

Causal Order, Temporal Order, and Becoming in Special Relativity

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ABSTRACT. I reconstruct from Rietdijk and Putnam's well-known papers an argument against the applicability of the concept of becoming in Special Relativity, which I think is unaffected by some of the objections found in the literature. I then consider a line of thought found in the discussion of the possible conventionality of simultaneity in Special Relativity, beginning with Reichenbach, and apply it to the debate over becoming. We see that it immediately renders Rietdijk and Putnam's argument unsound. I end by comparing my approach to others found in the literature, primarily Stein's.

Since the publication of Rietdijk and Putnam's papers in 1966 and 1967, the applicability of the concept of becoming in Special Relativity theory has been the subject of debate. Each paper's argument is problematic in various respects, which I shall mention below; however, an argument that can be reconstructed from them establishes, if sound, that nothing comes into being if the world is as Special Relativity says it is. In this paper I consider this reconstructed argument, to which, despite the reconstruction involved, I shall refer as Rietdijk and Putnam's argument.

A common response in the literature to Rietdijk and Putnam's argument is by rendering existence relative to an observer or frame of reference (Sklar 1974, p. 275; Godfrey-Smith 1979;¹ Hinchliff 2000). We shall later see how this relativization is supposed to answer the argument. However, even if this relativization of existence is indeed correct, I doubt whether it can prove the unsoundness of Rietdijk and Putnam's argument, for reasons I shall explain below. Moreover, since some have found this relativization objectionable (see (Savitt 2006) for an overview and references), it is at least of dialectical importance to show without recourse to it that the argument is unsound. This is what I shall attempt in this paper.

Interestingly, although another central philosophical debate engaged with temporal concepts in Special Relativity is that concerning the possible conventionality of simultaneity, almost no one has tried to rely on ideas developed within the latter debate in order to shed light on the former.² This is what I shall do here: I shall apply some conclusions of the conventionality of simultaneity debate in order to show why Rietdijk and Putnam's argument is unsound.

I turn to the argument. Accessible presentations accompanied by diagrams abound in the literature, so I shall allow myself to be brief (see (Savitt 2006, § 3), for a more detailed presentation). Also, most of Putnam's discussion (pp. 242ff) uses a version of the argument which is less general than Rietdijk's, yet towards the end of his paper (p. 246) he writes that his argument can be extended and then sketches Rietdijk's version. My reconstruction of the argument in the next paragraph is therefore closer to the more general version found in Rietdijk's paper.

¹ Godfrey-Smith later changed his name to *Grey*; I shall refer to him below by his present name.

² Tooley is an exception (1997, Chap. 11); however, he did that by arguing for absolute simultaneity in Special Relativity, but this seems *ad hoc*, as no phenomenon *within* the theory supports absolute simultaneity (see (Stein 1991), note 2 to pages 154-5).

Suppose then that we are given two events, e_1 and e_2 , in the history of an observer O_1 , such that e_2 is later than e_1 (O_1 need not be inertial). According to Special Relativity, an observer O_2 is possible, with an event e^* in his history— e^* being space-like relative to both e_1 and e_2 —such that at e_1 , e^* has already happened (or occurred, or become) relative to O_1 (it is then in O_1 's past), and at e^* , e_2 has already happened relative to O_2 . Now it seems unobjectionable to maintain that what has already happened relative to something that has already happened relative to x , has already happened relative to x (having-happened or having-become is transitive). If so, then it follows that (i) at e_1 , e_2 has already happened relative to O_1 . However, what is in our future has not yet happened relative to us, and therefore (ii) at e_1 , e_2 has *not* already happened relative to O_1 . We have a contradiction, and so the concept of having happened or of becoming is inapplicable in Special Relativity. If Special Relativity is true, becoming is an illusion.

