SPACETIME COMPOSITION, INTUITION AND FAMILIARITY

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ABSTRACT: Recent approaches to quantum gravity suggest that spacetime is not a fundamental entity but rather emerges from a non-spatiotemporal structure. To conceptualise how spacetime might emerge, it has been suggested that we should think of spacetime as being mereologically composed of spacetime regions which are in turn composed of non-spatiotemporal parts. However, Baron (2021) has argued that even if spacetime composition can be shown to be coherent, it would still be different from how we ordinarily conceive the mereology of concrete objects, and thus spacetime composition is unfamiliar. In this paper, I argue that this argument rests on the false premise that our intuitions apply equally to all domains. I then reformulate four principles that are taken to be intuitive for mereological composition. In their original formulations, these principles are violated by spacetime composition. But once reformulated, the tension with spacetime composition dissolves. I also show that these reformulations still satisfy our intuitions in the domain of everyday life but also extend beyond it into other domains. As a result, I maintain that spacetime composition is at least somewhat familiar with the potential that its familiarity will grow in the future. Therefore, there is no reason to reject it as unfamiliar.

KEYWORDS: Spacetime; Mereology; Composition; Familiarity; Intuition

INTRODUCTION

Recent approaches of quantum gravity (e.g. causal set theory, loop quantum gravity) seem to suggest that spacetime is not a fundamental entity but rather emerges at a higher level from a non-spatiotemporal structure. To conceptualise how emergent spacetime might come into being, Baptiste Le Bihan (2018 a; 2018b) has suggested that we ought to think of spacetime as being mereologically

composed of spacetime regions which are in turn composed of non-spatiotemporal parts. This framework utilises Paul's (2002; 2012) concept of qualitative or logical composition where concrete objects are composed of properties rather than of smaller concrete parts.

However, some philosophers have recently voiced their dissatisfaction with using mereological composition as a way to conceptualise the emergence of spacetime from non-spatiotemporal parts. The reason being is that *even if* spacetime composition can be shown to be coherent, it would still be radically different from how we ordinarily use mereology of concrete objects, and therefore, to say that spacetime is composed of non-spatiotemporal parts would not amount to saying much since it does not inherit the 'familiarity' of ordinary mereology.

For example, Baron (2021) argues that spacetime composition fails to meet four principles that seem very intuitive for ordinary mereology, and that this failure means that the framework of spacetime composition cannot be described as mereological, but rather as some other relation:

> ...the resulting notions of 'composition' and 'part' bear little resemblance to the common-sense notions that drive our understanding of the mereology of objects. These concepts appear to break down when they are used to model the relationship between spatiotemporal and non- spatiotemporal objects. Of course, one can always stipulate a relation that satisfies the formal axioms of mereology and maintain that it holds between spatiotemporal and non-spatiotemporal objects. But the question is whether the relation so defined deserves to be called a relation of composition. And I don't see that it does. (Baron 2021, p. 393)

In what follows, I show that Baron's argument fails because it assumes that we can infer from our intuition towards a concept (and thus our familiarity with it) in one domain into another domain where this intuition does not apply. I then reformulate the four principles that Baron provides, so that they can be met by spacetime composition thus dissolving the objection from unfamiliarity that he raises. I do not aim, however, to motivate the view that spacetime is composed of non-spatiotemporal parts but rather merely to show that such view should not be dismissed because of its supposed counterintuitivness and unfamiliarity.

THE ARGUMENT FROM INTIMACY

The first intuitive principle of mereology that Baron (2021) suggests is taken from

Sider (2007, p. 25):

Inheritance of Location (IL): If *x* is part of *y*, then *y* is located wherever *x* is located[1].

The inheritance of location can go in both directions, so upward inheritance of location goes from parts to the whole while downward inheritance of location goes from the whole to the parts. The inheritance of location poses a problem for spacetime composition since the non-spatiotemporal parts -which are obviously not located in spacetime- cannot inherit the location from spacetime regions that they compose and vice versa. But this is very different from how we usually speak about mereological composition. Minus the possibility of a very painful accident, my arm is always located where I am located. My arm inherits its spatiotemporal location from me. So, it seems very weird to say that spacetime regions are composed of parts that ***do not*** inherit their locations from those regions. This entails that spacetime cannot be composed of non- spatiotemporal parts, after all. Baron calls this the ***argument from intimacy.*** Some potential replies have been considered in the literature and they were shown to fail. I agree that they do and have nothing to add to them, so I will just state them briefly. One potential reply is to say that while there are objects that are spatiotemporally located such as books, people and trees, ***spacetime itself*** is not spatiotemporally located. This means that (IL) does not apply to the case of spacetime composition, and the argument above can be resisted. However, this is too quick. As Baron et al. (2022) maintain, we have good reason to believe that spacetime itself is spatiotemporally located since it is composed of spacetime regions and it sounds absurd to deny that these regions are not spatiotemporally located since they clearly have spatiotemporal properties. It seems also equally absurd to deny that spacetime is composed of spacetime regions, since under such a picture spacetime becomes unable to do its main job which is 'locating objects' (Baron 2020). Another potential reply is to say that the inheritance of location only takes place between ***located*** objects, so if the non-spatiotemporal parts are not located, then (IL) is not violated. Therefore, (IL) would be reformulated into the following from Baron et al. (2022, p. 140):

