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A Model-Theoretic Account of Representation (Or, I Don't Know Much about Art . . . but I Know It Involves Isomorphism)

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Discussions of representation in science tend to draw on examples from art. However, such examples need to be handled with care given a) the differences between works of art and scientific theories and b) the accommodation of these examples within certain philosophies of art. I shall examine the claim that isomorphism is neither necessary nor sufficient for representation and I shall argue that there exist accounts of representation in both art and science involving isomorphism which accommodate the apparent counterexamples and, moreover, allow us to understand how "impossible" artistic objects and inconsistent scientific theories can be said to represent.

1. Introduction. Most of us would accept that scientific theories represent, although there has been relatively little consideration of the *nature* of this representative function. What discussions there have been have tended to import preestablished conceptions from analyses of representation in the arts, language, cognition, and so forth. Of course, which of these analyses one favors will depend on how one conceives of theories in the first place. If one thinks of them in terms of an axiomatized set of logico-linguistic statements, then one might naturally be drawn to accounts of linguistic representation in which notions of *denotation,* for example, feature prominently. If, on the other hand, one conceives of theories in nonlinguistic

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terms, as in the model-theoretic approach, then one might look to analyses of representation in the arts where notions of *resemblance* tend to be brought to the fore.

Van Fraassen, for example, has imported such an analysis into his discussion of representation in science and argued that an appropriate account of resemblance can be given in terms of the set-theoretic relation of isomorphism (1994). This has been strongly criticized by Suarez, who argues that just as isomorphism cannot capture representation in art, so it is inappropriate in the scientific context as well (1999). Similarly, Hughes draws on Goodman's rejection of resemblance in art in favor of denotation and, rather confusingly perhaps, favors the latter whilst also maintaining the model-theoretic view of theories (1997). In what follows, I shall examine the debate in terms of three claims:

Isomorphism is not sufficient for representation;
Isomorphism is not necessary for representation;
Models denote and do not resemble.

Each of these claims will be questioned and I will conclude by suggesting that, through appropriate modifications, a form of isomorphism can serve to underpin representation in both the arts and science.

2. Isomorphism is Not Sufficient for Representation. That isomorphism is not sufficient for representation seems to be acknowledged by all participants in the discussion. Consider, for example, some markings left by wind and sea on a stretch of sand: even if these were isomorphic to a face for example, still, it is typically suggested, we would not say that the markings *represented* a face. The crucial element that is missing in such cases is that of *intention:* in order for something—a painting, a sculpture, markings in the sand, whatever—to represent, there must be the relevant intention involved (van Fraassen 1994; see also Suarez 1999). And—or so it is claimed—the same must hold for representation in science.

But why must it? Let us consider again the face in the sand. Here the issue, I suggest, is not so much the nature of representation but the prior one of whether such a face *constitutes* art or not. Consider the analogous case of the sea and wind carving the Lorentz transformations into the sand. Are we going to similarly insist that such markings do not represent relativistic phenomena of some sort because the relevant intention is absent? The difference seems to be that in the latter case we do not take the causal provenance of the markings themselves as having any bearing on the constitution of the theory *as an object*. The theory is "there" in the sand, in a sense, in a way in which the respective work of art is not. And, of course, this is what lies behind those recurrent and amusing stories of works of art being mistaken for heaps of rubbish for example (one of the most recent such examples being Damien Hurst's ad hoc gallery "installation" of the detritus of the artist's studio, which was subsequently swept away and put into bin liners by the gallery's caretaker).

What this relates to is an ontological issue: what *is* a theory? We should note immediately that a similar question can be asked about certain kinds of art—such as musical compositions for example, and some of the discussions here bear a similarity with those in the philosophy of science—but in the case of paintings, say, or sculpture, an answer is forthcoming comparatively easily. Putting things rather crudely for the moment, we could point to the massive rectangle of canvas on the wall of the Spanish pavilion and say "*That* is Picasso's *Guernica,*" or similarly, point to the tank full of formaldehyde and say "That is Hurst's cow and calf." However, we are typically reluctant to similarly appeal to ostension in picking out the theory of relativity, say. The black marks in my photocopy of Einstein's 1905 paper do not *constitute* the theory, any more than do the marks in Einstein's original draft or the wind-blown squiggles on the beach. And it is precisely this point that is drawn upon by adherents of the model-theoretic approach—such as van Fraassen—when they urge that theories should be regarded as *extra*-linguistic entities. But if they are so regarded then the distinction between marks that were intended by Einstein to represent certain phenomena and marks carved into the sand by the wind, appears to evaporate.

