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A Chair for Minkowski. An exdurantist solution to the problem of relativistic change

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This paper addresses the problem of relativistic change. This problem originates from the fact that while we ordinarily conceive of objects as having relatively invariant shapes, relativity seems to imply that their shape may vary dramatically across different reference frames. While the problem was originally presented by Sattig as affecting perdurantism, we propose that it equally affects endurantism and argue that exdurantism is naturally immune from it.

Keywords: relativistic change; perdurantism; endurantism; exdurantism; special relativity; shape.

I. Introduction

More than a century after its introduction, we are still exploring the consequences of relativity theory for our picture of reality. Oftentimes, this exploration reveals a tension between the manifest image of everyday life and the scientific image delivered by relativity itself. This is also true in the case of the so-called *problem of relativistic change* (Sattig 2015), which is the focus of this paper.

The problem, in a nutshell, is that we ordinarily conceive of objects as having relatively invariant shapes, whereas relativity seems to imply that their shape may vary dramatically across frames. A now-famous example involves a chair which, under certain relativistic conditions, would appear to have the

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shape of an unextended point. But can a chair really take the shape of a point (Gilmore 2006; Balashov 2010, 2014; Sattig 2015)?

Somehow surprisingly, Sattig suggests that the best way to couple our ordinary conception of objects with relativity is to adopt a form of perdurantist hylomorphism.[1] In this paper, we argue that an equally effective solution can be found in exdurantism. More precisely, we revisit Sattig's formulation of the problem, which arises from five plausible assumptions about ordinary objects (Section II.1–II.3); we then argue that the problem affects both endurantism and perdurantism equally (Section II.4), before showing how exdurantism provides the conceptual resources to retain those five assumptions in a relativistic context, without having to adopt hylomorphism (Section III.1). We conclude by discussing some worries that one might have with this exdurantist solution (Section III.2).[2]

II. The problem

In this section, we will introduce the problem of relativistic change. In order to understand how relativity theory generates this puzzle about ordinary objects, we begin by presenting five principles (P1–P5) that, according to Sattig (2015), capture our ordinary conception of such objects—specifically, how they exist, persist, and instantiate properties over time. These principles are first introduced in a four-dimensionalist framework (Section II.1) and then confronted with key relativistic insights (Section II.2–II.3), leading to a contradiction. We then show how the problem equally applies to endurantism (Section II.4) and review Sattig's own hylomorphic solution (Section II.5).

II.1 The received view of ordinary objects

Let us present the aforementioned five principles (P1–P5). First of all, we need to assume that ordinary objects exist. Thus, we have P1:

- P1: At least an ordinary object exists (Ordinary Existence)

Now, consider the chair I am sitting on. We suppose that it is indeed an ordinary object.[3] As part and parcel of its being an ordinary object, it belongs to a

[1]While in other publications, a careful distinction is drawn between perdurantism and four-dimensionalism (e.g. the former being a mereological thesis, while the latter being a locative one, see, for example, Gilmore Costa Calosi 2016), throughout this paper, we will use the two terms interchangeably. We will do the same for the terms 'endurantism' and 'three-dimensionalism'.

[2]We do not discuss whether the right response is the radical one according to which relativity theory suggests an ontology that is ultimately incompatible with ordinary objects.

[3]If one does not believe that chairs are ordinary objects, she can substitute 'chair' with her favourite example of an ordinary object.

particular kind, namely, the kind 'chair'.[4] Moreover, it exists only if it belongs to such a kind. In other words, if the chair on which I am sitting ceases to belong to the kind 'chair', that is, it ceases to be a chair, for example, because it was burned, it ceases to exist as well. The lesson here is that ordinary objects of a certain kind exist only as long as they instantiate that kind. For kind, here we intend—following Sattig (2015, p.15)—invariant sortals. Therefore, we have P2:

- P2: If *o* is a *K*, then if o exists at *t*, *o* is a *K* at *t* (Sattig 2015: 223–224) (*K*-invariance)

Consider the chair again. If it exists at *t*, then it is a chair at *t*. However, for it to be a chair, it needs to have a particular shape. After all, we might think of being of a certain kind *K* as a conjunctive property; thus, being a *K* entails instantiating a number of *K*-properties, among which there is 'being *K*-shaped'.[5] To see why this is the case, imagine that this chair underwent at some time *t1* a dramatic change of shape, such that at a later time *t2* it was no longer possible to sit on it.[6] It would cease to be a chair. Thus, given P2, it would cease to exist. Hence, we have P3:

- P3: If *o* is a *K* at *t*, then *o* is *K*-shaped at *t* (*K*-dependence)[7]

The received view of ordinary objects does not concern only their membership in a particular kind or some restriction on their qualitative change. It concerns their (spatio)-temporal profile as well. Let's introduce here a bit of technical jargon. Let us say that a stage of an object at *t* is an entity which is a part of that object, exists at and only at *t*, and overlaps all the parts of the object that exist at *t*. Thus, we have D1 (Sider 2001, 60):

- D1: x is a stage of *o* at $t =_{\text{df}}$ (i) x exists at and only at *t*, (ii) x is a part of *o*, and (iii) x overlaps all the parts of *o* that exist at *t* (stage-at-*t*).

At this point, we can say that an object *o* exists at *t* if and only if there is an object x that is a stage of *o* at *t*. Thus, we have P4:

- P4: *o* exists at *t* iff it has a stage at *t* (*t*-existence).[8]

[4] For the aims of this paper, one could consider kinds just to be properties, for example, complex conjunctive ones. However, everything we say would equally apply if a more substantive view of kinds is adopted.

[5] The property of 'being *K*-shaped' should not be understood as 'having a fully determinate chair shape'. A kind, intended in this sense, allows for some variation in shape, so that it is associated in fact with a family of possible fully determinate shapes.

[6] We say here that it would be hard to sit on the chair but just for the purpose of illustration. The general point is simply that a pointy entity does not possess a shape associated with the kind «chair», as mandated by P3. Thanks to an anonymous referee here.

