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The language of science: meaning variance and theory comparison

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Abstract

The paper gives an overview of key themes of twentieth-century philosophical treatment of the language of science, with special emphasis on the meaning variance of scientific terms and the comparison of alternative theories. These themes are dealt with via discussion of the topics of: (a) the logical positivist principle of verifiability and the problem of the meaning of theoretical terms, (b) the post-positivist thesis of semantic incommensurability; and (c) the scientific realist response to incommensurability based on the causal theory of reference. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

For much of the twentieth century, the philosophical imagination has been captivated by language. Few aspects of language, or of language use, have escaped philosophical scrutiny. Traditional philosophical problems have been recast as issues in the philosophy of language. And philosophers have employed techniques of linguistic and conceptual analysis in an attempt to solve or dissolve these problems.

The philosophy of science has been no exception. From the topics of confirmation and explanation to those of laws of nature and the dynamics of

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theory change, linguistic aspects of science have loomed large. One enduring theme has been an interest in the semantic and epistemic features of scientific discourse about the world. Here two key questions have been the focus of much attention. First, how does the vocabulary used by scientists acquire its meaning? Second, how is scientific vocabulary related to reality? One might characterize these two questions, respectively, as the question of the *meaning* of scientific terms as opposed to the question of the *reference* of such terms.

Debate about these two questions has in large part been conditioned by a distinction between two kinds of vocabulary employed in science. On the one hand, there is the *observational vocabulary* (e.g., 'red', 'smooth'), which scientists employ to report upon observable phenomena and objects, which are directly perceived by means of their senses. On the other hand, scientists employ *theoretical vocabulary* (e.g., 'electron', 'gene') when they speak about the unobservable entities which are postulated by scientific theories to explain observable phenomena. The distinction turns, at base, on a contrast between observable and unobservable entities. But it also reflects a difference in the conditions which govern the application of the two kinds of vocabulary. For, while observational terms may be applied on the basis of immediate experience of the items to which they refer, theoretical terms are unable to be employed on the basis of direct perception of their referents.

For philosophers of a broadly empiricist persuasion, the distinction between observational and theoretical terms marks an important semantic and epistemic difference. This is principally because observational terms may be defined, as well as applied, on the basis of experience alone. It is also due to the fact that the truth of empirical claims, which employ observational terms to describe observed phenomena, may be established by means of direct empirical test. By contrast, neither the meaning of a theoretical term, nor the truth of a claim about unobservable theoretical entities, may be established on the basis of observation alone.

For philosophers less inclined to empiricism, the distinction between observational and theoretical terms bears little significance, and may even seem misconceived. It has, for example, been argued by some philosophers that the distinction fails to correspond to a genuine difference in linguistic use, since theoretical terms may be applied to observable items, and vice versa. It has also been argued that, regardless of the validity of the distinction, scientists routinely describe observed phenomena using the terms of an operative scientific theory. Most importantly for present purposes, it has been argued that the meaning of observational terms depends upon theoretical context. Thus, while there may be a pragmatic distinction based on the conditions of application of terms, no semantic distinction may be drawn between observational and theoretical terms.[1]

The idea that the meaning of observational vocabulary depends on theoretical

[1] As argued, for instance, by Feyerabend ([1958]1981). For general discussion of these issues, see the Introduction to Grandy (1970).

context has serious implications for the rationality of scientific theory choice. For if the meaning of observational terms depends on theoretical context, rather than being fixed independently of theory, then the meaning of such terms may vary with theory. In the absence of a semantically invariant observation language, which is neutral between theories, the problem arises of how to compare the empirical claims which alternative scientific theories make about the world. If there is no shared observation language, then what one theory says about the world may neither agree nor disagree with any empirical claim made by an alternative theory. But if claims made by alternative theories cannot be compared, then there may be no rational basis on which to choose one theory over the other. The thesis that the content of theories may be incomparable for semantic reasons is known as *the incommensurability thesis*.

The issue of meaning variance interacts in complex ways with central currents in twentieth-century philosophy of science. In this paper, I employ meaning variance as a unifying theme to trace some major developments in philosophical accounts of the language of science which have occurred in this century. In Section 2, I briefly examine the empiricist account of scientific discourse associated in the first half of this century with the philosophical movement known as *logical positivism*. Sections 3 and 4 trace the problem of meaning variance to the emergence in the second half of the century of a *post-positivist* or *historical* school in the philosophy of science. Sections 5 and 6 consider the attempt to treat the problem as a problem about reference, with special emphasis on the use made by *scientific realist* philosophers of science of a causal theory of reference. In Section 7 I will briefly conclude by sketching my view of 'the current state of play' of the meaning variance issue. As with any survey of a complex subject, some matters of both substance and nuance will be neglected. But it cannot be denied that the issues discussed here number among the most significant themes in twentieth-century philosophical treatment of the language of science.

