Models, Representation, and Mediation

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Representation has been one of the main themes in the recent discussion of models. Several authors have argued for a pragmatic approach to representation that takes users and their interpretations into account. It appears to me, however, that this emphasis on representation places excessive limitations on our view of models and their epistemic value. Models should rather be thought of as epistemic artifacts through which we gain knowledge in diverse ways. Approaching models this way stresses their materiality and media-specificity. Focusing on models as multifunctional artifacts releases them from any preestablished and fixed representational relationships and leads me to argue for a twofold approach to representation.

1. Introduction. In view of the extensive critical discussions of representation in Continental philosophy, pragmatism and the humanities, the question of representation has entered philosophy of science only relatively recently.[1] To philosophy of science representation has found its way especially through the interest in models and modeling. It appears to me that one explanation for this is the fact that the things called models in science are truly heterogeneous ensembles. They can be diagrams, physical three-dimensional things, mathematical equations, computer programs, organisms and even laboratory populations. The problem becomes, then, how do all these diverse things add to our knowledge?

Interestingly, recent writers on the topic of models and representation have been nearly unanimous in saying that models have to be representative in order to give us knowledge (Bailer-Jones 2003; da Costa and French 2000; French and Ladyman 1999; Frigg 2002; Morrison and Morgan 1999; Suárez 2004; Giere 2004). Even so, their preferred accounts of representation differ widely from each other, ranging from structuralist conceptions to pragmatic ones. This poses several questions. Given the

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1. This also applies to analytical philosophy in general. Traditionally, the problem of 'representation' has been addressed in the more marginal areas of philosophy proper, notably in aesthetics and political philosophy.

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different analyses of representation, why do we want to tie the epistemic value of models to representation even though we do not agree on what representation involves? Is the problem that we lack an adequate conception of what scientific representation involves, or is the range of things that we wish to include under the category of representation too great or diverse? What other ways of approaching the epistemic value of models are there?

In the following I argue that the emphasis on representation does not do justice to the various roles of models in science and that a more material and practical approach to them should be adopted. I begin by reviewing some recent analyses of scientific representation and then discuss the approaches that shift the traditional focus from representation to those of mediation and production. I suggest that models could be fruitfully treated as epistemic artifacts that are used to gain knowledge in diverse ways. Focusing on models as multifunctional artifacts loosens them from any preestablished, fixed and well-defined representational relationships and causes us to rethink the question of representation. Consequently, I argue that in tackling the question of representation, we need an approach that distinguishes between the *medium* of representation and the *relation* of representation. I call this a *twofold approach* to representation.

2. From Dyadic to (at Least) Triadic Accounts of Representation. In the recent discussion on models, most writers have stressed, in one way or another, that representation is a triadic relation involving either the 'users' or 'interpretation' (For an opposite view, see da Costa and French 2000; French and Ladyman 1999). This means a shift away from the semantic, or structuralist, conception of models according to which representation is a dyadic relation between two things, the real system and its abstract and theoretical depiction. According to the structuralist conception models are interpreted as structures whose relationship with their target systems is analyzed in terms of isomorphism: a given structure represents its target system if both are structurally isomorphic to each other. (By isomorphism, I refer to a kind of mapping that can be established between the two that preserves the relations among elements.) Consequently the representative power of a structure derives from its being isomorphic with respect to some real system or a part of it. One of the advantages of speaking in terms of isomorphic relationships seems to be that isomorphism can be given a precise formal formulation, which cannot be given for instance to similarity, which is another candidate offered for the analysis of representative relationships.[2]

2. Giere (1988) has suggested that representation should be understood in terms of similarity.

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The abovementioned theoretical attractiveness of isomorphism vanishes once we realize that the parts of the real world we aim to represent are not 'structures' in any obvious way, at least not in the sense required by the structuralist theory. It is perhaps possible to ascribe a structure to some parts of the real world, but then they are already modeled (or represented) somehow. This has, of course, been noticed by the proponents of the semantic theory; Patrick Suppes has for instance invoked 'models of data' (1962). Thus the isomorphism required by the structuralist account concerns actually the relationship between a theoretical model and an empirical model.