[7] Note that *K*-dependence is a much more general principle, of which the one presented here is just a particular case. For any property *F*, such that *F* is a *K* property, then given an object *o*, such that *o* is a *K*, if *o* is a *K* at some time *t*, then *o* is *F* at *t*.

Given that an object exists at a time t if and only if it has a stage at t, we will also say that an object instantiates some property P at t if and only if its stage at t is P. P5 reflects this intuition:

- P5: o is P at t iff o's stage at t is P (t-instantiation)

One last *addendum* concerning the principles. Given P2 and P3, we get the following theorem, which will be relevant for what follows: if some object o is a K, then o exists at t only if it is K-shaped at t (Sattig 2015: 224). Assume that a chair exists at t, by P2, we have it that the chair belongs to the kind 'chair' at t. Hence, by P3, the chair is chair-shaped at t. Therefore, we can conclude that if the chair exists at t, then the chair is chair-shaped at t.[9]

II.2 Relativistic change

We shall now discuss how relativistic considerations affect the picture of ordinary objects presented in the previous section. We presuppose Minkowskian spacetime unitism (Gilmore, Calosi, Costa 2016) as well as four-dimensionalism (though we shall explain later why the problem equally applies to the case of three-dimensionalism). As a consequence, times are identified with spacetime hyperplanes composed of simultaneous spacetime points, where simultaneity is of course relative to a given reference frame. For example, 't-F' will pick out a hyperplane of spacetime points that are simultaneous with each other under the simultaneity relation of frame F.[10] As pointed out by (Sattig 2015: 220), this transition to Minkowskian spacetime unitism reflects itself in the formulation of the principles and definitions introduced in the previous section, which should now take into account that any temporal consideration should be relativized to frames. Accordingly:

- D1: x is a stage of o at t-$F =_{\mathrm{df}}$ (i) x exists at and only at t-F, (ii) x is a part of o, and (iii) x overlaps all the parts of o that exist at t-F (stage-at-t-F).[11]

[8] One might worry that there is some circularity if both D1 and P4 are accepted, for D1 defines stages in terms of existence at, and P4 defines existence at in terms of stages. This worry should be easily dispelled if one realizes that P4 is no definition, but a principle concerning existence at and stages. We are grateful to Lisa Vogt and Fabrice Correia for this point.

[9] P5 is the standard treatment of instantiation at-a-time for four-dimensionalism. Nonetheless, it is not immune to problems. Famously, it cannot be accepted in full generality (see Sider 2001: 57). For example, given a persisting object o, o's stage at t is instantaneous, yet o is not instantaneous at t. While we recognize this criticism, we defer to the relevant specialized literature for ways to restrict P5.

[10] In light of this conception of times as hyperplanes of simultaneity, different frames don't constitute mere vantage points from which an object could be considered. Rather, they constitute *times* at which the object exists at. And for an object to exist at a time is to be located as such hyperplanes. This also entails, as we shall see, that if an object is located at overlapping hyperplanes, it will exist at different times. The same holds, *mutatis mutandis*, for points of Minkowski's spacetime themselves.

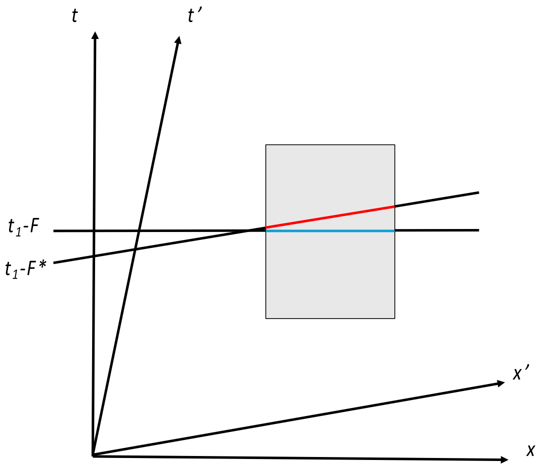

Figure 1. The spacetime career of a chair (in grey) and its intersections with two times (in red and blue, respectively).

- P1: There is at least one ordinary object *o* (Ordinary Existence).
- P2: If *o* is a *K*, then if *o* exists at *t-F*, *o* is a *K* at *t-F* (*K*-invariance).
- P3: If *o* is a *K* at *t-F*, then *o* is *K*-shaped at *t-F* (*K*-dependence).
- P4: *o* exists at *t-F* iff it has a stage at *t-F* (*t*-existence).
- P5: *o* is P at *t-F* iff *o*'s stage at *t-F* is *P* (*t*-instantiation).

At this point, we introduce the crucial phenomenon of shape relativity, whereby the spatial shape of an object varies across different frames (Balashov 2014: 10). Depending on the relevant couple of frames and times under consideration, and on the world volume[12] of the object, such variation might be more or less significant. For example, consider the spacetime career of a chair. In Fig. 1, two times t_1-*F* and t_1-*F** are considered, such that the times intersect the spacetime career of the chair in different ways, *F* being the rest frame of the chair and *F** that of an object moving at high speed with respect to it.

Now, a simple application of the revised set of principles and definitions introduced by Sattig will inform us about the shape of the chair at the relevant

[11]In the case of D1, the transition from times to frame-times might generate a sort of ambiguity. The ambiguity that we have in mind concerns condition (i), according to which x exists at, and only at, *t-F*. This might be read in two ways. The first one, is that x exists at *t-F* and at no other frame-time within the relevant frame *F* (but might exist at other frame-times, provided they are frame-times within a different frame such as, say, *t-F**). The second one, is that x exists at *t-F* and at no other frame-time, regardless of the frame (so, it could not exist at a time within a different frame such as, say, *t-F**). We take the letter and the spirit of D1 to fall squarely within the second reading. Thanks to Fabrice Correia for discussions on this.

[12]The world volume of an object in Minkowski's spacetime can be thought as the sum of its exact spatiotemporal location, as in Gilmore (2006).

