Sharing a Boundary at the Same Time: A Discussion about Material Collocation and Four-Dimensionalism

Compartiendo un límite al mismo tiempo: una discusión sobre colocación material y el tetradimensionalismo

Gonzalo Núñez Erices
Universidad Católica del Maule
Chile
gnunez@ucm.cl
https://orcid.org/0000-0002-6641-958X

Abstract

Is it possible for two material objects to share the very same boundary? Material collocation is a metaphysical thesis that allows for two qualitatively distinct objects to share the same boundary of a matter-filled region of space and, therefore, to be made of the same stuff despite them differing in some metaphysical respects (e.g., temporal or modal properties). This article addresses the metaphysical implications of material collocation on a boundary account and how things persist across time. It discusses endurantism and perdurantism in terms of boundaries: while the former postulates physical objects as entities having boundaries along the three spatial dimensions, the latter postulates them as entities having boundaries along four dimensions, considering time as an extra dimension. Finally, the article raises two criticisms against perdurantism: one related to Heller's commitment to boundary essentialism of four-dimensional objects, and the other to the resemblance argument between spatial and temporal boundaries.

Keywords: boundaries; material objects; collocation; persistence; endurantism; perdurantism.

Resumen

¿Es posible para dos objetos materiales compartir un solo límite? La colocación material es una tesis metafísica según la cual dos objetos cualitativamente diferentes comparten el mismo límite de una región espacial y, por ende, se componen de la misma materia a pesar de diferir en algunos aspectos metafísicos (por ejemplo, propiedades temporales y/o modales). Este artículo aborda las implicaciones metafísicas de la colocación en relación con una tesis sobre límites y persistencia temporal. Se plantea una discusión sobre endurantismo y perdurantismo: mientras el primero entiende los objetos físicos como entidades con límites en las tres dimensiones espaciales, el último los entiende como entidades que poseen límites en cuatro dimensiones, considerando el tiempo como una más. Finalmente, el artículo preesnta dos críticas al perdurantismo: una respecto del compromiso de Mark Heller con el esencialismo de límites en objetos tetradimensionales; la otra, con el argumento de la analogía entre límites espaciales y temporales.

Palabras clave: límites; objetos materiales; colocación; persistencia; perdurantismo; endurantismo.

1. Introduction[1]

Can we stand in two different places at once? Although it seems impossible due to our human capabilities, we might do it in some way: by standing on the equatorial line we are in two places at once, the southern hemisphere and the northern hemisphere. In this respect, boundaries seem to be entities that can share a place at the same time. In fact, we might think that the contact between the two hemispheres—x and y, for short—occurs when at least one part of x's boundary overlaps at least one part of y's boundary, i.e., when parts of the boundaries of x and y share some region of space at some given time. However, what if not just some parts of x's boundary and y's boundary spatially coincide, but all of them? If (i) a boundary sets the stopping place of the region of space filled by an object, and (ii) the entirety of x's boundary and the entirety of y's boundary exactly occupy one place at once, then it can be stated that both x and y exactly fill the same region of space at the same time; or, as metaphysicians traditionally say, x and y are collocated entities.

If two objects are made of the same stuff by sharing the same boundary of a matter-filled region of space, then, we might think, they should share the same properties too. Nonetheless, if two objects are really distinct, then they must differ at least in some *kind* of properties. Thus, two collocated objects share some physical properties (e.g., colours or textures) and causal powers (e.g., light reflection or corrosion), most of which occur on the surfaces of things. Nonetheless, they must differ in other kinds of properties (metaphysical properties, we can say) which are not physically perceptible. Traditional supporters of collocation thus argue that materially coinciding objects differ in their persistence conditions and modal properties. Although they can occupy the same

space at once, they differ in both the changes they can survive in time and the worlds they exist in.

This article firstly addresses the topic of collocation and temporal persistence as a metaphysical study about boundaries. It discusses endurantism and perdurantism: while the former contends that tables, chairs, or people persist over time having *all* their parts at every moment they exist, the latter contends that those objects are four-dimensional entities made of temporal parts without being *wholly* present at every time they exist. These theories differ in relation to a boundary account: while endurantists postulate physical objects as entities having boundaries along three spatial dimensions, perdurantists postulate them, considering time, as entities having boundaries along four dimensions. Secondly, this article raises critics against Heller's account of four-dimensional objects. It mainly focuses on his essentialist view of boundaries and the metaphysical implications about modality. This finally takes us to resist the analogy argument between space and time usually accepted by perdurantism insofar as it cannot rule out problems of a resemblance between spatial and temporal boundaries.

2. Two objects, one boundary

The idea of collocation seems to disturb a strongly embedded common-sense belief, namely: two compact and solid material objects cannot *pass through their boundaries* (or surfaces). Unless you are a sort of bodiless object such as souls or ghosts, if you try to cross a wall by *passing through* it, you will probably hit your head against the wall. This painful (and maybe embarrassing) situation occurs when parts of your boundary and parts of the wall's boundary (i.e., parts of your skin and the wall's surface) collide with each other. This is what Locke called *impenetrability*:[2] material objects fill space by excluding each other. However, metaphysicians are not talking about material coincidence or

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[2]   Unlike pure empty space, says Locke, impenetrability is a primary quality of a solid object that involves a resistance that keeps other bodies out of the space that it fills: "All bodies in the world, pressing a drop of water on all sides, will never be able to overcome the Resistance, which it will make, as soft as it is, to their approaching one another, till it be removed out of their way" (2008, II, IV, § 3). Bodies cannot be penetrated by other bodies; they resist to share a single spot in physical space at the same time.

collocation[3] in terms of penetration of objects' boundaries, but in terms of two quantitatively and qualitatively distinct objects composed of the same parts and the same spatial boundary at a given moment in time.

Collocation is thus based on two different statements: (i) the same portion of matter can compose two different objects; (ii) two spatially coinciding objects have different properties. This is the traditional case of the statue made of clay where both the statue and the piece of clay are made of the same physical stuff but differ in their modal and temporal properties. Thus, spatial collocation can be explained in terms of whole-part relation: "two physical objects could be composed of exactly the same parts at some level of decomposition" (Merricks, 2001, p. 38) and, therefore, "the whole of one object wholly occupies the place wholly and simultaneously occupied by the whole of another" (Burke, 1994, p. 591). That is, collocation arises at a fundamental level in which two distinct objects can be exactly made up of the same atomic configuration. We may contend that while heads, legs, or hands are non-fundamental parts that compose a statue of Achilles made of clay, the clay itself (and chunks of clay in general) has no parts such as heads, legs, or hands as Achilles does. Although the statue and the clay may differ in their non-fundamental parts, both are exactly made of the *same* sub-atomic parts. We can write it down in the following conditions:

> For every x, y, and ws, (i) the ws exactly fill a region of space R at some given time t, (ii) each of the ws is a part of both x and y, (iii) x and y share the same spatial boundaries (viz., R's boundary) at t, and (iv) x and y are qualitatively distinct objects.

How can two different physical objects have the same boundary? Since Franz Brentano's works on metaphysics of the *continua*,[4] the literature about boundaries has postulated that a boundary is the kind

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of entity whose existence ontologically depends upon the existence of the object it belongs to. Nonetheless, if we accept the thesis of collocation, then a boundary would not exclusively be the boundary of the very object it belongs to insofar as the same boundary would ontologically belong to two distinct objects composed of the same parts. According to Olson, "materially coinciding objects are made up entirely of exactly similar particles, related precisely the same way, in identical surroundings" (2001, p. 339). In fact, objects' surroundings are found in objects' boundaries. The boundary of a physical object separates all the matter that composes that object from the spatial environment where that object is physically located. Although two duplicate objects might be composed of the same kind of matter (e.g., two white billiard balls), we cannot make the same description of their surfaces because they do not have the same spatial environment given the different physical location. For two qualitatively distinct objects, the only way to strictly have the very same boundary and share the same spatial environment is to be composed of the very same parts.