Rietdijk maintained that his proof shows that determinism is true and indeterminism false. Putnam also concludes from his argument 'that the problem of the reality and *determinateness* of future events is now solved' (p. 247; italics added), so he also seems to think that his argument shows that determinism is true. But this is not so, at least on a common understanding of determinism. Determinism is the thesis that, given the laws of nature and the state of the world at a certain moment, the state of the world at any later moment is uniquely determined by them. It thus involves a logical relation between two states of the world at different times and the laws of nature. Yet nothing is implied about such a relation by the former argument. Even if becoming is an illusion, it can still be the case that although only one later state has 'always' existed, several possible later states are compatible, given the laws of nature, with a given earlier state, and so indeterminism holds. Accordingly, even if Rietdijk and Putnam's argument is sound, it does not prove determinism but rather that becoming is an illusion.³

Notice that in the reconstructed argument above I did not say that one event *exists* or is *real* relative to another, but that it *has happened* (or *occurred* or *become*) relative to the other. Sklar, Grey and others, following Putnam and formulating the argument with the former concepts, have tried to refute it by maintaining that what is real is observer relative and thus not transitive in the observer-independent way the argument assumes. I find the ascription of existence or reality to events strained: events *occur* or *happen* rather than exist; while a real event is to be contrasted with an imaginary or a hypothetical one, which is not the issue in this debate. If we decide to ascribe reality to events and to maintain that it is observer-dependent, this would be a stipulation and not an observation on our concept of the real. Rietdijk and Putnam, however, tried to determine something about the applicability in Special Relativity of a given concept, and not about that of a stipulated one.

Whatever we think of reality as ascribed to events, I think we conceive of having-happened as transitive in the way described above. And if the transitivity of having-happened is accepted, then common arguments against Rietdijk and Putnam are insufficient. Moreover, as noted earlier, it is in any case of dialectical significance to show that the argument is unsound independently of whether having-happened is a transitive relation.

In addition, our reliance on the transitivity of having-happened frees us from some problematic assumptions Putnam thought he had to make about existence and reality. For instance, he uses as an assumption the hardly meaningful view which he courageously ascribes to 'the man on the street', that 'all (and only) things that exist now are real'. He also considers this view as committing him to the even more dubious assumption about the concept *real*, that 'I-now am real', in which 'I-now' refers to a

³ I don't know who first drew this distinction in the literature, but it is found already in (Sklar 1974, p. 273).

different instantaneous ‘me’ each time this assertion is made (p. 240). As could be seen in my version of the argument, it involves no problematic claim about the relation of existence and reality or reference to instantaneous ‘T’s.

Let us now remind ourselves of some central ideas from the discussion of the conventionality of simultaneity. Reichenbach has famously maintained that two events are temporally ordered, e_1 occurring earlier than e_2 , just in case e_1 can influence e_2 (1928, § 22). As I have argued elsewhere (Ben-Yami 2006, § 2), since we should also allow for instantaneous causation, his considerations actually justify the claim that e_1 occurs earlier than *or at the same time as* e_2 just in case e_1 can influence e_2 . Reichenbach continued to draw the conclusion, still valid after this correction, that if it is impossible to connect two events by a causal process in either direction, then they are ‘indeterminate as to time order’. (p. 144)

Of course we may still introduce a definition of distant simultaneity, thus defining a temporal order also between events that are not causally connectible. But any such resulting specific order would only be, according to Reichenbach, a means for representing our physical theory, reflecting no objective temporal fact.

Applying these considerations in Special Relativity, the immediate result is that events which are space-like in relation to a given event are not temporally ordered relative to it. Any temporal coordinates that ascribe relative temporal order to two space-like separated events do not express any objective temporal order between these events, not even their temporal order relative to some observer or physical body.

Returning to Rietdijk and Putnam’s argument for the unreality of becoming in Special Relativity, the results of this Reichenbachian view are clear and immediate. Since the event e^* in the history of O_2 is space-like relative to both e_1 and e_2 , it cannot be maintained that e^* is earlier and therefore has happened or become relative to O_1 at e_1 , or that e_2 is earlier and therefore has happened relative to O_2 at e^* . The argument has a false premise, and it is therefore unsound. It has failed to show that the notion of becoming is inapplicable in Special Relativity.

According to this Reichenbachian position, the events e_x that *are* earlier or simultaneous and therefore *have* happened relative to a given event e are those inside or on the surface of its past light-cone. Only these events can causally affect e . Since any event that has happened relative to any such e_x is also inside or on the surface of e ’s past light-cone, it has therefore also happened relative to e . Becoming is transitive in Special Relativity.

