Absolute Distant Simultaneity in Special Relativity

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ABSTRACT. What is simultaneous with an event is what can interact with it; events have duration; therefore, any given event has distant events simultaneous with it, even according to Special Relativity.

Keywords: simultaneity; Special Relativity; events; Alexandroff intervals

> *There is no such thing as simultaneity of distant events.*
> (Einstein 1949: 60)

Einstein was wrong, I believe, at least for one sense of 'events'. With a proper understanding of simultaneity and of other temporal concepts, distant simultaneity in Special Relativity can be shown to be observer-independent for a significant set of events and to largely coincide with its ordinary pre-relativistic presumed extension, and this without introducing any privileged reference frame. I shall argue for this conclusion by first considering the concept of simultaneity, then those of event and of the present, and lastly by tying all threads together in Special Relativity.

I. Simultaneity

The concept of simultaneity, like other concepts of temporal order, is related to that of causation. The formulation of conceptual relations between the temporal and causal orders goes back to Hume,[1] Kant,[2] Reichenbach[3] and others, and I shall follow their lead here. I relate simultaneity to causality as follows:

> What can influence and be influenced by an event, what can *interact* with an event, is simultaneous with that event.

Similar formulations can be found in recent literature. Stein, for instance, while discussing the 'specious present' π of a perceiver, writes:

> [L]et us call an event *e* "contemporaneous" with π if signals—interaction—influence—can occur *mutually* between *e* and π. (1991: 159)[4]

Other concepts of temporal order can be related to that of causality along similar lines. The past of an event consists of what is or could be a cause of that event but cannot be

[1] Treatise, Vol. I Part III Sec. XV, Rule 2.
[2] Critique of Pure Reason, Second Analogy, B232*ff.*
[3] (1928: §§ 21-22); but see next footnote.
[4] Reichenbach thought that '[t]wo simultaneous events are so situated that a causal chain cannot travel from one to the other in either direction. [. . .] *Simultaneity means the exclusion of causal connection*' (1928: 145). But if we don't find the idea of instantaneous causation incoherent, then Reichenbach's conception of simultaneity should be rejected and one that allows interaction should replace it. For critical considerations of Reichenbach's reasons see (Ben-Yami 2005: 461-2).

influenced by it (a cause which is no effect); and the future of an event consists of what can be or is affected by, but cannot affect the event (an effect which is no cause).

Do these characterisations capture our concept of simultaneity? We characterise events as *occurring at the same time* without explaining the concept or having it explained to us in such an abstract, general way. So in virtue of what facts, if any, can such abstract characterisations claim to be analyses of the given concept?

The meaning of a concept is captured by its application and the criteria we adduce to correct misapplications or justify correct ones. The grandmother asks her grandchildren over the phone, 'What are you doing now, children?' and they respond, 'We are watching a movie': hearing them respond to her question justifies her when she reports, 'Yesterday at 9:00 I talked with Alice and Bob; they were just watching a movie'. The conductor waves his baton and hears the attentive players respond: he can thus judge whether they are punctual, too early or too late. While I was sitting and reading in my garden, my neighbour was mowing the lawn: he saw me sitting there, waved to me, and I waved back. In all these cases the application is justified by interaction, or presupposes such possible interaction. This role of interaction in the application of the concept of simultaneity justifies the characterisation above.

Such general characterisations are unlikely to coincide without any margins of error with a non-technical concept which is introduced and explained by means of examples. They are better interpreted as extracting from its use and explanations its dominant criteria of application, and giving them a definitional role in the implementation of the concept within a general theory. This is how the characterisation of simultaneity above should be seen and judged.

These conceptual characterisations are independent of any particular physical theory. When we apply them in Special Relativity (SR), they yield as the past of a point-event what is in its 'past', or affecting, apex-less full light cone; and as its future what is in its 'future', or affected, apex-less full light cone. ('Past' and 'future' are here in scare quotes in their occurrences before 'light cone' because otherwise they would involve a petitio.) However, according to this conception of simultaneity there is in SR no event simultaneous with a given point-event and different from it. Consequently, Stein, for instance, writes that 'in Einstein-Minkowski space-time *an event's present is constituted by itself alone*' (1968: 15; cf. 1991: 159). When something happens, nothing else happens with it.— But before accepting this radical conclusion, we should examine what 'event' means.