However, how can two objects made of the same stuff and boundary at once not share the same properties? A country and the territory where it is physically found are different things, but have the same boundary. For instance, the United Kingdom's border and the boundary of the territory where the United Kingdom is emplaced are identical, both entities (let's say 'UK' and 'Territory') having the same parts and surroundings. However, while UK is a place on Earth defined in virtue of the concept of nation and its social, cultural, and political rules, Territory is a piece of land as a natural feature of Earth's geography. Although UK and Territory have the same location given their spatial parts, they differ, for instance, in intentional and temporal properties: UK exists because of human conventions and decisions, but Territory does not; UK was founded at some time in human history, but Territory existed before UK. Therefore, both have the same boundary (and environment) of a given space region but differ in some properties.

Just like the borders of countries and their territories, the collocation puzzle is about everyday material objects and their boundaries. Collocation occurs when material things "have to *compete for room* in the world […] and they must tend to *displace* one another" (Wiggins,

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Brentano's view on boundaries and he, metaphorically, called them 'ontological parasites' (1976, p. 51).

1968, p. 94), because "there just is not enough room for them" (Heller, 2008, p. 14). In his *Essay*, Locke contends that "we never finding, nor conceiving it possible, that two things of the same kind should exist in the same place at the same time" (2008, II, XXVII, § 1). The world then has not enough room for two things of the same kind in one place at once. Wiggins (1968) takes Locke's constraint that collocation is not possible for things of the *same kind*, but it is for things of *different kinds*, i.e., things which satisfy different sortals.[5] What is it for objects to satisfy different sorts? Coinciding objects are made of the same matter and share some *perceptible properties* which are in principle discovered by simple observation at the time of coincidence (such as size, shape, colour, or weight), while they differ in some properties which are not clearly perceptible in that sense (cfr. Lowe, 2002).

Metaphysical properties are often taken to be the non-perceptible properties that make material objects fall in different sorts. Bennett (2004) calls perceptible properties *non-sortalish properties* and non-perceptible properties *sortalish properties*. Sortalish properties make for two different objects to differ in properties without competing for the same room in the world: they can be made of the same physical stuff and share some perceptible properties and yet differ in their non-perceptible properties. For instance, a statue (David) made of a piece of clay (Clay) differ in temporality, modality, and persistent conditions: (i) Clay existed before David; (ii) Clay can survive being shaped into any other non-David form, but David cannot; Clay can survive any change of shape at any time, but David cannot.[6] Even though Clay and David may differ in their sortalish properties, they are made of the *same* material and have the *same* boundary (and surroundings).

Everyday boundaries (surfaces) play a relevant role in collocation. Coinciding objects share the same *basic physical profile* (cfr. Levey, 1997): they have the same particles, electric charge, mass, shape, colours,

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[5]   Some philosophers state that it is possible for two things of the same kind to be temporally composed of the same matter (cfr. Shorter, 1977; Simons, 1985).

[6]   This argument is based on some kind of essentialism: while Clay is not essentially a statue, David is essentially a statue. If Clay and David do not fall essentially under the same sortal (to be essentially some F), then they cannot be identical; therefore, Clay and David are distinct spatially coinciding objects (cfr. Rudder, 1997).

perceptual features, and take up the same amount of space, and so on. Physical profiles, in that sense, can be mostly determined by the boundaries of material objects. As Doepke puts it:

> Why, just because *a* and *b* are in the same place (at time *t*), should they *also* be of the same weight, smell, and taste? Let us take note of the following facts: the place, shape and (spatial) size of an object are *determined by the places of its outermost parts*; the weight of an object is a function of the weights of its parts; its taste is determined by how certain of its parts affect our gustatory senses; the colour and smell of an object are determined by the qualities and interrelations of certain of its outermost parts (1997, p. 15).[7]

Many of the (non-sortalish) physical features that we attribute to coinciding objects are determined by the collection of the shared outermost parts that make up the objects' surfaces. Material objects have properties according to colours, textures, flavours, or sounds they produce and most of them can be perceived from their surfaces. Given that Clay and David both have the same boundary, they have the *same* physical features which can be perceived on the surface. The size and spatial extension of material objects can be related to objects' boundaries too: size is measured by measuring the boundaries that a physical object has along the three spatial dimensions; likewise, the spatial extension of an object reaches a boundary as the stopping place of the totality of space occupied by it. Given that Clay and David both have the same boundary, they have the same size and extension in physical space. Furthermore, shapes—the external form, contours, or outline of an object—are given by the object's boundaries. We identify the shape of ordinary material objects by following the form of their boundaries. Since Clay and David both have the same surface, they have the same shape. In this case, changes in shapes of boundaries determine how Clay and David can differ in persistence condition: while the change in the shape of Clay does not destroy Clay itself, David can be destroyed by squeezing it until David's shape is gone. Therefore, there are non-sortalish features occurring in the boundary shared by two spatially coinciding objects,

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7   The emphasis is mine.

but also changes of shape —observed in objects' boundaries—can determine those objects to fall in different sortals.

Surfaces therefore play an epistemic priority role in our perceptual knowledge of ordinary physical[8] objects that gives us the characteristics that allow for us to identify their physical profiles. However, surfaces can also play a metaphysical role in the ontological profile of three-dimensional objects. To find the shape of a bulky object is just needed to find its external boundary or surface—i.e., necessarily, the object's shapes spatially match the object's surface. If so, surfaces determine the property of an object: its shape. However, are shapes extrinsic or external to objects? Skow defines that "a shape is intrinsic if it can be completely analysed in terms of the fundamental spatial relations among the parts of things that instantiate it" (2007, p. 112). So, if two collocating objects share the same boundary, they also share the same shape as an intrinsic property given the spatial parts of an object which are in direct contact with the object's spatial environment.[9]

Although the picture of material collocation looks quite mysterious not only for common-sense beliefs but also for some philosophers (cfr. Olson, 2001; Burke, 1992), it is metaphysically reasonable for others who have adopted a sophisticated solution to collocation and persistence, namely: besides spatial parts, material objects also have temporal parts.

3. Boundaries in time: the problem of persistence

As we saw above, differences in persistence conditions are often evoked to explain how two materially coinciding objects are qualitatively distinct. Persistence necessarily entails commitments to both *time* and

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[8]   See Stroll (1988) for a more detailed work on surfaces of physical things.

[9]   Skow argues that, if dualism is true, shapes are not intrinsic, i.e., an object's shape, as a property, does not depend on how the object is. In this respect, a material object would have its shape in virtue of the shape of the region of space it occupies. So, the fact that something is square-shaped does not depend on its intrinsic features, but on the region of space where it is located. This idea may lead to postulate that, since surfaces spatially match with boundaries, then boundaries also are extrinsic. However, a surface should not be fully assimilated to a shape insofar as a boundary is an entity whose existence ontologically depends on the object it belongs to, i.e., a boundary can only exist in space if and only if it is a boundary of a spatial object. If so, it is hard to argue that an object's surface must be as extrinsic as an object's shape can be.

identity: to persist entails for a very *same* object to *last from one moment to another* despite having different properties at each moment. Hirsh (1982) explains persistence as the qualitative makeup and spatial location that a material object undergoes over an extended period and how those alterations occur *continuously* (small degrees). Despite locational, qualitative, or compositional changes, you, I, and the objects around can persist in space and time continuously. However, the steadiness of the continuous changes over time undergone by material objects seems to conflict with some metaphysical concerns. One of them is what Lewis called the problem of *temporary intrinsic properties* (cfr. 1986, pp. 203-204).[10] Lewis distinguishes between *intrinsic* and *extrinsic* properties: while, regarding the former, things have them *in virtue of the way they themselves are*, for the latter, things have them *in virtue of their relations or lack of relations* to other things (cfr. 1986, p. 61). The problem of change is basically how a unique object can instantiate two intrinsic properties which are plainly incompatible.

