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I.—STUDIES IN THE LOGIC OF CONFIRMATION (II.).

BY CARL G. HEMPEL.

7. *The Prediction-criterion of Confirmation and its Shortcomings.*—We are now in a position to analyze a second conception of confirmation which is reflected in many methodological discussions and which can claim a great deal of plausibility. Its basic idea is very simple: General hypotheses in science as well as in everyday usage are intended to enable us to anticipate future events; hence, it seems reasonable to count any prediction which is borne out by subsequent observation as confirming evidence for the hypothesis on which it is based, and any prediction that fails as disconfirming evidence. To illustrate: Let H_1 be the hypothesis that all metals, when heated, expand; symbolically: '(x) ((Metal (x) . Heated (x)) $\supset$ Exp(x))'. If we are given an observation report to the effect that a certain object a is a metal and is heated, then by means of H_1 we can derive the prediction that a expands. Suppose that this is borne out by observation and described in an additional observation statement. We should then have the total observation report. {Metal(a), Heated(a), Exp.(a)}.[1] This report would be qualified as confirming evidence for H_1 because its last sentence bears out what could be predicted, or derived, from the first two by means of

[1] An (observation) report, it will be recalled, may be represented by a conjunction or by a class of observation sentences; in the latter case, we characterize it by writing the sentences between braces; the quotation marks which normally would be used are, for convenience, assumed to be absorbed by the braces.

H_1; more explicitly: because the last sentence can be derived from the first two in conjunction with H_1.—Now let H_2 be the hypothesis that all swans are white; symbolically: '(x) (Swan$(x) \supset$ White(x))'; and consider the observation report {Swan(a), $\sim$ White(a)}. This report would constitute disconfirming evidence for H_2 because the second of its sentences contradicts (and thus fails to bear out) the prediction 'White(a)' which can be deduced from the first sentence in conjunction with H_2; or, symmetrically, because the first sentence contradicts the consequence '$\sim$ Swan(a)' which can be derived from the second in conjunction with H_2. Obviously, either of these formulations implies that H_2 is incompatible with the given observation report.

These illustrations suggest the following general definition of confirmation as successful prediction:

Prediction-criterion of Confirmation: Let H be a hypothesis, B an observation report, *i.e.* a class of observation sentences. Then

(*a*) B is said to confirm H if B can be divided into two mutually exclusive subclasses B_1 and B_2 such that B_2 is not empty, and every sentence of B_2 can be logically deduced from B_1 in conjunction with H, but not from B_1 alone.

(*b*) B is said to disconfirm H if H logically contradicts B.[1]

(*c*) B is said to be neutral with respect to H if it neither confirms nor disconfirms H.[2]

But while this criterion is quite sound as a statement of sufficient conditions of confirmation for hypotheses of the type illustrated above, it is considerably too narrow to serve as a general definition of confirmation. Generally speaking, this criterion would serve its purpose if all scientific hypotheses could be construed as asserting regular connections of observable features in the subject-matter under investigation; *i.e.* if they all were of

[1] It might seem more natural to stipulate that B disconfirms H if it can be divided into two mutually exclusive classes B_1 and B_2 such that the denial of at least one sentence in B_2 can be deduced from B_1 in conjunction with H; but this condition can be shown to be equivalent to (*b*) above.

[2] The following quotations from A. J. Ayer's book *Language, Truth and Logic* (London, 1936) formulate in a particularly clear fashion the conception of confirmation as successful prediction (although the two are not explicitly identified by definition): "... the function of an empirical hypothesis is to enable us to anticipate experience. Accordingly, if an observation to which a given proposition is relevant conforms to our expectations, ... that proposition is confirmed" (*loc. cit.* pp. 142-143). "... it is the mark of a genuine factual proposition ... that some experiential propositions can be deduced from it in conjunction with certain premises without being deducible from those other premises alone". (*loc. cit.* p. 26).

the form " Whenever the observable characteristic P is present in an object or a situation, then the observable characteristic Q will also be present." But actually, most scientific hypotheses and laws are not of this simple type ; as a rule, they express regular connections of characteristics which are not observable in the sense of direct observability, nor even in a much more liberal sense. Consider, for example, the following hypothesis : " Whenever plane-polarized light of wave length λ traverses a layer of quartz of thickness d, then its plane of polarization is rotated through an angle α which is proportional to $\frac{d}{\lambda}$."—Let us assume that the observational vocabulary, by means of which our observation reports have to be formulated, contains exclusively terms referring to directly observable attributes. Then, since the question of whether a given ray of light is plane-polarized and has the wave length λ cannot be decided by means of direct observation, no observation report of the kind here admitted could include information of this type. This in itself would not be crucial if at least we could assume that the fact that a given ray of light is plane-polarized, etc., could be logically inferred from some possible observation report ; for then, from a suitable report of this kind, in conjunction with the given hypothesis, one would be able to predict a rotation of the plane of polarization ; and from this prediction, which itself is not yet expressed in exclusively observational terms, one might expect to derive further predictions in the form of genuine observation sentences. But actually, a hypothesis to the effect that a given ray of light is plane-polarized has to be considered as a general hypothesis which entails an unlimited number of observation sentences ; thus it cannot be logically inferred from, but at best be confirmed by, a suitable set of observational findings. The logically essential point can best be exhibited by reference to a very simple abstract case : Let us assume that R_1 and R_2 are two relations of a kind accessible to direct observation, and that the field of scientific investigation contains infinitely many objects. Consider now the hypothesis

$$(H) \qquad (x)((y)R_1(x, y) \supset (\mathrm{E}z)R_2(x, z)),$$

i.e. : Whenever an object x stands in R_1 to every object y, then it stands in R_2 to at least one object z.—This simple hypothesis has the following property : However many observation sentences may be given, H does not enable us to derive any new observation sentences from them. Indeed—to state the reason in suggestive though not formally rigorous terms—in order to make a prediction concerning some specific object a, we should first have to know that a stands in R_1 to every object; and this necessary information clearly cannot be contained in any finite number, however large, of observation sentences, because a finite set of observation sentences can tell us at best for a finite number of objects that a stands in R_1 to them. Thus an observation report, which always involves only a finite number of observation sentences, can never provide a sufficiently broad basis for a prediction by means of H.[1]—Besides, even if we did know that a stood in R_1 to every object, the prediction derivable by means of H would not be an observation sentence; it would assert that a stands in R_2 to *some* object, without specifying which, and where to find it. Thus, H would be an empirical hypothesis, containing, besides purely logical terms, only expressions belonging to the observational vocabulary, and yet the predictions which it renders possible neither start from nor lead to observation reports.

