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The Legitimacy of the Criterion of Confirmability in Scientific Research

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Abstract
Contemporary philosophy has acquired a prominent place in philosophical thought because of the great diversity of philosophical trends. It has addressed major problems for which science has been unable to provide solutions. Philosophy therefore approached the problems of science from an epistemological perspective, a development that became especially evident during the twentieth century. The relative character of scientific knowledge altered the way philosophers of science viewed questions concerning the nature and methods of the sciences. This was particularly apparent in attempts to establish the structure of scientific theory by identifying a fixed rule or criterion that distinguishes scientific from non-scientific knowledge. Among the foremost philosophers in this field was Carl Gustav Hempel, who proposed the principle of confirmation, or the criterion of confirmability.
Keywords: philosophy of science; principle of confirmation; scientific research; scientific theories.

Introduction

After positivism had spread and come to dominate scientific thought, attempts were made to challenge its principles and foundations. Members of the Vienna Circle and other logical positivists sought to defend the principle of verification by formulating an alternative that could preserve its epistemological legitimacy. Carl Hempel was among the foremost philosophers engaged in this effort. He proposed a distinct epistemological alternative, which he called the principle of confirmation. Through this principle, he sought to clarify the interpretation of scientific theories and to identify the laws on which scientific hypotheses are founded.
This article examines Hempel's philosophy and presents the principal foundations of scientific theory from the standpoint of the criterion of confirmability. It therefore addresses the following question: What is the value of the criterion of confirmability in the construction of scientific theories?
First: Characteristics and conditions of confirmability.
Second: Types of confirmation.
Third: The paradox of confirmation.

1. Carl Hempel's Philosophy

Before examining the criterion of confirmability and the foundations on which it rests, it is necessary to consider Carl Hempel's philosophy and the main issues discussed in his philosophy of science. Hempel sought to save logical positivism from collapse after the criticisms directed against it, especially those of Karl Popper, and to restore its standing. In defining the field of scientific research, he began by dividing the sciences into two principal groups: empirical sciences and non-empirical sciences. "The empirical sciences seek to discover, describe, explain, and predict events in the world in which we live. Their statements must therefore be tested by reference to experience that provides empirical evidence in their support. Such evidence may be obtained in different ways, including experimentation and systematic observation" (Yafout, n.d.).

Hempel thus relied on empirical structure and treated it as the boundary between empirical sciences and non-empirical disciplines whose propositions do not require empirical results. Because empirical sciences depend on the hypothesis as a central step in the testing process, Hempel examined how hypotheses are invented and tested. He thereby placed the hypothetical method at the center of scientific research.

In establishing the contours of scientific research, Hempel also divided its branches into empirical and non-empirical sciences. "The former seek to discover, describe, explain, and predict events in the world in which we live. Their propositions must therefore be examined by comparing them with facts of experience, and they are accepted only when evidence properly supports them. Such evidence may be obtained through experiment, systematic observation, psychological surveys, or the careful examination of documents and other sources" (Hempel, Mousa, & Abu Rayan, 1976).[1]

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Empirical sciences are often divided into natural sciences and social sciences. Yet the criterion for this division is much less clear than the criterion that distinguishes empirical from non-empirical inquiry. Natural sciences are usually understood to include physics, chemistry, and the various biological sciences. Social sciences include political science, anthropology, economics, history, and related fields (Abd al-Majid, 2009).

Reliance on empirical evidence therefore distinguishes empirical sciences from non-empirical disciplines such as logic and pure mathematics, whose propositions are demonstrated without primary reference to the results of empirical research.

Hempel explained the purpose of this division by asking whether it has systematic significance. The issue is whether natural sciences differ fundamentally from social sciences in their subject matter, aims, methods, or presuppositions. Such basic differences have often been asserted on diverse grounds (Hempel, 1966).

Hempel consequently called for close attention to the language of the contemporary natural sciences, especially physics, through logical analysis and mathematical language. Ordinary language is often vague and lacks a fixed meaning. Expressing physical science in a logical language can therefore make it easier for scientists to understand and analyze its claims.