2. Logical positivism

'Logical positivism' is the name commonly used for a scientifically minded philosophical movement which emerged in Vienna in the 1920s and 1930s. The movement grew up around a group of like-minded philosophers and scientists known as the *Vienna Circle*, which included such figures as Moritz Schlick, Otto Neurath and Rudolf Carnap, who met regularly to discuss philosophical ideas at the University of Vienna. Also associated with the Circle, but not members, were Ludwig Wittgenstein and Karl Popper, as well as the English philosopher A.J. Ayer, who visited Vienna in the early 1930s. With the rise of Nazism in the mid-1930s, the Circle dispersed, its members moving to the United States and Great Britain, where their influence significantly shaped the subsequent development of philosophy in the English-speaking world.

Logical positivism has usually been understood as an extreme form of empiricism.[2] As such, its supporters adhered to the view that both the content of our empirical concepts and the evidential support for our beliefs about the world must derive from sensory experience. The historical roots of logical positivism trace back to eighteenth-century British empiricism, though the name 'positivism' derives from the *philosophie positive* of the nineteenth century French thinker Auguste Comte. What set the positivism of the Vienna Circle apart from its predecessors was a tendency to pose philosophical problems in terms of language, and a systematic attempt to apply the techniques of modern symbolic logic to the treatment of these problems.

I will now briefly discuss two central themes of logical positivism, which are of special relevance to the language of science: the principle of verifiability, and the meaning of theoretical terms.

2.1. The principle of verifiability

One central question addressed by logical positivism was the question of how cognitively significant discourse about the world is possible. The response favoured at first by positivists was that a significant assertion is one which may be tested for truth or falsity by means of experience. On the basis of such a response, positivists sought to enforce a sharp distinction between significant and non-significant discourse about the world. Since metaphysical claims about a transcendent reality lying beyond experience cannot be empirically verified, this led the positivists to dismiss metaphysics as meaningless nonsense.

The idea that significant assertion requires the possibility of empirical test is known as *verificationism*. Logical positivists expressed this idea in the form of *the principle of verifiability*, as exemplified by the following passage from Moritz Schlick:

> ... there is only one way of giving meaning to a sentence, of making it a proposition: we must indicate the rules for how it shall be used, in other words: we must describe the facts which will make the proposition 'true', and we must be able to distinguish them from the facts which will make it 'false'. In still other words: The Meaning of a Proposition is the Method of its Verification. The question 'What does this sentence mean?' is identical with (has the same answer as) the question: 'How is this proposition verified?' (Schlick, [1938]1981, p. 34).

The principle that meaning consists in method of verification serves two functions. First, as in the above quote, it specifies what the meaning of a sentence consists in, namely its conditions of verification. Second, it specifies a criterion of

[2] Recent scholarship suggests that the usual understanding of logical positivism may be misleading. Far from being simply an extreme outgrowth of earlier empiricism, logical positivists were equally responsive to neo-Kantian philosophy. See, for example, Coffa (1991), Friedman (1993) and Parrini (1998).

significance, which a sentence must satisfy in order to be meaningful. For, if no verification conditions are specified, then, as Schlick goes on to say, 'our words do not form a real proposition at all, they are mere noises without meaning' (Schlick, [1938]1981, p. 35).[3]

While many philosophers continue to associate meaning with verification, the strict identification of meaning with empirical verification conditions is now widely seen as untenable. As Schlick himself realized, meaning cannot require present testability, on pain of eliminating all currently untestable sentences as meaningless; it requires instead verification in principle. Nor may meaning be identified with conclusive verification, since, as Popper argued, that would render statements of the universal laws of science meaningless (Popper, 1959, p. 36). By the 1950s, the difficulties in applying verificationism at the level of sentences led C.G. Hempel to conclude that cognitive significance 'can at best be attributed to sentences forming a theoretical system, and perhaps rather to such systems as wholes' (Hempel, 1965, p. 117). Another problem that bedeviled positivism was the status of the principle of verifiability itself: since it is evidently not an empirical claim which may be verified by empirical test, the principle itself appears to be devoid of cognitive significance. While the positivists sought to meet this problem, for example by proposing the principle as a convention rather than a statement, some philosophers have taken it to show that positivism was fundamentally incoherent (e.g., Putnam 1981, p. 113).

2.2. The meaning of theoretical terms

Another approach to cognitive significance pursued by logical positivism focused on the meaning of individual terms, rather than sentences. But, while the verifiability criterion made the meaning of theoretical statements problematic, similar problems arose as well for theoretical terms. For if experience is the source of meaning, terms whose meaning cannot be directly given by appeal to experience may fail to have any meaning at all.

Positivists tended to assume that observational terms acquire meaning by direct reference to observable entities, e.g. by ostensive definition. Since a theoretical term may not be defined by means of a direct, ostensive identification of an unobservable theoretical entity, it was thought that theoretical terms might be defined by means of a connection with observational vocabulary. Some early positivists held that the meaning of a theoretical term might be fully specified by means of an explicit definition using only observational terms. On such a view, a theoretical term is exactly synonymous with a complex expression consisting entirely of observational terms, and its sole function is as convenient shorthand for the complex expression. But explicit definition fails even before the level of full-blown theoretical terms is reached. As shown by Carnap in 'Testability and

[3] For the distinction between a criterion of meaning and a criterion of meaningfulness, see Hanfling (1981, p. 5).