Weak Inheritance of Location (WIL): if x and y are both located and x is part of y,

[1] More precisely, if *x* is a part of *y*, and *x* is exactly located at a region *z*, then *y* is weakly located at region *z*. However, generic location is satisfactory for our purposes here.

then y is located wherever x is located.[2]

But by denying that the non-spatiotemporal parts are located ***at all***, it is entailed that they are mere abstract entities. For abstract entities like numbers, it does not make sense to ask where they are located[3]since they are not located in any ***metric structure.*** A metric structure refers to any set with elements and a notion of distance between these elements. In what follows, I will just use the term 'structure' to denote a metric structure. Therefore, adopting (WIL) forces us to adopt a worldview where the most fundamental constituents of reality are not located in any metric structure. Now some philosophers might be ready to bite the bullet at this stage. However, I think that we ought to leave this option as a last resort in case everything else fails.

INTUITION AND FAMILIARITY

The role of intuition in postulating metaphysical theories is still debated. However, most philosophers agree that *ceteris paribus*, a theory that satisfies our intuitions is more favorable than one that doesn't.[4] All of our everyday experiences of composite concrete objects- like people, trees and buildings- are of those spatiotemporally located. So, all of the wholes and parts that we observe in our daily life are located within the same structure, namely spacetime, meaning that the four reformulated principles are vindicated. Since we only experience spatiotemporal objects in our daily life, it is obvious that our intuitions are entered on spatiotemporal objects, but this however does not mean that positing *extra-intuitive* theses is the same as positing *counter-intuitive* ones. It sounds entirely plausible that our intuitions can be restricted to the portion of

[2] An advantage of (WIL) over (IL) is that it is not violated by mundane cases of composition where the whole is not located while the parts are. For example, the water polo team is not located anywhere whereas its individual members are.

[3] Technically speaking, mathematical Platonists hold that numbers as entities are located in some kind of mathematical abstract realm. In a similar way, theists hold that God is located outside of space and time in a special godly realm. However, in this paper, I will restrict myself to *physical* location. i.e. location in a metric structure.

[4] Baron and Le Bihan (2022) suggest that the mereological composition of spacetime does not necessarily satisfy the four principles above but only the axioms of classical mereology. This view would therefore deny the role of intuition in mereology and grant that role to physics instead. This is one way to go about it, but I don't think we need to trade off the role of intuition if it can be maintained otherwise.

reality with which we interact in our daily lives (spatiotemporal regions), while we can still add extra-intuitive theses as a result of scientific theorising such as the thesis that being located within the same structure is necessary for the inheritance of location between the wholes and their composing parts. This is different from our intuitions being falsified by scientific theories which was indeed the case with quantum mechanics falsifying our intuitions on there being a determined and objective reality at the subatomic level (at least under some interpretations). In the case of spacetime composition, on the other hand, no intuitions are falsified. The very weak reformulations of the four principles can be considered as extra-intuitive *additions* to our intuitions about mereology rather than *refutation* of those intuitions. To help understand the difference between additions and refutations to intuitions, let us consider the famous twin paradox in special relativity involving identical twins, one of whom makes a journey into space on a high-speed rocket and returns home to find that the twin who remained on Earth has aged more. This thought experiment gives us a result that *seemingly* contradicts our intuition; The twins are supposed to be of the same age but in this case one becomes older than the other. However, if we contemplate the result more closely, we find that the twin paradox does not refute our initial intuition. Twins who are born on Earth and spend all their lives there without either of them going on a trip in a high- speed rocket *are* of the same age. In other words, our intuitions are still valid for the domain of everyday life where high-speed trips into outer space are not a common part of our life. What the twin paradox does is that it *adds* an extra-intuitive result that only applies to a domain outside of our everyday life, and, thus, to which our intuitions do not extend. Similarly, our intuitions of mereological composition only extend to the domain of our everyday life i.e. spacetime. Any theses that we hold about non-spatiotemporal structures fall outside the domain of our intuitions and, therefore, are extra-intuitive rather than counter-intuitive.

