

To Save the Semantic View: An Argument for Returning to Suppes' Interpretation

Abstract: Recent work on the semantic view of scientific theories is highly critical of the position. This paper identifies two common criticisms of the view, describes two popular alternatives for responding to them, and argues those responses do not suffice. Subsequently, it argues that returning to Patrick Suppes' interpretation of the position provides the conceptual resources for rehabilitating the semantic view.

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0. Introduction

In 1969, a conference at the University of Illinois heralded the demise of the received view of scientific theories (Suppe 1974). Twenty years later, proponents of its alternative – the semantic view – could say it “probably is the philosophical analysis of the nature of theories most widely held among philosophers of science” (Suppe 1989, 3). Whether the same could be said today is unclear. Although its proponents remain numerous and prominent (*e.g.*, Giere 1988, 2004; French and Ladyman 1999; Da Costa and French 1990; Lloyd 1994; Schaffner 1993; Teller 2001), the semantic view has become the subject of increasing criticism (*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), and even its most prominent proponents concede it faces considerable challenges (Da Costa and French 1998, S119-S120).

Common criticisms often lodged at the semantic view include (1) that because it defines the notion of models too restrictively it excludes many scientific theories; and, (2) it privileges theory-driven accounts of phenomena while ignoring data- and model-driven accounts. There are two popular alternatives responding to these criticisms. One aim of this paper is to show that neither alternative alone provides a satisfying response to both (1) and (2), nor do they provide a good response to both criticisms when taken together, because their conjunction is

logically inconsistent. My other aim is to argue that returning to Patrick Suppes' interpretation of the semantic view may suffice for rehabilitating it. Although I explore Suppes' well known position in considerable detail, I say 'may suffice' because fully working out the details of *how* to rehabilitate the semantic view must, due to space limitations, lie beyond the present argument. My aim is to show what is necessary to save the view and to offer a well-defended suggestion for where the conceptual resources to do so can be found.

1. Two Criticisms of the Semantic View

Fairly and adequately considering the nature of criticisms against the semantic view (SV) is necessary for our argument because different authors characterize SV differently, so getting a sense of what SV is taken to be is an important first step for evaluating what it must become to be wholly defensible against popular criticisms.

Let us first consider the claim that the semantic view fails to accommodate notable instances of scientific models. While articulating this criticism Downes defines SV thusly:

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" (Downes 1992, 143)

Downes questions the validity of the claim that theories consist of families of (mathematical) models because this entails defining relationships between models and other entities in terms of isomorphism. Isomorphism corresponds to an exact (one-to-one) mapping between two sets that preserves the relations between the entities in the domains under consideration (Odenbaugh 2008, 512). Yet Downes demonstrates many scientific models do not meet this definition. Consider three models: a set of mathematical postulates and a model derived from them (a triangle); an equation from ecological theory describing logistic growth, where the model is found in the relations between mathematical objects in the equation; and, a typical textbook diagram of a cell (Downes 1992, 146). As the third model is a diagram, it lacks explicit mathematical content, and so, cannot be described using isomorphism. While the second model

may be so described, when it is applied to empirical systems isomorphism fails to apply. Because SV fails to capture some types of models it has been criticized for adopting an overly narrow definition of “model” in strictly mathematical terms.

The second common criticism is that SV overemphasizes the role of theory in explicating phenomena. This criticism differs from the one above in that it targets both whether theory aims to account for phenomena via abstract models and whether theory can (and indeed does) meet this aim. Recent works by a set of authors affiliated with the London School of Economics adopt this position (Cartwright 1999; Cartwright et. al 1995; Morgan and Morrison 1999; Suarez 2003). According to them, SV holds that the nature of theories lies in their being constituted by a set of models, where members of that set relate to and thereby explicate phenomena by a steady accumulation of truths, which may be understood as empirically confirmed values for the variables contained in the models. Of SV, they say,

“...a theory is a set of models and the representative models are to be found among these...[T]heory 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).

According to the London group, the error in this view is that it assumes models are derived from or must be consistent with theory. They demur; rather, they argue models are autonomous from theory; and, models play an independent role in science from the role of constituting theory. Thus, they adopt the slogan, “models mediate between theory and reality” (*ibid*). It is not that models follow from theory by the steady accumulation of facts. Instead, models are constructed to fit the world *independently* of their relationships with theories.