Even if we disregard the fact that the world does not present itself to us in readymade structures, isomorphism does not seem to provide any adequate account of representation. Isomorphism denotes a symmetric relation whereas representation does not: we want a model to represent its target system but not vice versa.[3] Moreover, the isomorphism account does not accept false representations as representations. The idea that representation is either an accurate depiction of its object or then it is not a representation at all does not fit our actual representational practices. Both problems appear to be solved once the pragmatic aspects of representation are taken into account. The users' intentions create the directionality needed to establish a representative relationship; something is being used and/or interpreted as a model of something else, which makes the representative relation triadic, involving human agency. This also introduces indeterminateness into the representative relationships: human beings as representers are fallible.

3. Pragmatic Approaches to Scientific Representation. The critical importance of the use to which representations are put has recently been expressed in various ways by Ronald Giere (2004), Mauricio Suárez (2004), and Daniela Bailer-Jones (2003). Of these pragmatic accounts of scientific representation, that advanced by Bailer-Jones is possibly the most traditional. She discusses representation in terms of propositions entailed by models. By entailment Bailer-Jones does not mean logical entailment, for models "use a whole range of different means of expression, such as texts, diagrams, and mathematical equations" and thus some

3. This also applies to the similarity account of representation. For thorough studies on the formal and other properties that we might expect an acceptable concept of representation to satisfy, see Suarez 2003, 2004 and Frigg 2002. Insightful though these studies are, especially as criticisms of the structuralist account, they appear to put the cart before the horse. It is as if we already knew the essentials of the representative relation, and the task remaining would be to find a (preferably formal) analysis for it—one that satisfies the conditions laid down. The unresolved issues regarding representation suggest the contrary.

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of the content of a model may be expressed in nonpropositional forms. As a result the number of the propositions entailed by a model cannot be conclusively determined. Moreover, models typically entail propositions that are known to be false. This leads Bailer-Jones to consider the functions of models, since models containing false propositions can be accepted for some "higher purpose." Because "a model is intended to meet a certain function . . . the attempt to meet the function overrides the striving for the model's proximity to truth" (2003, 70).

The proposal to speak of representation in terms of propositions entailed by models seems somewhat paradoxical, for as long as philosophy of science operated predominantly on the basis of propositions (derived from theories and models) and their fit with the data (via the procedure of testing), the question of representation did not arise. This question becomes acute once we grant that much scientific reasoning operates on other representative means than (propositional) language. Bailer-Jones admits for instance that large parts of models can be described by means of images. Nevertheless, she tries to justify her propositional account of representation by claiming that there will always be a 'commentary' on those images that relates them to the empirical world and that such a commentary would be propositional.

Is this so? It appears to me that this is not the case. The point of using various representative means arises out of their different affordances in conveying diverse kinds of information, much of which cannot be readily, if at all, propositionally presented. Consider for example how much information a picture or a diagram can convey us at a glance. Besides, as Bailer-Jones leaves the notion of 'entailing' unexplained, one is left wondering why it is that models 'entail' some propositions and not others. This seems to have something to do with the representative power of models, which this account of representation has actually left untouched.

Ronald Giere (2004), for his part, is explicit in stating what the representative power ultimately hinges on. Though his views on models and representation have changed substantially since the semantic conception propounded in *Explaining Science* (Giere 1988), he still claims that representation is based on a similarity of some kind. Giere notes that even though no objective measure of similarity can be given, "it is the existence of the specified similarities that makes possible the use of the model to represent the real system" (2004, 748). No general analysis of similarity is needed (and can be given) to explain scientific representation because of the irreducibly pragmatic nature of the scientific representation. Consequently, instead of concentrating on the two-place relation between representation and its target system, Giere proposes that representation can

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be thought of as having at least four places with roughly the following form:

S uses *M* to represent *W* for purposes *P*.

In the above form, *S* can be anything from an individual scientist to a scientific community. *M* is a model, and *W* stands for an "aspect of the real world, a (kind of) thing or event." More informally, the message of the form can be expressed as: "Scientists use models to represent aspects of the world for various purposes" (2004, 747). Yet, Giere is careful to point out that scientists also use models for other purposes besides representation (Giere 2002, 2).

