Scientific Representation, Denotation, and Fictional Entities

Abstract:

I critically review RIG Hughes' Denotation-Demonstration-Interpretation account of scientific representation, focusing in particular on the representation of fictional entities in science. I find the original account lacking, but argue that it can be extended in suitable ways. In particular I argue that an extension of this account that weakens the denotation and interpretation conditions can accommodate fictions. This extension also reveals the essential deflationary nature of scientific representation, by bringing into relief the functional roles of denotation and interpretation.

Keywords: Scientific Representation, Modelling, Fictions, Denotation.

Introduction

The influential Denotation-Demonstration-Interpretation (DDI) account of representation was developed in a short pioneering paper by RIG Hughes (1997). My purpose in this paper is to assess the DDI model in light of present day interest on the nature of fictional entities in science. I argue that the DDI model faces an insurmountable difficulty in dealing with such entities. However, an extended version of the DDI account may accommodate fictional entities. While the resulting account is more complex, this may just reflect the complexity of representation itself. In addition the extended version is clearer with respect to the key question regarding the deflationary nature of representation, since it makes it patent that representation is not a relation between its source and target systems, but a functional property of models within a representational practice.

In the first section, I review the original DDI proposal, emphasizing the role that the relation of denotation plays in this proposal. In the second section, I discuss and emphasize the deflationary nature of the DDI account. In section 3 I briefly review some examples of scientific fictions, particularly Maxwell's vortex model of the ether, and show that the DDI account fails to accommodate them. I argue instead for a weakening of the denotation and interpretation relations into correlative functional notions. The conclusion emphasizes the deflationary nature of the suitably extended account, and how it reveals that representation is not a relation *per se*, although it can be instantiated by means of certain relations in certain contexts.

1. The Denotation-Demonstration-Interpretation (DDI) account

The DDI account of representation was introduced by RIG Hughes in his now classic paper (Hughes, 1997). In order to outline and assess the DDI account we need first to fix some neutral terminology. We shall say that, in model-building science, a model source A typically represents a target B. This terminology implies no constraints on what types of objects A and B may be: These may be concrete or abstract, physical or mathematical, real or imaginary. Neither does it preclude the standard view according to which any scientific model must have a target in the real world and represent it via relations that hold between the properties of both source and target. Indeed, as discussed below, the standard view is constitutive of representation on most substantive accounts, which take representation to be a relation – and hence take both relata to be real. Yet, the terminology also leaves room for other views that do not require sources or targets (or both) to be real, and hence do not require representation to be a relation.

In other words many types of objects can play the role of representational sources – from concrete physical objects and diagrams to abstract mathematical structures or laws. And in addition, an indefinite number of different sources may represent one and only one target. Thus a concrete array of small balls carefully strung together by means of wires and Kepler's mathematical laws can both meaningfully represent the solar system, albeit to very different degrees of accuracy. Similarly for targets, the variation here can be large. Some models represent concrete physical systems and their dynamical evolution, such as the solar system; other models represent more general phenomena, or effects, such as the Ising model for phase transitions; or abstract properties, such as the second law of thermodynamics, which represents entropy as necessarily increasing in closed systems.

What do all these instances of 'scientific representation' have in common? This has not been an easy question to answer and there are a number of different proposals. We may, however, classify the proposals available in roughly two different kinds: substantive and deflationary. [1] Substantive approaches answer the question in terms of the properties of sources and targets – and their relation – that constitutes representation. By contrast, on a 'deflationary' approach there is in fact no substantive or explanatory property or relation that constitutes representation. What is rather in common between the different cases of representation is the cognitive role or function that sources play vis. a vis. their targets – i.e. the uses that they are put to by agents towards their specific goals in their particular contexts of inquiry. And that's that. There are no further conditions lurking, as it were, in the background. Hughes' DDI account is, at least prima facie, an approach to representation of this deflationary kind.

[1] For an elaboration of the distinction between deflationary and substantive accounts, see Suárez (2010) and, particularly Suárez (2014) of which the above is an abbreviated version.