Advocates of these criticisms both define SV, making clear what they take its foundational assumptions to be, and target those foundations, namely, SV’s claims about the structure and function of scientific theories. The first criticism argues against SV’s definition of

models and their relationships to theories and one another. The second criticism argues against SV's characterization of how theories relate to phenomena. Taken together they convey assumptions about what SV is and claims about what is wrong with it: there is good cause for skepticism about SV's characterizations of theories, models, and phenomena; and there is equal cause for doubting SV's characterization of how these entities relate to one another and explicate happenings in the world.

In the next section I consider whether this skepticism is warranted in light of two popular accounts of SV. Because neither can respond to these criticisms, I suggest it is.

2. Two Responses, Two Alternatives, Two Semantic Views

Bas van Fraassen has said, "In any tragedy, we suspect that some crucial mistake was made at the very beginning" (1987, 108). Because proponents of SV take his interpretation of it to be foundational, these words of wisdom are apt for thinking about the current problems it faces. For example, both Giere (1988, 49) and French and Ladyman (1999, 112) cite the following passage when defining the semantic view of scientific theories:

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).

In this passage, van Fraassen describes scientific theories in terms of models, which he refers to as "a family of structures." I believe this characterization of models is fundamentally mistaken and misleading and is an important source of the conceptual confusion underlying SV.

The problem with van Fraassen's account is that it succeeds because it relies on an ambiguous characterization of its basic concepts, theory, model, and appearance. In *The*

Scientific Image, van Fraassen defines theories and models by way of an example, a simple geometric system with six axioms. His “theory” is constituted by a subset of four of these axioms (A1 – A4). Of them, van Fraassen says, it “is easiest to show [the theory is consistent] by exhibiting a simple finite geometric structure of which axioms A1 – A4 are true.” We are next told, “Any structure which satisfies the axioms of a theory in this way is called a *model* of that theory” (*ibid.*, 42-43). By defining theories with reference to *geometric structure* and models merely as *structures* that “satisfy” the axioms of the theory, van Fraassen introduces a crucial ambiguity into the foundations of SV. By definition, geometric structures are mathematical structures. Yet the term ‘structure’ without qualification may or may not be mathematical. A concrete object has structure in a sense that is independent of its having explicit mathematical structure, as houses, stones, and cells do. In fact, models may have structure that is not readily captured in terms of mathematical structure, or that may be better captured in another way, including another type of model, depending upon the purposes of the modeler (cf. Weisberg 2007; Mitchell 2009). Thus, what it means for such models to “satisfy” the axioms of a theory is unclear, and this is exactly the point. What is at issue for critics of SV is exactly how models are defined and what relationships they bear to theories and phenomena. What must be conveyed, then, is how the notions of “structure” and “satisfaction” restrict some entities from membership into the class of models and not others.

Critics of SV assume that it aims to do two things: characterize the nature of theories (as constituted by models) and the nature of the theory-to-world relationship (in terms of isomorphism). There are two popular alternatives to responding to these criticisms, which take different approaches to describing how the view satisfies these two aims. This section describes these alternatives, arguing that the ambiguities in the conceptual foundations of SV have made it difficult to defend against the common criticisms against it. While each strategy for defending it disambiguates the problematic notions at the view’s foundations, neither does so in a way that adequately responds to critics. Moreover, when taken as a set the two alternatives

are logically inconsistent. Hence, I argue that they are unable to respond to critics both individually and when taken together.

2.1 *The Formalist Strategy*

One strategy for describing SV and responding to criticisms relies on sophisticated formal techniques to define crucial notions like isomorphism and appearance. For this reason, I call it *the formalist strategy*. On this view, often termed the “model theoretic” account, the central problems for SV can be stated in terms of two issues:

- “(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).

The formalist strategy is to treat these problems independently and attack them separately. They argue that a scientific theory can be represented by a set-theoretic predicate, defined in accordance with their methods. Doing so, they purportedly “can reproduce *all* extant mathematics (and practically all of scientific our thinking as well)” (Da Costa and French 1990, 253). For the sake of argument we may accept this definitional fiat. Doing so, the issue of what models can be accommodated by SV dissolves.

