

Spacetime and Conventionalism

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Salmon, following Reichenbach and others, maintained that distant simultaneity was conventional in a special relativistic world in a way in which this was not so in pre-relativistic spacetime. This paper surveys and criticizes a number of proposals to unpack this claim. It goes on to argue that if the claim has validity, it rests upon differing facts about epistemic accessibility of temporal relations in the different spacetimes, and not directly upon any facts about differing causal structures in these worlds.

1. The bulk of Professor Salmon's long career in the philosophy of science was devoted, of course, to issues of explanation and causation. He directed, however, substantial efforts to issues in the philosophy of space and time as well. Noteworthy are his contributions to the perennial issue of the meaning and importance of Zeno's paradoxes, and his thoughtful work on issues of the conventionality of claims of physical theories about the structure of space and time, or better, spacetime. Here his work continued in a long tradition with multiple routes in Riemann and Poincaré, Eddington and Reichenbach, and Grünbaum.

2. I will be focusing all of my attention upon the issue of the conventionality of simultaneity in special relativity and in other theories as discussed by Salmon. But the issues involved here are relevant to other claims about conventionality in physical theories that he discussed as well.

Let me first discuss one familiar claim that needs, I think, some revision, although it is not a claim that lies at the heart of the important issues. Salmon often speaks favorably of Reichenbach's famous assertion that the conventionality of simultaneity in special relativity can be summed up in the claim that " $\epsilon = \frac{1}{2}$." Use the Einstein method of reflecting a

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light signal between points to determine synchronization of clocks. Take at the emission/reception point the event halfway between emission and reception of bounced light signal as the event simultaneous with the distant reflection of that signal. That is $\varepsilon = \frac{1}{2}$. But one could take the event simultaneous with the reflection as being an event such that its time of occurrence on a local clock was equal to the time of emission plus ε times the interval between emission and reception of the light, where ε was any number between zero and one. So picking ε as $\frac{1}{2}$ is the convention of special relativity.

Salmon writes favorably of Winnie's rewriting of the Lorentz transformations with ε retained as a parameter, giving a set of metric transformations between moving observers empirically equivalent to the ordinary Lorentz transformations that took ε as $\frac{1}{2}$.

Now all of this is alright as far as it goes, but if you are going to be a conventionalist it doesn't go anywhere near far enough. Even if you take distant simultaneity to need a definition, and take that to be one that fixes the event here simultaneous with the reflection event there as being one between emission and reception event of the bounced light, why restrict oneself to definitions that use only the interval between emission and reception of light and not the specific events and their local clock times at which emission and reception occurred? And why restrict oneself to a linear function on these event times?

As Putnam pointed out, a true conventionalist would allow himself more scope. Just as one can force general relativistic worlds into flat spacetimes (if one is a conventionalist), one can put (pointlessly to be sure) special relativistic worlds into arbitrarily curved spacetimes. That, pretty much, is what dropping linearity and dependence only on the interval does. But if you are going to be a conventionalist, then in for a penny in for a pound. Why restrict the conventional choices to those that demand such things as flat spacetimes and symmetric relations between observers?

3. In the late 1960s Ellis and Bowman tried to cast doubt on the thesis of the conventionality of simultaneity in special relativity by rediscovering the fact, known to and published by Bridgeman, that one could establish a relationship of distant simultaneity in a relativistic world by using clocks transported slowly relative to an observer's frame to determine synchronization. Given the truth of special relativity, the relationship so determined would be lawlike coextensive with the relationship of distant simultaneity determined by the Einstein light method with the usual choice of ε as $\frac{1}{2}$.

Salmon, along with Grünbaum and others, argued, quite reasonably, that although the congruence of slow-clock transport and light reflection

simultaneities was interesting, it casts little doubt on allegations of conventionality for distant simultaneity.