The DDI account takes it that scientific modelling is a hybrid notion, containing both elements characteristic of a relation and others more of a piece with an activity. On this view, a source A represents a target B when the following three conditions are met: i) The source denotes the target; ii) A demonstration is carried out on the model; and iii) The results of this demonstration are then interpreted in terms of the target.

Hughes vividly illustrates these elements by reference to the model that Galileo introduces in the Third Day of his *Discourses Concerning Two New Sciences*. Galileo there describes a kinematical problem in geometrical terms, solves the problem in geometry, and then applies the solution back to the original kinematical problem. In particular he concludes that the space *s* traversed by a body in uniform motion with constant velocity in a given interval *t* is equal to that traversed by a uniformly accelerated body initially at rest, provided that the final speed of the accelerating body is twice that of the body in uniform constant motion. In terms of the DDI model, he reasons as follows. First, the kinematical situation must be described by means of a geometrical diagram that therefore denotes it (Figure 1). Thus Galileo denotes the time *t* that the body takes to traverse the space *s* by means of the segment AB of a line, and the speed of the body at any instant of the interval t by another segment of a line perpendicular to the first line. Thus AC denotes the speed of the body at A and BD the speed of the body at B. Second, a demonstration must be carried out on the diagram. Galileo demonstrates that the area of a rectangular shape ABCD is identical to the area of a triangle ABD’ where D’ is twice the value of D. Finally, the result is interpreted back in the terms of the original kinematical problem, by conceiving the overall area covered as the space traversed by the body in its motion over the *t* interval. Thus Galileo concludes that the time *t* that a body in uniform motion takes to traverse *s* is identical to the time taken by a body uniformly accelerated. QED. The three stages in Galileo’s reasoning coincide neatly with the denotation, demonstration and interpretation stages in the DDI account.

2. The Deflationary Nature of the DDI model

Hughes presents the DDI account in a rough and ready way as a deflationary approach to representation because he explicitly refrains from postulating necessary conditions in terms of robust relations between sources and targets (1997, p. 329): "Let me forestall possible misunderstandings. I am not arguing that denotation, demonstration, and interpretation constitute a set of speech acts individually necessary and jointly sufficient for an act of theoretical representation to take place". This is to deny that the DDI account provides us with a substantive explanatory property since it does not even provide necessary and sufficient conditions. [2] Nevertheless, there are a few features of the DDI account that may lead us to question the strength of its commitment to deflationism. These features all follow from the surprising appeal to denotation, which is commonly understood as a substantive relation between the denoting sign and the denoted object. [3]

Hughes' account may be summarized in a schema (figure 2) which should not hide its hybrid nature. Denotation is a relation between a source and a target; while demonstration and interpretation seem best understood as activities on the part of an interpreter / user. There is, of course, an activity of denoting – but this is commonly understood to either establish a relation, or ride upon an already established one. In other words, we may not use A to denote B without ipso facto establishing a relation of denotation between A and B. The relation substantially informs the notion of representation at play, as revealed by our use of the language. For instance, we speak of the geometrical diagram as in itself denoting the kinematical problem, independently of any activity carried out by Galileo, as if the relation of denotation was entirely independent of anything we can actually do or not with it. There is at least prima facie a question here regarding the nature of the relation that informs this conception of representation. The contrast is great with the notion of demonstration, which can only be conceived as a piece of reasoning carried out by someone entirely within the 'space of reasons' provided by the model source. It seems hopeless to attempt to interpret this as a relation, since at this stage of the modelling process, the target may not taken into consideration at all. So, on the DDI account, in order for the geometrical model to represent (for us) the kinematical situation, we must carry out Galileo's demonstration ourselves. It would not seem to be true that "there is a demonstration out there, waiting

[2] For a more detailed discussion of this point, see Suárez (2014).

[3] Goodman (1976); see also Elgin (1996, 2009).

for us to apprehend it". Here, by contrast with the denotation part, the activity itself is constitutive of representation, and there is no relation that may stand in its place.

