The Semantic View of Theories: Models and Misconceptions[1]

Micheal McEwan

Introduction

The semantic view, which has been dominant for more than thirty years, is a view of scientific theories which focuses on models. Over recent years it has attracted renewed interest, and criticism. This interest has been sparked, at least in part, by the development of structuralist approaches in the philosophy of science—many of which adopt the semantic view. Unfortunately the semantic view, as presented by many of its proponents, remains unclear and is easily misunderstood. In this paper I attempt to bring it into sharper focus by identifying one of the ways the semantic view can be misconstrued. Proponents of the semantic view of theories often claim to be using concepts from mathematical logic and model-theory in their formulations of the semantic view. I take this claim seriously and develop a semantic view of theories which I call the *naïve semantic view*, or the *naïve view* for short. However, as we shall see, the naïve view suffers many defects. Only by contrasting the semantic view with the naïve view can we see if and how the semantic view avoids the problems associated with the naïve view.

The Naïve View

As mentioned, the semantic view is characterized by its focus on models. The following slogan captures this point nicely:

A theory is a collection of models.

This slogan will serve as our basic starting point in developing the naïve view. Taking the slogan as a definition, it provides the basic framework for the naïve view. First we will assume that 'is' in the slogan specifies an identity relationship.[2] A theory, according to the naïve view, is then *identified* with a collection of models.

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[2] This assumption is denied by many of the proponents of the semantic view. For example, see French and Saatsi (2005).

We need now to clarify what sense of model the naïve view employs. The word 'semantic' is a clue as to what kind of models are of interest. Note that the semantic view is also, sometimes, called the model-theoretic view of theories (for example, French and Ladyman 1999). It is natural in this context to think immediately of Tarski's semantics and the models found in mathematical model-theory.[3] Tarski connects models to semantic concepts with his analysis of truth and logical consequence in terms of *satisfaction*. According to Tarski (1983, 416) the concept of a model can be defined in terms of the concept of satisfaction. We will call the models found in Tarski's analysis and the models of model-theory *model-theoretic models*. A model-theoretic model is an interpretation which satisfies some set of sentences (or sentential formulae). An interpretation specifies a set of individuals (the domain or universe of discourse) and defines of all the appropriate symbols (i.e., constant, function and predicate symbols) of the language on that set. A theory, according to the naïve view, is a collection of model-theoretic models.

Once we accept that "models" are model-theoretic models, a number of things fall into place. For one we can easily understand and incorporate a key doctrine of the semantic view: "to present a theory, we define the class of its models directly" (van Fraassen 2000, 179).

If a model-theoretic model is an interpretation on which some set of sentences are true, then one normally takes a theory to be a set of sentences expressed in some formal language.[4] We can call this the model-theoretic notion of a theory, or *model-theoretic theory*. A model-theoretic theory is true for a given model if and only if each of the theory's sentences are true in that model. Associated with every model-theoretic theory is a class of model-theoretic models, where the theory is true for each model which comprises this class. Notice that the relevant sense of 'collection' here is 'class'.

However, our slogan—a theory is a collection of models—clearly dictates that a theory, according to the naïve view, is identified with the models themselves rather than a set of sentences expressed in a formal language. So, the theories as specified by the naïve semantic view, which we will call *naïve-theories*, are a different type of theory than model-theoretic theories. There is an important relationship between the two types of theories though. When

[3]This connection between the semantic view and model-theory is made explicit by both Patrick Suppes (1969, 12) and Frederick Suppe (1977, 222).

[4]Typically a theory is not just associated with its axioms but also their consequences. We could then take a theory to be a set of (usually semantic) consequences of axioms expressed in some formal language.

a class of models is defined directly—i.e., when models are defined without reference to a set of sentences or axioms—this class of models can serve a dual purpose. The class of models can be identified with a naïve-theory and the class of models may also satisfy some model-theoretic theory. In this case the model-theoretic theory is an *axiomatization* of the naïve-theory.