As Hinchliff (2006) explains how a candle can be straight at some moment and bent at another, the problem of temporary intrinsic properties can be presented in four main claims: (i) the candle persists through change; (ii) shapes are properties, not relations; (iii) the candle itself has shapes; (iv) shapes are incompatible. The first claim can be taken as a common-sense fact that sets the problem to solve. The second claim assumes that properties are one-placed, while relations are many-placed. Properties such as being straight and being bent are directly possessed by the candle, requiring nothing more than the candle itself to be instantiated. Relations such as being taller than… or being brighter than… are not properties possessed by the candle itself insofar as they require something else to be instantiated. The third claim follows the second claim: the candle *itself* has different shapes. The fourth claim states the problem of change across time and the inconsistency of accepting those claims: "There can be two candles with incompatible shapes; but if the straight candle persists, it is then the bent candle. So there is only one candle with incompatible shapes, which is impossible" (Hinchliff, 2006, p. 287). Change across time is then problematic since if a candle is straight at some time and the alleged candle is bent at another time, then they cannot be the *same* candle since they differ in their intrinsic

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10   For a similar formulation of this problem, see Lewis (2006).

properties. The solution to this problem is therefore to explain how an object can have incompatible properties at different times; namely: "the demand for an account of where to locate the obvious sensitivity to time that is manifested in these sorts of property attributions" (Koslicki, 2008, p. 188).

4. Two different solutions: endurantism and perdurantism

There are two standard solutions for the problem of change over time: *endurantism* and *perdurantism*. Both have a different "sensitivity" to time (to take Koslicki's word): while endurantism conceives time as a *relation* to be found between physical objects and their properties, perdurantism conceives time as an extra *dimension* where physical objects are spread out. This distinction has a contradictory implication. According to endurantism, a physical object is a three-dimensional entity that persists by being "wholly" present at different times. According to perdurantism, a physical object is a four-dimensional entity that persists by having a succession of different temporal parts.

Let's start with endurantism. Philosophers often explain this solution to the problem of change over time saying that everyday objects have only the three spatial dimensions (length, width, and depth) and they *wholly* exist at different times. In this respect, Simons posits that "at any time at which it exists, a continuant is wholly present" (1987, p. 175); Wiggins contends that three-dimensional continuants "are conceptualized in our experience as occupying space but not time, and as a *persisting whole through time*" (1980, p. 25); Hawley explains that, for endurantists, "objects seem to 'move' through time in their entirety" (2001, p. 10); Lowe characterizes endurantism as the view in which "an object persists through time in virtue of being wholly present at every time at which it exists" (2002, p. 49); finally, Lewis, who endorses perdurantism, argues that something endures if and only if "it persists by being wholly present at more than one time" (1986, p. 202). Thus, endurantism is committed to the idea that a material object instantiates each of its properties by being wholly present at every time it exists.

Endurantism then sorts out the problem of temporary intrinsic properties by adopting the intuitive idea that a candle can be straight at t_1 and the same candle be bent at t_2. Thus, three-dimensional objects can instantiate incompatible intrinsic properties insofar as those properties are time-indexed. That is, endurantism adopts a temporally relativized

property instantiation that allows for three-dimensional objects to persist through either qualitative or compositional changes by being wholly present at some given time and wholly present at another. Given that property attribution is relativized to time, endurantism can avoid the inconsistency of incompatible properties. The endurantist proposal of change over time is thus a relational solution. The candle not only has the properties of either being straight or being bent, but it possesses them *in relation* to different times. The candle's properties are thus *related* to times in virtue of something being straight in relation to t_1 and being bent in relation to t_2.[11]

The perdurantist solution to persistence lays down that physical objects are four-dimensional entities having spatial parts as well as temporal parts. Objects do not persist *through* time by being wholly present at every moment of their existence, as endurantists have argued. Perdurantists instead contend that physical objects are *spread out* in time in a similar way as a road can be spread out in space: "Perdurance corresponds to the way a road persists through space; part of it is here and part of it there, and no part is wholly present at two different places" (Lewis, 1986, p. 202). On this account, ordinary material objects persist by having an extra temporal dimension in addition to the three spatial dimensions; "they have different spatial parts in different parts of the spatial region they occupy, and they have different temporal parts in different parts of the temporal interval they occupy" (Hawley, 2001, p. 10). Since a perduring object is temporally extended, the whole of it is the sum of each of the temporal parts or temporal slices that successively make up the object's career. Perdurantism argues for a thesis about atemporal property attribution. The strategy therefore is to deny time-indexed properties in favour of properties instantiated by temporal parts of four-dimensional objects (cfr. Lewis, 1986, p. 204). According to perdurantism, being straight and being bent are not incompatible

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[11]   A perdurantist may also not focus on the candle both having and not having a property like being straight in relation to t_1 and being non-straight (or bent) in relation to t_2, but on the *temporal way* in which the candle has its properties. That is, if the properties that the candle has are time-indexed, then the candle persists by having all its parts and instantiating *being straight in a t_1 way* and having all its parts and instantiating *being bent in a t_2 way*. This view is called *advervialism* and is endorsed by Lowe (1987), Johnston (2006) and Haslanger (1989).

properties of a candle since it is not the candle itself that is entirely straight at some time and entirely bent at another. Rather, there is a "straight" candle and a "bent" candle which are both temporal parts of the candle.

An endurantist solution to collocation may adopt the *material constitution* answer: Clay and David are constitutionally related. Although constitutionalists do not often explain what a constitution relation is, they seem to agree on what constitutes what in some cases: persons are constituted by bodies, statues are constituted by lumps, cardigans are constituted by threads (and not vice versa) (cfr. Olson, 2001). There are several puzzles about material objects, such as the ship of Theseus, Dion and Theon,[12] Tibbles the Cat (the body-minus problem), the paradox of increase (the Debtor's Paradox),[13] or the Statue and the Clay, all of which are instances of the problem of material constitution (cfr. Rea, 1995),[14] i.e., the different ways that composite things and their parts can be materially related to each other. Regarding David and Clay, the former is *constituted* by the latter insofar as Clay is a determined quantity of masses of matter that makes up David. Material constitution is thus understood as both *irreflexive* and *asymmetric*: nothing can constitute itself, and while Clay constitutes David, David does not constitute Clay.

Material coincidence then occurs when one object constitutes another object and *constitution is not identity*,[15] i.e., when the *constituting object* and the *constituted object* differ in some qualitative respects but coincide in others. Clay and David have the same parts at the same time and share all those physical properties that supervene on the atomic grid shared by them. So, according to the endurantist point of view, the coincidence between Clay and David occurs when they simultaneously share a boundary of a three-dimensional region of space where—within it—the same configuration of matter instantiates different time-indexed

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[12]   For an explanation of this puzzle and its possible solutions, see Burke (1994).

[13]   For an explanation of this paradox and its possible solutions, see Olson (2008).

[14]   For an explanation of each of these puzzles and a general view of the topic of material constitution, see Wasserman (2018).

[15]   See Johnston (1997) and Baker (1997) for those ones who support the thesis that constitution is not identity.

properties borne by both Clay and David which are constitutionally related, and constitution does not entail identity.[16]

One of the reasons often given by perdurantists to accept four-dimensionalism is that the metaphysics of temporal parts offers an elegant and unified theory to solve the puzzles of material coincidence (cfr. Heller, 2008; Sider, 2001, 2008).[17] Although endurantism may adopt a constitutionalist answer, the constitution relation does not seem clear to many philosophers yet. Nonetheless, perdurantism adopts a metaphysics that that does need to deal with the troubles of collocation: Clay and David are not made of the same parts, they rather are *spacetime worms sharing some of their temporal parts*. Both Clay and David are material objects filling up four-dimensional regions of spacetime and they are not identical since the former has a longer temporal career than the latter. The coincidence of Clay and David is just a partial overlap of temporal parts "and partial overlap is metaphysically innocent (who would raise question about roads partially overlapping?)" (McGrath, 2007, p. 164).