In line with Giere, Mauricio Suárez criticizes dyadic conceptions of representation because of their attempt to "reduce the essentially intentional judgments of representation-users to facts about the source and target objects or systems and their properties" (2004, 768). As opposed to Giere, however, Suárez does not want to 'naturalize representation'. This means that he resists saying anything substantive about the supposed basis on which the representational power of representative vehicles rests, i.e., whether it rests for instance on isomorphism, similarity or denotation. According to Suárez such accounts of representation err in trying to seek for some deeper constituent relation between the source and the target, which could then explain as a byproduct why, *firstly*, the source is capable of leading a competent user to a consideration of a target and *secondly*, why scientific representation is able to sustain 'surrogate reasoning'. Instead, Suárez builds his inferential account of representation directly on these byproducts. Consequently, Suárez calls his account of representation 'deflationary'—or 'minimalist': no deeper features are sought, instead one settles with the surface features.

The formulation Suárez (2004, 773) gives to the inferential conception of representation is the following:

> *A* represents *B* only if (i) the representational force of *A* points towards *B*, and (ii) *A* allows competent and informed agents to draw specific inferences regarding *B*.

This formulation presupposes the activity of competent and informed agents. The "representational force of a source," according to Suárez, is "the capacity of a source to lead a competent and informed user to a consideration of the target." This "relational and contextual property of the source" is fixed and maintained in part by the intended representational uses of the source by the agents (2004, 768). Part 2 of the formulation contributes to the objectivity that is required of scientific representation. Suárez claims that in comparison to Part 1, Part 2 depends in no way on an agent's existence or activity. Instead "it requires A to

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have the internal structure that allows informed agents to correctly draw inferences about B" (2004, 774). Thus even though Suárez does not want to specify what kind of a relation there is between the source and the target, it nevertheless has to be grounded on the structure of the representative vehicle somehow.

These pragmatic attempts to explain representation appear promising, especially those of Giere and Suárez. However, if we adopt a pragmatic approach to models, the focus on representation appears unnecessarily limiting. From the scientific practice point of view, representation is only one of the uses models are put to.

4. Mediation. Morrison and Morgan's view on models as mediators (1999) is an attempt to approach the epistemic functions of models from other angles in addition to that of representation. They consider models as autonomous agents, which through their construction, gain independence (at least partly) from theory and data. This is because besides being comprised of both theory and data, models typically also involve "additional 'outside' elements" (1999, 11). Once independent, models can mediate in different ways. They can function as tools because of their autonomous nature. But the models that are used in science are actually more than just instruments, being 'investigative instruments'. Thus, Morrison and Morgan stress the importance of the workability and manipulability of models for the scientific endeavor.

However, representation enters the scene when Morrison and Morgan try to account for how we can learn from models. They claim that learning from models is dependent on representation: we can learn from models because they represent. Thus even on their account, the epistemic value of models becomes, once again, tied to representation. Yet, Morrison and Morgan point out that they do not conceive of representation in a traditional way as 'mirroring' or as a correspondence. For them, representation is "a kind of rendering—a partial representation that either abstracts from, or translates into another form, the real nature of the system or a theory, or one that is capable of embodying only a portion of a system" (1999, 27). Despite their intention to the contrary, it seems to me that their struggle with representation only shows how difficult it is to get rid of the representationalist thinking according to which knowledge consists of representations that depict (more or less) accurately the entities and processes of the independently existing external world.

As I see it, Morrison and Morgan's approach actually has the potential to release the epistemic value of models from their supposed representative content due to its stress on models as *independent entities*. Concentrating on models as independent entities is a more radical move than it might seem at first glance. It has been customary thus far to understand models

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as abstractions, idealizations or theoretical replicas of something external to themselves. This is built into the semantic view of models: it is the 'underlying' abstract structure that matters. In contrast to this approach, the specific focus on models as independent entities makes us realize that scientific models are typically manmade things, artifacts that are made with a variety of ingredients,[4] or in the case of organisms, often manipulated according to a certain scheme, and utilized to gain knowledge in various ways.