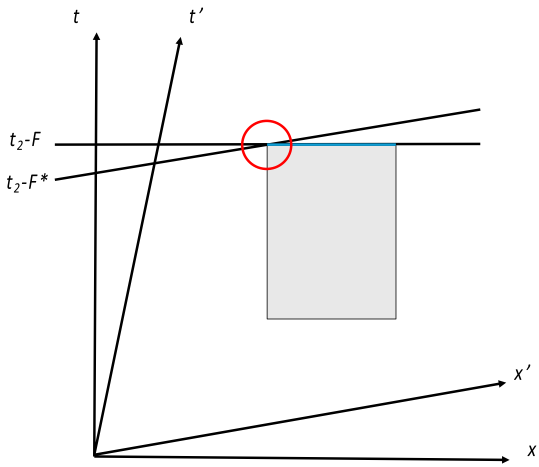

Figure 2. The spacetime career of a chair (in grey) and its intersections with two times, including one of its 'corner slices', at the centre of the red circle.

times. By P5, the shape of the chair at any time just is the shape of its stage at that time. By D1, the relevant stage of the chair will be the content of the spacetime region which is the intersection of the relevant time and the spacetime career of the chair, that is, the region in blue for t_1-*F* and the region in red for t_1-*F**. A simple measurement of the two stages will inform us that the shape of the chair in t_1-*F* and t_1-*F** are slightly different, insofar as the chair at t_1-*F** is shorter than the chair at t_1-*F*.

We shall now pass to cases of relativistic shape variation that are more dramatic and more relevant to out purposes. Consider two further times, viz. t_2-*F* and t_2-*F** which are the last times under the respective frames to intersect the chair's spacetime career.

What is the shape of the chair at the relevant times? Again, a simple application of the previous principles will give an answer to this question. And while the shape of the chair at t_2-*F* will be roughly the same as in the previous time t_1-*F* under the same frame, the shape of the chair at t_2-*F** will turn out to be dramatically different. Indeed, by P5, the shape of the chair at that time just is the shape of its stage at that time. And by D1, the relevant stage of the chair is going to be the content of the spacetime region which is the intersection of the relevant time and the spacetime career of the chair, one of its so-called 'corner slices' (Gilmore 2006; Sattig 2015), that is, a single spacetime point at the centre of the red circle in Fig. 2. In other words, the shape of the chair at t_2-*F** is going to be dramatically different from the shapes the chair has at other times: at t_2-*F**, the chair is going to have the shape of a point.

At this point, once it is recognized that at its 'corner slices' the chair is going to have the shape of a point, it is not difficult to follow Sattig and conclude that a contradiction ensues. By D1, there is a stage of the chair at time t_2-F^*. Hence, by P4, the chair exists at that time. But by P2, if the chair exists at t_2-F^*, it must also be a chair at that time, and therefore, by P3, be chair-shaped at that time. On the other hand, we have seen that by D1 and P5 the shape of the chair at t_2-F^* is that of a point. And if we agree with Sattig (as we should arguably do) that if something is point-shaped at a time it cannot be chair-shaped at that time, we shall conclude that the chair is not chair-shaped at that time. So, at t_2-F^* the chair is both chair-shaped and not chair-shaped.[13]

There is a general reaction to arguments of this kind that we think is worth addressing—albeit briefly—right away. This will also help the reader better understand the spirit behind Sattig's principles. On the one hand, they might be taken to be just ordinary language claims that we want to make sense of in our metaphysics. On the other hand, they might be taken as something more metaphysically laden. In fact, they might be taken to provide a metaphysics of ordinary objects. The first reading appears to align with usual strategies of deflating apparently metaphysical problems into semantics. Some four-dimensionalists might be happy to subscribe to them in the case of this argument too. Accordingly, the lesson of the argument is that some of these principles are a remnant of our pre-relativistic or pre-philosophical bias, and could, and should, simply be freely revised, or even rejected in light of relativity. However, it is clear that Sattig intends these principles according to the more robust reading. We don't aim to defend this general attitude here. We simply record that it seems more widespread than it used to be.[14] In the light of this, for the rest of the paper, we will follow Sattig in adopting the more robust reading. But it should be noted that our exdurantist solution side-steps this worry inasmuch as it works for both readings.[15]

[13]It is important to distinguish the problem of relativistic change we are concerned with here from issues in its vicinity. In particular, Himelright and Ramirez (2025) have argued that if spatial (three-dimensional) shape is understood as intrinsic, then four-dimensionalism, combined with the relativistic variance of 3D shapes, entails that no object has a 3D shape. Their argument overlaps significantly with the problem of relativistic change, in that both concern four-dimensionalism and the relativistic variance of 3D shapes. However, there are also crucial differences between the two arguments. First, while Himelright and Ramirez's argument essentially relies on the assumption that shapes are intrinsic, the problem of relativistic change does not. Second, while Himelright and Ramirez's argument concerns four-dimensionalism only, the problem of relativistic change affects three-dimensionalism too. Third, even granting that Himelright and Ramirez are right that relativistic four-dimensional objects can't have 3D shapes, the problem of relativistic change would still apply, in that if our chair does not have 3D shapes, then it is not chair-shaped at any time of its existence.

[14]One significant example is that of recent attempts to recover a robust metaphysics of ordinary objects out of revisionary quantum metaphysics, such as wave function realism. See, for instance, Ney (2020, 2021). She is explicit that the less demanding reading, championed by, for example, Albert (1996), would not be satisfactory.

[15]Thanks to an anonymous referee here.