Meaning' (Carnap, [1936]1970), dispositional terms (e.g., 'fragile', 'soluble') cannot be fully defined using observational terms alone. While the observational circumstances in which a disposition is displayed may be specified, the disposition itself obtains even when the observable circumstances do not. Yet the disposition *itself* (e.g., to dissolve if placed in water) is not something that can be observed.

In the absence of explicit definability, later positivists adopted a *partial interpretation* approach to the meaning of theoretical terms. In 'Testability and Meaning', Carnap showed how disposition terms may be introduced by means of 'reduction sentences' which specify the observable circumstances in which the disposition is manifest (e.g., 'If a glass is struck, then if it breaks it is fragile'). While reduction sentences do not fully define a disposition term, a set of such sentences partially defines the term by specifying empirical conditions in which it applies. Such specification of application conditions only partially defines the term because it fails to specify meaning for circumstances in which the observable conditions do not obtain (e.g., when the glass is not struck).

By the mid-1950s, the partial interpretation approach had come to form the basis of a liberalized positivist account of the language of science, known as the 'double language model'.[4] According to this account, the language of science divides into distinct observational and theoretical vocabularies, where theoretical terms are partially defined via 'correspondence rules' which link them to observational terms. However, while some theoretical terms derive their meaning via correspondence rules which link them directly to observation terms, others, having no such link, gain their meaning indirectly via links with other theoretical terms.

With the double language model, a holistic view of meaning starts to emerge. For on this account, the meaning of theoretical terms may depend on a variety of complex relations between observational and theoretical terms. As a result, the meaning of theoretical terms may be subject to variation with change of theory as the relations between theoretical and observational terms undergo revision in the course of theory change. In this way, the liberalized positivism of the 1950s allowed, at least in principle, for the possibility of meaning variance of theoretical terms. This possibility was not always recognized by advocates of the historical approach who sought to overcome positivist theory of language.[5]

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[4] For the double language model, see, for example, Carnap (1956) and Nagel (1961). As more liberalized forms of positivism appeared at the mid-century, it became increasingly common to refer to the approach by the name 'logical empiricism', rather than 'logical positivism', the latter sometimes being reserved for the more strictly empiricist approaches of the early part of the century.

[5] There is a growing literature which documents the anticipation of the meaning variance thesis in positivist accounts of scientific language. See, e.g. Reisch (1991), who discusses Carnap's letters to Kuhn, which Carnap wrote in his capacity as Editor of the *Encyclopedia of Unified Science*, in which Kuhn's *The Structure of Scientific Revolutions* appeared. One of the best early studies of the convergence between positivist theory of meaning and the meaning variance thesis remains English (1978). Other useful discussions of positivist theory of meaning may be found in Hempel (1965) and Papineau (1979).

3. The historical turn

In the 1950s and 1960s a new, post-positivist approach to the philosophy of science emerged, which highlighted developmental and contextual aspects of science, and placed great emphasis on the manner in which both scientific theories and scientific practice evolve as a historical process.[6] The main participants in this *historical turn* initially included such key figures as Paul Feyerabend, N.R. Hanson, Thomas S. Kuhn, Michael Polanyi, and Stephen Toulmin, though they were later joined by Imre Lakatos and Larry Laudan. Of those initially involved in the historical movement, most drew considerable inspiration from the later philosophy of Ludwig Wittgenstein, Gestalt psychology and anti-Whiggish historiography of science. The result was an approach to science more inclined to interpret science in terms of its past than to reconstruct it in terms of logic.

While historical philosophers of science divide among themselves on points of detail, it is possible to specify a number of salient themes which broadly characterize the historical approach as a philosophical school:

1. an emphasis on the role of large-scale, enduring traditions of scientific research;
2. rejection of a unique scientific method in favour of a variety of methodological standards of theory-appraisal;
3. denial of a sharp division between theory and fact, combined with assertion of the thesis that observation is 'theory-laden';
4. rejection of an independently meaningful observation language in favour of the context-dependence of the meaning of observation terms on theoretical context.

In what follows, I will briefly comment on each of these four themes, though point (4.) will receive more extended attention in the next section.

The importance of enduring traditions in the history of science was forcefully shown in the seminal text of the historical movement, T.S. Kuhn's *The Structure of Scientific Revolutions*, and further elaborated in subsequent work by Lakatos (1970) and Laudan (1978). These authors stress that individual scientific theories (e.g., Copernicus' or Kepler's theories of the solar system) are usually developed within the context of a set of underlying theoretical assumptions (e.g., heliocentric astronomy) which tend to be preserved through variation at the level of specific theory. Such underlying assumptions constitute a general perspective or world-view, and are the central ingredient in the deep-level theoretical frameworks which Kuhn described as 'paradigms'. They include both substantive assumptions about the way the world is and methodological ones about how to investigate the world. But unlike empirically testable predictions made by theories, such deep-level frameworks do not admit of empirical test, and may only be evaluated by comparison with rival sets of assumptions over a sustained period of time.

