CAN WE DESCRIBE POSSIBLE CIRCUMSTANCES IN WHICH WE WOULD HAVE *MOST* REASON TO BELIEVE THAT TIME IS TWO-DIMENSIONAL?

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Abstract

How one answers the question whether time could be two-dimensional depends upon what one takes to be the essential properties of time. I assume that it is essential to time that it has a 'sense' or 'direction'; and, on the basis of this assumption, I argue that no-one has yet succeeded in giving a clear account of how it could be that time is two-dimensional. In particular, I argue that no-one has yet succeeded in describing possible circumstances in which we would have serious reason to entertain the hypothesis that time is two-dimensional.

Some philosophers have claimed to describe possible circumstances in which we would have reason to believe that time is two-dimensional. There are two ways in which this kind of claim can be interpreted. On the one hand, these philosophers might be taken to be making the stronger claim that we can describe possible circumstances in which we would have most reason—more reason than not—to believe that time is two-dimensional. (That is, at least roughly, we can describe possible circumstances in which we have evidence which makes it more likely than not that time is two-dimensional.) On the other hand, these philosophers might be taken to be making the weaker claim that we can describe possible circumstances in which we would have some reason to believe that time is two-dimensional. (That is, at least roughly, we can describe possible circumstances in which we have evidence which makes it more likely than it was before we acquired that evidence that time is two-dimensional.)[1]

Given the motives which these philosophers have had for wanting to describe circumstances in which we would have reason to believe that time is two-dimensional, it is natural to think that these philosophers only needed to make the weaker claim. In particular, where these philosophers have wanted to establish that the claim that time is two-dimensional is a claim with empirical content, it is clear that it would be sufficient for them to describe possible circumstances in which we would have some reason to believe that time is two-dimensional.[2] Nonetheless, these philosophers have typically committed themselves to the stronger claim that they have managed to describe circumstances in which we would have most reason—more reason than not—to believe that time is two-dimensional.

This feature of the literature about two-dimensional time is not unique to that literature. There was a time when it was quite common for philosophers to argue about whether particular claims had empirical content, and for those who held that a given claim had empirical content to argue that they could describe possible circumstances in which we would have most reason to believe that the claim in question is true. So, for example, there were philosophers who claimed to be able to describe circumstances in which we would have most reason to believe that everything doubled in size overnight, or that there had been a period of time without change, or that there is interpersonal spectrum inversion, or the like.[3]

I propose to argue that, in the case of the question about two-dimensional time, no-one has managed to describe possible circumstances in which it is clear that we would have most reason to believe that time is two-dimensional. Moreover, I shall argue that the same is true of many of the other cases which I mentioned above: in particular, no-one has managed to describe possible circumstances in which we would have most reason to believe that there has been a period of time without change, or that everything has doubled in size overnight. However, I shall argue that the case of interpersonal spectrum inversion is different: here, there is some reason to think that it is possible to describe possible circumstances in which we would have most reason to believe that there is interpersonal spectrum inversion.

I also propose to argue that, in the case of the question of two-dimensional time, it is far from obvious that anyone has managed to describe possible circumstances in which it is clear that we would have at least some reason to believe that time is two-dimensional. This time, however, I shall argue that the same is not true of many of the other cases which I mentioned above: in particular, it seems to me that it is possible to describe possible circumstances in which we would have some reason to believe that there has been a period of time without change, or that everything has doubled in size overnight. Of course, given that it is possible to describe possible circumstances in which we would have most reason to believe that there is interpersonal spectrum inversion, it is plainly possible to describe possible circumstances in which we would have at least some reason to believe that there is interpersonal spectrum inversion.

The plan of the paper is as follows. In the first section, I give the standard descriptions of possible circumstances in which—it has been alleged—we would have most reason to believe that time is two-dimensional, or that there has been a period of time without change, or that there is interpersonal spectrum inversion. In the second section, I shall explain why it seems to me that, in the first two cases, the described circumstances are not ones in which it is plainly true that we would have most reason to believe the claims in question. In the third section, I shall explain why it seems to me to be doubtful that, in the case of two-dimensional time, the described circumstances are ones in which one would have any reason at all to believe that time is two-dimensional. In the fourth section of the paper, I shall consider some different attempts to describe circumstances in which we would have some reason to believe that time is two-dimensional, and I shall argue that it is doubtful whether any of these is successful either.

