Published in *The Monist* 83 (July 2000): 321–340

Persistence and Space-Time: Philosophical Lessons of the Pole and Barn

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Abstract

Although considerations based on contemporary space-time theories, such as special and general relativity, seem highly relevant to the debate about persistence, their significance has not been duly appreciated. My goal in the paper is twofold: (1) to reformulate the rival positions in the debate (i.e., endurantism (three-dimensionalism) and perdurantism (four-dimensionalism, the doctrine of temporal parts)) in the framework of special relativistic space-time; and (2) to argue that, when so reformulated, perdurantism exhibits explanatory advantages over endurantism. The argument builds on the fact that four-dimensional entities extended in space as well as time are relativistically invariant in a way three-dimensional entities are not.

1. Introduction

Persistence over time has become an industry in contemporary metaphysics. Two major rival theories of persistence are widely known as three-dimensionalism (3D), or endurantism, and four-dimensionalism (4D), or perdurantism. According to the former, a physical object is wholly present at all times at which it exists. Persistence, on this view, is a matter of strict transtemporal identity: it is literally one and the same 3D entity that is wholly present at a certain place at $\underline{t}_1$, at a possibly (but not necessarily) distinct place at $\underline{t}_2$, and so on. The opposite theory takes persistence to be a matter of having temporal parts, no part being wholly present at more than one time and one place. Instead of literal identity over time, one has to speak of the relation *being a temporal part of the same 4D entity as*. The perdurantist ontology features four-dimensional objects extended in time as well as space.

These categorizations are, to be sure, rough and broad. Much effort has gone recently into distinguishing various senses of three- and four-dimensionalism and the precise analysis of such notions as "temporal part" and "being wholly present at $\underline{t}$."[1] In this paper, I would like to take a somewhat more external approach to the issue by exploring its connections with the framework of space-time theories.

2. Persistence and Space-Time

This framework has proven very useful in delineating the range of implications contemporary physical theories, such as special and general relativity, have for the philosophy of time. Their significance for the issue of persistence, however, has not, in my mind, been duly appreciated. It seems natural to think that the revolutionary transformation in our views of space and time associated with the theory of relativity should be highly relevant to the 3D/4D debate. But relativistic considerations very seldom figure in it.[2] And when they do, their import is often unclear. For example, one sometimes hears that since endurantism entails presentism, the view that only the present exists, and special relativity entails its denial (because it denies the notion of the absolute present), endurantism is inconsistent with relativity. But it has been argued—convincingly, I believe—that the combination of endurantism with eternalism (roughly, the view that past, present, and future events all exist as parts of the four-dimensional space-time manifold) is perfectly viable (see, in this connection, van Inwagen 1990, Rea 1998, and Sider, forthcoming). A related point concerns the language of four-dimensional space-time diagrams widely employed in special relativity. Having appreciated the elegance of this language and, in particular, the idea of representing physical objects by world-lines or world-volumes, one is easily tempted to simply identify objects with their world-lines (world-volumes). Such an identification would prejudge the issue between endurantism and perdurantism in a rather naïve way. There is an unproblematic sense in which an enduring object can occupy a four-dimensional volume in space-time without being itself four-dimensional. Again, one can be a realist about the entire space-time framework of events[3] and deny the objective distinction among the past, present, and future and yet adhere to the endurantist ontology. The 3D/4D dilemma is different from the more traditional disputed topics in the philosophy of time. Finally, there is nothing specifically relativistic about the "eternalist" four-dimensional setting of space-time diagrams. Any physical theory—for example, classical mechanics—can be formulated in such a setting. Where special relativity differs from it is in the different intrinsic geometrical structure it imposes on the space-time manifold. The concept of such a structure is central to understanding relativity as a theory about the geometry of space-time.

Thus the language of space-time theories is neutral with respect to the endurantism versus perdurantism controversy. If there is a connection between relativity and the debate about persistence, it is by no means a straightforward one. My strategy in the paper is as follows. I show in Section 4 that the rival positions in the 3D/4D debate can, with minimal effort, be reformulated in the relativistic context. The primary goal of this exercise is to demonstrate that endurantism is by no means a non-starter in that context. But in the end, it doesn't fare well. In Section 5, I argue that perdurantism, but not endurantism, has explanatory resources to account for certain patterns of exemplification of properties by extended material objects. To illustrate this pattern in a particularly vivid way, I resort, in Section 6, to one of the famous "paradoxes" of special relativity.

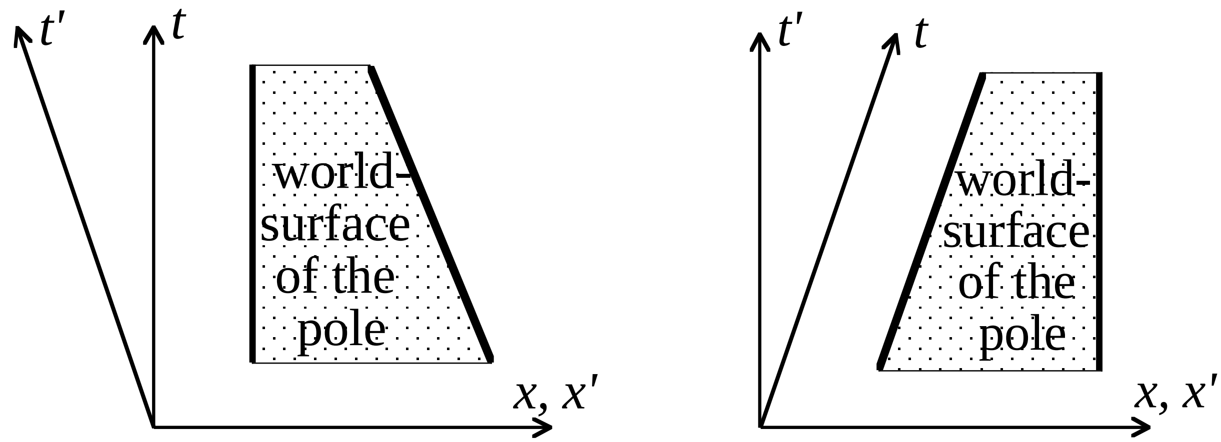
In a nutshell, my argument rests on the fact that four-dimensional entities extended in time as well as space are relativistically invariant in a way three-dimensional enduring entities are not. And invariance has become a touchstone of reality in modern physics. At least two authors, Quine (1960, pp. 172, 253ff; 1987) and Smart (1972), deserve credit for sketching the beginnings of such an argument.