Yet the second issue remains. In order to solve it – to describe the theory-to-world relationship – formalists invoke a number of technical notions defined in terms of set theory and mathematics. In this way, the issue is transformed into one of *representing* scientific practice rather than describing and defining how theories and models relate to the world. That is, “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” (French and Ladyman 1999, 107; cf. Bueno et al. 2002). Crucial for this strategy is the premise that 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” that relate to the world in terms of “partial isomorphism,” which is defined in terms of “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 also only need be in terms of partial relations (Da Costa and French 2003; Contessa 2006). Thus, treating the second issue merely requires depicting any and all scientific models as set-theoretic structures which exhibit partial isomorphism with phenomena (*qua* partial structures).

While this may sound easy enough to the initiated, to the skeptic it seems dubious. It appears that instead of directly describing how theory relates to the world, formalists have merely reframed the issue: they seek to describe how theories relate to “phenomena” and their definition of phenomena differs fundamentally from their critics. For example, French and Ladyman contend that theories (families of models) relate to appearances (phenomena), which are *models of the world specified in set theoretic formalisms*. That is, on the formalist account, models of theory do not relate to the world *simpliciter*; they do not relate to “empirical systems” or “real, complex phenomena,” as Downes and the London group presuppose (*op cit.*). Rather, theories relate to *appearances* – mathematical representations of the happenings of the world.

One cannot overstate the importance of this difference. French and Ladyman conclude that while the relationship between theories and empirical systems (appearances) is a complicated one, it can be captured as a “hierarchy of models.” But they acknowledge that a consequence of this strategy is that they cannot specify how the bottom of the hierarchy relates to the world.

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 (French and Ladyman 1999, 113).

Thus, in effect, the formalist response to the criticism that the semantic view fails to adequately describe how theories and models relate to the world is that this is not their problem. By their lights, theories relate to the world via a hierarchy of models; the bottom-most models exhibit a profound and mysterious relationship with the world; and, the semantic program need not be troubled with explicating this mystery.

2.2 *The Liberalist Strategy*

Another strategy for describing SV and responding to its critics is to relax the constraints imposed by characterizing the nature of theories and the theory-to-world relationship in formal mathematical terms found in van Fraassen's formulation of the approach. I call this *the liberalist strategy* because it liberalizes the key concepts at the foundation of SV, making it tolerant of the different types of models deployed in scientific practices and different ways of relating to phenomena than merely isomorphism.

Prominent examples of the liberalist strategy can be found in the work of Ronald Giere (1988, 2004) and Paul Teller (2001). According to Giere, there are many different kinds of models in science, including "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" (Giere 2004, 746-747). Giere thus defines models in terms of their function in science rather than their structure: what is important is how models are used, not whether they are formulated in set-theoretic terms.

Teller's account of models illustrates just how tolerant the liberalist strategy may be. He claims that, "in principle, anything can be a model" (Teller 2001, 397). Like Giere, he also holds that anything a modeler uses or regards as a representation is a model. Treating this commitment as a hallmark of the liberalist strategy, then, we find that on this approach the challenge that SV inaccurately restricts what may count as a model is parried by allowing anything to be a model, so long as it is used to represent the world in scientific practice. Thus, liberalists take the opposite tack from formalists: rather than redefine the issue by a definitional fiat, liberalists reject the move of defining models set-theoretically; instead, they permit anything that is used as a representation to count as a model, irrespective of its formal structure.

The liberalist approach for characterizing the theory-to-world relationship is also tolerant and non-formal. On it a theory specifies a set of models, which bear "similarities" to actual systems in the world: models represent and relate to the world by exhibiting similarity with it. According to Giere, scientists represent the world "by picking out features of the model that are then claimed to be similar to features of the designated real system" (Giere 2004, 748). Teller agrees: "models correspond to the world not by a relation of isomorphism but by a looser relation of similarity;" and he adds, "models are connected to the world by theoretical hypotheses" (Teller 2001, 395). The picture is thus that models relate to the world and they do so because theoretical hypotheses entail models have certain features. Moreover, models relate in terms of similarity because their features bear similarities to the designated real systems.

