Realism about Structure: The Semantic View and Nonlinguistic Representations

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The central concern of this article is whether the semantic approach has the resources to appropriately capture the core tenets of structural realism. Chakravartty (2001) has argued that a realist notion of *correspondence* cannot be accommodated without introducing a linguistic component, which undermines the approach itself. We suggest that this worry can be addressed by an appropriate understanding of the role of language in this context. The real challenge, however, is how to incorporate the core notion of 'explanatory approximate truth' in such a way that the emphasis on *structure* is retained.

1. Introduction. In his classic paper, Ladyman (1998) adopted Worrall's (1989) central intuition of responding to the pessimistic metainduction by appealing to structural continuity across theory change and supplemented this with two new dimensions. On the one hand, the semantic approach to theories offers a particularly suitable framework for structural realism due to its inherent emphasis on mathematical models, or structures. On the other hand, Ladyman's overall aim was to develop a realist position that was appropriate for modern physics: the metaphysical implications of quantum mechanics were to be accommodated through the structural reconceptualization of physical objects. It is important to distinguish these different motivations for 'ontic' structural realism and to appreciate that the connections between them are not completely straightforward. In the present article we shall focus on the potential merits of Ladyman's suggestion to shift the debate over structural realism to within the framework

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of the semantic approach. The central issues here have to do with (*a*) how to best understand the structuralist character of the semantic approach to begin with and (*b*) how to appropriate this in order to capture the underlying realist intuition of structural realism. Our discussion will by and large take the form of responding to prevalent arguments against structuralism at both of these levels.

Let us first briefly review these different strands of thought, beginning with the *epistemological motivation*, which presents the retention of structure as a response to Laudan's pessimistic metainduction. The principal idea, as is well known, is that although the ontology of theories may change—from light as a wave in the ether to light as an electromagnetic field, to repeat the classic example—the relevant structure is carried over through such changes. Worrall (1989), for example, appeals to the appearance of formally identical equations in both Fresnel's and Maxwell's theories as signifying the relevant kind of structural continuity. The pull of such intuition is strong, but it has turned out to be surprisingly difficult to make the central notion of structure precise in a way that satisfies the realist's requirements.

The original motivation for adopting the semantic approach as the appropriate framework for structural realism was to avoid certain seemingly insurmountable problems faced by the alternative linguistic-axiomatic way of spelling out structural content in terms of Ramsey sentences (such as the 'Newman problem') as well as to tap into the inherent 'structuralism' of the semantic approach itself. Although it now seems that the Newman problem can be defused, after all, the second motivation remains strong. Our intention here is to consider these different ways proposed for representing structure and the constraints imposed by the realist's agenda upon these conceptions.

2. Structure. How should the structure of structural realism be represented? In his original presentation of the epistemic version, Worrall focused on logico-mathematical structure, as represented by the relevant mathematical equations. However, this leads to an obvious dilemma: either the logico-mathematical structure is just that and left uninterpreted, in which case it is hard to see how it can *explain* a theory's novel predictive success, or it is understood as appropriately interpreted, in which case it is ontologically committing and we lose the distinction between structures and objects (or natures) with which we started (Psillos 1999; see also his criticisms in Psillos [2001, 2006, in this issue])

However, more recently, Worrall has advocated a form of Ramseyfication as a way of representing the relevant structure of a theory. The

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basic idea here is that one simply replaces the theoretical terms of a theory with variables bound by existential quantifiers, like so:

$$T(t_1, \ldots t_n; o_1, \ldots, o_m) \rightarrow (\exists x_1), \ldots, (\exists x_n)T(x_1, \ldots, x_n; o_1, \ldots, o_m).$$

It is an interesting question whether this is an adequate representation of theoretical structure, particularly as 'nonstructural' realists have also helped themselves to the Ramsey sentence to express their 'nonreferential' form of realism (Cruse and Papineau 2002; Cruse 2004).[1] As is well known, however, this approach is threatened by the infamous Newman problem, which suggests that, "given any 'aggregate' *A*, a system of relations between its members can be found having any assigned structure compatible with the cardinal number of *A*" (Newman 1928, 140). Hence, the statement "there exists a system of relations, defined over *A*, which has the assigned structure," yields information only about the cardinality of *A*, and, if we know only the *structure* of the world, then we actually know very little indeed. Thus, for any given aggregate, a variety of 'systems of relations' is possible, and the problem then is how to justify the choice.