The argument is geared to a particular species of four-dimensionalism sometimes referred to as the "worm theory" and probably won't carry much weight in the context of another variety of 4D known as the "stage theory" (see Sider, forthcoming, especially §5.7). The difference between the two theories boils down to the question of what entities, the four-dimensional wholes or their three-dimensional parts, to take as ontologically basic. On the worm view I favor, every perduring physical object occupies a definite 4D volume in space-time, much as any enduring object occupies, on the endurantist view, a definite 3D volume of space at a given time. The facts about the occupation of 4D volumes by perduring objects are fundamental and irreducible to the facts about the mereological relations between four-dimensional wholes and their three-dimensional parts. Put another way, 4D volumes in space-time occupied by perduring objects come first and their 3D slices second. What reasons does the four-dimensionalist (such as myself) have to accept the ontological priority of 4D wholes with well-defined boundaries over their 3D parts? The reasons are similar to those that many three-dimensionalists have in mind in speaking of the existence of 3D wholes at different moments of time. If there is such a thing as a 3D enduring pole occupying a definite volume of space at t, then there is such a thing as the 4D perduring pole occupying a definite volume of space-time. Here I put aside the question of what, if anything, can ground both sorts of facts. Perhaps certain metaphysical principles of unity are at work in both cases (cf. Heller 1993, 49ff). I also abstract from the issue of vagueness.[4] This, of course, pushes important problems to the background, problems that should be addressed in a more comprehensive study. I should note, at the same time, that part of my motivation to favor the worm theory over the stage theory is that the latter appears to commit one to the temporal analog of the counterpart theory (see Sider, forthcoming, §5.7). Another incentive is, of course, that, if my arguments below hold up, then special relativity gives the worm theory, but not the stage theory, an edge vis-à-via endurantism.

Contemporary discussions of persistence involve, almost exclusively, pre-relativistic notions, such as "moment of time," "being wholly present at *t*," "temporal part," and the like. These notions are assumed to be unproblematic and have a certain intuitive image going along with them. In the case of endurantism, one could envisage the totality of material objects somehow "moving" through time or, alternatively, one could imagine the "river of time" whose "waves" somehow "surge" toward the objects changing their momentary states from being future to being present and then past. In the case of perdurantism, one typically imagines an object that is "stretched out" in the temporal dimension and can be "sliced" into temporal parts. Both images apparently involve: (1) conceiving the world of objects as having spatial characteristics (such as extension or shape) in abstraction from time and, then, (2) *adding* time to the picture. But this conception: beginning with space and then adding time, is not as gratuitous as it might seem, even in the classical (that is, pre-relativistic) setting. To see what exactly is at stake here, it will be convenient to start by recapitulating the rival views of persistence in the classical space-time framework, Galilean space-time.[5]

3. Enduring and Perduring Objects in Galilean Space-Time

Let us imagine a 10-meter long pole that contracts to 5 meters. The space-time diagram in Figure 1a features the 2D world-surface of the pole (we neglect two spatial dimensions) in a reference frame in which its left end is at rest. The diagram in Figure 1b represents the situation in another reference frame, the rest frame of the right end.



(a) (b)

Figure 1. A contracting pole in two inertial reference frames. For convenience, both pairs of coordinate axes, ($\underline{x}$,$\underline{t}$) and ($\underline{x}'$,$\underline{t}'$), are included in both diagrams.

Which diagram reflects the way things really are? According to the Galilean principle of relativity, both do it equally well. There is simply no fact of the matter, in Galilean space-time, as to which end of the pole is at rest. Diagrams 1a and 1b provide apparently conflicting perspectival representations of the same state of affairs in reference frames ($\underline{x}$,$\underline{t}$) and ($\underline{x}'$,$\underline{t}'$). But if we are interested in the objective state of affairs standing itself behind both representations, we need to make an intellectual effort and "ignore the verticality"[6] of certain world-lines in Figures 1a and 1b. In fact, we need to *identify* the two diagrams, and one way of doing it is to attend to the invariant (that is, frame-independent) features of Galilean space-time itself.

These features include a unique family of parallel time 3-planes[7] common to all reference frames and an infinite set of straight lines intersecting time 3-planes at all non-zero angles. Such lines represent positions "across time" in various (inertial) reference frames. Since no frame is objectively privileged, what counts as the same position in space at different times, in the Galilean framework, is perspective-dependent and not part of the objective space-time structure. On the other hand, what counts as the same moment of time at different places is not so dependent: the structure of time 3-planes is common to all frame-restricted perspectives. To make this more intuitive, let us follow Geroch (1978, 42ff) and introduce a graphic model of switching between different perspectives. We shall imagine that space-time is composed of a densely packed deck of cards representing time 3-planes. The deck is pierced by straight "wires" representing positions across time in different frames of reference or, alternatively, world-lines of inertial objects. The transformation whereby one goes from one perspective, such as that of Figure 1a, to another (Figure 1b) could then be effected by uniformly "beveling the deck."[8] Various such transformations induce various perspectives on a common geometrical structure. This common structure is none other than Galilean space-time. Intrinsically, it only has those elements that survive under all arbitrary "beleving-the-deck" transformation.

Thus diagrams 1a and 1b should be regarded as frame-dependent, or perspective-restricted, representations of the same state of affairs—representations related by a "beveling-the-deck" Galilean transformation. In order to get to the state of affairs itself standing behind both representations, we need to nullify the significance of spatial coordinates attaching to different parts of the pole's world-surface in the two diagrams. The resulting structural features are shown in Figure 2. These features include the "slicing" of the world-surface of the pole by the invariant family of time planes and the lengths of the slices on each such plane.

