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Revisiting Inductive Confirmation in Science: A Puzzle and a Solution

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Abstract: When an empirical prediction E of hypothesis H is observed to be true, such observation is said to *confirm*, i.e., support (although not prove) the truth of the hypothesis. But why? What justifies the claim that such evidence supports the hypothesis? The widely accepted answer is that it is justified by *induction*. More specifically, it is commonly held that the following argument, (1) If H then E; (2) E; (3) Therefore, (probably) H (here referred to as 'hypothetico-deductive confirmation argument'), is inductively strong. Yet this argument looks nothing like an inductive generalization, i.e., it does not seem inductive in the term's traditional, enumerative sense. If anything, it has the form of the fallacy of affirming the consequent. This paper aims to solve this puzzle. True, in recent decades, 'induction' has been sometimes used more broadly to encompass any non-deductive, i.e., *ampliative*, argument. Applying Bayesian confirmation theory has famously demonstrated that hypothetico-deductive confirmation is indeed inductive in this broader, ampliative sense. Nonetheless, it will be argued here that, despite appearance, hypothetico-deductive confirmation can also be recast as *enumerative* induction. Hence, by being enumeratively inductive, the scientific method of hypothetico-deductive confirmation is justified through this traditional, more restrictive type of induction rather than merely by ampliative induction.

Keywords: enumerative induction; ampliative induction; hypothetico-deductive confirmation; scientific method; justification

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1. Introduction: HD Confirmation and Induction

The widely accepted view is that although empirical evidence cannot verify (i.e., prove) general hypotheses, such evidence can still confirm, i.e., lend support to, general hypotheses, and that such confirmation is given by induction (e.g., [1–3]) [1]. In other words, hypotheses are said to be *inductively confirmed* by empirical evidence. More specifically, given hypothesis H and empirical evidence E, 'the conclusion H of an inductively strong argument with premise E is confirmed by E' [2] (§1). Note that the meaning of 'strong' here ought not be that the conclusion H is *highly* supported (i.e., absolute confirmation), but simply that the inductive argument is a good argument and not a flawed one [2].

Now, let us look at the common scientific method of assessing hypothesis H by putting it to an empirical test. First, one needs to derive some empirical predictions E from H. Then, if E turns out false, H (along with background assumptions K) is falsified [7] (p. 38). This is based on a *deductive* inference: (1) If H(&K) then E; (2) Not E; (3) Therefore, not H(&K). If, by contrast, E turns out true, then H(&K) is said to be confirmed, i.e., supported (although not verified) by E [3]. This is based on a *non-deductive* inference: (1) If H(&K) then E; (2) E; (3) Therefore, (probably) H(&K) [9] (p. 110–111) [4]. Thus, this scientific method of confirmation can be summarized as follows: hypotheses are confirmed by their successful empirical predictions [12] (p. 498). This is also known as 'hypothetico-deductive confirmation' or 'HD confirmation' [5]. Accordingly, let us call the last argument here the 'HD confirmation argument'.

Though very central to the practice of science at large, HD confirmation has been famously heavily criticised, as it allegedly allows various absurd consequences, the most notorious of which are known as the 'tacking on paradoxes' [14] (p. 198) [6]. Thus, HD confirmation allows that the observation of the perihelion precession of Mercury HD-confirms the thesis, 'the general theory of relativity is true *and* the earth is flat' ('irrelevant conjunction'). Similarly, HD confirmation allows the general theory of relativity to be HD-confirmed by the observation of the perihelion precession of Mercury *or* the observation that the earth is a spheroid ('irrelevant disjunction'). These profound challenges (and others) to the widely used HD confirmation have preoccupied philosophers for decades, leading to numerous sophisticated solutions (notably, [12,16–18]). However, in this paper, I wish to highlight and propose a solution to another problem with HD confirmation, namely, its supposed justification by induction. It should be noted that this paper is not concerned with the meta-inductive justification of induction itself ('problems of induction') but only with the justification of HD confirmation *by* induction (assuming that induction is a legitimate form of logical inference). The sole objective here is thus to show that HD confirmation is inductive (in the traditional, enumerative sense), and hence HD confirmation is justified by such induction.

2. The Problem

The claim that a scientific hypothesis H is confirmed by its empirical prediction E through the HD confirmation argument, together with the claim that H is confirmed by E when H is the conclusion 'of an inductively strong argument with premise E,' amounts to the claim that HD confirmation is an inductively strong argument. But is it?

'Induction' in its canonical, traditional sense, is an inference from a set of instances to a lawlike generalization, i.e., *enumerative* induction, whose general form is,

(1) all examined Fs are Gs

(2) therefore, all Fs are Gs [7].