My suggestion, then, is that drawing on representation in art in order to power a discussion of representation in science is not entirely straightforward. In particular, whereas intentions are typically drawn upon in art in order to distinguish "artistic" objects from other kinds,[1] this is not the case in science. Hence arguments in which resemblance or its formal equivalent is not sufficient to capture the representational relationship in the case of theories, because intention needs to be added to the mix, may not be as powerful as might be first thought.

3. Isomorphism is Not Necessary for Representation. The principle argument for this claim is that there exist examples of works of art which are not, indeed, *cannot* be, isomorphic to anything because, at one extreme, they enter into a multiplicity of representational relationships and, at the other, they may enter into no such relationship (Suarez 1999). Thus, as an example of the first possibility, consider Picasso's *Guernica*. In this case—it is claimed—on the one hand it represents the "concrete pain" of the inhabitants of Guernica but on the other it also represents the "more abstract threat" posed by the rise of fascism in Europe. Therefore, "the canvas cannot be placed into a one-to-one correspondence, not to mention an

1. And also to pick out a preferred interpretation, although I shall not discuss this here.

isomorphism, with those things that it represents" (1999, 78). At the other extreme, the example of Mondrian is given and it is suggested that to focus on representation in such cases is to miss the point of the art: "[t]his type of abstract painting is capable of inducing esthetic, or emotive responses, but it does not do so by 'representing' anything" (1999, 79).[2]

However, such cases do not decisively rule out an account of representation based on isomorphism, as Budd, for example, demonstrates (Budd 1993). His approach begins with a crucial distinction between one's "visual world" and one's "visual field":

> My visual world at any time is the complete way the world is then represented to me by my visual experience. My visual field is a certain aspect of the way the world is represented to me by my visual experience. (Budd 1993, 158)

The relationship between the two can be understood in terms of *abstraction:* my visual experience represents the world as a collection of objects "spread out in three-dimensional space" and my visual field is what is left when we abstract the apparent distance of these objects from me. Thus, for example, if my visual world contains a circular object that is titled away from me, then within my visual field this object will appear elliptical. As Budd makes clear, one should not characterize this difference in terms of the visual world and visual field containing different objects, but rather in terms of different accounts of how my visual experience represents the world as being, one complete and one partial. This distinction then allows Budd to firm up the claim that a painting represents by sharing properties with its subject:

> [A] picture looks like what it depicts only with respect to properties of the spectator's visual field, not those confined to his visual world. (Budd 1993, 159)

This "sharing" of properties can then be captured via the notion of *isomorphism,* where this is taken to hold between the *structure* of the surface of the painting and the *structure* of the relevant visual field. So when you look at a painting, what you see is the structure of the surface of the

2. Mondrian is not, perhaps, the best example to give in support of such a claim, since he famously rejected the representational or nonrepresentational dichotomy, arguing that his work *was* "representational" in a broad sense that encompassed the representation of pure relationships, or structure. A better example might be that of Rothko's work but nevertheless one could still insist that, unlike such artistic objects, scientific models and theories are not intended to produce aesthetic or emotive responses (at least not primarily) and so to that extent, such cases do not count as legitimate counterexamples. In other words, pointing to cases of nonrepresentational art does nothing to undermine isomorphism-based accounts of representation in science.

painting as being isomorphic with the structure of the visual field of the state of affairs that the painting depicts. This yields the following account of pictorial representation:

> First, your experience must involve a visual awareness of the presence before you of a marked surface. Secondly, you must see the structure of the surface as being isomorphic with the structure of the visual field representation of the picture's subject when seen from a certain point of view, namely, that from which it has been depicted. (1993, 161)

Putting it in a nutshell, *representation consists in the perceived isomorphism of structure* (1993, 162; my emphasis).

As an illustration of this approach, Budd considers Holbein's famous picture, *The Ambassadors*. Here, as is well known, the foreground of the painting includes a depiction of a skull that is represented anamorphically, so that it appears as a skull only if looked at from one side of the picture. From Budd's point of view, the depiction of the skull is isomorphic with the representation in the visual field of a skull in the precise sense that there exists a one-to-one mapping between the points that compose the two, but

> you see it as being structurally isomorphic only when you see it from the side and accordingly, you see it as a depiction of a skull only from that unusual, oblique point of view, not when looking at it from straight on. (1993, 162)

