Minkowski Spacetime and the Dimensions of the Present[1]

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Abstract

In Minkowski spacetime, because of the relativity of simultaneity to the inertial frame chosen, there is no unique world-at-an-instant. Thus the classical view that there is a unique set of events existing now in a three dimensional space cannot be sustained. The two solutions most often advanced are (i) that the four-dimensional structure of events and processes is alone real, and that becoming present is not an objective part of reality; and (ii) that present existence is not an absolute notion, but is relative to inertial frame; the world-at-an-instant is a three dimensional, but relative, reality. According to a third view, advanced by Robb, Capek and Stein, (iii) what is present at a given spacetime point is, strictly speaking, constituted by that point alone. I argue here against the first of these views that the four-dimensional universe cannot be said to exist now, already, or indeed at any time at all; so that talk of its existence or reality as if that precludes the existence or reality of the present is a non sequitur. The second view assumes that in relativistic physics time lapse is measured by the time co-ordinate function; against this I maintain that it is in fact measured by the proper time, as I argue by reference to the Twin Paradox. The third view, although formally correct, is tarnished by its unrealistic assumption of point-events. This makes it susceptible to paradox, and also sets it at variance with our normal intuitions of the present. I argue that a defensible concept of the present is nonetheless obtainable when account is taken of the non-instantaneity of events, including that of conscious awareness, as (iv) that region of spacetime comprised between the forward lightcone of the beginning of a small interval of proper time τ (e.g. that during which conscious experience is laid down) and the backward lightcone of the end of that interval. This gives a serviceable notion of what is present to a given event of short duration, as well as saving our intuition of the "reality" or robustness of present events.

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1. The Problem of the Present

In classical physics the world-at-an-instant was assumed to be a well-defined concept. Each such instantaneous world was thought to exist in three spatial dimensions, so that when threaded together along the time dimension they constituted (at least in the conception of H. G. Wells, building on ideas of Hinton and Newcomb[2]) a unique four-dimensional structure, absolute spacetime. But in the Minkowski spacetime of Einsteinian Special Relativity, because of the relativity of simultaneity to the inertial frame chosen, there is no unique world-at-an-instant. Thus the classical view that there is a present, in the sense of a unique set of events existing now in a three dimensional space, cannot be sustained. The two solutions to this difficulty most often promoted are

(i) the so-called "block universe" or "manifold" view, that the four-dimensional structure of events and processes is alone real, and that becoming present is not an objective part of reality: *the present is an illusion (or mere facet of subjective experience)*; and

(ii) the "relativized present" view, that *present existence* is not an absolute notion, but *is relative to inertial frame*; the world-at-an-instant is a three dimensional, but relative, reality.

According to a third view, the "punctual present" view, described by Robb, Capek and Stein,

(iii) *what is present at a given spacetime point is* (strictly speaking) *constituted by that point alone.*

[2] In his *Time Machine* (1895) H. G. Wells alludes to Simon Newcomb's address on four dimensional geometry to the New York Mathematical Society of 1893, published as Newcomb (1894), and elaborated on in Newcomb (1898, 1-7). See Geduld (1987, 32 and 94, n. 14). But as Geduld points out (93), Wells's conceptions are more indebted to those of Charles H. Hinton, "What is the Fourth Dimension?" in Hinton (1884-85).

Against (i) I shall argue in section 2 that four-dimensional universe cannot be said to exist now, already, or indeed at any time at all; so that talk of its existence or reality as if that precludes the existence or reality of the present is a non sequitur. I then turn to an examination of (ii), the relativized present. I argue that this view, like Gödel's argument against the objectivity of time lapse, is vitiated by a misconception of the status of the time co-ordinate function in relativistic physics; this is illustrated by reference to the Twin Paradox, which demonstrates, so I argue, that time lapse is represented in relativistic physics by the proper time. This develops the conception of becoming as taking place along a worldline and in proper time, sketched in Stein (1968) and Arthur (1982), and defended in elaborate detail by Clifton and Hogarth (1995). In section 4 I argue that the punctual present view (iii), although formally correct, is tarnished by its unrealistic assumption of instantaneous or point-events, which makes it susceptible to paradox and sets it at variance with our normal intuitions of the present. Following a suggestion of Stein, I argue that a view more consistent with our experience of present events as "at hand" may be obtained by allowing for events extended in proper time, and once this is done a defensible conception of the present emerges:

(iv) the *present* of an object during an interval of its proper time π (e.g. that during which conscious experience is laid down) is that region of spacetime comprised within the forward lightcone of the beginning of this (usually short) interval and within the backward lightcone of the end of that interval.

2. The Manifold, Reality and Becoming Present

According to a view that has great currency among both philosophically inclined physicists and philosophers versed in physics, the present has no place in a scientific worldview. "The universe", writes Jack Smart, "is a four-dimensional space-time manifold. Present, past and future are all equally real." (Smart, 1968, 255).

Similarly, D. C. Williams writes in his classic paper, "I believe that the universe consists, without residue, of the spread of events in space-time… The theory of the manifold is the very paradigm of philosophic understanding." (Williams 1951, 132, 146). On this view, "all events—past, present and future—are equally real" (Davies 260).[3] That some events are occurring *now* means only that those events are occurring contemporaneously with the utterance of that observation.[4] But since it is equally true of any event that it is happening now at the time of its occurrence, this does nothing to mark out any one event from any other. Therefore, it is inferred, passage or becoming present is not a feature of objective reality.

There are two features of this argument on which I wish to concentrate: first, the sense in which it can truly be said that all events in the manifold are equally real; and secondly, once this sense is clarified, whether the inference to the unreality of the becoming of events can be sustained. I shall argue that it cannot, that the inference depends on a certain equivocation on the sense in which events can be said to exist.

Before I begin, however, I should first say something about the notion of "passage". When Smart, Williams and others object to becoming, one of their main targets is the notion of passage articulated by McTaggart in his (1908); and I believe they are correct to regard this notion of passage as indefensible. McTaggart, it will be remembered, supposed events to be laid out at certain positions in an antecedently given (absolute) time (1908/1993, 95), and demanded to know "What characteristics of an event are there which can change and yet leave the event the same event?" (97). His answer is that only the A-determinations can change; that is, an event can only change in the sense that it begins by being a future event, becomes present and is then past (97). Against this Williams and Smart objected

[3] Cf. J. J. C. Smart (1968, 255): "Present, past and future are all equally real."
[4] "The term 'the present' is the conventional way of designating the cross-section of events which are simultaneous with the uttering of the phrase." (D. C. Williams, in Westphal and Levenson (1993, 137.) "When we say that an event … is present, we are saying that it is simultaneous with our utterance." (J. J. C. Smart (1968, 255).

that change is already built into the spacetime manifold, and that to suppose the manifold static and in need of motion is to commit a kind of paralogism. "There is passage," grants Williams, "but it is nothing extra. It is the mere happening of things, their strung-along-ness in the manifold." (1951, 137) This applies equally to H. G. Wells' conception of passage. According to Wells's Philosophical Inventor, "Our consciousnesses, which are immaterial and have no dimensions, are passing along the time-dimension with a uniform velocity from the cradle to the grave." (Wells in Geduld 1987, 33, 156). This conception is echoed by Hermann Weyl: "Only to the gaze of my consciousness, crawling upward along the life line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time."[5] But such conceptions of a "moving present" are pure confusion. "There is clearly no room in the space-time picture for movement through space-time… What would movement through time be? Change of time with respect to what?" (Smart, 1968, 256). Consequently this notion of passage must be rejected.

But Smart, Williams, and all those belonging to the category of "B-theorists", go further, and infer that temporal becoming should be abandoned altogether: events simply ARE, and do not need also to "become". Their argument, in a nutshell, is this: if we assume that the universe is a four-dimensional space-time manifold and that this manifold is real, then the reality or existence of an event simply consists in its being contained in this manifold. It is therefore quite unnecessary to suppose that it also "becomes" or "becomes present".[6] If an event already exists, it does not also need to come into being.

Here I think we need to be very careful about the slippery word "exists". There are many senses of the words 'exists' and 'is' that can be distinguished. For current

[5] Weyl (1949, 116). He had said almost exactly the same thing in his earlier Mind and Nature (Philadelphia, 1934), p. 76.