More recently this problem has been discussed in the context of the axiomatic, Ramseyfied framework (Demopoulos and Friedman 1985), and the consensus seems to be that it fundamentally undermines structural realism thus expressed (e.g., Ketland 2004). The consensus is wrong, however, for there are natural ways for the realist to cut down the space of unintended models allegedly trivializing the Ramsey sentence's expression of theoretical content (Melia and Saatsi 2006). What needs to be recognized is the scope of predicates to be left outside of Ramseyfication (such as the so-called mixed predicates) as well as the need to take a stand regarding the interpretation of the second-order quantifiers.

As we indicated in our introduction, Ladyman himself is quite clear in his answer to our initial question: the semantic or model-theoretic approach offers the appropriate representational framework, or, more specifically, the partial structures variant of this approach (see Ladyman and French 1999; da Costa and French 2003). However, although this approach avoids the Newman problem as it is typically represented in the context of Ramseyfication, it cannot so easily escape the underlying issue. In very general terms the problem is that of ruling out unintended models. On the semantic view a relevant class of models is *directly presented* without recourse to axiomatization, and this can be done so as to pick out the intended models (in the Löwenhein-Skolem sense). Within such a framework, the Newman problem can be cast in general terms, which allow a corresponding challenge to be raised for those who argue that

1. Further discussion on the evolving use of the Ramsey sentence can be found in Cei and French (2006).

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mathematical structures (models) represent the world via a structural relationship such as isomorphism. Indeed, the way in which the unintended models of the Newman problem are generated in the axiomatic framework begins by assuming the existence of some model (which is empirically adequate and T-cardinality correct) relative to which isomorphic models are then 'carved out' of a world domain of right cardinality by using a one-to-one mapping. In the semantic approach, by contrast, we are directly given a model, a mathematical structure, which is said to stand in some structural relationship to the world. Assume that this structural relationship is isomorphism, say, as some realists might propose. It is meant to be a meaningful, nontrivial matter that there is such relation of isomorphism between the model and the world. But now we can 'carve out' a structure-in-extension of any world domain of right cardinality so that this structure is isomorphic to the model, completely trivializing the theoretical content of the statement that the model thus *represents* the world. So whereas in the syntactic case the worry is about the possibility of a cardinality-correct world always forming a model of the Ramseyfied axiomatized theory, here the worry is expressed in terms of representation: if the model directly presented represents the world by virtue of some purely structural relation of isomorphism (and how else could it represent, being a purely structural entity, the argument goes), then there is always such a relation to be had for domains of the right cardinality.

The model-theoretic reasoning appealed to in order to generate the unintended models of the Newman problem fails in the case of the axiomatic framework due to a misconstrual of theoretical language and misinterpretation of quantifiers, as indicated above. What saves the Ramseyfying structural realist is the fact that the theoretical content captured by her use of Ramseyfication goes well beyond the mere formal, logical structure of the unobservable world. What about the corresponding problem in the semantic framework—what over and above the purely structural content of mathematical structure and a structural representation relation is needed to avoid the problem? We shall return to this issue at the end of this article after we have discussed the role of language in the semantic approach.

3. Truth. Let us turn now to the realist side of structural realism. There is the further concern that whatever formal framework is chosen to represent the structural features, it may not be appropriate for capturing what are deemed to be the core principles of realism. There are at least two worries here. One might argue that in addition to theoretical content structurally expressed we need the standard linguistic correspondence—referring theoretical terms—to express our realist beliefs properly. This worry is independent of the structural realist agenda to escape the pes-

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simistic metainduction by structurally refining her realist commitment. Regarding this latter motivation there is the further worry that the notion of structure delineated is not explanatory in the appropriate sense of actually explaining the success of past false theories.

A version of the first worry can be called 'Chakravartty's Challenge', as Chakravartty has argued that if theories are *identified* with classes of models, as he takes them to be on the semantic approach, then realism cannot even be entertained because there is no way of expressing the requisite sense of correspondence with the world (Chakravartty 2001). Assertions of such correspondence require the deployment of linguistic formulations, but such formulations strike to the structuralist heart of the semantic approach. Now clearly any realist following this approach faces a fundamental dilemma: we want to represent theories in terms of set-theoretic models and to say that these theories can be true, in the usual correspondence sense as formalized by Tarski. But the models themselves cannot be regarded as true in this sense since it is precisely their role to satisfy the sentences of the theory in its linguistic formulation.

