To Save the Semantic View

Thomas Cunningham
History & Philosophy of Science Department
Center for Bioethics & Health Law
University of Pittsburgh
tvc4@pitt.edu

Abstract:

Proponents of the semantic approach to scientific theories (e.g. Giere 1988, 2004; French and Ladyman 1999) cite a number of critical publications as the origins of their positions. While the semantic view experienced widespread adoption by philosophers of science in the decades leading up to the 1990s, over the last two decades opposition to the view has increased demonstrably (e.g. Downes 1992; Cartwright et al. 1995). This growing disaffection suggests a two-part question: What exactly are the objections to the semantic view of scientific theories, and does the view have the conceptual resources to combat its opposition? This essay seeks to answer this question by performing a careful analysis of the positions of both advocates and adversaries of the semantic view. In addition, it is argued that to save the semantic view it is necessary to locate the source of the position's problems and to retool its conceptual foundations. To ensure that the semantic approach has the resources to meet objections to it, exegetical analysis is performed, which demonstrates that the source of the view's present-day woes lies in a subtle conflation contained in one seminal articulation of the view, van Fraassen's *The Scientific Image*. It is argued that supplanting central aspects of that work with ideas from Suppes is the remedy needed to provide the semantic view with the necessary resources for becoming wholly defensible against its oppositions.

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> *One of the besetting sins of philosophers of science is to overly simplify the structure of science. Philosophers who write about the representation of scientific theories as logical calculi then go on to say that a theory is given empirical meaning by providing interpretations or coordinating definitions for some of the primitive or defined terms of the calculus. What I have attempted to argue is that a whole hierarchy of models stands between the model of basic theory and the complete experimental experience.*
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> – Patrick Suppes [1962] 1969, 34.

Introduction

A perennial niche in philosophy of science is that of characterizing science via the structure of scientific theories. Long ago, the "received view" of scientific theories that was dominant for many decades became known as the "standard sketch" of scientific theories (Suppes 1967). That it is was a mere sketch was not necessarily cause for its rejection, but rather served as motivation for its enrichment. The process of wholly reevaluating, partially rejecting, and partially extending the sketch has resulted in a *new* received view of scientific theories, which is known as the 'semantic view', the 'model-theoretic approach', the 'model view', or pejoratively, the 'theory-driven view of models'.

The semantic view was developed during the 1960s and 1970s by a number of authors working in relative independence from one another. By 1989, one of its early champions could say, "The Semantic Conception of Theories today probably is the philosophical analysis of the nature of theories most widely held among philosophers of science" (Suppes 1989, 3). However, the view has come under sustained attack in the ensuing two decades (e.g. Downes 1992; Cartwright et al. 1995; Cartwright 1999; Morgan and Morrison 1999; Sloep and Van Der Steen 1987; Suárez 2003; Ereshefsky 1991; Godfrey-Smith 2006). One of the central contentions of this paper is that the reason these attacks appear so successful is that there is no single *locus classicus* of the semantic approach.

Contemporary advocates of the view (e.g. Giere 1988, 2004; French and Ladyman 1999; Da Costa and French 1990; Lloyd 1994; Schaffner 1993; Teller 2001) routinely cite the work of Beth (1949), Suppes (1957, 1960, 1962, 1967, 1969), Suppe (1974, 1989), and van Fraassen (1970, 1980, 1985, 1989) as points of origin for their own positions. Patently, this is a diffuse *point* of origination. It might be wondered how, given the many authors whom may rightly bear the attribution of the semantic view's fountainhead, it is possible to have a univocal interpretation of the position at all? Moreover, without such a unified interpretation, how can the position be defended against its steadfast opposition?

Indeed, answering these questions will be the focus of this paper. It will be argued here that there is no exclusive interpretation of the semantic approach to scientific theories; rather the position is more programmatic, and consists of a definitely articulable range of positions. To save the semantic view, we must characterize these positions, compare them, and decide which one is the most defensible. To do this, I will begin by recapitulating a common complex objection to the semantic approach and rebuttals to it (Sections 1 and 2). Pursuing the problem in this fashion culminates in a portrait of the semantic approach from the vantage points of both friend and foe. Surprisingly, though there are differences between these pictures, their similarities are most striking. Section 3 will pinpoint the textual source of the commonalities found in countervailing contemporaneous assessments of the view through an analysis of van Fraassen's (1980) influential depiction of the semantic program. I will conclude by arguing for renewed attention to the work of Suppes as a means to reintroducing heretofore-unacknowledged resources that are necessary for developing a thoroughgoing defensible interpretation of the semantic view (Section 4).