Even more significantly, cases of "abstract" art can also be accommodated. First of all, it must be acknowledged that in many cases the visual field representation of the picture surface may be "strikingly unlike" that of the relevant state of affairs. The perceived dissimilarities can take two (obvious) forms: the visual field representation of the picture surface can lack features possessed by the visual field representation of what is depicted, or the former can possess additional features that the latter does not. Of course, as Budd is clear to note, this absence or presence of features does not imply that the spectator sees *what is depicted* as lacking or possessing the relevant features. The absence of color in a black and white drawing, for example, is not understood by the spectator as indicative of a lack of color in what is being depicted but only as not indicating any color; as Budd puts it, "the object, as depicted, has an indefinite appearance in the dimension of color." By eschewing color, the artist's intention is simply "to depict only the spatial structure of a state of affairs and the comparative brightness of its parts, perhaps, not the colours of its constituent objects" (1993, 164). Likewise, a spectator viewing a painting or drawing in which stippling or cross-hatching is used to represent variations in tone does not read these features into the objects being depicted. In general, we typically—but not always—abstract from certain details of the picture surface.

Thus, in considering the example of Picasso's *Head of a Girl,* the loops and spirals of Picasso's drawing correspond to the visual-field representation of a girl's hair only when other features are abstracted away. In general, schematic depictions resemble the visual-field representations of the corresponding objects "only with respect to the structural features they depict" (1993, 164). As Budd emphasizes, the perceived isomorphism refers to structure "at a certain level of detail" (1993, 165) and one can easily see how this account also accommodates Picasso's *Guernica*. It can be extended to cover Mondrian's work as well, if this is understood as a form of schematic depiction in which what is being depicted is "pure relationship."[3]

More intriguingly, Budd claims that it can capture depictions of "impossible" or contradictory objects such as these featured in the works of Escher, for example. If we consider the famous case of the three-pronged tuning fork, which has two rectangular bars at one end and three cylindrical bars at the other, then what we have, in effect, are two incompatible isomorphisms:

> [I]f we direct our gaze at one end of the configuration of lines we see the structure of the lines as being isomorphic with that of visual field representation of two rectangular bars, whereas if we look at the other end the lines look to be structurally isomorphic with the visual field representation of three cylindrical bars. (1993, 166)

However, we cannot impose on the lines a single, consistent interpretation and attempts to do so lead to well-known visual discomfort.

What can we conclude from all this? First of all, that accounts of representation in art that invoke isomorphism cannot be so easily dismissed (at least not on the basis of the examples so far presented). Secondly, that one such account can accommodate what might, at first sight, seem to be the problematic cases of representation in "abstract" art, such as Picasso's *Guernica,* the representation of pure structure, as in Mondrian and the representation of "inconsistent" objects, as in Escher's drawings. As I shall indicate, in capturing such cases, this account offers a nice parallel to a generalization of the model-theoretic account as applied to theories and models in science.

3. Budd emphasizes that his account is not restricted to isomorphisms relating to spatial structure but can incorporate color, texture, brightness and so on: "there is not only a perceived isomorphism of spatial relations but a correspondence of perceived colour: the spectator sees the picture not merely as a structural spatial isomorph but also as a chromatic icon" (1993, 167).

4. Models Denote and Do Not Resemble. Budd's approach can be understood as part of the backlash to Goodman's classic rejection of resemblance-based accounts of representation in favor of one based on denotation (Goodman 1969). Moving back from art into science, Hughes has incorporated Goodman's account into the model-theoretic framework, yielding his own DDI (Denotation, Demonstration, and Interpretation) view (Hughes 1997). A model then "stands for" or refers to a physical system, and elements of the model denote elements of the subject. Furthermore, scientific representations possess an "internal dynamic" that allows us to make predictions of both everyday and, crucially, novel facts. Through this internal dynamic we "demonstrate" the relevant results. And a given model may provide the internal dynamic of another so that we get a hierarchy of models, and of representations, in which a model at one level of the hierarchy is the subject of and represented by a model at a higher level. Finally, these results that are demonstrated within the model have to be interpreted in terms of its subject. It is only after such interpretation that we can see "whether theoretical conclusions correspond to the phenomena, and hence whether the theory is empirically adequate" (1997, 333).

However, transporting Goodman's approach into the scientific context is not unproblematic. As is well known, the primary basis for his rejection of resemblance is the perceived lack of correspondence between the properties of resemblance and representation: the former is symmetric and reflexive, for example, whereas the latter is not (Goodman 1969, 4). The obvious way to overcome this objection is to insist that we do not simply model a phenomenon, we model it *as* something. Thus, for example, we model a gas as a system of billiard balls, or we model a superconductor as a giant diamagnet (see French and Ladyman 1997). Furthermore, even if it is granted that when it comes to artistic objects, "almost anything may stand for anything else" (Goodman 1969, 5), it is not clear that this is the case for models. Not anything can serve as a scientific model of a physical system; if the appropriate relationships are not in place between the relevant properties then the "model" will not be deemed scientific.