By identifying the naïve-theory with the model-theoretic models directly the hope is that many of the issues and difficulties surrounding the axiomatization of a theory are set aside. As Suppes points out, "it is often simpler to assert things about models of a theory than to talk directly and explicitly about sentences of the theory" and, moreover, a linguistic formulation of a theory can be "extremely awkward and tedious to formulate". (1967, 58–59) Foregoing these difficulties, a naïve-theory can be characterized by defining its models independently of any linguistic formulations or axiomatizations of the theory.

The last aspect of the naïve view that falls out of model-theory is an analysis of truth. Recall that a model-theoretic theory is true for its models; that is, the class of models that satisfy a model-theoretic theory specify all the instances when the model-theoretic theory is true. The naïve view also adopts this analysis of truth insisting that the class of models, which define the naïve-theory, exhaust all of the instances when the naïve-theory is true. So, a naïve-theory is true for a model just in case that model is a member of the class of models that define the naïve-theory. Thus we arrive at the full specification of the naïve view:

> **The Naïve Semantic View:**
> (1) A naïve-theory is identified with a class of model-theoretic models, M.
> (2) The models in M are defined directly.
> (3) A naïve-theory is true for model n if and only if $n \in M$.

The way the semantic view is often presented, there is little said by its proponents to distance themselves from the naïve view. Van Fraassen is a prime example of this:

> The use of the word 'model' in this discussion derives from logic and meta-mathematics.(1980, 44)
>
> . . . to present a theory, we define the class of its models directly, without paying any attention to the questions of axiomatizability, in any special language, however relevant or simple or logically

> interesting that might be. And if the theory as such, is to be identified with anything at all—if theories are to be reified—then a theory should be identified with its class of models. (2000, 179)
>
> Truth and falsity offer no special perplexity in this context. The theory is true if those real systems in 'the world' really do belong to the indicated defined classes. (2000, 181)

All three aspects of the of naïve view are supported by these passages. Judging by these alone, one might easily be convinced that van Fraassen is actually espousing the naïve view.

Problems with the Naïve View

Despite many virtues, a little reflection reveals some major problems with the naïve view. If we employ the terminology of *truth-bearers* and *truth-makers*, the peculiar nature of the naïve view becomes apparent. Truth-bearers are those things which are capable of being true or false. Truth-makers are those things in virtue of which truth-bearers are true or false. In model-theory sentences are truth-bearers: sentences are true or false in models. Models are then truth-makers for sentences and model-theoretic theories (which are sets of sentences). But, according to the naïve view, a naïve-theory is a class of models. Thus a naïve-theory is identified with a model-theoretic theory's truth-makers. If a naïve-theory is a class of models, what makes a naïve-theory true—what are the truth-makers for a naïve-theory? The answer according to the naïve view are models. Models are both truth-bearers and truth-makers on the naïve view.[5] This may not be a problem *per se*, but it does result in some undesirable characteristics—characteristic that are particularly problematic for realists and empiricists.

The first and, arguably, the most serious problem confronting the realist or empiricist who adopts the naïve view is the *problem of representation*: neither theories nor models on the naïve view play a representational role. This problem is a result of aspects (1) and (3) of the naïve view. A theory is identified with a class of models and the truth of a theory is wholly determined by class membership. In this analysis the only things considered are model-theoretic models and classes of model-theoretic models. Where then does 'the world' come into play? How can the properties of models and the

[5] Jones (2005) makes a similar point.

relationships between models tell us about 'the world'? The kind of relationship most realists would assert between models and physical systems is a representational relationship; models represent physical systems. However the naïve view says nothing about representation. If a theory is to confront 'the world' in some way, if, for example, it is to save the phenomena then some sort of relationship between a theory and the phenomena must be asserted. With models playing the role of both truth-bearers and truth-makers there is no place in this analysis for the phenomena.