1. What's wrong with the semantic view?

In order to understand what the semantic program is, it will be useful to begin by understanding what is purportedly wrong with it. As the semantic view was not unambigously proposed fully formed by a single philosopher at one time, while it spread through the ranks of philosophers, it became many things to many people. The purpose of this essay is to bring these distinguishable threads together and illustrate what core allegiances they share; once elucidated, this will be taken as the semantic program. Though it may seem arbitrary to begin the process of characterizing a position with its adversaries, this is not so. Such a beginning will bring differences between the statements of its advocates into sharper relief, and as such will ultimately enable a more nuanced appreciation of the depth and richness that the program affords.

In what follows I take the criticisms found in writings by Downes and what I call the London group as a comprehensive representation of extant opposition to the semantic approach. While their criticisms are launched at different proponents of the position, these two parties share the view that something is quite right about the semantic program; namely, its emphasis on the importance of *models* in science. At a course grain, they also share the same method, which is to construct a version of the semantic view to attack, as well as to submit the same complex objection against it.

1.1 Downes on the semantic view

In his criticism of the semantic view, Downes notes that the position has no univocal interpretation, which is taken as a license to introduce a working definition of the view to be the target for criticism:

> "Here is the definition: Scientific theories consist of families of (mathematical) models including empirical models and sets of hypotheses stating the connections between the empirical models and empirical systems" (1992, 143)

Taken one way, this is a strong formulation of the semantic program because it requires theories to be families of mathematical models. However, there is also a weaker interpretation of this definition to be had, given the use of parentheses. It could be that theories consist of families of models, regardless of whether this refers exhaustively to mathematical models. Indeed, this possibility is exactly what Downes targets when articulating his disaffection; he is concerned that there are multiple types of models in science, and as stated the position can not incorporate the majority of them.

Against the semantic view, Downes objects that it contains an intolerant notion of model, and that this skews our perception of how scientific theories have empirical import. Downes considers three different models. The first is a set of mathematical postulates and a model derived from them, which is a triangle. The second is an equation from ecological theory describing logistic growth, of which he claims a model is found in the relations between mathematical objects in the equation. The third is a typical biology textbook drawing of a cell, which, according to Downes, "is an idealized cell or model" (146). He contends that considering how these types of models could be handled by the semantic approach will indicate its weak points.

According to Downes, on the semantic account, the way to represent the connections between the models that constitute a theory and experimental (empirical) systems is in terms of isomorphism. Taken as a mathematical notion, isomorphism corresponds to an exact (one-to-one) mapping between two sets that preserves the relations between the entities in the domain under consideration. Trivially, on the face of it the third model contains no mathematics, so it is difficult to see how it could be handled by the semantic view, as interpreted above. Similarly, though the ecological model is generated within a mathematical framework, when applied to experimental systems it does not appear to exhibit an isomoporphic relation to such systems, when isomorphism is taken in a strict mathematical sense. This suggests that it too is poorly characterized by the semantic account, or that the notion of isomorphism is too strict to be applied in either case. By Downes' lights, both points ought to be recognized, which leads him to propose a "deflationary" account of the semantic view.

The deflationary account amounts to the view that model construction and usage is essential to science. Also, that the notion of models on the semantic approach must be made more inclusive so as to tolerate the types of examples given by Downes. Additionally, something more lenient than the notion of isomorphism will be needed to describe the relationship between theories, models, and empirical systems. Following Giere, Downes suggests that the notion of similarity may be sufficient for this job.

For the present purposes there are two points of interest in Downes' text. One is its portrayal of the semantic view as being potentially committed to a limiting notion of model. Another point is that the objection lodged against the account criticized is complex insofar as it contains two parts: first it is argued that the notion of models is too restrictive; second it is argued that the characterization of the relationship between theories and the world must be modified. These two features are also found in another prominent opposition to the semantic program.

1.2 The London group: against a 'theory-driven view'

A number of authors who share a connection to the London School of Economics have collaborated to oppose what they term a 'theory-driven view of models', of which the semantic view is only one instantiation (e.g. Cartwright 1999; Cartwright et. al 1995; Morgan and Morrison 1999; Suarez 2003). While these authors share the same criticisms as Downes, they illustrate an alternative way to express them. They too believe that there are multiple realizations of models in science; however the London group is keen to focus on the contention that the semantic view cannot account for the way theories and models relate to the world.

Like Downes, the London group paints a particular picture of the position they wish to combat. According to them, the theory-driven view has it that:

> "a theory is a set of models and the representative models are to be found among these…theory generally provides only ideal models, generally simple ideal models. To treat real, complex phenomena, more and more factors true of the real situation are added into the ideal model until a good enough representation of the phenomena is achieved" (Suárez and Cartwright 2008, 64-65).

As a representation of the semantic view, it should be noted that this portrayal already takes some license by including the notion of representative models in the definition of the position to be assailed. This notion is the London group's own, and such models are those that are intended to be reasonably accurate portrayals of the phenomena, including their sources. As will be clear below, depending on how one understand 'phenomena', this may be a slanted caricature of the view they oppose in favor of the one they defend.

