Logique & Analyse **164** (1998), 313–325

THE QUESTION OF THE REALITY OF TIME AND THE MODEL-THEORETIC APPROACH TO SCIENTIFIC THEORIES

MAURO DORATO

1. *A sketch of the model-theoretic approach to scientific theories*

In the recent years, a new approach to scientific theories has called attention to a *non-linguistic* dimension of science. The neopositivists had regarded theories mainly as sets of *sentences*, to be analyzed by purely *syntactic* means within a formalized *language*. Reacting to such a merely linguistic view, philosophers like Patrick Suppes (1967), Bas Van Fraassen (1980), Ronald Giere (1988) and Frederik Suppe (1989) in the United States, and Marisa Dalla Chiara and Giuliano Toraldo (1973) in Italy, have regarded theories mainly as *abstract, non-linguistic structures* or, simply, *models*. In the technical sense of logic, a model $M = < D, f >$ is whatever satisfies a set of axioms couched in a language L, namely an abstract domain of discourse D (a set of individuals), together with a function f assigning n-tuples of individuals in D to predicates (n=1) or relations (n>1) belonging to L.

The novelty of the model-theoretic conception of theories lies essentially in its attempt to liberate the philosophy of science from the grip of the philosophy of language, which has dominated so much of the philosophical discourse of our century, both in the continental and in the analytic tradition. By relying on the concept of *truth* or satisfaction, the notion of model is essentially *semantic*, and for this reason the view of scientific theories that identifies them with models is also known as the *semantic conception of theories*. The stress on the semantic dimension of science enables its defenders to remark that various different linguistic formulations of a theory may have the *same* model. Consequently, the particular language chosen to express the theory in question must fall in the background, since it loses unicity and becomes instrumental, while the notion of model gets central stage. If a scientific theory is regarded as a family of models, different linguistic formulations of a theory shouldn't give us a different theory, as the defenders of the linguistic conception had it. We can formulate quantum mechanics with Heisenberg's matrices calculus or with Schrödinger's differential equations, but the two formulations are *versions of the same theory* because their 'languages' have a common, underlying model, namely Hilbert space. As

an authoritative defender of the semantic conception of theories put it: "Van Fraassen's semantic conception of theories liberates the philosophical study of science from the linguistic shackles of its logical empiricist predecessor" (Giere 1988, p. 48).

(For the sake of historical precision, we should also recall that by appealing to a somewhat analogous, anti-linguistic sentiment, also Thomas Kuhn at a particular stage of his carrier (1970) —and Joseph Sneed (1971) and Wolfgang Stegmüller (1979) in a much more formal way— had developed a *structuralist* conception of theories, in which symbolic generalizations and exemplars —rather than language— played a key role both in learning and practicing science).

Rather than discussing in a general way the *pros* and *cons* of the semantic, non-linguistic conception of scientific theories, in what follows I will take it for granted, with the purpose of investigating within its framework the vexed question of the reality of time —regarded as the temporal aspect of space-time. The choice of time as a case-study will enable us (i) to find out how the semantic theory approaches the general issue of scientific realism with respect to the so-called "theoretical entities", (ii) to study the relative merits of the rival linguistic theory in approaching such a general issue, and, finally, (iii) to present some new ways of looking at the issue of the reality of time.

2. *Two puzzling questions about the reality of time: the kantian and the realist answer*

Despite the fact that in ordinary language we sometime say that "we feel the passage of time", time by itself, even more than space, appears to common sense as a "non-object" or a "non-entity ". With this expression I mean the well-known fact of our experience that we don't perceive time, or any of its properties, in the same way in which we perceive a table or a tree: obviously, time cannot be touched or heard, let alone seen. Since the time of our experience looks as though it is devoid of perceivable qualities in the ordinary sense, it would seem legitimate to conclude that time is also devoid of any causal power: after all, the *properties* of objects or events are *nothing but their causal powers and dispositions*. If time *does nothing* because it has no perceivable qualities, can't we regard it as mere *nothing*, in the same sense in which space was, for the ancient atomists, the instantiation of the Parmenideian *nothingness*?[1]

[1] With respect to the concept of space as nothing, see Nerhlich (1994). Analogous, important observations have been devoted to time by D. Shapere (199?). I thank Shapere for having sent me his manuscript.