2.3 Whence Dissatisfaction? Liberalism and Formalism are Logically Inconsistent

There are two popular alternatives for characterizing the semantic view of scientific theories. One opts for a functional definition of models that is radically permissive: for the liberalist, *anything* may be a model just so long as it is used as a means of representing aspects of the real world in scientific practice, and models relate to the world because their features bear similarities to the aspects of the world of interest to scientists. Another opts for a structural definition of models: for the formalist, scientific theories are set-theoretic predicates; models are

set-theoretic structures that relate to theories in terms of partial isomorphism. Yet just how the bottom-most models in the hierarchy of models relate to the world remains unspecified.

The differences in these alternatives follow from their different approaches to clarifying the ambiguities at the conceptual foundations of the semantic view. Formalists disambiguate the notions of theory, model, empirical substructures, and appearances by defining them in unambiguously formal terms. Liberalists disambiguate these notions by either rejection, as they do for empirical substructures and appearances, or by anarchy, in holding that they may be defined in any terms, irrespective of the level of formalism used to do so.

For those inclined toward SV it is unfortunate that neither of these alternatives provides a sufficient response to common criticisms against it.¹ Formalists are frank: they do not accept the claim that SV need articulate how models directly relate to phenomena. Thus they reject the second criticism dismissively, without a satisfactory justification for doing so. Liberalists exhibit the opposite failing. On their account, anything may be a model just so long as it is used to represent. Yet this merely pushes the issue along; it trades a clear definition of models as mathematical entities for one that relies exclusively on the notion of representation defining models as entities scientists use to represent. However, this notion is problematic too, as controversies over *the problem of representation* attest (cf. Callender and Cohen 2006; van Fraassen 2006). Thus, neither alternative provides a sufficient response to critics.

One might hope that combining these two alternatives together would provide a means for responding to critics of SV – where each fails to speak to one of the common criticisms on its own, perhaps together they provide an acceptable response. Unfortunately, this alternative also fails because the liberalist and formalist strategies form an inconsistent conjunction. Because liberalists and formalists individuate models so differently, together they face a problem of reference when demarcating the proper referents for their collective characterization of scientific theory.

¹ Downes (2009) comes to the same conclusion – that neither formalists nor liberalists interpretations of SV suffice for responding to common criticisms of the position – but presents a different argument for it.

For example, liberalists would count pendulums and globes as physical models whereas formalists would not. Formalists might count the set-theoretic *renderings* of those physical models as models, but this is a different and inconsistent way to individuate models within scientific practices. To use a toy example, in a case where scientists are studying a pendulum's motion liberalists would refer to the concrete pendulum as a model, whereas formalists would refer to the mathematical rendering of that object that scientists presumably share in their thinking about the concrete pendulum. Yet, liberalists might also count the mathematical rendering as a model too, and perhaps a diagram of the pendulum with no explicit mathematics as well. Thus where liberalists may see many models – perhaps innumerable many – formalists see only one, the model formally rendered in set-theoretic terms. Consequently, it seems highly unlikely that in any given case the formalist and liberalist strategies will be readily synthesized without fundamental and irreparable problems of reference.

The same issue arises when we consider how the two alternatives characterize the theory-to-world relationship assumed by their interpretations of SV. Isomorphism intelligibly applies only to mathematical entities. Similarity is expressly designed to apply to other abstract entities, such as pencil and paper diagrams, concrete objects, and other means of representing that lack explicit mathematical content. Thus similarity applies to many things that isomorphism will not. Because of this the two alternative interpretations of SV are very likely to be inconsistent in any given case.

While it is of course possible that an actual scenario exists such that both formalists and liberalists agree that a formal model exhibits isomorphism to a mathematical depiction of phenomena, and that no other types of models are also at play in the relevant scientific context; and hence, it is possible that the two positions fit together and are consistent in that scenario; nevertheless, this is a limiting case of agreement between the two positions. In most instances formalists will be far more restrictive in what they permit into the class of entities that may be referred to as “models,” and the ways in which those entities may relate to other entities than liberalists will. Hence, in most if not all cases the two positions will be logically inconsistent

because one will define “models of theory” as a small set of entities with a very restricted way of relating to other entities, while the other will define the same notion as a much larger – and perhaps infinitely large – set of entities with a much more tolerant description of the ways those entities may relate to others. Moreover, because of these differences in references it is evident that in most cases the referents of “entities” for each view will be different in both kind and number.