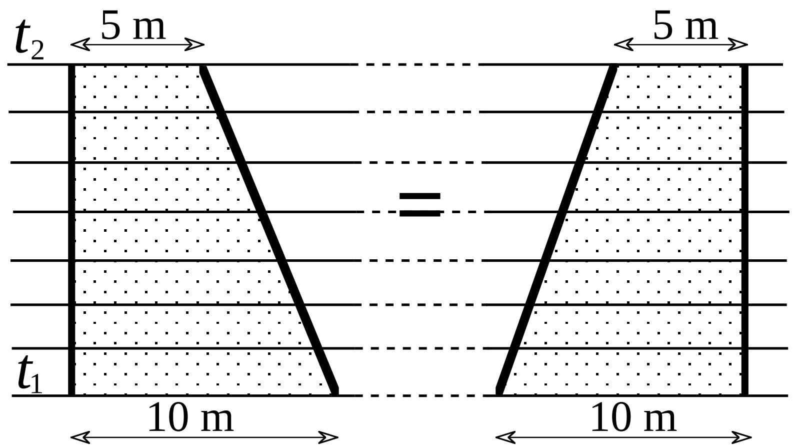


Figure 2. The contracting pole in Galilean space-time.

Every time plane in Figure 2 hosts a determinate intrinsic property: the length possessed by the pole at the time in question. The next step is to provide an analysis of this interaction between time and predication. The endurantist and the perdurantist discharge this task in different ways. Let us start with the perdurantist analysis.

On the perdurantism view, the pole is a four-dimensional entity having extension both in space and time. It persists by having momentary temporal parts wholly confined to their respective time planes. When we say that the pole $\underline{p}$ is long at $\underline{t}_1$ and short at $\underline{t}_2$, what we really mean is that the pole has, among its temporal parts, the $\underline{t}_1$-part, $\underline{p}_{t_1}$ and the $\underline{t}_2$ part, $\underline{p}_{t_2}$, the former being long and the latter short: $\underline{Lp}_{t_1}$ & $\underline{Sp}_{t_2}$.

The sense in which the properties of the pole's parts can be attributed to the 4D whole is, in many ways, similar to the sense in which the properties of the spatial parts of an extended object are sometimes attributed to the whole. When we say that the road is wide and smooth in town and narrow and bumpy elsewhere, we really mean that the road has, among its spatial parts, the town part, which is wide and smooth, and the elsewhere part, which is narrow and bumpy. Just as the road (and entire thing) changes from being wide and smooth to being narrow and bumpy, the pole (the entire perduring object) changes from being long to being short.

On the endurantism view, the pole is a three-dimensional being extended in space but not in time. It is wholly present at all time planes with which its world-surface intersects and any such intersection features the full set of properties the pole has at a corresponding time, including its spatial configuration, or length. Some of these properties are apparently incompatible, such as being long (10 meters) and being short (5 meters). How can literally one and the same object, the pole, exhibit incompatible properties? It can do so because the exemplification of such properties involves time. But how exactly?

Two somewhat distinct property exemplification schemes have been proposed to deal with the situation.[9] One is often referred to as *Indexicalism*. In difference from the perdurantist schema: Lp_{t_1} & Sp_{t_2}, involving the names of two temporal parts of a four-dimensional object, p_{t_1} and p_{t_2}, the indexicalist approach makes time modify, not the subjects, but the predicates of such expressions: $L_{t_1}p$ & $S_{t_2}p$. The properties such predicates denote are *time-indexed* properties *long-at-*t_1 and *short-at-*t_2. Unlike simple properties *long* and *short*, their time-indexed counterparts are clearly compatible and can be exemplified by a single enduring 3D object.

A close relative of Indexicalism is *Adverbialism*. In the adverbialist predication scheme, time does not enter into the subject or the predicate; rather, it becomes a structural part of the *copula* of the subject-predicate expressions: *p* is$_{t_1}$ long & *p* is$_{t_2}$ short. To put it differently, time modifies, not the properties themselves, but the *having* of them. The pole has both the property of being long and the property of being short, but the first one is had t_1-ly and the second t_2-ly.

Both Indexicalism and Adverbialism imply an interesting sense in which a 3D enduring object, such as a pole, can occupy a 4D space-time volume. What occupies such a volume is a mereological sum of what occupies all its 3D time cross sections, and what occupies such cross sections is the same 3D object, the pole. Thus both the perdurantist and the endurantist are entitled to say that a single object fills up a 4D region of space-time. The difference, of course, is that the perdurantist will insist that the object does so in virtue of being a 4D entity having extension both in space and time, whereas the endurantist will deny that the object itself is a 4D entity.

Some authors find the indexicalist and adverbialist analyses of property predication problematic. One oft-cited reason for discontent is that such analyses privilege time-indexed properties or time-restricted ways of having property over simple and natural properties (see, e.g., Lewis 1986, 204 and 1988, Merricks 1994, 1999). Other authors (e.g., Johnston 1988, Haslanger 1989) find this concern primarily epistemological and even question begging. But quite apart from this disagreement, one should realize that the endurantist wishing to adjust her view to the four-dimensional context is hard-pressed to accept Indexicalism or Adverbialism, to account for exemplification of incompatible properties by an enduring object. To avoid ascribing a pair of such properties to the same entity, one is forced to "temporalize" one of the terms of a subject-predicate expression. Temporalizing the subject leads directly to perdurantism; temporalizing the predicate or the copula, on the other hand, keeps endurantism running.[10]

The upshot of the above considerations is that one can be a realist about the 4D space-time manifold and yet retain the endurantist ontology in the classical (i.e., pre-relativistic) context. At the same time, it should be clear by now that the right of the endurantist to temporalize properties or the having of them—just like the right of the perdurantist to temporalize the subject of predication—is by no means gratuitous or automatic. It is grounded in the fact that classical space-time preserves the invariant family of time 3-planes and, hence, the time parameter is still available to track predication (in the endurantist or perdurantist way) and recover, among other things, the familiar pattern of change as instantiation of different properties at different times. Recall that, in Galilean space-time, what counts as the same position in space at different times is dependent on perspective and, hence, is not part of the objective space-time reality, but what counts as the same moment of time at different places is not so dependent and thus retains an objective status.

