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EXPLANATION AND "OLD EVIDENCE"

Peter Achinstein

1. *The Problem of "Old Evidence"*

An important objection to standard probabilistic accounts of evidence is the problem of "old evidence", raised originally by Clark Glymour.[1] Suppose that prior to the introduction of a theory T some phenomenon (or set of phenomena) O is known with certainty to obtain, so that its probability is 1. Furthermore, suppose that O is derivable from T. O will then be said to be *old evidence with respect to T*.[2] Normally in such cases O is thought of as explained (by derivation) from T. Although these comprise an important subclass of the cases in question, I shall state the problem with respect to the more general class of "derivations".

Let p(T/O) represent the probability of theory T given phenomenon O. According to Bayes' theorem,

(1) $$p(T/O) = p(T) \times p(O/T) \,/\, p(O)$$

Now if O is derivable from T, then $p(O/T) = 1$. And if O is known with certainty to be true, so that $p(O) = 1$, then from (1) we obtain

(2) $$p(T/O) = p(T),$$

i.e., the probability of the theory given the observed phenomenon is the same as its prior probability.

According to the most widely accepted probabilistic account of evidence, a piece of information O is evidence for (or "confirms") an hypothesis *h* if and only if O increases *h*'s probability. That is,

(3) O is evidence for *h* if and only if $p(h/O) > p(h)$.[3]

But this means that if O is "old evidence" with respect to T, that is, if O is known with certainty to obtain prior to the introduction of T, and if O is derivable from T, then O cannot be genuine evidence in favor of T. (The fact that (2) above obtains precludes O from being evidence for T, in the light of (3).) This strikes many as absurd, since the phenomena derivable from theories usually include at least some that are known to obtain prior to the theory, and the fact that they do obtain is frequently considered evidence in favor of those theories. But if (3) is accepted as a correct account of evidence, then previously known phenomena derivable from a theory cannot count as evidence for that theory. This is the problem of "old evidence".

There is an alternative probabilistic account of evidence proposed by some, which requires not increase in probability but high probability:

(4) O is evidence for *h* if and only if $p(h/O) > k$,

where *k* represents some threshold of "high" probability (e.g., 1/2).[4] Will this probability account fare better than (3) with respect to the problem of "old evidence"? Again, let us assume that O is old evidence with respect to T. Then $p(O) = 1$, and since O is derivable from T, $p(O/T) = 1$. From Bayes' theorem (1) we obtain (2). Now suppose T's prior probability is low (less than *k*). Then from (2) we obtain

(5) $p(T/O) < k$.

So on the "high probability" definition of evidence (4), "old evidence" cannot be evidence for T if T has low probability to begin with. Is this reasonable?

2. *Historical Considerations*

One response is to say that "old evidence" does not, and should not, ever count as genuine evidence in favor of a theory. Only "new evidence" does and should. On this viewpoint, if a phenomenon is *predicted* by a theory, but it is not known whether it occurs, then its occurrence would count as evidence for the theory; otherwise not. If O is predicted but not yet known, then $p(O) < 1$. Accordingly, if the prediction of O on the basis of T involves a derivation of O from T (as is frequently the case), then from (1) above we can infer

(6) $p(T/O) > p(T)$.

So, in accordance with the "increase-in-probability" definition (3), O would count as evidence for T.

Furthermore, if O is a prediction derivable from T, then, since $p(O/T)=1$, from (1) we obtain

(7) $p(T/O) = p(T) / p(O)$

The less probable O is, therefore, the higher is the probability of T given O. A very improbable phenomenon that is predicted from T can make T's probability quite high, and can count as evidence for T according to (4), the "high probability" account of evidence. But if O's probability is very high and T's prior probability is much lower, then from (7), the probability of T given O is low, and O will not count as evidence for T on the "high probability" account.

Historically, at least, the idea that only predictions count as evidence is not accurate. Scientists frequently regard "old evidence" as genuinely supporting a theory. Indeed, there are cases in which many if not all of the phenomena appealed to in support of a theory are ones whose existence is known prior to the theory or as it is being developed, rather than phenomena first predicted by the theory and later observed. For example, an important part of the defense that 19th century wave-theorists of light offered for their theory consisted in showing how various known optical phenomena, including rectilinear propagation, reflection, refraction, diffraction, and interference could be derived from their theory.[5] The existence of these phenomena and many others was known by the 1820's and 1830's when the wave theory, rather than the particle theory, came to be most widely accepted.