1

Here, then, are the three cases which I propose to compare:

1. Two-Dimensional Time: The earliest and best known example of the kind of argument which I have in mind is due to Thomson (1965). Variants of the argument are studied by MacBeath (1993). I shall begin with one of MacBeath's simple variants of Thomson's argument:

> Zoe is an eminent terrestrial astronomer. She observes that, in the galaxy Citius, physical processes seem to take half the time that they do in the Milky Way. Later, when she receives messages from the Citian astronomer Adrian, she is astonished to learn that he thinks that physical processes in our galaxy take half the time that they do in Citius.

Why should we think that Zoe has reason to believe that time is two-dimensional? Because—say Thomson and MacBeath—there is a symmetrical difference in the temporal perspectives which Adrian and Zoe have on one another.

2. Time Without Change: The famous example here is due to Shoemaker (1969). His argument has been discussed extensively: see, for example Scott (1995).

> Consider a world which is divided into three regions: A, B, and C. In this world, region A is subject to a local freeze—a cessation of change—throughout every third year; region B is subject to a local freeze every fourth year; and region C is subject to a local change every fifth year. Consequently, the entire world is subject to a global freeze every sixtieth year. Moreover, the inhabitants of the world can infer from the local pattern of freezes that there is a global freeze every sixtieth year. In these circumstances, surely we would have most reason to believe that there is time without change.

It is worth noting that exactly the same kind of example can be used to argue that we can describe possible circumstances in which we would have most reason to believe that everything has doubled in size overnight. Suppose that the world is divided into three regions: A, B, and C. Suppose that, in this world, region A is subject to a local doubling in size at the end of every third year; region B is subject to a local doubling in size at the end of every fourth year; and that region C is subject to a local doubling in size at the end of every fifth year. Consequently, the entire world is subject to a global doubling in size at the end of every sixtieth year. Moreover, the inhabitants of the world can infer from the local pattern of doublings in size that there is a global doubling in size at the end of every sixtieth year. In these circumstances, surely we would have most reason to believe that everything doubled in size overnight. (In order to avoid obvious difficulties, I shall suppose that the connection between any pair of regions consists in a single point, and—in order to ensure that evidence of doubling in size is available—I shall also suppose that technology is available to send signals and objects through these points.[4])

3. Interpersonal Spectrum Inversion: The final example is developed in Lycan (1971), and is explicitly modelled on Shoemaker's and Putnam's famous precedents.

> A neurophysiologist discovers that when he performs a given neural crossover operations on 10, 000 patients, those patients all report intrapersonal spectrum inversion: the sky looks yellow, people's faces look light green, and so on. Moreover, in each of these patients, the operation also produces partial deafness, a bright green birthmark on the bridge of the nose, and a fanatical and overwhelming love of the music of de Vitry. Then, sensationally, the neurophysiologist discovers a patient who has always been a partially deaf lover of the music of de Vitry with a bright green birthmark on her nose. Moreover, when the neurophysiologist performs the neural crossover operation on this patient, these characteristics disappear but, nonetheless, the patient reports intrapersonal spectrum inversion. In this circumstances, it seems plausible to claim that there is most reason to believe that there is someone who has interpersonal spectrum inversion with respect to the rest of the population.

Lycan actually provides further reasons for supposing that, in the situation described, we would have most reason to believe that the person in question is spectrally inverted with respect to the rest of us; however, the intuitive force of the case will suffice for my purposes.

2

Here are my reasons for thinking that the cases given in the previous section are arranged in increasing order of persuasiveness:

1. <u>Two-Dimensional Time</u>: There is an alternative way of understanding what is going on in the simple case described by MacBeath, as follows: The universe divides into two halves. The boundary between the two halves is a kind of spacetime

gate. Anything which crosses the boundary at time 2T according to date from the Big Bang on the side of departure arrives at time T according to date from the Big Bang on the side of arrival. In other words, the spacetime gate which separates the two halves of the universe shunts everything which crosses the boundary back in time. Since the boundary works the same way in both directions, it looks to inhabitants on each side that life happens twice as fast on the other side. In fact, of course, life occurs at the same rate on both sides of the divide—and, moreover, there is only one dimension of time.