It is, therefore, a considerable over-simplification to say that scientific hypotheses and theories enable us to derive predictions of future experiences from descriptions of past ones. Unquestionably, scientific hypotheses do have a predictive function; but the way in which they perform this function, the manner in which they establish logical connections between observation reports, is logically more complex than a deductive inference. Thus, in the last illustration, the predictive use of H may assume the following form: On the basis of a number of individual tests, which show that a does stand in R_1 to three objects b, c, and d, we may accept the hypothesis that a stands in R_1 to all objects; or, in terms of our formal mode of speech: In view of the observation report $\{R_1(a, b), R_1(a, c), R_1(a, d)\}$, the hypothesis that $(y)R_1(a, y)$ is accepted as confirmed by, though not logically inferable from, that report.[2] This process might be referred to as quasi-induction.[3] From the hypothesis thus established we

[1] To illustrate: a might be an iron object which possibly is a magnet; R_1 might be the relation of attracting; the objects under investigation might be iron objects. Then a finite number of observation reports to the effect that a did attract a particular piece of iron is insufficient to *infer* that a will attract every piece of iron.

[2] Thus, in the illustration given in the preceding footnote, the hypothesis that the object a will attract every piece of iron might be accepted as sufficiently well substantiated by, though by no means derivable from, an observation report to the effect that in tests a did attract the iron objects b, c, and d.

[3] The prefix " quasi " is to contradistinguish the procedure in question from so-called induction, which is usually supposed to be a method of discovering, or arriving at, general regularities on the basis of a finite

can then proceed to derive, by means of H, the prediction that a stands in R_2 to at least one object. This again, as was pointed out above, is not an observation sentence; and indeed no observation sentence can be derived from it; but it can, in turn, be confirmed by a suitable observation sentence, such as '$R_2(a, b)$'. —In other cases, the prediction of actual observation sentences may be possible; thus if the given hypothesis asserts that $(x)((y)R_1(x, y) \supset (z)R_2(x, z))$, then after quasi-inductively accepting, as above, that $(y)R_1(a, y)$, we can derive, by means of the given hypothesis, the sentence that a stands in R_2 to every object, and thence, we can deduce special predictions such as '$R_2(a, b)$', etc., which do have the form of observation sentences.

Thus, the chain of reasoning which leads from given observational findings to the "prediction" of new ones actually involves, besides deductive inferences, certain quasi-inductive steps each of which consists in the acceptance of an intermediate statement on the basis of confirming, but usually not logically conclusive, evidence. In most scientific predictions, this general pattern occurs in multiple re-iteration; an analysis of the predictive use of the hypothesis mentioned above, concerning plane-polarized light, could serve as an illustration. In the present context, however, this general account of the structure of scientific prediction is sufficient: it shows that a general definition of confirmation by reference to successful prediction becomes circular; indeed, in order to make the original formulation of the prediction-criterion of confirmation sufficiently comprehensive, we should have to replace the phrase "can be logically deduced" by "can be obtained by a series of steps of deduction and quasi-induction"; and the definition of "quasi-induction" in the above sense presupposes the concept of confirmation.

Let us note, as a by-product of the preceding consideration, the fact that an adequate analysis of scientific prediction (and analogously, of scientific explanation, and of the testing of empirical hypotheses) requires an analysis of the concept of confirmation. The reason for this fact may be restated in general terms as follows: Scientific laws and theories, as a rule, connect terms which lie on the level of abstract theoretical constructs rather than on that of direct observation; and from observation sentences, no merely deductive logical inference leads

number of instances. In quasi-induction, the hypothesis is not "discovered" but has to be *given* in addition to the observation report; the process consists in the acceptance of the hypothesis if it is deemed sufficiently confirmed by the observation report. *Cf.* also the discussion in section 1c, above.

to statements about those theoretical constructs which are the starting point for scientific predictions; statements about logical constructs, such as "This piece of iron is magnetic" or "Here, a plane-polarized ray of light traverses a quartz crystal" can be confirmed, but not entailed, by observation reports, and thus, even though based on general scientific laws, the "prediction" of new observational findings on the basis of given ones is a process involving confirmation in addition to logical deduction.[1]

8. *Conditions of Adequacy for any Definition of Confirmation.*—The two most customary conceptions of confirmation, which were rendered explicit in Nicod's criterion and in the prediction criterion, have thus been found unsuitable for a general definition of confirmation. Besides this negative result, the preceding analysis has also exhibited certain logical characteristics of scientific prediction, explanation, and testing, and it has led to the establishment of certain standards which an adequate definition of confirmation has to satisfy. These standards include the equivalence condition and the requirement that the definition of confirmation be applicable to hypotheses of any degree of logical complexity, rather than to the simplest type of universal conditional only. An adequate definition of confirmation, however, has to satisfy several further logical requirements, to which we now turn.

First of all, it will be agreed that any sentence which is entailed by—*i.e.* a logical consequence of—a given observation report has to be considered as confirmed by that report: Entailment is a special case of confirmation. Thus, *e.g.*, we want to say that the observation report "a is black" confirms the sentence (hypothesis) "a is black or grey"; and—to refer to one of the illustrations given in the preceding section—the observation sentence '$R_2(a, b)$' should certainly be confirming evidence for the sentence '$(Ez)R_2(a, z)$'. We are therefore led to the stipulation that any adequate definition of confirmation must insure the fulfilment of the

[1] In the above sketch of the structure of scientific prediction, we have disregarded the fact that in practically every case where a prediction is said to be obtained by means of a certain hypothesis or theory, a considerable mass of auxiliary theories is used in addition; thus, *e.g.* the prediction of observable effects of the deflection of light in the gravitational field of the sun on the basis of the general theory of relativity, requires such auxiliary theories as mechanics and optics. But an explicit consideration of this fact would not affect our result that scientific predictions, even when based on hypotheses or theories of universal form, still are not purely deductive in character, but involve quasi-inductive steps as well.

(8.1) *Entailment condition:* Any sentence which is entailed by an observation report is confirmed by it.[1]

This condition is suggested by the preceding consideration, but of course not proved by it. To make it a standard of adequacy for the definition of confirmation means to lay down the stipulation that a proposed definition of confirmation will be rejected as logically inadequate if it is not constructed in such a way that (8.1) is unconditionally satisfied. An analogous remark applies to the subsequently proposed further standards of adequacy.—

Second, an observation report which confirms certain hypotheses would invariably be qualified as confirming any consequence of those hypotheses. Indeed: any such consequence is but an assertion of all or part of the combined content of the original hypotheses and has therefore to be regarded as confirmed by any evidence which confirms the original hypotheses. This suggests the following condition of adequacy:

(8.2) *Consequence Condition:* If an observation report confirms every one of a class K of sentences, then it also confirms any sentence which is a logical consequence of K.

If (8.2) is satisfied, then the same is true of the following two more special conditions:

(8.21) *Special Consequence Condition:* If an observation report confirms a hypothesis H, then it also confirms every consequence of H.

(8.22) *Equivalence Condition:* If an observation report confirms a hypothesis H, then it also confirms every hypothesis which is logically equivalent with H.

