

CHAPTER THREE

THE STATEMENT ACCOUNT OF SCIENCE

1. INTRODUCTION

At least the fact that the model-theoretic notion of a scientific theory as a deductively closed set of sentences is also a feature of theories accepted by the advocates of the statement account of science seems to imply that model-theoretic realism might overlap with their views also in other ways. Well, for one thing, a defender of model-theoretic account of science also looks to a semantic analysis of scientific language to fulfil her goals. Defenders of model-theoretic *realism*, however, also want to be realists, and so they want something better (or "more") than Carnap's (1966, p.256) rather non-committal view of the instrumentalist-realist debate:

My own view ... is that the conflict between the two approaches is essentially linguistic. It is a question of which way of speaking is to be preferred under a given set of circumstances. To say a theory is a reliable instrument — that is, that the predictions of observable events that it yields will be confirmed — is essentially the same as saying that the theory is true and that the theoretical, unobservable entities it speaks about exist.

Nagel also seems to be sympathetic to such a portrayal of the realist-instrumentalist debate. He (1961, p.139) writes:

Moreover, as has already been suggested, questions can be raised about a theory when it is regarded as a leading principle [instrumentalism] that are substantially the same as those which arise when the theory is used as a premise [realism]. For whether or not a material leading principle happens to be a theory, the principle is a dependable one only if the conclusions inferred from true premises in accordance with the principle are in agreement with facts of observation to some stipulated degree. In consequence, there is on the whole only a verbal difference between asking whether a theory is satisfactory (as a technique of inference) and asking whether a theory is true (as a premise).

(Empirical) scientific theories may indeed be reconstructed as positivist logical structures of (created) statements, accountable to empirical input through their predictive consequences which are identifiable by observation (if this latter notion is given its broadest interpretation). Checking this accountability is however not a mere empirical matter but also a semantic one. Tying logical analyses to exact — in the sense of "unique" — determinations of the meaning of linguistic expressions cannot succeed, given the fact that these determinations are contingent on the nature of the very models they help define. I shall elaborate on this in what follows, but first, let us consider more closely the so-called statement account of science offered by the logical positivists.

2. THE TWO-LANGUAGE VIEW OF SCIENTIFIC THEORIES

I shall first briefly discuss the "two-language" aspect of the positivist statement account of science best depicted by the logical positivists of the Vienna Circle (such as Carnap, Nagel, Feigl, Braithwaite, Reichenbach, Campbell, Ramsey, and many others). The supporters of the positivist-statement account of science depict the rational reconstruction of the language of science as a syntactic system with an axiomatised deductive theory formulated within that system. Hempel (in Suppes et al. (1973, p.368)) explains that usually defenders of this view divide a theory analytically into two constituent classes of sentences. First we have the set of so-called "internal principles" of the theory which describes "underlying entities and processes postulated by the theory" and states the "laws" or "theoretical principles" that are taken to govern them. This set of internal principles is a set of formulas containing uninterpreted extra-logical constants (that is the so-called theoretical terms), which if axiomatised, form an uninterpreted axiomatised formal system or calculus. The extra-logical constants are composed of both undefined terms and certain defined terms. The so-called theoretical terms (which in this case are terms that do not have obvious relations with "observation" terms, i.e. terms like "electron", "particle", "mass", and so on) are thus set out in an abstract formal calculus (i.e., in a symbolic language). Nagel (1961, p.90) characterises this abstract calculus as the logical structure of the "explanatory system" (i.e. the theory), and claims it to "implicitly define the basic notions of the system".

The positivist depiction of science traditionally required that every theoretical term in a scientific theory be provided with an "explicit definition" composed entirely of observational terms. The second set of sentences identified in the statement view thus is such a set of explicit definitions. It might be noted here that, although Carnap, for instance, had already by as early as 1936 given up on the notion of explicit definitions, this notion is of sufficient importance to the key notions of theory structure and reference to deserve relatively lengthy discussions in what follows. Hempel refers to them as "bridge principles" (Hempel in Feigl et al. (1958, p.46)), but I shall refer to them as correspondence rules, or c-rules, following Carnap. This set of sentences "... indicate[s] ways in which occurrences at the [theoretical] level ... are held to be linked to the phenomena the theory is to explain" (ibid.). The sentences in this set of c-rules are "... viewed as affording interpretations of theoretical expressions in a vocabulary whose terms have fully determinable and clearly understood empirical meanings ..." (ibid.). This set of correspondence rules assigns empirical (observational) content to the logical calculus by providing "co-ordinating definitions" or "empirical interpretations" for at least some of the theoretical terms in the logical calculus in terms of "pure" observational terms, i.e. the c-rules are said to relate the abstract calculus to "the concrete materials of observation and experiment" (Nagel, 1961, p.90). Hempel (in Feigl et al., 1958, p.47) remarks that

... indeed, for the deductive development of the axiomatised system, no meanings need be assigned at all to its expressions, primitive or derived. However, a deductive system can function as a theory in empirical science only if it has been given an *interpretation* by reference to empirical phenomena. We may think of such interpretation as being effected by the specification of a set of *interpretative sentences*, which connect certain terms of the theoretical vocabulary with observational terms.