This is part of a deeper issue: what is the relationship between, for want of better words, the 'linguistic' and the 'model-theoretic' within the semantic approach? It seems to be a popular misconception of the semantic view that it says *nothing* but the following about theories: theories *are* (with 'is' of identity) just structures (models). This impression is perhaps fostered by the assertion that if a theory is to be identified with anything, it is with the relevant class of models (van Fraassen 1989, 222). However, one might follow the more moderate line that to *present* a theory, we should define its class of models directly (van Fraassen 1989, 222). It is this which is taken to be Suppes's essential insight. Of course, this leaves unanswered the question, What is a theory? Here we might adopt a 'quietist' view: in scientific practice, scientists present, argue about, draw implications from, and explain phenomena with theories, and whatever these entities *are*, ontologically, the issue we are primarily concerned with is what is the most appropriate representation of them for our purposes as philosophers of science (see da Costa and French 2003).

And, of course, there is more to the semantic approach than pure logico-mathematical structures; after all, we speak of particular models representing the unobservable world behind *particular* phenomena, we *interpret* theories by *describing* the properties and relations the state variables in a model stand for, and so forth. As a matter of fact the advocates of the semantic approach have never taken theories to be (with 'is' of identity) *just* structures, and representation to be *just* a structural relation, in the logico-mathematical sense of structure being determined only up to isomorphism. But this 'concession', by contrast, does not mean that theories

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are (with 'is' of predication) not structures or that representation is not structural, *in some significant sense*.

In particular, our epistemic attitudes—including, of course, those that separate the realist from the antirealist—are expressed via belief reports that are sentential in nature. And here the models act as 'possible realizations', which satisfy these sentences and allow truth and, significantly, approximate truth to be defined. Of course, the fact that belief *reports* are expressed in terms of sentences does not imply that the *objects* of the beliefs themselves are sentential in character. From this perspective theories are truth apt, as far as both the realist and constructive empiricist are concerned. The question, then, is how might these two perspectives—the representational and the epistemic—be reconciled?

One answer is to follow Suppes's distinction between the 'extrinsic' and 'intrinsic' characterizations of a theory (1967, 60–62). The former concerns the structure of the theory, and the relationships between theories themselves and between theories and 'the world', understood in terms of that structure. From the 'extrinsic' perspective we regard theories from 'outside' a particular logico-linguistic formulation, and it is in this respect that models play a *representational* role (see da Costa and French 2003, 29–36).

From the intrinsic perspective, however, theories can be taken to be the objects of epistemic attitudes and to be regarded as true, empirically adequate, approximately true, or whatever. To say that the models *themselves* can act as such objects is to switch inappropriately from one perspective to the other. Since our epistemic attitudes are expressed by belief reports that are sentential in nature, we must shift to the 'intrinsic' characterization of theories in order to accommodate them. In these terms, when a model or family of models are used as a representational 'device', as they are by the semantic approach, we can say that the models are 'true' as a '*façon de parler*' or 'abuse of language'. From the intrinsic perspective, when we consider the claim "I believe theory T to be true," we must accept that the relevant set of propositions stands for or represents T, only for the purposes of applying the Tarskian formal machinery. Attempts to extend that form of representation in order to try and capture various features of scientific practice will lead to the sorts of problems that shifting to the semantic approach is supposed to resolve (or avoid). Of course, we can only maintain this dual perspective if we refuse to identify theories with either sets of propositions or classes of models. If we can do that, then we can represent theories in terms of models and still regard them as true in the sense that the realist wants (for more on this, see da Costa and French [2003]).

However, Chakravartty (2001) anticipates something like this move. He notes that if theories are held to be distinct from their linguistic formu-

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lations, then they themselves are incapable of being truth apt—only their linguistic descriptions can be true or false. As he notes, an 'unforgiving critic' would object that this reduces theories to mere metaphors that can only be good or bad and might insist that whatever a theory is, ontologically, it should be capable of being regarded as true. A more forgiving realist might accept that it is the descriptions of the models, not the models themselves, that are truth apt, but then, Chakravartty asks, what has been gained? As far as the realist is concerned, her central interest is correspondence, or something like it, and if we have to resort to linguistic descriptions to be able to express that, why not stick with them in the first place?