(This follows from (8.21) in view of the fact that equivalent hypotheses are mutual consequences of each other.) Thus, the satisfaction of the consequence condition entails that of our earlier equivalence condition, and the latter loses its status of an independent requirement.

In view of the apparent obviousness of these conditions, it is interesting to note that the definition of confirmation in terms of successful prediction, while satisfying the equivalence condition, would violate the consequence condition. Consider, for example, the formulation of the prediction-criterion given in the earlier

[1] As a consequence of this stipulation, a contradictory observation report, such as {Black(a), $\sim$ Black(a)} confirms every sentence, because it has every sentence as a consequence. Of course, it is possible to exclude the possibility of contradictory observation reports altogether by a slight restriction of the definition of " observation report ". There is, however, no important reason to do so.

part of the preceding section. Clearly, if the observational findings B_2 can be predicted on the basis of the findings B_1 by means of the hypothesis H, the same prediction is obtainable by means of any equivalent hypothesis, but not generally by means of a weaker one.

On the other hand, any prediction obtainable by means of H can obviously also be established by means of any hypothesis which is stronger than H, *i.e.* which logically entails H. Thus, while the consequence condition stipulates in effect that whatever confirms a given hypothesis also confirms any weaker hypothesis, the relation of confirmation defined in terms of successful prediction would satisfy the condition that whatever confirms a given hypothesis, also confirms every stronger one.

But is this " converse consequence condition ", as it might be called, not reasonable enough, and should it not even be included among our standards of adequacy for the definition of confirmation ? The second of these two suggestions can be readily disposed of : The adoption of the new condition, in addition to (8.1) and (8.2), would have the consequence that any observation report B would confirm any hypothesis H whatsoever. Thus, *e.g.*, if B is the report " *a* is a raven " and H is Hooke's law, then, according to (8.1), B confirms the sentence " *a* is a raven ", hence B would, according to the converse consequence condition, confirm the stronger sentence " *a* is a raven, and Hooke's law holds " ; and finally, by virtue of (8.2), B would confirm H, which is a consequence of the last sentence. Obviously, the same type of argument can be applied in all other cases.

But is it not true, after all, that very often observational data which confirm a hypothesis H are considered also as confirming a stronger hypothesis ? Is it not true, for example, that those experimental findings which confirm Galileo's law, or Kepler's laws, are considered also as confirming Newton's law of gravitation ? [1] This is indeed the case, but this does not justify the acceptance of the converse entailment condition as a general rule of the logic of confirmation ; for in the cases just mentioned, the weaker hypothesis is connected with the stronger one by a logical bond of a particular kind : it is essentially a substitution instance of the stronger one ; thus, *e.g.*, while the law of gravitation refers to the force obtaining between any two bodies, Galileo's law is a specialization referring to the case where one of

[1] Strictly speaking, Galileo's law and Kepler's laws can be deduced from the law of gravitation only if certain additional hypotheses—including the laws of motion—are presupposed ; but this does not affect the point under discussion.

the bodies is the earth, the other an object near its surface. In the preceding case, however, where Hooke's law was shown to be confirmed by the observation report that *a* is a raven, this situation does not prevail; and here, the rule that whatever confirms a given hypothesis also confirms any stronger one becomes an entirely absurd principle. Thus, the converse consequence condition does not provide a sound general condition of adequacy.[1]

A third condition remains to be stated: [2]

(8.3) *Consistency Condition:* Every logically consistent observation report is logically compatible with the class of all the hypotheses which it confirms.

The two most important implications of this requirement are the following:

(8.31) Unless an observation report is self-contradictory,[3] it does not confirm any hypothesis with which it is not logically compatible.

(8.32) Unless an observation report is self-contradictory, it does not confirm any hypotheses which contradict each other.

The first of these corollaries will readily be accepted; the second, however,—and consequently (8.3) itself—will perhaps be

[1] William Barrett, in a paper entitled "Discussion on Dewey's Logic" (*The Philosophical Review*, vol. 50, 1941, pp. 305 ff., esp. p. 312) raises some questions closely related to what we have called above the consequence condition and the converse consequence condition. In fact, he invokes the latter (without stating it explicitly) in an argument which is designed to show that "not every observation which confirms a sentence need also confirm all its consequences", in other words, that the special consequence condition (8.21) need not always be satisfied. He supports his point by reference to "the simplest case: the sentence 'C' is an abbreviation of 'A.B', and the observation O confirms 'A', *and so* 'C', but is irrelevant to 'B', which is a consequence of 'C'." (Italics mine.)

For reasons contained in the above discussion of the consequence condition and the converse consequence condition, the application of the latter in the case under consideration seems to us unjustifiable, so that the illustration does not prove the author's point; and indeed, there seems to be every reason to preserve the unrestricted validity of the consequence condition. As a matter of fact, Mr. Barrett himself argues that "the degree of confirmation for the consequence of a sentence cannot be less than that of the sentence itself"; this is indeed quite sound; but it is hard to see how the recognition of this principle can be reconciled with a renunciation of the special consequence condition, since the latter may be considered simply as the correlate, for the non-gradated relation of confirmation, of the former principle which is adapted to the concept of degree of confirmation.

[2] For a fourth condition, see n. 1, p. 110.

[3] A contradictory observation report confirms every hypothesis (*cf.* n. 1, p. 103) and is, of course, incompatible with every one of the hypotheses it confirms.

felt to embody a too severe restriction. It might be pointed out, for example, that a finite set of measurements concerning the variation of one physical magnitude, x, with another, y, may conform to, and thus be said to confirm, several different hypotheses as to the particular mathematical function in terms of which the relationship of x and y can be expressed; but such hypotheses are incompatible because to at least one value of x, they will assign different values of y.

No doubt it is possible to liberalize the formal standards of adequacy in line with these considerations. This would amount to dropping (8.3) and (8.32) and retaining only (8.31). One of the effects of this measure would be that when a logically consistent observation report B confirms each of two hypotheses, it does not necessarily confirm their conjunction; for the hypotheses might be mutually incompatible, hence their conjunction self-contradictory; consequently, by (8.31), B could not confirm it.—This consequence is intuitively rather awkward, and one might therefore feel inclined to suggest that while (8.3) should be dropped and (8.31) retained, (8.32) should be replaced by the requirement (8.33): If an observation sentence confirms each of two hypotheses, then it also confirms their conjunction. But it can readily be shown that by virtue of (8.2) this set of conditions entails the fulfilment of (8.32).

If, therefore, the condition (8.3) appears to be too rigorous, the most obvious alternative would seem to lie in replacing (8.3) and its corollaries by the much weaker condition (8.31) alone; and it is an important problem whether an intuitively adequate definition of confirmation can be constructed which satisfies (8.1), (8.2) and (8.31), but not (8.3).—One of the great advantages of a definition which satisfies (8.3) is that it sets a limit, so to speak, to the strength of the hypotheses which can be confirmed by given evidence.[1]

The remainder of the present study, therefore, will be concerned exclusively with the problem of establishing a definition of confirmation which satisfies the more severe formal conditions represented by (8.1), (8.2), and (8.3) together.