First: Characteristics and Conditions of Confirmability

The advocates of logical positivism faced many criticisms, particularly concerning the criterion of verifiability whose foundations they sought to defend and develop. One development that emerged

[1] Scientific research is an organized intellectual process undertaken by a person called the researcher in order to investigate facts concerning a particular issue or problem, called the research topic, by following an organized scientific method, called the research method, with the aim of reaching solutions, called research findings. See Abd al-Fattah Khidr, The Crisis of Scientific Research in the Arab World, Salah al-Hujaylan Office, Riyadh, Saudi Arabia, 3rd ed., 1992, p. 17.

from this effort was Carl Hempel's criterion of confirmability. Under this criterion, the researcher formulates hypotheses and tests them. The test does not provide decisive verification. It provides confirmation based on certain data. Evidence has an important role because it is the basis on which the researcher confirms or rejects hypotheses (Ikhtiyar, 2010).

Confirmability, as this formulation makes clear, gives the scientific system only probabilistic results. A theory may be supported by many bodies of evidence, but that evidence does not make its truth absolute.

Before formulating the foundations and properties of confirmability, Hempel examined and rejected several competing positions. His reading of the history of science showed that neither conclusive verification nor decisive falsification is generally available in scientific inquiry. Because a researcher's observational capacities are limited, no investigation can encompass every component of the complex and interconnected natural world. Hempel therefore stated: "No finite amount of experiential evidence can conclusively verify a hypothesis that expresses a law of nature, such as the law of gravitation. Such a law applies to infinitely many possible cases, many of which belong to an inaccessible future or an irrecoverable past" (Hempel, 1997).

Nevertheless, a finite class of data may be organized in relation to a hypothesis and constitute confirming evidence for it. Similarly, an existential hypothesis that asserts the existence of an as yet unknown chemical element with specified properties cannot be conclusively falsified by any finite number of negative observations. Such observations may weaken the hypothesis or count against it, but they do not eliminate every possible case (Hempel, 1997, p. 280).

Hempel also emphasized the difficulty of beginning with experiential data and facts in order to propose hypotheses. In fact, the hypothesis determines which facts and evidence support or undermine it when it is tested. A researcher conjectures a hypothesis and then tests it against experience. Experience determines the degree to which the proposed hypothesis is supported. "The hypothesis determines the nature of the data or evidence related to it. An empirical discovery is relevant to a hypothesis if and only if it constitutes evidence for or against it, that is, if it confirms or disconfirms it" (Ikhtiyar, 2010, p. 84).

The characteristics and foundations of Hempel's criterion can be inferred from his book Philosophy of Natural Science, in which he analyzes events and experiments from the history of science. One case that illustrates confirmability concerns the Hungarian physician Ignaz Semmelweis, who studied puerperal fever at the Vienna General Hospital. Semmelweis observed that mortality among women giving birth in his division was much higher than in the second division of the same hospital. The deaths were caused by a dangerous disease known as puerperal fever. In 1846, mortality in the first division reached an alarming level, whereas the second division, which was supervised by midwives, maintained a normal death rate (Ikhtiyar, 2010, p. 85).

This situation led Semmelweis to propose several hypotheses in an effort to discover the cause of the disease and the deaths. One hypothesis attributed puerperal fever to fixed and mysterious cosmic, terrestrial, or atmospheric influences. Semmelweis rejected it. Another proposal attributed the deaths to overcrowding in the first division. He also rejected this proposal because the second division was likewise heavily crowded (Ikhtiyar, 2010, p. 86).

A third hypothesis stated that the deaths were caused by rough examinations conducted by medical students. Semmelweis rejected this explanation on the basis of several observations. The injuries caused by childbirth were more serious than those produced by rough examination. Moreover, midwives examined their patients in the same way in the second division without causing the same fatal outcomes (Ikhtiyar, 2010, p. 86).

Semmelweis had therefore proposed several hypotheses to solve the problem of puerperal fever and explain why mortality was higher in the first division. A chance incident involving one of his physician colleagues then provided the key to a more adequate hypothesis. The colleague suffered a deep wound to his finger when a medical student used a surgical scalpel that had been employed only minutes earlier in an autopsy. The physician developed a fatal fever and died. Semmelweis observed that his colleague displayed the same symptoms as the women who had died of puerperal fever (Abd al-Majid, 2009, p. 26).