II. Events

When we *apply* the concept of event, we always apply it to something with a *duration*, to an *interval*. A standard dictionary definition of an event is *a thing that happens or takes place*, and this certainly does not exclude events that take some, and even much time. Typical examples of the use of 'event' include 'The party was a great event' and 'WWII was the most significant event of the twentieth century': in both cases the events took some time, in the latter case six years. I shall call the events to which we actually apply our concept of event *actual* events, to distinguish them from theoretical ones, namely from those that are idealisations within a theory (in a sense clarified below). As far as our concept of an event is *applicable*, we apply it only to intervals, not to durationless points. The temporal point has no experiential reality.

Of course, in our physical theories we do talk about temporal points. And I am not arguing here that temporal points, in some sense, are physically impossible. However, the temporal point events of our theories do not function as designators of such hypothetical physical point events: their contribution to the theory is independent of the existence of any such hypothetical points. Rather, they function as the limit of a process

of precisification. They are the limit of a process of considering the properties of shorter and shorter interval events. Physics' temporal points are an *idealisation*—not in the sense of being better, but in the sense of taking a process of precisification to its mathematical, theoretical limit. This is their function within the theory.

The temporal point *is* probably an imaginary limit. Aristotle was probably right when he claimed that time is not composed of instants but of intervals (Physics 239b30). But whether or not this is so, the function of the temporal point in our physical theories is as the limit of a process and not as a designative term. Physical theory does not commit us to the existence of point events.

Moreover, actual events are also always *vague* intervals, in the sense of not having a beginning or end which can be defined with as high a degree of accuracy as we wish, namely, beginning and end which are point events. The party ended when the last group of people left our apartment, but this cannot be determined more accurately than an interval of a few seconds; WWII started with the German invasion to Poland and the ensuing declarations of war on Germany by Britain, France, and other countries—a process of days. Actual events are even *necessarily* vague: an actual event has actual events as its beginning and end, and therefore it begins and ends with events that have some duration.

III. *Now*

Similar considerations to those on the concept of event apply to other temporal concepts. I shall consider here our concept of the present, as designated by 'now'. I consider this concept because it is widely discussed in the literature of Special Relativity and the philosophy of time. I also wish to contrast my approach with related ones found in the literature, and these discuss mainly the concept of the present. However, my observations on the concept of the present also apply to all other relevant temporal concepts.

'Now', like 'event', always designates an interval. The very utterance of 'now' takes time, and therefore it cannot normally designate anything shorter than a few milliseconds. But usually it stands for longer intervals. When the grandmother asked her grandchildren over the phone, 'What are you doing *now*, children?' a period of at least several minutes was meant. An example of use in which the word stands for a much longer period is, 'We are *now* living in the information age'. Such an extended and highly vague interval is also apparent in book titles—*The Way We Live Now*; *Now We are Six*—and in other uses in fiction: 'We are *now* the knights who say ekki-ekki-ekki-pitang-zoom-boing!'. But even when we try to capture a shorter moment, as in the orders 'Now!' or 'Do it right now!', an interval is always meant, as can be seen if we think of what we would consider as complying and failing to comply with such orders. And these observations on 'now' apply to other phrases designating the present as well ('at present', 'at this very moment', etc.): these also always stand for a vague interval, whose duration changes according to circumstances.

Notice that I am *not* talking about any specious or psychological present, the present as the subject allegedly experiences it (whatever this might mean[5]). I am discussing *meaning*, not experience, and I claim that when we apply 'now' and similar phrases they always designate an interval. On my account, there is nothing *specious* in what 'now' stands for, and no reference to an experienced present is involved in my considerations.

[5] See (Le Poidevin 2011: § 4) for some of the problems the concept involves and for additional references.