The Suppesian distinction is not quite the same as the one Chakravartty has in mind, however. The latter distinguishes theories and their linguistic formulations; the former views theories—whatever they are—from two different perspectives. The realist's epistemic attitudes can be accommodated within the intrinsic perspective, and in particular, as we said, Tarskian formulations of correspondence can be accepted. Thus theories, and models, can be regarded as the objects of such attitudes, within this perspective. However, it is not the case that nothing is gained by such a move, since the realist is not only concerned with truth and correspondence. She is also concerned with theory change and intertheoretical relations in general, and those aspects of scientific practice are better captured by the semantic approach.

4. Explanatory Approximate Truth. Indeed, what is really at issue here is not capturing truth, per se, but approximate truth, in some shape or form, since it is in such terms that the pessimistic metainduction must ultimately be challenged. Now there have been various proposals for more or less formal accounts of this notion, but here we should focus on the fundamental idea of an approximately true theory latching onto reality in respects that are in some sense essential for the derivation and prediction of novel phenomena. It is this sense of approximate truth that is crucial for the realist: since the key argument for realism (i.e., the no miracles argument) relies on a notion of successfulness (and how hard that is allegedly to achieve), the end results of this argument must be qualified by this sense of approximate truth. Putting it bluntly, in the end the realist should only be committed to those elements of theories that are responsible for their successfulness.

The basic idea, then, is to show that the success of past science, by and large, did not depend on what we now take to be fundamentally flawed theoretical claims. The crucial question now is how to characterize these 'stable and invariant elements', or 'the theoretical laws and mechanisms', responsible for successfulness. Obviously the conclusion one reaches with

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respect to ontological commitment depends on how this question gets answered. For example, a structuralist like Worrall will focus on the formal equations as the 'stable and invariant elements', whereas a more traditional realist will want to see continuity at the level of objects as well. If we employ the neutral term 'theoretical constituents' to cover both possibilities, then the characterization of these constituents should (i) *explain* the theoretical successes and (ii) show the required level of continuity, or correspondence (not necessarily invariance!), in theory change.

Now, what exactly does this 'explaining the successfulness' amount to? As far as the standard realist is concerned, it amounts to an assertion that "the ontological commitment is to the theoretical constituents *explaining the derivation* of those equations," where these constituents are understood as the unobservables entities of science.[2] However, care must be taken here. What features in the relevant derivations are the theoretical properties, such as charge, spin, and so on, and it is these that are being referred to, not entities themselves, conceived metaphysically as objects, since, of course, scientific equations do not encode metaphysics. Furthermore, to see exactly which properties are actually 'fueling the derivation' we should consider in detail the classic example of theory change from Fresnel to Maxwell, where the crucial observation is that the equations derived from Maxwell's equations using continuity principles at the dielectric interface are formally *identical* to those derived by Fresnel from his mechanical principles. It turns out that one can derive these equations on the basis of metaphysically minimal premises that assume very little about the properties concerned (Saatsi 2006). The core of this analysis lies in the claim that the abstract continuity principles fueling Fresnel's derivation define dispositional descriptions (of properties) that are satisfied by the properties $\boldsymbol{E}$ and $\boldsymbol{B}$ in the solutions of Maxwell's equations. It is these principles describing higher-order properties of $\boldsymbol{E}$ and $\boldsymbol{B}$, which are central to the explanatory endeavor.

Could not the structural realist simply incorporate such principles into her view? There does not seem to be anything in principle preventing her from doing so and understanding these continuity principles as representing relations not between phenomena but between unobservable properties of light. However, it would seem that what is doing the philosophical work here—vis-à-vis no miracles argument and approximate truth—is certainly not something 'purely structural'.

This brings us back to the central concern of this section: Is it the case that taking into account the complementary role of language in theorizing renders the semantic view of theories essentially nonstructural? Well, it

2. For the sense of explanation involved, see Saatsi (2006).

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depends on what is meant by the question. If the question is whether the semantic view collapses into some syntactic view of theories to which it is typically compared, then the answer is *no*. The structuralism of the semantic approach resides in its insightful emphasis on the structural complement of theories vis-à-vis the question of theory identity, intertheory relations, and theory-data relations. Questions regarding these are nicely handled in a decidedly structural, holistic manner by focusing on the structural description of the variables open to interpretational descriptions. To present a theory is to present these structures directly, not through some syntactic axiomatic partially interpreted system.