Semmelweis concluded that the mothers had died from blood poisoning because young physicians used contaminated instruments during autopsies and did not disinfect their hands adequately. He therefore proposed that hands should be washed with a chemical disinfectant before patients were examined. When the resident physicians followed this instruction, mortality began to decline. In this way, the contamination hypothesis received empirical support (Hempel, 1966, pp. 3–5).

Semmelweis proposed several hypotheses in order to solve the problem of puerperal fever. He eventually found evidence supporting the hypothesis that contaminated material from corpses, transferred by instruments and hands, was responsible for the deaths.

Hempel noted that Semmelweis collected different kinds of data during his investigation. It would not be reasonable to collect data merely because they concern the same general problem; their relevance is determined by the empirical answer, or test, that the investigator formulates as a conjecture or hypothesis. Once Semmelweis adopted the final conjecture of contamination, data of the latter kind became clearly relevant, whereas the earlier data were not relevant at all (Hempel, 1966, p. 12).

This historical example, especially from medicine, shows that empirical facts or discoveries can be classified as logically relevant or irrelevant only with reference to a specified hypothesis, not merely with reference to a general problem.

The physician’s purpose in proposing several hypotheses was to reach criteria closely connected with the expected consequences. At the final stage, it became necessary to distinguish women treated by medical personnel with contaminated hands from women in the division in which the rate of death from puerperal fever was lower (Abd al-Majid, 2009, p. 29).

Empirical discoveries that explain phenomena must therefore be related to hypotheses that connect those phenomena. Without such hypotheses, analysis and classification remain blind. The Semmelweis case shows that he formulated several hypotheses to solve a medical problem. The first hypotheses were rejected because no evidence supported them.

When Semmelweis proposed a suitable hypothesis and found supporting evidence, he diversified and developed the facts that supported it. This raises a question: If an observed fact supports a hypothesis, does this mean that the hypothesis is true? Such reasoning may commit the fallacy of affirming the consequent. The truth of a consequence does not require the truth of the premises from which it was derived.

For Hempel, the relevant issue is confirmation rather than verification, and the laws reached by science remain probabilistic. “A favorable outcome in any number of tests, however large, does not provide final proof of a hypothesis. Each test could have had an unfavorable result and might have led to rejection. A favorable result does not establish the hypothesis completely, but it provides at least partial support or confirmation" (Ikhtiyar, 2010, p. 89).

Partial proof and the confirmatory form of hypotheses are consistent with the development of contemporary science, in which absolute proof is difficult to attain. Hempel used the Semmelweis experiment to show how a hypothesis may receive support. Empirical facts or discoveries can be judged logically relevant or irrelevant only in relation to a specific hypothesis, not merely in relation to a problem (Ikhtiyar, 2010, p. 90).

Although Hempel emphasized that inquiry must begin with a hypothesis that organizes test data, the hypothesis itself is connected with appropriate evidence. Scientific research therefore rests on inductive foundations in a broad sense.

Hempel did not reject induction as completely as Karl Popper did in presenting the criterion of falsifiability. To show the impossibility of a decisive test, Hempel discussed auxiliary hypotheses and their importance. Such hypotheses may be derived from, or connected with, the principal hypothesis. The diversification of evidence strengthens confirmation, whereas repeating the same test many times in the same way adds relatively little (Ikhtiyar, 2010, p. 90).

Hempel therefore called on researchers to seek varied evidence that supports the principal hypothesis from different directions. Several auxiliary hypotheses may provide strong support for the main hypothesis and contribute to the structure of science. Hempel's principle of confirmation concerns the rules governing the acceptance or rejection of hypotheses on the basis of empirical discoveries. It identifies the conditions under which evidence is said to confirm, or fail to confirm, an empirical hypothesis (Awad, 2006).

Hempel thus formulated a new mechanism that moved beyond the positivist demand for conclusive verification and complete rejection. Strict verification would almost exclude scientific laws in the same way that it excludes metaphysics. A scientist cannot obtain and verify all the evidence of the natural world. An empirical proposition covers an infinite number of individual cases that cannot be exhaustively enumerated. As Russell observed, a scientific law belongs to the domain of factual generalizations (Madi, n.d.). A law depends on observations and facts located in different times and places, including evidence that cannot be recovered or reproduced in order to verify it.