The issue of how to evaluate a scientific tradition points to the second major

[6] Overviews of the development of the philosophy of science in this century, which may be helpful in understanding the transition from positivist to post-positivist philosophy of science may be found in Chalmers (1982) and Gillies (1993).

theme of the historical school. Traditional philosophers typically approached scientific theory appraisal in terms of a unique scientific method, employed throughout the sciences in all stages of the history of science. By contrast, the historical school laid great stress on the historical variation of patterns of scientific reasoning and theory appraisal. In their view, the history of science does not show that scientific method remains fixed while theories change, but that method is open to revision along with theory. Kuhn argued, for example, that standards of theory appraisal vary with scientific paradigm, and seemed to deny the existence of any such standards independent of paradigm (Kuhn, 1970a, pp. 94, 103). Somewhat later, Feyerabend argued that all methodological rules proposed by philosophers of science have in fact been violated at some stage in the history of science, and that there have been good grounds for violating them (Feyerabend, 1975, p. 23). Such denial of a fixed method has given rise to a widespread epistemological relativist denial of objective criteria of rationality amongst those whose work has been influenced by the historical movement.

One might, of course, think that even in the absence of a fixed method, sense experience might provide a neutral arbiter between rival theories. But it is just here, however, that the historical school comes into most direct conflict with traditional empiricist philosophy of science. For where empiricists held that sense perception provides objective, observer-invariant grounds for theory appraisal, historical philosophers of science tend to deny a sharp divide between matters of observed fact and theory. As was famously argued by N.R. Hanson, in his *Patterns of Discovery*, scientific observation is 'theory-laden', due to the thoroughgoing influence of theoretical background upon the content of experience. Thus, despite being presented with identical external circumstances, scientists may have divergent visual experiences, because, as Hanson says, 'there is more to seeing than meets the eyeball' (Hanson, 1958, p. 7). In similar vein, the phenomenon of theory-ladenness led Kuhn to suggest that 'the proponents of competing paradigms practice their trades in different worlds' (Kuhn, 1970a, p. 150).

The theory-dependence of observation brings us back to language. For, it was argued, not just that observation is theory-laden, but that the very language used to report observation depends on theory as well. As a result, rather than being independent of theory, the meaning of an observation term varies with the theoretical context in which it is employed. The issue of meaning variance leads to the topic of the next section, the semantic incommensurability of theories.

4. Incommensurability

One of the most controversial claims to emerge from the historical turn was the claim made by Kuhn and Feyerabend that alternative scientific theories may be incommensurable. While the meaning of the term 'incommensurable' resists precise specification, for present purposes it may be understood to mean that there are limits on the comparison of theories for evaluative purposes. More specifically, I will treat the claim of incommensurability as the claim that the content of one

scientific theory may not be directly compared with the content of an alternative such theory.[7]

Kuhn set the claim of incommensurability within the context of his account of scientific theory change as revolutionary transition between paradigms. On Kuhn's account, the 'normal science' pursued by scientists under the guidance of a reigning paradigm differs in fundamental ways from that undertaken within the context of an alternative paradigm:

> ... the normal-scientific tradition that emerges from a scientific revolution is not only incompatible but often actually incommensurable with that which has gone before (Kuhn, 1970a, p. 103).

The incommensurability of paradigms sets limits on the extent to which competing paradigms may be evaluated in a comparative manner, for example, by appeal to shared standards of theory appraisal, or conflicting predictions about the world. As a consequence, it is obscure on Kuhn's view how scientists may decide between competing paradigms on a rational basis.

For Feyerabend, the notion of incommensurability formed part of his critique of the empiricist model of the relations between successive theories (see Feyerabend, [1962]1981). Empiricists held that an earlier theory is either explained by, or reduced to, a later, more comprehensive theory by deductive subsumption of the laws of the earlier theory under the laws of the later theory. Feyerabend argued that the deductive relations between theories required by this model entail a semantic condition of meaning invariance, which is routinely violated in the course of scientific practice, as the meaning of scientific terminology undergoes profound changes in the transition between alternative theories.

It will simplify exposition to formulate the incommensurability thesis in terms of the following three features of the semantic relations between the vocabulary of alternative scientific theories:

1. meaning variance;
2. translation failure;
3. content incomparability.

The basic idea of the incommensurability thesis is that the content of alternative scientific theories is unable to be compared because of translation failure due to meaning variance of their vocabulary. I will now briefly discuss each of these points in turn.

4.1. Meaning variance

The claim that meaning varies in the transition between theories may be presented by means of an argument which proceeds in three steps.

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[7] For a more nuanced discussion of the concept of incommensurability, see Sankey (1993), as well as Hoyningen-Huene (1993, pp. 206–222), who offers an opposing analysis of the concept.

The first step is to reject the empiricist assumption that there is a theory-neutral observation language which is meaningful independently of theory and semantically invariant between theories.[8] An independently meaningful observation language of the kind sought by empiricists would be a semantically neutral medium of expression which would provide common ground between scientific theories, on the basis of which such theories may be directly compared.

The second step is to argue, against the idea of an invariant observation language, that the meaning of observational terms depends on the theoretical context in which they are employed. According to such a 'contextual theory of meaning', an observational term obtains its meaning from the theory which is used to describe and explain the observed item to which the term is applied. Meaning is determined in a holistic manner, by means of the whole theoretical context in which the observational term is used.

