Induction and confirmation

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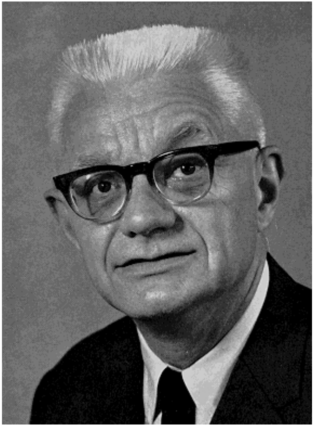
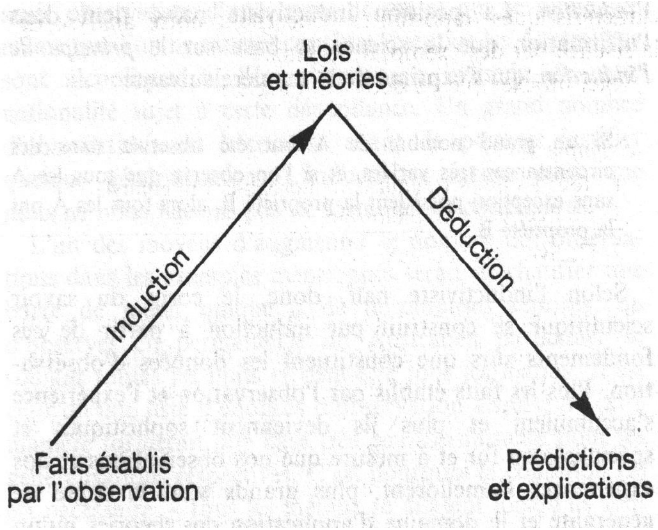
Carl Gustav Hempel (1905-1997)



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

Discovery and justification: ‘naive inductivism’



Discovery and justification: critique of naive inductivism

Carl G Hempel (1966). *Philosophy of Natural Science*, Prentice Hall.

- According to Hempel, 'naive inductivism' asserts that scientific research follows the following stages:
  1. observation and recording, without theoretical preconceptions or hypotheses, of all facts
  2. analysis and classification of these facts
  3. derivation of general statements by induction from these facts
  4. (additional checks of these statements)

Naive inductivism

- According to naive inductivism, inductive inference is a mechanical procedure (perhaps algorithmic) used to generate general statements that were not previously known.

⇒ Problem of this conception of research: It is not possible to collect 'all the facts', because their number and diversity are infinite.

Naive inductivism

- Is it enough to collect only significant facts?
- But significant in relation to what?
- 'Significant in relation to a phenomenon'; but how can we know whether a fact is really significant in relation to a phenomenon whose causes and nature we do not yet understand?

Example: Francis Bacon's tables

- Bacon gives lists of cases of the presence or absence of heat (which he takes as a starting point for inductive generalisations).
- Sunlight is on the positive list, while light from the moon, stars and comets is on the negative list.
- But is sunlight really an example of the presence/absence of heat?

- 'Significant in relation to a problem': no less obscure

⇒ It is hard to make sense of the starting points that we should just collect all facts.

The role of hypotheses

- Hempel: Facts or empirical data can only be described as significant if they are in relation to a given hypothesis.
- Without a guiding hypothesis, there is no point in collecting data: "tentative hypotheses are needed to give direction to a scientific investigation". (Hempel 1966, 13)

⇒ So Bacon's naive idea of starting a research project by collecting and classifying, without any theoretical preconception, all the significant facts is not tenable.

Significant data or observations

Hempel: an outcome is significant with respect to a hypothesis h if the fact that it does or does not occur can be inferred from h:

$$h \rightarrow e$$

"e is evidence for h"

- There are no other criteria for qualifying statements as significant or insignificant.

Example: Pascal and atmospheric pressure

- Blaise Pascal (1623-1662)
- Pascal devised an experiment to confirm his ideas on atmospheric pressure. The basic phenomenon was the behaviour of a column of quicksilver (mercury) in a Torricelli barometer.

