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HEURISTIC APPROACH TO SCIENTIFIC THEORY-CONFIRMATION

The controversy regarding the correct approach to confirmation of scientific theory by evidence or experimental results has been one of the two or three focal issues in philosophy of science over the past two decades. In this paper* my aim is to state, examine, and develop one recent approach - heuristic approach - due to J. Worrall (1985), one of a group of phillosophers of science of London School of Economics (LES). This group underlined the need to introduce heuristic ingredient into theory-confirmation. The idea, already there in William Whewell's classic work *History of the Inductive Sciences* (1837) although in an inchoate way, was brought back to life and articulated by E. Zahar (1973) of LSE and Worral (1978).

I

The first goal - that of explaining the heuristic position as regards one fundamental question of confirmation : 'When does a piece of evidence confirm a scientific theory ?' - is to be achieved partly by a negative and partly by a positive phase. The negative task is that of Worrall's pessimism about two other approaches-logical and temporal; while the positive phase is his arguing that with a view to answering this question it has to be ascertained if the piece of evidence was used in the construction of the theory, that is to say, his arguing that confirmation is discovery-dependent.

On the logical approach, the question can be answered by ascertaining whether evidence e is logically deducible from theory T, as Worrall says, who thinks that the simple usual phrase 'e is logically deducible from T' should be unpacked a bit:

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> "Ideally, the evidence statement will assert that certain initial conditions held and that the experiment or observation had a certain outcome *and* the theory together with the statement of initial conditions will logically ential the outcome statement". [Worrall (1985), p.302]

Then, formally, e confirms T if, and only if, e is divided into two parts i and j (where i is the statement of initial conditions and j the statment of outcome) and T & i→ j (where '→' is to be read as entail).

This view, Worrall argues, is amenable to 'tacking paradox'. Suppose we have a theory T_1, and evidence e (= i & j) independent of T_1. We can, then form a trifle theory T_2 by conjoining T_1 and e. The 'cobbled up' T_2 along with i entails j, but is not confirmed by e. The reason is this : the same strategy may be adoped by taking another theory S_1, and e (= i & j) independent of it; and by creating a different theory S_2 by simply conjoining S_1 and e—where S_2 together with i entails j but fails to be confirmed by e. This is the famous 'tacking paradox'. An almost similar case of 'tacking' is noticed, Worrall says, in the history of science, that is, in the case of scientific revolution in the field of optics in the early part of the nineteenth century. (See Worrall (1985), pp.303-4).

The second part of this negative phase concerns Worrall's repudiation of the temporal approach enunciated by Popper (1959) and later Popperians (for example, A. Musgrave (1974), I. Lakatos (1978)). According to this approach, Worrall writes : ".... a theory is supported by any fact which it describes correctly and which was first discovered as a result of testing this theory; and that a fact which was already known before the theory's proposal does not support it". (Worrall (1978), p.46) Arguing against the second part of this quotation Worrall cites a case from the history of science-that is, the case of Mercury's perihelion. The fact of a deviation of 42 seconds of arc per century in Mercury's orbit was known for a long time before Einstein gave his general theory of relativity. On the temporal approach the fact of Mercury's perihelion does not support the general relativity; but scientists pass judgement to the effect of the general relativity being supported by the already known fact.

Now, the positive phase of our explanation of the heuristic position. In Worrall words : ".... a theory is supported by any fact, a 'correct' description of which it implies, provided the fact was not used in the construction of the theory" (Worrall (1978), p.50). Again, he states his thesis in the context of examining Popper's intuitive remarks about testability in this way which he says he learned from R. Giere : "Popper is right that a theory is genuinely supported only by passing real tests, but in order to decide whether some empirical result constituted a real test of some theory, we have to look at how the theory was constructed" (Worrall (1985), p.313). That is to say, we are to inspect whether some empirical result, even if implied by a theory, was used in its construction. Then, confirmation, according to Worrall, is a triadic relation among evidential statement, a theory, and a class of facts used in the theory's construction. All this, now, leads to the heuristic criterion of confirmation : a piece of experimental result or evidence e confirms a theory T constructed in a particular way if, and only if, (i) e is implied by T, and (ii) e is not included in the class of facts used in the construcion of the theory in that particular way, (though e may have been established prior to the construction of T in some cases).