The London group seeks to supplant the theory-driven view with another position, which comes with its own "slogan: 'Models mediate between theory and reality'" (*ibid*). Models mediate because they are autonomous from theory. In this way they play essential roles in science that are independent from their role in constituting theory. Furthermore, models are distinct from theories insofar as they have a different relationship to the world, which is independent of any relationship theory has to world. On this interpretation of the semantic account, if phenomena are what are beheld in ones experience of the world, then the London group contends the view does not adequately explicate the relationship between theories, models, and phenomena (world).

The reasons the London group give for disputing the adequacy of the semantic view stem from a careful case study, the careful recapitulation of which will not be important for the present purposes. What will be focused upon instead is what they take their case study to demonstrate in relation to the view they oppose. They argue their case study makes it clear that models accounting for phenomena are not derived from theory in a logical sense, nor are they even generated from theory by filling in the theory's parameters with measured values. Rather, models that represent reality are constructed by *ad hoc* appeals to whatever theories are necessary to account for phenomena, irrespective of how they comports with any theory under consideration. In the London group's words, their case is one where some models are built such "that while providing accurate representations [they] do not follow from theory either by de-idealisation or by introducing otherwise acceptable descriptions of the facts" (70). Consequently, some models are not generated by way of theories. Hence, because the theory-driven view takes this to be the sole mode of genesis for models, it is mistaken. Moreover, because of this the theory driven view lacks the resources to describe how models or theories relate to the world.

1.3 The semantic program as it appears to its opponents

Between them, the contentions of Downes and the London group make clear what is wrong with the semantic view, provided the position is the same as that which they oppose. From the above discussion it is evident that the semantic view has the following characteristics to those who disagree with it:

- Scientific theories are to be identified with families of 'models'.
- The exact nature of said models is unclear, however they are routinely taken to be set-theoretical (mathematical) structures. Yet, it remains possible to conceive of the view as incorporating a broader notion of model.
- Models are generated from theories in a sense analogous to formal derivation. Making this comport with a broader notion of model appears difficult.
- Theories relate to the world by way of models. Models qua set-theoretic structures relate by a relationship of isomorphism. Alternative depictions of models might be said to relate to the world by a relationship of similarity.

Advocates of the semantic program have responded to the objections just discussed. We will now turn to them to further enrich our picture of the semantic program, as it is understood in contemporary philosophy of science.

2. Two strategies for defending the semantic program.

By taking the same exegetical approach to recent attempts to defend the view as was taken with its opponents, it will become apparent how the semantic program looks to those who champion it. Amongst those who defend the semantic view, the objections discussed above are commonplace and have received considerable attention. While it is not unexpected that the view's advocates portray it differently than its assailants, what is unusual is that proponents readily agree to most features of their opponents' portrayals of the view. Because of this, it has become impossible to develop a wholly defensible interpretation of the semantic program. Instead, aspects of it are cordoned off and defended piecemeal, which ultimately damages the view's tenability.

Contemporaneous defenses of the semantic approach are split into two camps that cite the same points of origin for their positions, however they deploy different methods and defend different interpretations of the program. For reasons that will become clear, these camps will be referred to as the *formalist* and *liberalist* strategies.

2.1 The formalist strategy for defending the semantic program

One approach to combating the problems confronting the semantic approach is to tackle them head on using sophisticated formal techniques. A particularly prominent adopter of this strategy is French, who has worked with a number of collaborators to develop a rigorous specification of the semantic view called 'the model-theoretic approach' (e.g. Da Costa and French 1990; French and Ladyman 1999). In a recent paper with Ladyman, the complex objections discussed above are bifurcated into problem-areas:

"(1) the model-theoretic representation of the kinds of models employed in scientific practice – such as iconic and material models;

(2) the model-theoretic representation of the relationship between theories and phenomena."   (French and Ladyman 1999, 103-104)

In this sense, a pivotal move defenders of the semantic view make is to divide the problem and then solve its components piecemeal. French and Ladyman argue that doing so allows them to decisively meet the first issue.

French and coauthors follow the work of Suppes by contending that a scientific theory can be represented by a set-theoretic predicate, defined in accordance with their methods   With such an approach they purportedly "can reproduce *all* extant mathematics (and practically all of scientific our thinking as well)" (Da Costa and French 1990, 253; italics in original). With scientific theories so represented, meeting problem number is not very difficult. The question is not whether 'model', as employed by scientists, comports with their approach, but whether the practice of representing science using set theoretic structures can adequately depict the various types of models one find scientists using.