By contrast, earlier philosophical work that has tried to save something of the apparent simultaneity of distant events has done that by reference to the alleged specious present (Stein 1991; Arthur 2006; Savitt 2009). Consequently, unlike me, they are committed to the coherence of the idea of a specious present, to its making sense. Arthur, for instance, after having noted that the concept of the specious present had been criticised, refers to defences of the idea, which shows that he depends on its being coherent. He also remarks, implying that this is problematic for him, that 'the notion of the specious present is not without its difficulties'. All these writers also try to give an estimation of the duration of this 'psychological present'. All this is irrelevant to my considerations.

Although my paper is indebted in some respects to these earlier works, the approaches are thus fundamentally different. As will be apparent soon, I am trying to give an account of distant simultaneity by relating considerations on meaning to the theory of Special Relativity. I am not referring at any stage to an experiencing subject. The mentioned earlier works, however, try to show how SR reality is projected into our psychology or subjective experience, often *contrasting* the results of this projection with the strict physics of SR. Stein tries to explain what he takes to be our alleged intuitions about simultaneity, intuitions which he finds 'illusory', and he discusses 'our ordinary experience, the time that we experience as a "moment"—a specious present' (p. 162). Arthur looks for 'an acceptable construal of becoming, and one that "saves the phenomenon" of our experience of the present too'.[6] And Savitt defines his project by the slogan, 'Philosophy of time should aim at an integrated picture of the experiencing subject with its felt time in an experienced universe with its spatiotemporal structure'; the specious present is then introduced. These writers also discuss the *present*, a focus which is a result of their interest in the experiencing conscious subject, while I primarily discuss distant simultaneity between *events*, be they past, present or future, and independently of whether they involve any conscious subject.[7]

IV. Distant Simultaneity in Special Relativity

Let us now tie the different threads together in SR. Any actual event in an observer's history, or in the history of any other physical entity (we are not giving any special status to consciousness or mentality) is an *interval*. What is simultaneous with this event, according to our causal conception of simultaneity, is what can influence and be influenced by the observer (or physical entity) during this interval, what can then interact with the observer. This is determined independently of frame of reference, and is thus absolute.

The set of events that stand in this double-causal relation to an event *e* is determined as follows. The past light cone that has as its apex the last moment of *e* consists of all events that can influence *e*, or at least some part of *e*; the future light cone that has as its apex the first moment of *e* consists of all events that can be influenced by *e*, or at least by some part of *e*; their intersection thus consists of all events that can both

[6] He similarly writes that 'this *discrepancy* between theory and experience can be bridged by introducing the concept of the specious present' (my italics).

[7] This difference in projects makes much of Dorato's (2011) criticism of the attempts by the mentioned philosophers to account for our psychological experience inapplicable to my arguments. Dorato also contrasts intending to refer to the events with which we are in possible mutual causal communication when we utter 'now' with intending to refer to those simultaneous with the utterance (385); however, as claimed above, almost any example one would give to explain what one means by 'now' shows the interdependence of the concepts, and therefore this contrast does not exist.

influence some parts of *e* and be influenced by some parts of *e*. This intersection is a double cone, called the *Alexandroff interval*[8] and illustrated as follows:

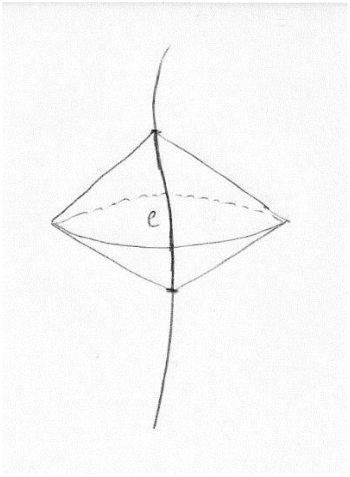

Figure 1

Any event inside the Alexandroff interval of an event can both be influenced by some earlier parts of the given event and influence some of its later parts. Any event outside the interval either cannot influence the event or cannot be influenced by it, or both. The Alexandroff interval of an event thus consists of the events simultaneous with the event.