That this criterion applies to actual scientific cases can be shown in the following way. The null result of Michelson - Morley experiments performed with a highly sensitive optical interferometer to determine the relative velocity between the earth and ether was in vogue in 1887 and known before Lorentz - Fitzgerald gave their contraction hypothesis and Einstein his theory of relativity to account for the null result. But the contraction hypothesis receives no support from this result, because it was arrived at by using the result, whereas the relativity theory receives enormous support from the result, because it was not involved in the phenomena used in the construction of the theory. Another case - the diffraction phenomena and polarisation effects do support Fresnel' wave theory of light, because they were not used in the construction of the theory; on the other hand, the corpuscular theory of light as a direct development of the ideas of Newton and Biot is not confirmed by those phenomona and effects, this is because they were used in the theory's development.

II

The heuristic approach has argued an important thesis : discovery of a theory plays a major role in its confirmation. Equally important are its other ingredients which will be considered in our final section.

Here, in the first place, my comment has to do with the meaning of the word 'discovery' used by Worrall : he has not indicated the exact sense in which the word is being used. As, according to R. McLaughlin (1982), the word is an ambiguous one : scientists and philosophers of science use it in different senses.

In scientists' usage, the word 'discovery' means as first encountering in nature something (not proposition) unexpectedly or by chance, for example, the discovery of new isotopes of an element by F. Soddy, of neutron by J. Chadwick. This is a well-established sense of the word, according to McLaughlin who allso mentions its other senses involved in philosophers' usage. H. Reichenbach (1938) used the word in the sense of "hitting upon" a hypothesis (proposition) as a result of mental grappling. Popper (1959), having ruled out the practicability of rationally characterising the discovery of hypothesis, has meant by discovery, the appraisal of scientific theorise. This is what is repeated by Lakatos (1978) while he equates 'logic of discovery' with 'logic of appraisal'. Finally, discovery of theories or laws, we think, refers to a particular historical process or mode of generation.

Let us, then, in order to avoid confusion, follow McLaughlin's terminological stipulations. The word 'discovery' should be used in the sense of first encountering in nature some particle or element or some natural phenomenon. The word 'invention' should be used to mean Reichenbach's notion of hitting upon a hypothesis; and for Popper's and Lakatos' usages the word 'appraisal' ought to be used.

Given these formulations, it is not hard to see that while Worrall brings into special prominence the issue of discovery into theory-confirmation, he is concerned with the issue of theory's invention or "hitting upon". As the latter involves some mental grappling, we prefer to use the word 'generation' (that is, particular historial process) or 'construction' (not, of course, interchangeable with'discovery' as has been done by Worrall) to 'invention'. However, Worrall's intention is quite obvious - he intends to use the word 'construction' to state his discovery-thesis but wrongly uses it synonymously with 'discovery'.

Then, an enquiry into heuristic theory reveals its attempt to account for the confirmation of a whole theory or system consisting of several hypotheses. Thus the theorists' settled mode of thinking is holistic : a theory in its entirety is confirmed or disconfirmed. But surely a genuine phenomenon is that of selective confirmation (that is, confirmation of some parts or hypotheses of a theory by some piece of evidence) argued by scientists and philosophers of science, for example, C. Glymour (1980).

Next, I am arguing against the sufficiency of the heuristic criterion of confirmation represented at the positive phase of this paper's section I. With a view to making my argument concrete, let us say, in the first place, following Kyburg Jr. (1985), that quantitative laws are representative of science. Then, for their testing and confirmation we must obtain values of the quantities occurring in a quantitative law by employing the procedure of measurement which involves error. The measuring process calls for computing intervals of experimental errors. (This phenomenon will be detailed in the final section). Now, values (measured or computed) of the quantities occurring in the law must fall within the intervals of experimental errors, if there is to be confirmation. But if those values do not fall within the intervals then they will not constitute confirming evidence for the law, even though the evidence complies with the heuristic criterion. This shows the criterion's insuffiency.

That the heuristic criterion is not sufficient may also be shown in another way. Thus, suppose that we have a set of values for the quantities occurring in a law, and that the set is implied by the law and is not used in the construction or generation of the law in a particular way, thereby satisfying the criterion. Again, suppose that instruments employed to obtain that set of values did not work properly or were internally disturbed. In that case, that set of values would not constitute confirming evidence for the law in question. We shall consider the role of instruments in confirmation later on.