[6] An explicit version of this argument is given by Craig Callender, in the course of criticizing so called "hybrid theories": "Because [upholders of] hybrid theories accept that a four-manifold is the arena of world history, they cannot —on pain of incoherency— analyze becoming in terms of the coming into existence of events. It simply doesn't make sense to say an existent event comes into being." (quoted from Savitt, 2005).

purposes, the main ones to consider would appear to be these: (i) to exist atemporally, as in '3 is prime';[7] (ii) to exist at a given time or spacetime location; (iii) to exist at all times, or sempiternally; and (iv) to exist for a certain duration.

Now consider a point-event *a*. What does it mean to say that this event exists or is real? A straightforward answer would be this: an objectively existing event is whatever occurs at the place and time at which it is represented to occur, independently of anyone's subjective experience. This involves existence in sense (ii); for point-events, clearly, senses (iii) and (iv) do not apply. At any rate, concerning the claim that all events in a spacetime manifold exist or are equally real, we can say that this is so in sense (ii): each of them is represented as being real, in the sense of occurring at the particular location in spacetime it occupies, independently of anyone's experiencing it.

This will not, however, license an inference to the claim that all the events are *already* real. For such a claim makes an implicit reference to the time at which the event is being represented (By the word 'represented' I mean 'considered', 'spoken of', 'pictured in a spacetime diagram', etc. I am not using it in any obscure technical sense). That a future event is represented as existing obviously does not make it exist at the time it is being represented. This point is granted by both Smart and Williams. Says Williams of his "theory of the manifold", it "does not assert, therefore, that future things 'already' exist, or exist 'forever'." (144); says Smart, "Of course it could be misleading to say that according to the theory of relativity the future is 'already in existence'" (1968, 226). Yet if there is no sense in which a given event "already" exists, it is hard to see the argument for the non-necessity of an event's becoming, which I summed up above in the words: "If an event already exists, it does not also need to come into being."

[7] I believe it can be seriously questioned whether the 'is' in '3 is prime' is an 'is' of existence. It appears rather to be an 'is' of predication, which does not exist in a language like Swahili. But I am allowing it here on the principle of charity. It is usually referred to as connoting "tenseless existence", on which more below. Savitt (2005) also explores other possible meanings of 'is', including the "detensed" 'is', where "x Is Φ" means "x either was, is or will be Φ".

Nevertheless, according to Smart and Williams there is an appropriate sense in which an event exists, namely in its being contained in the four-dimensional manifold. It IS in the manifold, where I have put the 'IS' in small capitals to denote that we are now using the atemporal 'is', the 'is' of sense (i) above. Thus if the manifold can be said to pre-exist in some sense, this will license an inference to the pre-existence of any of the events in it. But the conclusions we reached about the temporal existence of a singular event must apply *a fortiori* to the four-dimensional manifold. If future events do not exist at the time they are being represented, then the whole spacetime manifold cannot be said to exist then. The spacetime manifold cannot be thought of as a thing existing on a par with three-dimensional physical objects, which exist through time. To suppose that a four-dimensional object has this sort of existence is to commit a paralogism. But the paralogism does not reside merely in interpreting the word 'exists' as 'exists now', as is sometimes said—it runs deeper. The manifold not only cannot be said to exist now, *it does not exist at any time*.[8] Being four-dimensional, with time included as one of these dimensions, it simply does not have a temporal existence. This is why it is a mistake to talk of changing relations in the four dimensional manifold, and equally a mistake to talk of the static view of spacetime. To quote Smart again: "And if there can be no change in space-time, neither can there be any staying the same. As Schlick points out, it is an error to claim that the Minkowski world is static: it neither changes nor stays the same" (Smart 1964, 13).

There is a valid sense, however, in which we want to say that the spacetime manifold exists over and above the events in it. To say that a spacetime manifold exists objectively is to say that the metrical, topological and ordering relations among the events ARE as depicted, where the word 'ARE' is here being used

[8] Cf. the similar remark about time Leibniz made to Clarke: "Whatever exists of time and duration, being successive, perishes continually, and how can a thing exist eternally which (to speak exactly) does not exist at all?"; Fifth Paper, §49; Westphal and Levenson (1993, 51).

atemporally, in sense (i) above.[9] It is the copula we use to assert facts, and is not to be confused with the 'are' used to express duration in time. In the same way, if we say that event *a* IS before event *b*, we are stating a fact about their temporal relation. But it is a fallacy to speak of this relation as never changing or being "permanent", as does McTaggart,[10] since these things can only be said of things existing in time. Neither point-events, nor temporal relations connecting them, nor four-dimensional objects like worldlines or indeed the whole of spacetime, can be said to exist through time (for a duration, or forever—senses (iii) and (iv) above), and only some events (a proper subset of those in the manifold) exist *at* any given time (sense (ii) above). One can grant that events EXIST in the sense of being contained in a manifold; but since a manifold can also only be said to EXIST in an atemporal sense (sense (i) above), we have not succeeded in identifying any sense of 'exist' that will support the argument that since events already exist, they do not need also to become.

At this juncture an appeal is often made to a purported distinction between becoming present and the "tenseless occurrence" of events.[11] According to Adolf Grünbaum, "Becoming is mind-dependent because it is not an attribute of physical events per se, but requires the occurrence of certain *conceptualized conscious experiences* of the occurrence of physical events" (1971, 197). This seems to beg the question of the objectivity of becoming, since it is tantamount to *defining* the becoming of events as requiring a conscious mind. But Grünbaum and company equate this mind-dependent notion with "happening in the tensed sense", and contrast it with "occurring in the tenseless sense". The mind-dependence thesis, writes Grünbaum, although it "does deny that physical events themselves happen in

[9] This formulation, it seems to me, is fully in keeping with what Nerlich wants to say about the reality of spacetime and spacetime structure. See (Nerlich 1994, 40ff).
[10] "If N is ever earlier than O and later than M, it will always be, and has always been, earlier than O and later than M, since the relations of earlier and later are permanent." J. M. E. McTaggart (1908, 96).
[11] This distinction perhaps has its origin, as Grünbaum suggests, in Bertrand Russell's claim in his (1915, 212), that "past, present and future arise from time-relations of subject and object, while earlier and later arise from time-relations of object and object." Quoted from Grünbaum (1971, 215-216).

the tensed sense of coming into being apart from anyone's awareness of them", nevertheless "clearly avows that physical events do happen independently of any mind in the tenseless sense of merely occurring at later clock-times in the context of objective relations of earlier and later." (1971, 213-214).

Now, I submit that it is one thing to talk of verbs being used tenselessly, as when Grünbaum claims that "to assert tenselessly that an event exists (occurs) is to claim that there is a time or clock reading *t* with which it coincides" (215). But it is quite another to claim that "events happen tenselessly", as Grünbaum alleges Minkowski to have asserted (215). It seems to me that this whole notion of "tenseless occurrence" is a *contradictio in adjectivo*. An event occurs, happens or becomes exactly when it occurs, happens or becomes, independently of any minds or clocks. If we say an event OCCURS, using the verb 'occurs' tenselessly, then this describes the way we have used the verb, not a variant kind of existence or occurrence. A tensed use of a verb gives implicit information about the time of utterance; a tenseless use does not. I therefore take the valid core of Grünbaum's intuition to consist in this: (i) events occur quite independently of coming into anyone's awareness of them; and (ii) one can represent an event as occurring at a certain location in the manifold without any implicit reference to the 'now' at which the event is being represented. But this in no way validates a distinction between two types of occurrence of events, "tenseless occurrence" and "tensed occurrence". An event (*eventum*, the past participle of *evenire*, Latin for to come about or happen) is something that *has become*, both semantically and etymologically. An event cannot exist or occur without having become, since this would be to say that it could have become without having become, an evident self-contradiction. When we represent an event we therefore of necessity represent it as having become. Once we have represented all events and all processes on a spacetime diagram, we have

represented all becoming, so it is unreasonable to look for something else to be superadded.[12]

To sum up: the word 'exists' can be used temporally in a sense appropriate to things existing at a time or through time. In this sense, all events can indeed be said to be equally real, i.e. as occurring (i.e. becoming) at the particular times or spatiotemporal locations they do independently of anyone's awareness. But the spacetime manifold itself does not exist in this temporal sense. The word 'exists' or 'is' can also be used atemporally, as when we say that "event *a* IS before event *b*", and events "*a* and *b* ARE contained in the manifold". But this atemporal 'is' is inadequate to ground any notion of events *already existing*, which clearly requires a temporal sense of 'exists'. There is, therefore, no sense of 'exists' which will support the argument that events do not need to come into existence since they (and the spatiotemporal relations among them) already exist in a four-dimensional manifold.[13]

With this preface, let us look at some of the arguments from the relativity of simultaneity to the reality of all events in the manifold. That Einsteinian relativity rules out the idea of a unique, absolute present is easily seen: if the set of events that is simultaneous with a given event *e* depends upon the inertial reference frame chosen, and in fact is a completely different set of events (save for the given event *e*) for each choice of reference frame in inertial motion relative to the original, then there clearly is no such thing as *the* set of events happening at the same time as *e*. In the vivid example of Paul Davies, if I stand up and walk across my room, the

[12] Despite his championing of "the theory of the manifold" over the reality of becoming, D. C. Williams makes essentially this point in his (1951, 464), Westphal and Levenson (1993, 138): "World history consists of actual concrete happenings in a temporal sequence; it is not necessary or possible that happening should happen to them all over again."