Hempel's principle of confirmation instead holds that empirical propositions are testable when confronted with the results of observation and experiment (Baroudi, 1997). Difficult logical problems remain, but Hempel found no conclusive evidence that science uses complete verification. Science seeks a degree of confirmation because total verification is impossible. It is also tied to the problems of induction. Attempts to establish induction encounter internal difficulties, and scientific knowledge cannot be reduced to inductive statements such as "all metals expand when heated" (Al-Baghrati, 1999).

Hempel summarized his criticism of the traditional stages of inductive research, which begin with observation and analysis, proceed to inductive generalization, and end with testing. It is impossible to enumerate every observation, collect every fact, and verify them all. The same data can also be classified and analyzed in different ways, most of which do not disclose what is relevant to the purposes of scientific inquiry (Hempel, Mousa, & Abu Rayan, 1976).

Induction is sometimes understood as a method that leads by mechanical procedures from observed facts to corresponding general principles. On this account, inductive reasoning would provide effective rules for scientific discovery and induction would become an automatic procedure. Hempel regarded this conception of induction as unacceptable and unsuitable (Abd al-Majid, 2009, p. 63).

There are therefore no applicable inductive rules by which hypotheses and theories can be derived directly from empirical data. The movement from data to theory requires creative imagination. Scientific hypotheses and theories are not inferred from observational data; hypotheses are invented in order to explain those data.

Imagination and free invention play an important role in scientific inquiry, while results are assessed mainly through deductive reasoning and empirical tests. Hempel also recognized the internal difficulties of induction because it appears to require complete observational evidence and comprehensive knowledge of nature. This demand is impossible, since it would require infinitely many observations. A precise conception or coherent system of exhaustive induction cannot therefore be constructed. Hempel called for abandoning the idea that science builds its laws through induction and can claim absolute validity for them (Hempel, 1966, pp. 78–79).

Hempel was therefore correct, at least with regard to the form of induction treated by empiricists as both method and logic. Induction can no longer be understood merely as generalization from repeated experiments. It has developed into a procedure used in the critical assessment of competing hypotheses and theories (Hempel, 1966, p. 92).

Induction begins with existing hypotheses and searches for evidence that supports them through tests and experience. Because Hempel rejected the criterion of verification and replaced it with confirmation, his account necessarily retains induction in this broader sense.

Hempel thus maintained that tests do not provide decisive proof. A theory cannot count as scientific unless it is testable in principle, possesses empirical content, and receives support from empirical evidence.

Characteristics of Confirmation: Its Strength and Degree of Acceptability

The strength of confirmation for a hypothesis depends on several different properties. Comprehensive and precise tests do not usually provide decisive proof. They provide evidence that confirms a hypothesis to a greater or lesser degree. This degree contributes to what may be called the scientific acceptance of a hypothesis. The important factors are the character of the available evidence and the strength of the confirmation that the evidence gives to the hypothesis.

Confirmation therefore has a force that gives legitimacy to the acceptance of a hypothesis. After Hempel's reading of the history of science and his medical example, the main properties of the criterion of confirmability can be identified.

A. Quantity, Quality, and Precision of Supporting Evidence

In the absence of special considerations, the confirmation of a hypothesis increases as favorable test results increase. For example, each newly observed Cepheid variable whose period and luminosity agree with the Leavitt–Shapley relation counts as additional support for the law. However, the increase in confirmation produced by one positive instance generally becomes smaller as the number of existing supporting instances increases. When thousands of confirming instances are already available, one new positive case raises the degree of confirmation only slightly (Hempel, Mousa, & Abu Rayan, 1976, p. 49).

Confirmation must also increase through diversity. The support given to a hypothesis depends not only on the quantity of favorable evidence but also on its variety. The greater the diversity, the stronger the confirmation. Consider Snell's law, which states that when a ray of light passes from one optical medium to another, the ratio between the sines of the angles of incidence and refraction remains constant for each pair of media. Evidence obtained from varied media and conditions provides stronger confirmation than repeated evidence of only one kind (Hempel, Mousa, & Abu Rayan, 1976, p. 49).