Proponents of SV of scientific theories thus lack a satisfying response to their critics. I suggest that certain ambiguities in van Fraassen’s articulation of the position are responsible for this state of affairs, insofar as formalists and liberalists have adopted different strategies for disambiguating them, and consequently have formulated alternative semantic views. In the following section, I propose an alternative strategy for responding to critics, namely, developing an alternative foundation for SV. I propose adopting Patrick Suppes’ rendition of SV, particularly his characterization of theories in terms of a hierarchy of models with more or less degrees of exactness, including models of theory and data models. While this proposal is not novel in and of itself, my argument that doing so supplies sufficient conceptual resources for making the formalist and liberalist strategies compatible, and hence, for saving the semantic view, is.

3. Of Theories and the World, Models and Experience

Suppes is widely credited with being an originator and early champion of the semantic view. In the literature, he is primarily cited for his formal work (*e.g.*, Suppe 1974; Da Costa and French 1990; Schaffner 1993). Yet while this approach to understanding Suppes’ interpretation of the position is not mistaken, it is misleading and incomplete. Although Suppes made significant contributions to the formal understanding of scientific theories (*e.g.*, Suppes 1957, 1960, 1962, 1988), to adequately understand Suppes’ characterization of scientific theories one must also appreciate other aspects how he conceptualizes them. Specifically, there are three interrelated aspects of Suppes’ interpretation that provide the conceptual resources necessary to save the

semantic view, by suggesting a *compatibilist strategy* for defending it. The first is its commitment to a “hierarchy of models” account of theories, where the members of the hierarchy are ordered along a *dimension of exactitude*. The second is its *pluralism* about the nature of models and representational relationships. The third is its *idealism* about the theory-to-world relationship.

3.1 Theory: Models and a Dimension of Exactitude

According to Suppes, the appropriate way to answer the question, “What is a scientific theory?” is to recognize that the answer itself comes in degrees of formality or exactness (Suppes 1967, 55). To give an exact account of the nature of scientific theories, Suppes contends that they may be defined in terms of models, in a logical sense: “in the exact statement of the theory or in the exact analysis of data the notion of model in the sense of logicians provides the appropriate intellectual tool for making the analysis both precise and clear” ([1960] 1967, 17). This view is not that models of theory *are* formal entities; rather, it is that formal models are the most exact ways of characterizing models as used by scientists. As he says,

[The] exact analysis of the relation between empirical theories and relevant data calls for a hierarchy of models of different logical type. Generally speaking, in pure mathematics the comparison of models involves comparison of two models of the same logical type, as in the assertion of representation theorems. A radically different situation often obtains in the comparison of theory and experiment ([1962] 1967, 25).

Thus, unlike in pure mathematics, even in an exact analysis of a scientific theory – including the experimental evidence to which it relates – one should expect the hierarchy of models constituting the theory to be composed of heterogeneous types. One should also be mindful of the fact that there are less precise but still acceptable ways to describe scientific theories.

Moreover, even within a precise characterization of scientific theory, at the lowest level of the hierarchy is a type of model that, by its very nature, is resistant to exact treatment. Suppes refers to this lowest level of the hierarchy as a model of *ceteris paribus* conditions. Such a

model captures experimenters' intuitions about idiosyncratic affects on experiment that influence its fit with theory. According to him, "here is placed every intuitive consideration of experimental design that involves no formal statistics. Control of loud noises, bad odors, wrong times of day or season go here" ([1962] 1967, 32). As it is essentially *a representation of scientists' intuitions*, a model of *ceteris paribus* conditions may be given in naïve set theory – in terms of symbols or words that stand for the referents for which scientists have such intuitions. Thus, at the lowest level in the hierarchy is a model that is exact in the sense that it is rendered in naïve set-theoretic terms, however it need be exact only in this minimal sense.