The fulfilment of these requirements, which may be regarded as general laws of the logic of confirmation, is of course only a necessary, not a sufficient, condition for the adequacy of any proposed definition of confirmation. Thus, *e.g.*, if " B confirms

[1] This was pointed out to me by Dr. Nelson Goodman. The definition later to be outlined in this essay, which satisfies conditions (8.1), (8.2) and (8.3), lends itself, however, to certain generalizations which satisfy only the more liberal conditions of adequacy just considered.

H " were defined as meaning " B logically entails *H* ", then the above three conditions would clearly be satisfied ; but the definition would not be adequate because confirmation has to be a more comprehensive relation than entailment (the latter might be referred to as the special case of *conclusive* confirmation). Thus, a definition of confirmation, to be acceptable, also has to be materially adequate : it has to provide a reasonably close approximation to that conception of confirmation which is implicit in scientific procedure and methodological discussion. That conception is vague and to some extent quite unclear, as I have tried to show in earlier parts of this paper ; therefore, it would be too much to expect full agreement as to the material adequacy of a proposed definition of confirmation ; on the other hand, there will be rather general agreement on certain points ; thus, *e.g.*, the identification of confirmation with entailment, or the Nicod criterion of confirmation as analyzed above, or any definition of confirmation by reference to a " sense of evidence ", will probably now be admitted not to be adequate approximations to that concept of confirmation which is relevant for the logic of science.

On the other hand, the soundness of the logical analysis (which, in a clear sense, always involves a logical reconstruction) of a theoretical concept cannot be gauged simply by our feelings of satisfaction at a certain proposed analysis ; and if there are, say, two alternative proposals for defining a term on the basis of a logical analysis, and if both appear to come fairly close to the intended meaning, then the choice has to be made largely by reference to such features as the logical properties of the two reconstructions, and the comprehensiveness and simplicity of the theories to which they lead.

9. *The Satisfaction Criterion of Confirmation.*—As has been mentioned before, a precise definition of confirmation requires reference to some definite " language of science ", in which all observation reports and all hypotheses under consideration are assumed to be formulated, and whose logical structure is supposed to be precisely determined. The more complex this language, and the richer its logical means of expression, the more difficult it will be, as a rule, to establish an adequate definition of confirmation for it. However, the problem has been solved at least for certain cases : With respect to languages of a comparatively simple logical structure, it has been possible to construct an explicit definition of confirmation which satisfies all of the above logical requirements, and which appears to be intuitively rather adequate. An exposition of the technical details of this

definition has been published elsewhere ;[1] in the present study, which is concerned with the general logical and methodological aspects of the problem of confirmation rather than with technical details, it will be attempted to characterize the definition of confirmation thus obtained as clearly as possible with a minimum of technicalities.

Consider the simple case of the hypothesis H: '$(x)(\text{Raven}(x) \supset \text{Black}(x))$', where 'Raven' and 'Black' are supposed to be terms of our observational vocabulary. Let B be an observation report to the effect that $\text{Raven}(a) . \text{Black}(a) . \sim \text{Raven}(c) . \text{Black}(c) . \sim \text{Raven}(d) . \sim \text{Black}(d)$. Then B may be said to confirm H in the following sense: There are three objects altogether mentioned in B, namely a, c, and d; and as far as these are concerned, B informs us that all those which are ravens (*i.e.* just the object a) are also black.[2] In other words, from the information contained in B we can infer that the hypothesis H does hold true within the finite class of those objects which are mentioned in B.

Let us apply the same consideration to a hypothesis of a logically more complex structure. Let H be the hypothesis "Everybody likes somebody"; in symbols: '$(x)(Ey)\text{Likes}(x, y)$',

[1] In my article referred to in n. 1, p. 1. The logical structure of the languages to which the definition in question is applicable is that of the lower functional calculus with individual constants, and with predicate constants of any degree. All sentences of the language are assumed to be formed exclusively by means of predicate constants, individual constants, individual variables, universal and existential quantifiers for individual variables, and the connective symbols of denial, conjunction, alternation, and implication. The use of predicate variables or of the identity sign is not permitted.

As to the predicate constants, they are all assumed to belong to the observational vocabulary, *i.e.* to denote a property or a relation observable by means of the accepted techniques. ("Abstract" predicate terms are supposed to be defined in terms of those of the observational vocabulary and then actually to be replaced by their *definientia*, so that they never occur explicitly.)

As a consequence of these stipulations, an observation report can be characterized simply as a conjunction of sentences of the kind illustrated by '$P(a)$', '$\sim P(b)$', '$R(c, d)$', '$\sim R(e, f)$', etc., where 'P', 'R', etc., belong to the observational vocabulary, and 'a', 'b', 'c', 'd', 'e', 'f', etc., are individual names, denoting specific objects. It is also possible to define an observation report more liberally as any sentence containing no quantifiers, which means that besides conjunctions also alternations and implication sentences formed out of the above kind of components are included among the observation reports.

[2] I am indebted to Dr. Nelson Goodman for having suggested this idea ; it initiated all those considerations which finally led to the definition to be outlined below.

i.e. for every (person) x, there exists at least one (not necessarily different person) y such that x likes y. (Here again, 'Likes' is supposed to be a relation-term which occurs in our observational vocabulary.) Suppose now that we are given an observation report B in which the names of two persons, say 'e' and 'f', occur. Under what conditions shall we say that B confirms H? The previous illustration suggests the answer: If from B we can infer that H is satisfied within the finite class $\{e, f\}$; *i.e.* that within $\{e, f\}$ everybody likes somebody. This in turn means that e likes e or f, and f likes e or f. Thus, B would be said to confirm H if B entailed the statement "e likes e or f, and f likes e or f". This latter statement will be called the development of H for the finite class $\{e, f\}$.—

The concept of *development of a hypothesis, H, for a finite class of individuals, C*, can be defined in a general fashion; the development of H for C states what H would assert if there existed exclusively those objects which are elements of C.—Thus, *e.g.*, the development of the hypothesis H_1 = '$(x)(P(x) \vee Q(x))$' (*i.e.* "Every object has the property P or the property Q") for the class $\{a, b\}$ is '$(P(a) \vee Q(a)) . (P(b) \vee Q(b))$' (*i.e.* "$a$ has the property P or the property Q, and b has the property P or the property Q"); the development of the existential hypothesis H_2 that at least one object has the property P, *i.e.* '$(Ex)P(x)$', for $\{a, b\}$ is '$P(a) \vee P(b)$'; the development of a hypothesis which contains no quantifiers, such as H_3: '$P(c) \vee Q(c)$' is defined as that hypothesis itself, no matter what the reference class of individuals is.