One might object here that we might conceive of every case where some pre-philosophical intuition is violated by restricting the domain to which the intuition applies and then saying that we are adding to the intuition rather than violating it, and that this seems too easy to be a genuine solution. I agree that many of the cases that we normally think of as violating our intuitions would instead be classified under the distinction I propose as extra-intuitive theses rather than counter-intuitive ones. However, *many* other cases would still be classified as counter-intuitive. Consider for instance, the intuition prevalent among most

people living in the year 100 AD that the Earth is static and the Sun orbits it. Indeed, in this case the heliocentric model is considered a counter-intuitive thesis because the domain to which it applies is *the same* one to which the geocentric model applies. This is unlike the cases of the twin paradox and spacetime composition where the domain of applicability changed making us classify the corresponding theses as extra-intuitive rather than counter-intuitive. So, we conclude that this distinction that I propose is not trivial since it gives us cases of both extra-intuitive and counter-intuitive theses.

But someone might still object here that Baron's original complaint about spacetime composition still stands, namely, that it is too unfamiliar to us to be understood as a mereological relation. Here, I want to clarify the relationship between intuition and familiarity. If a thesis is intuitive, then it can be said to be familiar to us, and if a thesis is instead counter-intuitive, then it can be said to be unfamiliar to us. I think that this is plausible enough. What I want to suggest is that if a thesis is *extra-intuitive*, as I showed spacetime composition to be, then it can be said to be *somewhat familiar* to us. A thesis that is somewhat familiar to us would fall on the middle between theses entirely familiar and those entirely unfamiliar.

It is important to note also that intuitions are not fixed but rather vary from time to time even among members of the same culture or group. One reason for this shift of intuitions is due to the accumulation of new scientific or technical knowledge , for example. In the twin paradox case I mentioned above, it is plausible that if interplanetary travel at very high velocities becomes widespread in the future, then the fact that twins who travel at different velocities age at different rates- would strike us as completely intuitive rather than extra-intuitive as it is now. Accordingly, the thesis would change from being somewhat familiar to entirely familiar. Similarly, it is plausible to assume that in the future if we have a complete and empirically confirmed theory of quantum gravity, then the notion of spacetime composition would change from being somewhat familiar to entirely familiar.

The key advantage, I think, that an extra-intuitive thesis has over a counter-intuitive one is that former grants us a notion of somewhat familiarity while the latter does not. Therefore, we do not have to wait for our intuitions to shift so that spacetime composition can become familiar. It is ***familiar enough*** here and now,

and we hope that as we accumulate more scientific and technical knowledge, its familiarity would only increase.

REFORMULATING INHERITANCE OF LOCATION

Following this line of reasoning, we can now to turn to the principle of the inheritance of location. In the domain of everyday life, we tend to think of location as exclusively spatiotemporal. That is, for an object to be located, it ***must*** be located in spacetime. But recent developments in physics give us reason to doubt this. As Baron et al. (2022, p. 56) put it:

> In physics, it is commonplace to speak of location in a configuration space or a phase space, neither of which involve anything like space or time, but come complete with a great deal of structure. Typically, what we find in these spaces is a metric of some kind, with which we can speak meaningfully of the distances between points. The metric function is not a spatial or temporal function.

So non-spatiotemporal location is a coherent concept that is already utilised in physics. A physical theory supplies locations to entities as long as it provides enough structure to be able to produce a distance function over entities. Granted, it might be difficult for us to imagine how something cannot be located if not in spacetime (or space and time), but this is hardly a reason to reject the thesis. After all, many of our long-held beliefs about the world have been constantly challenged by scientific findings. Another valid question is to determine the exact nature of this non-spatiotemporal structure. The answer, however, is up to future physics. For instance, in loop quantum gravity, the fundamental non-spatiotemporal structure is whatever structure turns out to be represented by spin networks. For our purposes here, it is enough that we maintain the coherence of the notion of location in this non-spatiotemporal structure regardless of its exact nature that future developments in physics might reveal. To see how the concept of non-spatiotemporal location helps us resist the argument against spacetime composition, consider the following reformulation of (IL):

> *Very Weak Inheritance of Location (Very WIL)*: if x and y are both located within the same structure and x is part of y, then y is located wherever x is located.[5]

[5] Alternatively, we can also rephrase (WIL) so that it presupposes that location is exclusively spatiotemporal. This way the existence of non-spatiotemporal parts of spacetime would vacuously satisfy (WIL) and we would not need (Very WIL). However, as the referee also has noted, this paraphrase of (WIL), call it (WIL)*,

With (Very WIL), we can see how the location is not inherited between spacetime regions and the non-spatiotemporal parts that compose them. Although they are both located, they are located in ***different structures***, and thus spacetime composition does not violate (Very WIL). On the other hand, we can see that spacetime composition violates (WIL) even with allowing the possibility of non-spatiotemporal location. This is because while (Very WIL) requires both the whole and the part to be located within the ***same*** structure for location to be inherited, (WIL) only requires them to be both located within ***some*** structure. Since both spacetime regions and the non-spatiotemporal parts that compose them are located in some structure (albeit different ones), we should expect that the spatiotemporal location 'trickles down' from the spatiotemporal regions to the non-spatiotemporal parts, which of course is not the case since these parts are ***by definition*** not located in spacetime. In other words, reformulating (IL) into (Very WIL) rather than (WIL) is necessary to avoid being violated by spacetime composition.