Hughes's emphasis on denotation also puts him at odds with the model-theoretic approach he espouses. Words are typically held to have denotation and, of course, the analysis of how words represent might well be, and typically is, quite different from the analysis of pictorial representation.[4] Furthermore, denotation itself cannot do all the work, as Hughes acknowl-

4. It is worth noting that Hendry and Psillos have developed a view of theories according to which they combine elements from different representational media, such as mathematics and natural language (see Hendry 1999). On such a view, representation might be analyzed in terms of some combination of denotation and isomorphism although it is not clear quite

edges. One must also include some account of interpretation, but if one is going to do that, why bother with denotation to begin with? Why not return to an account based on isomorphism?[5]

More importantly, however, in describing the relationship between theories and models from the perspective of his approach, Hughes draws on an interesting example. Unlike Suarez, he allows for the possibility that both "low-level" models and "high-level" theories represent. In particular he notes that Bohr's famous atomic model can be described as a "local" model and represents a clearly specified type of system (1997, 330). Quantum mechanics, on the other hand, can be considered a "global" theory and deals with a heterogeneous collection of physical systems. In this case we can still say that there is representation insofar as each individual system in this collection can be represented by a particular model defined in terms of the theory. What a global theory defines is not a particular model but a class of models and in the application of the theory to a particular system, it is a "local" member of this class that represents. According to Hughes, "[t]here is thus no significant difference between the representations supplied by local and global theories" (1997, 331).

Now, in the case of the Bohr's model of the atom we have a famously *inconsistent* model and in this context it raises the issue of whether and in what sense one can have *inconsistent* representations. On the Goodman account, one would have to appeal to some notion of inconsistent denotation, that could perhaps be related to the various forms of paraconsistent logic that are widely available. Alternatively, one could try to accommodate such cases within the model-theoretic approach, although there have been relatively few studies along such lines.

Laymon, for example, notes that one of the advantages of the model theoretic approach is that it

> allows for easy and revealing consideration of computational concerns and . . . allows for the coherent use within a calculation of inconsistent theories. (Laymon 1988, 262–263)

Thus his primary concern is with the way in which theories that are inconsistent with one another are used to account for phenomena, rather than with the explanatory role of internally inconsistent theories *themselves*. However, he does emphasize the role of idealizations and approximations in generating a certain "looseness of fit" between theories and their computational consequences, sufficient to allow mutually inconsistent

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how this would work. In personal correspondence I have argued that anything this "interactive" view can do, the model-theoretic approach can do as well, but more straightforwardly, although I will not pursue this here.

5. I am grateful to my MA students for raising these latter issues.

theories to be used. Now, idealization and approximation can be accommodated within the model-theoretic approach through the introduction of "partial isomorphisms" as the fundamental relationship between theoretical and data models (see French and Ladyman 1998). In particular, they allow for the way in which two models can "share" parts of their structure.

The technical details have been given elsewhere, but, in summary, are as follows: A partial structure is a set-theoretic construct $a = \langle D, R_{i}, \rangle_{i' \in I}$, where D is a nonempty set and each R_i is a partial relation. A partial relation R_i, $i' \in I$ over D is a relation which is not necessarily defined for all n-tuples of elements of D (see da Costa and French 1990, 255). Each partial relation R can be viewed as an ordered triple $\langle R_1, R_2, R_3 \rangle$, where R_1, R_2, and R_3 are mutually disjoint sets, with $R_1 \surd R_2 \surd R_3 = A^n$, and such that: R_1 is the set of n-tuples that belong to R, R_2 is the set of n-tuples that do not belong to R, and R_3 is the set of n-tuples for which it is not defined whether they belong or not to R. If we have two partial structures

$$a = \langle D, R_k \rangle_{k' \in K}$$

and

$$a' = \langle D', R'_k \rangle_{k' \in K}$$

(where R_k and R'_k are partial relations as above, so that $R_k = \langle R_{k1}, R_{k2}, R_{k3} \rangle$ and $R'_k = \langle R'_{k1}, R'_{k2}, R'_{k3} \rangle$) then a function f from D to D' is a partial isomorphism between a and a$'$ if 1) f is a bijective and 2) for all x and y in D, $R_{k1}xy$ iff $R'_{k1}f(x)f(y)$ and $R_{k2}xy$ iff $R'_{k2}f(x)f(y)$ (French and Ladyman 1999; Bueno 1997). Of course, if $R_{k3} = R'_{k3} = \emptyset$, so that we no longer have partial structures but "total" ones, then we recover the standard notion of isomorphism (see Bueno 1997).