[13] I take the view that if 'is' or 'exists' is being used atemporally, then it is a confusion to add a temporal qualification such as "at time t", a qualification which only makes sense for a temporal sense of 'exists'. Savitt (2005) reports that this was the view of A. N. Prior regarding verbs used tenselessly, such as saying an event IS to take place tomorrow: "What place can a word like 'tomorrow' have in a strictly tenseless form?" Savitt himself allows such temporal qualification of tenseless verbs.

events happening "now" on some planet in the Andromeda Galaxy are different by a whole year than those that would be happening "now" if I had stayed seated. (Davies, 1995, 70). This much is clear and uncontroversial. But from it Davies concludes: "unless you are a solipsist, there is only one rational conclusion to draw from the relativity of simultaneity: events in the past and future have to be every bit as real as events in the present… To accommodate everybody's nows, … events and moments have to exist all at once across a span of time." (1995, 71)

But this is by no means a rational conclusion to draw. Events "exist all at once" in a spacetime manifold only in the sense that one represents them all at once as belonging to the same manifold. But one precisely represents them as occurring at different times, or different spacetime locations, and if one did not, one would have denied temporal succession. The rational conclusion to draw, I submit, is that (according to Special Relativity) distant events that are simultaneous with some given event—for example, the event of my considering them—cannot be supposed to be 'real' or 'existent' for that event, e.g. existent for me at the spacetime location from which I am considering them.

More elaborate arguments along the same lines as Davies' had previously been given (in papers written independently at nearly the same time) by Putnam (1967) and Rietdijk (1966). Although the details of their arguments differ, both depend on a scenario that can be described as follows. We are asked to imagine two spatially distant inertial observers, O_1 and O_2, with one moving at an appreciable fraction of the speed of light with respect to the other. At a certain time according to the observer O_1's own inertial system, an event *b* that is happening to O_2 is "present" or "now" for O_1, and we may imagine O_1's being aware of this as the event *a*; but to O_2, the event happening to O_1 that is simultaneous with *b* in her inertial system is not the event *a*, but another event *p*. Yet it is easy to set the relative velocity in such a way that *p* is in the future for O_1 at the time that he is experiencing *a*. It follows

that, if all those events are real which are present for a given observer in that observer's inertial system, then *b* is real for O_1 when he is experiencing *a*, and *p* is real for O_2 when she is experiencing *b*. Thus if *xRy* denotes "*x* is real for *y*" we have *bRa* and *pRb*, so that, if *R* is transitive, then *pRa* ("*p* is real for *a*") even though *p* is in the future for O_1 when he is experiencing *a*. We are forced to conclude, reasons Putnam, "that future things (events) are already real" (Putnam 1967, 242), or as Rietdijk puts it, "that, being 'past' or 'present' for only one inertial system, an event can be shown to be determined in all other systems" (1966, 342), so that "there is determinism" and "there is no free will" (343).

Putnam, it should be said, acknowledges that simultaneity, although transitive within any given frame of reference, is not transitive between frames: "the relation '*x* is simultaneous with *y* in the co-ordinate system of *x*' … is not transitive" (242-43). So he does not claim that all events exist "at once" in the sense of being mutually simultaneous. Nevertheless, he argues, the assumption that "all things that exist now according to my co-ordinate system are real", in combination with the principle that "there are no privileged observers", requires the relation *R* to be transitive (243). But if *R* is to be interpreted to mean that future events "already exist", as Putnam asserts, then this is to imply that they have, as of the earlier time, already occurred. A similar criticism applies to Rietdijk's conclusion: an event *p* can only be said to be "already 'past' for someone in our 'now'" (341) at location *a* in the sense that it has already occurred at *a*. But such a claim amounts to a denial of temporal succession.

In each case we are presented with an argument that begins with a premise that all events existing simultaneously with a given event exist or are real, and concludes that consequently all events in the manifold are real. But the conclusion only has the appearance of sustainability because of the equivocation analysed above. If a point-event exists in the sense of occurring at the spacetime location at which it occurs, it cannot also have occurred earlier. But if the event only exists in

the sense of EXISTING in the manifold, then the conclusion that it *already* exists earlier—that such a future event is "every bit as real as events in the present" (Davies), or "already real" (Putnam)—cannot be sustained. Thus, far from undermining the notion of becoming, their argument should be taken rather to undermine their starting premise, that events simultaneous with another event are already real or already exist for it in a temporal sense. For to suppose that this is so, on the above analysis of their argument, inexorably leads to a conclusion that denies temporal succession.

3. The Relativized Present

Putnam and Rietdijk, of course, did not advance their arguments to support the case for idealism. In contrast, Kurt Gödel (1949) gives an argument whose intent is explicitly idealist: from the relativity of simultaneity he infers that the lapse of time is itself unreal. His argument runs as follows:

> Change becomes possible only through the lapse of time. The existence of an objective lapse of time, however, means (or at least is equivalent to the fact) that reality consists in an infinity of layers of "now" which come into existence successively. But, if simultaneity is something relative in the sense just explained, reality cannot be split up into such layers in an objectively determined way. Each observer has his own set of "nows", and none of these various systems of layers can claim the prerogative of representing the objective lapse of time. (557-8)

Here Gödel assumes (i) that objective time lapse must be construed in terms of the successive coming into existence of layers of "now", i.e. classes of simultaneous events. He also assumes, reasonably, (ii) that if time lapse is to be counted as objective, it must be invariant under change of inertial frame (although he expresses this in a needlessly subjectivist manner in terms of "each observer having his own set of 'nows'".) He then infers that, since (iii) the layers of now are not

invariant, (iv) there is no objective time lapse in the sense he has defined it: the same event will be "real" or come into existence in one inertial system before or after it has come into existence in another.

Now I believe this to be a valid argument whose conclusion is self-contradictory. And, since I endorse the second premise about the frame invariance of time lapse, I believe it proves the first premise false. But many philosophers have not found this last statement self-contradictory, and are content to hold that the reality (in the sense of the coming-to-be) of an event is relative to the inertial frame selected. For instance, both Storrs McCall and Mario Bunge would endorse Gödel's first premise, construing objective time lapse in terms of the successive coming into existence of classes of simultaneous events.[14] But they would reject his equating of 'objective' with 'frame invariant' (premise (ii)), and therefore deny that there is anything contradictory about time lapse being relative to frame. They are thereby committed to the second of the construals of the present I detailed above: that present existence is not an absolute notion, but is relative to inertial frame; the world-at-an-instant is a three dimensional, but relative, reality.

