Induction, confirmation, and underdetermination

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The Mother of All Problems...

- logical empiricism: confirmation as abstract relation between sentences
- important role: 'inductive' inference
- justification impossible due to Hume's problem of induction
- confirmation not just relevant in cases of traditional induction (inferences from observed whiteness of swans to hypothesis that all swans are white), but also in cases such as how observational data supports Copernicus' heliocentric theory, how fossil records confirm Darwin's theory of evolution etc

Types of non-deductive inferences

1. induction narrowly construed or enumerative induction: Swan 1 observed at time t_1 was white, swan 2 observed at time t_2 was white... $\Rightarrow$ All swans are white
2. projection: Swan 1 observed at time t_1 was white,... swan $n-1$ observed at time t_{n-1} was white $\Rightarrow$ Swan n (the next one to be observed) will be white
3. abduction, inference to the best explanation, or explanatory inference: data $\Rightarrow$ hypothesis about a structure or process that would 'explain' the data

debate about which non-deductive inference is most basic: Reichenbach (induction) vs. Harman (abduction)

Nota bene: I will use the term 'induction' to refer to the first two types of inference above.

David Hume's problem of induction

Hume, *Enquiry*, Section V

- relations of ideas vs. matters of fact
- relations of ideas: can be known independently of observation, abstract realm of logic and mathematics, all analytic *a priori* beliefs
- matters of fact: everything that is not a relation of ideas, concerns material existence, synthetic knowledge
- matters of fact can be observed (e.g. 'there is a desk here'), or unobserved (e.g. 'the sun will rise tomorrow')
- In order to know any matter of fact beyond what is directly given by our sensory experience, inductive reasoning must be employed.

- Inductive inferences depend on a 'principle of the uniformity of nature': past acts as reliable guide to the future.
- Hume argues that such a principle cannot be justified; rational justification, were we to have it, could come in two different forms:
  1. demonstrative, *a priori* reasoning; but future does not depend logically on past because it is conceivable that future does not resemble past; we cannot ground induction in *a priori* reasoning
  2. inductive reasoning: our past success in using inductive inference warrants inductive inferences into the future; circular!
- Conclusion: inductive practices have no rational foundation.

A brief introduction to confirmation theory

- general goal of confirmation theory: to solve the problem of induction
- more precisely: we have seen that predictions about the future, as well as unrestricted universal generalizations are not logically implied by observational evidence, because the latter is always only about particular facts in the present and the past
- nevertheless, there is a sense in which observing white swans confirms the hypothesis that the next observed swan is white, and that all swans are white

Characterization (Confirmation theory)

Confirmation theory is the, sometimes formal, attempt to make sense of such confirmation in the wake of the problem of induction.

Models of confirmation of scientific hypotheses

Model (Instantial model of inductive confirmation)

A hypothesis of the form 'All F's are G' is supported *by its positive instances, i.e. by observed F's that are also G.*

(This is sometimes called Nicod confirmation)

Problems:

- observed instances not necessary for inductive support: inference to unobserved entities
- Hempel's paradox of the ravens (to be explained shortly)
- Goodman's 'new riddle of induction' (to be explained shortly)

Model (Hypothetico-deductive model of confirmation (Hempel))

A hypothesis or theory is confirmed if it, together with auxiliary statements, deductively entails a datum.

Question: does this sound familiar?

Attractive features:

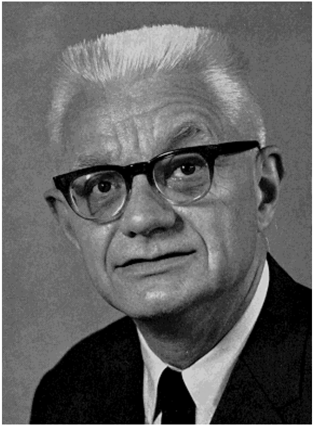
- allows for confirmation of hypotheses that appeal to unobservable entities and processes, as long as it has observable consequences
- 'reduces' inductive inferences to much better understood deductive principles
- seems to genuinely reflect scientific practice, it's "the scientists' philosophy of science" (Lipton, p. 422)

Problems of the hypothetico-deductive model

1. Glymour 1980:
   (A) Glymour's first problem:
   - any theory T deductively implies $T \vee S$ where S is any statement
   - $T \vee S$ can be conclusively established by observing the truth of S
   - if S is observational, then we can establish $T \vee S$ by observation, which confirms T

   (B) Glymour's second problem:
   - if theory T implies observation E, then theory $T\&S$ implies E as well
   - so $T\&S$ is confirmed by E
   - but S was entirely arbitrary
2. Hempel's paradox of the ravens
3. Goodman's 'new riddle of induction'