The third step is to conclude that meaning varies due to the context-dependence of meaning. In particular, it follows from the context-dependence of meaning, that the meaning of observational and theoretical terms must vary with respect to the theoretical context in which they are employed. Thus, in the transition between scientific theories, there is change of meaning from one theory to the next. More precisely, where the same terms occur in different theories, such terms will be employed with a different meaning in the context of each theory.[9]

4.2. Translation failure

The claim that the vocabulary employed by theories semantically varies between theories does not, by itself, entail incomparability of the content of theories. The latter requires, beyond mere difference of meaning, that there be failure to translate between the vocabulary employed by meaning variant theories.

There are a number of ways to argue for translation failure, of which perhaps the most straightforward is as follows. On the assumption that there is radical meaning change between theories, no term of one theory has the same meaning as any term of the other theory. As a result of such complete absence of common meaning, no statement entailed by one theory may be translated by means of a

[8] There are various ways to argue for such a rejection, e.g., by arguing against the ostensive-definition model of language learning, or to argue that neither the experience nor the conditions associated with use of an observational term fix its meaning. The latter option is pursued by Feyerabend ([1958]1981).

[9] It is important to make two qualifications about meaning variance. First, the claim of meaning variance admits of two interpretations: *radical* meaning variance occurs if all (or perhaps most) of the terms employed by theories change their meaning; meaning variance is *partial* if only a restricted class of the terms change. The radical version tends to be found in Feyerabend, the partial version in Kuhn. Second, the sort of meaning variance of present relevance is restricted to alternative theories about the *same domain* of phenomena. Since theories in different domains (e.g., continental drift and psychoanalysis) do not compete, semantic variation between such theories leads to no serious difficulties for theory choice. This requirement raises a serious difficulty for the incommensurability thesis, the so-called 'rivalry objection': how can theories whose terms have no meaning in common constitute rival explanations of the same phenomena?

statement entailed by the other theory. Thus, there is a total translation failure between the theories.[10]

4.3. Content incomparability

If meaning variance is understood to entail translation failure between theories, then a number of important consequences follow from meaning variance. For one thing, translation failure gives rise to difficulties of communication and understanding between the advocates of such rival theories. However, the consequence of most concern to philosophers of science is that the content of meaning variant theories is unable to be compared. That is, if it is impossible to translate from the vocabulary of one theory into another, then no statement of one theory can be matched with a corresponding statement of the other theory which asserts or denies the same thing: there may be neither agreement nor disagreement between theories. But, if this is so, then it is impossible to directly compare the claims about the world made by one theory with the claims made about the world by the other theory. In short, the content of such theories is not directly comparable.

One immediate consequence of the inability to compare content is the impossibility of 'crucial experiments'. A crucial experiment is a test designed to choose between rival, equally well-supported theories, by means of a test of an observational prediction on which the theories disagree. If the result of the observation is unambiguous, such a test supports one theory while refuting the other. However, if no common language exists in which the consequences of rival theories may be expressed, then no predictive consequence of one theory may be formulated with which the other theory disagrees. Therefore, there may be no crucial test between such theories.

4.4. The incommensurability thesis

It is now possible to formulate the thesis of incommensurability in a perspicuous manner. Two alternative scientific theories are incommensurable just in case:

1. the meaning of the vocabulary employed by theories varies between theories,
2. translation is impossible from the vocabulary of one theory into the vocabulary of the other,
3. as a result of (1.) and (2.), the content of such theories may not be compared.

[10] Of course, if the meaning variance is only partial, then the translation failure is also only partial. It should be added that a number of other ways of arguing for untranslatability have been employed. For instance, Feyerabend argues that the conditions of concept formation in one theory forbid the formation of concepts from another theory (Feyerabend, 1978, p. 68, note 118). Kuhn argues that within a theory a central complex of key terms is holistically interdefined in such a way that terms from another theoretical complex are unable to be translated into it (Kuhn, 1983).

5. Reference and theory comparison

The most influential objection to the incommensurability thesis has been the claim that while alternative scientific theories may be meaning variant they may still be compared with respect to content. The reason is that meaning variance between theories does not entail reference variance, and reference variance is what is needed for theories to be incomparable for content.

5.1. Scheffler and referential stability

The referential response to incommensurability was forcefully elaborated by Israel Scheffler in his book *Science and Subjectivity* (Scheffer, 1967, Chap. 3). Scheffler presented the response within the context of a Fregean distinction between sense and reference. According to this distinction, the meaning of a term divides into two components: the sense of a term is the concept or definition a speaker grasps when understanding what the term means, while the reference of a term is the object or set of objects which the term names.

Two features of the Fregean account of meaning are of most relevance in the present context. First, terms may differ in sense even though they refer to the same thing. Frege's classic example is that of the expressions 'Evening Star' and 'Morning Star', which have different senses though they refer to the same thing, viz., the planet Venus. Second, the sense of a term determines the term's reference. In particular, if we assume that the sense of a term is specified by means of a description, then the reference of the term is determined as that thing which satisfies the description which gives the sense of the term.

