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A choice-semantical approach to theoretical truth

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ABSTRACT

A central topic in the logic of science concerns the proper semantic analysis of theoretical sentences, that is sentences containing theoretical terms. In this paper, we present a novel choice-semantical account of theoretical truth based on the epsilon-term definition of theoretical terms. Specifically, we develop two ways of specifying the truth conditions of theoretical statements in a choice functional semantics, each giving rise to a corresponding logic of such statements. In order to investigate the inferential strength of these logical systems, we provide a translation of each truth definition into a modal definition of theoretical truth. Based on this, we show that the stronger notion of choice-semantical truth captures more adequately our informal semantic understanding of scientific statements.

1. Introduction

A central topic in the logic of science concerns the proper semantic analysis of theoretical terms and theoretical sentences. How, if at all, do theoretical terms refer to their objects? In what ways do the theoretical postulates of a theory contribute to the specification of the meaning of these terms? Finally, how should we evaluate semantically scientific statements that contain theoretical terms? Carnap and Ramsey were the first to address these question using formal tools, thus providing the foundation for virtually all subsequent research on the semantics of theoretical terms (cf. Friedman, 2011; Maxwell, 1970; Hempel, 1973; Lewis, 1970; Papineau, 1996; Schurz, 2014; Sneed, 1979; etc.).

Let us explain the challenges of a semantic analysis of theoretical terms with a simple example, taken from collision mechanics. Suppose we have two spherical objects s_1 and s_2. s_2 is at rest at time t, whereas s_1 moves toward s_2 with a certain velocity v_1. Then, s_1 collides with s_2 to the effect that s_1 is at rest at time t' ($t' > t$), whereas s_2 moves with the velocity $v_2' = v_1$ at t'. In other words, the first spherical object transfers its momentum to the second by an elastic collision. As is well known, this experiment lets us infer that the two objects must have the same mass.

How can we draw the distinction between theoretical and observational concepts in this experiment? Arguably, the concept of mass is theoretical because we understand this concept in terms of scientific theories, such as collision mechanics and classical mechanics. The metrical concepts of space, time and velocity may be argued to be theoretical as well because our understanding of these concepts depends on certain measurement theories. However, we can take these concepts as (relatively) observational in the context of classical and collision mechanics because classical and collision mechanics are not needed to understand space, time, and velocity in non-relativistic physics.

The challenge arising here is to devise a semantics that explains how classical and collision mechanics shape the meaning of the concept of mass. Ideally, this semantics should specify rules for the assignment of truth-values to statements about the mass of the two objects in our experiment. What may be described as standard semantics fails to account for the genuine semantic properties of

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theoretical terms. For when using a logical language $\mathscr{L}$ for the representation of statements about some domain, it is standard to assume a complete and direct extensional interpretation of the descriptive vocabulary of $\mathscr{L}$. Such an interpretation fails to display the semantic dependency of theoretical terms on a scientific theory.

Logical accounts of theoretical terms have in common that the scientific theory in question somehow constrains the interpretation of these terms. This constraint leaves some degree of indeterminacy as it does not result in a unique interpretation of theoretical terms. In our simple collision experiment, the interpretation of theoretical terms is constrained by the laws of elastic collisions, i.e. conservation of momentum as well as conservation of energy. Given the values of the velocities of the objects, before and after the collision, these two conservation laws are verified by a range of interpretations of the concept of mass. Hence, we have an indeterminacy of interpretation of the concept of mass. Yet, we want to say that certain statements about the mass of the two bodies are true, while others are false. By conservation of momentum, we know that $m_1 = m_2$ must come out true, whereas $m_1 < m_2$ should come out false; m_1 and m_2 designate the mass of the two objects, respectively.

The question thus arises how the truth-values of the statements about the mass of the two objects are determined by a range of interpretations. This is the key question to be addressed in what follows. We shall explain in detail how a scientific theory determines a range of interpretations of the theoretical terms and how these interpretations, in turn, determine the semantic values of theoretical statements.

2. Two logical accounts of theoretical terms

In Carnap's *logic of science* we can recognize two logical accounts of theoretical terms. One centers around the notion of an *indirect* and *partial* interpretation of theoretical terms (Carnap, 1939, 1956, 1958). Roughly, this account states that the interpretation of the theoretical terminology of a scientific theory is not specified directly through metatheoretic definitions but indirectly through the postulates of the theory.[1] The second account originates from the Ramsey sentence and makes use of Hilbert's epsilon operator, thereby aiming at an explicit definition of theoretical terms (Carnap, 1961; Psillos, 2000).[2] Whereas the former account is couched in semantic terms, the latter is purely syntactic. Neither approach, however, gives us an explication of theoretical truth, i.e. a fully-fledged semantics of theoretical statements.