5. Criticisms of four-dimensionalism

Four-dimensionalism can be seen as a "radical" solution to the problem of material collocation and temporal persistence (Olson, 2002). In fact, it challenges the common-sense view of how ordinary material objects are related to space and time. Some philosophers have raised objections to the metaphysics of temporal parts. For instance, McGrath points out that four-dimensionalism overpopulates the world since "within the temporal boundaries of any ordinary object there reside countless objects" (2007, p. 171). Given that the fundamental objects accepted by four-dimensionalism are temporal parts and every single change in properties is instantiated by different temporal parts, then the world is crowded with many temporal slices everywhere. That is why Thomasson characterizes four-dimensionalism as a "crazy metaphysics"

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[16]   Given the different sortalish properties between two constitutionally related objects and the application of the Leibniz's Law, according to which necessarily, for every x and every y, x and y are identical only if every property of x is also a property of y (and vice versa), *viz.*, $\Box\forall x\forall y[x=y\rightarrow\forall F(Fx\leftrightarrow Fy)]$, David and the Clay that constitutes it are two spatially coinciding objects.

[17]   For a critical view about four-dimensionalist solutions to the problem of material coincidence, see Moyer (2009) and McGrath (2007).

(2007, p. 78) in which just by having on our hands an ordinary material object, many objects (temporal parts) are constantly coming into existence *ex nihilo* at different times.[18] However, I will not focus on this kind of objection, but on two problems arising from an account of the boundaries of four-dimensional things taken from Heller's view.

5.1 Modal boundaries

According to Heller's four-dimensionalist account, objects have *spatial*, *temporal*, and *modal* boundaries in virtue of the *places* where they exist, the *times* at which they exist, and the *worlds* where they exist. To talk about 'modal boundaries' is not as clear as to talk about boundaries in space and time. However, it seems to be meant that an object can be spread out across possible worlds as much as they can exist in multiple locations in space or at different moments in time. It thus refers to whether an object has some of their properties essentially, i.e., whether it has them at every world it exists or not: "Asking about a thing's modal boundary is really just to ask about its essential properties. This is analogous to the fact that asking about a thing's temporal boundaries is, in effect, to ask about its persistence conditions" (Heller, 2008, p. 72).

For instance, the Taj Mahal is a building that has an extension determined by its spatial boundaries, a duration determined by its temporal boundaries, and some essential properties determined by its modal boundaries. In modal terms, there are many worlds at which the Taj Mahal has different properties from those ones it actually has. There are worlds where the Taj Mahal is green, with six minarets, having a bigger extension than seventeen hectares, and built in the 15th century in less than three years. As long as the Taj Mahal, as a four-dimensional object, is the mereological sum of its spatiotemporal parts, in modal terms, it can be also taken as the sum of all the possible worlds at which it exists. Therefore, as a modal object, every part of the Taj Mahal is the possible world at which the Taj Mahal exists having different properties from the given Taj Mahal without stopping being itself. In this respect, the Taj Mahal's modal boundaries are given by those essential properties that determine the worlds which are not metaphysically possible for the Taj Mahal to exist in without possessing such properties. For

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[18]   For a reply to Thomasson's attack to temporal parts, see Sider (2001, pp. 216-218) and Heller (2008, pp. 16-19).

instance, if for every world at which the Taj Mahal exists it cannot do so having a different atomic composition than it actually does, then that metaphysical condition sets the modal boundary where the Taj Mahal's modal extension stops (i.e., the sum of worlds which are metaphysically possible to postulate for the object).

Possible worlds, in Lewis' view, should be taken as concrete universes spatiotemporally disconnected from our own actual world. He makes clear this point:

> The worlds are something like remote planets; except that most of them are much bigger than mere planets, and they are not remote. Neither are they nearby. They are not at any spatial distance whatever from here. They are not far in the past or future, nor for that matter near; they are not at any temporal distance whatever from now. They are isolated: there are no spatiotemporal relations at all between things that belong to different worlds. Nor does anything that happens at one world causes anything to happen at another. Nor do they overlap; they have no parts in common, with the exception, perhaps, of immanent universals exercising their characteristic privilege of repeated occurrence (1986, p. 2).

If the Taj Mahal is modally composed of world parts which are fully disconnected from each other, how can such an object be composed of transworld parts if each of them are spatiotemporally isolated from each other? One way to make sense of a transworld individual and, therefore, the idea of things having modal boundaries taken from Heller's view, is to endorse an ontology of what Cartwright (1975) called "scattered object": the existence of composite objects having disconnected parts (i.e., parts which do not overlap), such as the solar system or the Indonesian archipelago. If this kind of objects exists, then we may posit that a transworld individual is a modally scattered object such that it has disconnected world parts and each of them is identical to the spacetime region it occupies. In this respect, the Taj Mahal has a world part in which it has six minarets that exists in a region of spacetime fully disconnected and isolated form the region of spacetime occupied by the actual Taj Mahal as much as the Indonesian archipelago is composed by many small islands fully separated from each other by portions of water.

Just like a four-dimensional object is not wholly present at a time, a transworld object is not wholly present at a world. So, the whole existence of the Taj Mahal is not just all its spatiotemporal parts, but also the total sum of the worlds in which it exists. Material objects would not only have a spatiotemporal career, but also a transworld career. Therefore, for any material object x, to have a modal boundary involves the following:

> 1. x has boundaries in all dimensions, and modality should be taken as one of them besides the spatial and temporal ones.
>
> 2. x has spatiotemporal parts as much as world parts.
>
> 3. A world part is a world in which x exists having different properties from those x actually has.
>
> 4. x does not fully exist in one world, but in every world where x has some property different from x's current properties.
>
> 5. There are essential properties which are possessed by x at every world it exists in which determine the boundaries of x's modal extension.
>
> 6. x is a modally scattered object and its whole existence is the sum of all its disconnected world parts.

Although Heller's account of four-dimensional hunks of matter does not explicitly take modality as an extra dimension, it does insofar as it takes modality as a kind of boundary. In fact, boundaries determine the dimensions where material objects are spread out: if an object has boundaries in space, then it has extension in two or three dimensions; if an object has spatiotemporal boundaries, then it has extension in four dimensions; thus, if an object has boundaries in space, time, and worlds, then it has extension in five dimensions by taking modality as an extra

dimension.[19] The idea of a material object as a transworld individual can be very controversial (as much as perdurantism can be). Indeed, (6) is quite doubtful insofar as the analogy between scattered objects in spacetime and scattered object across possible worlds is not clear at all. The Indonesian archipelago is a composite scattered object since each of its non-contiguous parts are spread out in the same spatiotemporal dimensions insofar as they exist in the same world. Instead, a transworld individual is a composite object whose world parts do not exist in the same spatiotemporal dimensions. They exist in neither distant nor far away worlds, but, literally, in other parallel worlds which are much like the actual world and yet metaphysically distinct. Therefore, it is hard to argue how those parts bear spatiotemporal relations to one another if their parts do not share the same spacetime. If so, the sort of disconnection of scattered objects across worlds cannot be directly assimilated to the sort of disconnection of scattered objects in spacetime. For a transworld composite object, being a scattered entity does not seem to be metaphysically enough to resolve how can such kind of entities exist.