A more detailed formal analysis based on considerations of this type leads to the introduction of a general relation of confirmation in two steps; the first consists in defining a special relation of direct confirmation along the lines just indicated; the second step then defines the general relation of confirmation by reference to direct confirmation.

Omitting minor details, we may summarize the two definitions as follows:

(9.1 Df.) An observation report B directly confirms a hypothesis H if B entails the development of H for the class of those objects which are mentioned in B.

(9.2 Df.) An observation report B confirms a hypothesis H if H is entailed by a class of sentences each of which is directly confirmed by B.

The criterion expressed in these definitions might be called the satisfaction criterion of confirmation because its basic idea consists in construing a hypothesis as confirmed by a given observation report if the hypothesis is satisfied in the finite class of those individuals which are mentioned in the report.—Let us now apply the two definitions to our last examples: The observation report B_1: '$P(a) . Q(b)$' diiectly confirms (and therefore also confirms) the hypothesis H_1, because it entails the development of H_1 for the class $\{a, b\}$, which was given above.—The hypothesis H_3 is not directly confirmed by B, because its development—*i.e.* H_3 itself—obviously is not entailed by B_1. However, H_3 is entailed by H_1, which is directly confirmed by B_1; hence, by virtue of (9.2), B_1 confirms H_3.

Similarly, it can readily be seen that B_1 directly confirms H_2.

Finally, to refer to the first illustration given in this section: The observation report 'Raven(a) . Black(a) . $\sim$ Raven(c) . $\sim$ Black(c) . $\sim$ Raven(d) . $\sim$ Black(d)' confirms (even directly) the hypothesis '(x)(Raven(x) $\supset$ Black(x))', for it entails the development of the latter for the class $\{a, c, d\}$, which can be written as follows: '(Raven(a) $\supset$ Black(a)) . (Raven(c) $\supset$ Black(c)) . (Raven (d) $\supset$ Black(d))'.

It is now easy to define disconfirmation and neutrality:

(9.3 Df.) An observation report B disconfirms a hypothesis H if it confirms the denial of H.

(9.4 Df.) An observation report B is neutral with respect to a hypothesis H if B neither confirms nor disconfirms H.

By virtue of the criteria laid down in (9.2), (9.3), (9.4), every consistent observation report, B, divides all possible hypotheses into three mutually exclusive classes: those confirmed by B, those disconfirmed by B, and those with respect to which B is neutral.

The definition of confirmation here proposed can be shown to satisfy all the formal conditions of adequacy embodied in (8.1), (8.2), and (8.3) and their consequences; for the condition (8.2) this is easy to see; for the other conditions the proof is more complicated.[1]

[1] For these proofs, see the article referred to in n. 1, p. 1. I should like to take this opportunity to point out and to remedy a certain defect of the definition of confirmation which was developed in that article, and which has been outlined above: this defect was brought to my attention by a discussion with Dr. Olaf Helmer.

It will be agreed that an acceptable definition of confirmation should satisfy the following further condition which might well have been included among the logical standards of adequacy set up in section 8 above: (8.4). If B_1 and B_2 are logically equivalent observation reports and B_1 confirms (disconfirms, is neutral with respect to) a hypothesis H, then B_2, too, confirms (disconfirms, is neutral with respect to) H. This condition is indeed satisfied if observation reports are construed, as they have been in this article, as classes or conjunctions of observation sentences. As was indicated at the end of n. 1, p. 108, however, this restriction of observation

Furthermore, the application of the above definition of confirmation is not restricted to hypotheses of universal conditional form (as Nicod's criterion is, for example), nor to universal hypotheses in general ; it applies, in fact, to any hypothesis which can be expressed by means of property and relation terms of the observational vocabulary of the given language, individual names, the customary connective symbols for 'not', 'and', 'or', 'if-then', and any number of universal and existential quantifiers.

Finally, as is suggested by the preceding illustrations as well as by the general considerations which underlie the establishment of the above definition, it seems that we have obtained a definition

reports to a conjunctive form is not essential ; in fact, it has been adopted here only for greater convenience of exposition, and all the preceding results, including especially the definitions and theorems of the present section, remain applicable without change if observation reports are given the more liberal interpretation characterized at the end of n. 1, p. 108. (In this case, if 'P' and 'Q' belong to the observational vocabulary, such sentences as '$P(a) \vee Q(a)$', '$P(a) \vee \sim Q(b)$', etc., would qualify as observation reports.) This broader conception of observation reports was therefore adopted in the article referred to in n. 1, p. 1 ; but it has turned out that in this case, the definition of confirmation summarized above does not generally satisfy the requirement (8.4). Thus, *e.g.*, the observation reports, $B_1 =$ '$P(a)$' and $B_2 =$ '$P(a) . (Q(b) \vee \sim Q(b))$' are logically equivalent, but while B_1 confirms (and even directly confirms) the hypothesis $H_1 =$ '$(x)P(x)$', the second report does not do so, essentially because it does not entail '$P(a) . P(b)$', which is the development of H_1 for the class of those objects mentioned in B_2. This deficiency can be remedied as follows : The fact that B_2 fails to confirm H_1 is obviously due to the circumstance that B_2 contains the individual constant 'b', without asserting anything about b : The object b is mentioned only in an analytic component of B_2. The atomic constituent '$Q(b)$' will therefore be said to occur (twice) inessentially in B_2. Generally, an atomic constituent A of a molecular sentence S will be said to occur inessentially in S if by virtue of the rules of the sentential calculus S is equivalent to a molecular sentence in which A does not occur at all. Now an object will be said to be mentioned inessentially in an observation report if it is mentioned only in such components of that report as occur inessentially in it. The sentential calculus clearly provides mechanical procedures for deciding whether a given observation report mentions any object inessentially, and for establishing equivalent formulations of the same report in which no object is mentioned inessentially. Finally, let us say that an object is mentioned essentially in an observation report if it is mentioned, but not only mentioned inessentially, in that report. Now we replace 9.1 by the following definition :

(9.1*a*) An observation report B directly confirms a hypothesis H if B entails the development of H for the class of those objects which are mentioned essentially in B.

The concept of confirmation as defined by (9.1*a*) and (9.2) now satisfies (8.4) in addition to (8.1), (8.2), (8.3) even if observation reports are construed in the broader fashion characterized earlier in this footnote.

of confirmation which also is materially adequate in the sense of being a reasonable approximation to the intended meaning of confirmation.

A brief discussion of certain special cases of confirmation might serve to shed further light on this latter aspect of our analysis.

10. *The Relative and the Absolute Concepts of Verification and Falsification.*—If an observation report entails a hypothesis *H*, then, by virtue of (8.1), it confirms *H*. This is in good agreement with the customary conception of confirming evidence; in fact, we have here an extreme case of confirmation, the case where *B conclusively confirms H*; this case is realized if, and only if, *B* entails *H*. We shall then also say that *B verifies H*. Thus, verification is a special case of confirmation; it is a logical relation between sentences; more specifically, it is simply the relation of entailment with its domain restricted to observation sentences.