If the Galilean view embodied the right theory of space-time, predicating properties of persisting material objects would be a relatively simple and convenient matter. But Nature does not care about the convenience for us of certain predication schemes. The Galilean framework is physically inadequate and has to give way to the relativistic one. To see how this transition affects the 3D versus 4D issue, let us first get a handle on the intrinsic structure of special relativistic space-time.

4. Enduring and Perduring Objects in Special Relativistic Space-Time

Consider the 4D world-volume (the 2D world-surface, in the idealized case with two spatial dimensions suppressed) of a 10-meter pole in special relativistic space-time (Figure 3). In the rest frame of the pole (x',t'), its length (called *proper* length) is 10 meters. In the reference frame (x,t) uniformly moving in the direction of the pole, however, this length is Lorentz-contracted to 5 meters. This effect is purely relativistic in nature and has nothing to do with the mechanical contraction bodies may undergo under pressure. Lorentz contraction is a space-time, not a dynamic phenomenon. One way to explain it is to focus on what is involved in attributing length to an extended object, such as our pole, in a given perspective, or reference frame. Clearly, it involves taking the difference of the pole's ends' coordinates in that frame. These coordinates must obviously refer to the *same* time. Put another way, the events of taking the measurements of these coordinates must be *simultaneous* and, hence, belong to the same time plane in the reference frame under consideration. Geometrically, the sought-for length is just the length of the intersection of the world-surface of the pole with a time plane in frame (x,t). Not surprisingly, it turns out to be different from the proper length of the pole.[11] One can see the relativity of simultaneity at play in fixing the reference of the frame-dependent notion of length.

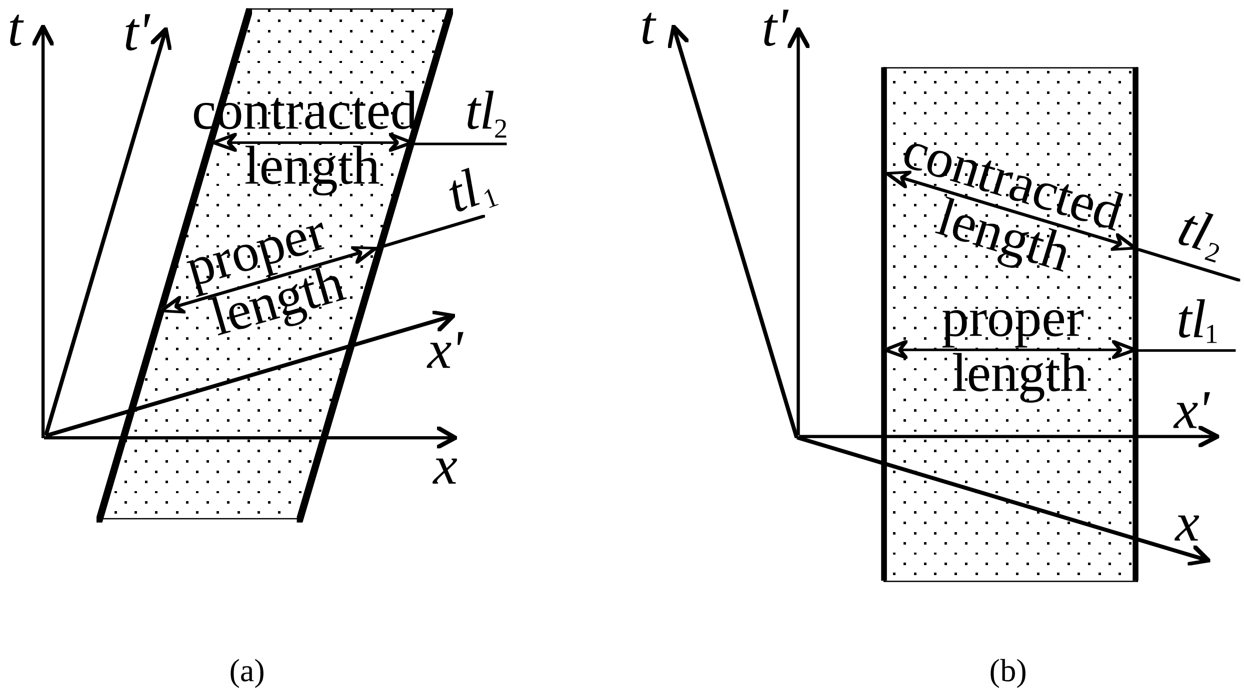


Figure 3. Lorentz contraction in special relativistic space-time. (a) and (b) represent the same state of affairs. For convenience, both pairs of coordinate axes, that is (*x*,*t*) and (*x*′,*t*′), are included in both diagrams. The lengths of the pole in the two frames are not drawn to scale.

Just as the structure of Galilean space-time was flexible up to arbitrary "beleving-the-deck" transformation, the structure of special relativistic, or Minkowski, space-time is flexible up to arbitrary "folding-unfolding" transformations affecting both space and time.[12] Only those features that survive under all such transformations are intrinsic to space-time and reflect the "way things really are." One should note, in this regard, that Figures 3a and 3b represent the same state of affairs in Minkowski space-time.

What implications does the transition from the Galilean to relativistic framework have for the issue of persistence? It is clear that, at the minimum, the whole issue needs to be reformulated. The very language in which it is framed in the classical context becomes inadequate after the transition at hand. In view of relativity of simultaneity, there is no objective—that is, perspective-independent—notion of *being at the same time* that would cut across space, in the relativistic context, just as there was no objective notion of the sameness of position across time in the classical context. Time and space now become genuinely “mixed”: what counts as a purely spatial dimension in one perspective “takes up” time in another perspective and vice versa. Relativistic space-time cannot be uniquely foliated into a family of time 3-planes (see Figure 4). Thus the central concepts of the endurantist and perdurantist.