The crux of Scheffler's objection to the incommensurability thesis is that the content of theories may be compared by means of common reference, even if their terms differ in sense. The reason is that two sentences may be jointly incompatible though their constituent expressions do not have the same sense. Thus, suppose someone says 'The Evening Star is a star', while someone else asserts that 'The Morning Star is a planet'. Because the Evening Star and Morning Star are the same thing, and stars are not planets, it is impossible for both assertions to be true. Thus, despite employing words which differ in sense, the assertions are incapable of both being true, since they are about the same thing.

In general, statements about the world may conflict even if they contain different terms, or terms which differ in sense, provided that their constituent terms refer to the same things. Because of this, it is possible to compare the content of rival theories whose terms differ in sense. For, while rival theories might employ terms with different meanings, if their terms refer to the same things, then it is possible for their claims about the world to agree or disagree.

5.2. Reference change

Despite the evident force of the referential objection, a reply to Scheffler's objection was readily available to Kuhn and Feyerabend. For they were able

simply to argue that in cases of meaning variance between theories, both the sense and the reference of terms employed by theories are subject to change (cf. Kuhn, 1970a, p. 102, 1970b, p. 269; Feyerabend, [1965]1981, p. 98). If they are right, Scheffler's appeal to the distinction between sense and reference is unavailing. For if reference is discontinuous between theories, there is no overlap of reference, and content cannot be compared.

There are a number of reasons to think there may be widespread change of reference between meaning-variant theories. For one thing, historical cases suggest that change of reference is prevalent in the history of science; e.g., modern use of the term 'atom' seems not to refer to the same kind of entity as did ancient use of the term. For another thing, the differences in descriptions which theories give of the entities to which they refer may be so extreme that the descriptive content associated with terms must pick out completely distinct sets of things. Alternatively, the descriptive content associated with terms by one theory may be incompatible with the content associated with terms by another theory, so that the descriptive content of the alternative theories may not be satisfied by the same sets of things.

The crux of the issue is the assumption that sense determines reference. This is because the descriptions which scientists give of the entities they study are themselves subject to revision as scientists alter their theories about the world. But if descriptions of entities change in the transition between theories, the senses of the terms used by the theories will also change. Hence, there may be discontinuity of reference between theories. But without shared reference, the content of theories cannot be compared.

Thus, Kuhn's and Feyerabend's reply to Scheffler is that meaning variance includes reference as well as sense. Hence, an appeal to reference is unable to serve as basis for an objection to the incommensurability thesis. Moreover, if reference varies radically between theories, the content of theories may not be compared due to absence of common reference of theories. In this way, reference change gives rise to a referential version of the incommensurability thesis — incommensurability due to reference variance.

6. The causal theory of reference

The claim by Kuhn and Feyerabend that reference varies in the course of scientific theory change is of particular concern to philosophers of a *scientific realist* persuasion. Scientific realists defend the view that the aim of science is to discover the truth about an objective reality, and that scientific progress consists in an increasing convergence on the truth about such a reality. But, if the history of science consists in repeated transitions between theories which refer to none of the same things, then it is impossible for progress to occur in the sense required by the scientific realist. For if later theories refer to none of the same things to which earlier theories referred, then it is impossible for the transition between such

theories to involve an increase of truths known about common items of a shared, objective reality.[11]

For this reason, scientific realists have sought to defend Scheffler's appeal to reference against Kuhn's and Feyerabend's claim of referential variance. They have done so by drawing attention to the issue of the determination of reference. Kuhn's and Feyerabend's reference change response to Scheffler turns on the assumption that sense determines reference. But, as has been suggested by scientific realist advocates of a causal theory of reference, reference need not be determined by sense at all (e.g., Putnam, 1975a). Rather, reference is determined by means of various causal and other pragmatic relations which speakers enter with their environment in the course of linguistic interaction with the world. If this is right, then the reference of a term may be unaffected by variation of sense, and it may be possible to vindicate Scheffler's objection to incommensurability by setting the objection within the framework of a causal theory of reference.

Before explaining this response to the incommensurability thesis, let me briefly introduce the causal theory of reference. I will first discuss an example designed to show that reference is not determined by sense, and will then say something about the mechanism of reference.

6.1. Water on Twin-earth

Hilary Putnam presents a science fiction example which is designed to elicit intuitions favouring the view that reference is not determined by descriptive content (Putnam, 1975b, pp. 223–227). This is his well known example of Twin-earth. We are to imagine a planet which is in many ways just like the earth. Its sole distinguishing feature is that the liquid which flows in its rivers, fills its oceans and falls from the sky in the form of rain is not in fact the same liquid as is found on earth. While the liquid found on earth is H_2O, the liquid on Twin-earth is another chemical compound, which Putnam calls XYZ. Yet despite its chemical difference, this substance is unable to be distinguished by any observable features from the water we find here on earth.

On Twin-earth there are also people who speak English. In particular, English speakers on Twin-earth use the word 'water' just as we do, to refer to the liquid that runs in their rivers and streams, and fills their lakes and oceans. Moreover, Twin-earth speakers of English associate exactly the same descriptive content with their word 'water' as we do with our word 'water'. We both conceive of water as the clear liquid which quenches thirst, extinguishes fires, falls from the sky as rain, and fills our lakes and rivers. There is no detectable difference whatsoever between

[11] In addition to the opposition highlighted in this paragraph between scientific realism and the historical school, scientific realism is also opposed to logical positivist accounts of meaning which seek to eliminate reference to theoretical entities in favour of discourse about observable entities. But, given limitations of space, this is an aspect of the recent historical development of the philosophy of science which I have chosen not to develop here. For detailed discussion of this issue, see the introduction to Suppe (1977).

the sense of 'water' as we use the term and the sense of 'water' as they use the term.

