Error, Falsification, Underdetermination

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Argue in groups: is astrology science?

Defend one position
Astrology

• In Europe (2001)
  – Is astrology rather scientific or not scientific.
  – 53% thought astrology was rather scientific
     • (European Commission, 2001).

• Mirriam Webster: “divination of the supposed influences of the stars and planets on human affairs and terrestrial events by their positions and aspects.”

• “diagram of the relative positions of planets and signs of the zodiac at a specific time (as at one’s birth) for use by astrologers in inferring individual character and personality traits and in foretelling events of a person’s life.”
What are the policies of science?
Knowledge in science

• Knowledge: justified true belief
  – Belief: mental state, propositional attitude
    • Propositional attitude:
      – Propositional: statement of a fact
      – Subject + predicate
        » E. g. this table is brown
        • Subject: table
        • Predicate: brown
  – True belief: a belief with a special epistemic status
    • Believing that P = believing that P is the case
  – Justified belief: belief with good reason
    • Mathematical propositions are supported by proofs
    • Observational propositions are supported by experience/testimony of experience
    • Theoretical propositions are supported by arguments, inferences, theories and hypothesis
If empiricism is the winning view

• Empiricist: Accept that we can acquire knowledge about the future and about laws by experience.

• Empiricism is a thesis about justification.
  – Experience justifies beliefs and scientific statements.

• Empiricism: experience causes and justifies our beliefs of knowledge.
Hypothesis and Scientific laws

• A scientific law is a universal claim:
  – Goes beyond the data available, because it makes a claim which, if true, is true everywhere and always, not just in the experience of the scientist who formulates the scientific law

• This of course makes science fallible: the scientific law, our current best estimate–hypothesis, may turn out to be wrong.
  – We discover this by experiment,
  – We improve it by experiment presumably getting closer to the natural law we seek to discover.
Propositions, predicates and relations

• Propositional logic
  – Is concerned with propositions connected by logical connectives
  – „Socrates is a man” = P

• First order (predicate) logic
  – Uses quantified variables over non-logical objects
  – „Socrates is a man” = X is a man = ∀x Px
    • All Socrates are men = ∀x Px
    • There is one Socrates that is a man = ∃x Px (but my dog is also called socrates)

• Second order logic
  – Is concerned with sets (of individuals).
Logical structure of the theory-evidence relation

• Hypothesis: All swans are white
  – $\forall x \ (Fx \supset Gx)$; For all things it is true that if that thing is a swan then that thing is white.

• Experience: There is a white swan
  – $\exists x \ (Fx \land Gx)$ - confirmation
    • Observation of a thing that is a swan and that thing is white

  – $\exists x \ (Fx \land \neg Gx)$ – falsification
    • Observation of a thing that is a swan and that thing is not white
Deduction and Induction

DEDUCTION
Criterion of adequacy:
A statement is a valid deductive consequence of a group of other statements if and only if it would be self-contradictory to assert all the statements in the group and to deny the statement of the conclusion.

Example
(1) "If you have a current password, then you can log on to the network"
(2) "You have a current password"

Therefore:
"You can log on to the network"

• Logically valid
  – Truth of the premises necessitate the truth of the conclusion
  – Deductive inference is truth-preserving
• Deductive nomological laws
• Laws of court
• Laws of Nature
**Deduction and Induction**

**INDUCTION**

**Criterion of Adequacy:**
As evidence accumulates, the *degree* to which the collection of true evidence statements comes to *support* a hypothesis, as measured by the logic, should tend to indicate that false hypotheses are probably false and that true hypotheses are probably true.

**Example:** 62 percent of voters in a random sample of 400 registered voters (polled on February 20, 2004) said that they favor John Kerry over George W. Bush for President in the 2004 Presidential election. This supports with a probability of at least .95 the hypothesis that between 57 percent and 67 percent of all registered voters favor Kerry over Bush for President (at or around the time the poll was taken)

**Inductive inference**
- Is not logically valid
  - Premises do not necessitate the conclusion
- Inductive statistical laws
- Statistical probabilities
David Hume: The problem of induction

• “Given our current sensory experience, how can we justify inferences from them and from our records of the past, to the future and to the sorts of scientific laws and theories we seek?” (Rosenberg 2013)

• Hume’s argument:
  – A conclusion is justified either deductively or inductively.
    • Deduction: premises contain the conclusion.
    • Induction: moves from the particular to the general
  – Induction cannot be justified deductively → induction is justified by induction → begs the question.

1711 – 1776
An Enquiry Concerning Human Understanding (1748)
Problems of induction I.
Deductive argument for induction

Deductive argument for induction:
1. If a practice has been reliable in the past, it will be reliable in the future.
2. In the past inductive arguments have been reliable.
3. Inductive arguments will be reliable in the future.