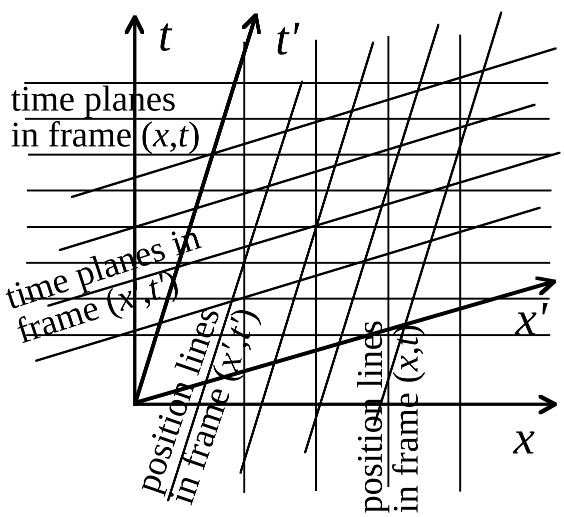


Figure 4. Position lines and time planes in two reference frames. Time in (*x′*,*t′*) “takes up” space in (*x*,*t*), and vice versa.

ontologies, such as “temporal part” and “being wholly present at a time,” lose their objective meaning and become relativized to a reference frame, or perspective. To ascribe properties to spatially extended objects or their parts, one now has to keep track, not only of time, but also of a frame to which that time refers.

To make the matter more precise, let us return to our 10-meter pole and ask how the perdurantist should properly speak about exemplification of properties by this object in the relativistic context. The pole, on the perdurantism view, is a 4D entity occupying a certain volume in Minkowski space-time. It has various 3D parts that may have different properties, such as being long or short. These parts, however, can no longer be indexed by times and, hence, cannot properly be called *temporal* parts. I suggest that we call them *time-like* parts. The reason for this designation is as follows. Each time-like part of a perduring object belongs to a certain 3-plane of simultaneity in a given reference frame, which is orthogonal (in the sense of orthogonality pertinent to Minkowski space-time) to the time axis in that frame. In this respect, a time-like part is a direct descendant of the classical temporal part: the former becomes *like* the latter when we restrict our attention to a particular frame.

If one wants to be formal, one can think of a time-like part as individuated by a complex index '$\underline{tl}$' that tracks two parameters, a frame $(\underline{x},\underline{t})$ and a time in that frame $\underline{t}$: $\underline{tl} = <(\underline{x},\underline{t}),\underline{t}>$. Thus the time-like part $\underline{p}_{tl_1}$ of the pole is a 3D part corresponding to its rest frame $(\underline{x}',\underline{t}')$ and a certain time in that frame (Figure 3). This part has a length of 10 meters. Let us say, for simplicity, that this part is long: $\underline{Lp}_{tl_1}$. Similarly, the time-like part $\underline{p}_{tl_2}$ of the pole corresponding to the frame $(\underline{x},\underline{t})$, in which the pole is moving parallel to $\underline{x}$ with velocity $\underline{v} \approx 2.6 \times 10^8$ m/sec, and a certain time in that frame, is short: because of Lorentz contraction, its length is 5 meters: $\underline{Sp}_{tl_2}$.

There is, of course, nothing problematic in attributing incompatible properties, such as being long and being short, to different 3D spatial objects: time-like parts of a 4D perduring entity. In fact, we can usefully extend a spatial analogy suggested earlier. A roadway is 5 meters wide in the north-south direction and 10 meters wide in the northwest-southeast direction (Figure 5).

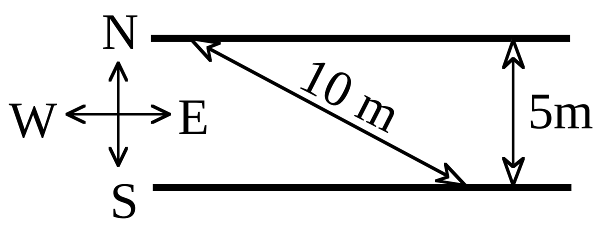


Figure 5.

Turning now to the endurantism view, one can adjust the predication schemes of Indexicalism and Adverbialism to the relativistic context by replacing temporal modifiers by more complex time-like modifiers. The endurantist would maintain that the pole is a 3D enduring entity having different time-like-indexed lengths: $\underline{L_{lt_1}p}$ & $\underline{S_{lt_2}p}$, or having length in different time-like ways: $\underline{p}$ is$_{\underline{lt}_1}$ $\underline{L}$ & $\underline{p}$ is$_{\underline{lt}_2}$ $\underline{S}$. Unlike simple properties, their time-like-indexed counterparts, or time-like ways of having a property, are always compatible with each other and can be attributed to literally one and the same 3D enduring object.

Furthermore, the sense in which a 3D enduring objects occupies a 4D volume of space-time remains valid in the relativistic setting. Once again, what occupies such a volume is a mereological sum of a class of objects that individually occupy its time-like slices, and all of the latter are occupied by one and the same 3D enduring entity. Of course, such an entity occupies a 4D region of space-time, not in virtue of being a 4D object, but rather in virtue of being wholly present at any of its time-like cross sections.

5. Explanatory Predicament

Thus both perdurantism and endurantism can with minimal effort be restated in the relativistic set-up. But this restatement suggests an ontological picture that is very different from the classical one. In the classical context, indexing parts of objects, their properties, or the having of a property by times could be done in a perspective-independent frame-invariant way. Having a part wholly confined to a time, for the perdurantist, just as exemplifying a definite time-indexed property, or exemplifying a property in a definite temporal way, for the endurantist, were objective matters of fact in classical space-time, thanks to the availability, in that space-time structure, of the notion of absolute time—or, speaking geometrically, of an invariant family of absolute time planes. This, in turn, made it possible to recover a familiar pattern of change as acquisition and loss of properties with time.