Indeed, the historian of science Stephen Brush has argued that "old evidence" which is explained by a theory is usually regarded as providing considerably stronger support for the theory than are successful predictions. One of the cases he cites is Einstein's general theory of relativity which both explained the advance of the perihelion of Mercury ("old evidence") and successfully predicted the bending of light (confirmed in later solar eclipse observations). Brush argues that the former was regarded by physicists as providing much more support than the latter.[6]

3. *Probabilistic Considerations*

Even if scientists regard "old evidence" as something that can support a theory, perhaps they are mistaken in doing so. Are there logical, particularly probabilistic, considerations that can justify this practice, at least ones that indicate under what conditions the practice is justified? In this section and the next I will suggest such conditions.

The first point to note is that if some phenomenon O is derivable from a theory T then

(8) $p(T/O) \geq p(T)$.

That is, T's probability is at least *sustained* by O if O is derivable from T. This is true even if O is some known phenomenon whose probability is 1. Of what importance is this fact?

Suppose that on the basis of some set of phenomena S the probability of T is high. Let $O_1,\ldots,O_n$ be some phenomena not in the set S that are derivable from T. Then the probability of T given $O_1,\ldots,O_n$ and the set S is also high. That is, if $p(T/S) > k$, where again k represents some threshold of high probability, then if $O_1,\ldots,O_n$ are derivable from T, $p(T/O_1,\ldots,O_n\&S) > k$. This situation reflects what frequently occurs in scientific reasoning. For example, it is an important part of the argument used by 19th century wave theorists of light in defense of their theory. Such theorists frequently begin with the assumption that light consists either of waves transmitted through a medium or else in a stream of particles emanating from luminous bodies. In defense of this assumption, which they regard as highly probable, wave theorists offer arguments of two sorts. First, there is one from authority: "leading physicists support one or the other assumption". Second, and perhaps more importantly, there is an argument from some observed property of light: for example, that light travels in space from one point to another with a finite velocity, and that in nature one observes motion from one point to another occurring either by the motion of a body or by the vibration of a medium.[7]

I shall write the first claim as follows:

(i) $p(W \text{ or } P/O\&b) \approx 1$,

where W is the wave theory, P is the particle theory, O contains certain observed facts about light including its finite motion, and *b* is background information that includes facts about modes of travel in other cases and about what leading physicists believe ($\approx$ means "is close to").

Next, wave theorists try to show that the particle theory is very improbable, given certain other known optical phenomena, most importantly, diffraction. I shall not here enter into the details of this argument.[8] For present purposes it will suffice to formulate its conclusion as

(ii) $p(P/O\&b) \approx 0$,

where in addition to facts about the finite motion of light, O contains a description of diffraction phenomena. From (i) and (ii), we obtain

(iii) $p(W/O\&b) \approx 1$,

that is, the probability of the wave theory is close to 1, given the background information and certain optical phenomena, including diffraction and the finite motion of light.

Now we come to the derivational step — the one of special interest for the present discussion. The wave theorist wants to show that his theory is probable not just given some limited selection of optical phenomena, but given other optical phenomena as well — ones that are known or predicted. This he can accomplish by deriving these phenomena from his theory, something he proceeds to do. Where $O_1,\ldots,O_n$ represent optical phenomena other than diffraction and the finite motion of light (e.g., rectilinear propagation, reflection, refraction, interference, etc.), if the wave theorist can derive these from his theory, then the probability of that theory will be at least sustained. That is,

(iv) $p(W/O_1,\ldots,O_n\&O\&b) \geq p(W/O\&b)$.

Now as a matter of fact almost all the optical phenomena derived by wave theorists were ones whose existence was known when the derivations were made. (One well-known exception is the Poisson spot in diffraction experiments. But let us simplify the situation by excluding this.) For the optical phenomena in the set $O_1,\ldots,O_n$ we choose ones whose existence was known with certainty prior to the theory, so that $p(O_1,\ldots,O_n) = 1$. (We choose "old evidence".) These phenomena sustain the probability of the wave theory but do not increase it, i.e.,

(v) $$p(W/O_1,\ldots,O_n\&O\&b) = p(W/O\&b).$$

Since by (iii) the probability of the wave theory, given just O&b, is already close to 1, it follows from (v) that

(vi) $$p(W/O_1,\ldots,O_n\&O\&b) \approx 1,$$

that is, the wave theory is highly probable given a range of known optical phenomena. This is the conclusion of the wave theorist's argument. The argument depends crucially on the fact that the optical phenomena in the set $O_1,\ldots,O_n$ are derivable from the theory, thus sustaining its high probability. This is so even though the phenomena constitute "old evidence" with respect to that theory.