There seems to be at least one important reason to reply to the above question in the *negative*. Time, together with space, is one of the main, if not *the* main, criterion for the reality of a concrete object or event. The difference between Santa Claus or the star wars of a science-fiction novel on the one hand, and my desk or the second world war on the other, is the fact that the latter object and event, but not the former, *are in space and time*. Except for the question of the existence of mathematical objects —which *could* involve real but non spatio-temporally extended, *abstract entities*— one can quite plausibly claim that *a concrete object or a concrete event x is real just in case x occupies a portion of space and time*, that is, just in case x is in spacetime. Keeping in mind these remarks, a rather striking question naturally arises:

> (*Q*) if time (together with space) were a non-entity, how could it yield, together with space, the most important criterion of the reality of things and events? Shouldn't this criterion imply by itself that time is, in some sense, real?

To my knowledge, questions like these have been strangely neglected by the obviously non-negligible, current philosophical literature on time. Of course, a reason of neglect could be an implicit assumption of the answer given by Immanuel Kant in the *Critique of Pure Reason*, according to which time is an a priori intuition that sentient beings like ourselves necessarily (transcendentally) presuppose to organize and structure the sensations of the external *and* the internal world.

Another, more realistic answer to (Q) consists in claiming that time itself is real, though its mode of existence is different from that of ordinary objects or events. In this paper, I will limit the scope of my inquiry only to such a realistic option; as far as Kant's theory of time is concerned, below I will just add a few comments, with the proviso that it would deserve to be discussed in a much more thoroughgoing way.

Despite the fact that the Kantian distinction between phenomenon and noumenon implies that, even for Kant, *time applied to the things in themselves is nothing*, it turns out that for Kant *time is real whenever is referred to the world of phenomena*. It is the celebrated Kantian slogan according to which *time is empirically real but transcendentally ideal*. In some sense, it would seem that the above dilemma between Kantian antirealism about time and the realistic option is misleading. Why can't we consider the Kantian solution as the correct one and maintain at the same time that time is empirically real?

The answer is simple: in the current analytic literature about the reality of time, the sense of "real" in question is generally regarded as equivalent to *mind-independent* (see Mellor 1981, Faye 1989, Dorato 1995). For Kant, however, time is *not real in this sense*: for him, without sentient beings,

there would be no temporal distinction between earlier and later events, or between past and future events. By suggesting that time is empirically real, Kant simply means to claim that the application of temporal distinctions to phenomena —which is made possible by transcendentally subjective and a priori intuitions of time and schemes— is *legitimate and objective, that is, intersubjectively valid*. Since he clearly denies that time or temporal distinctions could be applied to things as they are in themselves, he must also deny that the truth of the assertion "a is earlier than b" is independent of the existence of sentient beings. Summarizing, Kant seems to conflate the subjective, epistemic conditions that enable us to judge two events as temporally successive with the possibly objective, ontological or mind-independent *fact* about nature which might be the basis of the judgment.[2] Once we distinguish ontological from epistemic notions, whether events are objectively (i.e., mind-independently) successive or not depends on empirical reasons given by the reducibility of the relation earlier than to some irreversible, asymmetric physical process, and cannot be established *a priori*.

There is another, simple reason why we can safely assume that a Kantian answer to (Q) above is not being tacitly presupposed by contemporary philosophers of science: Kant's transcendental esthetics nowadays has been abandoned. The reasons are well known: after the Einsteinian revolution, time and temporal relations cannot be regarded as *absolute*, that is, as independent of particular inertial reference systems or of the large-scale matter distribution in the universe. Consequently, since it is widely acknowledged that Kant's *Critique of Pure Reason* was profoundly influenced by Newton's *Principia*, the great majority of the philosophers of science of our century has claimed that Kant's *philosophical theory* of space and time is doomed to follow the destiny of Newton's *physical theory* of absolute space and absolute time. With the exception of Ernst Cassirer (1920) and the Austrian logician Kurt Gödel —who claimed that the theory of relativity is a striking confirmation of Kant's claim that time is ideal in the sense already discussed[3] — the general wisdom of current philosophy of science has it that the Kantian philosophy of time has been superseded by the theory of relativity, in the same sense in which the latter has superseded Newton's theory of space and time.