But what stands behind the relativistic pattern (Figure 3) of the *unchanging* pole's exemplifying different lengths in different time-like perspectives? Clearly, a good candidate to host such an objective matter of fact is the entire space-time region, the 4D world-volume of the pole, shown in the figure as the shaded area. It is the invariant 4D shape of this volume that generates the whole multitude of 3D shapes (or just lengths, in the idealized 2D case) of its time-like slices. It seems natural to view these slices as containing parts of a single object, the pole. The existence, in space-time, of a 4D region with well-defined boundaries—the world-volume of the pole—serves as a geometrical underpinning for a harmonious unity among the shapes of its 3D parts.

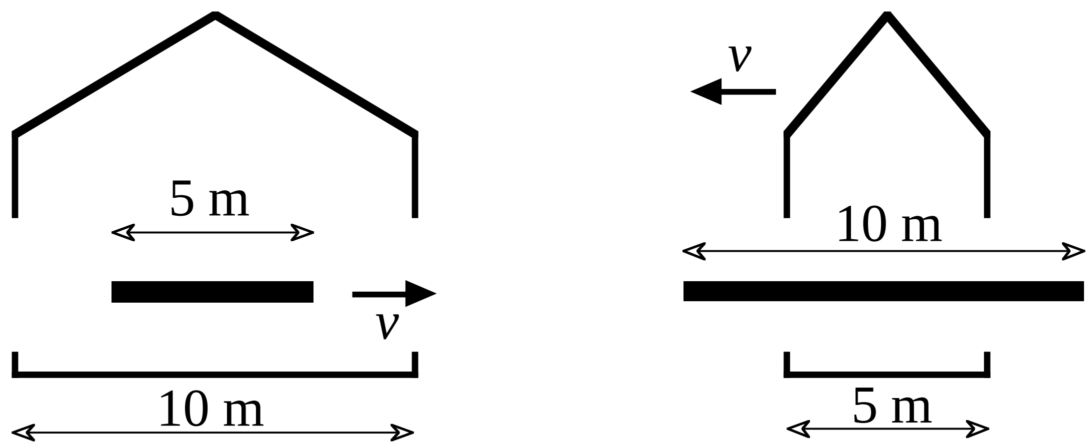
Thus the perdurantist has a natural way of explaining the unity displayed by the properties of the pole's space-time parts: such parts are "carved out" from a pre-existing ontological entity, the 4D perduring pole, occupying a definite space-time region. Hence the properties of its 3D parts are directly inherited from the properties of the 4D whole: the latter bear an ancestral relation to the former. The explanatory power of this account rests on the fact that four-dimensional space-time entities are relativistically invariant: they can objectively *stand behind* all their 3D parts, much in the way usual three-dimensional objects in space stand behind all their perspectival plane projections. A set of pictures of a house, say, taken from different vantage points display a considerable diversity of two-dimensional shapes. But behind this diversity stands the invariant three-dimensional shape of the house itself. Similarly, the pole displays a variety of lengths in different space-time perspectives. But behind this variety stands the invariant four-dimensional shape of the perduring whole.

Can the endurantism view match this explanatory power? Hardly so. The endurantist will say that the 4D region of space-time, the world-volume of the pole, is occupied by a 3D enduring object that manifests a variety of time-like-indexed shapes or manifests shape in a variety of time-like ways. All these 3D shapes taken together exhibit a remarkable unity: they can be lined up neatly in space-time to fill a nice 4D volume, without "corrugation" and "dents." How would the endurantist explain this unity among the 3D shapes? Her ontology is restricted to three-dimensional material entities. Therefore, unlike her perdurantist rival, she cannot start with a four-dimensional object and then "slice" it in various ways to produce a coherent family of 3D shapes of its parts. Rather, she has to start with “separate and loose” 3D shapes and then discover that they can arrange themselves into a “nice” 4D volume in space-time. But this arrangeability is precisely what needs to be explained. Whereas the perdurantist can ground the fact about a nice arrangeability of 3D-shaped space-time parts of an object in the four-dimensional nature of the object itself, the endurantist must regard a corresponding arrangeability of 3D perspectival shapes of a three-dimensional object as a brute fact.

My conclusion, then, is that endurantism does not fare as well as perdurantism when it comes to discharging certain explanatory tasks concerning the exemplification of properties by extended material objects. To illustrate the point in yet another way, let me briefly consider one of the famous “paradoxes” of special relativity.[13]

6. The Pole and Barn

Suppose our 10-meter pole moves at the speed $\underline{v} \approx 2.6 \times 10^8$ m/sec through the open doors of a 10-meter barn. Will the pole fit completely inside the barn? First, consider the situation from the point of view of the barn. In the barn rest frame, the pole is Lorentz-contracted to 5 meters and thus perfectly fits in (Figure 6a). In the pole rest frame, on the other hand, it is the barn that is Lorentz-contracted (and becomes only 5 meters wide). Consequently, both ends of the pole will protrude from the barn for a short time interval and the pole will never fit entirely inside the barn (Figure 6b). So will the pole fit inside or won’t it?



(a) (b)