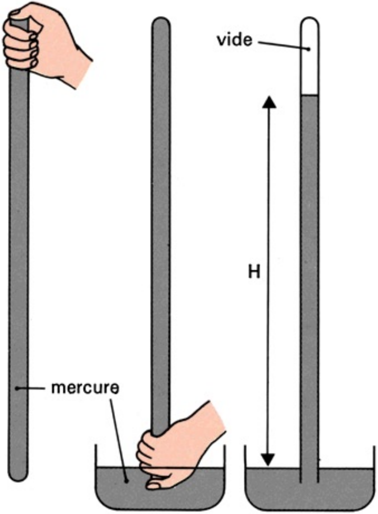
Example: Pascal and atmospheric pressure

- The preferred explanation in the 17th century for the elementary phenomenon (the fact that mercury does not leak from the barometer cylinder) was horror vacui (the idea that nature abhors a vacuum).
- Pascal rejected this idea. He devised an alternative explanation, according to which atmospheric pressure was responsible for the stability of the mercury column.

How the barometer works

https://www.youtube.com/watch?v=EkDhlzA-lwI

Example: Pascal and atmospheric pressure



The Puy de Dôme experiment

- Pascal asked his brother-in-law Florin Périer to carry out the following experiment:
- Climb the Puy de Dôme (Massif Central, 1465m) and observe the height of the column of mercury in a Torricelli barometer. If the theory of atmospheric pressure were correct, the height should decrease.

Deduction of the prediction

Reconstruction by Hempel (1966, 50):

(a) At any location, the pressure that the mercury column in the closed branch of the Torricelli apparatus exerts upon the mercury below equals the pressure exerted on the surface of the mercury in the open vessel by the column of air above it.

(b) The pressures exerted by the columns of mercury and of air are proportional to their weights; and the shorter the columns, the smaller the weights.

(c) As Périer carried the apparatus to the top of the mountain, the column of air above the open vessel became steadily shorter.

(d) (Therefore), the mercury column in the closed vessel grew steadily shorter during the ascent.

Hypothetico-deductive reasoning

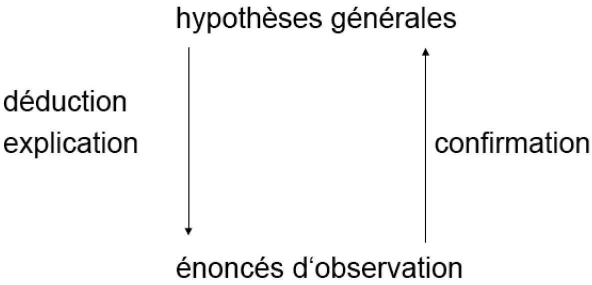
Hempel (1966, 50):

> *Thus formulated, the explanation is an argument to the effect that the phenomenon to be explained, as described by the sentence (d), is just what is to be expected in view of the explanatory facts cited in (a), (b), and (c); and that, indeed, (d) follows deductively from the explanatory statements. The latter are of two kinds; (a) and (b) have the character of general laws expressing uniform empirical connections; whereas (c) describes certain particular facts. Thus, the shortening of the mercury column is here explained by showing that it occurred in accordance with certain laws of nature, as a result of certain particular circumstances. The explanation fits the phenomenon to be explained into a pattern of uniformities and shows that its occurrence was to be expected, given the specified laws and the pertinent particular circumstances.*

Hypothetico-deductive reasoning

- The laws of nature in conjunction with particular facts (specific circumstances, initial conditions) allow the deduction of observable facts (general or particular) where this deduction serves two epistemic goals:
  - explanation of the deduced facts
  - confirmation of the statements which describe the general laws
- So the proper procedure in research is to devise hypotheses that describe general laws and to deduce, from these hypotheses, facts that can be observed. If these facts occur, the hypotheses are *ipso facto* confirmed.

Hypothetico-deductive reasoning



Where do the hypotheses come from?