Independently of the current viability of Kant's philosophy of time, or of the implication upon it emerging from the theory of relativity, I now want to ask whether it is possible to question Gödel's famous argument against the reality of time, based on the theory of relativity, *by fully reversing its*

[2] For this claim, see Dorato (1997, pp. 112–113).

[3] For Gödel's theory of time, see Yourgrau (1991), Savitt (1994) and Earman (1995, ch. 6).

conclusion. Let us recall that Gödel had claimed that for time to be real, there should be real change, given by the coming into being in the present of previously future, unreal events. According to Gödel, such a coming into being in the present presupposes, in its turn, the possibility of partitioning space-time in a set of "layers of nows", each of which should "come into existence successively" (Gödel 1949, in Yourgrau 1990, p. 262). Gödel's argument continues by noting that the *special* theory of relativity implies that any such *global* partition of spacetime into future, present and past events, is *conventional and relative*, since it is dependent on the inertial observer's state of motion. Moreover, Gödel notes that according to his own solutions to Einstein's field equations of *general* relativity, it is physically possible for observers to travel into their past, as the worldlines of his model are circular: in such a universe, a cosmic time (which is the same for all observers) cannot even be defined. Since for Gödel it is essential to the reality of time that future events come into being, according to him *both* the special *and* the general theory of relativity give us a very strong argument to conclude that this kind of ontological change cannot be objective. In conclusion, time for Gödel is unreal exactly in the Kantian sense.[4]

As many commentators have noted, a simple rebut of this empirical argument from the theory of relativity lies in the remark that the *coming into being of future events is not a necessary condition for the reality of time*. If we claimed that time is real if and only if the tenseless relation of temporal precedence *earlier than* is mind-independent, the usual ontology assumed by the tenseless theorists of time (see, for instance, Faye 1989) would enable us to avoid the pitfalls of the ontological change in the reality of future events. In such a tenseless ontology, in fact, past and future events are on a par.

These admittedly sketchy arguments should be sufficient to exclude that Kant's philosophy might have been tacitly invoked to explain the neglect of the questions (Q) above. By surmising that they could be answered also by assuming that *time and space are themselves fundamental ingredient of reality*, couldn't our best theory of space and time, the general theory of relativity, yield an argument in favor of the reality of time?

3. *Three options in favor of the reality of time*

In order to argue for the reality of time by relying on the general theory of relativity, it is necessary to start with a conceptual point, which also serves as

[4] For a reconstruction of this argument, see Dorato (1995, ch. 9) and Earman (1995, ch. 6). In his unpublished and published papers, Gödel has reiterated this point about the ideality of time (see Yourgrau 1990, ch. 13).

a clarification of the terminology adopted above. Although in what follows I shall be discussing "the reality of time" independently of space, the notion that will be tacitly referred to in my discussion is really *space-time*, of which time by itself is only an *inseparable aspect*. As Minkowski put it: "Henceforth, space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality".[5] My referring exclusively to the reality of time (rather than space-time) in a relativistic context is justified by the fact that the *inseparability* between space and time sanctioned by relativity is not equivalent to the their indistinguishability: the importance of the notion of proper time, just to give an example, is certainly not mirrored, in the economy of the theory, by that of proper place.

Within the semantic conception of theories, the general theory of relativity is constituted by the structure M = < M, g, T >, where M is a four dimensional, Riemannian manifold, g is the metric tensor and T is the stress energy tensor, or the matter field. If we try to formulate the problem of the reality of time (space-time) in this semantic framework, we basically have two different options: (i) the set of theoretical relations among spacetime points in M postulated by the model is *isomorphic* to the set of temporal and physical relations exemplified by real events; (ii) the set of mathematical relations among spacetime points in M postulated by the model is *in some sense similar* to the set of temporal and physical relations exemplified by real events. A third option (iii), which, however, *does not typically belongs to the semantic, but rather to the more traditional linguistic conceptions of theories*, consists in claiming that the abstract, mathematical object *M genuinely refers* to physical time (spacetime).