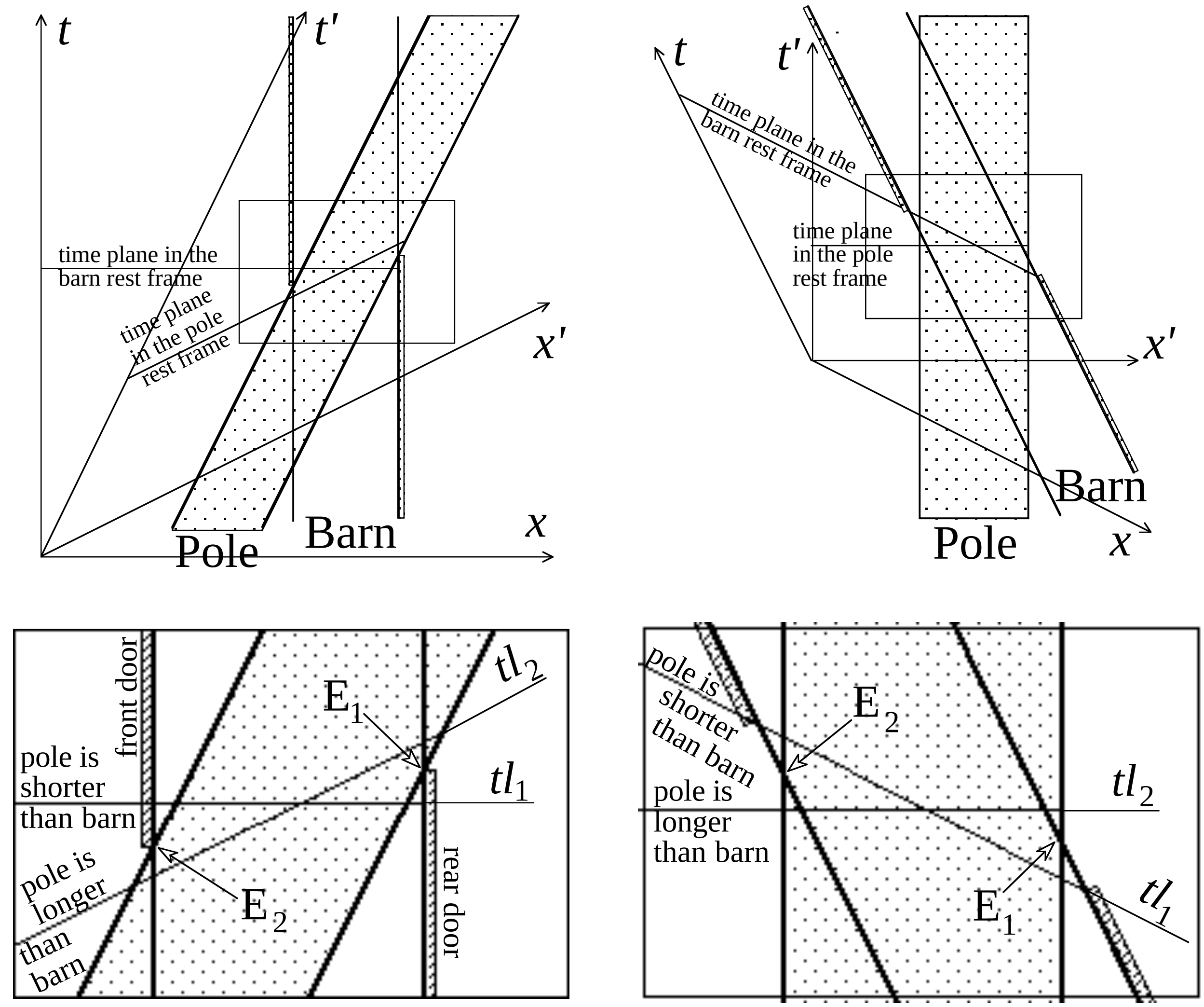
Figure 6. The Pole and Barn scenario: (a) in the barn's rest frame; (b) in the pole's rest frame.

To make the situation a bit more dramatic, suppose the rear door of the barn is initially shut and the front door open. As soon as the trailing end of the pole has cleared the front door, it gets shut. And when the forward end of the pole is about to collide with the rear door, it is opened thus letting the pole to pass through. From the barn point of view, at a certain point, the pole finds itself completely inside the barn, both doors shut. From the pole point of view, it is never completely inside but it also never collides with any door: for a short interval, the pole protrudes from both open doors of the barn.

The paradox is resolved by taking into account the relativity of the temporal order of two events: E_1, at which the forward end of the pole passes through the rear door (while the door opens immediately before), and E_2, at which the trailing end of the pole passes through the front door (and the door is shut immediately thereafter). In the rest frame of the barn ($\underline{x}, \underline{t}$), E_1 occurs *after* E_2 thus allowing the pole to be entirely inside the barn. In the pole frame ($\underline{x}'$,$\underline{t}'$), E_1 happens *before* E_2 thus allowing the pole to protrude from both ends of the barn (Figure 7).

So in the end, both parties are right: there is simply no fact of the matter as to what event happens first, and there is no conflict between two relative, perspective-restricted versions of the scenario. What implications does it have for the 3D versus 4D debate?

Both the endurantist and the perdurantist may be required to provide a metaphysical account of what goes on in the pole and barn scenario. The perdurantism story is rather straightforward. One should simply take the diagram in Figure 7 literally. It features two four-dimensional objects: the pole (occupying the shaded area) and the barn, and various relations among their spatio-temporal parts. Thus the $\underline{tl}_1$ part of the pole is shorter than the $\underline{tl}_1$ part of the barn, whereas the $\underline{tl}_2$ part of the pole is longer than the $\underline{tl}_2$ part of the barn. These seemingly contradictory relations hold, not because the objects change their length (the scenario involves no such change), but because the pole and barn are "viewed," in their mutual relationship, from different angles in space-time. But in order for them to be capable of being viewed in so different perspectival ways, both objects must be four-dimensional. Their invariant 4D configuration stands behind apparently conflicting frame-restricted 3D representations. Four-dimensionality is invoked to explain the conflict away.



(a) (b)

Figure 7. The pole is shorter than the barn in the barn rest frame (perspective $\underline{tl}_1$) and longer than it in the pole rest frame (perspective $\underline{tl}_2$). (a) and (b) represent the same state of affairs in relativistic space-time. The lengths of the pole and barn are not drawn to scale here.

To resort to the spatial analogy once again, consider two pictures of a rotunda and two trees (Figures 8a and 8b). Does the rotunda fit in between the trees or not?

(a) Figure 8. (b)

Speaking two-dimensionally, it both does and doesn’t. Figures 8a and 8b are 2D perspectival representations of the invariant 3D configuration depicted in Figure 9. Three-dimensionalism is invoked to explain such allegedly conflicting two-dimensional states of affairs.