3.2 Pluralism About Models and Representation

By characterizing theories in terms of a hierarchy of models ordered along a dimension of exactitude, Suppes' interpretation of SV is explicitly pluralistic while also making an explicit commitment regarding the role of formalization required for characterizing the nature of scientific theories. In a sense, Suppes' account is agnostic with regard to what models *really* are, if this is read in an ontological sense. Models may be physical entities, as liberalists allow and formalists do not; but like formalists, Suppes' view is that models should be rendered in set-theoretic terms when stating the nature of scientific theories *with any precision*. Thus, this view makes the assumption explicit that *precision* is a central desideratum in SV of scientific theories. Moreover, this assumption should be understood in *epistemic* terms; in that, it claims that models ought to be *rendered* or known in at least naïve set-theoretic terms. Thus, the view grants that models may be physical, graphical, and so forth. But it assumes that to understand scientific theory – to have knowledge about it – is at least to represent the models that relate to it with some degree of precision, and therefore, to state them in at least minimally formal terms.²

² Cf. Suppe (2000, S111) for a similar interpretation of Suppes' characterization of scientific models, as requiring some degree of precision or formalization. Support for this interpretation is also found in Suppes' writings. For example, he says: "To define formally a model as a set-theoretical entity which is a certain kind of ordered tuple consisting of a set of objects and relations and operations on these objects is not to rule out the physical model of the kind which is appealing to physicists, for the physical model may be simply taken to define the set of objects in the set-theoretical model" (Suppes [1960] 1967, 13; cf. Suppes [1988] 1993, 69).

When coupled with an explicit commitment to an epistemic orientation to characterizing models, Suppes' pluralism provides a good foundation for a compatibilist strategy. On the one hand it emphasizes the formal character of scientific theories even at the lowest level of the hierarchy of models that mediate between theory and experiment. Yet on the other hand it allows for other uses of the word "model," such as in physical model, scale model, or graphical model. But it also restricts the latter usages by excluding them from being proper constituents of philosophically explicated scientific theory. So Suppes' view is consistent with the formalist strategy, and it also suggests a way to redefine the liberalist strategy in a consistent manner too. As it stands, the liberalist position permits anything to be a model so long as it is used to represent in the course of scientific experimentation or reasoning. Suppes' account suggests an amendment: anything may be a model so long as it is used to represent in the course of scientific experimentation or reasoning; however, only if something is rendered in minimally formal terms may it count as a model in the sense that it is a candidate for relating to scientific theory, where theory is understood in minimally formal terms. Thus physical models may remain models, they just may not directly relate to scientific theory as such. Rather, it is the characterization of those models in at least minimally formal terms that directly relates to theory. And it does so by being a member of the hierarchy of models.

Liberalists may find this suggestion unappealing, as it may appear to undermine one of their core convictions. But this response is mistaken. Rather than undermine a central commitment of the liberalist strategy, this view accepts and adopts the view that models may be demarcated functionally, only with the concession that they must be rendered with some degree of precision to be understood philosophically. So understood, the liberalist account of models is made compatible with the formalist once a distinction is granted between giving a philosophic account of models and the constitutive role they play for scientific theories, and referring to models in other contexts.

3.2 Idealism About the Theory-to-World Relationship

To synthesize the formalist and liberalist views, the compatibilist strategy may also draw on Suppes' idealism about the relationship between theory and phenomena and his concomitant pluralism about the many types of relationships models may have to theories, models, and phenomena. The sense of 'idealism' intended here is exhibited by the above discussion of the assumption of precision in Suppes' interpretation. Given that models are understood as rendered set-theoretic entities, these entities ought to be understood as *ideal* entities, entities that are thought of by cognitive agents. Suppes' account implies that at the lowest level of a hierarchy of models are representations of individual agents' intuitions about *ceteris paribus* conditions. Above this level are explicit representations of other aspects of experiments, models of sets of data from many experiments, models of various subsidiary and higher theories, and so forth. Though this is a sketch of the hierarchy of models, it provides sufficient detail to show that each of these models are understood as "structures," much as they are in van Fraassen's account; only on Suppes' interpretation this notion is explicated in terms of agents' thoughts, intuitions, or other ways of knowing. Thus, it is an idealist account insofar as it suggests models (as understood philosophically) are entities if and only if they are known – and thereby rendered in minimally formal terms – by cognitive agents. On this account, one may be agnostic regarding whether humans are the only types of cognitive agents or whether other organisms, groups of organisms, machines, or groups of persons and machines may also count as cognitive agents.³ Regardless, on Suppes' interpretation of SV, the bottom-most model in the hierarchy is a cognitive entity; it is something that a cognitive agent renders in order to represent phenomena.