Problem with the argument: The first premise requires inductive justification therefore the argument takes it for granted that induction is a reliable way of justification.
Problems of induction II.
Uniformity of nature

- A further requirement for induction is that nature is uniform
  - justification that inductive inferences were grounded on a commitment to the uniformity of nature: that the future will be similar to the past.

- The argument for the uniformity of nature is inductive $\rightarrow$ begs the question:
  - In the recent past, its near future was like the more distant past, in the more distant past, its near future was like the even more distant past, and so on.
  - Therefore, hereafter the future will be like the recent past, the more distant past and the very distant past.
The nature of the testing relation 1.

Confirmation

What is the logical \textit{relationship of test} between evidence and hypotheses.

\begin{itemize}
  \item \textbf{Confirmation}: cannot be conclusive
    \begin{itemize}
      \item the hypothesis will be about an indefinite number of As and experience can provide evidence only about a finite number of them.
    \end{itemize}
  \item Evidence supports a hypothesis to some degree but it may also support many other hypotheses to an equal degree.
    \begin{itemize}
      \item Scientists will rightly embrace a hypothesis as expressing a strict law of nature, true everywhere and always, on the basis of a very small number of experiments or observations
    \end{itemize}
\end{itemize}
The paradox of confirmation.

• Carl G. Hempel (1905-1997)
• “All As are Bs” if and only if “All non-Bs are non-As.”
  – What is an exception to “All As are Bs”?
  – It would be an A that was not a B.
  – But this would also be the only exception to “All non-Bs are non-As”

• All swans are white if and only if all non-white things are non-swans. The two sentences are logically equivalent formulations of the same statement.
  – A black boot confirms that non-white things are non-swans.
Possible solutions for the paradox

• Two strategies:
  – Hempel: accept that black boots confirm the hypothesis about all swans being white
  – Necessity: if “all swans are white” is a law, it must express some necessary connection between being a swan and whiteness.
    • The claim that “all non-white things are non-swans,” lacks any natural or physical necessity.
    • Problem: robust nature of lawlike (nomic) or physical necessity (metaphysics).
The nature of the testing relation 2. Falsification

• Falsification: to show that All As are Bs is false, one needs only to find an A which is not a B:
  – One black swan refutes the claim that all swans are white
  – Science progresses by subjecting a hypothesis to increasingly stringent tests, until the hypothesis is falsified, so that it may be corrected, improved, or give way to a better hypothesis.
Problems with falsification I.
The problem of **auxiliary assumptions/hypothesis**

- What to do when a hypothesis is falsified?
- Which part of the hypothesis should be changed?

- Strict falsifiability is impossible for nothing follows from a general law alone.
  - To test the generalization about swans we need to independently establish that there is at least one swan and then check its color.
  - This depends on the definition of swan and the definition of white or color.

- **All theories are dependent on “auxiliary hypotheses” or “auxiliary assumptions”:** further statements about the conditions under which the hypothesis is tested.

- No single falsifying test will tell us whether the fault lies with the hypothesis under test or with the auxiliary assumptions we need to uncover the falsifying evidence.
Example:

testing the ideal gas law

Ideal gas law: \( PV = nRT \)

- \( P \) is the pressure of the gas
- \( V \) is the volume of the gas
- \( R \) is the specific gas constant
- \( T \) is the temperature of the gas
- \( n \) is the amount of substance of gas in moles

• For the test we measure two of the three variables, say the volume of the gas container and temperature, use the law to calculate a predicted pressure, and then compare the predicted gas pressure to its actual value.

• If the predicted value is identical to the observed value, the evidence supports the hypothesis.

• If it does not, then presumably the hypothesis is falsified.
Example: testing the ideal gas law

Ideal gas law: $PV = nRT$

- $P$ is the pressure of the gas
- $V$ is the volume of the gas
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• For the test we needed to measure the volume of the gas and its temperature.
  – Measuring its temperature requires a thermometer, and employing a thermometer requires us to accept one or more rather complex hypotheses about how thermometers measure heat (auxiliary hypothesis)
  – What are our hypotheses for the thermometer design?
Example: testing the ideal gas law

Ideal gas law: $PV = nRT$

- $P$ is the pressure of the gas
- $V$ is the volume of the gas
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- If the predicted value of the pressure of the gas diverges from the observed value,
  - maybe our thermometer was defective,
  - or that our hypothesis about how expansion of mercury in an enclosed tube measures temperature change is false.
  - To show that a thermometer was defective, because say the glass tube was broken, presupposes another general hypothesis: thermometers with broken tubes do not measure temperature accurately.
Experimental residue, interpretation and discovery

„Discovering heat-rays”

• „I shall here only consider them as an additional part, annexed to the different quantities of heat which are found to go along with the visible spectrum”
Problems with falsification II.
The problem of underdetermination

• Empiricism requires: observation, data collection, and experiment.