Given the story told by MacBeath, it seems to me that this way of understanding which is going on is to be preferred to the hypothesis that time is two-dimensional. That is, it seems to me that, given the evidence possessed by Zoe and Adrian, they ought to give more credence to the claim that there is a spacetime gate of the kind which I have described than they give to the claim that time is two-dimensional. However, for now, all I need to argue is that it is clear enough that the hypothesis that time is two-dimensional is not clearly preferable to the hypothesis that there is a spacetime gate of the kind described: for, if that is right, then in the circumstances described, Zoe does not have more reason than not to suppose that time is two-dimensional. (We shall return to the question of what Zoe has most reason to believe in the next section.)

2. Time Without Change: There is a very similar alternative way of understanding what is going on in the case described by Shoemaker. Instead of supposing that the regions A, B and C are subject to local freezes—or to local periods of extremely rapid acceleration—we might suppose instead that the boundaries between the regions are spacetime gates which connect together different years in the

various regions according to regular patterns. The description which I am about to give is no doubt not the most simple one available; however, it is reasonably simple.

For any pair of regions X and Y, there are four kinds of relations between connections between years in these regions which can hold:

(N) If year x in X is connected to year y in Y, then year x+1 in X is connected to year y+1 in Y.

(S) If year x in X is connected to year y in Y, then year x+1 in X is connected to year y+2 in Y, and year y+1 in Y is connected to no year in X

(P) If year x in X is connected to year y in Y, then year x+2 in X is connected to year y+1 in Y, and year x+1 in X is connected to no year in Y

(A) If year x in X is connected to year y in Y, then year x+2 in X is connected to year y+2 in Y, and year x+1 in X is connected to no year in Y, and year y+1 in Y is connected to no year in X

The repeating pattern of connections between regions A and B is: SASNNN; the repeating pattern of connections between regions A and C is: ASNSANNN; and the repeating pattern of connections between regions B and C is: SNAPANSNNNNN.

On this way of interpreting the data, there are no local freezes or periods of acceleration: events progress uniformly in all three regions. However, owing to the properties of the boundaries between the three regions, the “simultaneity” relations between regions vary in regular and predictable ways. (Note that, if a local region froze, no signals could pass in or out of that region. So, from the standpoint of a neighbouring region, it would just as if that region disappeared. Of course, it remains to be said what happens to objects and signals which approach the “edge” of the region to which they belong. We could assume that they are “reflected” by the boundary; we could assume that they are “absorbed” by the boundary; we could even assume that signals do not suffer the same fate as objects. I don't think that it matters for my discussion which assumption is made.)

Is this alternative hypothesis plainly worse than the hypothesis that there are local freezes? I don't think so. True enough, the "boundary" hypothesis—at least in the version which I have given—does not have the same mathematical simplicity as the "freeze" hypothesis. However, I think that if I were in possession of the data which would be available in the scenario which Shoemaker describes, I would not suppose that this mathematical simplicity is a sufficient reason to prefer the "freeze" hypothesis to the "boundary" hypothesis. Moreover, I think that it is unclear what would need to be added to the scenario in order to make it the case that I had more reason to prefer the "freeze" hypothesis. Shoemaker himself considers a more elaborate scenario in which there are "periods of sluggishness" prior to the "freezes"; however, it seems to me that this data could be explained, for example, in terms of the energy which is required by the boundaries when the spacetime gate is "reset". Perhaps there is some more elaborate version of the scenario in which it is obvious that the "freeze" hypothesis must be accepted by any reasonable person; however, I do not think that any such version has yet been produced.

3. Interpersonal Spectrum Inversion: I do not think that it is easy to find plausible alternative explanations of the evidence which Lycan describes. (It is especially difficult to think of alternative explanations which involve spacetime gates! As Daniel Nolan pointed out to me, it could be that the neurophysiologist performs his crossover operation on an infant who then travels back in time and grows up to become the "sensational" new patient. However, I take it that it is obvious that this is nowhere near as plausible an explanation as the one which Lycan offers.) In the circumstances—for the kinds of reasons which Lycan himself offers—it seems to me

that it would be plausible to suppose that one has most reason to hold that there is interpersonal spectrum inversion.

