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The Problem of Reference of Theoretical Terms and the Dynamics of Scientific Knowledge

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***Abstract*—The elements of the program for the substantiation of scientific knowledge proposed by logical positivism were the dichotomy of the scientific theory's proposals for analytical and synthetic, as well as the cumulative model for the development of scientific knowledge. The result of the criticism of these elements of the program of logical positivism was the confirmations about the complete incompatibility of alternating theories and the impossibility of distinguishing between analytical and synthetic statements in their composition. This paper substantiates the point of view that such radical conclusions are erroneous. One of the reasons for such conclusions is not sufficiently accurate consideration of the intentional and extensional characteristics of the concepts included in the assumptions of the theory. The use of modern methods of logical analysis and some systems of non-classical logic allows successfully solving a number of methodological problems posed in the program of logical positivism.**

Keywords—standard interpretation of the theory; standard formalization of the theory; intension; extension; scope of the concept; content of the concept

I. INTRODUCTION

The logically-positivist program of the analysis of scientific theories based on the idea of the clarification of their structure via axiomatization of theories in some formalized languages (mostly, in the language of first-order predicate logic with equality; henceforth F.O.P.L. - 1 =). All terms of the formalized language were to be divided into empirical and theoretical. Respectively, all statements of the formalized theory were to be divided into containing only theoretical terms, only empirical terms and terms belonging to both classes [1]. As a result, the corresponding theory should have been presented as partially interpreted axiomatic system, the axioms of which were the fundamental laws of the corresponding theory, expressed in the theoretical language L_T. The observable consequences of these laws were to be formulated in a separate observation language L_O, and the relationship between concepts from languages L_T and L_O ought to have been represented via so-called correspondence rules C, containing terms from both classes. Only concepts from the language L_O had direct semantic meanings.

The theory itself was considered as a set of statements (the fundamental postulates of the theory T and the rules of correspondence C), (partially) ordered by the relation of logical consequence (formal derivation). Such an interpretation of a scientific theory is usually called "received" or "statement view".

On the basis of these ideas about the structure of a scientific theory, a linear-cumulative model of the development of scientific knowledge was constructed; this model presupposed the possibility of reduction of a preceding theory to a succeeding one. Such a reduction was interpreted as a relation of deductive logical consequence between sets of statements of various theories.

The excessively schematized and unrealistic nature of this model has become the object of criticism by opponents of the logically-positivist program, which, among other things, resulted in a thesis of incommensurability of fundamental scientific theories replacing each other [2].

According to Thomas Kuhn, in a situation of a "paradigm shift", it is not only the sets of empirically verifiable deductive consequences from the postulates of the corresponding theories that differ — the very interpretation of the basic metric and theoretical concepts underlying these theories (such as "mass" "space", "time interval", "elementary particle", etc.) undergoes radical change [3]. As a result, the meanings of terms belonging to the vocabularies of different theories prove to be fundamentally different, and theories themselves appear to be formulated in incompatible languages, which render meaningless all questions about their comparative evaluation.

This paper aims to disprove such a pessimistic conclusion.

II. LOGICAL THEORY OF CONCEPT AND THE PROBLEM OF REFERENCE OF THEORETICAL TERMS

It seems to us that the abovementioned thesis about the radical incompatibility of the vocabularies of different fundamental scientific theories essentially depends on the well-known element of the logically-positivist program, namely, on the verification theory of meaning.

According to this theory, meanings to the terms of scientific theories should have been assigned on the basis of

certain empirical procedures, and the extensional languages of classical logic were considered to be the most appropriate tool for theory formalization [4].

As a result, the *intentional* features of linguistic expressions, characterizing semantic specificity of referential relations, had been systematically confused with extensional ones (for example, the phrases "morning star" and "evening star" denote the same object - Venus, the second planet from the Sun, but they do it in a different ways).

Modern formal logic differentiates between intentional and extensional characteristics of a concept (or notion) as a special form of thought [5].

The extension of a concept is understood as a certain set (class) of objects united by a common set of attributes, and the sense (or content) of a concept is the corresponding set of attributes.

Furthermore, *the logical content* of the concept is the information expressed purely by logical form of the system of attributes, by means of which certain set of objects (the extension of the concept) is specified; *the logical extension of the concept* is a class of objects with an appropriate system of attributes [6].