Here, then, we have an example of an important probabilistic role the derivation of "old evidence" plays. Even if it does not increase the probability of a theory that entails it, it sustains that probability. If other known phenomena render this probability high, the probability will remain high given (perhaps) *all* known phenomena that are relevant. Still, there is the question of whether in such cases the "old evidence" is genuine evidence. Is it legitimate to regard it as supporting or confirming the theory when it simply sustains its high probability? To answer this question more needs to be said about the concept of evidence.

4. *A Probabilistic-Explanatory Concept of Evidence*

If evidence requires increase in probability, i.e., if (3) above obtains, then "old evidence" will not count as evidence. However, there are independent reasons for rejecting (3) as an adequate account of evidence.

In other writings I have proposed examples that I believe show that (3) provides neither a necessary nor a sufficient condition for evidence.[9]

What about the other standard probabilistic definition of evidence, viz. (4), according to which high probability is both necessary and sufficient for evidence? In the same writings I have argued that high probability is necessary but not sufficient. Several other conditions, including an important explanatory one, are also necessary. The conditions for evidence that I have proposed are these:

(9) O is evidence for T, given *b*, if and only if
   (1) O and *b* are true,
   (2) T is not entailed by O&b,
   (3) p(T/O&b) > k, and
   (4) p(there is an explanatory connection between T and O / T&O&b) > k.

For our purposes the two most important conditions are the third and fourth. The third is the high probability condition that definition (4) makes both necessary and sufficient, but that according to (9) is only necessary. The fourth condition is that the probability is high that there is an explanatory connection between T and O, given T&O&b. There is an "explanatory connection" between T and O if and only if either T correctly explains why O is true, or O correctly explains why T is true, or something correctly explains why both T and O are true. This, of course, leaves open the question of what is to count as a "correct explanation". (See section 5 below; more details about this and about (9) can be found in my *The Nature of Explanation*.) For the present it will suffice to note — what writers on explanation generally accept — that there are correct explanations that are not derivations, and there are derivations (the most trivial being a derivation of *p* from *p*) that are not correct explanations.[10] In the subsequent discussion scientific examples will be offered in which it will be claimed that, given some particular O, T, and *b*, it is (or is not) probable that there is an explanatory connection between O and T. The examples, and the claims about them, should, I think, find acceptance among a variety of explanation theorists.

What I propose to do is invoke the concept of evidence expressed by (9) in answering the question of whether "old evidence" is genuine evidence. The answer that (9) will provide is "sometimes Yes, sometimes

No". Let us look first at two cases in which "old evidence" is not evidence for T.

Case 1: Maxwell's first kinetic theory of gases
In 1860 James Clerk Maxwell published his first paper on kinetic theory. He postulated that gases are composed of numerous spherical molecules that move in rapid motion in straight lines and exert forces only at impact. From these and other assumptions he derived various known phenomena involving gases — phenomena pertaining to pressure, volume, viscosity, heat conduction, and diffusion. These phenomena were known to Maxwell and others prior to his theory: they were "old evidence" with respect to that theory. Condition 1 and 2 of (9) are satisfied, since the phenomena derived do obtain and they do not entail the theory itself. Condition 4 is satisfied, since, given that gases do contain molecules of the sort Maxwell postulates, and given the gaseous phenomena, it is highly probable that gases exhibit these phenomena *because* they contain molecules of the sort Maxwell postulates. (For example, given that gases exert pressure on the walls of the containing vessel, and given that gases contain molecules "striking against the sides of the containing vessel and thus producing pressure"[11], it is highly probable that the reason that gases exert such pressure is that their molecules do.)

The condition that is not satisfied, and that Maxwell himself does not take to be satisfied, is 3. His theory is not highly probable, given just the known gaseous phenomena and the background information available to him. Maxwell had arguments that purported to show some of his assumptions probable (e.g., the assumption that gases are composed of unobservable molecules, that these molecules are in motion, and that this motion is responsible for heat).[12] However, he had and offered no arguments for other fundamental assumptions (e.g., that molecules travel in straight lines, that they exert forces only at impact, and that they are spherical). The theory as a whole was not highly probable. Nor did Maxwell regard it as such, but rather as an "exercise in mechanics" to see whether known gaseous phenomena are derivable from mechanical assumptions. From the fact that they are he did not conclude that the theory is true or probable, but only that it is a subject of "rational curiosity".[13] Maxwell explicitly rejected the method of hypothesis, according to which an hypothesis is shown to be true or probable if from it one derives a range of observed phenomena.[14] The most one can conclude is that the hypothesis is worth considering. In particular, he nowhere takes the fact that gases exhibit known qualitative and quantitative properties of pressure, volume, viscosity, heat conduction, and diffusion to be evidence that molecules are spherical, that they move in straight lines, that they exert only contact forces, and so forth. Maxwell, quite reasonably, does not regard this "old evidence" as evidence for such assumptions.