Carl Gustav Hempel (1905-1997): logical empiricism



- one of the main representatives of logical empiricism
- studied at Göttingen, Heidelberg, Berlin (PhD 1934)
- 1937 emigration to USA
- taught at Chicago, City College of New York, Yale, Princeton, Pittsburgh
- deductive-nomological model of explanation, hypothetico-deductive model of confirmation

Hempel's raven paradox

Two important principles of confirmation:

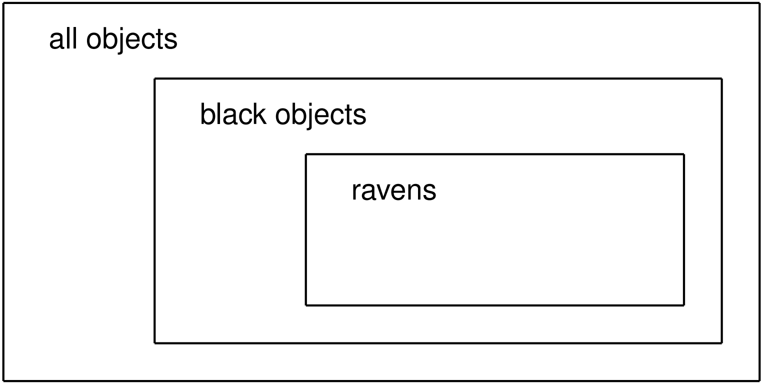
1. Equivalence condition: if evidence E confirms hypothesis H_1, and hypothesis H_2 is logically equivalent to H_1, then E also confirms H_2
2. Instance condition: universal generalizations are confirmed by their positive instances

To illustrate the instance condition, consider the universal generalization

H_1: 'All ravens are black.'

Pedantically, H_1 asserts that: For any x, if x is a raven, then x is black.

Diagrammatically:



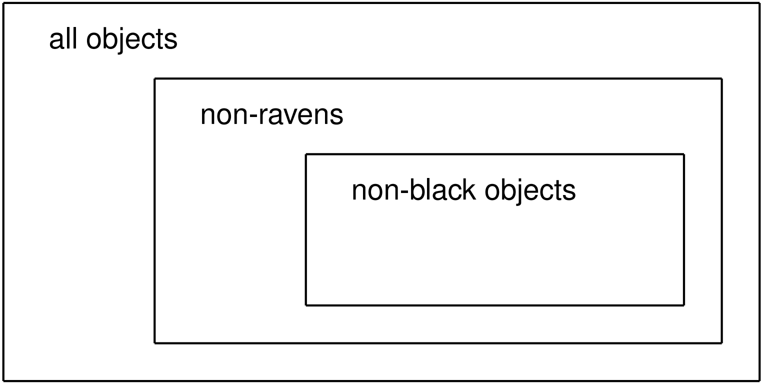
- Let E_1 be the evidence that object *a* is a raven and that *a* is black.
- Since the object *a* satisfies both the antecedent and the consequent of the ravens hypothesis H_1, we have a positive instance of H_1.
- By the instance condition then, E_1 confirms H_1.

Now consider the generalization

H_2: 'All non-black things are non-ravens.'

Pedantically, H_2 asserts that: For any x, if x is not black, then x is not a raven.

Diagrammatically:



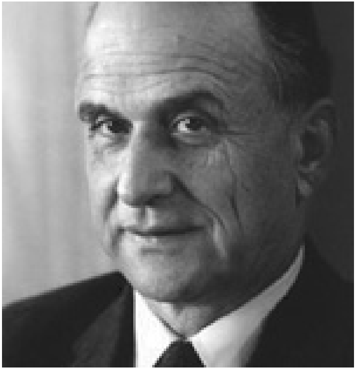
- Let evidence E_2 be the evidence that *b* is white and that *b* is a shoe.
- Since *b* satisfies both the antecedent and the consequent of H_2 we have a positive instance.
- So by the instance condition E_2 confirms H_2.
- But note that H_2 is logically equivalent to H_1.
- So by the equivalence condition, E_2 confirms H_1, i.e. a white shoe confirms 'All ravens are black'!
- Does this mean that indoor ornithology is possible?

Resolutions

1. reject equivalence condition not very attractive
2. reject instance condition not very attractive, but we might modify it...
3. H_1 about *ravens*, so E_2 does not really confirm it $\Rightarrow$ test or relevance requirement: objects must be potential falsifiers; ravens are potential falsifiers, but shoes are not (but universal quantifier; order is important! cf. Godfrey-Smith p. 49f)
4. swallow consequence:
   - a consider H_3: 'All sodium salt burns yellow', but chemical at issue does not burn yellow, and subsequent analysis shows that it's not sodium salt $\Rightarrow$ may count as weak confirmation, although analogous to raven example
   - b in our world, set of non-black things $\gg$ set of ravens; E_2 exhausts a little bit of instances and thereby confirms H_1 a little bit; possible world with ravens $\gg$ non-black objects $\Rightarrow$ more confirmation (Hempel's reply)

But next paradox suggests rejection of instance condition...