The sorts of models French and coauthors seek to represent using their formalisms are iconic models or material models, such as the cell model discussed by Downes or the famous physical model of DNA proposed by Watson and Crick, respectively. With their formal account on hand, French and Ladyman claim, "to present iconic models, material models, and so on, at the level of philosophical analysis, is to present certain (partial) set-theoretical structures. Thus…the issue is how they should be *represented* so as to best capture relevant aspects of [scientific] practice" (1999, 107; italics in original).

The formal technique deployed by French and collaborators stems from work in set theory and mathematics (see Da Costa and French 1990 for references). Here I will suppress their notational formalisms and focus solely on how they contend their formalisms do the work they take it to do, and what work that is, exactly. According to the formalist strategy, a theory may be identified with the class of set-theoretic models it entails. Each such model is a mathematical model, or also a *structure*, "in the sense of relational structures for which all of the sentences of the theory express true properties about the structure when the latter acts as an interpretation of the theory" (Da Costa and French 1990, 249-250).

For any given theory, taken to be a set of statements, or sentences, there are families of models that the theory entails. Such models exhibit relational structures, which formalists argue exhibit some relationship to the world. The question is, what are the structures, and how does one characterize this relationship? More recent instantiations of the formalist strategy claim this relationship is one of partial isomorphism, a notion which is predicated upon another one, partial structures. A partial structure specifies only part of the complete relations of a definite mathematical entity. According to formalists, since scientists only specify such partial relations when modeling phenomena, this means that philosophical representations of models only need to be in terms of partial relations too. With models so understood, the philosophical work to be done by formalist's methods is to depict any and all scientific models as set-theoretic structures so that they can be demonstrated to exhibit partial isomorphism with phenomena, qua partial structures.

If one accepts the formal techniques specified by the formalist strategy, problem number one at the beginning of this subsection then appears easy to solve. Provided it is agreed that their formal definitions of theory, model, (partial) structure, and (partial) isomorphism are sound, then they can indeed represent all the different sorts of scientific models used in empirical science. This is because structures are sets of entities and their partial relations. So, any model can be so described, and as such can be represented by their techniques (da Costa and French, 260-260; French and Ladyman 1999, 107-110). Yet, while problem one thus finds an easy resolution, this is decidedly not the case for problem two.

Recall that the central contention of the London group was that portraying models as being generated solely from theories will mean that such a theory-driven view will be inadequate for describing how theory relates to the world. *This* is problem two. Instead of directly describing how theory relates to the world, the formalist strategy reframes the issue; they seek to describe how theories relate to 'phenomena'. On such an account, the world is characterized according to its 'appearances', *sensu* van Fraassen (1980, 64). French and Ladyman argue that theories, associated with the class of mathematical models they entail, do not bear any clear relation to the world *simpliciter*. Theories qua families of models, relate to appearances, or phenomena, which are models of the world that can be adequately dealt with by their set theoretic formal approach. Accordingly, they contend that while the relationship between theories and empirical systems (appearances) is a complicated one, it can be captured as a "hierarchy of models":

> [T]he relationship between theory and empirical reality is mediated by a series of representations and so the use of isomorphism and related notions is perfectly legitimate. *Of course there is the more profound issue of the relationship between the lower most representation in the hierarchy – the data model perhaps – and reality itself, but of course, this is hardly something that the semantic approach alone can be expected to address*. (1999, 113; italics added)

What is gained by adopting the formalist strategy is a straightforward solution to problem one, the fact that there are many types of models in science of which the semantic program is apparently intolerant. However, what is lost is any capacity to characterize the relationship of theories, models, and the world *per se*. By such lights, models, which constitute theories, exhibit a profound, mysterious, relationship with the world, *and* the semantic program need not address this.

2.2 The liberalist strategy for defending the semantic program

There is another strategy for rebutting the two components of the common objection to the semantic approach. This strategy is to liberalize the commitments of the view with regards to how one understands scientific models on the one hand, while on the other hand also liberalizing the characterization of how theories relate to the world. On this strategy the gains and losses of the formalist strategy are swapped; what is gained is a way to represent the relationship between theory and world, however what is lost is any capacity to specify what exactly a model is.

Two examples of the liberalist strategy can be found in the work of Giere (1988, 2004) and Teller (2001). Both authors decompose the complex objection launched by opponents into two components and argue for similar solutions to them. According to Giere, there are many different kinds of models, such as "physical models, scale models, analogue models, and mathematical models;" furthermore, all of these models "are designed so that elements of the model can be identified with features of the real world…Scientists use *models* to represent aspects of the world for various purposes. On this view it is models that are the primary (though by no means the only) representational tools in the sciences" (2004, 746-747; italics in original). By this account, models are not defined structurally, but functionally, as things scientists use to represent. This means that whatever scientists use to represent could be a model. Yet, somehow Giere wishes to allow for some non-models to be representational tools. This view puts his analysis in the awkward position of claiming that anything scientists use to represent can be a model, however some things they use to represent are not models.