Another problematic characteristic of the naïve view is that it trivializes truth. This I will call the *trivial truth problem*. It arises as consequence of aspects (2) and (3) of the naïve view. By (3) a theory is true for model n just in case n is a model of the theory—or in other words, just in case n is a member of the class of models which define the theory. However, by (2), the naïve view stipulates that we define the class of models directly. When defining a theory, we must independently identify all the theory's models. This means, by (3), that when defining the theory we must independently identify all the instances when the theory is true. So, theory $\mathcal{T}$ is true for some particular model, n, if and only if we stipulated in the definition of $\mathcal{T}$ that it is true for n. Thus, the theory, $\mathcal{T}$, is true for n only trivially.

Consider, as an example, Newtonian mechanics. In accordance with the naïve view, let's assume the theory is identified with some class of models, S. Now we ask ourselves whether the solar system is a model of Newtonian mechanics. In other words, we inquire as to whether Newton's theory is a true theory regarding the motions of the planets in our solar system. According to the naïve view the solar system is a model of Newtonian mechanics just in case we stipulated in the definition of Newton's theory that the solar system is in S.[6] The definition of Newton's theory, regardless of our observations concerning planetary orbits, answers our question. Obviously this is not going to be a useful characterization of truth for realists or empiricists. The question as to whether our solar system is a Newtonian system is meant to be a non-trivial question. The answer to this question must depend on the observed behavior of the solar system.

[6] One might object that in this example I have made a category mistake: the solar system can't be a model-theoretic model, it is a concrete object of the physical world. But this is exactly the problem of representation. Since models don't represent physical systems, the only way for the solar system to be a model of the theory—that is the only way the theory can be true of the solar system or be empirically adequate to the observed phenomena of the solar system—is for the solar system to be a model.

Yet another undesirable characteristic of the naïve view arises from the combination aspects of (1) and (2). Since a naïve-theory is its models and these models are directly defined, the original definition of a theory specifies, once and for all, what models are associated with a theory. In this way, a naïve-theory's domain is fixed. If you change a theory's models, then you change the theory. I will call this the *fixed domain problem*. By contrast, a model-theoretic theory's (where a model-theoretic theory is a set of sentences) domain is not fixed in the *same* way. The axiomatization of a model-theoretic theory can be given without knowing which interpretations will satisfy the model-theoretic theory. The existence of unintended models in mathematics is a prime example of this.[7]

We can extend the above example to illustrate how a fixed domain is problematic. Imagine that astronomers have discovered another planetary system beyond our galaxy and have carefully observed the orbits of the planets in this planetary system. Now we ask whether this newly discovered planetary system is also a Newtonian system. This is a reasonable question to ask. It is possible that relativistic effects in this newly discovered planetary system are non-negligible resulting in planetary orbits very different from those predicted by Newton's theory. Unfortunately, the naïve view does not provide the means to answer this question in a meaningful way. Since the planetary system is newly discovered, it will not have been included amongst the models that define Newton's theory. This means, regardless of the physical characteristics of the system, Newton's theory cannot be true of the system.

We might consider amending Newton's theory so that it would include this new system, but what grounds might we have for doing this? Working within the naïve view, it seems perfectly acceptable to include this model, or any other model, in the class of models that defines Newton's theory. There need not be any particular relationship between the models in S since we can define S however we like. One might ask, "don't the equations of the theory restrict what models populate S?" No—this is exactly the point. If it were the equations that 'picked out' the models in S, then it would be the equations which were doing the work. Aspect (2) of the naïve view expressly forbids this situation by insisting the models are defined directly. Also, by (1), the naïve view does not associate any sentences, like those that express

[7] In science the discovery of new models can be very fruitful. For example, when Einstein laid down the equations for his theory of General Relativity he was not aware of the Schwarzschild solution to these equations. This solution predicts the existence of black holes.

Newton's laws of motion, with a naïve-theory. So, we can't rely on any sentences to guide the extension of the theory to new models—there are no such privileged sentences. A theory is exclusively a collection of models on the naïve view. There is nothing above and beyond the models themselves to decide whether a theory is applicable to some model or not.