The way of putting (iii), and in particular the use of the verb 'to refer', makes it evident that the third option approaches the reality of time as a particular instance of the more general problem of establishing the reality of the so-called theoretical entities, referred to by terms belonging to the theoretical vocabulary of the theory, seen as a set of sentences.

It should be obvious that within a genuinely linguistic framework —in which the problem is establishing the relation between a word ('Riemannian manifold') and its putative *denotatum*— the model theoretical approach loses it relevance. Note that I am *not* claiming that the third option cannot be formulated within the semantic approach. By discussing these three options in turn, my aim is rather to show that in trying to rescue (against Kant) some form of realism about time, (iii) could produce an argument that is simpler and more efficacious than the arguments that can be offered by relying on the first two, model-theoretical options.

[5] Minkowski (1952, p. 75).

4. *The structural-realist view of science, or the first two options*

The proposal to explain the relationship between models and reality by using the notion of isomorphism is due to van Fraassen (1980, p. 43–46). Given a bijection F from the model M (or a part thereof) to a set R of real objects or events ('reality'), we can establish an isomorphism between M and R if the relations between elements of the model and those between entities of the real world are preserved by F.

If we claim that F holds only when it acts on the *empirical substructure* of the model, its range is restricted to the 'part' of the model that is linked *via F* to observable entities. In this way we can draw the distinction, dear to van Fraassen's heart, between *accepting the theory as empirically adequate* and *believing it to be true* (1980, p. 46). The former epistemic attitude is reserved to the *theoretical* substructure of the theory M, since F guarantees *only* the existence of directly observable entities. Van Fraassen does not exclude that the isomorphism F can be extended to the theoretical substructure of M, but in this case the set of theoretical relations attributed to the theoretical entities *may or may not exist*. If one has to be delivered by metaphysics, as Van Fraassen recommends, one must remain *agnostic* as to whether the spatio-temporal structure postulated by the Riemannian manifold is really instantiated by physical space-time.

In other words, in this first option, the claim about the reality of time gets translated into the claim that the model of general relativity *correctly represents* the world, where 'correctly represents' is understood as necessarily pointing to the existence of an isomorphism. In van Fraassen's view, the problem of establishing whether time is real would amount to decide whether the temporal substructure of the model belongs to the empirical structure or the theoretical substructure. If we assume, as is plausible, that we do not observe time or the spatio-temporal structure directly, within a constructive empiricist position, time (and spacetime) must be regarded as part of the *theoretical* substructure. We must remain agnostic about it, and realism about time could not be established.

What if we were able to treat time as a relation that is perceived directly, as something observable? After all, don't we directly perceive that an event is *before* another event? Well, suppose we do. The question then become: how do we regard time as real in this *relational* sense? We would have to ask whether the temporal relation is question is instantiated by events independently of our mind, a problem that would be translated into the thorny issue of the objectivity of the arrow of time (Savitt 1995, Price 1996). Interesting as this issue is, at the moment there does not seem to exist any agreement with respect to its solution: it seems very difficult to try to establish the reality of time in this roundabout way.

In any case, it is necessary to stress that to the extent that physical spacetime (and time as its temporal aspect) should be regarded as an *entity*, a model theoretical approach based on the idea that a "correct representation of the model" is realized *via* an isomorphism, *whether restricted to the empirical substructure or not*, fails to capture its reality. Clearly, at most the defender of the semantic conception of science can claim that the *model captures the relations that the world instantiates*, but the theoretical entities are somewhat "gone by the board". If time exists as an observable relation, the constructive empiricist can establish its reality. If time exists as an unobservable relation, only a structural realist can affirm its reality, though in a relational sense. However, *if time (spacetime) is entity-like* —that is, if it is something more than just a *relation— and if it exists independently of objects ad events, as substantivalism has it, the model-theoretic approach cannot even hope to establish this fact*. As it is obvious, a structural realist conception of theories can at most claim that the physical universe instantiates the relation postulated in the model, but as to the bearers of the relations —spacetime as an entity— it must remain agnostic.