Nelson Goodman (1906-1998)



- studied at Harvard (PhD 1941)
- taught at Tufts, U of Pennsylvania, Brandeis, Harvard (his students include Noam Chomsky and Hilary Putnam)
- contributions in aesthetics, epistemology, philosophy of science, and philosophy of language
- was "at odds with rationalism and empiricism alike, with materialism and idealism and dualism, with essentialism and existentialism, with mechanism and vitalism, with mysticism and scientism, and with most other ardent doctrines."

  (Goodman, *Ways of Worldmaking* (1978): x)

Goodman's 'new riddle of induction'

Consider the following argument:

(E_1) raven a_1 & black a_1
(E_2) raven a_2 & black a_2
...
($E_{10,000}$) raven $a_{10,000}$ & black $a_{10,000}$

(H_1) All ravens are black.

Now consider the alternative argument:

(E_1) raven a_1 & blite a_1
(E_2) raven a_2 & blite a_2
...
($E_{10,000}$) raven $a_{10,000}$ & blite $a_{10,000}$

(H_4) All ravens are blite.

Gruesome predicates

The second argument used a new predicate:

Definition (Blite)

An object is blite *iff it was first observed before 2020CE and is black,* or *if it was not first observed before 2020CE and is white.*

⚠ Objects do *not* have to change colour in order to be blite!

If all evidence E_1 through $E_{10,000}$ is based on observation made before 2020CE, then the second argument should be considered as good as the first...

Resolutions

1. reject instance condition
2. only allow 'projectable' predicates, i.e. ones not needing a reference to a particular time, or ones that are parasitic on other predicates (black and white in this case)
3. base predicates in language on 'natural kinds'

Problem with second resolution:

Definition (Whack)

An object is whack iff it was first observed before 2020CE and is white, or if it was not first observed before 2020CE and is black.

Now consider blite and whack as basic and black and white as parasitic...

Definition (Black)

An object is black iff it was first observed before 2020CE and is blite, or if it was not first observed before 2020CE and is whack.

An unsettling conclusion...

Goodman's new riddle of induction shows that it's actually much worse than Hume thought:

- Hume's solution to his problem of induction doesn't explain why some forms of constant conjunction ('white', 'black') give rise to habits of expectation, whereas others don't ('blite', 'whack')...

Application: curve-fitting problem
The problem of alternative hypotheses: Boyle's Law

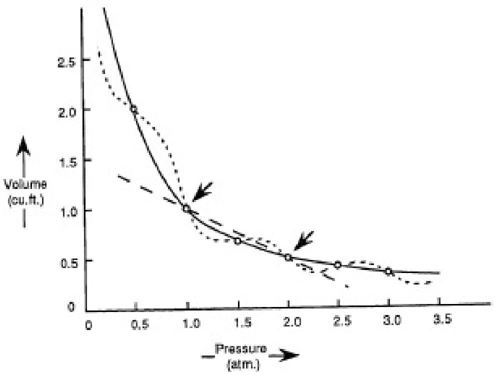


Figure: Boyle's Law (solid line) and alternative laws (from Earman and Salmon, p. 48)

⇒ There's always an infinity of mutually contradictory hypotheses that fit the data, but which is best confirmed?

Other approaches to confirmation

- Carnap's application of the mathematical theory of probability and its present-day successor theory of Bayesianism
- models of causal inference (from effects to their probable causes), such as Mill's 'methods of experimental enquiry' [cf. history of philosophy of science]
- learning theory
- ...

Newtonian method: inductivism

Newtonian method: direct demonstration of every proposition of a theory by drawing from phenomena and generalizing by induction

Example: according to Newton, his law of universal gravitation

$$F_{12} = G\frac{m_1 m_2}{r^2}$$

is directly inductively inferred from Kepler's laws; but...

"The principle of universal gravity, very far from being derivable by generalization and induction from the observational laws of Kepler, formally contradicts these laws. If Newton's theory is correct, Kepler's laws are necessarily false." (Duhem, p. 268)

[Kepler's laws assume e.g. that Earth is attracted to the sun, but not vice versa]

"[I]f the certainty of Newton's theory does not emanate from Kepler's laws, how will this theory prove its validity? It will calculate, with all the high degree of approximation that the constantly perfected methods of algebra involve, the perturbations which at each instant remove every heavenly body from the orbit assigned to it by Kepler's laws; then it will compare the calculated perturbations with the perturbations observed by means of the most precise instruments and the most scrupulous methods.