Although geometrically the Alexandroff interval is a double cone, to describe it as such might be somewhat misleading: from an ordinary human perspective it looks much more like a cylinder. If we measure distances in metres and time in seconds, then the opening angle of the Alexandroff double cone is 179.9999996 degrees; if we measure them in kilometres and hours, it is 179.99999990: a straight angle for all standard intents and purposes.

Accordingly, any actual event has a substantial set of distant events simultaneous with it. If we go back to the grandmother, say in Europe, talking with her grandchildren in distant Australia, then her present, designated by her use of 'now' in the question 'What are you doing now, children?' and standing for a vague interval of several minutes, coincides with that of her distant grandchildren. Special Relativity doesn't force us to change anything in *this* use of our concept of distant simultaneity. And this would be true for the great majority of standard ascriptions of simultaneous occurrence to distant actual events. Thus, frame-independent distant simultaneity between events exists in Special Relativity, and it largely coincides with common ascriptions of simultaneity.

Some distinctions from common ways of thinking of simultaneity should, however, be noted. My definition of simultaneity by means of causal concepts was intended to capture, or at least approximate, our *concept* of simultaneity, and not our *judgments* of simultaneity. Certainly it was not meant to yield a concept that coincides with our pre-theoretical judgments of simultaneity. Before we learn about the finiteness of the speed of light, we take the night sky to show us the stars as they are at the moment we see them; but once we learn that, as we had done long ago with Römer, before SR was developed, we judge what we see to belong to the past. Our concept of simultaneity was not affected by this discovery, although our applications of it were.—All the same, concept and judgments are not independent: we explain our concepts and learn them by means of particular applications, so the correctness of at least most of these applications is presupposed by the meaningfulness of the concept. Accordingly, ordinary applications

[8] For more on Alexandroff intervals, see (Winnie 1977: § III)

of a concept must *as a rule* be preserved by its analysis, if it is to be meaningful or coherent. As can be seen, the causal definition above does that.

Extension-wise, the concept of simultaneity as applied in SR is different from the one that applies in Newtonian mechanics. Simultaneity in SR is limited in space: if an event lasts time t, then events simultaneous with it exist only up to a distance of ct/2 from its location. In Newtonian mechanics, by contrast, due to the fact that there is no upper limit on the speed of propagation of causal influence, any event has at any distance from it events simultaneous with it. Newton's world allows for a cosmic present, unbounded in space.

However, this aspect of the Newtonian concept of simultaneity is not included in our pre-theoretical one but is a result of its application within the world as described by Newtonian mechanics. We introduce, explain and apply our concepts of *at the same time, earlier* and *later* not by means of describing the temporal relations between ourselves and distant galaxies but when talking about mundane events. The Newtonian theoretical extrapolation of our spatio-temporal concepts might be the simplest one, but it is still an extrapolation, and one that in fact proved to be wrong. Pace Stein, our ordinary concept of *at the same time* does not involve any "'intuitions" of something like "cosmic simultaneity", or a "cosmic present"' (1991: 162). The fact that the question 'What's going on now in Australia?' makes sense doesn't entail that so does the question 'What's going on now in Andromeda, 2.5 million light-years from Earth?'. Accordingly, although Special Relativity forces us to abandon some aspects of our concept of simultaneity as applied in Newtonian mechanics, *this* does not mean that it modifies the concept or makes it inapplicable.

Special Relativity did have some unforeseen consequences for the applicability of our concept of simultaneity. The fact that when we look beyond the moon talk of simultaneity doesn't always make sense wasn't anticipated (the Alexandroff interval has finite dimensions, and therefore the simultaneous has spatial boundaries). Equally unanticipated was the fact that events lasting for a few nanoseconds can't be said to be exactly simultaneous with similar events occurring just a few miles away (as we converge towards a point-event, the Alexandroff interval converges to zero in all dimensions). But these unexpected facts about inapplicability to the very distant or the very brief do not mean that there is anything problematic in the ordinary, pre-theoretical applications of the concept.