Now what exactly it takes for some feature described in a theory to be a “matter of convention” is something we shall have to look at shortly. Suffice it to say now that this is never made completely clear in the literature on the subject of conventionality of simultaneity. But it is pretty clear that the notion of conventionality means something to the effect that a portion of a theory can be changed without the total theory suffering any changes in its prediction in a certain specified class, be that class the class of “causal facts” or the class of “directly observable consequences.” And what Salmon and the others argue for with some plausibility is that the stipulations for distant synchrony of clocks established by limiting motions of ideal clocks can be as varied as the stipulations involving reflected light rays “saving the relevant phenomena” that must be saved under the allowed transformations internal to the theory.

4. In his arguments for the conventionality of the slowly transported clock method for stipulating simultaneity in special relativity, Salmon draws an alleged contrast with a method for determining distant simultaneity in another theoretical situation, a method that is, allegedly, nonconventional.

In the Newtonian theoretical situation we consider it possible to send a causal signal from one place to another with any finite velocity whatever. Indeed, in some Newtonian pictures we may even allow causal signals that move with infinite speed, such as in a pure action-at-a-distance theory of gravitational force. But we do not allow causal signals that move at a speed that is “faster than infinite,” or that, in other words, arrive at some distant place before they have started.

So now we have an easy way in such a world of specifying distant simultaneity by using causal signals. Take as the event There simultaneous with some event Here that event There which is the earliest event There reachable by a causal signal sent from Here simultaneously with the given event Here. Or, if one allows signals of arbitrarily high finite speed but denies instantaneous action-at-a-distance, take the event There simultaneous with an event Here to be the greatest lower bound of the set of events There reachable by a causal signal sent from Here simultaneously with the event in question Here.

The basic claim is that this stipulation of distant simultaneity is “non-conventional.” Why? Because any other association of a different event There as simultaneous with some specified event Here, that is other than the one picked out by the causal stipulation noted, will lead to a description of the world in which there will be possible causal signals that arrive elsewhere earlier in time than when they are sent from Here. And that is unacceptable. In a special relativistic world, of course, such a “noncon-

ventional” stipulation for distant simultaneity is impossible, since light provides a maximal, finite speed for causal propagation. In the well known way, then, this leads to a whole set of distinct events There being causally on a par with the event Here and blocks the “causal definition” of distant simultaneity.

As we shall see, there are many puzzling aspects of this argument. But for the moment I want to put them to the side and focus on another but related matter.

The contrast between a causally specified and allegedly nonconventional notion of distant simultaneity in the nonrelativistic case, and the impossibility of such a stipulation of simultaneity in the relativistic case necessitating resort to allegedly conventional stipulations such as the reflected light definition of Einstein or the slowly transported clock definition of Bridgeman suggests a slogan: “Distant simultaneity is nonconventional if and only if it can be defined by means of causal connection relationships alone.”

But then Winnie reminded us of a long-forgotten fact, that as early as 1910 Robb had shown that distant simultaneity, indeed all of the metric structure of the Minkowski spacetime of special relativity, can be defined in terms of the causal connectivity among events alone. Robb’s demonstration uses elaborate synthetic geometry, postulating a number of axioms true of causal connectivity in Minkowski spacetime and giving explicit definitions of the metric notions made legitimate (existence and uniqueness conditions being demonstrated) by the postulates. Much later the same results are shown far more quickly by Zeeman using group theoretic methods. Later still Malament showed that if we demand certain formal conditions of distant simultaneity, the causal definition of that relationship provided by Robb is uniquely determined.

Distant simultaneity is, then, causally definable in special relativity. Does that mean that it is nonconventional?

To see that this claim would be dubious one need only widen one’s horizon to consider the generally curved pseudo-Riemannian spacetimes of general relativity. Now in most of those Robb’s axioms just don’t hold of causal connectivity. And one can certainly show that there are causally isomorphic general relativistic spacetimes that are not metrically isomorphic, making even implicit definition of the metric by causal connectability impossible in general relativity. Here, though, we might mention Malament’s important result that any two general relativistic spacetimes whose sets of continuous timelike paths are isomorphic are metrically isomorphic.