Teller instead sidesteps this awkwardness by holding that, "in principle, anything can be a model" (2001, 397). Similarly though, Teller holds that anything a model user regards or uses as a representation is a model. So, adopting the liberalist strategy, the challenge that the semantic view inaccurately proscribes what counts as a model is parried by allowing anything to be a model, so long as it is used to represent the world. This of course immediately suggests the question of how one demarcates models from things that are non-models but are also used to represent. Or, is everything a scientists uses to represent just then referred to as a model, and if so, does this supersede commonplace usage of the term?

Provided we ignore the question of how models are to be demarcated from other potentially representing entities, on the liberalist approach there is a straightforward way to characterize the relationship between theories and the world. A theory specifies a set of models, and these models bear similarities to actual systems in the world. That is why models can be used to represent the world and also how they relate to the world – by exhibiting similarity with it.

According to Giere, scientists use models to represent the world, and they do so "by picking out features of the model that are then claimed to be similar to features of the designated real system" (2004, 748). This is also how Teller views the relationship of theory and model to world. He contends, "models correspond to the world not by a relation of isomorphism but by a looser relation of similarity." Yet, also: "Models are connected to the world by theoretical hypotheses" (Teller 2001, 395). Theoretical hypotheses are what specify that a system in the world is similar to a model, as well as how it is taken to be so.

2.3 The Semantic Program

Having considered common objections to the semantic program as well as common rebuttals thereof, it is now possible to combine into one sketch the many available interpretations of the position. At a minimum, the program makes a number of commitments regarding the nature of scientific theories and models, as well as how they relate to the world. Yet, though these commitments may be expressed in alternative ways, the core commitment of the position cannot be violated, which is that *theories are to be identified with families of models*. I suggest that there are three specific qualitative parameters, which once interpreted together with the core commitment, constitute an interpretation of the semantic program. These parameters are (i) requisite degree of formalism, (ii) specification of the notion of models, and (iii) characterization of the relationship between theory and world. Table 1 summarizes how formalists, liberalists, and opponents can be sorted according to this approach to classifying alternative interpretations of the program.

Table 1

Parameter \ Strategy	Formalists	Liberalists	Opponents
Is a high degree of formalism required?	**Yes**	**No**	**Yes**
Are models solely understood as mathematical?	**Yes**	**No**	**Yes**
Do theories relate to the world, *simpliciter*?	**No**	**Yes**	**Yes**

Summarizing the three interpretations of the semantic view discussed above in this way indicates that when proponents of the view are taken together, as a group their positive position is essentially committed to the same interpretation offered by their opponents. However, taken separately they are inaccurately represented by their opponents, yet nonetheless cannot wholly meet their adversaries' objections. This brings contemporary debates over the semantic program into sharp relief because it shows that opponents have high expectations of the view, which proponents do not share. However, as one who would like to defend the view, I wonder whether this is really the case. Is it impossible to construct a semantic view that can mirror the commitments expected of it by its opponents, yet also meet their objections?

The remainder of this essay seeks to specify a version of the semantic program that does meet the two-pronged objection belabored above. To do this, it will be necessary to reconsider what is in many instances taken to be the view's foundation.

3. A tragic mistake: the semantic approach *sensu* van Fraassen

Bas van Fraassen once said: "In any tragedy, we suspect that some crucial mistake was made at the very beginning" (1987, 108). I take the fact that contemporaneous champions of the semantic approach cannot articulate a defensible interpretation of their positions against a common objection to indicate that a crucial mistake was made in formulating shared aspects of their views at the very beginning. In this section I will locate this mistake in chapter three of van Fraassen's *The Scientific Image*. I argue that a crucial conflation occurs there between two distinguishable renderings of the term 'structure'. This is of paramount importance because on many accounts of the semantic approach, the notion of structure plays an essential role in the definitions of familiar notions we have encountered in the discussion above, theory, model, and isomorphism. Recognizing this ambiguity suggests that it has persisted in present discussions of the semantic program, and is the reason that the position remains indefensible.

The notion of structure given found in the classic text articulating the semantic view, *The Scientific Image,* conflates a qualified, mathematical sense of structure with an unqualified, vernacular sense of structure. To see this, consider how the notions of theory and model are introduced by way of the notion of structure (van Fraassen 1980, 41-44). The text specifies six geometric axioms ($A0 – A5$), and states that a subset of them can be considered as a theory ($A1 – A4$). To show that this theory is consistent, it "is easiest to show by exhibiting a simple finite geometric structure of which axioms $A1 – A4$ are true" (42). We are next told, "Any structure which satisfies the axioms of a theory in this way is called a *model* of that theory" (1980, 42-43; italics in original). Note that the adjective, 'geometric' has been dropped and in its place we have simply 'structure'. This surreptitious removal of the qualifier, geometric, persists as the notions of embeddedness and isomorphism are defined: "one structure can be embedded in another, if the first is isomorphic to a part (substructure) of the second. Isomorphism is of course total identity of structure and is a limiting case of embeddability" (43). Consequently, though the articulation of the semantic program in one of its foundational interpretations begins with precision by defining models as geometric structures, for the most part, the essential notion of structure is left unqualified, and thereby ambiguous between mathematical structure and vernacular structure.