Analogously, we shall say that *B conclusively disconfirms H*, or *B falsifies H*, if and only if *B* is incompatible with *H*; in this case, *B* entails the denial of *H* and therefore, by virtue of (8.1) and (9.3), confirms the denial of *H* and disconfirms *H*. Hence, falsification is a special case of disconfirmation; it is the logical relation of incompatibility between sentences, with its domain restricted to observation sentences.

Clearly, the concepts of *verification* and *falsification* as here defined are *relative;* a hypothesis can be said to be verified or falsified only with respect to some observation report; and a hypothesis may be verified by one observation report and may not be verified by another. There are, however, hypotheses which cannot be verified and others which cannot be falsified by any observation report. This will be shown presently. We shall say that a given *hypothesis is verifiable* (*falsifiable*) if it is possible to construct an observation report which verifies (falsifies) the hypothesis. Whether a hypothesis is verifiable, or falsifiable, in this sense depends exclusively on its logical form. Briefly, the following cases may be distinguished:

(*a*) If a hypothesis does not contain the quantifier terms "all" and "some" or their symbolic equivalents, then it is both verifiable and falsifiable. Thus, *e.g.*, the hypothesis "Object *a* turns blue or green" is entailed and thus verified by the report "Object *a* turns blue"; and the same hypothesis is incompatible with, and thus falsified by, the report "Object *a* turns neither blue nor green".

(*b*) A purely existential hypothesis (*i.e.* one which can be symbolized by a formula consisting of one or more existential quantifiers followed by a sentential function containing no quantifiers) is verifiable, but not falsifiable, if—as is usually assumed—the universe of discourse contains an infinite number of objects.—Thus, *e.g.*, the hypothesis " There are blue roses " is verified by the observation report " Object a is a blue rose ", but no finite observation report can ever contradict and thus falsify the hypothesis.

(*c*) Conversely, a purely universal hypothesis (symbolized by a formula consisting of one or more universal quantifiers followed by a sentential function containing no quantifiers) is falsifiable but not verifiable for an infinite universe of discourse. Thus, *e.g.*, the hypothesis " $(x)(\text{Swan}(x) \supset \text{White}(x))$ " is completely falsified by the observation report $\{\text{Swan}(a), \sim \text{White}(a)\}$; but no finite observation report can entail and thus verify the hypothesis in question.

(*d*) Hypotheses which cannot be expressed by sentences of one of the three types mentioned so far, and which in this sense require both universal and existential quantifiers for their formulation, are as a rule neither verifiable nor falsifiable.[1] Thus, *e.g.*, the hypothesis " Every substance is soluble in some solvent "—symbolically ' $(x)(Ey)\text{Soluble}(x, y)$ '—is neither entailed by, nor incompatible with any observation report, no matter how many cases of solubility or non-solubility of particular substances in particular solvents the report may list. An analogous remark applies to the hypothesis " You can fool some of the people all of the time ", whose symbolic formulation ' $(Ex)(t)\text{Fl}(x,t)$ ' contains one existential and one universal quantifier. But of course, all of the hypotheses belonging to this fourth class are capable of being confirmed or disconfirmed by suitable observation reports ; this was illustrated early in section 9 by reference to the hypothesis ' $(x)(Ey)\text{Likes}(x, y)$ '.

This rather detailed account of verification and falsification has been presented not only in the hope of further elucidating the meaning of confirmation and disconfirmation as defined above, but also in order to provide a basis for a sharp differentiation of two meanings of verification (and similarly of falsification) which have not always been clearly separated in recent discussions of the character of empirical knowledge. One of the two meanings of verification which we wish to distinguish here is the relative concept just explained ; for greater clarity we shall sometimes

[1] A more precise study of the conditions of non-verifiability and non-falsifiability would involve technicalities which are unnecessary for the purposes of the present study. Not all hypotheses of the type described in (*d*) are neither verifiable nor falsifiable ; thus, *e.g.*, the hypothesis ' $(x)(Ey)(P(x) \vee Q(y))$ ' is verified by the report ' $Q(a)$ ', and the hypothesis ' $(x)(Ey)(P(x) \,.\, Q(y))$ ' is falsified by ' $\sim P(a)$ '.

refer to it as *relative verification.* The other meaning is what may be called *absolute or definitive verification.* This latter concept of verification does not belong to formal logic, but rather to pragmatics [1]: it refers to the acceptance of hypotheses by "observers" or "scientists", etc., on the basis of relevant evidence. Generally speaking, we may distinguish three phases in the scientific test of a given hypothesis (which do not necessarily occur in the order in which they are listed here). The first phase consists in the performance of suitable experiments or observations and the ensuing acceptance of observation sentences, or of observation reports, stating the results obtained; the next phase consists in confronting the given hypothesis with the accepted observation reports, *i.e.* in ascertaining whether the latter constitute confirming, disconfirming or irrelevant evidence with respect to the hypothesis; the final phase consists either in accepting or rejecting the hypothesis on the strength of the confirming or disconfirming evidence constituted by the accepted observation reports, or in suspending judgment, awaiting the establishment of further relevant evidence.

The present study has been concerned almost exclusively with the second phase; as we have seen, this phase is of a purely logical character; the standards of evaluation here invoked—namely the criteria of confirmation, disconfirmation and neutrality—can be completely formulated in terms of concepts belonging to the field of pure logic.

The first phase, on the other hand, is of a pragmatic character; it involves no logical confrontation of sentences with other sentences. It consists in performing certain experiments or systematic observations and noting the results. The latter are expressed in sentences which have the form of observation reports, and their acceptance by the scientist is connected (by causal, not by logical relations) with experiences occurring in those tests. (Of course, a sentence which has the form of an observation report may in certain cases be accepted not on the basis of direct observation, but because it is confirmed by other observation reports which were previously established; but this process is illustrative of the second phase, which was discussed before. Here we are considering the case where a sentence is accepted directly "on the basis of experiential findings" rather than because it is supported by previously established statements.)

The third phase, too, can be construed as pragmatic, namely as consisting in a decision on the part of the scientist or a group of

[1] In the sense in which the term is used by Carnap in the work referred to in n. 1, p. 22.

scientists to accept (or reject, or leave in suspense, as the case may be) a given hypothesis after ascertaining what amount of confirming or of disconfirming evidence for the hypothesis is contained in the totality of the accepted observation sentences. However, it may well be attempted to give a reconstruction of this phase in purely logical terms. This would require the establishment of general "rules of acceptance"; roughly speaking, these rules would state how well a given hypothesis has to be confirmed by the accepted observation reports to be scientifically acceptable itself;[1] *i.e.* the rules would formulate criteria for the acceptance or rejection of a hypothesis by reference to the kind and amount of confirming or disconfirming evidence for it embodied in the totality of accepted observation reports; possibly, these criteria would also refer to such additional factors as the "simplicity" of the hypothesis in question, the manner in which it fits into the system of previously accepted theories, etc. It is at present an open question to what extent a satisfactory system of such rules can be formulated in purely logical terms.[2]

[1] A stimulating discussion of some aspects of what we have called rules of acceptance is contained in an article by Felix Kaufmann, 'The logical rules of scientific procedure', *Philosophy and Phenomenological Research*, June, 1942.

