory" and deducing "predictions" can be stated in the form of a premise:

If the theory is true, then the prediction is true.

Popper shows that we cannot prove that a theory is true, but we can certainly show that a prediction is false. If the scientist tests one of these predictions and finds out that it is not true, he uses good 'ole modus tollens to conclude that the theory cannot be true.

If the theory is true, then the prediction is true.
The prediction is not true.
Therefore, the theory is not true.

Of course, there is more to Popper's philosophy of science than this. We must consider what he means by a "scientific" theory, and by empirical, and how this method can apply to "parts" of theories as well as to "whole" theories, etc.

The key feature of Popper's theory exemplified by the modus tollens argument is "critical testing". In order for critical testing to give valid results, the theory to be tested must be free from any "looseness";

Popper lists four criteria or levels of evaluating, for determining whether a proposed theory is sufficiently "tight" to be admitted as a "scientific" theory.

We may if we like distinguish four different lines along which the testing of a theory could be carried out. First there is the logical comparison of the conclusions among themselves, by which the internal consistency of the system is tested. Secondly, there is the investigation of the logical form of the theory, with the object of determining whether it has the character of an empirical or scientific theory, or whether it is, for example, tautological. Thirdly, there is the comparison with other theories, chiefly with the aim of determining whether the theory would constitute a scientific advance should it survive our various tests. And finally, there is the testing of the theory by way of empirical applications of the conclusions which can be derived from it.⁽¹⁾

Before looking at these four criteria let us see what Popper means, in general, by a theory. For Popper, a *theory* consists of a set of statements. Some of these statements are dependent upon other ones, and some are independent of other ones. The statements can be classified according to "levels"; one statement is at a lower level if it can be derived from statements at a higher level. I will call the lower level statements which depend upon, or can be deduced from, one or more higher level statements dependent statement. Higher level statements have the character of a "hypothesis" in relation to dependent statements at a lower level. Statements which are at the lowest level are called "basic statements", and correspond to specific singular facts (including "initial conditions") or predictions. Statements which are at the highest levels (universal statements), are related to the other statements in much the same manner that axioms are related to theorems in geometry. Statements at higher levels are said to "explain" dependent lower level statements.

We have two different kinds of statements, both of which are necessary ingredients of a complete causal explanation. They are (1) universal statements, i.e. hypotheses of the character of natural laws, and (2) singular statements, which apply to the specific event in question and which I shall call "initial conditions". It is from universal statements in conjunction with initial conditions that we deduce the singular statement, . . . a specific or singular prediction.

The initial conditions describe what is usually called the "cause" of the event in question. . . . And the prediction describes what is usually called "effect". Both these terms I shall avoid. . . .⁽²⁾

To give a causal explanation of an event means to deduce a statement which describes it, using as premises of the deduction one or more universal laws, together with certain singular statements, the initial conditions.⁽³⁾

The first criterion Popper requires for a set of statements to be admitted as a theory is that it must be internally consistent from a formal, logical point of view. In order to meet this criterion the following conditions must be satisfied. The set of "axiom" statements must be independent and not contradict one another. Also, there must be no dependent statements which contradict other dependent statements. Another condition is that none of these axiom statements may have a "built-in" contradiction (self-contradictory). When a theory satisfies these conditions, all of the "basic statements" of the theory can be deduced, in the strictly logical sense, from the axiom statements. This criterion is necessary to permit "falsification" to extend to higher level theories. By insuring that this criterion is met, we guarantee that:

If a higher level statement is true, then an immediately lower level, dependent, statement is true. (Call this "Premise 1")

We can show what this means by two steps of modus tolens. Suppose we have a simple theory with one axiom, one "middle level" statement which, for this example, we will call the "hypothesis", and only one basic statement, the "prediction". Since Premise 1 is true for this theory, we can show the relationships among the statements of the theory:

- P1. If the axiom is true then the hypothesis is true.
- P2. If the hypothesis is true then the prediction is true.

Suppose the prediction turns out false. Then we would say:

- P3. The prediction is not true.