Now, Putnam asks, does the word 'water' as used by Twin-earth English speakers refer to the same substance as does the word 'water' as used by English speakers here on earth? Putnam argues that it does not. Our use of the word 'water' refers to H_2O, and Twin-earthians' use of 'water' refers to XYZ. Thus, in spite of the fact that English speakers on earth and Twin-earth associate the same sense with the word 'water', they refer to different things. Consequently, terms with the same sense may refer to different things, and so the sense of a term does not determine its reference.

The reason, Putnam argues, is that there is a broadly contextual element involved in the determination of reference. In our use of the word, the word 'water' was introduced by English speakers here on earth to refer to the stuff that as a matter of fact flows in our rivers and streams, and fills our lakes and oceans. In particular, when the word was introduced it was applied to paradigmatic samples of such stuff (e.g., glasses of water, or babbling brooks, or falling rain). The operative referential intention in such cases was to refer to the substance, whatever it happens to be, which is the same kind of substance as the paradigmatic samples of water. In other words, the word 'water' was introduced to refer to stuff that is the same kind as standard cases of the stuff that we here on earth call water.

The moral of the story is that speakers of a language need to be in some kind of causal relation to a thing in order to be able to refer to it. Ordinarily it is being in such a causal relation to a thing which determines that we do indeed refer to that thing.

6.2. Initial baptisms

The core idea of how reference is determined by causal relations is found in Saul Kripke's idea of an initial baptism (cf. Kripke, 1980, pp. 96–97, 135 ff.). For proper names, Kripke suggests a commonsense approach to how people are named. For example, when a child is named, a ceremony takes place in which the baby is given a name. You can imagine the parents, looking at the baby in a cradle, saying 'We name that child William'. Given the parents' intentions to call their child William, and given that the context determines which child they are talking about, the reference of the name is fixed at such an initial baptism.

As for use of the name by speakers not present at the baptism, Kripke suggests that there is a causal chain linking later use of the name, via the use of other speakers, with the initial baptism at which the name was introduced. Unlike the use of speakers present at the initial baptism, use of the name by later speakers not present for the baptism depends on their being appropriately linked by a causal chain of earlier uses of the name back to that ceremony.

On this account, neither the reference of those present at the baptism nor of those linked to the baptism by a causal chain is determined by description. Rather, in the case of the introducers of the name reference is determined by such

things as their intention to refer to the baby, perceiving the baby, being present when the naming takes place, etc. In the case of later use of the name, reference is determined by the causal chain linking later use back to the initial baptism. Thus, in general it is causal connections with the referent, rather than some shared descriptive content or sense, which determines reference.

This account may seem plausible for naming babies. But babies are particular observable objects, individual things which we may point to and perceive. There will be little confusion when we name a baby by pointing at it and giving it a name. But what about entire kinds of things like water? What about unobservable entities which we are unable to perceive, like electrons and protons?

The causal account of proper names may be extended to observable *natural kinds* of things, such as water. The basic idea is that, in the case of observable natural kinds, a term is introduced in the presence of a sample of the natural kind. Thus, when the term 'water' is introduced, it is applied to a sample of water. For example, I point to a glass of water and say "By 'water' I refer to that stuff".

The operative intention in introducing a term for a natural kind in the presence of a sample is not to attach the word specifically to that particular instance of the natural kind. Rather, the intention is to introduce the term as referring to the entire kind of which the sample is an exemplary instance. Thus, by saying 'That stuff is water', pointing to a glass of water, one is introducing a term to refer to the substance of which the water in the glass is a sample, namely H_2O.

In this way it is possible to extend the initial baptism account of naming from proper names to natural kind terms for observables. But what about theoretical natural kind terms, such as 'electron'?

One approach pursued by Kripke and Putnam is to extend the account to theoretical terms by means of causal descriptions employed in the presence of observable phenomena.[12] On such an account, we are to imagine that a scientist, in the presence of an observable phenomenon thought to be produced by some specific unobservable causal process described by theory, may introduce a term to refer to the unobservable causal process. In this way the observable phenomenon may be picked out pragmatically by means of ostension, a causal description is given (e.g., 'the cause of that phenomenon'), and the term is thereby applied to the unobserved cause of the observable phenomenon.

6.3. The causal-theoretic reply to incommensurability

Assuming the causal theory of reference, one might reply to the incommensurability thesis somewhat as follows. The meaning, in the sense of 'sense', of scientific terms may well vary in the course of theoretical change. However, it does not follow that reference must also vary as a result of such

[12] For example, Putnam describes how Benjamin Franklin, holding a metal string attached to a kite struck by lightning, might have introduced the term 'electricity' to refer to that, whatever it is, that is responsible for that phenomena, i.e., the shock he receives in his hand. See Putnam (1975a, p. 200).

change of meaning. For reference is not determined by sense, but by causal chains which link the present use of terms with initial baptisms at which their reference was fixed. So reference does not vary with the changes of descriptive content which occur during theoretical change. Hence, reference is held constant across theoretical transitions, and theories may be compared by means of reference. Thus, there is no referential discontinuity, no incomparability of content, and no incommensurability.