5. Models as Epistemic Artifacts. To call models artifacts might seem unfortunate to start with. In science are we not trying to distinguish the artificial phenomena from the real ones? But the problem of the artifacts arises exactly because science makes extensive use of different kinds of tools—often quite sophisticated ones—and yet philosophy of science has not paid too much attention to their role in the production of knowledge. However, a growing body of literature in cognitive science suggests that our knowledge is importantly bound to our ability to construct tools and manipulate our external material environment (see e.g., Clark 1997). Basing partly on this insight I suggest that we should approach models as epistemic artifacts, that is, as intentionally constructed things that are materialized in some medium and used in our epistemic endeavors in a multitude of ways (Knuuttila and Voutilainen 2003). As parts and products of our scientific (and other) activities, models are endowed with intended uses, one of which is representation. This is in line with the aforementioned pragmatic approaches to representation. However, the most interesting properties of models are due to the way in which intentionality and materiality intersect in their diverse uses. Even though it has become commonplace to speak of theoretical or formal models as 'tools' or 'theoretical technologies', much of that talk is still metaphorical, attributing no material dimension to those things (see Klein 2003, 1–4). Yet it is precisely the material dimension of models and representations in general that makes them collective objects of knowledge and enables them to mediate between different people and various practices. Without materiality mediation is empty.

I want to stress that models should not be taken as simply material objects but rather as things that are variously materialized. There is a strong tendency to distinguish material things from theoretical, abstract or ideal things. Nevertheless, as parts of collective human environment,

4. See Boumans 1999 for an insightful discussion of how many ingredients can enter into a model. The business cycle models Marcel Boumans studied contained analogies, metaphors, theoretical notions, mathematical concepts, mathematical techniques, stylized facts, empirical data and, finally, relevant policy views.

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material things are already endowed with interpretations, meanings and knowledge concerning them. This concerns even things that are usually taken as pure tools, such as laboratory instruments and apparatus (see Galison 1997). On the other hand theoretical ideas that are presented with diagrams, pictures or formal and natural languages are also materialized as various inscriptions on paper or on a screen. All objects of human culture have both ideal (or virtual, if you like) and material dimensions—even totally fictional ones that are nevertheless materialized as texts and pictures concerning them. Thus I do not see how it is possible to make any strict demarcation between what is material and what is not. Instead, one should, especially in the context of models and scientific representations, take into account the medium through which they are materialized, that is, one should be media-specific.

The media-specific approach to models focuses on their constraints and affordances, which are to a large extent due to the characteristics of the media they make use of.[5] As materialized things models have their own construction and thus their distinctive ways of functioning. They are not open to all possible interpretations and uses, which simplifies or modifies the cognitive task scientists face in their work. In scientific work one typically tries to turn into affordances the limitations of the models or the constraints built into them; one devises the model in such a way that one can learn from using or 'manipulating' it. Learning is thus made possible through the material dimension of models, which provides scientists a working object. The material dimension, which is actually required of models if they are to be 'independent' in the sense that they can be transferred to other tasks and contexts, is also critical for their productivity. Models often produce something unexpected and they typically breed, in addition to new applications, new problems and lines of inquiry. Finally, the stress on the artifactuality and materiality of models can accommodate what Baird (2003) calls 'thing knowledge', which is often tacit and bound more to local environments and expertise than to explicit theoretical knowledge.

The artifactual approach to models stresses their multifunctionality in science and suggests that the links between models and reality are more complex than appears when we focus only on representation. This emerges

5. See de Chadarevian and Hopwood 2004 for studies of the epistemic and didactic importance of the three-dimensional scientific models made out of diverse materials such as wood, plastic and wax. Klein 2003 is a beautiful study of the importance of the materiality of the different 'paper tools' that scientists use. She ascribes the productivity of the quasi-algebraic Berzelian formulas in the nineteenth century chemistry to their visual suggestiveness, syntactic and semantic compositionality and simple maneuverability.

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from several recent studies of models. In our study in the field of language technology we argue that the epistemic value of a parser is largely due to its implementation (Knuuttila and Voutilainen 2003). This runs counter to the tenets of the semantic approach to models. According to the semantic approach one would focus on the linguistic grammar underlying the parser, and the (epistemic) question would be whether it correctly represents our linguistic competence. Yet this question cannot be answered until one succeeds in making the parser work. Once the parser produces correct output, it can be used as a starting point in trying to answer several questions concerning language and cognition. Furthermore, as soon as we start building parsers, their fabrication becomes an interesting epistemic and methodological issue in its own right (Knuuttila 2002). Thus new artefacts create new objects of research that in turn produce a host of new problems.