Gödel's first premise is, I believe, demonstrably false: it depends on a mistaken notion of time lapse in relativity theory. Since I have argued this at length elsewhere (2003), my exposition here will be correspondingly brief. Suppose, as does Gödel, that for each individual observer, "the existence of an objective lapse of time … is equivalent to the fact that reality consists in an infinity of layers of 'now' which come into existence successively." That is, the time lapse between, for

[14] In his (1967-8) Mario Bunge defines time T as a mapping from the set of all ordered quadruples <event, event, physical reference frame, chronometric scale> onto the set of real numbers; see esp. pp. 358, 359. Similarly but independently, Storrs McCall (1976) has defined time in terms of a mapping into "a set [T] of time co-ordinates (i.e. real numbers)" by a function h which, for each co-ordinate frame f which partitions the set U of spacetime points into simultaneity classes, "assigns each u of U a time" (1976, 337-362, 356-57). More recently McCall has upheld this view in his (1995, 158): "No frame-independent or hyperplane-independent pattern of illumination could possible represent temporal becoming… Temporal becoming is frame-dependent." In his (2006) McCall argues that what the triangle inequality difference in lengths of the twins' paths "demonstrates is that elapsed time is not path-dependent, but frame-dependent" (9).

instance, two events in anyone's life history is given by the difference in the values of the time co-ordinate function in some particular inertial reference frame.[15] Now consider the classical "Twin Paradox", where one twin (H) stays at Home, stationary in his rest frame for twenty years, while his twin (A) speeds Away at six tenths of the speed of light, turns around, and then returns home at the same speed. Because of time dilation, twin A will find time running more slowly by a factor of $\gamma = (1 - \beta^2)^{-1/2}$, where $v = \beta c$, and will therefore take only $\sqrt{(1 - 0.36)} = \sqrt{(0.64)} = 0.8$ times as long for each leg, and therefore 8 years for each. If we idealize for the sake of simplification, and treat the turn-around as instantaneous, when the twins meet again, twin H will be 20 years older, but twin A will have aged only 16 years. That is, the time lapse between parting and re-uniting will be 20 years for twin H, but only 16 years for twin A. Now, I shall not stop to explain how this apparent paradox is resolved, since this has been done many times elsewhere. But the point is that this time difference is a real effect; it is *not* an apparent effect, the result of there being something improper about A's timekeeping. The reality of the time dilation effect has been demonstrated, for example, by two scientists flying cesium clocks around the world on commercial jets.

But according to the construal of time lapse as relative to a particular inertial frame, this difference in time lapse for the two travelers is impossible! The time difference between the two events of parting and re-uniting reckoned according to H's rest frame is 20 years, and when they reunite the same time will have elapsed for both relative to this frame. If the time lapse is reckoned according to the rest frame of A on her outward journey, the difference would be 16 years: for eight years she would have been stationary as twin H went off at 0.6c in the other direction, and then, instantaneously accelerated to a speed of almost 0.8c in the

[15] Rietdijk (1966), Putnam (1967), and Fitzgerald (1969) also assume that becoming must occur relative to a co-ordinate frame, with time-lapse measured by the time co-ordinate function, as a premise in their reductio arguments against the reality of becoming [real or determinate]. For this reason I find Clifton and Hogarth's description of their (and Maxwell's) view as "a worldline dependent conception of becoming" (1995, 356) very misleading. It is a frame-dependent view, as McCall rightly calls it.

direction of twin H, she would have caught up with him eight years later, and, again, the same time will have elapsed for both when they reunite. But *in neither frame could there be a difference in time lapse between the two events*, contrary to fact. The Gödelian view is unable to account for the fact that 20 years will have elapsed between parting and re-uniting for twin H, whereas only 16 will have elapsed for twin A, a fact that both will be able to verify perfectly objectively!

The mistake lies precisely in Gödel's construal of time lapse. If the quantity of time elapsed were measured by the time co-ordinate function in some given inertial reference frame, then, although this quantity would differ depending on what reference frame might be chosen (as in the above example), it could not differ for two processes—say, the life histories of two "observers" who happened to take different paths through spacetime. Since such histories are paradigm cases of processes for which time is elapsing, and yet a different time has elapsed for each, it follows that Gödel's first premise is wrong: co-ordinate time is not the correct measure of how much time has elapsed.

The reason, I believe, why this consequence has not been seen clearly by the defenders of the relativized present is that they assume that time lapse must be measured not by the time co-ordinate in some one inertial frame for the entire journey, but *by the time co-ordinate in the rest frame of each twin*. This is, for instance, how McCall defends the relativist view. Twin A, on this account, would reckon time elapsed by the time co-ordinate function t in her own rest frame on the outward leg, and then by the function t' in the different rest frame appropriate to the return leg. Since in this idealized case her journey is the sum of these two independent legs, and each leg is inertial, the time will be precisely as measured by her clock: 16 years.

But this is to adopt a different premise: we are no longer assuming that becoming takes place in some one inertial frame, but rather that *the frame must be*

selected and reselected in such a way that it is always the rest frame of the object under consideration. Against this it must be objected that there is nothing in Special Relativity to dictate this privileged nature of the rest-frame as being the only appropriate inertial frame. One is at liberty to choose any inertial frame to describe a given process: the centre-of-mass frame, the frame in which one or the other twin was initially at rest, etc.[16] Moreover, this solves the twin paradox by trading on an accidental feature of the above set-up, namely that each observer is in inertial motion at every point (excluding the singularity of the instantaneous acceleration). In a more realistic set-up, where one twin remained on a gently rotating reference frame while the other gradually accelerated then gradually decelerated on both legs, neither twin would have been at rest in an inertial frame at any instant of their journeys through time. Yet one could arrange this situation in such a way that there would be precisely the same difference in the readings on their clocks when they reunite on Earth. The clocks will measure time elapsed for each twin even though no part of their journeys is inertial.

The reason for this, in turn, is that the quantity of time elapsed for a given process (such as a clock keeping time) is measured by the *proper time*, a quantity that is calculated by taking the integral along the world line of that process of the quantity

$\tau = \int d\tau$, where $d\tau = \sqrt{(c^2dt^2 - dx^2 - dy^2 - dz^2)}/c$

where x, y, z and t are the co-ordinates in some given inertial frame, and are considered as functions of the proper time τ.

[16] Suppose, for example, I throw a tennis ball very hard against a wall, and suppose the rebound instantaneous. What would be natural about describing this motion in the rest frame of the ball? Nothing physical would correspond to the fact that the 'nows' of that frame do not completely cover my worldline as I watch it. It appears that this privileging of the rest frame is founded on a conception according to which each observer "inhabits an inertial frame" (namely her rest frame) (cf. McCall (2006, ?). See Stein (1968), Myrvold (2003) and Arthur (2003) for a critique of such views.

The proper time so calculated is invariant to change of frame: it will come out the same no matter what inertial frame (with co-ordinate values x, y, z and t) is chosen. It therefore meets the criterion implicitly assumed by Gödel, namely that if time lapse is to be counted as objective, it must be invariant under change of inertial frame. Thus the time taken for each twin to make the trip through spacetime from the point of A's departure to their eventual reunion is found by integrating the proper time along that twin's particular world line, and this is so whether the line in question is piecewise straight, as in this case, or whether it is sometimes or even always curved. In the above case it comes out as 20 along H's straight world line, and 16 along A's crooked one. (Because of the peculiar metric of Minkowski spacetime, a straight line between two points connectible by a world line is not the shortest but the *longest* interval between these two points.) Proper time in general is not time according to the time co-ordinate in an inertial frame, or several such frames taken piece-wise; it is calculated along the spacetime path, and is invariant to which reference frame is chosen to perform the calculation. As Kent Peacock has summarized this view, "The physiological difference between the twins is strictly a function of their elapsed proper times. Hence real physical changes are tied to *proper* time …, not the time coordinate." (2005, 5)

In sum, there is nothing in Special Relativity to impugn the reality of time, contrary to Gödel's intent. Instead, his argument now becomes a *reductio ad absurdum* against the construal of time lapse that is assumed in the account of becoming given by the proponents of the relativized present. To suppose that time lapse is given by the time co-ordinate function in some one reference frame is incompatible with there being a difference in time elapsed for the twins; to suppose that time lapse is calculated piece-wise by adding inertial components of a journey is to ignore the fact that proper time is calculated by integrating along the path in any chosen inertial frame, and does not require that either twin perform inertial motion.

But this does not at all mean that temporal becoming is eliminated. Indeed becoming *is* represented on an Einstein-Minkowski diagram, since a process is nothing other than a sequence of events becoming, and in the Special Theory of Relativity every process is represented by a worldline.[17] That is, just as there is no invariant plane of simultaneity, there is no plane of becoming, no worldwide instant at which all simultaneous events come to be. But there is nevertheless a perfectly well defined sequence of becoming along each and every worldline in spacetime. The proper time, calculated by integrating along such a worldline, is an invariant measure of time lapse. So construed, time lapse does not depend on reference frame, nor on the existence of inertial motions, nor on any considerations of what events are simultaneous with the experiences of an observer.