II.3 An ultimately unsuccessful reply

We would like now to have a second look at the situation. We have so far followed Sattig and accepted that by D1, there is going to be a stage s of the chair at time t_2-F^*, which basically corresponds to the pointy entity exactly located at the spacetime region that is the intersection of t_2-F^* and the world-volume of the chair. On a closer look, this turns out not to be the case. That's because, more accurately, the pointy entity s does not count as a stage of the chair at t_2-F^*. On closer look, *nothing* counts as a stage of the chair at t_2-F^*. To see why, recall that D1 says:

- D1: x is a stage of o at t-F $=_{\mathrm{df}}$ (i) x exists at and only at t-F, (ii) x is a part of o, and (iii) x overlaps all the parts of o that exist at t-F (stage-at-t-F)

So, in order for something to count as the chair's stage at t_2-F^*, that thing needs to be a part of the chair and overlap all the parts of the chair that exist at t_2-F^*. The pointy entity s, and only the pointy entity s, does indeed fit the bill. However, in order for s to count as a stage of the chair, it also needs to exist at, *and only at*, t_2-F^*. This is not the case. Indeed, the same pointy entity s also exists at other frames (See Fig. 4). For example, it exists at t_2-F. This is why, on closer look, the pointy entity s does not count as a stage of the chair at t_2-F^*. But, since this was one of the steps of Sattig's argument, it seems that the argument is now blocked. If s is not a stage of the chair at t_2-F^*, the chair does not exist there (P4) and does not need to be chair-shaped at that frame-time (P2, 3).

Does this consideration undermine the problem of relativistic change? We don't think so. Indeed, this consideration applies only to the case of the extreme corner slices, that is, those at which only a pointy part of the four-dimensional object under consideration exists. However, the relevant relativistic phenomena do not concern the extreme corner slices only. To see this, consider a less extreme, but still problematic case of corner slice depicted in Fig. 3.

Here, we are considering the same frame F^* of the previously problematic corner slice, but at a previous frame-time t_3-F^*. The entity exactly at the spacetime region which is the intersection of t_3-F^* and the world-volume of the chair is depicted in red. As it can be seen here, it is not a pointy entity, and some of its parts do not overlap the stage of the chair at t_2-F, depicted in blue. So, unlike the previous case, the entity depicted in red in Fig. 3 does not exist at t_2-F as well. So, the red entity in Fig. 3 can, and in fact does, count as a stage of the chair at t_3-F^*. What shape will that red entity have? Considering its relation to the world-volume of the chair and of its parts, it will presumably have the shape of half of a chair. We can speculate that under the right circumstances and the right frame of reference, it will appear as an entity composed

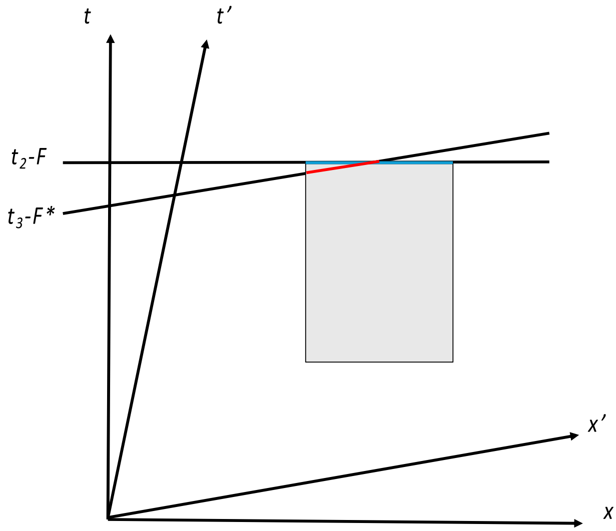

Figure 3. A less extreme but still problematic case of corner slice.

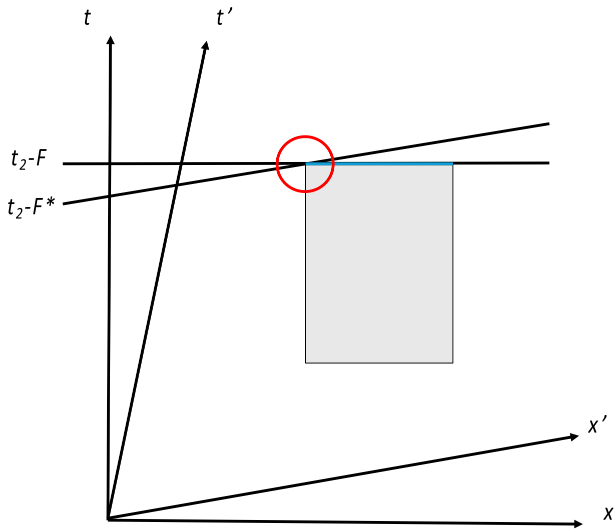

Figure 4. The spacetime career of a chair (in grey) and its intersections with two times, including one of its 'corner slices', at the centre of the red circle.

of, say, just two legs and half a seat, and will arguably not be chair-shaped. Still, insofar as it counts as a stage of the chair at the relevant time, because of P2 and P3, it would indeed have to be chair-shaped. Therefore, the problem arises again.

II.4 The problem affects three-dimensionalism too

So far, we have considered the problem from the perspective of the four-dimensionalist. While the four-dimensionalist is likely bound to accept P1–P5, the three-dimensionalist is expected to reject at least P4 and P5. Indeed, P4 and P5 commit one to the existence of instantaneous parts of a persisting object—a commitment a three-dimensionalist is likely to reject. This raises the question of whether accepting three-dimensionalism would effectively solve the problem under discussion. We suspect it would not. Principles P1–P5 are the perdurantist specifications of general schematic principles. Thus, while we expect the endurantist to reject these specific principles, we expect them to accept their corresponding endurantist specifications. Here are the schematic formulations:

(1) $P4^{\text{schema}}$: An ordinary object o exists at t (t-F) if and only if, for some entity y, oRy and y is located[16] at t.
(2) $P5^{\text{schema}}$: An ordinary object o has some property P at t (t-F) if and only if, for some entity y, oRy and $\varphi(y)$.

In summary, the schematic version of P4 asserts that o exists at a time if and only if there is some entity y such that o and y are R-related and y is located at that time, where location is understood broadly. Similarly, the schematic version of P5 states that o has P at some time if and only if there is some entity y such that o and y are R-related and y satisfies some formula φ. It is straightforward to verify that P4 and P5 are perdurantist specifications of these schematic principles (hence, a more perspicuous name for them, would be $P4^{\text{perdurantism}}$ and $P5^{\text{perdurantism}}$; we will adopt these more perspicuous labels from now on); one simply substitutes the temporal part relation for R and $P(y)$ for $\varphi(y)$. The question, then, is what the endurantist specifications of such principles would be. Consider the following two principles:

(1) $P4^{\text{endurantist}}$: An ordinary object o exists at t (t-F) if and only if, for some entity x, x is identical to o and is entirely located at t (t-F).
(2) $P5^{\text{endurantist}}$: An ordinary object o has some property P at t (t-F) if and only if, for some entity y, o=y and y has property P at t (t-F).