If an explicit definition of the degree of confirmation of a hypothesis were available, then it might be possible to formulate criteria of acceptance in terms of the degree to which the accepted observation reports confirm the hypothesis in question.

[2] The preceding division of the test of an empirical hypothesis into three phases of different character may prove useful for the clarification of the question whether or to what extent an empiricist conception of confirmation implies a "coherence theory of truth". This issue has recently been raised by Bertrand Russell, who, in ch. x of his *Inquiry into Meaning and Truth*, has levelled a number of objections against the views of Otto Neurath on this subject (*cf.* the articles mentioned in the next footnote), and against statements made by myself in articles published in *Analysis* in 1935 and 1936. I should like to add here a few, necessarily brief, comments on this issue.

(1) While, in the articles in *Analysis*, I argued in effect that the only possible interpretation of the phrase "Sentence S is true" is "S is highly confirmed by accepted observation reports", I should now reject this view. As the work of A. Tarski, R. Carnap, and others has shown, it is possible to define a semantical concept of truth which is not synonymous with that of strong confirmation, and which corresponds much more closely to what has customarily been referred to as truth, especially in logic, but also in other contexts. Thus, *e.g.*, if S is any empirical sentence, then either S or its denial is true in the semantical sense, but clearly it is possible that neither S nor its denial is highly confirmed by available evidence. To assert that a hypothesis is true is equivalent to asserting the hypothesis

At any rate, the acceptance of a hypothesis on the basis of a sufficient body of confirming evidence will as a rule be tentative, and will hold only " until further notice ", *i.e.* with the proviso that if new and unfavourable evidence should turn up (in other words, if new observation reports should be accepted which disconfirm the hypothesis in question) the hypothesis will be abandoned again.

Are there any exceptions to this rule ? Are there any empirical hypotheses which are capable of being established definitively, hypotheses such that we can be sure that once accepted on the basis of experiential evidence, they will never have to be revoked ? Hypotheses of this kind will be called absolutely or definitively verifiable ; and the concept of absolute or definitive falsifiability will be construed analogously.

While the existence of hypotheses which are relatively verifiable or relatively falsifiable is a simple logical fact, which was illustrated in the beginning of this section, the question of the existence of absolutely verifiable, or absolutely falsifiable, hypotheses is a highly controversial issue which has received a great deal of attention in recent empiricist writings.[1] As the problem

itself; therefore the truth of an empirical hypothesis can be ascertained only in the sense in which the hypothesis itself can be established: *i.e.* the hypothesis—and thereby *ipso facto* its truth—can be more or less well confirmed by empirical evidence ; there is no other access to the question of the truth of a hypothesis.

In the light of these considerations, it seems advisable to me to reserve the term ' truth ' for the semantical concept ; I should now phrase the statements in the *Analysis* articles as dealing with confirmation. (For a brief and very illuminating survey of the distinctive characteristics of truth and confirmation, see R. Carnap, " Wahrheit and Bewährung," *Actes Ier Congrès Internat. de Philosophie Scientifique 1935*, vol. 4 ; Paris, 1936.)

(2) It is now clear also in what sense the test of a hypothesis is a matter of confronting sentences with sentences rather than with " facts ", or a matter of the " coherence " of the hypothesis and the accepted basic sentences : All the logical aspects of scientific testing, *i.e.* all the criteria governing the second and third of the three phases distinguished above, are indeed concerned only with certain relationships between the hypotheses under test and certain other sentences (namely the accepted observation reports) ; no reference to extra-linguistic " facts " is needed. On the other hand, the first phase, the acceptance of certain basic sentences in connection with certain experiments or observations, involves, of course, extra-linguistic procedures ; but this had been explicitly stated by the author in the articles referred to before. The claim that the views concerning truth and confirmation which are held by contemporary logical empiricism involve a coherence theory of truth is therefore mistaken.

[1] *Cf.* especially A. Ayer, *The Foundations of Empirical Knowledge* (New York, 1940) ; see also the same author's article, " Verification and Experience ", *Proceedings of the Aristotelian Society* for 1937 ; R. Carnap,

is only loosely connected with the subject of this essay, we shall restrict ourselves here to a few general observations.

Let it be assumed that the language of science has the general structure characterized and presupposed in the previous discussions, especially in section 9. Then it is reasonable to expect that only such hypotheses can possibly be absolutely verifiable as are relatively verifiable by suitable observation reports; hypotheses of universal form, for example, which are not even capable of relative verification, certainly cannot be expected to be absolutely verifiable: In however many instances such a hypothesis may have been borne out by experiential findings, it is always possible that new evidence will be obtained which disconfirms the hypothesis. Let us, therefore, restrict our search for absolutely verifiable hypotheses to the class of those hypotheses which are relatively verifiable.

Suppose now that H is a hypothesis of this latter type, and that it is relatively verified, *i.e.* logically entailed, by an observation report B, and that the latter is accepted in science as an account of the outcome of some experiment or observation. Can we then say that H is absolutely confirmed, that it will never be revoked? Clearly, that depends on whether the report B has been accepted irrevocably, or whether it may conceivably suffer the fate of being disavowed later. Thus the question as to the existence of absolutely verifiable hypotheses leads back to the question of whether all, or at least some, observation reports become irrevocable parts of the system of science once they have been accepted in connection with certain observations or experiments. This question is not simply one of fact; it cannot adequately be answered by a descriptive account of the research behaviour of scientists. Here, as in all other cases of logical analysis of science, the problem calls for a "rational reconstruction" of scientific procedure, *i.e.* for the construction of a consistent and comprehensive theoretical model of scientific inquiry, which is then to serve as a system of reference, or a standard, in the examination of any particular scientific research. The

"Ueber Protokollsätze", *Erkenntnis*, vol. 3 (1932), and § 82 of the same author's *The Logical Syntax of Language* (see n. 1, p. 3). O. Neurath, "Protokollsätze", *Erkenntnis*, vol. 3 (1932); "Radikaler Physikalismus und 'wirkliche Welt'", *Erkenntnis*, vol. 4 (1934); "Pseudorationalismus der Falsifikation", *Erkenntnis*, vol. 5 (1935). K. Popper, *Logik der Forschung* (see n. 1, p. 4). H. Reichenbach, *Experience and Prediction* (Chicago, 1938), ch. iii. Bertrand Russell, *An Inquiry into Meaning and Truth* (New York, 1940), especially chs. x and xi. M. Schlick, "Ueber das Fundament der Erkenntnis", *Erkenntnis*, vol. 4 (1934).

construction of the theoretical model has, of course, to be oriented by the characteristics of actual scientific procedure, but it is not determined by the latter in the sense in which a descriptive account of some scientific study would be. Indeed, it is generally agreed that scientists sometimes infringe the standards of sound scientific procedure ; besides, for the sake of theoretical comprehensiveness and systematization, the abstract model will have to contain certain idealized elements which cannot possibly be determined in detail by a study of how scientists actually work. This is true especially of observation reports : A study of the way in which laboratory reports, or descriptions of other types of observational findings, are formulated in the practice of scientific research is of interest for the choice of assumptions concerning the form and the status of observation sentences in the model of a "language of science" ; but clearly, such a study cannot completely determine what form observation sentences are to have in the theoretical model, nor whether they are to be considered as irrevocable once they are accepted.