Case 2: The Martian orbit

Let

T = the planet Mars moves in an elliptical orbit (Kepler's hypothesis), and

O = the planet Mars exists.

b contains a description of Tycho Brahe's data which led Kepler to T. O is "old evidence" with respect to T: it is known to be true prior to T, so that its probability is 1, and it is derivable from T. Furthermore, conditions 1, 2, and 3 of (9) are satisfied: O and *b* are true; T is not entailed by O&b; and p(T/O&b) is high, since p(T/b) is high and T entails O. But while b is evidence for T, it seems absurd to say that O is. On definition (9) this is precluded by condition 4. The probability of an explanatory connection between T and O, given T&O&b is not high. Given just the information that Mars exists, that it moves in an elliptical orbit, and that Brahe's data are accurate, the probability is not high that a correct explanation of why Mars moves in an elliptical orbit is that Mars exists,[15] or that a correct explanation of why Mars exists is that its orbit is elliptical, or that something correctly explains both why Mars exists and why it moves in an elliptical orbit. In this case, although conditions 1, 2, and 3 of definition (9) hold, the explanatory condition 4 does not.

Finally, for a case in which "old evidence" is genuine evidence for a theory we may return to the 19th century wave theory of light. In the discussion of this example in section 3, it was noted that "old evidence" — in this case a set of derivable phenomena including the rectilinear propagation of light, reflection, refraction, and interference — at least sustains whatever probability other phenomena confer upon the theory. Assuming, as the wave theorist claims, that these other phenomena do confer high probability, the probability of the theory on the "old evidence" will remain just as high. Accordingly, condition 3 of definition (9) will be satisfied. There is an important difference between this case and Maxwell's. The wave theorist offers an eliminative argument that first shows that it is highly probable that either his theory or the rival particle theory is true, and then shows why the latter is highly improbable, thus making the former highly probable. This probability is sustained by "old evidence". By contrast, Maxwell offers no eliminative argument, or any other, that renders the probability of his theory high.

The wave theory also satisfies the fourth condition of (9). It provides not simply a derivation of optical phenomena but an explanation of them. What is shown, e.g., is not simply that interference is entailed by the wave theory (the way that "the planet Mars exists" is entailed by "the planet Mars moves in an elliptical orbit"). What is shown, or at least claimed, is that the reason (constructive) interference occurs is that light is a wave motion and that when waves "from different origins coincide, either perfectly or very nearly in direction, their joint effort is a combination of the motions belonging to each".[16] More precisely, in terms of the fourth condition of evidence, given that light is a wave motion of the sort described by the theory, and given that interference occurs, the claim is not simply that in all probability the latter is entailed by the former. It is rather that, given the assumptions in question, in all probability a correct explanation of why light exhibits interference is that it is a wave phenomenon of the sort in question. By contrast, in the case of the Martian orbit, although O (that the planet Mars exists) is entailed by the theory T (that Mars moves in an elliptical orbit), given just O and T and *b*, the probability of an explanatory connection between O and T is not high.

According to (9), then, in the case of the wave theory of light, "old evidence" does count as genuine evidence. Indeed, wave theorists cited known phenomena derivable from their theory in its defense. Their claim was not simply that these phenomena sustained the high probability of the theory, but that they constituted genuine evidence in its favour.

In sum, my answer to the question "When is "old evidence" genuine evidence?", is this: when the probability of the theory is high, given the "old evidence" and the other available information, and when, assuming the truth of the theory and the "old evidence," it is probable that there is an explanatory connection — not simply a derivational one — between them.

5. *Correct Explanations*

Finally, let me comment briefly on the concept of "correct explanation" needed for the account of evidence in (9). It is objective in the sense that whether something correctly explains something else does not depend upon what anyone knows, or believes, or understands. Whether the fact that gases contain molecules that strike against the sides of the container correctly explains why gases exert pressure on these sides does not depend upon whether anyone knows or believes the kinetic theory of gases or knows or believes that gases exert pressure. It depends simply on whether

(10) Gases exert pressure on the sides of their container because gases contain molecules that strike against the container's sides.

The truth of (10) is an objective fact about the world that is not affected by beliefs. How, if at all, such an objective concept of "correct explanation" can be defined is another matter. (I refer the reader to my *Nature of Explanation*, ch. 4, for a definition).