3

Even if I am right that the simple story which MacBeath adapts from Thomson fails to be a case in which there is most reason to believe that time is two-dimensional, it might be claimed that the story does succeed in describing circumstances in which there is some reason to believe that time is two-dimensional. Surely, it might be urged, in the envisaged circumstances, there would be *some* reason for Zoe to entertain the hypothesis that time is two-dimensional. Well, would there be? The key question here is whether the conditional probability that time is two-dimensional given the evidence which Zoe possesses is greater than the prior probability that time is two-dimensional. That is, does the evidence make it any more likely that time is two-dimensional? It is not clear to me that it does.

In the case of the hypothesis that there is a spacetime gate, it is clear exactly how this hypothesis offers to explain the data. However, in the case of the hypothesis that time is two-dimensional, I do not think that it is at all clear how this hypothesis is supposed to raise the probability of the described evidence. If there were two temporal dimensions, how would this help to explain the observations which Zoe and Adrian make? In order to answer this question, we need to think more about what a universe in which there is two-dimensional time would be like.

Some philosophers have supposed that the requirements imposed by the claim that time is two-dimensional are so stringent that we can know *a priori* that they cannot be met. Thus, for example, Richard Swinburne (1981:172) writes that:

> To say that time was two-dimensional would be to say that temporal instants had to each other the relations of before and after in two ways. Of two instants t_1 and t_2, t_1 could be before t_2 in one direction yet after it in the other. For to say that time is two-dimensional is to say that some instants have this relation to each other. But this—of logical necessity—could not be.

And, in similar vein, John Lucas (1979:39,178f.) writes:

> To have two or more dimensions is to have two or more metrical relations between points and *a fortiori* two or more orderings. … Hence, two dimensional time cannot be completely ordered. … Time cannot have more than one dimension because a multi-dimensional space must be isotropic between different directions, and between different senses of the same direction.

The requirements being insisted on here seem to me to be too strong. Suppose that we accept the claim that it is essential to time that it has a ‘sense’ or ‘direction’. When we move to the two-dimensional case, we could say that a time (t_x, t_y) is earlier than a time ($t_{x'}$, $t_{y'}$) just in case $x<x'$ and $y<y'$; and we can say that a time (t_x, t_y) is later than a time ($t_{x'}$, $t_{y'}$) just in case $x>x'$ and $y>y'$; and we can say that a time (t_x, t_y) is identical to a time ($t_{x'}$, $t_{y'}$) just in case $x=x'$ and $y=y'$. Of course, there will be pairs of times which are related in none of these three ways, e.g. if $x<x'$ and $y>y'$. But—*contra* Lucas—while it is true that two-dimensional time cannot be completely ordered, it doesn’t follow from this fact that two-dimensional time lacks a ‘sense’ or ‘direction’, and nor does it follow from the fact that it is two-dimensional that two-dimensional time must be isotropic. Moreover—*contra* Swinburne—it is not true that, merely because time is two-dimensional, there are pairs of instants for which it is true that one is earlier than the other along one dimension and yet later than the other along a second dimension.[5]

If we suppose that the requirement which I have suggested in the previous paragraph is both necessary and sufficient[6], then what will be required in order for time to be two-dimensional is that (almost all) events have many different histories, and that the temporal intervals between events are different along those different histories. Sticking to the simple case of five-dimensional Euclidean spacetime, we can see that any pair of events which lies on a curve which is nowhere decreasing with respect to either of the two temporal dimensions will be historically related—either one will be earlier than the other, or the pair will be simultaneous—and events which do not lie on any such curve are simply not historically related—they are not simultaneous, and neither is earlier than the other. However, this further consequence—i.e. that there are non-simultaneous events such that neither is earlier than the other—is not one which is distinctive of two-dimensional time; for, of course, this kind of absence of "historical relation" also shows up in relativistic spacetimes in which time is one-dimensional.