Hempel also linked the confirmation of theories to highly diverse empirical results. Newton's theory of gravitation and motion includes laws governing free fall, pendulum motion, the Moon's motion around the Earth, and the motion of planets around the Sun. Independent experimental and observational results concerning these different laws confirm Newton's theory (Hempel, Mousa, & Abu Rayan, 1976, p. 51).

The diversity of evidence is therefore important. Results that support a hypothesis in substantially different ways can greatly raise its degree of confirmation, as shown by the evidence supporting Newtonian theory.

B. Confirmation by New Test Implications

A hypothesis designed to explain observed phenomena will naturally be constructed so that it includes the occurrence of those phenomena. The phenomena to be explained therefore provide some confirming evidence. Yet scientific hypotheses are much more strongly supported when they receive confirmation from new data that were not known or considered when the hypotheses were formulated. Many hypotheses and theories in the natural sciences have been confirmed by new phenomena, thereby increasing their degree of confirmation. Hempel illustrated this point through the Swiss teacher Johann Balmer, who proposed a formula expressing the regular wavelengths of a series of lines in the emission spectrum of hydrogen. He based the formula on Ångström's measurements of four spectral lines (Hempel, Mousa, & Abu Rayan, 1976, p. 55).

Balmer's work on gaseous spectra provided evidence that correct predictions of new facts greatly increase confidence in a hypothesis. In geometrical terms, when a set of points representing measurements can be connected by a simple curve, confidence in an underlying general law is greater than it would be if the curve were complex and displayed no clear regularity (Hempel, Mousa, & Abu Rayan, 1976, p. 56). Hempel's position therefore relates the force of confirmation to what a hypothesis states and to the character of the data supporting it.

The form in which a hypothesis is stated includes the phenomenon it was designed to explain, and that phenomenon constitutes evidence for it. Yet the phenomenon alone cannot serve as evidence for itself. The hypothesis should also be supported by new data that were not previously known but are covered by the hypothesis. Many hypotheses in the natural sciences have received support from newly discovered phenomena (Maher, n.d., p. 206).

Newton's gravitational hypothesis was initially formulated to explain falling bodies and planetary motion. It later received support from new phenomena such as the tides, although it had not originally been proposed to explain them. Confirmation by new facts therefore increases confidence in a hypothesis.

Conditions of Confirmation

An adequate definition of confirmation in Hempel's account must satisfy several logical conditions. The entailment condition states that any sentence entailed by an observation report is confirmed by that report. The consequence condition states that if an observation report confirms every sentence in a class K, it also confirms every logical consequence of K. The special consequence condition states that confirmation of a hypothesis entails confirmation of its relevant consequence (Awad, 2006, p. 260).

Hempel added two further conditions. The equivalence condition states that if an observation report confirms a hypothesis H, it also confirms every hypothesis logically equivalent to H. The consistency condition requires that a logically consistent observation report be compatible with the class of theories it confirms (Awad, 2006, p. 620). Hempel thus proposed five conditions for confirmability. In simplified form, confirmation depends on observational entailment, logical consistency, and support through equivalent formulations.

Second: Types of Confirmation

After identifying the properties that determine the strength or weakness of evidence supporting a hypothesis, three types or factors that increase confirmation can be distinguished: theoretical confirmation, simplicity, and the probability of hypotheses.

A. Theoretical Confirmation

The support claimed for a hypothesis need not consist entirely of tested inductive evidence. It need not be composed only of data confirming the test implications derived from the hypothesis. Confirmation may come "from above," from broader hypotheses or theories that include the stated hypothesis and are themselves supported by independent evidence. For example, consider a hypothetical law of free fall on the Moon expressed as $s = 2.7t^2$ feet. Even before any direct test is carried out on the lunar surface, the law has theoretical confirmation because it follows deductively from Newton's theories of gravitation and motion (Hempel, Mousa, & Abu Rayan, 1976, p. 67).

Strong confirmation is therefore related to a substantial diversity of evidence. A hypothesis with inductive support may also require auxiliary hypotheses that connect it to the evidence.

Hempel elsewhere clarified that support for a hypothesis need not be entirely inductive. Auxiliary hypotheses may themselves receive support and allow a theory to include additional hypotheses that confirm the principal hypothesis.