$P4^{\text{endurantist}}$ asserts that o exists at a time t if and only if it is entirely located at that time. This is arguably because the object has an exact location which is a subregion of t-F. $P5^{\text{endurantist}}$, on the other hand, is a tautology: o has P at t if and only if some entity identical to o has P at t. It is difficult to see why an endurantist would object to these specifications. After all, one simply states that an object exists at a time if it is entirely located there, which squares nicely with the

[16] Here, «located» stands for a disjunction of various modes of location, as distinguished, for example, in (Gilmore, Calosi, and Costa 2024). As we shall see, different theories of persistence will pick different modes here.

nowadays standard multilocationist account of endurantism (Gilmore, Calosi, and Costa 2024), while the other reflects the standard endurantist attitude towards temporary intrinsics; while the perdurantist accounts for their temporary exemplification in terms of their timeless exemplification by some temporal part, the endurantist tends to consider temporary exemplification as a primitive phenomenon.

However, these principles become problematic in a relativistic context. With relativity in play, the endurantist must adopt a principle regarding which regions are suitable for enduring entities to (exactly) occupy. A strong candidate is Cody Gilmore's 'Every Slice Principle' (2006: 2009), which states that an object is exactly located at each achronal (i.e. temporally unextended) subregion of its world volume. At this point, it is easy to see that the problematic slices—specifically, the corner slices—are achronal subregions of the chair's path. By Gilmore's principle, the chair is exactly located there. Therefore, by P4^{endurantist}, the chair exists at *t2-F**. In location theory (see Gilmore, Calosi, and Costa 2024), it is uncontroversial that an object shares its shape with its exact location (and with it all other spatial relations). Hence, because the region shown in Fig. 2 is pointy and the chair is exactly located there, the chair is also pointy. Therefore, the chair exists at *t2-F** and is point-shaped at *t2-F**. Notably, this generates a contradiction: by P3, since the chair exists at *t2-F**, it must also be chair-shaped at *t2-F**. However, if it is point-shaped at *t2-F**, then it cannot also be chair-shaped at *t2-F**—a contradiction. Some might object to our framing of the problem, arguing that the 'Every Slice Principle' is the real culprit and that choosing another principle would dissolve the issue. As a first rejoinder, we note that the burden of proof now lies with the objector; she must show which independently motivated principle avoids this problem. Moreover, it is not obvious that modifying the 'Every Slice Principle' resolves the issue.[17] Consider a plausible modification presented by Gilmore (2006) and endorsed by Balashov (2014): the 'Every Maximal Slice Principle.' Under this principle, for an achronal subregion of an object's path to be its exact location, it must also be maximal (i.e. not part of any other achronal subregion

[17]First, one might note that what we have labelled P4^{endurantist} and P5^{endurantist} are not the only possible endurantist instances of the schemas introduced before. Other formulations are possible. A particularly interesting one that uses exact locations thus delivering:

(1) P4^{*endurantist}: An ordinary object o exists at *t (t-F)* if and only if, for some entity x, x is an exact location of o and x is entirely located at *t (t-F)*.

(2) P5^{*endurantist}: An ordinary object o has some property P at *t (t-F)* if and only if, for some entity x, o is exactly located at x, and x has property P, and x is entirely located at *t (t-F)*.

Two things worth noting. First, clearly, there would have to be significant restrictions on the properties in P5^{*endurantist} (not all temporary properties of objects are also properties of their exact locations). Second, entire location for regions boils down to parthood. The starred principles are interesting because, together with the restriction that will be presented in the next section, they offer a principled alternative to the Every Slice Principle.

of the object's path). In this case, the corner slices would not count as exact locations of the chair. Thus, the chair would not be exactly located there and would not be pointy at *t2-F**, as it arguably does not exist at *t2-F**. While this resolves the specific issue of the pointy region shown in Fig. 2, it does not address the problem generally. For the same reasons discussed in Section II.3, the chair will not be exactly located at the pointy region in Fig. 2, but it will be exactly located at other problematic regions that are not chair-shaped—such as the red region depicted in Fig. 3. Hence, the problem persists.

This effectively constitutes an extension insofar as Sattig's original formulation explicitly and exclusively targeted four-dimensionalism. However, the same feature of relativity, namely frame-dependence of 3D shapes, has been the starting point of other arguments directed against three-dimensionalism (Balashov 1999, 2014; Gilmore 2006). Hence, the fact that Sattig's problem could equally affect three-dimensionalism is not totally unexpected. It is a substantive question what the relation among those arguments is and whether replies to one argument—such as the one we will provide—also constitute a reply to another, and under what conditions. But this, we think, should be investigated on independent grounds.[18]

II.5 Sattig's solution and some possible restrictions

According to Sattig (2015: 240), the best solution to this problem is to embrace a form of hylomorphism. Here, we won't go into the details of his proposal, because that would take us too far astray. Let us just highlight it. Sattig's perspectival form of hylomorphism allows to distinguish between two levels in which ordinary objects can be analysed. On the one hand, they can be seen as structured objects, falling under a sortal cover, on the other, they can be seen as mere aggregates of their material components. Take the computer on which we are writing this paper. On the one hand, it can be seen as a mereological configuration falling under a particular sortal predicate (being a computer in the present case). On the other, it can be seen as a mere lump of its material components.

Thus, it is possible to distinguish between the material existence of ordinary objects, where they are seen as mere sums of their material components, and their formal existence, where they are seen as mereological configurations instantiating some sortal properties. These considerations allow for restrictions of the principles we were considering above. Consider P2*:

- P2*: If *o* is a *K*, then if *o* exists formally at *t-F*, *o* is a *K* at *t-F* (*K*-invariance*)

[18] At first sight, it seems clear that there are significant differences. By way of illustration, consider (Balashov 1999). That argument is an argument to the best explanation to the point that the four-dimensionalist explanation of the *remarkable unity* of the four-dimensional relativistic volume is much better than any purported three-dimensional explanations. *K*-invariance, which plays a crucial role in Sattig's argument, does not appear there. Thanks to an anonymous referee for this journal.