But consider even those general relativistic worlds in which Robb’s axioms do hold. They are not all metrically isomorphic to Minkowski spacetime, but constitute a set of spacetimes all of whose metrics can be

mapped onto Minkowski spacetime by a global conformal transformation. In those worlds if they are not Minkowski spacetime one could still define the metric notions using Robb's definitions. But if one did the metric could not be correctly discerned by the other standard methods of rods and clocks. Nor would timelike geodesics correspond to the paths of ordinary free particles.

So now forget about general relativity. Suppose all our experimental facts are those predicted by special relativity. We explore causal connections and find that they obey Robb's axioms. Must we then use Robb's definitions to determine the metric features of the spacetime? In particular, must we accept Robb's definition of distant simultaneity?

It follows from what we noted above that one could choose to imbed all of the special relativistic causal facts into a spacetime that was not Minkowski spacetime but was, instead, a spacetime globally conformal to Minkowski spacetime but not isomorphic to it. If we did so, of course, our standard ideal clocks would no longer properly determine time intervals. Nor would our standard ideal rods measure lengths properly. And intuitively free particles wouldn't travel timelike geodesics.

But what we have here is just a kind of "inverse" to the standard situation discussed in the context of metric conventionalism about general relativity. We could stick the general relativistic facts into flat spacetime (at least locally) if we made enough postulates about "universal" fields that distort the rates of clocks, the lengths of transported rods, and the paths of particles. In just the same way here we can take the facts that we usually would stick into a flat spacetime and put them into a nonflat spacetime by invoking Reichenbachian distortion fields that work in the reverse direction from those invoked in the conventionalist case for general relativity.

So, it would appear, the fact that we can, if we want, define distant simultaneity and the other metric notions causally in special relativity using Robb's method doesn't seem to change the fact that we can imbed the "facts" of special relativity into a variety of different spacetime structures that take different pairs of distant events as simultaneous and, in general, postulate distinct metric relations among the events in the world. And if that isn't "conventionality" for these notions, what on earth is?

What is going on here?

5. What does the thesis of conventionalism amount to? And what facts about how things behave in the world are relevant to conventionalist claims? We have seen that a slogan such as, "A spacetime feature is conventional if and only if it is not causally definable," won't do. But what will?

We can gain some insight by reexamining the distinction between the

prerelativistic and the relativistic case. What is it that underlies the intuition Salmon and others had that in a prerelativistic world distant simultaneity is not a matter of convention, but that in a relativistic world it is a matter of convention? It can't just be, as we have seen, that in the former distant simultaneity is causally definable but in the latter it isn't. So what can it be?

The thesis of the conventionalist is always, I believe, a thesis to the effect that one can choose alternative theoretical formulations all of which will be true to the "relevant facts." These relevant facts being all there really is to the world which the theory is meant to handle, the alternative accounts should all be taken as equally acceptable. Now, even having fixed on the set of "relevant facts" to be preserved, the conventionalist thesis may very well be controversial. The anticonventionalist may, for example, take it that there can be very good reasons to accept one theoretical account and deny another, even if both are equivalent with regard to their predictions regarding the correlations among the relevant facts. But my purpose here is not to debate the issues of the legitimacy of conventionalism, but only to try and figure out what intuitions may lie behind a conventionalist thesis that takes it that conventionalism is plainly out of the question for prerelativistic physics but is a defensible doctrine in the relativistic context.

Now Salmon points out, as did others such as Reichenbach, that in the prerelativistic picture of the world any choice of an event There simultaneous with a given event Here that differs from the standardly chosen event will result in the possibility of causal signals being sent from Here to There (or from There to Here) that arrive earlier in time than the time at which they were sent out. But the limitation of the speed of propagation of causal signals in a relativistic world to those that travel no faster than light means that no choice of distantly simultaneous event will result in such an anomaly so long as the choice is of some event at a distance outside the past and future light cones of the event Here to be the event simultaneous with the event Here.