Argument 1

- If the hypothesis is true then the prediction is true. (P2)
- The prediction is not true. (P3)
- Therefore, the hypothesis is not true. (modus tolens)

Argument 2

- If the axiom is true then the hypothesis is true. (P1)
- The hypothesis is not true. (from argument 1)
- Therefore, the axiom is not true. (modus tolens)

Because this first criterion was satisfied in this simple theory, a false prediction "carried through" to prove the axiom of the theory false. If this first criterion had not been satisfied, this technique of using modus tolens could not have been used, and we would not know how a false prediction affected the theory as a whole. In more complex theories, a false prediction might show only that a combination of axioms is inconsistent in regard to their consequences, but not which of the axioms is the one which caused the trouble. Because of this, a false prediction may cause the whole theory to be falsified, or only a part of it.

A theoretical system may be said to be axiomatized if a set of statements, the axioms, has been formulated which satisfies the following four fundamental requirements. (a) the system of axioms must be free from contradiction (whether self-contradiction or mutual contradiction). This is equivalent to the demand that not every arbitrarily chosen statement is deducible from it. (b) The system must be independent, i.e. it must not contain any axiom deducible from the remaining axioms. (In other words, a statement is to be called an axiom only if it is not deducible within the rest of the system.) These two conditions concern the axiom system as such; as regards the relation of the axiom system to the bulk of the theory, the axioms should be (c) sufficient for the deduction of all statements belonging to the theory which is to be axiomatized, and (d) necessary, for the same purpose; which means that they should contain no superfluous assumptions.

In a theory thus axiomatized it is possible to investigate the mutual dependence of various parts of the system. For example, we may investigate whether a certain part of the theory is derivable from some part of the axioms. Investigations of this kind . . . have an

contradicted by experience. Some basic statements must have been tested with successful results many times. Not all basic statements must have been tested; they must simply be capable of being tested. Testability also meant repeatability; Popper says:

Indeed the scientifically significant physical effect may be defined as that which can be regularly reproduced by anyone who carries out the appropriate experiment in the way prescribed.⁽⁷⁾

Additionally, Popper claims we must describe the rules of the method of science. What he means is a description of the context in which "science" occurs. For example:

Methodological rules are here regarded as conventions. . . . They might be described as the rules of the game of empirical science. Two simple examples of methodological rules may be given. . . .

(1) The game of science is, in principle, without end. . . .

(2) Once a hypothesis has been proposed and tested, and has proved its mettle, it may not be allowed to drop out without "good reason". A "good reason" may be, for instance: replacement of the hypothesis by another which is better testable; or the falsification of one of the consequences of the hypothesis.⁽⁸⁾

What happens if this methodology is used in conjunction with Popper's criteria, in particular, to the body of "scientific" knowledge, as a function of time? At any given time, there will be the "current (accepted) theory" for that time. As new hypotheses or "laws of nature" are proposed and tested, some will be, from time to time, refuted or falsified. Along with the current theory, educators teach some of those theories which have been "shown to be false". The common view is that as we eliminate falsity, what we have left is closer to the truth. In other words, along with the current theory, we have a list of theories or hypotheses which have been discarded, never to be entertained again.

It is as much of a mistake to think that these "refuted" hypotheses are "false" as it is to think that the "accepted" theory is "true". Popper himself was aware of this.

but those who uphold it dogmatically [a system] . . . are adopting the very reverse of that critical attitude which in my view is the proper one for the scientist. In point of fact, no conclusive disproof of a theory can ever be produced. [italics mine] . . . If you insist on strict proof (or strict disproof) in the empirical sciences, you will never benefit from experience, and never learn from it how wrong you are.⁽⁹⁾

Wherein lies the flaw in our thinking? Different theories may equally account for the facts. If we were starting out with two theories to compare, our criteria would provide a means to select between them. What about when a sub-theory, or part of a theory has been "refuted", and we are considering among alternative sub-theories? In such a case, the selection is relative to the overarching part of the theory which was not in question. A single hypothesis could be disconfirmed within a sub-theory, when a change to the main part of the theory might prevent the disconfirmation!