- According to Hempel (and Popper), there is no mechanical procedure for generating hypotheses or theories.
- Theories in physics (and also in biology, psychology, sociology, etc.) are inventions; they are not inferred from empirical data.
- In order to generate new hypotheses, we need creative work of the imagination, not rules of induction.

What is the role of induction?

- Induction is not used to generate new hypotheses or new theories, but to test or justify them (nota bene: 'confirmation' means 'inductive proof').
- Recall Hans Reichenbach's distinction between the context of discovery and the context of justification in the module 'Logical Empiricism' (slides 14f).

Reconsideration of the role of induction

Question

Do Mill's methods of causal inference (for example) belong to the context of discovery or the context of justification?

- The methods can be used to justify statements such as 'smoking causes lung cancer' $\Rightarrow$ sign of the context of justification
- But it also seems that it is possible to generate hypotheses using these methods $\Rightarrow$ sign of the context of discovery
- It even seems that the methods have an mechanical or algorithmic character (computer programs can be designed to implement these methods under certain circumstances).

Reconsideration of the role of induction

- Perhaps the distinction between context of discovery and justification is not as strict as Reichenbach thought, but the following caveat should be noted:
- Hempel admits that "mechanical procedures for inductively 'inferring' a hypothesis on the basis of given data may be specifiable for situations of special, and relatively simple, kinds" (1966, 14).

Example: extrapolation, or curve fitting)

A fitted curve represents a new hypothesis, but contains no new terms.

Question

Do Mill's methods introduce new terms?

A brief introduction to confirmation theory

- general goal of confirmation theory: to solve the problem of induction
- More specifically, we have seen that predictions about the future, as well as unrestricted universal generalisations, are not logically implied by observational data, since the latter always relate to particular facts in the present or the past.
- Nevertheless, there is a sense in which the observation of white swans confirms the hypothesis that the next swan observed will be white and that all swans are white.

Characterisation (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.

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

Clark Glymour (1980). *Theory and Evidence*. Princeton University Press.

1. Clark Glymour (1980):
    - If theory t implies observation e, then theory $t\&s$ also implies e, where s is any statement.
    - So $t\&s$ is confirmed by e.
    - But s was completely arbitrary.
2. in general: any statement confirms any statement
3. Hempel's paradox of the ravens
4. Goodman's 'new riddle of induction'

Preparation: Wason selection task

Wason, P. C. (1966). Reasoning. In Foss, B. M. (ed.). *New Horizons in Psychology*. Harmondsworth: Penguin.

Source: Wikipedia

Each card has a number on one side and color on the other. Which card or cards must be turned over to test the idea that if a card shows an even number on one face, then its opposite face is blue?

Hempel's raven paradox

Carl G Hempel. Studies in the logic of confirmation I. *Mind* 54 (1945): 1-26.

Carl G Hempel. Studies in the logic of confirmation II. *Mind* 54 (1945): 97-121.

Two important principles of confirmation:

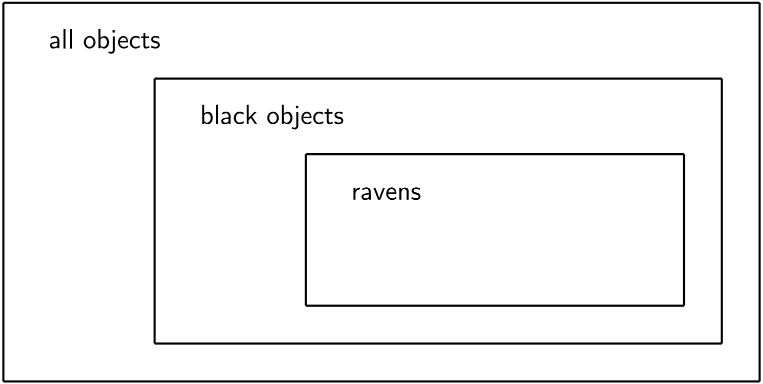
1. Equivalence condition: if evidence e confirms hypothesis h_1, and hypothesis h_2 is logically equivalent to h_1, then e also confirms h_2.
2. Instance condition: universal generalizations are confirmed by their positive instances.