As a consequence of its pluralism and idealism, Suppes' interpretation of SV is tolerant of many ways of understanding the theory-to-world relationship, and indeed the relationships between theories, models, and phenomena (or any "structures" rendered in minimally formal

³ For example, perhaps a set of interacting persons and computational artifacts in a distributed (or extended) cognitive system may count as a cognitive agent in more developed account of Suppes' interpretation (see Hutchins 1995; Magnus 2007; Clark 2010).

terms). Suppes' suggests a variety of ways members of the hierarchy of models may relate to one another, including homomorphism and embedding, which are each less strict than isomorphism (Suppes [1988] 1993). Though such relationships are more strictly defined and must be applied with more restrictions than the relationship of similarity – and hence, though they remain incompatible with a liberalist view in the same way as the notion of isomorphism – that Suppes' account explicitly endorses their application suggests a step toward compatibilism.⁴

To make this move requires a full understanding of the implications of Suppes' idealism. That is, given that members of the hierarchy of models do not relate to physical phenomena in a direct way, one must first render such concrete occurrences in some minimally formal terms to compare those renderings to other members of the hierarchy of models: "We cannot literally take a number in our hands and apply it to a physical object. What we can do is to show that the structure of a set of phenomena under certain empirical operations is the same as the structure of some set of numbers under arithmetical operations and relations" (1967, 59ff.). Moreover, in order to render phenomena in terms of a structured set of empirical operations, one must first make shared assumptions about the language being used for describing those operations. Or in other words: "When we ask ourselves whether or not two distinct objects have the same structure, we obviously ask relative to some set of concepts under which the objects fall" (Suppes [1988] 1993, 70). Thus, by Suppes' lights, the notion of 'similarity' or of some rendered structures being "the same as" another rendered structure, is a way of capturing a relationship that bears a metaphorical relationship to "isomorphism" in pure mathematics. Notice here that Suppes' endorses describing relationships between models in the hierarchy of models in terms of a variety of ways of relating, which have a less definite notion of "sameness" as their basis. Because of this, Suppes' account demonstrates compatibility with the liberalist strategy; in that,

⁴ This suggestion may be consistent with Beuno and colleagues' (2002) discussion of partial homomorphism as a means for explicating the relationship between "bottom" level descriptions of appearances. Yet as it is unclear whether their account is consistent with the interpretation of Suppes' view argued for here, this is an open question

it also presumes a basis in a sense of similarity, albeit one that may be made more precise as one moves along the ordered hierarchy of models towards ever-increasing precision, and consequently types of relationships that may be more precisely defined.

If Suppes' view is in this sense compatible with the liberalist view's reliance on the concept of a similarity relationship between members of the hierarchy of models, then just as the liberalist view requires emendation in order to be made consistent with the compatibilist view, so the formalist view also requires amendment. As it stands, the formalist view is based upon a notion of isomorphism and its derivatives, namely, partial isomorphism. It should be altered by adopting an explicit pluralism regarding the types of relationships between members of a hierarchy of models of scientific theory. If the formalist account admits of other types of relationships that vary along the dimension of exactness, then at the lower level of the hierarchy members may exhibit less definite relationships between models, including the relationship of similarity.

To summarize, by characterizing the hierarchy of models that mediates between theory and phenomena in explicitly pluralistic and idealistic terms, Suppes provides a foundation for a new, compatibilist strategy for defending SV because his account is tolerant of the many types of models that scientists use in their epistemic practices; it is tolerant of the many types of relationships that may hold between models and theory, models, and phenomena; and, it makes explicit that a philosophic account of scientific theories presumes a degree of precision that implies an epistemic orientation to the nature of scientific models and theories. Altogether, these conceptual resources provide a foundation that may be consistent with the formalist strategy, so long as it is altered to allow a typology of relationships including far more ways of relating between models and other structures than merely isomorphism and its derivatives. And, it may also be consistent with the liberalist strategy, if that view is altered to incorporate restrictions on the acceptable referents of 'scientific model' when understood philosophically.