Hempel illustrated this point with a report in a New York scientific record. Dr. Caldwell claimed that during the exhumation of a grave he observed that the hair and beard of a man who had been buried clean-shaven had grown through openings in the shroud. Although the claim was presented as eyewitness testimony, it could be rejected without much hesitation because it conflicted with established findings concerning the continuation of human hair growth after death (Hempel, Mousa, & Abu Rayan, 1976, p. 59).

Science aims at a comprehensive body of empirical knowledge formed by a well-supported system of empirical propositions. It must remain prepared to reject or modify hypotheses that were previously accepted. Yet findings used to reject a well-established theory must carry sufficient weight. Hempel maintained that conflicting experimental results must be reproducible. A strong and useful theory may continue to be used in contexts in which it is not expected to create difficulties, even when it conflicts with certain repeated experimental results (Hempel, Mousa, & Abu Rayan, 1976, p. 59).

A wide-ranging theory that has succeeded in many fields is usually abandoned only when a more satisfactory alternative becomes available. Good theories are therefore generally difficult to replace.

B. The Principle of Simplicity

Another factor affecting the acceptance of a hypothesis is its simplicity. The simplicity of a hypothesis matters in comparison with alternative hypotheses that explain the same phenomena. If two hypotheses agree with the same data and do not differ in any respect relevant to their confirmation, the simpler hypothesis is normally preferred.

Hempel linked simplicity with economy. Nature itself is not simple but complex, and it is not necessarily economical in the form in which it appears to us. Scientists simplify nature and economize in applying its laws for reasons connected with their own purposes. Newton's law of gravitation appears very simple in its general statement. Yet if it were applied with complete exactness, it would become extremely complex. To calculate the gravitational force between the Earth and the Sun, for example, one would have to include the effects of the masses and positions of the other planets in Newton's equation (Shams al-Din, 2009). Hempel therefore related simplicity to economy. The laws of nature are not as simple as they appear; researchers deliberately disregard many complex factors and simplify them for practical and explanatory purposes.

Hempel was among the philosophers who established the principle of simplicity as a criterion. He argued that another consideration affecting the acceptance of a hypothesis is its simplicity in comparison with alternative hypotheses that explain the same phenomena (Hempel, Mousa, & Abu Rayan, 1976, p. 59).

Hempel offered the Copernican conception of the solar system as another example. The heliocentric conception was considered simpler than the geocentric view it replaced. The Ptolemaic system was ingenious and precise, but it was also highly complex, consisting of subsidiary circles, different speeds, magnitudes, and directions (Hempel, Mousa, & Abu Rayan, 1976, p. 60).

The Copernican system was simpler and more coherent than the Ptolemaic system. Its guiding idea was that nature should be understood by the simplest means. By placing the Sun at the center, Copernicus laid the foundations of modern astronomy and took a decisive step that changed the course of modern scientific thought, freeing it from anthropomorphic elements that had prevailed in earlier periods (Nafadi, 2009). Hempel also gave a mathematical example involving alternative hypothetical systems. Suppose the observed values of x are 0, 1, 2, and 3, and the corresponding values of y are 2, 3, 4, and 5. Assume that no relevant background knowledge is available concerning the probable form of the functional relation. Three hypotheses may then be proposed on the basis of the same data (Hempel, Mousa, & Abu Rayan, 1976, p. 60).

H_1: $y = x^4 - 6x^3 + 11x^2 - 5x + 2$

H_2: $y = x^5 - 4x^4 - x^3 + 16x^2 - 11x + 2$

H_3: $y = x + 2$

Each of these hypotheses agrees with the data. For each of the four tested values of x, it gives exactly the associated value of y (Hempel, Mousa, & Abu Rayan, 1976, p. 61).

The three hypotheses therefore agree completely for the observed cases. If the values of x and y were plotted for each hypothesis, the tested points would coincide. Hempel's example shows that the data alone do not force one algebraic expression. Such formulas are not easily obtained; in practice, researchers may first obtain a graphical relation between x and y without immediately possessing its algebraic form.