"Such a comparison will not only bear on this or that part of the Newtonian principle, but will involve all its parts at the same time; with those it will also involve all the principles of dynamics; besides, it will call in the aid of all propositions of optics, the statics of gases, and the theory of heat, which are necessary to justify the properties of telescopes in their construction, regulation, and correction, and in the elimination of the errors caused by diurnal or annual aberration and by atmospheric refraction. It is no longer a matter of taking, one by one, laws justified by observation, and raising each of them by induction and generalization to the rank of principle; it is a matter of comparing the corollaries of a whole group of hypotheses to a whole group of facts." (Duhem, p. 269)

"[In an applied science such as physiology,] so long as the experiment lasts, the theory should remain waiting, under strict orders to stay outside the doors of the laboratory; it should keep silent and leave the scientist without disturbing him while he faces the facts directly; the facts must be observed without a preconceived idea and gathered with the same scrupulous impartiality, whether they confirm or contradict the predictions of the theory..." (p. 258)

"[But in a fundamental science such as physics,] it is impossible to leave outside the laboratory door the theory that we wish to test, for without theory it is impossible to regulate a single instrument or to interpret a single reading." (p. 259)

$$\Downarrow$$

Thesis (Holism)

When a physical theory is put to test, it is an entire collection of theories and auxiliary hypotheses, rather than that single theory alone, which are tested.

Duhem's theses of holism

T:	theory to be tested
$A_1, ..., A_n$:	auxiliary hypotheses and assumptions
O_1:	testable prediction, observational statement

Thesis (D1)

It is not the case that T alone implies O_1.

Thesis (D2)

The conjunction of T with A_1 and... and A_n implies O_1.

Ambiguity of falsification

It follows quite directly from (D1) and (D2) that falsification is ambiguous:

Thesis (D3)

It is not the case that if O_1 is false, then T is false.

Thesis (D4)

If O_1 is false, then the conjunction of T with A_1 and... and A_n is false.

Remarks on the ambiguity of falsification

- example: Newton's law of universal gravitation as discussed above
- nothing is implied about which conjunct should be given up
- (D3) and (D4) do not imply that it is always possible to modify the auxiliaries such as to retain belief in a theory no matter what the evidence
- 'good sense' and mature scientific judgment demand that ailing theory should not be maintained obstinately at any cost (example of Biot who finally gave up his emission theory of light in the light of Foucault's experiment showing that light travelled more slowly in water than in air)
- needed: general argument for holism; Duhem: theory-ladenness of observation

Theory-ladenness of observation

“An experiment in physics is not simply the observation of a phenomenon; it is, besides, the theoretical interpretation of this phenomenon... An experiment in physics is the precise observation of the phenomena accompanied by an *interpretation* of these phenomena; this interpretation substitutes for the concrete data really gathered by observation abstract and symbolic representations which correspond to them by virtue of the theories admitted by the observer.” (p. 358)

- physical theories use theoretical terms such as voltage, force, pressure, entropy, current, temperature etc in order to formulate their laws
- in order to connect theoretical predictions with direct observation, physicist must translate from everyday language of untrained observer to theoretical language of physicist
- theory thus plays an indispensable role in experiment
- this theory-ladenness of observation offers a general argument for holism

Crucial experiments in physics

Definition (Crucial experiment)

A crucial experiment is an experiment that conclusively falsifies one of two competing hypotheses (or theories), thereby establishing its rival as confirmed.

- candidates: Wiener's experiment on the direction of oscillation of polarized light; Foucault's measurement of the velocity of light in air and water
- Duhem: none of these are crucial experiment as defined above
- his holism implies (by (D3) and (D4)) that no experiment or observation can conclusively falsify a physical theory, and that therefore there cannot be crucial experiments in physics

- not possible to perform a variant of Mill's method of difference because the alternative to a theory T is not its logical contrary not-T, but a rival, call it T^*
- truth of T^* does not follow from the falsity of T:

Thesis (D5)

It is not the case that if T is false, then T^* is true.

- example: wave theory and particle theory of light do not exhaust range of possibilities
- there are no crucial experiment in physics because
  1. ambiguity of falsification (D3) and (D4)
  2. rival theories not logically exhaustive (D5)

Against conventionalism

Thesis (conventionalism)

Many fundamental postulates of physics (e.g. Newton's laws of motion, conservation principles, law of multiple proportions in chemistry, law of rational indices in crystallography) are not empirical hypotheses but conventional definitions, unrefutable by experiment.

Duhem maintained that no hypothesis or postulate was completely immune from refutation:

"[H]ypotheses which by themselves have no physical meaning undergo experimental testing in exactly the same manner as other hypotheses. Whatever the nature of the hypothesis is, ... it is never in isolation contradicted by experiment..." (p. 277)