Unlike transworld composite entities, Lewis' counterpart theory is committed to ordinary physical individuals which wholly exist in just one world. However, since they do not have all their properties essentially (i.e., they could have been otherwise), the theory says that every object having modal properties has its counterparts, that is, a sort of replica that exists in a possible world: a parallel entity identical at least in the relevant aspects regarding the alleged world-bound entity. If so, the Taj Mahal only exists in the actual world, but it might be built in a different place than India in virtue of the modal fact that there exists a possible world at which a building just like the Taj Mahal is not located in India. Unlike Heller's four-dimensionalism, this proposal is neither committed to the idea of modal boundaries nor, therefore, to the existence of transworld individuals having world parts. By taking Heller's view

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[19]   See Yagisawa (2010, chap. 6), who has endorsed this view in which modality is taken analogously to the perdurance account of identity over time. In this case, ordinary material beings are extended over possible worlds by having not only spatial and temporal parts, but also modal stages where the very same thing has different properties in each of them. Therefore, the parts composing a material object cannot only be tracked in space and time, but also in each of the possible worlds where that object exists.

of modal boundaries, if we are willing to accept the existence of four-dimensional objects, the acceptance of transworld objects should not be too hard a metaphysical step to take. So, the idea of modal boundaries that comes from a perdurantist metaphysics of ordinary material things can lead us to further ontological commitments which can be difficult to keep safely.

5.2 Essential boundaries

Modality basically is about how an object exists, i.e., whether some of its possessed properties are essential to it or not. For an object, having essential properties entails that it is how it is by necessity: it could not have existed otherwise. In this respect, Heller's account of modal boundaries takes four-dimensional hunks as entities having its *spatiotemporal boundaries essentially*. That is, there is no possible world where a four-dimensional hunk exists having different spatiotemporal boundaries from those it actually has. Every world part of such kind of object instantiates the very same boundaries and the properties associated with them:

> The temporal boundaries of *four*-dimensional hunks are not selected by us. […] A given four-dimensional object goes out of existence at the time that it does because the object's boundaries are its defining characteristics. […] It is because of the nature of a four-dimensional object that it has just those spatiotemporal boundaries and no others. A four-dimensional hunk that is now one cubic meter, could not have now been any other size. Any hunk of a different size at this time would have had different spatiotemporal boundaries, and, hence, would have been a different hunk. Therefore, a four-dimensional hunk of matter, by its very nature, has its spatiotemporal boundaries essentially (2008, p. 53).

Talking about boundaries involves a talk about vagueness. The physical extension of a material object can be said to be vague when there is no clear stopping place between the object and its spatial environment. A cloud, for instance, is a vague object insofar as there are portions of droplets and frozen crystals such that it is indetermined whether they are parts of the cloud or parts of the cloud's environment. Similarly, the

temporal boundaries of the cloud can be vague if there is no clear cut to determine when its existence begins and when it finishes. For instance, it might be vague when the cloud comes into existence in the vaporization process and when goes out of existence in the sky due to the winds and atmospheric conditions. Modally speaking, boundaries can also be vague if there are properties such that it is undetermined whether they are essential for an object or not. There are many worlds where a cloud has different shapes other than the one it actually has, but there might be some world where a specific shape makes metaphysically unclear whether the cloud maintains its existence or not. Wherever vagueness might come up, a boundary zone can be found there.

According to the literature, vagueness is usually taken to be sourced in language, knowledge, or the world itself. That is, the cloud can be said to be vague because either our predicates are semantically imprecise, we ignore where the cloud's precise boundary is, or the cloud itself has imprecise boundaries. Four-dimensional hunks of matter, following Heller's account, are not ordinary objects having imprecise and arbitrary boundaries; they exactly fill determined regions of spacetime having their boundaries essentially. Clouds, the Taj Mahal, trees and every ordinary material object are conventional things having conventional boundaries and their vagueness or sharpness come from either our linguistic agreements or our lack of knowledge. Our decisions and preferences design in different ways not only the spatial and temporal boundaries of such kind of object (i.e., their persistence conditions and material configuration), but can also determine their modal boundaries, i.e., the properties which are meant to be essential to them. According to Heller's proposal, four-dimensional hunks of matter are the ontological stuff that does not depend on the arbitrariness of our conventionality and, therefore, the vagueness that might come from it; they are the genuine ontological items of the world having mind-independent and sharp spatiotemporal boundaries.

Heller's account accepts a moderate nihilism in which there are no everyday material objects as individual things to be logically quantified, but only four-dimensional stuff or lumps of matter in different quantities having sharp and essential spatiotemporal boundaries. The world as we find it, according to this view, is not a vague place. Their spatiotemporal location is ontologically given by the sharpness of the boundaries of the spacetime region they fill up. Given that they have their spatiotemporal boundaries essentially, there are no possible worlds where they could

have existed in a different way: the region of spacetime occupied by four-dimensional stuff has all the properties it has necessarily. In this respect, insofar as Heller's account of essential spatiotemporal boundaries does not only take a commitment to trasnsworld entities, but also to supersubstantivalism. While substantivalism is the view that there are regions of spacetime which are distinct from the material objects that occupy them, supersubstantivalism is the claim that a material object is identical to a spacetime region.

If a four-dimensional material object is such that, according to Heller, it takes time, space, and modality to determine its boundaries, it has an identity relationship with the region of space it occupies. A material object, in this view, is spread out in the spacetime having unchangeable boundaries in terms of the space it occupies, the time it lasts, and the worlds in which it exists. So, the boundaries of a material object are, in fact, the boundaries which are ontologically found in the spacetime, and not those conventionally found in the preferences or choices of linguistic agreements, sensory perceptions, and mental representations. If the boundaries of a material object are the boundaries of the spacetime region it essentially occupies, then this can be taken as an identity relationship between the object and the spacetime region where it is found necessarily. Put it differently, given an identity relationship between boundaries, a hunk of matter *is* a four-dimensional region of spacetime.[20] This essentialism must be thought as a *de re* identity relationship:

> For any x and R, if x is a material object and R the region of spacetime that x occupies, then x is *necessarily* identical to R.

A hunk of matter is not just identical to a spacetime region in virtue of a *de dicto* relationship, i.e., for any material object x, there is some region of spacetime that is identical to x. Given Heller's commitment to essential boundaries in which a four-dimensional hunk of matter exists having its spatial extension, temporal persistence, and modal properties it necessarily has, a material object necessarily *is* the very region of spacetime that occupies in virtue of a *de re* ontological identity relationship.

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[20]   See Schaffer (2009) for a supersubstantivalist and monist account of material objects as spacetime regions.

Taking Heller's view as a *de re* supersubstantivalist account, a hunk of matter does not bare a fundamental relation with spacetime as the substantivalist account does. Instead, the acceptance of a the supersubstantivalist thesis of material objects is a more parsimonious ontological commitment. In this view, there is no fundamental relation between material objects and spacetime since material objects *are* the region of spacetime where they are spread out: there is no ontological distinction between them. Although this entails that it is not necessary to increase the number of fundamental relations in the world, it does entail that an object has the boundaries it has essentially to the extent that it is necessarily identical to the very region of spacetime where is specially, temporally, and modally found. If a material object necessarily is the region of spacetime where it is found, then it cannot be found elsewhere than where it is found. This supersubstantivalist view can be put as follows:

1. x is a material object that occupies the region of spacetime R.

2. x is identical to R.

3. (2) means that if x occupies R, then x necessarily *is R*.

4. If (3) is true, then x's boundaries necessarily are R's boundaries.

5. x has its boundaries essentially if supersubstantivalism is true.

This view also entails mereological essentialism. If a stuff of matter has its boundaries essentially in virtue of being identical to the region of spacetime it occupies, then it has all its parts necessarily. For such kind of object to lose or gain a part entails changing its spatiotemporal boundaries. However, if a four-dimensional object changes its spatiotemporal boundaries, then its boundaries are not essential to it. From a supersubstantivalist view, each of the parts that an object is composed of are identical to each of the subregions of spacetime they exactly occupy. So, necessarily, any change in the mereological structure of a four-dimensional object entails a change of its spatiotemporal boundaries and, therefore, its annihilation.