The third element in the DDI account appears less clear-cut. In model theory, of instance, the notion of 'interpretation' may be understood as a relation: [4] It is a function mapping the elements of the language into a domain of independent entities endowed with their own properties. Hence, take a set of sentences in some particular language; the 'interpretative mapping', on this account, provides them with a 'semantics' under which they may be said to be true or false. But it is doubtful that this is the same 'interpretation' that is involved in the DDI account, since to the extent that the model source contains sentences at all, they already come fully interpreted in terms of the model itself. It seems more appropriate to think of it as an instance of 'application': it applies the model source to the target in order to derive results of interest regarding the target itself. Now, there is no doubt that the application of the model is constrained by the relation of denotation established in the first stage of the DDI account, but it also brings a large degree of freedom in two respects at least. Firstly, the denotation relation by itself does not stipulate which parts of the target object correspond to which parts of the source object, and there is always plenty of leeway at this point. In the Galileo example the mere fact that the geometrical diagram denotes the kinematical situation does not settle which parts of the diagram stand for which parts of the kinematics. But more importantly the mere fact of denotation does not determine how the source is to be conceived in the first place, i.e. how it is to be divided into parts that can then be related to the target. And it is, however, clear that the application of the source to the target does require a partition of the source into relevant parts and properties (a "structure"), and the relating of such "structure" to a similar "structure" of parts and properties in the target. Thus in Galileo's modelling example, the geometrical diagram must clearly distinguish vertical and horizontal lines at every point, and the area therein comprised. Similarly the kinematical problem must clearly identify time intervals, speed of motion at every instant, and constant or accelerated motion across the interval. Etc.

In other words, 'interpretation' requires at least two types of activity on the part of the modellers. First, it requires the ascribing of some structure to the source and

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[4] For instance see Chang and Kleiser (1990, p. 20ff).

target objects, by judiciously partitioning them into an appropriate set of features and their properties. Second, it calls for a mapping of the elements of the source structure onto some corresponding parts and properties of the target, again under some suitable partition, which is typically ascribed on pragmatic grounds. [5] Both steps ('partitioning' and 'mapping') are activities within the modelling practice without which interpretation is impossible. However, only mapping issues in a sort of relation akin to denotation between (elements of) the source and (elements of) the target. Therefore, on the DDI account, modelling is a hybrid of a relation (denotation, mapping), and a number of activities (demonstrating, ascribing, partitioning). The activities are a part of some normative practice of modelling, but the relations seem independent of that practice. They are at least conceptually distinct since they can be in principle described without appeal to the practice itself.

A deflationary strategy would recommend replacing both denotation and mapping with functional activities or features of the representational practice as well. I have argued (Suárez, 2014) that there are functional replacements for both denotation and mapping, referred to as *denotative* and *inferential function* respectively. The resulting Denotative Function-Demonstration–Inferential Function (or DFDIF) account is more faithful to modelling practice because it relates all its various components directly to a number of salient features of the practice of model building. In addition, as I discuss in the next section, it possesses the additional advantage to deal with fictional entities in science in a natural fashion.

3. The DDI Model and the Role of Fictions in Modelling

The recent modelling literature emphasizes how scientific models can represent fictional or imaginary entities, processes, or phenomena. There is no need to review any of the case studies in detail; their upshot is that any adequate account of scientific representation must accommodate representations with fictional or imaginary targets. To give just one illustrious example, Maxwell's famous vortex model of the ether is of course a representation; and it is a representation even though the various components,

[5] See e.g. Van Fraassen, 2008, Ch. 6.

including for that matter the ether itself, have a rather dubious ontological status. [6] Thus fictions are a key testing ground for any account of representation and particularly so for those that presuppose representation is a relation. Thus the requirement of denotation would rule out fictional representation. However, Elgin (2009, pp. 77-78) has emphasised that this requirement can be weakened: “A picture that depicts a unicorn, a map that maps Atlantis, and a graph that charts the increase in phlogiston over time are all representations, although they do not represent anything. To be a representation, a symbol need not itself denote, but it needs to be the sort of symbol that denotes”. That is to say, a source may function ‘as a representation’ without actually denoting its target. It is enough that the source has “denotative function”, and this function can be carried out without eventuating in actual denotation. In other words, one crucial difference between denotation and denotative function is that the former is a success term (for it is impossible for it to be true that ‘x denotes y’ unless y is real) but the latter is not (since ‘x has denotative function and its purported denotation is y” may be true even though y is not real but imaginary or fictional). And while the former (denotation) requires the latter (denotative function) the converse is not true: Denotative function does not require successful denotation – not even in the long term or in a hypothetical future.