Vernacular structure is just tangible material structure familiar of everyday objects. As such, houses have structure; billiard balls have structure; metal rods and pieces of tin have structure. They may also have *mathematical* structure, however I contend this is *prima facie* distinguishable from having *vernacular* structure. The crucial importance of these alternative notions of structure can be made evident by again looking at the text, where the example of Newton's scientific achievements concerning the nature of planetary motion is utilized as an example supporting the semantic program.

In the case of planetary motion, van Fraassen accepts and builds upon a distinction made by Newton between the phenomena to be saved, or apparent motion, and the reality to be postulated, or true motion. On a Ptolemaic characterization of the planets, there is no distinction because "the true motion is exactly what is seen in the heavens" (45). Yet, Newton postulates that the motion described by astronomers is motion relative to the moving earth and moving planets. Thus planetary motion as recorded is relative to the earth, and hence is apparent motion. It is at this point that the notion of structure is invoked, which further plays on its textual ambiguity: "the 'apparent motions' form relational structures defined by measuring relative distances, time intervals, and angles of separation," which van Fraassen calls "*appearances.* In the mathematical model…we can define structures that are meant to be exact reflections of those appearances" (*ibid*; italics in original). Here the ambiguity between mathematical and vernacular senses of structure is essential because one wants to know whether these appearances, qua mathematical structures, bear any relation to the unqualified structures one would see gazing at the stars.

The relationship between qualified (mathematical) and unqualified (vernacular) senses of structure may be difficult to consider when speaking of planets, so I will redraw the distinction by imagining not Newton's theory of planetary motions, but of plant motions. Specifically, let us imagine an apple falling from a tree, hitting Newton's noggin, and his attempting to explain the occurrence. Let us also suppose a rival (Ptolemaic) theory has offered an explanation of this event. The latter theory would have it that the earth is stationary and that the apple fell along some such trajectory. Newton would demur, stating that the earth was in fact moving, and consequently, the apparent trajectory, or motion, was different from the real motion to be postulated. According to van Fraassen, "when Newton claims empirical adequacy for his theory, he is claiming that his theory has some model such that *all actual appearances are identifiable with* (*isomorphic to*) *motions* in that model" (*ibid*; italics in original). As such, for Newton to claim empirical adequacy for the theoretical description of the apple example, he would need to supply a model such that any and all appearances of the apple's descent would be identifiable with, or isomorphic to, the motions in that model. Given that appearances are relational structures defined by measurement, then we can ask Newton a question and witness the import of the distinction between mathematical and vernacular structure. Do the 'appearances' of the apple's motion have any relationship to the actual apple's falling and bonking Newton atop the head?

Here is where the semantic program, as given in *The Scientific Image*, abdicates any resources it may have for characterizing the relationship of theory to world. All that can be said of Newton's theory is that it relates to the appearances by way of specifying models that exhibit isomorphism with them. Yet, as anyone familiar with ordinary size objects such as apples, they have vernacular structure, which is *experienced* whenever one comes into contact with a token tangible object we routinely refer to as an apple. But surely, we want to say something more about Newton's theory. For instance, returning to the example of planetary motion, astronauts who landed on Mars certainly beheld its vernacular structure, irrespective of whether the planet can only be understood theoretically as having mathematical structure.

I am arguing that the source of the present issues facing the semantic program can be located in a crucial mistake of ambiguously characterizing the critical notions employed by the view: theory, model, and isomorphism. Textual evidence indicates that these notions are ambiguously characterized because of their dependence upon an understanding of structure which is itself ambiguous. What is highly problematic about this is that this ambiguity was neither recognized in the text, nor have other proponents of the view recognized it. Hence those who would defend the semantic view might take the following quote as foundational (e.g. Giere 1988, 49; French and Ladyman 1999, 112):

> To present a theory is to specify a family of structures, its *models*; and secondly, to specify certain parts of those models (the *empirical substructures*) as candidates for the direct representation of observable phenomena. The structures which can be described in experimental and measurement reports we can call *appearances*: the theory is empirically adequate if it has some model such that all appearances are isomorphic to empirical substructures of that model. (van Fraassen 1980, 64; italics in original)

Given the argument above, to take this formulation of the semantic approach as a basis for a contemporary defense of the position would be to inherit the ambiguity between qualified (mathematical) and unqualified (vernacular) senses of "structure." To resolve this ambiguity one could either stipulate that theories relate only to mathematical structures or that theories relate to vernacular structures, characterized in terms of actual systems in the world. As depicted in Table 1 above, this is exactly what proponents of the semantic approach have done. Formalists opt for the former strategy while liberalists opt for the latter.