On the other hand, according to substantivalism, a property relation must be held between a material object and the region of spacetime it occupies; there must be a necessary connection between the properties of the former and the properties of the latter. For instance, it is necessary that a square-shaped object occupies a square-shaped region of space. However, if material objects and space are ontologically independent, then why should we accept such kind of necessary property relation between objects and space? Supersubstantivalism does not need to give an explanation: if the object is identical to the spacetime region it occupies, then both share the same properties as much as Batman and Bruce Wayne share the same DNA. This view can be put as follows:

1. x is a material object that occupies a region of spacetime R.

2. x is identical to R.

3. Given the principle of the identity of indiscernibles, (2) means that x and R are identical since every property possessed by x is also possessed by y, and vice versa.

4. If (3) is true, then, necessarily, for every dimension that x has a boundary, R has the same boundaries.

5. Therefore, x has its boundaries essentially if supersubstantivalism is true.

Heller's definition of four-dimensional hunks of matter having their boundaries essentially has led us to accept a supersubstantivalist thesis. The expression "having boundaries essentially" basically means that a material object *is* a spacetime region and, given that identification, each of its spatial, temporal, and modal properties are possessed necessarily. Therefore, unlike conventional objects, a four-dimensional object is an ontological item of the world that has an exact location insofar as it is identical to the region of spacetime where is found. This supersubstantivalist proposal discards the possibility of multilocated material objects: since it is a necessary truth that a material object is identical to any exact location it might have, and it is metaphysically impossible for something to be identical to two different entities (two locations), then it is not possible for an object to have two different exact

locations. Therefore, necessarily, a four-dimensional hunk of matter can only be exactly located where its spatial boundaries are found. Since time is a further dimension added to the three spatial dimensions, a four-dimensional object has its exact temporal boundaries, so, necessarily, it lasts what it lasts. Similarly, if the temporal boundary of an object refers to its temporal properties, the modal boundaries refer to its modal properties. If a four-dimensional object has its exact spatiotemporal boundaries necessarily, then its modal boundaries too; so, the properties that it instantiates as much as the worlds at which it exists can only be those ones. Consequently, for a four-dimensional object, the fact that its boundaries are essential to it entails that its spatial location, duration, and properties cannot be otherwise.

Heller's version of four-dimensionalism therefore maintains that the atemporal conception of parthood is held by necessity. If a temporal part is part of a spacetime worm, it is essentially part of it. The world (beyond our conventionality) consists of a huge number of hunks of matter filling up sharply bounded regions of spacetime having their spatiotemporal boundaries essentially.[21] This essentialist account about boundaries of four-dimensional objects is close to Sider's definition of a temporal part:

> x is an *instantaneous temporal part* of y at instant $t =_{df}$ (1) x exists at, but only at, t; (2) x is part of y at t; and (3) x overlaps at t everything that is part of y at t (2001, p. 59).

Sider's definition captures the idea that a temporal part of a four-dimensional object exists only at the precise instant at which it is part of that four-dimensional object and overlaps any other part that the object has at *that* instant. There is however a modal difference between Heller's account of essential boundaries and Sider's definition of temporal parts. This can be formulated as a *de dicto* modal claim: *necessarily*, every four-dimensional object has a temporal part at every instant at which it exists. On the other hand, Heller's essentialist view on boundaries of spatiotemporal objects demands a *de re* modality of temporal parts:

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21   Jubien also posits that the fundamental objects are four-dimensional worms which have their temporal boundaries essentially; but, unlike Heller, he conceives their spatial boundaries accidently: "The thought that a thing's *spatial* boundaries might have been different was in essence the product of an everyday intuition that we have chosen not to abandon. […] Now, in contrast, we have chosen to regard a thing's *temporal* boundaries as essential" (1993, p. 33).

every four-dimensional hunk of matter *necessarily* has the temporal parts it has at every instant at which it exists. This is what encourages van Inwagen's attack to perdurantism, who contends that the metaphysics of temporal parts entails *modally inductile* objects. Van Inwagen presents the argument as follows:

> If there are objects of the sort the [worm-theorist] calls temporal parts, then their temporal extents must belong to their essence. […] If [the worm theory] is correct, then Descartes is composed of temporal parts, and all temporal parts are modally inductile. But Descartes himself is one of his temporal parts—the largest one, the sum of all of them. But then Descartes is himself modally inductile. Which means he could not have had a temporal part extent greater than fifty-four years. But this is obviously false, and [the worm theory] is therefore wrong (2001, p. 119).

The problem of modal inductility is that, as we said above, it implies *four-dimensional mereological essentialism*, *viz.*, temporal worms possessing the temporal parts it is composed of essentially. Temporal parts exist at a time and only at *that* time: a temporal part of a four-dimensional object could not have existed at a time different from that at which it actually exists. Descartes is a four-dimensional object, i.e., it is never wholly present at a given time since it is an aggregate of temporal parts. Following van Inwagen's argument, Descartes is composed of temporal parts whose boundaries are held essentially, so the temporal part in which Descartes wrote the *Discourse on the Method* could have not been otherwise as it in fact was. The temporal part Descartes-writing-*Discourse-on-the-Method* is therefore modally inductile. The sum of the modally inductile temporal parts of Descartes could not have been temporally longer or shorter than they actually are. If Descartes is identical to the sum of its temporal parts, then Descartes *essentially* lived fifty-four years having all the properties he had. Hence, Descartes has its temporal boundaries essentially: its temporal career could not have been otherwise. However, this is false: Descartes could have lived longer or shorter; even more, Descartes could have existed without the temporal part that instantiates the property being-a-philosopher. As van Inwagen claims: "If there are philosophers who think that temporal parts have their temporal extensions and their careers essentially, I can't

see how what they believe could be true" (2001, p. 133). To say that everything happens essentially seems to be an absurd consequence of perdurantism.[22]

This leads us to another problem with four-dimensionalism. Unlike a constitutionalist answer to the coincidence puzzle taken by endurantists, perdurantism is not committed to the idea that, for instance, Clay and David are objects sharing all their parts. The problem with constitutionalism is that it is not clear at all how two objects physically identical to each other at some time can yet differ qualitatively at that time. Four-dimensionalism is not supposed to deal with that problem because Clay and David do not coincide, it is just that *some* of their temporal parts overlap. However, four-dimensionalism must still deal with a similar problem if we think of two perduring objects that share *all* their spatiotemporal parts. That is, imagine that God creates David *ex nihilo,* and, at some later time, she annihilates it: both David and Clay come into existence and go out of existence exactly at the same time. In this case, according to four-dimensionalism, David and Clay would be two coinciding spatiotemporal worms sharing not only *some* of their temporal parts but *all* of them. They would exactly fill the same four-dimensional region of spacetime and, therefore, share the same spatiotemporal boundaries. What now puzzles four-dimensionalism theorists is just what puzzles constitutionalism. Despite David and Clay being made of the same configuration of spatiotemporal parts, they yet differ in their modal properties and persistence conditions. Is this not a similar objection to that of which endurance theorists who adopt constitutionalism are accused? It looks inconsistent to say that Clay and David are identical (given that they share all their spatiotemporal parts) if the former could survive squashing but the latter could not. This is what Olson (2007, p. 111) calls the *problem of modal incompatibility*.

As we know, Heller takes a radical solution in which four-dimensional objects are such that they have their spatiotemporal boundaries essentially. If David and Clay share the same boundaries and they have them essentially, then, necessarily, they share the very same persistence conditions, location in spacetime, and worlds in which they exist. Thus, the problem of modal incompatibility is solved

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[22]   See Sider (2001, 218-224) and Hawley (2001, 191-194) for more details about four-dimensionalist responses to van Inwagen's objection of modal inductility.

by assuring that two alleged coinciding spatiotemporal objects share a boundary that is essential to them and, therefore, no modal differences can be seen. Hence, if David and Clay have the same boundary essentially, then David and Clay are essentially identical: they have neither physical differences nor metaphysical differences. So, while van Inwagen argues that perdurantism entails *modally inductile* objects, i.e., objects which cannot be otherwise, taking Heller's view, objects cannot be otherwise since they have their boundaries essentially; and so, if two four-dimensional objects share the same boundary, then they cannot be *modally incompatible* objects. They would instead hold an identity relation.