However, as we have seen, the general form of HD confirmation is,

(1) If H(&K) then E

(2) E

(3) Therefore, H(&K),

which looks nothing like enumerative induction at all. Indeed, if anything, this HD confirmation argument has the form of the *fallacy of affirming the consequent* [9] (p. 110–111) [8]. Hence, the claim that HD confirmation is inductively strong generates a substantial puzzle. True, since Carnap [21], the term 'induction' has received a new, broader sense that simply means any non-deductive argument (including enumerative induction, abduction, causal inferences, and more), or *ampliative* induction. By utilising Bayesian confirmation theory, it is standardly shown that HD confirmation is indeed inductively strong in this ampliative, broader sense of the term [9]. However, many may feel that traditionally, when scientists and philosophers have been repeatedly claiming over the centuries that hypotheses are inductively confirmed by their empirical predictions, they have been meaning 'induction' in its canonical, enumerative sense, and not merely in the new ampliative broad sense. The following passage from Norton [25] (p. 12) seems to express this basic sentiment about the use of induction in science:

> The actual inductive practice of science has always used enumerative induction, and this is not likely to change. For example, we believe all electrons have a charge of -1.6×10^{-19} Coulombs simply because all electrons measured so far carry this charge.

Whether this intuition is correct or not, this paper aims to show that, even though the HD confirmation argument looks nothing like an enumerative induction, HD confirmation can nevertheless be recast as a form of enumerative induction, i.e., it can be shown that HD confirmation is inductive not only in the broader, ampliative sense but also in the more restrictive, traditional canonical sense of the term. In short, it will be shown here that, despite appearance, the standard scientific method of confirmation is indeed enumeratively, and not merely ampliatively, inductive.

3. Solution—The Case of Simple Generalizations

Consider the following case. Let H and E be,

H—All Fs are Gs

E—All observed Fs are Gs

Now, let us plug those into the HD confirmation argument. What we obtain is,

1. If all Fs are Gs, then all observed Fs are Gs (Tautology)
2. All observed Fs are Gs (Observation)
3. Therefore, (probably) all Fs are Gs (2, enumerative induction)

Looking at this argument, the following features emerge. Premise (1) is a tautology (for if all Fs are Gs, then clearly a subgroup of Fs must also be Gs). Premises (2) + (3), taken together, are just a standard enumerative induction. Hence, the whole argument is a strong enumerative induction. In other words, although the form of the HD confirmation argument is not that of enumerative induction, in the special case where H ('All Fs are Gs') is a simple generalization of observation E ('All *observed* Fs are Gs'), the HD confirmation argument does become a strong enumerative inductive argument.

4. Solution—The General Case

But what about scientific confirmations in which hypothesis H is not a simple generalization of observations E? For example, what about a case like the following [10]?

H—General Theory of Relativity (GTR) [11]

E—Perihelion precession of Mercury

Surely, the overwhelming majority of confirmations in our scientific practice are of that latter type. Yet if we plug *such* E and H into the HD confirmation argument, we obtain,

1. If GTR(&K), then perihelion precession of Mercury
2. Perihelion precession of Mercury
3. Therefore, (probably) GTR(&K) [12].

In this case, since H is not a simple generalization of E, the two statements are articulated in different terms (unlike in the case discussed in the previous section), and so (2) + (3) do *not* appear to form a case of enumerative induction. Can our above device somehow be made to work in such a general case as well and reveal that, despite appearance, this argument, too, is enumeratively inductive? The following steps aim to illustrate that, ultimately, it can.

4.1. Meta-Statements

Let *Meta H* be a meta-hypothesis *about* the hypothesis H(&K):

Meta H—All empirical predictions of H(&K) are true.

In addition, let *Meta E* be the meta-observation *about* the already examined empirical predictions of H:

Meta E—All *examined* empirical predictions of H(&K) are true.

Now, if we plug *those* two *meta*-statements into the HD confirmation argument, we get,

1. If all empirical predictions of H(&K) are true, then all *examined* empirical predictions of (H&K) are true
2. All *examined* empirical predictions of H(&K) are true
3. Therefore, (probably) all empirical predictions of H(&K) are true

Applying this to, for example, the case of GTR and its empirical predictions (including the perihelion of Mercury), we obtain,

1. If all empirical predictions of GTR(&K) are true, then all *examined* empirical predictions of GTR(&K), are true
2. All *examined* empirical predictions of GTR(&K) are true
3. Therefore, (probably) all empirical predictions of GTR(&K) are true

And in this case, our device does work: Indeed, (1) is a tautology, and (2) + (3), taken together, form an inductive generalization. Hence, again, the whole argument *is* a strong enumerative induction. Does this solve our problem? Unfortunately, not yet, because this argument is an HD confirmation of *meta*-H by *meta*-E, not of H (e.g., GTR&K) by E (e.g., the perihelion precession of Mercury), which is what we are really looking for. Therefore, we need to work a little harder to reach our desired goal. The following steps achieve this.