In terms of this framework, one can then understand how "computational consequences" can be obtained from an "internally" inconsistent theory such as Bohr's (see da Costa and French forthcoming). It is by acknowledging that there is a certain internal "looseness of fit" between the component elements of the model, that inconsistency can be comfortably accommodated. However, my concern here is with the issue of how such a model might be said to *represent,* for, in a sense, the corresponding "object" or system is an impossible one.

Here I can only sketch a response (some of the details can be found in da Costa and French forthcoming): putting things a little crudely, Bohr's theory contains elements of both quantum and classical physics and if we were to focus on each element to the exclusion of the other, we might be tempted to say the theory represents a quantum or classical system respectively. However, this would be to ignore what effectively "binds" the theory into a whole and allows the two disparate elements to coexist, as it were, and that is Bohr's central notion of a "stationary state." It is here that the two contradictory elements come together: classical mechanics applies to the *dynamics* of the electron in the stationary state, while quantum theory comes in when the transition between such states is considered. However, it is important to note that it is not only in the discreteness of the stationary states that we have conflict between quantum and classical physics but also in what has been called "one of the most audacious postulates ever seen in physics" (Pais 1991, 147), namely, the assertion that the ground state is *stable,* so that an electron in such a state will not radiate energy and spiral into the nucleus as determined by classical physics. *This* is the central inconsistency of the Bohr model and together with their discrete nature it is what makes the stationary states so peculiar.

Of course, as the Bohr model evolved and came to be supplanted, this peculiarity was eventually understood in terms of the new quantum mechanics and as a consequence, the formal inconsistency evaporated (or, better, came to be replaced by "higher-order" or interpretational incongruences that the principle of complementarity was intended to resolve; see da Costa and French forthcoming). At the time the model was proposed, however, the notion of a stationary state was not understood at all, or at best, only partially, and if one were to represent Bohr's model in terms of partial structures, the stationary states would have to be located among the R_3, as relationships which had not yet been established to hold or not. Characterizing the model in this way one can accommodate the partial and conceptually "blurred" nature of the stationary states that allows for the internal "looseness of fit" between the component elements of the model. And this in turn, gives us an idea of how the model can still be said to represent: what it represents is a system that has elements of classical and quantum physics but has at its heart this poorly understood and conceptually indistinct notion.

There is a nice parallel here with Budd's account of the artistic representation of impossible objects: if we focus on, or abstract out, the classical and quantum aspects of Bohr's model, then each can be taken to represent, respectively, classical and quantum objects. It is when these aspects are brought together, and we wonder what the model as a whole represents, that we experience a kind of cognitive discomfort akin to the visual discomfort we encounter when we look at one of Escher's drawings. Of course, in the Bohr case this comfort was eventually assuaged or, perhaps, merely transposed to the level of interpretation, through the introduction of a formally consistent theory but—and this is marks a difference between the scientific and artistic cases—no such developments can, or should, be expected in the case of Escher's work. More generally, Budd's account can be seen as the counterpart, for artistic objects, of the partial-structures approach for scientific ones. Analogously to the latter case, pictorial depictions resemble the visual-field representations of the corresponding objects only with respect to certain features and, as I noted, the perceived isomorphism refers to structure only at a certain level of detail.

5. Conclusion. My aim in this paper has been to suggest that the "isomorphic" account of representation is not ruled out by the kinds of examples that have been deployed against it. First of all, we need to be careful in importing conclusions drawn from examples in art into the domain of science. Secondly, even in the artistic realm a notion of isomorphism has been defended. Furthermore, this notion is interestingly partial: in particular, if we characterize both the *structure* of the surface of the painting and the *structure* of the relevant visual field in terms of something akin to partial structures, then Budd's central idea that the visual-field representation of the picture-surface can lack features possessed by the visual-field representation of what is depicted, or the former can possess additional features that the latter does not, can be captured in terms of partial isomorphisms holding between these partial structures. The parallels are perhaps most striking when it comes to the interesting case of inconsistent representations.

Of course, this is not to deny the differences between scientific objects and artistic ones; we could certainly invoke Budd's account to capture the relationships between Picasso's sketches and the finished *Guernica* (as an exercise parallel to French and Ladyman's partial structures analysis of the construction of the London-London model of superconductivity, for example; see French and Ladyman 1997), but still we might balk at taking Picasso's masterpiece to be diachronically "open" in the way theories are. Nevertheless, there are enough parallel aspects to suggest that what we have here is a common account of representation and one that encourages further exploration.

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