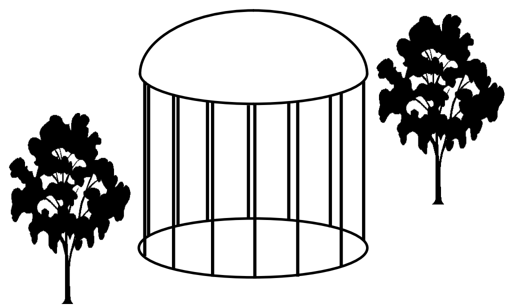


Figure 9.

The endurantist interpretation of the pole and barn situation confronts a similar task of reconciling two apparently incompatible states of affairs: (1) the pole is shorter than the barn: $\underline{pSb}$; and (2) the pole is longer than the barn: $\underline{pLb}$. The reconciliation requires “perspectivalizing” the relevant relations. This can be done by perspective-indexing either the relations themselves (Indexicalism): $\underline{pS_{tl_1}b}$ & $\underline{pL_{tl_2}b}$, or the having of them (Adverbialism): $\underline{p}$ is$_{\underline{tl}_1}$ shorter than $\underline{b}$ & $\underline{p}$ is$_{\underline{tl}_2}$ longer than $\underline{b}$). Besides these two perspectives tied up to the rest frames of the pole and the barn, there is an infinite number of others associated with frames in which neither the pole nor the barn are at rest. All such perspectives host further relational facts about the lengths of these objects. The endurantist must then set out to reduce the multitude of such three-dimensional perspective-restricted facts. But her possibilities are limited. Unlike her perdurantist counterpart, she cannot put a four-dimensional configuration of objects behind the facts to be reduced because 4D objects are absent from her ontology. She also cannot select any particular 3D perspective, or reference frame—say, the rest frame of one of the objects—for special treatment and grant it the status of reality, at the expense of others: since the pole and barn are in relative motion, no single frame is their common rest frame (and no other frame can be objectively privileged) (cf. Smart 1972, 63–64). Finally, she cannot resort to the physical facts about the occupation of space-time points and subregions by various spatial parts of enduring objects in different frames and at different moments of time in those frames: the peculiar combination of these multitudinous facts is precisely what needs to be explained and no fruitful explanation can be achieved just by restating the explanandum.[14] In the end, the endurantist must regard the infinite variety of perspectival relations as brute facts, with no unifying ground behind them.

7. Conclusion

To sum up, endurantism is at an explanatory disadvantage in relativistic space-time. Perdurantism fares better in it.

An important by-product of the above discussion should be specifically noted. If one is inclined to take the physics of space-time seriously, both positions on the issue of persistence need first be reformulated. It is no longer reasonable to assume that such notions as "temporal part" and "being wholly present at a time" are readily available in any space-time context. They are not gratuitous even in the classical framework, as they require the support by the relevant features of the intrinsic geometry of Galilean space-time. The further transition to special relativistic framework renders these notions altogether meaningless. They must give way to more complex constructs involving time-like perspectives. This may be somewhat inconvenient. But it is an inconvenience to be dealt with.[15]

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Endnotes

[1] See, in this regard, Heller 1993, Markosian 1994, Zimmerman 1996, Sider 1997 and forthcoming, Merricks 1999.

[2] See, however, Smart 1972, Rea 1998, Sider, forthcoming, Balashov 1999, 2000a, 2000b.

[3] The notion of a point event employed in space-time theories is a technical term that should be distinguished from a different notion of event used in the current metaphysical

literature. In my exposition, the context makes it clear what notion is being used on each particular occasion.

[4] This issue is thoroughly discussed in Sider, forthcoming, §4.9.

[5] My simplified account of Galilean and relativistic space-times largely follows Geroch 1978. For a rigorous treatment, the reader is advised to consult Friedman 1983 or Earman 1989.

[6] By the felicitous expression of Geroch (1978, 48).

[7] A time 3-plane is a three-dimensional hyperplane in the four-dimensional space-time.

[8] The reader will recognize the "beveling-the-deck" transformation as a disguised form of the Galilean coordinate transformation: $\underline{x} \to \underline{x}' = \underline{x} - \underline{vt}$; $\underline{t} \to \underline{t}'$.

[9] For a more comprehensive catalog of endurantist and perdurantist schemes for predicating temporal properties of objects, see Simons 1991.

[10] A more radical option not considered here is to endorse *presentism*, the view that only the present exist. If only the present properties are real, no contradiction arises from exemplification of incompatible properties by an enduring object at different times. See, in this connection, Merricks 1994, Hinchliff 1996, Zimmerman 1998. I am firmly of the opinion that presentism is not a live option, because the concept of the *absolute present* on which it hinges is ruled out by relativity (see, in this connection, Section 8 below). And the attempts to modify the notion of the present so as to make it relativistically invariant, that is, to ground it in the intrinsic geometry of Minkowski space-time, look quite hopeless (see Savitt 2000).

Rea 1998, especially Sections 2–3, offers a more extensive discussion of the endurantist options in the non-presentist ("eternalist") context and a defense of Adverbialism. Earlier champions of Adverbialism include Johnston (1987) and Haslanger (1989). van Inwagen (1990) mentions Adverbialism as one of the strategies the endurantist might pursue in the four-dimensional setting, without favoring it over Indexicalism.

[11] It turns out to be shorter that the latter, although it *looks* longer in Figure 3b. This is an unfortunate distortion pertaining to the necessity to represent non-Euclidean relations inherent to relativistic space-time in purely spatial Euclidean diagrams.

[12] Informally, switching between different frame-dependent representations, such as Figures 3a and 3b, is effected by "rotating" both the space and time axes by the same angle toward or away from the diagonal.

[13] The Pole and Barn paradox considered below figures prominently in relativity textbooks. My exposition owes much to Sartori 1996, Section 6.2.

[14] See Balashov 2000, Section 3, where this endurantist defense strategy in a similar context is discussed in detail.

[15] My thanks to three anonymous referees for their helpful comments. The work on the paper was supported by a junior faculty grant from the University of Georgia Research Foundation.