To illustrate the instance condition, consider the universal generalization

$$h_1\text{: 'All ravens are black.'}$$

Pedantically, h_1 asserts that: For any x, if x is a raven, then x is black.

Diagrammatically:



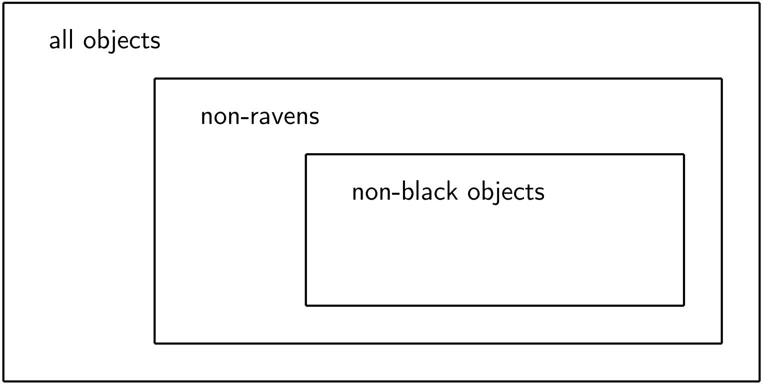
- Let e_1 be the evidence that object a is a raven and that a is black.
- Since the object a satisfies both the antecedent and the consequent of the ravens hypothesis h_1, we have a positive instance of h_1.
- By the instance condition then, e_1 confirms h_1.

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

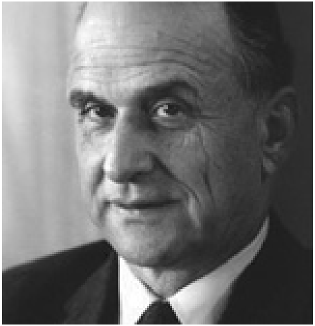
1. reject equivalence condition not very attractive
2. reject instance condition not very attractive, but we might modify it...
3. h_1 about *ravens*, so e_2 does not really confirm it $\Rightarrow$ test or relevance requirement: objects must be potential falsifiers; ravens are potential falsifiers, but shoes are not

Resolutions

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 (cf. again with the Wason selection task)
   - 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
- nominalist: properties do not exist

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

> *According to himself, Goodman 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's 'new riddle of induction'

Nelson Goodman (1955). *Fact, Fiction, and Forecast*. Harvard University Press.

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 2037 and is black,* or *if it was not first observed before 2037 and is white.*

Attention:

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

Conclusion

If all evidence e_1 through $e_{10,000}$ is based on observation made before 2037, then the second argument should be considered as good as the first...

Resolutions

1. reject instance condition
2. base predicates in language on 'natural kinds'
3. 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)

Problem with third resolution:

Definition (Whack)

An object is whack iff it was first observed before 2037 and is white, or if it was not first observed before 2037 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 2037 and is blite, or if it was not first observed before 2037 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

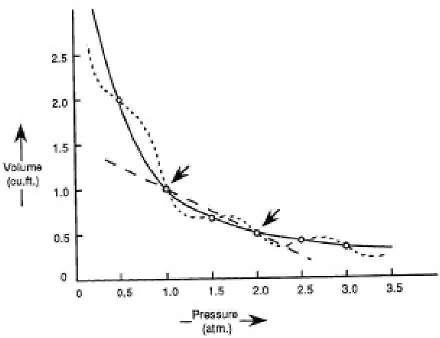


Figure: Boyle's Law (solid line) and alternative laws (from Earman and Salmon, p. 48)

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

Lessons:

- It is not possible to give a purely logical definition of the concept of confirmation; the relationship '*e* confirms *h*' is a very subtle and complex relationship.
- The conditions under which statements containing specific predicates confirm a hypothesis must be hidden in the meaning (content) of the statements.
- Deductive relationships between hypotheses and empirical facts are not enough to confirm a scientific theory.

⇒ Thus, hypothetico-deductivism is an inadequate theory of confirmation.