The main factual content of the concept is the set/system of attributes, on the basis of which certain set of objects is specified; besides, this system is considered "by itself", that is regardless from the whole body of knowledge about specified objects and the relations between them.

Accordingly, the *main factual extension* of the concept is the class of objects possessing a given set of attributes.

The full factual content of the concept is its content, including the whole body of knowledge about the objects that are generalized and specified in the concept.

An outstanding Russian logician E. K. Voishvillo singled out the following forms of the development of the concept:

- *expansion* of the factual content of the concept in the context of a certain theory, which is a purely "quantitative" change of the concept, retaining its basic content and universum (domain);
- change of the main content of a concept, which is a "qualitative" process, usually triggered by some fundamental and irreversible changes in the theory itself, especially by a transition from one fundamental theory to another. For example, the transition from the classical model of the atom to its quantum-mechanical model is associated with the transition from classical physics to quantum [7].

Since the meanings of the concepts used in different theories differ, these concepts, according to proponents of the idea of "paradigmatic incommensurability", designate different objects (in classical mechanics mass is understood as an invariable characteristic of an object, while in relativistic mechanics this parameter changes depending on the velocity of the object).

The point is that, as E. K. Voishvillo remarks, a change of the content of a certain concept (the meaning of a certain term) does not necessarily lead to a change of the extension of the concept. The philosophers of science do not distinguish between the questions "what is denoted by this term?" and "how exactly is it understood or interpreted?" By the term "mass" both representatives of classical mechanics and representatives of relativistic mechanics mean the same thing, namely, the ability of a body to resist a change in velocity. Eventually they both use the same empirical concept. "

In other words, when the basic content of concepts included in the theory changes, the way of reference to an object/class of objects changes, but the class itself (the basic factual extension of the concept) may well stay unaltered.

In our opinion, these ideas resemble to certain extent the idea of so-called "law-cluster concepts" proposed by H. Putnam [8] with regard to a completely different problem — the problem of differentiation of empirical and theoretical terms of scientific theory.

The dichotomy of these classes of terms implied the possibility of solution of a more fundamental problem — an unambiguous distinction between analytical and synthetic statements within a certain theory.

According to the definition of R. Carnap, the truth values of analytical statements depend on their logical forms, as well as on the meanings of the logical and descriptive terms included in them.

The truth values of synthetic statements cannot be assigned to them (only) on the basis of the values of their logical and descriptive terms, since they are determined by factual information about the physical world. In combination with the verification theory of the meaning, the distinction between analytical and synthetic statements means that all meaningful statements necessarily belong (exactly) to one of these classes. This thesis can be considered as a criterion of meaningfulness: statement is meaningful if only it is analytically true/false or synthetically true/false.

How do the analytical and synthetic statements differ in the aforementioned parts L_o L_t of the language L of some theory TC?

Analytical statements belonging to L_o are logical tautologies and propositions which are true due to the peculiarities of their logical forms, the meanings of logical functions and descriptive terms of language ("All bachelors are not married"). The other part of correctly constructed statements of the language L_o will be synthetic, that is, their truth status can be figured out only by direct observation.

Further, all statements of the L_t language that are "substitutional" variants of tautologies will be analytical.

The truth-values of theoretical statements that are not tautologies, but can be attributed to analytical due to their logical forms and meanings of their logical and descriptive terms, is solved as follows.

In the structure of non-tautological analytical statements of L_t and "hybrid" statements (containing both empirical and theoretical terms), it is necessary to distinguish *factual components* and *meaning components.* The meaning components are explicitly fixed in the so-called *meaning postulates for the language L* and its subclasses L_o, L_t. In this case the analytical statements of L will include logical tautologies and logical consequences of the meaning postulates. Provided this procedure is implemented correctly, the analytical statements of L will be a subset of the consequences of the TC and the postulates of meaning for L_o. As a result, any statement of L_t, as well as any "hybrid" statement will have verifiable consequences in the L_o language, the truth of which can be established inductively on the basis of direct observations.

A natural consequence of these considerations is the division of all correctly constructed statements of the language L into analytical and synthetic [9].

One of the most famous works containing criticism of these criteria for distinguishing the analytical and synthetic statements is the article by W. Quine "Two Dogmas of Empiricism" [10].