It seems also that the question of representation in modeling is too often approached from the point of view of the 'end-use' of models. It is characteristic of modeling that models are built by representing, and that this task is dependent on what data, knowledge and computational methods are available. The readymade models then, if they ever become ready, are valued often rather for what they produce than for being truthful representations of their (supposed) natural target systems—usually we do not know enough about those systems, which is exactly the point of modeling. Thus in connection with models in evolutionary biology, Anya Plutynski argues that "because we can rarely see evolution in action, evolutionary biologists use models as tools for investigation, existence proofs, and arguments for or against the plausibility of one or another mechanism at work in nature" (2001, S234). Also Robert Sugden, a theoretical economist himself, finds plausibility (though he talks about credibility) important in assessing the relevance of theoretical models for real-world phenomena (2002). After studying two celebrated and innovative papers in economics he finds that in neither of them are the results that the authors derive deductively within their models the ones they want us to entertain. Both writers try to move from the particular result in the model to a broader hypothesis that could be true of the world as well. Consequently, Sugden proposes that we are actually inferring inductively on the basis of our models, thus rather than being any abstractions of reality models should be conceived as *parallel realities.* Moreover, Sugden suggests that, to take an example, the inferences made from the models of housing markets to actual housing markets are not very different from those that are made comparing the housing markets of two different towns. Why this is, he does not say. I suspect that it has something to do with the circumstance that the objects in question, whether natural or

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theoretical, are already being considered from a certain point of view and described accordingly.

6. Conclusion: A Twofold Approach to Representation. Seeing models as epistemic artifacts helps us to understand that a model can give us knowledge in many other ways than simply by virtue of some kind of preestablished abstract representative function. Most of the information models give us is indirect, a result of inferences of various kinds. The representative links to reality provided by models are less straightforward and more fragile and complexly mediated than philosophical tradition would have us to believe. This should lead us to take a new look at representation by approaching representation provided by models as a *twofold* phenomenon, comprised of both a material sign-vehicle and an intentional relation of representation that connects the sign-vehicle to whatever it is that is being represented. The sign-vehicle should be thought of as a materially constructed historical artifact, which leads us to consider the complex culturally constructed artifactual chains through which our knowledge of the world is actually mediated. The relation part of the representation reminds us that no sign-vehicle is representative in and of itself, but that representation is both a process and a result of diverse, intentional human actions taking place in highly specialized activities.

Representation as a twofold phenomenon is implicit in the pragmatic accounts of representation of Giere (2004) and Suárez (2004). Suárez takes representation to be inferential activity that relates the source to the target (i.e., creates the relation of representation) and is also somehow grounded on the structure of the source (i.e., on the stucture of the sign-vehicle). Giere relies on similarity. Though it is based on the properties of the sign-vehicle, similarity is nevertheless established in the specific uses of the model that relate it to 'something in the world'. The structuralist account, for its part, tries to merge the two aspects of representation into one by claiming that representation is grounded on the structural properties of both the model and its target system only. It is as if the things taken as representations did their representing job, i.e., created the relation of representation by themselves, by virtue of what they (and their target systems) are. This actually appears to be often the case—when the application or the interpretation of the model in question has become routine.

The distinction between the material sign-vehicle and the relation of representation is largely conceptual; in practice, as parts of intentional human activity, models come with interpretations and are thus already embedded in epistemic relations of diverse kinds. Yet the sign-vehicle can be detached from the relations in which it is embedded. This is actually a characteristic feature of modeling; in modeling, sign-vehicles are often transferred to different contexts and uses. The heuristic value of models

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has been ascribed to this procedure of describing the entities of one domain with the help of already existing theoretical tools from another domain (e.g., Black 1962; Hesse 1966). In discussing computational models Paul Humphreys notes the "multiple applicability of formal descriptions," which he calls 'computational templates'. These templates are applied across a number of different disciplines. Nevertheless, Humpreys claims that "templates with different interpretations are not reinterpretations of the same model but different models entirely" (2002, S7). The same applies to representations more generally; same sign-vehicles can sustain different interpretations and are thus different representations.

The twofold account gives what must minimally be involved in representation. Although it is not much, it is difficult to say anything more substantive about representation. As I see it, the difficulty with representation arises in science, as elsewhere, when we realize the materiality and media-specificity of our representations. Thus we need to examine the constraints and affordances that are specific to diverse (re)presentative means and the histories and uses of the actual scientific artifacts. Whether or not this kind of work is bound to lead to new analyses of representation or to new conceptualizations that ultimately displace much of the discussion on representation remains an open question.

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