Formulated in this way, it no longer generates the problem, as the chair will not formally exist in the point-shaped region. For the chair will formally exists if and only if it instantiates the kind properties. Hence, it will materially, but not formally, exist in the problematic spatiotemporal regions.

In light of Sattig's own reply, one might think that a possible strategy to avoid the problem is to suitably restrict the principles above. After all, Sattig himself, as we saw, restricts some principles. Suppose one restricts P4 Schematic as follows (R for Restricted):

- P4R$^{\text{schema}}$: An ordinary object *o* exists at *t* (*t*-*F*) if and only if, for some *K*-shaped entity *y*, *oRy* and *y* is located at *t*.

This will deliver the following two instances in the relativistic case (in 'abbreviated formulations' for the sake of readability):

- P4R$^{\text{perduranrantism}}$: An ordinary object *o* exists at *t-F* if and only if, it has a *K*-shaped stage that is exactly located at *t-F*.
- P4R$^{\text{enduranrantism}}$: An ordinary object *o* exists at *t-F* if and only if, it has a *K*-shaped exact location at *t-F*.

A third instance could be formulated for the third theory of persistence, to be discussed shortly, namely exdurantism:

- P4R$^{\text{exduranrantism}}$: An ordinary object *o* exists at *t-F* if and only if, it has a *K*-shaped counterpart that is exactly located at *t-F*.

It should be clear that all of them entail that the given ordinary object does not exist at the problematic location and therefore is not point-shaped there, thus undermining the argument. One may even go as far as claiming that such restrictions are actually well-motivated. In effect they are motivated by the very picture of ordinary objects Sattig defends in the first place (where existence and being *K*-shaped are so tightly linked). And the restrictions of P4 seem to deliver a very similar result to the one that Sattig claims to solve the problem, namely that the ordinary object does not exist at the problematic location. Naturally, it is open to Sattig to respond that restricting P2 is kosher whereas restricting P4 is not. It seems that the burden of the proof is on the defender of this asymmetry between P2 and P4 here. But we will not push this line of argument. What we will show is that actually exdurantism needs not restrict P4 after all—thus setting exdurantism apart from other (alleged) solutions. This is because exdurantists could use the 'inner workings' of the counterpart relation itself—so to speak—to deliver the desired result while sticking to P4$^{\text{exduranrantism}}$ without switching to P4R$^{\text{exduranrantism}}$.

III. An exdurantist solution

III.1 The exdurantist solution

So far, we have considered the problem from the perspective of either the perdurantist or the endurantist. But what would happen if we went exdurantists? This section puts forward a new solution to the puzzle of relativistic change. The solution is based on exdurantism. According to it, in place of a single enduring or perduring object, exdurantism posits a series of numerically different instantaneous objects, one for each time at which the ordinary object was supposed to exist. Moreover, it claims that whenever we refer to an ordinary object, we are in fact referring to one of these instantaneous stages (Hawley 2001; Sider 2001; Varzi 2003). In a sense, exdurantism denies the persistence of ordinary objects, insofar as one cannot find the numerically same object at different times. Still, exdurantists sometime try to recover a sense in which an object can be said to persist, that is, by having counterparts at various times (Hawley 2001; Balashov 2007).

Sometimes, the instantaneous entities posited by exdurantism are called 'stages' (Sider 2001). This might be confusing, insofar as the same term is used for the instantaneous temporal parts of a four-dimensional object. What, then, is the difference between exdurantism and four-dimensionalism? There are actually a few. First, four-dimensionalism has it that ordinary language refers to four-dimensional objects, while exdurantism has it that it refers to the stages. Further differences include the fact that exdurantism is not necessarily committed to the existence of the four-dimensional aggregates of the stages, and that four-dimensionalism is not necessarily committed to the existence of instantaneous stages—for example, a four-dimensionalist might claim her four-dimensional objects to be temporally gunky (Varzi 2003: 18).

Let us now introduce the suitably modified versions of principles P4 and P5, first focussing on the pre-relativistic case:

(1) $\mathrm{P4}^{\mathrm{exdurantist}}$: An ordinary object *o* exists at *t* if and only if there is an entity *y*, such that *y* is a counterpart of *o* and *y* is entirely located at *t*.
(2) $\mathrm{P5}^{\mathrm{exudrantist}}$: An ordinary object *o* has some property *P* at *t* if and only if, for some entity *y*, *y* is a counterpart of *o*, is entirely located at *t* and is *P*.

As it is clear from our formulation of exdurantism and of the principles, the counterpart relation plays a pivotal role here. Usually, determining factors to establish whether a counterpart relation holds between x and y include spatiotemporal contiguity, causal connectedness, and similarity. Hence, it should not sound as a surprise to the reader that counterpart relations tend to be very flexible. For example, some exdurantists are ready to accept that I am now in a counterpart relation with a dinosaur living millions of years ago (Sider 2001: 206–7; Varzi 2003: 24). At this point, a serious concern arises.