It has been repeatedly noted that Quine's conclusions, based on a radical empiricist methodology, appear to be unduly rigorous. The analysis presented by Quine proves the impossibility of an unambiguous distinction between the analytical and synthetic statements on the bases of standard interpretation of scientific theory and verification theory of meaning. However, it does not inevitably lead to the conclusion of the *principle* impossibility of distinguishing between analytical and synthetic statements, as well as the impossibility of formulating effective criteria of the empirical meaningfulness of the statements of the theory.

The analysis of this problem, proposed by H. Putnam, seems to be more constructive and promising. Putnam admits the possibility of effective distinction between analytical and synthetic statements of a theory, although he does not suppose the division of statements into these two classes to be exhaustive. Fully in compliance with the standard interpretation of scientific theory, Putnam characterizes the analytical statements of the theory as true/false owing to the meanings of their descriptive terms (a true analytic statement can be converted into false only by changing the meanings of the terms included in it); synthetic statements are treated as potentially refutable by a certain experimental operation and verifiable via simple enumerative induction. Besides this, according to Putnam, it is possible to specify a very extensive third class of statements, which can be ascribed neither to analytical nor to synthetic. This class embraces most of scientific laws and definitions used in physics [11].

To prove this thesis, Putnam turns to the idea of a *cluster concept*. Cluster concepts differ from the usual ones by its "information superfluity": in order for a certain object to be included in the extension of a cluster concept, it should not have *all* the attributes which compose the content of this concept. These considerations led Putnam to the definition of a *law-cluster concept*. The elements of the content of such a concept are not just a set of certain predicates (attributes), but sets of laws. Each particular law can be excluded from the corresponding set without changing the extension of the initial concept.

The sets of laws constituting the content of such a concept, as a rule, do not simply specify its extension, but also characterize factual connections between the elements of the extension of the concept and the objects that are not included in it.

As an elementary example of such law-cluster concept H. Putnam gives the definition of the kinetic energy $e = 1/2 \times mv^2$. The formulation of Einstein's theory of relativity changed the content of this concept but did not affect its extension in any way. The formulations of the main postulates of Euclidean geometry also contain concepts of this type.

Law-cluster concept cannot be referred to as analytical, since changing of the meanings of the terms they contain (changing the set of laws constituting the content of a concept) does not necessarily lead to a change of their factual extensions and, accordingly, to a change of the truth values of the statements containing such concepts.

At the same time, such concepts cannot be referred to as synthetic, since they cannot be refuted on the basis of some particular experimental procedure and cannot be confirmed by a simple enumerative induction. (For example, the postulates of Euclidean geometry can be tested only in combination (conjunction) with the postulates of some applied theory (say, geometrical optics)). If the empirically verifiable consequences of this conjunction prove refuted by the observable data, this may point toward the falsehood of the whole conjunction, rather than the falsehood of the postulates of Euclidean geometry.)

This, however, does not mean that in the structure of scientific theories there are not analytical and synthetic. The statement "All bachelors are not married" does not contain any cluster concepts and can be classified as analytical. The theory may contain elementary generalizations of experimental data that can be falsified using isolated experimental procedures and therefore should be referred to as synthetic [12].

This, however, means that at least some of the postulates of meaning that determine the relationship between the descriptive terms of the theory in its standard interpretation are such cluster concepts. Accordingly, some laws and principles that are elements of the content of these concepts will belong to *other theories* from the certain domain of exploration or even to theories from related branches of scientific knowledge. Therefore, all such postulates are rather factual than analytical statements and the attempt to tell apart the factual and sense content of the theory (only) on the basis of the postulates of meaning can hardly be considered productive.

III. CONCLUSION

Thus, both the thesis of "paradigmatic incommensurability" of the vocabularies of different fundamental theories, and the thesis of the impossibility of distinguishing between analytical and synthetic statements,

proposed by the critics of the "received view" of scientific theory, are the result of neglect of certain semantic characteristics of theoretical concepts [13]. The proper analysis of these characteristics is realizable on the basis of some systems non-classical (intentional) logic and modern logical theory of concept. The advance of these areas of logical science, in its own turn, was largely stimulated by the need of resolution of technical problems which had emerged in the process of the implementation of the formal program of logical positivism.

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