However, the option that settles the problem of modal incompatibility by accepting things having essential boundaries seems to pay a high metaphysical price. It does not look metaphysically preferable to settle the problem of modal incompatibility by endorsing, as it were, an ontology in which the world consists of spatiotemporally "frozen" hunks of matter. A perdurance theorist might rather answer to the inductility objection by adopting a counterpart-theoretic account of modality inspired by Lewis' modal thesis. A modal counterpart can be understood as follows:

> A modal counterpart x of an object y in a world w is an object that resemblances y in w in so many relevant aspects such that x should be considered a genuine version of y itself in w.

In the case of Descartes, there are two counterpart relations: one is a *person* counterpart relation and other a *temporal-part* counterpart relation in which Descartes himself is a temporal part, but the largest one that fuses every proper temporal part of Descartes. As Olson (2007, p. 111) explains, this entails that there are no unqualified modal properties but only qualified or kind-relative modal properties. This is traditionally put as follows: given that Descartes is both a person and a temporal part, Descartes, *qua* temporal-part, could not have had either greater or lesser temporal extent, whereas Descartes, *qua* person, could have had a different temporal extent. So, on the one hand, x is a modal counterpart of Descartes *qua* temporal-part in a world w only if x resembles Descartes in w in the relevant aspects of having exactly the same temporal extension of Descartes. On the other hand, x is a modal counterpart of Descartes *qua* person in a world w only if x resembles Descartes in w

in the relevant aspects that define what is for something to be a person (whatsoever they might be); x could therefore have a longer or shorter life than Descartes (or even have a different biography), but to the extent that x meets the relevant aspects that define what it is for something to be a person, x can be treated as a modal counterpart of Descartes, but only Descartes *qua* person.

Thus, a four-dimensional object O, *qua* temporal-part, has its *spatiotemporal boundaries* essentially since O's modal counterparts cannot differ from O's temporal extent. However, O, *qua* some kind K (that is not a temporal-part), does not have its spatiotemporal boundaries essentially; but, so to speak, essentially, O has the boundary that determines what falls under K and what does not. If a metaphysics of temporal parts is a radical and strongly counterintuitive theory to be accepted, to add a modal counterpart-theoretic account makes everything even harder to swallow, as we saw above. So, if four-dimensionalism entails either considering the idea of essential modal boundaries, mereological essentialism, or accepting a metaphysics of modal counterparts, then, for some philosophers (cfr., e.g., van Inwagen, 2001), it is a good and sufficient reason to deny perdurantism.

5.3 Do temporal boundaries resemble spatial boundaries?

Four-dimensionalism is a revisionist theory that gets rid of everyday material objects. Particularly, Heller's view only posits hunks of matter which, according to a supersubstantivalist interpretation, are identical to the spacetime regions they occupy. That is, the genuine furniture of the world is not composed of chairs, trees, or planets, but of lumps of matter which *are* four-dimensional spacetime regions. For perdurantism, the cost of giving up our common beliefs about material beings is not high insofar as the way the theory solves some metaphysical puzzles seems to be simpler and efficient. Thus, one of the main reasons often invoked by perdurantists to underpin four-dimensionalism is the *analogy argument*: being spread out in space is as much as being spread out in time. Heller contends that "insofar as time is just one more dimension, roughly alike in kind to the three spatial dimensions, we should expect that our claims about an object's spatial characteristics have analogues with respect to its temporal characteristics" (2008, p. 5). On the other hand, Sider acknowledges that "the heart of four-dimensionalism is the claim that the part-whole relation behaves with respect to time analogously to how it behaves with respect to space" (2006, p. 59). The analogy argument

seems to be a fundamental piece in the perdurance conceptual device to explain temporal persistence: if it is not the case that time is a dimension where objects are physically extended similar in many aspects to space, then four-dimensionalism fails.

The similarity between spatial and temporal characteristics is well expressed by Quine: "physical objects, conceived thus four-dimensionally in space-time, are not to be distinguished from events or, in the concrete sense of the term, processes" (1960, p. 156). According to this view, ordinary physical objects *literally* are events which are materially spread out in time. There is no ontological distinction between objects and events; four-dimensional objects are sums of temporal slices composing temporal processes. We do not thus perceive plain physical objects, but material events or processes which are neither abstract nor mental objects. A physical object not only is located *here* rather than *there*, but also *begins at t* and *finishes at t+1*. And the other way around regarding events such as a musical concert: it not only begins and finishes at some given times but also takes some region of space rather than another.

The four-dimensionalist view does not take time as a dimension separated from space. As we have seen with Heller's perdurantist account, dimensionality is directly related to boundaries, so that a material object can exist in four dimensions (taking time as one of them) if and only if it has a boundary for each of them. In this view, temporal boundaries are not separated from spatial boundaries: they must come together to specify the dimensions where material beings exist. Since abstract objects (e.g., properties, propositions, relations, etc.) and mental entities (e.g., ideas, sense-data, thoughts, etc.) do not have boundaries (at least, not as clear as physical and temporal objects do), they cannot take any space or time. Therefore, although boundaries take neither space nor time for themselves (they are ontologically dependent entities), objects can only exist having some spatial or temporal dimension if they have a boundary. Dimensionality therefore is a relevant factor to regard objects and events as different sorts of ontological categories. As Hacker writes:

> Objects are not 'cross sections' of events, and events are not kinds of objects. […] For events do not occupy space as objects do, hence are neither two-dimensional nor three-dimensional. While many events need space to take place, they do not themselves have any spatial *dimensions* (1982, p. 7).

Hacker argues against the treatment of objects and events as similar entities. In his view, objects and events belong to different ontologies despite the analogy argument defended by perdurantism. The main idea, as I see it, is that time cannot be reduced to the dimensionality of space. The main argument about this point is that temporal boundaries cannot be fully assimilated to spatial boundaries; if so, it is hard to argue how spatial and temporal things can be part of a same ontology. Perdurantists take this for granted insofar as they find more similarities than differences between objects and events in virtue of their boundaries, so that the analogy argument "allows us to understand the notion of temporal boundaries as analogous to that of spatial boundaries" (2008, p. 6). However, according to Heller's view, if boundaries are essential to four-dimensional hunks of matter, then it a specific explanation of how temporal and spatial boundaries can be taken in the same kind of ontology is begged. If there are good reasons to resist the analogy between temporal and spatial boundaries, then there also are good reasons to resist the analogy argument presented by perdurantism.

Taylor (2006) defends the analogy argument from a set of claims that emphasizes different dissimilarities between space and time. For example, an object cannot be in two places at once, but it can occupy two or more times at only one place; things can change their spatial positions, but not their temporal ones; time is something moving or flowing, but space is unchanging; or a thing can move either backward or forward in space, but it cannot do so in time. Although Taylor gives an answer to all those objections and others, I would like to focus on another sort of dissimilarity between space and time not considered by Taylor. However, I will offer some arguments to show that spatial boundaries and temporal boundaries do not resemble each other so clearly.