6.4. Three problems with the causal theory

The causal theory of reference undoubtedly yields a promising rebuttal to the incommensurability thesis. For, if reference is continuous through theory-change, then it is possible for later theories to assert more truths than earlier theories about common objects of reference. However, a number of serious problems face the causal theory of reference in the current context, which raise doubts about the effectiveness of this rebuttal.

6.4.1. Reference change

The first problem arises because the original version of the causal theory of reference eliminates the possibility of reference change altogether. According to Kripke, reference is established at an initial baptism, and subsequent use of a term traces back to the initial baptism. But if the reference of a term is fixed at such a baptism, then reference cannot change. But there appear to be cases in the history of science in which the reference of terms has changed. So the causal theory of reference must be modified to allow for the possibility of reference change; e.g., by allowing usage subsequent to initial baptism to affect reference. But this permits reference variance between theories, which was what the causal theory was supposed to avoid.[13]

6.4.2. The 'qua problem'

There are difficulties with the causal theory's account of how reference is determined for observational natural kind terms. Kim Sterelny describes voyagers to Mars:

> Suppose I go to Mars and come across a catlike animal: I introduce the term 'schmat'. Schmats are animals bearing a certain relation to this paradigm local schmat I have just encountered. But what determines which relationship this is? For the schmat will be a member of many kinds. A non-exhaustive list would include: physical object, animate object, animate object of a certain biochemical kind, animate object with certain structural properties, schmats, schmats of a certain sex, schmats of a certain maturational state (Sterelny, 1983, p. 121).

[13] For the objection that the causal theory rules out reference change in science, see Fine (1975).

The problem is that the causal relations involved in ostensive introduction of the term do not specify which of the numerous kinds instantiated by paradigmatic schmats is the kind designated by 'schmat'. Some descriptive apparatus is required to pick this out, e.g., a verbal specification of whether 'schmat' is the name of a genus or a species.

6.4.3. Reference of theoretical terms

A further problem for the causal theory involves the reference of theoretical terms. Suppose we introduce the term 'phlogiston' to refer to that, whatever it is, which causes that phenomenon, pointing to a fire. If oxygen is what causes fire, then 'phlogiston' refers to oxygen. But phlogiston does not exist, so that rather than mistakenly referring to oxygen, the term 'phlogiston' fails to refer to anything at all. This suggests that there is a need to build into the causal description of the referent of a theoretical term a certain amount of descriptive apparatus besides the mere causal description 'whatever causes that phenomenon'. Plausible suggestions include description of the natural kind to which the supposed cause belongs and a description of the causal role fulfilled by the unobservable causal agency.

7. Conclusion

I will conclude by briefly outlining the current 'state of play' of the incommensurability debate, as I see it (cf. Sankey, 1997). The problems just highlighted for the causal theory lead me to endorse a modified 'causal-descriptive' theory of reference (Sankey, 1994). According to the view I favour, not only may reference vary in post-baptismal use, but causal role descriptions play a role in determining the reference of theoretical terms. On the basis of this view, I argue that translation may fail between theories, since reference may be unable to be determined in the context of one theory in the same manner as it is determined in the context of another. Given that reference may vary in post-baptismal use, I allow that reference may change in the transition between theories. However, the scope for referential variance is much reduced, given that reference is not entirely determined by means of the descriptive content associated with terms.

This view ties in well, I believe, with some aspects of a modified, *taxonomic* version of the incommensurability thesis, which was developed by Kuhn in writings published late in his career (see Sankey, 1998). According to this later view, scientific revolutions are characterized by changes in the taxonomic schemes by means of which theories classify the entities in their domains of application. Such changes include redistribution of members among existing taxonomic categories, modification of criteria of category membership, and introduction of new categories. At the semantic level, taxonomic change gives rise to change in the meaning of preserved vocabulary, which in some cases involves change of reference. In the case of new categories, it may also result in introduction of new

vocabulary which differs semantically from previous vocabulary. The result of such taxonomic change is restricted translation failure between local sub-sets of the theoretical vocabulary employed by scientific theories, since the meanings of these terms are crucially affected by taxonomic variation between theories.

Where my view differs most fundamentally from Kuhn's is that where Kuhn derives anti-realist consequences from incommensurability, I set the issue of conceptual change squarely within the framework of scientific realism. This divergence has attracted critical comment from Paul Hoyningen-Huene, who has developed a non-realist Kantian interpretation of Kuhnian incommensurability.[14] This opposition between realist and anti-realist approaches to the phenomenon of conceptual change in science constitutes, in my view, one of the key unresolved problems currently exercising philosophers of science working in this area.

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[14] Hoyningen-Huene proposes his neo-Kantian interpretation of Kuhn in Hoyningen-Huene (1993). For the critical commentary, see Hoyningen-Huene et al. (1996).

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