The comparisons with art are very pertinent and enlightening on this point, which surely explains why they get recurrently used in this regard. A portrait always has denotative function but does not always denote. Velázquez’s portrait of Pope Innocent VI both denotes and has denotative function; but it would be a mistake to say of any of the series of canvasses that it inspired Francis Bacon to produce that it also denotes in spite of the obvious fact that they too are portraits. Or, consider the case of Leonardo’s Mona Lisa, which notoriously raises historical questions concerning whom exactly it denotes, and how. These questions are logically and historically independent of the uncontroversial fact that the portrait has denotative function. Similarly, Maxwell’s models of the ether may not denote anything. We nowadays take them to have no referent, even though Maxwell, like any other 19th century physicist – at least at the time that he introduced the vortex model of the ether – was certainly committed to a

[6] For more case studies see the various essays contained in Suárez, 2009; Woods, 2011. For a discussion of Maxwell’s (1961/2) model, see e.g. Nersessian (2008).

carrier of electromagnetic waves. Yet, his attitude to both vortexes and particularly idle wheels was more nuanced. He thought of both as useful analogies but not as literal descriptions of the mechanisms underlying electromagnetic phenomena. In spite of all this, the models seem to function undeniably in a representational fashion. More particularly, there is no substantial difference between the methodology employed for both demonstration and application in such 'fictional' models and the methodology employed in non-fictional models, such as that employed by Galileo. The same patterns and rules of inference seem perfectly to apply in both cases regardless of whether or not denotation obtains. Since denotative function allows us to account for a much larger family of bona fide scientific representations it seems reasonable to substitute denotative function in an appropriately extended version of the DDI account. In other words there is a striking asymmetry between "denotative function" and "denotation" that is best understood perhaps, in comparing the concepts' respective extensions, since the extension of the former strictly includes the extension of the latter. (No denoting symbol fails to also be in the set of those symbols that possess denotative function; but the converse is not true.) [7]

The nature of denotative function may now be further clarified. For as was noted earlier in the paper, one thing that stands in the way of a deflationary reading of Hughes' original DDI account is the appeal to denotation. A deflationary account of any concept eschews any reference to any substantive relation between that concept and anything else other than the use of the concept, or the norms that inform such use. There can be no explicit or covert appeal in its definition to a relation between the concept and the world – beyond the aspects of the world that constitute or inform use. Thus on a deflationary account, 'representation' is not understood as a relation between representational models, on the one hand, and facts, states, effects, phenomena, etc, on the other hand. It is instead essentially related to features of the use of representations. And this is exactly where the crucial difference between denotation and denotative function has bite. While denotation is a relation between symbols in a language system and their putative referents, denotative function is merely a feature of our use of those

[7] Note that the asymmetry does of course not entail that denotative function is in the end also a success term. Denotative function is a more general term that covers cases of successful denotation and cases of unsuccessful denotation alike. Hence it is not per se a success term, even though of one of its subclasses certainly is so.

symbols. More specifically, a symbol has denotative function if its use within some symbolic practice is in accordance with the typical norms applied to denotative symbols in that practice. In other words, what matters for denotation is whether the putative relation obtains; but what matters for denotative function is independent of whether or not the relation obtains. It depends exclusively on features of our use of symbol systems. [8] Consequently, the revised DFDIF account is deflationary also in the sense of connecting all the essential features of representation to some features of use within representational practice.

