Holes as Regions of Spacetime

1. Introduction

There are holey objects. In fact, many of us own and use them. Some such objects would not function properly without their holes. That they have holes is part of our explanation of how they function. One example of such an object is a colander. A colander without holes is just a bowl![1]

Although there are holes all around us, they are commonly thought to be mysterious entities. There is no generally accepted theory of what they are. In this paper we will introduce a novel view according to which holes are regions of spacetime. We will compare our view with theories of holes discussed in Lewis and Lewis 1970 and Casati and Varzi 1994. Finally, we will argue that those who favor the Lewises' view over that of Casati and Varzi on the basis of parsimony would be better off adopting the view we propose here.

2. Theories of Holes

Holes are plausibly thought to be closely associated with the things in which they are holes. Following Casati and Varzi, we will call such things 'hosts'. The Lewises suggest that this relation between holes and their hosts is just partial identity or overlap. Consider a doughnut and its hole. The hole is hosted by some portion of sweet, delicious dough. But, if the view suggested by the Lewises is correct, the hole just is some portion of sweet, delicious dough. It is that portion of dough that we would intuitively judge to surround the hole. In fact, for every such portion of dough, there is a hole identical to it. Since there are many such portions, it follows that doughnuts are very holey indeed.[2]

One significant virtue of this theory is that our commitment to holes seems far less mysterious. Holes are material objects. Unfortunately, the view also has several counter-intuitive consequences.[3] For example, as noted above, the theory has the consequence that a doughnut has many more holes than one might have thought. Following the Lewises, call any part of an object that we would intuitively judge to surround a hole a 'hole-lining'. Then one might avoid this objection by either claiming that holes are minimal hole-linings or that they are maximal hole-linings.[4] On either of the resulting views, however, given that the dough is delicious, it follows that the hole is delicious as well. Also, it would

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follow on either of these views that you pass your finger through a doughnut hole only by passing your finger through some portion of dough.

For reasons similar to those just considered, Casati and Varzi reject this view in favor of one according to which holes are *sui generis* entities constituted by regions of space. Holes are "immaterial bodies" that are located at discontinuities in the surfaces of material objects and depend on those material objects for their existence. For example, whenever there is a divot or hollow in the surface of an object, there is a hole located at that surface. On the other hand, a mound in the surface of an object, although accompanied by a discontinuity, is not typically the location of a hole.

Although some of us are attracted to Casati and Varzi's view, some philosophers might find it objectionable to introduce a new kind of *sui generis* entity in order to account for our seeming commitment to holes. We will suggest that those philosophers who are adverse to such a commitment should hold that holes are simply regions of spacetime. According to this view, holes are (roughly) regions of spacetime that are located at certain discontinuities in the surfaces of material objects. Consider, for example a compact disc. As a compact disc persists through time, it sweeps out a certain spacetime region.[5] Call that region 'CD Region'. Now consider the smallest spacetime region that has CD Region as a sub-region and is such that any straight line drawn from one boundary point of it to another never passes through a point not in that region. Call this second region 'Disc Region'. According to our proposed view, the hole in the center of that compact disc is just the spacetime region that results from subtracting CD Region from Disc Region.[6] Let's call this 'the spatiotemporal theory'.

A view similar to the one we are proposing has been discussed in the literature. In particular, Casati and Varzi consider and reject a view according to which holes are regions of space.[7] They note that whereas holes can move, regions of space cannot. It is clear that this consideration counts against the spatial theory of holes. However, it does not count against the view we are proposing. On the spatiotemporal theory, a hole persists through time in virtue of having temporal parts.[8] Because of this, a hole moves in virtue of having one temporal part at one place at a time and another temporal part at a distinct place at some other time. So, it is compatible with the spatiotemporal theory that a hole moves.

The spatiotemporal theory accommodates the virtues of the view suggested by the Lewises' while avoiding its vices. Like the Lewises and unlike Casati and Varzi, proponents of the spatiotemporal theory do not postulate some strange category of entity to which holes belong. Holes belong to a category that we already accept; namely, the category of spacetime regions. Moreover, we can pass our fingers through whatever holes we want without thereby passing our fingers through material objects. Also, no spacetime region is sweet and delicious. These facts give some reason to favor the spatiotemporal theory over that of the Lewises and that of Casati and Varzi.