Simplicity cannot therefore be denied in scientific research. It is an essential scientific requirement. Yet it is difficult to formulate clear criteria for simplicity in the strict sense or to justify the priority given to simpler hypotheses and theories. Any acceptable criterion of simplicity must, of course, be objective.

C. The Probability of Hypotheses

The factors determining confidence in scientific hypotheses depend on the total body of accepted scientific knowledge. Confidence in a hypothesis must therefore be discussed relative to a specified amount of knowledge. Rudolf Carnap paid particular attention to this problem. He developed a general method for defining what he called the degree of confirmation of any hypothesis expressed in a language relative to a specified body of information. His epistemic conception satisfies the principles of probability theory (Hempel, Mousa, & Abu Rayan, 1976, p. 70). Carnap thus treated confirmation as the logical or inductive probability of a hypothesis relative to the available information. He developed this approach through highly formalized languages whose logical construction was considered simpler for scientific purposes.

Third: The Paradox of Confirmation (Paradox of Ravens)

Before presenting Hempel's thesis concerning this paradox, commonly known as the ravens paradox and often contrasted with Popper's example of the black swan, the meaning of paradox should be clarified. André Lalande defined a paradox as anything contrary to generally accepted opinion, expectation, or probability. An epistemic paradox is an apparent contradiction generated within knowledge and can be resolved only by examining the pattern that produces it (Lalande & Khalil, 2001). A paradox therefore asks how an apparently reasonable argument can lead to a conclusion that appears unreasonable. Resolving the paradox requires showing why the argument only seems to entail that conclusion.[2]

A paradoxical argument has three features. First, it appears valid, so that a person who accepts the truth of its premises seems compelled to accept its conclusion. Second, its premises appear true, or at least consistent, when they express factual propositions. Third, its conclusion conflicts with a judgment that people take to be true (Al-Hassadi, 1990). There are therefore three principal ways to resolve a paradox: show that its premises do not entail the conclusion, question the truth or consistency of one or more premises, or explain how denying the conclusion commits the thinker to another unacceptable belief.

The paradox of confirmation reveals the complexity of the logic of evidential support. The generalization "All ravens are black" is logically equivalent to "All non-black things are non-ravens." Evidence that supports one statement must also support statements logically equivalent to it. The existence of a white polar bear, which is neither black nor a raven, should therefore appear to support

[2] A paradox (paradoxe) is a statement that provokes thought and appears contrary to reason; it asserts something that seems contradictory in order to establish a particular idea. Examples include the claim that we master nature only by obeying it, or that freedom is the recognition of necessity. Among the best-known ancient philosophical paradoxes are Zeno of Elea's arguments against motion, including Achilles and the tortoise. See Jalal al-Din Sa'id, Dictionary of Philosophical Terms and Textual Evidence, previously cited, p. 439.

the generalization that all ravens are black. A white polar bear cannot falsify that generalization, whereas a white raven would falsify it (Hempel, 1966, p. 107).
Hempel explained this paradox as a psychological illusion arising from mistaken views about conditional inference and from the improper introduction of additional background information.
The formal structure may be represented by the hypothesis H: for every object x, if x is a raven, then x is black. Let B be an observation report concerning a finite set of objects. It may state that a is a raven and black, that c is not a raven and is black, and that d is neither a raven nor black. The report B can confirm H because every raven among the objects specified in B is black. In other words, from the information contained in B, the hypothesis is satisfied with respect to the specified class of objects (Hempel, 1966, p. 107).

Conclusion

The philosophy of science is a major branch of philosophical inquiry. Its problems have become some of the issues that receive the greatest attention from philosophers of science. One of the most important can be summarized as the problem of determining criteria within the structure of scientific theory. The purpose is to clarify the legitimacy of such criteria in interpreting scientific research and defining the structure of scientific theory. Because this subject requires a close connection between philosophical questions and scientific problems, with all their overlap and complexity, it has been widely discussed by philosophers of science through the epistemological treatment of the problem.
Carl Hempel's philosophy criticized the ideas of his colleagues in logical positivism and of other contemporaries concerning the criteria for establishing scientific theory. It reflected a critical sensibility and a scientific and philosophical spirit. Through this work, Hempel attained a place among the major philosophers of science of the twentieth century.

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