Perhaps an analogy may further elucidate this view concerning the character of logical analysis : Suppose that we observe two persons whose language we do not understand playing a game on some kind of chess board ; and suppose that we want to "reconstruct" the rules of the game. A mere descriptive account of the playing-behaviour of the individuals will not suffice to do this ; indeed, we should not even necessarily reject a theoretical reconstruction of the game which did not always characterize accurately the actual moves of the players : we should allow for the possibility of occasional violations of the rules. Our reconstruction would rather be guided by the objective of obtaining a consistent and comprehensive system of rules which are as simple as possible, and to which the observed playing behaviour conforms at least to a large extent. In terms of the standard thus obtained, we may then describe and critically analyze any concrete performance of the game.

The parallel is obvious ; and it appears to be clear, too, that in both cases the decision about various features of the theoretical model will have the character of a convention, which is influenced by considerations of simplicity, consistency, and comprehensiveness, and not only by a study of the actual procedure of scientists at work.[1]

[1] A clear account of the sense in which the results of logical analysis represent conventions can be found in §§ 9-11 and 25-30 of K. Popper's *Logik der Forschung*. An illustration of the considerations influencing the

This remark applies in particular to the specific question under consideration, namely whether "there are" in science any irrevocably accepted observation reports (all of whose consequences would then be absolutely verified empirical hypotheses). The situation becomes clearer when we put the question into this form: Shall we allow, in our rational reconstruction of science, for the possibility that certain observation reports may be accepted as irrevocable, or shall the acceptance of all observation reports be subject to the "until further notice" clause? In comparing the merits of the alternative stipulations, we should have to investigate the extent to which each of them is capable of elucidating the structure of scientific inquiry in terms of a simple, consistent theory. We do not propose to enter into a discussion of this question here except for mentioning that various considerations militate in favour of the convention that no observation report is to be accepted definitively and irrevocably.[1] If this alternative is chosen, then not even those hypotheses which are entailed by accepted observation reports are absolutely verified, nor are those hypotheses which are found incompatible with accepted observation reports thereby absolutely falsified: in fact, in this case, no hypothesis whatsoever would be absolutely verifiable or absolutely falsifiable. If, on the other hand, some—or even all—observation sentences are declared irrevocable once they have been accepted, then those hypotheses entailed by or incompatible with irrevocable observation sentences will be absolutely verified, or absolutely falsified, respectively.

It should now be clear that the concepts of absolute and of relative verifiability (and falsifiability) are of an entirely different character. Failure to distinguish them has caused considerable misunderstanding in recent discussions on the nature of scientific knowledge. Thus, *e.g.*, K. Popper's proposal to admit as scientific hypotheses exclusively sentences which are (relatively) falsifiable by suitable observation reports has been criticized by means of arguments which, in effect, support the claim that scientific hypotheses should not be construed as being absolutely falsifiable—a point that Popper had not denied.—As can be seen from our earlier discussion of relative falsifiability, however, Popper's proposal to limit scientific hypotheses to the form of (relatively) falsifiable sentences involves a very severe restriction

determination of various features of the theoretical model is provided by the discussion in n. 1, p. 24.

[1] *Cf.* especially the publications by Carnap, Neurath, and Popper mentioned in n. 1, p. 116; also Reichenbach, *loc. cit.*, ch. ii, § 9.

of the possible forms of scientific hypotheses [1]; in particular, it rules out all purely existential hypotheses as well as most hypotheses whose formulation requires both universal and existential quantification ; and it may be criticized on this account ; for in terms of this theoretical reconstruction of science it seems difficult or altogether impossible to give an adequate account of the status and function of the more complex scientific hypotheses and theories.—

With these remarks let us conclude our study of the logic of confirmation. What has been said above about the nature of the logical analysis of science in general, applies to the present analysis of confirmation in particular : It is a specific proposal for a systematic and comprehensive logical reconstruction of a concept which is basic for the methodology of empirical science as well as for the problem area customarily called " epistemology ". The need for a theoretical clarification of that concept was evidenced by the fact that no general theoretical account of confirmation has been available so far, and that certain widely accepted conceptions of confirmation involve difficulties so serious that it might be doubted whether a satisfactory theory of the concept is at all attainable.

It was found, however, that the problem can be solved : A general definition of confirmation, couched in purely logical terms, was developed for scientific languages of a specified and relatively simple logical character. The logical model thus obtained appeared to be satisfactory in the sense of the formal and material standards of adequacy that had been set up previously.

I have tried to state the essential features of the proposed analysis and reconstruction of confirmation as explicitly as possible in the hope of stimulating a critical discussion and of facilitating further inquiries into the various issues pertinent to this problem area. Among the open questions which seem to deserve careful consideration, I should like to mention the exploration of concepts of confirmation which fail to satisfy the general consistency condition ; the extension of the definition of confirmation to the case where even observation sentences containing quantifiers are permitted ; and finally the development of

[1] This was pointed out by R. Carnap ; *cf.* his review of Popper's book in *Erkenntnis*, vol. 5 (1935), and " Testability and Meaning " (see n. 1, p. 5) §§ 25, 26. For the discussion of Popper's falsifiability criterion, see for example H. Reichenbach, " Ueber Induktion and Wahrscheinlichkeit ", *Erkenntnis*, vol. 5 (1935) ; O. Neurath, " Pseudorationalismus der Falsifikation ", *Erkenntnis*, vol. 5 (1935).

a definition of confirmation for languages of a more complex logical structure than that incorporated in our model.[1] Languages of this kind would provide a greater variety of means of expression and would thus come closer to the high logical complexity of the language of empirical science.

[1] The languages to which our definition is applicable have the structure of the lower functional calculus without identity sign (*cf.* n. 1, p. 108); it would be highly desirable so to broaden the general theory of confirmation as to make it applicable to the lower functional calculus with identity sign, or even to the higher functional calculus; for it seems hardly possible to give a precise formulation of more complex scientific theories without the logical means of expression provided by the higher functional calculus.