All three of these problems undermine the naïve view as a plausible account of scientific theories. As I tried to show, the semantic view, might easily be conflated with the naïve view. If the semantic view and the naïve view agree on points (1),(2) and (3) of the naïve view, then these problems afflict semantic view as well. In light of this, it is critical to distinguish between the two views. Only by highlighting the differences between the semantic view and the naïve view we can see if and how versions of the semantic view avoid these problems.

van Fraassen and the Naïve View

As pointed out earlier, van Fraassen at times appears to be advocating a version of the naïve view. We want to know then if van Fraassen's view suffers the same problems the naïve view does. However, when we examine his view more carefully it becomes clear that it differs in important ways from the naïve view and can, thereby, avoid the aforementioned problems. But what is interesting is that the steps required to avoid these problems lead to other difficulties.

To make good on all these claims would require the development van Fraassen's view in detail, contrasting it with the naïve view, and identifying how his view avoids these problems. Unfortunately, I won't have time for all this. Instead, I will restrict myself to just one example: van Fraassen's solution to the representation problem. This example is intended to show two things: (*i*) that the problems faced by the naïve view are also relevant problems for the semantic view; and (*ii*) avoiding the these problems can have serious consequences which undermine the plausibility of the semantic view.

The Representation Problem Revisited

The representation problem arises for the naïve view because it fails to describe the relationship between the models, which presumably function as representations, and the physical systems which a scientific theory pertains to. Aspects (1) and (3) of the the naïve view were identified as the source of the problem. By these aspects, a theory is identified with a class of models and a theory is true for a model if the given model is a member of this class.

There are two basic strategies for confronting this problem that can be identified in the literature.[8] The first strategy I call the *physical model* approach. By this approach both aspects (1) and (3) are affirmed, but we amend our notion of a model. If, *somehow*, physical systems can be construed as models, then these *physical models* may be members of a theory's class of models.[9] A theory is then true of some physical system if the appropriate physical model is one of the theory's models. The problem with this approach is rather obvious: in what sense can a physical system be a model-theoretic model—i.e., how can a physical system *be* an interpretation of a formal language? This seems like a category mistake. For example, an interpretation specifies a set of individuals as its domain, but it is not clear if there is a unique domain one can associate with a physical system.

The second strategy, which accepts aspect (1) but amends (3), is to assert some sort of privileged relationship between particular models and 'the world'. For example, if we have some reason to believe that a particular model, call it n, is a good or faithful representation of a physical system, then our theory would be true provided that n is one of the theory's models. This approach seems to incur a huge cost: we now need some sort of analysis with which to delineate models that do have the appropriate privileged relationship to 'the world' from models that do not. If the semantic view must provide such an analysis then much of the motivation for the semantic view is lost—no longer can proponents claim that the semantic view's focus on models facilitates a less problematic analysis of the connection between a theory and 'the world'.[10]

As we can see, both of these strategies come with their own difficulties. Now which, if either, of these approaches does van Fraassen take? Judging by the following passage we might think he is opting for the physical model approach:

> Truth and falsity offer no special perplexity in this context. The

[8]These strategies can be identified in the views of Suppes and van Fraassen, however neither the strategies nor the representation problem are explicitly articulated.

[9]This is the type of move, I think, that Patrick Suppes makes. For him, models are set-theoretic entities, but physical objects are also set-theoretic entities for Suppes. So physical objects can thereby be constituents of models on his view.

[10]This is essentially the point made by Chakravartty (2001).

> theory is true if those real systems in the world really do belong to the indicated defined classes. . . . so the theory is true if the real world itself is (or is isomorphic to) one of these models. (2000, 181)

However, despite appearances, the physical model approach is not what van Fraassen has in mind.

To understand his solution, we first need to note a couple of things about van Fraassen's view. For one, models are not model-theoretic models, but rather mathematical models or structures. A theory, if identified with anything, it should be identified with a class of mathematical structures. Also, in accordance with his constructive empiricism, theories are the types of things capable of being true or false, but truth (or approximate truth) is not the characteristic important for successful theories. Rather, he focuses on *empirical adequacy.* As he says:

> the empirical structures in the world are the parts which are at once actual and observable; and empirical adequacy consists in the embeddability of all these parts in some single model of the world allowed by the theory. (2000, 182)

Empirical adequacy is characterized by an embedding relationship between a theory's model(s) and the empirical structures. Now the pressing question: what the are empirical structures? Are they mathematical structures, or the phenomena, 'out there' in the world? If the latter, then it appears that van Fraassen is taking the physical model approach.