4. Prospects for the Semantic View of Scientific Theories

This paper describes two common interpretations of the semantic view and two common criticisms against them, and argues for returning to Patrick Suppes' interpretation of the position in order to rehabilitate it. The paper is thus compelling only insofar as Suppes' interpretation is up to this task. To conclude, we may evaluate whether it is, and in so doing, evaluate the proposal given above, which reveals potential weaknesses of a compatibilist strategy for defending the semantic view.

I have argued that SV may be saved by recognizing the ambiguities in its core notions, and by looking to Suppes' work for an alternatives strategy for disambiguating them. There are three aspects of Suppes account of use for rehabilitating SV: (i) its characterization of scientific theories in terms of a 'hierarchy of models' ordered along a dimension of exactitude; (ii) its pluralism about the nature of scientific models and their relationships with theories, models, and phenomena; and, (iii) its idealism about the theory-to-world relationship. By drawing upon these resources, I claim that the compatibilist strategy provides a satisfying response to the two criticisms against SV.

The compatibilist response to the first criticism is that mathematical equations and scientific diagrams may be rendered in minimally formal terms in the sense described above. The same holds for physical or scale models. They may still be understood as models, but with the proviso that, *qua* scientific models, only their epistemic content directly relates to theory. Consequently, only models rendered with minimal formalisms are proper referents of a philosophic account of scientific theories. Nevertheless, this does not undermine a commitment to pluralism about models. It merely entails that models that are not formally rendered models are restricted from inclusion in the "hierarchy of models." Thus, cell diagrams, physical models, and so forth remain models; but in the context of a philosophical account of scientific theories, the precision implied thereof entails such models are only directly related to *theory* to the extent they are minimally formally rendered. However, they may relate to *practice* in myriad other ways.

The compatibilist response to the second criticism is similarly anchored in Suppes' pluralism and idealism. This criticism assumes that SV aims to account for how theories relate to real, complex phenomena, which presumably means that scientific theories are taken to relate to concrete worldly objects. On this reading, the second criticism presumes an ontic interpretation of SV; however, the compatibilist strategy eschews this. A compatibilist approach adopts an epistemic stance with regard to the nature of the theory-to-world relationship. Understood scientifically, the world is rendered by cognitive agents. Only once rendered are modeled phenomena candidates for direct relation to theory, via the models constituting the members of its hierarchy of models. If "phenomena" is understood in an ontic sense by critics of SV, then the compatibilist response rejects this assumption. It remains agnostic with regard to whether it is possible to explicate the theory-to-world relationship ontically. Instead, the compatibilist strategy makes it explicit that on SV the theory-to-world relationship is understood epistemically.

A number of problems with this account may be anticipated, which are likely to stem from its provisional and underdeveloped nature. For example, one wonders whether it will be possible to develop a typology of models and a concomitant typology of relationships for characterizing the nature of scientific theories with sufficient precision. One also wonders whether the idealism in Suppes' interpretation is licit or whether it foists an implicit ontological presumption onto SV, namely, that scientific theories are 'in the head,' so to speak. Finally, even on a charitable reading of the compatibilist strategy, one wonders just how compatible it actually is. That is, would formalists and liberalists endorse the proposed amendments to their positions, and even if so, would the amendments suffice to make the two alternatives compatible?

These worries are indeed legitimate. As given above, the proposed solution for saving SV is indeed merely a proposal. To satisfyingly rebut criticisms against the view will require developing it further. Only after describing the different types of models, their relationships, and their ordering on a dimension of exactitude, will it be possible to evaluate the extent to

which the proposed compatibilist strategy can indeed save the position. Yet sketching the compatibilist strategy and the reasons motivating it is progress toward that goal. It is also progress one hopes will inspire additional contributions to the development of a satisfying semantic view of scientific theories.

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