One might be disposed to respond to the foregoing remarks by claiming that nowhere in *The Scientific Image* is it argued that theories relate to the world, and consequently, those who take the liberalist or oppositionist approaches above are simply misguided. However, it would then be difficult to make sense of a discussion therein of Suppes' interpretation of the semantic view, an interpretation which utilizes the same distinctions as van Fraassen:

> [W]hile I consider the work of Suppes's account of the structure of scientific theories an excellent vehicle for the elucidation of these general distinctions, I do regard it as relatively shallow. In this book *I am mainly concerned with the relation between physical theories and the world* rather than with that other main topic, the structure of physical theory. (van Fraassen 1980, 67; italics added)

Therefore, while the majority of the arguments in *The Scientific Image* aim at articulating an anti-realist interpretation of the semantic program, one does find there an occasional instance where a surreptitious realism lingers. This is most evident in the conflation between qualified and unqualified senses of structure. To remedy this, I will now move to consider the semantic program, as articulated by Suppes.

4. Of theories and world, models and experience: Patrick Suppes

Though Suppes is widely credited with being an early champion of the semantic view, his contribution is predominantly described only in terms of formal methods useful for articulating the position (e.g. Suppe 1974; Da Costa and French 1990; Schaffner 1993). On this reading, one finds emphasis primarily upon Suppes' publications containing his set-theoretic formalisms (e.g. Suppes 1957, 1960, 1962). However, in these and elsewhere (e.g. 1967), Suppes expresses additional informal characteristics of his interpretation of the semantic view. Only by paying due attention to these statements can we save the semantic view.

From the standpoint of the present discussion, I will assume that Suppes' formalisms are quite useful, as indicated by the role they have played in the interpretation of the semantic program given by the formalists discussed above. As such, they will not be considered further here, either positively or negatively. Yet, I note that Suppes' work contains the formalisms opponents have taken as a hallmark of the semantic view. As such, this is one resource his work contains.

Another resource one can find in Suppes' work is a pluralistic, permissive characterization of models. In his (1960) article on the meaning and uses of models in mathematics and empirical sciences, Suppes quotes a number of publications where the term 'models' is employed. Suppes states that the quotes are taken from publications in "mathematical logic… physics… the social sciences… [and] mathematical statistics." Yet, "Additional uses of the word 'model' could easily be collected in another batch of quotes. One of the more prominent senses of the word missing in the above is… an actual physical model" ([1960] 1969, 11). Suppes then claims that the logical concept of model "may be used without distortion and as a fundamental concept in all of the disciplines from which the above quotations are drawn. In this sense I would assert that the meaning of the concept of model is the same in mathematics and the empirical sciences" (12). What is essential here is that Suppes *does not* claim that the meaning of the concept of model *is* the same in mathematics and logic as it is in the empirical sciences, *tout court*. On the contrary, Suppes qualifies his claim by saying that only insofar as the logical sense of model fits with the *quoted instances* of empirical sciences can it be said to exhibit the same meaning as the empirical sciences. Importantly, these instances do not include any examples from biology, medicine, or psychology.

Others have interpreted the above passages as making an unqualified claim that the models of mathematical logic and the empirical sciences are the same (e.g. French and Ladyman 1999, 106). This is an egregious error because it downplays Suppes pluralism to the point of suppressing it altogether. Later in the same essay, Suppes summarizes his efforts regarding the meaning of models as follows:

> I have tried to argue that the concept of model used by mathematical logicians is the basic and fundamental concept of model *needed for an exact statement of any branch of empirical science*. To agree with this statement it is not necessary to rule out or to deplore variant uses or variant concepts of model… I am myself prepared to admit the significance and practical importance of the notion of physical model. (17; italics added)

Rather than assert that the logical notion is *the same as* that found in empirical sciences, Suppes is admirably far more cautious and articulate. He states that the mathematical notion of model is *needed for* constructing an exact statement of any branch of empirical science. This is patently different from a claim that the alternative notions of model are identical.

As further evidence of Suppes' pluralistic characterization of models, I submit his development of the notion of models of data. In "Models of Data," Suppes (1962) attempts to represent data generated from experiments using formal methods. Depicting this data, Suppes notes that there are "obvious respects in which a possible realization of the theory cannot be a possible realization of experimental data" (Suppes [1962] 1969, 26). These respects are that an experiment cannot include an infinite number of trials, nor are certain theoretical parameters directly observable in the sense that they can be experienced during the course of experiment. While Suppes does believe that models of data have the same logical structure as models of theory, he argues that they are distinguishable entities, or distinct types of models.