3. Objections

Despite the simplicity of the spatiotemporal theory, there are some potential difficulties with it. In this section we will consider and respond to objections. One problem that arises immediately involves our use of the notion of a discontinuity in stating the theory. Remember that, in our rough characterization of the spatiotemporal theory, we said that holes are regions of spacetime located at certain discontinuities in the surfaces of material objects. However, we have yet to identify the discontinuities at which holes are located, much less explained what a discontinuity is.

We will begin to meet this objection by characterizing what a discontinuity is. Take some arbitrary object. Call it 'Arbie'. Whether or not Arbie persists through time, take that spacetime region swept out by Arbie during its life. Call that region 'Smalls'. Now consider the smallest spacetime region that has Smalls as a sub-region and is such that any straight line drawn from one boundary point of it to another never passes through a point not in that region. Call this region 'Biggie'.[9] If there is a remainder when you subtract Smalls from Biggie, then Arbie has at least one discontinuity at its surface; otherwise not.

Our method for identifying which objects have discontinuities at their surfaces can be extended so as to allow us to determine how many discontinuities an object has at its surface. Remember that Arbie has a discontinuity at its surface just in case Biggie minus Smalls has a remainder. That remainder will have at least one maximally continuous sub-region.[10] Moreover, the maximally continuous sub-regions of that remainder will be equinumerous with the discontinuities in Arbie's surface.

We have, then, both a method for determining when an object has discontinuities at its surface and one for determining how many discontinuities it has there. However, we have yet to say which discontinuities are holes. Unfortunately, we don't have much to say in this regard. It might be that Casati and Varzi have an account that successfully distinguishes those discontinuities at which there are holes from those at which there are not.[11] If so, then we will happily adopt their account. If not, we are no worse off than anyone else with respect to this objection.

There are more pressing objections, ones that are unique to the spatiotemporal theory. The first such objection concerns the possibility of spinning holes.[12] Suppose there is a disk with a circular hole in its center. Like an old 45, it is spinning about the center point of the hole. One might think that the hole in the center of this disk is spinning as well. However, it seems that there cannot be a spinning region of spacetime. So, if it is possible for there to be a spinning hole, then holes are not regions of spacetime.

This objection should not be taken lightly, for we can bolster the case for the possibility of spinning holes. Consider again our disk. Suppose that, unlike an old 45, it is not spinning about the center point of its hole. Rather, the disk is on a pottery wheel and its hole does not cover the center of the wheel. In this case, when the pottery wheel is spinning, the hole in the disk is orbiting about the center of the wheel. However, now suppose that we gently push the disk so that its hole moves toward the center of the wheel. Eventually, the center of the hole will line up with the center of the wheel. At every moment during its journey toward the center, the hole is moving (either in a rotational way or a wobbly way). So, if the hole is not moving when its center lines up with the center of the wheel, it must have stopped moving instantaneously. But that's crazy. So, there are spinning holes.

There are at least two responses to this objection. The first response denies the possibility of spinning holes on the following grounds. Consider again that rotating disk. At the center of the disk is a region of space at which its hole is located. But outside of the disk there is a region of space as well. Moreover, for any reason we have in favor of the claim that there is a hole located at the first region, there is an equally strong reason to believe that there is something similar located at the second region. Call that kind of thing an 'anti-hole'. The disk hosts the hole and seems to bear a similar relation to the anti-hole. But we don't believe that the anti-hole rotates in virtue of the disk rotating. So, it seems that we have little reason to believe that the hole itself rotates in virtue of the disk rotating.[13]

The second response to the spinning holes objection draws an analogy between the case described above and the following: Consider a solid disk and the point at its center. Suppose that the disk is placed on a pottery wheel slightly off center. When the disk is spinning, the point at its center is rotating about the center of the pottery wheel. Now suppose that we gently push the disk so that its center point slowly moves toward the center of the pottery wheel. At every moment during its journey toward the center, the point is moving. However, we do not think that the point is moving once it has reached the center of the pottery wheel. There is nothing strange about the point instantaneously stopping its motion. So, perhaps there is nothing strange about a hole doing so as well.