By contrast, if the question is whether theories tell us only about the structure of the world, then the answer is *yes*. The semantic view is not, by itself, a vehicle for structural realism. And it was never meant to be. The semantic view is a form of structuralism about theories, emphasizing the role of structures in both our representation of theories and their representation of the world. Structural realism, however, is the view that our best theories represent the world 'approximately right', where approximately right is spelled out by a structural version of explanatory approximate truth. Developing this realist position within the semantic approach is motivated by the possibility of acquiring a level of independence from the linguistic referential matters by somehow incorporating the notion of explanatory approximate truth into the appropriate structural notion of representation. Hence, whether or not the word 'electron' refers, the relevant models of the electron theory have the right structural relationship to the unobservable world to explain the success the theory. This idea can be further developed within the framework of a structuralist approach to representation in science (French 2003).

5. Newman Revisited. We recall van Fraassen's comment on models and representation: "in science models are used to represent nature, used by us, and of the many possible ways to use them, the actual way matters and fixes the relevant relation between model and nature—relevant, that is, to the evaluation as well as application of that theory" (1997, 523). This can be interpreted as his preferred answer to the Newman problem as presented above, and it is indeed thus interpreted by Hendry (2001). Hendry finds it interesting that van Fraassen is forced to 'qualify' his pure structuralism by bringing in some sort of contextualism. But what is this 'pure structuralism' just referred to? As we have indicated, it is something of a 'straw man', and as soon as we acknowledge and incorporate the complementary role of language, the concerns about qualifying structuralism, or introducing nonstructural elements, dissolve.

With this in mind, we can respond to Hendry's 'dissolution' of the Newman problem via a focus on the linguistic context, which "serves to

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make representation a determinate, non-stipulative relation that may admit of (degrees of) non-trivial success or failure" (2001, 229). It is indeed the linguistic complement of the semantic framework that allows us to sidestep the problem of unintended models: the problem is unavoidable in only those ill-advised readings of the framework that take there to be only the structural side of the story. But we do not even know how we could depict anything like our interpreted theories of real science by pure structure, so we take it that in reality there has never been such a purely structural view of theories. Here we can apply our considerations of the complementary role of language.

Let us begin with a typical characterization of the notion of structure in the semantic view: "On the semantic conception of theory, structures specify state transitions where states are n-tuples of simultaneous values for the theory's variables or, in theories like quantum mechanics or natural selection, probability distributions over such values. Realism debates concern the nature of the mapping relationship between theory structure and the world" (Suppe 1998).

Already in this general statement about theory structure there is a significant element of interpretation. This characterization obviously applies only to nonrelativistic theories, but with this qualification accepted it should be obvious that in the above the domain structured is assumed to be such that it is meaningful to speak of *simultaneity* and *time-wise state-transitions*. This already cuts down the number of possible domains that can be represented by a state-space structure thus understood. It is not the case that any unobservable domain of suitable cardinality can be extensionally 'carved out' into isomorphic structure in a way that satisfies this constraint on the members of the domain. Yet, provided that this constraint is satisfied, it is meaningful to speak of representing the structure of the domain.

Assume now that some such structure is given. Of course, the content represented by that structure is still widely underdetermined: out of any cardinality-correct domain satisfying the above (weak) constraints we can 'carve out' a structure-in-extension isomorphic to this. Therefore we cannot say that this structure as such, by itself, has much interesting theoretical content. But of course it does not—we have not even specified the field of science under theorizing yet! To the general characterization of theories in terms of state-space structure we must add other information to do this, and that information imposes further constraints on the domain that can possibly be represented by the structure. The theoretical variables for which the simultaneous values and their change are given by the structure are *theoretically interpreted*: they refer to physical properties and relations. It is not the case that all the theoretical content about these variables is encoded in the structure of their interrelations at each moment

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of simultaneity and over time—there is interpretational content about these properties that is captured linguistically: "the difference in the values of these variables expresses a difference in the spatial location of point particles in some reference frame," and so on. This content imposes further constraints on the domain represented, radically cutting down the number of possible isomorphism relations between the model and the modeled.

It is interesting to notice that the way out of Newman's problem is very much the same for both the Ramsey sentence and the semantic approach. In both cases we include theoretical content going over and above the pure logico-mathematical structure, linguistically specified, constraining the possible systems in the world that can be taken to be represented by a Ramsey sentence or a model-theoretic structure. This 'extra' content going over and above pure structure does not rule out the possibility of structural *realism*, however, since the idea that explanatory approximate truth is spelled out in structural terms does not require purely structural content to begin with. How exactly such a notion is to be developed is still an open question.

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