The “mapping” relation involved in the original DDI account is susceptible to a similar deflationary strategy (see Suárez, 2014, pp. 10-11). The crucial function of this ‘mapping’ relation is to allow for a transfer of the results of the demonstrations carried out on the source over to the target. Thus in Hughes’ Galileo’s model example, the overall area of the triangle is interpreted as the space traversed by the body in its motion over the *t* interval. This is a sort of mapping that thus connects an element in the source system (area in the geometrical figure) with an element in the target system (space traversed by the body in motion in the kinematical system). The point of this mapping in practice is to allow some inferences with respect to the target, and in particular the inference that the time *t* that a body in uniform motion takes to traverse *s* is identical to the time taken by a body uniformly accelerated to a greater speed. Thus the ‘mapping’ relation’s functional role is to constrain the set of inferences about the target that may be performed on the basis of a consideration of the source about the target – i.e. what is technically known as the set of legitimate surrogative inferences.

The deflationary thought is then that this constraint can be stipulated independently of any actual relation between the source and the target. In other words, “taking area to stand for space traversed” sets up a rule of inference with, amongst others, the conclusion that equal areas correspond to equal times travelled. It is still the case that certain claims about the source get transferred over to claims about the target,

[8] See Elgin (2009, p. 78) for a similar distinction as applied to what she refers to as ‘P-representations’ as opposed to ‘representations-of-P’. The latter are defined by their relation to a particular kind of things, while the former are, by contrast, defined entirely in terms of features of symbol systems – so belonging in that class is entirely determined by compliance with the norms of use within a practice.

but note that this transference is achieved without any need for an independently existing actual 'relation' or mapping between the source and target. The transference instead, on this view, maps a set of *claims* about the source over to a set of *claims* about the target. But a mapping between claims of some sort and claims of some other sort does not require any relation between the objects of those claims. In particular, a mapping between claims about A and claims about B does not require that B, or A for that matter, be real entities.

To be sure, the discussion above presupposes the standard metaphysical account of relations, whereby a relation between A and B requires both A and B to be real. It may be possible to weaken this postulate by e.g. requiring existence but not physical reality, or by not requiring existence at all. Thus on some accounts abstract entities may enter into relations, even though they are not concrete physical entities; and on some other accounts relations can obtain even amongst fictional entities that do not exist either as concrete physical entities, abstract entities, or any other way. In either of these cases, the account above regarding claims about A and B requiring no relations would be trivially false, and nothing would be gained in pursuing the deflationary strategy. However, this weakening of the standard metaphysics of relations patently amounts to exactly the same deflationary strategy as applied to the very notion of relation. So in fact the same deflationary strategy is enacted here, but at an earlier stage. Hence it is clear that some deflationary strategy will need to be implemented at some or other stage for the claim above to go through regarding claims in the absence of mapping relations between their objects. Whatever strategy that is, it will see the 'mapping' between source and target as merely an inference generation rule that determines the legitimate move from claims about the source to claims about the target. Talk about 'mapping' then is only genuinely responsive to talk about such inferential rules, and a 'mapping' is acceptable (or not) if the rule that it enacts is correspondingly acceptable (or not). It is in particular not possible to assess the propriety of the mapping independently, as it were – by merely looking into the source and target properties and assessing their similarity or resemblance. For the critical aspect of the 'mapping' does not lie in any relation between their properties but rather in the generation rule for inferences that it enacts. And while it is possible that the inference generating rules laid down also coincide with a genuine mapping between aspects of a real source and a real target, this mapping is of a piece with the set of generating rules and not independent or prior to it. In particular it need not coincide with any recognizable antecedent similarity or resemblance. Thus in Hughes's example of Galileo's model, we would be at a loss to find any similarities or resemblances between the area of the geometrical figure and space traversed in a certain interval in the kinematical system – until of course the correspondence between area and space is set up, and the set of legitimate surrogative inferences is naturally revealed.