What is true, new, and revolutionary is that these sequences of becoming don't match up: in Mauro Dorato's picturesque imagery, becoming on this view is like water flowing through "an uncorrelated, non-denumerable set of narrow creeks."[18] This is how it is that twin A manages to travel 4 years into the future: twin H, and everything else at home, will be 20 years older, while twin A and everything with her will have aged only 16 years. In this sense time will have passed more quickly for the stay-at-home twin H —contrary to Jack Smart's oft-repeated jibe at proponents of passage, it *does* make sense to talk of time passing more or less quickly. Yet when the twins are together again, despite the difference in their lifetimes, they will share the same present. But this cannot be the relativized present, for, by the above arguments, the objective lapse of time is *not* "equivalent to the fact that reality consists in an infinity of layers of 'now' which come into existence successively."

[17] Cf. Arthur (1982, 107): "… a proper time function [is] associated with each timelike line segment of spacetime (of a sufficiently smooth nature). It is this proper time which is understood to measure the rate of becoming for the possible process following this timelike line (or worldline)." Dieks (1988, 456): "Only time along worldlines (proper time) has an immediate and absolute significance as an ordering parameter of physical processes."

[18] Quoted by Barry Dainton (2001, 275) from Mauro Dorato, Time and Reality: Spacetime Physics and the Objectivity of Temporal Becoming (Bologna, CLUEB, 1995), p. 185.

4. The Punctual Present

This brings me to the third of the construals of the present in relativity theory outlined in the introduction above. On this view, what is present at a given spacetime point is, strictly speaking, constituted by that point alone. This view was first articulated by Alfred A. Robb in 1911, writing within six years of Einstein's original 1905 paper, and only three years after Minkowski's.[19] Taking exception to Einstein's proposal that "events could be simultaneous for one observer but not simultaneous for another moving with respect to the first",[20] Robb "avoided any attempt to identify instants of time at different places."[21] Instead he concentrated on the "absolute relations" identified by Minkowski: one instant, or the event *a* happening at it, is *absolutely before* another, *b,* if a physical influence can be propagated from *a* to *b*.[22] As he showed in 1914, this means that—restricting temporal relations to these absolute ones only—a given event can be related to any in its future or past light cones, but cannot be so related to any event outside these cones (in what Minkowski called the "elsewhere"). Thus there is no linear time, because events do not occur in a serial order, but rather in a strict partial order, which Robb called a "conical order". As for simultaneity, Robb's theory had the immediate consequence that "*the only events which are really simultaneous are events which occur at the same place*." Thus "*there is no identity of instants at*

[19] Alfred Arthur Robb (1914); his (1936) is essentially a second edition of this book. Robb had previously published a draft of his theory in the short tract Optical Geometry of Motion (1911), and later gave a simpler exposition without proofs of the theorems in his (1921).
[20] A. A. Robb (1936, 11); cf. (1921, v).
[21] This is Robb's description of his 1911 tract in (1914, 3), in which he presents himself as opposing Einstein's relativism with an independent development of relativity theory deriving directly from the work of Larmor and Lorentz. I believe it is more accurate, though, to see Robb as deriving Einstein-Minkowski spacetime on the basis of the same absolute relations of before and after as delineated by Minkowski, defined in terms of the possibility of propagation of physical influence from one point to another. In this I follow John Winnie (1977).
[22] Robb tended to talk in terms of instants, rather than events, and even wrote of one's being "directly conscious" of them (1914, 8). By "instant", therefore, I take him to mean an instantaneous event, a point-event, or what Broad (1938, 280) aptly called an "event-particle".

different places at all," so that "*the present instant, properly speaking, does not extend beyond here*."[23]

Robb's view was taken up by Milic Capek (1966), (1975), and also by Howard Stein (1968) (although here without attribution to Robb) in their critiques of the arguments of Putnam and Rietdijk discussed above. "Like Rietdijk," objects Capek, "Putnam retains the old notion of the universal present spread as a 'world-wide instant' across the whole universe, and uses this notion in order to conclude that, in a sense, *everything* is present" (1975, 612-13). But this neglects "the one essential idea of relativity that … 'Here-Now' can never be extrapolated to 'Everywhere-Now'" (613). Similarly, Stein objected that "in Einstein-Minkowski space-time *an event's present is constituted by itself alone*." (1968, 15). Stein proceeds to object to the arbitrariness of Putnam's "maintaining the implication 'present implies real'", suggesting we might as well insist on its converse, the presentist assumption that "*only* things that exist now are real." Then we would be "led to conclude that *for any event, it and it alone, is real*" (18). Stein characterizes this position (resulting from combining the punctual present of relativity with presentism) as "a peculiarly extreme (but pluralistic!) form of solipsism" (18). This recalls Davies's "Unless you are a solipsist," remark quoted above.

Of course, we are by no means obliged to uphold presentism. Indeed, once the world-wide instant is jettisoned, presentism loses much of its intuitive appeal. If to be real no longer means to come into existence in a world-wide plane of simultaneous becoming, then it is difficult to see what it does mean. Since whatever we perceive to be present has already become (real), Stein suggests replacing "is real for" by "has become real for":

[23] Robb (1914, 6, 12, 13). This sentiment is later echoed by Broad in connection with his notion of "absolute becoming": "But a literally instantaneous event-particle can significantly be said to 'become present'; and indeed, in the strict sense of "present" only instantaneous event-particles can be said to 'become present'" (Broad, 1938, 280).

> For an event—a man considering, for example—at a spacetime point *a*, those events, and only those, *have already become* (real or determinate), which occur at points in the topological closure of the past of *a* [i.e. in Minkowski spacetime, within or on *a*'s backward light cone]. (1968, 14)

The justification for this is that

> At a spacetime point *a* there can be cognizance of—or information or influence propagated from—only such events as occur in the past of *a*. (16)

On this view, what is real or actual at some specific spacetime point does not depend on the reference frame, since it is whatever *has occurred* at that point: and what has occurred at a spacetime point is what lies in its absolute past. This tallies well with Robb's own definitions of his absolute relations of *before* and *after*:

> Thus if I can send out any influence or material particle from a particle *P* at the instant *A* so as to reach a distant particle *Q* at the instant *B*, then this is sufficient to show that *B* is *after* and therefore distinct from *A*. (1921, 11)

It also tallies with Robb's rejection of solipsism: "A normal individual who is not a solipsist (and a solipsist could hardly be regarded as a normal individual) believes in the existence of more than his own self and his own perceptions, and one is accustomed to regard these perceptions, under normal circumstances, as representing things as real as one's self but in some sense external" (1936, 7-8). In other words, both Robb and Stein are inclined to count all events in the past of a given event as real. But this is "real" in the sense of "having become determinate for"; it does not imply that past events *co-exist* with those of the present. For co-existence, we need a mutual relation, "compresence" or "presentness to each other". As Stein points out, if this relation "is taken to mean that *each has, for the other, already become*," then in the classical case we recover the ordinary concept: because "topological closure of the past" includes the limiting condition of

instantaneous interaction, two events will be compresent if and only if they are simultaneous.[24] But in the relativistic case, this definition will yield only the punctual present: to paraphrase Robb, the only events compresent with a given event are events which occur at the same place. Thus even if we reject presentism, Stein's definition of compresence still leads to the punctual present.

The punctual present, however, is very problematic. To say that what is compresent to an event, such as a person considering, is merely what shares the very same spacetime point is, to say the least, decidedly harsh on our normal intuitions of presentness. It also seems susceptible to a version of one of Zeno's paradoxes, since temporal becoming can no more take place in an instant than can motion. Therefore, if becoming takes place in the present and all that is present at some point is what is at that spacetime point, then, since there is no becoming in an instant, there is no temporal becoming.[25] Russell proposed something like this argument as an objection to becoming. This is curious, for his solution to Zeno's parallel argument against motion is that, although there is indeed no motion in an instant, this does not refute the reality of motion, since this consists in a body's having a different position at a later instant.[26] By parity of reasoning one might argue that, although a Zenonian argument shows that a process cannot be composed of point-events, it does not preclude there being a process whereby something becomes different at a later time from what it was at an earlier one.

This last consideration, in fact, points the way to an acceptable construal of becoming, and one that "saves the phenomenon" of our experience of the present

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[24] Here Stein's definition of the "topological closure of the past" of an event is such as to include the events on the backward null-cone, i.e. those connectible to it by any process including a light ray in vacuo.

[25] Cf. Zeno's B4: "What is moving is moving neither in the place in which it is nor in the place in which it is not." Aristotle: "The now is not a part of time, because a part measures the whole and the whole must consist of its parts; time, however, does not seem to consist of nows." Physics iv.10, 218a6-8 (Aristotle 1996, 103).