Dissimilarities between spatial and temporal boundaries are fundamentally given by dissimilarities between the objects they ontologically depend on. Perdurantism theorists would say that both spatial and temporal boundaries belong to the same kind of things: four-dimensional objects. If ordinary material objects such as tables, chairs, planets, animals, or people are spread out over time as well as they are in space, then the boundaries of such kind of things should not make a distinction between spatial and temporal boundaries. Nonetheless, I will present some ideas to reject this four-dimensionalist view on boundaries:

(a) *A fundamental difference between spatial and temporal boundaries is given by the kind of object they belong to.* Spatial boundaries are found where some object occupies a place in space. Ordinary material objects such as trees, billiard balls, and tables are found in physical space, so they have ordinary boundaries which are found where those objects are found in physical space. Many of the physical features (e.g., colours or textures) and physical phenomena (e.g., light reflection or physical damages) attributed to them often occur on their external boundaries or surfaces. On the other hand, temporal boundaries seem to belong to different sorts of things which are not concrete at all. We may talk about temporal boundaries by referring to *events* of different sortsm such as processes, procedures, biographies, stages, periods, ages, epochs, and so on. Unlike physical objects, which can have different *locations* in space, events *happen* or *occur* in time and only at some given time. A table can be located in different places at different times, but WW2 happened once from 1939 to 1945 and only during that particular period of time. Whereas spatial boundaries demarcate *where* the spatial extent of physical objects ends, temporal boundaries demarcate *when* the temporal extent of events either starts or stops; nothing of an event occurs before its starting point and after its stopping point. However, temporal boundaries of events do not have the physical features and cannot undergo the physical phenomena that can be attributed to boundaries of physical objects (i.e., surfaces). It seems nonsensical to say that the WW2 has a red boundary in a similar way as a table might have a red surface. Thus, spatial and temporal boundaries are found in several objects: objects having a location and objects having a duration; objects which are *placed somewhere* and objects which *occur sometime*. Although ordinary material objects have temporal duration (they exist for a while) and can be part of events (e.g., a rifle shot during WW2), they have some features held by their ordinary spatial boundaries (or surfaces) which cannot be held by the temporal boundaries of events in which they can be part.

Endurantism contends that ordinary physical objects fill up three-dimensional regions of space at different times. So, for any object, to exist along a three-dimensional space entails having a two-dimensional boundary (or surface); a two-dimensional object has a one-dimensional boundary (lines); a one-dimensional object has zero-dimensional boundaries (points). So, boundaries always have a lower spatial dimensionality than the objects they belong to. What

about four-dimensional objects? If zero-dimensional entities (points) are boundaries of one-dimensional entities (lines), one-dimensional entities are boundaries of two-dimensional entities (surfaces), and two-dimensional entities are boundaries of three-dimensional entities (bodies), then three-dimensional entities should be the boundaries of four-dimensional entities (perduring objects). If (i) time is an additional dimension for bodies (i.e., physical objects do not only have boundaries along the three traditional dimensions of space but also along an extra temporal dimension) and (ii) objects that fill spacetime regions cannot exist without having a boundary (just like the spatial existence of three-dimensional objects depend upon having some boundary), then for any four-dimensional entity, there must be some three-dimensional entity that is its boundary. This entails that three-dimensional entities should be boundaries of four-dimensional objects.

This is quite an odd picture. Just as a three-dimensional object has a boundary that cannot be divided into three-dimensional parts (since surfaces only have boundaries along length and height), a four-dimensional object should have a boundary that cannot be divided into four-dimensional parts. If boundaries always have a lower dimensionality than the objects they belong to, then boundaries of four-dimensional objects cannot be four-dimensional entities, but beings that can be divided into three-dimensional parts. We can understand this as an analogy with events or processes by saying that the beginning and the end of a perduring object are durationless three-dimensional entities, i.e., atemporal bulky objects. However, we have again the odd picture in which just as the boundaries of a three-dimensional object are the collection of those simple parts in contact with the object's surroundings, the boundary of a four-dimensional object should be the collection of durationless three-dimensional parts in contact with the object's spacetime surroundings. Perhaps these views can be right according to a theory of what boundaries are and the kind of ontological dependence that boundaries and objects have, but it still seems to be a quite strange picture.

(b) *Unless they are points, spatial boundaries can be divided into parts; temporal boundaries cannot.* Since points are zero-dimensional boundaries, they cannot be divided into further parts. Unlike points, while lines can be divided into segments along their one-dimensionality, surfaces can be divided into parts along their two-dimensionality. On the other hand, temporal boundaries seem to be durationless. Events have some

duration; they last for a while. Events can be divided into temporal parts: during WW2, from the 10th of May to the 22nd of June of 1940, the "Lighting War" occurs when Germany took control of most of Western Europe. The "Lighting War" is a part of WW2 that happened during some particular period of time and can be studied in its different moments. However, boundaries of events—beginnings and endings—do not have temporal parts because they do not last; they are temporally indivisible instants. Someone might object, however, that either beginnings or endings of events can be long processes. For instance, Germany's invasion of Poland is often pointed out as the beginning of WW2. The invasion was not an instant, but an internal event (the starting event) of WW2 which happened during 1939. Therefore, temporal boundaries of events can last for a while and have internal moments. Nonetheless, if a temporal boundary had duration, then it must have had boundaries; if these boundaries had duration, then they must have had boundaries, and so on *ad infinitum*. Hence, temporal boundaries of events cannot have temporal parts in the same way that spatial boundaries like surfaces and lines have spatial parts.

(c) *Spatial boundaries may have different dimensionality, but temporal boundaries do not.* As we have already said, spatial boundaries can have two, one, or zero dimensions. Each of these boundaries ontologically depends on higher-dimensional objects: two-dimensional boundaries are surfaces that exist as boundaries of three-dimensional (or bulky) objects; one-dimensional boundaries are lines that exist as boundaries of two-dimensional objects (surfaces); zero-dimensional boundaries are points that exist as boundaries of one-dimensional objects (lines). Thus, ordinary material objects have surfaces as boundaries separating them from their spatial surroundings; and both one-dimensional and zero-dimensional boundaries such as edges and joints can be found in the discontinuities of their surfaces. On the other hand, temporal boundaries do not have different dimensionality in time as spatial boundaries in space do; there are no boundaries having different "temporal dimensions" as boundaries having different spatial dimensions. Unlike objects located in physical space, which can have spatial boundaries of different dimensionality, events that happen in time do not have boundaries of different temporal dimensionality. Across time, there seem to be only boundaries that indicate when an event either starts or finishes. Unlike the relationship between ordinary physical objects and their boundaries, events are not "objects" having a higher dimensionality

than the boundaries they have. Temporal boundaries are durationless entities in the extremities of events and they do not differ in "temporal dimensionality".

(d) *Physical objects have one boundary (their surfaces), but events always have two boundaries (beginnings and endings).* As we said above, events can start and finish at some given times. Unless an event had an infinite duration (i.e., it has neither a beginning nor an ending) or it begins at some time but never ends, most of the events have two temporal boundaries which indicate *how long they last*. Put differently, nothing of an event happens *before* its temporal beginning and nothing of that event happens *after* its temporal ending. By contrast, objects do not have two boundaries or surfaces (or, at least, they do not have two boundaries as events have them). If a physical object is a matter-filler of regions of space, then its spatial boundary is the set of boundary-points in contact with the object's surroundings of unoccupied space. Unlike events that have two temporal extremities, physical objects have one extremity which is the collection of its boundary-points. Talking about boundaries of ordinary material objects (surfaces), material objects have a surface which is the boundary that indicates *where* an object's physical extension terminates; *where*, beyond that boundary, nothing of what composes that object can be found. Thus, while two temporal boundaries are required for an explanation about how events have temporal extent, only one spatial boundary can be required for an explanation about how material objects have physical extent.

The analogy of space and time is a key point to support the four-dimensionalist thesis. This analogy should be taken literally and not just rhetorically. Even though we take the space/time analogy as a serious business to be endorsed, it could not rule out problems with the spatial boundaries/temporal boundaries analogy. These arguments may not be sufficient to reject the fundamental four-dimensionalist space/time analogy but can give us a leading thought: by taking the space/time analogy literally, if spatial boundaries and temporal boundaries are not alike, then four-dimensionalism has fewer chances to succeed. This divergence regarding boundaries can thus be significant to become suspicious of a four-dimensionalist metaphysics and its elegant solutions to the problem of collocation and other philosophical puzzles.

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