Elsewhere I have referred to this function as the surrogative inference generating function, or inferential function for short (Suárez, 2014, pp. 11ff.), and I have argued that it should take the place of the "interpretation" third stage in Hughes' original account. The resulting Denotative Function – Demonstration – Inferential Function (DFDIF) account is an extension of the DDI account, suitably weakened to accommodate the representation of fictional entities such as Maxwell's model of the ether. Maxwell's vortex model is genuinely a representation of the ether, even though the ether is nowadays known not to be real. The model represents the ether because it has denotative function and its putative referent is the ether; and because it yields empirical predictions regarding the electromagnetic field when it is so interpreted in the light of the features of the ether. Such denotative and inferential functions are successfully carried out without any successful reference or denotation to the ether. They are carried out because the appropriate norms and rules of inference are enacted in the modelling practice that allows its correct use as a tool in inference. The model is used to all purposes 'as if' it denotes the ether and its elements are interpreted in the light of the features that the ether is assumed to possess. If a model of a fictional entity is functionally indistinguishable from a model of a real entity, then from a deflationary point of view it *is* properly a representation.

4. Conclusions

The DFDIF account here developed has two great virtues. Firstly, it accommodates the representation of fictional entities ubiquitous in scientific practice, which the original DDI model cannot do. And second, it displays the genuine deflationary nature of scientific representation. The role of 'denotation' and 'interpretation' is suitably weakened in this account into their corresponding functional roles. Since a representation can have denotative and inferential functions without actually denoting, the DFDIF account is able to accommodate the representation of fictional entities in science. It also shows representation to be essentially deflationary: the carrying out of the appropriate functions in modelling practice is sufficient for representation. There is in particular no need for a relation to obtain between the source A and the target B. Of course, the target may be real, and a relation between source and target may obtain, even though it is not necessary for representation. Indeed many representational sources are similar to their targets in some relevant respects. In such cases, the relevant functions may be performed via this relation – but it is important to acknowledge that even in these cases representation is not constituted by the relation. On the account provided here, representation is instead constituted by its denotative, demonstrative and inferential functions in modelling practice.

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Figures

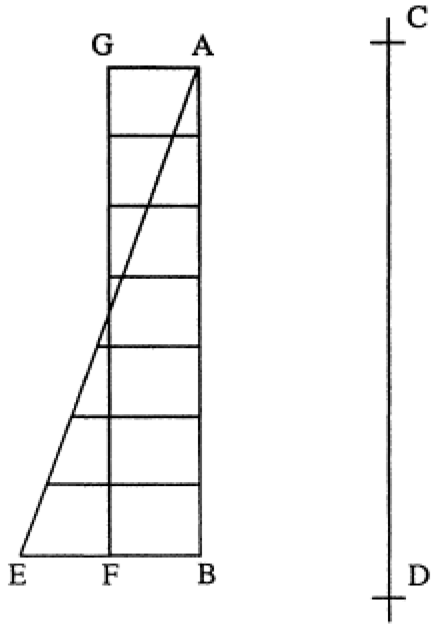

Figure 1: Galileo's geometrical model

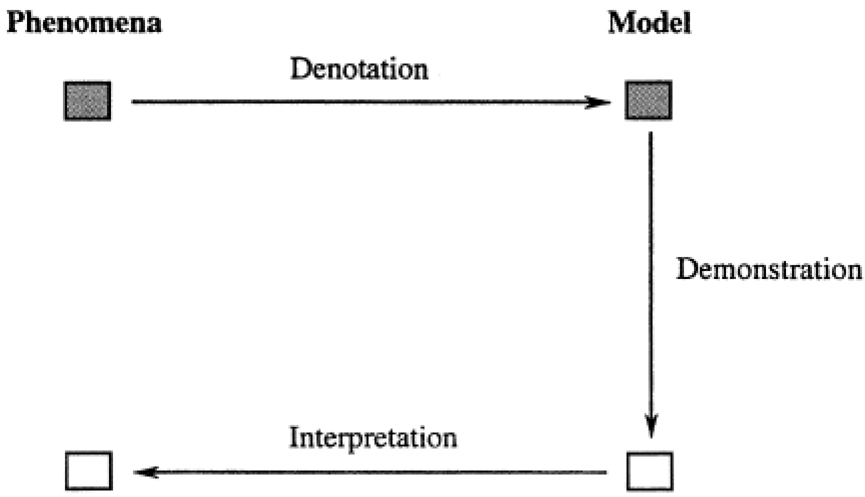

Figure 2: The DDI model