[26] "People used to think that when a thing changes, it must be in a state of change, and that when a thing moves, it is in a state of motion. This is now known to be a mistake. ... Motion consists merely in the fact that bodies are sometimes in one place and sometimes in another, and that they are at intermediate places at intermediate times." Bertrand Russell, "Mathematics and the Metaphysicians" (1929, 83-84).

too. This is achieved by recognizing that becoming occurs over a short (even arbitrarily short) duration; even the event of a person considering or apperceiving another event cannot be strictly instantaneous.

5. The Extended Present

In presenting their theory of the punctual present both Robb and Stein were careful to qualify their characterization of it with the phrases "properly speaking" and "strictly speaking". As they were both aware, the punctual present depends on the abstraction of "instantaneous" or "point-events", and in relating these to experience ("a man considering") it also assumes that the perceptions or awarenesses of such events themselves occur in a point. Obviously, these are the typical abstractions of a mathematical physicist, necessary for a strict understanding. But they are also responsible for the gulf between this theory and our palpable experiences of events. As has long been recognized, when we experience—to give a hackneyed example—the postman's knock, we hear it as a "rat-tat-tat", and not as a "rat", then a "tat", then another "tat"; and similarly with speech and phrases of music.

As several authors have pointed out, however, this discrepancy between theory and experience can be bridged by introducing the concept of the *specious present*.[27] The idea, as originally developed by William James, is that the present or now as we cognize it in practice is "no knife-edge, but a saddle-back with a certain width of its own."[28] By this means, our intuitions of presentness as comprising brief processes and also as encompassing a considerable spatial extent can be preserved. For we do not have to restrict our notion of contemporaneity to what is present to a *point-event* or *instant*, but can apply it to a small extended event of apperception. As

[27] See in particular the discussions of H. A. C. Dobbs (1951). Dobbs builds on the speculations of Eddington in his (1946) about the two-dimensionality of time, as well as Russell's discussion of the paradoxes associated with the specious present in his (1948).
[28] Broad (1938, 281ff.) is extremely critical of the idea of a specious present. But see Davies (1995, 265-278) and Dainton (2001, 96-109) for contemporary discussions.

Stein argues, a natural way of construing contemporaneity is in terms of *mutual communication or influence*. He writes:

> Let us consider a "specious present" π of some percipient being; and let us call an event *e* "contemporaneous" with π if signals—interaction—influence—can occur *mutually* between *e* and π. In the Newtonian case, the spatial extent of the set of events contemporaneous with a given specious present is infinite; and it is rather natural to see in this fact the precise correlate, in the physical theory, of the "intuitive" notion of a "present" throughout all of space. The situation in the relativistic case is significantly different…[29]

Here Stein is linking the notion of mutual communication with what the physics in question says about interaction. In the case of Newton's theory, gravitational interaction is assumed to be instantaneous. But there is a second strand in Stein's discussion, his "plausible anthropological hypothesis" that our "intuitive" notion of the present as grounded in mutual communication "first arises 'naturally' in the course of human development and socialization" (1991, 159). If we pick up this strand instead, a different construal of interaction suggests itself. After all, perception does not occur by gravitation; what is relevant to the intuitive present is not the worldwide instant of Gassendi presupposed by Newton in his theory of gravity, but interaction of objects with perceivers, especially visual interaction. And, given the collapse of the world-wide instant entailed by relativity theory, Stein's suggestion permits us to redeem the notion of the present as having a spatial extent that is, in fact, extremely large.

In a lyrical passage, Stein compares his account of the spatially extended present with Schrödinger's answer to the question, "Why are atoms so small?" Just

[29] Stein (1991, 159). This amplifies on a point in a footnote in his earlier article: "for processes of more than instantaneous duration, a meaningful and intuitively satisfying notion of 'contemporaneity' can be defined: two such processes may be said to be contemporaneous if part of each is past to part of the other—in other words, if mutual influence ("communication") is possible between them (1968, 15 n. 14).

as Schrödinger transposed this into the more easily answerable question, "Why are we so large in comparison to atoms?", Stein tries to answer the question "Why is it that, in the geometry of spacetime, we are so long and thin?"—that is, why is that the ratio in the Minkowski metric between the spatial extent of our bodies and the temporal length of the specious present is so exceedingly small?—by transforming it into the question, "Why is it that, during a specious present, light travels a distance that bears a very large ratio to the spatial extent of our bodies?" His answer is that, even though we know very little about the conditions for conscious awareness, we do know that "the things we perceive must possess a degree of stability (and must interact with us in stable patterns)" (161). And in order for this to occur, it is necessary for there to be very many interactions between the thing perceived and the perceiver; this in turn requires that the moments of experience (specious presents) be long enough to enable there to be very many such interactions between an organism and its immediate environment.[30] It follows that the distance light can travel in such a specious present is very many times greater than the dimensions of our bodies. And this in turn explains why, if our intuitions concerning compresent bodies are laid down in such a time interval, we come to expect the present to have a very large spatial extent.

Accordingly, if *a* is the extended event of our becoming aware of some other extended event *e* during some short interval π of our proper time, then both *a* and *e* will be short processes, and accordingly both will be represented as segments of world lines in a Minkowski diagram. Actually, it is more appropriate to talk in terms of short segments of worldlines than events, since the notion of interaction requires two temporal continuants, objects enduring through time, and thus tracing segments of worldlines in spacetime. (It is a strain on language if not ontology to

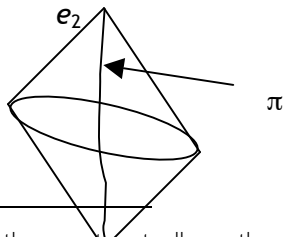
[30] There's a fascinating remark of Leibniz's in one of his papers of 1676 which seems to convey a similar idea: "Every mind is organic and learns something, but with difficulty and over a very long time, in proportion to the periods [of repetition] of the things it senses."; "Notes on Science and Metaphysics", in Arthur (ed.), 2001, 59). See also the note on periodus on p. 459.

talk of two events interacting with one another.) Now any segment of a worldline that is contained within the absolute past of the end of the worldline segment of proper duration π, but within the absolute future of the beginning of that segment, will represent the path of a process or enduring object with which the person perceiving could be in interaction during that time.[31] So if the present of an event or enduring object *a* consists in all those events or enduring objects compresent with it, we arrive at the fourth theory of the present described in the introduction, the *interactive present*. That is, if we define all and only those extended events or enduring objects to be compresent with a section of an object's worldline *a* which are capable of mutual physical connection with it during an interval of its proper time π then:

(iv) the *present* of an object during an interval of its proper time π (e.g. that during which conscious experience is laid down) is that region of spacetime comprised within the absolute future of the beginning of this (usually short) interval and within the absolute past of the end of that interval.[32]

In terms of Minkowski spacetime, the absolute future is the forward lightcone, and the absolute past the backward lightcone. The result is that the present of an object during an interval of its proper time is a region of spacetime finite in extent, the intersection of two "cones", as in the figure below.

The interactive present:



[31] I am here excluding the events actually on the past null cone as having become. For an interesting discussion of this point, see Clifton and Hogarth (1995, 364-65). In their terms the becoming I have described is "chronological becoming", as opposed to "causal becoming".
[32] This is indebted to Stein's formulation in his (1968). See fn. 28 above.

Here e_1 and e_2 are the point events marking the beginning and end of the worldline of the object in question during the interval of its proper time π. Thus the events in this present are all the events chronologically between e_1 and e_2. Technically, this is known as the *Alexandroff interval between e_1 and e_2*.[33] The figure, of course, contains two distortions. One is that the units are represented as if they are equal, i.e. as if c = 1 in everyday units, whereas for a lapse of proper time of 1 second the spatial extent of the present is of the order of 1 light second, or 300,000 km or 3×10^{10} cm. The other distortion is that in our Minkowski diagrams one spatial dimension is suppressed: the 3-dimensional "cones" we represent in two dimensions are in fact 4-dimensional objects.