• Problem: if the simplest hypothesis comes face to face with experience only in combination with other hypotheses, then
  – a negative test may be the fault of one of the accompanying assumptions,
  – a positive test may reflect compensating mistakes in two or more of the hypotheses involved in the test that cancel one another out
Example:
Testing the melting temperature of copper

• “All copper melts at 1,083 degrees centigrade.”
  – Unfalsifiability by meaning:
    • If “the yellowish-greenish metal which conducts electricity and melts at 1,083 degrees centigrade,”
    • then the hypothesis “All copper melts at 1,083 degrees centigrade” will be unfalsifiable owing to the meanings of the words.

– Redefine copper:
  • the yellowish-greenish metal which conducts electricity
  • for many samples you identify as copper, they either melt well below or well above 1,083 degrees centigrade
  • thermometer was defective, or there were impurities in the sample, or it wasn’t copper at all, but some similar yellowish-greenish metal, or it was aluminum and illuminated by yellowish-greenish light, or you were
Underdetermination in unobservables

• Take a hypothesis constituting a theory that describes the behavior of unobservable entities and their properties
  – Such a hypothesis can be reconciled with falsifying experience by making changes in it that cannot themselves be tested except through the same process all over again—one which allows for a large number of further changes in case of falsification.
  – impossible to establish the correctness or even the reasonableness of one change over another.
Problems with falsification III.
The proliferation problem

**Proliferation**: empirical tests lead to the emergence of empirically equivalent but logically incompatible theories

Two scientists beginning with the same theory, subjecting it to the same initial disconfirming test, and repeatedly “improving” their theories in the light of the same set of further tests will almost certainly end up with completely different theories both equally consistent with the data their tests have generated.

- Experience does not determine which one of the tested theories is the preferable one.
Two+1 methodological answers

First: the methodological principles we add to observation in order to eliminate the threat of underdetermination could be vouched safe to us by some sort of *a priori* considerations. (Epistemology, logic etc)

Second: extra-observational criteria of theory choice have been vindicated by observation and experiment.

- A theory’s consistency with other already well-established theories confirms that theory only because observations have established the theories it is judged consistent with.

+1: theoretical developments are epistemically guided by non-experimental, non-observational considerations
Core concepts so far: basic concepts

• **Empiricism**: Accept that we can acquire knowledge about the future and about laws by experience.

• **A scientific law is a universal claim**: Goes beyond the data available, because it makes a claim which, if true, is true everywhere and always, not just in the experience of the scientist who formulates the scientific law.

• **Fallible scientific law**: the scientific law, our current best estimate–hypothesis, may turn out to be wrong.
Core concepts so far: testing relation

- **Confirmation**: the observation report that an object a displays properties F and G (e.g., that a is a swan and is white) confirms the universal hypothesis that all F-objects are G-objects (namely, that all swans are white).

- **Falsification**: it is logically impossible to conclusively verify a universal proposition by reference to experience (as Hume saw clearly), but a single counter-instance conclusively falsifies the corresponding universal law. In a word, an exception, far from ‘proving’ a rule, conclusively refutes it.
Core concepts so far: Logic

• **Deductive:** A statement is a valid deductive consequence of a group of other statements if and only if it would be self-contradictory to assert all the statements in the group and to deny the statement of the conclusion.

• **Inductive:** As evidence accumulates, the degree to which the collection of true evidence statements comes to support a hypothesis, as measured by the logic, should tend to indicate that false hypotheses are probably false and that true hypotheses are probably true.

• **Problem of induction:** A conclusion is justified either deductively or inductively. Induction cannot be justified deductively therefore induction is justified by induction which begs the question.
Core concepts so far: Problems with falsification

- **Underdetermination**: if the simplest hypothesis comes face to face with experience only in combination with other hypotheses, then a negative test may be the fault of one of the accompanying assumptions while a positive test may reflect compensating mistakes in two or more of the hypotheses involved in the test that cancel one another out.

- **Proliferation**: Two scientists beginning with the same theory, subjecting it to the same initial disconfirming test, and repeatedly “improving” their theories in the light of the same set of further tests will almost certainly end up with completely different theories both equally consistent with the data their tests have generated.

- **Auxiliary hypotheses or auxiliary assumptions**: further statements about the conditions under which the hypothesis is tested or established.