Nagel (*ibid.*) also identifies a third component of theories, which he describes as "... an interpretation or a model for the abstract calculus, which supplies some flesh for the skeleton structure in terms of more or less familiar or visualisable materials". What Nagel has in mind here is much closer to a kind of Hesse-ian analog model than to the mathematical Tarskian structures I call models (see also Chapter 1). Notice that all three of the above components of theories are formulated within a "... linguistic framework of a clearly specified logical structure, which determines, in part, the rules of deductive inference" (Hempel in Feigl et al. (*ibid.*., p.46)).

Now, in the context of our discussion in terms of model-theoretic semantics, the positivist claim is thus (Przelecki, 1991, p.287) that observational terms are assigned their interpretation(s) independent of the theory. Theoretical terms, in their turn, however, "acquire [their interpretation(s)] through their connections with the observational terms as established by theory T (or rather by its definitional, analytic component)" (*ibid.*)—i.e. the set of correspondence rules. "The observational terms are thus said to be interpreted directly by ostensive (or operational) procedures, [and] the theoretical terms indirectly, by postulates [definitions] relating them to the former" (*ibid.*). Both kinds of interpretational procedure are problematic. As Przelecki (*ibid.*) claims, the interpretation of observational terms is indeterminate because of their vague ostensive nature, but also, more importantly, because the positivist procedure assigns in fact a whole class of interpretations to an observational term, each of which corresponds to a possible way of making the term precise. Theoretical terms "inherit" (*ibid.*) this indeterminacy because their interpretational procedure implies that they are interpreted through postulates (the c-rules) connecting them with the observational terms. Furthermore these (c-)postulates are themselves indeterminate. (It is in this sense that one may refer to the "openness" (*ibid.*) of theoretical terms.) Before we elaborate on the problematic nature of c-rules, the following.

Carnap (1966, p.258) divides the terms in a scientific language into three main groups: logical terms (including all the terms of pure mathematics), observational terms, and theoretical terms (which are "constructs" (*ibid.*)). He offers an analogous division of the sentences of a scientific language: Logical sentences which contain no descriptive terms; observational sentences which contain observational terms but no theoretical terms; and theoretical sentences which may be of two kinds: mixed sentences containing both theoretical and observational terms, and purely theoretical sentences containing only theoretical terms. In this way he claims that the "... entire language of science is conveniently divided into two parts. Each contains the whole of logic (including mathematics). They differ only with regard to their descriptive, nonlogical elements". He (in Hintikka (1975, p.75)) claims that the

... observational language contains only an elementary logic. The sentences of this language are assumed to be fully understood. The meaning of the theoretical language, on the other hand, always remains incomplete. It possesses a very comprehensive logic which contains all of classical mathematics.

So, in this sense, the observational language (L_O) contains observational sentences, but no theoretical terms, while the theoretical language (L_T) contains logical and theoretical sentences, with or without observational terms. In this way, it is

understood that theoretical terms

... are introduced into the language of science by a theory, T , which rests upon two kinds of postulates — the theoretical, or T -postulates, and the correspondence, or C -postulates. The T -postulates are the laws of the theory. They are pure theoretical sentences. The C -postulates, the correspondence rules, are mixed sentences, combining theoretical terms with observational terms. (Carnap, 1966, pp.258, 259)

In other words, (Carnap in Hintikka (1975, p.76)) the languages L_O and L_T are sublanguages of the scientific language L such that the constants of L are divided into logical and nonlogical (or descriptive) constants. (All mathematical constants are logical.) The primary descriptive constants of L_T are theoretical terms (which are terms not explicitly definable by observational terms), while the primary descriptive terms of L_O are observational terms.

The sublanguage L_T is obtained by adding descriptive theoretical terms to the mathematical language via theoretical postulates (the "laws" of the theory in question) containing only T -terms and correspondence postulates containing both T - and O -terms. Carnap (in Hintikka (*ibid.*, p.79)) remarks that

For the assertion of facts and the formulation of laws, in any empirical scientific theory, descriptive terms are obviously necessary. In this, it seems to me the old saying that the book of nature is written in the language of mathematics is quite misleading.