The present so construed is objective, in that although it can accommodate what may be present to an observer's conscious experience—and thus preserve our intuitions about the great extent of the present at any moment of consciousness—it does not depend on it. *Any segment of a worldline will have a region of spacetime that is present to it* according to this definition. In particular, this construal accommodates the kind of extended conception of 'now' mentioned by Aristotle: "it is also used when the time of what is called 'now' is close: 'He will come now', because he will come today." (*Physics* IV.13 222a21-22, (1996, 113)). One can even use it in a cosmological context: when a cosmologist refers to 'now', she means 'the present era' —perhaps the twenty-first century, perhaps the whole of recorded history— as opposed to some earlier or later epoch. This present would be the region of spacetime referred to the Earth's worldline between either 6 or about

[33] The Alexandroff interval is discussed by John Winnie in his (1977, 156-57), with a diagram depicting this interval for two chronologically connectible events. (Thanks to Steve Savitt for this reference.) As Winnie explains, Alexandroff intervals have a profound foundational significance, since a topology for Minkowski spacetime may be defined taking these intervals as basis. This is discussed in detail in Hawking and Ellis (1973, 196ff.), who show that they are also a sufficient basis for defining topologies of spacetimes in general relativity, provided the strong causality condition is met.

6000 years ago and today, and would comprise all those events happening in the absolute future of the beginning of that worldline segment and the absolute past of its end here today.

Although I have defined the present as relative to a segment of a worldline bounded by e_1 and e_2, one could conceivably have defined a present for any two point-events e_1 and e_2 as the Alexandroff interval between them. For that interval is still well defined even for two events that are not chronologically connectible, for instance the events in Davies' example mentioned above, that of my beginning to walk across the room (e_1), and an event e_2 somewhere in the Andromeda galaxy which is simultaneous with e_1 in my rest frame. Of course, in such a case the Alexandroff interval is null, so that there is no present relative to such a pair. This neatly underscores the point made by Capek and Stein, that in relativistic physics simultaneity of distant events precisely entails their non-presence to one another.

But as explained above, the motivation for the above construal of the present based on the possibility of interaction is that it reconstitutes what we intuitively mean when we think of present objects or events. In particular, if we consider the event of one's having a conscious experience during a brief (perceptually subliminal) interval of proper time, *what is present will be all those enduring objects compresent with oneself* during this time, i.e. all those enduring objects with which one could mutually interact *during a specious present*.[34]

That this construal of the present in terms of interaction corresponds fairly well with our own intuitions of the robustness of present objects can be seen by reference to a numerical example. Although the notion of the specious present is not without its difficulties—apparently varying in length depending on the context chosen—we may for the sake of definiteness take the minimum perceived time lapse

[34] Note that if the present includes only objects that could mutually interact, and hence only those existing for a finite proper duration, then this would automatically exclude point-events on the cones' surfaces from the present.

to be the time between successive frames in a standard movie. Since this runs at 25 frames a second, all those objects are visually compresent with us during this time to which light could travel in 1/50 of a second, returning to us in an equal time. Since the speed of light is 3×10^5 km s^{-1}, if we ignore any mutual motion between perceiver and perceived, this means any object within three thousand kilometres is visually present to us. Given this, of course, it is really not surprising that most thinkers have considered the speed of light to be practically infinite. (But it is worth noting that even the Epicureans, whom Newton studied assiduously, considered the speed of light finite.) Of course, the speed of sound is considerably slower; we are all familiar with the discordant phenomenon of a distant hammer blow (or bat hitting ball) being "present" visually before it is heard. Thus I believe it can fairly be concluded that consideration of the extended present is sufficient to reconcile the Robbian position with everyday intuitions. This gives a serviceable notion of what is present to a given event of short duration, as well as saving our intuition of the "reality" or robustness of events that are present in the sense of "at hand".

This interactive present is not the same, however, as the *passive* or *subjective present*, the set of all those events of which we are consciously aware at the moment of considering them. For on the one hand, which particular events one is aware of will depend on where one's attention is directed. On the other, there will be events among those one perceives that occurred possibly in the very distant past: the present experienced by two lovers gazing at the stars will include events that actually happened many eons earlier (light from very distant stars may take billions of years to reach us). Some might think that this argues for regarding all events within (and even on) the past light cone as present, and that this definition captures better our normal intuition of what is happening now.[35] But this is to eliminate any distinction between past and present. On the account offered here,

[35] If I understood him correctly, Robert Rynasciewicz suggested such a construal of the present to me in Montreal in a conversation after my talk.

one can still say that the two lovers are presently perceiving events that took place in the distant past. For each can be perceiving the same long past events during intervals of their proper times in such a way that each is compresent with the other while having these perceptions.

6. Conclusion

In closing, though, it will be worth stressing which of our intuitions concerning the present this notion of the interactive present does *not* preserve. First, it is at variance with the idea of a "moving present" discussed in section 2 above. At least, it is when this notion is conceived as by McTaggart or in the passages from Wells and Weyl cited earlier, where the present is depicted as a 'now' or consciousness moving along a world line. For that would entail superadding time to a representation that is already four-dimensional. That is, we may think of a worldline as having been traced by some stationary or moving worldpoint. But we cannot superpose such a motion onto a spacetime diagram without paralogism. For in constructing a spacetime diagram we represent processes and events, that is, things that are supposed to have occurred. Becoming—or at least, having become—is already included in the diagram.

Secondly, this conception of the extended present is not an absolute one: *the interactive present is meaningful only relative to a segment of a worldline*, usually of short duration. This does not, however, make it subjective or somehow dispensable. Indeed, it is false to say that physics does not take the 'now' into account. Of course, it is not to be expected that its laws or theories will refer to the 'now', any more than they would refer to 'here'.[36] As many authors have pointed out, these are indexicals, specific to particular places and times, and as such have no place in laws. But application is a different matter. To see this, consider the cosmological now noted above. This still involves an indexical sense of 'now'. But it

[36] Dennis Dieks makes a similar point in his (1988, 459-460).

makes a great deal of difference with respect to available observational evidence whether it is supposed that the Big Bang occurred 14 billion years ago or 26 bya. (A billion years ago—meaning a billion years before *now*—is an accepted unit used by astronomers, abbreviated 'bya'.)[37] For the superclusters we can see (or infer) to have existed earlier than now ('now' in this cosmic sense) may have taken longer than 14 billion years to have evolved, as has been charged by some critics of the Big Bang Theory. Thus the relativity of the 'now' to certain events, such as humans having theories, does not detract from its objectivity.

Third, on this view events come to be in the present in a quite specific sense: if one extended event *b* lies in the present of another *a*, then *b* comes about during the proper time of the event *a*. Such a notion is neither symmetric (even though a part of *a* will lie in *b*'s present) nor transitive. So there is no question of this construal supporting the notion of the present as an equivalence class of events separating the past from the future.

Finally, I have said nothing above about one of the crucial issues that has motivated all recent debate about the reality of becoming in the Special Theory of Relativity: namely, its compatibility with the essential indeterminism of Quantum Theory. The particular form of incompatibility alleged by Nicholas Maxwell (1985) and criticized by Dieks (1988) and Stein (1991), depends on the relative present view I have criticized above. However, Mauro Dorato (1996) has argued that even the type of worldline dependent becoming I have defended here is incompatible with a realistic picture of the collapse of the wavefunction on a spacelike hyperplane. Echoing the closing remarks of Clifton and Hogarth (1995), who elaborate in great technical detail an account of becoming along worldlines based on Stein (1968) (cf. also Arthur (1982) and Dieks (1988)), Dorato suggests this is may be too high a

[37] In his (1995, 71-77, 283) Paul Davies subscribes (with some misgivings) to the "block universe view", claiming (258) that "physicists can find nothing of this [i.e. no 'now', "no privileged present"] in the objective world". Ironically, each of his diagrams of expanding universes on pp. 133 and 154 has an ineliminable 'now' clearly marked on it.

price to pay for the reality of becoming. Wayne Myrvold (2003) has recently argued that this allegation of incompatibility is misplaced, and has suggested that the Steinian notion can be extended to spacelike slices of extended objects. Should his defence be rejected, however, I still see two possibilities for upholding the reality of becoming in quantum theory. One is to deny that wavefunction collapse is an event or process, and there are perhaps several ways of doing this; the other is that of Kent Peacock, who accepts that collapse is a real causal process because information is exchanged, but abandons the idea that it must occur on a hyperplane, and proposes instead that it occurs on a hypersurface of equal phase.