Can we make sense of the idea that events have many different histories, and that the temporal intervals between events are different along those different histories? I think so, at least in very simple cases. Suppose, for example, that there are only two properties of the world which can vary over time: call them TEMPERATURE and MASS. For simplicity, suppress the spatial dimensions, and think in terms of a single point. Let TEMPERATURE increase continuously from zero to some maximum value along one temporal axis; and let MASS increase continuously from zero to some maximum value along the other temporal axis. Each combination of TEMPERATURE and MASS occurs exactly once; that is, there is a unique time at which our point takes on each possible pairing of TEMPERATURE and MASS. Given the earlier than / later than relation defined two paragraphs back, we have now described a very simple world which at the BIG BANG is of MINIMUM TEMPERATURE and MASS and at the BIG CRUNCH is of MAXIMUM TEMPERATURE and MASS, and which occupies every possible state in between without ever seeing a decrease of either MASS or TEMPERATURE with time. Moreover, in this world, time is two-dimensional, and fits the conditions which I gave two paragraphs back.

Of course, even if I am right—both about the simple case, and about what is required if time is to be two-dimensional—there are serious questions about whether there could be two-dimensional time in more interesting worlds; and, in particular, there are serious questions about whether there could be creatures like us in worlds in which there is two-dimensional time. (What would it be like to have many different histories? What kind of conception can we form of the character of experience in worlds in which time is two-dimensional? What would it be like to remember a continuum of different life histories?) However, on the assumption that I am right about what is required for time to be two-dimensional, it should now be clear why I am sceptical that the hypothesis that time is two-dimensional could be invoked to explain the data in the case of Zoe and Adrian. There is nothing in the data which they possess which suggests that a given event has many different histories; on the contrary, it is made quite explicit in the story that there is a single history which is perceived differently by differently positioned observers. But, as far as I can see, postulating two-dimensional time just won't give you a good explanation of that kind of data.

4

I shall conclude by discussing three more cases of descriptions of circumstances in which it is alleged that we would have most reason to believe that time is two-dimensional.

1. Thomson (1965): As I mentioned when I first introduced it, the case of Adrian and Zoe is a simplified version of the case which was originally given in Thomson (1965). In that article, Thomson supposes that Adrian and Zoe are inhabitants of the very same planet, and that it nonetheless seems to each of them that the other is living twice as fast. On my view, this change to the story does not make the postulation of two-dimensional time any more plausible; at best, it merely raises further questions about the coherence of the situation which is under description. In the simplified case, it is relatively easy to explain how signals can travel in such a way as to make it seem to each of the observers that the other is living twice as fast; if Zoe and Adrian share the same planet, then it is much harder to explain how signals can behave in such a way as to secure this result.[7]

2. Richmond (2000): Richmond begins with the suggestion that there could be circumstances in which it would be appropriate for us to say that we have evidence that there is a fourth spatial dimension. Suppose, in particular, that someone were somehow transposed into an incongruent counterpart, as in H. G. Wells' "The Plattner Story". In Richmond's view, the most reasonable inference to make in this case is that the person in question occupies a non-orientable four-dimensional space, i.e. a four-dimensional space in which handedness is not invariant over all translations. Richmond then goes on to suggest that, if someone were somehow transposed into a "time-reversed" counterpart, then—in line with the reasoning of the previous case—the most reasonable inference to make would be that the person in question occupies a

non-orientable two-dimensional time, i.e. a two-dimensional time in which temporal direction is not an invariant over all translations.

Clearly, there are many questions which might be raised about this argument. I shall mention only two which seem to be particularly pressing. (Of course, if what I have said previously is right then, since there is no evidence of multiple histories in Richmond's story, there is no reason to suspect that there is two-dimensional time either. However, I shall focus on some further reasons for being sceptical about the inference of two-dimensional time in this case.)