An explanation may be correct without being particularly good. Goodness in explanations is a highly contextual matter that depends on the interests and beliefs of the explainer and audience. The explanation of gaseous pressure given above is perfectly good if what is appropriate in the context is a simple qualitative account (of the sort that Maxwell gives at the beginning of his paper to introduce the subject). It is not a good explanation if the context requires a quantitative account showing how gaseous pressure can be explained by deriving formulas from Newtonian laws governing a mechanical system containing a large number of moving particles. (This is the sort of explanation Maxwell gives later in his paper when he offers quantitative derivations.) The qualitative explanation, while correct, is a good explanation for one context but not for another.

This contextual nature of goodness derives from the aim of an explaining act, which, I have argued, is to produce a certain state of understanding in an actual or potential audience.[17] Accordingly, in judging the goodness of the product of this act - the explanation - one must consider, among other things, the needs of the audience. Will or should the audience be interested in answering the question at that level? Will such an explanation produce a state of understanding in that audience? In judging the (mere) correctness of an explanation, by contrast, such considerations are irrelevant. In deciding whether Maxwell's first explanation of gaseous pressure is correct, we are simply determining whether proposition (10) is true, not whether (10) is a good explanation to invoke in one context or another.

Evidence, I claim, requires the probability of an explanatory connection between the hypothesis and the putative evidence. The concept of explanation needed here is a non-contextual idea of correct explanation. If we can assume (as I do) that the probabilities invoked in the definition of evidence are objective probabilities, then we can conclude that the resulting concept of evidence is also objective. Whether some fact O is evidence that T is true does not depend on whether anyone knows about or believes O or T. (The fact that Johnny has those spots is evidence that he has measles, whether or not anyone knows about those spots or about measles.) Returning, then, to "old evidence", O is old evidence with respect to theory T only if O is known with certainty to obtain prior to T. So "old evidence", at least, requires the knowledge, and hence the belief, that O is true. What it does not require is the knowledge or belief that O is "old evidence" with respect to T.[18]

Johns Hopkins University

NOTES

1. Clark Glymour, *Theory and Evidence* (Princeton, 1980), pp. 85-93.
2. For 0 to be called "old evidence" Glymour requires only that O be known before the introduction of T. He does not in addition require that O be derivable from T. However, to generate the problem he must assume at least that T is logically compatible with O. Moreover, the cases in which he wants to count old evidence as evidence *for T* are ones in which O is derivable from T. Accordingly, I introduce the expression "old evidence with respect to T" for cases of the sort that motivate the problem.
3. See Rudolf Carnap, *Logical Foundations of Probability* (Chicago, 1962, 2nd ed.), pp. xv-xx and p. 463; Wesley Salmon, "Confirmation and Relevance," reprinted in Peter Achinstein, ed., *The*

Concept of Evidence (Oxford, 1983), pp. 95-123.

4. See Carnap, *op. cit.*, Salmon, *op. cit.*
5. See my *Particles and Waves* (New York, 1991).
6. Stephen G. Brush, "Prediction and the Evaluation of Theories by Scientists: The Case of Gravitational Light Bending", *Science*, vol. 246 (1989), pp. 1124-1129.
7. See *Particles and Waves*, Essay 3.
8. See *Ibid.*
9. Peter Achinstein, "Concepts of Evidence", *Mind*, 87 (1978), pp. 22-45; *The Nature of Explanation* (New York, 1983), ch. 10.
10. Both assertions would be made by those defending quite different accounts of explanation, including Hempel's covering law models, Salmon's statistical-causal conception, and van Fraassen's pragmatic theory.
11. Maxwell, "Illustrations of the Dynamical Theory of Gases", *The Scientific Papers of James Clerk Maxwell*, ed. W.D. Niven (New York, 1965), vol. 1, p. 377.
12. See *Particles and Waves*, Essay 8.
13. Maxwell, *op. cit.*, p. 377.
14. Maxwell, *op. cit.*, vol. 2, p. 419.
15. Nor is it that Mars exists and the sun exerts a gravitational force on Mars in accordance with Newton's law of gravity. The latter is not being assumed as part of Kepler's background information.
16. Thomas Young, *Philosophical Transactions of the Royal Society*, 92 (1802), reprinted in Henry Crew, ed., *The Wave Theory of Light* (New York, 1900), quotation on p. 60.
17. *The Nature of Explanation*, ch. 2.
18. I am indebted to Laura J. Snyder, Robert Rynasiewicz, and the editor of this journal for perceptive comments.