To conclude: I have argued that the block universe view founders on a kind of equivocation about the "reality" of events: although we represent events and their spatiotemporal relations as real, this does not license an inference to their "already" existing, or indeed to the existence of the spacetime manifold of events at any time. I argued that the relativized present view, like Gödel's denial of objective time lapse, is vitiated by a misconception of the status of the time co-ordinate function in relativistic physics, and that becoming in Minkowski spacetime must be construed as taking place along worldlines and at a rate measured by the proper time of the object traversing the worldline. I examined the punctual present view, which results from insisting that only point events that have become for each other are real, and found that taken literally it is susceptible to paradox, and in any case runs counter to our normal intuitions of the present. Finally, I elaborated a view of the present that avoids these problems, construing it as relative to an extended event or segment of a worldline, usually of short duration. The present in Minkowski spacetime is neither null (0-D) nor punctual (1-D) nor hyperplanar (3-D), but is a finite four dimensional region contained within the two hypercones centered on that segment.

References

Aristotle (1996), *Physics*, tr. Robin Waterfield. Oxford/New York: Oxford University Press.

Arthur, Richard T. W. (1982), "Exacting a Philosophy of Becoming from Modern Physics," *Pacific Philosophical Quarterly* 63, 2, pp. 101-110, April.

Arthur, Richard T. W. (ed.) (2001), *G. W. Leibniz: Labyrinth of the Continuum* (New Haven: Yale University Press).

Arthur, Richard T. W. (2003), "The Degeneracy of Time: Proper Time and Becoming in Einstein-Minkowski Spacetime." Pre-print.

Broad, Charlie Dunbar (1938), *Examination of McTaggart's Philosophy* (2 vols.). Cambridge: Cambridge University Press.

Bunge, Mario (1967-68), "Physical Time: the Objective and Relational Theory", *Philosophy of Science* **34**, 355-388.

Capek, Milic (1966), "Time in Relativity Theory: Arguments for a Philosophy of Becoming," pp. 434-454 in J. T. Fraser, ed., *Voices of Time*, (New York: Brazilier, 1966).

Capek, Milic (1975), "Relativity and the Status of Becoming," *Foundations of Physics* **5**, 4, 607-617.

Clifton, Rob, and Hogarth, Mark (1995), "The Definability of Objective Becoming in Minkowski Spacetime", *Synthese* **103**: 355-387.

Dainton, Barry (2001), *Time and Space*. Montreal & Kingston/Ithaca: McGill-Queens University Press.

Davies, Paul (1995), *About Time*. New York: Touchstone.

Dieks, D. (1988), "Discussion: Special Relativity and the Flow of Time", *Philosophy of Science* **55**: 456-460.

Dieks, D. (2006), "Becoming, Relativity and Locality," this volume, pp. 155-176?

Dobbs, H. A. C. (1951), "The Relation between the Time of Psychology and the Time of Physics," *British Journal for the Philosophy of Science* **2**, 1951, 122-137; **7**, 1951, 177-190.

Dorato, Mauro (1996), "On Becoming, Relativity and Nonseparability," *Philosophy of Science* **63**, 4, 585-604.

Eddington, Arthur Stanley (1946) *Fundamental Theory*. Cambridge: Cambridge University Press.

Fitzgerald, Paul (1969), "The Truth About Tomorrow's Sea Fight," *Journal of Philosophy* **66**, 11, June 5.

Geduld, Harry M., ed., (1987),*The Definitive Time Machine: A Critical Edition of H. G. Wells's Scientific Romance*. Bloomington: Indiana University Press.

Gödel, Kurt (1949), "A Remark about the Relationship between Relativity Theory and Idealistic Philosophy", 557-562 in *Albert Einstein: Philosopher-Scientist*, ed. P. A. Schilpp. New York: Tudor.

Grünbaum, Adolf (1971), "The Meaning of Time," pp. 195-230 in *Basic Issues in the Philosophy of Time*, ed. Eugene Freeman and Wilfrid Sellars. LaSalle: Open Court.

Hawking, S. W. and Ellis, G. F. R. (1973), *The large scale structure of space-time*. Cambridge: Cambridge University Press.

Hinton, Charles H. (1884-85), *Scientific Romances*. London: Swan Sonnenschein & Co.

Maxwell, Nicholas (1985), "Are Probabilism and Special Relativity Incompatible?" *Philosophy of Science* **52**: 23-43.

McCall, Storrs (1976),"Objective Time Flow," *Philosophy of Science* **43**, 337-362.

McCall, Storrs (1995), "Time flow, non-locality and measurement in quantum mechanics," 155-172 in Savitt (1995).

McCall, Storrs (2006),"Philosophical Consequences of the Twin Paradox", this volume, pp. 193-206.

McTaggart, J. M. E. (1908), "The Unreality of Time," *Mind* **17**, 457-474; quoted from the reprinted version in Westphal and Levenson (1993, 94-111). It was later reworked by McTaggart into Chapter 33, 'Time', of his *The Nature of Existence*, **2** (Cambridge: Cambridge University Press, 1927).

Myrvold, Wayne (2003), "Relativistic Quantum Becoming," *British Journal for the Philosophy of Science* **54**, September, 475-500.

Newcomb, Simon (1894), "Modern Mathematical Thought", *Nature* **49**, February 1.

Newcomb, Simon (1898), "The Philosophy of Hyper-Space", *Science* **7**, 1-7.

Nerlich, Graham (1994), *What spacetime explains: Metaphysical essays on space and time*, Cambridge: Cambridge University Press.

Peacock, Kent (1992a), "A New Look at Simultaneity", in *Philosophy of Science Association 1992,* Volume I, D. Hull, M. Forbes, and K. Okruhlik (eds.). East Lansing: Philosophy of Science Association, pp. 542-552.

Peacock, Kent (2006), "Temporal Presentness and the Dynamics of Spacetime," this volume, pp. 251-266?

Putnam, Hilary (1967), "Time and Physical Geometry", *Journal of Philosophy* **64**, 8, April 27, 240-247.

Rietdijk, C. W. (1966). "A Rigorous Proof of Determinism Derived from the Special Theory of Relativity," *Philosophy of Science*, XXXIII, 4 (December), 341-344.

Robb, Alfred Arthur (1911), *Optical Geometry of Motion*. Cambridge: Cambridge University Press.

Robb, Alfred Arthur (1914), *A Theory of Time and Space*. Cambridge: Cambridge University Press.

Robb, Alfred Arthur (1921), *Absolute Relations of Time and Space*. Cambridge: Cambridge University Press

Robb, Alfred Arthur (1936), *Geometry of Time and Space*. Cambridge: Cambridge University Press.

Russell, Bertrand (1915), "On the Experience of Time", *The Monist*, **25**.

Russell, Bertrand (1929), *Mysticism and Logic*. New York, W. W. Norton.

Russell, Bertrand (1948), *Human Knowledge: Its Scope and Limits*. London: Allen and Unwin.

Savitt, Steven ed., (1995), *Time's Arrows Today*. Cambridge: Cambridge University Press.

Savitt, Steven (2002), "Absolute Becoming and the Myth of Passage", pp. 153-167 in Craig Callender, ed., *Time, Reality and Experience*. Cambridge: Cambridge University Press..

Savitt, Steven (2005), "Presentism and Eternalism in Perspective", prepublished draft, available at http://philsci-archive.pitt.edu/achive/00001788.

Smart, J. J. C. (1964), *Problems of Space and Time.* New York: Macmillan.

Smart, J. J. C. (1968), *Between science and philosophy*. New York: Random House.

Stein, Howard (1968), "On Einstein-Minkowski Space-Time", *The Journal of Philosophy* **65**: 5-23.

Stein, Howard (1991), "On Relativity Theory and Openness of the Future", *Philosophy of Science* **58**: 147-167.

Wells, H. G. (1895), *The Time Machine*; in Geduld 1987.

Westphal, Jonathan and Carl Levenson eds. (1993), *Time*. Indianapolis: Hackett, 1993.

Weyl, Hermann (1949) *Philosophy of Mathematics and Natural Science*. Princeton: Princeton University Press.

Whitehead, Alfred North, (1925). *Science and the Modern World*. New York: Macmillan.

Williams, Donald C. (1951), "The Myth of Passage", *Journal of Philosophy* **48,** 464; reprinted as pp. 131-147 in (Westphal and Levenson, 1993).

Winnie, John (1977), "The Causal Theory of Spacetime", 134-205 in *Foundations of Space-Time Theories*. John Earman, Clark Glymour and John Stachel (eds.) Minneapolis: Minnesota University Press.