The present paper has two principal objectives. The first one is to provide an explicit model-theoretic analysis of the epsilon account of theoretical terms based on a *choice-functional* semantics for the epsilon operator (Asser, 1957; Leisenring, 1969; Meyer Viol, 1995). In particular, we shall develop two different choice-semantical approaches to the semantics of theoretical statements, each giving rise to a corresponding logic of such statements. The second objective of the paper is to investigate the inferential strength of the two logics underlying the different choice-semantical approaches to theoretical truth. This will be done by relating them to recent work on the model-theoretic explication of Carnap's *indirect interpretation* view of theoretical terms.[3] More precisely, we shall exploit the modal reconstruction of theoretical truth by Andreas (2010). According to this account, a scientific sentence (containing both observational and theoretical terms) is theoretically true if and only if it is true in *all* admissible extensions of its intended observational model, that is, in all model extensions that interpret the theoretical terms in accordance with the theory's axioms. This modal explication turns out to be equivalent with the particular choice-semantical explication of theoretical truth to be developed here.[4]

Moreover, the equivalence between the modal explication of the indirect interpretation view of theoretical terms and the choice functional account of the epsilon reconstruction of theoretical knowledge also shows that the two accounts are *conceptually* similar in several respects. In particular, the meaning of theoretical terms is specified *contextually*, i.e. relative to a given theoretical context in both approaches. Moreover, both accounts make precise in different ways a central intuition driving systematic work on theoretical terms since Carnap, viz., that the determination of such terms by a scientific theory remains *incomplete* (see Andreas, 2010; Schiemer & Gratzl).

The paper will be organized as follows: Section 3 briefly outlines the epsilon-term reconstruction of scientific theories as well as the epsilon logic and choice semantics underlying it. Based on this, we present two possible model-theoretic explications of theoretical truth in line with Carnap's general approach. Section 4 will then turn to a closer comparison between these choice-semantical explications and the above mentioned modal account of theoretical truth. By means of this comparison, we shall investigate the inferential strength of the two choice-semantical explications of theoretical truth in Section 5. Finally, Section 7 will give a summary of our findings.

3. Choice semantics and theoretical truth

In this section, we develop a choice-semantical account of theoretical truth based on Carnap's epsilon-term definition of theoretical terms (Carnap, 1961; Psillos, 2000). According to the syntactic (or received) view of theories, a scientific theory T can be expressed in a higher-order language $\mathscr{L}(V_o,V_t)$ that contains a set of observational terms V_o and a set of theoretical terms V_t. To keep the discussion simple, we will assume that the descriptive vocabulary consists only of unary predicates and relational symbols. A complex sentence TC of this language is usually said to express the conjunction of the axioms of T (see, e.g., Andreas, 2010; Ketland, 2004).

Carnap's logical reconstruction of theories is based on two steps.[5] The first one is the elimination of the theoretical terms in $\mathscr{L}(V_o,V_t)$ by the *ramsification* of a theory. As is well know, the Ramsey sentence of a given T is constructed by substituting its theoretical terms by existentially quantified variables of the proper logical category:

$$\exists X_1 \ldots \exists X_n \, TC(X_1, \ldots, X_n, O_1, \ldots O_m)$$

The Ramsey sentence—henceforth abbreviated by $RS(T)$—is expressed in the "observational" sublanguage $\mathscr{L}(V_o)$ of the theoretical language $\mathscr{L}(V_o,V_t)$. Roughly speaking, it says that there exist theoretical relations in the universe of the language that have the features which the theory attributes to them.

Carnap's second step consists in the subsequent reintroduction of the theoretical vocabulary through an explicit definition in

[1] See Andreas (2013) for a survey of different model-theoretic explications of this view in the modern literature.

[2] Compare Schiemer & Gratzl for a systematic study of the epsilon reconstruction of theories and its compatibility with scientific structuralism.

[3] Compare Friedman (2011) for a detailed discussion of this account of theoretical terms and its historical development in Carnap's work.

[4] The modal explication is inspired by supervaluation logic, as readers will easily recognize in Section 4.

[5] See also Schiemer & Gratzl for a more detailed presentation of the epsilon reconstruction of scientific theories.