So one way in which we could defend the thesis of conventionality for distant simultaneity in a relativistic world as something contrasted to the nonconventionality of distant simultaneity in a Newtonian world would be to say that the future directedness of a causal signal, that its reception always succeed its emission, is the relevant fact that must be preserved in any version of our theory that is to describe the world. Relativistically this still leaves choices for distant simultaneity, since the alternative descriptions of the world using Minkowski spacetime and its globally conformal alternatives all still maintain the same absolute time orders among events. This is so because the conformal transformations preserve an isomorphic light-cone structure shared by all the alternative redescr-

tions. In the Newtonian world the alternatives all do create reversals in absolute time order from the standard picture. So one could argue that it is the special need to preserve this causal ordering that can only be done one way in a Newtonian world, and can be done lots of ways in a relativistic world even if a Robbian definition of standard simultaneity can be given in that world, that makes distant simultaneity in relativity conventional and in a Newtonian world nonconventional.

But we must be careful here. It is far from obvious that there is anything unacceptable about a characterization of distant simultaneity that permits causal signals arriving There “before” they have left Here. All we are doing after all, it might be argued, is just “recoordinatizing” the facts in a novel and unfamiliar way. Our intuitive rejection of such a redescription might be based upon some worry that characterizing things in such a way forces us to countenance closed causal loops and maybe even causal paradoxes. If a signal gets There “before” leaving Here, couldn’t we use the arrival of the signal There to initiate a signal that gets Here before the first signal is emitted and blocks its emission?

Now it is true that in our ordinary description of things, with the standard stipulation for distant simultaneity in a Newtonian world, we have assumed that signals of arbitrarily high velocities (possibly infinite ones) are possible, but that causal propagation “into the past” is not. But that is with the ordinary sense of the time order of events. In the peculiar redescription we are imagining, our assertions about the allowed possible causal signals will look quite different. Further, if the ordinary description forbids paradoxical closed causal loops, the new description must also, for it is a description of the same invariant facts.

From our current perspective, having been through explorations of tachyon theory and of general relativistic worlds in which closed causal loops are posited, we are well aware of the subtle but perfectly respectable ways in which one can exclude causal paradox in the face of closed timelike loops. Of course a price must be paid in the restriction of initial states of the world to those consistent with themselves, but it can be argued that such a price is smaller than it might seem to be at first glance. It isn’t at all clear that there is anything impermissible with a redescription of the world in which a signal arrives at a distant location at a time earlier than that at which it was sent.

Beyond question there is a difference between the relationship of causation and distant simultaneity in Newtonian and relativistic worlds. But it isn’t clear that the difference in the relationship will be such as to forbid as much redescription by variation in the notion of distant simultaneity in the Newtonian world as in the relativistic.

6. But there is another, although related, way in which the prerelativistic

and relativistic worlds differ. And, I suggest, it may be this difference that lies behind the strong intuition of Salmon and the others that distant simultaneity is not conventional in a prerelativistic world but is conventional in a relativistic world.

Conventionalism is the thesis that a number of alternatives exist that are equally legitimate in preserving the “relevant facts.” But what is the criterion of relevance here? I have suggested that if it is just facts about causal relations that need to be conserved, one could argue that distant simultaneity is just as conventional in Newtonian as in relativistic worlds.

But, as Salmon notes Reichenbach having asserted, simultaneity for coincident events cannot be taken as conventional. Why? Because the facts about coincidence of events are open to “direct observation.” Now Reichenbach actually has varied views about this, sometimes arguing that physical coincidence isn’t really a matter of direct observability. But it seems clear that the core theme of conventionalist literature is that there are spatiotemporal facts that are open to direct observational determination, and that it is the preservation of these facts that is the constraint upon any theory. Going along with this is the idea that any “facts” that are beyond the realm of being directly observable can only be established by adopting some appropriate theory. Since the theories in question have complex structure, allowing for adjustments that save the directly observable predictions in a variety of ways, the assertions of the theory that go beyond its predictions for the direct observables are the ones open to variation without predictive penalty. And it is here that conventionalism takes its hold. So one line of argument has been from Poincaré, through Reichenbach, to Salmon.