Before drawing some moral about this structuralist approach, we should take a look at the second option, defended by Giere (1988). He claims that "*resemblance to a certain degree and in certain respects*" is the correct relation between models and reality (1988, p. 81), since it is a weaker requirement than that of isomorphism, and has furthermore more connections with empirical findings from the cognitive sciences, in particular from studies concerning mental images, schemes and their representational features. According to Giere, the relationship between model and reality cannot be linguistic, because neither models nor reality are linguistic entities, but it can be expressed by a *linguistically formulated theoretical hypothesis*, which states the existence of some *degrees* of *similarity* (under certain respects) between model and world. According to Giere, while isomorphisms cannot be *the* relations linking models and reality, because there are obviously many relationships between entities in the models that are not instantiated in reality and *viceversa*, resemblance has the advantage of expressing a typical feature of the scientific enterprise, essentially involving *errors and approximations* (Mayo 1996).

However, note that, besides the obvious vagueness of the relation of 'resemblance under certain respects', such a relation applies, strictly speaking, only between images and aspects of objects; in this sense, it necessarily presupposes visual perceptions or intuitions. Consequently, even if Goodman's critiques to similarity as a non-necessary character of representations (1949) can be met, in order to claim the existence of a relationship of resemblance between models and reality, one must give center stage to *visual* features

of models. In fact, it is implausible to claim that other perceptual modalities are capable of bearing the relation of resemblance with their objects: *resemblance* clearly applies to spatial relations of images and their objects.

It is precisely these features that make also this second option thoroughly inadequate in treating the issue of the reality of time, *if* the latter, together with space, needs to be treated as a *substance*. In fact, time does not possess visual properties, and does not seem to share much of the visual mode of experience: how are we going to try to answer the questions (Q) posed at the beginning of the paper? Why do we consider the spatio-temporal structure as a criterion of reality if time by itself cannot be regarded as real neither in the first option (time cannot be observed directly) nor in the second (time has no perceptual features)?

A structural realist could reply that time is no entity after all, and structural realism is about as much realism that a realist about time can get. However, this position would make spacetime substantivalism false by definition. It is physics, not just philosophical analyses, that should tell us whether time or spacetime should be treated as a relation or as an entity. It is not by chance that Giere treats the problem of the existence of entities in a separate chapter: models cannot tell us anything about the reality of entities they are about, and it is rather the laboratory practice which enables us to assume a *natural ontological attitudes* (Fine 1984) of belief about entities. It is crucial to remark that such an attitude is usually (and correctly) justified by an appeal to direct or indirect *causal interactions* between observers and the entities in question (Hacking 1983, Cartwright 1983, Giere 1988, ch. 5). The same kind of strategy could be applied, although it has not been done, in the case of time.

5. *Time (spacetime) as a causally active entity: the third option*

In this final chapter, I will sketch an argument in favor of the reality of time that invokes some kind of causally active role with respect to matter.[6] The idea of the argument is simple: if x interacts causally with y, x is real, so that if we can prove that time meant as the temporal aspect of spacetime can be causally active, we have a strong argument to believe that it is real independently of us. It is in this sense that the linguistic conception of theories, by relying on a very naive causal theory of reference, can provide a reasonable argument in favor of the reality of time.

[6] Together with some peculiarities of the structural-realist view of science, this argument is analyzed in more detail in a forthcoming paper.

When Newton and Leibniz were discussing about the nature of space-time (*via* Samuel Clarke and his letters to Leibniz),[7] they took something for granted, despite the different positions they were defending. Space and time were for both of them causally inert,[8] a sort of passive background for all events, which for Newton existed independently of them, and for Leibniz was a set of relations among them.