For it is unclear whether exdurantism can accommodate the received view of ordinary objects, not only after the relativistic revolution, but even in the *pre-relativistic* case. Indeed, if a dinosaur can count as one of my counterparts at some time, then either I don't exist at that time despite having a counterpart at that time (hence $P4^{exdurantist}$ is rejected) or I am not a human being at that time, despite existing at that time (hence P2 or P3, or both, have to be rejected). While some exdurantists might happily accept this as a consequence of their theory, they don't need to do so. In other words, accepting exdurantism alone does not force us to reject any of the principles that constitute what we have called the ordinary conception of objects. To see this, we should again appeal to the flexibility of the counterpart relation. If exdurantists desire to make their view compatible with the principles, they need to pick a more rigid account of the counterpart relation. For example, one in which the similarity condition is strict enough to make sure a dinosaur cannot count as one of my counterparts and, more generally, one that is sensitive to kinds and shapes, so to obey P2 and P3. The same applies for whatever principle one may think ordinary objects need to obey. For instance, suppose that one has independent reasons to think that the spatiotemporal career of an ordinary object as a chair can't be gappy. Then, she should select a counterpart relation that is sensitive to this continuity constraint. If this is correct, it also shows that these worries are not worries about relativistic change. In effect, they are not relativistic worries after all.[19]

So, with a relatively rigid account of the counterpart relation, exdurantism seems to be perfectly equipped to track the persistence of ordinary objects. How is exdurantism changed by the transition from a pre-relativistic perspective to Minkowskian spacetime unitism? The change is rather straightforward. Since times are replaced with frame-times, exdurantism is going to be the view that in place of a single persisting object, there is going to be a series of numerically different instantaneous objects, one for each frame-time at which the ordinary object was supposed to exist. For example, *in* Fig. 1, there is going to be an instantaneous chair exactly located at the red spacetime region, and a numerically different one exactly located at the blue region. Interestingly, some of those instantaneous chairs are going to overlap with each other. This can be immediately appreciated in Fig. 1, insofar as the two chairs overlap where the red and blue regions overlap. To see this point from a more abstract perspective, consider that there is going to be a numerically different chair for each frame-time at which the chair was supposed to exist, and that under Minkowskian spacetime unitism, some of those frame-times overlap with each other.

We are now in a position to see why exdurantism is immune from the problem of relativistic change considered so far. Indeed, in order for the

[19] Thanks to an anonymous referee for this journal.

problem to present itself, we would have to find a chair that exists at a *t-F* and is not chair-shaped at that *t-F*. To be sure, here are the relativistic versions of $P4^{\text{exdurantist}}$ and $P5^{\text{exdurantism}}$:

(1) $P4^{\text{exdurantist-r}}$: An ordinary object *o* exists at *t-F* if and only if there is an entity *y,* such that *y* is a counterpart of *o* and *y* is entirely located at *t-F.*
(2) $P5^{\text{exudrantist-r}}$: An ordinary object *o* has some property *P* at *t-F* if and only if, for some entity *y, y* is a counterpart of *o,* is entirely located at *t-F* and is *P.*

Hence, to establish whether or not exdurantism can solve the problem, it is crucial to determine whether or not the chair has a counterpart at the corner slices, and more generally at all those regions that exhibit a substantial change in shape. And we are sure that there is not going to be such a thing. Indeed, as we have already explained, in order to make Sattig's view of ordinary objects compatible with exdurantism, we need to adopt, already in the pre-relativistic case, a relatively rigid account of the counterpart relation, that is, one that is sensitive to kinds and shapes. There is no reason to believe that this feature would not carry over to the relativist case, since the counterpart relation was left untouched during the transition. Hence, since there is nothing similar enough to the chair at the problematic slices (nothing with the right kind or shape), the chair will have no counterparts at those slices. The problem is thus apparently completely solved.

III.2 Three worries

We are now going to discuss some possible worries against our proposed exdurantist solution. Before delving into this discussion, a methodological point is in order. Just like any philosophical theory, exdurantism too is subject to some general objections, such as the counting objection, the coming into being objection, or the objection from mental events, among many others.[20] At least some of the authors of this paper share some of these objections. However, this would not be the right place for a defence of exdurantism from these general objections—just as much as it would not be the right place to remind the reader about general arguments in favour of it. The focus here is on the relativistic consequences for the existence of ordinary objects. This is why we shall focus here on worries pertaining specifically to our suggested solution to the problem of relativistic change.

The first worry concerns the use of exdurantism in an attempt to save the ordinary conception of objects. Isn't exdurantism too radical a departure from such an ordinary account of objects (e.g. because it identifies ordinary objects

[20] See, for example, Costa (2020) for an overview of objections against exdurantism.

with instantaneous entities) to be of interest in this context? We are here going to mention three possible replies to this worry. First, strictly speaking, in this paper, we are in the business of reconciling relativity with Sattig's five principles. The question of whether these five principles effectively capture our ordinary conception of reality, or whether further principles (such as the principle that objects persist) should be added to the list, goes beyond the scope of this paper. However, as a first step towards dealing with this problem, let us add a few words as our second and third point on this issue. We have already seen that the exdurantist can recover a sense in which ordinary objects persist (by having counterparts at various times). The question here might be whether this sense of persistence is in a worse position to capture what we ordinarily have in mind with respect to other options, such as the «strict» diachronic identity of the three-dimensionalist, or the «loose» mereological identity (the temporal parts being parts of a same whole) of the four-dimensionalist. Is what we ordinarily have in mind when talking about an object still being there after a while really so precise to differentiate between these three options? One might think it is not (Varzi 2003: 25). On top of this first defensive reply, there is a second more straightforward reply. Again, the problem of relativistic change was supposed to target our ordinary conception of objects as it impacts relativistic physics. It would simply be a valuable lesson to learn that exdurantism is best suited to cope with this problem and hence enhances its credentials for being the theory of persistence that is best suited to withstand the relativistic revolution. In the same spirit, one might add that it is simply of interest to the exdurantist to learn that her view has the capacity of solving yet another problem which affects both its three- and four-dimensionalist opponents.

A second worry has to do exactly with the exdurantist versions of P4 and P5. For someone might contend we should have used the 4-dimensionalist principles to show that criticism does not apply to the exdurantist case. In other words, we should not have shown that there is no *counterpart* of the chair existing at the problematic slices, but rather that the chair has no *stage* there, in the sense defined above. For this worry to have any grip, we would have to find a chair such that one of its stages at the corner slices is not chair-shaped. However, under exdurantism, no chair is such to have stages that satisfy this description. In order to see this, recall that, under exdurantism, any singular term apparently referring to the ordinary persisting chair does in fact refer to an instantaneous entity. Which instantaneous entity is picked out, precisely, is going to depend on the context, of course. Suppose for the sake of the argument, that our present talk of the chair is going to pick out the blue entity, call it c, indicated in Figs 2 and 3. The problem would require there to be a stage s of said chair c, that is not chair-shaped. But there is no such stage. Let us review a couple of candidates in order to see why they do not count as stages of the chair c and start with the extreme corner slice of Fig. 2.