Now from this perspective look at the difference between prerelativistic and relativistic worlds. We take coincidence of events to be directly observable and so nonconventional. Actually, in all of the discussions continuity along traversable spacetime paths (or the limit of such paths) is assumed directly observable as well. If it weren’t, how would we know it is one and the same light-ray whose emission and reception we are clocking in the Einstein reflected light method for stipulating distant simultaneity.

In the relativistic world observers have their motion bounded by the speed of light. But in the prerelativistic world one and the same observer can move from Here to There as fast as one likes. In a Newtonian world consider observer *S*. Consider two spatially separated events *A* and *B*. Let *B'* be an event shortly after *B* and at the same place as *B* relative to *S*’s reference frame. Let *S'* move relative to *S* so that *A* and *B'* are two events in *S'*’s experience. *A* and *B'* will then be events that are not only close together in time, but close together in time in the experience of a single observer. Notice that *S'* will also think of *A* and *B'* as close to one another in space (in *S'*’s reference frame). Then think of simultaneous

events such as *A* and *B* as follows: *B* is the past limit point of a sequence of events that, relative to an observer who experiences *A*, are at the same place and that are closer and closer together in time in the experience of observers moving relative to the first observer in the direction from event *A* to event *B* at faster and faster speeds.

Given, then, unlimited relative velocities for observers (rather than for causal signals), we can think of distant simultaneity in prerelativistic spacetimes as the limit of “directly experienced almost” simultaneity, i.e., almost coincidence, for some observers for whom the experienced events are not distant from one another at all! And these kinds of possible experiences will pick out uniquely the pairs of events we think of as simultaneous with one another in a nonrelativistic world.

The idea is, then, that it is not the special causal structure of the non-relativistic world that makes its distant simultaneity relationship nonconventional. It is the fact that a simultaneity that is distant almost simultaneity for one observer, and hence not directly observable for that observer, is a local almost simultaneity, an almost coincidence, for some other (idealized) observer—and, hence, a directly observable fact of the world. And, therefore, not something suitable for being classified as a matter of convention.

7. Nothing in these remarks is meant as a defense of or as a critique of the doctrine of spacetime conventionalism. Conventionalism, I believe, is always founded on a belief in a distinction between the facts predicted by a theory that fall within the domain of direct observability and those which do not; a belief that the predictions made by a theory about the directly observable facts rest upon the application of multiple components of the theory; a belief that the same set of directly observable predictions can be made by alternative theories in which the differences between the theories on one set of theoretical components are compensated for by differences between the theories in another set of components; and a belief that insofar as the two theories have the same predictive content with regard to the directly observable facts, they ought to be viewed as merely conventional alternatives to one another and not as genuinely alternative theories about the nature of the world.

All of this is controversial, of course. But what I have tried to do here is find some way of understanding the view held by Salmon and many others that there is some important sense in which distant simultaneity is a matter of convention in a relativistic world and not a matter of convention in a prerelativistic world.

What I have argued is that the view held by Salmon and the others may be understood as resting, as they claim, on the factual difference between the prerelativistic and relativistic worlds that in the former there

is no limit to the speed with which material can travel but in the latter there is.

But, I have argued, the truly important difference between the two kinds of worlds as far as conventionalism for distant simultaneity is concerned may not reside as Salmon and the others maintained in the different causal structures of the two worlds, but, rather, in the fact that in a prerelativistic world all simultaneities distant for one observer are coincidences for another (idealized) observer. Then all simultaneities fall within the class of the directly observable facts about the world and whatever conventionally alternative accounts of the world there may be, all must agree on the facts about simultaneity in general. In the relativistic world simultaneities distant for one observer are distant for all, since spacelike separation is invariant. So now distant simultaneity is, unlike coincidence of events which remains in the class of directly observable facts, a “fact” always outside the domain of the directly observable, and hence a candidate for the claim of being merely a conventional matter.