For example, a long time ago in a far away land, it was believed that Earth was the center of the universe. That was the accepted theory of the day. With Galileo's theory, the hypothesis that Earth was the center of the universe was falsified; the Sun held that distinction. Newton's theory did not disconfirm this, but made it less tenable. What has happened now that we have relativistic theories? One basic characteristic of general relativity is that the natural laws of the universe look the same to all observers, wherever they may be. There is no way to tell that any place is not the center of the

important bearing on the problem of falsifiability. They make it clear why the falsification of a logically deduced statement may sometimes not affect the whole system but only some part of it, which may then be regarded as falsified.⁽⁴⁾

II A second criterion concerns the logical form of the theory. Popper admits only theories capable of being tested by experience. If the form of a theory is such that its basic statements simply don't correspond to experience, or are otherwise not testable, then that theory does not qualify as empirical scientific. It may be some other kind of theory, but it is definitely not to be considered scientific. For a theory to be *scientific* it **must be testable**.

The task of formulating an acceptable definition of the idea of an "empirical science" is not without its difficulties. Some of these arise from the fact that there must be many theoretical systems with a logical structure very similar to the one which, at any particular time, is the accepted system of empirical science. This situation is sometimes described by saying that there is a great number -- presumably an infinite number -- of "logically possible worlds". Yet the system called "empirical science" is intended to represent only one world: the "real world" or the "world of our experience".

In order to make this idea a little more precise, we may distinguish three requirements which our empirical theoretical system will have to satisfy. First, it must be synthetic, so that it may represent a non-contradictory, a possible world. Secondly, it must satisfy the criterion of demarcation . . . , i.e. it must not be metaphysical, but must represent a world of possible experience. Thirdly, it must be a system distinguished in some way from other such systems as the one which represents our world of experience.⁽⁵⁾

III The third criterion concerns the comparison of one theory with another, and can be considered a decision process in selecting among theories which satisfy the other criteria. This is chiefly appropriate when one considers adding a new "axiom" to a currently accepted theory. Conditions which apply to this criterion include whether the proposed revision has fewer axioms (Stuart refers to this condition, which has been known through the ages as Occam's Razor, as "Popper's Chopper"), whether the proposed revision produces more and different basic statements (predictions), and, which is particularly significant in selecting from among competing theories, whether the new axiom produces basic statements (predictions) which contradict basic statements produced without that new axiom.

IV The fourth criterion again concerns testability but of the empirical applications of the basic statements. If the theory is to be "about reality", its statements must be correlated with the world of our observations. The few "axiom" statements would correspond to "laws of nature", and the "basic statements" would correspond to individual facts or predictions. Acceptance (tentatively) of a theory requires that it be highly "corroborated" by actual experience.

But how is the system that represents our world of experience to be distinguished? The answer is: by the fact that it has been submitted to tests, and has stood up to tests. This means that it is to be distinguished by applying to it that deductive method which it is my aim to analyze, and to describe.

"Experience", on this view, appears as a distinctive method whereby one theoretical system may be distinguished from others; so that empirical science seems to be characterized not only by its logical form but, in addition, by its distinctive method.⁽⁶⁾

Several factors go to make up this criterion. No basic statement (fact or prediction) may be

universe! Naturally, that Earth is the center of the universe is no longer falsified. Of course, neither is it corroborated. So, the hypothesis that Earth is the center of the universe was held to be true in early science, "falsified" in later science, and is now no longer falsified. (Of course, this view is not held by many either.) As a practical matter, Earth is chosen as the center of the spatial coordinate system for many purposes.

In addition to this theoretical consideration, there is the matter of what Popper calls "inter-subjectivity". Inter-subjectivity operates at the level of our holding up some material object and agreeing to call it a "stone". Such inter-subjectivity provides room for tacit and concealed assumptions about what the nature of the world is like. In many cases, the progress of science has required rethinking the most simple and thoroughly accepted so-called "basic facts". *

Any significant revision of the expression of any of these "basic facts" will change the primary facts to be accounted for by a theory. Such a change in basic facts could result in a previously disconfirmed hypothesis becoming, under the revised theory, not disconfirmed. So "falsity" seems to be no more "find-outable" than "truth".

Note

1. Quotation marks were updated to agree with On the Use of Quotation Marks on January 12, 2004.

References

1. Karl R. Popper, *The Logic of Scientific Discovery*, New York: Harper & Row, 1968, pp. 32-33
2. *ibid.*, p. 60
3. *ibid.*, p. 59
4. *ibid.*, pp. 71-72
5. *ibid.*, p. 39
6. *ibid.*, p. 39
7. *ibid.*, p. 45
8. *ibid.*, pp. 53-54
9. *ibid.*, p. 50

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