Thus, in two works often cited solely for their formal apparatus, Suppes distinguishes between at least three types of models, models of theory, models of data, and physical models. He also welcomes attempts to clarify alternative notions of model and incorporate them into a coherent interpretation of the semantic view. Therefore, it is should be recognized that a second conceptual resource may be found in Suppes' work; namely, that the notion of models on Suppes articulation of the semantic view is *not* exclusively that of the mathematical logician.

There is another, final, and essential, resource contained in Suppes articulation of the semantic view, which is the characterization of the relationship between theory and world. According to Suppes, theory relates to world by way of models, which relate to experience in a complex way. This way of characterizing the relationship between theory and world is discussed in a number of Suppes' works (e.g. [1960] 1969, 20; [1962] 1969, 34; 1969, 3-4; 1993, 12). However, it is most eloquently expressed in his (1967) article, "What is a Scientific Theory?". Here Suppes notes that the (then) standard sketch of theories comes in two parts, the first representing theories in terms of "an abstract logical calculus", and the second providing "co-ordinating definitions" of that calculus in order to apply it to the world (56). After suggesting a characterization of theories by the semantic view as a way to complement and extend the first part of the standard sketch, he then suggests to the reader how the second part ought to be reconsidered. He says:

> The concrete experience that scientists label an experiment cannot itself be connected to a theory in any complete sense. *That experience must be put through a conceptual grinder that in many cases is excessively coarse.* Once the experience is passed through the grinder, often in the form of the quite fragmentary records of the complete experiment, the experimental data emerge in canonical form and constitute a model of the experiment. It is this model of the experiment rather than a model of the theory for which co-ordinating definitions are provided. It is also characteristic that the model of the experiment is of relatively different logical type from that of the model of the theory." (62-63; italics added)

If we ignore Suppes metaphor of putting experience through a conceptual grinder in order to get a model of the experiment, this passage fits quite well with the formalist interpretation of the semantic program above. This reading would have it that theories relate to appearances, or data models, rather than the world, *per se*. Yet, such a reading would also do injustice to Suppes' insight; that theories relate to models of experiment, or canonical representations of data, *and these relate to the world through a scientist's active experimentation*.

The work of Patrick Suppes contains the necessary resources to save the semantic view because it takes on the profound issue of how theories relate to the world while also remaining pluralistic with regards to how models can be conceived. And, this is all performed within a formal framework, though it has been suppressed here. However, while Suppes' interpretation of the semantic approach does offer needed resources, they remain woefully underdeveloped. Of utmost importance is the fact that the relationship between models and experience, and thereby theory and world, which is predicated upon it, is so sketchy as to seem almost useless. I say almost though because it so strongly points in the right direction.

On Suppes account of the semantic view, it would be unlikely that the notions of isomorphism or similarity will be sufficient to capture what he calls, " the maddeningly diverse and complex experience which constitutes an experiment" ([1960] 1969, 20). Suppes' position certainly incorporates a 'hierarchy of models view' as seen on the formalist strategy above. As such, isomorphism would be able to characterize some relationships in a hierarchy, and even all relationships down to the level of models of data. Yet, something more will be necessary to characterize how low level models relate to experience. Despite this, by analyzing the foundations of the semantic program, it is possible to demonstrate that the semantic view does have something to say about how theories relate to the world. While more must be said on this head, this should be enough to placate the position's critics.

5. Conclusion

I have argued that the semantic view is actually a loose confederation of views, as evidenced by the fact that it has no clear point of origin in any single author or collaborative set of authors. That this is the case also enjoys support from the status of present debates concerning the adequacy of the semantic program. The analysis above demonstrates that present-day proponents of the position can be separated into two camps, and that neither of these camps can alone adequately defend the common complex objection put to them. In this sense, the semantic program is inadequate as routinely interpreted in philosophy of science today.

To save the semantic view, I have suggested that the source of error leading to its current status can in part be located in a classic text articulating the view; furthermore, I argue that by reorienting the position towards the work of Suppes, this error can be overcome. The principle error I diagnose occurs in chapter three of *The Scientific Image*, where the crucial notion of structure is ambiguously characterized. As this notion is used to define the other notions in the semantic theorist's arsenal, I contend they all suffer from its ambiguity. What is essential about this ambiguity is that if it remains unacknowledged, the position cannot simultaneously be permissive in its understanding of models as well as say anything about the relationship of theory to the world. By returning to Suppes' work, we can keep the important distinctions needed for the view, and at the same time characterize how theories relate to the world, which is by way of models that relate to experimental experience. What remains to be done is to pick up where Suppes left off and develop an account of the activity of experimentation in terms of how it leads to model building, the results of which can ultimately be related to theory.

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