THE ARGUMENTS FROM SUB-REGIONS, SIZE AND EXTENSION

After seeing how reformulating (IL) helps us resist the argument from intimacy against spacetime composition, we move on to the other three arguments. I think that a similar strategy can be applied to resist those as well, so I will just go over them briefly. First, consider this principle from Markosian (2014, p. 5):

> *Sub-region Theory of Parthood (STP)*: For any x and for any y, x is a part of y iff the region occupied by x is a subregion of the region occupied by y.

Following from (STP), an argument against spacetime composition can be sketched along these lines. If a spacetime region R is composed of non-spatiotemporal parts, then these parts would not occupy a subregion of R violating (STP) and rendering spacetime composition untenable. This is the *argument from sub-regions*. As before, we can reformulate (STP) to be:

> *Very Weak Sub-region Theory of Parthood (Very WSTP)*: For any x and for any y, where x and y are located within the same structure, x is a part of y iff the region

would be merely a special case of (Very WIL). The downside for adopting (WIL)* rather than (Very WIL) is that it would not be satisfied when both the whole and the parts are non-spatiotemporal. As (Very WIL) proves more comprehensive in this regard, it makes sense for us to adopt it instead of both (WIL) and (WIL)*.

occupied by x is a subregion of the region occupied by y.[6]

As before, (Very WSTP) helps us resist the argument from sub-regions by saying that since spacetime regions and their composing non-spatiotemporal parts are not located within the same structure, and so (Very WTSP) is not violated. Let's take another principle which Baron (2021) adopts from Donnelly (2011):

> *Smaller Part (SP)*: For any x and y, where x is a part of y, x is a smaller part of y iff x occupies a subregion of the region occupied by y.

From (SP), the argument against spacetime composition follows from the fact that the non-spatiotemporal parts ***do not*** occupy subregions of the spatiotemporal regions they compose, so they only can be smaller parts if (SP) is violated. This is the ***argument from size.*** It should be clear now how our strategy would work by reformulating (SP):

> *Very Weak Smaller Part (Very WSP)*: For any x and y, where x is a part of y, and x and y are located within the same structure, x is a smaller part of y iff x occupies a subregion of the region occupied by y.

Since the spatiotemporal regions and their composing non-spatiotemporal parts are not located in the same structure, then it follows that we should not expect the non- spatiotemporal parts to occupy a subregion of the spatiotemporal regions that they compose. In other words, spacetime composition does not violate (Very WSP). Finally, we take the fourth principle from Baron (2021, p. 391):

> *The Compositionality of Extension (CE)*: For any spatiotemporal object y and for any x1...xn, if x1...xn compose y, then the spatiotemporal extent of y is a function of the spatiotemporal extensions of x1...xn and the spatiotemporal relations between x1...xn.

We can see how (CE) is in tension with spacetime composition. Since spacetime regions are composed of non-spatiotemporal parts, these parts do not

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[6] As is the case with (IL), we can also reformulate (STP) into (WSTP) where for any x and for any y, where x and y are both located, x is part of y iff the region occupied by x is a subregion of the region occupied by y. (WSTP) faces the same problems that (WIL) faces since adopting (WSTP) also entails a view of the world where non-spatiotemporal regions are not located at all which entails that the fundamental structure of reality is not metric. So, from now on, and for the sake of brevity, I will skip the weak formulations and discuss the very weak ones directly.

have any spatiotemporal extent and, thus, they cannot contribute to the spatiotemporal extent of spacetime regions. Again, a reformulation of (CE) is in order:

> *The Very Weak Compositionality of Extension (Very WCE)*: For any spatiotemporal object y and for any x1...xn, where y and xn are located within the same structure, if x1...xn compose y, then the spatiotemporal extent of y is a function of the spatiotemporal extensions of x1...xn and the spatiotemporal relations between x1..xn.

Spacetime composition does not violate (Very WCE) since the spacetime regions and their composing non-spatiotemporal parts are not located within the same structure, and therefore, no compositionality of extension takes place in this case.

CONCLUSION

I have shown that the four intuitive principles of mereology can be reformulated in a way that makes them compatible with spacetime composition while being extra-intuitive rather than counter-intuitive. Spacetime composition happens in a domain different from the one in which composition normally happens, and therefore there is no reason to reject it as counter-intuitive. As a result, spacetime composition is certainly familiar enough to us, and thus, it should remain as a valid candidate relation to account for spacetime emergence in theories of quantum gravity.

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