It has the right shape to generate the problem of relativistic change, provided it is a stage of the chair c at the relevant time t_2-F^*. But is it? It is not, for a reason already explained in Section II.4. Indeed, in order for it to be a stage of anything at t_2-F^*, the pointy entity would have to exist at, *and only at*, t_2-F^*. However, the pointy entity exists also at other frame-times, such as t_2-F.

Consider now the red entity depicted in Fig. 3, another problematic corner slice. As explained before, it too has the right shape to generate the problem of relativistic change, provided it is a stage of the chair c at the relevant time t_3-F^*. However, it too is no stage of the chair c at the relevant time. Indeed, in order for it to be a stage of the chair c, it would need to be part of the chair c. But recall that c is just an instantaneous entity, namely the entity depicted in blue in Fig. 3. So, the red entity is no part of the chair c and thus can't be a stage of it at any time.

More generally, what holds for either case, holds for any other putative case. Either a putative stage of the chair c turns out to be a part of x, but also to exist at other frame-times, or it turns out to exist at a time only, but also not to be part of the relevant chair c. The same arguably holds not only for the instantaneous chair c, but for any other instantaneous chair which the exdurantist posits in place of the persisting chair itself. Now, since the problem of relativistic change required the chair to have a stage with a wrong shape, and since no such thing can be here identified, the problem does not get off the ground.

A third worry concerns the relatively rigid account of the counterpart relation which constitutes the core of the exdurantist solution to the problem of relativistic change. One might see this as a sort of restriction, so to speak, of the usually more flexible notion of counterpart. However, if the exdurantist is allowed to apply this kind of restriction, why shouldn't the perdurantist or the endurantist be allowed to adopt a similar restriction too?

Of course, in order to properly evaluate this objection, one would have to see first how this restriction works, precisely, and the burden of presenting us with the details would entirely be on the objector's shoulders. However, in what follows, we will present a straightforward way in which this restriction can be applied to the perdurantist case.[21] Just like the exdurantist is now using a counterpart relation such that counterparts are going to be suitably similar, so, the perdurantist could use a restricted notion of *stage* such that stages are also going to be suitably similar, such as the following one:

[21] When it comes to the endurantist case, we suspect that the relevant restriction would have to be applied to the Every Slice Principle, roughly along the following lines: an object is exactly located at each achronal (i.e. temporally unextended) and *suitably shaped* subregion of its world volume. We expect everything we are going to say as regards the perdurantist case to apply, *mutatis mutandis*, to this restriction too.

- D1*: x is a stage of o at t-F $=_{\mathrm{df}}$ (i) x exists at and only at t-F, (ii) x is a part of o, (iii) x overlaps all the parts of o that exist at t-F (stage-at-t-F), and (iv) $\varphi(x)$.

Where $\varphi(x)$ specifies the relevant conditions of the restriction. For example, in the case of the chair, $\varphi(x)$ will specify that x needs to be a chair and to be chair-shaped.

In response to this worry, we say that we take the case of the exdurantist's restriction to be crucially different from the other cases. As we have explained above, regardless of relativity, the exdurantist needs to uphold a rigid conception of the counterpart relation in order to salvage the ordinary conception. In other words, the restriction of the counterpart relation is, so to speak, intrinsic to exdurantism itself, and independently motivated even before the relativistic shift. The possibility of this restriction rests on the very flexibility of the counterpart relation, which can be restricted depending on the context of application. Thus, although similar restrictions can be applied in the context of other theories of persistence, they would constitute additions to those theories and should be independently motivated and justified.

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References

Albert, D. (1996) 'Elementary Quantum Metaphysics'. In: J.T. Cushing, A. Fine, and S. Goldstein (eds.). *Bohmian Mechanics and Quantum Theory: An Appraisal*. pp. 277–84. Dordrecht: Kluwer.

Balashov, Y. (1999) 'Relativistic Objects', *Noûs*, 33: 644–62.

Balashov, Y. (2007) 'Defining ‚exdurance', *Philosophical Studies*, 133: 143–9.

Balashov, Y. (2010) *Persistence and Spacetime*. New York, NY: OUP.

Balashov, Y. (2014) 'On the invariance and intrinsicality of four-dimensional shapes in Special Relativity', *Analysis*, 74: 608–12.

Costa, D. (2020) 'Persistence in Time', *Internet Encyclopedia of Philosophy*, ISSN 2161-0002, https://iep.utm.edu/per-time/

Gilmore, C. (2006) 'Where in the Relativistic World Are We?', *Philosophical Perspectives*, 20: 199–236.

Gilmore, C., Calosi, C., and Costa, D. (2024) 'Location and mereology,' In: E. Zalta and U. Nodelman (eds.) *Stanford Encyclopedia of Philosophy*. Online publication, available at https://plato.stanford.edu/entries/location-mereology/

Gilmore, C., Costa, D., and Calosi, C. (2016) 'Relativity and Three Four-Dimensionalisms,' *Philosophy Compass*, 11: 102–20.
Hawley, K. (2001) *How Things Persist*. Oxford: OUP.
Himelright, J. and Ramirez, M. (2025) 'Getting Back in Shape: Persistence, Shape, and Relativity', *Philosophy and Phenomenological Research*, 110: 75–96.
Ney, A. (2020) 'Finding the World in the Wave Function: Some Strategies for Solving the Macro-object Problem', *Synthese*, 197: 4227–49.
Ney, A. (2021) *The World in the Wavefunction*. Oxford: OUP.
Sattig, T. (2015) *The Double Lives of Objects*. Oxford: OUP.
Sider, T. (2001) *Four-Dimensionalism*. Oxford: OUP.
Varzi, A. (2003) 'Naming the Stages', *Dialectica*, 57: 387–412.