Another unexpected result, related to those just mentioned, is that if one event e_1 lasts less time than another event e_2, then it is possible that e_1 happens during e_2 although no part of e_2 is simultaneous with e_1. This happens if the Alexandroff interval of e_2 contains e_1, while e_2 is outside the Alexandroff interval of e_1. For instance, when we watch (e_2) an almost instantaneous nuclear reaction in a bubble chamber (e_1), the reaction occurs while we are watching it, although no stage in our history can be said to be simultaneous with it. In causal terms this means that although the scientist during the experiment can both influence and be influenced by the nuclear reaction, no stage in the scientist's history could both influence and be influenced by the reaction. Such temporal relations, with which we are not familiar from our ordinary experience, arise when e_1 and e_2 are either very far away from each other, or when e_1 lasts much less time than e_2. For this reason the result also shows the limitations of the extrapolation of our concept of simultaneity to new kinds of circumstance, and therefore, although unanticipated, it does not reveal any problem with the ordinary applications of the concept of distant simultaneity.

Relativistic space-time is usually divided into three or four regions relative to a given event: a time-like region, which can be further divided into a future region and a past region; a light-like surface, which I shall here count as belonging to the time-like

regions (a classification justified by the causal conception of past and future); and a space-like region, containing all events which are neither in the future nor in the past of the given event. This trifold classification—past, future, and space-like—is justified relative to point-events. However, if we consider actual events, which always have a duration, then relative to each actual event space-time should be divided into *four* regions: a past region, constituted by the full light cone with its apex at the earliest moment of the event; a similar future region; a present region, constituted by the Alexandroff interval; and a space-like region. Moreover, given that actual events always have vague boundaries, and that a more realistic diagram of lines representing the propagation of light should have them more horizontal, the boundaries between the past and present regions, as well as those between present and future ones, should merge in the vicinity of the event. The space-like region should start only some distance from the event, this distance depending on the degree of vagueness of the event's beginning and end. The resulting diagram should therefore have only three regions in the vicinity of events: past, present and future:

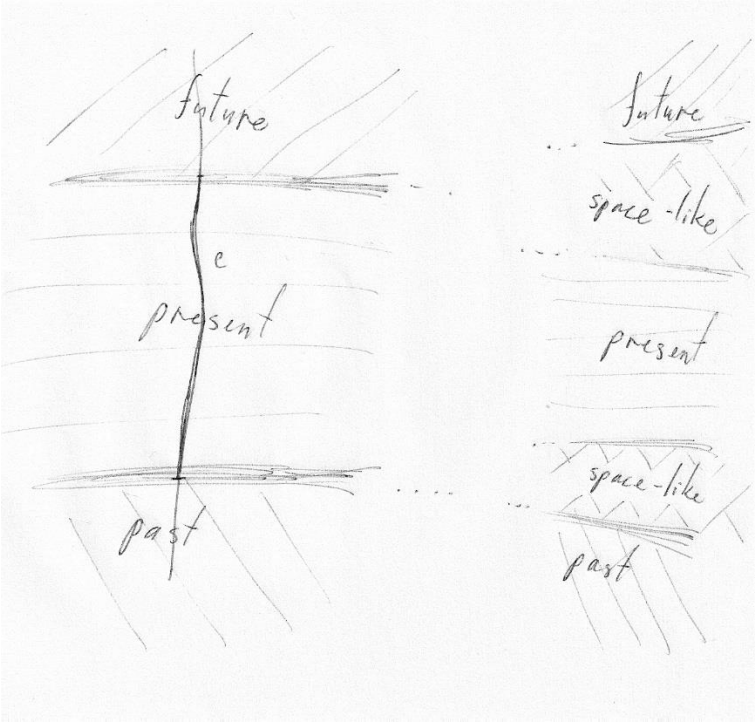

Figure 2

This diagram of space-time without idealisation to point-events clearly shows that Special Relativity affects the applicability of our concept of simultaneity when very large distances are concerned, but that otherwise there is no problem in the classification of distant events as simultaneous. Closer to home, we have only past, present and future.

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