However, van Fraassen has recently (2005) made it clear that the embedding relationship is a relationship holding between mathematical structures. But, if a theory is associated exclusively with mathematical structures and empirical adequacy is a relationship between mathematical structures, how can a theory be said to save the phenomena? It seems that, after all, his semantic approach does suffer the representation problem.

Van Fraassen offers a response, though. He opts for the second strategy and attributes a special status to specific mathematical structures, the *data models*, which he takes to represent the phenomena. *Van Fraassen asserts that, in the appropriate context, the adequacy of the data model as a representation of the phenomena cannot be denied.* With this assurance that the data models reliably represent the phenomena, all we need to do in order to check the empirical adequacy of a theory is to investigate the relationship between the theory's models and the data models. According to van Fraassen, the key to understanding the relationship between data models and the phenomena is to include the 'users', i.e., the people that use mathematics for representing the phenomena, in our analysis. Consider van Fraassen's example:

> Suppose that I have represented the deer population growth in Princeton, by means of a graph. I point out that theory T provides models that fit very well with the structure displayed in that representation – call it S.

Van Fraassen considers the following challenge: "Yes, T fits well with this representation S, but does it fit the actual deer population growth in Princeton?" He responds by saying,

> Although I can see the logical leeway, there is no leeway for me in this context. For if I were to opt for a denial or even a doubt, I would in effect be saying: "The deer population growth in Princeton is thus or so, but the sentence 'The deer population growth in Princeton is thus or so' is not true, for all I know or believe." (2005, 8)

This response is ruled out by van Fraassen as pragmatically inconsistent: logically consistent but, in the given context, a statement that cannot be believed. For this reason, the adequacy of the data model as a representation of the phenomena is undeniable—it is a *pragmatic tautology*.[11]

Van Fraassen's response is not so much a solution to the representation problem as it is a denial that there is a problem when we restrict ourselves to the evaluation of a theory's empirical adequacy.

Conclusions

I will not say much here in criticism or defense of van Fraassen's appeal to pragmatics in response to the representation problem. I want to point out,

[11] According to van Fraassen the following claim is a pragmatic tautology: "*For us* the claim (A) that the theory is adequate to the phenomena and the claim (B) that it is adequate to the phenomena as represented, i.e. as represented by us, are indeed the same!" (2005, 8) He claims this statement is logically contingent but undeniable. If (A) and (B) are the pragmatically the same, then we cannot deny one without denying the other. Likewise, if we assert that we are using some model to represent the phenomena, then we are also compelled to agree that this model adequately represents the phenomena.

instead, some of the consequences of his approach. First, if this appeal to pragmatics is unsuccessful, then van Fraassen's semantic approach still faces the representation problem—a problem which threatens to undermines his empiricism.

Second, his solution to the representation problem is not going to be a line of defense that the realist, who advocates the semantic view, could employ. Van Fraassen's solution requires that, in the correct context, the adequacy of the data models in representing the phenomena be undeniable. For the realist who wants to show the truth of a theory in this way, they must show that, in the correct context, a theory's models (not just the empirical substructures of theses models) are, undeniably, a faithful representation of 'the world' . But, as history shows, the reliability of these representations will be deniable. The fact that theories can and have been falsified demonstrates that the reliability of our scientific representations can and, perhaps, should be denied.

For the realist, or anyone unsympathetic to van Fraassen's appeal to pragmatics, the representation problem signifies a major hurdle for the semantic view. It seems that the semantic view is no better equipped than other views (which do not focus on models) to meet the challenges that face both realist and empiricist approaches. The claim that the semantic view is a superior vehicle for structuralism—either structural realism or structural empiricism—is threatened by these difficulties.

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