In Einstein's general theory of relativity, however, space-time plays a dynamic role as gravity is an effect of spacetime curvature. Such a curvature must be intended as a variable geometric feature of the four-dimensional manifold that is used to represent the physical universe, a feature that in its turn is influenced by the presence of a gravitational source: in Wheeler's expressive words, matter tells spacetime how to bend, spacetime tells matter how to curve. In particular, *relativistic time* becomes *elastic*, since its rate of "flow" *depends* on relative velocity (in the special theory) and on the intensity of the gravitational field (in the general theory). It is especially this latter dependence of time on matter that is important here. When we refer to such an intimate relation of time with gravity, we can either explain it with the claim that time itself is causally interactive, or we can *identify* the rate of flow of time with gravity, which is an obvious property of matter or of a material field.[9] In both options, to be discussed in turn, there seems to remain little doubt about the reality of time, despite the different interpretations that are given to its ontological *status*.

Within the former, casual interpretation, we can observe that the *sufficiency* of the criterion of reality yielded by (spatio-)temporal 'extendedness' —the criterion tells us that if entity x is in space-time, then x it is real— can be *explained* by the conceptual remark that anything located in (space)time —*an event*— is causally active. Note that the above sufficient criterion cannot apply to time itself: of course, when x above ranges on time, we cannot say that *time is in time*. Even though time *is* in some sense part of space-time, provided that it can be regarded as "an aspect" of spacetime, in order to argue in favor of the reality of time, we should use the converse implication. As anticipated above, the reason why something occupying a region of space-time is real is its causal efficacy, true enough; but we can also maintain the converse implication, namely that

[7] See Alexander (1956).

[8] This aspect is stressed by Shapere (199?).

[9] This second, less common interpretation of the role of time in the general theory is defended by William Unruh (Unruh 1995).

(IMPL) Something is causally active only if it is real.

It is this latter implication that we rely on to argue for the reality of time. Of course, it remains to be shown that *the general theory of relativity can be taken to imply that time (as part of space-time) is causally active*, a complex problem that cannot be discussed here.[10] It will be enough to recall that physicists and the standard presentation of the theory readily admit that spacetime in the general theory of relativity has a dynamic role, that is, it acts and can be acted upon. Not only is the causal role of the spacetime curvature usually regarded as a determining element for the trajectory of a body, *but the effect on time on the part of gravity* is widely acknowledged. If one could rely on this rather informal way of talking, the truth of (IMPL) by itself would guarantee the reality of time and certainly a more detailed analysis of this informal talk seems a promising direction of philosophical inquiry. For instance, an antirealist could reinterpret every talk about the rate of flow of time as a talk about the motion of particular bodies. If this move were possible, the causal argument above —that in my presentation did not rely on any appeal to a causal theory of reference, nor to a naturalization of the semantic notions (Field 1972)— could be jeopardized.

Let me now move on to consider the second formulation of the relation between time and gravity, the one appealing to their *identity*. In this case, the argument in favor of the reality of time is even more straightforward: if time is identical with a particular, variable property of the gravitational field, it is real as any other material property. Also in this case, of course, the ontological status of time would not be that of a *substance*, but rather of a *property* thereof: the "field" would be the basic, "substance-like" constituent of reality. Which of these two different ways of understanding the role of time in the theory is more correct? Presumably the question will be decided when we will possess a sound quantum theory of gravity. Notoriously, in the yet-to be built theory, time plays a role that is not yet fully understood, or does not play a role at all.

In conclusion, my claim about the greater efficacy of the third, causal option in favor of the reality of time is by no means to be interpreted as a rejection of the model-theoretic conception of scientific theories. To say the least, the model-theoretic conception has been an important, much needed complement to the linguistic conception of theories. The claim is just meant to remind us that the kind of structural realism that follows from the first two options seems irrelevant for the issue of entity realism. To the extent that the empirical sciences still require an ontology of individuals, some sort

[10] See note 6.

of causal arguments showing that we causally interact, directly or indirectly, with unobservable entities should be an integral component of the methodology of science, independently of the fate of the causal theory of reference.

University of Rome 3, Department of Philosophy,
Via Ostiense 234, 00146 Rome, Italy
E-mail: dorato@uniroma3.it

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