First, it seems highly questionable that the original Plattner story does require an inference to four-dimensional space. Richmond claims that either we make this inference or else we accept "a host of brute regularities". But this claim relies on the assumption that there are no competing explanations of Plattner's transformation which are about as plausible as the one which Richmond favours, but which do not suppose that the space which we regularly inhabit is four-dimensional. In my view, there are almost certainly many such explanations to be found. On the one hand, if we insist on strictly geometrical explanations, then, for instance, we might suppose that Plattner was transported through a spacetime wormhole into an otherwise unconnected spacetime with strange geometry—e.g. that of a Klein bottle—and then returned to our spacetime through another spacetime wormhole. (Less imaginatively, we might suppose that our own spacetime surprisingly turns out to have a strange geometry on a large scale, and that Plattner has been travelling on a very fast rocket.) And, on the other hand, there are surely many non-geometrical explanations which might be advanced: perhaps there are strange fields, or gods, or machines, with the power to bring about this kind of transformation. Given all of these possibilities, the inference which Richmond proposes seems incautious.[8]

Second, even if it were true that the best inference to make in the original case is to a fourth spatial dimension, it is not at all obvious that the latter case is sufficiently similar to warrant an inference to a non-orientable two-dimensional time. After all, in the latter case, the crucial point is that Plattner travels through time in the reverse direction to everyone else—and it is not at all clear how the postulation of a second time-dimension can help to explain either how this is possible or how the direction of travel of a given person could be reversed. (In the first case, what we seek to explain is transformation into an incongruent counterpart in an isotropic space; in the second case, what we seek to explain is transformation into an "anti-traveller" with respect to an anisotropic dimension. The cases are plainly quite different, and in apparently relevant respects.[9])

3. Meiland (1974): Meiland claims that it is possible to provide a two-dimensional passage model of time which can allow for time travel into an altered past. Given that we have evidence—based on testimony, returned artefacts, and so forth—of time travel into an altered past, we would plausibly have evidence that time is two-dimensional: there can hardly be time travel into an altered past if time is only one-dimensional. (Meiland's passage model has as its core the suggestion that each "present" moment may have a different past associated with it (159). Suppose that we have some "present" moments: t_1, t_2, t_3, t_4, t_5, t_6, t_7… . Suppose that associated with each of these "present" moments is a past P_1, P_2, P_3, P_4, P_5, P_6, P_7 … . Suppose, finally, that $P_i it_j$ is the position of the moment t_j in the past P_i. Then, on Meiland's scheme, what happens at $P_m t_n$ can be quite different from what happens at $P_k t_n$ when $m \neq k$. We need two different temporal coordinates in order to specify a given event, since the past changes as the "present" moment does.)

There may be various ways in which Meiland's proposal can be criticised. Here, I shall just focus on the thought that Meiland's model gives up on the idea that a given event has a determinate location in spacetime. If we ask *What happened at point x at time* t_i? Meiland's answer is: it depends at which time you ask the question (i.e. whether you ask the question at t_i, or t_j, or t_k, …). In my view, this means that whatever Meiland is talking about, he isn't talking about time—and hence, *a fortiori*, he isn't talking about two-dimensional time. What a spatio-temporal framework does is to provide a structure within which each event has a unique location; hence, there has to be a unique correct answer to the question *What happened at point x at time* t_i? (No doubt Meiland will say that this is just to beg the question against the possibility that the past might change; however, I take it that it is simply incoherent to suppose that the past might change.)

Of course, even if one supposes that Meiland's proposal is coherent, there are still further questions to raise. In particular, one would need to know more about the alleged evidence before one could evaluate the proposal that one had evidence for travel to an altered past (as opposed to, say, travel to a nearby parallel universe). However, I don't propose to take up these further considerations here.

Even if I am right about the cases presented by Thomson, Richmond, and Meiland, it remains possible that there is some other way of describing circumstances in which we would have most reason to believe that time is two-dimensional. In particular, my account of how things would have to be if time were to be two-dimensional might be taken as a model. However, in that particular case, it seems impossible to say what the character of experience would need to be like (in order to provide the necessary evidence); and, on the argument which I have given, there doesn't seem to be any other possible alternative. So I take it that the argument which

I have given makes a reasonable *prima facie* case for the conclusion that, actually, we can't describe possible circumstances in which we would have most reason to believe that time is two-dimensional.