Let's now consider two more objections to the spatiotemporal theory. The first objection is modeled after Peter van Inwagen's famous Descartes/Descartes-minus objection to Four-Dimensionalism.[14] This morning someone ate a doughnut. Suppose that this doughnut and its hole persisted for exactly 30 minutes before that person's scrumptious experience. It seems obvious that the person could have devoured his doughnut five minutes earlier. Moreover, if he had done so, then the hole would still have existed, but would have had a slightly shorter life. However, if he had done so, then it is not the case that any region of spacetime would have had a slightly shorter life. So, it is not the case that the hole is identical to any region of spacetime.

The second objection is rather similar. Suppose that our doughnut eater picked up his delicious snack with his left hand rather than his right. It is clear, though, that he could have picked it up with his right hand rather than his left. If he had done so, then the region occupied by the hole would have been slightly different than the one it in fact occupies. However, if the spatiotemporal theory is correct, then a hole is identical to whatever region it occupies. It follows that if the spatiotemporal theory is correct, then although a hole is in fact identical to one region it could have been identical to another. But identity is not contingent. So, the spatiotemporal theory is false.

A counterpart theoretic account of *de re* modal claims concerning holes allows for a plausible response to both of these objections. According to such an account, a *de re* modal claim concerning a particular hole is true if that hole stands in a counterpart relation to something with the appropriate properties. So, for example, to say that a hole could have had a slightly shorter life is to say that it stands in a certain counterpart relation to another hole that does have a shorter life. Since holes just are regions of spacetime, it follows that some regions of spacetime, *qua* holes, could have had shorter lives simply in virtue of standing in an appropriate counterpart relation. Similarly, a hole could have occupied a different region of spacetime in virtue of standing in an appropriate counterpart relation to something that does occupy a distinct region of spacetime. Since, on the spatiotemporal theory of holes, a hole is identical to the region that it occupies, it would follow that a hole could have been identical to a region distinct from the one with which it is in fact identical. That is, in a sense, identity is contingent. So, one who accepts a counterpart theoretic account of *de re* modal claims concerning holes can plausibly respond to the proceeding two objections.

4. Conclusion

At the outset, we noted that holes are mysterious entities. The Lewises attempt to demystify holes by identifying them with certain material objects. However, the Lewises' view has many strange consequences, such as those discussed in Section 2. On the other hand, Casati and Varzi's view entails that holes are a *sui generis* type of entity. Some philosophers might find such a commitment undesirable. The spatiotemporal theory treads an attractive middle trail between these other views. It is not committed to the strange consequences of the Lewises' view nor must it postulate that holes are a *sui generis* type of entity; they are simply regions of spacetime. In addition, there are plausible responses to each of the major objections to the spatiotemporal theory. It would seem, then, that the proponent of the spatiotemporal theory can make a strong case for the claim that, on his view, holes are less mysterious than on competing views.

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NOTES

1. We must admit that the interior of a bowl is probably a hole as well. So, strictly speaking we should say that a colander without certain smallish holes is merely a bowl.
2. Strictly, this does not follow. We need, in addition, some principle of decomposition such as the Doctrine of Arbitrary Undetached Parts (DAUP). See van Inwagen 1981.
3. Casati and Varzi (1994) consider many such consequences. Here we consider only a few.
4. Casati and Varzi (1994: 30–32) consider both of these variations.
5. For the purposes of this example, it doesn't matter which view of persistence you hold.
6. It is interesting to note that this view of holes is compatible with both the three-dimensional and four-dimensional theories of the persistence of material objects. Regardless of whether or not material objects persist in virtue of temporal parts, it's clear that spacetime regions do. So, if holes are regions of spacetime, then holes persist in virtue of temporal parts.
7. Casati and Varzi 1994: 2.
8. There's another view similar to ours according to which holes really are spatial regions but they persist through time in virtue of bearing certain temporal counterpart relations to other spatial regions. It also avoids Casati and Varzi's objection. This view is analogous to Sider's theory of the persistence of material objects. See Sider 2001.
9. Note that Biggie may or may not be bigger than Smalls.
10. Where R is a maximally continuous subregion of R′ iff: (i) R and R′ are regions, (ii) R is a subregion of R′, (iii) R is continuous, and (iv) there is no other subregion R′′ of R′ such that R is a subregion of R′′ and R′′ is continuous.
11. It's unclear to us whether Casati and Varzi's account is in fact successful in this regard.
12. On spinning and rotating holes, see Casati and Varzi 1994: 118–124.
13. This response was suggested to us by Rich Feldman in conversation.
14. Van Inwagen 1990, 1981.

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