4.2. HD Confirmation as Enumerative Induction

Meta H, in fact, states that all claims that H(&K) makes about empirical phenomena are correct. Now, within the framework of modern empirical science, such empirical accuracy provides at least a massively strong support for H(&K). Hence, *within such a framework*, the next move is warranted:

1. All empirical predictions of H(&K) are true
2. Therefore, (probably) H(&K)

Next, when we put a hypothesis to an empirical test, we inevitably must assume that no *hitherto examined* empirical observations are inconsistent with H, viz., that 'the hypothesis under test must not contradict what we already know' [12] (p. 499). (Surely, if we observed some white ravens in the past, the hypothesis that 'all ravens are black' is no longer a candidate for confirmation) [13]. So, in the context of scientific confirmation, the following presupposition is also warranted:

All *examined* empirical predictions of H are true.

Combining the above insights concerning Meta H and Meta E, we can construct the following argument.

1. If H(&K) then E (Tautology)
2. E (Observation)
3. All *examined* empirical predictions of H(&K) are true (Consistency)
4. Therefore, all empirical predictions of H(&K) are true (3, enumerative induction)
5. Therefore, (probably) H(&K) (4, empiricism)

Let us go through each step in this argument. First, by assumption, E is an empirical prediction entailed by H(&K), and hence premise (1) is a tautology. Premise (2) is the observation that E indeed obtains. Premise (3) (i.e., Meta E) is presupposed by the framework of empirical confirmation, for the reasons given in the previous sub-section. Premise (4) (i.e., Meta H) is an enumerative inductive generalization from (3). And (5) follows from (4) due to the relation between empirical accuracy and the likelihood of truth within modern empirical science (as described in the previous sub-section). Thus (5) follows from (1)–(4).

Now statements (1), (2), and (5) are just the HD confirmation argument, and (3) and (4) are intermediate steps that warrant the move from (1) and (2) to (5). And thanks to the enumerative inductive move from (3) to (4), the whole argument (1)–(5) turns out to be enumeratively inductive [14]. It thus follows that, by utilising the intermediate meta-statements (3) and (4), the conclusion H indeed inductively follows from the premises 'if H then E' and 'E', viz., the HD confirmation argument is revealed to be *enumeratively* inductive.

If all this is sound, we may conclude that, despite appearance, hypotheses are indeed *enumeratively*, and not merely ampliatively, inductively confirmed by their empirical predictions. The textbook view is correct, and now we have managed to show why.

5. Summary

According to the common practice of scientific confirmation, known as 'hypothetico-deductive confirmation', hypothesis H is said to be inductively confirmed by its empirical predictions E. More specifically, the following argument, (1) If H(&K) then E; (2) E; (3) Therefore, (probably) H(&K), is said to be inductively strong. Yet, this HD confirmation argument does not resemble a typical inductive generalization, thus an apparent puzzle emerges. The term 'induction' has been used in different ways. Traditionally, it has designated enumerative induction, which involves generalizing from specific instances. However, more recently, 'induction' has also been used to merely mean ampliative argument, i.e., any non-deductive argument (which may, but need not be, enumerative). By using Bayesian confirmation theory, hypothetico-deductive confirmation has been shown to be inductive in this broader, ampliative sense. And yet, there is a common intuition that, in the context of scientific confirmation, 'induction' refers specifically to the canonical, enumerative induction and not just to ampliative reasoning generally. Regardless of whether this intuition is correct, it has been argued here that HD confirmation can indeed be recast as a strong enumerative induction, contrary to its initial appearance. This has been achieved by introducing two meta-statements into the HD confirmation argument as intermediate steps. In other words, it has been established that the common scientific method of HD confirmation is enumeratively inductive and hence can be justified by the latter and not merely by ampliative induction [15].