My final comment consists in the fact that the heuristic theorist has not considered the question of 'how' we go about confirming quantitative laws. This is a major and fundametal question, because its solution has an important bearing upon the answer to the question of 'when' a quantitative law is confirmed.

III

In attempting to develop the heuristic approach, the comments made in the previous section will be concreted here. In the first place, we address ourselves to the question of how quantitative laws are confirmed. Confirmation, in my view, is a three-staged process, First, we are to look at the particular historical process, or mode of generation, or construction of a quantitative law. Specifically, in consonance with the heuristic position we propose to inspect if some empirical results (that is, values) were used in the construction of the law; if used, the law will not be confirmed by those values. Secondly, we look at the issue of errors of measurement. In quantitative laws all the quantities may be measurable, or some are measurable and some unmeasurable. Attention is focussed not on the first alternative. We go about confirming a law having all its quantities measurable by obtaining values for all of these. This is done by employing the procedure of measurement which, as said earlier, involves error. We merely suppose here that a small size (as for example, ten) of successive measurements of all the quantities occurring in the law is made. Certainly we never get true values of the quantities measured, but only a distribution of values; thereby we can obtain only computed mean values for all the measured quantities. There is, thus, difference between real values and the computed mean values. Barring the questions of theoretically possible deviation which is arbitrarily great, we intend to know the actual possible deviation whose size is based on what is called in standard books on statistics, the *root mean square deviation* denoted by σ (Sigma). This is the square root of the sum of the squared deviation divided by the number of measurements. In symbols :

$$\sigma = \sqrt{\frac{(a_1 - a)^2 + (a_2 - a)^2 + ... + (a_n - a)^2}{n}}$$

Where a is the arithmetic mean, and the values obtained by measurement are denoted by a_1, a_2, ... a_n, and n is the number of measurements.

Now, given a small sample of ten measurements of each of the quantities in a law, the deviation of true value of each from its computed arithmetic mean value can not be more than σ. We, then, go on to calculate the interval of experimental errorss : $a \pm \sigma$ for each of the quantities in the law. Finally, for the law's confirmation, we need to obtain value of each of its quantities by making further measurements and to check whether the value thus obtained falls within the corresponding interval for each of the quantities. If not, then the law will not be confirmed by the values obtained from further measurements.

The same course is to be adopted in case of confirmation of laws, some quantities of which are measurable and some unmeasurable; the only difference being this. We shall have to calculate the interval of experimental errors for the unmeasurable quantities from the values of the measurable quantities. The second stage of the process of confirmation ends here.

We now enter into the third stage where the role of measuring instruments or mechanisms employed to obtain values of the quantities in a law is to be considered. Here, following Nils - Eric Sahlin (1986), we must ascertain that the instruments used in measurements work properly. If the instruments do not work properly due to some internal disturbances or other reasons, the values they indicate would falsely support the law. In order to prevent this possibility, proper working of the instrument must be ensured. An instrument is said to be working properly if the propability of its working is high or 0.995; that is to say, 99.5% of the time it indicates values that fall within the interval of experimental errors computed to test previous laws. In other words, the probability of the 'correct' working of the instrument will be 0.995, if out of 1000 times a quantity is measured the instrument had shown values falling within the interval 995 times. We will define this sort of instrument as a 'tested instrument' in this paper. This concludes the third and final stage of the process of confirmation.

Depending on what has been said so far I am now directing myself to the question of when a quantitative law is confirmed. A piece of evidence (constituted by a set of values) confirms a quantitative law if, and only if,

i) the set of values falls within the corresponding intervals of experimental errors computed for each quantity occuring in the law depending on a small sample (as for example, 10) of measurements of each quantity;

ii) the set of values is implied by the law and initial conditions;

iii) the set of values is not a subset of the set of values which was used in the generation of the law;

iv) each of the instruments employed to measure the quantities in the law is a tested instrument (as defined earlier).

This criterion certainly is an improvement on the heuristic position characterised by Worrall. The clauses (i) and (iv) are new additions, while clauses (ii) and (iii) are reconstructions of Worrall's heuristic position.

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NOTES

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