Reichenbach also concluded that any definition of distant simultaneity that complies with the mentioned causal constraint on temporal order is conceptually acceptable (although some may yield a simpler presentation of Special Relativity). If we accept this conclusion, then it cannot even be maintained that the temporal *coordinate* of some event that is space-like relative to e_1 is, or should be, earlier than that of e_1 relative to O_1 . Rietdijk and Putnam’s argument doesn’t get off the ground.

Notice that my reliance on the Reichenbachian approach fails Rietdijk and Putnam’s argument at a different place than do the counterarguments found in the literature relying on the alleged relativity of having-become or of reality. The latter counterarguments maintain that since reality, say, is observer-relative it is not transitive, and we cannot therefore infer from (i) the reality of e^* relative to O_1 at e_1 and (ii) that of e_2 relative to O_2 at e^* to (iii) that of e_2 relative to O_1 at e_1 . Namely, these counterarguments accept (i) and (ii) but say that (iii) does not follow from them. By contrast, relying on Reichenbach’s claim, I have argued that already the assertion, that e^* has happened relative to O_1 at e_1 , should be rejected, for it does not express any fact but a mere convention. While the standard objections challenge the *validity* of the argument, I challenged *the truth of its premises*.

One might think that the plausibility of my refutation of Rietdijk and Putnam's argument coincides with that of the Reichenbachian view on the relation of temporal and causal orders. My counterargument, however, relies on weaker assumptions. Already Einstein, in his first paper on relativity, presented his definition of distant simultaneity as a stipulation (*Festsetzung*), mentioning in the same section an additional possible definition of the same relation (1905, pp. 893-4). He repeated the same position in his book on relativity (1920, Chap. 8), and in a later work he even claimed that 'there is no such thing as simultaneity of distant events' (1949, p. 60). If we accept these claims of Einstein's, then they leave us with *no* objective way of determining a temporal order between distant events and Rietdijk and Putnam's argument is refuted, for such an order is necessary for its soundness. Reichenbach's discussion, by contrast, introduces *some* constraints on the definition of distant simultaneity and allows us to determine *some* objective temporal relations between distant events. These, however, are insufficient for saving Rietdijk and Putnam's argument. Yet if all one does is reject Reichenbach's position, then one is left with *no* way of determining an objective temporal order between distant events. Accordingly, rejecting this position cannot in itself save the argument. To do that, one would have to provide a different way of determining objective temporal relations between distant events in Special Relativity, and I am not aware of any such way.

Given the decisive results of the application of this line of thought to Rietdijk and Putnam's argument, the fact that it has not been considered in this form in the literature requires some explanation. Rietdijk mentions, in a few lines, Grünbaum's version of Reichenbach's view, and comments:

I cannot accept Professor Grünbaum's interpretation which, in fact, denies both the influence of an observer's velocity on his interpretation of simultaneity and any real physical sense of making a three-dimensional hyperplane-intersection of the four-dimensional space-time continuum correspond with the place and velocity of the observer. (p. 343)

Denying the reality of becoming is surely not less outrageous than denying whatever Rietdijk took Grünbaum to be denying. Moreover, I think this note shows that Rietdijk might have been insufficiently familiar with the philosophical discussion of the relation between the causal and temporal orders and its implications for the definition of distant simultaneity. This is understandable, for as a physicist Rietdijk may have had only partial acquaintance with the relevant philosophical discussion. It is more surprising that Putnam, having been Reichenbach's student, does not mention it at all in his paper.

Why wasn't the Reichenbachian line of thought applied to Rietdijk and Putnam's argument by those who tried to refute it? Grey and Hinchliff, who in contrast to Rietdijk come from philosophy, seem not to be familiar with the more technical discussion of the conventionality of simultaneity issue. Sklar rejected, on the one hand, the thesis of the conventionality of simultaneity (§ IV.C.2), and on the other hand he thought that the relativization of reality to observer sufficiently answers Rietdijk and Putnam; for that reason the possibility of applying ideas from the former debate to the latter probably did not suggest itself to him. I do not know why Stein, who comes close to these ideas in his 1968 paper, did not mention the former debate there; but neither Reichenbach nor Grünbaum is referred to in that paper, and he seems to take for granted that only one definition of distant simultaneity relative to an inertial observer is possible in Special Relativity (pp. 10-11). In a later paper (1991), in which Stein, invoked by (Maxwell 1985), again discusses these issues, he rejects the thesis of the conventionality of simultaneity, relying on Malament's 1977 paper (Stein 1991, p. 153).