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Notes

1. This: of course, goes against Popper [4], who rejected the use of induction in science and consequently of confirmation as well (but cf. Popper [5], where he accounts for the degree of confirmation as the extent to which the hypothesis successfully survived empirical tests). However, as opposed to his falsification principle, the rejection of induction remains largely unaccepted by the scientific and philosophical communities. We shall follow suit here.
2. Notably, HD confirmation entails that a single evidence E (e.g., an observation of a black raven) is enough to confirm H ('all ravens are black'), and hence, although E *increases* the evidential support of H, E need not necessarily make H *highly* supported. To use a common terminology, HD confirmation is *incremental* and not *absolute* (e.g., [6] p. 146).
3. Descriptions of this method go back to at least Whewell [8] (pp. 62–63).
4. Deductive and non-deductive arguments are standardly distinguished by the fact that the former is monotonic, i.e., the conclusion of a valid deductive argument can still be derived if more premises are added. The same does not apply to non-deductive arguments, viz., they are not monotonic [10] (Section 1.5); [11] (Section 2.1).
5. Additional conditions are that, a. (H&K) is consistent and, b. E is not entailed by K alone, i.e., the evidence is not already contained in the background knowledge. Accordingly, a more complete definition of HD confirmation is 'E confirms H relative to background evidence K if (H&K) is consistent, (H&K) $\vdash$ e, and ~(K $\vdash$ e)' [13] (p. 323).
6. Mostly popularized by Glymour [15] (p. 31).
7. Indeed, some use 'enumerative induction' to refer to inference from a set of instances to *the next instance*. However, the present discussion will follow the common practice (e.g., [19,20]) in using the term to refer to an inference from a set of instances to *a lawlike generalization*.
8. Yet this last fact need not worry us, since any non-deductive argument is invalid when evaluated as deductive.
9. The following proof is an adaptation from Earman [22] (p. 64). Cf. [23] (p. 51). First, we adopt the Bayesian confirmation principle whereby,

1. If $P(H|E)/P(H) > 1$, then E confirms H—(positive relevance)
   We then combine this principle with Bayes theorem—$P(H|E)/P(H) = P(E|H)/P(E)$—and get,
2. If $P(E|H)/P(E) > 1$, then E confirms H—(1 + Bayes theorem)
   Now, when hypothesis H *entails* an empirical observation E (as in the case of HD confirmation), then $P(E|H) = 1$. And since $1 > P(E) > 0$, it follows that the quotient $P(E|H)/P(E)$, must be greater than 1. Formally,
3. If H entails E then $P(E|H)/P(E) > 1$—(Tautology)
   From (3) and (2)—by transitivity—we get:
4. If H entails E, then E confirms H—(3, 2 HS)
   Since (4) is just another way of expressing HD confirmation, it turns out that HD confirmation is *entailed by* Bayesian confirmation theory. Now, the whole Bayesian argument above is ampliatively inductive due to its first premise, namely the positive relevance principle. To see this, we can transform this principle into the following argument:

1. P(H | E)/P(H) > 1
2. E
3. Therefore, (probably) H—(positive relevance)
   In this last argument, the premises raise the probability of the conclusion and hence support it, which makes the argument ampliatively inductive by definition (in the incremental sense. See note 2). It thus follows that the whole Bayesian argument above is ampliatively inductive, and hence, that HD confirmation (which is the conclusion (4) of that argument) is indeed justified by ampliative induction. (But see [24] for some important reservations.)

10 This standard example is due to Earman [22] (p. 114-115).

11 Famously, Mercury's Perihelion precession was one of the three empirical outcomes of general relativity that Einstein proposed as the theory's empirical tests ("The Classical Tests"), and the only outcome already known at the time of the final publication of his theory. The other two are the bending of light and the gravitational redshift [26].

12 Some are careful to distinguish between auxiliaries, which refer to mathematical and conceptual tools, "these include, e.g., that the spacetime metric is of Lorentz signature, that material particles follow geodesics of the metric, that light follows null geodesics of the metric, that the field of the Sun is to good approximation spherically symmetric" [27] (p. 205), and between background assumptions, which refer to physical reality, e.g., that "(i) the mass of the Earth is small in comparison with that of the Sun, so that the Earth can be treated as a test body in the Sun's gravitational field, and (ii) the effects of the other planets on the Earth's orbit are negligible." [28] (p. 138). However, since the present discussion does not hinge on such a nuanced distinction, I shall ignore it for the present argument. (I thank an anonymous referee for drawing my attention to this distinction.)

13 Interestingly, although Einstein himself declared that "if a single one of the conclusions drawn from [GTR] proves wrong, it must be given up; to modify it without destroying the whole structure seems to be impossible" [29], early observations did not support Einstein's redshift formula, which seemed a potential disconfirmation of Einstein's theory [27] (p. 175). However, since then, many subsequent empirical measurements of various redshifts matched the theory's prediction to a very high degree. (I thank an anonymous referee for highlighting this historical fact.)

14 It should be noted, though, that the complete HD confirmation argument (1)–(5) includes two non-deductive steps, namely, the step from (3) to (4), which is the enumerative induction, as well as the step from (4) to (5). Each non-deductive step in an argument weakens its conclusion (while still providing some support to it). Hence, since the entire argument includes two non-deductive steps, of which enumerative induction is but one, it follows that, strictly speaking, HD confirmation is somewhat weaker than enumerative induction.

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