Simultaneously though, he (*ibid.*, pp.80, 81) points out that

... it is not necessary to assume new sorts of objects for the descriptive T -terms of theoretical physics. These terms designate mathematical objects ... which, however, are physically characterised, ... so they have the relations to the observational processes established by the C -postulates while simultaneously satisfying the conditions given in the T -postulates.

This almost reminds one of the distinction between linguistic, conceptual (interpretative), and empirical levels of science as portrayed in Chapter 2.

3. THEORIES AND NON-OBSERVABLES

Let us now focus a little closer on how exactly two of the main figures of the positivist, statement, or "received" view (namely Rudolf Carnap and Ernest Nagel) define the above concepts. Contributing to the theoretical/observational distinction, is the traditional statement view distinction between empirical laws and theoretical laws. Carnap (1966, p.225) defined empirical laws as "... laws that can be confirmed directly by empirical observations", and he explains that since the term "observable" "... is often used for any phenomenon that can be directly observed, ... it can be said that empirical laws are laws about 'observables'" (*ibid.*).

To Carnap the distinction between what can be termed as an observable, and what as a non-observable, has to be made according to whether an object is directly observable by the senses or measurable by relatively simple techniques (this would be an observable object), and objects that need complex and indirect procedures for measurement (unobservables) (*ibid.*, pp.225 - 226). Obviously, these points of distinction can not be regarded as offering us any final criterion for observability.

Carnap (*ibid.*, p.226) remarks that "There is a continuum which starts with direct sensory observations and proceeds to enormously complex, indirect methods of observation. Obviously no sharp line can be drawn across this continuum; it is a matter of degree".

Nagel (1961, p.80) defines what he calls an "experimental law" as formulating

... a relation between things (or traits of things) that are observable ["experimentally observable" (*ibid.*, p.81)] in the admittedly loose sense of 'observable' ... and ... the law can be validated (even if only with some 'degree of probability') by controlled observation of the things mentioned in the law.

In his context, Carnap (1966, pp.226, 227) adds that these (empirical) laws generalise the results of observation and measurement and are therefore sometimes referred to as empirical generalisations. — "The scientist makes repeated measurements, finds certain regularities, and expresses them as a law. These are empirical laws ... they are used for explaining observed facts and for predicting future observable events" (*ibid.*).

Theoretical laws, on the other hand, are laws that contain terms of a different nature than the terms contained in empirical laws. Carnap (*ibid.*, p.228) states that

The terms of a theoretical law do not refer to observables even when the physicist's wide meaning for what can be observed is adopted. They are laws about such entities as molecules, atoms, electrons, protons, electromagnetic fields, and others that cannot be measured in simple, direct ways.

Nagel (1961, p.82), in his turn, writes that

... though the commonly cited examples of theories are statements about things that in an obvious sense are unobservable, it is frequently possible to determine indirectly, by way of inferences drawn from experimental data in accordance with certain rules, important characteristics of what is ostensibly not observable.

This implies Carnap's (1966, p.228) point that theoretical laws are not generalisations of empirical laws, or an abstract way of capturing regularities among empirical generalisations. Rather, as Carnap (*ibid.*, p.229) writes, theoretical laws help explain empirical laws and predict "new" not as yet observed facts.

Just as the single, separate facts fall into place in an orderly pattern when they are generalised in an empirical law, the single and separate empirical laws fit into the orderly pattern of a theoretical law. This raises one of the main problems in the methodology of science. How can the kind of knowledge that will justify the assertion of a theoretical law be obtained? An empirical law may be justified by making observations of single facts. But to justify a theoretical law, comparable observations cannot be made because the entities referred to in theoretical laws are nonobservables.

Thus, notice that theoretical laws, rather than stated as generalisations of "particular concrete facts that can be spatiotemporally specified" (*ibid.*), are stated as hypotheses. How do we "test" theoretical hypotheses though? We derive some empirical laws from the hypothesis and test these empirical laws by observation of facts. If such "derived" empirical laws are observationally "confirmed", indirect (or partial) confirmation of the theoretical law in question has been provided. Nagel (1961, p.79) affirms this position when he writes that

Scientific knowledge takes its ultimate point of departure from problems suggested by

<http://www.springer.com/978-1-4020-0729-3>

A Model-Theoretic Realist Interpretation of Science

Ruttkamp, E.

2002, XV, 203 p., Hardcover

ISBN: 978-1-4020-0729-3