I shall soon discuss Malament's work, but I first contrast the Reichenbachian counterargument above with Stein's argument in his 1968 paper. Stein relies on the light-cone structure of Minkowski space-time and defines as the past of an event e one open lobe of the light-cone at e , and as e 's future the other open lobe (p. 8). Stein notes there that the cone structure in itself affords no basis for singling out a *specific* open lobe as the past of e , but that this is 'a new element of structure'. Once we accept his definition of the past and future of an event, Stein's refutation of Rietdijk and Putnam's argument proceeds similarly to mine (pp. 15-16).—Yet unlike Reichenbach, nowhere does Stein define the past events relative to e as those that can causally influence e . Moreover, the availability of the light-cone structure is insufficient in itself as a justification of Stein's definition of the past of an event. Stein provides no reason for choosing the 'past' or affecting open lobe of the light-cone of an event and not its other open lobe as constituting what has happened relative to that event (either choice would give us a transitive relation). In addition, if Stein's reason for his definition of the past relation is that it yields a transitive relation, then other definitions are also available in Rietdijk and Putnam's framework. If we consider not only events but observers as well, as they do, we can define as what has happened relative to an observer at e all and only the events on the observer's half worldline with e as endpoint, and have a different transitive 'having become' relation. Stein leaves us with no sufficient reason for preferring his open-lobe choice to other possibilities. Lastly, as Robb has shown (1914), we can define the standard, Einstein simultaneity relative to an inertial observer by reliance on the light-cone structure of Minkowski space-time. So reliance on that structure can provide a relation of present relative to an inertial observer, and consequently—choosing one half-space of the two generated by the present hyper-plane as 'a new element of structure', the way Stein chose one half light-cone—a relation of past relative to an inertial observer. But this time there will be, in the observer's past, events space-like relative to the observer, and Rietdijk and Putnam's argument would still apply. Rejecting this choice of a past relation because it leads to undesirable results would amount to a *petitio*. Accordingly, Stein needs some additional reason to justify choosing the affecting open lobe of the light-cone, and not any other available spatiotemporal structure, as the one constituting an event's past, or an observer's past at a certain moment of his history. Yet no such additional reason is found in his discussions. By contrast to Reichenbach, Stein does not sufficiently justify choosing the affecting lobe of the light-cone as constituting an event's past. One might say that Stein marked the correct target, but failed to show the way of getting there.⁴

Turning to Malament's 1977 paper, in it Malament tried to prove that, given the causal theory of time, only standard simultaneity is definable relative to an inertial observer. If that were indeed the case, one could claim that to the extent that we can talk about objective temporal order in Special Relativity, some events that are space-like relative to an observer at stage e of his history belong to his present or past, and then Rietdijk and Putnam's argument would be sound. However, as I argued in Section 4 of (Ben-Yami 2006), in his uniqueness proof Malament unjustifiably relied on the

⁴ Like Stein, Clifton and Hogarth stipulate a time orientation and work with a 'beefed-up structure of time-oriented Minkowski spacetime'. What justifies taking 'time-orientation [...] to be an objective property of the world' they deem a difficult issue, which they don't try to resolve (1995, p. 359). In this way much of the work of refuting Rietdijk and Putnam's argument is done by an unjustified stipulation. Referring to Reichenbachian causal considerations, by contrast, justifies an additional directional element and also immediately yields the desired result. When Clifton and Hogarth discuss causality's relation to becoming, they consider impossible travels in the speed of light; subjects' alleged psychological sense of becoming, including that of such subjects who, *per impossibile*, move in the speed of light; and the suggestion to take all points on a backward light cone of an event as sharing the same 'now' with it (364-365). Their approach to the relation of causality to temporal concepts is thus quite unlike the one considered in this paper.

symmetrical relation of *causal connectibility* between events, instead of relying on the non-symmetrical *causal* relation between them. As I have shown there, if the causation relation is substituted for the causal connectibility one, uniqueness cannot be proved. I therefore think that Malament's considerations cannot save Rietdijk and Putnam's argument.

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