5

It can hardly be said that the foregoing discussion has been rigorous. I have said nothing at all about how to analyse the notion of "dimension", and I have done nothing to justify my conception of the essential properties of two-dimensional time. Nonetheless, I think that what I have said does serve to advance the discussion: those who claim to have described circumstances in which we would have most reason to believe that time is two-dimensional clearly have more work to do.[10]

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[1] As a referee pointed out, there is a third claim which ought to be considered, viz. that we can describe possible circumstances in which we have strong reason to believe that time is two-dimensional. Apart from worries about how to characterise reasons which are strong but not decisive, there is no reason to ignore this claim. However, given the conclusions which I go on to draw, it will be clear what I would say about it. (When some of the writers I discuss talk about "best reasons", it may be uncharitable to interpret them to be talking about decisive reasons, and more charitable to talk them to be talking merely about strong reasons. However, if what I go on to argue is right, then no serious harm will be done.)

[2] Strictly speaking, what I have written here isn't quite right. What is required is that the evidence available in the circumstances provides support for the belief. Describing circumstances in which one ascribes a prior probability of one to the claim that time is two-dimensional but in which one is stipulated to be rational does not count!

[3] It might be said: these questions are trivial—for any consistent claim whatsoever, it could be that you know that God has revealed its truth to you. So, in every case, we need only describe the possible circumstances in which God's testimony is your evidence … . Clearly, there is a constraint which needs to be mentioned—and which I shall hereafter assume to be in force: the evidence in question cannot be the testimony of reliable witnesses, or the like. Of course, there are tricky questions about what "or the like" amounts to here; however, I don't propose to try to investigate those questions in this paper.

[4] Putnam (1963) famously presents other reasons which one might have for thinking that the hypothesis that everything doubled in size overnight has empirical consequences. I don't mean to suggest that I disagree with Putnam here; the point which I am making is that, even if there were no other empirical consequences of the kind which Putnam describes, it would still be possible to develop a Shoemaker-style argument on behalf of the suggestion that the claim that everything doubled in size overnight has empirical content. (As a referee reminded me, it is well-known that overnight doubling would have empirical consequences in various kinds of non-Euclidean spaces. If I am right, we can get the same result in Euclidean space.)

[5] On the proposal which I have given, the fundamental notion is "earlier than", not "earlier than along a given dimension". Because this relation is merely a partial ordering, there is no difficulty of the kind which Swinburne claims to find.

[6] That is, we suppose that time is two-dimensional iff the 'earlier than' and 'later than' relations behave as described in that paragraph, so that these relations are only partially defined over a two-dimensional space in such a way that neither of the "components" retreats as time advances. As a referee for this paper pointed out, this assumption is controversial. One might suppose instead, for instance, that any

manifold with signature [+ + + – –] is a manifold in which there is two-dimensional time; and, if so, then the inference to "multiple histories" which I draw may well not go through. However, while I concede that the assumption is controversial, it seems to me to be plausible; at the very least, it seems to be worth asking what follows if the assumption is made.

[7] If one rejects my assumptions about what is required for two-dimensional time, then—as a referee pointed out—one might think that stories in which there are many observers "with different temporal inclinations to one another" do succeed in describing circumstances in which the kind of alternative hypothesis that I have proposed is ruled out (or, at any rate, relegated to a much lower level of plausibility). Even if one rejects my assumptions, it is not obvious that this is correct. It seems to me to be plausible to suppose that the postulation of a "many-gated" spacetime will be able to fit the data just as well. However, I do concede that it is plausible to maintain that this hypothesis should receive a lower prior probability than the hypothesis of the "single-gated" spacetime receives in the simple case described in the main text.

[8] A referee objected that the alternative explanations mentioned here seem *ad hoc* and explanatorily capricious (whereas the postulation of further temporal dimensions is nomologically simple and yields clear results). However, I take it that this is not true of the alternative geometrical explanations which I mention: wormholes are hardly more exotic than extra dimensions or strange topology.

[9] As a referee pointed out, there is more which could be said here about why these differences between the two cases might matter. Of course, if I am right in my earlier assumptions about what is essential to time, then it is clear what more to say: there is nothing in Richmond's hypothesis which requires multiple histories. If I am wrong in my earlier assumptions, then what is left here amounts to no more than a demand for

more information: what reason do we have for thinking that these differences between the two cases don't undermine the suggested inference?

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